10-YEAR NETWORK DEVELOPMENT PLAN 2014

European Network of
Transmission System Operators
for Electricity

entsoe

Table of contents

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0 Executive summary

0.1 ENTSO-E delivers the TYNDP 2014 package

The European Network of Transmission System Operators for Electricity (ENTSO-E) provides herewith the 2014 release of the community-wide Ten-Year Network Development Plan (TYNDP).

This publication meets the requirements of Regulation EC 714/2009; whereby "ENTSO-E shall adopt a non-binding Community-wide 10 year network development plan". However, with each TYNDP release, **ENTSO-E widens the scope and goals of the report based on wider and growing interest from stakeholders**.

Grid development is a vital instrument in achieving European energy objectives, such as security of supply across Europe, sustainable development of the energy system with renewable energy source (RES) integration and affordable energy for European consumers through market integration. As a community-wide report, the TYNDP contributes to these goals and provides the central reference point for European electricity grid development. Together with this report, the 6 Regional Investment Plans and the Scenario Outlook and Adequacy Forecast 2014-2030 outline, in more granular detail, the various investment needs for pan-European grid development in the coming future.

0.2 Reg (EU) 347/2013 sets a new role for the TYNDP

The formal role of the TYNDP in European electricity system development is further strengthened via Regulation (EU) 347/2013, in force since April 2013, through which the ENTSO-E **TYNDP is mandated as the sole instrument for the selection of Projects of Common Interest** (PCIs).

ENTSO-E has anticipated this new regulation in order to foster its implementation. In close collaboration with ACER, ENTSOG and many stakeholders, ENTSO-E designed and consulted the **Cost Benefit Analysis** (CBA) for the assessment of PCIs, and submitted it to ACER for their opinion. Member States and the EC are being consulted for their comments, with the final documents expected at the end of 2014. In parallel, this new methodology has also been tested within the current TYNDP 2014.

The benefits of projects of pan-European significance, whether from transmission system operators (TSOs) or by non-ENTSO-E member promoters, including storage projects, are all quantified accordingly in the current report.

0.3 Active stakeholder contribution to the TYNDP 2014

ENTSO-E strongly encourages and factors in stakeholder involvement to the TYNDP process. During the two-year development period, ENTSO-E both provided information and sought input from stakeholders during several phases of the process via 17 European and regional public workshops, 6 public web consultations and numerous requests for contributions and bilateral meetings[1].

[1] https://www.ENTSO-E.eu/major-projects/ten-year-network-development-plan/tyndp-2014/stakeholder-interaction/

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Additionally, a Long-Term Network Development Stakeholder Group was created, gathering European stakeholder organisations to provide views on related long-term grid development issues[2]. The scenarios and the CBA methodology reflect the very valuable input collected within this framework.

Lastly, 33 non-ENTSO-E member promoters completed transmission and storage project submissions for assessment.

0.4 The TYNDP 2014 is the product of a rigorous 2-year process

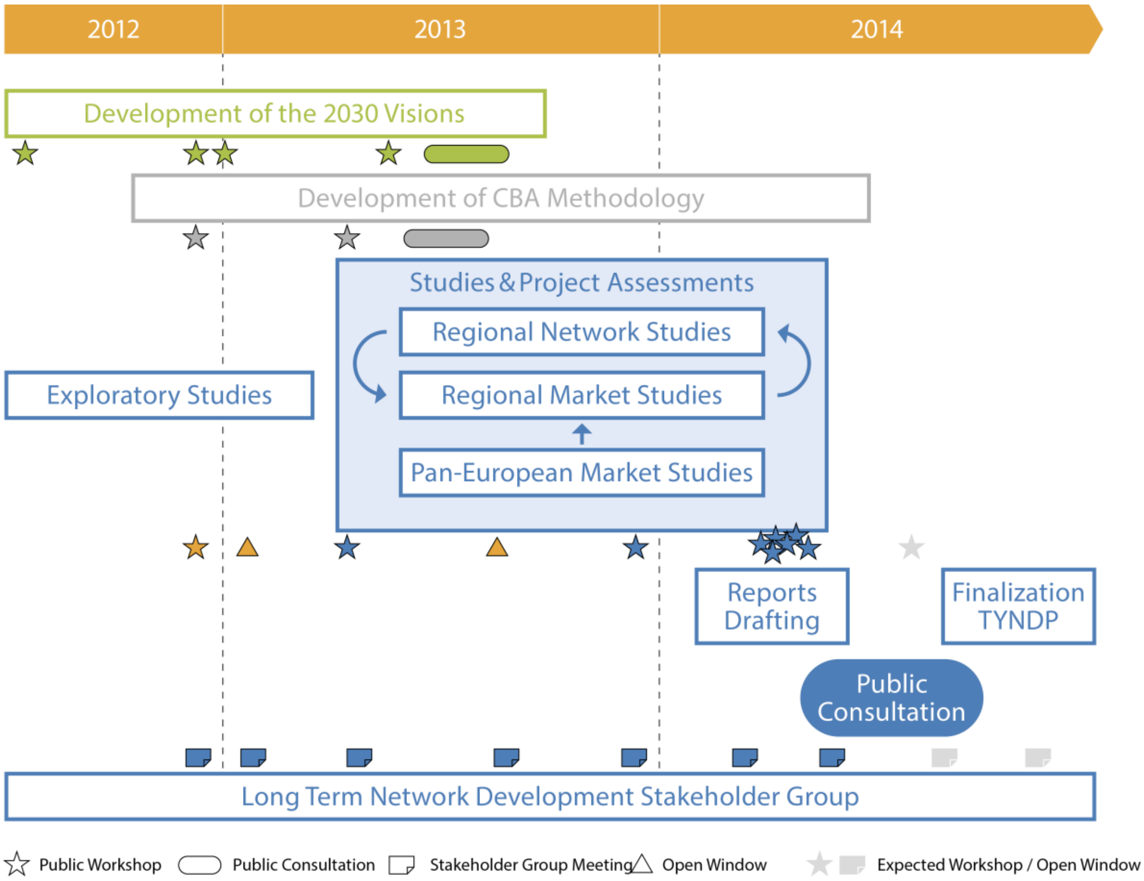

Figure 0-1 Overview of the TYNDP 2014 process

ENTSO-E strives to improve both the TYNDP process and content with each release. Improvements were based on stakeholder feedback either from the previous release, during the preparation of the TYNDP 2014 and/or in anticipation of the Energy Infrastructure Regulation (EU) 347/2013 implementation. The TYNDP 2014 incorporates significant improvements, such as the construction and exploration of longer-run scenarios, more refined methodologies and enriched results.

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[2] https://www.ENTSO-E.eu/major-projects/ten-year-network-development-plan/tyndp-2014/long-term-network-development-stakeholder-group/

0.5 What is new in the TYNDP 2014?

The TYNDP is a continuously evolving process that began with the pilot TYNDP published in June 2010 ahead of the entry into force of Regulation (EU) 714/2009. New features of the TYNDP 2014 are:

- The exploration of a longer-run horizon beyond the 10-year scope through to 2030, applied to four contrasting "Visions", encompassing the possible futures that stakeholders have requested ENTSO-E to consider.
- New clustering rules to define projects of pan-European significance, focusing on the core investment items (Other regionally significant supporting investments are presented in the respective Regional Investment Plans).
- A numerical quantification of every project's benefit assessment according to the consulted CBA methodology, with refined definitions for security of supply, RES integration, socio-economic welfare, resilience, flexibility and robustness, and social and environmental indicators.
- A synthetic appraisal of the interconnection target capacities in the different scenarios.
- Easier and more frequent opportunities for stakeholder participation, particularly for non-ENTSO-E member transmission or storage project promoters.

For the TYNDP 2014, ENTSO-E has also improved the study tools and process to speed up and strengthen data collection, model calibration, consistency checks and the merging of pan-European and regional results. The quality of the integrated market and network modelling relies on the knowledge of all the specific features of every local power system in Europe, a detailed grid description, and the resulting ability to master and aptly cut through numerous parameters of high uncertainty. Thus, more than 100 grid concerns and investment projects from across Europe have been investigated within the limited timeframe of 2 years.

Overall, the TYNDP 2014 presents a more holistic view of grid development, combining power transmission issues with environmental and resilience concerns.

0.6 The TYNDP 2014 explores a large spectrum of possible 2030 outcomes

The TYNDP 2014's analysis is based on extensive exploration of the 2030 horizon. The year 2030 provides a bridge between the European energy targets for 2020 and 2050. This choice was based on stakeholder preference for a large scope of credible contrasting longer-run scenarios rather than a more limited number on the intermediate horizon of 2020.

The basis for the TYNDP 2014 analysis is four 2030 Visions. The Visions are not so much forecasts of the future, but rather plausible future states selected as wide-ranging possible alternatives. This ensures that the selected pathway actually falls within the range described by the Visions with a high level of certainty. The span of the four Visions is large to meet the various stakeholder expectations. The Visions mainly differ with respect to:

- The trajectory towards the Energy Roadmap 2050: Visions 3 and 4 maintain a regular pace from now until 2050, whereas Visions 1 and 2 assume a slower start before an acceleration after 2030. Fuel and CO2 prices favour coal (resp. gas) in Visions 1 and 2 (resp. Visions 3 and 4).
- Consistency of the generation mix development strategy: Visions 1 and 3 build from bottom-up, based upon each country's energy policies but still with a harmonised approach across Europe, whilst Visions 2 and 4 assume a consistent top-down pan-European approach.

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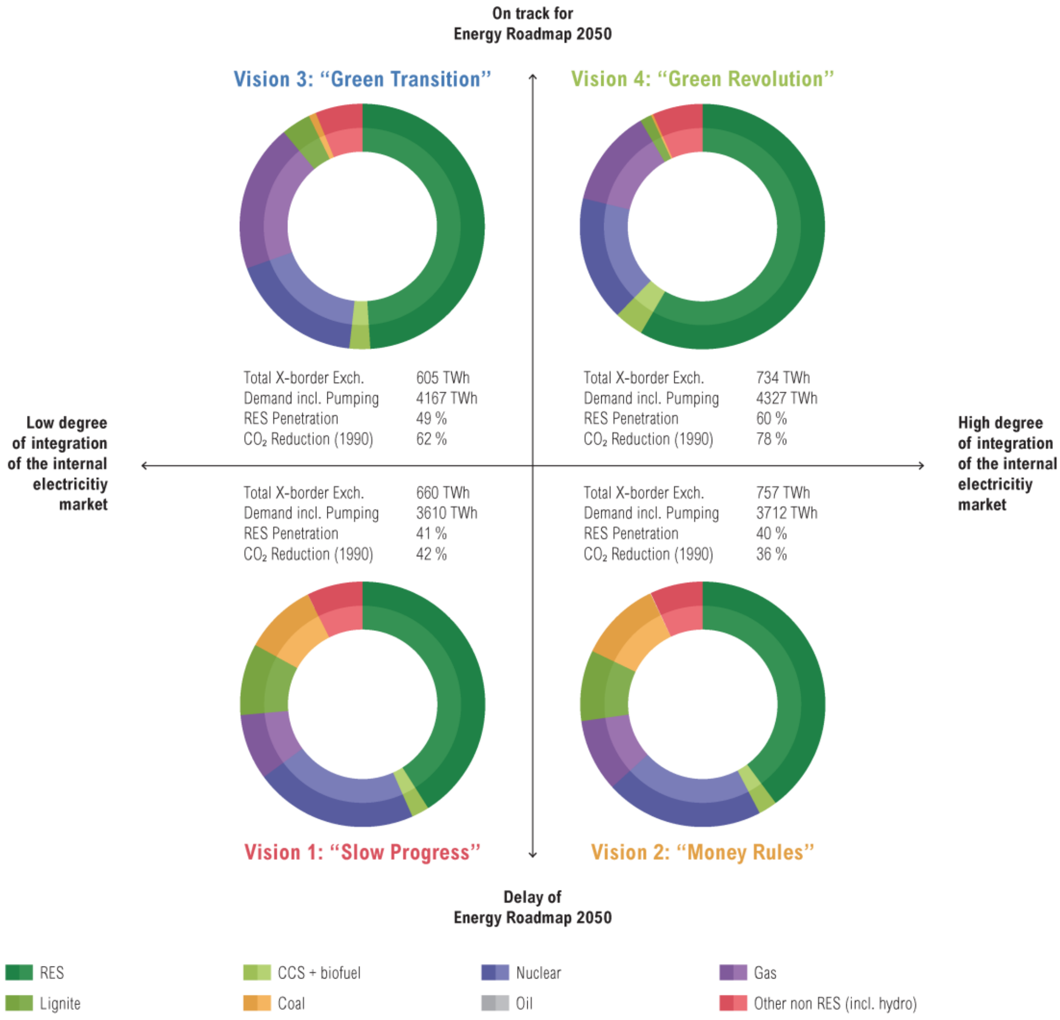

Figure 0-2 4 2030 Visions

All the scenarios assume significant RES generation development (supplying 40% to 60% of the total annual demand, depending on the Vision) paired with a huge reduction in CO2 emissions (-40% to -80% compared to 1990). One will also remark that the main outputs for Vision 1 and Vision 2 appear similar at the pan-European level, although the breakdown per country shows differences.

0.7 The TYNDP 2014 confirms and enriches the key findings of the TYNDP 2012

The TYNDP 2012 analysed the first steps towards an energy transition by 2020 characterised by large increases in RES development. The TYNDP 2014 confirms and completes these trends identified in 2012 through to 2030. The key findings of TYNDP 2014 are summed up below.

The €150 billion grid expansion proposed by the TYNDP 2014 brings significant positive economic and environmental impact. The enhanced market integration will reduce bulk power prices by 2 to 5 €/MWh, enable the mitigation of 20% of power sector CO2 emissions by 2030 and enable the expected major shift in the generation pattern due to increase in RES. This will be achieved with only a limited percentage of the proposed projects (<10%) crossing protected and urbanised areas. More details are provided below.

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0.7.1 RES development is the major driver for grid development until 2030

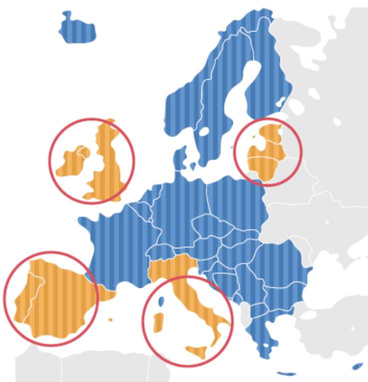
The generation fleet will experience a major shift by 2030, with the replacement of much of the existing capacities with new ones, most likely located differently and farther from load centres, and involving high RES development. **This transformation of the generation infrastructure is the major challenge for the high voltage grid**, which must be adapted accordingly.

Local smart grid development will help to increase energy efficiency and improve local balance between generation and load. Nevertheless, ENTSO-E forecasts **larger, more volatile power flows, over larger distances across Europe**; mostly North-South driven by this energy transition, characterized by the increasing importance of RES development. The power flows are therefore very large in Vision 3 and 4.

The vast majority of the proposed investments address RES integration issues, either where direct connection of RES is required, or because the network section or corridor is a key-hole between RES and load centres.

Projects of pan-European significance help avoid 30 to 100 TWh of RES spillage globally, reducing it to less than 1% of the total supply. Liquidity in power markets will thus be enhanced, thereby limiting the volatility of prices.

0.7.2 About 100 major investment needs



The TYNDP 2014 explores the evolution of the electricity system until 2030 in order to identify potential system development issues and to be able to address these proactively.

The TYNDP 2014 pinpoints about 100 spots on the European grid where bottlenecks exist or may develop in the future if reinforcement solutions are not implemented. The magnitude of the power flows across these sections of the grid essentially increases from Vision 1 to Vision 4, matching the higher RES development.

The most critical area of concern is the stronger market integration to mainland Europe of the four main "electric peninsulas" in Europe. The Baltic States have a specific security of supply issue, requiring a stronger interconnection with other EU countries. Spain with Portugal, Ireland with Great Britain, and Italy show a similar pattern. These are all large systems (50-70 GW peak load) supplying densely populated areas with high RES development prospects, and as such, they require increasing interconnection capacity to enable the development of wind and solar generation.

Transporting the power generated along the shores of the North Sea to major load centres in the respective coastal states also triggers a significant investment need by 2030.

The scope of the TYNDP methodology would need to be widened considerably to fully analyse the benefits of grid investments regarding security of supply. Through the construction of the scenarios, the four Visions assume that generation is sufficient to balance load in all countries, i.e. addressing at a macroscopic level, security of supply concerns. In case the assumed generation mix develops more slowly, tensions may appear on the power supply, but this intermediary period is still to be investigated and the corresponding hedging benefits of transmission projects is not measured here.

Additionally, a project may well be critical to ensure security of supply locally, but the TYNDP focuses specifically on the pan-European level. As a result, security of supply may not always be reported as a primary driver for some projects of pan-European significance included in the TYNDP. An example is the North-South transmission corridors within Germany, which do deliver local security of supply benefits.

0.7.3 Interconnection capacity must double on average throughout Europe

Driven by RES development concentrated at a distance from load centres, and allowing for the required market integration, interconnection capacities should double on average by 2030. Discrepancies are however high between the different countries and Visions.

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In particular, capacity between the Iberian Peninsula and mainland Europe should increase from 1 GW to more than 10 GW in Vision 4 compared to the 2013 situation, whilst the interconnection capacity between the three Baltic States and their EU neighbours is predicted to multiply by three in all Visions. Between Ireland, Great Britain and the continent, the present 3 GW capacity is also expected to increase, at least doubling in Vision 1 and possibly multiplying by more than three in Vision 3 and Vision 4 for higher RES integration. In line future editions of the TYNDP will consider, and mention, the European Council and European Commission conclusions, for instance regarding specific quantitative targets for interconnection capacity which will be decided by the European Institutions.

0.7.4 Investment needs call for appropriate grid reinforcement solutions, adapted to each specific situation

To successfully deliver all investment needs, TSOs have proposed appropriate grid reinforcement solutions adapted to each specific situation.

The complete grid modelling enables an accurate appraisal of every bottleneck and allows the design of the most appropriate solution. As a result, a large range of available technologies is implemented. In about 10 %% of cases, the upgrade of existing overhead lines should prove sufficient to achieve the required capacity increase, with a limited impact on crossed areas.

Conversely, DC technology is required for over-sea connections. In certain limited situations, DC technology is also resorted to onshore, or to transport large amounts of energy through new interconnection corridors. These DC lines set new operating challenges that TSOs are currently analysing, to deliver both the safe operation of parallel AC and DC assets, and to coordinate and optimise the use of several DC links to create an offshore grid across the Northern seas.

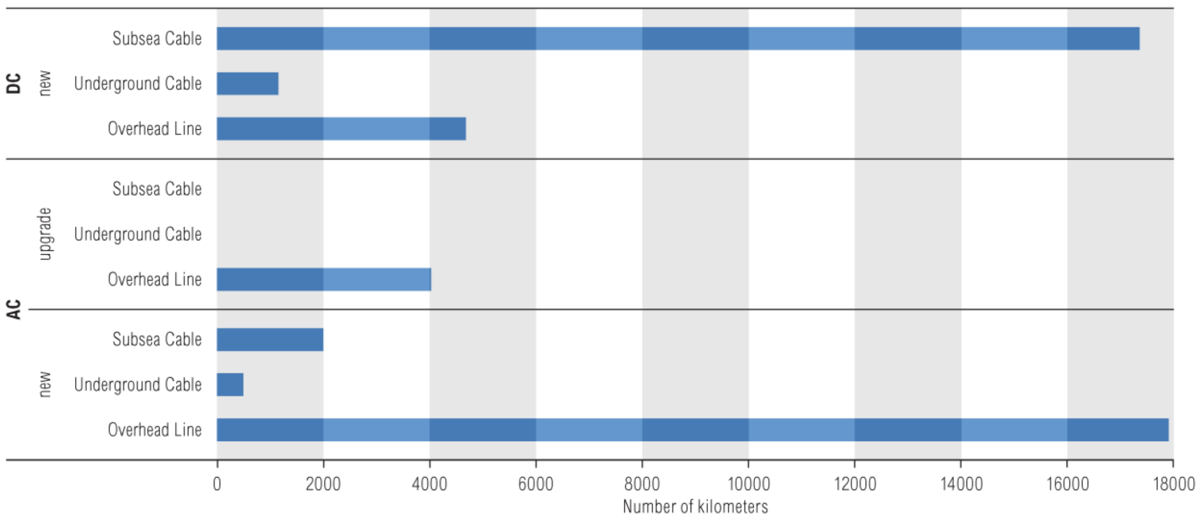

Figure 0-3 TYNDP 2014 investment portfolio - breakdown per technology

Project designs are thus built on cutting-edge technologies, some of which are demonstrators of new technology and world firsts. For instance, the largest DC VSC equipment, the longest AC cable route, DC and AC parallel operation, etc. In addition to the proposed extra high voltage investments, TSOs also actively contribute to the development of smart grids[3]: the latest electronic tools and IT systems, which help optimise the operation of existing assets, in particular to monitor, forecast and control distributed RES and load management.

0.7.5 €150 billion of investment by 2030, with a positive effect on European social economic welfare

Total investment costs for the portfolio of projects of pan-European significance amount to approximately €150 billion, of which €50 billion relates to subsea cables.

These figures are in line with the previous TYNDP 2012, although the horizon has shifted from 2020 to 2030. (These projects of pan-European significance must also however be complemented at regional or national levels to achieve overall consistent development of the entire energy system.)

This effort represents very significant financial engagement for TSOs. However, it only represents about 1.5-2 €/MWh of power consumption in Europe, i.e. about 2% of the bulk power prices or approximately 1% of the total electricity bill.

Meanwhile, through the implementation of projects of pan-European significance, the increased market integration leads to an overall levelling of electricity prices in Europe, **mitigating electricity prices on average from 2 (in Vision 1) to 5 €/MWh (in Vision 4).**

Investing in the project portfolio generally represents a payback after 20 years in the worst-case scenario.

0.7.6 The project portfolio has a positive environmental impact

The electricity grid has an indirect, but essential positive effect on CO2 emissions as it is a prerequisite to the implementation of clean generation technologies. By either directly connecting RES, avoiding spillage or enabling more climate-friendly units to run, **the TYNDP project portfolio contributes directly to approximately 20% of the CO2 decrease by 2030**.

Grid extensions foreseen in the TYNDP represent an increase in the total network length of 1%/yr. This figure is relatively low when compared to the 3% to 5%/yr generation capacity growth rate. Moreover, one third of these new grid assets are subsea and about 10% are upgrades of existing equipment.

TSOs optimise the routes to avoid interference with urbanised or protected areas as much as possible. In densely populated countries or where a significant share of the land is protected, such as Belgium or Germany, this presents a real challenge. Globally however, the **cross-urbanised (resp. protected) areas of TYNDP projects account for less than 4% (resp. 10%) of the total routes**, i.e. less than 2000 km (resp. 4000 km).

Transmission losses are not expected to vary significantly in the coming 15 years with the implementation of the TYNDP, as multiple effects will neutralise each other. On the one hand, building new transmission facilities or shifting voltage levels upwards reduces the overall resistance of the network; and on the other hand, the relocation of generation facilities further from load centres, specifically for wind or hydro energy, increases the transmission distance.

Projects of pan-European significance are hence key to making the European energy transition possible, with a positive impact on the environment and minimum residual effect.

[3] See ENTSO-E R&D Plan

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0.7.7 The resilience of the project portfolio opens a large choice of options to fulfil European energy policy goals

Thousands of market situations considering all hazards that may affect the power system have been simulated and processed for the TYNDP 2014. Both frequent and rare situations, resulting in particularly extreme flow patterns, were then identified for further analysis in order to test the grid's ability to withstand these and define if necessary, required rectification measures. Typical situations are peak loads in winter or summer, with extreme but likely low or high wind/solar generation.

These thorough investigations were carried out for all four contrasting Visions up to 2030.

Thus, TSOs can ensure the proposed investments are well adapted and robust. The previously proposed grid investments from the TYNDP 2012 remain valid; the only exceptions are a small number projects that were in a very early phase in 2012 that have since proved technically unfeasible, and so have been substituted with other prospects.

The proposed projects reflect most of the investment needs. Conversely, some additional reinforcements to cover investment needs specific to the most ambitious scenarios of RES development by 2030 are yet to be designed.

The set of projects of pan-European significance is still to be completed in order to meet the energy revolution proposed in Vision 4. Validated only in October 2013, Vision 4 could be used only to assess the portfolio of already identified projects. Investigation of investment needs in this Vision requires additional input and feedback from stakeholders (notably, more precise location of generation) so that a more comprehensive picture of the grid infrastructure can be supplied.

Such interaction and continuous adaptation is normal, considering uncertainties regarding the realisation of the challenging transformation of the generation mix or the interconnection of Europe with Africa or Russia. The following map summarises the situation in this respect: the boundaries where the project portfolio is sufficient to cover the target capacity in all Visions are shown in green, those in no Vision are in red, and others are in orange.

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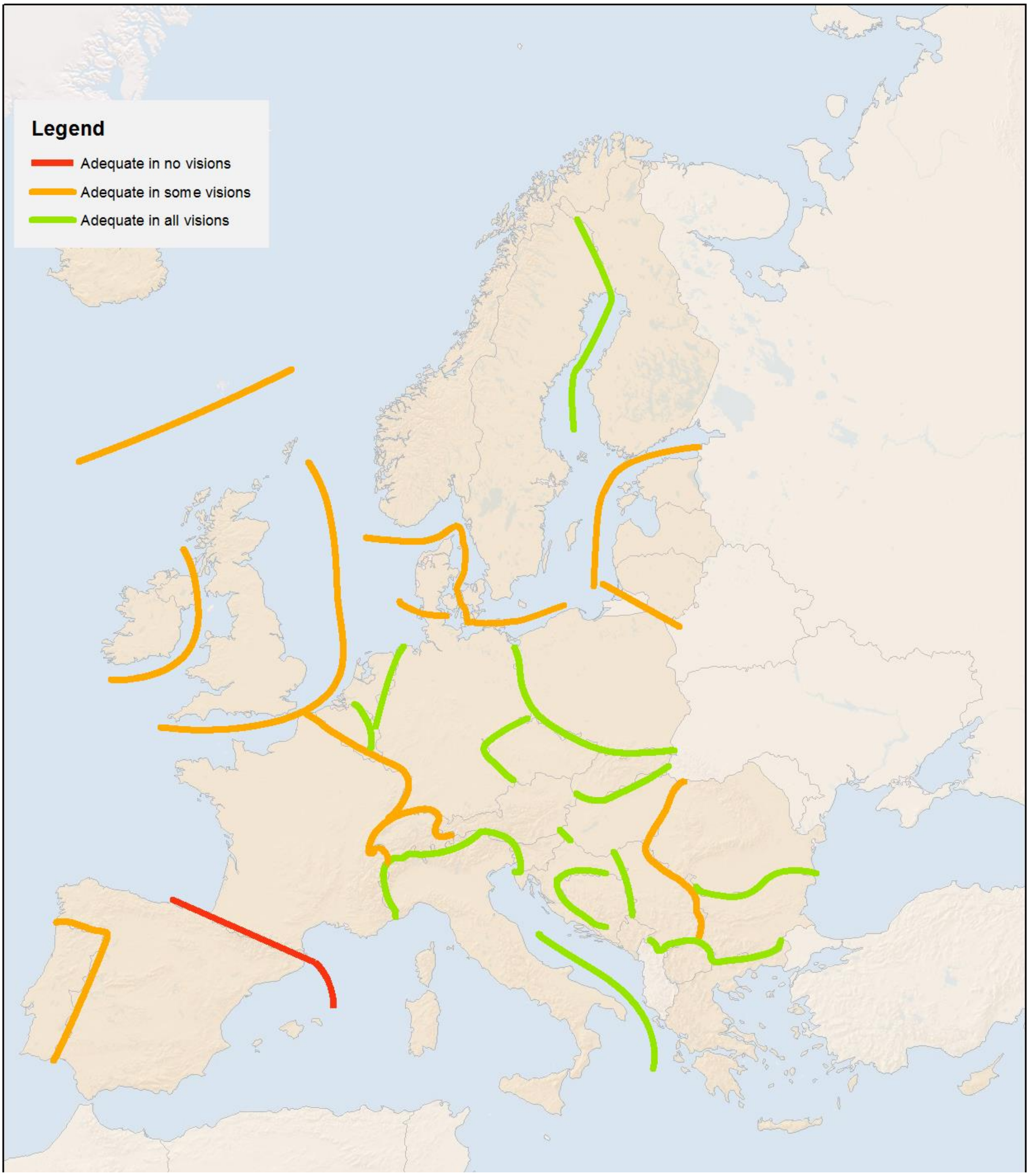

Figure 0-4 Transmission adequacy by 2030

Where boundaries are orange or red, the Plan may require additional development. However, all the listed projects are prerequisite and in this respect, the project portfolio shows strong resilience. **The TYNDP thus paves the way for the implementation of the 2050 European energy goals.**

It should be noted that the present project assessment refers predominantly to steady state analyses. Dynamic system behaviour under severe contingencies (particularly frequency stability) may be subject to complementary studies. Larger, more volatile over longer distances transit flows will trigger new technical challenges regarding system operation (frequency control, reserve management, voltage control...).

0.8 The preparation of the TYNDP 2016 is already underway

0.8.1 Through the TYNDP 2014, ENTSO-E supports the EIP implementation

With the late finalisation of the scenarios, the CBA methodology and non-ENTSO-E member project submissions in Q3 2013, completing the TYNDP 2014 for consultation by summer 2014 was a challenge. The timely delivery of the TYNDP 2014 is awaited as an important input to the EIP process: with a systematic assessment now available for all transmission and storage PCIs, in time for the elaboration of the second PCI list in 2015.

0.8.2 The TYNDP methodology continues to evolve and improve

For future TYNDPs and assessments, **ENTSO-E and all interested stakeholders will continue the evolution of the CBA to better match the needs of decision makers.**

In particular, it is foreseen that the current methodology be improved with respect to the so-called "capacity" value of assets (compared to the "energy" value). Storage projects in particular, bring great capacity and flexibility to the power system, and this will be better reflected in future assessments.

Additionally, as mentioned above, the larger transit flows that are more volatile over longer distances will trigger new technical challenges regarding system operation (frequency control, reserve management, voltage control, etc.). New dynamic operating concerns will thus require specific studies to anticipate potential risks.

Finally, the TYNDP 2016 will continue to build on the findings of the e-Highways project led by ENTSO-E, further depicting the path to the 2050 master plan.

0.9 Successful energy transition requires the grid, and the grid requires everyone's support

A major challenge is that grid development may not be completed in time to meet the planned RES target requirements by 2030. At present, many stakeholders support grid development to facilitate the changes within the energy system; while those stakeholders directly impacted by proximity to new lines or new plants show a lower level of acceptance for the new infrastructure. **This lack of acceptance, in addition to lengthy permit granting procedures regularly result in commissioning delays**. Most of the projects featured in the TYNDP 2014 that have entered the permitting process have thus experienced delays.

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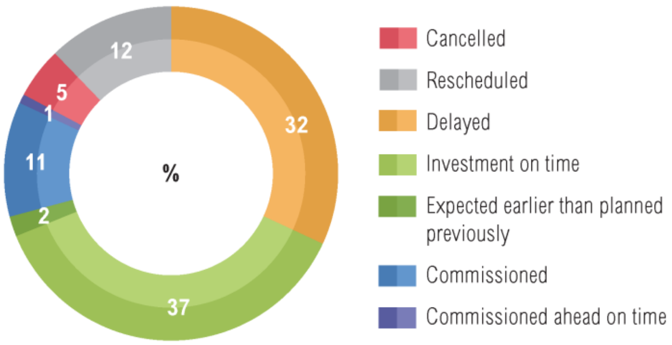

If energy and climate objectives are to be achieved, it is of utmost importance to smooth authorisation processes and gain active political support on all levels. In this respect, ENTSO-E welcomes Regulation 347/2013, which features many positive elements regarding the permitting process, which will facilitate the fast tracking of transmission infrastructure projects, including proposals on one-stop-shops and defined timelines.

More thorough analysis is however required to ensure the measure can be successfully implemented, in particular in relation to whether the timelines proposed are achievable, notably in the context of the public participation process and the potential for legal delays. It is also important to note that the supporting schemes are limited to the Projects of Common Interest, while there are many significant national transmission projects, which are equally crucial to the achievement of Europe's targets for climate change, renewable energy and market integration.

Finally, a stable regulatory framework is also essential to ensure that grid reinforcement is completed on time. Although grid projects prove beneficial for the European community as a whole, with a net reduction of the power supply costs, they represent large investments and financing still remains an issue for TSOs in times of limited public finances. Thus, securing investment plans is key for success.

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1 Introduction

1.1 ENTSO-E compiles a vision for grid development: the TYNDP package 2014

The European Network of Transmission System Operators for Electricity (ENTSO-E) provides herewith the 2014 release of the Community-wide Ten-Year Network Development Plan (TYNDP).

The objectives of the TYNDP are to ensure transparency regarding the electricity transmission network and to support decision-making processes at the regional and European level. This pan-European report and the appended Regional Investment Plans (RgIPs) form the most comprehensive and up-to-date European-wide reference for the transmission network. They point to significant investments in the European power grid in order to help achieve the European energy policy goals.

Since the 2012 release, ENTSO-E supplies a TYNDP "package", a group of documents consisting of the following:

- the present Community-wide TYNDP report 2014
- the six Regional Investment Plans 2014; and
- the Scenario Outlook and Adequacy Forecast (SOAF) 2014.

Collectively, these documents present information of European importance. They complement each other, with only limited repetition of information between documents when necessary to ensure they are all sufficiently self-supported. Scenarios are comprehensively depicted in the SOAF, investments needs and projects of European importance are comprehensively depicted in the Regional Investment Plans, whilst the Community-wide TYNDP only reports synthetic information regarding concerns and projects of pan-European significance. ENTSO-E hopes to meet the various expectations of their stakeholders, leading to grid development and detailed perspectives at the same time.

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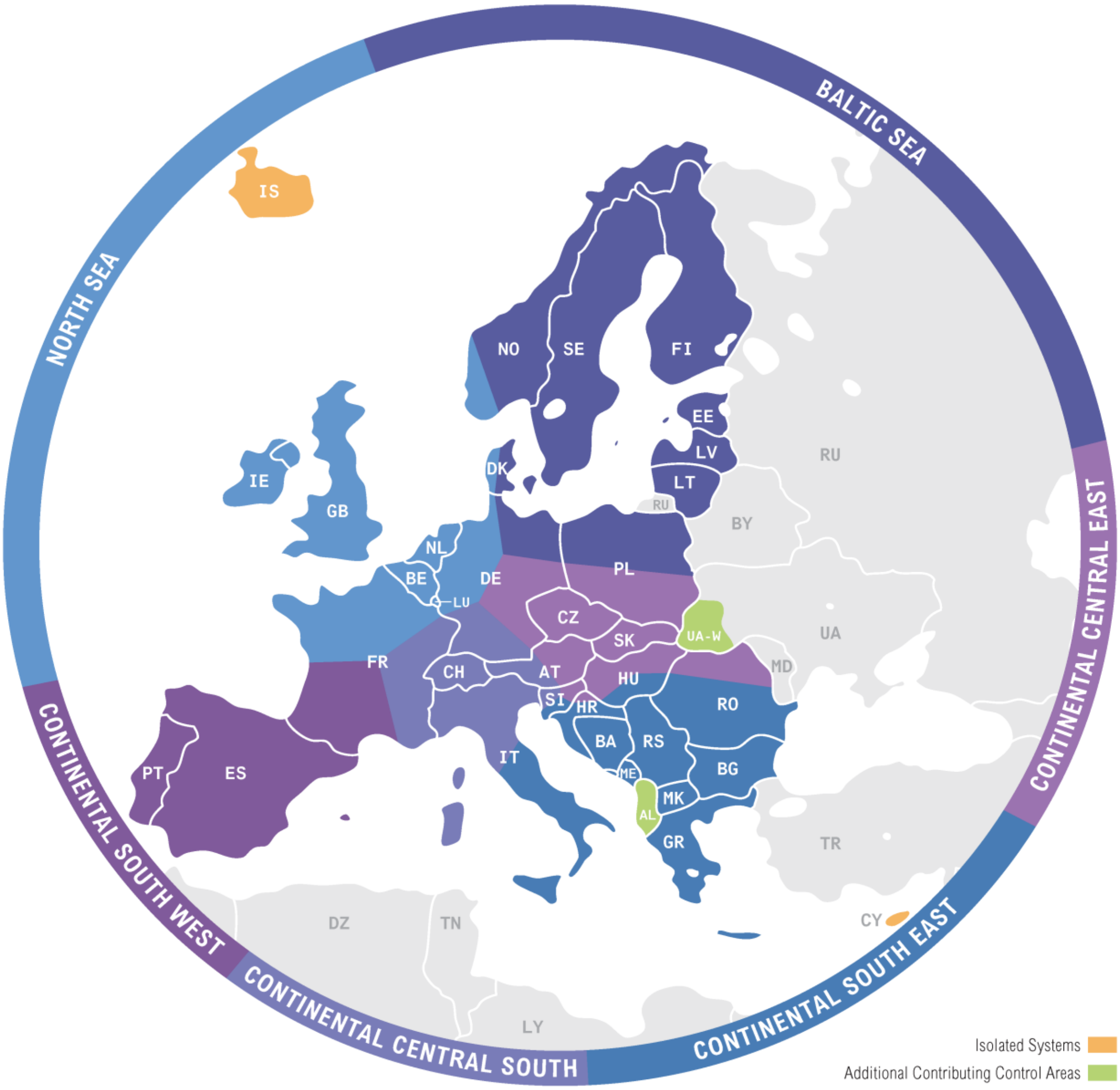


Figure 1-1 ENTSO-E System Development Regions

ENTSO-E cannot be held liable for any inaccurate or incomplete information received from third parties or for any resulting misled assessment results based on such information.

The TYNDP 2014 package was consulted during summer 2014 in order to be finalised in December 2014.

1.2 Regulation EC 347/2013 sets a new role for the TYNDP

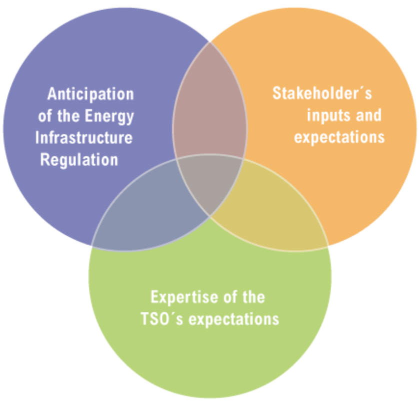
The present publication complies with the requirements of Regulation EC 714/2009 (the Regulation), in force since March 2011, whereby "ENTSO-E shall adopt a non-binding Community-wide 10 Year Network Development Plan, including a European generation adequacy outlook, every two years".

The Regulation set forth that the TYNDP must "build upon national investment plans" (the consistency of which is monitored by the Agency for the Cooperation of Energy Regulators, ACER), "and if appropriate the guidelines for trans-European energy networks". In addition, it must "build on the reasonable needs of different system users". Finally, the TYNDP must "identify investment gaps, notably with respect to cross-border capacities".

The present TYNDP package has also pre-empted the implementation of Regulation EC 347/2013 (the **Energy Infrastructure Regulation**), in force since April 2013 and normally applying to the TYNDP 2016. **This regulation** organises a new framework to foster transmission grid development in Europe. Regulation EC 347/2013 defines the status of **Projects of Common Interest** (PCIs), foresees various supporting tools to support the realisation of PCIs, and establishes the **TYNDP the sole basis for identifying and assessing the PCIs** according to a standard **Cost Benefit Analysis** (CBA) methodology.

The TYNDP is therefore not only a framework for planning the European grid and supplying a long-term vision; it now also serves as the assessment of every PCI candidate, whatever their commissioning time. The preparation of the TYNDP will be even more demanding as these are two different, although complementary goals and additional resources are required.

1.3 A top-down, open and constantly improving process



The first Ten-Year Network Development Plan was published by ENTSO-E on a voluntary basis in spring 2010, in anticipation of Directive 72/2009 and Regulation 714/2009. The 2012 release built on this experience and the feedback received from stakeholders, proposing the first draft of a systematic CBA. For the 2014 release, ENTSO-E has launched a large project founded on three main pillars: **the inputs and expectations from their stakeholders; the anticipation of the Energy Infrastructure Regulation; and the expertise of the TSOs**, Members of ENTSO-E.

In the last two years, ENTSO-E has organised exchanges with stakeholders at four levels to ensure transparency as much as possible:

- Public workshops and consultations[4]: non-specific conferences and events to which ENTSO-E had been invited, 17 dedicated workshops, organized by ENTSO-E and its members in Brussels or regionally, and 6 consultations paved the construction of the scenarios (the so-called "Visions"), the preparation of the CBA methodology and the production of the first results and project assessments. The last consultation on scenarios was concluded in October 2013.

[4] https://www.entsoe.eu/major-projects/ten-year-network-development-plan/tyndp-2014/stakeholder-interaction/

- A "Long-Term Network Development Stakeholders Group"[5], gathering 15 members, designed to debate and finalise the methodology (scenarios, CBA) improvements, either regarding the TYNDP itself or grid development more generally. The group contributed in particular to refining the social and environmental indicators of the CBA and rethinking the basis for more transparent scenario development.
- A non-discriminatory framework enabling non-ENTSO-E Members to submit transmission and storage project candidates for assessment. Two submission windows were opened officially in February and September 2013.
- Dedicated bilateral meetings, especially with DG Energy, ACER and market players also contributed by sharing concerns, jointly developing more and more harmonised methodologies and agreeing on the expected outcomes of the process.

The preparation of the TYNDP 2014 was a bigger challenge as **ENTSO-E decided to anticipate the implementation of the Energy Infrastructure Regulation** and support DG Energy in beginning its implementation:

- ENTSO-E started drafting and consulting the CBA methodology in 2012 and has tested it throughout the whole TYNDP 2014 portfolio, even before the validation of the CBA methodology end 2014. The CBA is implemented in the TYNDP 2014 for four 2030 Visions. This choice has been made based on stakeholder feedback, preferring a large scope of contrasting scenarios instead of a more limited number and an intermediate horizon of 2020.
- ENTSO-E invited non-ENTSO-E Members to submit transmission and storage project candidates for assessment, with the latest submission window in September 2013.
- ENTSO-E included an assessment of storage projects in the TYNDP 2014 in addition to Transmission projects.

In a volatile environment, the TYNDP and its methodology are bound to evolve. ENTSO-E targets a regular delivery of an enhanced product every two years, introducing methodology improvements to ensure timely and consistent results, and achieving efficiency rather than aiming at perfection. The following chart sums up the TYNDP evolution since 2010:

[5] https://www.entsoe.eu/major-projects/ten-year-network-development-plan/tyndp-2014/long-term-network-development-stakeholder-group/

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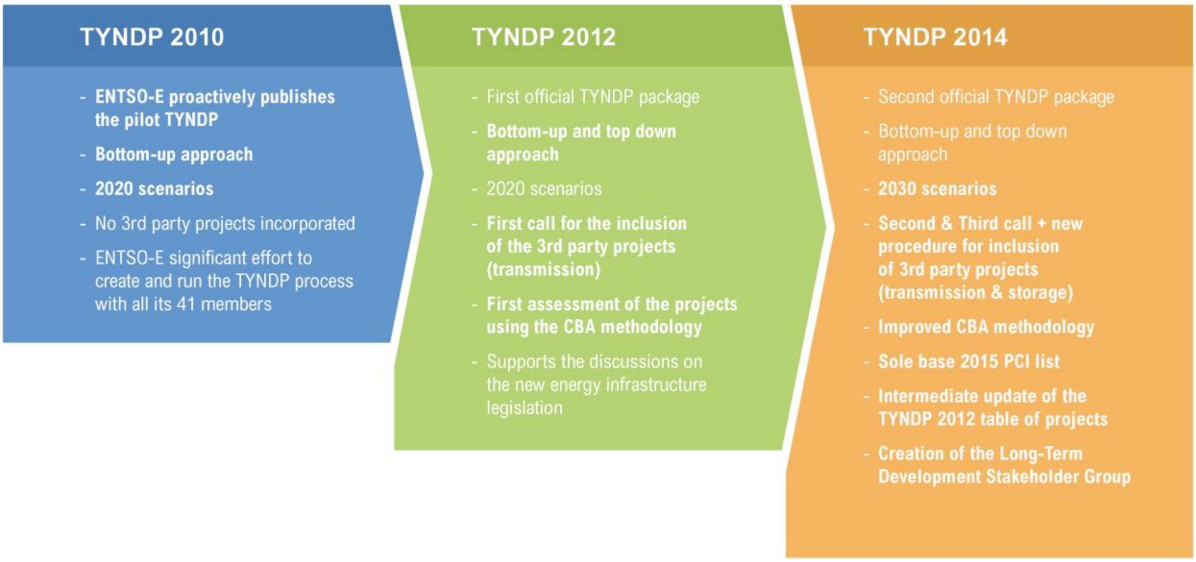

Figure 1-2 Overview of the TYNDP development over the versions

1.4 How to read the TYNDP 2014 report

The document is structured in the following way:

- Chapter 0: Executive summary.
- Chapter 1: The present Introduction.
- Chapter 2: The methodology, which describes the overall process and specific methods used to elaborate the TYNDP 2014 package. (Regional parameters used to apply the methodology, as the case may be, or specific regional outlooks are presented in the Regional Investment Plans.)
- Chapter 3: Scenarios, which gives a synthetic overview of the basic scenarios underlying the present TYNDP (A detailed description of the scenarios and the generation adequacy forecast is provided in the SOAF 2014 report).
- Chapter 4: Investment needs, which details the evolution of the European grid capacity from the present situation, highlighting the drivers of grid development, locations of grid bottlenecks and bulk power flows across these bottlenecks.
- Chapter 5: The projects portfolio, which presents a synthetic overview of all planned projects of pan-European significance (The technical details of the projects are in Appendix 1, see also the Regional Investment Plans).
- Chapter 6: Transmission adequacy, which illustrates the adequacy of the project portfolio towards the target capacities set across the boundaries in the 2030 Visions.
- Chapter 7: Environmental concerns, which sums up the environmental impact of the planned projects.
- Chapter 8: Assessment of resilience.
- Chapter 9: Assessment of TYNDP 2012, which points out the main changes that have occurred with respect to the investments presented in the TYNDP 2012 submission.

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- Chapter 10: Conclusion.
- Appendix 1: Sums up all the information regarding projects of pan-European significance. ‘Transmission’ PCIs are specifically marked and can be easily located thanks to a specific correspondence table. ‘Storage’ PCIs are grouped in a separate list. ‘Smart grid’ PCIs are also recalled in a separate list (but are not subject to assessment in the TYNDP).
- Appendix 2: Supplies the definition of key-concepts and a glossary.
- Appendix 3: Describes the CBA methodology[6].
- Appendix 4: Sums up the state of the art regarding transmission technologies.
- Appendix 5: Deals with the new dynamic concerns to address in order to secure the energy transition.
- Appendix 6: Sums up the status of the E-Highways project.
- Appendix 7: Focuses on the best practices to mitigate the environmental impacts of the high grid development projects.
- Appendix 8: List the main abbreviations used.

[6] More information on the CBA methodology (e.g. FAQ) can be accessed here: www.entsoe.eu

2 Methodology and Assumptions

2.1 General overview of the TYNDP 2014 process

ENTSO-E has taken into account stakeholder feedback from the previous TYNDP releases and developed an enhanced methodology for TYNDP 2014. The process was developed with input from all of the regional groups and working groups involved in the TYNDP, whilst also ensuring equal treatment for TSO projects and third party projects.

This chapter outlines the TYNDP macro-process, including methodological improvements developed for the 2014 edition of the TYNDP. The improvements are deemed necessary in order to ensure compliance with the implementation of the Energy Infrastructure Package (Regulation (EU) No 347/2013), which was enacted in 2013 and formalised the role of the TYNDP in the Project of Common Interest selection process.

Figure 2-1 provides an overview of the TYNDP 2014 process; the stars represent stakeholder workshops held during this two-year process.

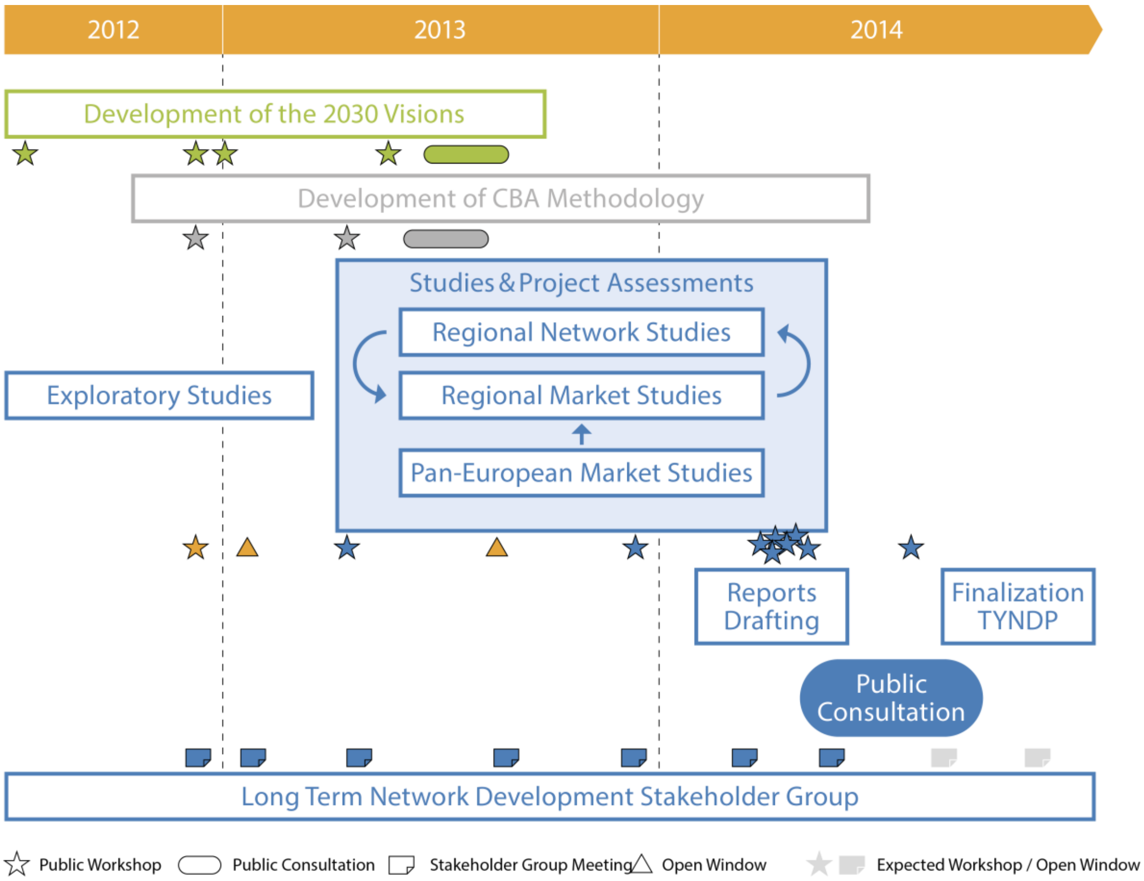

Figure 2-1 Overview of the TYNDP 2014 process

2.1.1 Scenarios to encompass all possible futures

The TYNDP 2014 analysis is based on an extensive exploration of the 2030 horizon. The year 2030 is used as a bridge between the European energy targets for 2020 and 2050. This choice has been made based on stakeholder feedback, preferring a large scope of contrasted longer-run scenarios instead of a more limited number and an intermediate horizon of 2020.

The 2014 version of the TYNDP covers four scenarios, known as the 2030 Visions. The 2030 Visions were developed by ENTSO-E in collaboration with stakeholders through the Long-Term Network Development Stakeholder Group, multiple workshops and public consultations.

The Visions are contrasted in order to cover every possible development foreseen by stakeholders. The Visions are less forecasts of the future than selected possible extremes of the future so that the pathway realised in the future falls with a high level of certainty in the range described by the Visions. The span of the four Visions is large and meets the various expectations of stakeholders. They differ mainly with respect to:

- The trajectory toward the Energy roadmap 2050: Visions 3 and 4 maintain a regular pace from now until 2050, whereas Visions 1 and 2 assume a slower start before an acceleration after 2030. Fuel and CO2 price are in favour of coal in Visions 1 and 2 while gas is favoured in Visions 3 and 4.
- The consistency of the generation mix development strategy: Visions 1 and 3 build from the bottom-up for each country's energy policy with common guidelines; Visions 2 and 4 assume a top-down approach, with a more harmonised European integration.

The 2030 visions are further developed in the SOAF report and chapter 3 of the present report.

2.1.2 A joint exploration of the future

Compared to the TYNDP 2012, the TYNDP 2014 is built to cover a longer-term horizon which 41 TSOs in the framework of the six Regional Groups have jointly explored both during the exploratory studies prior to the assessment phase.

The objectives of the exploratory studies are to establish the main flow patterns and indicate the subsequent investment needs. When applicable, the exploratory phase resulted in the proposal of new projects, with further justification based on the CBA assessment in the TYNDP 2014.

With the validation of Vision 4 in October 2013, further investigation may be necessary to devise appropriate reinforcement solutions to the investment needs identified in the studies. More information on the investment needs can be found in Chapter 4.

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2.1.3 A complex process articulating several studies in a two-year timeframe

The articulation of the studies performed within the framework of TYNDP 2014 to assess projects are described in Figure 2-2 and in the following section.

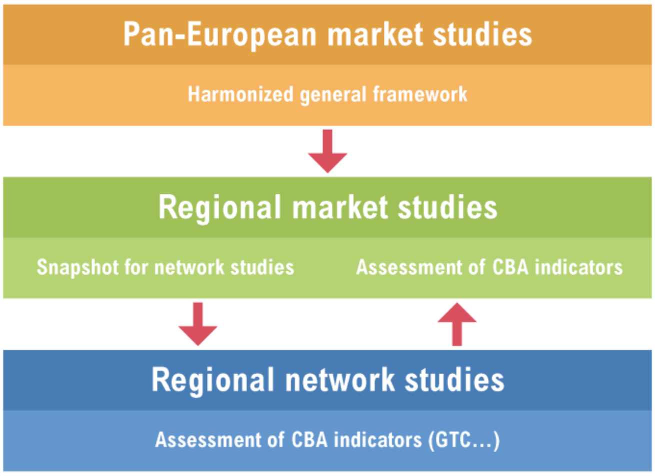

Figure 2-2 An iterative process towards the preparation of TYNDP 2014

Pan-European market studies have been introduced in the TYNDP 2014 process to improve both the scenario building and the assessment of projects. These studies, performed jointly by a group of TSOs experts from all regional groups, are set-up to both:

- define parameters and datasets necessary to perform the market simulation based on the four 2030 Visions developed.
- provide the boundary conditions for the regional market studies necessary to ensure a consistent and harmonised framework for the regional assessment of the projects with the CBA methodology.

More details on the modelling and the tools used can be found in sections 2.3 and 2.4 of the report.

Building on the common framework set by the pan-European market studies, every Regional Group undertook more detailed **regional market and network studies** in order to explore every Vision and perform the CBA assessment of the TYNDP 2014 projects:

- Regional market studies deliver bulk power flows and pinpoint which specific cases need to be further studied via network studies; they also deliver the economic part of the CBA assessment.
- Regional network studies analyse exactly how the grid handles the various cases of generation dispatch identified during the previous step and deliver the technical part of the CBA assessment.

Further details on the methodology of the regional studies can be found in each Regional Investment Plan.

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2.1.4 A TYNDP 2014 built with active involvement from stakeholders

As mentioned in the introduction chapter of the report, ENTSO-E has improved the process of the TYNDP in order to include, in every phase, interactions with stakeholders. These are key in the process because of the TYNDP's increased relevance in the European energy industry and the need to enhance common understanding about the transmission infrastructure in Europe. ENTSO-E organised six public web-consultations and requests for input as well as 17 open workshops at the regional and European levels or bilateral meetings:

Table 2-1 Example of stakeholder involvement

Phase of the process	Interactions[7]
Scenario building	4 workshops including requests for inputs + 1 two-month public consultation
Definition of the improved 3rd party procedure	1 workshop
Development of the CBA methodology	2 workshops and 2 two-month public consultation
Call for 3rd party projects	1 workshop and 2 calls during the process (last one in September-October 2013)
Assessment of projects	1 pan-European workshop + 7 Regional workshops
Final consultation	1 two-month public consultation + 1 workshop

ENTSO-E has also launched a **Long-Term Network Development Stakeholders Group** (LTND SG), gathering European organisations and incorporating the major stakeholders of ENTSO-E. As views on the TYNDP, the broader challenges facing the power system and the best methods of addressing those challenges differ across countries and regions, the target is to create an open and transparent environment in which all involved parties can discuss and debate.

A particularly concrete outcome of this cooperation is a specific appraisal of the benefits of the projects with respect to potential spillage from RES generation and the replacement of the former social and environmental indicators by two more specific indicators with respect to the crossing of urbanised areas and protected areas.

The LTND SG also organised a task force to provide recommendations on the involvement of stakeholders in the scenario building for future releases of the TYNDP. The report is published together with the TYNDP 2014 package[8].

[7] All the material from the workshops (agenda, presentations…) can be accessed from ENTSO-E website.
[8] Link to the report.

2.2 Implementation of Cost Benefit Analysis (CBA)

The prospect of climate change combined with other factors such as the phase-out of power plants due to age or environmental issues has lead to a major shift in the generation mix and means that the energy sector in Europe is undergoing major changes. All these evolutions trigger grid development and the growing investment needs are currently reflected both in European TSOs' investment plans and in the ENTSO-E TYNDP.

In this uncertain environment and with huge needs for transmission investment, several options for grid development have arisen. Cost Benefit Analysis, combined with multi-criteria assessment is essential to identify transmission projects that significantly contribute to European energy policies and that are robust enough to provide value for society in a large range of possible future energy projections, while at the same time being efficient in order to minimise costs for consumers. The results of project assessment can also highlight projects which have a particular relevance in terms of achieving core European energy policy targets, such as RES integration or completing the Internal Electricity Market.

Figure 2-3 Scope of the cost benefit analysis (source: THINK project)

ENTSO-E developed the Cost Benefits Analysis Methodology

ENTSO-E developed a multi-criteria assessment methodology in 2011. The methodology was applied for the TYNDP 2012 and detailed in Annex 3 of the TYNDP. The CBA methodology has been developed by ENTSO-E as an update of this methodology, in compliance with Regulation (EU) 347/2013. It takes into account the comments received by ENTSO-E during public consultation and includes the outcome of an extensive consultation process through bilateral meetings with stakeholder organisations, continuous interactions with a Long-Term Network Development Stakeholder Group, the report on target CBA methodology prepared by the THINK consortium, several public workshops and direct interactions with ACER, the European Commission and Member States.

The CBA methodology takes into account the comments received by ENTSO-E during the public consultation of the “Guideline for Cost Benefit Analysis of Grid Development Projects – Update 12 June 2013”. This consultation was organised between 03 July and 15 September 2013 in an open and transparent manner, in compliance with Article 11 of Regulation (EU) 347/2013.

More information can be found in the following chapter on the CBA and its implementation in the TYNDP 2014.

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2.2.1 Scope of Cost Benefit Analysis

Regulation (EU) No 347/2013, in force since 15 May 2013, aims to ensure strategic energy networks[9] by 2020. To this end, the Regulation proposes a regime of "common interest" for trans-European transmission grid projects contributing to implementing these priority projects (Projects of Common Interest; PCIs), and entrusts ENTSO-E with the responsibility of establishing a cost benefit methodology[10] with the following goals:

- System wide cost benefit analysis, allowing a homogenous assessment of all TYNDP projects;
- Assessment of candidate Projects of Common Interest.

The system wide Cost Benefit Analysis methodology is an update of ENTSO-E's Guidelines for Grid Development intended to allow an evaluation of all TYNDP projects in a homogenous way. Based on the requirements defined in the Reg. (EU) No 347/201311, ENTSO-E has defined a robust and consistent CBA methodology to apply to future TYNDP project assessments. This CBA methodology has been adopted by each ENTSO-E Regional Group, which have responsibility for pan-European development project assessments.

The CBA describes the common principles and procedures, including network and market modelling methodologies, to be used when identifying transmission projects and for measuring each of the cost and benefit indicators in a multi-criteria analysis in view of elaborating Regional Investment Plans and the Community-wide TYNDP. In order to ensure a full assessment of all transmission benefits, some of the indicators are monetised (inner ring of Figure 2-3), while others are measured through physical units such as tons or kWh (outer ring of Figure 2-3).

This set of common indicators forms a complete and solid basis both for project evaluation within the TYNDP and for the PCI selection process. With a multi-criteria approach, the projects can be ranked by the Member States in the groups foreseen by Regulation 347/2013. Art 4.2.4 states: « each Group shall determine its assessment method on the basis of the aggregated contribution to the criteria […] this assessment shall lead to a ranking of projects for internal use of the Group. Neither the regional list nor the Union list shall contain any ranking, nor shall the ranking be used for any subsequent purpose ».

The CBA assesses both electricity transmission and storage projects.

2.2.2 A multicriteria assessment

The cost benefit analysis framework is a multi-criteria assessment, complying with Article 11 and Annexes IV and V of Regulation (EU) 347/2013.

The criteria set out in this document have been selected on the following basis:

- To enable an appreciation of project benefits in terms of EU network objectives.
- To ensure the development of a single European grid to permit the EU climate policy and sustainability objectives (RES, energy efficiency, CO_2).
- To guarantee security of supply.

9 Recital 20, Regulation (EU) 347/2013 : http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:115:0039:0075:EN:PDF
10 Article 11, Regulation (EU) 347/2013
11 Reg. (EU) 347/2013, Annexes IV and V

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- To complete the internal energy market, especially through a contribution to increased socio-economic welfare.
- To ensure the technical resilience of the system.
- To provide a measurement of project costs and feasibility (especially environmental and social viability).

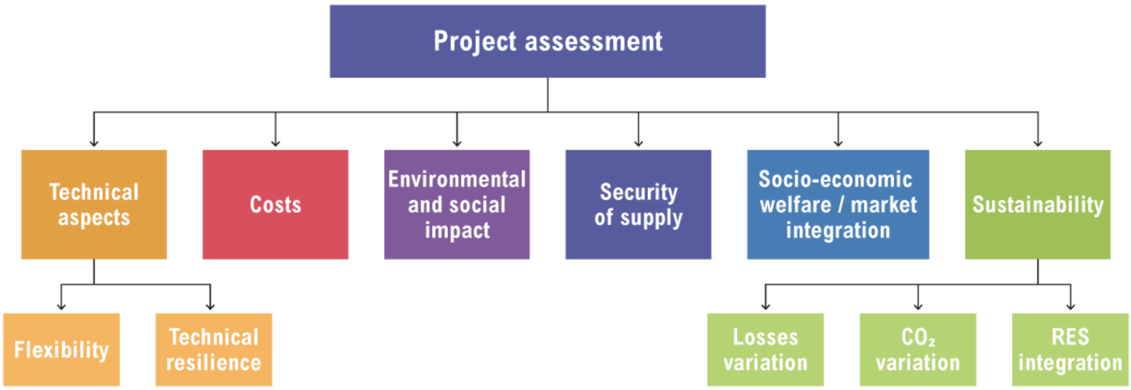

Figure 2-4 Main categories of the project assessment methodology

The indicators used are as simple and robust as possible. This leads to simplified methodologies for some indicators. Some projects will provide all the benefit categories, whereas other projects will only contribute significantly to one or two of them. Other benefits also exist such as the benefit of competition; these are more difficult to model and will not be explicitly taken into account.

The different criteria are explained below, grouped by Benefits, Cost, impact on surrounding areas and Grid Transfer Capability.

The **Benefit Categories** are defined as follows:

B1. Improved security of supply[12] (SoS) is the ability of a power system to provide an adequate and secure supply of electricity under ordinary conditions[13].

[12] Adequacy measures the ability of a power system to supply demand in full, at the current state of network availability; the power system can be said to be in an N-0 state. Security measures the ability of a power system to meet demand in full and to continue to do so under all credible contingencies of single transmission faults; such a system is said to be N-1 secure.

[13] This category covers criteria 2b of Annex IV of the EU Regulation 347/2013, namely "secure system operation and interoperability".

B2. Socio-economic welfare (SEW)[14] or market integration is characterised by the ability of a power system to reduce congestion and thus provide an adequate GTC so that electricity markets can trade power in an economically efficient manner[15].

B3. RES integration: Support for RES integration is defined as the ability of the system to allow the connection of new RES plants and unlock existing and future "green" generation, while also minimising curtailments[16].

B4. Variation in losses in the transmission grid is the characterisation of the evolution of thermal losses in the power system. It is an indicator of energy efficiency[17] and is correlated with SEW.

B5. Variation in CO_2 emissions is the characterisation of the evolution of CO_2 emissions in the power system. It is a consequence of B3 (unlock of generation with lower carbon content)[18].

B6. Technical resilience/system safety is the ability of the system to withstand increasingly extreme system conditions (exceptional contingencies)[19].

B7. Flexibility is the ability of the proposed reinforcement to be adequate in different possible future development paths or scenarios, including trade of balancing services[20].

The **project costs**[21] are defined as follows:

C1. Total project expenditures are based on prices used within each TSO and rough estimates of project consistency (e.g. km of lines).

The **project impact on the surrounding areas** is defined as follows:

S.1. Protected areas characterises the project impact as assessed through preliminary studies, and aims to provide a measure of the environmental sensitivity associated with the project.

S.2. Urbanised areas characterises the project impact on the (local) population that is affected by the project as assessed through preliminary studies, aiming to give a measure of the social sensitivity associated with the project.

These two indicators refer to the remaining impacts after potential mitigation measures defined when the project definition becomes more precise.

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[14] The reduction of congestions is an indicator of social and economic welfare assuming equitable distribution of benefits under the goal of the European Union to develop an integrated market (perfect market assumption).

[15] This category contributes to the criteria 'market integration" set out in Article 4, 2a and to criteria 6b of Annex V, namely "evolution of future generation costs".

[16] This category corresponds to criterion 2a of Article 4, namely "sustainability", and covers criteria 2b of Annex IV.

[17] This category contributes to criterion 6b of Annex V, namely "transmission losses over the technical lifecycle of the project".

[18] This category contributes to the criterion « sustainability » set out in Article 4, 2b and to criteria 6b of Annex V, namely " greenhouse gas emissions"".

[19] This category contributes to the criterion "interoperability and secure system operation" set out in Article 4, 2b and to criteria 2d of Annex IV, as well as to criteria 6b of Annex V, namely "system resilience" (EU Regulation 347/2013).

[20] This category contributes to the criterion "interoperability and secure system operation" set out in Article 4, 2b , and to criteria 2d of Annex IV, as well as to criteria 6e of Annex V, namely "operational flexibility" (idem note 26).

[21] Project costs, as with all other monetised values, are pre-tax.

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The Grid Transfer Capability (GTC) is defined as follows:

The GTC reflects the ability of the grid to transport electricity across a boundary, i.e. from one bidding area (an area within a country or a TSO) to another or within a country, increasing security of supply or generation accommodation capacity.

The GTC is expressed in MW. It depends on the considered state of consumption, generation and exchange, as well as the topology and availability of the grid, and accounts for the safety rules described in the ENTSO-E CBA Methodology document. The Grid Transfer Capability is oriented, which means that there may be two different values across a boundary. A boundary may be fixed (e.g. a border between states or bidding areas), or vary from one horizon or scenario to another.

More details on the CBA methodology are available in Appendix 3.

2.2.3 Implementation of CBA in the TYNDP 2014

The CBA methodology shall be validated by EC by end 2014. ENTSO-E has used the TYNDP 2014 as an opportunity to conduct a real-life test of the methodology in order to be able to tune it if necessary. The implementation of the CBA in this trial phase hence focuses on checking the feasibility of its implementation while also answering actual stakeholder concerns.

Every single indicator has been computed for a large selection of project cases. In this respect, the RES – avoided RES spillage – indicator (resp. the SoS – loss of load expectation – indicator) must be completed in order to get the full picture of the benefits of projects with respect to RES integration or security of supply; projects of pan-European significance may incidentally also be key for indirectly enabling RES connection in an area, although no spillage is entailed resp. to solve local SoS issues. However, the pan-European modelling implied by the CBA is too broad to capture these effects and underestimates the benefits. This is commented in the projects assessments sheets, whenever appropriate.

Projects assessments against four contrasted Visions enable the applicability of the methodology to be tested in markedly different scenarios. The practical implementation shows the importance of finalising the planning phase before running every project assessment.

Performing more than 100 project assessments against four Visions is sufficient to compare the relative values of all projects for all criteria measured, mitigating the need for analysing an intermediate horizon or technically implementing NPV computation.

The CBA clustering rules have been fully implemented, although they proved challenging for complex grid reinforcement strategies. Essentially, a project clusters all investment items that have to be realised in total to achieve a desired effect. Therefore, a project consists of one or a set of various strictly related investments. The CBA rules state:

- Investment items may be clustered as long as their respective commissioning dates do not exceed a difference of five years;
- Each of them contributes to significantly developing the grid transfer capability along a given boundary, i.e. it supports the main investment item in the project by bringing at least 20% of the grid transfer capability developed by the latter.

The largest investment needs (e.g. offshore wind power to load centres in Germany, the Balkan corridor, etc.) may require some 30 investments items, scheduled over more than five years but addressing the same concern. In this case, for the sake of transparency, they are formally presented in a series of smaller projects, each matching the clustering rules, with related assessments; however, an introductory section explains the overall consistency of the bigger picture and how each project contributes to it.

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2.3 Market studies methodology

For every scenario, a market study answers the question "which generation (location/type) is going to serve which demand (location) in any future instant?". Its outcomes are market balances in every country/price zone and in particular generation and exchange patterns ("bulk power flows").

The purpose of the market studies is to investigate the impact of the new interconnection projects by comparing two different grid situations in terms of economic efficiency, the ability of the system to schedule plants to their intrinsic merit-order, the overall resulting variable generation costs as well as the overall amount of CO_2 emissions and volumes of spilled energy. An economic optimisation is conducted for every hour of the year taking into account several constraints, such as the flexibility and availability of thermal units, wind and solar profiles, load profile and uncertainties, and transmission capacities between countries.

The pan-European market studies results are used as boundary conditions to ensure the overall consistency of the regional market studies. CBA assessment of the TYNDP projects is then performed using regional market and network studies.

2.3.1 System Modelling in market studies

In order to perform a market study, the demand must be modelled and is usually dependent on weather conditions. Additionally, generation connected to the distribution level and thus seen as negative demand by TSOs or smart grids may lead to the need to enrich this model. At the same time, the generation features (especially a cost function) must be modelled, and these depend on several parameters such as raw material prices, financial situations, geopolitical evolutions, meteorological conditions, etc. Systems experiencing energy constraints, for example those with significant hydro storage capacities, need to adopt annual or pluri-annual scopes in order to take into account time of production optimisation.

The modelling of the behaviour of all market components is thus huge. Most market study tools rely on probabilistic modelling. Conversely, the modelling of the transmission grid itself must rely in most cases on a 1-node-per-country (or price zone) principle with simplified transmission capacity limitation modelling between the nodes: it is assumed that there is no internal constraint within the country, whereas the expected transmission capacities with the connected countries are accounted for.

The pan-European market studies derive from a consistent dataset for all ENTSO-E countries and every Vision. The datasets and assumptions on electricity demand, generation, fuel and CO2 prices are harmonised, as well as the modelling of RES with the use of the Pan-European Climate Database (PECD).

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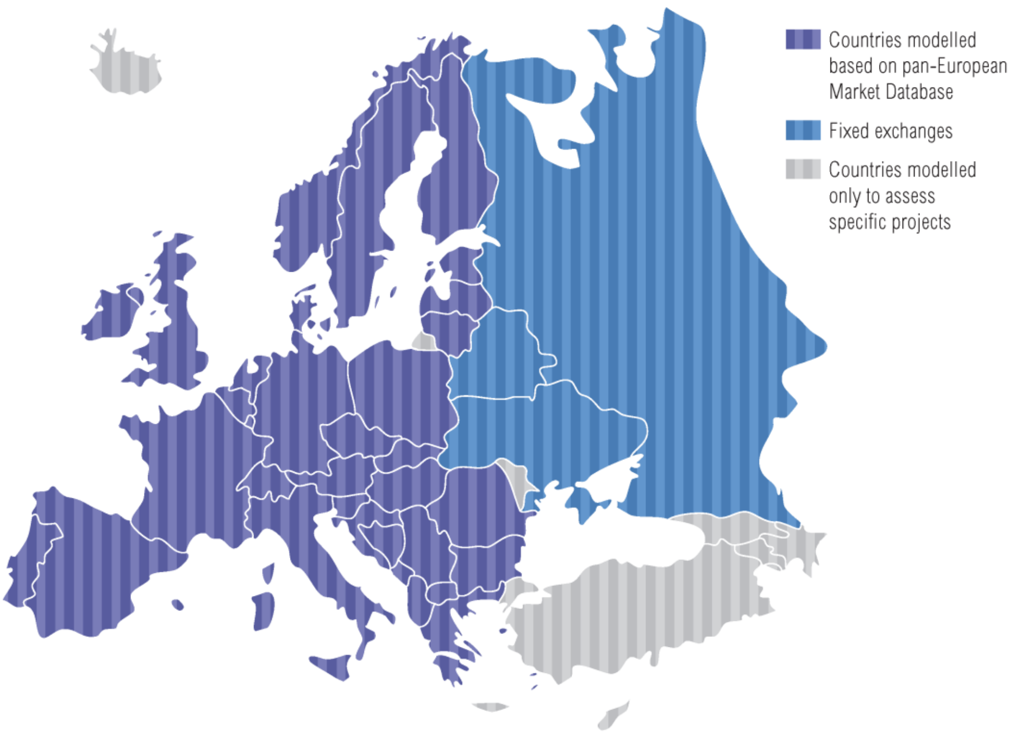

Figure 2-5 Perimeter of the pan-European market studies

The expected exchange capacity between two price zones models the interconnection capacity available to market players. The modelling may be more complex with multiple interlinked restrictions (e.g. for Poland or the Netherlands) that are driven by the structure of the grid. Total import or export possibilities for a country may be lower than the total capacity on all borders as exchanges capacities may not be simultaneously achievable.

Because of computation limitations the available tools show different trade-offs, with more or less detailed modelling of every market item versus network features. They have been developed to match specific characteristics of hydro-systems here or delicate thermal unit commitments. In this respect, regional market studies with specifically adapted tools are refined compared to their pan-European equivalent in order to model important specific features of the regional systems in more detail. See the Regional Investment Plans for more information.

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2.4 Network Studies Methodology

For every scenario, network studies answer the question "will the dispatch of generation and load given in every case generated by the market study result in power flows that endanger the safe operation of the system (accounting especially for the well-known N-1 rule)?". If yes, transmission projects are then designed, tested and evaluated for all relevant cases. Studied cases explore a variety of dispatch situations: frequent ones or rare ones that result in particularly extreme flow patterns.

2.4.1 Market Studies as an Input to the Network Studies

The objective of the market and network studies is to achieve a proper assessment of the projects based on the evaluation of the CBA assessment indicators. Some of these indicators stem from market studies and some from network studies, therefore we need to analyse projects using both study types. Commonly, market studies are done first as some of their outputs serve as inputs for the network studies. While in market models one country is represented primarily by one node with generation, consumption and transfer capacities between countries (nodes) and results are available for every hour in a year, in network models detailed transmission systems with all busses, lines and transformers are modelled and results are for one "Point In Time". Therefore, one of the key questions is how to get from the market studies to the network studies.

With network studies, it is difficult to assess all 8760 hours (for each scenario) that have been analysed using market studies. This is possible only with automatic tools that can provide 8760 network calculations or which integrate both market and network simulations (See the orange arrow in Figure 2-6).

The other method commonly used is to select the most representative Points In Time based on the interdependence of the relevant technical parameters of the system (e.g. demand, weather conditions, season…). These Points In Time are each representative of a number of hours during the year. A full representation of the year is obtained the following way:

$$Yearly\ calculation = calculation\ of\ the\ Point\ in\ Time * representativity\ of\ the\ Point\ in\ Time$$

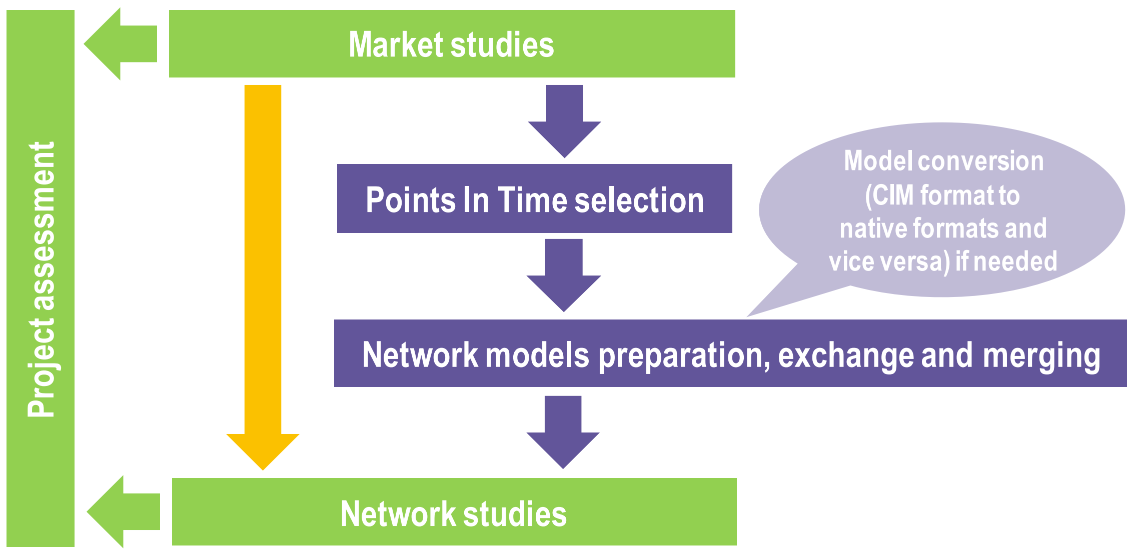

Figure 2-6 Assessment process of the projects in a nutshell, describing two possible ways of getting from the market studies to network studies (depicted in orange and violet)

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The purpose of the network studies is to find out whether or not the power flows from the market studies jeopardises the security and reliability of the transmission systems, i.e. if all transmission system elements are loaded up to their rating values during normal operation, have maintenance or outage contingencies occurred (fulfilment of the N-1 criterion). This was kept in mind throughout the whole network study process. Assessment of the network based CBA indicators (ticked with X in Table 2-2) explains what type of study is the source for the computation of every indicator.

Table 2-2 Table of CBA assessment indicators stemming from the network and market results

Criteria	Study	
	Market	Grid
B1. Improved security of supply	X	X
B2. Social and economic welfare	X	
B3. RES integration	X	X
B4. Variation in losses		X
B5. Variation in CO_2 emissions	X	
B6. Technical resilience/system safety		X
B7. Flexibility		X
GTC		X

2.4.2 Network modelling and network studies

Network studies enable detailed assessment of the behaviour of the transmission grid under different assumptions (among others the effect of the growing installed capacities of RES, peak demand, weather conditions, etc.) that are not captured by the market studies.

Network models used in regional network studies include detailed modelling of the transmission system with all busses, lines and transformers and of the generation and demand. In terms of complexity, a continental Europe model for example includes more than 6000 nodes and 10000 grid elements.

The basic computation is a steady-state load flow, i.e. simulating the power flows on every grid element resulting from a specific generation dispatch. Voltage at every node and currents in every branch must remain within secured ranges. The check is performed with all grid elements available and with consideration of the outage of every grid element and power unit (N-1 criterion), and thus for every Point in Time, possibly considering several options for grid topology and testing remedial measures. Additional investigations can be performed regarding short circuit current limitations or transient phenomena, depending on the background.

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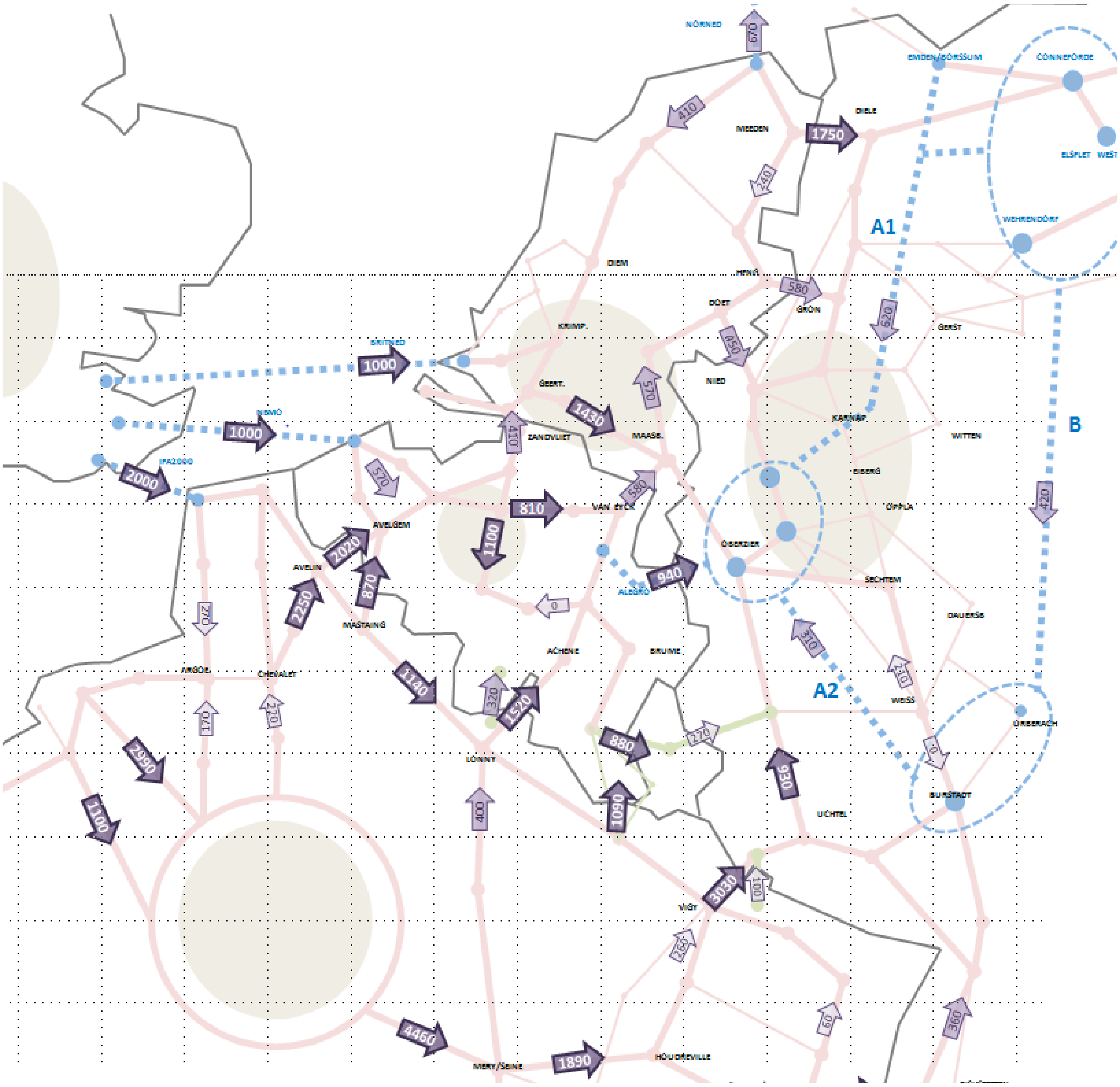

Figure 2-7 Illustration of a load flow

The example in Figure 2-7 shows a simplified representation of a case where Great Britain exports to continental Europe through the three HVDC connections. This "Point in Time" implements the market study results (demand and generation patterns from the market simulation) of one of the 8760 hourly simulations of 2030 Vision 1.

Further examples and network study results can be found in the Regional Investment Plans.

2.4.3 Network Study Tools Used

As there are high diversities in the generation mix, consumption, type of line and so on as well as contrasts between all regional groups, there are also notable diversities in the use of network studies tools, which can cause an increase in coordination effort but also increases the reliability of the results.

Despite the diversities mentioned above, the main characteristics of the different network study tools are quite similar. The quality of the results mainly depends on the level of detail used to model the national grids merged in the common model. Exchanges of Power System Model (PSM) data are done using the common CIM format.

The assessment of the projects based on the network studies was done on a common basis. Every TSO representative, in particular regional groups, made their own model for a certain time horizon and scenario in a "native" format, then translated it to the CIM and sent it to a network studies subgroup expert in order to merge all models in one. This merged model was then sent to all regional group members in CIM format and experts teams run exploratory studies and projects assessments.

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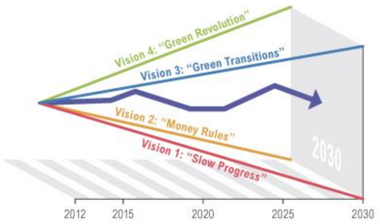
3 Scenarios

3.1 Consistency of the four Visions for 2030

This section qualitatively describes the scenario approach used for the preparation of the TYNDP 2014. A quantitative description of the scenarios is provided in the Scenario Outlook and Adequacy Forecast 2014-2030.



The TYNDP 2014 analysis is based on a large exploration of the 2030 horizon. The year 2030 is used as a bridge between the European energy targets for 2020 and 2050. This choice has been made based on stakeholder feedback, preferring a large scope of contrasting longer-run scenarios instead of a more limited number and an intermediate horizon of 2020.

The basis for the TYNDP 2014 analysis is **four Visions for 2030**. The Visions are less forecasts of the future than possible extremes of the future so that the pathway realised in the future falls with a high level of certainty in the range described by the Visions. In addition, these Visions are not optimised scenarios (e.g. no assessment was performed of where solar development would be most economically viable). The Visions have been formulated taking into account the results of an extensive consultation with several workshops and a formal consultation during summer 2013.

This is a markedly different concept from that taken for the scenarios up to 2020 used in the TYNDP 2012; these aimed to estimate the evolution of parameters under different assumptions, while the 2030 Visions are designed to estimate the extreme values between which the evolution of parameters is expected to occur.

The four Visions differ mainly with respect to:

- The trajectory toward the Energy roadmap 2050: Visions 3 and 4 maintain a regular pace from now until 2050, whereas Visions 1 and 2 assume a slower start then an acceleration after 2030. Fuel and CO_2 prices favour coal (resp. gas) in Visions 1 and 2 (resp. Visions 3 and 4).
- The consistency of the generation mix development strategy: Visions 1 and 3 build from the bottom-up on each country's energy policy; Visions 2 and 4 assume a top-down approach, with a more harmonised European integration.

The top-down approach used to build Vision 2 and 4 has been designed with input from stakeholders and consulted beginning of 2013[22]: Vision 2 and 4 are derived from Visions 1 and 3, in view of greater harmonisation of the data from all countries.

22

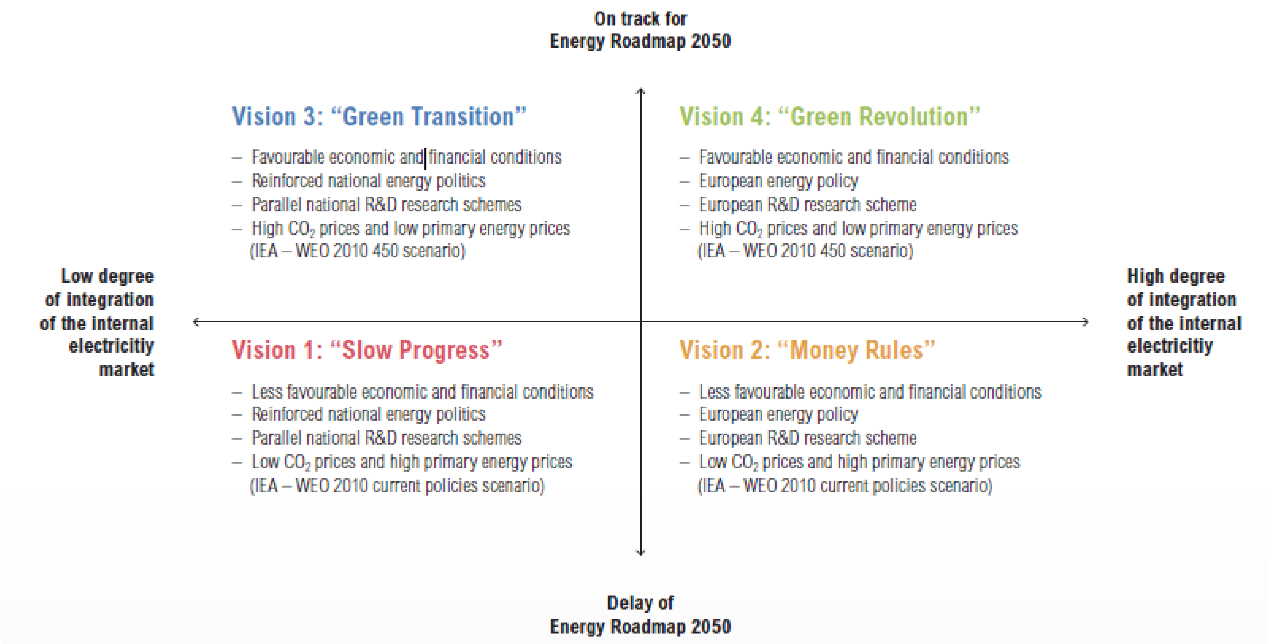


Figure 3-1 Overview of the political and economic frameworks of the four Visions

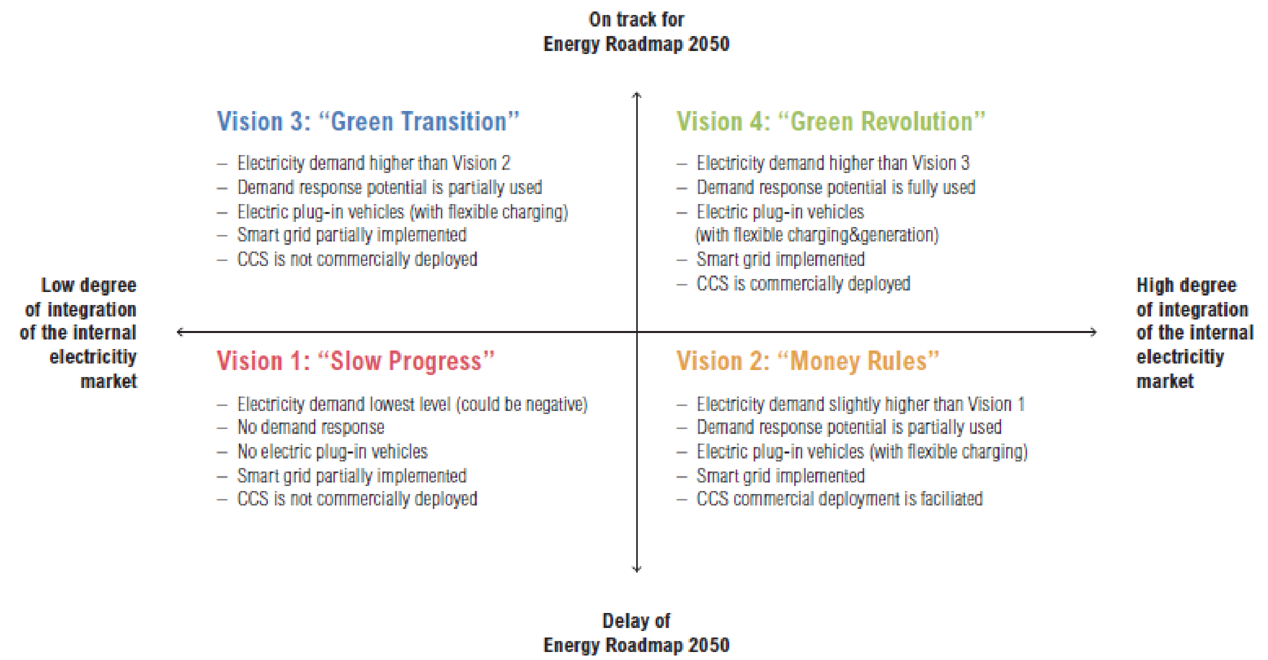


Figure 3-2 Overview of the generation and load frameworks of the four Visions

		Scenario 2020	vision 1 2030	vision 2 2030	vision 3 2030	vision 4 2030
Fuel prices (€/Net GJ)	Nuclear	0,377	0,377	0,377	0,377	0,377
	Lignite	0,44	0,44	0,44	0,44	0,44
	Hard coal	2,8	3,48	3,48	2,21	2,21
	Gas	7,99	10,28	10,28	7,91	7,91
	Biofuel	same price as primary fuel type				
	Light oil	16,73	23,2	23,2	16,73	16,73
	Heavy oil	9,88	13,7	13,7	9,88	9,88
	Oil shale	2,3	2,3	2,3	2,3	2,3

	Scenario 2020	vision 1 2030	vision 2 2030	vision 3 2030	vision 4 2030
CO_2 prices (€/ton)	93	31	31	93	93

Source: IEA
Visions 1 & 2:
Fuel & CO_2: IEA World Energy Outlook 2011, Current Policies, year
Visions 3 & 4:
Fuel: IEA World Energy Outlook 2011, 450 scenario, year 2030
CO_2: IEA World Energy Outlook 2011, 450 scenario, year 2035

Figure 3-3 Main economic assumptions for generation modelling

For a further insight on the assumptions please see the presentations from the 3rd 2030 visions workshop 2nd July 2014. This workshop took place at the end of the scenario building process, and the displayed material gives a comprehensive overview of the assumptions behind the Visions; highlight the inputs from stakeholders and details in appendices to the presentations the consistency checks that were implemented.

Data spreadsheets are also displayed along with the SOAF 2014 (generation and load assumptions); pan-European market studies results are also displayed in spreadsheets accompanying the final release of the TYNDP 2014.

The source of data is summed up hereafter (notwithstanding the feedback brought by the consultations):

Data	Source	Comment
Scenarios major characteristics (electric vehicles volumes, DSR potential, storage, etc.)	Stakeholders' survey	Guidance from the survey + implementation by ENTSO-E expert team
Peak load, load curves (V1, V3)	ENTSO-E members (basic inputs) + ENTSO-E expert team (for EV charging, heat pumps, ...)	Consistency checks and tuning by ENTSO-E expert team
Peak load, load curves (V2, V4)	V1, V3 data evolved by ENTSO-E expert team	According to the consulted methodology
Generation means (V1, V3)	ENTSO-E members, complying with common standard guidelines	V3 RES assumptions derived from NREAPs (or other national goals)
Generation means (V2, V4)	V1, V3 data evolved by ENTSO-E expert team	According to the consulted methodology

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Data	Source	Comment
Fuel and CO2 costs	IEA WEO 2011	
Grid models 2030	ENTSO-E members, complying with common standard guidelines	
Projects technical details	Project promoters (if pre-existing) ENTSO-E experts (if new)	

Modelling of Demand Side Response (DSR) in the TYNDP 2014

DSR has been addressed when building the scenarios, and modelled in the market studies and network studies.

DSR in itself is one of the thirteen key parameters for the Visions (and four others are closely related: development of smart metering and smartgrid devices; of electric vehicles; of decentralised storage ; of PV). In a survey performed by ENTSO-E21 beginning of 2012, 40% of the responding stakeholders said DSR could represent 5-10% of the total load by 2030 (and less than 10% said DSR could address more than 20% of the load by 2030).

During the scenario building process, a specific attention has been brought to the evolution of load curves, especially in order to reflect the development of electric vehicle and heat pumps. The charging of electrical vehicles is assumed smarter in Vision 4 than in Vision 1 (e.g. it takes rather place off-peak in the winter time or at noon in the summertime, taking advantage of the photovoltaic generation). These adapted (but not adapting) load curves are inputs to market studies.

Market studies model DSR potential as fictitious generation peak units, which would start when prices rise, basically before actual peak units in the system start. Summing it all over the year, the volumes in GWh are negligible compared to the whole consumption. No extra load, to catch up with the not-consumed power is modelled, as volumes (and hence prices) are negligible, and the modelling is quite complex to implement.

Network studies model DSR potential as a remedial measure to congestions, with up to 10% of the total load potentially activated. However DSR does not prove efficient to address grid development issues of pan-European significance: the major concern is conveying large amount of RES to load centers, especially when the generating output of RES facilities is close to their capacity.

3.2 Vision 1

The first scenario is Vision 1, “Slow progress”. Vision 1 reflects slow progress in energy system development with less favourable economic and financial conditions.

Vision 1 fails to meet the EU goals for 2030 but in the present context of economic downturn, it is a plausible, even if non-desirable, scenario. Compared to the present days, the consumption and generation mix have evolved by less than in other Visions entailing a lower pressure for more market integration and interconnection capacity.

In Figure 3-4 and Figure 3-5 the details of the generation mix are reported in terms of installed capacity and annual generation.

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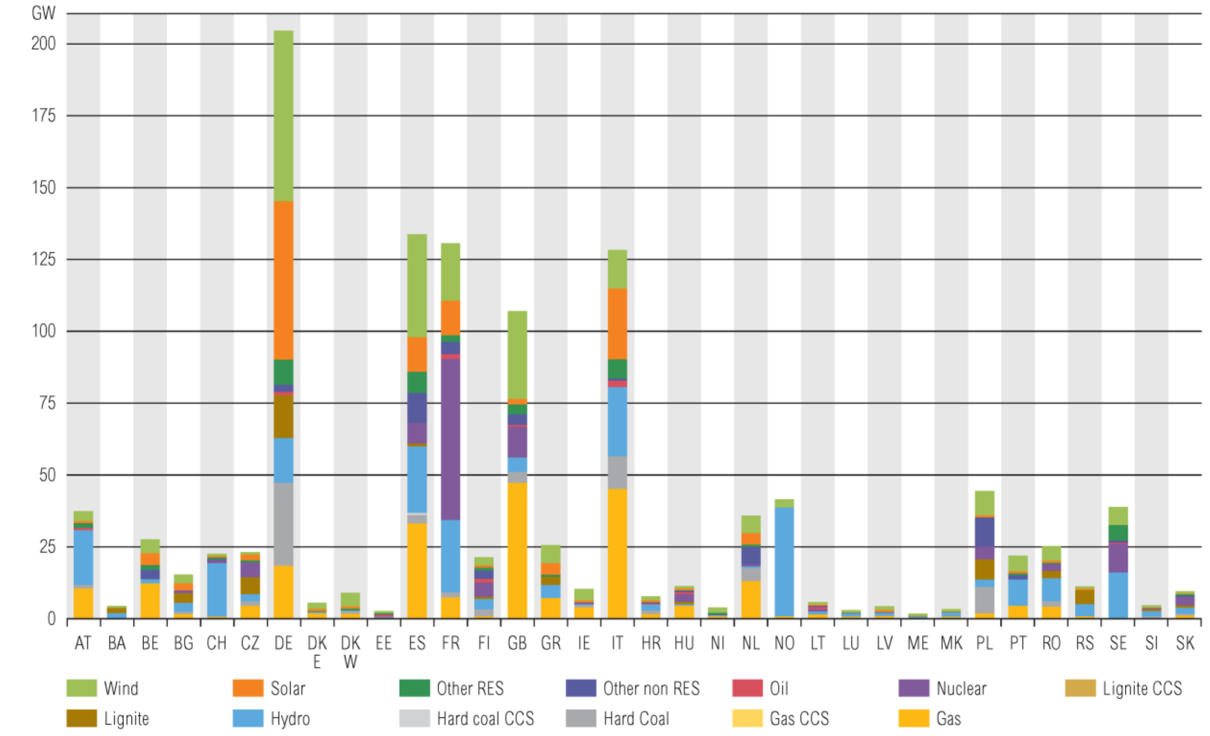

Figure 3-4 Installed capacity in Vision 1 in ENTSO-E (GW)

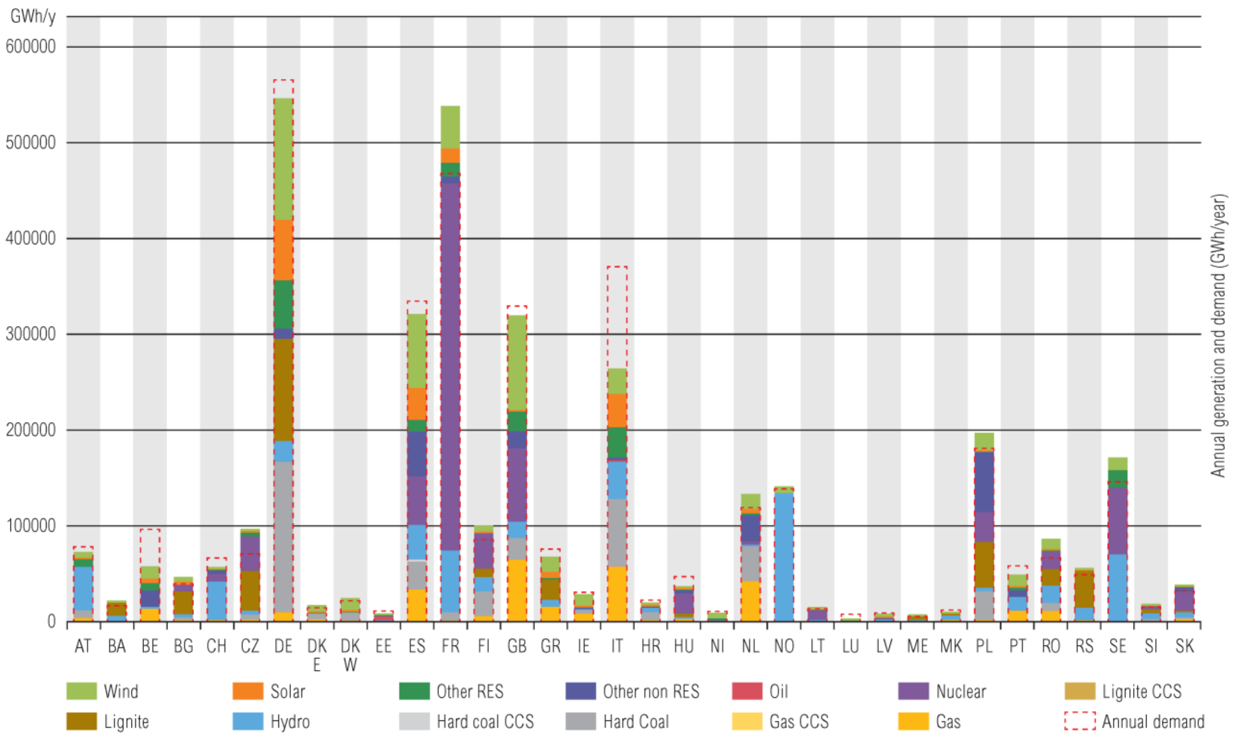

Figure 3-5 Annual generation and demand in Vision 1 in ENTSO-E (GWh/year)

The increase of RES is the prominent feature, reaching 41% penetration from now until 2030. The main change in installed capacity is the increase in wind and solar in all countries, but mostly in Germany. Vision 1 is however the scenario with the lowest RES development of all four.

Regarding nuclear energy, the status varies depending on the country. For example, Germany, Belgium and Switzerland have planned a nuclear phase-out, whereas eight countries are expected to commission new nuclear units.

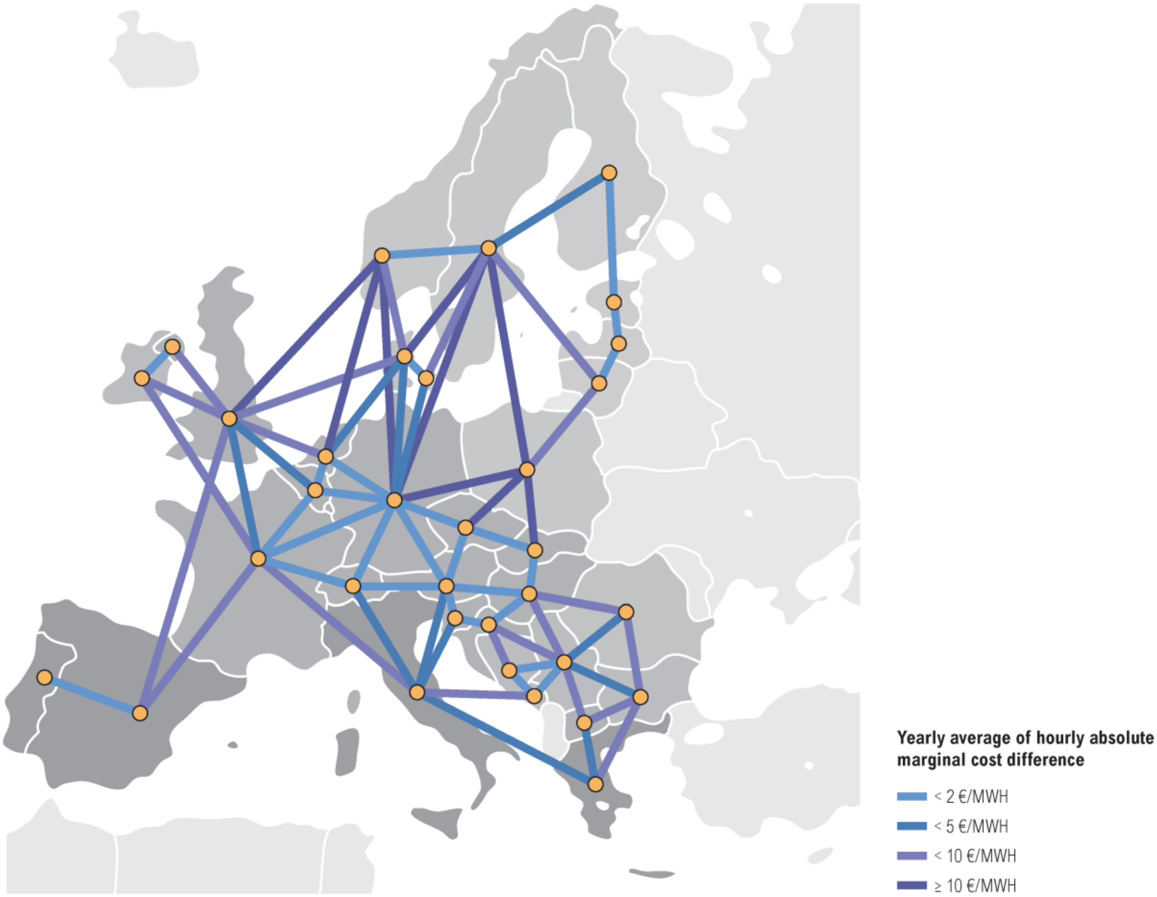

Figure 3-6 Yearly average marginal cost difference in Vision 1 in ENTSO-E[23]

Figure 3-6 shows the yearly average figures regarding marginal costs per country and cost differentials between countries. Yearly averages are not sufficient indicators to make decisions regarding grid extensions (hourly values are more useful in this respect), but the picture does however give an overview of the main trends:

- Nordic, Baltic and eastern countries are on average cheaper than western and southern countries. In this Vision, coal-fired units are cheaper than gas-fired units, which explains the lower costs in Poland, Romania and Bulgaria compared to Ireland and Great Britain.

[23] For layout reasons, the link between Luxembourg and Belgium is not represented on this map

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- As a result, strong price differentials appear between Norway, Sweden, Poland and their southern neighbours. (Such high price differentials may trigger new interconnection capacities in order to mitigate them, provided the investment costs are covered.)

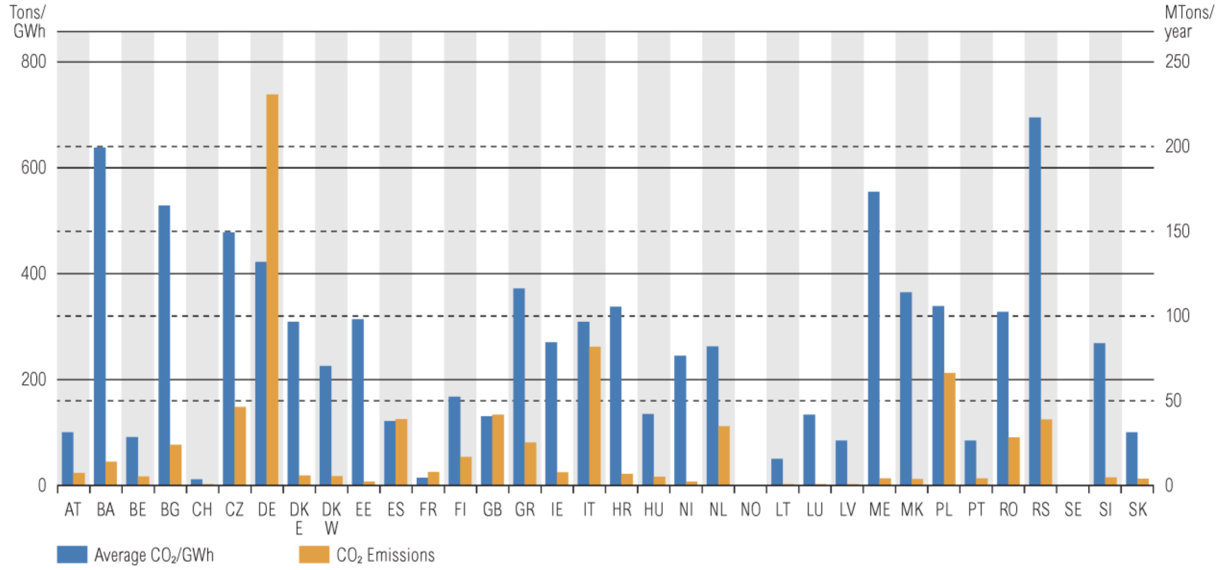

Figure 3-7 CO2 emissions in Vision 1 in ENTSO-E (MT/year)

Figure 3-7 depicts the CO2 emissions in Vision 1 both in terms of yearly CO2 emissions per country (MTons/y) and in terms of the CO2 intensity of the electricity generation (Tons/GWh). Compared to the 1990 level, the emissions are reduced by 42% in the ENTSO-E perimeter.

In Vision 1, generation is sufficient to cover the load in all circumstances except very rare, negligible situations. Residual spillage of RES is negligible as well, amounting to 1.5 TWh compared to 1500 TWh of RES generation at the ENTSO-E perimeter (< 0.1%).

3.3 Vision 2

The second scenario is Vision 2, “money rules”. Vision 2 reflects a cautious progress towards the 2050 European energy goals, driven by quick return on investments rates.

Vision 2 is similar to Vision 1 with respect to consumption and generation mix. Hence it fails as well to meet the EU goals for 2030 but in the present context of economic downturn it is a plausible, even if non desirable, scenario. Compared to Vision 1 however, it builds on more European cooperation and the reference situation assumes more interconnection capacity.

In Figure 3-8 and Figure 3-9 the details of the generation mix are reported in terms of installed capacity and annual generation.

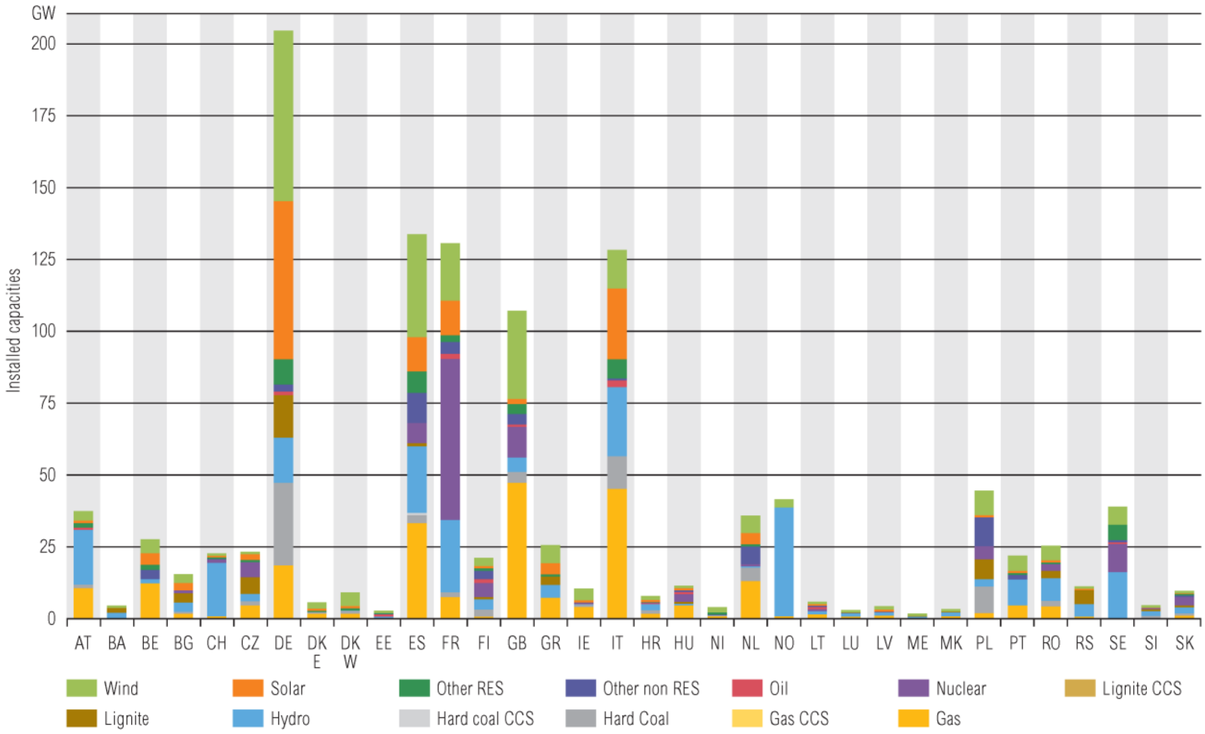

Figure 3-8 Installed capacity in Vision 2 in ENTSO-E

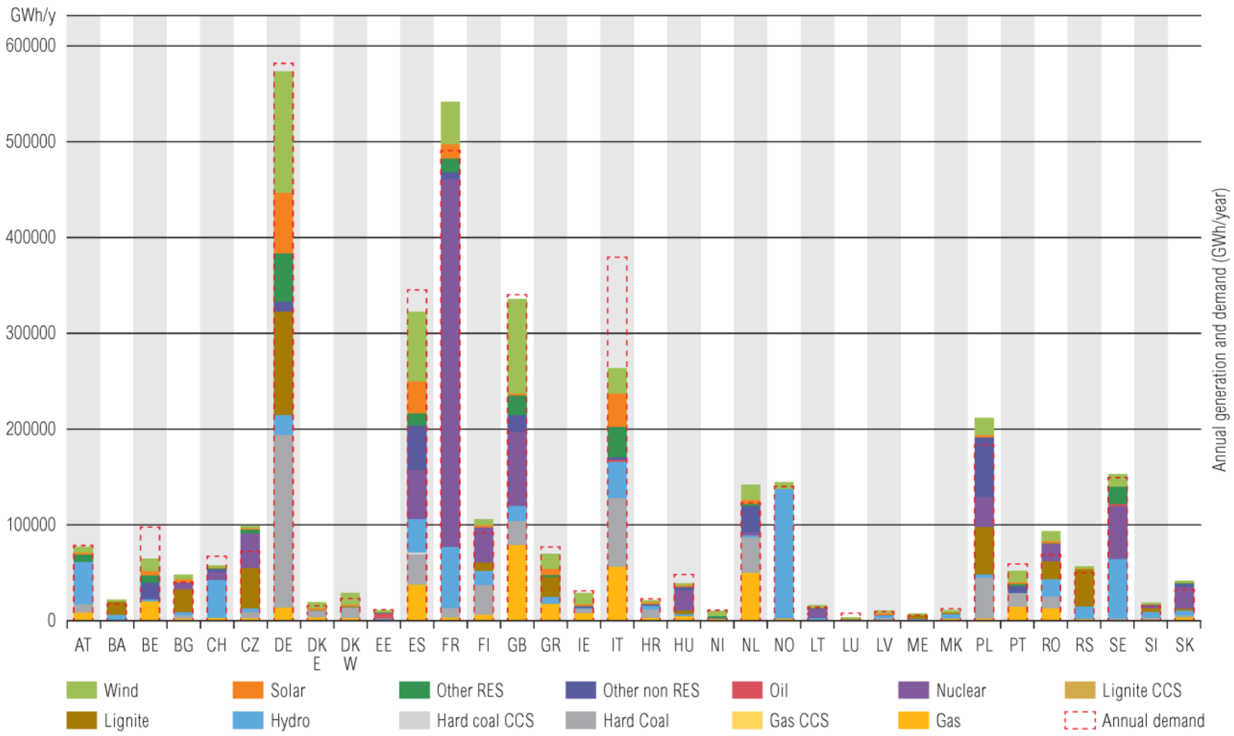

Figure 3-9 Annual generation and demand in Vision 2 in ENTSO-E (GWh/year)

The overall energy mix is similar to Vision 1. Compared to Vision 1, only marginal changes regarding load curves and installed thermal capacity were required to achieve a sufficient European harmonisation.

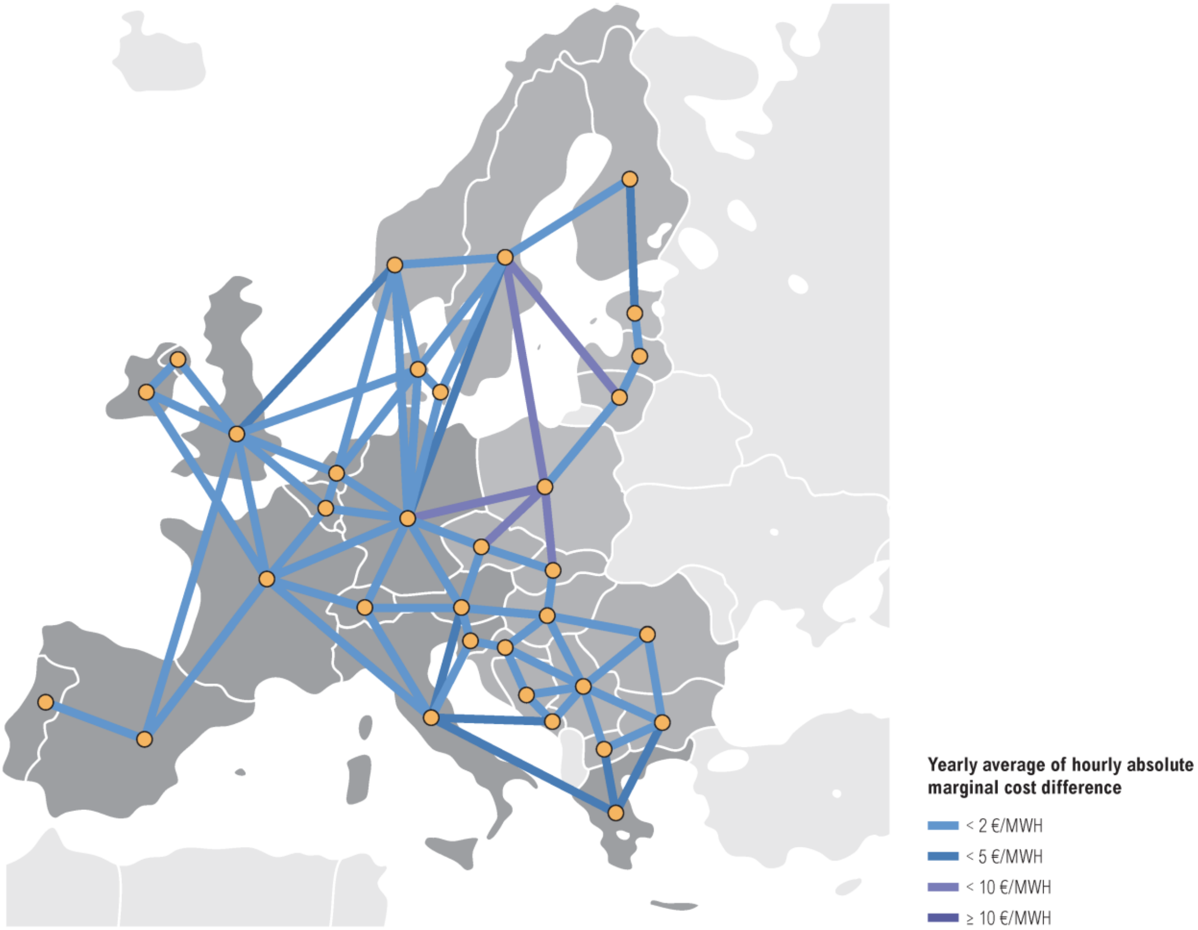

Figure 3-10 Yearly average marginal cost difference in Vision 2 in ENTSO-E[24]

Figure 3-10 shows the yearly average figures regarding marginal costs per country and cost differentials between countries. Yearly averages are not sufficient indicators to make decisions about grid extensions (hourly values are more useful in this respect).

Compared to Vision 1 (Figure 3-6), the picture however shows milder price differentials on almost all borders a more homogenous price all over Europe. The reason is the higher values considered for interconnection capacities in this scenario compared to Vision 1. The global trends are however similar to those depicted in the previous section for Vision 1.

[24] For layout reasons, the link between Luxembourg and Belgium is not represented on this map

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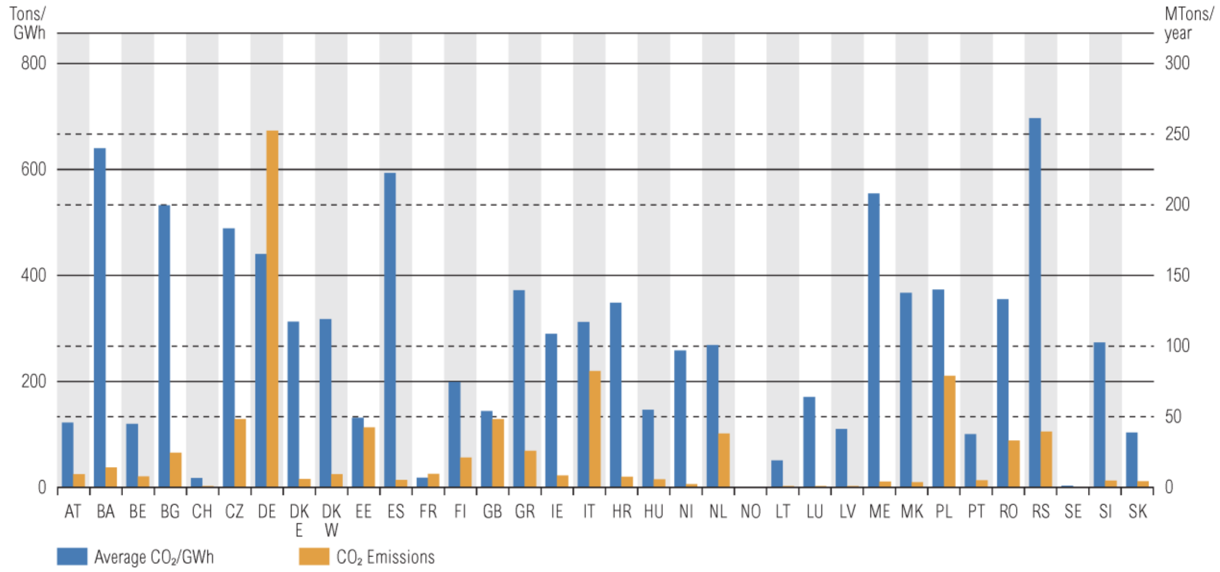

Figure 3-11 CO2 emissions in Vision 2 in ENTSO-E

Figure 3-11 depicts the CO2 emissions in Vision 2 both in terms of yearly CO2 emissions per country (MTons/y) and the CO2 intensity of the electricity generation (Tons/GWh). Compared to the 1990 level, the emissions are reduced by 40% in the ENTSO-E perimeter.

In Vision 2, generation is sufficient to cover the load in all circumstances except very rare, negligible situations. Residual spillage of RES is down to zero in this Vision, thanks to the higher interconnection capacity compared to Vision 1 in their reference situation.

3.4 Vision 3

The third scenario is Vision 3, “green transition”. Vision 3 reflects an ambitious path towards the 2050 European energy goals, where every Member State develop its own effort achieving overall 50% of European load supplied by RES in 2030.

Vision 3 meets the EU goals by 2030. However in this Vision, every country tends to secure its own supply independently from the other, resulting probably into an overinvestment in generation assets at European level. (Conversely, the valuation of interconnection projects often shows less value than in other Visions, as all countries are equipped with similar facilities – wind power, gas units – in large, and sufficient amount.)

In Figure 3-12 and Figure 3-13 the details of the generation mix are reported in terms of installed capacity and annual generation.

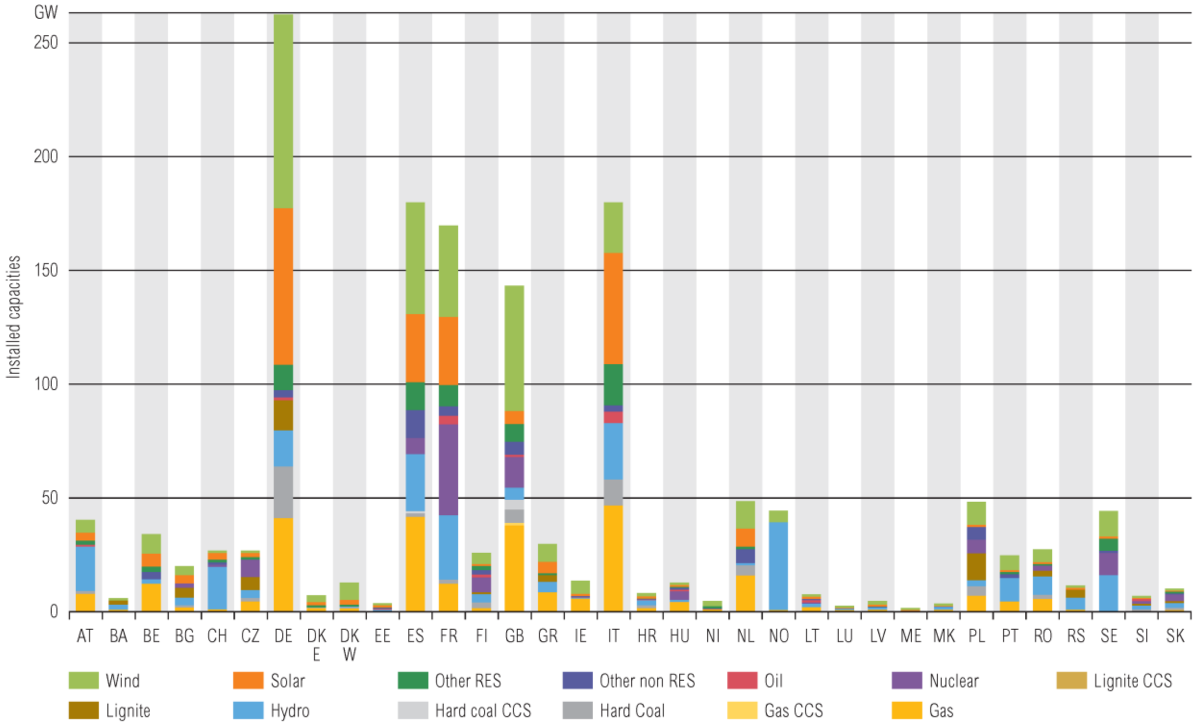

Figure 3-12 Installed capacity in Vision 3 in ENTSO-E (GW)

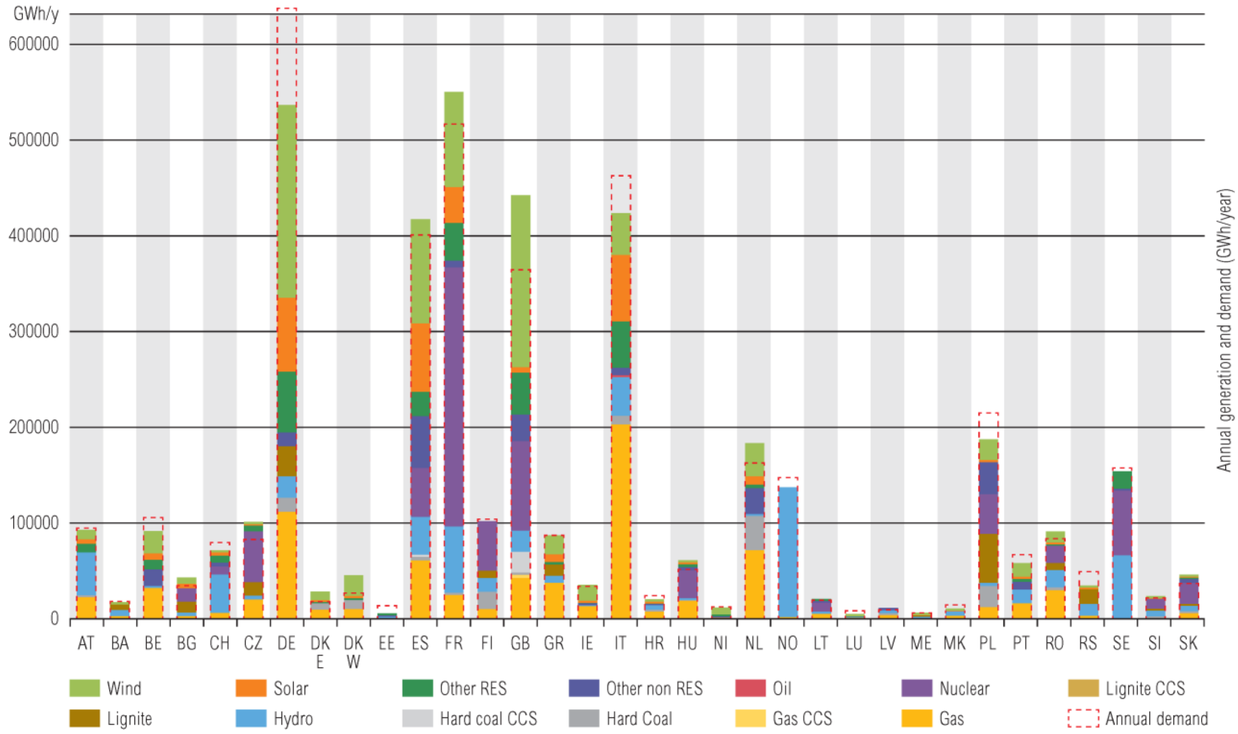

Figure 3-13 Annual generation and demand in Vision 3 in ENTSO-E (GWh/year)

The increase of RES is large, all over Europe. Solar power jumps from 69 GW today to 224 GW, while wind power increases from 105 GW to 361 GW.

Regarding nuclear energy, the status varies depending on the countries. Germany, Belgium and Switzerland for instance have planned a nuclear phase-out, whereas eight countries are expected to commission new nuclear units. Coal capture and storage technology is also introduced in this Vision and is especially expected to be in use in the UK to cope with the high CO2 price assumption.

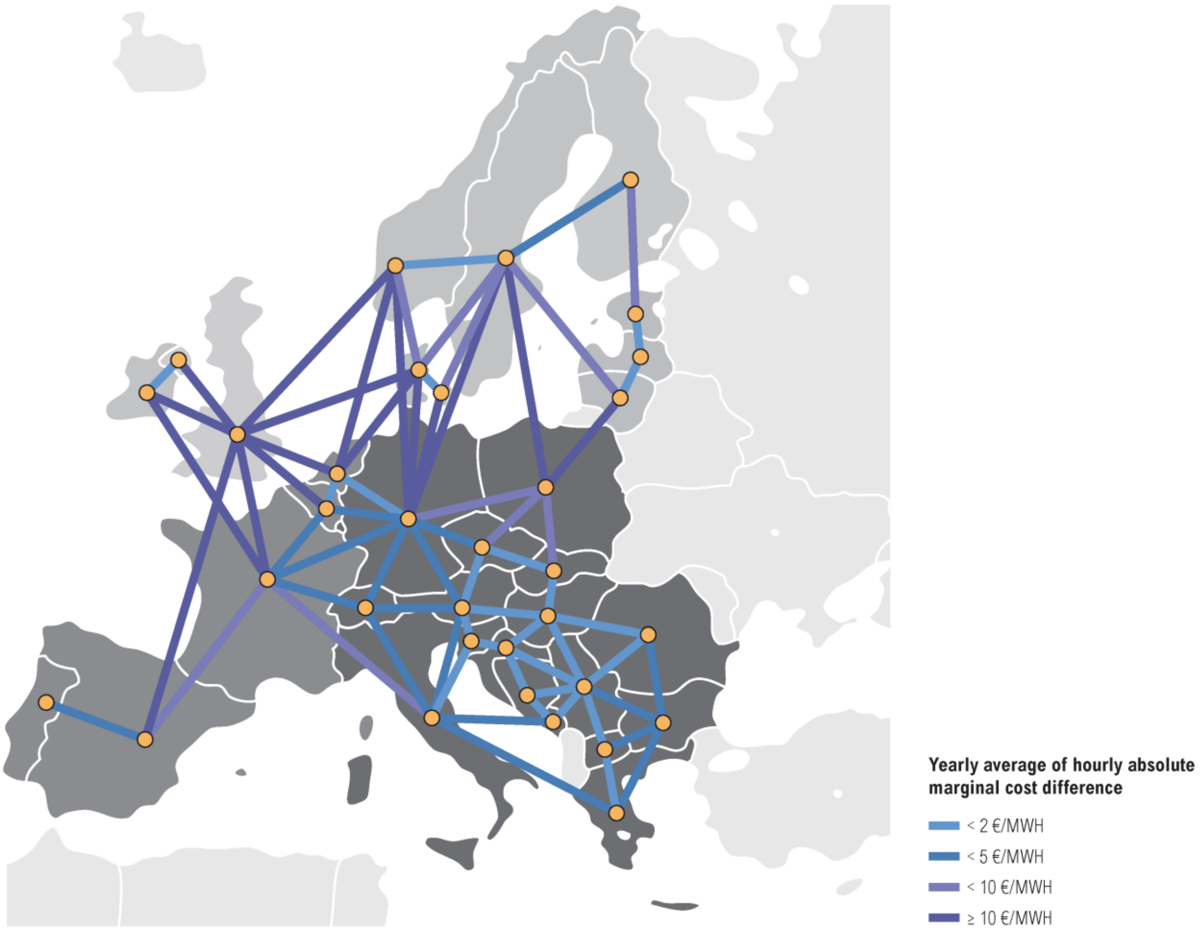

Figure 3-14 Yearly average marginal cost difference in Vision 3 in ENTSO-E[25]

Figure 3-14 shows the yearly average figures regarding marginal costs per country and cost differentials between countries. Yearly averages are not sufficient indicators to make decisions about grid extensions (hourly values are more useful in this respect), but the picture does however give an overview of the main trends:

[25] For layout reasons, the link between Luxembourg and Belgium is not represented on this map

- Average prices are rather high in Europe compared to Vision 1 and 2 due to higher fuel and CO2 costs.
- Nordic and Baltic countries as well as the United Kingdom and Ireland are on average cheaper than western and southern countries. The large increase of RES, bidding with a zero marginal cost in the market, explains this trend.
- As a result, strong price differentials appear between Norway, Sweden, Great Britain, Ireland and continental Europe. (Such high price differentials may trigger new interconnection capacities in order to mitigate them, provided the investments costs are covered.)
- Between Norway and UK, or between France and Spain, high price differentials are also displayed, with congestion possibly occurring both ways, despite Norway and UK or France and Spain show very close yearly average prices.
- Price differentials within continental Europe are higher than in Vision 1 as a general indication of the need for larger interconnections.

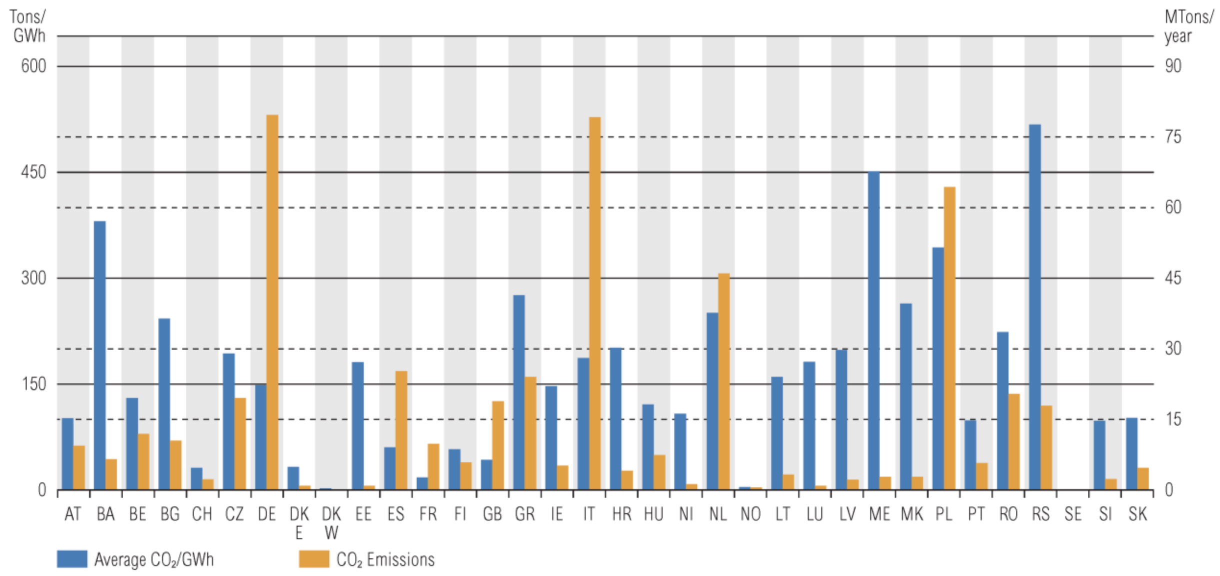

Figure 3-15 CO2 emissions in Vision 3 in ENTSO-E

Figure 3-15 depicts the CO2 emissions in Vision 3 both in terms of yearly CO2 emissions per country (MTons/y) and the CO2 intensity of the electricity generation (Tons/GWh). Compared to the 1990 level, the emissions are reduced by 64% in the ENTSO-E perimeter.

In Vision 3, generation is sufficient to cover the load in all circumstances except very rare, negligible situations. Residual spillage of RES is the highest in all Visions: it amounts to 48 TWh, compared to more than 2100 TWh of RES generation at the ENTSO-E perimeter, i.e. about 2%. It is lower than in Vision 4, because of a lower interconnection capacity in the reference situation. Figure 3-15 highlights the dumped energy in Vision 3. The numbers are significant in the UK, Ireland and Spain with around 18 TWh/yr in total, highlighting the need for further grid connections with continental Europe as stressed in the investment needs chapter.

3.5 Vision 4

The fourth scenario is Vision 4, "green revolution". Vision 4 reflects an ambitious path towards the 2050 European energy goals, with 60% of load supplied by RES in 2030.

Vision 4 meets the EU goals by 2030, with all countries playing as a team. Compared to Vision 3, the power supply is optimised, taking advantage of every country's situation and of interconnection capacity. (With its validation only in October 2013, Vision 4 requires however additional investigation of the specific investment needs it may entail and simplified grid modelling may have been resorted whenever needed.)

In Figure 3-16 and Figure 3-17 the details of the generation mix are reported in terms of installed capacity and annual generation.

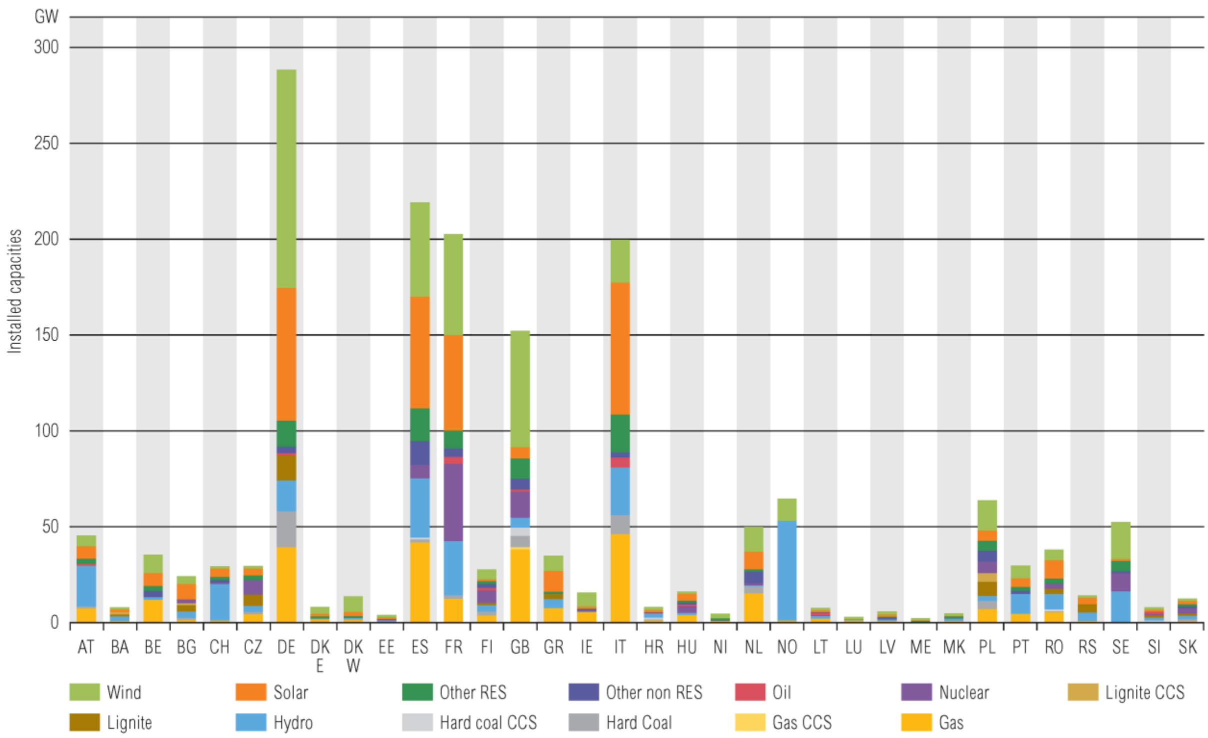

Figure 3-16 Installed capacity in Vision 4 in ENTSO-E (GW)

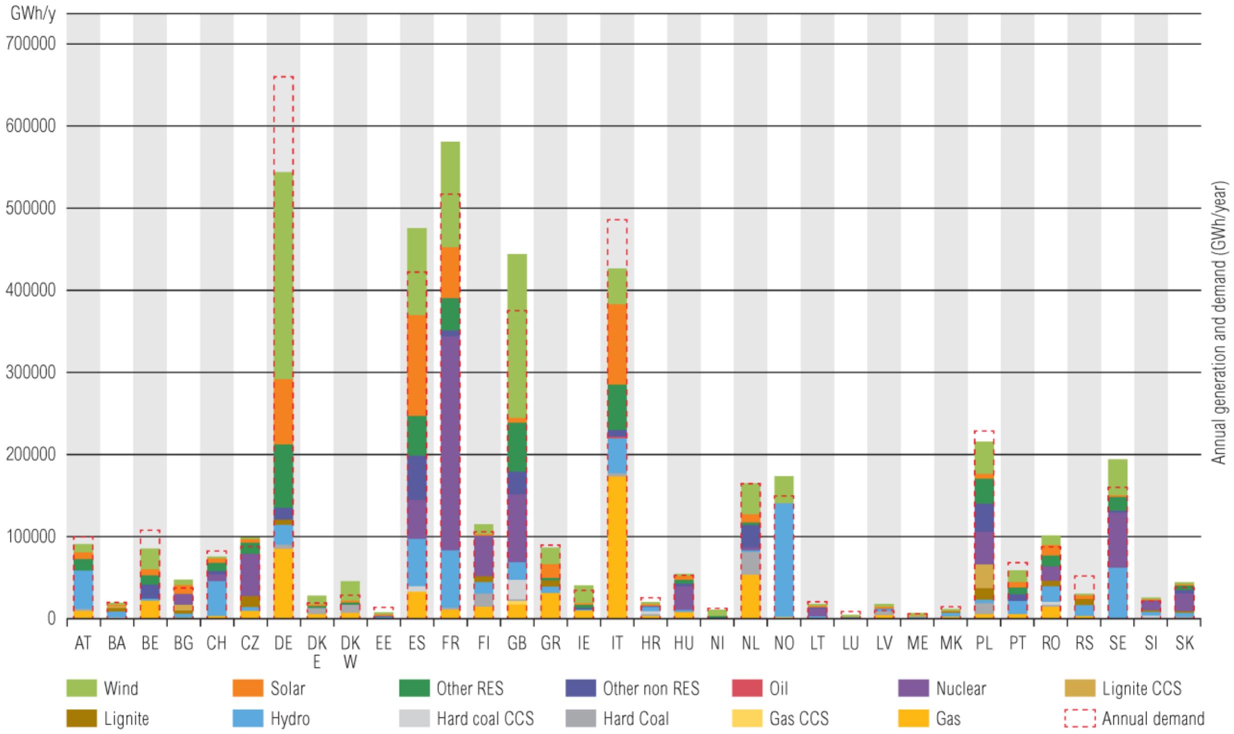

Figure 3-17 Annual generation and demand in Vision 4 in ENTSO-E (GWh/year)

The increase of RES is very large and happens all over Europe. The main change in installed capacity is the increase in wind and solar in all countries. For instance, solar jumps from 69 GW today to 339 GW, while wind power increases from 105 GW to 431 GW.

Nuclear development is the same as in Vision 3. Coal capture and storage technology is assumed to be available to all countries in this Vision (and is especially expected to be in use in Poland and Great Britain) to cope with the high CO2 price assumption.

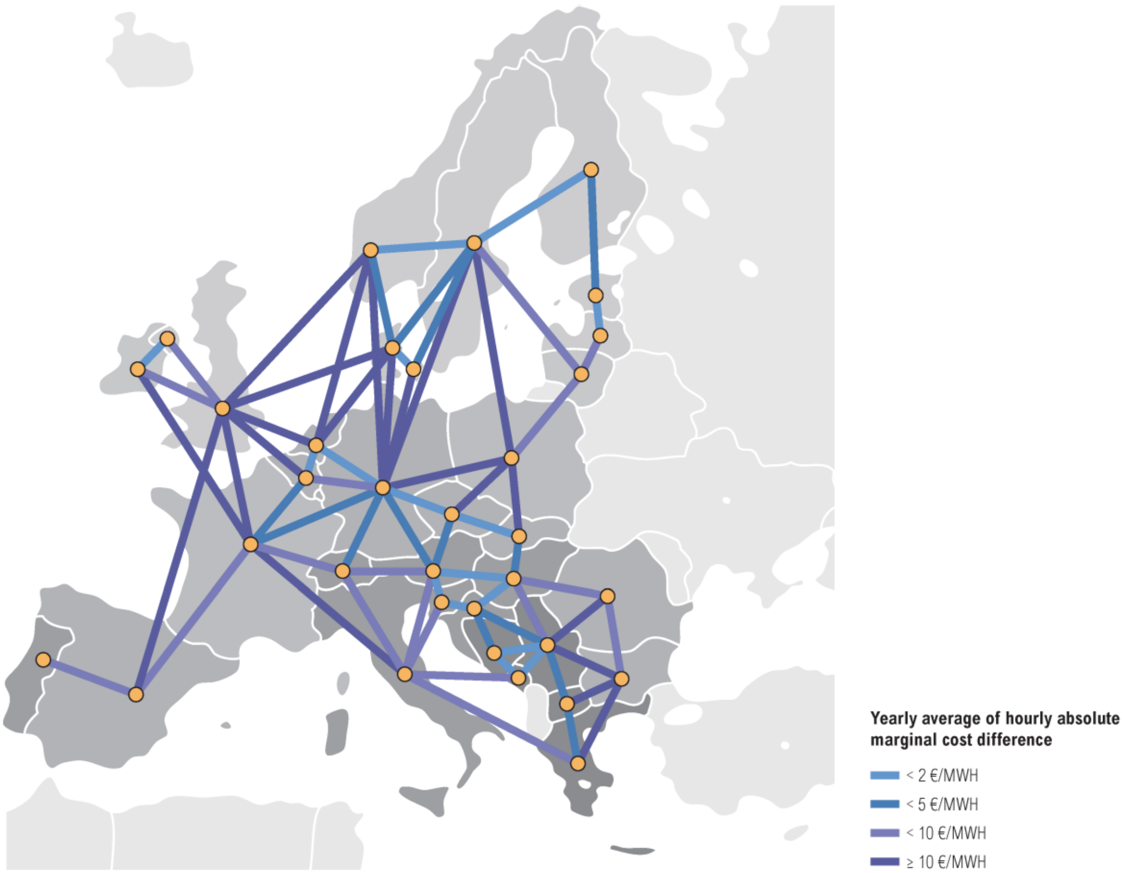

Figure 3-18 Yearly average marginal cost difference in Vision 4 in ENTSO-E[26]

Figure 3-18 shows the yearly average figures regarding marginal costs per country and cost differentials between countries. Yearly averages are not sufficient indicators to make decisions about grid extensions (hourly values are more useful in this respect), but the picture does however give an overview of the main trends:

- Yearly, average prices in Europe are similar to those in Vision 1 and 2 due to the higher penetration of RES, compensating for the higher fuel and CO2 costs.
- Nordic and Baltic countries as well as the United Kingdom and Ireland are on average cheaper than western and southern countries. The large increase of RES, bidding with a zero marginal cost in the market, explains this trend.
- As a result, strong price differentials appear between Norway, Sweden, Great Britain, Ireland and continental Europe. (Such high price differentials may trigger new interconnection capacities in order to mitigate them, provided the investments costs are covered.)

[26] For layout reasons, the link between Luxembourg and Belgium is not represented on this map

- Between Norway and UK, or between France and Spain, high price differentials are also displayed, with congestion possibly occurring both ways, despite Norway and UK or France and Spain show very close yearly average prices.
- Price differentials within continental Europe are higher than in other Visions as a general indication of the need for larger interconnections to compensate variation of RES production.

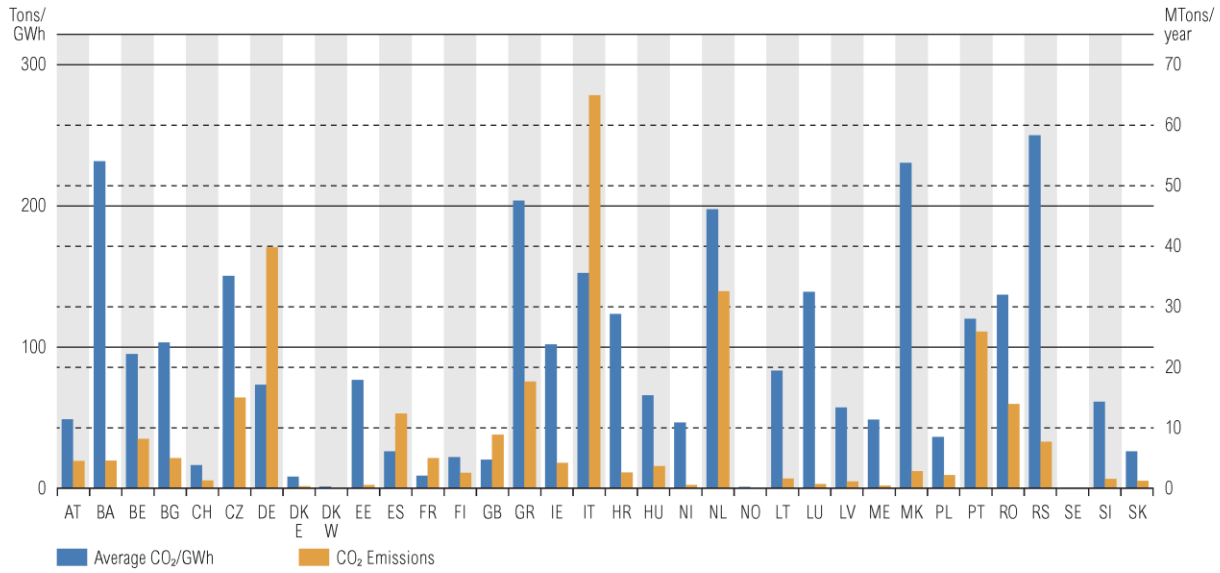

Figure 3-19 CO2 emissions in Vision 4 in ENTSO-E

Figure 3-19 depicts the CO2 emissions in Vision 4 both in terms of yearly CO2 emissions per country (MTons/y) and the CO2 intensity of the electricity generation (Tons/GWh). Compared to the 1990 level, the emissions are reduced by 78% in the ENTSO-E perimeter.

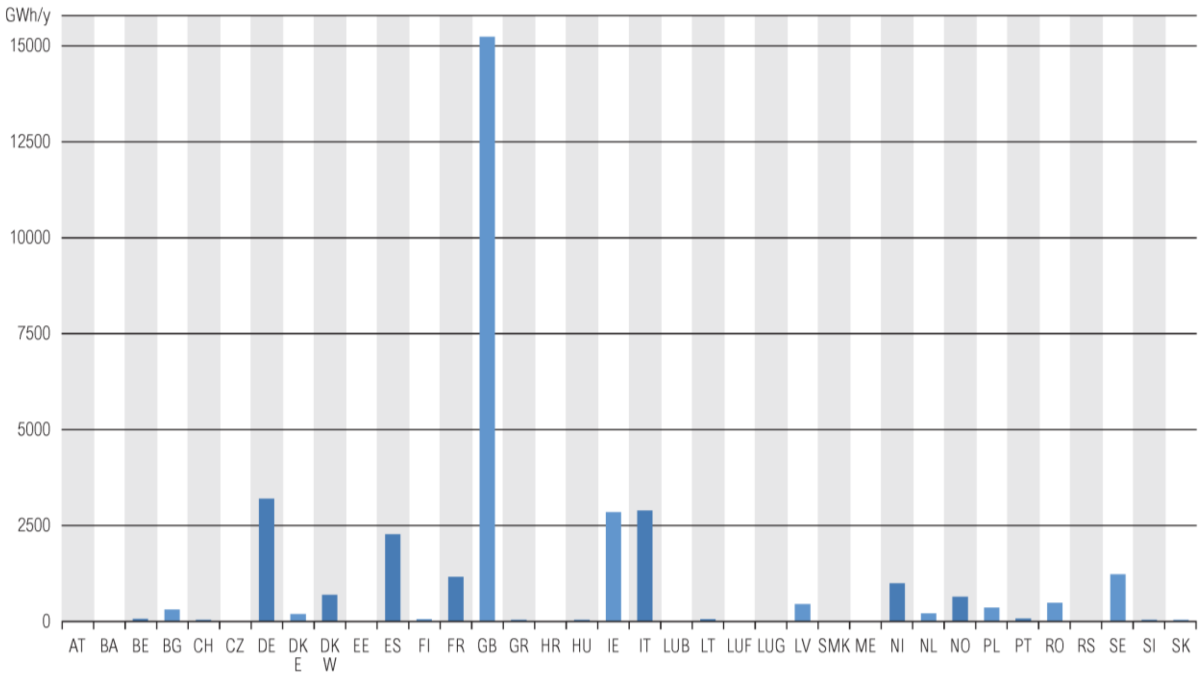

Figure 3-20 Dumped energy in Vision 4 in ENTSO-E (GWh/year)

In Vision 4, generation is sufficient to cover the load in all circumstances except very rare, negligible situations. Residual spillage of RES is however significant: it amounts to 33 TWh, compared to more than 2600 TWh of RES generation at the ENTSO-E perimeter, i.e. about 1%. Figure 3-20 highlights the dumped energy in Vision 4. The numbers are significant in the UK and Ireland with around 18 TWh/yr in total, highlighting the need for further grid connections with continental Europe as stressed in the investment needs chapter.

3.6 Comparison of the Visions

The aim of this section is to provide the reader with a synthetic view of the four Visions by comparing their main characteristics.

The most important monitored characteristic parameters, which differ through the visions, are total yearly consumption, generation mix and RES share in the total supply, CO2 emissions, and average energy price.

Differences in the high-level assumptions of the Visions are manifested among others in markedly different fuel and CO2 prices sets in Visions 3 and 4 compared to Visions 1 and 2, resulting in a reversed merit order for gas and coal units.

In the figure below, the evolution of the total yearly consumption through the Visions is depicted.

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How the consumption is supplied all over the year, i.e. the generation mix, is the second main feature to appraise for each Vision. The chart below shows the relative share of every primary source in the total supply. RES in particular gets a higher share from Vision 1 to Vision 4.

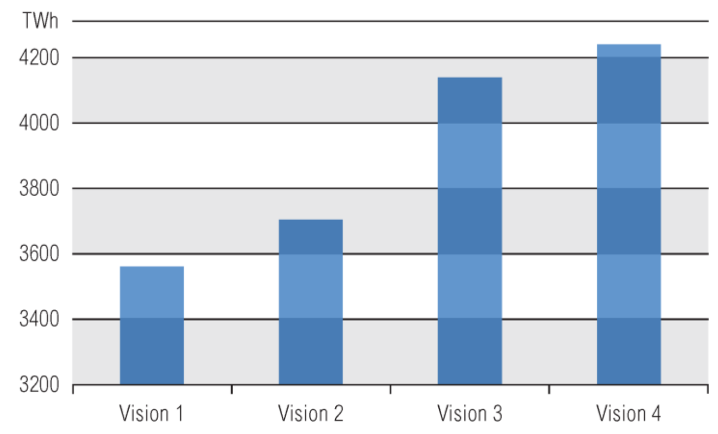

Figure 3-21 Comparison of the total yearly consumption in all the 2030 Visions

As a consequence of the chosen mix, the average CO2 content of electricity is about 220 g/MWh in Visions 1 and 2, 120 g/MWh in Vision 3 and 70 g/MWh in Vision 4, compared to about 350 g/MWh in 2007, before the crisis. Globally CO2 emissions of the power sector are divided by two to three from Vision 1 to Vision 4 as depicted on the chart below, achieving CO2 emission levels 40% to 80% lower compared to 1990.

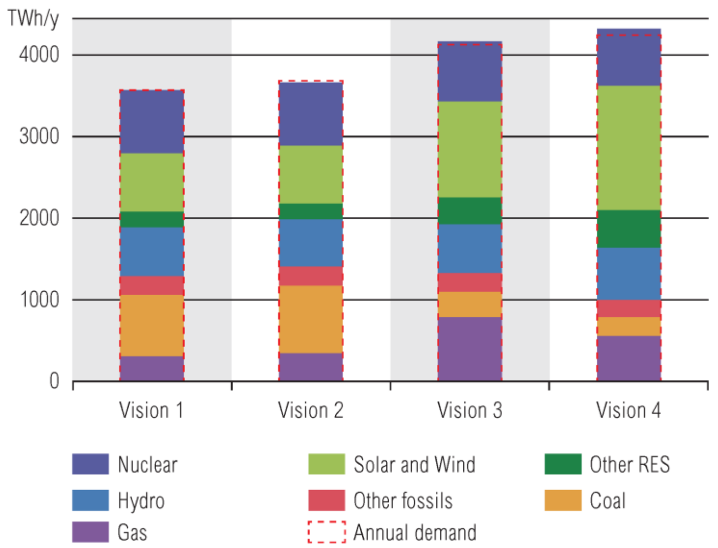

Figure 3-22 Comparison of the share of the yearly production of different types of generation in the total yearly consumption in all the 2030 Visions

With a marginal cost of 0 €/MWh, the increased share of RES in the mix from Vision 1 to Vision 4 also makes the average MWh cost in Europe close to 30-40 €/MWh in all Visions, however for slightly different reasons: a lower (resp. higher) set of fuel and CO2 prices combined with a 40% (resp. 60%) RES penetration in Vision 1 (resp. Vision 4). This cost price per kWh is similar to the present wholesale market costs. However, the two figures are not exactly comparable, as a "capacity" component, per MW, must be added in a context of higher RES penetration where specific incentives for back up steerable generation capacities are required.

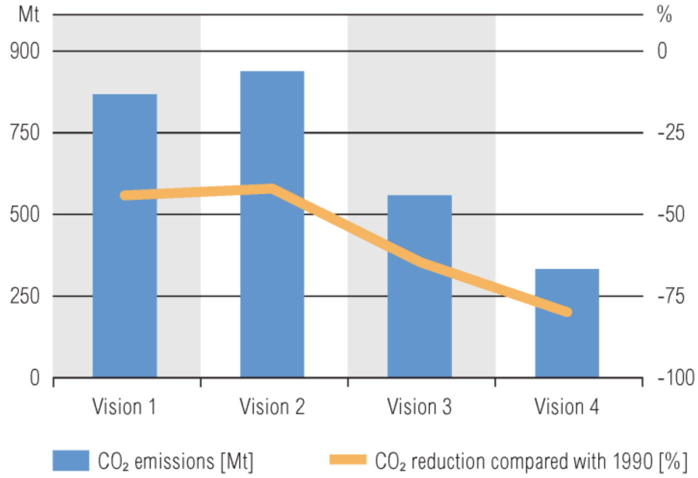

Figure 3-23 Comparison of the yearly amount of CO2 emissions produced and the CO2 reductions comparing 1990 in all the 2030 Visions

Eventually, RES development appears to be by far the major factor differentiating the Visions. As a result, all findings obtained in the TYNDP analyses display a gradation from Vision 1 to Vision 4. In order to make the report lighter, only Visions 1 (as the lowest scenario) and Vision 4 (as the highest scenario) are displayed in the report.

Because of the high ambitions regarding RES development, Vision 4 required more investigation efforts compared to Vision 1 and 3 (and practical measures to answer some investment needs specific to Vision 4 are yet to be devised in the framework of the preparation of TYNDP 2016).

One will also remark that the main outputs for Vision 1 and Vision 2 appear similar at the pan-European level, although the breakdown per country shows differences. Vision 2 assessments have hence been performed last in the process, with often fewer resources allotted from the Regional Groups.

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4 Investment needs

Once the scenarios have been defined the next phase of network planning consists of characterising the investment needs. An investment need refers to every concern on the regional grid which is of European significance. Investment needs are likely to trigger extra-high voltage grid investments in order to restore the grid's ability to fulfil the duties and services expected from the infrastructure.

Investment needs are described in the present chapter and solutions to accommodate them are summed up in Chapter 5.

4.1 Present situation

Figure 4-1 shows a diverse level of Net Transfer Capacities (NTC) in Europe. The NTC is the maximum total exchange program between two adjacent control areas that is compatible with security standards and applicable in all control areas of the synchronous area, whilst taking into account the technical uncertainties on future network conditions.

NTC values for the same equipment change under different conditions, for example the topology of the network or the load pattern at the given point in time that the study is conducted. It is also important to note that the presentation of capacities per international border can be misleading as geography makes more relevant to consider at once the boundary between Poland and its three western and southern neighbours; or between Italy and its four northern neighbours for instance.

The differences in NTC, on the whole, the geography and demography of Europe, with the highest NTC levels and highest grid densities generally being found in the central part of the continent. This is the area between London and Milan, where there is the highest population density and therefore higher consumption levels, as well as installed generation. The interconnection of the Iberian peninsula with mainland Europe is relatively low and shows frequent congestion. On the other hand, southeast Europe shows a consistent pattern with comparable interconnection capabilities across the area, albeit at a lower level than in more densely populated areas.

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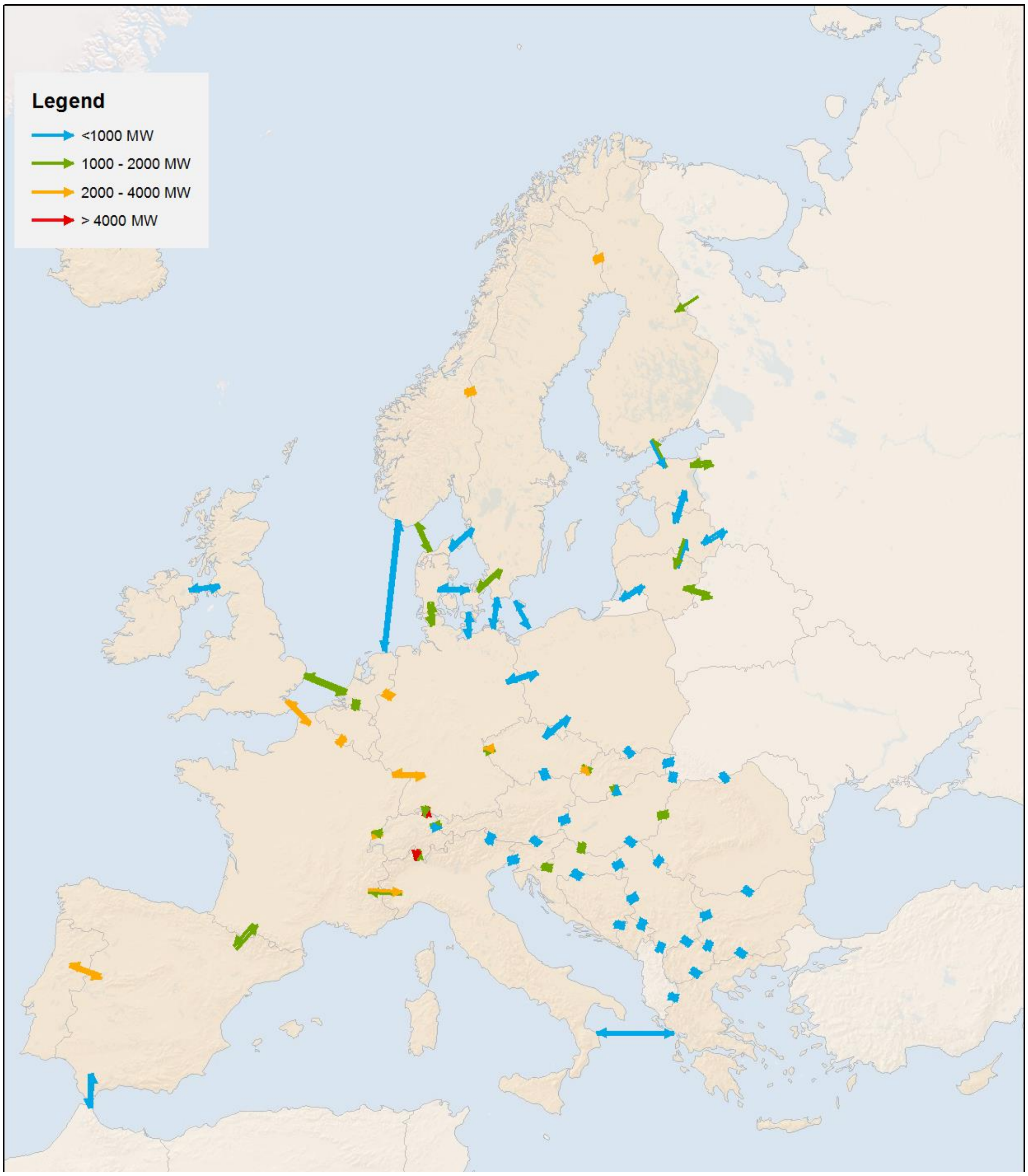

Figure 4-1 Illustration of Net Transfer Capacities in ENTSO-E perimeter (2013)

4.2 Drivers for power system evolution

Drivers for power system evolution are directly derived from EU energy policy goals, security of supply, internal electricity market integration, climate change mitigation and RES integration.

Climate change mitigation and competition will require energy efficiency measures such as the transfer from fossil-fuel based end-uses to CO2-free energy sources. This will mean for instance more trains, electric vehicles and heat pumps. European power peak load is thus expected to grow by 2030, spreading from 8% in Vision 1 to 28% in Vision 4. This represents between 0.4%/yr and 1.3%/yr for the load growth. Local security of supply issues may arise, but no actual issue of pan-European significance would be entailed by load growth.

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Security of supply is however a concern for Cyprus, Iceland and the Baltic states, which are isolated systems with a relatively low interconnection capacity with neighbouring EU Member States.

By 2030, the main driver for power system evolution and grid development is generation. Europe has initiated a major shift of the generation fleet, with net generating capacity expected to grow from a bit less than 1000 GW today to almost 1200 GW in Vision 1 and more than 1700 GW in Vision 4. The construction effort must account not only for the net increase but also for the replacement of present units that will come to the end of their asset life within the coming 15 years. For the adaptation of the generation fleet, this represents a rate of 3.1%/yr in Vision 1 and up to 4.6%/yr in Vision 4.

The main features of the generation mix in 2030 are the following:

- The new generation capacities are mostly RES, especially wind and solar. In 2013, installed capacities of wind power, solar and biomass amount to 105, 69 and 22 GW respectively for a total of 197 GW. This capacity is expected to double by 2030 in Vision 1 (up to 405 GW) and more than triple in Vision 4 (up to 876 GW).
- These capacities are concentrated mostly in Germany (about 20-25% of the total), countries with favourable wind conditions such as the Iberian and Italian Peninsulas and countries neighbouring the North Sea (see the SOAF for more information).
- New hydropower capacities are also envisaged. The present capacity of 198 GW is expected to increase by 20% to 40% depending on the Visions. The three most promising areas are the Alps, the Iberian peninsula, and Norway.
- The nuclear phase-out in Germany (by 2022), Belgium (by 2025) and Switzerland (by 2034) will hence almost be complete by 2030. All present nuclear units in the UK are scheduled to be shut down and France plans to reduce their share of nuclear to 50% of the power supply by 2025. As a result, depending on the scenarios, between 30 and 45 GW of nuclear capacity is expected to be shut down in total. Conversely, 20 to 30 GW of new nuclear capacities are expected to be brought onto the system. This is mainly in the UK but also includes Finland and Central Europe.
- The new generation capacities are also located on new spots compared to the existing ones. New wind farm development is to be located where wind speeds are favourable whereas new thermal capacities are being built on existing generation sites, where new assets are replacing obsolete ones. Nevertheless, a significant share in western Europe is being built on new sites, mostly in harbours.
- Combined with the shutdown of nuclear and fossil-fired units along the Rhine corridor, this entails that globally the average distance between generation and load centres is tending to increase, requiring more grid to transport the power further.

Among the other possible drivers for investing on grids is the refurbishment of aging equipment. The corresponding costs are important for TSOs, however it is also important to note that refurbishment issues are only displayed in the TYNDP when they are upgrades or reconstruction of existing facilities that lead to greater Grid Transfer Capability.

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4.3 Main Bottleneck locations and typologies

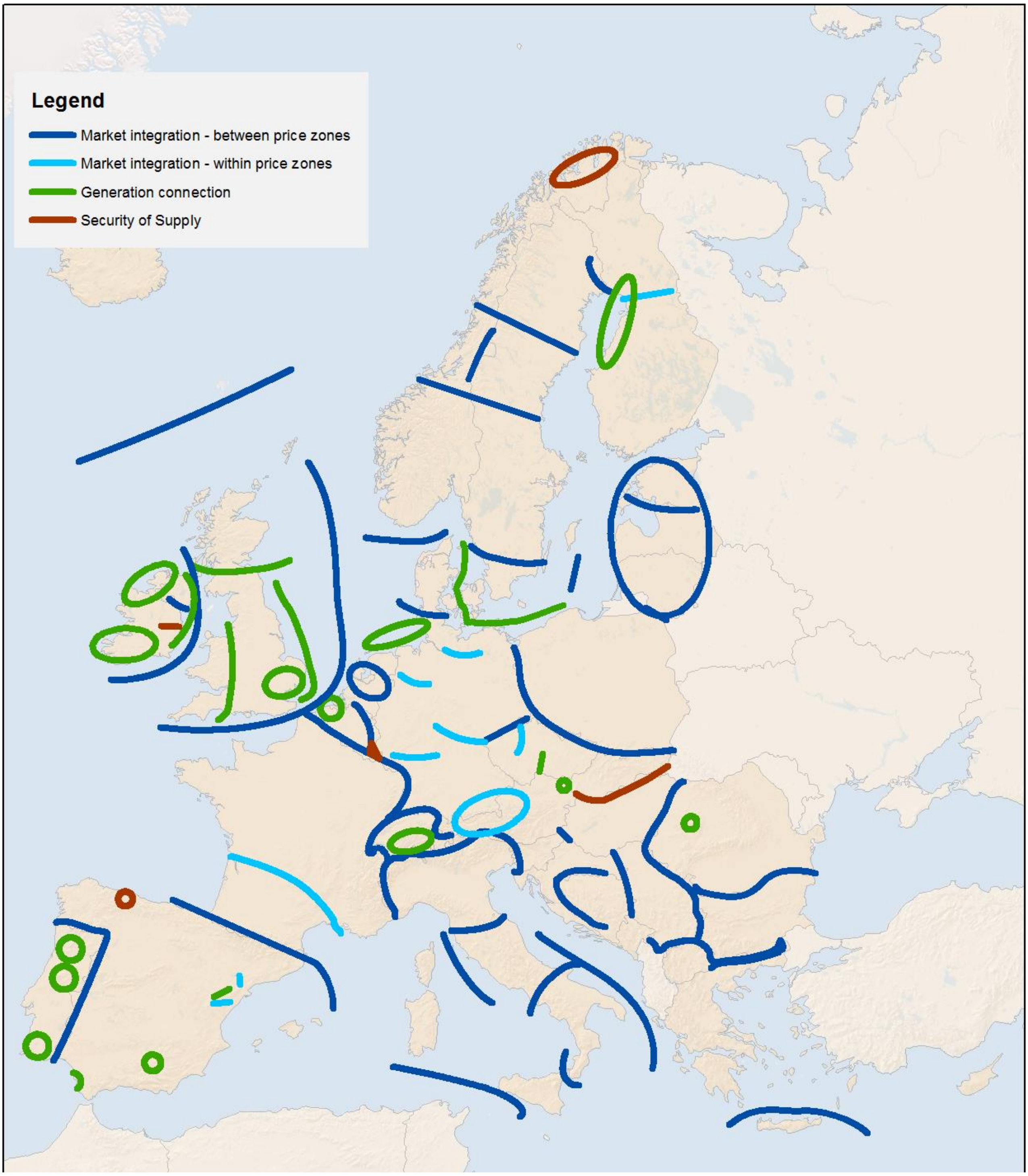

Figure 4-2 Map of main bottlenecks in the ENTSO-E perimeter

As a result of the market and network study process, about 100 bottlenecks have been identified for the European electricity system in the coming decade requiring new transmission assets in order to be removed. Figure 4-2 shows their locations, i.e. the grid sections (the "boundaries"), the transfer capabilities of which may not be large enough to accommodate the likely power flows that will need to cross them.

In order to ease the understanding, the likely bottlenecks have been sorted according to three types of concerns:

1. **Security of supply:** when some specific areas may not be supplied according to expected quality standards and no other issue is at stake.

2. **Direct connection of generation:** both thermal and renewable facilities.

3. **Market integration:** if inter-area balancing is at stake, what is internal to a price zone and what is between price zones (cross-border) needs to be distinguished.

When a boundary can be flagged with more than one concern, market integration prevails over generation connection and security of supply. 60% of the boundaries are primarily related to this issue with 40% cross-border and 20% internal. Boundaries associated to market integration issues may correspond to bilateral borders between countries, but actual interconnection concerns often have to be addressed at a larger scale:

- Interconnection of the Baltic States as a whole with other EU countries.
- Interconnection capacity of Great Britain and Ireland to mainland Europe. (Which country will they be interconnected to is a secondary, although important, issue).
- Interconnection of Italy and its northern neighbours.
- Interconnection of the Iberian Peninsula with mainland Europe.

Generation connection is the second main driver concerning primarily 30% of the boundaries. The displayed boundaries relate to already public and mature applications for connections of large generation plants, storage PCIs, or areas where more than 1 GW of RES / 1000 km² is planned. (Many additional generation projects of regional or more local importance are hence not reported.)

Overall, integration of new renewable generation is the main driver for system evolution in Europe. New wind power plants are planned in the North Sea and Baltic Sea regions, mainly concentrating on the coastal areas (including many offshore wind parks) and the highlands in the north. In the Continental South West region RES generation connection concerns mainly shore-wind and solar but also hydro, including pumping storage in northern Portugal and different areas in Spain, while in the Continental South East region an important renewable generation connection is expected in Bulgaria, Romania and Serbia. Significant needs in terms of renewable connection and integration are expected also in the Continental Central South region (hydro pumping generation in the Alps, Solar and Wind generation especially in Germany, Italy and France).

Through the construction of the scenarios, the four Visions assume generation is sufficient to balance load; security of supply may remain a concern locally, and investment of pan-European significance may contribute to enhanced security of supply (e.g. the north-south transmission corridors within Germany), but only seldom will it show up as a primary driver for projects of pan-European significance by 2030.

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4.4 Bulk Power Flows in 2030

A **Bulk power flow** is the typical power flow triggering grid development across a boundary. They are quantified in the following sections for every concern: market integration, generation direct connection and security of supply. Bulk power flows range from about 500 MW to more than 10000 MW.

4.4.1 Generation Connections

The following maps (Figure 4-3 below) display the boundaries that are related to the direct connection of renewable or conventional facilities to the grid in Vision 1 and in Vision 4.

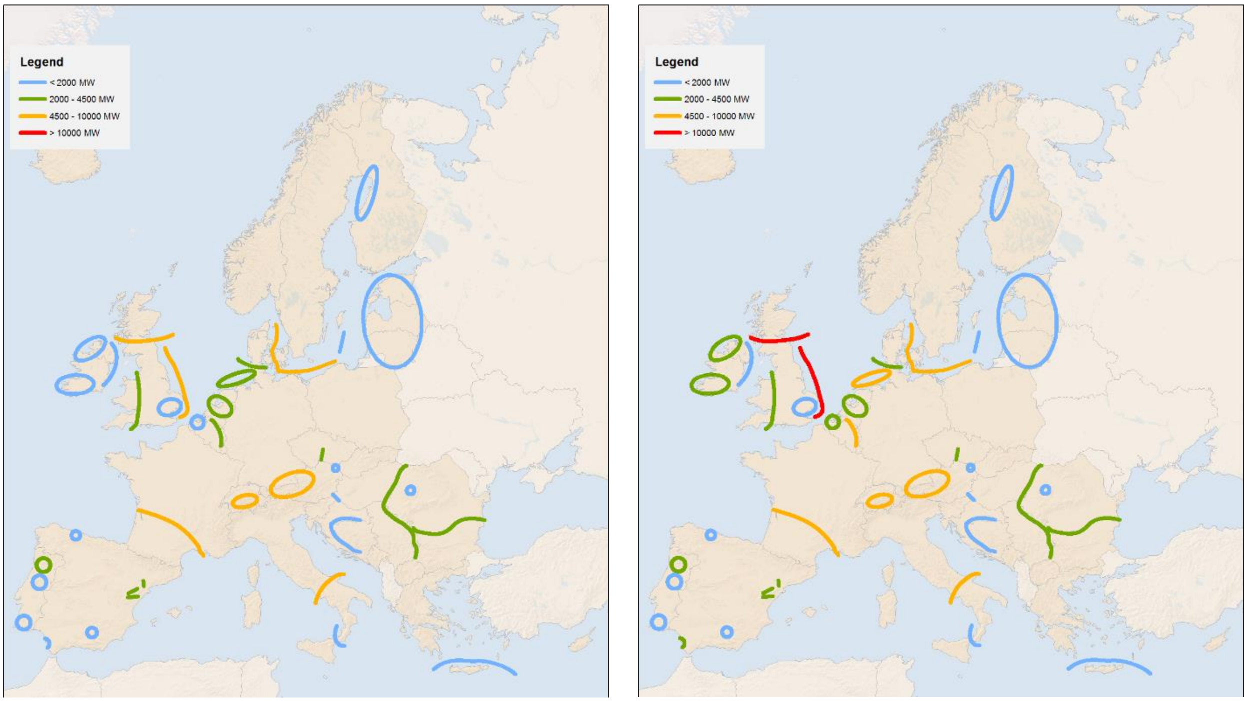

Figure 4-3 Maps of bulk power flows related to generation connections in Vision 1 (left) and Vision 4 (right)

Both maps display essentially the same set of boundaries. They relate to direct connection of power plants that are expected to be built by 2020 (hence present in all Visions) or areas where RES development is planned (only the magnitude of RES development varies from one Vision to another).

Higher bulk power flows (amber and red) are highlighted where the new generation develops in a limited area (especially offshore wind in the North Sea) or adds up to an already large concentration of generation (Scotland, Wales, the Alps, Southern Italy etc.). Where relatively little generation has been installed before large amounts of RES are planned, bulk power flows is lower (blue and green): Ireland, Portugal, Spain, Greece, Bulgaria and Romania, Poland, Nordic countries. Large but relatively isolated thermal or hydro storage plants are located when a specific boundary is applied corresponding to their capacity (blue) in Poland, Lithuania, Romania, etc.

4.4.2 Market Integration

The following maps (Figure 4-4 below) display market integration concerns in Vision 1 and in Vision 4. (Maps for Vision 2 and Vision 3 would be similar, with some intermediate patterns.)

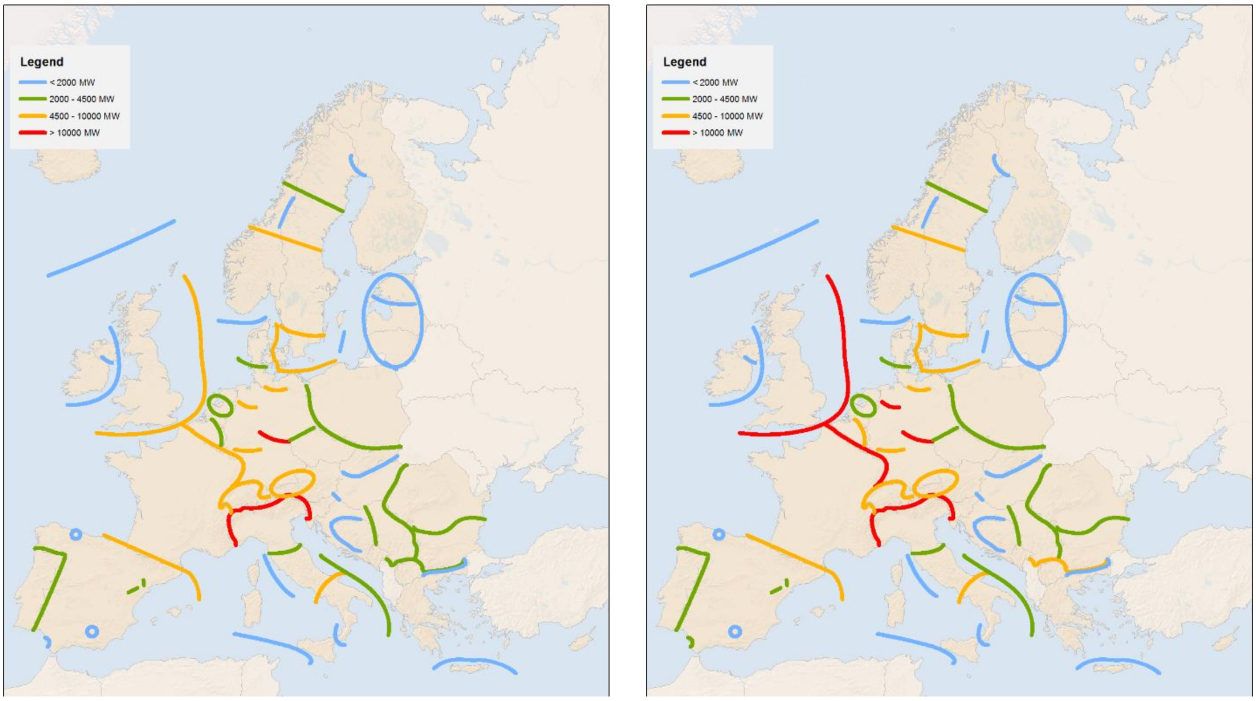

Figure 4-4 Maps of bulk power flows related to market integration in Vision 1 (left) and Vision 4 (right)

On both maps, bulk power flows are oriented mostly north-south, except in southeast Europe where they are primarily from East (Romania Bulgaria) to the west (up to Italy) and south (Greece).

Geography explains the pattern of very large power flows between contrasted areas:

- Large RES development areas, especially from Ireland to Denmark, along and off the North Sea shores or in the Iberian peninsula and south of Italy;
- The densely populated areas spreading from England to the north of Italy, along the Mediterranean shores from Spain to Greece and in the main cities, importing most of their electricity from neighbouring areas;
- Hydro storage in Scandinavia, and the Alps, with pumping capacity, and Finland

Thus, from north to south, the power system alternatively shows generation and consumption areas. As a result, the power flows are large, but also more volatile than today.

On a parallel corridor, the Baltic States display a similar flow pattern, exchanging power with hydro dominated systems (Finland, Sweden) and a fossil fuel dominated system (Poland).

These patterns are constant from one Vision to another. Only the magnitude of the bulk power flows increases (resp. decreases), as the contrasts augment (resp. are mitigated) between the regions and specifically as RES capacities increase. Hence, bulk power flows are globally higher in Vision 4 compared to Vision 1.

4.4.3 Security of Supply

The following maps (Figure 4-5 below) display the boundaries that are related to security of supply in Vision 1 and in Vision 4.

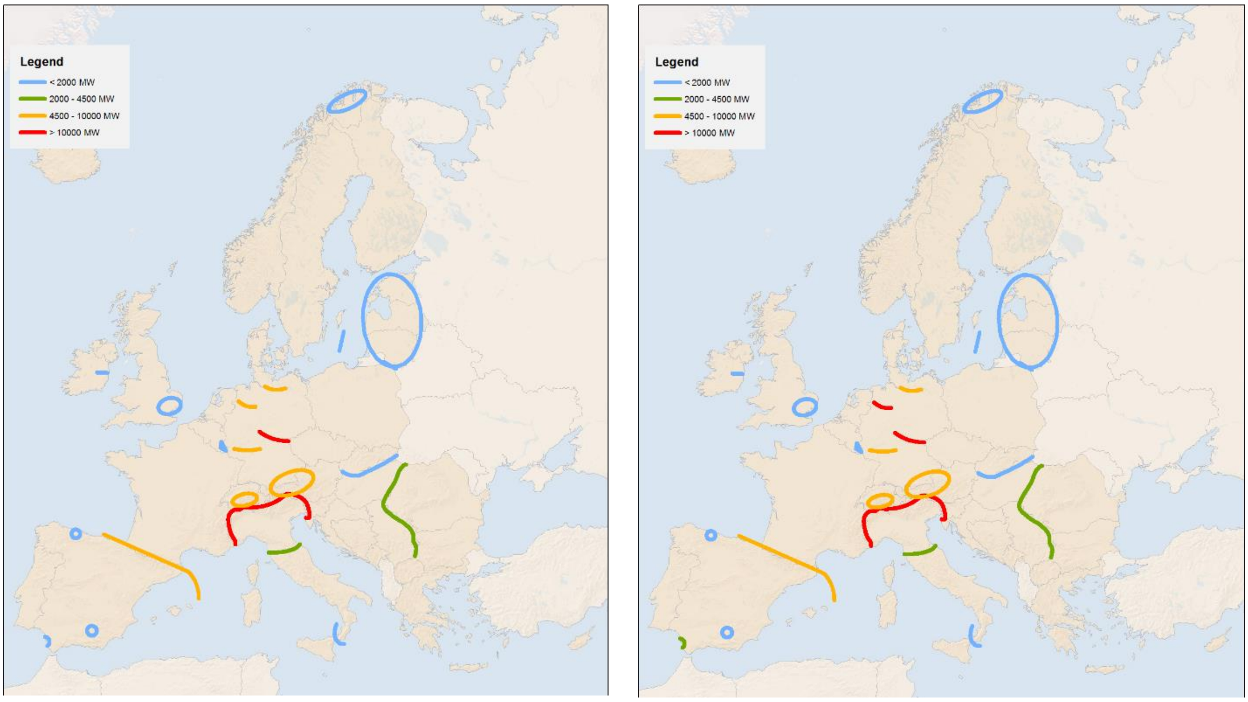

Figure 4-5 Maps of bulk power flows related to security of supply Vision 1 (left) and Vision 4 (right)

In most cases, security of supply concerns are limited to relatively small areas and are therefore often efficiently mitigated by investments at the local/national level that are not reported here. At the pan-European level, security of supply relates to three main concerns:

- The densely populated areas of Luxembourg, the west and south of Germany, showing potentially a negative adequacy forecast by 2030 and needing to import most of their power;
- Baltic States requiring a higher interconnection with EU countries to ensure their supply;
- The integration of Ireland and the UK, Spain and Portugal, and Italy to the European power system.

5 Project portfolio

5.1 Criteria for Project Inclusion

5.1.1 Transmission projects of pan-European significance

A project of pan-European significance is a set of Extra High Voltage assets, matching the following criteria:

- The main equipment is at least 220 kV if it is an overhead AC line or at least 150 kV otherwise and is, at least partially, located in one of the 32 countries represented in TYNDP.
- Altogether, these assets contribute to a grid transfer capability increase across a network boundary within the ENTSO-E interconnected network (e.g. additional NTC between two market areas) or at its borders (i.e. increasing the import and/or export capability of ENTSO-E countries vis-à-vis others).
- An estimate of the above mentioned grid transfer capability increase is explicitly provided in MW in the application.
- The grid transfer capability increase meets at least one of the following minimums:

– At least 500 MW of additional NTC; or

– Connecting or securing an output of at least 1 GW / 1000 km² of generation; or

– Securing load growth for at least ten years for an area representing a level of consumption greater than 3 TWh / yr.

A refined project definition and a substantial evolution of the portfolio

Around 30% of the investments from TYNDP 2012 are now only depicted in the Regional Investment Plans.

First, as highlighted in section 2.2.3, the stricter CBA clustering rules led to a refined list of projects in the TYNDP 2014. Some TYNDP 2012 projects included investments with a commissioning gap of longer than five years. Some secondary investments are hence presented only in the Regional Investment Plans and their supporting role for the project of pan-European significance is recalled in the comments on the latter in the TYNDP.

Besides, the new focus on 2030 and the time constraints of systematically assessing all projects with the CBA methodology and the four Visions validated quite late in 2014 has led ENTSO-E to focus on the longer-run projects and mitigate assessments efforts for mid-term projects. Decisions for these projects have already been made; construction works may have even started so their assessment is of limited interest for all stakeholders. As a result, most mid-term projects, except when they have a PCI label or when their assessment is relevant, are only presented in the Regional Investment Plans, whereas projects to be completed after 2020 have been given priority, taking advantage of the limited resources.

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5.1.2 ENTSO-E and Non ENTSO-E Member Projects

Most of the transmission projects are proposed by licensed TSOs, who are members of ENTSO-E. In the framework of transmission system development, it is possible however that some transmission projects are proposed by 'third party' promoters. In light of Regulation (EU) 347/2013, entered into force on 15 May 2013, which makes the ENTSO-E TYNDP the sole basis for the electricity Projects of Common Interest (PCI) selection, in 2013 ENTSO-E developed the "Procedure for inclusion of third party projects – transmission and storage – in the 2014 release of the TYNDP[27]", hereafter called the Third Party Procedure.

In the Third Party Procedure, ENTSO-E categorises third party projects, which must be projects of pan-European significance, into three different forms promoted by:

- Promoters of transmission infrastructure projects within a regulated environment, which can be either promoters who hold a transmission -operating license and operate in a country not represented within ENTSO-E, or any other promoter.
- Promoters of transmission infrastructure projects within a non-regulated environment: promoters of these investments are exempted in accordance with Article 17 of Regulation (EC) No 714/2009
- Promoters of storage projects.

The Third Party Procedure has been devised with ACER and EC, the LTND SG and consulted upon in November 2012. Two application windows were opened to enable project promoters to candidate, in January and September 2013.

Projects proposed by non-ENTSO-E promoters are assessed simultaneously by ENTSO-E according to the same cost benefit analysis methodology adopted for TSO projects. Late comers were assessed using the PINT approach if the capacity increase anticipated for the corresponding boundary was not greater than their project capacity.

ENTSO-E and non-ENTSO-E projects are displayed the same way in the reports.

ENTSO-E received 33 applications and in total the TYNDP 2014 assesses 24 projects proposed by non-ENTSO-E Members (13 transmissions projects and 11 storage projects). Out of the 24 projects accepted in the TYNDP 2014[28], 19 are listed as Projects of Common Interest (nine transmission and 10 storage projects).

5.1.3 Projects of Common Interest

All Projects of Common interest except those already commissioned have been assessed. The assessment of transmission (resp. storage) PCIs summarised in section A1.2 (resp. A1.3) of Appendix 1.

In the course of this chapter, only transmission projects of pan-European significance are addressed.

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[27] https://www.entsoe.eu/major-projects/ten-year-network-development-plan/tyndp-2014/

[28] Regarding the nine other applications, one application was rejected as it regards two countries outside the ENTSO-E perimeter; the eight others failed to provide the required documentation.

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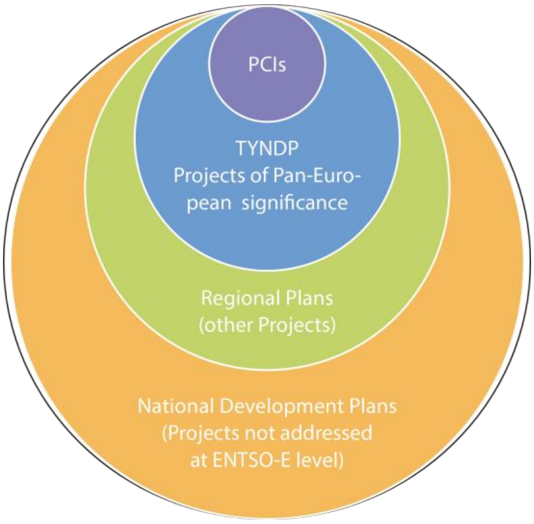
5.2 Transmission projects portfolio



This chapter provides details on the projects of pan-European significance of the TYNDP 2014, especially regarding the locations, the technology used and the status of the investments. In addition, section 5.3 describes the assessment of this projects portfolio using the CBA methodology.

Several of the projects of pan-European significance are Projects of Common Interest (PCI). Some have been proposed by non-ENTSO-E Members.

Complementary to the projects of pan-European significance, regional investments are not included in the TYNDP but are described in the six Regional Investment Plans. In many cases they support, sometimes directly, projects of pan-European significance.

5.2.1 Overview of the pan-European projects foreseen in the coming decades

The two maps in the following pages geographically display all projects of pan-European significance from the TYNDP 2014, divided into two periods: the mid-term (2014 – 2018) and the long-term (2019 and beyond). The maps show basic information regarding locations, routes and technology. When the precise location of an investment is not yet clear, an ellipse shows where the investment is likely to occur.

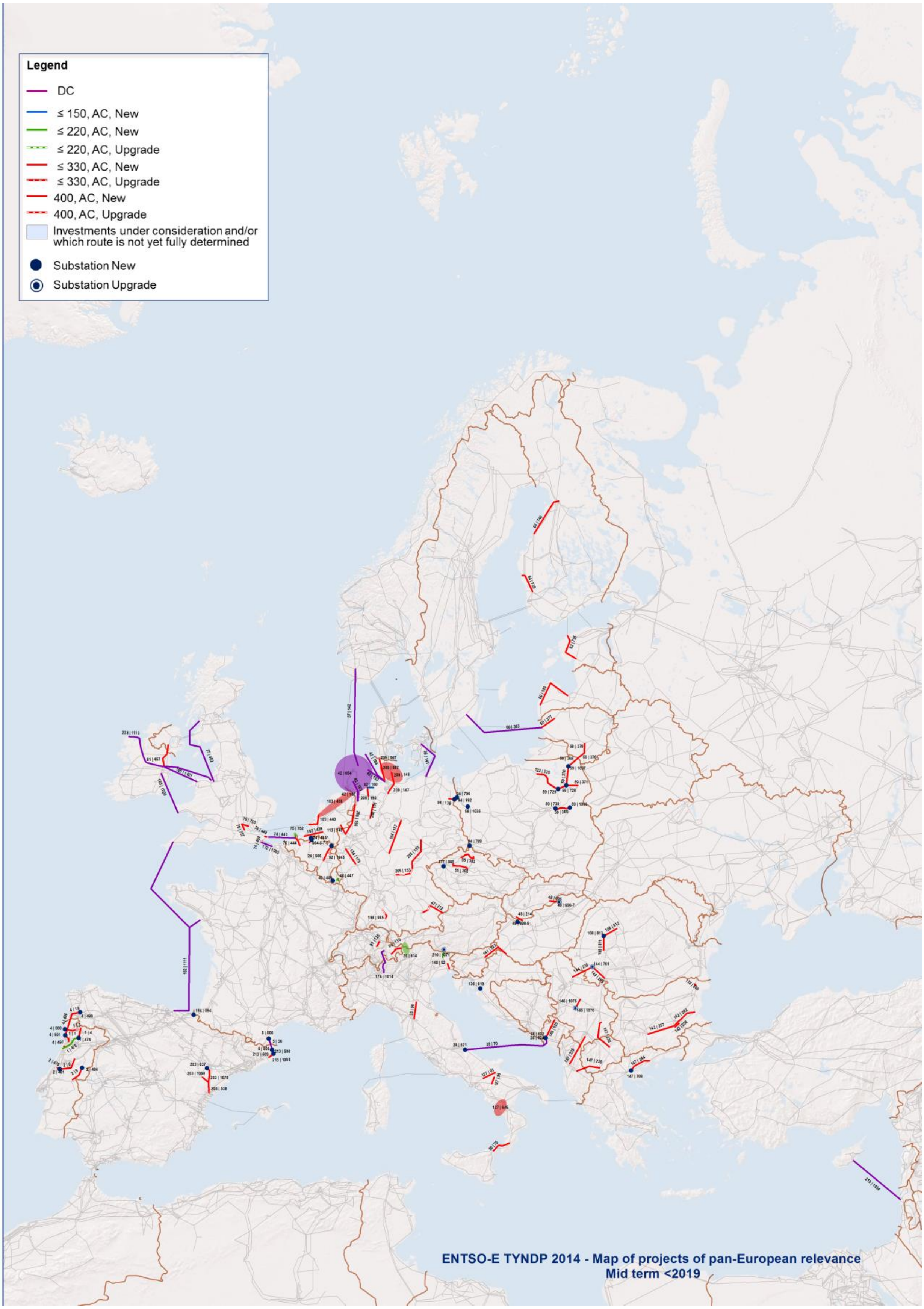


Figure 5-1 Pan-European Significance investments – Mid-term horizon (<2019)

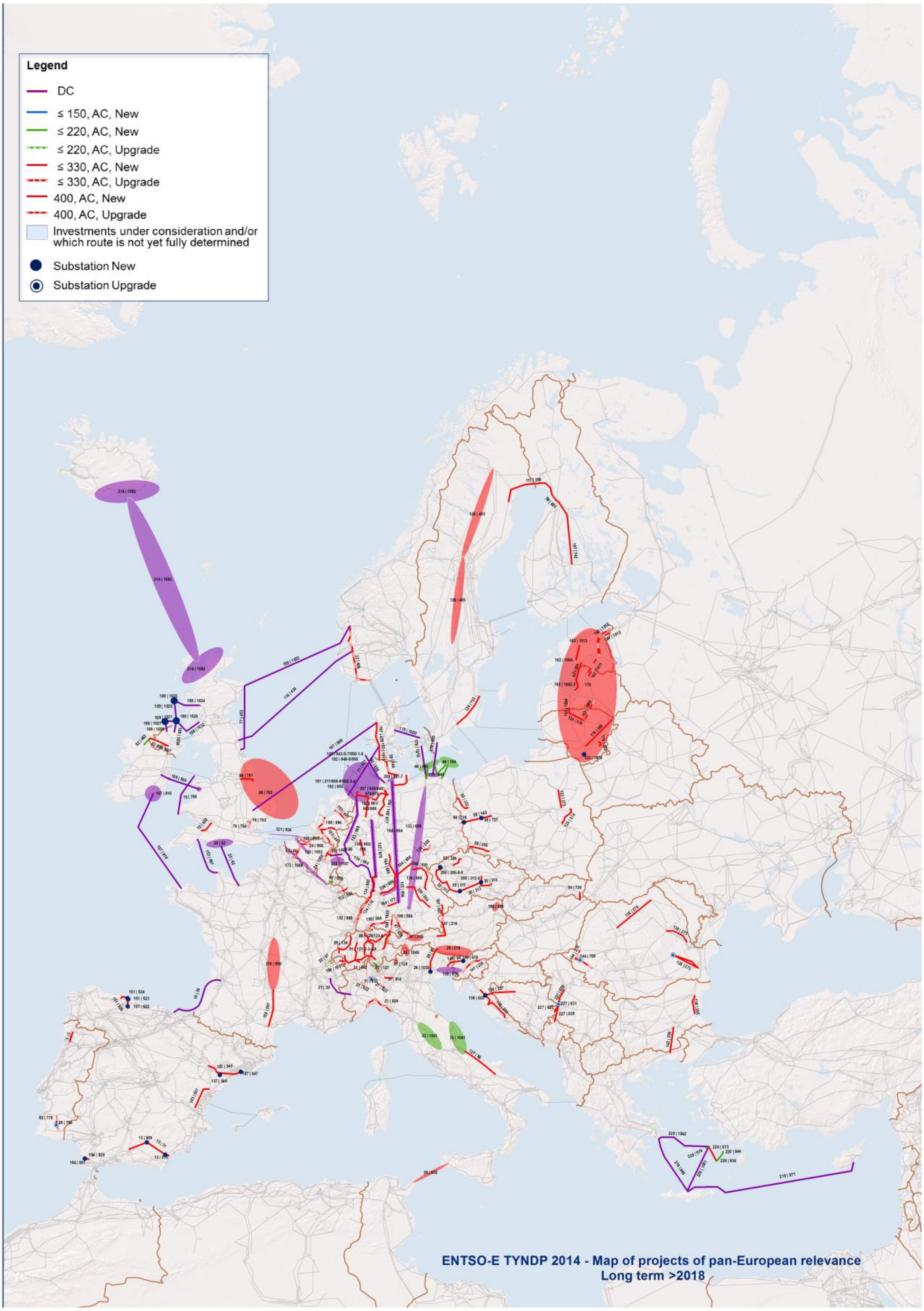


Figure 5-2 Pan-European Significance investments – Long-term horizon (>=2019)

5.2.2 About 20000 km of High Voltage Direct Current (HVDC) lines, representing 40% of the TYNDP 2014

The TYNDP 2014 amounts to approximately 48000 km of new or upgraded lines, corresponding to 120 projects in the coming decade (i.e. about 400 investments of pan-European significance).

Figure 5-3 above illustrates the typology of the TYNDP 2014 portfolio of projects.

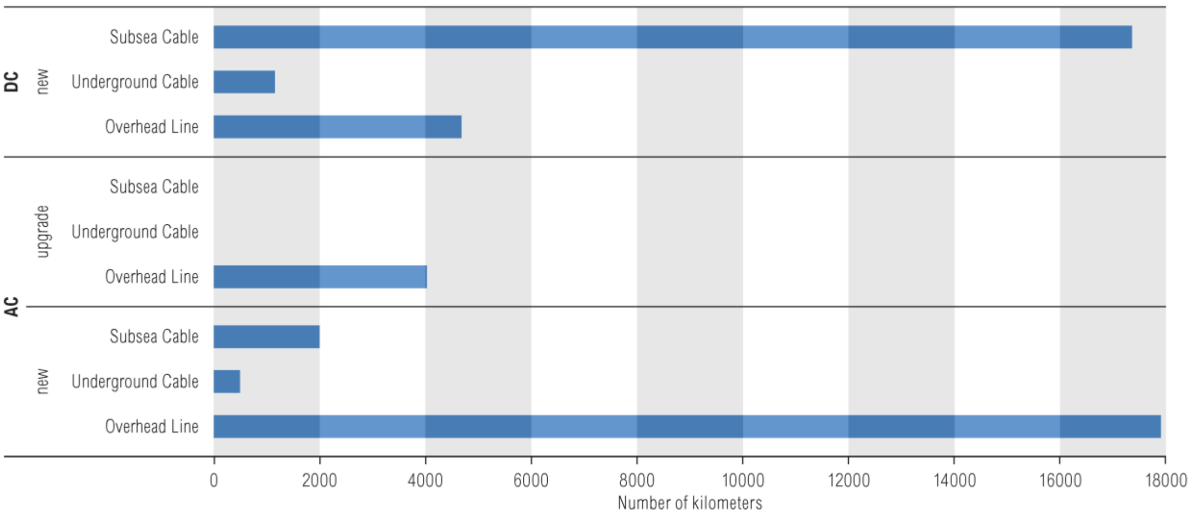


Figure 5-3 TYNDP 2014 investment portfolio - breakdown per technology

AC – with about 21000 km of new lines planned – is expected to remain the prominent technology. Around 10% of the investments actually consist of upgrades or refurbishments of existing AC assets. Most new overhead lines planned will be built using AC technology, which is still the easiest to implement for inland applications. Partial undergrounding of sensitive areas will increasingly complement overhead lines.

However, DC is now heavily utilised, with about 20000 km of new HVDC lines in the Plan, i.e. more than 40% of the total additional infrastructure. The main drivers for the HVDC choice are:

- The connection of some offshore RES, especially in the North Sea area (but most offshore connections still being AC);
- The integration of the Iberian peninsula, Italy, the Baltic States, Ireland and the UK with mainland Europe in line with the IEM;
- The need to bring power generated far from the consumption to cities and industrialised areas (e.g. wind in Scotland, wind in the north of Germany leading to the setting up of German corridors, etc.).

The expected growth of new cables almost corresponds to the development of the new HVDC projects included in the TYNDP 2014. More than 75% of the total amount of HVDC lines will be built using cables. Submarine cables will represent the greatest length planned, although almost 5000 km of HVDC projects are planned onshore.

Submarine HVDC cables in the North Sea build an offshore grid, even though they are point to point or in a few cases three-terminal devices. More important offshore meshings do not appear as a pre-requisite by 2030, even for integrating the large amount of RES anticipated in the Visions.

A significant number of kilometres of HVDC overhead lines has been planned as well.

5.2.3 EU energy policy goals require steady investment efforts by 2030

Grid planning requires the long-term evolution of the power system to be studied to develop a robust and cost effective system. In the TYNDP 2014, TSOs have jointly explored the 2030 time horizons for various scenarios have and identified several investments needed before 2030. Almost 70% of the total investments are to be commissioned in the long-term, after 2018.

The status of the investments breakdown shows a rather balanced picture, with about half of the investments having reached at least the design and permitting phase.

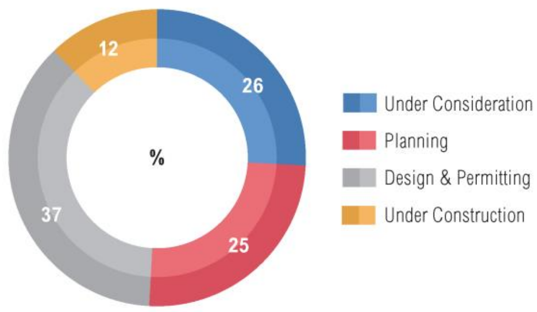


Figure 5-4 TYNDP 2014 investment portfolio- breakdown by status

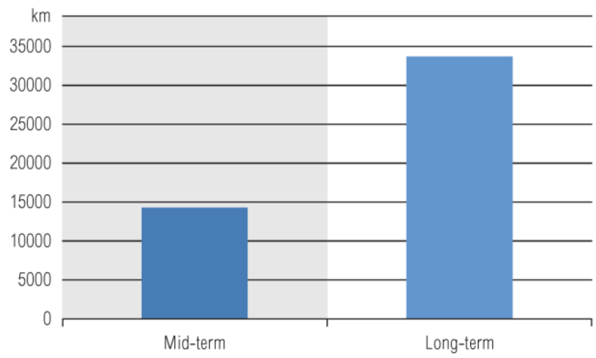


Figure 5-5 TYNDP 2014 investment portfolio - breakdown by commissioning time

Some additional reinforcements are still to be designed to cover investment needs specific to the most ambitious scenarios of RES development by 2030. The set of projects of pan-European significance is still to be completed in order to meet the energy revolution proposed in Vision 4; with its validation first in October 2013, Vision 4 could only be used to assess the portfolio of already identified projects. Investment needs investigation in this Vision requires additional input and feedback from stakeholders (more precise locations of generation especially) so that a more comprehensive picture of the grid infrastructure can be supplied. Such interaction and continuous adaptation is normal, considering uncertainties regarding the realisation of the challenging transformation of the generation mix.

In addition, as introduced in the chapter 9.4, the high RES penetration creates further challenges for the operation of the grid that must be carefully planned for.

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5.3 Assessment of the project portfolio

5.3.1 Interconnection capacity will double all over Europe

The challenge for the coming decades is to facilitate larger and more power flows across Europe. The new projects increase the Grid Transfer Capacity (GTC) among the main generation areas and consumption areas. The values of gained GTC are oriented by needs and cover a huge range of transmission capacity increase efforts: projects of pan-European significance are very diverse, adapting to the specific geographical areas they are inserted in. The GTC has been developed from a few hundred MW to several GW, as shown in the following chart.

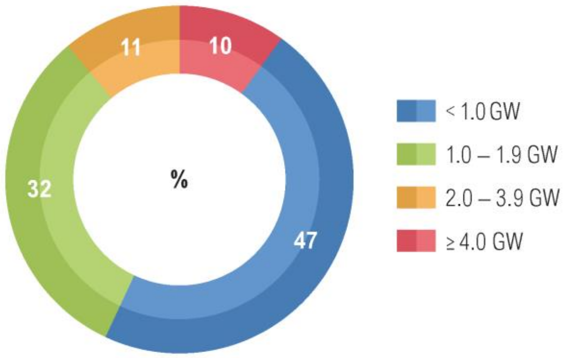

Figure 5-6 Grid transfer capability increases breakdown

Most of the projects of pan-European significance are AC interconnections, with a capacity of about 1000 to 2000 MW, or DC interconnectors with individual capacities ranging from 700 MW to 1400 MW. Hence, 80% of the projects develop from 500 to 3000 MW. Larger projects cluster investments for direct RES connection, especially in the UK or Germany.

5.3.2 Grid reinforcements increase the social and economic welfare of Europe

Social and Economic Welfare (SEW) is characterised by the ability of a power system to reduce congestion and thus provide an adequate transmission capacity so that electricity markets can trade power in an economically efficient manner. A project that increases transmission capacity between two bidding areas allows generators in the lower-priced area to export power to consumers in the higher-priced area. The new transmission capacity reduces the total cost of electricity supply. Therefore, a transmission project in general will increase social and economic welfare.

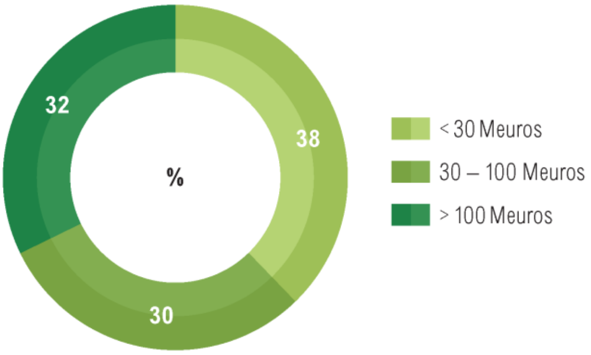

Figure 5-7 Increase in Social Economic Welfare of the TYNDP 2014 in 2030 vision 1

In Vision 1, 38% of the projects are on the lower indicator-scale with a SEW-value lower than 30 M€/year. The main reason for this is related to the fact that the marginal cost differences between the countries are lower in Vision 1, as explained in chapter 4. The less constrained situation on the grid is due to a generation mix with a more limited amount of RES than Visions 3 and 4, and even more important the relatively lower costs for fossil fuel fired units in Vision 1.

In Vision 1, 30% of the projects have medium SEW-values, while 32% of the projects show high positive SEW-values (more than 100 M€/year). The highest values are shown for interconnectors connecting different markets together with different generation fleets. (Most of these investments also have the highest costs.)

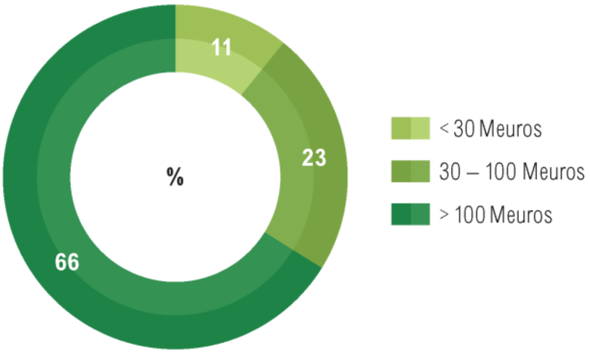

Figure 5-8 Increase of Social Economic Welfare of TYNDP 2014 in 2030 vision 4

The pan-European Vision 4 calculations show that the analysed projects in general have particularly high SEW-values. In Vision 4, about 66% of the projects show SEW-values greater than 100 M€/year, while 23% of the investments show SEW-values between 30 and 100 M€/year. Only 11% of the projects show SEW-values at the lower end of the scale.

The reasons for the higher SEW-values in Vision 4 compared to the other Visions is the greater amount of RES and a higher cost for fossil fuel fired units. The highest values are shown for interconnectors connecting different markets together, especially the four electric peninsulas to mainland Europe, as well as the German corridors.

The enhanced market integration enabled by the project portfolio reduces total generation costs in Europe (and hence the bulk power prices) by 2 to 5 €/MWh, depending on the assumptions on fuel and CO2 prices.

5.3.3 Grid reinforcements are pre-requisites for RES development

RES integration is defined as the ability of the power system to allow the connection of new renewable power plants and unlock existing and future "green" generation, while also minimising curtailments. The RES indicator both calculates the RES effect for either direct connection of RES or avoiding RES spillage.

The RES indicator intends to provide a standalone value showing additional RES available for the system. The indicator measures the influence new grid investments have on this RES integration.

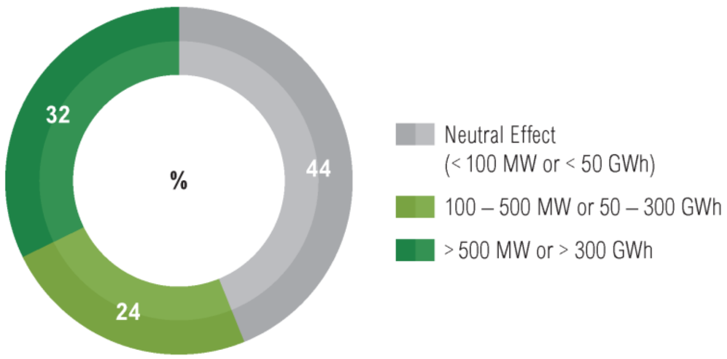

Figure 5-9 Impact of TYNDP 2014 projects on the integration of RES in 2030 vision 1

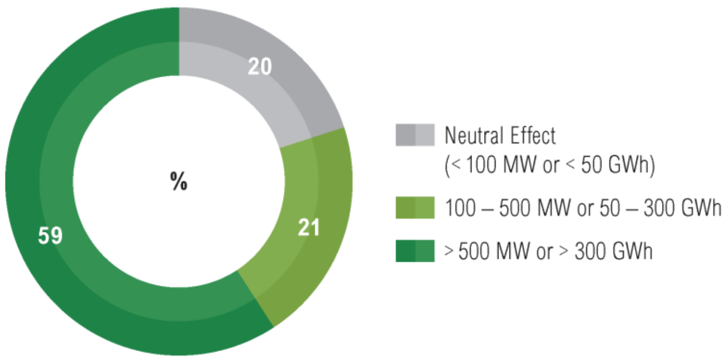

Figure 5-10 Impact of TYNDP 2014 projects on the integration of RES in 2030 vision 4

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44% of the projects have a significant impact on RES integration in Vision 1, although only 20 projects directly connect RES and RES spillage is a relatively marginal issue in this scenario.

In Vision 4 – where RES supplies 60% of the annual demand – spillage becomes a more serious issue, especially offshore, in UK and Ireland, or in Spain. As a result, around 80% of the projects of pan-European significance end up with a medium or high mark for the RES indicator.

5.3.4 A significant mitigation of CO2 emissions

By relieving congestion, reinforcements may enable low-carbon generation to generate more electricity, thus replacing conventional plants with higher carbon emissions.

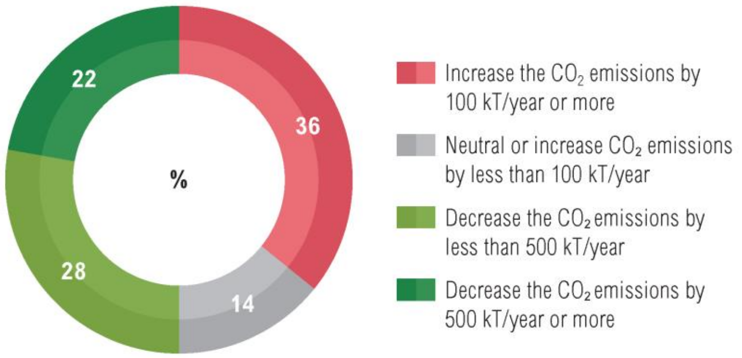

Figure 5-11 Impact of TYNDP 2014 projects on the CO2 emissions in 2030 vision 1

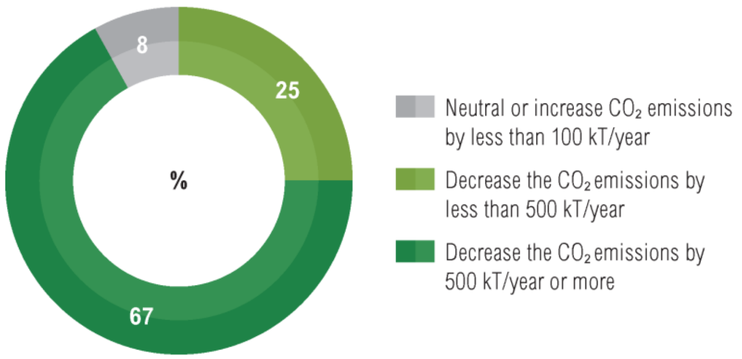

Figure 5-12 Impact of TYNDP 2014 projects on the CO2 emissions in 2030 vision 4

50% of the projects in Vision 1 and 92% in Vision 4 mitigate CO2 emissions significantly. They enable more RES to find their way to consumers, limiting the use of fossil fuel fired units.

In Vision 1 however, coal fired units are relatively cheap, and about 36% of the projects actually help these cheap but high in CO2-emissions power plants to find new outlets. The same applies in Vision 2.

The same projects can get an opposite valuation in Vision 4 (and Vision 3), with higher RES volumes and relatively expensive coal fired units.

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The highest values are shown for projects connecting Scandinavia to Continental Europe, taking advantage of the relatively cheap hydro system.

5.3.5 The TYNDP methodology fails to capture the benefits of projects regarding Security of supply

Security of supply is the ability of a power system to provide an adequate and secure supply of electricity in ordinary conditions, in a specific area. The CBA criterion measures the improvement of security of supply when a transmission project is introduced.

Very few projects are reported with a mark greater than 0 for this indicator in the TYNDP 2014. The indicator must however be completed in order to get the full picture of the benefit of projects with respect to security of supply; projects of pan-European significance may incidentally also be key for solving local SoS issues. However, the pan-European modelling is at too high level to capture these effects and underestimates the benefits:

- Through construction of the scenarios, the four Visions assume generation is sufficient to balance load in all countries, resulting in no energy not supplied in the market studies and hence none that the projects can prevent. The hedging benefits of the projects if the assumed generation mix develops more slowly, with tensions in the power supply, are not measured here.
- By nature, the TOOT method, which consists of measuring the marginal benefit of a project, also limits any energy not supplied in the valuation.

For instance, no interconnection to Belgium has been valued as useful for Belgium's security of supply as generation development is assumed to be sufficient in Belgium, denying likely tension in the power supply before 2030 which the interconnections can mitigate. Additionally, as the benefit of each interconnection is assessed separately assuming all others already been commissioned, its marginal benefit with respect to ensuring the power supply is zero. Conversely, these interconnections and at the very least the first ones commissioned altogether create actual security for the country’s supply.

Whenever the project has an explicit, although possibly local, benefit regarding the security of supply, it is mentioned as a comment in the project assessment sheet. The indirect, induced benefits that every project brings by increasing the meshing of the grid are however not reported.

5.3.6 Globally, a neutral impact on transmission losses in Europe

Variations in electrical losses are an indicator of the energy efficiency of a power system. The energy efficiency benefit of a project is measured through the reduction of these losses in the system. For the same consumption and generation dispatch, network development generally decreases losses, thus increasing energy efficiency. Specific projects may also lead to a better load flow pattern when they decrease the distance between production and consumption. Increasing the voltage level and the use of more efficient conductors also reduce losses. However, the main driver for transmission projects is currently the higher need for transit over long distances, often leading to increased losses. Transmitting renewable energy sources from remote renewable sources will often tend to increase transmission losses, but with an overall benefits of decarbonisation and cost optimisation.

The charts below show that transmission losses are not expected to vary significantly in the coming 15 years with the implementation of the TYNDP project portfolio:

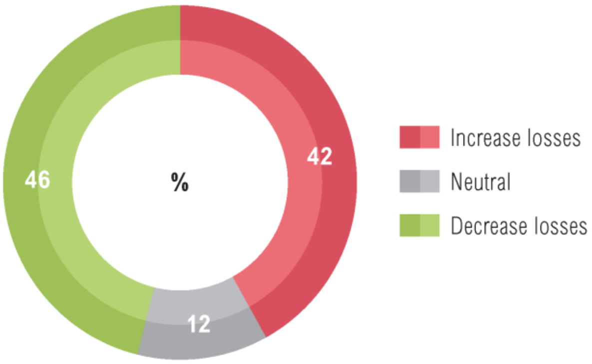

Figure 5-13 Impact of the TYNDP 2014 on the overall losses in 2030 vision 1

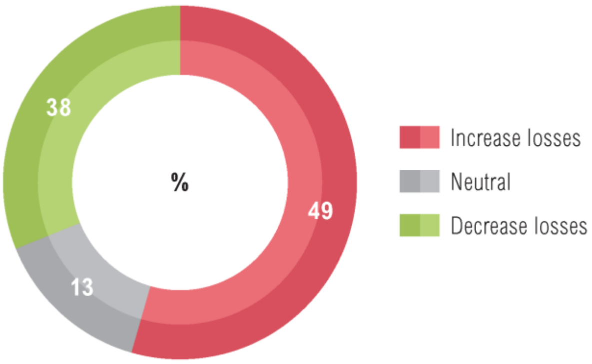

Figure 5-14 Impact of the TYNDP 2014 on the overall losses in 2030 vision 4

Both charts show projects increasing and projects decreasing losses, with sensibly equivalent amounts. In Vision 4, the number of projects with increasing losses is only slightly higher.

The reason for this pattern is that all the effect mentioned in the introductory paragraph of this section tend to compensate for themselves. With higher offshore RES development in Vision 4 compared to Vision 1, power transits occur on longer paths and losses tend to increase.

5.3.7 An Anticipation of extreme system conditions

Making provisions for resilience while planning transmission systems contributes to system security during contingencies and extreme scenarios. The "Technical resilience/system safety" criterion shows the ability of the system to withstand increasingly extreme system conditions (exceptional contingencies). This indicator measures each project's ability to comply with three key performance indicators (KPI) and aggregates these to provide the total score of the project:

- failures combined with maintenance (N-1 during maintenance);
- ability to cope with steady state criteria in case of exceptional contingencies; and

- ability to cope with voltage collapse criteria.

These technical characteristics depend on the typology of each project more than the scenario. Each KPI is scored from 0 to 2, resulting in a total score ranging from 0 to 6, where 0 is the worst value and 6 is the best value.

Each KPI has been appraised in a conservative manner, marking 1 or 2 whenever the project develops outstanding performance compared to other projects. For instance, all reinforcements ease the maintenance of other assets, and for that they score 0; only if the maintenance of existing assets becomes impossible without the new asset would a mark be granted.

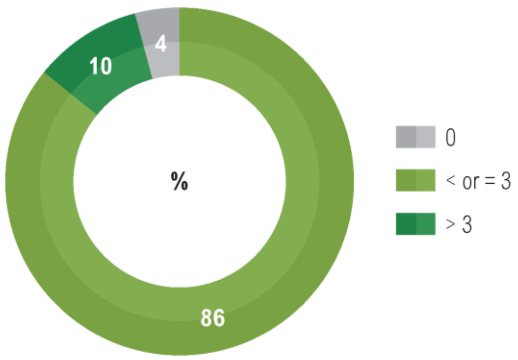

Figure 5-15 Technical resilience/system safety margin indicator

Very few projects score 5 or 6 the maximum: a new AC interconnection between Sweden and Finland and reinforcements of the internal transmission grid with several HVDC-Links in a meshed AC grid in Germany. These projects are the new reinforcement transmission lines on the borders between the areas with weak interconnections or new HVDC-lines in a highly meshed AC grid for long distance transmission. They contribute to the handling of maintenance situations in the grid; they also help to improve the steady state stability issues and voltage collapse issues in specific areas.

5.3.8 An anticipation of all possible futures

The "Robustness and flexibility" indicator shows the ability of each project to withstand very wide conditions. This indicator measures each project's ability to comply with:

- important sensitivities (scenarios):
- commissioning delays and local objections to the construction of the infrastructure,;
- sharing balancing services in a wider geographical area (including between synchronous areas).

Each KPI is scored from 0 to 2, resulting in a total score ranging from 0 to 6, where 0 is the worst value and 6 is the best value. Each KPI has been appraised in a conservative manner, marking 1 or 2 whenever the project develops outstanding performance compared to other projects.

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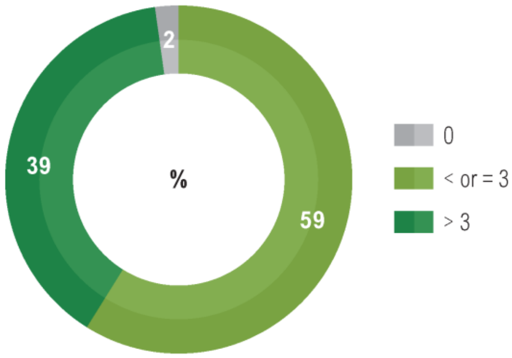


Figure 5-16 Robustness and flexibility indicator

Some projects highly depend on the realisation of a specific future score of 0. For instance, projects dedicated to the connection of a power plant fall in this category: they are useful only if the power plants actually materialise. Projects scoring 0 or 1 are useful only if Vision 3 or 4 materialise.

Most of the projects are necessary in all the visions and therefore show a score of more than 2.

5.3.9 A limited impact on protected and urbanised areas

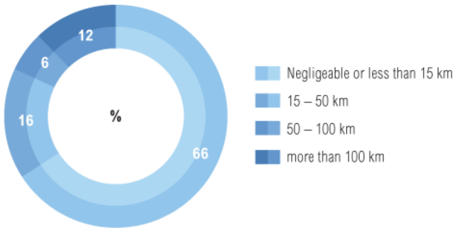
The indicators 'protected areas' (S1) and 'urbanised areas' (S2) are used to show:

- where potential impacts have not yet been internalised i.e. where additional expenditures may be necessary to avoid, mitigate and/or compensate for impacts but where these cannot yet be estimated with enough accuracy for the costs to be included in indicator C.1.
- the *residual* social and environmental effects of projects, i.e. effects which may not be fully mitigated in final project design and cannot be objectively monetised.

The two indicators replace the former "social and environmental indicator" from the TYNDP 2012. They have been developed in the framework of the Long-Term Network Development Stakeholders Group over the last two years. In order to provide a meaningful yet simple and quantifiable measure for these impacts, these indicators give an estimate of the length (number of kilometres) of a new line that might have to be located in an area that is sensitive due to its nature or biodiversity ("protected areas"), or that is densely populated ("urbanised areas").

It is often difficult in the early stages of a project to assess its social and environmental consequences, since precise routing decisions are taken later. The quantification on these indicators is hence presented in the form of a range. For the same reason, projects under consideration or for which paths are not defined are not assessed; they are to be scored only in a successive version of the TYNDP when further studies have been done.

The two indicators have been calculated based on input from TSOs regarding the routing of projects and on data from the European Environment Agency (the Common Database for Designated Areas and Corine Land Cover Urban Morphological Zones[29] and the Natura 2000 database).



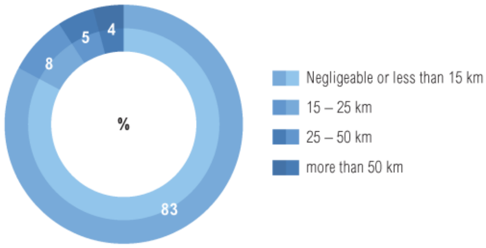


Figure 5-17 Breakdown of projects of pan-European interest depending on their length across sensitive areas

The statistics show that less than 20% (resp. less than 40%) of the projects of pan-European significance cross particularly densely populated (resp. environmentally sensitive) areas over more than 15 km. Globally, the TYNDP projects cross urbanised (resp. protected) areas for less than 2000 km (resp. 4000 km), i.e. over less than 4% (resp. 10%) of the total routes (about 46000 km); TSOs optimise the routes so as to avoid such interferences as much as possible.

The situation of every project is however unique and the two indicators are better analysed on a case by case basis.

Unsurprisingly, the projects showing the longest routes in urbanised or in protected areas occur in countries that are densely populated or where a significant share of the land is protected, such as Germany.

Several projects appear to cross neither urbanised nor protected areas. These often consist of substation works.

[29] http://www.eea.europa.eu/data-and-maps/data/urban-morphological-zones-2006
http://www.eea.europa.eu/data-and-maps/data/nationally-designated-areas-national-cdda-8

5.4 €150 billion by 2030: a financial challenge

Total investments costs for the portfolio of projects of pan-European significance amount up to €150 billion. The breakdown of the total investment cost per country for all projects of pan-European significance is supplied in Table 5-1:

Table 5-1 Investment cost breakdown in billion €

AT	1.9	**IE**	2.0
BA	0.1	**IS**	0.0[30]
BE	2.0-4.0	**IT**	5.9
BG	0.3	**LT**	0.7
CH	1.6	**LU**	0.2
CY	0.0	**LV**	0.4
CZ	1.5	**ME**	0.1
DE	34.8-54.2	**MK**	0.1
DK	3.7	**NI**	0.5
EE	0.2	**NL**	3.3
ES	4.3	**NO**	7.9
FI	0.8	**PL**	1.9
FR	8.4	**PT**	0.7
GB	15.9-16.2	**RO**	0.5
GR	2.6	**RS**	0.4
HR	0.2	**SE**	3.6
HU	0.1	**SI**	0.6
		SK	0.3
Total	**110-150**		

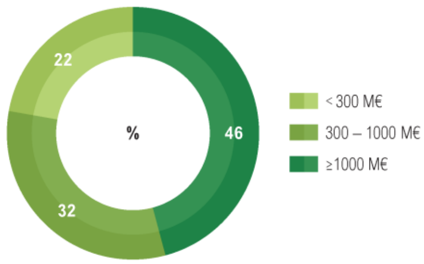


Figure 5-18 Investment cost breakdown

Remarks about costs figures computations:

- Cost figures for every country correspond to investments items in projects of pan-European significance still to be commissioned from July 2014 to the longer-term horizon explored for the present TYNDP package, and provided the figures are known to ENTSO-E.
- Figures may not be known to ENTSO-E for some projects submitted by non-members. In this latter case, an estimate has been derived and is included in the upper bound of the "total" cost range presented in the table.
- Costs of tie lines is splitted between the two concerned countries. When the exact allotment is not known, the total costs have been splitted 50/50.

[30] TYNDP 2014 includes a project between Iceland and GB, nevertheless, cost figures are not allotted to the two countries due to the very long term status.

- Ranges are provided for some countries where certain projects would not be built in all the 2030 Visions (e.g. additional facilities to connect offshore wind power in Belgium or Germany in Visions 3 and 4).

The cost of the TYNDP 2014 portfolio appears much higher than the TYNDP 2012 portfolio. The main reasons for this increase are:

- A focus in the TYNDP 2014 on a longer term horizon, 2030 instead of 2020;
- The integration of more RES (41% of the electricity generation in Vision 1, 60% in Vision 4), especially the costly offshore production;
- The interconnection of different regions via long distance cables (e.g. Norway to the UK);
- The use of cutting edge technologies (e.g. HVDC VSC) mainly to enable more power to be shifted over a longer distance.

In Table 5-1, cost figures correlate relatively with the land size and population.

Fig 5-18 highlights that most of the projects cost more than 300 million Euros individually, while 22% shows an investment cost higher than 1 billion Euros (e.g. subsea HVDC interconnections). About one third are investments in HVDC subsea interconnections, with a cost per km approximately from seven to 10 times higher than the cost of AC overhead lines.

The portfolio of projects of pan-European significance must however be completed at the regional or national level to achieve an overall consistent development of the whole energy system. Some additional infrastructure may also be required to completely support the Vision 4 environment. More precise location of generation in particular would be required to supply a more comprehensive picture of the grid infrastructure.

The financial challenge

The European transmission infrastructure will require massive investments in the coming decades in order to achieve the European Energy policy targets. Approximately 80% of the TYNDP 2014 projects contribute to RES integration, thus reducing CO_2 emissions in Europe. TYNDP 2014 projects furthermore facilitate European Market Integration and improve the overall system reliability. In addition, transmission investments in the TYNDP 2014 will pave the way for the attainment of the forthcoming 2030 and 2050 EU Energy and Climate goals.

Financial significance of TYNDP 2014 projects for consumers and for investors

Even though TYNDP projects directly contribute to the achievement of crucial policy goals, they only constitute a small percentage of the total electricity bill. Total TYNDP 2014 investments amount to approximately 1.5 - 2 €/MWh of the power consumption in Europe by 2030, i.e. about 2% of the bulk power prices or approximately 1% of the total end user´s electricity bill.

Nevertheless, TYNDP 2014 projects impose a significant financial challenge on TSOs and investors. This is due to the large volume of the TYNDP 2014 investment portfolio and the fact that TYNDP 2014 projects represent only a subset of all transmission investments needed in Europe.

The challenge

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TYNDP 2014 investments will take place in a challenging context. Rising investment volumes are likely to be accompanied by higher risk profiles, thus leading to increased capital costs (debt and/or equity) for TSOs and investors. For instance, many TYNDP 2014 investments are based on innovative technologies, which incur more uncertainties than proven technologies. Moreover, there is a lack of incentives within the current regulatory framework of most European countries, which tend to focus on lowering tariffs and setting relatively low returns for transmission investments. Similarly, most of current regulatory regimes fail to take into account financeability issues sufficiently. This reduces current cash flows and delays the payment of investments for the future.

At the same time, existing financial instruments are insufficient to bridge the financial gap. Project bonds with subordinated debt and guarantee facilities may represent a viable option in specific circumstances, but they have limited applicability to transmission investments due to the scarce availability of resources and the fact that the majority of TSO projects cannot be ring-fenced. More importantly, project financing may be more expensive when compared to traditional corporate finance options for most TSOs. Grants may also help to overcome difficulties in raising capital for TSOs or projects with severe financial problems. However, their volume is scant and their applicability is restricted to projects being "commercially not viable". In addition, they represent a more costly option, as grants are direct subsidies with no significant leveraging.

In this challenging framework, projects promoters face the risk of having their credit ratings lowered and their financial ratios deteriorating.

The solution

In order to prevent the transmission business from being perceived as unattractive for investors in the global financial market, regulatory frameworks need to provide stable and investor-friendly conditions and instruments. The long lifetime of network assets requires long-term capital commitment. Transmission investments should generate a stable and predictable regulatory return throughout their lifetime, thus keeping the costs of capital as low as possible. Moreover, the return on investments should equal the remuneration for comparable investments so that generated cash flows are sufficient to maintain the ability of project promoters to raise funds in global capital markets. Once again, by improving the risk-reward balance of projects, lower costs of capital will be achievable for the development of the necessary transmission investments.

One efficient, simple, cheap and effective solution to attract investors and help finance the required transmission investments is the Priority Premium, i.e. an add-on or supplement on top of the typical regulatory rate of return, which could be applied to important projects. This mechanism would improve the ability of investors to raise the funds necessary for the timely delivery of the transmission investments which are vital for achieving the EU energy policy goals.

Other possible solutions to these issues have been identified in the ENTSO-E public position paper "Incentivising European investments in transmission networks"[31].

[31] [See https://www.ENTSO-E.eu/fileadmin/user_upload/_library/position_papers/130523__Incentivising_European_Investments_in_Transmission_Networks_Final.pdf]

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6 2030 transmission capacities and adequacy

This chapter confronts investment needs and project assessments to derive cross border target capacities for boundaries in every Vision. Then, comparing the target capacity and the project portfolio for cross border boundaries, a transmission adequacy index can be supplied.

6.1 Target capacities by 2030

For every boundary, the target capacities correspond in essence to the capacity above which additional capacity development would not be profitable, i.e. the economic value derived from an additional capacity quantum cannot outweigh the corresponding costs.

Synthesising the investment needs and projects assessments, target capacities can be sketched for every boundary in every Vision. The practical evaluation however is complex, for instance:

- In a meshed grid, parallel boundaries are interdependent and for a very similar optimum a different set of values can be envisaged, although only one is displayed.
- The value of additional capacity derives directly from the nature of the scenario. A very different perspective for the generation mix in one country compared to present 2030 Visions may give a very different result for target capacities beyond this country's borders.
- The computation is also undermined by the assumptions that must be made for the cost of an additional project on the boundary wherever no feasibility studies are available. Similar costs to former or similar projects can then be considered.

Overall, target capacities are not simultaneously achievable, i.e. building such transmission capacity would not imply they could be saturated all at the same time.

Additionally, ENTSO-E checked whether the interconnection capacity of every country meets the criterion set by the European Council[32] for interconnection development, asking for a minimum import capacity level from every Member State equivalent to 10% of its installed production capacity. Meeting this criterion led to an increase in the target capacity between Spain on the one hand and France and the UK on the other hand.

The outcome of such computation must hence be considered carefully. Target capacities are displayed as ranges as accurate values and can only be misleading. Globally, the maps displayed in this section should therefore be considered as illustrative.

[32] Presidency Conclusions, Barcelona European Council, 15 and 16 March 2002.

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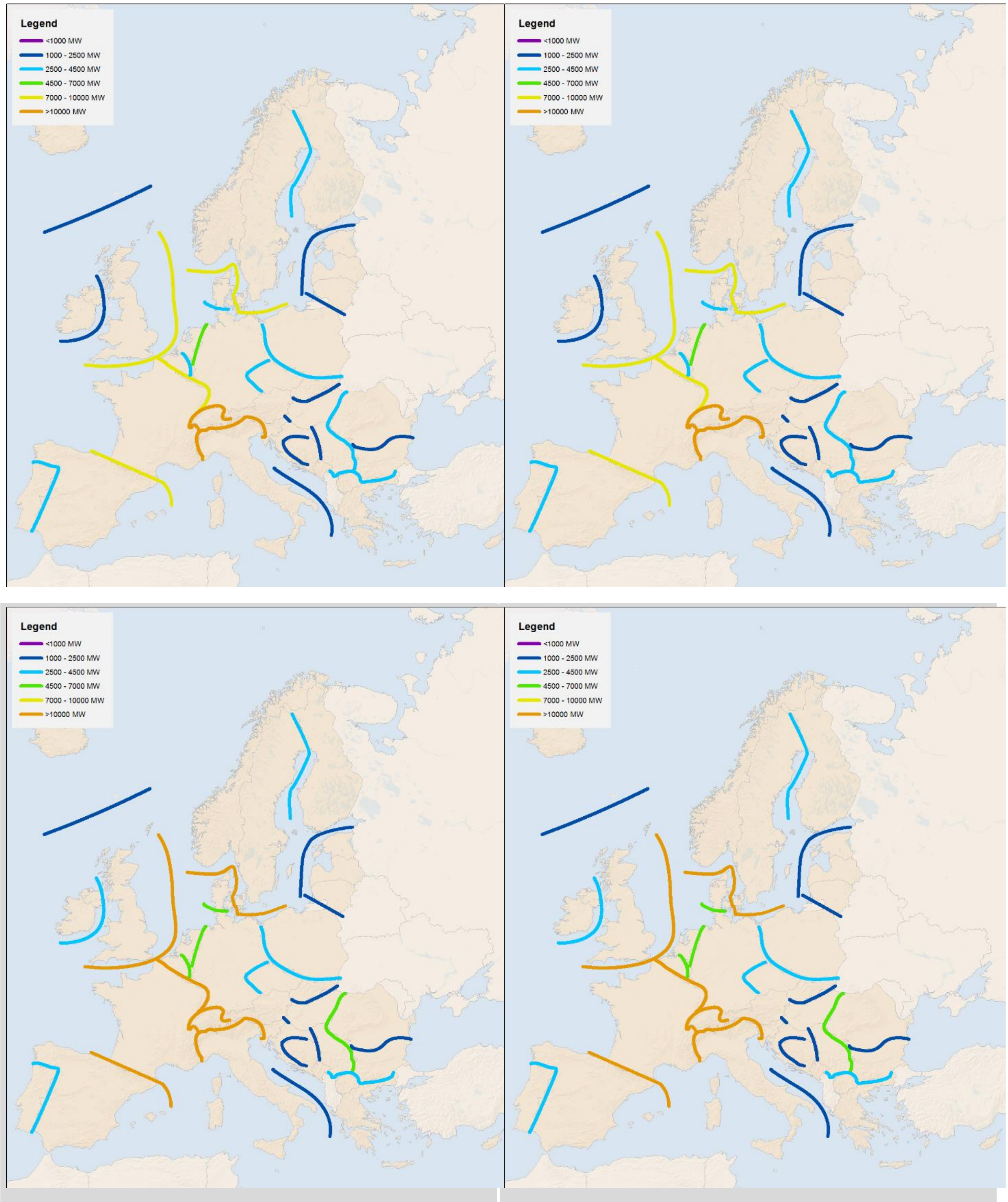

Figure 6-1 Target capacities by 2030 in all four Visions

(Vision 1 top-left, Vision 2 top-right, Vision 3 bottom-left and Vision 4 bottom-right)

Both maps show similar patterns: the magnitude of the target capacities is relatively higher in Western Europe compared to the eastern part, the main reason being the relatively higher RES development in the west.

Target capacities fall in the same range of magnitude in both Visions for most boundaries in the Eastern part of Europe with the exception of the boundary between Romania and Bulgaria on the one hand and Hungary and Serbia on the other hand. Otherwise, moving from Vision 1 to Vision 4 – i.e. effectively integrating more RES – means that the magnitude of the target capacities increases by one range category.

6.2 Transmission adequacy by 2030

Transmission Adequacy shows how adequate the transmission system is in the future in the analysed scenarios, considering that the presented projects are already commissioned. It answers the question: "is the problem fully solved after the projects are built?".

The assessment of adequacy merely compares the capacity developed by the present infrastructure and the additional projects of pan-European significance with the target capacities. The result is synthetically displayed on the following map: the boundaries where the project portfolio is sufficient to cover the target capacity in all Visions are in green, those sufficient in no Vision at all are in red, and others are in orange.

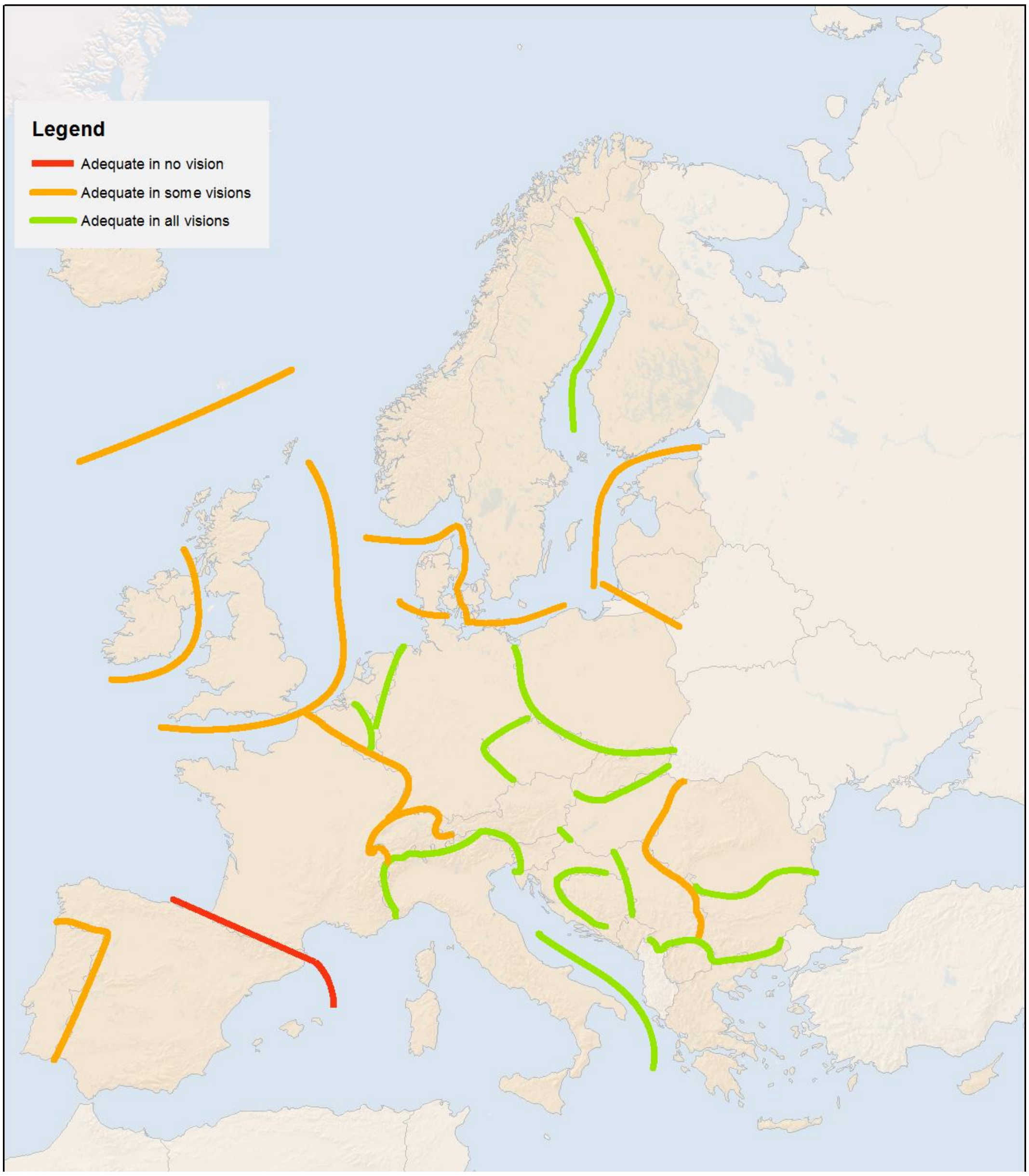

Figure 6-2 Transmission adequacy by 2030

Figure 6-2 shows that for about a third of all boundaries, the project portfolio provides the appropriate solutions to meet the target capacity. These boundaries correspond to the boundaries where the uncertainties regarding RES development are relatively low and where the target capacity in Visions 1 and 4 are close to one another.

Most of the boundaries are orange: for these, all the listed projects are prerequisites to meet target capacities goals but some additional grid reinforcements are required to cover investment needs specific to the most ambitious scenarios of RES development by 2030.

In particular, Vision 4 could only be used to assess the portfolio of already identified projects; investment needs investigation in this Vision requires additional input and feedback from stakeholders (more precise locations of generation especially) so that a more comprehensive picture of the grid infrastructure can be supplied. Such interaction and continuous adaptation is normal considering uncertainties regarding the realisation of the challenging transformation of the generation mix or the interconnection of Europe with Africa or Russia.

One boundary is red, between the Iberian Peninsula and the rest of Europe. With all projects included in the Plan, the capacity is yet below target capacity in Vision 1 and needs to be extended in Vision 4. However, the presently foreseen projects are complex (e.g. for crossing the submarine canyon between France and Spain). They must be implemented step by step and it will be a challenge to implement additional capacities by 2030. Planning studies continue in the framework of the Regional Group Continental South West.

7 Synthetic environmental assessment

This chapter supplies a synthetic overview of the environmental assessment of the grid development depicted in the TYNDP. Detailed environmental assessments are run for every project by their promoters and more information is supplied in the National Development Plans.

Compared to the TYNDP 2012, the methodology for assessing the projects has been improved through a fruitful dialog with the ENTSO-E TYNDP's stakeholders, especially in the framework of the Long-Term Network Development Stakeholders Group over the last two years. The outcome is a specific appraisal of the benefits of the projects with respect to potential spillage of RES generation and the replacement of the former social and environmental indicator by two more specific indicators with respect to the crossing of urbanised areas and protected areas.

This enhanced methodology enables strong conclusions to be demonstrated: the projects of pan-European significance are key to establishing an energy transition in Europe – i.e. a significant increase of power generated from RES, CO2 emissions mitigation and a major shift in the generation pattern – possible, with optimised use of natural resources.

7.1 Grid development is key for RES development in Europe

The shift of the generation mix, with a reduction of conventional power generation capacity and RES development, is the first driver for grid development, and depending on the Visions RES is expected to develop in large amounts by 2030; compared to less than 400 GW today, installed RES capacity ranges from 647 GW in Visions 1 and 2 to 920 GW in Vision 3 and 1150 GW in Vision 4. The share of the load covered by RES increases therefore from 40% in Vision 1 to 60% in Vision 4. The reason for such high volumes of installed capacity is that wind and photovoltaic require a variable and not steerable output and a higher installed capacity compared to conventional generation to supply the same amount of electricity throughout the year.

As a result, approximately 80% of the projects of pan-European significance help integrate RES either by directly connecting RES or by transporting RES power to end-consumers.

First, about 20 projects of pan-European significance directly connect RES (for a total volume of 40 GW in Vision 1 and 90 GW in Vision 4.) There were more in the TYNDP 2012 (resp. about 50 projects and about 110 GW by 2020), as a consequence of the reshuffling of the portfolio according to the CBA criteria: a lot of projects directly connecting RES in the TYNDP 2012 now only appear in the Regional Investment Plans.

Besides, projects improving market integration, especially those developing new interconnection capacity, actually help integrate RES; essentially, they enable any RES surplus in one area to find outlets in a neighbouring one, making the market more resilient and less subject to price tensions (e.g. prices equal to zero).

In the most severe cases, projects of pan-European significance avoid RES spillage. The German corridors show the largest benefits with respect to avoiding RES spillage (from 10 TWh/yr in Vision 1 and up to 30 TWh/yr in Vision 4). Interconnections between the Iberian Peninsula and mainland Europe or between Great Britain and Ireland and mainland Europe also show major benefits in this respect.

7.2 The TYNDP makes ambitious CO2 emissions mitigation targets possible

Mitigating CO2 emissions in the power sector above all requires measures regarding the generating fleet. The following picture shows the CO2 emissions decrease for the European power sector, as a percentage of the 1990 level, in the different ENTSO-E Visions:

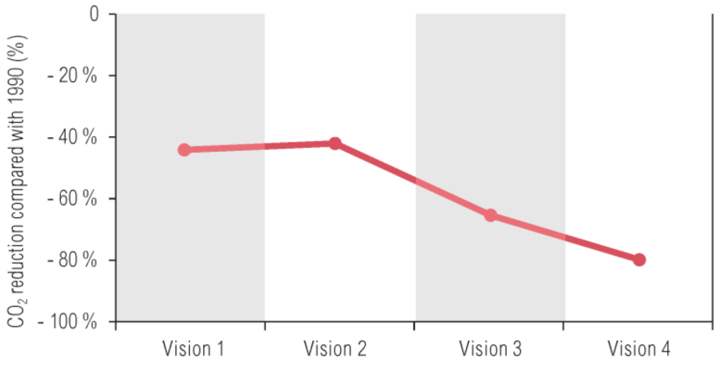

Figure 7-1 CO2 emissions decrease for the European power sector, as a percentage of the 1990 level, in all Visions

The average CO2 content of electricity is about 220 g/MWh in Visions 1 and 2, 120 g/MWh in Vision 3 and 70 g/MWh in Vision 4, compared to about 350 g/MWh in 2007, before the crisis.

A lower consumption and the development of carbon-free technology (RES, nuclear, carbon capture and storage, etc.) instead of fossil fuel technology without carbon capture and storage are the two keys to reducing CO2 emissions in the power industry.

The grid has an indirect but essential positive effect on CO2 emissions as it is a prerequisite for implementing clean generation technologies; the grid provides these with outlets possibly far from the load centres and the grid enables market mechanisms to remove the most expensive, fossil fuel fired high CO2 emitting power plants from the merit order. However, either by directly connecting RES, avoiding spillage or enabling more climate friendly units to run, the portfolio of projects of pan-European significance contributes more directly to about 20% of the CO2 decrease by 2030 (the magnitude is the same in every Vision).

7.3 A neutral effect on transmission losses

Transmission losses are not expected to vary significantly in the coming 15 years with the implementation of the TYNDP project portfolio as multiple effects neutralise each other:

- Building new transmission facilities reduces the overall resistance of the network, and this will tend to reduce the overall transmission losses. This positive effect would be measurable if the generation fleet (and load profile) had remained the same.
- The new generation assets tend to be built further from load centres than they are presently; the transmission distance hence increases, as do the losses.
- Increasing the interconnection capacity aims at improved competition where more desirable generators can prevail over less preferred ones. This results in cheaper electricity and a more reliable and optimised supply, but also by essence it tends to enable longer power exchanges and therefore induce higher losses.

Incidentally, one can also remark that resorting to a large share of HVDCs does not result in significant savings in terms of transmission losses. In essence, HVDC lines show lower transmission losses compared to HVAC lines when transporting the same amount of power at the same voltage. However, HVDC projects are hindered by the losses at their converter stations (about 2% of the transported flow). Additionally, these projects aim precisely at connecting offshore wind farms or increasing interconnection capacities, and, as explained above, contribute indirectly to an increase the amount of overall losses in Europe.

7.4 A relatively limited network growth despite major shifts in the generation mix

By 2030, the generation fleet will experience a major shift. The net generating capacity is expected to grow from a slightly more than 900 GW today up to almost 1200 GW in Vision 1 and more than 1700 GW in Vision 4. The construction effort will have to account not only for the net increase but also for the replacement of almost half of the present units, which will come to the end of their lifetime within the coming 15 years. For the adaptation of the generation fleet this represents a rate of 3.1%/yr in Vision 1 and up to 4.6% in Vision 4.

On the other hand climate change mitigation and competition will require energy efficiency measures (including in the power sector) but also the transfer from fossil-fuel based end-uses to CO2-free energy sources (e.g. more trains, electric vehicles and heat pumps). European power peak load is thus expected to grow from 8% in Vision 1 to 28% in Vision 4 by 2030. This represents between 0.4%/yr and 1.3%/yr for the load growth.

The major driver for grid development is therefore generation. New generating capacities are almost all located farther from load centres, especially RES (wind generation develops mostly as large wind farms, also offshore). The major shift in generation mix will hence induce a massive relocation of generation means and, with large wind and solar capacities, more volatile flows, requiring the grid to adapt. Still, in comparison to the generation adaptation rate of 3% to 5%/yr the grid's growth rate looks relatively modest, with about 1%/yr. This illustrates once more the "network effect", where the output developed by all elements together is greater than the summated output of every individual element.

7.5 New transmission capacities with optimised routes

The European transmission network presently consists of ca. 300000 km of routes. Completing the projects of pan-European significance leads to about 4000 km of existing assets being refurbished, with a limited if not neutral impact on the surrounding area, and 43000 km of new assets being built by 2030[33].

TSOs optimise the routes so as to avoid interferences with urbanised or protected areas as much as possible. In densely populated countries or where a significant share of the land is protected, such as Belgium or Germany, this is a challenge.

Globally however, the TYNDP projects cross urbanised (resp. protected) areas for less than 2000 km (resp. 4000 km), i.e. over less than 4% (resp. 10%) of the total routes.

Quite a few projects appear to cross neither urbanised nor protected areas. These often consist of substation works.

[33] The set of projects of pan-European significance is still to be completed in order to meet the energy transition proposed in Vision 4. With its validation only in October 2013, the Vision 4 scenario could only be used to assess the portfolio of already identified projects. Investment needs investigation in this Vision and requires additional input and feedback from stakeholders (more precise locations of generation especially) so that a more comprehensive picture of the grid infrastructure can be supplied.

Besides, among the new assets, more than one third are subsea, with by nature a limited length crossing protected or urbanised areas; about 4000 km of the new subsea cables will connect offshore wind farms (half with AC and half with DC technology), and about 12000 km of DC subsea cables will increase the interconnection capacities, especially in the North Sea. One can also notice subsea cables in parallel to onshore AC assets in order to increase north-south transfer capability, along the British coast to transport wind energy from Scotland to England and Wales, or between Spain and France.

Onshore, more than 4000 km of projects of pan-European significance are upgrades of existing corridors. They hence have a neutral or very limited impact on the surrounding areas, and especially occur in protected and urbanised areas.

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7.6 Appropriate measures are adopted to mitigate any disturbance on the environment

Projects for new power transmission infrastructure are carefully designed to avoid, mitigate or compensate any undesirable impacts on the environment and people in general. Adequate track design based on environmental criteria as well as considering available technology options may improve the social acceptance of new projects.

In this respect, TSOs work in close cooperation with authorities and stakeholders in general (universities, NGOs, landowners, councils, etc.) about the proposed options to find the best solutions.

Choosing the route and the technology – AC or DC, cable or overhead, etc. – are the two key decisions in order to avoid or mitigate any undesirable effect on the environment, with no a priori 'better solution'. The situation always needs to be analysed on a case-by-case basis as environmental impacts are vastly different between overhead lines and underground cables technology. Partial undergrounding complementing overhead lines in sensitive areas may in some cases be a cost efficient compromise and an acceleration of the permitting procedure.

It is also important to define the location of substations, because new overhead lines and underground cables that will be built in the future must begin or end in those locations.

Here are a few examples:

- Building new power lines in the corridor of other existing infrastructures (other power lines, motorways, etc.) minimise the disturbed areas.
- AC 220 kV or 400 kV cables can be appropriate in densely urbanised areas where a large amount of power must be supplied over a relatively short route crossing a particularly cramped area.
- On the other hand, overhead technology may be more suitable than cabling when two 400 kV circuits must cross a forest; compared to large trench cabling , this would require taller towers 500 m apart and would enable small trees to grow behind the line, causing minimum disturbance to the biotopes (with anchorage every 500 m), and be fairly invisible to anybody in the forest or admiring it from a distance.
- The geometry of the power line is also key to limit electromagnetic fields in the vicinity, with a specific design arranging phases to make their electromagnetic fields mitigate themselves mutually.

Appendix 7 of the present report provides further insights into the potential impacts and mitigation measures taken by TSOs.

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8 Assessment of resilience

Detailed results of the studies can be found in the Regional Investment Plans.

High voltage investments are expensive infrastructure projects with a long lifetime, setting a precedence of standards for coming projects and requiring years to be completed. Therefore, TSOs evaluate the resilience of their investment projects in order to avoid stranded costs and to meet grid users' expectations over time with appropriate solutions.

Every project has also been assessed individually with respect to its ability to support the system in extreme circumstances (see § 5.3.7), and the opportunity to build it in each Vision (see § 5.3.8). In addition, this chapter appraises the resilience of the project portfolio as a whole, considering:

- Have all possible circumstances by 2030 been accounted for to identify investment needs and value projects?
- Is the TYNDP properly anticipating the 2050 perspective, by 2050?
- Are edge technologies taken advantage of to design projects in order to maximise their usage?

8.1 A plan robust for all reasonably likely situations

The transmission grid is designed for future needs. It needs to cope with the situation that will be there, not only fix problems encountered today. For this aim, several future scenarios or sensitivity cases are needed as the basis for the plan. The new infrastructure should fit in with the existing infrastructure, and should also not hinder any long-term future development.

ENTSO-E has devised four Visions, encompassing all possible futures suggested by all stakeholders. A pan-European market study has been performed for every Vision, setting the pan-European patterns (but with limited modelling of the regional specific features). On top of this, depending on their specific concerns, Regional Groups also analysed additional sensitivity scenarios in their market and network studies. They also adopted different modelling tools with the relevant focus for their area (hydro modelling in Nordic countries, sensitivity to temperature in France, combined market and grid modelling of the sparse network in Continental South East, etc.), possibly involving several tools to mutually challenge their outcomes and supply more robust results. All market study tools perform 8760h.year simulations.

Except for Continental South East, where one tool addresses both market and grid analysis steps, all Regional Groups selected several "cases" from their market studies to analyse in their grid studies. They thus checked the system behaviour either for particularly common situations or under more extreme conditions; high load cases, low load cases, high/low renewable production cases, different hydro years in the Nordic system and other regionally constrained cases have been studied.

Eventually, in every Regional Group, millions of hourly market situations have been tested, simulated and processed for this TYNDP 2014, considering all hazards that may affect the power system. Depending on the area, between tens and hundreds of cases have been thoroughly analysed with detailed grid modelling. For each case, the variations with and without every project have been measured.

North Sea	Baltic Sea	Continental Central East	Continental South East	Continental Central South	Continental South West
Four (final) pan-European market studies +					
Four Visions x (various sets of transmission capacities) + sensitivities	Four Visions x (various sets of transmission capacities) + sensitivities	Four Visions x (various sets of transmission capacities) + sensitivities	Four Visions x (various sets of transmission capacities) + sensitivities	Four Visions x (various sets of transmission capacities) + sensitivities	Four Visions x (various sets of transmission capacities) + sensitivities
4 market modelling tools 8760h/year x Monte Carlo sampling for main exogenous factors (outages, temperature, wind, hydro...) &/o unit commitment modelling	2 market modelling tools 8760h/year x Monte Carlo sampling for main exogenous factors (outages, , wind, hydro...) &/o detailed hydro modelling	1 market modelling tools 8760h/year x Monte Carlo sampling for main exogenous factors (outages, wind, hydro...) &/o unit commitment modelling	1 combined market and grid modelling tool 8760h/year	3 market modelling tools 8760h/year x Monte Carlo sampling for main exogenous factors (outages, temperature, wind, hydro...) &/o unit commitment modelling	2 market modelling tool (one with integrated grid modelling) 8760h/year x Monte Carlo sampling for main exogenous factors (outages, temperature, wind, hydro...) &/o unit commitment modelling
Grid modelling (several point in times/cases x grid configurations (base case + taking in/out each and every project))	Grid modelling (several point in times/cases x grid configurations (base case + taking in/out each and every project))	Grid modelling (several point in times/cases x grid configurations (base case + taking in/out each and every project))	Grid modelling (several point in times/cases x grid configurations (base case + taking in/out each and every project))	Grid modelling (several point in times/cases x grid configurations (base case + taking in/out each and every project))	Grid modelling (several point in times/cases x grid configurations (base case + taking in/out each and every project))

Detailed results of the studies can be found in the Regional Investment Plans.

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Challenging dynamic studies are still required to ensure a reliable power system with a high RES penetration

New grid components must at least maintain, and possibly improve, the high standards to which European end-users are accustomed. When planning, TSOs perform network and engineering studies to this aim, taking into account new types of generating units and transmission equipment (with specific behaviours and possibly design constraints).

However, the high RES penetration (up to 60% of the total supply in Vision 4) sets new challenges for the system as a whole, with respect to its dynamic behaviour: how can frequency be maintained if the system inertia is dramatically reduced? What voltage supporting equipment would be needed and where when power plants close to load centres and traditionally contributing to voltage control are massively shut-down? How will long distance bulk power flows be managed on AC grids? How will several HVDC equipment working in parallel actually interact with each other? How will embedded generation in the distribution system behave? Etc.

These new (or sometimes reborn) challenges call for system dynamic studies. They are still to be addressed, and they demand a holistic approach. Beyond the grid reinforcements, they will demonstrate which new procedures and rules for transmission systems are needed. Thus, all stakeholders – TSOs, DSOs, end-users, conventional and renewable generation units – need to cooperate to maintain system stability after normative and exceptional contingencies. This cooperation includes exchanges of data and models to perform necessary dynamic studies but also contributions to measures aiming to increase system stability. This effort should allow the aforementioned European goals to be maximised in an efficient manner both from the technical and economic prospective. (See Appendix 5 for more details.)

8.2 The TYNDP paves the way to the pan-European Electricity Highways System for 2050

With the objective of reducing Green House Gas (GHG) emissions to 80%-95% below 1990 levels by 2050 the European Union has analysed the implications for the energy sector in the Energy Roadmap 2050, where how this goal can be achieved is investigated, taking into account different scenarios.

In this perspective of very ambitious targets for GHG emissions reduction, the renewable energy sources should represent the main part of the energy mix in Europe and be developed in different locations, often far away from major consumption sites. Electricity should be transported over longer distances, across national borders, to be delivered where consumption needs arise. Such a long distance and meshed transmission network at the pan-European level introduces the opportunity for an innovative 'Electricity Highways System' (EHS) concept.

In response to the ENERGY.2012.7.2.1 call of the 7th Framework Program (FP7) of the European Commission, a consortium of 28 partners involving a wide spectrum of stakeholders launched the "e-Highway2050" project in September 2012. The project aims at delivering a top-down methodology to support the planning of a pan-European EHS capable of meeting European needs for electricity transmission between 2020 and 2050. The final results of the project should be published by the end of 2015.

The project develops methods and tools to support the planning of an Electricity Highways System based on various future power system scenarios, including back-up and balancing generation as well as storage capacities, and develops options for a pan-European grid architecture under different scenarios, taking into account the benefits, costs and risks for each one. The newly developed top-down methodology, which addresses the transition planning between 2020, 2030, 2040 and 2050, is constructed around five main steps (see Figure 8-1):

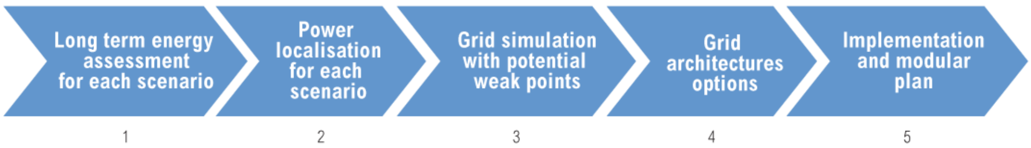

Figure 8-1 The five main steps of e-Highway2050 project.

The first period of the project has been focused on the definition of the scenarios, the modelling to apply for the system simulation, and the method to define the grid architecture for 2050. In this respect, a clustering technique to describe the pan-European grid has been developed in order to model the complex meshed network. Grid architecture options are proposed, capable of alleviating the detected overloads in 2050, and a portfolio of candidate grid architectures is selected, taking into account the available technologies and solutions such as AC interconnections, DC interconnections, hybrid AC/DC interconnections, or power electronics to better control flows over long distances.

Appendix 6 presents the first results of the e-Highway2050 project, focused on scenario building and the construction of the grid architecture, which are key issues of the project.

The next steps concerns the description of the path to follow in order to implement a modular grid development plan from 2020 to 2050.

The e-Highway2050 project is still to be completed, but available interim results confirm the results of the TYNDP 2014 with respect to the most sensitive corridors and investment solutions. All TYNDP projects fit in the e-Highway2050 perspective and will need to be further complemented to meet the higher RES integration perspectives set for 2050.

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8.3 Implementation of edge technologies

New technological advances are taken into account with consideration of the overall consistency of the interconnected system. TSOs strive to ensure best use of existing assets, implementing technologies such as FACTS, PST, HTLS in order to optimise grid development or as an interim measure where grid extension cannot be realised in a timely manner; when grid extension is needed, novel and unconventional technologies can also be applied (DC connections, underground cables, etc.) to overcome barriers. TSOs also anticipate future challenges involving live-testing of promising new technologies through pilot projects.

The advancement in power technology, measurement and information communication technology provides TSO with different technological solutions for grid development. To keep pace, TSOs cannot simply rely on proven technologies, but also need to deploy new solutions and cost-effective technologies. The technologies employed to date in the transmission grids are efficient, reliable, well-engineered and are widely available for transferring energy in high-voltage grids. The ongoing technology progression, predominantly driven by special applications, has led to new technologies that may have the potential to be employed in the future transmission grid.

The edging technologies, i.e. known technologies that have not been widely used for various reasons, can be sorted into four categories depending on their maturity: mature (PST), the large scale testing phase (real-time thermal rating, low sag conductors), the development phase (FACTS) and the research phase (superconductors).

The integration of edging technologies with the existing grid infrastructure requires thorough assessment to ensure interoperability and a secure system. Therefore, TSOs stipulated an ENTSO-E R&D Roadmap for 2013-2022 to prepare the necessary steps to bring prototypes from the lab into the field.

For instance, many important power technologies were demonstrated in the Twenties project such as power devices and power flow management, direct-current grid structures, balancing fast winds in storm conditions, balancing winds using virtual power plants, and system services provided by wind farms. A direct-current circuit breaker prototype was tested successfully in the Twenties project. This has established confidence in continuing the Best Paths project, which will demonstrate large scale integration of innovative transmission systems and operational solutions for inter-connecting renewable electricity production. An offshore multi-terminal solution is also being considered by Kriegers Flak for instance. Other projects demonstrate 220 kV static synchronous series compensator devices for power flow control, wind power to heat pumps, demand response technology, early warnings systems with power measurement units and wide-area monitoring systems.

Some illustrations of edging technologies that have been selected for the projects in this plan: are as follows:

Underground and submarine HVDC XLPE (Cross-Linked Poly-Ethylene) cables: some of the above-mentioned HVDC projects consider the use of XLPE cables. XLPE DC cables are state of the art up to +/- 200kV with a capacity of 500MW with some projects having reached voltages of +/- 320kV with a capacity of 800-1000 MW. Operational experience is limited to less than one decade. The technology has so far mainly been used in submarine applications, either connecting offshore wind farms to land or transmitting high electrical power over long distance through the sea where overhead lines cannot be used. Increasingly, HVDC cables are beginning to be used also for large on-shore transmission projects or power highways. At the same time HVDC Mass Impregnated (MI) cable technology continues to remain a reliable power transmission cable technology up to 525kV as it has been for the past 25 years.

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Underground and submarine HVAC XLPE (Cross-Linked Poly-Ethylene) cables have been deemed as an appropriate technology selection for special applications for more than 20 years. On land, cabling will mostly be found in densely populated areas and sensitive rural areas with outstanding natural or environment heritageas a limited length of an overhead line. Looking ahead,the major technical evolution expected for XLPE HVAC cables is an increase in transmission capacity beyond today's 500kV technology. Furthermore, there is worldwide experience of their use offshore to connect synchronous networks and remote load centres such as island communities. AC cabling has so far been the preferred technology for the connection of offshore wind farms located close to land. A key limitation of all types of AC cables is their high electrical capacitance, which means that for longer lengths of cable the capacitive charging current becomes significant and results in a reduction in their ability to transmit real power. This is mitigated by the installation of reactive compensation plants in the form of shunt reactors.

High Temperature Conductors (HTCs). This technical choice has been made for several projects in the TYNDP: the 260 km long 400 kV overhead line between France and Italy, 275 km in the French Rhône Valley, 80 km 400 kV double circuit between Belgium and France and an ongoing upgrade of a 220 kV line in Poland. HTLS conductors cover a broad family of technologies with different degrees of maturity; while some of them are mature enough and are already implemented in reconductoring programmes or in the construction of new lines, some others (such as composite based HTCs) are fairly young with few commercial installations, and some more futuristic cables, based on organic composites, are still at the R&D stage.

The HVDC –VSC (Voltage Source Converter) Technology has developed strongly over the last 13 years and further development is expected in the coming years. Building on a two-level converter, it is possible to construct a three-level converter. However, recent developments have led to the use of multi-level converters. It is understood that all three European suppliers have either developed or are developing a multi-level VSC converter system. VSCs provide many technical and operational benefits compared with CSC based HVDCs. For example, all internal German HVDC connections are planned to be completed using VSC Technology.

Kriegers Flak - Combined Grid Solution (CGS). This concept can be compared to combined grid solutions based on DC or hybrid technology, where the grid connection of the offshore wind farms would also function as an interconnector between Denmark and Germany. The CGS is the preferred technical solution since it allows for a modular, step-wise development and maximum flexibility with moderate additional costs. The CGS has a significant strategic dimension and is a pilot project as such a solution involving both AC and DC technology has never been built before.

Gas Insulated Line (GIL) is mature and exhibits a high degree of reliability. The technology is derived from the Gas Insulated Switchgear (GIS) technology, which has been in use since for more than four decades. Many projects have been realised worldwide, and the latest GIL project as a part of European transmission grid was commissioned in 2011 (1.9km, Kelsterbach, Germany). However, GIL is only expected to offer a very limited contribution to the network by 2030.

Phase Shifting Transformers (PSTs), which help better control active power through preventive or curative strategies. There are several projects including PST devices, for example a dozen Phase Shifting Transformers are to be installed in Europe in the coming 10 years, for example in Zandvliet (4th PST on the Belgian north border).

Flexible Alternating Current Transmission System (FACTS). Several projects in the Plan include FACTS devices, such as SVCs. The design of FACTS devices is based on the combination of traditional power system components (transformers, reactors, switches, capacitors) with electronic power elements such as transistors and thyristors of various types, with the latter components playing a crucial role. Because of the benefits of converter-based FACTS, R&D efforts are focused on reducing the cost of solid-state devices such as IGBTs, IGCTs, etc. and alleviating the burden of initial capital investment during installation.

Several edge technologies can be mentioned that can be considered as possibly helpful in operations, but do not appear as a full part of the TYNDP list of investments.

Real-Time Thermal Rating (RTTR)-monitored cables/lines, or Dynamic Line Rating, are on their way to become a mature technology based on real-time control of the thermal rating of a line or cable. RTTR technology is rather mature, but needs further development to address integration challenges. In areas with especially high system loads, the possibility of installing modules without the need for any system outage has also been tested and validated.

Fault Current Limiters (FCLs) comprise technologies with different degrees of maturity. The first conventional applications were in distribution systems, however current Superconducting FCL applications are progressively targeting the transmission system and are mostly still in the R&D phase.

A Wide Area Monitoring System (WAMS) is an information platform with monitoring purposes. Based on Phasor Measurement Units (PMUs), WAMS allow transmission system conditions to be monitored over large areas in view of detecting and further counteracting grid instabilities. This early warning system contributes to increasing system reliability by avoiding the spread of large area disturbances and optimising the use of assets. There are several on-going projects and investments involving synchrophasors. Currently, one of the CE TSO's WAM data concentrators has links to 22 PMUs from nine TSOs.

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9 Monitoring of the TYNDP 2012

This chapter monitors the evolution of the projects included in the TYNDP 2012.

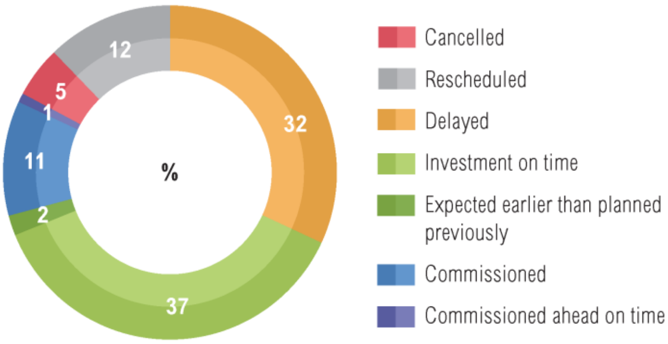

Figure 9-1 Evolution of the TYNDP 2012 portfolio

Figure 9-1 presents the status of the investments of pan-European significance contained in the Community wide TYNDP 2012 Table of Projects.

As shown in this diagram, the majority of investments are currently on schedule for their stated delivery with less than 1% of the investments having been commissioned ahead of schedule.

Since 2012, **72 investments have been completed** throughout Europe, i.e. around 10% of the TYNDP 2012 portfolio.

Some investments have been rescheduled, when they are i/ still under consideration or planning (i.e. the final investment decision has not been made yet), ii/ expected beyond 2020, or iii/ postponed compared to the TYNDP 2012 notification. The status "rescheduled" corresponds to long-term or conceptual investments at the early stage of the planning process for which further studies have allowed the provision of a more accurate commissioning date, based for instance on a better understanding of the technical challenges or of the socio-economic environment. **Most of the rescheduled investments merely adapt to the postponement of the generation development project triggering them**.

Confirming the trend of the *"2013 monitoring update of the TYNDP 2012"* published in June 2013, **more than one third of investments are delayed** compared to the initial schedule, mostly because of social resistance and longer than initially expected permitting procedures, possibly leading to project reengineering. This phenomenon is not specific to certain countries or regions.

Other common causes for delays include securing financing or longer than expected studies necessary to prepare an optimal technical design. Most of these investments are delayed on average by only two years. More details are provided in Figure 9-2 below:

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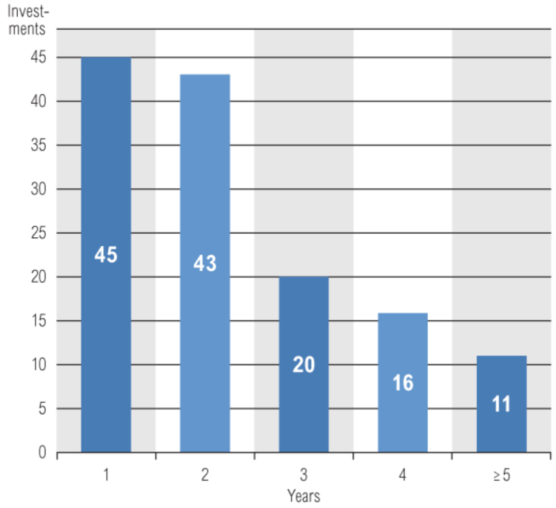

Figure 9-2 Breakdown of delayed investments (number of years)

The implementation of Regulation 347 is expected to secure commissioning times for Projects of Common Interest. In addition, Public Authorities are invited to support non-PCIs also showing positive cost benefit analysis in order to build a consistent and reliable grid, as all investments support each other.

5% of the investments have been cancelled. In most cases, the cancellation is entailed by the abortion of the generation development scheme specifically triggering the transmission project. In other cases, the cancellation is rather technical as the initial scheme has evolved and the "cancelled" investment is actually replaced by a new, more appropriate one.

The commissioned and cancelled investments from TYNDP 2012 appear in a dedicated section of the appendices in every Regional Investment Plan.

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10 Conclusion

10.1 The TYNDP 2014 confirms the conclusions of the TYNDP 2012

Looking towards 2030, the TYNDP 2014 confirms the main results and conclusions of the TYNDP 2012.

Firstly, **the generation fleet will experience a major shift by 2030** with the replacement of existing capacities by new ones, probably located differently and farther from load centres and also involving high RES development. This renewal of the generation infrastructure is the major challenge for the power system. As a result, ENTSO-E forecasts larger and more volatile power flows over larger distances across Europe; therefore, it is essential that the energy transition, i.e. RES development, is strong. The huge transit flows will have a significant impact on the security of the system. In particular, new dynamic phenomena will make the system operation (frequency control, reserve management, voltage control, etc.) more complex.

80% of the proposed investments address RES integration issues, either because direct connection of RES is at stake, because the network section or corridor is a keyhole between RES and load centres, or in order to avoid spillage of RES. In this respect, stronger interconnection of the Iberian and Italian peninsulas, Ireland and Great Britain to mainland Europe is essential, as well as between offshore generation and major cities.

The project portfolio in the TYNDP 2014 is a prerequisite for any energy transition. It amounts to approximately €150 billion, of which €50 billion is for subsea cables. The figures are in line with the expectations founding the Energy Infrastructure Package. This effort is significant for the financial means., It only represents however about 1.5-2 €/MWh of power consumption in Europe over the 10-year period, i.e. about 2% of the bulk power prices or approximately 1% of the total electricity bill.

By definition, these projects of pan-European significance must however be complemented at the regional or national level to establish a consistent picture.

Besides, the set of projects of pan-European significance may have to be completed in order to meet the future European energy policy goals for 2030. With more precise input in this respect, the Vision 4 scenario can be updated, additional investment needs may be identified and a more comprehensive picture of the grid infrastructure required by 2030 in this context will be supplied in the next release of the TYNDP.

10.2 With the TYNDP 2014, ENTSO-E supports the EIP implementation

With the late finalisation of the scenarios, the CBA methodology, and third party project submission by fall 2013, completing the TYNDP 2014 for consultation by Summer 2014 was a challenge. The timely delivery is however expected as an important input to the EIP process.

Systematically, all projects in the TYNDP 2014, regardless of whether they have been proposed by ENTSO-E Members or by other promoters, have been assessed according to a standard methodology: the CBA. The CBA has been prepared, shared and consulted since 2012. It is implemented in the TYNDP 2014 for the four 2030 Visions. This choice has been made based on stakeholder feedback, preferring a large scope of contrasted scenarios instead of a more limited number and an intermediate horizon of 2020.

A systematic assessment is now available for all transmission and storage PCIs.

For future TYNDPs and assessments, ENTSO-E and all interested stakeholders plan to evolve the CBA as far as needed to better match the needs of decision makers. In particular, it is already foreseen that the present methodology can be improved with respect to the so-called “capacity” value of assets (compared to the “energy” value, mirroring the future organisation of markets). Storage projects in particular create substantial capacity and flexibility in the power system that will be better reflected in their assessment in the future.

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10.3 The energy transition requires the grid, the grid requires everyone's support

A major challenge is that the grid development may not be completed in time if the RES targets are met as planned by 2030. Permit granting procedures are lengthy, and often cause commissioning delays. If energy and climate objectives have to be achieved, it is of upmost importance to smooth the authorizations processes. In this respect, ENTSO-E welcomes Regulation 347/2009 as there are many positive elements in the permitting section which will facilitate the fast tracking of transmission infrastructure projects, including the proposals on one stop shop and defined time lines.

Further analyses are however required to ensure the measure can be successfully implemented, in particular in relation to whether the timelines proposed are achievable, especially in the context of the public participation process and the potential for legal delays. One must also notice that the supporting schemes are limited to the Projects of Common Interest, whereas there are also many significant national transmission projects that are crucial to the achievement of Europe's targets for climate change, renewable energy and market integration.

Finally, in times of limited public finances, financing of the necessary grid development is a big challenge. Increasing grid tariffs due the financing of the new grid infrastructure on the one hand and possible reduction of generating costs on the other hand are two sides of the same coin; nevertheless, the benefit of the grid development goes hand in hand with a functioning pan-European integrated market.

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Appendices

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1 Appendix 1 - Technical description of projects

All detailed information about this assessment of projects is displayed in this Appendix. The organisation of Appendix 1 reflects the various roles and evolution of the TYNDP since 2012:

- First are displayed the assessments of transmission projects:
    - Section 1.1 displays the detailed assessment of Projects of Pan-European significance, i.e. transmission projects stemming from ENTSO-E analyses or submitted by third parties, and matching the criteria of pan-European significance, be they eventually PCIs or not;
    - Section 1.2 displays the assessments for transmission Projects of Common Interest (sometimes recalling information from Section 1.1).
- Section 1.3 displays the assessment of storage projects, complying with Reg 314/2013.
- Section 1.4 reminds the smart grid projects, complying with Reg 314/2013, but these are not to be assessed using the CBA methodology.

1.1 Transmission projects of pan-European significance

This section displays all assessments sheets for projects of pan-European significance. It gives a synthetic description of each project with some factual information as well as the expected projects impacts and commissioning information.

1.1.1 Transmission projects of pan-European significance

A **Project of Pan-European Significance** is a set of Extra High Voltage assets, matching the following criteria:

- The main equipment is at least 220 kV if it is an overhead line AC or at least 150 kV otherwise and is, at least partially, located in one of the 32 countries represented in TYNDP.
- Altogether, these assets contribute to a grid transfer capability increase across a network boundary within the ENTSO-E interconnected network (e.g. additional NTC between two market areas) or at its borders (i.e. increasing the import and/or export capability of ENTSO-E countries vis-à-vis others).
- An estimate of the abovementioned grid transfer capability increase is explicitly provided in MW in the application.
- The grid transfer capability increase meets least one of the following minimums:
    - At least 500 MW of additional NTC; or
    - Connecting or securing output of at least 1 GW/1000 km² of generation; or
    - Securing load growth for at least 10 years for an area representing consumption greater than 3 TWh/yr.

PCIs and projects meeting the criteria of Regulation 347/2013 (Article IV.1.c) which do not fulfil the criteria of pan-European significance are also included.

NB: Regional Investment Plans and National Development Plans can complement the development perspective with respect to other projects than Projects of Pan-European Significance.

1.1.2 Corridors, Projects, and investment items

Complying with the CBA methodology, a **project** in the TYNDP 2014 can cluster several **investment items**, matching the CBA clustering rules. Essentially, a project clusters all investment items that have to be realised in total to achieve a desired effect.

The CBA clustering rules proved however challenging for complex grid reinforcement strategies: the largest investment needs may require some 30 investments items, scheduled over more than five years but addressing the same concern. In this case, for the sake of transparency, they are formally presented in a series – a **corridor** – of smaller projects, each matching the clustering rules.

As far as possible, every project is assessed individually. However, the rationale behind the grid reinforcement strategy invited sometimes to assess some projects jointly (e.g. the two phases of Nordbalt, the transbalkan corridor, etc.), or even a whole corridor at once (e.g. German corridors from north to south of Germany).

One investment item may contribute to more than one project. It is then depicted in the investment table of each of the projects it belongs to.

1.1.3 Labelling

Labelling of investment items and projects started with the first TYNDP, in 2010. They got a reference number as soon as they were identified, regardless where (in Europe) and why (a promising prospect? a mere option among others to solve a specific problem?) they were proposed, and with what destination (pan-European significance or regional project?). Projects are also lively objects (with commissioning of investment items, evolution of consistency, etc.). Hence, now, there is simply no logic in the present labelling. It is a mere reference number to locate projects on maps and track their assessments.

Since the TYNDP 2010, the TYNDP contains

- 125 projects with reference numbers between 1 to 227;
- 377 Investment items with individual reference numbers from 1 to about 1200. On maps, the reference numbers are Project_ref|Investment_Item_ref (e.g. 79|459 designates the investment item with the label 459, contributing to project 79).

Corridors have no reference number.

1.1.4 How to read every assessment sheet

Every project of pan-European significance is displayed in an **assessment sheet, i.e. 1-3 pages of standard information** structured in the following way:

- A short description of the consistency and rationale of the project;
- A table listing all constituting investment items, with their technical description, commissioning date, status, evolution and evolution drivers since last TYNDP, and its contribution to the Grid Transfer Capability of the project.
- The project’s CBA assessment, in two parts,
    - on the one hand, the CBA indicators that are independent from the scenarios: GTC increase, resilience, flexibility, length across protected areas, length across urbanised areas, costs;
    - on the other hand, the CBA Vision-dependent indicators: SoS, SEW, RES, Losses variation, CO2 emissions variations;
- Additional comments, especially regarding the computation of CBA indicators.

Remarks

- Uncertainties are attached to these forecasts, hence assessment figures are presented as ranges.
- In the same respect, a '0' for losses or CO2 emissions variations means a neutral impact, sometimes positive or negative and not a strict absence of variation.
- Some projects of pan-European significance build on already commissioned investment that were mentioned in the TYNDP (as well as they all build on the existing grid assets), or other investments that are of regional importance. This is mentioned in the 'additional comments' as the case may be.
- The indicator C1 (cost) in Meuros provides the current best estimate.

1.1.5 Assessment of projects of pan-European significance

Corridor	Concerned country/ies	Project name	Project ID
	ES, PT	Portugal-Spain	4
	ES, FR	Eastern interconnection ES-FR	5
	ES, FR	Santa Llogaia - Bescano	213
	ES, FR	PST Arkale	184
	ES, FR	Western interconnection ES-FR	16
	ES, FR, GB	BRITIB	182
	FR, GB	IFA2	25
	FR, GB	France-Alderney-Britain	153
	FR, GB	ElecLink	172
	BE, FR	France-Belgium Interconnection Phase 1	23
	BE, FR	France-Belgium Interconnection Phase 2	173
	DE, FR	France Germany	152
	DE, NL	Doetinchem - Niederrhein	113
	BE, DE	ALEGrO	92
	BE, DE	2nd Interconnector Belgium - Germany	225
	BE, LU	Belgium-Luxembourg	40
	BE, GB	NEMO & Thames Estuary	74
	BE, GB	Belgium-GB 2	121
	FR, IE	Celtic Interconnector	107
	IE, GB	Ireland GB Interconnector	106
	IE, GB	Greenwire	185
	IE, GB	Marex	229
	IE, NI	North South Interconnector	81
	IE, NI	RIDP I	82
	GB, NI	Irish-Scottish Isles	189
	IS, GB	Iceland-Great Britain	214
	GB, NO	Norway-Great Britain 1	110

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	GB, NO	Norway-Great Britain 2	190
	DE, NO	Germany-Norway	37
	DKW, NL	COBRA	71
	DKW, GB	Denmark W-Great Britain	167
	DE, DKW	Denmark W-Germany, Westcoast	183
	DE, DKW	Denmark W-Germany, step 3	39
	DKW, DKE	Great Belt II	175
	DE, DKE	Denmark East-Germany	179
	DE, DE, DKE	Kriegers Flak CGS	36
	DE, SE	Hansa PowerBridge	176
NordBalt	LV, SE	NordBalt phase 1	60
	LV, SE	NordBalt phase 2	124
	FI, SE	3rd AC Finland-Sweden north	111
	EE, LV	Estonia-Latvia third interco.	62
LitPol	LT, PL	LitPol Link Stage 1	59
	LT, PL	LitPol Link Stage 2	123
	EE, LV, LT	Baltic Corridor	163
	EE, LV, LT	Baltics synchro with CE	170
	DE, PL	GerPol Power Bridge	58
	DE, PL	GerPol Improvements	94
Czech Corridor	CZ, DE	CZ 1 North-South	35
	CZ, DE	CZ 3 North-South	200
	CZ, DE	CZ 2 West-east	55
	CZ, DE	PST Hradec	177
	AT, DE	Austria-Germany 1	47
	AT, DE	St. Peter - Pleinting	187
	AT, DE	German part of Lake Constance	198
	AT, CH, DE	Swiss Roof	90
	CH, FR	Lake Geneva West	22
	CH, FR	Lake Geneva South	199
	FR, IT	France-Italy	21
	CH, IT	Italy-Switzerland	31
	CH, IT	Greenconnector	174
	AT, IT	Austria - Italy	26
	AT, IT	E15	210
	IT, SI	Italy Slovenia 1	148
	IT, SI	Italy Slovenia 2	150
	IT, ME	Italy-Montenegro	28
Transbalkan Corridor	BA, ME, SR	Transbalkan Corridor, phase 1	146
	BA, ME, SR	Transbalkan Corridor, phase 2	227
	BA, HR	CSE1	136
	HR, HU, SI	CSE3	141

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	HU, SK	HU-SK phase 1	48
	HU, SK	HU-SK phase 2	54
	RO, RS	Mid Continental East corridor	144
	BG, RO	Black Sea Corridor	138
	BG, GR, TR	CSE4	142
	BG, RO, RS, AL, MK, GR	CSE9	147
	IR, CY, GR	Euroasia interconnector	219
	IT, TN, DZ	Italy-North Africa	29
	AT	RES East of Austria	186
	BE	OWP integration 1, Stevin	75
	BE	OWP integration 2	120
	CH	Swiss Ellipse	91
Offshore wind parks Germany	DE	OWP North Sea TenneT part 1	42
	DE	OWP North Sea TenneT part 2	191
	DE	OWP North Sea TenneT part 3	192
	DE	OWP North Sea TenneT part 4	129
	DE	OWP Baltic Sea	46
North South Eastern German Corridor	DE	Eastern, Section East	130
	DE	Eastern, Central Section	164
	DE	Eastern, supporting measures 1	205
	DE	Eastern, supporting measures 2	204
	DE	Reinforcement Southern DE	206
	DE	Reinforcement North-Eastern DE	209
North South Western German Corridor	DE	Western, Section North 1	208
	DE	Western, Section North 2	132
	DE	Western, supporting measures	135
	DE	Western, Section South	134
	DE	Reinforcement North-Western DE	207
	DE	Long term German RES	133
	ES	Baza project	13
	ES	Aragón-Catalonia south	157
	ES	Asturian Ring	151
	ES	Godelleta-Morella/La Plana	193
	ES	Cartuja	194
	ES	Aragón-Castellón	203
	FI	Keminmaa-Pyhänselkä	96
	FR	Massif Central South	158
	FR	Massif Central North	216
	GB	East Anglia Cluster	69
	GB	London Cluster	76
	GB	Anglo-Scottish Cluster	77

	GB	South West Cluster	78
	GB	Wales Cluster	79
	GB	East Coast Cluster	86
	GR	Southern Aegean Interconnector	220
	IT	Center of Italy	33
	IT	South of Italy	127
	IT	Sicily-mainland Italy	30
Dutch ring	NL	Dutch Ring	103
	NL	Dutch ring (Spaak)	168
	PT	RES Portugal, North	1
	PT	RES Portugal, Center	2
	PT	RES Portugal, South (Alentejo)	85
	SE	North-South corridor in Sweden	126
	RO	HPP Tarnita connection	108
	BE	Belgian North Border	24
	FI	N-S Finland (P1) stage 1	64
	FI	N-S Finland P1 stage 2	197
	North Sea countries	North Seas offshore grid scheme	230

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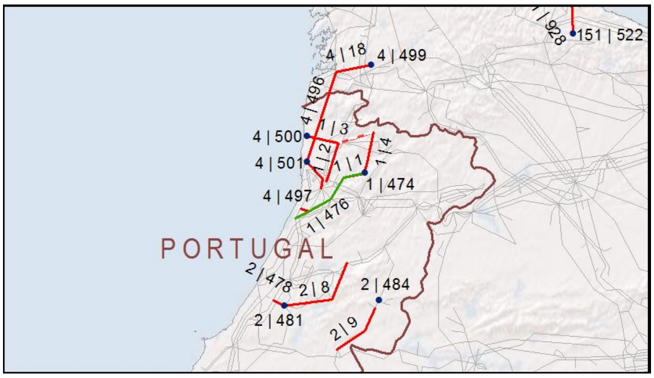
Project 4: Interconnection Portugal-Spain

Description of the project

This project increases the interconnection capacity between Portugal and Spain. Larger and more volatile flows are expected between both countries due to the huge increase of volatile sources and the market interchanges. The project includes two 400kV interconnection routes, besides the 400kV internal reinforcements required, one in the North (Fontefría - V.Conde) and other in the South (P.Guzman – Tavira that will be commissioned in 2014), due to the important loop flows between the two countries. Only with these both new 400kV interconnections is possible to reach the interconnection capacity of 3200 MW agreed between Portugal and Spain.
This project will also have a benefit in reducing the spilled energy in the Iberian Peninsula.

PCI 2.17



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
18	Beariz (ES)	Fontefria (ES)	New northern interconnection. New double circuit 400kV OHL between Beariz (ES) - Fontefria (ES).	1000	Design & Permitting	2016	Delayed	Delays in authorization process due to a change on the route and on the location of substations, induced by environmental concerns
496	Fontefría (ES)	Vila do Conde (PT) (By Viana do Castelo)	New northern interconnection. New 400kV OHL Fontefría (ES) - Viana do Castelo (PT) - Vila do Conde (PT).	1000	Design & Permitting	2016	Delayed	Delays in authorization process due to a change on the route and on the location of substations were induced by environmental concerns
497	Vila do Conde (PT)	Recarei/Vermoim (PT)	New double circuit 400kV OHL between Vila do Conde (PT) - Recarei/Vermoim (PT).	1000	Design & Permitting	2015	Delayed	Partial sections from the line found environmental problems in his original route. The problems are being solved with the identification of new routes, prompting a delay in the commissioning date.
498	Fontefria (ES)		New northern interconnection. New 400kV substation	1000	Design & Permitting	2016	Delayed	Delays in the authorization process, due to a change of

			Fontefria (ES), previously O Covelo.					location of the substation. Timing correlated to investment 18
499	Beariz (ES)		New northern interconnection. New 400kV substation Beariz (ES), previously Boboras	1000	Design & Permitting	2016	Delayed	Delays in the authorization process, due to a change of location of the substation. Timing correlated to investment 18
500	V. Castelo (PT)		New 400/150kV substation V.Castelo (PT).	1000	Design & Permitting	2016	Delayed	Delays in the authorization process, due to a change of location of the substation. Timing correlated to investment 496.
501	Vila do Conde (PT)		New 400kV substation Vila do Conde (PT).	1000	Design & Permitting	2015	Delayed	Delays in the authorization process, due to a change of location of the substation. Timing correlated to investment 497.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
PT=>ES: 400	ES=>PT: 1000	3	4	Negligible or less than 15km	Negligible or less than 15km	130-160

CBA results	**for each scenario**				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[4;30]	[7200;8800] MWh	[-14000;-12000]	[180;220]
Scenario Vision 2 - 2030	-	[3;33]	[7900;9600] MWh	[-13000;-11000]	[160;200]
Scenario Vision 3 - 2030	-	[20;50]	[160000;200000] MWh	[3600;4400]	[-110;-90]
Scenario Vision 4 - 2030	-	[64;130]	[630000;770000] MWh	[8100;9900]	[-330;-270]

Additional comments

Comment on the security of supply: Increasing the interconnection capacity between Portugal and Spain allows to better accommodate the volatility associated to the RES generation which is predicted for these two countries of the Iberia Peninsula in 2030 increasing in this sense the overall security of supply of the electrical systems. The project increases the interconnection ratio of Spain in 0,2 - 0,3% in 2030, depending on the scenario.

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Comment on the RES integration: This project facilitates the integration of new RES generation, mainly in the North of Portugal and in the Galiza (Spain), by increasing the interconnection capacity between Portugal and Spain and as a consequence take advantage of the complementarity of the both Iberian electrical systems. This project will also reduce the spilled energy in the Iberian Peninsula.

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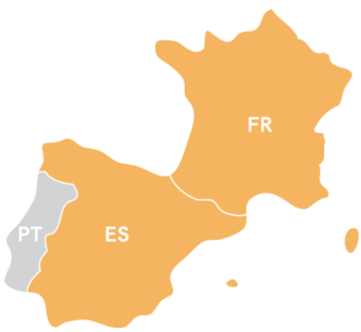
Project 5: Eastern interconnection ES-FR

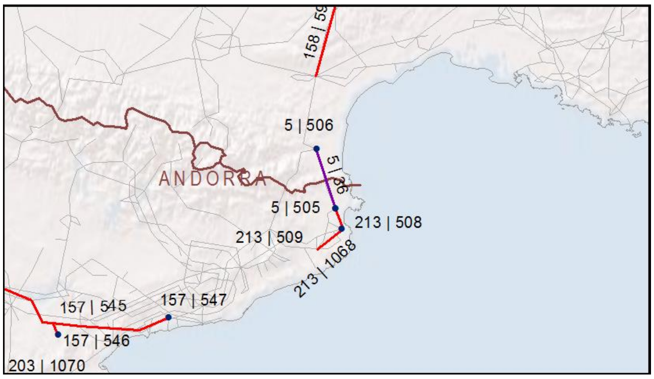
Description of the project

In order to fulfil the governmental 2800 MW objective of exchange capacity between France-Spain, the Eastern interconnection was planned. After being classified as a Priority Project by the European Commission, and after the involvement of Prof. Monti as European Coordinator, it was stated that the unique feasible alternative for the development of the Spanish-French interconnection by the Eastern Pyrenees was a solution in DC totally buried for the cross-border section of the interconnection, with a terrestrial drawing up, as well as using, as far as possible, existing infrastructure corridors within a certain area.

The interconnection link based on the new VSC technology will connect Baixas (France) to Santa-Llogaia (Spain), via a 65-km long HVDC +/- 320 kV underground cable system, with 2*1000 MW rated power and AC/DC converters at both ends. This project is carried out by INELFE, a REE-RTE joint venture, created for this purpose.

Some internal reinforcements, both in Spain and France, are required. In France, the uprate of Baixas –Gaudiere 400kV is already commissioned. In Spain, reinforcements are included in project 213 in addition to certain individual investments of regional relevance.
The project allows important Social Economic Welfare, as it allows the use of more efficient and cheaper technologies, and avoids spillage of RES, especially in the Iberian Peninsula.





Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
36	Sta.Llogaia (ES)	Baixas (FR)	New HVDC (VSC) bipolar interconnection in the Eastern part of the border, via 320kV DC underground cable using existing infrastructures corridors and converters in both ending points.	1400	Under Construction	2015	Delayed	Answering all concerns expressed during the authorization process in Spain and environmental issues in France led to postponing the investment. Both issues are solved by now.
505	Sta.Llogaia (ES)		Converter station of the new HVDC (VSC) bipolar interconnection in the Eastern part of the border, via 320kV DC underground cable using	1400	Under Construction	2015	Delayed	Works completed in 2014; commercial operation expected after test period at the same time as the cable (investment 36).

			existing infrastructures corridors.					
506	Baixas (FR)		Converter station of the new HVDC (VSC) bipolar interconnection in the Eastern part of the border, via 320kV DC underground cable using existing infrastructures corridors.	1400	Under Construction	2015	Delayed	Works completed in 2014; commercial operation expected after test period at the same time as the cable (investment 36).

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
ES=>FR: 1400	FR=>ES: 1200	1	4	Negligible or less than 15km	Negligible or less than 15km	700

CBA results	**for each scenario**				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	[100;250]	[20;130]	[110000;130000] MWh	[450000;550000]	[1600;2000]
Scenario Vision 2 - 2030	[110;260]	[22;140]	[120000;150000] MWh	[280000;380000]	[1800;2200]
Scenario Vision 3 - 2030	[120;270]	[70;150]	[590000;720000] MWh	[180000;280000]	[-1100;-870]
Scenario Vision 4 - 2030	[120;280]	[210;280]	[1300000;1500000] MWh	[360000;460000]	[-1500;-1300]

Additional comments

Comment on the security of supply: The project avoids potential Energy Not Supplied in the area of Gerona (Spain). In addition, the project increases the interconnection ratio of Spain in 0,6-1,05% in 2030 depending on the scenario.

Comment on the RES integration: Values of spillage are results from market studies without considering internal network constraints. Avoided spillage concerns RES in Iberian peninsula as a whole.

Comment on the CO2 indicator: the very high scores reflect that the project enables a better use of RES.

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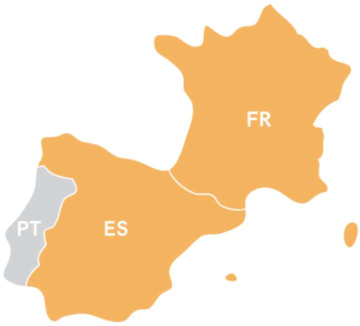
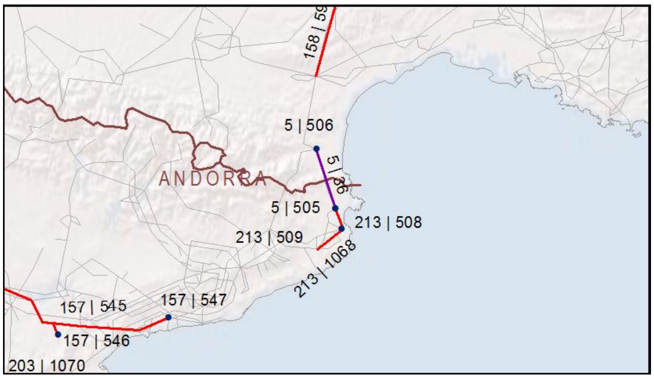
Project 213: Santa Llogaia - Bescano

Description of the project

This project consists of a double 400kV circuit from Santa Llogaia to Bescanó which first is needed to connect the Spain-France Eastern HVDC interconnection project (project 5) to the existing transmission network in Spain. Secondly, the projects contributes to improve the security of supply of the area of Gerona with the new injection from the new 400 kV Ramis and Santa Llogaia substations to the distribution network. Therefore, the benefits attached to this project join the cross border benefits and the local benefits.
This project have been included in the 2013 PCI list (PCI 2.6).





Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
508	Ramis (ES)		New 400kV substation in Ramis with two 400/220kV transformers; connection as input/output in Santa Llogaia - Bescano line	1400	Design & Permitting	2015	Delayed	Answering all concerns expressed during the authorization process led to postponing the investment.
509	Santa Llogaia (ES)		New 400kV substation Sta.Llogaia.	1400	Under Construction	2014	Delayed	Answering all concerns expressed during the authorization process led to postponing the investment.
1068	Bescanó	Santa Llogaia	New OHL 400kV AC double circuit Bescano-Santa Llogaia, required to connect the new HVDC interconnection to the existing network and secure the supply in the area of Gerona	1400	Under Construction	2014	Investment on time	Progress as planned

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CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
ES=>FR: 1400	FR=>ES: 1200	1	4	Negligible or less than 15km	Negligible or less than 15km	50-56

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	[100;250]	[20;130]	[110000;130000] MWh	[19000;23000]	[1600;2000]
Scenario Vision 2 - 2030	[110;260]	[22;140]	[120000;150000] MWh	[21000;26000]	[1800;2200]
Scenario Vision 3 - 2030	[120;270]	[70;150]	[590000;720000] MWh	[18000;22000]	[-1100;-870]
Scenario Vision 4 - 2030	[120;280]	[210;280]	[1300000;1500000] MWh	[26000;32000]	[-1500;-1300]

Additional comments

Comment on the security of supply: The project avoids potential Energy Not Supplied in the area of Gerona (Spain). In addition, the project increases the interconnection ratio of Spain in 0,6-1,05% in 2030 depending on the scenario.

Comment on the RES integration: Values of spillage are results from market studies without considering internal network constraints. Avoided spillage concerns RES in Iberian peninsula as a whole.

Comment on the CO2 indicator: the very high scores reflect that the project enables a better use of RES (by bringing it to load centers or to and from storage facilities)

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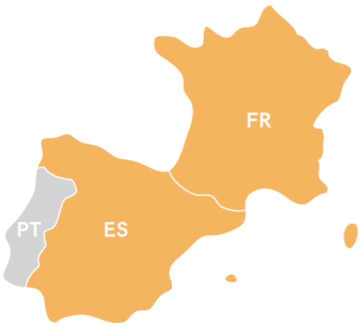
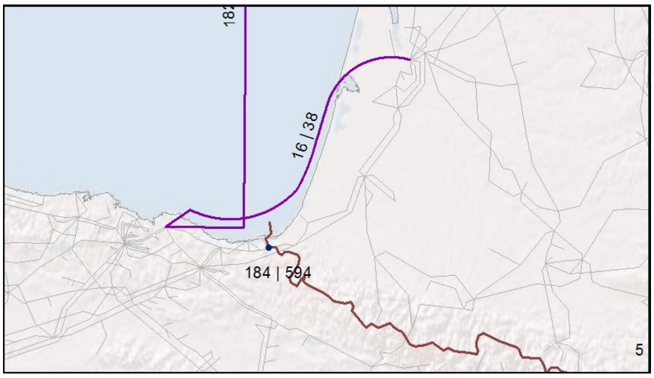
Project 184: PST Arkale

Description of the project

This project is a new PST (phase shifting transformer) in the Spanish substation Arkale 220 kV with affection to the Arkale-Argia cross border line between France and Spain.
This device is required to increase the France-Spain exchange capacity, especially from Spain to France, and not only is able to have an independent good impact in the exchange capacity without taking into account the Eastern and Western interconnections (projects 5 and 16), but also helps making the most of these projects. In addition, as this project avoids the tripping of the Arkale-Argia tie line in case of contingencies, it helps improving the Security of supply in the French Basque country.
This project have been included in the 2013 PCI list – 2.8





Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
594	Arkale (ES)		New PST in Arkale-Argia 220 kV interconnection line	-	Planning	2016	Investment on time	Draft NDP expected to be published during the preparation of TYNDP 2012 was not finally approved and published, so the investment is yet in a planning stage. If the new NDP is published by 2014, as expected, commissioning date would not be affected.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
ES=>FR: 500-900	FR=>ES: 100-500	3	3	Negligible or less than 15km	Negligible or less than 15km	19-23

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	[22;27]	[5;13]	[8700;11000] MWh	[7000;11000]	[210;250]
Scenario Vision 2 - 2030	[23;28]	[7;15]	[8900;11000] MWh	[7500;12000]	[230;290]
Scenario Vision 3 - 2030	[27;33]	[12;26]	[54000;66000] MWh	[10000;14000]	[-190;-150]
Scenario Vision 4 - 2030	[36;45]	[33;53]	[150000;190000] MWh	[14000;18000]	[-280;-230]

Additional comments

Comment on the security of supply: The project increases the interconnection ratio of Spain in 0.2-0,4% in 2030 depending on the scenario. This project improves the security of supply in the French Basque Country

Comment on the RES integration: Values of spillage are results from market studies without considering internal network constraints. Avoided spillage concerns RES in the Iberian peninsula.

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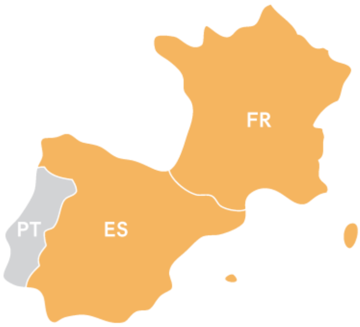
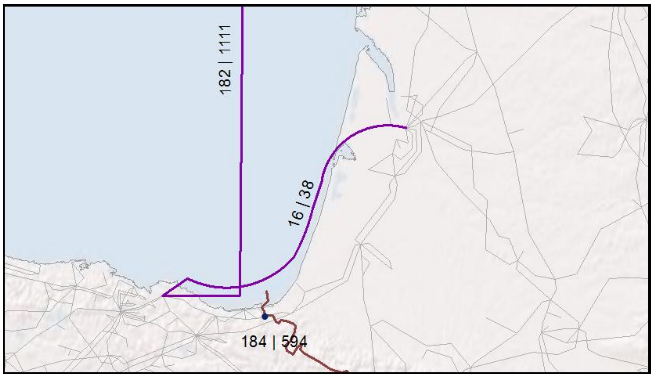
Project 16: Western interconnection FR-ES

Description of the project

In order to fulfil the governmental long term objective of exchange capacity between France-Spain, the Western interconnection is under analysis.
Deep technical and environmental prefeasibility studies across the whole French-Spanish border showed that the preferential strategy was a new HVDC submarine interconnection through the Biscay/Gascogne Bay from the Basque Country in Spain to the Aquitaine area in France.
Since the last TYNDP the analysis on technical feasibility and environmental aspects, especially for the subsea route have had good process. However, the project is still under analysis and final definition is in progress.
The project allows important Social Economic Welfare, as it allows the use of more efficient and cheaper technologies, avoids spillage of RES, especially in the Iberian Peninsula and reduces the consideration of Spain as an electric island.

PCI 2.7





Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
38	Gatica (ES)	Aquitaine (FR)	New HVDC interconnection in the western part of the border via DC subsea cable in the Biscay Gulf.	-	Planning	2023	Investment on time	The technical consistency of the project progresses and the commissioning date is now defined more accurately.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	GTC direction 2 (MW)	B6 Technical Resilience	B7 Flexibility	S1 - protected areas	S2 - urban areas	C1 Estimated cost (Meuros)
ES=>FR: 2500	FR=>ES: 2200	2	4	Negligible or less than 15km	Negligible or less than 15km	1600-1900

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[90;210]	[130000;160000] MWh	[200000;300000]	[3300;4000]
Scenario Vision 2 - 2030	-	[95;220]	[140000;170000] MWh	[210000;310000]	[3500;4300]
Scenario Vision 3 - 2030	-	[90;250]	[900000;1100000] MWh	[240000;340000]	[-1900;-1500]
Scenario Vision 4 - 2030	-	[310;470]	[2100000;2600000] MWh	[390000;490000]	[-2400;-2000]

Additional comments

Comment on the security of supply: The project increases the interconnection ratio of Spain in 1-1,6% in 2030 depending on the scenario.

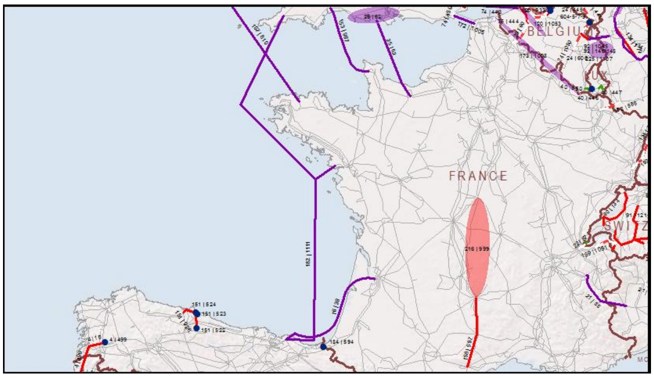
Comment on the RES integration: Values of spillage are results from market studies without considering internal network constraints. Avoided spillage concerns RES in Iberian peninsula as a whole.

Project 182: BRITIB (GB-FR-ES)

Description of the project

Project promoted by COBRA (ACS Group)

Interconnection project between Indian Queens (Great Britain), Cordemais (France) and Gatica (Spain) in a multiterminal HVDC configuration with 2 sections of 1000 MW each, and a submarine route from Spain to Great Britain along the French coast. It is proposed to take advantage of complementarity of resources in the three countries involved in the project.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
1111	Gatica	Indian Queens	Interconnection project between Indian Queens (Great Britain), Cordemais (France) and Gatica (Spain) in a multiterminal HVDC configuration with 2 sections and 3 terminals of at least 1000MW each, that allows for direct exchange of electricity between ES-FR, FR-UK and UK-ES.	-	Under Consideration	2018	New Investment	Project application to TYNDP 2014.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
Multiterminal configuration (MT): From/to ES; From/to FR; From/to GB: 1000		2	5	50-100km	Negligible or less than 15km	1700-2800

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[65;130]	[93000;110000] MWh	[200000;300000]	[900;1100]
Scenario Vision 2 - 2030	-	[75;140]	[110000;130000] MWh	[230000;330000]	[780;960]
Scenario Vision 3 - 2030	-	[200;280]	[1800000;2200000] MWh	[430000;530000]	[-1700;-1400]
Scenario Vision 4 - 2030	-	[280;350]	[2100000;2500000] MWh	[510000;610000]	[-1800;-1400]

Additional comments

Comment on the security of supply: The project increases the interconnection ratio of Spain in 0,4-0,8% in 2030 depending on the scenario

Comment on the RES integration: avoided spillage concerns RES both in the Iberian peninsula on the one hand and Great-Britain and Ireland on the other hand.

Comment on the CO2 indicator: the very high scores reflect that the project enables a better use of RES

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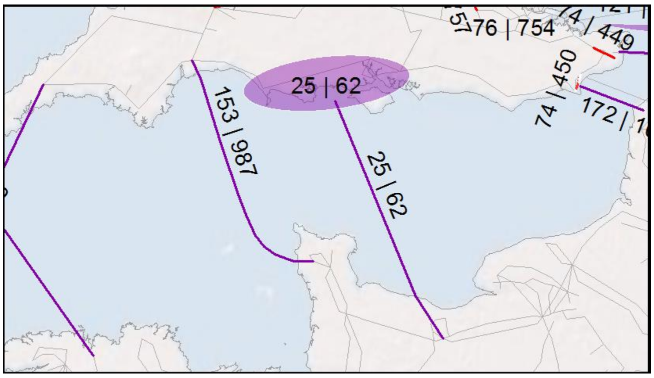
Project 25: IFA2

Description of the project

IFA2 is a new subsea HVDC VSC interconnection that will develop between the area of Caen in France and the region of Southampton in Great Britain. The objective is to increase the interconnection capacity between Great Britain and continent and to integrate RES generation, especially wind in Great Britain. It has been selected as PCI 1.7.2 in the NSCOG corridor on 14/10/13. Some mutual support is also expected but this is not reflected in the security of supply indicator assessed according to the CBA rules.



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
62	Tourbe (FR)	Chilling (GB)	New subsea HVDC VSC link between the UK and France with a capacity around 1000 MW. PCI 1.7.2 (NSCOG corridor)	-	Design & Permitting	2020	Investment on time	Extensive feasibility studies (e.g. seabed surveys) have been conducted to determine the most suitable route; on the French side, the ministry of energy acknowledged the notification of the investment on 08/04/14.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	GTC direction 2 (MW)	B6 Technical Resilience	B7 Flexibility	S1 - protected areas	S2 - urban areas	C1 Estimated cost (Meuros)
FR=>GB: 1000	GB=>FR: 1000	1	4	15-50 km	Negligible or less than 15km	540-830

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[35;75]	[230000;280000] MWh	[200000;240000]	[170;210]
Scenario Vision 2 - 2030	-	[0;60]	[36000;44000] MWh	[200000;240000]	[220;260]
Scenario Vision 3 - 2030	-	[170;250]	[1700000;2000000] MWh	[190000;240000]	[-1400;-1200]
Scenario Vision 4 - 2030	-	[180;210]	[1500000;1800000] MWh	[190000;240000]	[-1100;-940]

Additional comments

Comment on the RES integration: Avoided spillage concerns RES in Great-Britain and Ireland mostly, but also France.

Comment on the CO2 indicator: The very high scores reflect that the project enables a better use of RES

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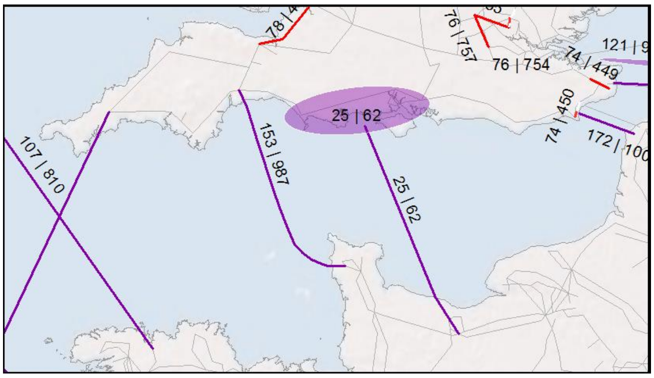
Project 153: France-Alderney-Britain

Description of the project

France-Alderney-Britain (FAB) is a new HVDC subsea interconnector between Exeter (UK) and Cotentin Nord (France) with 1.4 GW capacity.
The project will not only increase the interconnection between Great Britain and continent but also integrate additional RES (especially wind generation from Great Britain); 2.8 GW of future tidal generation could also be connected to this link when it develops off the Cotentin coasts.
The investment has been selected as PCI 1.7.1 in the NSCOG Corridor.



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
987	Cotentin Nord	Exeter	France-Alderney-Britain (FAB) is a new 220km-long HVDC subsea interconnection between Exeter (UK) and Cotentin Nord (France) with VSC converter station at both ends. Expected rated capacity is 2*700 MW.	-	Planning	2022	New Investment	Studies conducted after TYNDP2012 release have shown the economic viability of this interconnection and lead to develop this investment. Feasibility studies (marine surveys) are starting to find a suitable subsea route.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
FR=>GB: 1400	GB=>FR: 1400	1	4	Negligible or less than 15km	Negligible or less than 15km	470-1100

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[40;100]	[300000;360000] MWh	[270000;340000]	[260;310]
Scenario Vision 2 - 2030	-	[0;90]	[59000;72000] MWh	[270000;340000]	[270;340]
Scenario Vision 3 - 2030	-	[230;350]	[2400000;2900000] MWh	[260000;320000]	[-2000;-1600]
Scenario Vision 4 - 2030	-	[260;300]	[2100000;2500000] MWh	[260000;320000]	[-1700;-1400]

Additional comments

Comment on the RES integration: avoided spillage concerns RES in Great-Britain and Ireland mostly, but also France.

Comment on the CO2 indicator: the very high scores reflect that the project enables a better use of RES

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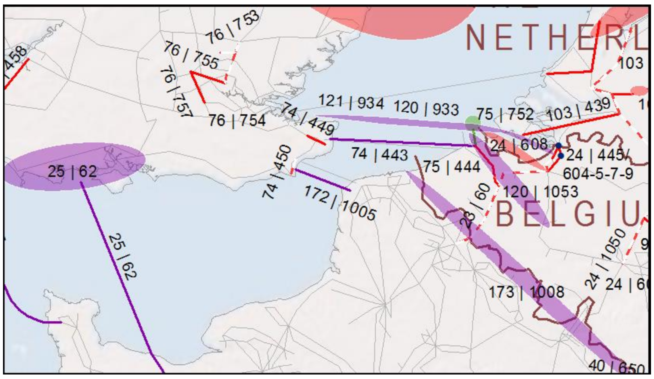
Project 172: ElecLink

Description of the project

Eleclink is a new HVDC interconnection between France and the United Kingdom with 1000 MW capacity through the Channel tunnel. This project has been selected as PCI n°1.7.3 in the NSCOG Corridor on 14/10/13.



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
1005	Sellindge (UK)	Le Mandarins (FR)	Eleclink is a new FR – UK interconnection cable thought the channel Tunnel between Selindge (UK) and Mandarins (FR). Converter stations will be located on Eurotunnel concession at Folkestone and Coquelles. This HVDC interconnection is a PCI project (Project of common interest). It will increase by 1GW the interconnection capacity between UK and FR by 2016.	-	Design & Permitting	2016	New Investment	Project application to TYNDP 2014.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
FR=>GB: 1000	GB=>FR: 1000	1	4	Negligible or less than 15km	Negligible or less than 15km	260-440

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[35;75]	[230000;280000] MWh	[200000;240000]	[170;210]
Scenario Vision 2 - 2030	-	[0;60]	[36000;44000] MWh	[200000;240000]	[220;260]
Scenario Vision 3 - 2030	-	[170;250]	[1700000;2000000] MWh	[140000;170000]	[-1400;-1200]
Scenario Vision 4 - 2030	-	[180;210]	[1500000;1800000] MWh	[140000;170000]	[-1100;-940]

Additional comments

Comment on the RES integration: avoided spillage concerns RES in Great-Britain and Ireland mostly, but also France.

Comment on the CO2 indicator: the very high scores reflect that the project enables a better use of RES

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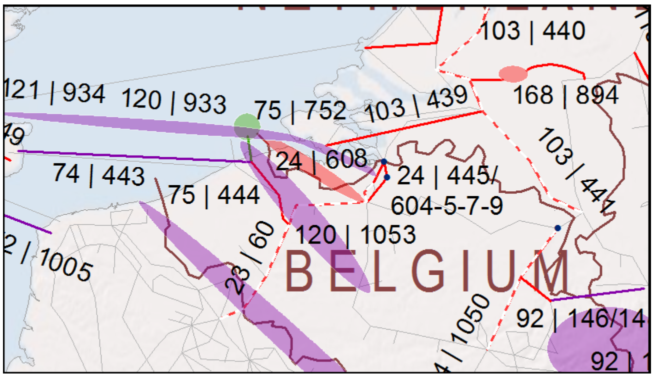
Project 23: France-Belgium Interconnection Phase 1

Description of the project

The project aims at ensuring reliable grid operation to cope with more volatile south-north flows, and at increasing the exchange capacities between France & Belgium to sustain an adequate level of market integration.



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
60	Avelin/Mastaing (FR)	Horta (new 400-kV substation) (BE)	Replacement of the current conductors on the axis Avelin/Mastaing - Avelgem - Horta with high performance conductors (HTLS = High Temperature Low Sag)	-	Planning	2021	Rescheduled	Investment was at conceptual stage in TYNDP2012; on-going feasibility studies lead to a more accurate commissioning date.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
FR=>BE: 600-1300	BE=>FR: 600-1300	1	3	Negligible or less than 15km	Negligible or less than 15km	110-170

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[5;15]	[18000;22000] MWh	0	[-120;-99]
Scenario Vision 2 - 2030	-	[0;10]	[19000;23000] MWh	0	[27;33]
Scenario Vision 3 - 2030	-	[10;20]	[77000;94000] MWh	0	[-130;-100]
Scenario Vision 4 - 2030	-	[20;60]	[200000;240000] MWh	0	[-240;-200]

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Additional comments

Comment on the security of supply: a reinforced interconnector contributes to the security of supply of Belgium as a whole, since it offers market players additional import capacity which they can use to balance their portfolio provided that excess generation is available abroad. Given the changing production mix with ongoing nuclear phase out and decommissioning of old power plants, this benefit materializes itself as soon as the project is realized.

Comment on the RES integration: avoided spillage concerns RES in France and Belgium mostly.

Comment on the Losses indicator: basically, the project enables power exchanges over greater distances (increasing losses), and conversely reduce the overall resistance of the grid. Losses variation is hence symbolically 0, with depending on the point in times losses being lower or greater, with variation close to the model accuracy range.

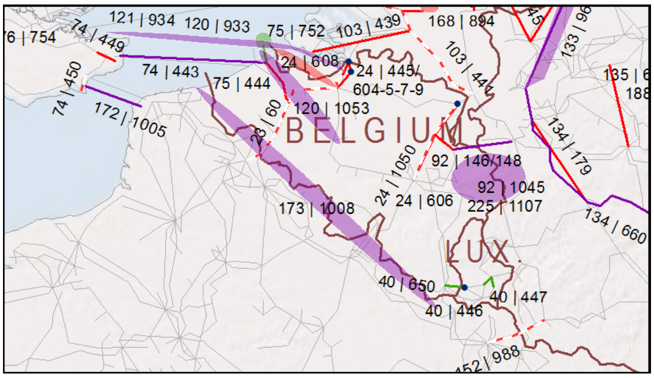
Comment on the S1 and S2 indicators: by definition, the reconductoring implies no new route, hence the indicators value is negligible.

Project 173: FR-BE phase 2

Description of the project

Preliminary analyses show the need for an additional reinforcement in visions 3&4 between France & Belgium, complementary to project # 23.

The determination of the amount of additional market exchange that can be secured with this project, its optimal location & technology are subject to further studies.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
1008	tbd(FR)	tbd(BE)	The following (combination of) options are envisioned and will be further studied: - Lonny-Achène-Gramme (reconductoring with High Temperature Low Sag conductors or HVDC) - Capelle-Courcelles (HVDC) - Warande-Zeebrugge/Alfa (HVDC)	-	Under Consideration	2030	New Investment	Preliminary analyses show the need for an additional reinforcement in visions 3 & 4 (2030) between France & Belgium, complementary to project # 23.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
FR=>BE: 1400	BE=>FR: 1400	2	1	NA	NA	150-450

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 3 - 2030	-	[20;30]	[160000;200000] MWh	0	[-210;-180]
Scenario Vision 4 - 2030	-	[60;100]	[360000;430000] MWh	0	[-540;-450]

Additional comments

Comment on the RES integration: avoided spillage concerns RES in France and Belgium mostly.

Comment on the CO2 indicator: the very high scores reflect that the project enables a better use of RES

Comment on the Losses indicator: basically, the project enables power exchanges over greater distances (increasing losses), and conversely reduce the overall resistance of the grid. Losses variation is hence symbolically 0, with depending on the point in times losses being lower or greater, with variation close to the model accuracy range.

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

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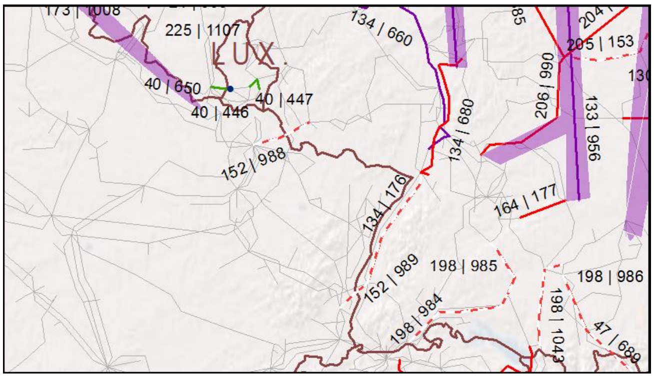
Project 152: France Germany Interconnection

Description of the project

The project aims at increasing the cross-border capacity between Germany and France by reinforcing the existing axes in Lorraine-Saar and Alsace-Baden areas. Studies in progress showed positive impact, with main benefits in terms of market and RES generation integration.

Detailed timeline is under discussion between RTE, Amprion and TransnetBW.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
988	Vigy	Ensdorf or further (tbd)	Upgrade of the existing transmission axis between Vigy and Ensdorf (Uchtelfangen) to increase its capacity.	1500	Under Consideration	2030	New Investment	Studies in progress showed positive impact on FR-DE exchange capacity (investment contribution to GTC highly dependent on the scenario and on generation/load pattern). Technical feasibility under investigation. Commissioning date depends on the scope of the investment.
989	Muhlbach	Eichstetten	Operation at 400 kV of the second circuit of a 400kV double circuit OHL currently operated at 225 kV; some restructuration of the existing grid may be necessary in the area.	300	Under Consideration	2026	New Investment	Studies in progress showed the feasibility of upgrading the existing asset in order to provide mutual support to increase exchange capacity between FR and DE.. The detailed timeline of the investment is under definition.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
FR=>DE: 1000-2000	DE=>FR: 1000-2000	1	4	NA	NA	100-140

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[18;22]	0	0	0
Scenario Vision 2 - 2030	-	[48;59]	0	0	[1200;1400]
Scenario Vision 3 - 2030	-	[140;170]	[130000;160000] MWh	0	[-860;-700]
Scenario Vision 4 - 2030	-	[220;270]	[200000;250000] MWh	0	[-1400;-1100]

Additional comments

Comment on the RES integration: avoided spillage concerns RES in Germany and France mostly.

Comment on the CO2 indicator: the very high scores reflect that the project enables a better use of RES

Comment on the Losses indicator: basically, the project enables power exchanges over greater distances (increasing losses), and conversely reduce the overall resistance of the grid. Losses variation is hence symbolically 0, with depending on the point in times losses being lower or greater, with variation close to the model accuracy range.

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

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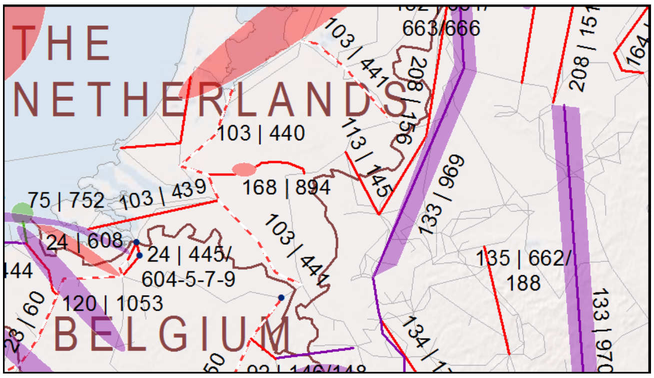
Project 113: Doetinchem - Niederrhein

Description of the project

This new AC 400-kV double circuit overhead line will interconnect The Netherlands and Germany (Ruhr-Rhein area). Upon realization of the project, the border between The Netherlands and Germany will consist of four double circuit interconnections in total. The project will increase the cross border capacity and will facilitate the further integration of the European Energy market especially in Central West Europe.

PCI 2.12



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
145	Niederrhein (DE)	Doetinchem (NL)	New 400kV line double circuit DE-NL interconnection line. Length: 57km.	-	Design & Permitting	2016	Delayed	Permitting procedures take longer than expected

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
NL=>DE: 1400	DE=>NL: 1400	3	3	15-50km	25-50km	190-220

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[0;10]	[4500;5500] MWh	[-39000;-32000]	[-11;-9]
Scenario Vision 2 - 2030	-	[4;5]	0	[-39000;-32000]	[-27;-22]
Scenario Vision 3 - 2030	-	[15;65]	[100000;130000] MWh	[-180000;-150000]	[-770;-630]
Scenario Vision 4 - 2030	-	[40;60]	[63000;77000] MWh	[-180000;-150000]	[-1000;-1200]

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Additional comments

Comment on the security of supply: The new capacity will also contribute to the Security of Supply by providing new energy exchange channels which increases the system flexibility.

Comment on the RES integration: facilitate the further integration of RES in the Netherlands and Germany

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Project 92: ALEGrO

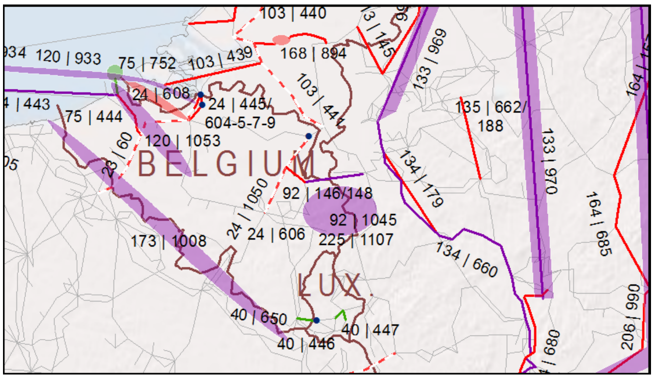
Description of the project

The ALEGrO (Aachen Liège Electricity Grid Overlay) project involves the realization of a HVDC link with a bidirectional rated power of approximately 1.000 MW capacity, as the first interconnection between Belgium and Germany.

First of all, it enhances the internal market integration by enabling direct power exchanges between these countries

Secondly, the new interconnection will play a major role for the transition to a generation mix which is undergoing structural changes in the region (high penetration of RES, nuclear phase-out, commissioning and decommissioning of conventional power plants etc.). Given these major changes in the production mix, the new interconnection also contributes to the security of supply in facing the arising challenges for secure system operation.

The project has been selected as PCI 2.2.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
146	Area of Oberzier - Aachen/Düren (DE)	Area of Lixhe - Liège (BE)	ALEGrO Connection between Germany and Belgium including new 100 km HVDC underground cable with convertor stations and extension of existing 380 kV substations. The assessment of the Final Investment Decision is planned in 2015.	1000	Design & Permitting	2019	Delayed	BE: Several months delay due to authorization procedure in Belgium longer than expected (modification of "Plan de secteur" in Wallonia). DE: Delay due to unclear permitting framework (legal framework for planning approval is presently under development
1045	Lixhe	Herderen	AC BE Reinforcements Internal reinforcements in AC network in Belgium have started in the context of securing infeed from the	1000	Design & Permitting	2017	Investment on time	This investment item is split off from the generic Alegro investment item which up to now

			380kV network into the Limburg & Liège area's. These reinforcements are also needed to facilitate the integration of ALEGrO into the Belgian grid. The reinforcements consist of - extension of an existing single 380 kV connection between Lixhe and Herderen by adding an additional circuit with high performance conductors (HTLS) - creation of 380kV substation in Lixhe, including a 380/150 transformator - creation of 380kV substation in Genk (André Dumont), including a 380/150 kV traformator					included also the internal reinforcements
1048	Lixhe	Herderen	Potentially additional AC BE Reinforcements Envisions the installation of a second 380 kV overhead line between Herderen to Lixhe. And the installation of a 2nd 380/150 transformator in Limburg area (probably substation André Dumont). These reinforcements are conditional to the evolution of production in the Limburg-Liège area and to the evolution of the physical (transit)flux towards 2020-2025.	900	Under Consideration	2020	New Investment	Evolution of generation in the Limburg-Liège must be accounted for in the perimeter of the Alegro project. This conditional project has a commissioning date set to 2020 as indication for further monitoring of the need.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
BE=>DE: 1000	DE=>BE: 1000	3	3	Negligible or less than 15km	Negligible or less than 15km	450-570

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[5;15]	[9000;11000] MWh	[150000;180000]	[140;170]
Scenario Vision 2 - 2030	-	[5;15]	[4500;5500] MWh	[150000;180000]	[-22;-18]
Scenario Vision 3 - 2030	-	[35;45]	[100000;130000] MWh	[120000;140000]	[-800;-650]
Scenario Vision 4 - 2030	-	[45;75]	[180000;210000] MWh	[120000;140000]	[-1100;-900]

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Additional comments

Comment on the security of supply: A new interconnector contributes to the security of supply of Belgium as a whole, due to the diversification it offers to the market players to import energy from countries where excess generation could be available. Given the changing production mix with ongoing nuclear phase out and decommissioning of old power plants, this benefit materializes itself as soon as the project is realized.

The internal reinforcements in the Belgian grid which are part of this project also contribute to the security of supply from a more local perspective, namely by securing in feed from 380kV to 220kV/150kV in Liège & Limburg.

Comment on the RES integration: avoided spillage concerns RES in Germany and Belgium mostly

Comment on the S1 and S2 indicators: Definitive route to be determined, but taking perspective of minimizing impact.

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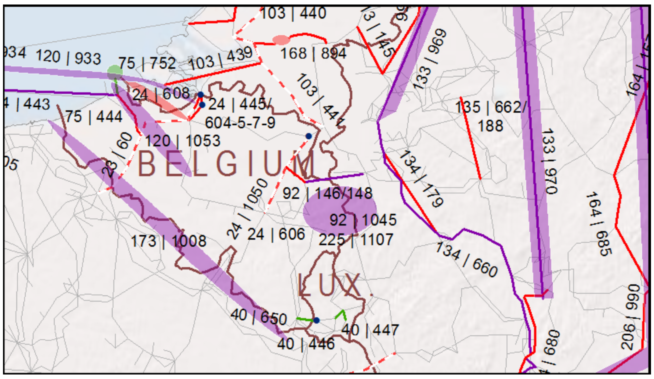
Project 225: 2nd Interconnector Belgium – Germany

Description of the project

This is a conceptual project that could be considered as an investment option, triggered by high RES scenario's. Preliminary analysis shows potential of justifying additional regional welfare & RES integration increase via the construction of an additional +- 1000MW interconnection between Germany and Belgium.
The determination of the optimal capacity, timing (2025-2030), location, technology, and potential needed internal grid reinforcements are subject of further studies.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
1107	BE (TBD)	DE (TBD)	This investment item envisions the possibility of a second 1 GW interconnection between Belgium and Germany. Subject to further studies.	-	Under Consideration	2030	New Investment	Preliminary studies on high RES scenario's have indicated potential for further regional welfare & RES integration increase by further increasing the interconnection capacity between Belgium & Germany towards time horizon 2025-2030.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
BE=>DE: 1000	DE=>BE: 1000	2	1	NA	NA	400-600

CBA results	**for each scenario**				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 4 - 2030	-	[45;55]	[150000;180000] MWh	[120000;140000]	[-850;-690]

Additional comments

Comment on the RES integration: avoided spillage concerns wind farms offshore Belgium mostly.

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

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Project 40: Luxembourg-Belgium Interco

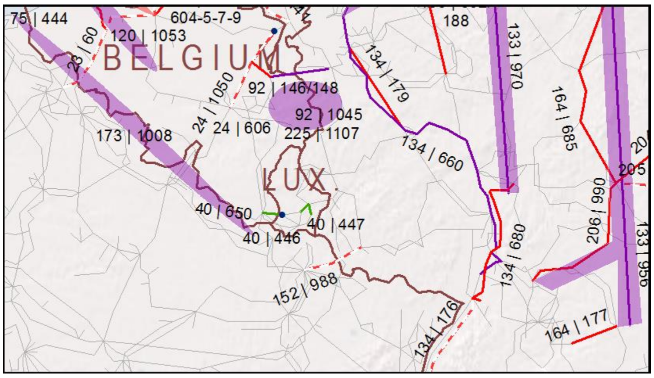
Description of the project

The project envisions the realization of an interconnection between Luxembourg and Belgium allowing to increase the transfer capability between LU, DE, BE and FR and contributing to the security of supply of both countries.

The interconnection is realized in two steps
- On short-term (end 2015) a phase shift transformer is integrated and connected to existing overhead line via an additional cable, in order to control the transit flows from Germany to Belgium
- On longer-term (2020) a solution with cables is under study envisioning an 1000 MVA path between Belgium and Luxembourg

In parallel a 1000 MVA reinforcement of the internal Luxembourg network is being constructed in order to create a loop around Luxembourg city, including substations for in feed in lower voltage levels.

PCI 2.3



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
446	Schifflange (LU)		BELUX INTERIM As a first interim step a PST will be integrated in Schifflange, and connected to an existing OH-line to control the transit flows from Germany to Belgium as from end 2015.	400	Under construction	2015	Investment on time	Studies for interim step are finalized; Investment decision has been taken mid-2014 and PST is planned to be operational end 2015.
447	Heisdorf (LU)	Berchem (LU)	Erection of a new 20km 225kV double-circuit mixed (cable+OHL)line with 1000 MVA capacity in order to create a loop around Luxembourg city including substations for in feed in lower voltage levels.	700	Design & Permitting	2017	Investment on time	Substation Blooren is authorized and under construction, Authorization for line section is still pending
650	Bascharage (LU)	Aubange (BE)	BELUX LT In a second step: new 220 kV interconnection with neighbour(s) between Creos grid in LU and ELIA grid in BE	300	Under Consideration	2020	Investment on time	An ongoing network study investigates the robustness of the planned 220kV

			via a 16km double circuit 225kV underground cable with a capacity of 1000 MVA.					connection between LU and BE.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
LU=>BE: 700	BE=>LU: 700	2	4	Negligible or less than 15km	Negligible or less than 15km	150-170

CBA results	**for each scenario**				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	[900;1100]	[0;10]	[16000;20000] MWh	0	[80;97]
Scenario Vision 2 - 2030	[900;1100]	[0;10]	[9000;11000] MWh	0	[54;66]
Scenario Vision 3 - 2030	[900;1100]	[20;30]	[9000;11000] MWh	0	[-530;-440]
Scenario Vision 4 - 2030	[900;1100]	[30;50]	[130000;160000] MWh	0	[-870;-710]

Additional comments

Comment on the security of supply:
Luxembourg: principal driver for the project is the security of supply.
Belgium: a new interconnector contributes to the security of supply of Belgium as well due to the diversification it offers to the market players to import energy from countries where excess generation could be available.

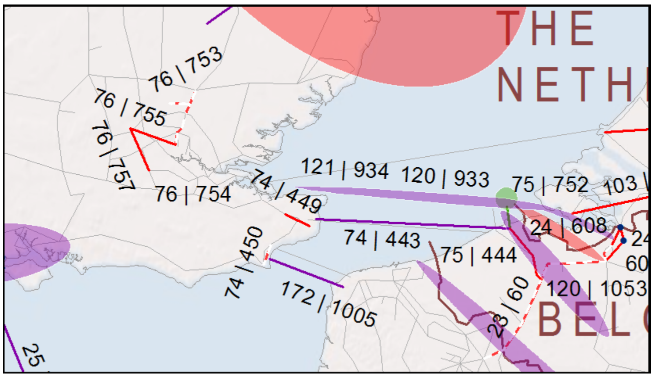
Comment on the Losses indicator: basically, the project enables power exchanges over greater distances (increasing losses), and conversely reduce the overall resistance of the grid. Losses variation is hence symbolically 0, with depending on the point in times losses being lower or greater, with variation close to the model accuracy range.

Project 74: Thames Estuary Cluster (NEMO)

Description of the project

This group of investments includes the 1 GW NEMO interconnector between Great Britain and Belgium and a number of onshore UK reinforcements to facilitate this and other potential interconnector connections within the Thames Estuary region.

The project includes the PCI 1.1.1, 1.1.2 and 1.1.3.



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
443	Richborough (GB)	Under analysis(BE)	NEMO New DC sea link including 135km of 400kV (voltage level subject to outcome of detailed engineering) DC subsea cable with 1000MW capacity. The assessment of the Final Investment Decision is planned in 2015.	1000	Design & Permitting	2018	Investment on time	Investment on time, with a technical commissioning planned end 2018 leading to commercial operation in 2019
449	Richborough (GB)	Canterbury (GB)	New 400kV double circuit and new 400kV substation in Richborough connecting the new Belgium interconnector providing greater market coupling between the UK and the European mainland.	1000	Planning	2018	Investment on time	Progress as planned.
450	Sellindge (GB)	Dungeness (GB)	Reconductoring the existing circuit which runs from Sellindge - Dungeness with a higher rated conductor. This will facilitate the connection of more interconnectors on the South coast and prevent thermal overloading of this area.	400	Design & Permitting	2015	Investment on time	Progress as planned.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
BE=>GB: 1000	GB=>BE: 1000	2	5	Negligible or less than 15km	Negligible or less than 15km	600-700

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[32;74]	[220000;270000] MWh	[410000;420000]	[180;220]
Scenario Vision 2 - 2030	-	[20;30]	[50000;61000] MWh	[370000;460000]	[160;190]
Scenario Vision 3 - 2030	-	[200;280]	[1800000;2200000] MWh	[190000;230000]	[-1300;-1400]
Scenario Vision 4 - 2030	-	[240;280]	[1100000;1400000] MWh	[190000;230000]	[-1700;-1400]

Additional comments

Comment on the security of supply: A new interconnector contributes to the security of supply of Belgium as a whole, due to the diversification offered to market players to import energy from countries where excess generation could be available. Giving the changing production mix with ongoing nuclear phase out and decommissioning of old power plants, this benefit materializes itself as soon as the project is realized.

Comment on the RES integration: avoided spillage concerns RES in UK and Belgium mainly.

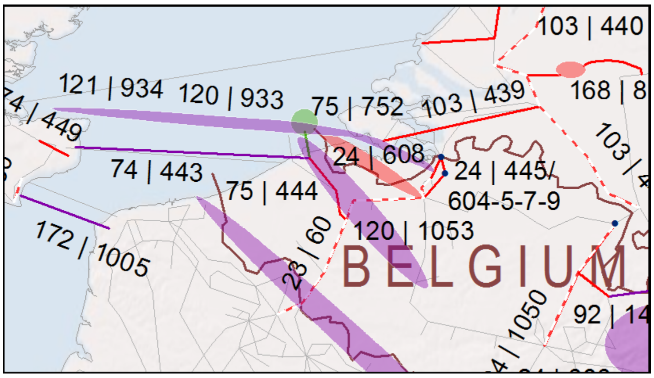
Comment on the flexibility indicator: the project appears useful in all visions, depends on a key-investment and interconnects two synchronous areas.

Project 121: 2nd Interco Belgium - UK (1GW)

Description of the project

This is a conceptual project that could be considered as a long-term investment option, triggered by the vision 3 & 4 scenario's where preliminary analysis shows potential of justifying additional regional welfare & RES integration increase via the construction of an additional +- 1000MW HVDC interconnection between the UK and Belgium.

The determination of the optimal capacity, location, technology, potentially needed internal grid reinforcements and possible synergies on the integration of this interconnector in relation to the BE offshore platform Alfa are subject of further studies.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
934	Kemsley (UK) for example - TBD	Doel/Zandvliet (BE) for example - TBD	NEMO 2: UK to BE 380kV inland This investment item envisions the possibility of a second 1GW HVDC connection, between UK (Kemsley) and a Belgian 380kV substation further inland in the Antwerp area (Doel, Zandvliet are indicative locations). Subject to further studies.	-	Under Consideration	2030	New Investment	Preliminary studies on vision 3&4 scenario's have indicated potential for further regional welfare & RES integration increase by further increasing the interconnection capacity between Belgium & UK up to 2 GW.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
BE=>GB: 1000	GB=>BE: 1000	2	2	NA	NA	450-650

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 3 - 2030	-	[170;260]	[1700000;2000000] MWh	[220000;260000]	[-1700;-1400]
Scenario Vision 4 - 2030	-	[210;250]	[1400000;1700000] MWh	[220000;260000]	[-1400;-1100]

Additional comments

Comment on the RES integration: avoided spillage concerns RES in Great-Britain and Ireland mostly.

Comment on the CO2 indicator: the very high scores reflect that the project enables a better use of RES

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

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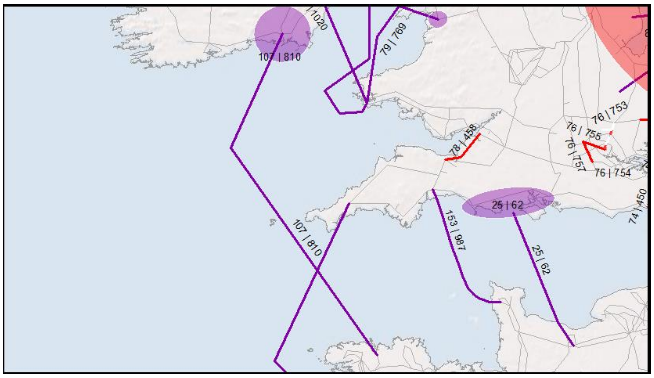
Project 107: Celtic Interconnector

Description of the project

Celtic Interconnector will be the first interconnection between Ireland and France. This HVDC (VSC) link with 700 MW capacity will connect Great Island or Knockraha (Ireland) to the Finistère in France. It will not only create a direct link between the French and Irish markets, but also increase RES integration, especially wind in Ireland. Some positive impact on the security of supply is also expected, in particular for Brittany, although this is not shown by the corresponding indicator assessed according to the CBA rules. The project has been selected as PCI 1.6 in the NSCOG corridor on 14/10/13.



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
810	Great Island or Knockraha (IE)	La Martyre (FR)	A new HVDC subsea connection between Ireland and France	-	Under Consideration	2025	Investment on time	Feasibility studies are progressing

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
FR=>IE: 700	IE=>FR: 700	1	4	NA	NA	900-1200

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CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[30;70]	[270000;320000] MWh	[200000;300000]	[63;77]
Scenario Vision 2 - 2030	-	[20;30]	[170000;200000] MWh	[200000;300000]	[-33;-27]
Scenario Vision 3 - 2030	-	[140;170]	[1300000;1600000] MWh	[170000;270000]	[-970;-790]
Scenario Vision 4 - 2030	-	[150;200]	[1500000;1800000] MWh	[170000;270000]	[-920;-760]

Additional comments

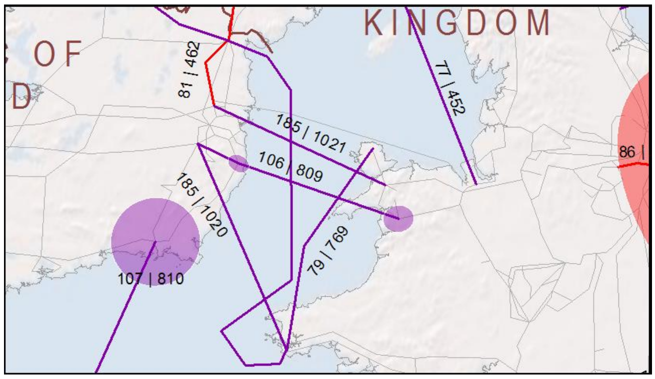
Comment on the RES integration: avoided spillage concerns RES in Ireland mostly.

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

Project 106: Ireland GB Interconnector

Description of the project

A second Ireland GB HVDC interconnector



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
809	Dunstown (IE)	Pentir (GB)	A new HVDC subsea connection between Ireland and Great Britain; this may be achieved by a direct link or by integrating an interconnector with a third party connection from Ireland to GB.	-	Under Consideration	2025	Investment on time	Joint studies between National Grid and EirGrid indicate a strong benefit for a second interconnector between Ireland and GB.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
IE=>GB: 700	GB=>IE: 700	2	4	NA	NA	440-660

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[10;24]	[140000;170000] MWh	[69000;84000]	[-74;-61]
Scenario Vision 2 - 2030	-	[10;20]	[110000;130000] MWh	[72000;88000]	[-130;-100]
Scenario Vision 3 - 2030	-	[45;65]	[390000;470000] MWh	[72000;88000]	[-290;-240]
Scenario Vision 4 - 2030	-	[57;93]	[540000;660000] MWh	[77000;94000]	[-370;-300]

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Additional comments

Comment on the RES integration: avoided spillage concerns RES in Ireland mostly.

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

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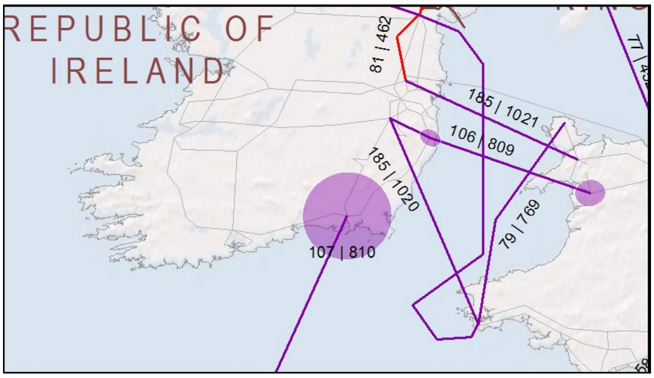
Project 185: Greenwire IE-GB

Description of the project*

Project promoted by Element Power
Greenwire Interconnector spurs, enables additional 1500MW of interconnection between UK and Irish market

PCI 1.9.1



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
1020	Dunstown	Pembroke	Greenwire Interconnector spur 1, enables additional 500MW of interconnection between UK and Irish market	500	Planning	2018	New Investment	Opportunity to connect Irish RES to GB market
1021	Woodland	Pentir	Greenwire Interconnector spur 2, enables additional 1000MW of interconnection between UK and Irish market	1000	Planning	2017	New Investment	Project application to TYNDP 2014.

** Elementpower ltd delivered to ENTSO-E the following updated information on Nov 24th (after submission of the draft TYNDP2014 to ACER):*

- *Description: Greenwire enables wind exports from Ireland directly to GB and enables Interconnection between GB and Irish Markets of up to 1500MW. The Interconnection is expected to be developed in 3x500MW building blocks due to the current 500MW largest infeed loss limit in Ireland. Greenwire has 3GW of transmission connection capacity secured with National Grid, a mix of Interconnection and direct transmission of generation could utilise that capacity. A first stage project, called Greenlink, for interconnection between UK and Ireland, has been declared eligible for assessment under Cap and Floor regulation by the national regulator Ofgem. Greenwire interconnector 1 (resp. 2) has a capacity of 1000 MW (resp. 500 MW).*
- *Location: CBA assessment is made based on the connection in the Irish system to Dunstown / Woodland. The project promoter informed ENTSO-E that other locations (on the Irish side) may be possible still*
- *Expected date of commissioning: the date of commissioning of the 2 investments has been shifted to 2020.*
- *Evolution driver: the same driver applies for both investments: the opportunities to further interconnect GB and Irish grids and/or connect Irish RES to GB market.*

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
IE=>GB: 1500	GB=>IE: 1500	6	4	15-50km	15-25km	1925-2225

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[510;660]	[7000000;8600000] MWh	[360000;440000]	[-4500;-3700]
Scenario Vision 2 - 2030	-	[590;670]	[7200000;8800000] MWh	[360000;440000]	[-4600;-3800]
Scenario Vision 3 - 2030	-	[420;640]	[5100000;6200000] MWh	[490000;600000]	[-2400;-1900]
Scenario Vision 4 - 2030	-	[360;390]	[4200000;5200000] MWh	[490000;600000]	[-1600;-1300]

Additional comments

Comment on the RES integration: avoided spillage concerns RES in Ireland mostly.

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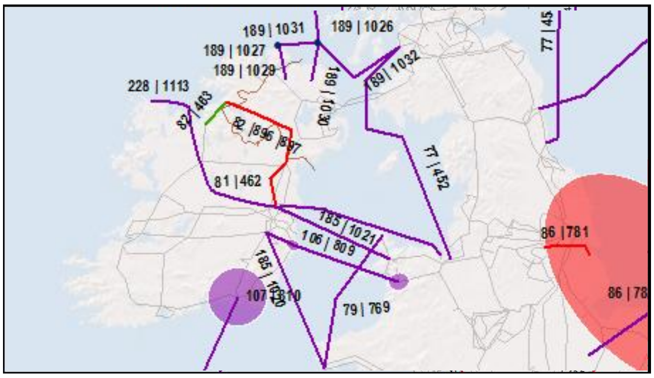
Project 228: Marex

Description of the project

Project promoted by Organic Power Limited.
Combined 1900MW wind generation, with 6.1GWh storage in mayo Ireland, connected to GB via 1500mw HVDC VSC cable

PCI 1.11.4



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
1113	Glinsk 400kV	Connah's Quay 400kV	1500 MW HVDC VSC cable	-	Planning	2018	New Investment	Project application for TYNDP 2014.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
IE=>GB: 1900	GB=>IE: 1900	0	0	More than 100km	Negligible or less than 15km	1100-1500

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[290;400]	[190000;240000] MWh	0	[-2800;-2300]
Scenario Vision 2 - 2030	-	[58;71]	[370000;380000] MWh	0	[-2800;-2300]
Scenario Vision 3 - 2030	-	[200;240]	[1900000;2300000] MWh	0	[-930;-760]
Scenario Vision 4 - 2030	-	[170;180]	[1700000;2100000] MWh	0	[-580;-470]

Additional comments

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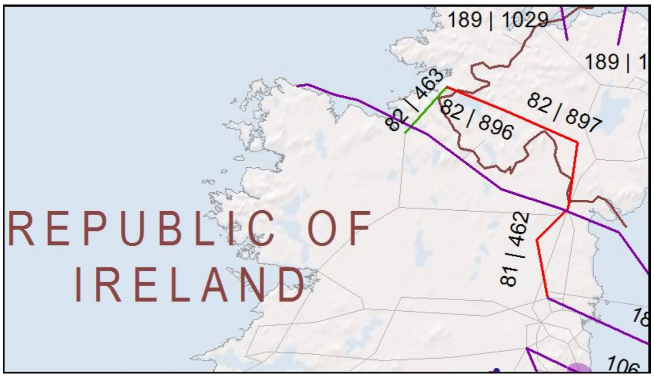
Project 81: North South Interconnector

Description of the project

A new 400 kV interconnector between Woodland in Ireland and Turleenan in Northern Ireland.

PCI 2.13.1



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
462	Woodland (IE)	Turleenan (NI)	A new 140 km single circuit 400 kV 1500 MVA OHL from Turleenan 400/275 kV in Northern Ireland to Woodland 400/220 kV in Ireland. This is a new interconnector project between Ireland and Northern Ireland.	-	Design & Permitting	2017	Delayed	Further studies required before re-submission for planning consents

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
IE=>NI: 660	NI=>IE: 580	3	3	Negligible or less than 15km	Negligible or less than 15km	270-330

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[18;36]	[6300;7700] MWh	[-50000;-41000]	[-45;-36]
Scenario Vision 2 - 2030	-	[12;15]	[9000;11000] MWh	[-47000;-39000]	[-27;-22]
Scenario Vision 3 - 2030	-	[27;34]	[45000;55000] MWh	[-47000;-39000]	[-49;-40]
Scenario Vision 4 - 2030	-	[55;77]	[1800;2200] MWh	[-45000;-37000]	[-110;-90]

Additional comments

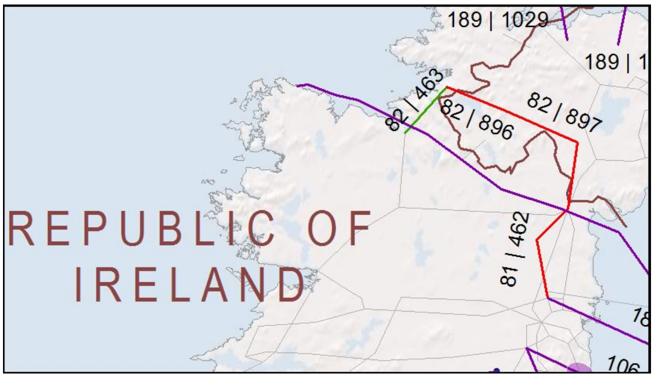
Comment on the RES integration: avoided spillage concerns RES in Ireland as a whole

Project 82: RIDP I

Description of the project

The infrastructure development is required to facilitate connection of renewables in the North and West of the Island; It will further integrate the Ireland and Northern Ireland transmission systems and provide capacity for substantial demand growth in the area.

PCI 2.13.2



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
463	Sranangh (IE)	New substation in South Donegal (IE)	A new EHV overhead line from Srananagh in Co. Sligo to a new substation in south Co. Donegal	500	Planning	2020	Investment on time	The preferred scheme has been selected since the last TYNDP; this is one of the elements of the preferred scheme.
896	South Donegal (IE)	Omagh South (NI)	A new 275 kV cross border link between a new substation in South Donegal in Ireland and a new substation established south of Omagh in Northern Ireland	500	Planning	2024	New Investment	Investment 82.463 of the previous TYNDP described the as then undefined scheme that was the subject of a joint study between NIE and EirGrid. That study has since been completed. This investment is one of a number emerging from the study.
897	Omagh South	Turleenan	A new 275 kV overhead line from a new substation established south of Omagh to a new 400/275 kV substation, established at Turleenan by the North South Interconnection Development	500	Planning	2020	New Investment	Investment 82.463 of the previous TYNDP described the as then undefined scheme that was the subject of a joint study between NIE and EirGrid. That study has since been completed. This investment is one of a number emerging from the study.

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CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
IE=>NI: 570	NI=>IE: 570	3	4	Negligible or less than 15km	Negligible or less than 15km	317-475

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[120;140]	[120000;150000] MWh	[-52000;-64000]	[-1100;-920]
Scenario Vision 2 - 2030	-	[140;150]	[32000;39000] MWh	[-59000;-72000]	[-120;-94]
Scenario Vision 3 - 2030	-	[70;100]	[810000;1000000] MWh	[-59000;-72000]	[-400;-320]
Scenario Vision 4 - 2030	-	[55;75]	[970000;1200000] MWh	[-70000;-86000]	[-190;-160]

Additional comments

Comment on the RES integration: avoided spillage concerns RES in Ireland as a whole

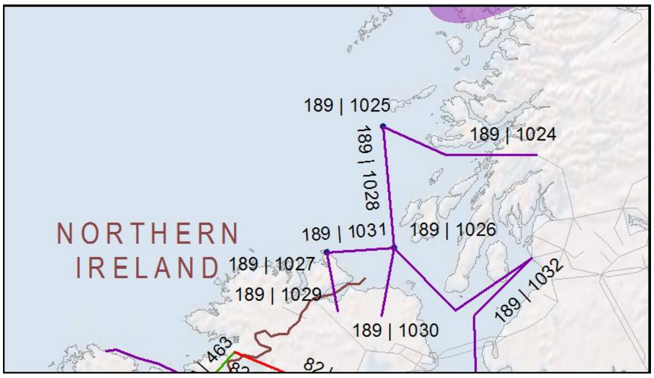
Project 189: Irish-Scottish Isles

Description of the project

Project partners are the Scottish Government, the Department of Communications, Energy and Natural Resources in Ireland and the Department of Enterprise Trade & Investment in Northern Ireland. The project is part-financed under the EU INTERREG IVA Programme for Ireland, Northern Ireland and Scotland.

Conceived as a number of complementary multi-terminal HVDC connections that can be operated without the need for DC breakers and without breaching existing onshore loss of in feed limits but which can be reconfigured post-fault to re-establish power transfer paths. The benefits of the design are that offshore wind or tidal power can be brought to either of two shores, there is redundancy in connections and, in particular, interconnection capacity is provided between the GB market and the Single Electricity Market on the island of Ireland. Thus, while not 'dedicated to security of supply', it contributes to it.

PCI 1.9.2



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
1024	Cruachan	Argyll hub	HVDC link between Cruachan (onshore) to Argyll offshore hub	1000	Under Consideration	2030	New Investment	The ISLES project will serve the development of multiple offshore generation resources in the waters of Scotland, Ireland and Northern Ireland and facilitate increased inter-connection between the GB and the SEM on the island of Ireland.
1025	Argyll hub		A new dedicated offshore HVDC hub platform to allow connection of offshore renewable generation and interconnection capacity.	1000	Under Consideration	2030	New Investment	
1026	Coleraine hub		A new dedicated offshore HVDC hub platform to allow connection of offshore renewable generation and interconnection capacity.	1000	Under Consideration	2030	New Investment	
1027	Coolkeeragh hub		A new dedicated offshore HVDC hub platform to allow connection of offshore renewable generation and interconnection capacity.	1000	Under Consideration	2030	New Investment	

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1028	Argyll	Coleraine	HVDC link between Argyll offshore hub and Coleraine offshore hub	1000	Under Consideration	2030	New Investment
1029	Coolkeeragh	Coolkeeragh hub	HVDC link between Coolkeeragh onshore and Coolkeeragh offshore hub	1000	Under Consideration	2030	New Investment
1030	Coleraine	Coleraine hub	HVDC link between Colerain onshore and Coleraine offshore hub	1000	Under Consideration	2030	New Investment
1031	Coleraine hub	Coolkeeragh hub	HVDC link between Coleraine offshore hub and Coolkeeragh offshore hub	1000	Under Consideration	2030	New Investment
1032	Hunterston	Coleraine hub	HVDC link between Hunterston (onshore) to Argyll offshore hub	1000	Under Consideration	2030	New Investment

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
NI=>GB: 1000	GB=>NI: 1000	3	5	NA	NA	1600 - 3700

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[0;10]	[30000;40000]	[180000;220000]	[-30;-40]
Scenario Vision 2 - 2030	-	[0;10]	[9000;11000]	[180000;220000]	[-75;-95]
Scenario Vision 3 - 2030	-	[30;40]	[180000;220000]	[270000;330000]	[-190;-160]
Scenario Vision 4 - 2030	-	[45;55]	[400000;490000]	[270000;330000]	[-310;-250]

Additional comments

Comment on the RES integration: avoided spillage concerns RES connected by the project.

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

Comment on the flexibility indicator: the project may not be useful in all visions, consists of various investments complementing each other, and integrates two synchronous areas

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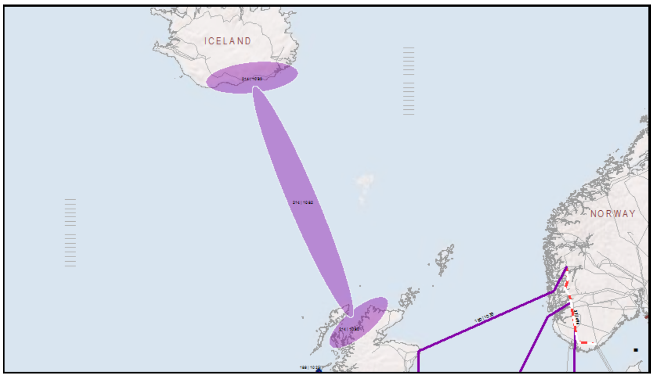
Project 214: Interco Iceland-UK

Description of the project

Interconnector (Sea cable) between Iceland and Great Britain. The Cable is DC with 800-1200 MW capacity and 1.000 km long. 99.98% of the generation in Iceland is RES.

Iceland's hydro generation is highly flexible and ideal for complementing intermittency of GB's growing wind sector. It will provide flexible electricity for fast delivery of energy during peak periods and is also able to provide ancillary services to GB



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
1082	tbd	tbd	Interco Iceland-UK	-	Under Consideration	2030	New Investment	

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
IS=>GB: 1000	GB=>IS: 1000	2	3	NA	NA	2200-2500

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[410;470]	[63000;77000] MWh	[810000;990000]	[-2900;-2300]
Scenario Vision 2 - 2030	-	[420;460]	[14000;17000] MWh	[810000;990000]	[-2800;-2300]
Scenario Vision 3 - 2030	-	[340;370]	0	[810000;990000]	[-1600;-1300]
Scenario Vision 4 - 2030	-	[290;310]	0	[810000;990000]	[-1300;-1000]

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Additional comments

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

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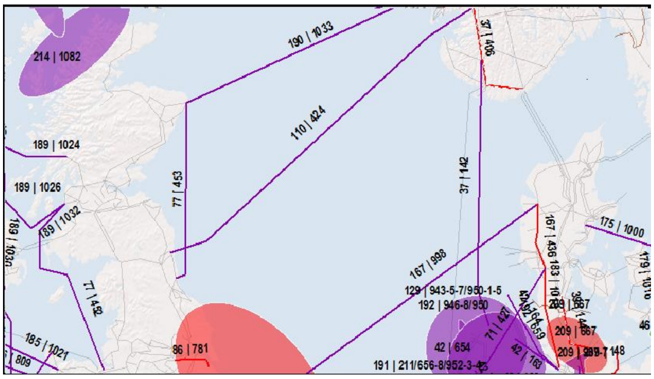
Project 110: Norway-Great Britain

Description of the project

A 720 km long subsea interconnector between Norway and England is planned to be realized in 2020. If realized it will be the world's longest. The main driver for the project is to integrate the hydro-based Norwegian system with the thermal/nuclear/wind-based British system. The interconnector will improve security of supply both in Norway in dry years and in Great Britain in periods with negative power balance (low wind, low solar, high demand etc.). Additional the interconnector will be positive both for the European market integration, for facilitating renewable energy and also for preparing for a power system with lower CO2-emission. The interconnector is planned to be a 500 kV 1400 MW HVDC subsea interconnector between western Norway and eastern England.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
424	Kvilldal (NO)	Blythe (GB)	A 720 km long 500 kV 1400 MW HVDC subsea interconnector between western Norway and eastern England.	-	Design & Permitting	2020	Investment on time	Progress as planned.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
GB=>NO: 1400	NO=>GB: 1400	2	4	Negligible or less than 15km	Negligible or less than 15km	1700

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[150;220]	[1000000;1200000] MWh	[760000;930000]	[-440;-360]
Scenario Vision 2 - 2030	-	[90;170]	[900000;1100000] MWh	[760000;930000]	[-240;-190]
Scenario Vision 3 - 2030	-	[280;360]	[2700000;3300000] MWh	[760000;930000]	[-2000;-1700]
Scenario Vision 4 - 2030	-	[280;300]	[2100000;2600000] MWh	[760000;930000]	[-1800;-1500]

Additional comments

Comment on the RES integration: Both the NSN and the NorthConnect-project are showing very high values regarding RES-integration. The reason for this is that the projects leads to both decreased spillage in Great Britain (when windy) and in the Nordic countries (when wet).

Comment on the CO2 indicator: the very high scores reflect that the project enables a better use of RES (by bringing it to load centres or to and from storage facilities)

Comment on the Losses indicator: the load factor of the cable is similar in all Visions, leading to the same and very high additional losses.

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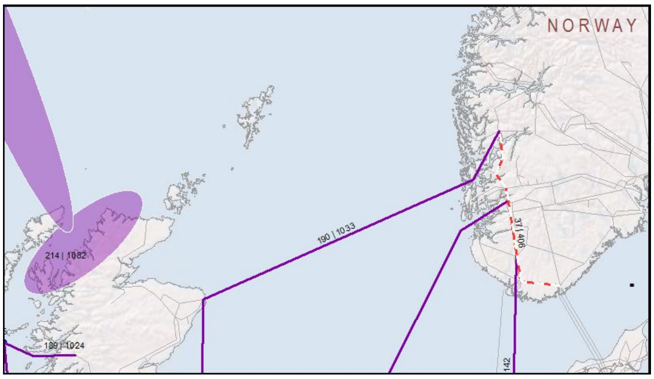
Project 190: Norway-Great Britain

Description of the project

A 650 km long subsea interconnector between Norway and Scotland is planned to be realized in 2021. The main driver for the project is to integrate the hydro-based Norwegian system with the thermal/nuclear/wind-based British system. The interconnector will improve security of supply both in Norway in dry years and in Great Britain in periods with negative power balance (low wind, low solar, high demand etc.). Additional the interconnector will be positive both for the European market integration, for facilitating renewable energy and also for preparing for a power system with lower CO2-emission. The interconnector is planned to be a 500 kV 1400 MW HVDC subsea interconnector between western Norway and eastern Scotland.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
1033	Sima	Peterhead	A 650 km long 500 kV 1400 MW HVDC subsea interconnector between western Norway and eastern Scotland.	-	Design & Permitting	2020	New Investment	Project application to TYNDP 2014.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
GB=>NO: 1400	NO=>GB: 1400	2	4	Negligible or less than 15km	Negligible or less than 15km	1700

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[150;220]	[1000000;1200000] MWh	[760000;930000]	[-440;-360]
Scenario Vision 2 - 2030	-	[90;170]	[900000;1100000] MWh	[760000;930000]	[-240;-190]
Scenario Vision 3 - 2030	-	[280;360]	[2700000;3300000] MWh	[760000;930000]	[-2000;-1700]
Scenario Vision 4 - 2030	-	[280;300]	[2100000;2600000] MWh	[760000;930000]	[-1800;-1500]

Additional comments

Comment on the SEW: the results for NorthConnect (Norway-Scotland) is the same as for project 110 NSN (Norway-England), this because Great Britain in the analysis is modelled as one node. If there are price-differences between England and Scotland, this would make the values different for the two projects. In addition, according to current plans, NorthConnect is expected to be commissioned after NSN.

Comment on the RES integration: both the NSN and the NorthConnect are showing very high values regarding RES-integration. The reason for this is that the projects leads to both decreased spillage in Great Britain (when windy) and in the Nordic countries (when wet).

Comment on the Losses indicator: the load factor of the cable is similar in all Visions, leading to the same and very high additional losses.

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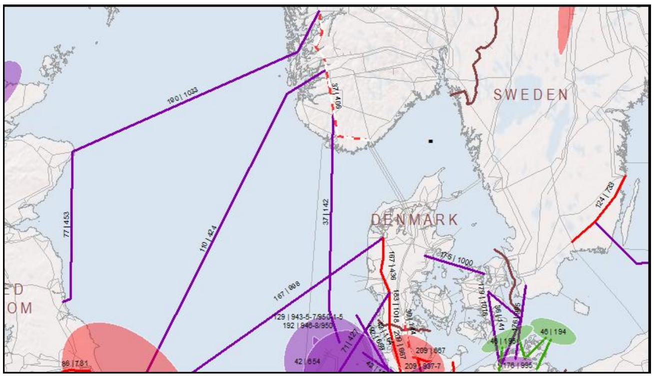
Project 37: Southern Norway - Germany

Description of the project

A 514 km long subsea interconnector between Norway and Germany is planned to be realized in 2018. The main driver for the project is to integrate the hydro-based Norwegian system with the thermal/wind/solar-based Continental system. The interconnector will improve security of supply both in Norway in dry years and in Germany in periods with negative power balance (low wind, low solar, high demand etc.). Additional the interconnector will be positive both for the European market integration, for facilitating renewable energy and also for preparing for a power system with lower CO2-emission. The interconnector is planned to be a 500 kV 1400 MW HVDC subsea interconnector between southern Norway and northern Germany.

PCI 1.8



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
142	Tonstad (NO)	Wilster (DE)	A 514 km 500 kV HVDC subsea interconnector between southern Norway and northern Germany.	1400	Design & Permitting	2018	Investment on time	Agreement between the two TSOs on commissioning date.
406	(Southern part of Norway) (NO)	(Southern part of Norway)(NO)	Voltage uprating of existing 300 kV line Sauda/Saurdal - Lyse - Ertsmyra - Feda - 1&2, Feda - Kristiansand; Sauda-Samnanger in long term. Voltage upgrading of existing single circuit 400kV OHL Tonstad-Solhom-Arendal. Reactive power devices in 400kV substations.	1000	Design & Permitting	2020	Delayed	Revised progress due to less flexible system operations in a running system (voltage upgrade of existing lines). Commissioning date expected 2019-2021.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific

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GTC direction 1 (MW)	GTC direction 2 (MW)	B6 Technical Resilience	B7 Flexibility	S1 - protected areas	S2 - urban areas	C1 Estimated cost (Meuros)
DE=>NO: 1400	NO=>DE: 1400	3	4	50-100 km	Negligible or less than 15km	2500

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[120;140]	[510000;620000] MWh	[910000;1100000]	[-930;-760]
Scenario Vision 2 - 2030	-	[65;110]	[950000;1200000] MWh	[910000;1100000]	[-670;-550]
Scenario Vision 3 - 2030	-	[210;280]	[1500000;1800000] MWh	[910000;1100000]	[-2200;-1800]
Scenario Vision 4 - 2030	-	[350;400]	[1700000;2100000] MWh	[910000;1100000]	[-3400;-2800]

Additional comments

Comment on the RES integration: avoided spillage concerns mainly RES in Germany and Norway.

Comment on the CO2 indicator: the very high scores reflect that the project enables a better use of RES (by bringing it to load centres or to and from storage facilities)

Comment on the Losses indicator: the load factor of the cable is similar in all Visions, leading to the same and very high additional losses.

Comment on the cost of the project: the cost of investment 142 (Nord.Link) is estimated to 1600 MEuros while the cost of investment 406 is estimated to 900 MEuros.

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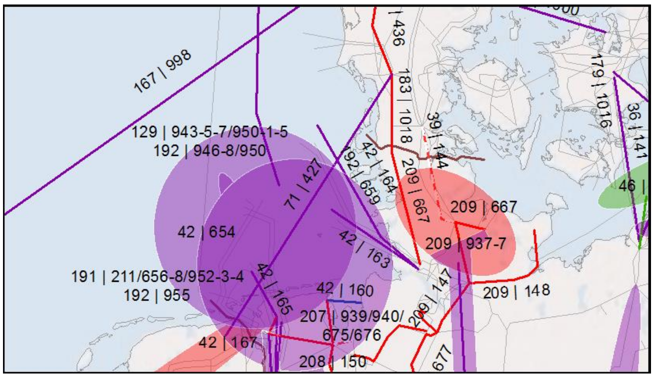
Project 71: COBRA cable

Description of the project

The project is an interconnection between Endrup (Denmark) and Eemshaven (The Netherlands). The purpose is to incorporate more renewable energy into both the Dutch and the Danish power systems and to improve the security of supply. Moreover, the cable will help to intensify competition on the northwest European electricity markets. The project consists of a 320 kV 700 MW DC subsea cable and related substations on both ends, 320-350 km apart, applying VSC DC technology. The project is supported by the European Energy Programme for Recovery (EEPR) and is labelled by the EC as project of common interest (PCI 1.5).



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
427	Endrup (DK)	Eemshaven (NL)	COBRA: New single circuit HVDC connection between Jutland and the Netherlands via 350km subsea cable; the DC voltage will be 320kV and the capacity 700MW.	-	Design & Permitting	2019	Delayed	Rescheduled to develop a solid regional business case (including additional project partners); and to account for the time needed for the acceptance by the authorities of a preferred route.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
DKW=>NL: 700	NL=>DKW: 700	3	3	15-50 km	Negligible or less than 15km	560-680

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[5;25]	[45000;55000] MWh	[44000;54000]	[-120;-94]
Scenario Vision 2 - 2030	-	[0;10]	[27000;33000] MWh	[44000;54000]	[-44;-36]
Scenario Vision 3 - 2030	-	[25;85]	[180000;220000] MWh	[110000;130000]	[-560;-460]
Scenario Vision 4 - 2030	-	[100;150]	[350000;420000] MWh	[110000;130000]	[-920;-760]

Additional comments

Comment on the security of supply: the project improves the SoS of Western Denmark and the Netherlands.

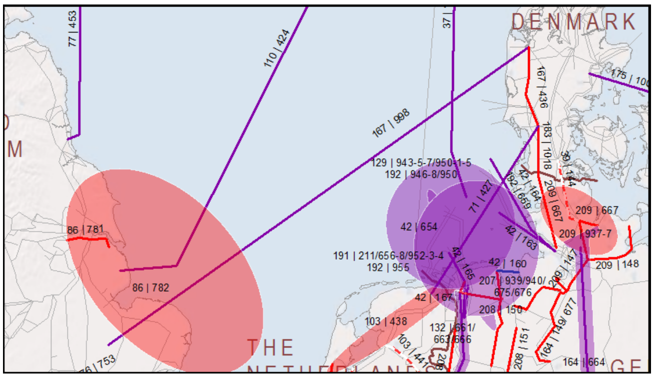
Comment on the RES integration: The significant increase of RES between Vision 1 and Vision 4 in both countries contributes to an increased number of hours with more volatile prices and thus higher flows in both directions. Additionally, the higher CO2 price in vision 4 causes a shift between coal and gas in the merit order, which increases the price spread between high and low RES hours. This explains the spread of the SEW indicator between these two extreme visions.

Project 167: Viking DKW-GB

Description of the project

This project, known as Viking Link and under development by National Grid Interconnector Holdings Limited and Energinet.dk, investigates a connection of up to 1400MW between Denmark West and Great Britain by two parallel up to 700 MW HVDC subsea cables and related substations on both ends. A final route is not designed yet - the investigated project is one out of several possible alternatives.

The project cluster includes in Denmark additionally the establishment of a 400 kV AC underground cable system between the 400 kV substation Idomlund and the existing 400 kV substation Endrup with needed compensation arrangements. The parts of national investments already known from TYNDP12 are included in this project cluster.
The project adds cross-border transmission capacity between both countries, thereby facilitating the incorporation of more RES, as the wind is not correlated between both markets.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
436	Idomlund (DK)	Endrup (DK)	New 74km single circuit 400kV line via cable with capacity of approx. 1200MW.	1360	Under Consideration	2030	Rescheduled	In national plan route is replaced by different project, upgrading an existing route from Tjele to Idomlund (72.898). The known route (Endrup-Idomlund) from the TYNDP12 would additionally be necessary as soon as the interconnection to GB is built.
998	Idomlund (DKW)	Stella West (GB)	2x700 MW HVDC subsea link across the North Seas.	1400	Under Consideration	2030	New Investment	New opportunity to integrate markets, new opportunity to exploit non correlated RES

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CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
DKW=>GB: 1400	GB=>DKW: 1400	2	4	NA	NA	1700-1900

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[75;110]	[320000;400000] MWh	[200000;250000]	[570;690]
Scenario Vision 2 - 2030	-	[25;45]	[77000;94000] MWh	[240000;290000]	[380;460]
Scenario Vision 3 - 2030	-	[220;300]	[2300000;2900000] MWh	[360000;440000]	[-2000;-1600]
Scenario Vision 4 - 2030	-	[240;270]	[1800000;2200000] MWh	[350000;420000]	[-1800;-1400]

Additional comments

Comment on the CBA assessment: The significant increase of RES between Vision 1 and Vision 4 in both countries contributes to an increased number of hours with more volatile prices and thus higher flows in both directions. Additionally, the higher CO2 price in vision 4 causes a shift between coal and gas in the merit order, which increases the price spread between high and low RES hours. This explains the spread of the SEW indicator between these two extreme visions.

Comment on the security of supply: the project improves the SoS of Western Denmark and the Wash area in Great Britain.

Comment on the CO2 indicator: the very high scores reflect that the project enables a better use of RES

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

Comment on GB and DK Connection: Since the time of the origi-nal project assessment for TYNDP, the project has received a connection offer from the GB national TSO for a grid connection at Bicker Fenn substation, with a capacity of 1000MW and a con-nection date in late 2020. In Denmark the connection point has been set to Revsing substation. The project proponents are now working to this timescale. The expected capex of a 1000MW link is in the range €1700-€1900 M€.

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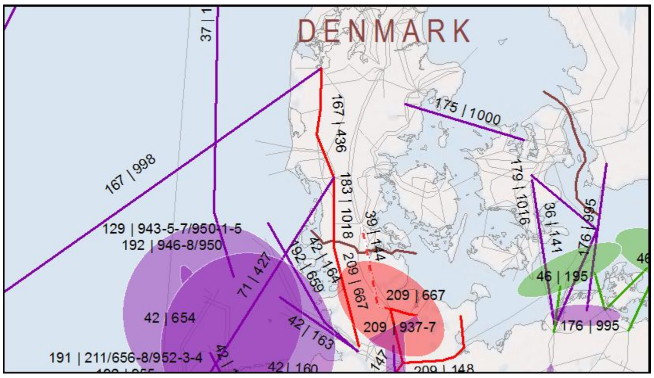
Project 183: DKW-DE, Westcoast

Description of the project

The project consists of a new 400 kV line from Endrup (Denmark) to Niebüll (Germany), adding another 500 MW at the West Coast between these countries. On the Danish side, this project includes the establishment a 400 kV AC underground cable system from the existing 400 kV substation Endrup, via Ribe and Bredebro to the border, from where the interconnector continues to Niebüll. The project helps to integrate RES and to strenghten the connection between the Scandinavian and Continental market. The project is labelled by the EC as project of common interest (PCI 1.3.1).



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
1018	Niebüll (DE)	Endrup (DKW)	new 380 kV cross border line DK1-DE for integration of RES and increase of NTC	-	Planning	2022	Investment on time	in TYNDP12 this investment was part of 43.A90

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
DKW=>DE: 500	DE=>DKW: 500	2	3	Negligible or less than 15km	Negligible or less than 15km	170-210

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[0;10]	[14000;17000] MWh	[-11000;-9000]	[-88;-72]
Scenario Vision 2 - 2030	-	[4;5]	[14000;17000] MWh	[-11000;-9000]	[-22;-18]
Scenario Vision 3 - 2030	-	[20;60]	[120000;140000] MWh	[-12000;-9900]	[-440;-360]
Scenario Vision 4 - 2030	-	[80;100]	[260000;310000] MWh	[-12000;-9600]	[-830;-680]

Additional comments

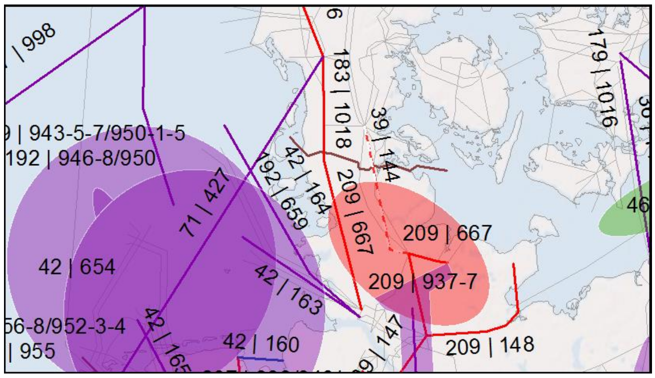
Comment on the security of supply: the project improves the SoS of Western Denmark and the area of Schleswig Holstein in Germany.

Comment on the RES integration: avoided spillage concerns RES in Germany and Denmark mostly.

Project 39: DKW-DE, step 3

Description of the project

This project is the third phase in the Danish-German agreement to upgrade the transfer capacity between Denmark West and Germany. The investments of the second phase were included in the TYNDP 2012 edition and have been commissioned in the meantime, thus increasing the cross border capacity since then.
The third-phase project consists of a new 400 kV line from Kassoe (Denmark) to Audorf (Germany). It mainly follows the trace of an existing 220 kV line, which will be substituted by the higher voltage line. The project helps to integrate RES and to strenghten the connection between the Scandinavian and Continental market. The project is labelled by the EC as project of common interest (PCI 1.4.1).



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
144	Audorf (DE)	Kassö (DK)	Step 3 in the Danish-German agreement to upgrade the Jutland-DE transfer capacity. It consists of a new 400kV route in Denmark and In Germany new 400kV line mainly in the trace of an existing 220kV line.	-	Planning	2019	Delayed	Planning ongoing - minor delay due to coordination with project 183.1018

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
DKW=>DE: 720	DE=>DKW: 1000	3	3	15-50km	15-25km	220-270

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[10;30]	[54000;66000] MWh	[-46000;-38000]	[-120;-94]
Scenario Vision 2 - 2030	-	[0;10]	[110000;130000] MWh	[32000;39000]	[-38;-31]
Scenario Vision 3 - 2030	-	[35;95]	[190000;230000] MWh	[50000;62000]	[-680;-560]
Scenario Vision 4 - 2030	-	[120;150]	[370000;460000] MWh	[51000;62000]	[-1300;-1000]

Additional comments

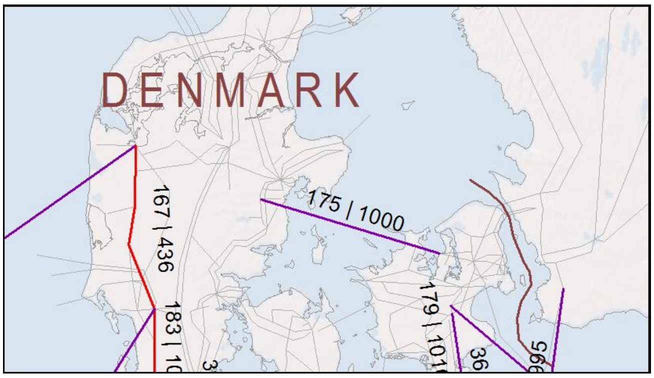
Comment on the security of supply: the project improves the SoS of Western Denmark and the area of Schleswig Holstein in Germany.

Comment on the RES integration: The significant increase of RES between Vision 1 and Vision 4 in both countries contributes to an increased number of hours with more volatile prices and thus higher flows in both directions. Additionally, the higher CO2 price in vision 4 causes a shift between coal and gas in the merit order, which increases the price spread between high and low RES hours. This explains the spread of the SEW indicator between these two extreme visions.

Project 175: Great Belt II

Description of the project

This project candidate includes a 1x 600 MW HVDC connector between Denmark-West (DKW) and Denmark-East (DKE). The connector is called Great Belt-2. It could among other variants be located between the 400 kV substation Malling in DKW and the reconstructed 400 kV substation Kyndby in DKE. The main purpose of this project is to incorporate more RES into the Danish system by sharing reserves between both systems and improve market integration.



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
1000	Malling (DKW)	Kyndby (DKE)	600 MW HVDC subsea link between both DK systems (2 synchr. areas, 2 market areas)	-	Under Consideration	2030	New Investment	In case of an expanded DKE-SE connection this link could be beneficial.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
DKW=>DKE: 600	DKE=>DKW: 600	3	3	NA	NA	390-480

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	0	0	[72000;87000]	[190;230]
Scenario Vision 2 - 2030	-	0	0	[72000;88000]	[65;80]
Scenario Vision 3 - 2030	-	[0;1]	[18000;22000] MWh	[62000;76000]	[-50;-41]
Scenario Vision 4 - 2030	-	[2;3]	[45000;55000] MWh	[62000;76000]	[-40;-33]

Additional comments

Comment on the security of supply: The price difference between both Danish market areas is marginal, thus the SEW indicator is very small. Anyhow, the project improves the SoS of both Danish synchronous systems by facilitating sharing reserves.

Comment on the RES integration: In Vision 1 there is only a relative small amount of RES in the region which can be absorbed by the system. Thus the curtailment value does not change due to the project - it stays at zero.

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

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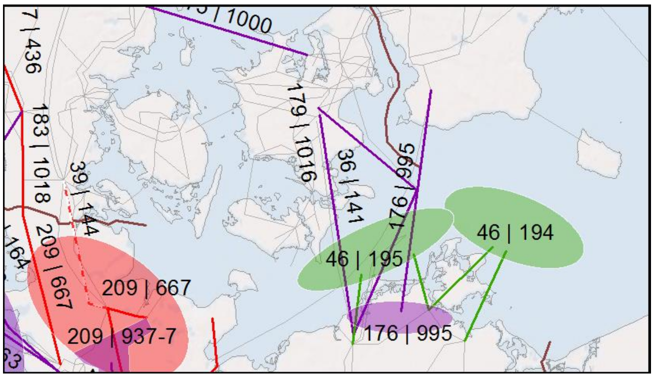
Project 179: DKE - DE

Description of the project

This project includes a 600 MW HVDC subsea interconnector between Denmark-East (DKE) and Germany (DE) and is called Kontek-2. A final grid-connection solution is not prepared yet; one of the possible alternatives could establish the Danish HVDC converter station in the area of Lolland-Falster. This alternative has been investigated for the TYNDP and comprises among other things an HVDC converter station being connected to the existing 400 kV substation Bjæverskov via 400 kV underground cables and/or 400 kV OHL. Some additional investments in eastern Danmark would be necessary, which are not described in detail in this document.



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
1016	Bjæverskov (DK2)	Bentwisch (DE)	new 600 MW HVDC subsea cable connecting DK2 and DE	-	Under Consideration	2030	New Investment	RGBS common investigations for TYNDP14

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
DKE=>DE: 600	DE=>DKE: 600	3	3	NA	NA	500-610

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[31;38]	[54000;66000] MWh	[17000;21000]	[82;100]
Scenario Vision 2 - 2030	-	[22;27]	[54000;66000] MWh	[-2200;-1800]	[73;90]
Scenario Vision 3 - 2030	-	[22;27]	[63000;77000] MWh	[120000;150000]	[-890;-720]
Scenario Vision 4 - 2030	-	[140;170]	[63000;77000] MWh	[120000;150000]	[-1900;-1600]

Additional comments

Comment on the CBA assessment: The significant increase of RES between Vision 1 and Vision 4 in both countries contributes to an increased number of hours with more volatile prices and thus higher flows in both directions. Additionally, the higher CO2 price in vision 4 causes a shift between coal and gas in the merit order, which increases the price spread between high and low RES hours. This explains the spread of the SEW indicator between these two extreme visions.

Comment on the security of supply: the project improves the SoS of Eastern Denmark and the Mecklenburg-Vorpommeranian area in Germany.

Comment on the RES integration: avoided spillage concerns RES in Germany and Denmark mostly.

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

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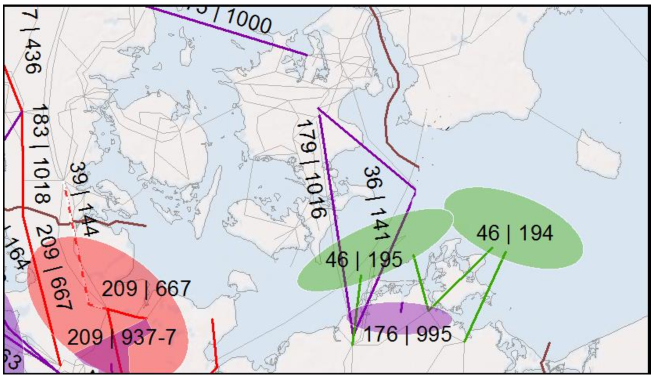
Project 36: Kriegers Flak CGS

Description of the project

The Kriegers Flak Combined Grid Solution (CGS) is a new DC offshore connection between Denmark and Germany. It had been designed and was simulated for this TYNDP as a combined grid connection of the offshore wind farms Kriegers Flak (Denmark), Baltic 1 and 2 (Germany) and a 400 MW interconnection between both countries connecting Ishøj/Bjæverskov (Denmark) and Bentwisch/Güstrow (Germany). The project facilitates RES connection and increased trade of electricity. The modelling results refer to the infrastructure part only, not to the benefit of the involved offshore wind farms, which would be an evaluation of the benefit of new generation, which is beyond the scope of the TYNDP. Thus also the cost reflect only the extra cost compared to the usual way of connecting the offshore wind farms to the two systems. The project is supported by the European Energy Programme for Recovery (EEPR) and labelled by the EC as project of common interest (PCI 4.1).



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
141	Ishøj / Bjæverskov (DK)	Bentwisch (DE)	Three offshore wind farms connected to shore combined with 400 MW interconnection between both countries	-	Design & Permitting	2018	Investment on time	Commissioning date must be achieved in order to ensure grid connection for further renewable energy.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
DKE=>DE: 400	DE=>DKE: 400	3	3	Negligible or less than 15km	Negligible or less than 15km	300

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[19;24]	[54000;66000] MWh	[-62000;-51000]	[-130;-110]
Scenario Vision 2 - 2030	-	[7;8]	[9000;11000] MWh	[-62000;-50000]	[-4;-3]
Scenario Vision 3 - 2030	-	[10;13]	[18000;22000] MWh	[4500;5500]	[-390;-320]
Scenario Vision 4 - 2030	-	[36;44]	[18000;22000] MWh	[4500;5500]	[-760;-620]

Additional comments

Comment on the security of supply: the project improves the SoS of Eastern Denmark and the Mecklenburg-Vorpommeranian area in Germany.

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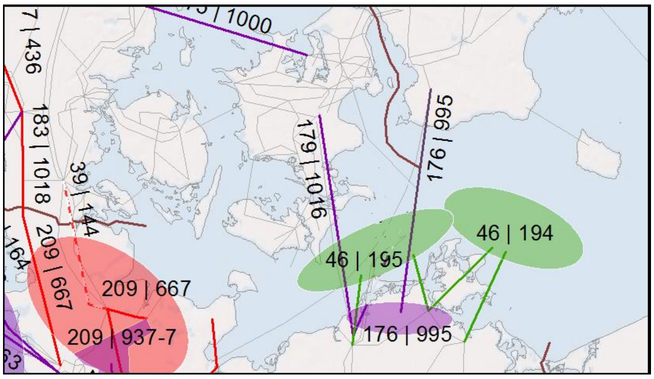
Project 176: Hansa PowerBridge

Description of the project

New interconnector between Sweden (SE4) and Germany (50 Hertz).
There has been joint studies with 4 options for this project. The other options were new interconnectors Latvia-Sweden, Lithuania-Sweden and Poland-Sweden. CBA indicators are based only on the SE4-DE interconnector.



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
995	Station SE4	Station DE	New DC cable interconnector between Sweden and Germany.	-	Under Consideration	2025	New Investment	RGBS common investigations for TYNDP 2014

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
DE=>SE: 600	SE=>DE: 600	3	3	NA	NA	200-400

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[72;88]	[36000;44000] MWh	[420000;520000]	[590;720]
Scenario Vision 2 - 2030	-	[15;18]	[36000;44000] MWh	[190000;230000]	[340;420]
Scenario Vision 3 - 2030	-	[28;35]	[90000;110000] MWh	[62000;75000]	[-710;-580]
Scenario Vision 4 - 2030	-	[220;270]	[90000;110000] MWh	[280000;350000]	[-2200;-1800]

Additional comments

Comment on the RES integration: The project helps integrating wind power on both sides and improves power balancing.

Comment on the S1 and S2 indicators: The project will have a social and environmental impact. However, the project is in an early stage and there is not enough facts regarding the impact.

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NordBalt

Nordbalt is splitted into two projects (60, 124), representing its 2 phases spanning from now to 2023.

Nordbalt will connect the Baltic grid to the Nordic and integrate the Baltic countries with the Nordic electricity market and also increases security of supply.

It consists of a 700 MW DC interconnector between Sweden and Latvia and associated internal grid reinforcements. Before phase 2 is implemented, the Nordbalt cable can be fully utilized thanks to a temporary system protection scheme.

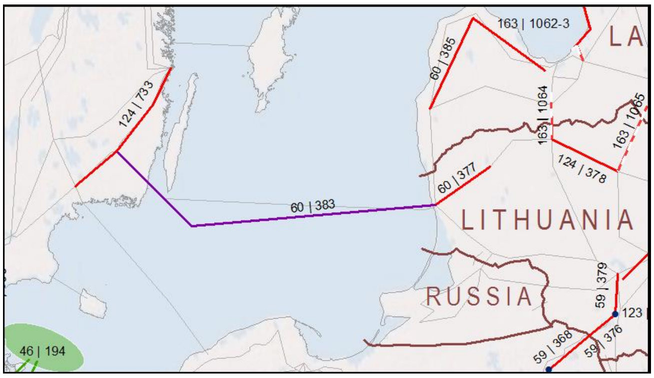
The assessment of project 124 is complementary to the one presented for project 60.

Project 60: NordBalt phase 1

Description of the project

NordBalt project - phase one: investments before 2020. DC interconnector between Lithuania and Sweden and internal investments in Lithuania, Latvia and Sweden. The project will connect the Baltic grid to the Nordic and integrate the Baltic countries with the Nordic electricity market and also increases security of supply.

PCI 4.4.1



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
377	Klaipeda (LT)	Telsiai (LT)	New single circuit 330kV OHL (943 MVA, 85km).	600	Under Construction	2014	Investment on time	Progress as planned.
383	Klaipeda (LT)	Nybro (SE)	(NordBalt) A new 300kV HVDC VSC partly subsea and partly underground cable between Lithuania and Sweden	700	Under Construction	2015	Investment on time	Progress as planned.
385	Grobina (LV)	Imanta (LV)	The reinforcement for Latvian grid project with the new 330kV OHL construction and connection to the Riga node. New 330kV OHL construction mainly instead of the existing 110kV double circuit line route, 110kV line will be renovated at the same time and both will be assembled on the same towers. Length 380km, Capacity 800MW	150	Under Construction	2018	Investment on time	The part of reinforcement for Kurzemes ring

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
LT=>SE: 700	SE=>LT: 700	4	4	Negligible or less than 15km	Negligible or less than 15km	690-1200

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[16;19]	[18000;22000] MWh	[280000;340000]	[-90;-73]
Scenario Vision 2 - 2030	-	[35;42]	[18000;22000] MWh	[320000;390000]	[1100;1300]
Scenario Vision 3 - 2030	-	[9;12]	[110000;130000] MWh	[140000;170000]	[-650;-530]
Scenario Vision 4 - 2030	-	[180;220]	[110000;130000] MWh	[350000;430000]	[-1400;-1200]

Additional comments

Comment on the security of supply: The project is a key for the SoS of the Baltic states

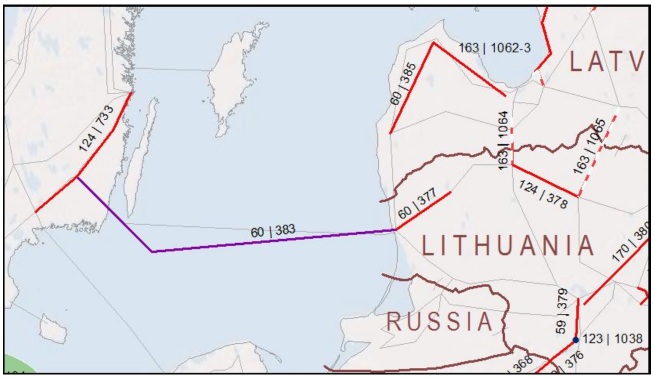
Comment on the RES integration: The project helps integrating RES, especially in the Baltic states but also in the southern Sweden.

Project 124: NordBalt phase 2

Description of the project

NordBalt - phase two: internal investments after 2020 in Lithuania and Sweden to be able to fully utilize the interconnector between Lithuania and Sweden (project 60) that will connect the Baltic grid to the Nordic and integrate the Baltic countries with the Nordic electricity market.

PCI 4.4.2



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
378	Panevezys (LT)	Musa (LT)	New single circuit 330kV OHL (1080 MVA, 80km).	150	Planning	2022	Rescheduled	Investment 60 is postponed in the new national transmission grid development plan. Construction of new NPP, which has impact to the necessity of this investment is unclear, so priority was taken to the other internal investments needed.
733	Ekhyddan (SE)	Nybro/Hemsjö (SE)	New single circuit 400 kV OHL. A key investment to accomplish full utilization of the NordBalt cable between Lithuania and Sweden (project 60) at all times.	700	Planning	2021	Rescheduled	Thanks to postponement, other internal investments will be commissioned on time. Congestions due to the delay will be handled by investing in a temporary system protection scheme.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	GTC direction 2 (MW)	B6 Technical Resilience	B7 Flexibility	S1 - protected areas	S2 - urban areas	C1 Estimated cost (Meuros)

LT=>SE: 700	SE=>LT: 700	4	3	NA	NA	170-270

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	0	0	[-23000;-19000]	0
Scenario Vision 2 - 2030	-	0	0	[61000;75000]	0
Scenario Vision 3 - 2030	-	0	0	[83000;100000]	0
Scenario Vision 4 - 2030	-	0	0	[11000;13000]	0

Additional comments

Comment on the GTC: The project will fully utilize the GTC increase of 700 for NordBalt HVDC interconnector and will replace the temporary system protection scheme. The total delta GTC for project 60 and 124 is then 700.

Comment on the security of supply: The project is a key for the SoS of the Baltic states.

Comment on the RES integration: The project helps integrating RES, especially in the Baltic states but also in the southern Sweden.

Comment on the S1 and S2 indicators: The project will have a social and environmental impact but the investments are in an early stage so it's not possible to give any facts regarding the impact

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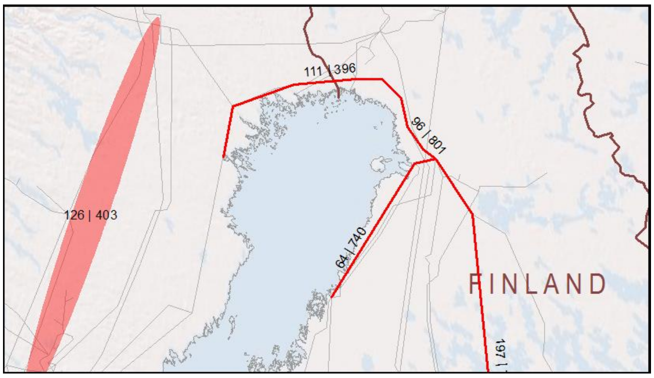
Project 111: 3rd AC Finland-Sweden north

Description of the project

Third AC 400 kV interconnector between Finland north and Sweden SE1. Strengthening the AC connection between Finland and Sweden is necessary due to new wind power generation, larger conventional units and decommissioning of the existing 220 kV interconnector.



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
396	Finland North (FI)	Sweden bidding area SE1/SE2	Third single circuit 400kV AC OHL between Sweden and Finland	-	Under Consideration	2025	Rescheduled	Rescheduled following a review of priorities and dependencies for all grid reinforcements in Sweden. Thanks to postponement of this investment, other internal investments will be commissioned on time

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
FI=>SE: 500	SE=>FI: 800	6	6	Negligible or less than 15km	Negligible or less than 15km	64-120

CBA results	**for each scenario**				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[12;15]	[19000;23000] MWh	[230000;280000]	[230;280]
Scenario Vision 2 - 2030	-	[4;5]	[1800;2200] MWh	[210000;250000]	[440;530]
Scenario Vision 3 - 2030	-	[4;5]	[23000;28000] MWh	[110000;130000]	[-48;-39]
Scenario Vision 4 - 2030	-	[54;66]	[54000;66000] MWh	[170000;210000]	[-120;-96]

Additional comments

Comment on the security of supply: The project enhances system security of whole Finnish system, especially during outages on other interconnections between the countries.

Comment on the RES integration: The project helps integrating 500-800 MW wind power in Northern Sweden and Finland and improves the possibilities of balancing the system.

Project 62: Estonia-Latvia 3rd IC

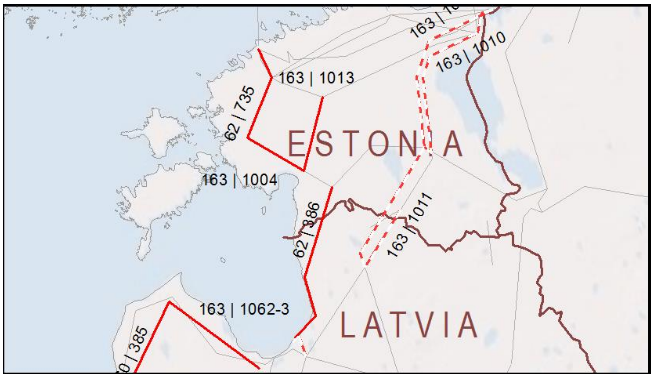
Description of the project

Project nr 62 is a planned third 330 kV interconnection between Estonia and Latvia. The project consists of 2 investments of which nr 386 is the main inter-area investment, AC 330 kV OHL between Kilingi-Nõmme substation in Estonia and TEC2 substation in Latvia. Estonia-Latvia third interconnection associated investment nr 735 AC 330 kV OHL Harku-Lihula-Sindi in Estonian. It increases the capacity between Estonia and Latvia by 600 MW.

The project also helps to improve SoS and contributes to RES increase in the Baltics western coastal areas. The project is also a precondition for construction of off-shore wind parks in Estonia and Latvia.

The Estonia-Latvia third interconnection is the significant project for all the Baltic region, because it will increase competition for electricity market in Baltic States and between Baltic States and Nordic countries. It will provide reliable transmission network corridor will improve interoperability between Baltic states. In addition after commissioning the projects forming the Baltic Energy Interconnection Plan the reinforced Baltic States transmission system and its connections to Nordic and Central Europe can also serve as an alternative route for exporting Nordic surplus to the Central European power system.

PCI 4.2



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
386	Kilingi-Nomme (EE)	R-TEC2 (LV)	330 kV AC OHL between Kilingi-Nõmme substation in Estonia and R-TEC2 substation in Latvia. New 330 kV power transmission line is planned to take route along already existing 110 kV power transmission lines, by constructing both 110 kV and 330 kV lines on the same towers. Under the framework of the project it is planned to reconstruct the open-air switchyard of the 330/110 kV substation „TEC-2” by	500	Planning	2020	Investment on time	Progress as planned.

			constructing new open-air connection point for the 330 kV line „Kilingi Nomme-TEC-2".					
735	Harku (EE)	Sindi (EE)	New double circuit OHL with 2 different voltages 330 kV and 110 kV and with capacity 1200 MVA/240 MVA and a length 140 km. Major part of new internal connection will be established on existing right of way on the western part of Estonian mainland.	250	Design & Permitting	2018	Investment on time	Progress as planned.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
EE=>LV: 450-600	LV=>EE: 450-600	4	4	More than 100km	Negligible or less than 15km	105-195

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[8;9]	[36000;44000] MWh	[53000;65000]	[90;110]
Scenario Vision 2 - 2030	-	[10;13]	[36000;44000] MWh	[91000;110000]	[7;8]
Scenario Vision 3 - 2030	-	[0;1]	[9000;11000] MWh	[-1100;-900]	[-9;-8]
Scenario Vision 4 - 2030	-	[8;9]	[11000;13000] MWh	[11000;13000]	[-31;-26]

Additional comments

Comment on the SEW: The outcome of study shows that the 3rd interconnector between LV-EE is not so beneficial in all four Visions because Visaginas NPP is in operation and caused opposite power flows as it is now. To refer on the last statements of government of Lithuania Visaginas NPP project is very uncertain now and further evolution depends on common decisions made by governments of Baltic States. SEW benefit for this project is strongly influenced by Vision assumptions related specifically to large scale RES integration into the concentrated area inside of Baltics power system and that assumption might not be fully realistic due to the limitation of district heat demand and biofuels availability. Another factor is the assumption of self-sufficient installed generation-consumption balance on country-level. The 3rd interconnector looks less beneficial comparing the indicators of other projects but in reality main bottleneck is on border EE-LV. Special sensitivity cases, especially Baltic Sea Green vision show potential for much higher benefit than highest benefit in studied visions. According to study prepared by RGBS 3rd interconnector improves the resilience and robustness and allows connect high amount of RES.

Due to congestion removal and transfer capacity increase the Project has an impact to socio-economic benefits increase in the whole Baltic Sea region and Central Europe.

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Comment on the security of supply: although the CBA calculated value for SoS was 0, other studies show the project improves significantly Security of Supply internally in Estonia and Latvia. Especially on the west south of Estonia and in Latvia capital, Riga area.

Comment on the RES integration: the project enables indirectly to increase up to 1000 MW of RES capacity in the Baltics power system, especially in Estonia and Latvia western coastal areas. The project is also a precondition for construction of off-shore wind parks in Estonia and Latvia.

LitPol

"LitPol" consists of two projects (59, 123), representing its 2 phases spanning from now to 2020, and each adding a 500 MW interconnection capacity.
The LitPol Link Project is an HVDC interconnection between Poland and Lithuania. It removes an energy island by connecting the Baltic States to the Continental Europe and completes Baltic Sea ring.
The assessment of project 123 is complementary to the one presented for project 59.

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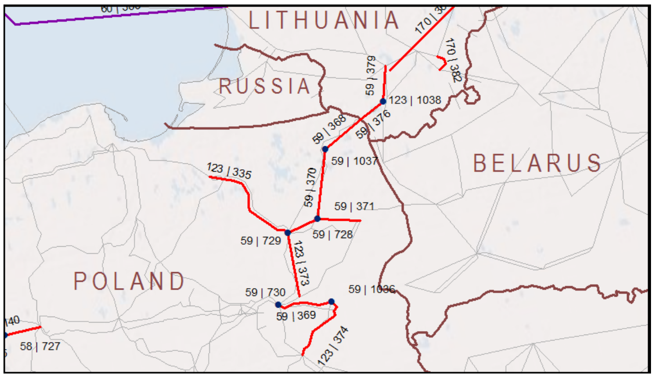
Project 59: LitPol Link Stage 1

Description of the project

The LitPol Link Project is an interconnection between Poland and Lithuania. The first stage of the LitPol Link interconnection project is realized by the construction of new double circuit 400 kV interconnector between Ełk and Alytus together with 500 MW back-to-back convertor station in substation Alytus and strengthening of the internal high voltage transmission grid in Poland and Lithuania in order to utilize the capacity of the interconnection. The capacity increase in first stage is 500 MW (on the direction from Lithuania to Poland; the capacity in opposite direction is curtailed by the limitations of the internal Polish transmission grid) and the expected commissioning date is 2015. The project removes an energy island by connecting the Baltic States to the Continental Europe and completes Baltic Sea ring.

PCI 4.5.1



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
368	Elk (PL)	PL-LT border	Construction of a new 400 kV interconnector line from Ełk to PL-LT border.	400	Under Construction	2015	Investment on time	Progress as planned.
369	Siedlce Ujrzanów (PL)	Milosna (PL)	Construction of new 400 kV line Siedlce Ujrzanów - Miłosna.	100	Under Construction	2015	Investment on time	The project is in the construction phase.
370	Elk (PL)	Lomza (PL)	Construction of new 400 kV line Ełk-Łomża.	400	Under Construction	2015	Investment on time	The project is under construction.
371	Ostroleka (PL)	Narew (PL)	Construction of new 400 kV line Ostrołęka-Łomża-Narew + extension of substation Narew.	400	Under Construction	2015	Investment on time	The project is under construction.
376	Alytus (LT)	PL-LT border	Construction of 500 MW Back-to-Back convertor station near Alytus 330kV substation. Construction of double circuit 400kV OHL between Alytus and PL-LT border (51 km).	500	Under Construction	2015	Investment on time	Progress as planned.
379	Kruonis (LT)	Alytus (LT)	New double circuit 330kV OHL Alytus–Kruonis (2x1080 MVA, 53km).	300	Design & Permitting	2016	Delayed	Several months delay due to difficulties with the acquisition of the land

728	Lomza (PL)		Construction of new substation Łomża to connect the line Ełk-Łomża.	400	Under Construction		2015	Investment on time	The project is under construction.
729	Ostroleka (PL)		A new 400 kV switchgear in existing substation Ostroleka (in two stages) with transformation 400/220kV 500 MVA and with transformation 400/110kV 400 MVA.	400	Under Construction		2015	Investment on time	The project is under construction.
730	Stanislawów (PL)		New substation 400kV Stanisławów will be connected by splitting and extending existing line Miłosna-Narew and Miłosna-Siedlce.	400	Under Construction		2015	Expected earlier than planned previously	In TYNDP 2012 the building of the substation Stanisławów was reported as part of a line Ostrołęka-Stanisławów. The commissioning time has been aligned with the construction of the line Miłosna-Siedlce Ujrzanów which is expected in 2015.
1036	Siedlce Ujrzanów		New Substation Siedlce Ujrzanów will be connected by new line Miłosna-Siedlce Ujrzanów and later by new line Kozienice-Siedlce Ujrzanów	100	Under Construction		2015	Investment on time	The investment was previously included in the investment no. 369 as "new 400 kV switchgear in existing Substation Siedlce". The concept has changed and there is a new substation in a different location.
1037	Elk Bis		New 400/110 kV Substation Ełk Bis connected by two double 400 kV lines Łomża-Ełk and Ełk-Alytus creating an interconnector Poland-Lithuania.	400	Under Construction		2015	Investment on time	The inv. was part of inv. no 370 in TYNDP2012 as "new 400kV switchgear in existing Substation Ełk". The concept has changed, it is not possible to extend the existing substation and there is a new substation in a different location, expected in 2015.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
PL=>LT: 0-0	LT=>PL: 0-500	3	5	50-100km	25-50km	510

CBA results	**for each scenario**				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[40;49]	[54000;66000] MWh	[170000;200000]	[-280;-230]
Scenario Vision 2 - 2030	-	[52;63]	[9000;11000] MWh	[200000;240000]	[750;920]
Scenario Vision 3 - 2030	-	[23;28]	[9000;11000] MWh	[-1100000;-890000]	[-2000;-1700]
Scenario Vision 4 - 2030	-	[160;200]	[9000;11000] MWh	[-1100000;-900000]	[-2500;-2000]

Additional comments

Comment on the RES integration:
The analysis shows that the project helps integrating RES – avoided spillage (equivalent to installed capacity of 5-30 MW, assuming capacity factor of 2000 h/a) in the region of Baltic States and Poland.

Comment on the flexibility indicator: the project appears useful in all visions, depends on a key-investment and interconnects two synchronous areas.

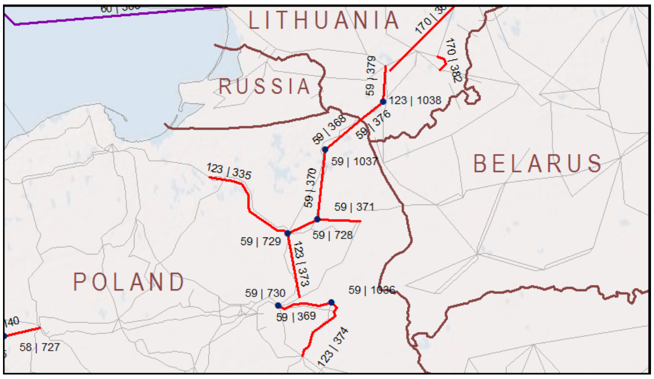
Project 123: LitPol Link Stage 2

Description of the project

The LitPol Link Stage 2 is a continuation of building of the interconnection between Poland and Lithuania in order to achieve the planned transmission capacity of 1000 MW in both directions. Building of additional internal investments in Poland and Lithuania are necessary. In Poland three additional lines will be erected (Ostrołeka-Olsztyn Mątki, Ostrołęka-Stanisławów and Kozienice-Siedlce Ujrzanów). In Lithuania a second 500 MW back-to-back converter station will be built in substation Alytus.

The project improves connection the Baltic States to the Continental Europe and Baltic Sea ring.

PCI 4.5.2 and 4.5.3



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
335	Ostroleka (PL)	Olsztyn Matki (PL)	Construction of new 400 kV line Ostrołęka - Olsztyn Mątki after dismantling of 220kV line Ostrołęka - Olsztyn with one circuit from Ostrołęka to Olsztyn temporarily on 220 kV.	500	Design & Permitting	2017	Investment on time	The investment in on time.
373	Ostroleka (PL)	Stanislawów (PL)	Construction of new 400 kV line Ostrołęka-Stanisławów.	500	Design & Permitting	2020	Investment on time	The project is at the design stage.
374	Kozienice (PL)	Siedlce Ujrzanów (PL)	Construction of new 400 kV line Kozienice-Siedlce Ujrzanów.	300	Design & Permitting	2019	Expected earlier than planned previously	The commissioning date has been adjusted compared to the previous national plan and TYNDP.
1038	Alytus		Construction of the second 500 MW back-to-Back converter station in Alytus	500	Planning	2020	New Investment	This investment was missing not explicitly mentioned in TYNDP 2012, but was already foreseen.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
PL=>LT: 0-1000	LT=>PL: 0-1000	1	5	15-50km	25-50km	310

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[36;45]	[18000;22000] MWh	[190000;230000]	[-350;-290]
Scenario Vision 2 - 2030	-	[32;39]	[18000;22000] MWh	[170000;210000]	[290;360]
Scenario Vision 3 - 2030	-	[36;44]	[27000;33000] MWh	[-670000;-550000]	[-1900;-1600]
Scenario Vision 4 - 2030	-	[150;180]	[27000;33000] MWh	[-290000;-240000]	[-2200;-1800]

Additional comments

Comment on the RES integration:
The analysis shows that the project helps integrating RES – avoided spillage (equivalent to installed capacity of 10-15 MW, assuming capacity factor of 2000 h/a) in the region of Baltic States and Poland.

Comment on the flexibility indicator: LitPol appears useful in all visions, depends on a key-investment and interconnects two synchronous areas.

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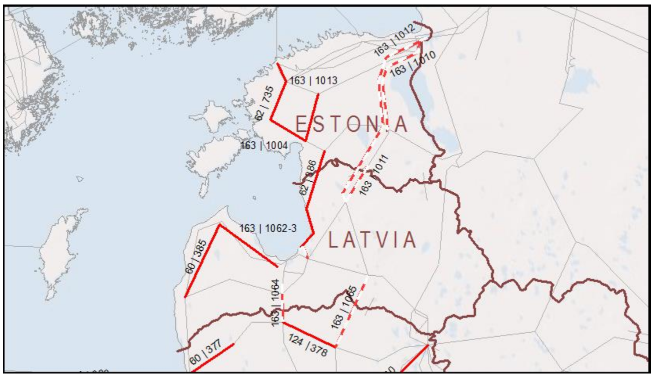
Project 163: BalticCorridor

Description of the project

Baltic corridor project includes several investments to enable the increase of 600MW though the Baltic States starting from North Estonia until Lithuania - Poland border in the south of Baltics. The project is strongly related to Baltic market integration to common European market and enables great new possibilities for large scale RES integration up to 1200MW. Additionally, this project can be considered as an alternative possibility to transfer electricity from North Scandinavia to continental Europe. The investments in this project are also seen as relevant preconditions for synchronous operation of Baltic States with the Continental Europe. So it means the project serves also as a backbone for project Baltics Synchronization with CE (project nr 170).
The project includes reinforcement of existing 330 kV lines internally and on the borders of Baltic States. The new standards of line construction enable significant increase of the line capacity, up to 50%.



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
1004	Sindi	Paide	Reinforcement of existing 330 kV OHL between Paide and Sindi 330 kV substations in Estonia. Old line will be replaced with new towers and wires of 3x400 mm2 in phase. The thermal capacity of the line is planned 1143 MVA. The investment is also a backbone for Baltics Synchronization with CE (project nr 170).	200	Planning	2030	New Investment	-
1010	Tartu	Valmiera	Reinforcement of existing 330 kV OHL with new towers and wires of 3x300 mm2 in phase. The thermal capacity of the line is planned 1000 MVA. The investment is also a backbone for Baltics Synchronization with CE (project nr 170).	200	Under Consideration	2030	New Investment	-
1011	Tsirguliina	Valmiera	Reinforcement of existing 330 kV OHL with new towers and wires of 3x300 mm2 in phase. The thermal capacity of the line	200	Under Consideration	2030	New Investment	-

			is planned 1000 MVA. The investment is also a backbone for Baltics Synchronization with CE (project nr 170).					
1012	Balti	Tartu	Reinforcement of existing 330 kV OHL between Balti and Tartu 330 kV substations in Estonia. Old line will be replaced with new towers and wires of 3x400 mm2 in phase. The thermal capacity of the line is planned 1143 MVA. The investment is also a backbone for Baltics Synchronization with CE (project nr 170).	200	Under Consideration	2030	New Investment	-
1013	Eesti	Tsirguliina	Reinforcement of existing 330 kV OHL between Eesti and Tsirguliina 330 kV substations in Estonia. Old line will be replaced with new towers and wires of 3x400 mm2 in phase. The thermal capacity of the line is planned 1143 MVA. The investment is also a backbone for Baltics Synchronization with CE (project nr 170).	200	Under Consideration	2030	New Investment	-
1062	TEC2	Salaspils	Internal reinforcement for Baltic Corridor 600 MW	600	Under Consideration	2030	New Investment	-
1063	TEC1	TEC2	Investment is necessary to strengthening internal grid in Latvia due to get transmission capacity of 600 MW via Latvia	600	Under Consideration	2030	New Investment	-
1064	Viskali (LV)	Musa (LT)	To get 600 MW of capacity via Baltic States additionally.	600	Under Consideration	2030	New Investment	-
1065	Aizkraukle (LV)	Panevežys (LT)	To increase transmission capacity by 600 MW via Baltic States	600	Under Consideration	2030	New Investment	-

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
North=>South: 600	South=>North: 600	2	1	More than 100km	More than 50km	120-140

CBA results	**for each scenario**				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	0	[36000;44000] MWh	[-59000;-49000]	[60;73]
Scenario Vision 2 - 2030	-	[1;2]	[36000;44000] MWh	[38000;46000]	[-22;-18]
Scenario Vision 3 - 2030	-	[2;3]	0	[18000;22000]	[-69;-56]
Scenario Vision 4 - 2030	-	[3;4]	[54000;66000] MWh	[83000;100000]	[-17;-14]

Additional comments

Comment on the RES integration: Even the spillage reduction calculations shows relevantly low values the project enables indirectly to increase technical possibilities to connect RES capacity to the Baltics power system around 1200 MW.

Project 170: Baltics synchro with CE

Description of the project

The PCI project 4.3 Estonia/Latvia/Lithuania synchronous interconnection with the Continental European networks is aimed at infrastructure development for deeper market integration and synchronous operation of the power systems of the Baltic States with the Continental European networks.

Two different landing points and two differently routed interconnections are required to achieve physical separation of the two redundant interconnections in order to establish a reliable synchronous connection between the transmission systems of Baltic States and Continental Europe networks. The first Lithuania – Poland connection (LitPol Link) is already decided and it will be the first connection. The second connection is still under investigation.

The projects consists mainly of the 330-400 kV cross-border lines and internal lines in order to reinforce internal grids to handle the situation.

Baltics synchronization with EU is unique project as main driver for it is not to increase GTC but to disconnect from Russia system and connect with Continental European networks synchronously.

Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
380	Visaginas (LT)	Kruonis (LT)	New single circuit 330kV OHL (1080 MVA, 200km) for the internal grid reinforcement.	150	Under Consideration	2022	Rescheduled	Investment depending on Visaginas NPP construction time.
382	Vilnius (LT)	Neris (LT)	New single circuit 330kV OHL (943 MVA, 50km).	150	Planning	2022	Rescheduled	Investment 61 is postponed in the new national transmission grid development plan. Construction of new NPPP is unclear, so priority was taken to the other internal investments needed.
1034	Substation in Lithuania	State border	400 kV interconnection line for synchronous interconnection of Baltics	600	Under Consideration	2023	New Investment	-

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
North=>South: 600	South=>North: 600	2	4	NA	NA	96-100

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[26;31]	0	0	[-340;-280]
Scenario Vision 2 - 2030	-	[12;15]	0	0	[86;110]
Scenario Vision 3 - 2030	-	[34;41]	0	0	[-2600;-2100]
Scenario Vision 4 - 2030	-	[120;140]	[54000;66000] MWh	0	[-2000;-1700]

Additional comments

Comment on the CBA assessment: During 2012-2013, Lithuanian, Latvian and Estonian TSOs carried out the Feasibility study “Interconnection Variants for the Integration of the Baltic States to the EU Internal Electricity Market“ to evaluate the possible technical and economic consequences and benefits of synchronizing power systems of Baltics within synchronous area of Continental Europe. The study was prepared by Gothia Power Company.

The list of investments is not final and is very preliminary including just a few of probable necessary investments.

Only SEW was analysed via simplified capacity increase approach and no grid studies were performed in this stage as the exact route and investments are not decided yet.

Comment on the RES integration: avoided spillage in Vision 4 concerns RES in the whole Baltic area.

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

Project 58: GerPol Power Bridge

Description of the project

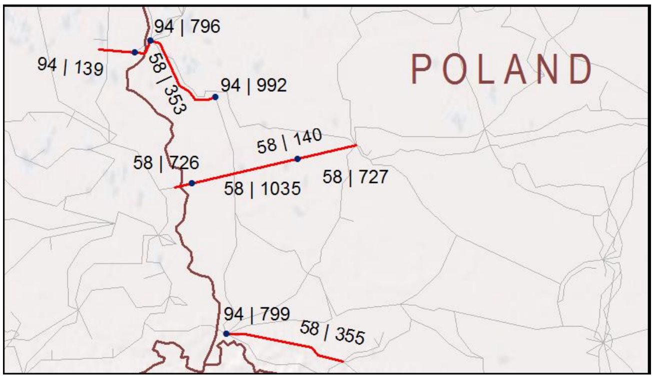
The construction of a new (third) interconnection between Polish and German power systems includes the construction of the interconnector between Eisenhuetenstadt and Plewiska as well as two internal lines (Mikułowa-Świebodzice and Krajnik -Baczyna) and substations Plewiska BIS, Gubin and Zielona Góra to connect the new line in the Polish transmission system and contributes to the following:

• increase of market integration between member states - additional NTC of 1500 import and 500 MW export on PL-DE/SK/CZ synchronous profile;

• integration of additional Renewable Energy Sources on the area of western and north-western Poland as well as eastern part of Germany;

• improving network security - project contributes to increase of security of supply and flexibility of the transmission network (security of supply of Poznań agglomeration area).

PCI 3.14



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
140	Eisenhüttenstadt (DE)	Plewiska (PL)	Construction of new 400 kV double circuit line Plewiska (PL)-Eisenhüttenstadt (DE) creating an interconnector between Poland and Germany.	800	Planning	2030	Rescheduled	Change of the commissioning date – see comment in the next page
353	Krajnik (PL)	Baczyna (PL)	Construction of new 400 kV double circuit line Krajnik – Baczyna.	400	Planning	2020	Investment on time	Investment is in the tendering procedure.
355	Mikulowa (PL)	Swiebodzice (PL)	Construction of new 400 kV double circuit line Mikułowa-Świebodzice in place of existing 220 kV line.	400	Planning	2020	Investment on time	Investment on time.
726	Gubin (PL)		New 400 kV substation Gubin located near the PL-DE border. The substation will be connected by the new line Plewiska (PL)-Eisenhüttenstadt (DE).	800	Planning	2030	Rescheduled	Change of the commissioning date as the investment is correlated with the investment 140

727	Plewiska (PL)		Construction of new substation Plewiska Bis (PL) to connect the new line Plewiska (PL)-Eisenhüttenstadt (DE).	800	Planning		2020	Investment on time	The project is at the planning stage.
1035	Baczyna		Construction of new 400/220 kV Substation Baczyna to connect the new line Krajnik-Baczyna.	400	Planning		2018	Investment on time	The investment was part of n°58.353 in TYNDP 2012 and is now presented stand alone. It is in the tendering procedure (design and build scheme).

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
PL=>DE: 0-500	DE=>PL: 0-1500	1	4	15-50km	Negligible or less than 15km	390-400

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[69;84]	0	[-170000;-140000]	[760;930]
Scenario Vision 2 - 2030	-	[67;82]	0	[-160000;-130000]	[1000;1200]
Scenario Vision 3 - 2030	-	[99;120]	[300000;370000] MWh	[-770000;-630000]	[-81;-66]
Scenario Vision 4 - 2030	-	[98;120]	[650000;800000] MWh	[-910000;-740000]	[87;110]

Additional comments

Comment on the RES integration:
The project, depending on the vision, helps integrating RES in the region of north-west Poland as well as eastern part of Germany.

The analysis evaluating the effectiveness of the construction of the third interconnection with German power system was performed, which took into account the assessment of the technical conditions of the existing highest voltage lines, system conditions as well as domestic needs in the area of transmission network expansion and the need to increase the import capacity.
The analysis was performed using current internal forecasts in terms of demand for power and energy in the Polish Power System, including the assessment of the ability to balance the demand for power by generation sources (conventional and RES) located in the north-western part of the country.
The assessment took into account the intention to improve conditions of the cross-border power exchange over synchronous cross-section considering the installation of phase shifting transformers (PSTs) on the Mikułowa-Hagenwerder and Krajnik-Vierraden interconnection lines, and the planned upgrade of Krajnik-Vierraden line to 400 kV.
The results of PSE’s analysis show that it is possible to achieve the increase of cross border capacity to 1800-2000 MW with a different approach.

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The reinforcements in the internal Polish transmission network, which prove necessary despite the cross border capacity increase needs, yield comparable results with significantly lower costs.
The proposed reinforcements include:

- 2x400 kV line Krajnik-Baczyna (planned currently)
- 2x400 kV line Mikułowa-Świebodzice (planned currently)
- Rebuilding of existing single 400 kV line Mikułowa-Pasikurowice to 2x400 kV (internal replacement)
- 2x400 kV line Baczyna-Plewiska (instead of Eisenhüttenstadt-Plewiska)

Based on the above described conditions PSE and 50Hertz intend to concentrate in a first step on the proposed reinforcements and to consider the construction of the third interconnection line between Poland and Germany in a second step, in 2030 as the earliest date.
The decision on the construction of the third interconnection will be taken after the internal infrastructure development has been completed and after the evaluation of the needs for further development has been performed.

When the project was assessed with the CBA during the TYNDP 2014 assessment phase, the CBA clustering rules were respected. This was reflected in the draft TYNDP 2014 for consultation published in July 2014. Given the changes above-mentioned the project now does not fulfil anymore the CBA clustering rules.

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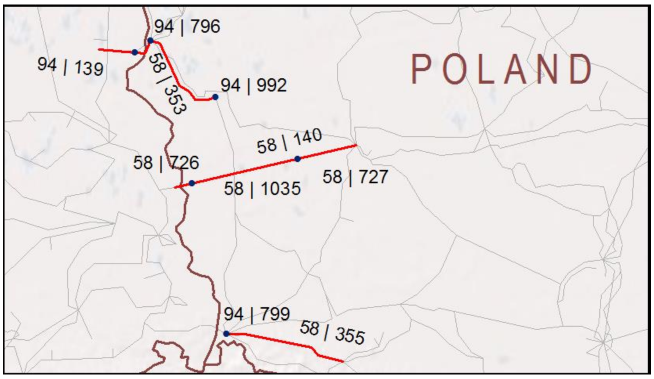
Project 94: GerPol Improvements

Description of the project

Upgrade of the existing 220 kV double interconnection line between Krajnik and Vierraden to 400 kV double line in the same direction together with installation of Phase Shifting Transformers on two existing interconnection lines (Krajnik-Vierraden by 50Hertz Transmission GmbH in Vierraden and Mikułowa-Hagenverder by PSE S.A. in Mikułowa) on the PL/DE border including an upgrade of substations Vierraden, Krajnik and Mikułowa contribute to the following:

• decreasing of unscheduled flow from Germany to Poland, Poland to Czech Republic and Poland to Slovakia by increasing of controllability on entire synchronous profile;
• enhancement of market capacity on Polish synchronous profile - PL/DE as well as PL-CZ/SK border in case of both import and export. The project provides additional capacity (NTC – Net Transfer Capability) of 500 MW in terms of import and 1500 MW export; greater level of safety and reliability of operation of the transmission network in Poland due to enhanced control of power flow.

PCI 3.15



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
139	Vierraden (DE)	Krajnik (PL)	Upgrade of existing 220 kV line Vierraden-Krajnik to double circuit 400 kV OHL.	1500	Design & Permitting	2017	Investment on time	A delay in the permit process for the line Neuenhagen-Bertikow-Vierraden (DE) as a prerequisite caused an adaptation in the time schedule for the line between Vierraden and Krajnik from to 2017.
796	Krajnik (PL)		Upgrade of 400/220 kV switchgear in substation Krajnik (new 400/220 kV switchyard).	1500	Design & Permitting	2017	Delayed	The commissioning time of the investment has been aligned with the schedule for the investment 139.
799	Mikulowa (PL)		Installation of new Phase Shift Transformer in substation Mikułowa and the upgrade of substation Mikułowa for the purpose of PST installation.	1500	Design & Permitting	2015	Delayed	Investment postponed because of prolongation of the tendering process. Due to complexity of the technical solutions more time is needed for the tendering procedure.

992	Vierraden		Installation of new PSTs in Vierraden	1500	Planning	2017	New Investment	Based on a common agreement between PSE and 50Hertz the investment was specified in more detail in close cooperation between PSE and 50Hertz. The common solution consists of PST in Vierraden (DE) and PST in Mikułowa (PL) Investment 799.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
PL=>DE: 0-1500	DE=>PL: 0-500	2	3	Negligible or less than 15km	Negligible or less than 15km	150

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[250;300]	[110000;130000] MWh	[-60000;-49000]	[2000;2400]
Scenario Vision 2 - 2030	-	[240;300]	[41000;50000] MWh	[-49000;-40000]	[2800;3400]
Scenario Vision 3 - 2030	-	[75;92]	[130000;160000] MWh	[-140000;-110000]	[1300;1600]
Scenario Vision 4 - 2030	-	[270;330]	[800000;970000] MWh	[-190000;-150000]	[50;61]

Additional comments

Comment on the security of supply:
By improving the control over the unscheduled flows, which in certain conditions cause severe overload of the system elements, the project has a positive impact on Security of Supply in the region of north-west and south-west Poland as well as eastern part of Germany.

Comment on the RES integration:
The project, depending on the vision, helps integrating RES in the region of north-west Poland as well as eastern part of Germany.

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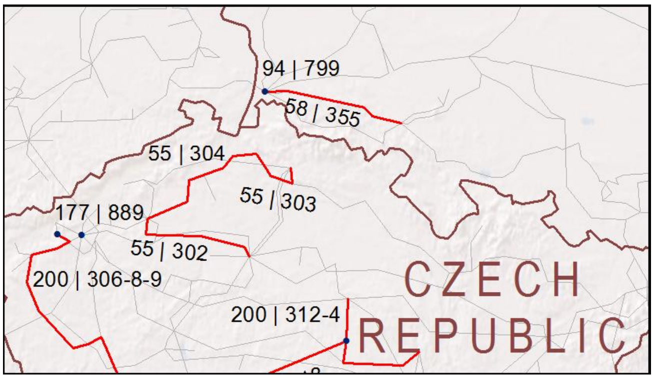
Project 55: CZ West-east corridor (West)

Description of the project

This project is required to ease power flows West to East and enables market integration of generation with high flexibility in to the power grid. Project consists of 400kV OHL lines in existing corridors by building new double circuit with target capacities of 1700MVA per circuit. Project also brings ability to current and new connected generation free access to cross-border ancillary market.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
302	Vyskov (CZ)	Cechy stred (CZ)	New second circuit 400kV OHL; Target capacity 2x1730 MVA.	1000	Design & Permitting	2016	Delayed	Delayed due to permitting procedured difficulty
303	Babylon (CZ)	Bezdecin (CZ)	New second circuit 400kV OHL; 1385 MVA.	350	Design & Permitting	2018	Delayed	Delay caused by permitting process difficulty
304	Babylon (CZ)	Vyskov (CZ)	New second circuit 400kV OHL; 1385 MVA.	750	Design & Permitting	2021	Delayed	Delayed due to permitting procedure difficulty

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
West=>East: 1250-1750	East=>West: 1400-1600	2	3	15-50km	Negligible or less than 15km	230-290

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[77;97]	0	[-88000;-110000]	[210;260]
Scenario Vision 2 - 2030	-	[79;99]	0	[60000;72000]	[280;350]
Scenario Vision 3 - 2030	-	[67;87]	0	[-48000;-58000]	[-2200;-2600]
Scenario Vision 4 - 2030	-	[35;45]	0	[-19000;-36000]	[-1600;-2000]

Additional comments

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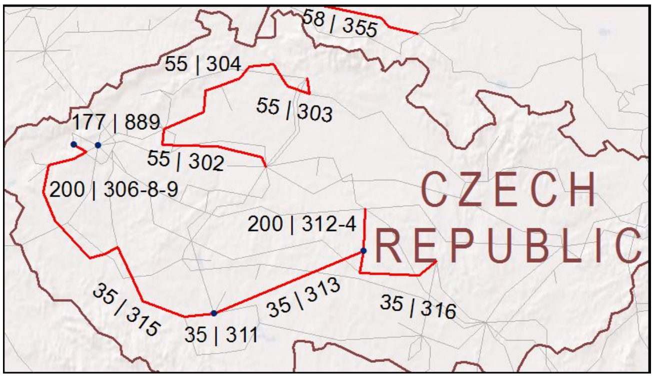
Czech North South Corridor

Description of the corridor

The "Czech North South Corridor" consists of two projects (200, 35), representing its 2 phases spanning from 2016 to 2028.
This reinforcement strategy enables the power flow from northwester border to southeastern border. This project is required to facilitate power flows in the direction North-South and East-West, enhance the grid transfer capability between Czech Republic and Germany and supports the future thermal generation evacuation and RES - connection point of wind generation is substation Vernerov. In addition the project ensures security of supply of the North-western part of Czech Republic in general terms.
The two projects have been assessed as a whole and share the same common assessment.

PCI 3.11



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
Project 200								
306	Vitkov (CZ)		New 400/110kV substation equipped with transformers 2x350MVA.	500	Design & Permitting	2020	Delayed	Complication of permitting procedure
307	Vernerov (CZ)		New 400/110kV substation equipped with transformers 2x350MVA.	500	Design & Permitting	2017	Delayed	Complication with permitting procedure.
308	Vernerov (CZ)	Vitkov (CZ)	New 400kV double circuit OHL, 1385 MVA.	500	Design & Permitting	2019	Investment on time	Progress as planned.
309	Vitkov (CZ)	Prestice (CZ)	New 400kV double circuit OHL, 2x1730 MVA.	500	Design & Permitting	2021	Investment on time	Progress as planned.
312	Mirovka (CZ)		Upgrade of the existing substation 400/110kV with two transformers 2x350MVA.	300	Design & Permitting	2020	Delayed	Project delayed due to reschedulling of transmission projects together with commission rescheduled on the generation investor's side
314	Mirovka (CZ)	V413 (CZ)	New double circuit OHL with a capacity of 2x1385 MVA and 26.5km length.	200	Design & Permitting	2020	Delayed	Project delayed due to reschedulling of transmission projects together with commission rescheduled

								on the generation investor's side
Project 35								
311	Kocin (CZ)		Upgrade of the existing substation 400/110kV; upgrade transformers 2x350MVA.	500	Design & Permitting	2024	Delayed	Project commissioning date postponed due to reschedulling of transmission projects together with commission rescheduled on the generation investor's side
313	Kocin (CZ)	Mirovka (CZ)	Connection of 2 existing 400kV substations with double circuit OHL having 120.5km length: and a capacity of 2X1700 MVA.	500	Design & Permitting	2024	Delayed	Project commissioning date postponed due to reschedulling of transmission projects together with commission rescheduled on the generation investor's side. Permitting procedure issues and wiring change.
315	Kocin (CZ)	Prestice (CZ)	Adding second circuit to existing single circuit line OHL upgrade in length of 115.8km. Target capacity 2x1700 MVA.	500	Design & Permitting	2028	Delayed	Project commissioning date postponed due to reschedulling of transmission projects together with commission rescheduled on the generation investor's side. Wiring change to higher capacity.
316	Mirovka (CZ)	Cebin (CZ)	Adding second circuit to existing single circuit line (88.5km, 2x1700 MVA).	100	Design & Permitting	2028	Delayed	Project is dependent on other investments which are delayed.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	GTC direction 2 (MW)	B6 Technical Resilience	B7 Flexibility	S1 - protected areas	S2 - urban areas	C1 Estimated cost (Meuros)
CZ=>DE: 0-500	DE=>CZ: 0-500	2	3	15-50km	Negligible or less than 15km	190-450

CBA results	for each scenario				
Scenario	B1 SoS (MWh/year)	B2 SEW (MEuros/year)	B3 RES integration	B4 Losses (MWh/yr)	B5 CO2 Emissions (kT/year)
Scenario Vision 1 - 2030	-	[250;310]	[200000;250000] MWh	[-220000;-260000]	[-2100;-2500]
Scenario Vision 2 - 2030	-	[270;330]	[200000;240000] MWh	[-260000;-320000]	[-1800;-2100]
Scenario Vision 3 - 2030	-	[1400;1700]	[210000;260000] MWh	[-340000;-580000]	[-7900;-9500]
Scenario Vision 4 - 2030	-	[1200;1500]	[210000;260000] MWh	[-280000;-300000]	[-7000;-8600]

Additional comments

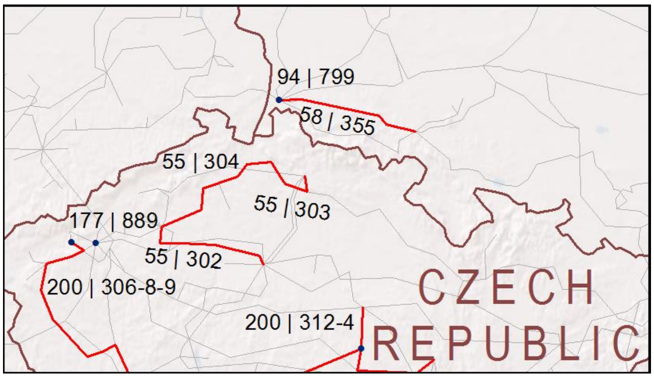
Comment on the RES integration: avoided spillage concerns RES in Czech Republic and Germany mostly.

Comment on the CO2 indicator: the very high scores reflect that the project connects RES sources to load centres

Project 177: PST Hradec

Description of the project

Construction of this project enables control of power flow on the border to support system security - in terms of N-1 security, effective utilization of the infrastructure and cross-border market exchanges. The target capacity of phase shifting transformers is 1700MVA per each circuit of tie-lines between CEPS and 50Hertz, that means 3400MVA of thermal capacity. Devices are located in 400kV substation Hradec.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
889	Hradec		Construction of new PST in substation Hradec with target capacity 2x1700MVA	-	Design & Permitting	2016	Investment on time	Progress as planned

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
CZ=>DE: 0-500	DE=>CZ: 0-500	2	3	NA	NA	87-110

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[10;14]	0	[110;150]	[140;160]
Scenario Vision 2 - 2030	-	[79;99]	0	[110;160]	[170;210]
Scenario Vision 3 - 2030	-	[14;18]	[62000;76000] MWh	[130;230]	[-58;-78]
Scenario Vision 4 - 2030	-	[20;24]	[210000;250000] MWh	[190;320]	[-120;-140]

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Additional comments

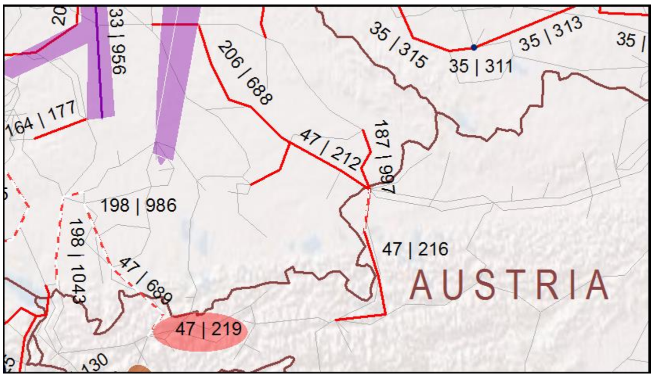
Comment on the RES integration: avoided spillage concerns RES in Czech Republic and Germany mostly.

Project 47: AT - DE

Description of the project

This project reinforces the interconnection capacity between Austria and Germany. The national investments comprised are a precondition to achieve the full benefit of the cross border investments and are vital for the Austrian security of supply (e.g. part of the Austrian 380-kV-Security Ring). It supports the interaction of RES in Northern Europe (mainly in Germany) and in the eastern part of Austria with the pump storages in the Austrian Alps and therewith facilitates their utilisation.

PCI 2.1, 3.1.1 and 3.1.2



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
212	Isar (DE)	St. Peter (AT)	New 400kV double circuit OHL Isar - St. Peter including new 400kV switchgears Altheim, Pirach, Simbach and St. Peter. Also including 4. circuit on line Ottenhofen - Isar.	2320	Design & Permitting	2018	Delayed	delayed due to long permitting process
216	St. Peter (AT)	Tauern (AT)	Completion of the 380kV-line St. Peter - Tauern. This contains an upgrade of the existing 380kV-line St. Peter - Salzburg from 220kV-operation to 380kV-operation and the erection of a new internal double circuit 380kV-line connecting the substations Salzburg and Tauern (replacement of existing 220kV-lines on optimized routes). Moreover the erection of the new substations Wagenham and Pongau and the integration of the substations Salzburg and Kaprun is planned.	1740	Design & Permitting	2020	Investment on time	In Sept. 2012 the application for granting the permission (EIA) was submitted to the relevant authorities. According to the experience of similar projects the commissioning is expected for 2020.
219	Westtirol (AT)	Zell-Ziller (AT)	Upgrade of the existing 220kV-line Westtirol - Zell-Ziller and erection of an additional 220/380kV-Transformer. Line length: 105km.	470	Planning	2021	Investment on time	The upgrade of the line and substation Westtirol is currently in the planning process.
689	Vöhringen (DE)	Westtirol (AT)	Upgrade of an existing overhead line to 380 kV, extension of existing and	585	Planning	2020	Investment on time	Progress as planned.

			erecting of new 380-kV-substations including 380/110-kV-transformers. Transmission route Vöhringen (DE) - Westtirol (AT). This project will increase the current power exchange capacity between the DE, AT.					

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
DE=>AT: 2900	AT=>DE: 2900	1	4	15-50km	15-25km	830-1400

CBA results	**for each scenario**				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[53;64]	0	[-450000;-370000]	[530;650]
Scenario Vision 2 - 2030	-	[110;140]	0	[-420000;-340000]	[390;480]
Scenario Vision 3 - 2030	-	[310;380]	[300000;360000] MWh	[-330000;-270000]	[-1500;-1300]
Scenario Vision 4 - 2030	-	[470;490]	[690000;850000] MWh	[-300000;-330000]	[-1300;-1500]

Additional comments

Comment on the security of supply:
The security of supply (SoS) indicator is to be understood in the way it is defined within the Cost Benefit Analysis methodology which focuses merely on the connection of partly isolated grid areas. In general in rather meshed parts of the transmission grids other aspects are more significant for the security of supply (e.g. n-1-margin, cascade effects, etc.) and therefore the project benefit indicator on SoS according to the CBA methodology underestimates the real value of the project. The considered project is vital for the Austrian SoS. It comprise an important part of the Austrian 380-kV-Security Ring, enforces the east-west connection in Tyrol and improves the connection to distribution grids.

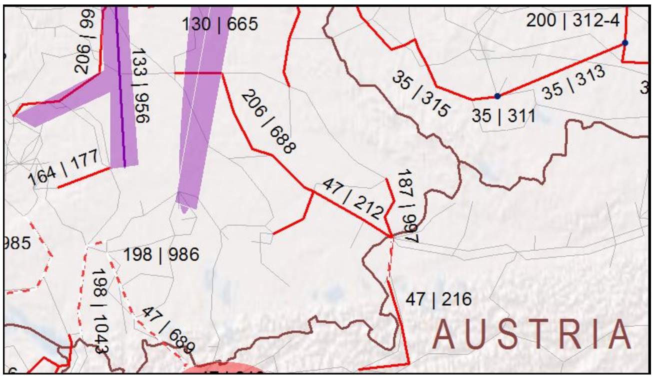
Comment on the RES integration:
The project supports the interaction of RES in Northern Europe (mainly in Germany) and in the eastern part of Austria with the pump storages in the Austrian Alps and therewith facilitates their utilisation.

Comment on the CO2 indicator: the very high scores reflect that the project enables a better use of RES (by bringing it to load centres or to and from storage facilities)

Project 187: St. Peter - Pleinting

Description of the project

Increase of the cross border transmission capacity by erecting a new 380kV line between St. Peter (Austria) and Pleinting (Germany). This leads to an improved connection of the very high amount of RES in Germany and the pump storages in the Austrian Alps.



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
997	Pleinting (DE)	St. Peter (AT)	new 380-kV-line Pleinting (DE) - St. Peter (AT) on existing OHL corridor	-	Under Consideration	2022	New Investment	new investment

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
AT=>DE: 1500	DE=>AT: 1500	1	3	Negligible or less than 15km	Negligible or less than 15km	130-190

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[13;16]	0	[-79000;-65000]	[140;170]
Scenario Vision 2 - 2030	-	[15;18]	[4400;5400] MWh	[-83000;-68000]	[560;680]
Scenario Vision 3 - 2030	-	[100;130]	[140000;170000] MWh	[-88000;-72000]	[-520;-420]
Scenario Vision 4 - 2030	-	[190;230]	[220000;260000] MWh	[-110000;-90000]	[-720;-590]

Additional comments

Comment on the RES integration:
The project supports the interaction of RES in Northern Europe (mainly in Germany) and in the eastern part of Austria with the pump storages in the Austrian Alps and therewith facilitates their utilisation.

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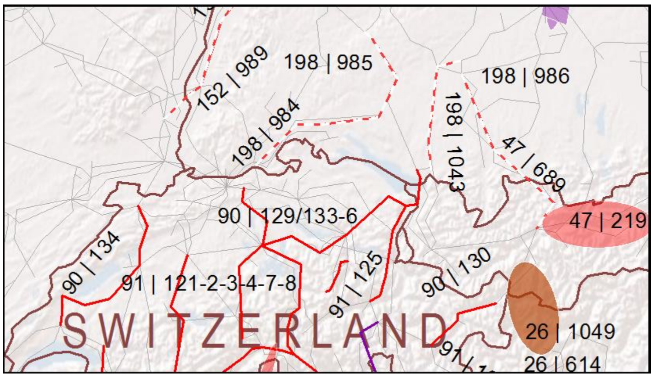
Project 198: Area of Lake Constance

Description of the project

The transmission capacity of the 380-kV-grid in this grid area and especially the cross-border lines between Germany and Austria are extended significantly by this project. Capacity overloads with existing lines are eliminated and therefore connection between the German and the Austrian transportation grid is strengthened.

PCI 2.11.2



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
136	Border area (DE-AT)	Rüthi (CH)	380 kV Rüthi – Meiningen and 380 kV Meiningen - Border Area AT-DE	1200	Planning	2022	Investment on time	Investment 136 now comprises the cross-border part of former investment 136, and investment 1099 is the Swiss part of former investment 136.
984	Herbertingen	Tiengen	Herbertingen – Tiengen: Between the two substations Herbertingen and Tiengen a new line will be constructed in an existing corridor. Enhancement of the grid, which will increase transmission capacity noticeably, is needed at the substation Herbertingen.	400	Planning	2020	Investment on time	Progress as planned. This project is a concretion of TYNDP12 project 44.A77. Due to the ongoing planning stage, this section was developed and an own investment item was created.
985	point Rommelsbach	Herbertingen	Rommelsbach – Herbertingen: Between point Rommelsbach and substation Herbertingen a new line will be constructed in an existing corridor. This will significantly increase transmission capacity (grid enhancement).	400	Planning	2018	Investment on time	Progress as planned. This project is a concretion of TYNDP12 project 44.A77. Due to the ongoing planning stage, this section was developed and an own investment item was created.
986	point Wullenstetten (DE)	point Niederwangen (DE)	Point Wullenstetten – Point Niederwangen Between point Wullenstetten and point Niederwangen an upgrade of an existing 380-kV-line is necessary (grid enhancement).	2000	Planning	2020	Investment on time	This project is a concretion of TYNDP 2012 project 44.A77. Due to the ongoing planning stage, this section was developed

			Thereby, a significantly higher transmission capacity is realized. The 380 kV substation station Dellmensingen is due to be extended (grid enhancement).					and an own investment item was created.
1043	Neuravensburg	border area (AT)	Point Neuravensburg – Point Austrian National border (AT) Between switching point Neuravensburg and Austrian National border (AT) a new line with a significantly higher transmission capacity will be constructed in an existing corridor (grid enhancement).	2000	Planning	2023	Investment on time	This project is a concretion of TYNDP 2012 project 44.A77. This investment is caused by the investment 136 "Bodensee Studie". Due to the ongoing planning stage, this section was developed and an own investment item was created.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
DE=>CH: 3400	CH=>DE: 1400	1	4	50-100km	Negligible or less than 15km	390-530

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[90;110]	0	[-99000;-81000]	[820;1000]
Scenario Vision 2 - 2030	-	[140;170]	0	[-140000;-110000]	[1900;2400]
Scenario Vision 3 - 2030	-	[310;380]	[450000;550000] MWh	[-91000;-75000]	[-1200;-950]
Scenario Vision 4 - 2030	-	[480;580]	[900000;1100000] MWh	[-180000;-150000]	[-2100;-1700]

Additional comments

Comment on the clustering: the project also takes advantage of investment items n°1100, depicted in the Regional investment plan.

Comment on the RES integration: avoided spillage concerns RES in Germany mostly.

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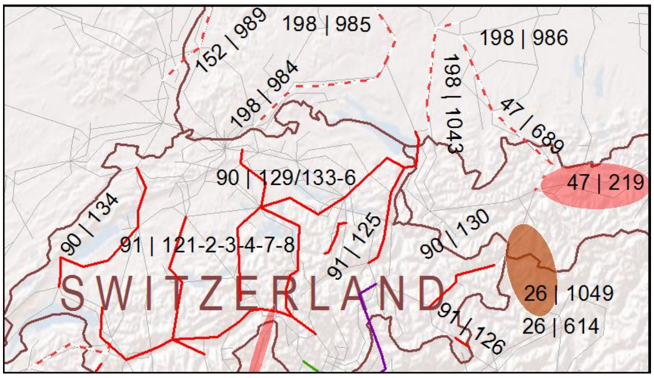
Project 90: Swiss Roof

Description of the project

This project increases the capacity between CH and its neighbours DE and AT. This enables to connect large renewable generation in Northern Europe to pump storage devices in the Alps, thus noticeably increasing the mutual balancing between both regions. Project 90 is completed by Project 198.

PCI 2.11.1



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
129	Beznau (CH)	Mettlen (CH)	Upgrade of the existing 65km double circuit 220kV OHL to 400kV.	800	Design & Permitting	2020	Delayed	Long permitting procedure (comprising several phases). In this case, Federal Court decision for partial cabling.
130	La Punt (CH)	Pradella / Ova Spin (CH)	Installation of the second circuit on existing towers of a double-circuit 400kV OHL (50km).	650	Planning	2017	Investment on time	Progress as planned.
133	Bonaduz (CH)	Mettlen (CH)	Upgrade of the existing 180km double circuit 220kV OHL into 400kV.	340	Under Consideration	2020	Investment on time	Progress as planned.
134	Bassecourt (CH)	Romanel (CH)	Construction of different new 400kV line sections and voltage upgrade of existing 225kV lines into 400kV lines; total length: 140km. Construction of a new 400/220 kV substation in Mühleberg (= former investment 132 'Mühleberg Substation')	660	Design & Permitting	2020	Delayed	lines: long permitting procedure (comprising several phases)- Mühleberg substation: under construction
136	Border area (DE-AT)	Rüthi (CH)	380 kV Rüthi – Meiningen and 380 kV Meiningen - Border Area AT-DE	1200	Planning	2022	Investment on time	Investment 136 now comprises the cross-border part of former investment 136, and investment 1099 is the Swiss part of former investment 136.

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1099	Rüthi	Bonaduz - Grynau	Rüthi - Grynau 2 x 380 kV Rüthi - Bonaduz 1 x 380 kV	1200	Planning	2022	Investment on time	Investment 136 now comprises the cross-border part of former investment 136, and investment 1099 is the Swiss part of former investment 136.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
upstream=>upstream: 0	upstream=>upstream: 0	1	4	Negligible or less than 15km	Negligible or less than 15km	490

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[90;110]	0	[-200000;-160000]	[820;1000]
Scenario Vision 2 - 2030	-	[140;170]	0	[-270000;-220000]	[1900;2400]
Scenario Vision 3 - 2030	-	[310;380]	[450000;550000] MWh	[-180000;-150000]	[-1200;-950]
Scenario Vision 4 - 2030	-	[480;580]	[900000;1100000] MWh	[-360000;-300000]	[-2100;-1700]

Additional comments

Comment on the GTC:
GTC increases, Vision 1, 2, 3 and 4 2030

DE>CH: 3400 MW
AT>CH: 1000 MW
CH>DE: 1400 MW
CH>AT: 1000 MW

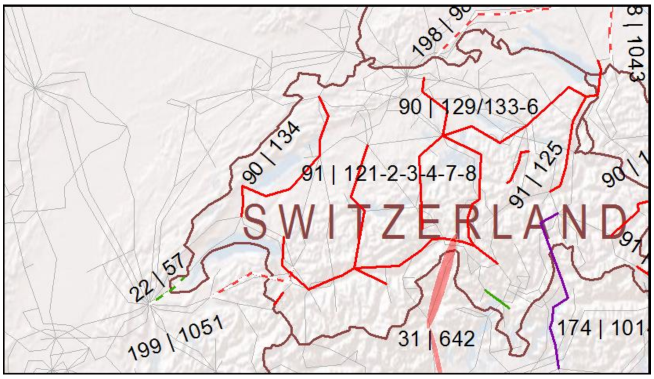
Comment on the RES integration: avoided spillage concerns RES in Germany mostly

Comment on the CO2 indicator: the very high scores reflect that the project enables a better use of RES (by bringing it to load centres or to and from storage facilities)

Project 22: Lake Geneva West

Description of the project

The project will increase the France-Switzerland cross-border capacity and secure the supply to Geneva by uprating the existing 225kV cross-border line Genissiat (FR)-Verbois (CH).



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
57	Genissiat (FR)	Verbois (CH)	Reconductoring of the existing 225kV double circuit line Genissiat-Verbois with high temperature conductors.	-	Planning	2020	Investment on time	Progress as planned.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
FR=>CH: 500	CH=>FR: 200	1	3	Negligible or less than 15km	Negligible or less than 15km	8-12

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[3;4]	0	[9000;11000]	0
Scenario Vision 2 - 2030	-	[4;5]	0	[9000;11000]	0
Scenario Vision 3 - 2030	-	[27;33]	[16000;19000] MWh	[9000;11000]	[-190;-160]
Scenario Vision 4 - 2030	-	[72;89]	[90000;110000] MWh	[23000;28000]	[-510;-420]

Additional comments

Comment on the RES integration: avoided spillage concerns RES in France mostly.

Comment on the S1 and S2 indicators: by definition, the reconductoring implies no new route, hence the indicators value is negligible.

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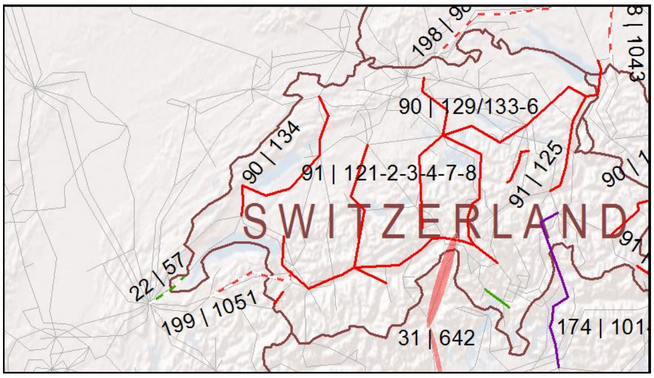
Project 199: Lake Geneva South

Description of the project

This project comes on top of the Lake Geneva West project and will further increase the France-Switzerland cross-border capacity by upgrading to 400 kV the existing 225kV line south of Lake Geneva; some grid restructuration in Genissiat area will allow taking full benefit of this new axis. Main benefits are expected in terms of market integration and better integration of Swiss hydro generation, especially storage.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
1051	CORNIER (FR)	CHAVALON (CH)	Upgrade of the double circuit 225 kV line between Cornier (France) and Riddes and Saint Triphon (Switzerland) to a single circuit 400 kV line between Cornier and Chavalon (Switzerland). In order to take most benefit from this, the existing 400 kV Genissiat substation will be connected in/out to the existing line Cornier-Montagny.	-	Under Consideration	2025	New Investment	grid studies conducted after TYNDP2012 release allowed to define the investment

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	GTC direction 2 (MW)	B6 Technical Resilience	B7 Flexibility	S1 - protected areas	S2 - urban areas	C1 Estimated cost (Meuros)
FR=>CH: 1000	CH=>FR: 1500	0	3	NA	NA	110-140

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[8;9]	0	[-39000;-32000]	[-130;-100]
Scenario Vision 2 - 2030	-	[7;8]	0	[-37000;-31000]	[700;860]
Scenario Vision 3 - 2030	-	[63;77]	[36000;44000] MWh	[-33000;-27000]	[-430;-350]
Scenario Vision 4 - 2030	-	[150;180]	[180000;220000] MWh	[9000;11000]	[-1000;-840]

Additional comments

Comment on the RES integration: avoided spillage concerns RES in France mostly.

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

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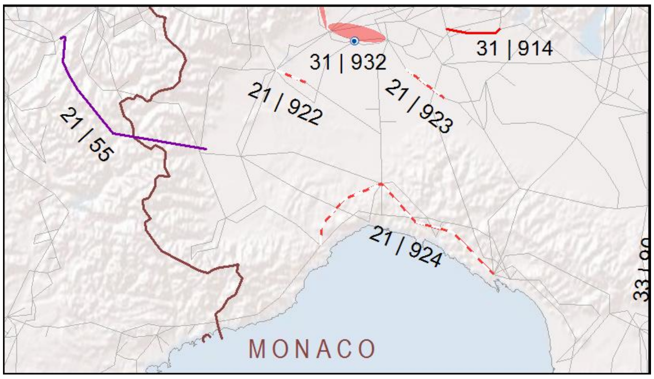
Project 21: Italy-France

Description of the project

The Project comprises a new HVDC interconnection between France and Italy as well as the removing of limitations on existing 380 kV internal Italian lines. The removing of limitation is necessary to take full advantage of the increase of interconnection capacity provided by the cross-border line. The project favours the market integration between Italy and France as well as the use of the most efficient generation capacity; it also increases possible mutual support of both countries. In addition, the project can contribute to RES integration in the European interconnected system by improving cross border exchanges. Such benefits are ensured within different future scenarios.

PCI 2.5.1



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
55	Grande Ile (FR)	Piossasco (IT)	"Savoie - Piémont" Project : New 190km HVDC (VSC) interconnection FR-IT via underground cable and converter stations at both ends (two poles, each of them with 600MW capacity). The cables will be laid in the security gallery of the Frejus motorway tunnel and also along the existing motorways' right-of-way.	1200	Under Construction	2019	Delayed	After some delay in the works of the Frejus service gallery of the motorway, in which the cables will be installed, the project timeline has been updated. Works are already in progress.
922	Rondissone (IT)	Trino (IT)	Removing limitations on the existing 380 kV Rondissone-Trino	300	Planning	2019	New Investment	The item contributes to get the full advantage of the new HVDC cables was planned for the first time in the Italian National Development Plan 2013
923	Lacchiarella(IT)	Chignolo Po(IT)	Removing limitations on the existing 380 kV Lacchiarella-Chignolo Po	300	Planning	2019	New Investment	The item contributes to get the full advantage of the new HVDC cables was planned for the first time in the Italian National Development Plan 2013

924	Vado (IT)	La Spezia (IT)	Removing limitations on the existing 380 kV Vado-Vignole and Vignole-Spezia	300	Planning	2019	New Investment	The item contributes to get the full advantage of the new HVDC cables was planned for the first time in the Italian National Development Plan 2013

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
FR=>IT: 1200	IT=>FR: 1000	1	4	Negligible or less than 15km	Negligible or less than 15km	1100-1300

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[43;53]	0	[250000;310000]	[220;260]
Scenario Vision 2 - 2030	-	[29;36]	0	[250000;300000]	0
Scenario Vision 3 - 2030	-	[94;120]	[49000;60000] MWh	[8100;9900]	[-440;-360]
Scenario Vision 4 - 2030	-	[190;230]	[290000;350000] MWh	[36000;44000]	[-1200;-970]

Additional comments

Comment on the security of supply: the new HVDC cable link can help to reduce risks of energy not supplied mainly in northern Italy.

Comment on the RES integration:
Benefits in terms of RES integration are possible even in V1 and V2 because the new interconnection improves the balance capacity of the system. This kind of benefits is not captured in all visions by market simulations because it is sometimes beyond the accuracy of the tool. Avoided spillage concerns RES in France and Italy mostly.

Comment on the Losses indicator: The flows on the Italian North border (Import of Italy) are more often very high in Visions 1 and 2 compared to Vision 3 and 4.

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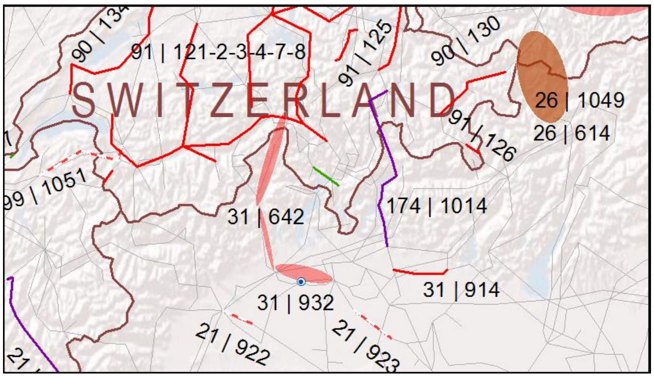
Project 31: Italy-Switzerland

Description of the project

The project consists of a new 400 kV line San Giacomo-Pallanzeno, conversion from AC to DC of the 220 kV line, including the realization of the 2 AC/DC converter stations and 220 kV to 400 KV substation upgrade.
Additional internal lines in Italy and in Switzerland are required to get full advantage from the interconnection capacity provided by the cross-border line. The project significantly increases interconnection capacity between Switzerland and Italy; favours the market integration; helps to use of the most efficient generation capacity and could potentially contribute to RES integration. Such benefits are assured according to different future scenarios.

PCI 2.15.1 and 2.15.2



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
124	Mettlen (CH)	Airolo (CH)	Upgrade of existing 225kV OHL into 400kV. Line length: 90km.	750	Under Consideration	2020	Investment on time	Progress as planned.
642	Airolo (CH)	Pallanzeno(IT)-Baggio(IT)	New interconnection project between Italy and Switzerland;	1000	Design & Permitting	2022	Investment on time	permitting process started on the Italian side since September 2012
914	Cassano (IT)	Chiari (IT)	Upgrade to 380 kV of part of existing 220 kV Cassano Ric.Ovest	500	Design & Permitting	2022	New Investment	The interconnection scheme envisaged in TYNDP 2012 is now defined. The upgrade of Chiari-Cassano is identified as critical to get full advantage of the Giacomo project.
932	Magenta(IT)		new 400 kV section in Magenta substation	1000	Design & Permitting	2020	Investment on time	HVDC link between Pallanzeno and Baggio will be realized using existing 220 kV line connecting the Magenta 220/132 kV substation. Consequently, a new 400 kV section will be needed to reconnect the Magenta substation to

								the 400 kV line Turbigo – Baggio

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
CH=>IT: 1000	IT=>CH: 950	1	4	Negligible or less than 15km	Negligible or less than 15km	1080

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[26;31]	0	[230000;290000]	[190;230]
Scenario Vision 2 - 2030	-	[32;39]	0	[230000;290000]	[-340;-280]
Scenario Vision 3 - 2030	-	[26;31]	0	[17000;21000]	0
Scenario Vision 4 - 2030	-	[54;66]	0	[50000;61000]	[-140;-120]

Additional comments

Comment on the RES integration:
Additional benefits in terms of RES integration are possible because the new interconnection improves the balance capacity of the system. This kind of benefits is not captured by market simulations because it is lower than the sensibility threshold of the tool

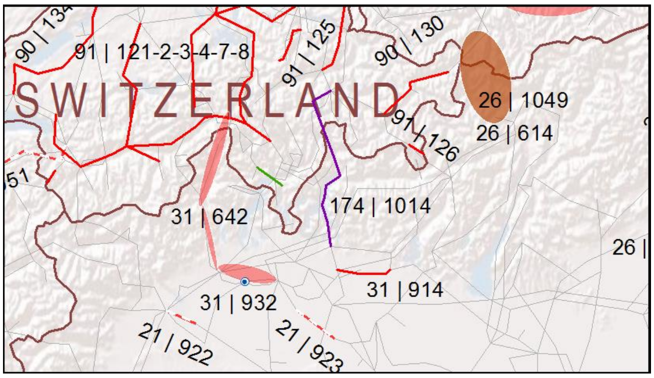
Comment on the Losses indicator: The flows on the Italian North border (Import of Italy) are more often very high in Visions 1 and 2 compared to Vision 3 and 4.

Project 174: Greenconnector

Description of the project

Project promoted by Worldenergy.
The projects consists of a new HVDC interconnection between Italy and Switzerland which will increase the transmission capacity between the two countries. The project, promoted by non-ENTSO-E member, could potentially contribute to market and RES integration in the future European interconnected system.

PCI 2.14



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
1014	Verderio (I)	Sils (CH)	New +/- 400 kV DC cable and subsea link between Switzerland and Italy. Very short AC cable (380 kV) between the site of the converter station and the substation of Sils i.D.	-	Design & Permitting	2018	New Investment	Project application to TYNDP 2014.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
CH=>IT: 800	IT=>CH: 800	1	3	Negligible or less than 15km	Negligible or less than 15km	500

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[19;24]	0	[-20000;-16000]	[170;210]
Scenario Vision 2 - 2030	-	[17;20]	0	[-24000;-20000]	[-500;-410]
Scenario Vision 3 - 2030	-	[18;23]	0	[1800;2200]	0

Scenario Vision 4 - 2030	-	[42;51]	0	[-17000;-14000]	[-120;-99]

Additional comments

Comment on the CBA assessment: costs figures have not been provided to ENTSO-E.

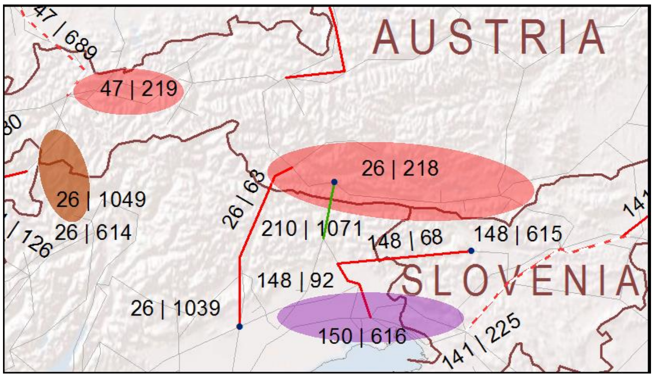
Comment on the RES integration:
Additional benefits in terms of RES integration are possible because the new interconnection improves the balance capacity of the system. This kind of benefits is not captured by market simulations because it is lower than the sensibility threshold of the tool

Project 26: Austria - Italy

Description of the project

Reinforcement of the interconnection between Italy and Austria via two new single circuit cross-border lines and closure of the 380-kV-Security Ring in Austria. The project supports the interaction between the RES in Italy and the eastern part of Austria with the pump storage power plants in the Austrian Alps.

PCI 3.3, 3.2.1 and 3.2.2



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
63	Lienz (AT)	Veneto region (IT)	The project foresees the reconstruction of the existing 220kV-interconnection line as 380kV-line on an optimized route to minimize the environmental impact. Total length should be in the range of approx. 140km.	800	Planning	2023	Investment on time	Planning in progress coordinated between TERNA and APG
218	Obersielach (AT)	Lienz (AT)	New 380kV OHL connecting the substations Lienz (AT) and Obersielach (AT) to close the Austrian 380kV-Security Ring in the southern grid area. Line length: 190km.	320	Under Consideration	2023	Investment on time	Progress as planned.
614	Nauders (AT)	Glorenza (IT)	interconnector IT-AT (phase 1)	300	Design & Permitting	2018	Investment on time	Progress as planned.
1039	Volpago (IT)		New 380/220/132 kV substation with related connections to 380 kV Sandrigo Cordignano and 220 KV Soverzene Scorzè where removing limitations are planned	800	Planning	2020	Delayed	The Volpago Substation was included in the TYNDP 2012 as part of the item 26.83 which had as commissioning date 2015. Permitting process delayed due to territorial constraint
1049	tbd (IT)	tbd (AT)	interconnector IT-AT (phase 2)	350	Under Consideration	2023	New Investment	project progress

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
AT=>IT: 1450	IT=>AT: 1350	1	4	Negligible or less than 15km	Negligible or less than 15km	780-1180

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[57;70]	0	[-510000;-410000]	[520;640]
Scenario Vision 2 - 2030	-	[89;110]	[2700;3300] MWh	[-520000;-420000]	[-490;-400]
Scenario Vision 3 - 2030	-	[56;69]	[1100;1300] MWh	[-200000;-160000]	[-130;-100]
Scenario Vision 4 - 2030	-	[100;130]	[11000;14000] MWh	[-280000;-230000]	[-300;-240]

Additional comments

Comment on the security of supply:
The security of supply (SoS) indicator is to be understood in the way it is defined within the Cost Benefit Analysis methodology which focuses merely on the connection of partly isolated grid areas. In general in rather meshed parts of the transmission grids other aspects are more significant for the security of supply (e.g. n-1-margin, cascade effects, etc.) and therefore the project benefit indicator on SoS according to the CBA methodology underestimates the real value of the project. The considered project is vital for the Austrian SoS. It comprises an important part of the Austrian 380-kV-Security Ring, enforces the east-west connection in Carinthia and improves the connection to distribution grids.

Comment on the RES integration:
The considered project improves the transport of renewable energy from Italy and the eastern part of Austria to the alpine pump storage power plants. This leads to a better utilisation of the RES generation. Avoided spillage concerns also RES in Germany.

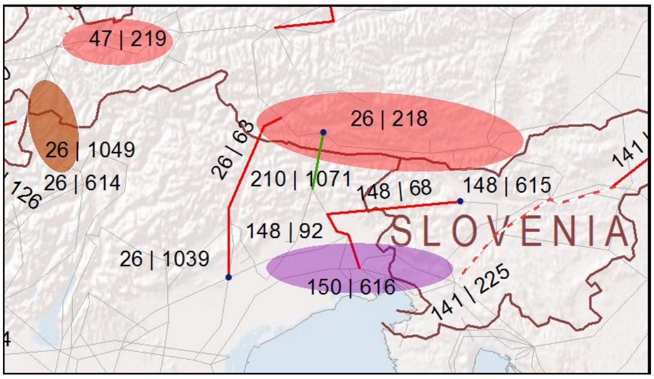
Comment on the Losses indicator: The flows on the Italian North border (Import of Italy) are more often very high in Visions 1 and 2 compared to Vision 3 and 4.

Project 210: E15

Description of the project

A 3rd party project promoted by Alpe Adria Energia SpA - planned 220kV line from Würmlach (Austria) to Somplago (Italy).

PCI 3.4



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
1071	Würmlach (AT)	Somplago (IT)	Würmlach - Somplago	-	Design & Permitting	2017	New Investment	Project application to TYNDP 2014.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
AT=>IT: 150	IT=>AT: 150	1	3	Negligible or less than 15km	Negligible or less than 15km	45-75

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[4;5]	0	[-13000;-11000]	0
Scenario Vision 2 - 2030	-	[9;11]	0	[-13000;-11000]	0
Scenario Vision 3 - 2030	-	[2;3]	0	[-2600;-2200]	0
Scenario Vision 4 - 2030	-	[5;6]	0	[-3600;-3000]	0

Additional comments

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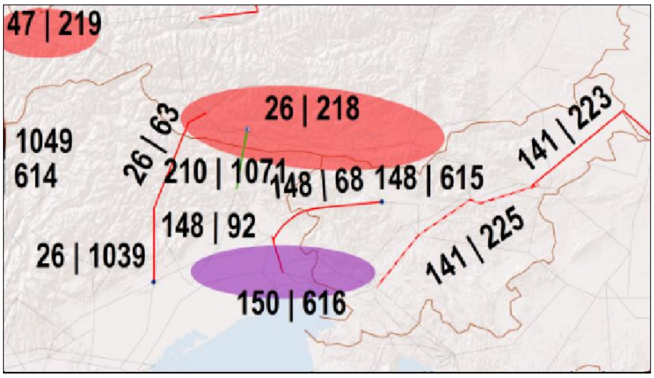
Project 148: CCS new

Description of the project

The project consists in the new 400 kV overhead cross-border line Udine – Okroglo, including a phase-shifter in the Okroglo substation in Slovenia and the 400 kV internal line in Italy. The internal reinforcements are necessary to allow the realization of the interconnection and to take full advantage of the increase of cross-border capacity. The project increases the transmission capacities between Slovenia and Italy and allows stronger market integration between Italy and Slovenia and broader region. Such benefits are ensured according to different future scenarios. The project improves reliability and security of supply by allowing mutual support of both countries. PCI project.

PCI 3.20



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
68	Okroglo (SI)	South Udine (IT)	New 120km double circuit 400kV OHL between Okroglo(SI) and future substation of South Udine (IT) with PST in Okroglo. The thermal rating will be 1870 MVA per circuit.	800	Planning	2021	Investment on time	There are some issues with social acceptance and territorial constraints. End of construction works are planned by the end of 2021.Full operation is expected by end of 2021(beginning of 2022).
92	West Udine (IT)	Redipuglia (IT)	New 40km double circuit 400kV OHL between the existing substations of West Udine and Redipuglia, providing in and out connection to the future 400kV substation of South Udine.	600	Under Construction	2016	Delayed	Permitting only recently completed (March 2013) and construction work had to be rescheduled accordingly. Note that the expected commissioning date for the project is December 2016
615	Okroglo (SI)		Installation of a new 400kV PST in Okroglo which is a part of a double 400 kV OHL Okroglo (SI)-Udine (IT).	800	Planning	2021	Investment on time	End of construction works are planned by the end of 2021. Full operation is expected by end of 2021 (beginning of 2022).

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	GTC direction 2 (MW)	B6 Technical Resilience	B7 Flexibility	S1 - protected areas	S2 - urban areas	C1 Estimated cost (Meuros)
SI=>IT: 800	IT=>SI: 350	1	4	More than 100km	15-25km	420

CBA results	for each scenario				
Scenario	B1 SoS (MWh/year)	B2 SEW (MEuros/year)	B3 RES integration	B4 Losses (MWh/yr)	B5 CO2 Emissions (kT/year)
Scenario Vision 1 - 2030	-	[23;28]	0	[-110000;-90000]	[220;270]
Scenario Vision 2 - 2030	-	[49;60]	0	[-140000;-120000]	[-260;-210]
Scenario Vision 3 - 2030	-	[15;18]	0	[-41000;-33000]	[0;1]
Scenario Vision 4 - 2030	-	[18;23]	0	[-260000;-220000]	0

Additional comments

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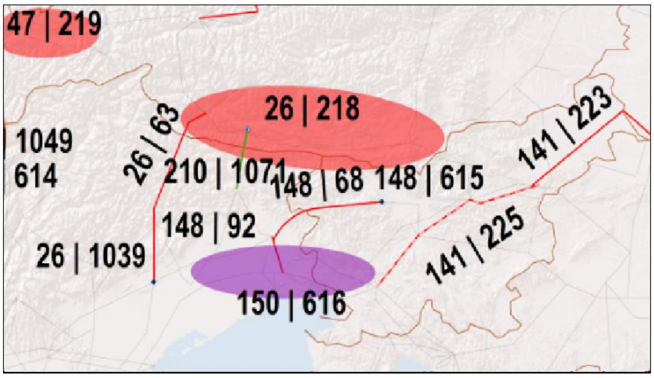
Project 150: CCS new 10

Description of the project

The project consists in a new HVDC link between Salgareda (Italy) and Divača\Beričevo (Slovenia) which will strengthen the connection between Slovenia and Italy. The project increases the transmission capacity between Slovenia and Italy and allows stronger market integration between Italy and Slovenia and broader region. Such benefits are ensured according to different future scenarios. The project could also improve the reliability and security of supply by allowing mutual support of both countries. PCI project 3.21.



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
616	Slovenia (SI)	Salgareda (IT)	New HVDC link between Italy and Slovenia.	-	Under Consideration*	2022	Investment on time	Project is under feasibility study*.

* The project is under permitting on the Italian side since 2012. The status under consideration refers only to the Slovenian side, where some project feasibility study is still in progress.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
SI=>IT: 800	IT=>SI: 700	1	3	NA	NA	870

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[22;27]	0	[1800;2200]	[220;270]
Scenario Vision 2 - 2030	-	[49;60]	0	[900;1100]	[-230;-190]

Scenario Vision 3 - 2030	-	[15;18]	0	[3600;4400]	[12;15]
Scenario Vision 4 - 2030	-	[19;24]	0	0	0

Additional comments

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

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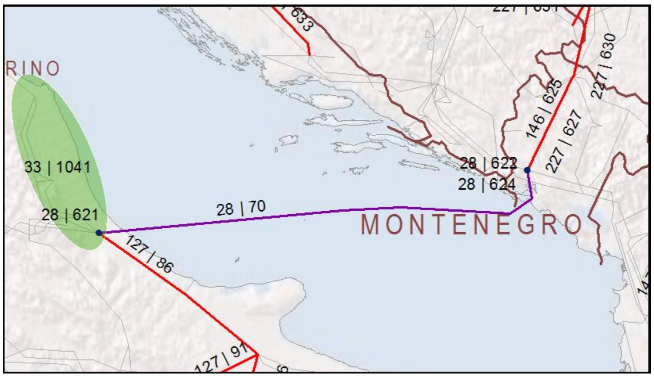
Project 28: 28

Description of the project

The Italy-Montenegro interconnection project includes a new HVDC subsea cable between Villanova (Italy) and Lastva (Montenegro) and the DC converter stations. The project is also correlated to cluster 146 where Montenegrin internal line and Montenegro- Serbia-Bosnia interconnections are planned. The project allows the market development between Italy and the Balkans; increases the transmission capacities; helps to use most efficient generation capacity; enables possible mutual support of Italian and Balkan power systems; contributes to RES integration in the European interconnected system by improving cross border exchanges. Such benefits are ensured within different future scenarios.

PCI 3.19.1



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
70	Villanova (IT)	Lastva (ME)	New 1000MW HVDC interconnection line between Italy and Montenegro via 375km 500kV DC subsea cable and converter stations at both ending points.	1000	Under Construction	2017	Delayed	rescheduling of work due to further secondary permitting during land rights acquisition and construction phase
621	Villanova (IT)		Converter station of the new 1000MW HVDC interconnection line between Italy and Montenegro via 375km 500kV DC subsea cable.	1000	Under Construction	2017	Delayed	rescheduling of work due to further secondary permitting during land rights acquisition and construction phase
622	Lastva (ME)		Converter station in Montenegro of the new 1000MW HVDC sub-sea 500 kV cable between Italy and Montenegro.	1000	Under Construction	2017	Delayed	rescheduling of work due to further secondary permitting during land rights acquisition and construction phase
624	Lastva (ME)		New 400 kV substation Lastva in Montenegro will be connected to the existing line 400kV Podgorica 2(ME)-Trebinje (BA), with two transformers 2X300MVA 400/110kV. This substation will enable secure supply of the	1000	Design & Permitting	2015	Investment on time	Progress as planned.

			Montenegrin coastal network, and connection of the convertor station for the HVDC cable between Montenegro and Italy.					

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
IT=>ME: 1000	ME=>IT: 1000	1	3	Negligible or less than 15km	Negligible or less than 15km	1130

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[140;170]	[13000;15000] MWh	[-18000;-14000]	[1400;1700]
Scenario Vision 2 - 2030	-	[110;130]	0	[-18000;-14000]	[1100;1300]
Scenario Vision 3 - 2030	-	[290;360]	[330000;410000] MWh	[1800;2200]	[-650;-530]
Scenario Vision 4 - 2030	-	[290;350]	[990000;1200000] MWh	[3600;4400]	[-1700;-1400]

Additional comments

Comment on the RES integration: benefits in terms of RES integration are possible even in Vision 2 because the new interconnection improves the balance capacity of the system. This kind of benefits is not captured in all visions by market simulations because it is sometimes beyond the accuracy of the tool. Avoided spillage concerns mainly RES in the Italian and Balkan peninsulas.

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Transbalkan Corridor

Description of the corridor

The “Transbalkan Corridor” is splitted into two projects (146, 227), representing its 2 phases spanning from 2015 to 2020.
Accompanying the new HVDC 400 kV cable between Montenegro and Italy (project 28), the reinforcement strategy along the corridor aims at supporting the increase of power transfers from north-west towards south-east part of this area and enabling further market integration. Investments which form this cluster are located on the territory of three countries: Serbia, Bosnia and Hertzegovina, Montenegro.
The two projects have been assessed as a whole and share the same common assessment.

Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
Project 146								
625	Lastva (ME)	Pljevlja (ME)	Reinforcement of the Montenegrin internal 400 kV transmission network with new 160 km double circuit 400kV AC OHL between existing substation Pljevlja and new substation Lastva. The investment will enable secure supply of Montenegrin power system and power transits directed to new HVDC link towards Italy. Also, this investment will enable connection of Renewable energy sources along its route.	1095	Design & Permitting	2016	Investment on time	Progress as planned.
1075	Kragujevac	Kraljevo	New internal 400 kV OHL will connect existing SS Kragujevac with SS Kraljevo which is planned for upgrade to 400 kV voltage level. This investment will enhance the possibility of energy transits in direction north-east to south-west and east to west.	1095	Design & Permitting	2018	Delayed	New axis for transits from East to the West, typically from Bulgaria to Bosnia and Montenegro, and further to the west.

1076	Kraljevo		Upgrade of the existing 220/110kV substation Kraljevo 3 by constructing the 400 kV level.	1095	Design & Permitting	2017	Delayed	This upgrade is required for the construction of new 400 kV OHL Kragujevac - Kraljevo which will increase local security of supply and power transfer from Eastern to Western part of region.
Project 227								
627	Bajina Basta (RS)	Visegrad (BA)	Description of broader context - New double circuit 400kV OHL connecting existing substation Pljevlja (ME) and substation Bajina Basta (RS) and new double circuit 400kV OHL connecting existing substation Visegrad (BA) and substation Bajina Basta (RS). In the first phase one 400 kV circuit would be equiped. In the second phase New SS Bistrica (RS) would be connected to the exisitng double circuit 400 kV OHL between SS Bajina Basta (RS), SS Visegrad (BA) and SS Pljevlja (ME). Part of regional transmission corridor northeast-southwest.	500	Planning	2020	Investment on time	Ongoing Regional trilateral feasibility study (financed by WBIF and supported by EC) between three TSOs (EMS, NOS BiH and CGES), including ESIA and preliminary design. Expected finalization time mid 2014.
628	SS Bajina Basta (RS)	SS Obrenovac (RS)	Double circuit 400 kV OHL between upgraded substation Bajina Basta and substation Obrenovac. Part of larger regional transmission corridor northeast-southwest.	500	Design & Permitting	2019	Delayed	Feasibility study, ESIA and preliminary design finalized (financed by WBIF and supported by EC). Ongoing process of adoption to local legislation needs.
630	Bajina Basta (RS)	Pljevlja (ME)	Description of broader context - New double circuit 400kV OHL (105km RS + 16km ME) connecting existing substation Pljevlja (ME) and substation Bajina Basta (RS) and new double circuit 400kV OHL connecting existing substation Visegrad (BA) and substation Bajina Basta (RS). In the first phase one 400 kV circuit would be equiped. In the second phase New SS Bistrica (RS) would be connected to the exisitng double circuit 400 kV OHL between SS Bajina Basta (RS), SS Visegrad (BA) and SS Pljevlja (ME). Part of regional transmission corridor northeast-southwest.	500	Planning	2020	Investment on time	Ongoing Regional trilateral feasibility study (financed by WBIF and supported by EC) between three TSOs (EMS, NOS BiH and CGES), including ESIA and preliminary design. Expected finalization time mid 2014.
631	Bajina Basta (RS)		Upgrade of existing 220/110 kV substation in Bajina Basta to 400/220/110 kV substation as part of overall western Serbia system upgrade to 400 kV voltage level. Part of larger regional transmission corridor northeast-southwest.	500	Design & Permitting	2019	Delayed	Feasibility study, ESIA and preliminary design finalized (financed by WBIF and supported by EC). Ongoing process of adoption to local legislation needs.

CBA results

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The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
East=>West: 1095	West=>East: 1095	1	4	Negligible or less than 15km	Negligible or less than 15km	85

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[330;410]	1000 MW	[-440000;-360000]	[500;620]
Scenario Vision 2 - 2030	-	[450;550]	1000 MW	[-740000;-610000]	[-3700;-3000]
Scenario Vision 3 - 2030	-	[280;340]	1000 MW	[-660000;-540000]	[-730;-590]
Scenario Vision 4 - 2030	-	[620;760]	1000 MW	[-390000;-320000]	[-4400;-3600]

Additional comments

Comment on the RES integration: the project helps connecting directly or indirectly about 1000 MW in the Balkan peninsula.

Project 136: CSE1

Description of the project

The project in Croatia include a new 400 kV OHL replacing the aging 220 kV OHL between existing substations Brinje and Konjsko, interdepending with the construction of two new 400/(220)/110 kV substations Brinje and Lika. The new 400 kV interconnection BanjaLuka (BA)-Lika (HR) will support market and RES integration in the area – South and Mid Croatia and North and Mid Bosnia and Herzegovina. The increased transfer capacity will enable higher diversity of supply&generation sources and routes, increasing resilience and flexibility of the transmission network.

PCI 3.5

Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
227	Banja Luka (BA)	Lika (HR)	New 400kV interconnection line between BA and HR	504	Under Consideration	2021	Rescheduled	Feasibility study is expected to be launched.
617	Lika(HR)	Brinje(HR)	New 55 km single circuit 400 kV OHL replacing aging 220 kV overhead line	215	Planning	2020	Investment on time	Feasibility study is expected to be launched.
618	Lika(HR)	Velebit(HR)	New 60 km single circuit 400 kV OHL replacing aging 220 kV overhead line	215	Planning	2020	Investment on time	Feasibility study is expected to be launched.
619	Lika (HR)		New 400/110 kV substation, 2x300 MVA	215	Planning	2018	Delayed	Feasibility study is expected to be launched.
620	Brinje (HR)		New 400/220 kV substation, 1x400 MVA	215	Planning	2020	Investment on time	Feasibility study is expected to be launched.
633	Konjsko(HR)	Velebit(HR)	New 100km single circuit 400 kV OHL replacing ageing 220 kV overhead line	215	Planning	2020	Investment on time	Feasibility study is expected to be launched.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
HR=>BA: 612	BA=>HR: 594	1	4	Negligible or less than 15km	15-25km	150

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[50;61]	830 MW	[9900;12000]	[-320;-260]
Scenario Vision 2 - 2030	-	[130;160]	830 MW	[-110000;-89000]	[-300;-240]
Scenario Vision 3 - 2030	-	[420;510]	900 MW	[-5300;-4300]	[-2700;-2200]
Scenario Vision 4 - 2030	-	[270;330]	900 MW	[8100;9900]	[-2300;-1900]

Additional comments

Comment on the RES integration: avoided spillage concerns RES in the Balkan peninsula.

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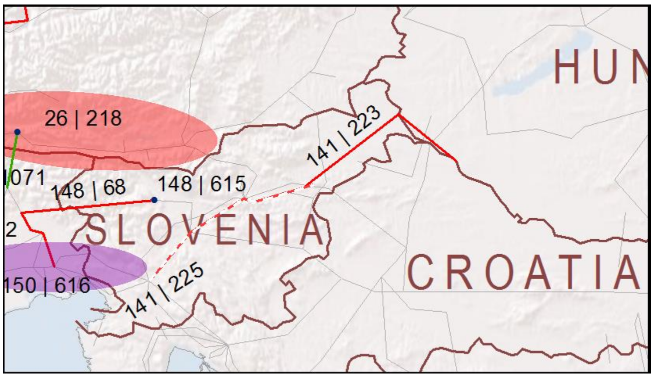
Project 141: CSE3

Description of the project

The project consists of a new double circuit 400 kV line Cirkovce-Pince and a new 400 kV Cirkovce substation (Slovenia) by which a new connection to one circuit of the existing double circuit interconnection line between Hungary and Croatia will be made, thus creating two new cross border interconnection between Slovenia and Hungary and between Slovenia and Croatia. Existing 220 kV lines of the corridor Cirkovce-Divaca will be upgraded to 400 kV level. PCI project 3.9



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
223	Cirkovce (SI)	Heviz (HU) Zerjavenec (HR)	The existing substation of Cirkovce(SI) will be connected to one circuit of the existing Heviz(HU) -Zerjavinec(HR) double circuit 400kV OHL by erecting a new 80km double circuit 400kV OHL in Slovenia. The project will result in two new cross-border circuits: Heviz (HU)-Cirkovce (SI) and Cirkovce (SI)-Žerjavenec (HR).	1085	Design & Permitting	2016	Investment on time	Progresses as planned.
225	Divaca (SI)	Cirkovce (SI)	Upgrading 220kV lines to 400kV in corridor Divaca-Klece-Bericevo-Podlog-Cirkovce.	800	Design & Permitting	2020	Investment on time	Progresses as planned.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
HU=>SI: 765	SI=>HU: 1085	0	4	More than 100km	15-25km	240-360

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[42;51]	0	[-120000;-95000]	[-200;-160]
Scenario Vision 2 - 2030	-	[40;49]	0	[-460000;-370000]	[-44;-36]
Scenario Vision 3 - 2030	-	[480;580]	0	[-240000;-190000]	[-3800;-3100]
Scenario Vision 4 - 2030	-	[300;370]	0	[-190000;-150000]	[-1700;-1400]

Additional comments

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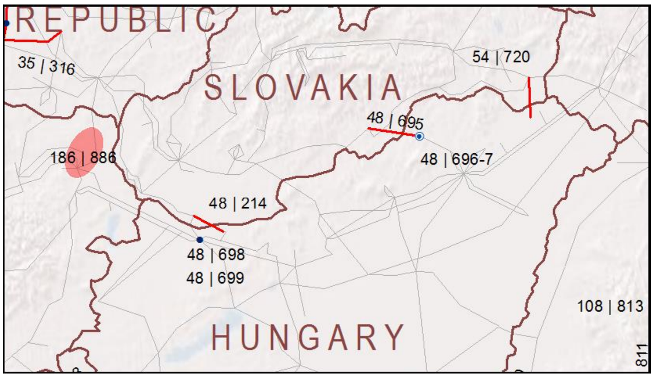
Project 48: New SK-HU intercon. - phase 1

Description of the project

This project will increase the transfer capacity between Slovak and Hungarian transmission systems, improve security and reliability of operation both transmission systems and support North - South RES power flows in CCE region. Main investments of this project are double circuit 400 kV line from new Gabcikovo (Slovakia) substation to Gönyű (Hungary) substation and double circuit 400 kV line from Rimavska Sobota (Slovakia) substation to Sajóivánka (Hungary) substation.

PCI 3.16 and 3.17



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
214	Gabcikovo (SK)	Gonyü area (HU)	New interconnection (new 2x400 kV tie-line) between SK and HU starting from Gabčíkovo substation (SK) to the Gőnyü substation on Hungarian side (preliminary decision). Project also includes the erection of new switching station Gabčíkovo next to the existing one.	1000	Planning	2018	Delayed	Expected commission date postponed on 2018 by reason of difficulties associated with finding the common national border crossing point.
695	Rimavská Sobota (SK)	Sajóivánka (HU)	Connection of the two existing substations (R.Sobota (SK) - Sajoóivánka (HU)) by the new 2x400 kV line (preliminary armed only with one circuit).	800	Planning	2018	Delayed	Expected commission date postponed on 2018 by reason of difficulties associated with finding the common national border crossing point.
696	Sajóivánka (HU)		2x70 Mvar shunt reactors in station Sajóivánka (HU)	800	Planning	2018	Delayed	Expected commission date postponed to 2018 as a result of negotiations between SEPS and MAVIR.
697	Sajóivánka (HU)		Second 400/120 kV transformer in station Sajóivánka (HU)	800	Planning	2018	Delayed	Expected commission date postponed to 2018 as a result of negotiations between SEPS and MAVIR.
698	Gyor (HU)		70 Mvar shunt reactor in station Győr (HU)	200	Planning	2018	Delayed	Investment rescheduled as a result of changes in planning input data (need delayed)

699	Gyor (HU)		Third 400/120 kV transformer in station Győr (HU)	200	Planning	2018	Delayed	Investment rescheduled as a result of changes in planning input data (need delayed)

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
SK=>HU: 0-500	HU=>SK: 0-425	1	3	Negligible or less than 15km	Negligible or less than 15km	97-98

CBA results	**for each scenario**				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[27;34]	0	[-160000;-150000]	[410;500]
Scenario Vision 2 - 2030	-	[23;28]	0	[-220000;-180000]	[500;610]
Scenario Vision 3 - 2030	-	[31;38]	0	[2500;8300]	[65;80]
Scenario Vision 4 - 2030	-	[66;81]	0	[-12000;3600]	[-260;-220]

Additional comments

Comment on the security of supply: The project enhances system security of both Slovak and Hungarian system, especially during outages and maintenances on other interconnections between the countries

Comment on the RES integration: The project supports the North - South power flow from wind and photovoltaic power in Northern part of Continental Europe by increasing GTC of SK-HU profile and improves the possibilities of balancing the system.

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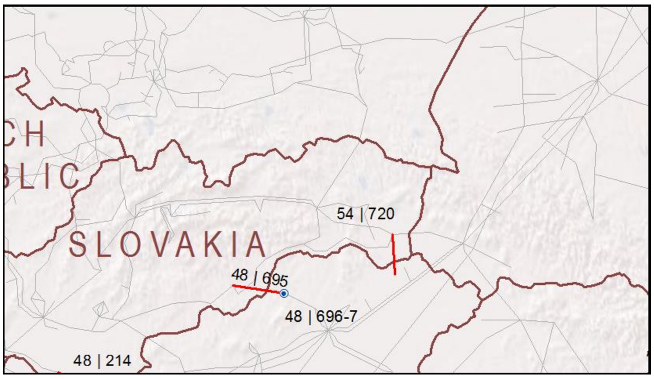
Project 54: New SK-HU intercon. - phase 2

Description of the project

This project will increase the transfer capacity between Slovak and Hungarian transmission systems, improve security and reliability of operation both transmission systems and support North - South RES power flows in CCE region. Realization of this project is tightly connected to the negotiations between Slovak and Ukrainian TSOs regarding future operation of the existing Slovak interconnection with Ukraine. Main and only investment of this project is double circuit 400 kV line from Velke Kapusany (Slovakia) substation to Kisvárda region (Hungary).

PCI 3.18



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
720	Velké Kapušany (SK)	tbd (HU)	Erection of new 2x400 line between SK and Hungary (substation on Hungarian side still to be defined). The Investment is under consideration.	-	Under Consideration	2021	Investment on time	Progress as planned.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
SK=>HU: 0-500	HU=>SK: 0-500	1	3	Negligible or less than 15km	Negligible or less than 15km	21-22

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[2;3]	0	[-27000;-21000]	[-53;-44]
Scenario Vision 2 - 2030	-	[3;4]	0	[-37000;-45000]	[87;110]
Scenario Vision 3 - 2030	-	[12;15]	0	[-57000;-50000]	[-16;-13]
Scenario Vision 4 - 2030	-	[26;31]	0	[-27000;-19000]	[-92;-75]

Additional comments

Comment on the security of supply: The project enhances system security of both Slovak and Hungarian system, especially during outages and maintenances on other interconnections between the countries

Comment on the RES integration: The project supports the North - South power flow from wind and photovoltaic power in Northern part of Continental Europe by increasing GTC of SK-HU profile and improves the possibilities of balancing the system.

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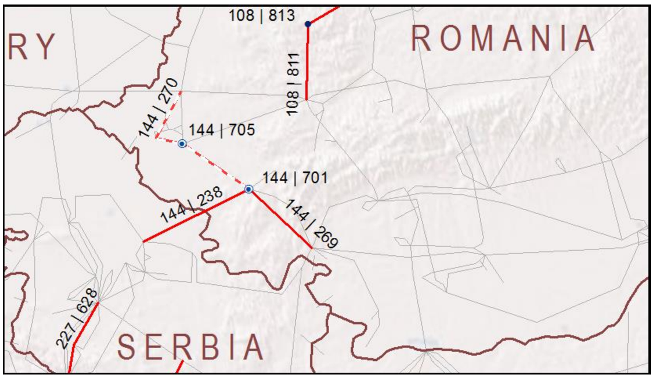
Project 144: Mid Continental East corridor

Description of the project

The project consists of one double circuit 400 kV line between Serbia and Romania and reinforcement of the network along the western border in Romania: one new simple circuit 400 kV line from Portile de Fier to Resita and upgrade from 220 kV double circuit to 400 kV double circuit of the axis between Resita and Arad, including upgrade to 400 kV of three substations along this path. The project aims at enhancing the transmission capacity along the East-West corridor in south-eastern and central Europe. It will provide access to the market for more than 1000 MW installed new wind generation in Banat area (Serbia and Romania) as well as to the pumped storage plant of more than 1000 MW in north-western Romania. The project improves operational regimes from the point of vue of stability and voltage collapse and facilitates maintenance of the network in the area.

PCI 3.22.1, 3.22.2 and 3.22.3.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
238	Pancevo (RS)	Resita (RO)	New 131 km double circuit 400kV OHL between existing substation in Romania and Serbia (63 km on Romanian side and 68 km on Serbian side) 2x1380 MVA.	350	Design & Permitting	2017	Investment on time	Activities are mostly synchronized on both sides. The main problem is right of land along the line path.
269	Portile de Fier (RO)	Resita (RO)	New 116 km 400kV OHL between existing substation 400 kV Portile de Fier and new 400 kV substation Resita; 1380 MVA.	287	Design & Permitting	2017	Delayed	The investment was coordinated with investment 50|238. The main problems are right of land along the line path and permitting.
270	Resita (RO)	Timisoara-Sacalaz-Arad (RO)	Upgrade of existing 220kV double circuit line Resita-Timisoara-Sacalaz-Arad to 400kV double circuit. Line length: aprox. 100 km d.c. + 74,6 km s.c.;2x1380 MVA; 1204 MVA the circuit between Sacalaz and C. Aradului	180	Design & Permitting	2022	Investment on time	Planned to start after investment 269 is finalized.
701	Resita (RO)		New 400 kV substation Resita (T400/220 kV 400 MVA + T 400/110 kV 250 MVA), as development of the existing 220/110 kV substation.	350	Design & Permitting	2017	Investment on time	Investment has been split. It is expected that the substation will be commissioned in two stages. In TYNDP 2012,

								timing referred only to the adjacent lines.
705	Timisoara (RO)		Replacement of 220 kV substation Timisoara with 400 kV substation (2x250 MVA 400/110 kV)	180	Design & Permitting	2022	Investment on time	Investments 269 and 701 have to be finalized first.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
East=>West: 737	West=>East: 453	3	4	15-50km	Negligible or less than 15km	130-220

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[170;210]	258 MW	[-96000;-78000]	[1200;1500]
Scenario Vision 2 - 2030	-	[66;81]	258 MW	[-160000;-130000]	[700;860]
Scenario Vision 3 - 2030	-	[18;22]	258 MW	[-220000;-180000]	[-380;-310]
Scenario Vision 4 - 2030	-	[190;230]	258 MW	[-340000;-280000]	[-330;-270]

Additional comments

Comment on the clustering: the project also takes advantage of investment items n°706, depicted in the Regional investment plan.

Comment on the RES integration: The projects directly connects 258 MW of RES in 400 kV substation Vrani (connected in-out to 400 kV line Resita-Pancevo, in Romania). The project helps integrate about 1000 MW of RES in the region of South-West Romania and North-East Serbia. It avoids 100-800 GWh of RES (spillage avoided, depending on Vision).

GTC is increased between (RO+BG) / (HU+RS)

Project 138: Black Sea Corridor

Description of the project

The project reinforces the corridor along the coast of the Black Sea (Romania-Bulgaria) and between this coast and the rest of Europe and Turkey.
Regional and European market integration will be enhanced, allowing for increased exchanges in the area.
Development of intermittent RES will be made possible by the capacity of the grid to transport their generation to consumption and storage centres and to accommodate balancing at regional/continental level.
The project improves operational regimes from the point of vue of stability and voltage collapse and facilitates maintenance of the network in the area.

PCI 3.8

Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
265	Vidno (BG)	Svoboda (BG)	New 400kV double circuit OHL to accommodate 2000 MW RES generation in N-E Bulgaria (Dobruja region). Line length: 2x70km.	165	Planning	2019	Delayed	Delayed due to lack of funding.
273	Cernavoda (RO)	Stalpu (RO) and Gura Ialomitei (RO)	Reinforcement of the cross-section between the Western coast of the Black Sea (Eastern Romania) and the rest of the system. New 400kV double circuit OHL between existing substations Cernavoda and Stalpu, with 1 circuit derivation in/out in 400 kV substation Gura Ialomitei, situated in the vicinity of the new line. Line length:159km.2x1380 MVA	808	Design & Permitting	2019	Delayed	Longer than expected delay regarding clarification of legal framework for right of land acquirement and regarding environment permitting procedure.
275	Smardan(RO)	Gutinas(RO)	Reinforcement of the cross-section between the Western coast of the Black Sea (Dobrogea area) and the rest of the system. New 400kV double circuit OHL (one circuit wired) between existing substations. Line length:140km; 1380 MVA	560	Design & Permitting	2020	Investment on time	Rapid increase of wind generation connected in the area. Efforts to be made to speed construction.

276	Suceava(RO)	Gadalin(RO)	Reinforcement of the cross-section between developing wind generation hub in Eastern Romania and the rest of the system. New 400kV simple circuit OHL between existing substations. Line length: 260km. 1204 MVA	165	Design & Permitting	2021	Investment on time	No change of status.
715	Stalpu (RO)		To reinforce the cross-section between the Black Sea coast wind generation in Romania and Bulgaria and the consumption and storage centres to the West, the 220 kV OHL Stalpu-Teleajen-Brazi is upgraded to 400 kV, as a continuation of the 400 kV d.c. OHL Cernavoda-Stalpu. The 220/110 kV substation Stalpu is upgraded to 400/110kV (1x250MVA).	808	Planning	2019	Delayed	The investment was rescheduled in correlation with project 273.
800	Dobrudja(BG)	Burgas (BG)	New 140km single circuit 400kV OHL in parallel to the existing one.	165	Planning	2018	Delayed	Delayed due to lack of funding.
1112	Svoboda (BG)	splitting point	Construction of a new 400/110kV power line breaking up the existing 400kV Saedinenie OHL and connecting 400/110kV Svoboda substation.	165	Planning	2019	Delayed	Delayed due to lack of funding

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
RO=>BG: 1260	BG=>RO: 2196	3	3	Negligible or less than 15km	Negligible or less than 15km	173-403

CBA results	**for each scenario**				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[110;130]	1330 MW	[-66000;-54000]	[-420;-340]
Scenario Vision 2 - 2030	-	[61;74]	1330 MW	[27000;33000]	[-780;-640]
Scenario Vision 3 - 2030	-	[410;500]	1330 MW	[-170000;-140000]	[-3400;-2700]
Scenario Vision 4 - 2030	-	[360;440]	1330 MW	[-25000;-20000]	[-2100;-1800]

Additional comments

Comment on the RES integration: The projects directly connects 1330 MW of RES in 400 kV substations Gheraseni (connected in-out to 400 kV line Gura Ialomitei – Stalpu), Independenta (connected in-out to 400 kV line Gutinas-Smardan), Vidno, Ustrem (Svoboda). The project helps integrating about 5000 MW of RES on the Black Sea coast more generally. It avoids about 9000 GWh spillage of RES in the region of the Black Sea Coast in Romania and Bulgaria. The assessment of spillage and indirect integration considers reinforcement of internal corridors in Romania and Bulgaria connecting the Black Sea Coast windy area to the rest of the system, not only cross-border transfer capacities.

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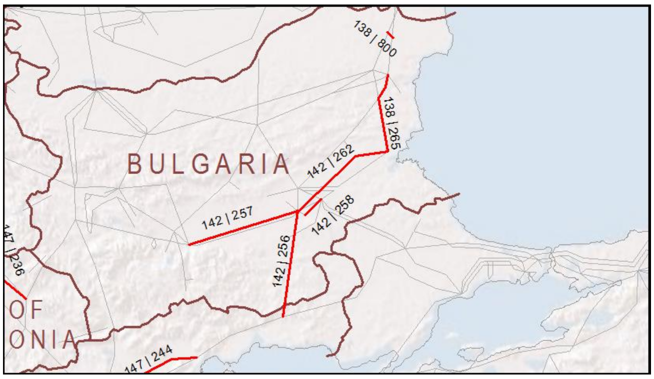
Project 142: CSE4

Description of the project

This project will facilitate market integration by increasing the transfer capacity in the Bulgaria-Greece borders. It will also contribute to increase the volume of exchanges between the Continental Europe synchronous area and Turkey. Furthermore it will contribute to the safe evacuation of the power from the wind farms expected to be installed in the North-East part of Greece and the North-East of Bulgaria as well as photovoltaic power plants in the South part of Bulgaria.
Mentioned project will be composed of a new 400kV AC interconnection between Bulgaria and Greece as well as two new 400kV OHL aiming at the strengthening of the transmission network at the South part of Bulgaria.

PCI 3.7



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
256	Maritsa East 1 (BG)	N.Santa (GR)	New interconnection line BG-GR by a 130km single circuit 400kV OHL.	648	Design & Permitting	2021	Delayed	Delayed due to lack of funding.
257	Maritsa East 1 (BG)	Plovdiv (BG)	New 100km single circuit 400kV OHL in parallel to the existing one.	648	Design & Permitting	2016	Delayed	Delayed due to difficulties with the acquisition of the land
258	Maritsa East 1 (BG)	Maritsa East 3 (BG)	New 13km single circuit 400kV OHL in parallel to the existing one.	648	Design & Permitting	2016	Delayed	Delayed due to difficulties with the acquisition of the land
262	Maritsa East 1 (BG)	Burgas (BG)	New 400kV OHL. Line length: 150km.	648	Design & Permitting	2016	Delayed	Delayed due to difficulties with the acquisition of the land

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
BG=>GR: 648	GR=>BG: 82	2	4	15-50km	Negligible or less than 15km	100

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[54;67]	250 MW	[-110000;-88000]	[-22;-18]
Scenario Vision 2 - 2030	-	[200;250]	250 MW	[-140000;-110000]	[-150;-130]
Scenario Vision 3 - 2030	-	[100;120]	250 MW	[-170000;-140000]	[-510;-410]
Scenario Vision 4 - 2030	-	[150;180]	250 MW	[-130000;-110000]	[-970;-790]

Additional comments

Comment on the RES integration: the project helps connecting directly or indirectly 250 MW in the Balkan peninsula.

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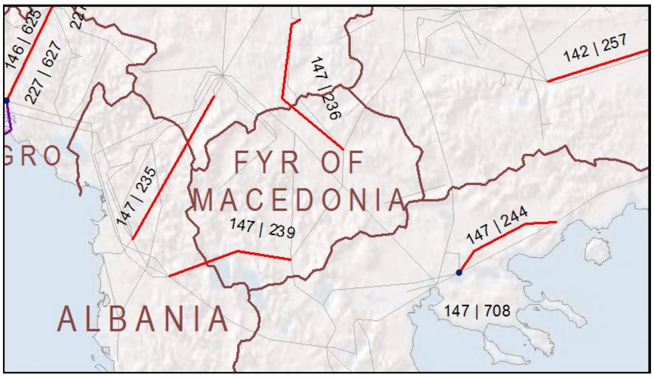
Project 147: CSE9

Description of the project

The project aims to increase the transfer capacity in the predominant North-South direction that is from Romania, Serbia and Bulgaria towards Greece, FYR of Macedonia and Albania. In addition, a part of this project will increase the security of supply in the South-West part of the FYR of Macedonia.
The investments forming the project are 400 kV lines and corresponding substations located in Greece, FYR of Macedonia, Serbia and Albania.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
235	Tirana(AL)	Pristina (RS)	New 238km 400kV OHL; on 78km the circuit will be installed on the same towers as the Tirana-Podgorica OHL currently in construction ; the rest will be built as single circuit line.	160	Under Construction	2016	Delayed	Slight delay, due to procedural reasons. In particular the previous tender has been cancelled and a new one was launched. Currently the project is under construction
236	Leskovac(RS)	Shtip (MK)	New 170km 400kV single circuit overhead interconnection between Serbia and FYR of Macedonia.	620	Under Construction	2014	Delayed	land acquisition
239	Bitola (MK)	Elbasan (AL)	New 150km cross-border single circuit 400kV OHL between existing substation Bitola and Elbasan	160	Design & Permitting	2017	Delayed	additional investigation of feasibility
244	Filippi(GR)	Lagadas (GR)	Connection of the new 400kV substation in Lagadas in Thessaloniki area to the existing substation of Filippi via a new 110km double circuit 400kV OHL.	301	Design & Permitting	2016	Delayed	Delays in the expropriation and permission process. These issues have been resolved.
708	Lagadas (GR)		New 400kV substation in Lagadas in Thessaloniki area.	301	Under Construction	2014	Delayed	Delays due to environmental licensing process

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CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
North=>South: 1157	South=>North: 2709	1	4	Negligible or less than 15km	Negligible or less than 15km	210

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[380;460]	300 MW	[-210000;-170000]	[-55;-45]
Scenario Vision 2 - 2030	-	[190;230]	300 MW	[-86000;-70000]	[120;140]
Scenario Vision 3 - 2030	-	[510;620]	300 MW	[-61000;-50000]	[-2200;-1800]
Scenario Vision 4 - 2030	-	[600;730]	300 MW	[-100000;-85000]	[-5300;-4400]

Additional comments

Comment on the RES integration: the project helps connecting directly or indirectly about 300 MW in the Balkan peninsula.

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Project 219: EUROASIA interconnector

Description of the project

Promoted by DEH Quantum Energy LTD

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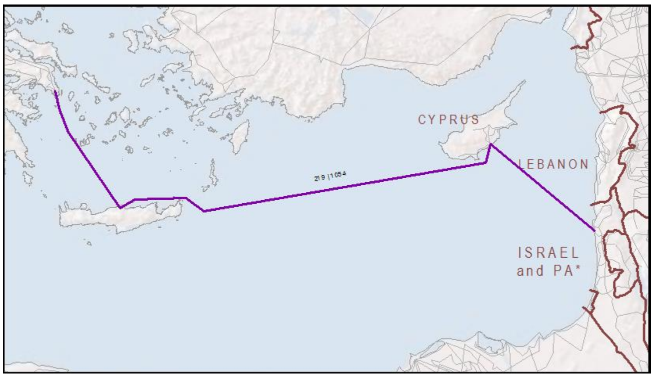
A 2000 MW link between Israel, Cyprus, and Greece (Creta and mainland).

PCI 3.10



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
949	Korakia site (CRETE)	Athens site (GREECE)	New HVDC interconnection between Crete and Athens	2000	Planning	2020	New Investment	Project application to TYNDP 2014.
971	Vasilikos site (CYPRUS)	Korakia site (CRETE)	New HVDC interconnection between Cyprus and Crete Islands	2000	Planning	2022	New Investment	Project application to TYNDP 2014.
1054	Hadera site (ISRAEL)	Vasilikos site (CYPRUS)	New HVDC interconnection between Israel and Cyprus	2000	Planning	2018	New Investment	Project application to TYNDP 2014.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	GTC direction 2 (MW)	B6 Technical Resilience	B7 Flexibility	S1 - protected areas	S2 - urban areas	C1 Estimated cost (Meuros)
East=>West: 2000	West=>East: 2000	2	3	NA	NA	2300-5300

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[530;640]	[3400000;4100000] MWh	[1400000;1700000]	0
Scenario Vision 2 - 2030	-	[530;650]	[3600000;4400000] MWh	[1400000;1700000]	0
Scenario Vision 3 - 2030	-	[330;410]	[3500000;4200000] MWh	[1200000;1400000]	0
Scenario Vision 4 - 2030	-	[310;380]	[3500000;4300000] MWh	[1100000;1400000]	0

Additional comments

Comment on the RES integration: avoided spillage concerns mainly wind farms in Creta.

Comment on the Losses indicator: the load factor of the cable is maximum in all Visions, leading to the same and very high additional losses.

Comment on the S1 and S2 indicators: additional data are necessary to compute these indicators

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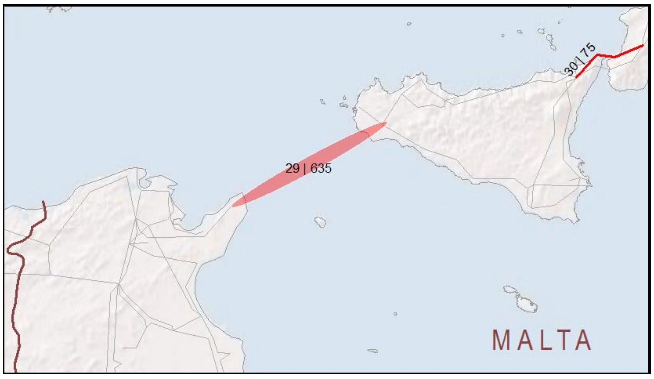
Project 29: Italy-North Africa

Description of the project

The project consists in a new interconnection between Italy and North Africa to be realized through an HVDC submarine cable. The project favours the use of the most efficient capacity in the PAN European interconnected system. The project also increases the system operational flexibility. Such benefits are ensured according to different future scenarios.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
635	Sicily Area (IT)	North Africa node	New interconnection between Italy and North Africa-new DC submarine cable	-	Under Consideration	2030	Investment on time	Progress as planned.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
IT=>South: 600	South=>IT: 600	1	4	NA	NA	600

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[81;99]	0	[18000;22000]	0
Scenario Vision 2 - 2030	-	[81;99]	0	[18000;22000]	0
Scenario Vision 3 - 2030	-	[81;99]	0	[18000;22000]	0
Scenario Vision 4 - 2030	-	[81;99]	0	[18000;22000]	0

Additional comments

Comment on the CO2 indicator: the project will mostly substitute thermal based power in Europe with North African, hence a symbolic 0 is supplied.

Comment on the Losses indicator: the load factor of the cable is steady in all Visions, leading to the same and high additional losses.

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

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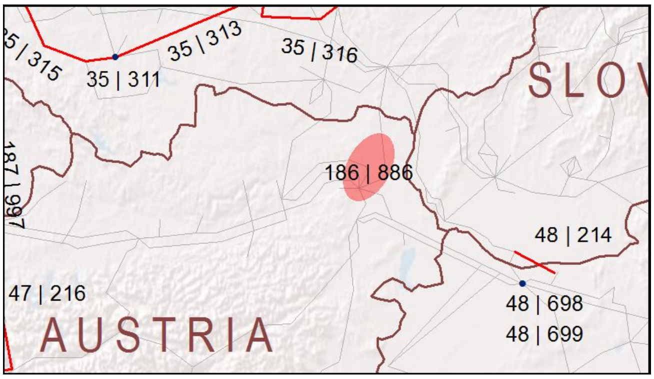
Project 186: east of Austria

Description of the project

To allow the grid integration of the planned renewable energy generation (mainly wind power) in the north-eastern part of Austria ("Weinviertel") the transmission grid infrastructure (currently a rather weak 220kV line) has to be enforced and new substations for the connection need to be erected.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
886	tbd	tbd	To allow the grid integration of the planned renewable energy generation (mainly wind power) in the north-eastern part of Austria ("Weinviertel") and to cover the foreseen load growth in that region the transmission grid infrastructure has to be enforced and new substations for the connection need to be erected	-	Planning	2021	Rescheduled	The development of wind energy in Lower Austria was temporarily stopped by the federal state government to establish a concept for land use. Final concept was published in beginning of 2014 – project now continues with planned commissioning in 2021.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
outside=>inside: 1500	inside=>outside: 1500	1	2	NA	NA	120-280

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[220;260]	1100 MW	[-5500;-4500]	[-1000;-840]
Scenario Vision 2 - 2030	-	[130;160]	1100 MW	[-1100;-900]	[-320;-260]
Scenario Vision 3 - 2030	-	[300;370]	1500 MW	[-2600;-2200]	[-1200;-990]
Scenario Vision 4 - 2030	-	[230;280]	1500 MW	[-7900;-6500]	[-1200;-990]

Additional comments

Comment on the RES integration:
This project facilitates the direct connection of RES in the given amount.

Comment on the CO2 indicator: the very high scores reflect that the project directly connects RES sources

Comment on the S1 and S2 indicators: no indicator can be assessed as no route is defined yet for the project.

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Project 75: Stevin (backbone)+BE offshore

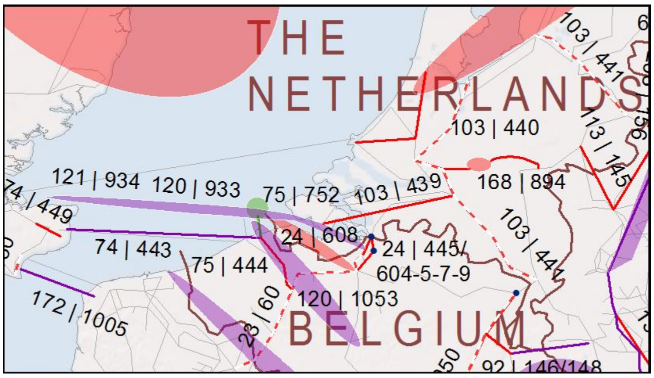
Description of the project

This project facilitates the integration of up to 2,3 GW of offshore wind production into the Belgian grid via the construction of an offshore hub (BOG: Belgian Offshore Grid project) and the extension of the 380kV backbone to the coastal area (STEVIN project) to which the offshore hub will be connected.

The final design as well as the legal, ownership & regulatory framework for BOG is being defined in concertation with stakeholders (wind farm developers,...).

Note that the STEVIN project is also required for the integration of the NEMO interconnector (BE-UK) into the BE 380kV network.

PCI 1.2



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
444	Zomergem (BE)	Zeebrugge (BE)	STEVIN The Stevin project envisions the extension of the 380kV backbone to the coastal area, via the construction of new +-50km (40km OHL; 10km cable) double-circuit (3000MVA for each circuit) between Zomergem and Zeebrugge., including the construction of a new substation in Zeebrugge.	3000	Design & Permitting	2018	Delayed	Delay due to request of 3rd parties to examine more alternatives, and procedures launched , and due to appeals against the GRUP (land use act) by 3rd parties in States Council. Meanwile arrangements have been made, and the updated planning envisions end 2017/begin 2018 as new commissioning date.
752	Offshore hub (BE)	Stevin (Zeebrugge)	Belgian Offshore Grid (BOG) The Belgian Offshore Grid investment consists of the eruption of an offshore hub connected to onshore AC grid (at Zeebrugge) via underground cables, including the necessary reactive compensation for the cables.	1835	Design & Permitting	2018	Delayed	2018 is the earliest possible date: project is subject to outcome of ongoing design, legal, ownership & regulatory framework concertation with stakeholders.

			Subject to result of ongoing design, legal, ownership & regulatory concertation with stakeholders.					

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
North=>South: 3000	South=>North: 0	2	3	Negligible or less than 15km	Negligible or less than 15km	600-900

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[390;490]	1800 MW	[27000;33000]	[-4100;-3300]
Scenario Vision 2 - 2030	-	[420;490]	1800 MW	[27000;33000]	[-3400;-2700]
Scenario Vision 3 - 2030	-	[510;520]	1800 MW	[27000;33000]	[-2600;-2100]
Scenario Vision 4 - 2030	-	[330;460]	1800 MW	[27000;33000]	[-2000;-1600]

Additional comments

Comment on the SEW: the SEW is decreasing in Vision 4 because of the competition of other RES developments

Comment on the security of supply: the STEVIN project contributes to the SoS of Belgium because it allows the integration of the new interconnector NEMO. And also contributes to the SoS of the Coastal Area by integrating this area into the 380kV backbone in a structural way (in feed from 380kV to 150kV in Zeebrugge)

Comment on the Losses indicator: connected RES is assumed to be the same in all 4 Visions, leading to the same additional losses.

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Project 120: 2nd Offshore-Onshore Corridor

Description of the project

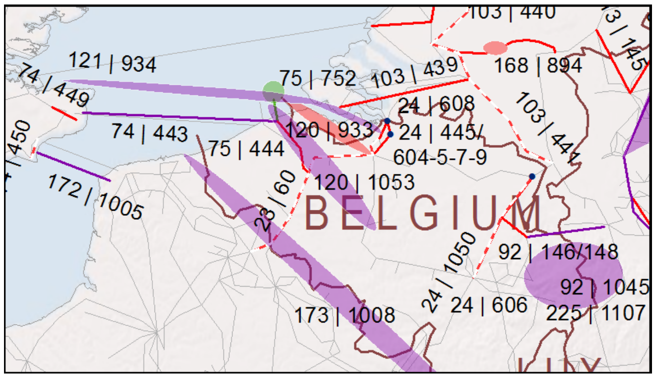
Second Offshore-Onshore Corridor

This is a conceptual project that could be considered as a long-term investment option, triggered by the vision 3 & 4 scenario's where up to 4GW of offshore wind capacity is envisioned in the Belgian part of the North Sea (note that this 4 GW is not ensured in official government plans for offshore wind development).

Compared to the current forecast of 2,3 GW of offshore wind as to which Elia's portfolio is designed, it implies an additional reinforcement under the form of a second offshore-onshore corridor.

Preliminary analysis indicates that this corridor could consist of multiple reinforcements to different inland locations.

The determination of optimal location/route, technology and the integration of this corridor in relation to the BE offshore hub Alfa and nearby onshore substation Stevin at Zeebruge are subject of further studies.



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
933	Offshore Hub OR Stevin - TBD	Izegem - TBD	Further connection to inland: phase 2 Preliminary analysis shows the need to reinforce the 380kV network with a second offshore-onshore corridor in order to evacuate up to 4 GW of offshore wind. The solutions under study consist of multiple investment items. This investment item envisions the possibility of an AC OR DC solution going from an offshore hub OR onshore substation Stevin in Zeebrugge towards a further inland location.	1000	Under Consideration	2030	New Investment	Additional offshore-onshore corridor needed in order to evacuate full potential of up to 4GW (compared to current target of 2,3 GW) of offshore wind in the Belgian part of the North Sea in visions 3 & 4.

			The reference solution presented here is an AC corridor towards Izegem. To be confirmed by further detailed studies in the coming years. The cost estimation does not take into account the offshore part of the corridor.					
1053	Offshore Hub - TBD	Doel - TBD	1 GW connection to inland: phase 1 Preliminary analysis shows the need to reinforce the 380kV network with a second offshore-onshore corridor in order to evacuate up to 4 GW of offshore wind. The solutions under study consist of multiple investment items. This investment item envisions the possibility of a 1 GW DC solution between an offshore hub towards an inland location (substation Doel or further inland could be a possible location). Subject to further studies. The cost estimate does not take into account the construction of an eventual offshore hub.	1000	Under Consideration	2030	New Investment	Additional offshore-onshore corridor needed in order to evacuate full potential of up to 4GW (compared to current target of 2,3 GW) of offshore wind in the Belgian part of the North Sea in visions 3 & 4.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
outside=>inside: 1800	inside=>outside: 0	2	1	NA	NA	600-900

CBA results	**for each scenario**				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 3 - 2030	-	[510;520]	1800 MW	[170000;210000]	[-2600;-2200]
Scenario Vision 4 - 2030	-	[430;450]	1800 MW	[170000;210000]	[-2000;-1600]

Additional comments

Comment on the CO2 indicator: the very high scores reflect that the project connects RES sources to load centres

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

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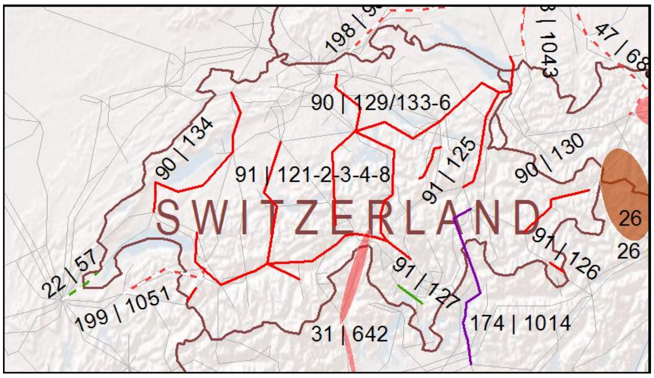
Project 91: Swiss Ellipse

Description of the project

The project helps accommodating new pumping storage units which mainly support the increasing RES generation in the European areas with solar or wind generation.
While importing or exporting, the Swiss Ellipse project uses the capacity of the 'Italy - Switzerland' (31), 'Swiss Roof' (90) and 'France - Switzerland' (22) projects.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
121	Bickigen (CH)	Romanel (CH)	Construction of different new 400kV OHL sections and voltage upgrade of existing 225kV lines into 400kV lines. Total length: 250km.	900	Design & Permitting	2020	Delayed	long permitting procedure (comprising several phases)
122	Chippis (CH)	Lavorgo (CH)	Construction of different new 400kV line sections and voltage upgrade of existing 225kV lines into 400kV. Total length: 120km.	680	Design & Permitting	2020	Delayed	long permitting procedure (comprising several phases)
123	Mettlen (CH)	Ulrichen (CH)	Construction of different new 400kV line sections and voltage upgrade of existing 225kV lines into 400kV lines. Total length: 90km.	600	Planning	2019	Investment on time	Progress as planned.
125	Schwanden (CH)	Limmern (CH)	New 400kV double circuit (OHL and underground cable) between Schwanden and Limmern. OHL part	1000	Under Construction	2015	Investment on time	Progress as planned.
126	Golbia (CH)	Robbia (CH)	New 2x 400kV cable connection between Golbia and the Bernina line double circuit.	1000	Under Consideration	2019	Investment on time	Progress as planned.
127	Magadino (CH)	Verzasca (CH)	Upgrade of existing 150kV line into 220kV line.	400	Under Consideration	2020	Investment on time	Progress as planned.
128	Bâtiaz (CH)	Nant de Drance (CH)	New 400kV double circuit OHL between Bâtiaz and Châtelard. New 2x 400kV cable connection between Châtelard and Nant de Drance. Total length: 22km.	900	Design & Permitting	2020	Delayed	long permitting procedure (comprising several phases)

795	Schwanden (CH)	Limmern (CH)	New 400kV double circuit (OHL and underground cable) between Schwanden and Limmern. Underground cable part	1000	Under Construction	2015	Investment on time	Progress as planned.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
inside=>outside: 5000	outside=>inside: 5000	1	3	NA	NA	1100

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[18;23]	[170;200] MWh	0	[730;890]
Scenario Vision 2 - 2030	-	[21;26]	[1000;1300] MWh	0	[440;530]
Scenario Vision 3 - 2030	-	[200;250]	[36000;44000] MWh	0	[-480;-390]
Scenario Vision 4 - 2030	-	[310;380]	[230000;280000] MWh	0	[-800;-650]

Additional comments

Comment on the RES integration: avoided spillage concerns RES in Germany and hydro storage in Switzerland.

Comment on the Losses indicator: basically, the project enables power exchanges over greater distances (increasing losses), and conversely reduce the overall resistance of the grid. Losses variation is hence symbolically 0, with depending on the point in times losses being lower or greater, with variation close to the model accuracy range.

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

German Offshore wind parks connection

This section presents alongside the 5 projects (42, 191, 192, 129, 46) foreseen for direct connection of offshore wind park, the first four in the North Sea, the fifth in the Baltic Sea.

Each project has been independently assessed.

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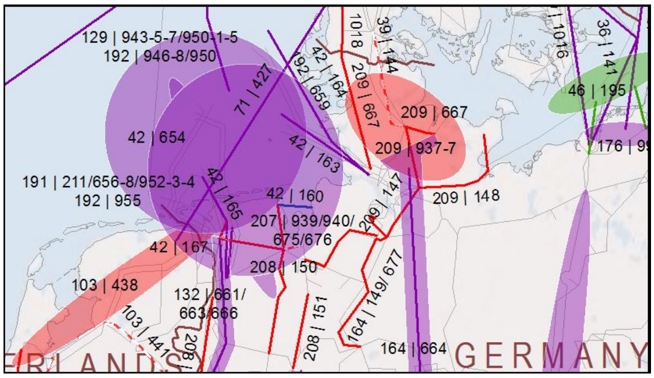
Project 42: OWP TenneT Northsea part 1

Description of the project

Germany is planning to build a big amount of offshore wind power plants in the Northsea. The OWP will help to reach the European goal of CO2 reduction and RES integration. This project is for the connection of the OWP with the German grid.



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
160	Offshore-Wind park Nordergründe (DE)	Inhausen (DE)	New AC-cable connection with a total length of 32km.	111	Under Construction	2016	Delayed	Delay due delay of wind farms
163	Cluster HelWin1 (DE)	Büttel (DE)	New HVDC transmission system consisting of offshore platform, cable and converters with a total length of 133km. Line capacity: aprox. 576 MW.	576	Under Construction	2014	Investment on time	Progress as planned.
164	Cluster SylWin1 (DE)	Büttel (DE)	New line consisting of underground +subsea cable with a total length of 206 km. Line capacity: aprox.864MW.	864	Under Construction	2015	Delayed	
165	Cluster DolWin1 (DE)	Dörpen/West (DE)	New line consisting of underground +subsea cable with a total length of 167 km. Line capacity: 800MW.	800	Under Construction	2014	Delayed	
167	Cluster BorWin2 (DE)	Diele (DE)	New HVDC transmission system consisting of offshore platform, cable and converters with a total length of 205km. Line capacity: 800MW.	800	Under Construction	2015	Delayed	
654	Cluster DolWin2 (DE)	Dörpen/West (DE)	New HVDC transmission system consisting of offshore platform, cable and converters with a total length of 138 km. Line capacity: 900 MW	900	Under Construction	2015	Investment on time	Progress as planned.
655	Cluster DolWin3 (DE)	Dörpen/West (DE)	New HVDC transmission system consisting of offshore platform, cable and converters with a total length of 162 km. Line capacity: 900 MW	900	Under Construction	2017	Investment on time	Progress as planned.

657	Cluster HelWin2	Büttel (DE)	New HVDC transmission system consisting of offshore platform, cable and converters with a total length of 133 km. Line capacity: 690 MW	690	Under Construction	2015	Investment on time	Progress as planned.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
North=>South: 5750	South=>North: 5750	2	3	More than 100km	Negligible or less than 15km	6000-8000

CBA results	**for each scenario**				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[1300;1600]	4033 MW	0	[-13000;-11000]
Scenario Vision 2 - 2030	-	[620;760]	4033 MW	0	[-8500;-7000]
Scenario Vision 3 - 2030	-	[1900;2300]	5748 MW	0	[-10000;-8400]
Scenario Vision 4 - 2030	-	[1600;2000]	5748 MW	0	[-8900;-7300]

Additional comments

Comment on the clustering: for the sake of consistency, and by exception to the rule, the project has been assessed including two investment items connecting wind farms for 111 MW and 108 MW, the latter being commissioned, hence not matching the clustering rule requiring each investment to contribute to more than 20% of the major investment of the project

Comment on the CO2 indicator: the very high scores reflect that the project directly connects RES sources

Comment on the Losses indicator: the losses variation for this direct connection project have not been valuated.

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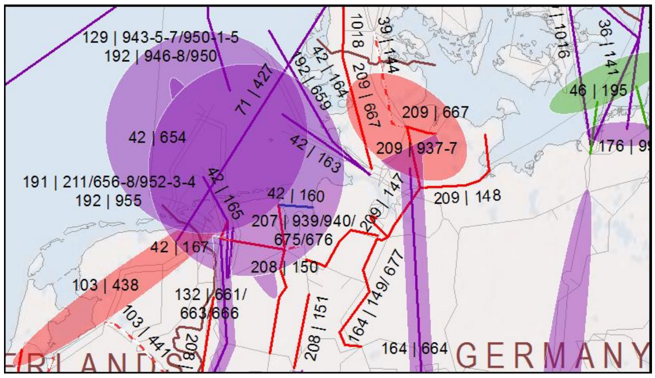
Project 191: OWP TenneT Northsea Part 2

Description of the project

Germany is planning to build a big amount of wind offshore power plants in the Northsea. The OWP will help to reach the European goal of CO2 reduction and RES integration. This project is for the connection of the OWP with the German grid.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
211	Cluster DolWin 4 (NOR 3-2)	Unterweser	New HVDC transmission system consisting of offshore platform, cable and converters with a total length of 190km. Line capacity: 900 MW	900	Under Consideration	2020	Investment on time	Progress as planned.
656	Cluster BorWin3	Emden/Ost (DE)	New HVDC transmission system consisting of offshore platform, cable and converters with a total length of 160 km. Line capacity: 900 MW	900	Design & Permitting	2018	Investment on time	Progress as planned.
658	Cluster BorWin4 (DE)	Emden/Ost (DE)	New HVDC transmission system consisting of offshore platform, cable and converters with a total length of 172 km. Line capacity: 900 MW	900	Design & Permitting	2019	Investment on time	Progress as planned.
952	Cluster DolWin 5 (NOR-1-1)	Halbemond	New HVDC transmission system consisting of offshore platform, cable and converters with a total length of 250 km. Line capacity: 900 MW	900	Under Consideration	2021	New Investment	new investment
953	Cluster DolWin 6 (NOR-3-3)	Halbemond	New HVDC transmission system consisting of offshore platform, cable and converters with a total length of 60km. Line capacity: 900 MW	900	Under Consideration	2021	New Investment	new investment
954	Cluster BorWin 5 (NOR-7-1)	Halbemond	Connecton of new offshore wind parks. New HVDC transmission system consisting of offshore platform, cable and converters with a total length of 260km. Line capacity: 900 MW	900	Under Consideration	2022	New Investment	new investment

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
inside=>DE: 5400	DE=>inside: 5400	4	3	More than 100km	Negligible or less than 15km	8000-10000

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[520;640]	3788 MW	0	[-6200;-5100]
Scenario Vision 2 - 2030	-	[330;400]	3788 MW	0	[-5600;-4500]
Scenario Vision 3 - 2030	-	[1700;2100]	5401 MW	0	[-9400;-7700]
Scenario Vision 4 - 2030	-	[1500;1900]	[5300;5500] MW	0	[-8700;-7100]

Additional comments

Comment on the CO2 indicator: the very high scores reflect that the project directly connects RES sources

Comment on the Losses indicator: the losses variation for this direct connection project have not been valued

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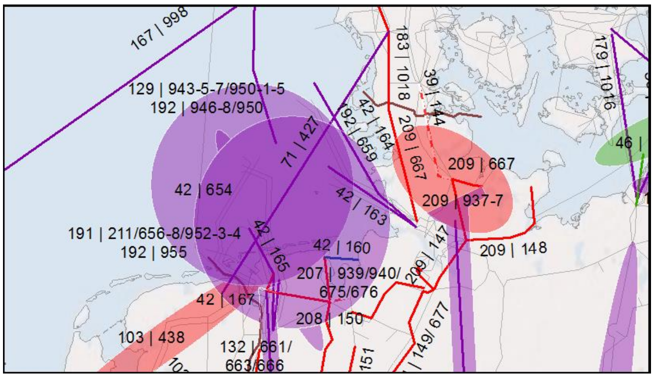
Project 192: OWP Northsea TenneT Part 3

Description of the project

Germany is planning to build a big amount of wind offshore power plants in the Northsea. The OWP will help to reach the European goal of CO2 reduction and RES integration. This project is for the connection of the OWP with the German grid. This project becomes necessary in case of further long-term strong increase in OWP generation like in Vision 3 and 4. The project is not in focus of Vision 1 and 2.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
659	Cluster SylWin2 (DE)	Büttel (DE)	New HVDC transmission system consisting of offshore platform, cable and converters with a total length of 205 km. Line capacity: 900 MW	900	Under Consideration	2023	Investment on time	Progress as planned.
946	NOR-11-1	Elsfleth/West	Connection of new offshore wind parks. New HVDC transmission system consisting of offshore platform, cable and converters with a total length of 230km. Line capacity: 900 MW	900	Under Consideration	2026	New Investment	new investment
948	NOR-12-1	Wilhelmshafen	Connection of new offshore wind parks. New HVDC transmission system consisting of offshore platform, cable and converters with a total length of 230km. Line capacity: 900 MW	900	Under Consideration	2027	New Investment	new investment
950	NOR-13-1	Kreis Segeberg	Connection of new offshore wind parks. New HVDC transmission system consisting of offshore platform, cable and converters with a total length of 330km. Line capacity: 900 MW	900	Under Consideration	2025	New Investment	new investment
955	Cluster BorWin6 (NOR-7-2)	Unterweser	Connection of new offshore wind parks.New HVDC transmission system consisting of offshore platform, cable and converters with a total length of 180km. Line capacity: 900 MW	900	Under Consideration	2023	New Investment	new investment

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
inside=>DE: 4500	DE=>inside: 4500	4	3	More than 100km	Negligible or less than 15km	5500-9500

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 3 - 2030	-	[1400;1700]	4499 MW	0	[-7400;-6000]
Scenario Vision 4 - 2030	-	[1100;1400]	[4400;4600] MW	0	[-6100;-5000]

Additional comments

Comment on the CO2 indicator: the very high scores reflect that the project directly connects RES sources

Comment on the S1 and S2 indicators: „Detailed values for most lines are not available due to the early state in the planning process“

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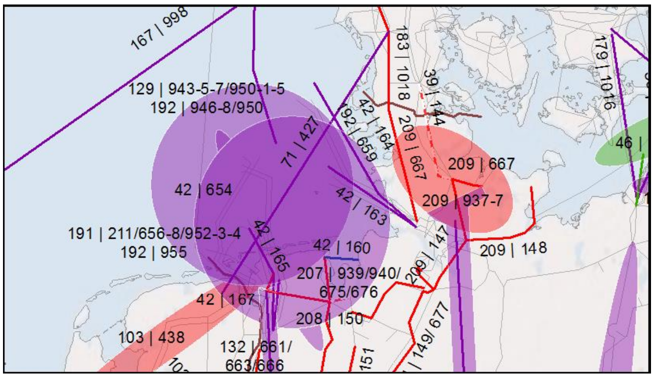
Project 129: OWP Northsea TenneT Part 4

Description of the project

Germany is planning to build a big amount of wind offshore power plants in the Northsea. The OWP will help to reach the European goal of CO2 reduction and RES integration. This project is for the connection of the OWP with the German grid. This project becomes necessary in case of further long-term strong increase in OWP generation like in Vision 3 and 4. The project is not in focus of Vision 1 and 2.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
943	NOR-9-1	Cloppenburg	Connection of new offshore wind park. New HVDC transmission system consisting of offshore platform, cable and converters with a total length of 255 km. Line capacity: 900 MW	900	Under Consideration	2028	New Investment	new investment
945	NOR-10-1	Cloppenburg	Connection of new offshore wind parks. New HVDC transmission system consisting of offshore platform, cable and converters with a total length of 260km. Line capacity: 900 MW	900	Under Consideration	2029	New Investment	new investment
947	NOR-11-2	Wilhelmshafen	Connection of new offshore wind parks. New HVDC transmission system consisting of offshore platform, cable and converters with a total length of 270km. Line capacity: 900 MW	900	Under Consideration	2031	New Investment	new investment
951	NOR-13-2	Kreis Segeberg	Connection of new offshore wind parks. New HVDC transmission system consisting of offshore platform, cable and converters with a total length of 330km. Line capacity: 900 MW	900	Under Consideration	2030	New Investment	new investment

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	GTC direction 2 (MW)	B6 Technical Resilience	B7 Flexibility	S1 - protected areas	S2 - urban areas	C1 Estimated cost (Meuros)
inside=>DE: 3600	DE=>inside: 3600	2	3	More than 100km	Negligible or less than 15km	4000-8000

CBA results	for each scenario				
Scenario	B1 SoS (MWh/year)	B2 SEW (MEuros/year)	B3 RES integration	B4 Losses (MWh/yr)	B5 CO2 Emissions (kT/year)
Scenario Vision 3 - 2030	-	[900;1100]	3074 MW	0	[-4900;-4000]
Scenario Vision 4 - 2030	-	[770;940]	3074 MW	0	[-4300;-3500]

Additional comments

Comment on the CO2 indicator: the very high scores reflect that the project directly connects RES sources

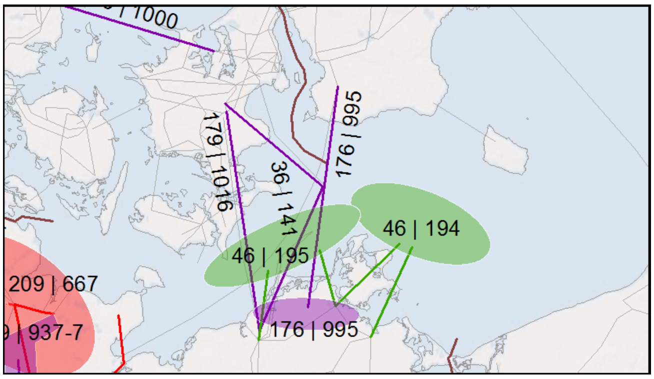
Comment on the Losses indicator: the losses variation for this direct connection project have not been valuated.

Comment on the S1 and S2 indicators: Detailed values for most lines are not available due to the early state in the planning process

Project 46: Offshore Wind Baltic Sea

Description of the project

Grid connections of offshore wind farms (using AC-technology), connecting offshore wind farms in the Baltic Sea to the German transmission grid in Bentwisch, Lüdershagen and Lubmin. According to German law, the grid connection has to be constructed and operated by the TSO (50Hertz Transmission).



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
194	OWF Cluster Baltic Sea East (DE)	Lüdershagen/Lubmin (DE)	Grid Connection of offshore wind farms (using AC-technology). According to German law, the grid connection has to be constructed and operated by the TSO (50Hertz Transmission).	3000	Design & Permitting	2031	Investment on time	The investment is split into different stages with different commissioning dates (starting in 2017) depending on the predicted installed capacity of offshore wind. For further informations see the national "Offshore Grid Development Plan"
195	wind farm cluster Baltic Sea West (DE)	Bentwisch/Lüdershagen (DE)	Grid Connection of offshore wind farms (using AC-technology). According to German law, the grid connection has to be constructed and operated by the TSO (50Hertz Transmission).	1500	Design & Permitting	2032	Investment on time	The investment is split into different stages with different commissioning dates (starting in 2026) depending on the predicted installed capacity of offshore wind. For further informations see the national "Offshore Grid Development Plan"

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
North=>South: 4500	South=>North: 4500	0	3	NA	NA	1700-4500

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[300;360]	1568 MW	0	[-3300;-2700]
Scenario Vision 2 - 2030	-	[210;250]	1568 MW	0	[-3000;-2400]
Scenario Vision 3 - 2030	-	[1300;1600]	4342 MW	0	[-7300;-6000]
Scenario Vision 4 - 2030	-	[1100;1400]	4342 MW	0	[-6400;-5200]

Additional comments

Comment on the CO2 indicator: the very high scores reflect that the project directly connects RES sources

Comment on the Losses indicator: the losses variation for this direct connection project have not been valuated.

North South Eastern German Corridor

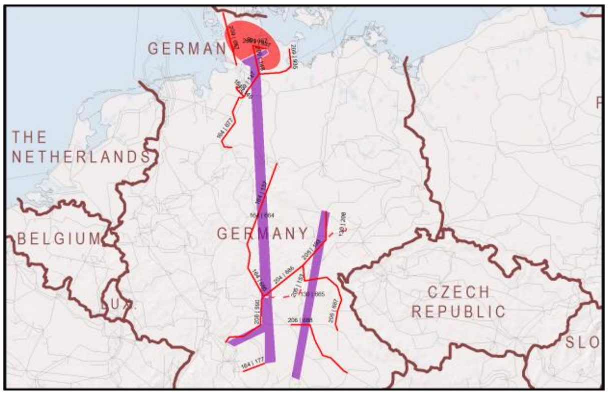
Description of the corridor

This corridor is necessary, due to the strong increase in RES generation, meeting the goals of the European and especially German energy policy. It connects areas with high installed capacities of RES and areas with high consumption and storage capabilities. For this reason the development of new North-South and Northeast-Southwest electricity transmission capacity in Germany is necessary. This corridor begins in the North-East of Germany, an area with high RES generation (planned and existing), conventional generation and connections with Scandinavia (planned and existing).The corridor ends in the South of Germany, an area with high consumptions and connections to Austria and Switzerland (transit to Italy and pump storage in the Alps). Thus, the corridor is an essential element for the integration of renewable energy sources into the German power system and the provision of additional transmission capacities in order to meet the increasing demand of the European electricity market and to avoid unscheduled transit flows to neighboring countries. Moreover, due to the nuclear phase out in Germany, the amount of reliable available capacity in southern Germany decreases and the security of supply of this area require additional transmission capacity to areas with conventional generation units.

The corridor consists of 6 projects:

- project 209 groups all investments needed to collect wind in-feed north east of Germany;
- project 130 and 164 represents the 2 sections of new HVDC lines aiming at transporting this power to the south of the country;
- project 206 groups all investments needed to secure the supply south of Germany in this corridor;
- projects 205 (resp. 204) group all supporting measures on existing assets in the short (resp; longer) term.

Working together, the six projects have been assessed as a whole and share the same common assessment.



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Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
Project 209								
147	Dollern (DE)	Hamburg/Nord (DE)	New 380kV double circuit OHL Dollern - Hamburg/Nord. Length: 43km. First circuit 2015, second circuit 2017	2008	Under Construction	2017	Delayed	Delay due to long permitting process
148	Audorf (DE)	Hamburg/Nord (DE)	New 380kV double circuit OHL Audorf - Hamburg/Nord including two new 380/220kV transformers in substation Audorf and new 380 kV Switchgear in Kummerfeld. Length: 65km.	2410	Design & Permitting	2017	Delayed	delay due to long permitting process
667	Brunsbüttel (DE)	Niebüll	About 135 km new 380-kV-lines and around 10 new transformers for integration of onshore Wind in Schleswig-Holstein and increase of NTC between DE and DK	2014	Planning	2018	Delayed	The old investment 43.A90 is now divided in several parts.
935	Kreis Segeberg	Göhl	New 380-kV-lineKreis Segeberg - Lübeck - Siems - Göhl, including five new transformers	4482	Under Consideration	2021	Rescheduled	Investment was part of investment 43.A90 in TYNDP 2012. Now separately
937	Audorf	Kiel	New 380-kV-line in existing OHL corridor including 4 new transformers and new 380-kV-switchgears in Kiel/West and Kiel/Süd	2299	Under Consideration	2021	Rescheduled	In TYNDP 2012 this investment was part of investment 43.A90
Project 130								
208	Pulgar (DE)	Vieselbach (DE)	Construction of new 380kV double-circuit OHL in existing corridor Pulgar-Vieselbach (103 km). Support of RES and conventional generation integration, maintaining of security of supply and support of market development.	2063	Planning	2024	Investment on time	The project is part of the results of the national grid development plan and included in the list of national interest (Bundesbedarfsplan). Within this process the commissioning dates of the included projects have been aligned with the current situation.
665	Lauchstädt (DE)	Meitingen (DE)	New DC- lines to integrate new wind generation from control area 50Hertz especially Mecklenburg-Vorpommern, Brandenburg and Sachsen-Anhalt towards Central/south Europe for consumption and storage.	3583	Planning	2022	Investment on time	Result from National Grid Development Plan
Project 164								
149	Dollern (DE)	Stade (DE)	New 380kV double circuit OHL Dollern - Stade including new 380kV switchgear in Stade. Length: 14km.	3749	Design & Permitting	2022	Delayed	The investment is delayed because of changes in the investment driver

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157	Wahle (DE)	Mecklar (DE)	New 380kV double circuit OHL Wahle - Mecklar including two new substations. Length: 210km.	2264	Design & Permitting	2018	Delayed	delay due to long permitting process
177	Goldshöfe (DE)	Bünzwangen (DE)	AC-extension of the "C corridor" at one ending point in Southern Germany towards the consumption areas allowing the existing grid to deal with the additional flows from DC-link	2070	Design & Permitting	2020	Investment on time	Anticipation of design and permitting phase due to foreseen difficulties (protected area in the Swabian Alps)
664	Brunsbüttel, Wilster, Kreis Segeberg	Großgartach, Goldshöfe, Grafenrheinfeld	New DC-lines to integrate new wind generation from Northern Germany towards Southern Germany and Southern Europe for consumption and storage.	3575	Planning	2022	Investment on time	The expected commissioning date is 2017 - 2022
677	Dollern (DE)	Landesbergen (DE)	New 380 kV line in existing OHL corridor Dollern-Sottrum-Wechold-Landesbergen (130 km)	3749	Planning	2022	Investment on time	Progress as planned.
685	Mecklar (DE)	Grafenrheinfeld (DE)	New double circuit OHL 400-kV-line (130 km)	2387	Planning	2022	Investment on time	Progress as planned.
Project 206								
682	Großgartach (DE)	Endersbach (DE)	AC-extension of the "C corridor" at one ending point in Southern Germany towards the consumption areas allowing the existing grid to deal with the additional flows from DC-link	1340	Planning	2019	Investment on time	Standard processing 2018-2019
687	Redwitz (DE)	Schwandorf (DE)	New double circuit OHL 380 kV line in existing OHL corridor Redwitz-Mechlenreuth-Etzenricht-Schwandorf (185 km)	1218	Planning	2020	Investment on time	Progress as planned.
688	Raitersaich (DE)	Isar (DE)	New 380 kV line in existing OHL corridor Raitersaich - Ludersheim - Sittling - Isar or Altheim (160 km)	1902	Under Consideration	2024	Rescheduled	Delay due to missing confirmation by the regulator
990	Grafenrheinfeld (DE)	Großgartach (DE)	AC-extension of the "C corridor" between two of its ending points in Southern Germany allowing the existing grid to deal with the additional flows from DC-link	4310	Planning	2019	New Investment	Standard processing
Project 205								
153	Redwitz (DE)	Grafenrheinfeld (DE)	Upgrade of 220kV connection Redwitz - Grafenrheinfeld to 380kV, including new 380kV switchgear Eltmann. Line length: 97km.	2473	Design & Permitting	2015	Delayed	Delayed due to delayed of related investment 45.193 and unexpected long permitting process of the investment itself
193	Vieselbach (DE)	Redwitz (DE)	New 380kV double-circuit OHL between the substations Vieselbach-Altenfeld-Redwitz with 215km length combined with upgrade between	3583	Design & Permitting	2015	Delayed	Previously "mid-term" is now updated to specific date. Partly under construction (section Vieselbach – Altenfeld). 3rd section

			Redwitz and Grafenrheinfeld (see investment 153). The Section Lauchstädt-Vieselbach has already been commissioned. Support of RES integration in Germany, annual redispatching cost reduction, maintaining of security of supply and support of the market development. The line crosses the former border between Eastern and Western Germany and is right downstream in the main load flow direction. The project will help to avoid loop flows through neighbouring grids.					(Altenfeld – Redwitz) in permitting process, long permitting process with strong public resistance.
Project 204								
686	Schalkau / area of Altenfeld (DE)	area of Grafenrheinfeld (DE)	New double circuit OHL 380-kV-line (130 km)	-	Under Consideration	2024	Rescheduled	Delay due to missing confirmation by the regulator

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
North=>South: 11800	South=>North: 11800	5	5	More than 100km	More than 50km	6200-8600

CBA results	**for each scenario**				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[340;420]	[3100000;3700000] MWh	[-4200000;-3400000]	[-1500;-1200]
Scenario Vision 2 - 2030	-	[310;380]	[3000000;3600000] MWh	[-4300000;-3500000]	[110;130]
Scenario Vision 3 - 2030	-	[1300;1600]	[8700000;11000000] MWh	[-5200000;-4200000]	[-7300;-6000]
Scenario Vision 4 - 2030	-	[2000;2400]	[14000000;17000000] MWh	[-6400000;-5200000]	[-12000;-9700]

Additional comments

Comment on the CBA assessment: As the existing tools are not designed to assess single internal projects within a price zone, the above-mentioned projects are assessed together as one corridor. Additionally the main goal of the corridor is to integrate new RES in Northern and North East Germany and can only be reached with all projects in.

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Comment on the security of supply: Market simulations are not able to take internal bottlenecks inside one bidding area into account in a comprehensive way. Therefore, to evaluate the SOS-indicator for internal projects a more detailed and specialized survey is indispensable. In Germany the quick decommissioning of nuclear power plants has led to the "Reservekraftwerksverordnung" regulation, which goal is to ensure the security of supply until the necessary investments for the grid have been realized, especially in Southern Germany. This regulation is only temporary and shall ensure the system security thanks to contracted reserve power plants dedicated to the security of supply. (see also : http://www.bundesnetzagentur.de/)

Comment on the CO2 indicator: the very high scores reflect that the project connects RES sources to load centres

Comment on the Losses indicator: without the project the grid would be overloaded; so the amount of lower losses with compared to without the project is theoretical.

Comment on the S1 and S2 indicators: Detailed values for most lines are not available due to the early state in the planning process

Comment on the technical resilience indicator: The corridor is necessary to enable switch-off of assets for maintenance. The corridor includes VSC-DC-Links, which are necessary for (n-1)-security, voltage control and system stability.

Comment on the flexibility indicator: the project appears useful in all visions, consists of various investments complementing each other, and integrates two control zones

Comment on the GTC: The main objective of the project is to deliver an internal GTC increase.In addition,the PCI 2.10 provides cross border capacity between DE/NO and DE/DKW (1800 MW), the PCI 3.12 provides cross boarder capacity between DE/CZ, DE/PL and DE/AT (600-650 MW). And the PCI 3.13 provides cross border capacity between DE/CZ (550 MW).

North South Western German Corridor

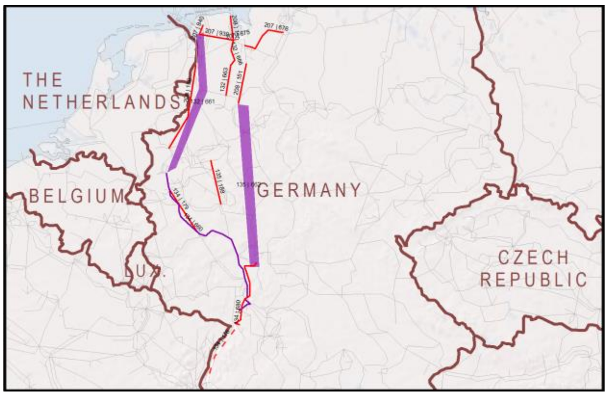
Description of the corridor

This corridor is necessary, due to the strong increase in RES generation, meeting the goals of the European and especially German energy policy. It connects areas with high installed capacities of RES and areas with high consumption and storage capabilities. For this reason the development of new North-South and Northeast-Southwest electricity transmission capacity in Germany is necessary. This corridor begins in the North of Germany, an area with high RES generation (planned and existing), conventional generation and connections with Scandinavia (planned and existing).The corridor ends in the South of Germany, an area with high consumptions and connections to Austria and Switzerland (transit to Italy and pump storage in the Alps). Thus, the corridor is an essential element for the integration of renewable energy sources into the German power system and the provision of additional transmission capacities in order to meet the increasing demand of the European electricity market and to avoid unscheduled transit flow to neighboring countries. Moreover, due to the nuclear phase out in Germany, the amount of reliable available capacity in southern Germany decreases and the security of supply of this area requires additional transmission capacity to areas with conventional generation units.

The Corridor consist of 5 projects:

- project 207 groups all investments needed to collect wind in-feed north west of Germany;
- project 132 and 208 represents the 2 sections of new HVDC lines aiming at transporting this power to the south of the country;
- project 134 groups all investments needed to secure the supply south of Germany in this corridor;
- project 135 group all supporting measures on existing assets.

Working together, the five projects have been assessed as a whole and share the same common assessment.



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Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
Project 208								
150	Conneforde (DE)	Fedderwarden (DE)	New 380kV double circuit (OHL, partly underground) Conneforde - Wilhelmshaven (Fedderwarden, former Maade) including new 400kV switchgear Fedderwarden. Length: 35 km.	3668	Design & Permitting	2018	Investment on time	Progress as planned.
151	Wehrendorf (DE)	Ganderkesee (DE)	New line (length: ca. 95km), extension of existing and erection of substations, erection of 380/110kV-transformers.	3538	Design & Permitting	2017	Delayed	delay due to long permitting process
156	Niederrhein (DE)	Dörpen/West (DE)	New 380 kV double circuit overhead line Dörpen - Niederrhein including extension of existing substations.	988	Design & Permitting	2018	Delayed	The project is delayed due to delays in public-law and civil-law licensing procedures.
Project 132								
661	Emden East (DE)	Osterath (DE)	New HVDC-lines from Emden to Osterath to integrate new wind generation especially from North Sea towards Central Germany for consumption.	3049	Planning	2022	Investment on time	Progress as planned.
663	Cloppenburg East (DE)	Merzen (DE)	New 380-kV double circuit over-head-line Cloppenburg East - Merzen with a total length of ca. 55 km. New erecting of a 380-kV substation Merzen.	3386	Planning	2022	Investment on time	Progress as planned.
666	Conneforde (DE)	Cloppenburg (DE)	New 380-kV-line in existing OHL corridor for integration of on- and offshore Wind generation. Incl. new 380-kV-switchgear in Cloppenburg and new transformers in Cloppenburg	3386	Planning	2022	Investment on time	TYDNP 2012 investment 43.A89 is divided in serveral parts
Project 135								
188	Kruckel (DE)	Dauersberg (DE)	New 380 kV overhead lines in existing rout. Extension of existing and erection of several 380/110kV-substations.	774	Design & Permitting	2020	Investment on time	Progress as planned.
662	Wehrendorf (DE)	Urberach (DE)	New lines in HVDC technology from Wehrendorf to Urberach to integrate new wind generation especially from North Sea towards Central-South Europe for consumption and storage.	2856	Under Consideration	2022	Rescheduled	The need for this long-term investment was not confirmed by the regulatory authority within the national grid development plan 2012. Therefore further studies on this project are ongoing.
680	Urberach (DE)	Daxlanden (DE)	New line and extension of existing line to 380 kV double circuit overhead line Urberach - Weinheim - Daxlanden. Extension of	1833	Planning	2021	Investment on time	Progress as planned.

			existing substations are included.					
Project 134								
176	Daxlanden (DE)	Eichstetten (DE)	This AC project is necessary in order to evacuate the energy arriving from HVDC corridors towards southern Germany and reinforce the interconnection capacity with Switzerland	754	Under Consideration	2020	Investment on time	Progress as planned.
179	Rommerskirchen (DE)	Weißenthurm (DE)	New380 kV overhead line in existing route. Extension and erection of substations incl. erection of 380/110kV-transformers.	900	Under Construction	2017	Delayed	The section Rommerskrichen to Sechtem is delayed because the permitting procedures take longer than planned. The 36 km section from Sechtem to Weißenturm is already commissioned.
660	Osterath (DE)	Philippsburg (DE)	New HVDC-lines from Osterath to Philippsburg to integrate new wind generation especially from North Sea towards Central-South Germany for consumption and storage.	3049	Design & Permitting	2019	Investment on time	Progress as planned.
680	Urberach (DE)	Daxlanden (DE)	New line and extension of existing line to 380 kV double circuit overhead line Urberach - Weinheim - Daxlanden. Extension of existing substations are included.	1833	Planning	2021	Investment on time	Progress as planned.
Project 207								
675	Conneforde (DE)	Unterweser (DE)	Upgrade of 220-kV-circuit Unterweser-Conneforde to 380kV , Line length: 32 km.	4068	Under Consideration	2024	Rescheduled	Delay due to missing confirmation by the regulator
676	Dollern (DE)	Elsfleht/West (DE)	New 380 kV line in existing OHL corridor Dollern - Elsfleht/West Length:100 km	2849	Under Consideration	2024	Rescheduled	Delay due to missing confirmation by the regulator
939	Conneforde	Emden/Ost	New 380-kV-line in existing OHL corridor for integration of RES	3336	Planning	2019	Delayed	In TYNDP 2012 part of investment 43.A89
940	Emden/Ost	Halbemond	New 380-kV-line Emden - Halbemond for RES integration incl. new transformers in Halbemond	3336	Under Consideration	2021	Rescheduled	In TYNDP 2012 part of investment 43.A89

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
North=>South: 5500	South=>North: 5500	5	4	More than 100km	More than 50km	4900-6600

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[410;500]	[6000000;7300000] MWh	[-2500000;-2100000]	[-4600;-3800]
Scenario Vision 2 - 2030	-	[290;350]	[5400000;6600000] MWh	[-1200000;-1000000]	[-3600;-2900]
Scenario Vision 3 - 2030	-	[1400;1700]	[14000000;17000000] MWh	[-6200000;-5000000]	[-6700;-5500]
Scenario Vision 4 - 2030	-	[1300;1600]	[15000000;18000000] MWh	[-5100000;-4100000]	[-6500;-5300]

Additional comments

Comment on the CBA assessment:
As the existing tools are not designed to assess single internal projects within a price zone, the above-mentioned projects are assessed together as one corridor. Additionally the main goal of the corridor is to integrate new RES in Northern and North East Germany and can only be reached with all projects in.

Comment on the security of supply:
Market simulations are not able to take internal bottlenecks inside one bidding area into account in a comprehensive way. Therefore, to evaluate the SOS-indicator for internal projects, a more detailed and specialized survey is indispensable. In Germany, the quick decommissioning of nuclear power plants has led to the "Reservekraftwerksverordnung" regulation, which goal is to ensure the security of supply until the necessary investments for the grid have been realised, especially for the reliably power supply of Southern Germany. This regulation is only temporary and shall ensure the system security thanks to contracted reserve power plants dedicated to the security of supply. (see also : http://www.bundesnetzagentur.de/) The necessary reserve capacity is in the range of some GW.

Comment on the CO2 indicator:
the very high scores reflect that the project connects RES sources to load centres

Comment on the Losses indicator: without the project the grid would be overloaded; so the amount of lower losses with compared to without the project is theoretical.
Comment on the S1 and S2 indicators:
Detailed values for most lines are not available due to the early state in the planning process.

Comment on the technical resilience indicator:
The project is necessary to enable switch-off of assets for maintenance. The project includes VSC-DC-Links, which are necessary for (n-1)-security, voltage control and system stability.

Comment on the flexibility indicator: the project appears useful in all visions, consists of various investments complementing each other, and integrates two control zones

Comment on the GTC: The main objective of the project is to deliver an internal GTC increase.In addition,the PCI 2.9 provides cross border capacity between DE/NL and DE/CH (500-600MW).

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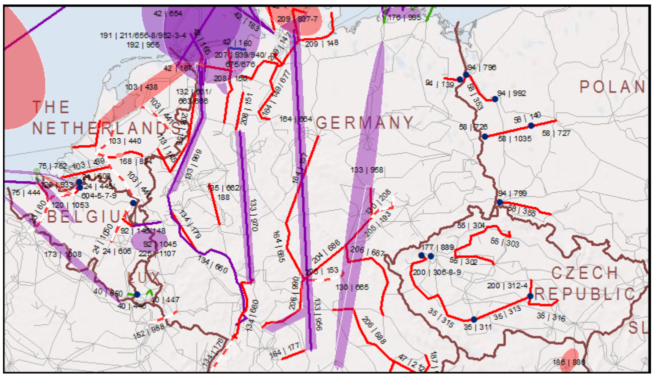
Project 133: Longterm German RES

Description of the project

This project becomes necessary in case of further long-term strong increase in RES generation like in Vision 3 and 4. The project is not in Vision 1 and 2. It connects areas with high installed capacities of RES and areas with high consumption and storage capabilities. For this reason the development of new North-South and Northeast- Southwest electricity transmission capacity in Germany is necessary. This project begins in the North and North-East of Germany, areas with high RES generation (planned and existing) and connections with Scandinavia (planed and existing).The project ends in the South of Germany, an area with high consumptions and connections to Austria and Switzerland (transit to Italy and pump storage in the Alps).



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
956	Schleswig-Hostein	Baden-Würtemberg / Bavaria	New DC- line in HVDC technology to integrate new wind generation from northern Germany toward southern Germany and southern Europe for consumption and storage. Connections points north: Brunsbüttel, Wilster, Kreis Segeberg, Stade, and Alfsted. South: Großgartach, Goldshöfe, Raitersaich, Vöhringen	8000	Under Consideration	2030	New Investment	new investment
958	Güstrow (DE)	Meitingen (DE)	New DC- lines to integrate new wind generation from Baltic Sea and control area 50Hertz especially Mecklenburg-Vorpommern towards Central/south Europe for consumption and storage.	2000	Under Consideration	2034	New Investment	New Investment
969	lower saxony	NRW	New HVDC line to integrate new wind generation especially from North Sea towards Central Germany for consumption and storage. Connections points north: Emden, Conneforde. South: Oberzier, Rommerskirchen	4000	Under Consideration	2030	New Investment	new investment

970	lower saxony	Hessen/Baden-Würtemberg	New HVDC line to integrate new wind generation especially from North Sea towards South Germany for consumption and storage. Connections points north: Cloppenburg, Elsfelth/West. South: Bürstadt, Philipsburg	4000	Under Consideration	2030	New Investment	new investment

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
North=>South: 18000	South=>North: 18000	5	4	NA	NA	5100-6800

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 3 - 2030	-	[57;140]	[860000;1000000] MWh	[-3300000;-2700000]	[-380;-310]
Scenario Vision 4 - 2030	-	[180;260]	[1600000;2000000] MWh	[-4000000;-3200000]	[-1200;-960]

Additional comments

Comment on the CO2 indicator: the very high scores reflect that the project connects RES sources to load centres

Comment on the Losses indicator: without the project the grid would be overloaded; so the amount of lower losses with compared to without the project is theoretical.

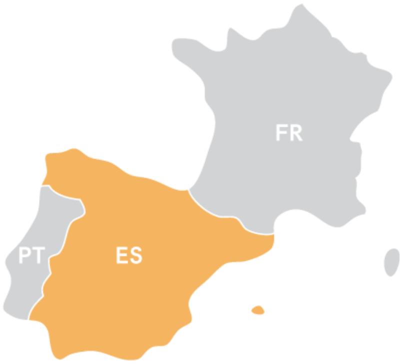
Comment on the S1 and S2 indicators:
Values for this project are not available due to the early state in the planning process

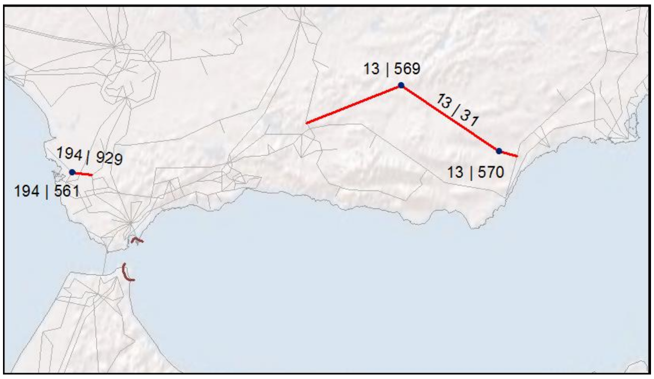
Comment on the technical resilience indicator:
The project is necessary to enable switch-off of assets for maintenance. The project includes VSC-DC-Links, which are necessary for (n-1)-security, voltage control and system stability.

Project 13: Baza project

Description of the project

A new double circuit Caparacena-Baza-La Ribina 400 kV OHL, with two new 400 kV substations in Baza and La Ribina, will allow integrating an important contingent of wind and solar generation, both at transmission and distribution level in an area of Jaen where the transmission network is very weak. Moreover, a new pumping hydropower plant with pumping storage is expected in this area.
On the other hand, the project will help reducing congestion in the existing single circuit Litoral-Tabernas-Hueneja-Caparacena 400 kV, between Almeria and Granada.





Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
31	Caparacena (ES)	La Ribina (ES)	New double circuit Caparacena-Baza-La Ribina 400kV OHL.	2060	Under Consideration	2025	Rescheduled	Investment rescheduled due to, and in accordance with, delayed development of new power plant, as considered in the Master Plan 2020 in progress
569	Baza (ES)		New 400kV substation in Baza	2060	Under Consideration	2025	Rescheduled	Investment rescheduled due to, and in accordance with, delayed development of new power plant, as considered in the Master Plan 2020 in progress
570	La Ribina (ES)		New 400kV substation in La Ribina (will be connected as an input/output in Carril-Litoral 400kV line).	2060	Under Consideration	2025	Rescheduled	Investment rescheduled due to, and in accordance with, delayed development of new power plant, as considered in the Master Plan 2020 in progress

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
inside=>outside: 550-770	outside=>inside: 3280-3630	2	3	Negligible or less than 15km	Negligible or less than 15km	110-140

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[33;40]	[380000;470000] MWh	[-18000;-14000]	[-180;-140]
Scenario Vision 2 - 2030	-	[35;42]	[400000;490000] MWh	[-18000;-15000]	[-190;-150]
Scenario Vision 3 - 2030	-	[180;230]	[2000000;2500000] MWh	[-20000;-16000]	[-870;-710]
Scenario Vision 4 - 2030	-	[230;280]	[2400000;3000000] MWh	[-20000;-16000]	[-790;-640]

Additional comments

Comment on the RES integration: In Vision 1, 400kV Baza substation considered 150 MW of wind, 275 MW of pumping and 35 MW of solar. In Vision 4, 400kV Baza substation considered 490 MW of wind, 500 MW of pumping and 1100 MW of solar.

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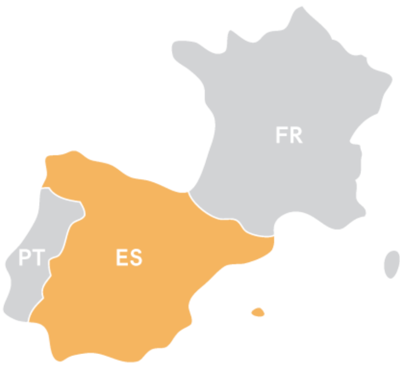
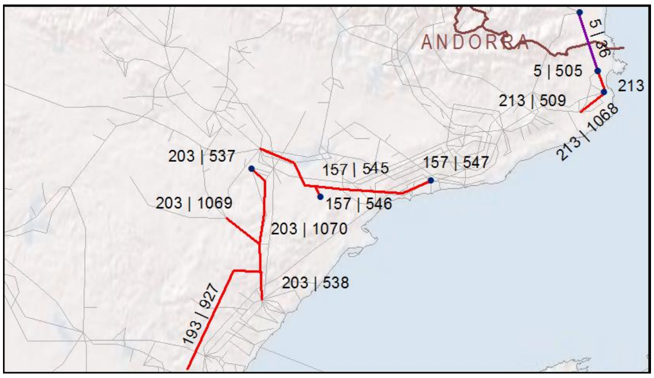
Project 157: Aragón-Catalonia south

Description of the project

This project is a reinforcement between Aragón and Cataluña required to solve the congestion on the existing grid, due to unbalanced production and consumption between Aragón and Cataluña, mainly between Teruel and Tarragona.
The project consist of a new 400 kV double circuit OHL line between Escatrón and La Secuita (Spain), and includes new substations in Els Aubals (with direct connection of wind power) and in La Secuita (400/220 kV).





Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
545	Escatron (ES)	La Secuita (ES)	New single circuit Escatrón-Els Aubals-La Secuita 400kV OHL.	200	Under Consideration	2027	Rescheduled	Investment rescheduled as a result of changes in planning data inputs (demand reduction and projects of new thermal units are in standby)
546	Els Aubals (ES)		New 400kV substation in Els Aubals.	200	Under Consideration	2027	Rescheduled	Investment rescheduled as a result of changes in planning data inputs (demand reduction and projects of new thermal units are in standby)
547	La Secuita (ES)		New 400kV substation in La Secuita with 400/220kV transformer.	200	Under Consideration	2027	Rescheduled	Investment rescheduled as a result of changes in planning data inputs (demand reduction and projects of new thermal units are in standby)

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
East=>West: 0-30	West=>East: 0-500	2	2	Negligible or less than 15km	Negligible or less than 15km	97-120

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[37;46]	[370000;450000] MWh	[-32000;-26000]	[-180;-150]
Scenario Vision 2 - 2030	-	[41;50]	[400000;490000] MWh	[-35000;-29000]	[-200;-160]
Scenario Vision 3 - 2030	-	[84;100]	[590000;730000] MWh	[-30000;-24000]	[-270;-220]
Scenario Vision 4 - 2030	-	[110;140]	[840000;1000000] MWh	[-30000;-24000]	[-310;-250]

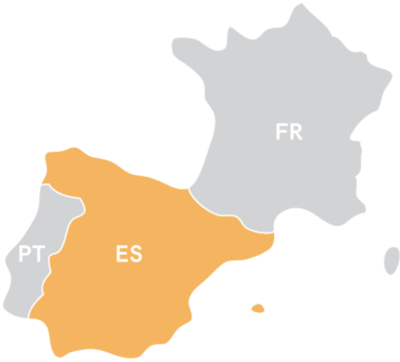
Additional comments

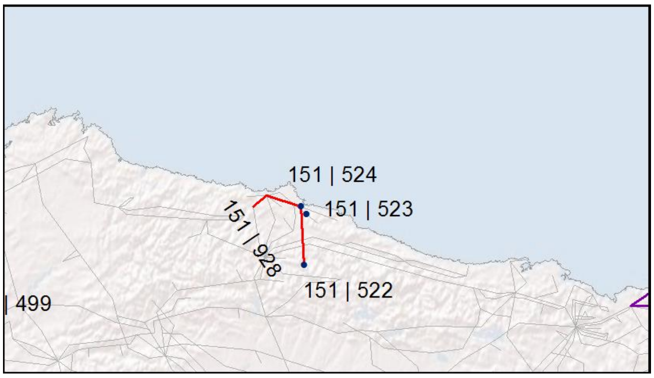
Comment on the RES integration: required to solve restrictions that cause spillage of RES energy (onshore wind but mainly solar) in the areas of Navarra, Aragón and Tarragona. In addition, the project directly connects RES in Els Aubals

Project 151: Asturian Ring

Description of the project

This project consist of closing the 400kV Asturias Ring in the northern part of Spain, and comprises a new 400 kV line between Gozón and Sama, with two new 400kV substations in Reboria and Costa Verde (Spain) , which main purpose is support the distribution network. Therefore, this project is required to ensure the security of supply in the area of Asturias in a future with very low thermal generation in the region.





Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
522	Sama (ES)		New 400kV substation Sama in the new Asturias Ring with connection to Lada and a new reactance.	1220	Under Consideration	2026	Rescheduled	Investment rescheduled as a result of changes in planning data inputs (demand reduction and projects of new thermal units are in standby)
523	Reboria (ES)		New 400kV substation Reboria in the Asturian ring with 2 transformers 400/220 kV	1220	Under Consideration	2026	Rescheduled	Investment rescheduled as a result of changes in planning data inputs (demand reduction and projects of new thermal units are in standby)
524	Costa Verde (ES)		New 400kV substation Costa Verde in the Asturian Ring with 2 new transformer units 400/220 kV	1220	Under Consideration	2026	Rescheduled	Investment rescheduled as a result of changes in planning data inputs (demand reduction and projects of new thermal units are in standby)
928	GOZON (ES)	SAMA (ES)	Asturian Ring. New double circuit Gozon-Reboria-Costa Verde-Sama 400 kV	1220	Under Consideration	2026	Rescheduled	Investment rescheduled as a result of changes in planning data inputs (demand reduction and projects of new thermal units are in standby)

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
outside=>inside: 400-500	inside=>outside: 700-700	2	2	Negligible or less than 15km	Negligible or less than 15km	53-65

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	[2300;2800]	[1;2]	0	[-17000;-14000]	0
Scenario Vision 2 - 2030	[2300;2800]	[1;2]	0	[-17000;-14000]	0
Scenario Vision 3 - 2030	[2600;3200]	[18;23]	0	[-34000;-28000]	[-11;-9]
Scenario Vision 4 - 2030	[3000;3700]	[20;25]	0	[-34000;-28000]	[-12;-9]

Additional comments

Comment on the security of supply: It is required to secure the supply in the central area of Asturias creating a 400kV ring This project contributes to the security of supply of the Asturias area

Comment on the RES integration: the effect on RES integration is negligible (hence, a value=0 is given for the RES contribution)

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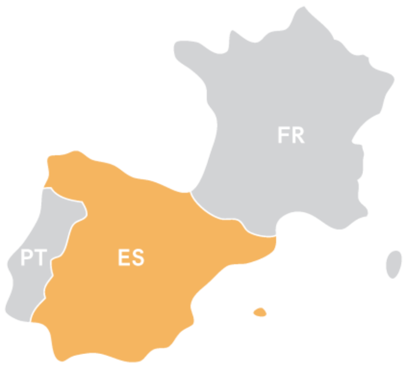
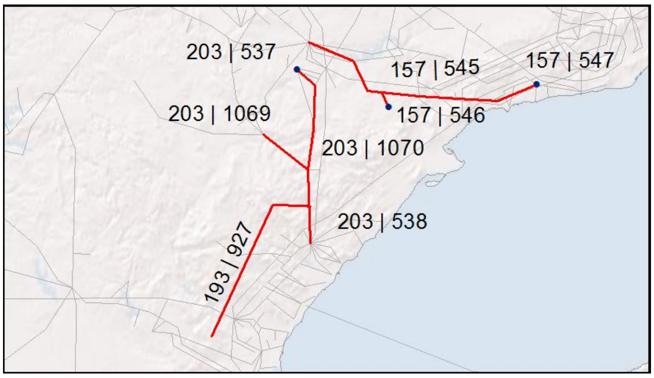
Project 193: Godelleta-Morella/La Plana

Description of the project

This projects consist of a new OHL 400 kV AC axis Godelleta-Morella/La Plana (Spain) and represents the reinforcement of the Mediterranean axis needed to accommodate geographical unbalances between North and South, especially between Castellón and Valencia, which besides are influenced by the exchanges with France. Congestions are expected due to important south-north flows caused by renewable energy sources (onshore wind but mainly solar), which result in dumped energy without the project.





Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
927	La Plana/Morella	Godelleta	New 400 kV axis Godelleta-Morella/La Plana (Spain)	-	Under Consideration	2023	Rescheduled	Investment rescheduled as a result of changes in planning data inputs.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
North=>South: 670-850	South=>North: 1400-1500	2	2	Negligible or less than 15km	Negligible or less than 15km	81-99

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[11;14]	[23000;28000] MWh	[23000;28000]	[-14;-11]
Scenario Vision 2 - 2030	-	[12;15]	[25000;30000] MWh	[25000;30000]	[-15;-12]
Scenario Vision 3 - 2030	-	[120;140]	[880000;1100000] MWh	[350000;430000]	[-210;-170]
Scenario Vision 4 - 2030	-	[290;350]	[3800000;4700000] MWh	[290000;350000]	[-1400;-1200]

Additional comments

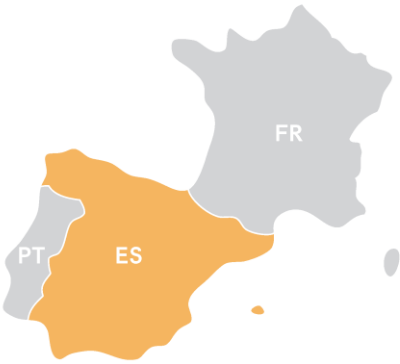
Comment on the RES integration: required to solve restrictions that cause spillage of RES energy (onshore wind but mainly solar) in the central eastern part of Spain

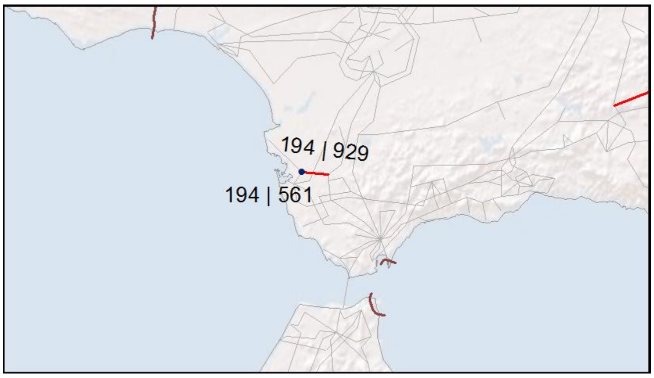
Comment on the CO2 indicator: the very high score in Vision 4 reflects that the project directly connects RES sources

Project 194: Cartuja

Description of the project

The 400 kV double circuit Cartuja-Arcos de la Frontera and the Cartuja 400 kV substation intend to be the connection point of an important amount of wind power energy in the coastal area of Cadiz, mainly offshore but also onshore. In case of low wind production, the project will be useful as an additional injection for secure the load in the area of Cadiz.





Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
561	Cartuja (ES)		New 400kV substation Cartuja with a 400/220kV transformer.	1320	Under Consideration	2022	Rescheduled	Investment rescheduled as the associated new wind power plants have been postponed
929	Cartuja	Arcos	New double circuit Cartuja-Arcos 400 kV	1320	Under Consideration	2022	Rescheduled	Investment rescheduled as the associated new wind power plants have been postponed

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
South=>North: 425-600	North=>South: 1560-2700	1	2	Negligible or less than 15km	Negligible or less than 15km	31-38

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[77;94]	[95000;120000] MWh	[-35000;-29000]	[-420;-340]
Scenario Vision 2 - 2030	-	[81;99]	[100000;120000] MWh	[-37000;-30000]	[-440;-360]
Scenario Vision 3 - 2030	-	[96;120]	[1100000;1400000] MWh	[-1100;-900]	[-460;-380]
Scenario Vision 4 - 2030	-	[99;120]	[1200000;1500000] MWh	[3600;4400]	[-390;-320]

Additional comments

Comment on the RES integration: 400kV Cartuja substation considered direct connection of 400 MW of wind in Vision 1 and 1000 MW in Vision 4

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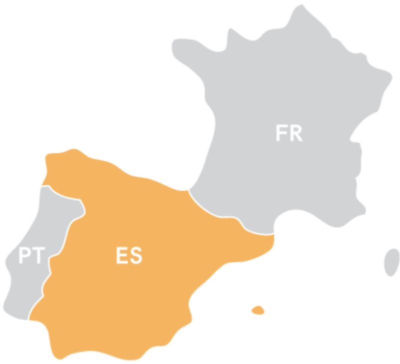
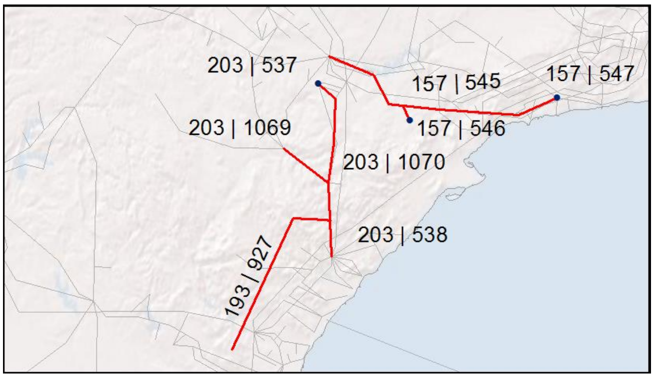
Project 203: Aragón-Castellón

Description of the project

This project represents the reinforcement of the Cantabric-Mediterranean axis needed to accommodate geographical unbalances between Northern Spain and the Mediterranean area, which otherwise would produce congestions in the 400 kV corridors. Therefore, this project is required to solve constraints in the existing and future network, caused by existing and new RES and because of flows in both directions between Aragón and Castellón.
The project consists of two 400kV axis Mudejar-Morella and Mezquita-Morella that converge in an axis Morella-La Plana. The project also includes a new 400kV substation Mudejar with connection to the axis Aragón-Teruel (Spain).





Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
537	Mudejar (ES)		New 400kV substation Mudejar and connection to the axis Aragón-Teruel	1420	Design & Permitting	2016	Delayed	Delayed because National law RDL 13/2012 has frozen the permitting process until publication of the next NDP
538	Morella (ES)	La Plana(ES)	Southern part of the new Cantabric-Mediterranean axis. New double circuit Morella-la Plana 400kV-OHL.	1420	Design & Permitting	2018	Delayed	Delayed because National law RDL 13/2012 has frozen the permitting process until publication of the next NDP
1069	Mezquita	Morella	Mezquita-Morella 400 kV line	1420	Design & Permitting	2017	Delayed	Delayed because National law RDL 13/2012 has frozen the permitting process until publication of the next NDP
1070	Mudejar	Morella	OHL 400kV AC Mudejar-Morella	1420	Design & Permitting	2017	Delayed	Delayed because National law RDL 13/2012 has frozen the permitting process until publication of the next NDP

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
West=>East: 100-900	East=>West: 1900-2600	2	2	15-50 km	Negligible or less than 15km	150-180

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[52;63]	[25000;30000] MWh	[-89000;-73000]	[-58;-47]
Scenario Vision 2 - 2030	-	[57;70]	[27000;33000] MWh	[-98000;-80000]	[-63;-52]
Scenario Vision 3 - 2030	-	[87;110]	[920000;1100000] MWh	[310000;380000]	[-210;-170]
Scenario Vision 4 - 2030	-	[380;470]	[4800000;5900000] MWh	[490000;600000]	[-1800;-1500]

Additional comments

Comment on the RES integration: required to solve restrictions that cause spillage of RES energy (onshore wind and solar) in the areas of Navarra, Aragón and Valencia

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Project 96: Keminmaa-Pyhänselkä

Description of the project

The project is 400 kV overhead line in North Finland. Integration of new generation at Bothnian bay and increased transmission capacity demand. Will help utilizing the Swedish/Finnish cross border capacity.

Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
801	Keminmaa (FI)	Pyhänselkä (FI)	Integration of new generation + increased transmission capacity demand.	-	Under Consideration	2024	Rescheduled	Investment progresses as planned, rescheduled slightly since last TYNDP due to expected development on the drivers behind the investment.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	GTC direction 2 (MW)	B6 Technical Resilience	B7 Flexibility	S1 - protected areas	S2 - urban areas	C1 Estimated cost (Meuros)
North=>South: 500-1000	South=>North: 500-1000	2	4	Negligible or less than 15km	Negligible or less than 15km	41-48

CBA results	for each scenario				
Scenario	B1 SoS (MWh/year)	B2 SEW (MEuros/year)	B3 RES integration	B4 Losses (MWh/yr)	B5 CO2 Emissions (kT/year)
Scenario Vision 1 - 2030	-	[0;14]	1050 MW	[-30000;-60000]	[0;240]
Scenario Vision 2 - 2030	-	0	[800;1200] MW	[-30000;-60000]	[0;500]
Scenario Vision 3 - 2030	-	[0;6]	1000 MW	[-35000;-65000]	[0;-40]
Scenario Vision 4 - 2030	-	[0;68]	[1300;1800] MW	[-20000;-80000]	[0;-100]

Additional comments

Comment on the RES integration:
The project help integrating 1000-1800 MW of RES in Coastline of Bothnian bay in Finland

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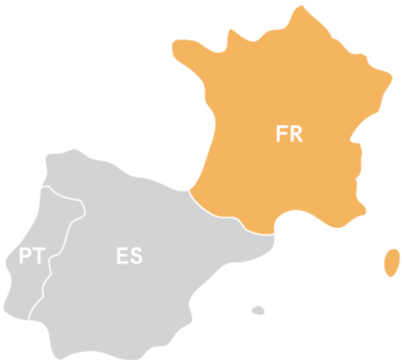
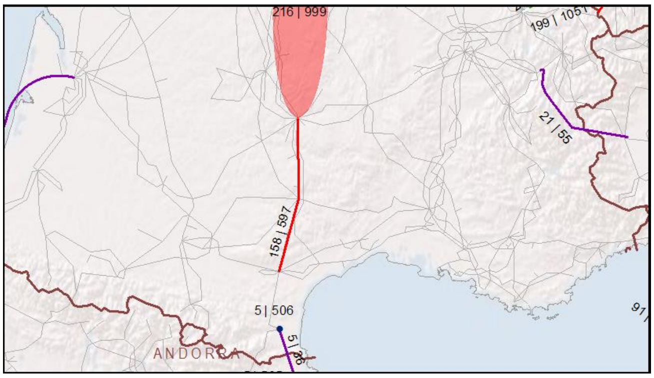
Project 158: Massif Central South

Description of the project

The main driver for the project is the integration of existing and new wind &hydro generation in the Massif Central (France) including possible pump storage. The project will develop in the north-south direction, mainly consisting of a new 400kV line substituting to the existing one. For visions 3&4, it will be complemented by a northern part (project 216). In TYNDP2012, both parts were described as a single investment.





Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
597	La Gaudière (FR)	Rueyres (FR)	New 175-km 400kV double circuit OHL Gaudière-Rueyres substituting to the existing single circuit 400kV OHL	-	Under Consideration	2023	Investment on time	Studies conducted after TYNDP2012 release have led to better investment definition.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
North=>South: 3300	South=>North: 3800	2	2	NA	NA	300-400

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[18;22]	[90000;110000] MWh	[-41000;-33000]	[-220;-180]
Scenario Vision 2 - 2030	-	[18;22]	[90000;110000] MWh	[-41000;-33000]	[-220;-180]
Scenario Vision 3 - 2030	-	[85;100]	[540000;660000] MWh	[-99000;-81000]	[-770;-630]
Scenario Vision 4 - 2030	-	[85;100]	[540000;660000] MWh	[-99000;-81000]	[-770;-630]

Additional comments

Comment on the RES integration: avoided spillage concerns RES in Massif central, wind farms and hydro.

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

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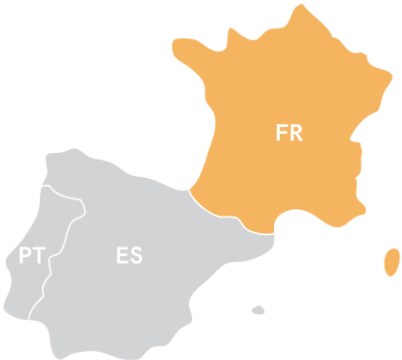
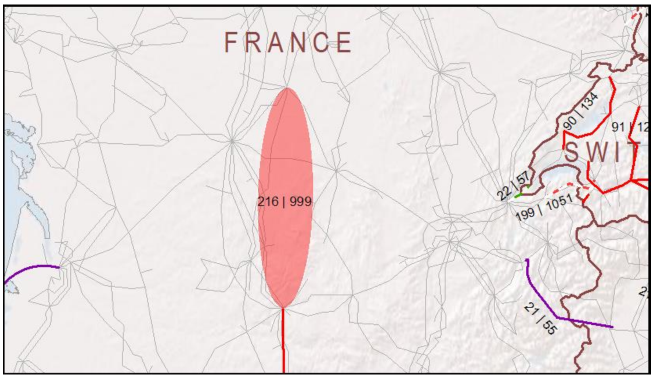
Project 216: Massif Central North

Description of the project

The main driver of the project is the integration of existing and new wind&hydro generation in the Massif Central (France) including possible pump storage. The project will develop in the north to south direction, north of project 158 that it complements.
It is needed only for visions 3 and 4. Studies are ongoing to define the scope of the project.





Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
999	Marmagne	Rueyres	Erection of a new 400-kV double circuit line substituting an existing 400-kV single circuit line.	-	Under Consideration	2030	Investment on time	This long term investment is only needed for scenarios with high RES development in the area, especially wind and hydro; additional studies are needed for better investment definition.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
North=>South: 3300	South=>North: 3800	2	2	NA	NA	440-660

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 3 - 2030	-	[85;100]	[540000;660000] MWh	[-230000;-190000]	[-770;-630]
Scenario Vision 4 - 2030	-	[85;100]	[540000;660000] MWh	[-230000;-190000]	[-770;-630]

Additional comments

Comment on the RES integration: voided spillage relates directly to new hydro power plants in Massif central.

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

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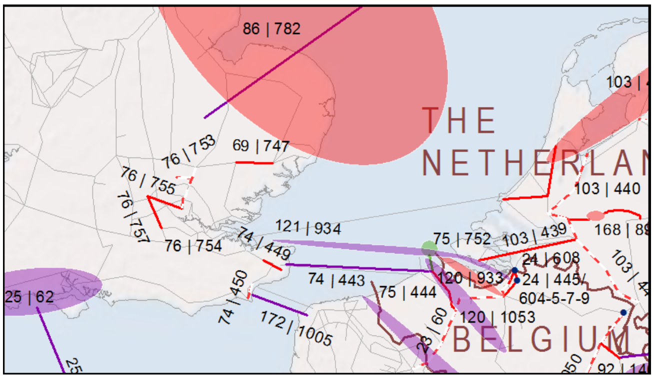
Project 69: East Anglia Cluster

Description of the project

This group of investments are in response to an expected growth in offshore wind and nuclear generation in and around the Norfolk and East Anglia region.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
747	Bramford (GB)	Twinstead (GB)	Construction of a new transmission route from Bramford to the Twinstead Tee Point creating Bramford - Pelham and Bramford - Braintree - Rayleigh Main double circuits; the rebuild of Bramford substation and the installation of an MSC at Barking.	-	Design & Permitting	2022	Investment on time	Delay in project requirement due to generation going back.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
inside=>downstream: 3600	downstream=>inside: 3600	2	3	15-50km	Negligible or less than 15km	350-370

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[170;200]	[4000;4500] MW	[350000;450000]	[-8700;-9400]
Scenario Vision 2 - 2030	-	[160;200]	[4000;4500] MW	[360000;440000]	[-9900;-8100]
Scenario Vision 3 - 2030	-	[590;720]	[8600;11000] MW	[450000;550000]	[-6500;-5300]
Scenario Vision 4 - 2030	-	[580;720]	[8600;11000] MW	[440000;560000]	[-4900;-6900]

Additional comments

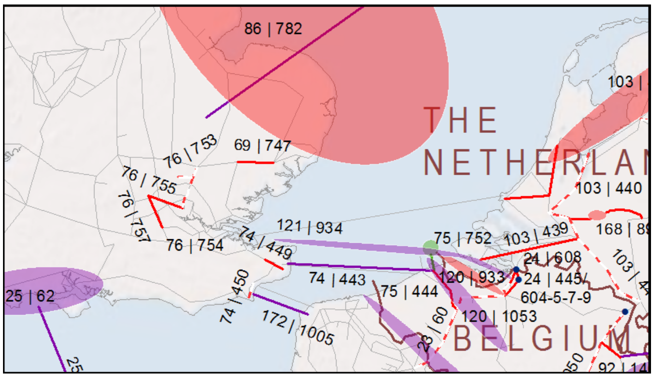
Comment on the clustering: the project also takes advantage of investment items n°748,749,750 depicted in the Regional investment plan.

Comment on the RES integration: RES at stake is located north and east to London.
Comment on the CO2 indicator: the very high scores reflect that the project connects RES sources to load centres

Project 76: London Cluster

Description of the project

All of these investments are required due to a combination of age related asset replacement, increasing power flows and changing customer demand connection requirements. A further driver for all of these projects is that power flows through London increase during interconnector export to mainland Europe. Power flows from the north through London to the interconnectors within the Thames Estuary.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
753	Pelham (GB)	Waltham Cross (GB)	Reconductoring the existing circuit which runs from Pelham - Rye House - Waltham Cross with a higher rated conductor.	800	Design & Permitting	2021	Delayed	Postponed due to the slow build-up of generation in the East Anglia area and also in demand within London.
754	Hackney (GB)	Waltham Cross (GB)	Uprating and reconductoring of the Hackney - Tottenham - Brimsdown - Waltham Cross double circuits. Construction of a new 400kV substation at Waltham Cross and modifications to the Tottenham substation and the installation of two new transformers at Brimsdown substation.	800	Design & Permitting	2021	Delayed	Postponed due to the build-up of generation schemes in the East Anglia area and demand increases in London.
755	Hackney (GB)	St. John's Wood (GB)	This is a new Hackney - St. John's Wood 400kV double circuit. It will replace an old asset rated at 275kV that has come to the end of its life.	800	Under Construction	2018	Investment on time	Progress as planned.
757	St. John's Wood (GB)	Wimbledon (GB)	New St. John's Wood - Wimbledon 400kV double circuit.	800	Design & Permitting	2018	Investment on time	Progress as planned.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
North=>South: 800	South=>North: 800	2	1	NA	NA	760

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	[130;210]	[11;19]	[1600;2000] MW	[-290000;-410000]	[20000;40000]
Scenario Vision 2 - 2030	[160;240]	[14;22]	[1600;2000] MW	[-350000;-490000]	[24000;48000]
Scenario Vision 3 - 2030	[1200;1500]	[130;170]	[1600;2000] MW	[230000;330000]	[-9200;-10000]
Scenario Vision 4 - 2030	[1400;1800]	[170;220]	[1600;2000] MW	[290000;410000]	[-10000;-12000]

Additional comments

Comment on the CBA assessment: high values for SEW and SoS indicators reported in Visions 3 and 4 reflect much higher north south power flows, challenging the London grid. The project is key for the security of supply of London in these Visions.

Comment on the clustering: the project also takes advantage of investment items n°756,758 depicted in the Regional investment plan.

Comment on the CO2 indicator: the very high scores reflect that the project connects RES sources to load centres.

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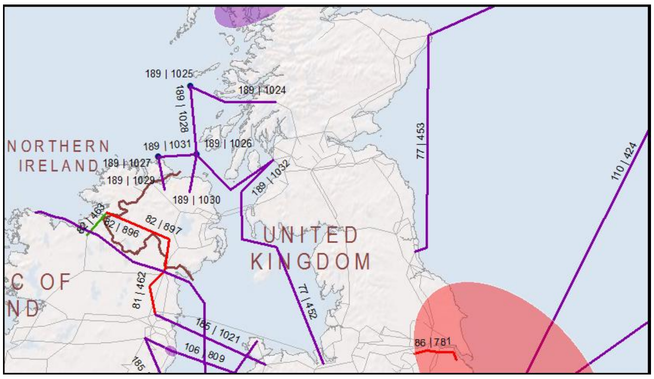
Project 77: Anglo-Scottish Cluster

Description of the project

These projects facilitate the connection of RES and the connection of the remote Scottish Islands.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
452	Hunterston (GB)	Deeside (GB)	A new 2.4GW (short term rating) submarine HVDC cable route from Hunterston to Deeside with associated AC network reinforcement works at both ends.	2400	Design & Permitting	2016	Investment on time	Progress as planned.
453	Peterhead (GB)	Hawthorn Pit (GB)	A new ~2GW submarine HVDC cable route from Peterhead to Hawthorn Pit with associated AC network reinforcement works at both ends with possible offshore HVDC integration in the Firth of Forth area.	2000	Under Consideration	2020	Investment on time	Progress as planned.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
North=>South: 4200	South=>North: 4200	2	1	NA	NA	3000

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[160;310]	[7500;8500] MW	0	[-9000;-11000]
Scenario Vision 2 - 2030	-	[240;330]	[7700;11000] MW	0	[-9000;-11000]
Scenario Vision 3 - 2030	-	[420;490]	[9300;12000] MW	[-600000;-900000]	[-18000;-20000]
Scenario Vision 4 - 2030	-	[520;600]	[11000;14000] MW	[-600000;-900000]	[-18000;-20000]

Additional comments

Comment on the clustering: the project also takes advantage of investment items n°454-457, 761-766, depicted in the Regional investment plan.

Comment on the CO2 indicator: the very high scores reflect that the project directly connects RES sources

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

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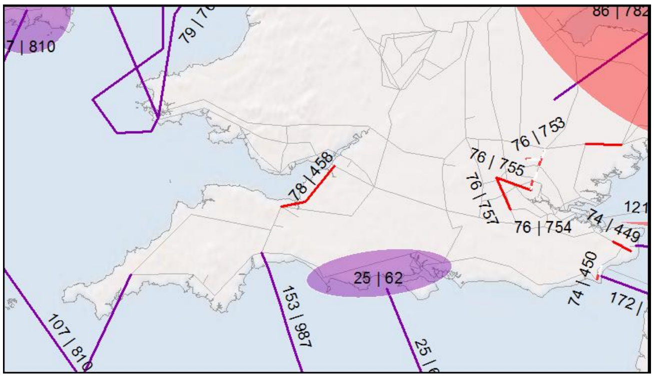
Project 78: South West Cluster

Description of the project

Project needed for renewables off of the South West peninsula, the replanting of Hinkley Point nuclear power station and further CCGT at Seabank.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
458	Hinkley Point (GB)	Seabank (GB)	New 400kV substation at Hinkley Point. New 400kV transmission route from Hinkley Point to Seabank. Reconstruction of Bridgewater substation for 400kV operation. Uprate Bridgewater - Melksham to 400kV.	-	Design & Permitting	2019	Investment on time	Based on current generation connection dates this investment is progressing on time.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
West=>East: 3200	East=>West: 3200	1	1	Negligible or less than 15km	Negligible or less than 15km	550

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[1600;1800]	1100 MW	[200000;240000]	[-290000;-390000]
Scenario Vision 2 - 2030	-	[2000;2300]	1100 MW	[200000;240000]	[-290000;-390000]
Scenario Vision 3 - 2030	-	[3500;3800]	[2000;4400] MW	[-300000;-400000]	[-810000;-890000]
Scenario Vision 4 - 2030	-	[4300;4700]	[3600;6000] MW	[-300000;-400000]	[-810000;-890000]

Additional comments

Comment on the RES integration: the very high scores reflect that the project directly connects RES sources.

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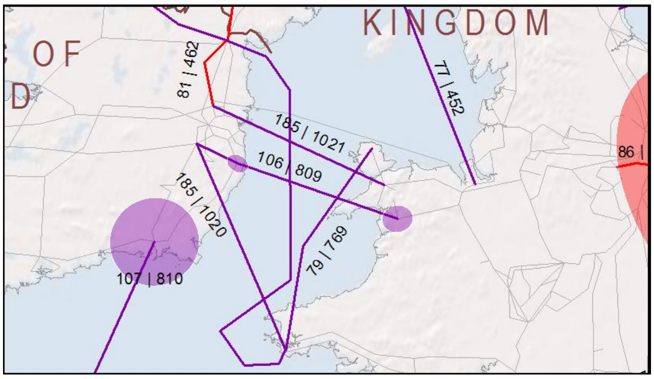
Project 79: Wales Cluster

Description of the project

Reinforcement of the internal grid to facilitate the integration of nuclear plant and RES.



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
769	Wylfa (GB)	Pembroke (GB)	A new ~2GW submarine HVDC cable route from Wylfa/Irish Sea to Pembroke with associated AC network reinforcement works at both ends.	-	Planning	2025	Rescheduled	Delayed due to anticipated changes in the local generation background.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	GTC direction 2 (MW)	B6 Technical Resilience	B7 Flexibility	S1 - protected areas	S2 - urban areas	C1 Estimated cost (Meuros)
West=>East: 2000	East=>West: 2000	2	1	50-100km	Negligible or less than 15km	780-790

CBA results	for each scenario				
Scenario	B1 SoS (MWh/year)	B2 SEW (MEuros/year)	B3 RES integration	B4 Losses (MWh/yr)	B5 CO2 Emissions (kT/year)
Scenario Vision 1 - 2030	-	[15;240]	[2200;2800] MW	[-330000;-470000]	[-850;-1400]
Scenario Vision 2 - 2030	-	[140;170]	[2500;3500] MW	[-330000;-470000]	[-12000;-9900]
Scenario Vision 3 - 2030	-	[400;490]	[5200;9200] MW	[-44000;-64000]	[-19000;-20000]
Scenario Vision 4 - 2030	-	[520;610]	[6800;11000] MW	[-44000;-64000]	[-19000;-20000]

Additional comments

Comment on the clustering:
the project also takes advantage of investment items n°459-460, 767, 770, depicted in the Regional investment plan.

Comment on the RES integration: RES at stake is located in Wales

Comment on the CO2 indicator: the very high scores reflect that the project connects RES sources to load centres

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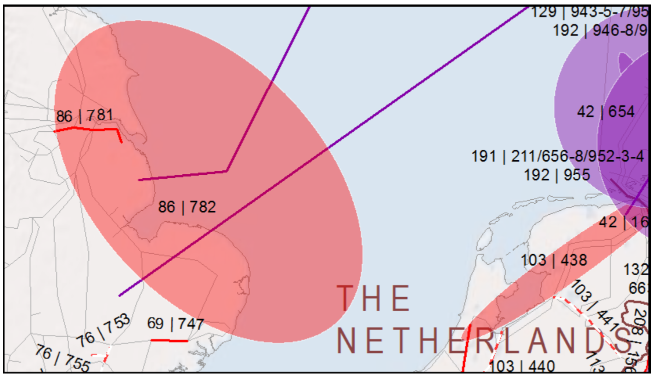
Project 86: East Coast Cluster

Description of the project

A very high level indication of the works required for GB East Coast. In detail the projects will consist of multiple offshore HVDC and AC circuits and connecting platforms joining to multiple onshore connection points with their own reinforcement requirements.



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
781	Under Consideration (GB)	Under Consideration (GB)	A very high level indication of the works required for GB East Coast. In detail the projects will consist of multiple offshore HVDC and AC circuits and connecting platforms joining to multiple onshore connection points with their own reinforcement requirements. It enables significant connection of offshore wind farms and provides alternative to onshore reinforcement at a cheaper overall cost.	3000	Under Consideration	2023	Investment on time	Progress as planned.
782	Under Consideration (GB)	Under Consideration (GB)	Connection of Triton Knoll, Doggerbank & Hornsea GB Wind Farms and all associated works. This is in the region of 11GW of offshore generation.	3000	Under Consideration	2020	Investment on time	Progress as planned.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
East=>West: 3000	West=>East: 3000	2	2	NA	NA	3400-3600

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[58;110]	[5700;7700] MW	0	[-26000;-30000]
Scenario Vision 2 - 2030	-	[81;140]	[7500;11000] MW	0	[-26000;-30000]
Scenario Vision 3 - 2030	-	[680;920]	[16000;21000] MW	[-1500;-1900]	[-33000;-38000]
Scenario Vision 4 - 2030	-	[920;1000]	[20000;27000] MW	[-1500;-1900]	[-32000;-38000]

Additional comments

Comment on the RES integration: the very high scores reflect that the project directly connects RES sources

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

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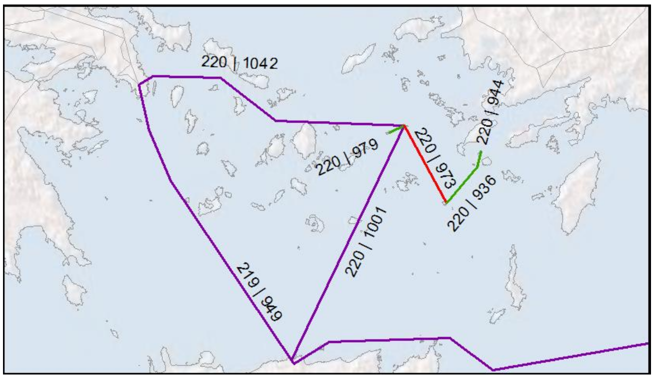
Project 220: Southern Aegean Interconnector

Description of the project

Promoted by Kykladika Meltemia S.A.
The project consists of collecting about 600 MW of RES in the Islands north-east to Crete via HVDC cables.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
936	Kandeliousa	Syrna	AC Subm. Cable to connect Kandeliousa offshore WF HV substation (18MW) to Syrna SS	200	Design & Permitting	2020	New Investment	Project application to TYNDP 2014. Commissioning date: 2018-2020
944	Kandeliousa	Pergousa	AC Subm. Cable to connect Pergousa offshore WF HV substation (42MW) to the Kandeliousa SS	200	Design & Permitting	2020	Investment on time	Project application to TYNDP 2014.Commissioning date: 2018-2020
973	Syrna	Levitha	AC Subm. Cable to connect Syrna offshore WF HV substation (156MW) to the AC part of the Levitha Converter SS	400	Design & Permitting	2020	New Investment	Project application to TYNDP 2014. commissioning date: 2018-2020
979	Kinaros	Levitha	AC Subm. Cable to connect Kinaros offshore WF HV substation (111MW) to the AC side of the Levitha Converter SS	200	Design & Permitting	2020	New Investment	Project application to TYNDP 2014. commissioning date: 2018=2020
1001	Levitha island	Korakia (new s/s in Crete)	New DC link (2 converter SS + 250 km DC subm. cable) to Crete	600	Design & Permitting	2020	New Investment	Project application to TYNDP 2014. commissioning date: 2018-2020
1042	Lavrion 400kv S/S	Levitha island	New DC link (2 converter SS + 270 km DC subm. cable) to connect 537MW of offshore WF generation to the mainland	600	Design & Permitting	2020	New Investment	Project application to TYNDP 2014. commissioning date expected: 2018-2020

			(Area of Athens)					

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
North=>South: 650	South=>North: 650	2	2	Negligible or less than 15km	Negligible or less than 15km	1400-3200

CBA results	**for each scenario**				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[150;180]	[2000000;2400000] MWh	[120000;150000]	0
Scenario Vision 2 - 2030	-	[140;170]	[2000000;2400000] MWh	[130000;160000]	0
Scenario Vision 3 - 2030	-	[160;200]	[2000000;2400000] MWh	[110000;130000]	0
Scenario Vision 4 - 2030	-	[150;190]	[2000000;2400000] MWh	[100000;130000]	0

Additional comments

Comment on the RES integration: the project helps connecting directly or indirectly about 600 MW of RES in the Greek Islands that will be almost entirely spilled without the project.

Comment on the S1 and S2 indicators: no indicator can be assessed as the project is still under consideration.

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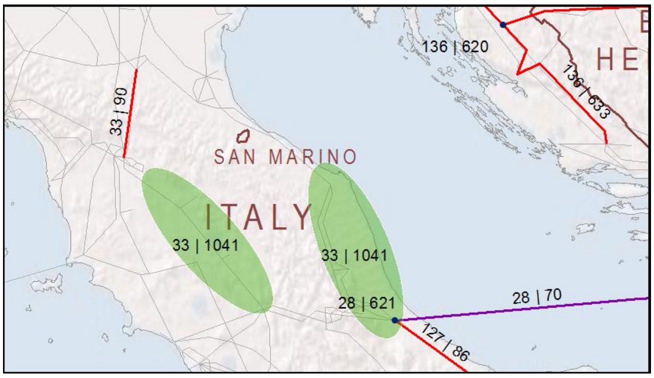
Project 33: 33

Description of the project

The project consists in the strengthening of interconnection between the northern and the central part of Italy. It will involve the upgrading of existing 220 kV over-head line to 400 kV between Colunga and Calenzano substations as well as the removing of limitations on the existing 220 kV network in Central Italy. The projects allows removing internal bottlenecks and increases market and RES integration.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
90	Calenzano (IT)	Colunga (IT)	Voltage upgrade of the existing 80km Calenzano-Colunga 220kV OHL to 400kV, providing in and out connection to the existing 220/150kV substation of S. Benedetto del Querceto (which already complies with 400kV standards).	400	Design & Permitting	2018	Delayed	delay in the permitting process (EIA)
1041	Villanova (IT)	S. Barbara (IT)	Removing limitations on existing 220 kV grid between Villanova e S.Barbara	600	Planning	2020	New Investment	The item 1041 has a significant effect on the grid transfer capacity

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
North=>South: 600	South=>North: 600	1	3	15-50km	Negligible or less than 15km	280

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[110;130]	[1100000;1400000] MWh	[-340000;-280000]	[-680;-550]
Scenario Vision 2 - 2030	-	[100;130]	[1100000;1300000] MWh	[-340000;-280000]	[-640;-520]
Scenario Vision 3 - 2030	-	[170;200]	[1300000;1500000] MWh	[-310000;-260000]	[-940;-770]
Scenario Vision 4 - 2030	-	[180;220]	[1500000;1800000] MWh	[-350000;-290000]	[-1100;-900]

Additional comments

Comment on the RES integration: the project allows to overcome the limitations to RES power plants installed in central part of Italy where in Vision 1 are expected about 9 GW of wind and solar power plants

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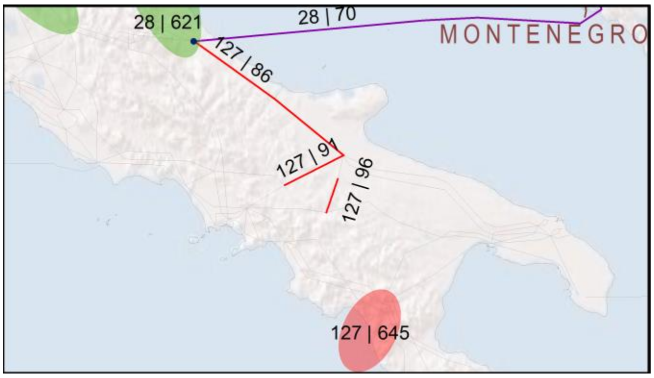
Project 127: 127

Description of the project

The project consists in the reinforcement of southern Italy 400 kV network through new 400 kV lines as well as upgrading of existing assets. The activities will involve the network portions between the substation of Villanova and Foggia, Foggia and Benevento, Deliceto and Bisaccia as well as Laino and Altomonte. The projects allows removing internal bottlenecks and increases market and RES integration.

PCI 3.19.3



Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
86	Foggia (IT)	Villanova (IT)	New 178km double circuit 400kV OHL between existing Foggia and Villanova 400kV substations, also connected in and out to the Larino and Gissi substations.	600	Design & Permitting	2019	Delayed	delay in the permitting process (EIA) concerning the part Foggia-Gissi still under authorization; the part Villanova Gissi is already authorized
91	Foggia (IT)	Benevento II (IT)	Upgrade of the existing 85km Foggia-Benevento II 400kV OHL.	250	Under Construction	2014	Investment on time	Progress as planned.
96	Deliceto (IT)	Bisaccia (IT)	New 30km single circuit 400kV OHL between the future substations of Deliceto and Bisaccia, in the Candela area.	400	Design & Permitting	2017	Delayed	delay in the permitting process (EIA)
645	Laino (IT)	Altomonte (IT)	New 400kV OHL between the existing substations of Laino and Altomonte in Calabria.	250	Design & Permitting	2017	Delayed	delay in the permitting process (EIA)

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**

North=>South: 0	South=>North: 1250	1	3	Negligible or less than 15km	Negligible or less than 15km	610

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[370;450]	[4600000;5600000] MWh	[-170000;-140000]	[-3100;-2600]
Scenario Vision 2 - 2030	-	[350;420]	[4300000;5300000] MWh	[-170000;-140000]	[-3000;-2400]
Scenario Vision 3 - 2030	-	[460;560]	[5100000;6200000] MWh	[-130000;-110000]	[-3500;-2900]
Scenario Vision 4 - 2030	-	[460;560]	[5100000;6300000] MWh	[-280000;-230000]	[-3500;-2900]

Additional comments

Comment on the RES integration: The considered project allows to overcome the limitations to RES power plants installed in the south of Italy where in Vision 1 are expected about 11 GW of Wind and Solar power plants. The reason of this benefits in terms of RES integration is due to the huge quantity of RES expected in the area (especially in V4) where high power flows from south to north of Italy make necessary additional transmission capacity to evacuate all the generation exceeding local load

Comment on the CO2 indicator: the very high scores reflect that the project enables a better use of RES

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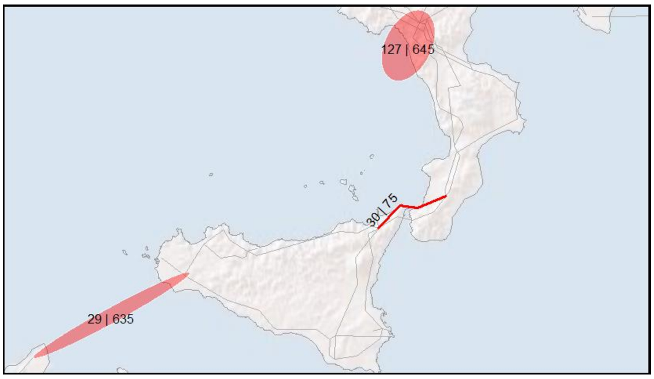
Project 30: 30

Description of the project

The project consists in the strengthening of Sicily - mainland 400 kV interconnection through a new double circuit line which will be realized partly as a subsea cable as well as over-head line. The activity is part of the wider network reinforcement program which involves the Sicilian 400 kV grid. The project allows removing internal bottlenecks and increases market and RES integration.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
75	Sorgente (IT)	Rizziconi (IT)	New 90km double circuit 400kV line, partly via subsea cable and partly via OHL. This line is part of a larger project that foresees the creation of the future 400kV grid of Sicily.	-	Under Construction	2015	Delayed	rescheduling of 6 months work due to technical issues during construction phase

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	GTC direction 2 (MW)	B6 Technical Resilience	B7 Flexibility	S1 - protected areas	S2 - urban areas	C1 Estimated cost (Meuros)
South=>IT: 1000	IT=>South: 1000	1	2	Negligible or less than 15km	Negligible or less than 15km	780

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	[18000;22000]	[320;390]	[1500000;1900000] MWh	[-39000;-32000]	[-1400;-1200]
Scenario Vision 2 - 2030	[19000;23000]	[300;370]	[1500000;1800000] MWh	[-39000;-32000]	[-1300;-1100]
Scenario Vision 3 - 2030	[23000;28000]	[490;590]	[2000000;2400000] MWh	[-55000;-45000]	[-2000;-1700]
Scenario Vision 4 - 2030	[37000;45000]	[410;510]	[2000000;2400000] MWh	[-61000;-50000]	[-2000;-1600]

Additional comments

Comment on the security of supply:
The project reinforces the interconnection between Sicily island and the mainland so improves the security of supply and local network security of the island.

Comment on the RES integration:
The considered project allows to overcome the limitations to RES power plants installed in Sicily island where in Vision 1 are expected about 4GW of Wind and Solar power plants

Comment on the CO2 indicator: the very high scores reflect that the project enables a better use of RES from Sicily

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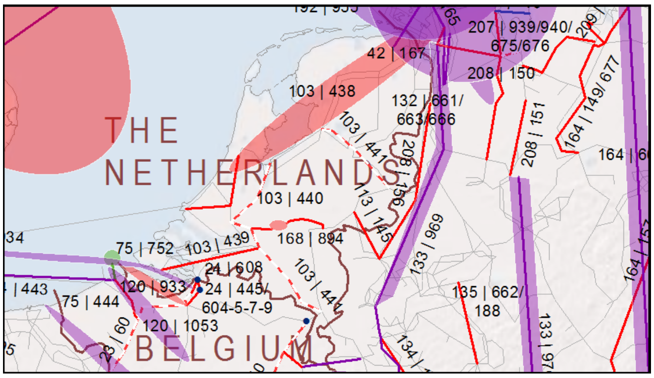
Dutch ring

Description of the corridor

The “Dutch ring” associates to project 103 a second phase “Spaak” (project 168), spanning overall from 2017 to 2025.

The project reinforces the Dutch grid to accommodate new conventional and renewable generation, to handle new flow patterns and to facilitate the cross-border capacity increase with neighbouring countries.

The two projects have been assessed as a whole and share the same common assessment.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
Project 103								
438	Eemshaven (NL)	Diemen (NL)	New 175-200km AC overhead line with capacity of 2x2650 MVA of 380kV. In the first phase a connection between Eemshaven Oude Schip and Vierverlaten will be built as well as an upgrade of the existing line Diemen - Lelystad - Ens	125	Design & Permitting	2018	Investment on time	Changes in plans of thermal plants at Eemshaven offers the opportunity to phase the grid expansions. The a first phase consists of a new 380 kV connection between Eemshaven-Oudeschip and Vierverlaten and the upgrade the circuits form Diemen-Lelystad-Ens
439	Borssele (NL)	Tilburg (NL)	New 100-130km double-circuit 380kV OHL with 2x2650 MVA capacity.	125	Design & Permitting	2016	Investment on time	With a 380 kV substation at Rilland, the Zuid-West 380 kV project can be taken into service in two parts. The first part consists of the Borssele - Rilland line including substation Rilland and the second part consist of the Rilland – Tilburg line.
440	Maasvlakte (NL)	Beverwijk (NL)	New 380 kV double-circuit mixed project (OHL+ underground cable) including approximately 20km of underground cable for 2650	125	Under Construction	2017	Delayed	Permitting procedures took longer than expected. The part from Maasvlakte to Bleiswijk has been commissioned.

			MVA. The cable sections are a pilot project. The total length of cable at 380kV is frozen until more experience is gained.					
441	Zwolle (NL)	Maasbracht (NL)	Upgrade of the capacity of the existing 300km double circuit 380kV OHL to reach a capacity of 2x2650 MVA along the Dutch Central ring (Hengelo-Zwolle-Ens Diemen-Krimpen-Geertruidenberg-Eindhoven-Maasbracht)	125	Under Consideration	2019	Investment on time	The investment is merged with the Ring Zuid project
Project 168								
894	Sliedrecht area	Dodewaard	New Overhead line from Sliedrecht to Dodewaard of 2x2633 MVA in Wintrack, 65 km	-	Under Consideration	2025	New Investment	This new investment has been identified as a beneficial project in the NSCOGI study and is part of the national grid development plan

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
NL=>DE: 500	DE=>NL: 500	1	3	More than 100km	More than 50km	1800-3100

CBA results	**for each scenario**				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	0	0	[-190000;-160000]	[13;16]
Scenario Vision 2 - 2030	-	0	0	[-190000;-160000]	[-27;-22]
Scenario Vision 3 - 2030	-	[5;15]	[45000;55000] MWh	0	[-210;-180]
Scenario Vision 4 - 2030	-	[5;15]	[23000;28000] MWh	0	[-270;-220]

Additional comments

Comment on the security of supply: The project enables the long term high level of Security of Supply in The Netherlands.

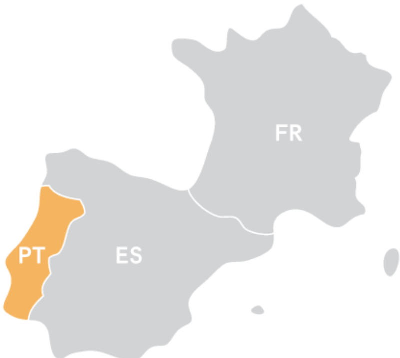
Comment on the RES integration: avoided spillage concerns RES in the Netherlands as a whole

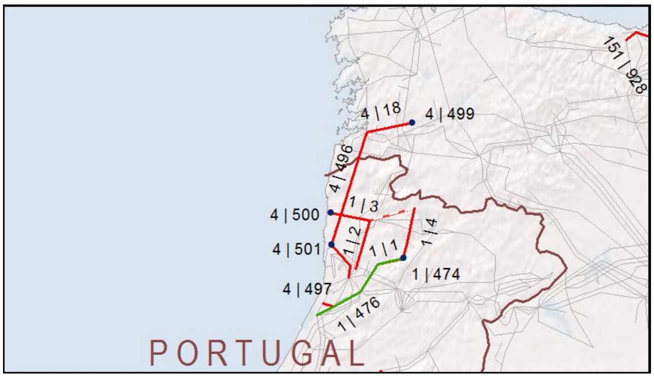
Project 1: RES in north of Portugal

Description of the project

This project integrates new amounts of Hydro Power Plants in the Northern region of Portugal and creates better conditions to evacuate Wind Power already existent and new with authorization for connection (with the reinforcement of the local 220kV network). These new amounts of power will increase the flows in the region, and it is expected that the flows could reach 3800 MW, which must be evacuated to the littoral strip and south Portugal through three new 400kV independent routes. Part of these flows will interfere and accumulate with the already existent flows entering in Portugal through the international interconnections with Spain on the North, the 400kV Alto Lindoso-Riba de Ave-Recarei and Lagoaça-Aldeadávila axis, which induces additional needs for reinforcement of this axis in a coordinated way.

PCI 2.16.1, 2.16.2 and 2.16.3





Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
1	V.Minho (PT)	Pedralva (PT)	Connection of the new 400kV substation V.Minho to Pedralva substation by means of two new 400kV lines (2x43) km. The realization of this two connections can take advantage of some already existing 150kV single lines, which will be reconstructed as double circuit lines 400+150kV line and partially sharing towers with those 400kV circuits.	1650	Under Construction	2015	Delayed	Although the investment is already under construction some constraints regarding environmental issues led the commissioning date to delay
2	Pedralva (PT)	Sobrado (PT)	New 47km double circuit Pedralva (PT) - Sobrado (PT) 400kV OHL, (only one circuit installed in a first step).	830	Planning	2020	Delayed	Due to the expected delay of the connection of new RES generation in North of Portugal, the commissioning date of this investment item is delayed
3	Pedralva (PT)	V. Castelo (PT)	New 57,5km double circuit Pedralva - V. Castelo 400kV OHL (one circuit installed).	680	Design & Permitting	2015	Investment on time	Progress as planned.
4	V.Minho (by Ribeira de	Feira (by Ribeira de	New 129km double-circuit 400kV OHL V.Minho (PT) -	890	Design & Permitting	2018	Delayed	Due to the expected delay of the connection

	Pena and Fridão)	Pena and Fridão)	Ribeira de Pena (PT) - Fridão (PT) - Feira (PT) (one circuit operated at 220kV between V.P. Aguiar and Estarreja) with a new 400/60kV substation in Rib. Pena. In a first step, only the 139km section Rib. de Pena (PT) - Feira (PT) will be constructed and operated at 220kV as Vila Pouca Aguiar (PT) - Carrapatelo (PT) - Estarreja (PT). In a second step, one circuit of this line will be operated at 400kV.					of new hydro power plants, the commissioning date of this investment item was delayed.
474	Ribeira de Pena (PT)		New 400/60kV substation in Rib. Pena.	890	Design & Permitting	2017	Delayed	Due to the expected delay of the connection of new hydro power plants, the commissioning date of this investment item was delayed.
476	V. P. Aguiar (by Carrapatelo)	Estarreja (by Carrapatelo)	New 400+220kV double circuit OHL (initially only used at 220kV) Vila Pouca Aguiar - (Rib. Pena) - Carrapatelo - Estarreja . Total length of line: 2x (96+49) km. 220kV circuit.	600	Design & Permitting	2017	Delayed	Due to the expected delay of the connection of new RES generation in Portugal, the commissioning date of this investment item is delayed
941	Fridão		New substation to connect a new hydro power plant.	890	Planning	2017	New Investment	No changes expected

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
inside=>outside: 3700-5100	outside=>inside: 0-0	1	3	Negligible or less than 15km	15-25km	230-300

CBA results	**for each scenario**				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[110;130]	2432 MW	[46000;56000]	[-410;-340]
Scenario Vision 2 - 2030	-	[110;130]	2432 MW	[50000;61000]	[-410;-340]
Scenario Vision 3 - 2030	-	[120;150]	2900 MW	[55000;68000]	[-500;-410]
Scenario Vision 4 - 2030	-	[92;110]	3000 MW	[4100;5100]	[-390;-320]

Additional comments

Comment on the clustering: the project also takes advantage of investment item n°472 depicted in the Regional investment plan.

Comment on the RES integration: This project directly connect connects around 2700MW of new hydro generation (part of them with pumping) in the North of Portugal (Cávado and Tâmega rivers)

Comment on the S1 and S2 indicators: In order to minimize the social and environmental impacts, part of this project is implemented taking advantage of some already existing 150kV single lines, which will be reconstructed as double circuit lines 400+150kV and partially sharing towers with those 400kV circuits.

Comment on the GTC: the project aims to ensure the 3000 MW of interconnection capacity between Portugal and Spain, maintaining the integration of high levels of RES penetration and ensuring the security of the system. In fact, without investments 1.2 (Pedralva-Sobrado) and 1.3 (Pedralva-V.Castelo) the interconnection capacity could be reduced by more than 800 MW, which means, more precisely, that this cluster will increase the interconnection capacity between Portugal and Spain of more than 2000 MW in some scenarios, with an average annual increase around 800 MW.

Specifically, the new line Pedralva-Sobrado 400kV allows an increase of more than 1800 MW in some scenarios in the interconnection capacity between Portugal and Spain, with an average annual increase around 500 MW. The new line Pedralva-V. Castelo increases the interconnection capacity between Portugal and Spain of more than 1500 MW in some scenarios, with an average annual increase around 300 MW.

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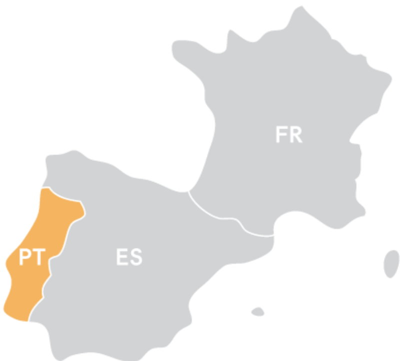
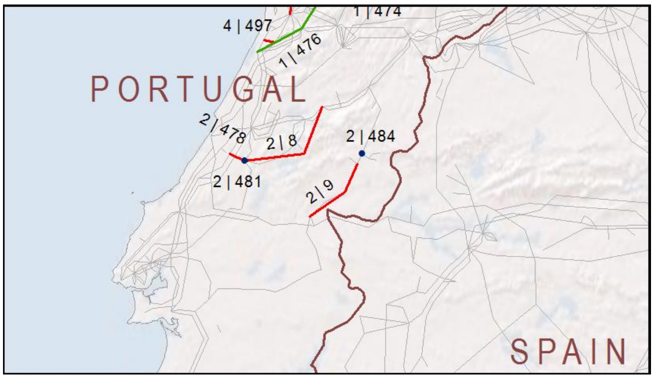
Project 2: RES in centre of Portugal

Description of the project

This project integrates new hydro power plants (some of them with pumping) and evacuates the existent and new wind generation in the inner central region of Portugal (the wind target in this region overcomes surmounts of more than 2000 MW). The existing network of 220 kV and 150kV is no more adequate to integrate these new amounts of power, and a new 400kV axis should be launched in this region in two major routes: one to the littoral strip (Penela/Paraimo/Batalha) and another by the interior, establishing a connection to Falagueira substation, where there is an interconnection with Spain (Falagueira-Cedillo).





Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
8	Seia	Penela	New single circuit 400kV OHL Seia-Penela (90km).	1780	Design & Permitting	2016	Investment on time	Project on time
9	Fundão (PT)	Falagueira (PT)	New 400kV double circuit OHL Fundão (PT) -'Castelo Branco zone'-Falagueira (PT)	450	Design & Permitting	2017	Delayed	Adjustments resulting from the new date of renewables projects.
478	Penela (PT)	Paraimo / Batalha (PT)	New double circuit 400kV OHL (15km) to connect Penela substation to Paraimo-Batalha line.	1780	Design & Permitting	2016	Investment on time	design & permitting
481	Penela (PT)		Expansion of the existing Penela substation to include 400kV facilities.	1780	Design & Permitting	2016	Investment on time	Design & Permitting
484	Fundão (PT)		New 400/220kV substations in Fundão.	450	Design & Permitting	2017	Delayed	Due to the expected delay on the connection of new RES generation in the centre of Portugal, the commissioning date of this investment item is delayed

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
upstream=>downstream: 1200-1600	downstream=>upstream: 0-0	1	3	Negligible or less than 15km	Negligible or less than 15km	90-120

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[29;36]	576 MW	[9200;11000]	[-110;-90]
Scenario Vision 2 - 2030	-	[29;36]	576 MW	[10000;12000]	[-110;-90]
Scenario Vision 3 - 2030	-	[76;93]	1000 MW	[17000;21000]	[-320;-260]
Scenario Vision 4 - 2030	-	[63;77]	1050 MW	[1400;1700]	[-260;-210]

Additional comments

Comment on the clustering:
the project also takes advantage of investment item n°10 now commissioned, and depicted in the Regional investment plan.

Comment on the RES integration: This project directly connects around 700MW of new hydro generation (part of them with pumping) in the Centre of Portugal (Mondego and Ocreza rivers)

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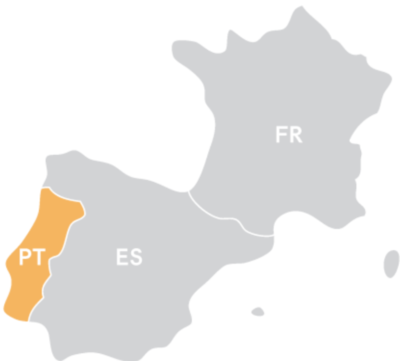
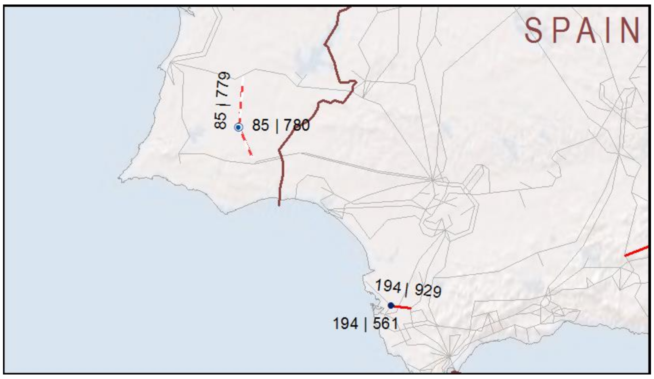
Project 85: Integration of RES in Alentejo

Description of the project

This project integrates new amounts of solar (and also some wind) generation in the south of Portugal. The existing network of 150 kV is not sufficient to integrate these amounts of power and a new 400 kV axis should be launched in this region, establishing a connection between the two Southern interconnections between Portugal and Spain, the Ferreira do Alentejo-Alqueva-Brovales and Tavira-Puebla de Gusman. This axis will also close a ring of 400 kV in the Southern part of Portugal that will guarantee the load growth in the region (Algarve is one of the regions that presents the biggest growth rate in Portugal) in a safe, secure and quality way.





Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
779	F. Alentejo (by Ourique)	Tavira (by Ourique)	New 122km double-circuit 400+150 kV OHL F. Alentejo-Ourique-Tavira. The realization of this connection can take advantage of some already existing 150kV single lines, which can be reconstructed as double circuit line 400+150kV, investments needs the investment which consist of the extension of existing Ourique substation to include 400 kV facilities.	1400	Planning	2025	Rescheduled	Due to the expected delay on the connection of new RES in Portugal, the commissioning date of this project is delayed
780	Ourique (PT)		Extension of existing Ourique substation to include 400 kV facilities.	1400	Planning	2025	Rescheduled	Due to the expected delay on the connection of new RES in Portugal, the commissioning date of this project is delayed

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
inside=>outside: 1400	outside=>inside: 0	1	2	Negligible or less than 15km	Negligible or less than 15km	50-100

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[22;27]	150 MW	[-9800;-8000]	[-89;-72]
Scenario Vision 2 - 2030	-	[22;27]	150 MW	[-11000;-8800]	[-89;-72]
Scenario Vision 3 - 2030	-	[37;46]	350 MW	[-15000;-13000]	[-150;-120]
Scenario Vision 4 - 2030	-	[120;150]	1350 MW	[41000;50000]	[-490;-400]

Additional comments

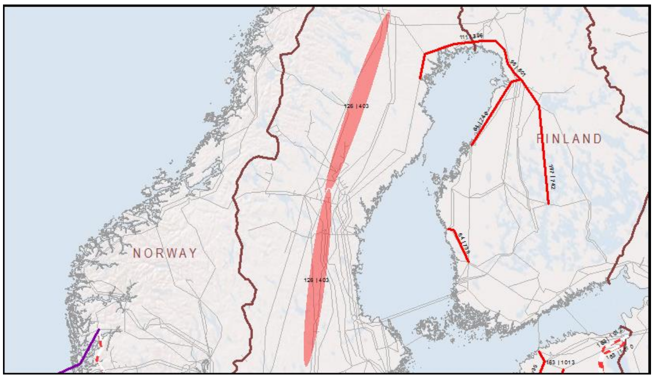
Comment on the RES integration: This project directly connect more than 1000MW of new solar generation in the South of Portugal, namely on the Ourique, Ferreira do Alentejo and Tavira area in Vision 4.

Comment on the S1 and S2 indicators: In order to minimize the social and environmental impacts, this project takes advantage of some already existing 150kV single lines, which can be reconstructed as double circuit line 400+150kV

Project 126: SE North-south reinforcements

Description of the project

Reinforcements, both lines and stations, in and between bidding area SE1, SE2 and SE3 will accomplish RES integration in northern Sweden.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
403	Sweden bidding area SE1	Sweden bidding area SE3	Based on a joint Statnett & Svenska Kraftnät study for North-South reinforcements, this contains reinforcements in cut 1 and 2 in Sweden	-	Under Consideration	2025	Investment on time	The investment now combine new investments and the previous 399, 786, 787, 788 and 806. All of the old investments appear only in the list of cancelled investments in the regional plan

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
North=>South: 700	South=>North: 700	2	4	NA	NA	800-1400

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[69;84]	[70000;86000] MWh	[110000;130000]	[9;12]
Scenario Vision 2 - 2030	-	[39;48]	[15000;19000] MWh	[120000;150000]	[36;44]
Scenario Vision 3 - 2030	-	[44;53]	[28000;34000] MWh	[110000;130000]	[18;22]
Scenario Vision 4 - 2030	-	[32;39]	[380000;460000] MWh	[230000;280000]	[-52;-43]

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Additional comments

Comment on the RES integration: the project will help integrating 700-800 MW of RES in northern Sweden and Norway.

Comment on the S1 and S2 indicators: the project will have a social and environmental impact but the investments are in early stages so there are no facts regarding the impact.

The project will increase the GTC with 700MW between Sweden Bidding areas 1 and 2, and 800 MW between Sweden Bidding areas 2 and 3

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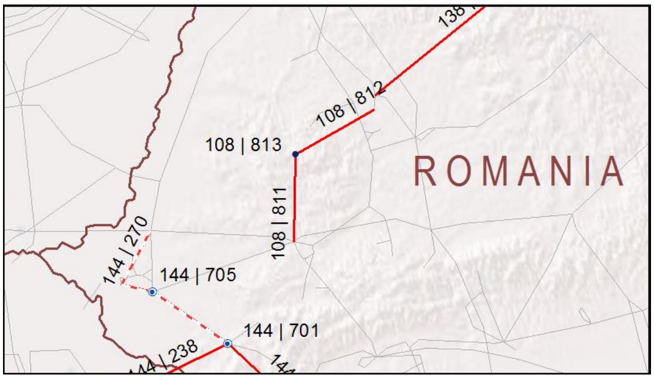
Project 108: 1000MW HPS Tarnita connection

Description of the project

The project consists of two double circuit 400-kV lines that are needed to connect to the grid the future 1000MW Hydro Pumped Storage Tarnita-Lapustesti, situated in the North-West of Romania. The project will supply reserve/balancing services for Romania and possibly for neighboring countries (Hungary, Serbia, Bulgaria, other). It will support integration of intermittent RES generation.



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
811	Tarnita (RO)	Mintia (RO)	New double circuit 400kV OHL Tarnita(RO)-Mintia(RO) 2x1380 MVA.	1000	Planning	2018	Investment on time	The project shall be built only if the Hydro Pumped Storage plant shall be built. Final investment decision is pending.
812	Tarnita (RO)	Cluj E - Gadalin (RO)	New double circuit 400kV OHL Tarnita(RO)- Cluj E-Gadalin (RO) 2x1380 MVA.	1000	Planning	2018	Investment on time	The project shall be built only if the Hydro Pumped Storage plant shall be built. Final investment decision is pending.
813	Tarnita (RO)		New 400kV substation connecting 1000 MW Hydro Pumped Storage Tarnita Lapustesti to the grid.	1000	Planning	2018	Investment on time	The project shall be built only if the Hydro Pumped Storage plant shall be built. Final investment decision is pending.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	GTC direction 2 (MW)	B6 Technical Resilience	B7 Flexibility	S1 - protected areas	S2 - urban areas	C1 Estimated cost (Meuros)
inside=>outside: 1000	outside=>inside: 1000	3	3	Negligible or less than 15km	Negligible or less than 15km	100-170

CBA results	for each scenario				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[9;12]	[35000;43000] MWh	[-47000;-39000]	[400;490]
Scenario Vision 2 - 2030	-	[4;5]	[9900;12000] MWh	[-21000;-17000]	[250;310]
Scenario Vision 3 - 2030	-	[3;4]	[19000;23000] MWh	[-200000;-170000]	[-46;-37]
Scenario Vision 4 - 2030	-	[94;120]	[660000;800000] MWh	[51000;62000]	[-550;-450]

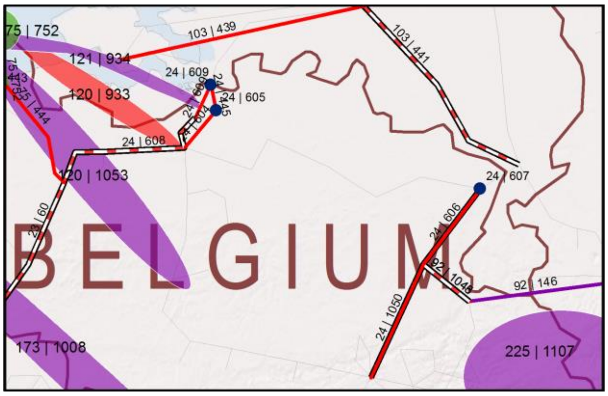
Additional comments

Project 24: Belgian North Border

Description of the project

The need to reinforce the Belgian North Border is driven by a congruation of factors
- ensuring reliable grid cooperation in a context of increasing & more volatile international fluxes on Belgian's north-south axis (Zandvliet to Horta; Van Eyck to Gramme) which could cause internal congestions and negatively effect market capacity
- desire to further develop market capacity between Belgium & the Netherlands with +- 1000 MW
- possible connection of new central production units on these north-south axis: potential projects exist on each axis of 900-1000 MW each
- increasing industrial demand around Antwerp harbour area

The project as such consists of the following subprojects facilitating its realization in a modular way:
- Brabo & PST4 (+upgrade Doel-Zandvliet): integration of 4th PST on Belgian North Border and the realization of a new 380kV circuit via Lillo creating a parallel path to the existing Zandvliet-Mercator connection
- Horta-Mercator in HTLS: the upgrade of this central link to transport fluxes between France, Stevin & the Netherlands consists in replacing the existing 380kV double circuit with high-performance conductors (HTLS).
- Gramme-Van Eyck: capacity increase by going from 1 to 2 380kV circuits and creating a subsequent substation Van Eyck
- Gramme-Van Eyck + Massenhoven-Meerhout-Van Eyck: the need to futher upgrade these axis has been identified but depends heavily on the evolution of production in the Limburg-Liège area in combination with the evolution of the (transit)flux, and will as such be further monitored



Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
445	Zandvliet (BE)	Lillo (BE)	Brabo: part Zandvliet-Lillo: Brabo allows to realize the intended market capacity increase on the North Border in a more robust way (greater scenario	1000	Design & Permitting	2018	Delayed	Permitting procedure for adapation of land use (GRUP) had to be reinitiated, in order to comply with the demand of

			independence compared to PST 4 only), and reinforces the network to facilitate increased demand and connection of possible new generation around Antwerp Harbor area. It consists of constructing a new 380kV circuit Zandvliet-Lillo (new substation)-Mercator, in addition to the existing Zandvliet - Mercator connection. This investment item concerns the part between Zandvliet and Lillo substations.					investigating alternative solutions.
604	Lillo (BE)	Mercator (BE)	Brabo: part Lillo-Mercator + restructuring 150kV. Brabo allows to realize the intended market capacity increase on the North Border in a more robust way (greater scenario independence compared to PST 4 only), and reinforces the network to facilitate increased demand and connection of possible new generation around Antwerp Harbor area. It consists of constructing a new 380kV circuit Zandvliet-Lillo (new substation)-Mercator, in addition to the existing Zandvliet - Mercator connection. This investment item concerns the part between Lillo and Mercator substations, involving a restructuring of the adjacent 150kV network.	1000	Design & Permitting	2018	Delayed	'Permitting procedure for adapation of land use (GRUP) had to be reinitiated, in order to comply with the demand of investigating alternative solutions.
605	Lillo (BE)		Brabo - substation Lillo 380: Brabo allows to realize the intended market capacity increase on the North Border in a more robust way (greater scenario independence compared to PST 4 only), and reinforces the network to facilitate increased demand and connection of possible new generation around Antwerp Harbor area. It consists of constructing a new 380kV circuit Zandvliet-Lillo (new substation)-Mercator, in addition to the existing	1000	Design & Permitting	2018	Delayed	'Permitting procedure for adapation of land use (GRUP) had to be reinitiated, in order to comply with the demand of investigating alternative solutions.

			Zandvliet - Mercator connection. This investment item concerns the erection of new 380kV substation Lillo.					
606	Gramme (BE)	Van Eyck (BE)	Gramme-Van Eyck: second 380kV circuit First phase of reinforcement on the axis Gramme-Van Eyck, needed to facilitate connection of possible new central generation and to prepare for increasing transit fluxes whilst securing market capacity between BE & NL. This investment consist of creating a second 380kV line on the axis Gramme-Van Eyck - Section Van Eyck - Zutendaal (30 km): need to erect a new single circuit. Done with high performance conductors in order to be future proof (cfr. phase 2) - Section Grammme - Zutendaal (55km): reconfiguration of 150kV network so that an existing 150kV line can be operated at 380kV	1400	Under Construction	2015	Delayed	Implementation of the project has been aligned with maintenance period of nuclear units ==> commissioning now foreseen in 2015 instead of end 2014
607	Van Eyck (BE)		Gramme-Van Eyck: substation Van Eyck 380 First phase of reinforcement on the axis Gramme-Van Eyck, needed to facilitate connection of possible new central generation and to prepare for increasing transit fluxes whilst securing market capacity between BE & NL. This investment item consists of construction a 380kV substation named "Van Eyck", needed to integrate the second 380 kV line on the axis Gramme-Van Eyck.	1400	Under Construction	2015	Delayed	Commissioning date of this inv. item aligned with implementation of inv. item 606 thus now 2015 instead of 2014
608	Horta (BE)	Mercator (BE)	Horta-Mercator in HTLS The axis Horta-Mercator needs to be upgraded in order to transport the envisioned higher fluxes between France, Stevin & the Netherlands, and to facilitate connection of possible new generation (+-1000 MW) .	1500	Design & Permitting	2019	Investment on time	The expected commissiong date of 2019 is based on the hypothesis of acquiring all necessary permits as planned, followed by the assessment of the final investment decision in 2016. Meanwhile the

			Upgrade consists of replacing the current double circuit 380kV by high performance conductors allowing to double its transport capacity. The line currently passing Mercator going to Doel will be integrated into Mercator substation to obtain a better flux balance and avoid an upgrade between Mercator & Doel at this stage.					drivers behind this investment will be further monitored and its timing managed accordingly.
609	Zandvliet (BE)		BE PST 4 (+upgrade Zandvliet - Doel): New PST in Zandvliet substation making it the 4 th PST on the Belgian North Border, allowing a more symmetrical utilization of the PST's. Enabling this PST to increase import capacity from NL to BE implies that the current 150kV line Zandvliet-Doel is converted to 380kV, involving adaptations to be made to the configurations of Zandvliet & Doel substations and a solution to cover the supply of Doel 150kV (probably transformer 380/150). Integrating this PST at Zandvliet also implies that a "langskoppeling" is put at Zandvliet as temporary interface between Zandvliet and the NL network until the post "Rilland" is constructed in NL (investment item 439 as part of project # 103 "Reinforcements Ring NL"). Note that the realisation of investment item 439 is needed as well to allow a capacity increase direction BE to NL.	1000	Under construction	2016	Investment on time	Installation of PST (plus upgrade of line Doel-Zandvliet) will be done as a first reinforcement in the Antwerp area. The PST has been ordered, as such the status of this investment is "under construction" with an expected commissioning date of 2016.
1050	Gramme (BE)	Massenhoven (BE)	Conditional: Gramme-Van Eyck + Massenhoven-Meerhout-Van Eyck Envisions to double the transport capacity by upgrading the Gramme-Van Eyck axis to high-performance conductors, and by putting a second 380kV circuit on the Massenhoven-Meerhout-Van Eyck axis.	1400	Planning	2020	Investment on time	This investment is a split off from invest item 445a from in TYNDP 2012, and complemented with the Massenhoven-Meerhout-Van Eyck section. This investment is subject to further monitoring towards 2020-2025 given its dependency on

			The need to upgrade is conditional to the evolution of production in the LImburg-Liège area and to the evolution of the physical (transit)flux towards 2020-2025. This need will be further monitored.					production in the area in combination with evolution of the (transit)flux.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
NL=>BE: 1000-1500	BE=>NL: 1000-1500	5	2	15-50km	25-50km	350-450

CBA results	**for each scenario**				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
S1 EU202020 - 2020	[300;570]	[18;22]	[45000;55000] MWh	0	[0;500]

Additional comments

Comment on the security of supply: A reinforced interconnector contributes to the security of supply of Belgium as a whole, since it offers market players additional import capacity which they can use to balance their portfolio provided that excess generation is available abroad. Given the changing production mix with ongoing nuclear phase out and decommissioning of old power plants, this benefit materializes itself as soon as the project is realized.

Additionally, the BRABO project ensures the SoS of the Antwerp Harbor

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Project 64: N-S Finland (P1) stage 1

Description of the project

Several 400 kV AC lines are planned in Finland to be built to increase the North-South transmission capacity thus enabling the integration of new renewable and conventional generation in northern Finland and to compensate the dismantling of the obsolescent exiting 220 kV lines. The commissioning of the lines is scheduled to take place in segments both in mid and long term.
Project changed in TYNDP 2014, stage 1 includes the investments up until 2016.

Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
392	Yllikkälä (FI)	Huutokoski (FI)	New 155km single circuit 400kV OHL and renovation of 400kV substations in Yllikkälä and Huutokoski. Expected capacity: 1850 MVA.	-	Commissioned	2013	Commissioned	Investment progressing as planned, has been commissioned May/2013
393	Seinäjoki (FI)	Tuovila (FI)	First line part of the four new single circuit 400kV OHL are part of project in upgrading Ostrobothnian 220kV system into 400kV, and strengthening the 400 kV grid in Northern Finland. Total length of lines: 520 km. Total Expected capacity: 1850 MVA.	-	Commissioned	2011	Commissioned	Investment is commissioned
739	Ulvila (FI)	Kristinestad (FI)	Second line part of the four new single circuit 400kV OHL are part of project in upgrading Ostrobothnian 220kV system into 400kV, and strengthening the 400 kV grid in Northern Finland. Total length of lines: 520 km. Total Expected capacity: 1850 MVA.	700	Under Construction	2014	Investment on time	Investment progress as planned
740	Hirvisuo (FI)	Pyhänselkä (FI)	Third line part of the four new single circuit 400kV OHL are part of	700	Design & Permitting	2016	Expected earlier than	Station name updated from Ventusneva to

			project in upgrading Ostrobothnian 220kV system into 400kV, and strengthening the 400 kV grid in Northern Finland. Total length of lines: 520 km. Total Expected capacity: 1850 MVA.				planned previously	Hirvisuo. Investment decision has been made and schedule has been updated.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
North => South: 700-1400	South=> North: 700-1400	2	4	NA	NA	190-260

CBA results	**for each scenario**				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
S1 EU202020 - 2020	[30;300]	[30;100]	[500;1500] MW	[0;-3000]	[500;1000]

Additional comments

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Project 197: N-S Finland P1 stage 2

Description of the project

Several 400 kV AC lines are planned in Finland to be built to increase the North-South transmission capacity thus enabling the integration of new renewable and conventional generation in northern Finland and to compensate the dismantling of the obsolescent exiting 220 kV lines. The commissioning of the lines is scheduled to take place in segments both in mid and long term. Change in TYNDP 2014, taken the latest investment as its own project. This project is 400 kV overhead line from connecting North Finland to South.

Investment index	Substation 1	Substation 2	Description	GTC contri bution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
742	Pyhänselkä (FI)	Petäjävesi (FI)	New single circuit 400 kV OHLs will be built from middle Finland to Oulujoki Area to increase the capacity between North and South Finland. Will replace existing 220 kV lines.	-	Design & Permitting	2023	Delayed	Rescheduled due to timing of system changes that trigger the investment. End station name updated.

CBA results

The tables below summarize the Cost Benefits Analysis results of this project.

CBA results non scenario specific						
GTC direction 1 (MW)	GTC direction 2 (MW)	B6 Technical Resilience	B7 Flexibility	S1 - protected areas	S2 - urban areas	C1 Estimated cost (Meuros)
North=>South: 1000	South=>North: 1000	2	4	NA	NA	86-98

CBA results	for each scenario				
Scenario	B1 SoS (MWh/year)	B2 SEW (MEuros/year)	B3 RES integration	B4 Losses (MWh/yr)	B5 CO2 Emissions (kT/year)
S1 EU202020 - 2020	[30;300]	[30;100]	[500;1500] MW	[0;-3000]	[500;1000]

Additional comments

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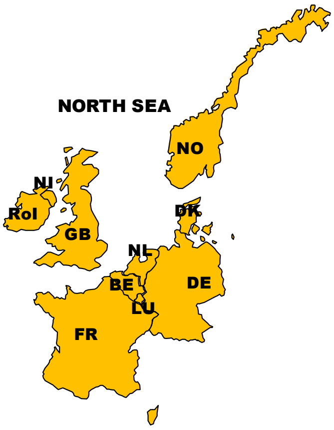
Project 230: North Seas offshore grid infrastructure scheme

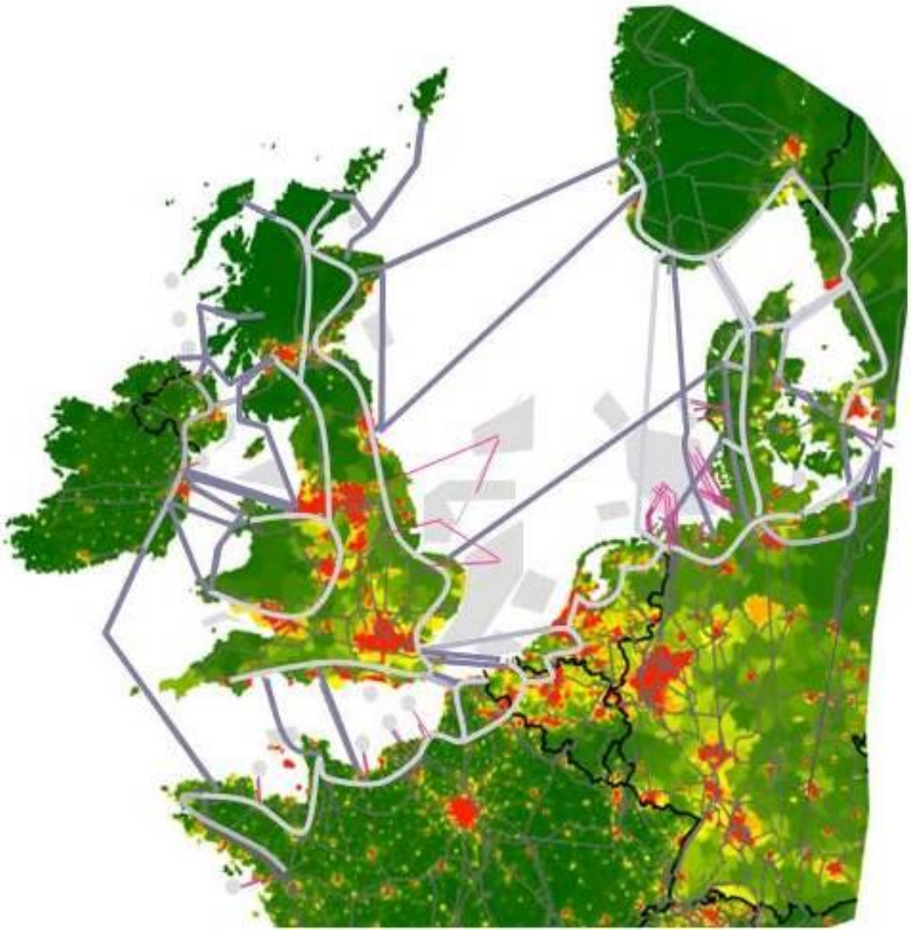
Description of the project

19 projects of the TYNDP 2014 (including 3 proposed by non-ENTSO-E members) develop into a global scheme for offshore grid infrastructure in the North Seas. This total scheme including its assessment is presented below.
The 19 projects combine altogether and complete existing assets in order to enable the integration of wind generation (on- and offshore) and increase the interconnection level between the regions's synchronous areas and neighbouring countries as well. The interconnections crossing the Northern Seas waters are completed with onshore reinforcements.
The offshore grid infrastrucute represents more than 10000 km of new DC subsea cables by 2030 in the area. Every element is taylor-made and the proposed scheme below highlights astutely both, new assets and existing ones (both offshore and onshore) to maximise its efficiency.

Four projects of the TYNDP combine both generation connection and interconnection capability between countries in the North Seas and constitute so called "hybrid projects": Kriegers' flak combined grid solution, FAB (France-Alderney-Britain), BOG (Belgian offshore grid) depending on how its design will be finalized and potentially Isles. Only three of them resort to offshore hubs to support the two functions (FAB's intermediate hub is the Alderney island). Such a design appears the exception, where the rule is on the one hand the connection of offshore wind farms to shore (through dedicated AC or DC offshore hubs), and on the other hand a point to point interconnection to connect countries. Such a separated design saves costs, as it often appears cheaper to build and operate the large AC/DC converter station required by interconnection *onshore* instead of offshore. In some specific cases does the scheduling and technology required for interconnection and wind connection (DC or AC, voltage level) actually match so that a compact design offshore could be envisaged. Different geographical conditions leads locally to different optima and ENTSO-E concludes to a design which takes advantage of all possible connection and interconnection models. Except in the examples mentioned above hybrid projects do not appear yet. The RegIP from the North Sea Region shows that integrating ("meshing") emerges at specific locations and further optimizations in the design of the offshore grid infrastructure will by nature be part of the further planning process.

The overall scheme is expected to save between € 1.0 billion per year and € 4.1 billions per year depending on the Visions, for a cost of about € 17 – 22 billions.





Investment index	Substation 1	Substation 2	Description	GTC contribution (MW)	Present status	Expected date of commissioning	Evolution since TYNDP 2012	Evolution driver
62	Tourbe (FR)	Chilling (GB)	New subsea HVDC VSC link between the UK and France with a capacity around 1000 MW. PCI 1.7.2 (NSCOG corridor)	-	Design & Permitting	2020	Investment on time	Extensive feasibility studies (e.g. seabed surveys) have been conducted to determine the most suitable route; on the French side, the ministry of energy acknowledged the notification of the investment on 08/04/14.
987	Cotentin Nord	Exeter	France-Alderney-Britain (FAB) is a new 220km-long HVDC subsea interconnection between Exeter (UK) and Cotentin Nord (France) with VSC converter station at both ends. Expected rated capacity is 2*700 MW.	-	Planning	2020	New Investment	Studies conducted after TYNDP2012 release have shown the economic viability of this interconnection and lead to develop this investment. Feasibility studies (marine surveys) are starting to find a suitable subsea route.
1005	Sellindge (UK)	Le Mandarins (FR)	Eleclink is a new FR – UK interconnection cable thought the channel Tunnel between Selindge (UK) and Mandarins (FR). Converter stations will be located on Eurotunnel concession at Folkestone and Coquelles. This HVDC interconnection is a PCI project (Project of common interest).	-	Design & Permitting	2016	New Investment	

			It will increase by 1GW the interconnection capacity between UK and FR by 2016.					
443	Richborough (GB)	Zeebrugge (BE)	Nemo Project: New DC sea link including 135km of 400kV (voltage level is subject to outcome of detailed engineering) DC subsea cable with 1000MW capacity	1000	Design & Permitting	2018	Investment on time	Investment on time, with a technical commissioning planned end 2018 leading to commercial operation in 2019
449	Richborough (GB)	Canterbury (GB)	New 400kV double circuit and new 400kV substation in Richborough connecting the new Belgium interconnector providing greater market coupling between the UK and the European mainland.	1000	Planning	2018	Investment on time	Progress as planned.
450	Sellindge (GB)	Dungeness (GB)	Reconductoring the existing circuit which runs from Sellindge - Dungeness with a higher rated conductor. This will facilitate the connection of more interconnectors on the South coast and prevent thermal overloading of this area.	400	Design & Permitting	2015	Investment on time	Progress as planned.
934	Kemsley (UK) for example - TBD	Doel/Zandvliet (BE) for example - TBD	NEMO 2: UK to BE 380kV inland This investment item envisions the possibility of a second 1GW HVDC connection, between UK (Kemsley) and a Belgian 380kV substation further inland in the Antwerp area (Doel, Zandvliet are indicative locations). Subject to further studies.	-	Under Considera tion	2030	New Investment	Preliminary studies on vision 3&4 scenario's have indicated potential for further regional welfare & RES integration increase by further increasing the interconnection capacity between Belgium & UK up to 2 GW.
810	Great Island or Knockraha (IE)	La Martyre (FR)	A new HVDC subsea connection between Ireland and France	-	Under Considera tion	2025	Investment on time	Feasibility studies are progressing
809	Dunstown (IE)	Pentir (GB)	A new HVDC subsea connection between Ireland and Great Britain; this may be achieved by a direct link or by integrating an interconnector with a third party connection from Ireland to GB.	-	Under Considera tion	2025	Investment on time	Joint studies between National Grid and EirGrid indicate a strong benefit for a second interconnector between Ireland and GB.
1020	Dunstown	Pembroke	Greenwire Interconnector spur 1, enables additional 500MW of interconnection between UK and Irish market	500	Planning	2018	New Investment	Opportunity to connect Irish RES to GB market
1021	Woodland	Pentir	Greenwire Interconnector spur 2, enables additional 1000MW of interconnection between UK and Irish market	1000	Planning	2017	New Investment	Project application to TYNDP 2014.
1113	Glinsk 400kV	Connah's Quay 400kV	1500 MW HVDC VSC cable	-	Planning	2018	New Investment	Project application for TYNDP 2014.
1024	Cruachan	Argyll hub	HVDC link between Cruachan (onshore) to Argyll offshore hub	1000	Under Considera tion	2030	New Investment	The ISLES project will serve the development of multiple offshore generation resources in the waters of Scotland, Ireland and Northern Ireland and facilitate increased inter-connection between the GB and the SEM on the island of Ireland.
1025	Argyll hub		A new dedicated offshore HVDC hub platform to allow connection of offshore renewable generation and interconnection capacity.	1000	Under Considera tion	2030	New Investment	
1026	Coleraine hub		A new dedicated offshore HVDC hub platform to allow connection of offshore renewable generation and interconnection capacity.	1000	Under Considera tion	2030	New Investment	
1027	Coolkeeragh hub		A new dedicated offshore HVDC hub platform to allow connection of offshore renewable generation and interconnection capacity.	1000	Under Considera tion	2030	New Investment	
1028	Argyll	Coleraine	HVDC link between Argyll offshore hub and Coleraine offshore hub	1000	Under Considera tion	2030	New Investment	

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1029	Coolkeeragh	Coolkeeragh hub	HVDC link between Coolkeeragh onshore and Coolkeeragh offshore hub	1000	Under Consideration	2030	New Investment	
1030	Coleraine	Coleraine hub	HVDC link between Colerain onshore and Coleraine offshore hub	1000	Under Consideration	2030	New Investment	
1031	Coleraine hub	Coolkeeragh hub	HVDC link between Coleraine offshore hub and Coolkeeragh offshore hub	1000	Under Consideration	2030	New Investment	
1032	Hunterston	Coleraine hub	HVDC link between Hunterston (onshore) to Argyll offshore hub	1000	Under Consideration	2030	New Investment	
424	Kvilldal (NO)	Blythe (GB)	A 720 km long 500 kV 1400 MW HVDC subsea interconnector between western Norway and eastern England.	-	Design & Permitting	2020	Investment on time	Progress as planned.
1033	Sima	Peterhead	A 650 km long 500 kV 1400 MW HVDC subsea interconnector between western Norway and eastern Scotland.	-	Design & Permitting	2020	New Investment	Project application to TYNDP 2014.
142	Tonstad (NO)	Wilster (DE)	A 514 km 500 kV HVDC subsea interconnector between southern Norway and northern Germany.	1400	Design & Permitting	2018	Investment on time	Agreement between the two TSOs on commissioning date.
406	(Southern part of Norway) (NO)	(Southern part of Norway)(NO)	Voltage uprating of existing 300 kV line Sauda/Saurdal - Lyse - Ertsmyra - Feda - 1&2, Feda - Kristiansand; Sauda-Samnanger in long term. Voltage upgrading of existing single circuit 400kV OHL Tonstad-Solhom-Arendal. Reactive power devices in 400kV substations.	1000	Design & Permitting	2020	Delayed	Revised progress due to less flexible system operations in a running system (voltage upgrade of existing lines). Commissioning date expected 2019-2021.
427	Endrup (DK)	Eemshaven (NL)	COBRA: New single circuit HVDC connection between Jutland and the Netherlands via 350km subsea cable; the DC voltage will be 320kV and the capacity 700MW.	-	Design & Permitting	2019	Delayed	Rescheduled to develop a solid regional business case (including additional project partners); and to account for the time needed for the acceptance by the authorities of a preferred route.
436	Idomlund (DK)	Endrup (DK)	New 74km single circuit 400kV line via cable with capacity of approx. 1200MW.	1360	Under Consideration	2030	Rescheduled	In national plan route is replaced by different project, upgrading an existing route from Tjele to Idomlund (72.898). The known route (Endrup-Idomlund) from the TYNDP12 would additionally be necessary as soon as the interconnection to GB is built.
998	Idomlund (DKW)	Stella West (GB)	2x700 MW HVDC subsea link across the North Seas.	1400	Under Consideration	2020	New Investment	New opportunity to integrate markets, new opportunity to exploit non correlated RES
1000	Malling (DKW)	Kyndby (DKE)	600 MW HVDC subsea link between both DK systems (2 synchr. areas, 2 market areas)	-	Under Consideration	2030	New Investment	In case of an expanded DKE-SE connection this link could be beneficial.
1016	Bjæverskov (DK2)	Bentwisch (DE)	new 600 MW HVDC subsea cable connecting DK2 and DE	-	Under Consideration	2030	New Investment	RGBS common investigations for TYNDP14
141	Ishøj / Bjæverskov (DK)	Bentwisch (DE)	Three offshore wind farms connected to shore combined with 400 MW interconnection between both countries	-	Design & Permitting	2018	Investment on time	Commissioning date must be achieved in order to ensure grid connection for further renewable energy.
995	Station SE4	Station DE	New DC cable interconnector between Sweden and Germany.	700	Under Consideration	2025	New Investment	RGBS common investigations for TYNDP 2014

996	LV-Grobina	SE3	A new HVDC link between LV-SE3, only as alternative of interconnector DE-SE4	600	Planning	2030	New Investment	Market integration

CBA results

The tables below summarize the Cost Benefits Analysis results of this portfolio of offshore projects.

CBA results non scenario specific						
GTC direction 1 (MW)	**GTC direction 2 (MW)**	**B6 Technical Resilience**	**B7 Flexibility**	**S1 - protected areas**	**S2 - urban areas**	**C1 Estimated cost (Meuros)**
Irland / GB : +5 GW Irland & GB / mainland: +10 GW NO & SE / DK & DE: +5 GW DK / DE & NL : +2 GW		2	5	More than 100km	15-25 km	17000-22000

CBA results	**for each scenario**				
Scenario	**B1 SoS (MWh/year)**	**B2 SEW (MEuros/year)**	**B3 RES integration [TWh]**	**B4 Losses (MWh/yr)**	**B5 CO2 Emissions (kT/year)**
Scenario Vision 1 - 2030	-	[1600 – 2300]	[10-15]	[4.8;5.8] TWh	[-5.7;-6.9] Mt/yr
Scenario Vision 2 - 2030	-	[1000 - 1600]	[3-5]	[4.5;5.6] TWh	[-5.3;-6.5] Mt/yr
Scenario Vision 3 - 2030	-	[2900 - 4000]	[20-25]	[5.2;6.3] TWh	[-19.3;-23.6] Mt/yr
Scenario Vision 4 - 2030	-	[3500 - 4100]	[25-30]	[5.4;6.6] TWh	[-20.8;-25.5] Mt/yr

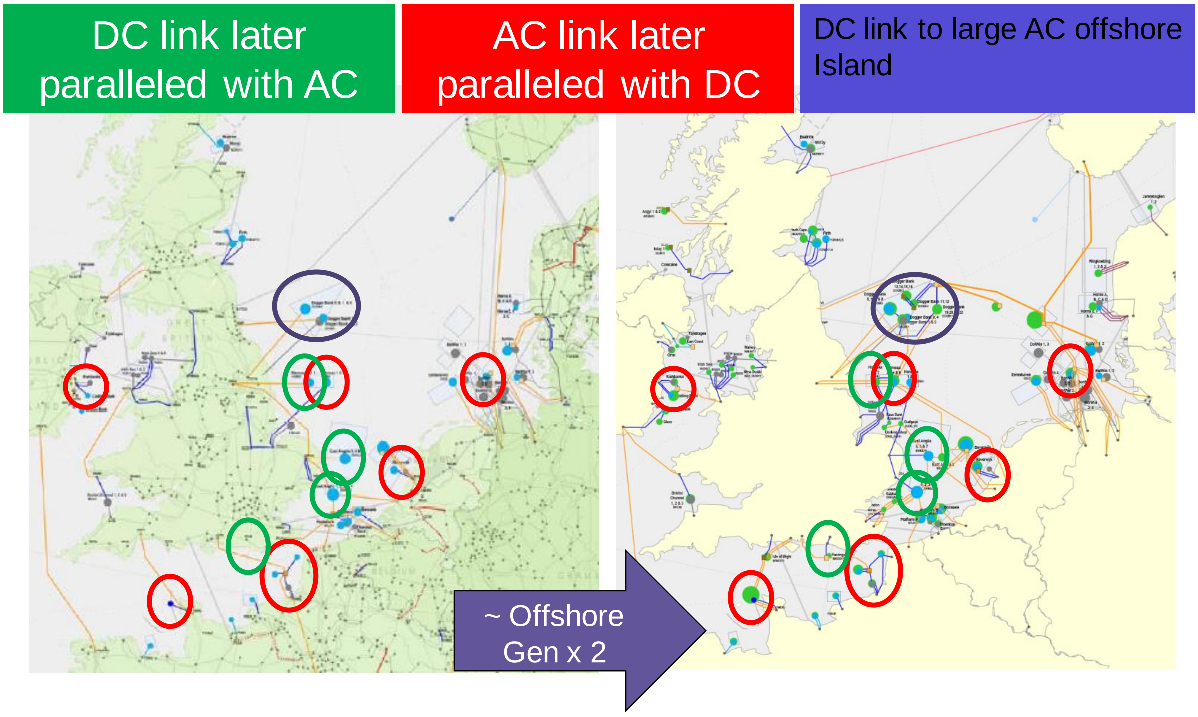
Additional comments

Comment on the RES indicator: spillage occurs almost exclusively in Ireland and Great-Britain.

Comment on the CBA assessment: by exception, CBA clustering rules are not complied with for this project, but they are for all its contributing parts. The offshore grid project integrates a certain capacity of offshore wind into the system, ranging up to 112 GW in vision 4. The RES indicator refers to the amount of RES spillage that is being avoided due to the market integration effect of this project, knowing that in vision 3 and 4 potential remains for further developments (there is still RES spillage left).

Furthermore, the socio-economic welfare in visions 1 and 2 are based on target capacities which do not reflect the full benefits of this integrated offshore grid. As such caution has to be applied when comparing costs to benefits.

General comment:
The present scheme is a basis, that will further develop with wind farms development, as indicated in the picture below, originating from NSCOGI grid study, which has further been analysed for the TYNDP 2014, see RegIP RGNS, chapter 10:


DC link later paralleled with AC
AC link later paralleled with DC
DC link to large AC offshore Island
~ Offshore Gen x 2

1.2 Transmission Projects of Common Interest

This section wraps up the assessment of transmission Projects of Common Interest, last updated by EC on 9th January 2014. All PCIs but those already commissioned have been assessed.

The assessment table hereafter:

- briefly recalls the project description;
- lists all the assessment indicators, comparably to the projects.

Some transmission PCIs are Projects of Pan-European significance, or subsets of investments of Projects of Pan-European significance and more details are available in the corresponding detailed sheet in the first section of this Appendix.

Caveats

Some input data are still required so that the assessment of PCIs from non-ENTSO-E members are completed.

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		all visions	Vision 1				Vision 2				Vision 3				Vision 4				all visions				
No	Definition	GTC / investment	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/ yr	RES	Losses MWh/yr	B6 - Resilience	B7 - Flexibility	S1 - "environmental impact"	S2 - "social impact"	Comments
1.1	Cluster Belgium – United Kingdom between Zeebrugge and Canterbury [currently known as the NEMO project] including the following PCIs:																						
	1.1.1 Interconnection between Zeebrugge (BE) and the vicinity of Richborough (UK)	1000	[32;74]	[180;220]	[220000;270000] MWh	[410000;420000]	[20;30]	[160;190]	[50000;61000] MWh	[370000;460000]	[200;280]	[-1300;-1400]	[1800000;2200000] MWh	[1900000;2300000]	[240;280]	[-1700;-1400]	[1100000;1400000] MWh	[190000;230000]	2	5	Negligeable or less than 15km	Negligeable or less than 15km	
	1.1.2 Internal line between the vicinity of Richborough and Canterbury (UK)	1000	[32;74]	[180;220]	[220000;270000] MWh	[410000;420000]	[20;30]	[160;190]	[50000;61000] MWh	[370000;460000]	[200;280]	[-1300;-1400]	[1800000;2200000] MWh	[1900000;2300000]	[240;280]	[-1700;-1400]	[1100000;1400000] MWh	[190000;230000]	2	5	Negligeable or less than 15km	NA	
	1.1.3 Internal line between Dungeness to Sellindge and Sellindge to Canterbury (UK)	400	[19;23]	[73;89]	[88000;110000] MWh	[150000;180000]	[9;11]	[63;77]	[20000;24000] MWh	[150000;180000]	[85;100]	[-600;-490]	[730000;890000] MWh	[740000;910000]	[94;110]	[-700;-570]	[450000;550000] MWh	[74000;91000]	1	3	Negligeable or less than 15km	NA	
1.2	PCI Belgium – two grid-ready offshore hubs connected to the onshore substation Zeebrugge (BE) with anticipatory investments enabling future interconnections with France and/or UK	1835	[390;490]	[-4100;-3300]	1800 MW	[27000;33000]	[420;490]	[-3400;-2700]	1800 MW	[27000;33000]	[510;520]	[-2600;-2100]	1800 MW	[27000;33000]	[330;460]	[-2000;-1600]	1800 MW	[27000;33000]	2	3	Negligeable or less than 15km	Negligeable or less than 15km	
1.3	Cluster Denmark - Germany between Endrup and Brunsbüttel including the following PCIs:																						
	1.3.1 Interconnection between Endrup (DK) and Niebüll (DE)	500	[0;10]	[-88;-72]	[14000;17000] MWh	[-11000;-9000]	[4;5]	[-22;-18]	[14000;17000] MWh	[-11000;-9000]	[20;60]	[-440;-360]	[120000;140000] MWh	[-12000;-9900]	[80;100]	[-830;-680]	[260000;310000] MWh	[-12000;-9600]	2	3	Negligeable or less than 15km	Negligeable or less than 15km	
	1.3.2 Internal line between Brunsbűttel and Niebűll (DE)	2014	[59;72]	[-260;-210]	[520000;640000] MWh	[-710000;-580000]	[53;65]	[18;22]	[510000;620000] MWh	[-740000;-600000]	[230;280]	[-1200;-1000]	[1500000;1800000] MWh	[-880000;-720000]	[340;420]	[-2000;-1700]	[2300000;2800000] MWh	[-1100000;-890000]	2	5	Negligeable or less than 15km	Negligeable or less than 15km	
1.4	Cluster Denmark - Germany between Kasső and Dollern including the following PCIs:																						

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		all visions	Vision 1				Vision 2				Vision 3				Vision 4				all visions				
No	Definition	GTC / investment	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	B6 - Resilience	B7 - Flexibility	S1 - "environmental impact"	S2 - "social impact"	Comments
	1.4.1 Interconnection between Kassö (DK) and Audorf (DE)	720	[13;16]	[-83;-68]	[39000;48000] MWh	[-33000;-27000]	[3.2;4]	[-28;-23]	[78000;95000] MWh	[23000;28000]	[42;51]	[-490;-400]	[140000;170000] MWh	[36000;44000]	[84;100]	[-900;-740]	[270000;330000] MWh	[36000;44000]	3	3	15-50km	15-25km	
	1.4.2 Internal line between Audorf and Hamburg/Nord (DE)	2410	[70;86]	[-310;-250]	[630000;760000] MWh	[-850000;-700000]	[63;77]	[22;26]	[610000;740000] MWh	[-880000;-720000]	[270;340]	[-1500;-1200]	[1800000;2200000] MWh	[-1100000;-860000]	[410;500]	[-2400;-2000]	[2800000;3400000] MWh	[-1300000;-1100000]	1	5	Negligeable or less than 15km	Negligeable or less than 15km	
	1.4.3 Internal line between Hamburg/Nord and Dollern (DE)	2008	[58;71]	[-260;-210]	[520000;640000] MWh	[-710000;-580000]	[53;64]	[18;22]	[510000;620000] MWh	[-740000;-600000]	[230;280]	[-1200;-1000]	[1500000;1800000] MWh	[-880000;-720000]	[340;410]	[-2000;-1700]	[2300000;2800000] MWh	[-1100000;-890000]	1	5	Negligeable or less than 15km	Negligeable or less than 15km	
1.5	PCI Denmark - Netherlands interconnection between Endrup (DK) and Eemshaven (NL)	700	[5;25]	[-120;-94]	[45000;55000] MWh	[44000;54000]	[0;10]	[-44;-36]	[27000;33000] MWh	[44000;54000]	[25;85]	[-560;-460]	[180000;220000] MWh	[110000;130000]	[100;150]	[-920;-760]	[350000;420000] MWh	[110000;130000]	3	3	more than 100km	Negligeable or less than 15km	
1.6	PCI France – Ireland interconnection between La Martyre (FR) and Great Island or Knockraha (IE)	700	[30;70]	[63;77]	[270000;320000] MWh	[200000;300000]	[20;30]	[-33;-27]	[170000;200000] MWh	[200000;300000]	[140;170]	[-970;-790]	[1300000;1600000] MWh	[170000;270000]	[150;200]	[-920;-760]	[1500000;1800000] MWh	[170000;270000]	1	4	NA	Negligeable or less than 15km	
1.7	Cluster France-United Kingdom interconnections, including one or more of the following PCIs:																						
	1.7.1 France – United Kingdom interconnection between Cotentin (FR) and the vicinity of Exeter (UK) [currently known as FAB project]	1400	[40;100]	[260;310]	[300000;360000] MWh	[270000;340000]	[0;90]	[270;340]	[59000;72000] MWh	[270000;340000]	[230;350]	[-2000;-1600]	[2400000;2900000] MWh	[260000;320000]	[260;300]	[-1700;-1400]	[2100000;2500000] MWh	[260000;320000]	1	4	Negligeable or less than 15km	Negligeable or less than 15km	
	1.7.2 France - United Kingdom interconnection between Tourbe (FR) and Chilling (UK) [currently known as the IFA2 project]	1000	[35;75]	[170;210]	[230000;280000] MWh	[200000;240000]	[0;60]	[220;260]	[36000;44000] MWh	[200000;240000]	[170;250]	[-1400;-1200]	[1700000;2000000] MWh	[190000;240000]	[180;210]	[-1100;-940]	[1500000;1800000] MWh	[190000;240000]	1	4	more than 100km	Negligeable or less than 15km	
	1.7.3 France - United Kingdom interconnection between Coquelles (FR) and Folkestone (UK) [currently known as the ElecLink project]	1000	[35;75]	[170;210]	[230000;280000] MWh	[200000;240000]	[0;60]	[220;260]	[36000;44000] MWh	[200000;240000]	[170;250]	[-1400;-1200]	[1700000;2000000] MWh	[140000;170000]	[180;210]	[-1100;-940]	[1500000;1800000] MWh	[140000;170000]	1	4	Negligeable or less than 15km	NA	

		all visions	Vision 1				Vision 2				Vision 3				Vision 4				all visions				
No	Definition	GTC / investment	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/ yr	RES	Losses MWh/yr	B6 - Resilience	B7 - Flexibility	S1 - "environmental impact"	S2 - "social impact"	Comments
1.8	PCI Germany - Norway interconnection between Wilster (DE) and Tonstad (NO) [currently known as the NORD.LINK project]	1400	[120;140]	[-930;-760]	[510000;620000] MWh	[910000;1100000]	[65;110]	[-670;-550]	[950000;1200000] MWh	[910000;1100000]	[210;280]	[-2200;-1800]	[1500000;1800000] MWh	[910000;1100000]	[350;400]	[-3400;-2800]	[1700000;2100000] MWh	[910000;1100000]	3	4	NA	NA	
1.9	Cluster connecting generation from renewable energy sources in Ireland to United Kingdom, including one or more of the following PCIs:																						
	1.9.1 Ireland – United Kingdom interconnection between Co. Offaly (IE), Pembroke and Pentir (UK)	1500	[12;28]	[-120;-95]	[170000;200000] MWh	[360000;440000]	[570;690]	[-4600;-3800]	0	[360000;440000]	[470;580]	[-2400;-1900]	0	[490000;600000]	[94;140]	[-610;-500]	[800000;970000] MWh	[490000;600000]	2	4	Negligeable or less than 15km	NA	
	1.9.2 Ireland – United Kingdom interconnection between Coolkeragh - Coleraine hubs (IE) and Hunterston station, Islay, Argyll and Location COWFs (UK)	1500	[12;26]	[-110;-86]	[160000;200000] MWh	[190000;230000]	[30;40]	[-190;-160]	0	[190000;230000]	[30;40]	[-190;-160]	0	[270000;330000]	[43;55]	[-310;-250]	[400000;490000] MWh	[270000;330000]	3	5	NA	NA	
	1.9.3 Ireland – United Kingdom interconnection between the Northern hub, Dublin and Codling Bank (IE) and Trawsfynyd and Pembroke (UK)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	The data of the project were not submitted to ENTSO-E, therefore no assessment has been made.
	1.9.4 Ireland – United Kingdom interconnection between the Irish midlands and Pembroke (UK)	1250	[190;280]	[-1800;-1500]	[3000000;3500000]	0	[210;280]	[-1800;-1500]	[3000000;3500000]	0	[130;160]	[-600;-500]	[3000000;3500000]	0	[3;4]	[-400;-330]	[3000000;3500000]	0	0	0	NA	NA	The 2 KPI were not assessed
	1.9.5 Ireland – United Kingdom interconnection between the Irish midlands and Alverdiscott, Devon (UK)	2500	[280;560]	[-3600;-3000]	[6000000;7000000]	0	[420;560]	[-3600;-3000]	[6000000;7000000]	0	[260;320]	[-1200;-1000]	[6000000;7000000]	0	[6;8]	[-800;-660]	[6000000;7000000]	0	0	0	NA	NA	The 2 KPI were not assessed

		all visions	Vision 1				Vision 2				Vision 3				Vision 4				all visions				
No	Definition	GTC / investment	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/ yr	RES	Losses MWh/yr	B6 - Resilience	B7 - Flexibility	S1 - "environmental impact"	S2 - "social impact"	Comments
	1.9.6 Ireland – United Kingdom interconnection between the Irish coast and Pembroke (UK)	1250	[190;280]	[-1800;-1500]	[3000000;3500000]	0	[210;280]	[-1800;-1500]	[3000000;3500000]	0	[130;160]	[-600;-500]	[3000000;3500000]	0	[3;4]	[-400;-330]	[3000000;3500000]	0	0	0	NA	NA	The 2 KPI were not assessed
1.10	PCI Norway – United Kingdom interconnection																						
	Solution Norway - United Kingdom interconnection between Kvilldal (NO) and Blyth (UK)	1400	[150;220]	[-440;-360]	[1000000;1200000] MWh	[760000;930000]	[90;170]	[-240;-190]	[900000;1100000] MWh	[760000;930000]	[280;360]	[-2000;-1700]	[2700000;3300000] MWh	[760000;930000]	[280;300]	[-1800;-1500]	[2100000;2600000] MWh	[760000;930000]	2	4	Negligeable or less than 15km	Negligeable or less than 15km	
	Solution Norway - United Kingdom interconnection between Sima or Samnanger (NO) and Peterhead (UK)	1400	[150;220]	[-440;-360]	[1000000;1200000] MWh	[760000;930000]	[90;170]	[-240;-190]	[900000;1100000] MWh	[760000;930000]	[280;360]	[-2000;-1700]	[2700000;3300000] MWh	[760000;930000]	[280;300]	[-1800;-1500]	[2100000;2600000] MWh	[760000;930000]	2	4	Negligeable or less than 15km	NA	
1.11	Cluster of electricity storage projects in Ireland and associated connections to United Kingdom, including one or more of the following PCIs:																						
	1.11.2 PCI Ireland – United Kingdom interconnection between North West Ireland (IE) and Midlands (UK)	1500	[290;400]	[-2800;-2300]	[190000;240000] MWh	0	[58;71]	[-2800;-2300]	[370000;380000] MWh	0	[200;240]	[-930;-760	[1900000;2300000] MWh	0	[170;180]	[-580;-470]	[1700000;2100000] MWh	0	0	0	NA	NA	The 2 KPI were not assessed
	1.11.4 PCI Ireland – United Kingdom interconnection between Glinsk, Mayo (IE) and Connah's Quai, Deeside (UK)	1500	[290;400]	[-2800;-2300]	[190000;240000] MWh	0	[58;71]	[-2800;-2300]	[370000;380000] MWh	0	[200;240]	[-930;-760	[1900000;2300000] MWh	0	[170;180]	[-580;-470]	[1700000;2100000] MWh	0	0	0	NA	NA	The 2 KPI were not assessed
2.1	PCI Austria internal line between Westtirol and Zell-Ziller (AT) to increase capacity at the AT/DE border	470	[8.6;11]	[86;100]	0	[-73000;-60000]	[19;23]	[63;78]	0	[-68000;-55000]	[51;62]	[-250;-200]	[48000;59000] MWh	[-53000;-44000]	[70;86]	[-250;-210]	[110000;140000] MWh	[-56000;-46000]	0	0	NA	NA	
2.2	Cluster Belgium - Germany between Lixhe and Oberzier [currently known as the ALEGrO																						

		all visions	Vision 1				Vision 2				Vision 3				Vision 4				all visions				
No	Definition	GTC / investment	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/ yr	RES	Losses MWh/yr	B6 - Resilience	B7 - Flexibility	S1 - "environmental impact"	S2 - "social impact"	Comments
	project] including the following PCIs:																						
	2.2.1 Interconnection between Lixhe (BE) and Oberzier (DE)	1000	[5;15]	[140;170]	[9000;110000] MWh	[150000;180000]	[5;15]	[-22;-18]	[4500;5500] MWh	[150000;180000]	[35;45]	[-800;-650]	[100000;130000] MWh	[120000;140000]	[45;75]	[-1100;-900]	[180000;210000] MWh	[120000;140000]	3	3	Negligeable or less than 15km	Negligeable or less than 15km	
	2.2.2 Internal line between Lixhe and Herderen (BE)	1000	[5;15]	[140;170]	[9000;110000] MWh	[150000;180000]	[5;15]	[-22;-18]	[4500;5500] MWh	[150000;180000]	[35;45]	[-800;-650]	[100000;130000] MWh	[120000;140000]	[45;75]	[-1100;-900]	[180000;210000] MWh	[120000;140000]	3	3	Negligeable or less than 15km	Negligeable or less than 15km	
	2.2.3 New substation in Zutendaal (BE)	1000	[9;11]	[140;170]	[9000;110000] MWh	[150000;180000]	[9;11]	[-22;-18]	[4500;5500] MWh	[150000;180000]	[36;44]	[-800;-650]	[100000;130000] MWh	[120000;140000]	[54;66]	[-1100;-900]	[180000;210000] MWh	[120000;140000]	3	3	Negligeable or less than 15km	Negligeable or less than 15km	
2.3	Cluster Belgium - Luxembourg capacity increase at the BE/LU border including the following PCIs:																						
	2.3.1 Coordinated installation and operation of a phase-shift transformer in Schifflange (LU)	400	[2.6;3.1]	[46;56]	[9300;110000] MWh	0	[2.6;3.1]	[31;38]	[5100;6300] MWh	0	[13;16]	[-300;-250]	[5100;6300] MWh	0	[21;25]	[-490;-400]	[74000;90000] MWh	0	1	3	NA	NA	
	2.3.2 Interconnection between Aubange (BE) and Bascharage/Schifflange (LU)	300	[1.9;2.4]	[34;42]	[6900;8500] MWh	0	[1.9;2.4]	[23;28]	[3900;4700] MWh	0	[9.6;12]	[-230;-190]	[3900;4700] MWh	0	[15;19]	[-370;-300]	[55000;67000] MWh	0	1	4	Negligeable or less than 15km	Negligeable or less than 15km	
2.4	PCI France - Italy interconnection between Codrongianos (IT), Lucciana (Corsica, FR) and Suvereto (IT) [currently known as the SA.CO.I. 3 project]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	The investment is not assessed as it has been reconsidered taking into account the actual feasibility conditions according to the National Development Plan. Therefore at the moment no implementation activities are planned in

		all visions	Vision 1				Vision 2				Vision 3				Vision 4				all visions				
No	Definition	GTC / investment	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/ yr	RES	Losses MWh/yr	B6 - Resilience	B7 - Flexibility	S1 - "environmental impact"	S2 - "social impact"	Comments
																							the next years.
2.5	Cluster France - Italy between Grande Ile and Piossasco, including the following PCIs: 2.5.1 Interconnection between Grande Ile (FR) and Piossasco (IT) [currently known as Savoie-Piemont project]	1200	[57;70]	[330;410]	0	[250000;310000]	[29;36]	0	0	[250000;300000]	[94;120]	[-440;-360]	[49000;60000] MWh	[8100;9900]	[290;360]	[-1700;-1400]	[410000;510000] MWh	[36000;44000]	1	4	Negligeable or less than 15km	Negligeable or less than 15km	
	2.5.2 Internal line between Trino and Lacchiarella (IT)	Commissioned	Commissioned																				The investment is already commissioned
2.6	PCI Spain internal line between Santa Llogaia and Bescanó (ES) to increase capacity of the interconnection between Bescanó (ES) and Baixas (FR)	1400	[20;130]	[1600;2000]	[110000;130000] MWh	[450000;550000]	[22;140]	[1800;2200]	[120000;150000] MWh	[280000;380000]	[70;150]	[-1100;-870]	[590000;720000] MWh	[180000;280000]	[210;280]	[-1500;-1300]	[1300000;1500000] MWh	[360000;460000]	1	4	Negligeable or less than 15km	Negligeable or less than 15km	
2.7	PCI France - Spain interconnection between Aquitaine (FR) and the Basque country (ES)	2500	[70;240]	[3300;4000]	[130000;160000] MWh	[200000;300000]	[74;250]	[3500;4300]	[140000;170000] MWh	[210000;310000]	[90;250]	[-1900;-1500]	[900000;1100000] MWh	[240000;340000]	[310;470]	[-2400;-2000]	[2100000;2600000] MWh	[390000;490000]	2	4	Negligeable or less than 15km	Negligeable or less than 15km	
2.8	PCI Coordinated installation and operation of a phase-shift transformer in Arkale (ES) to increase capacity of the interconnection between Argia (FR) and Arkale (ES)	500	[4.5;5.5]	[120;140]	[4900;5900] MWh	[4500;5500]	[5.5;6.7]	[130;160]	[5000;6100] MWh	[4800;5800]	[9.5;12]	[-100;-85]	[30000;37000] MWh	[6000;7300]	[22;26]	[-150;-130]	[85000;100000] MWh	[8000;9800]	0	0	NA	NA	
2.9	PCI Germany internal line between Osterath and Philippsburg (DE) to increase capacity at Western borders	3049	[230;280]	[-2500;-2100]	[3300000;4000000] MWh	[-1400000;-1100000]	[160;190]	[-2000;-1600]	[3000000;3700000] MWh	[-690000;-570000]	[750;920]	[-3700;-3000]	[7900000;9600000] MWh	[-3400000;-2800000]	[720;880]	[-3600;-3000]	[8100000;9900000] MWh	[-2800000;-2300000]	5	4	NA	NA	

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No	Definition	GTC / investment	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	B6 - Resilience	B7 - Flexibility	S1 - "environmental impact"	S2 - "social impact"	Comments
2.10	PCI Germany internal line between Brunsbüttel-Groβgartach and Wilster-Grafenrheinfeld (DE) to increase capacity at Northern and Southern borders	3575	[100;130]	[-460;-380]	[930000;1100000] MWh	[-1300000;-1000000]	[94;110]	[32;39]	[900000;1100000] MWh	[-1300000;-1100000]	[410;500]	[-2200;-1800]	[2600000;3200000] MWh	[-1600000;-1300000]	[600;740]	[-3600;-3000]	[4100000;5000000] MWh	[-1900000;-1600000]	5	5	NA	NA	
2.11	Cluster Germany – Austria - Switzerland capacity increase in Lake Constance area including the following PCIs:																						
	2.11.1 Interconnection between border area (DE), Meiningen (AT) and Rüthi (CH)	1200	[90;110]	[820;1000]	0	[-200000;-160000]	[140;170]	[1900;2400]	0	[-270000;-220000]	[310;380]	[-1200;-950]	[450000;550000] MWh	[-180000;-150000]	[480;580]	[-2100;-1700]	[900000;1100000] MWh	[-360000;-300000]	1	4	15-50km	Negligeable or less than 15km	
	2.11.2 Internal line in the region of point Rommelsbach to Herbertingen, Herbertingen to Tiengen, point Wullenstetten to point Niederwangen (DE) and the border area DE-AT	2000	[53;65]	[480;590]	0	[-58000;-48000]	[83;100]	[1100;1400]	[-4300;-3500] MWh	[-80000;-66000]	[180;220]	[-680;-560]	[260000;320000] MWh	[-54000;-44000]	[280;340]	[-1200;-1000]	[530000;650000] MWh	[-110000;-87000]	1	3	Negligeable or less than 15km	Negligeable or less than 15km	
2.12	PCI Germany – Netherlands interconnection between Niederrhein (DE) and Doetinchem (NL)	1500	[0;10]	[-11;-9]	[4500;5500] MWh	[-39000;-32000]	[4;5]	[-27;-22]	0	[-39000;-32000]	[15;65]	[-770;-630]	[100000;130000] MWh	[-180000;-150000]	[40;60]	[-1000;-1200]	[63000;77000] MWh	[-180000;-150000]	3	3	15-50km	25-50km	
2.13	Cluster Ireland – United Kingdom (Northern Ireland) interconnections, including one or more following Projects of Common Interest:																						
	2.13.1 PCI Ireland – United Kingdom interconnection between Woodland (IE) and Turleenan	700	[18;36]	[-45;-36]	[6300;7700] MWh	[-50000;-41000]	[12;15]	[-27;-22]	[9000;11000] MWh	[39000;47000]	[27;34]	[40;49]	[45000;55000] MWh	[39000;47000]	[55;77]	[-110;-90]	[1800;2200] MWh	[-45000;-37000]	3	3	Negligeable or less than 15km	Negligeable or less than 15km	

		all visions	Vision 1				Vision 2				Vision 3				Vision 4				all visions				
No	Definition	GTC / investment	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/ yr	RES	Losses MWh/yr	B6 - Resilience	B7 - Flexibility	S1 - "environmental impact"	S2 - "social impact"	Comments
	(UK – Northern Ireland)																						
	2.13.2 PCI Ireland – United Kingdom Interconnection between Srananagh (IE) and Turleenan (UK – Northern Ireland)	500	[100;120]	[-970;-790]	[100000;130000] MWh	[60000;74000]	[110;140]	[-100;-81]	[27000;33000] MWh	[50000;62000]	[66;81]	[-340;-280]	[700000;860000] MWh	[50000;62000]	[50;62]	[-160;-130]	[830000;1000000] MWh	[45000;55000]	3	3	Negligeable or less than 15km	NA	
2.14	PCI Italy – Switzerland interconnection between Thusis/Sils (CH) and Verderio Inferiore (IT)	800	[19;24]	[170;210]	0	[-20000;-16000]	[17;20]	[-500;-410]	0	[-24000;-20000]	[18;23]	0	0	[1800;2200]	[42;51]	[-120;-99]	0	[-17000;-14000]	1	3	Negligeable or less than 15km	Negligeable or less than 15km	
2.15	Cluster Italy – Switzerland capacity increase at IT/CH border including the following PCIs:																						
	2.15.1 Interconnection between Airolo (CH) and Baggio (IT)	1000	[26;31]	[190;230]	0	[230000;290000]	[32;39]	[-340;-280]	0	[230000;290000]	[26;31]	0	0	[17000;21000]	[54;66]	[-140;-120]	0	[50000;61000]	1	4	Negligeable or less than 15km	Negligeable or less than 15km	
	2.15.2 Upgrade of Magenta substation (IT)	1000	[26;31]	[190;230]	0	[230000;290000]	[32;39]	[-340;-280]	0	[230000;290000]	[26;31]	0	0	[17000;21000]	[54;66]	[-140;-120]	0	[50000;61000]	1	4	NA	NA	
	2.15.3 Internal line between Pavia and Piacenza (IT)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	The investment is not assessed as it has been reconsidered taking into account the actual feasibility conditions according to the National Development Plan. Therefore at the moment no implementation activities are planned in the next years.

		all visions	Vision 1				Vision 2				Vision 3				Vision 4				all visions				
No	Definition	GTC / investment	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	B6 - Resilience	B7 - Flexibility	S1 - "environmental impact"	S2 - "social impact"	Comments
	2.15.4 Internal line between Tirano and Verderio (IT)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	The investment is not assessed as it has been reconsidered taking into account the actual feasibility conditions according to the National Development Plan. Therefore at the moment no implementation activities are planned in the next years.
2.16	Cluster Portugal capacity increase at PT/ES border including the following PCIs:																						
	2.16.1 Internal line between Pedralva and Alfena (PT)	830	[17;21]	[-67;-55]	[360;440] MW	[7400;9100]	[17;21]	[-67;-55]	[360;440] MW	[8100;9900]	[20;24]	[-81;-67]	[420;520] MW	[9000;11000]	[15;18]	[-63;-51]	[440;540] MW	[670;820]	1	3	NA	Negligeable or less than 15km	
	2.16.2 Internal line between Pedralva and Vila Fria B (PT)	680	[14;17]	[-55;-45]	[290;360] MW	[6100;7500]	[14;17]	[-55;-45]	[290;360] MW	[6700;8100]	[16;20]	[-67;-55]	[350;430] MW	[7400;9000]	[12;15]	[-51;-42]	[360;440] MW	[550;670]	1	3	Negligeable or less than 15km	Negligeable or less than 15km	
	2.16.3 Internal line between Frades B, Ribeira de Pena and Feira (PT)	890	[18;22]	[-72;-59]	[380;470] MW	[8000;9800]	[18;22]	[-72;-59]	[380;470] MW	[8700;11000]	[21;26]	[-87;-71]	[460;560] MW	[9600;12000]	[16;20]	[-67;-55]	[470;580] MW	[720;880]	1	3	NA	NA	
2.17	PCI Portugal - Spain interconnection between Vila Fria - Vila do Conde – Recarei (PT) and Beariz - Fontefría (ES)	1000	[4;30]	[180;220]	[7200;8800] MWh	[-14000;-12000]	[3;33]	[160;200]	[7900;9600] MWh	[-13000;-11000]	[20;50]	[-110;-90]	[160000;200000] MWh	[3600;4400]	[64;130]	[-330;-270]	[630000;770000] MWh	[8100;9900]	3	4	NA	NA	
3.1	Cluster Austria - Germany between St. Peter and Isar including the following PCIs:																						

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No	Definition	GTC / investment	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	B6 - Resilience	B7 - Flexibility	S1 - "environmental impact"	S2 - "social impact"	Comments
	3.1.1 Interconnection between St. Peter (AT) and Isar (DE)	2320	[42;52]	[420;520]	0	[-360000;-290000]	[91;110]	[310;380]	0	[-330000;-270000]	[250;310]	[-1200;-1000]	[240000;290000] MWh	[-260000;-220000]	[350;420]	[-1300;-1000]	[550000;680000] MWh	[-280000;-230000]	1	4	Negligeable or less than 15km	Negligeable or less than 15km	
	3.1.2 Internal line between St. Peter and Tauern (AT)	1740	[32;39]	[320;390]	0	[-270000;-220000]	[69;84]	[230;290]	0	[-250000;-210000]	[190;230]	[-920;-760]	[180000;220000] MWh	[-200000;-160000]	[260;320]	[-940;-770]	[420000;510000] MWh	[-210000;-170000]	1	3	Negligeable or less than 15km	Negligeable or less than 15km	
	3.1.3 Internal line between St. Peter and Ernsthofen (AT)	580	[11;13]	[110;130]	0	[-90000;-73000]	[23;28]	[78;96]	0	[-84000;-68000]	[63;77]	[-310;-250]	[59000;73000] MWh	[-66000;-54000]	[87;110]	[-310;-260]	[140000;170000] MWh	[-69000;-56000]	1	2	NA	NA	
3.2	Cluster Austria - Italy between Lienz and Veneto region including the following PCIs:																						
	3.2.1 Interconnection between Lienz (AT) and Veneto region (IT)	800	[32;39]	[290;350]	0	[-280000;-230000]	[49;60]	[-270;-220]	[1500;1800] MWh	[-290000;-230000]	[31;38]	[-69;-57]	[600;730] MWh	[-110000;-89000]	[57;70]	[-160;-130]	[6200;7600] MWh	[-150000;-120000]	1	4	Negligeable or less than 15km	Negligeable or less than 15km	
	3.2.2 Internal line between Lienz and Obersielach (AT)	320	[13;16]	[120;140]	0	[-110000;-91000]	[20;24]	[-110;-89]	[600;730] MWh	[-110000;-93000]	[13;15]	[-28;-23]	[240;290] MWh	[-44000;-36000]	[23;28]	[-66;-54]	[2500;3000] MWh	[-61000;-50000]	1	3	NA	NA	
	3.2.3 Internal line between Volpago and North Venezia (IT)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	The investment is not assessed as it has been reconsidered taking into account the actual feasibility conditions according to the National Development Plan. Therefore at the moment no implementation activities are planned in the next years.
3.3	PCI Austria - Italy interconnection between Nauders (AT) and Milan region (IT)	300	[12;15]	[110;130]	0	[-100000;-86000]	[18;23]	[-100;-83]	[560;680] MWh	[-110000;-88000]	[12;14]	[-26;-21]	[220;270] MWh	[-41000;-34000]	[21;26]	[-61;-50]	[2300;2800] MWh	[-57000;-47000]	0	0	Negligeable or less than 15km	Negligeable or less than 15km	

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No	Definition	GTC / investment	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	B6 - Resilience	B7 - Flexibility	S1 - "environmental impact"	S2 - "social impact"	Comments
3.4	PCI Austria – Italy interconnection between Wurmlach (AT) and Somplago (IT)	150	[4;5]	0	0	[-13000;-11000]	[9;11]	0	0	[-13000;-11000]	[2;3]	0	0	[-2600;-2200]	[5;6]	0	0	[-3600;-3000]	1	3	Negligeable or less than 15km	Negligeable or less than 15km	
3.5	Cluster Bosnia and Herzegovina - Croatia between Banja Luka and Lika including the following PCIs:																						
	3.5.1 Interconnection between Banja Luka (BA) and Lika (HR)	504	[42;51]	[-260;-210]	[620;750] MW	[8200;10000]	[110;130]	[-240;-200]	[620;750] MW	[-89000;-73000]	[340;420]	[-2200;-1800]	[670;820] MW	[-4400;-3600]	[220;270]	[-1900;-1500]	[670;820] MW	[6700;8200]	1	4	Negligeable or less than 15km	Negligeable or less than 15km	
	3.5.2 Internal lines between Brinje, Lika, Velebit and Konjsko (HR)	215	[18;22]	[-110;-92]	[260;320] MW	[3500;4300]	[45;55]	[-100;-85]	[260;320] MW	[-38000;-31000]	[150;180]	[-950;-780]	[280;350] MW	[-1900;-1500]	[96;120]	[-800;-650]	[280;350] MW	[2800;3500]	1	3	Negligeable or less than 15km	Negligeable or less than 15km	
3.6	Cluster Bulgaria capacity increase with Greece and Romania including the following PCIs:																						
	3.6.1 Internal line between Vetren and Blagoevgrad (BG)	65	[180;220]	[-120;-99]	0	[-31000;-25000]	[84;100]	[-280;-230]	0	[-41000;-33000]	[480;580]	[-1200;-940]	0	[-47000;-38000]	[55;67]	[-740;-600]	0	[-35000;-29000]	2	2	Negligeable or less than 15km	Negligeable or less than 15km	
	3.6.2 Internal line between Tsarevets and Plovdiv (BG)	65	[180;220]	[-120;-99]	0	[-31000;-25000]	[84;100]	[-280;-230]	0	[-41000;-33000]	[480;580]	[-1200;-940]	0	[-47000;-38000]	[55;67]	[-740;-600]	0	[-35000;-29000]	2	2	Negligeable or less than 15km	Negligeable or less than 15km	
3.7	Cluster Bulgaria - Greece between Maritsa East 1 and N. Santa including the following PCIs:																						
	3.7.1 Interconnection between Maritsa East 1 (BG) and N. Santa (EL)	648	[54;67]	[-22;-18]	250 MW	[-110000;-88000]	[200;250]	[-150;-130]	250 MW	[-140000;-110000]	[100;120]	[-510;-410]	250 MW	[-170000;-140000]	[150;180]	[-970;-790]	250 MW	[-130000;-110000]	2	4	Negligeable or less than 15km	Negligeable or less than 15km	
	3.7.2 Internal line between Maritsa East 1 and Plovdiv (BG)	648	[54;67]	[-22;-18]	250 MW	[-110000;-88000]	[200;250]	[-150;-130]	250 MW	[-140000;-110000]	[100;120]	[-510;-410]	250 MW	[-170000;-140000]	[150;180]	[-970;-790]	250 MW	[-130000;-110000]	2	4	Negligeable or less than 15km	Negligeable or less than 15km	
	3.7.3 Internal line between Maritsa East 1 and Maritsa East 3 (BG)	648	[54;67]	[-22;-18]	250 MW	[-110000;-88000]	[200;250]	[-150;-130]	250 MW	[-140000;-110000]	[100;120]	[-510;-410]	250 MW	[-170000;-140000]	[150;180]	[-970;-790]	250 MW	[-130000;-110000]	2	4	Negligeable or less than 15km	Negligeable or less than 15km	

		all visions	Vision 1				Vision 2				Vision 3				Vision 4				all visions				
No	Definition	GTC / investment	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/ yr	RES	Losses MWh/yr	B6 - Resilience	B7 - Flexibility	S1 - "environmental impact"	S2 - "social impact"	Comments
	3.7.4 Internal line between Maritsa East 1 and Burgas (BG)	648	[54;67]	[-22;-18]	250 MW	[-110000;-88000]	[200;250]	[-150;-130]	250 MW	[-140000;-110000]	[100;120]	[-510;-410]	250 MW	[-170000;-140000]	[150;180]	[-970;-790]	250 MW	[-130000;-110000]	2	4	NA	Negligeable or less than 15km	
3.8	Cluster Bulgaria – Romania capacity increase including the following PCIs:																						
	3.8.1 Internal line between Dobrudja and Burgas (BG)	165	[8;9.8]	[-31;-26]	[90;110] MW	[-4900;-4000]	[4.6;5.6]	[-59;-48]	[90;110] MW	[2000;2500]	[30;37]	[-250;-210]	[90;110] MW	[-13000;-11000]	[27;33]	[-160;-130]	[90;110] MW	[-1900;-1500]	1	3	NA	Negligeable or less than 15km	
	3.8.2 Internal line between Vidino and Svoboda (BG)	165	[8;9.8]	[-31;-26]	[90;110] MW	[-4900;-4000]	[4.6;5.6]	[-59;-48]	[90;110] MW	[2000;2500]	[30;37]	[-250;-210]	[90;110] MW	[-13000;-11000]	[27;33]	[-160;-130]	[90;110] MW	[-1900;-1500]	1	3	Negligeable or less than 15km	Negligeable or less than 15km	
	3.8.3 Internal line between Svoboda (BG) and the splitting point of the interconnection Varna (BG) - Stupina (RO) in BG	165	[8;9.8]	[-31;-26]	[90;110] MW	[-4900;-4000]	[4.6;5.6]	[-59;-48]	[90;110] MW	[2000;2500]	[30;37]	[-250;-210]	[90;110] MW	[-13000;-11000]	[27;33]	[-160;-130]	[90;110] MW	[-1900;-1500]	1	3	NA	NA	
	3.8.4 Internal line between Cernavoda and Stalpu (RO)	808	[39;48]	[-150;-130]	[440;540] MW	[-24000;-20000]	[23;28]	[-290;-240]	[440;540] MW	[10000;12000]	[150;180]	[-1200;-1000]	[440;540] MW	[-64000;-52000]	[130;160]	[-790;-650]	[440;540] MW	[-9100;-7400]	1	3	Negligeable or less than 15km	Negligeable or less than 15km	
	3.8.5 Internal line between Gutinas and Smardan (RO)	560	[27;33]	[-110;-87]	[310;370] MW	[-17000;-14000]	[16;19]	[-200;-160]	[310;370] MW	[6900;8400]	[100;130]	[-860;-700]	[310;370] MW	[-44000;-36000]	[92;110]	[-550;-450]	[310;370] MW	[-6300;-5100]	1	3	NA	Negligeable or less than 15km	
	3.8.6 Internal line between Gadalin and Suceava (RO)	165	[8;9.8]	[-31;-26]	[90;110] MW	[-4900;-4000]	[4.6;5.6]	[-59;-48]	[90;110] MW	[2000;2500]	[30;37]	[-250;-210]	[90;110] MW	[-13000;-11000]	[27;33]	[-160;-130]	[90;110] MW	[-1900;-1500]	1	3	Negligeable or less than 15km	15-25km	
3.9	Cluster Croatia – Hungary - Slovenia between Žerjavenec /Heviz and Cirkovce including the following PCIs:																						
	3.9.1 Interconnection between Žerjavenec (HR)/Heviz (HU) and Cirkovce (SI)	1085	[42;51]	[-200;-160]	0	[-120000;-95000]	[40;49]	[-44;-36]	0	[-460000;-370000]	[480;580]	[-3800;-3100]	0	[-240000;-190000]	[300;370]	[-1700;-1400]	0	[-190000;-150000]	0	4	15-50km	15-25km	
	3.9.2 Internal line between Divača and Beričevo (SI)	800	[31;38]	[-150;-120]	0	[-85000;-70000]	[30;36]	[-32;-27]	0	[-340000;-280000]	[350;430]	[-2800;-2300]	0	[-170000;-140000]	[220;270]	[-1200;-1000]	0	[-140000;-110000]	1	3	50-100km	25-50km	

No	Definition	all visions	Vision 1				Vision 2				Vision 3				Vision 4				all visions				Comments
		GTC / investment	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/ yr	RES	Losses MWh/yr	B6 - Resilience	B7 - Flexibility	S1 - "environmental impact"	S2 - "social impact"	
	3.9.3 Internal line between Beričevo and Podlog (SI)	800	[31;38]	[-150;-120]	0	[-85000;-70000]	[30;36]	[-32;-27]	0	[-340000;-280000]	[350;430]	[-2800;-2300]	0	[-170000;-140000]	[220;270]	[-1200;-1000]	0	[-140000;-110000]	1	3	Negligeable or less than 15km	25-50km	
	3.9.4 Internal line between Podlog and Cirkovce (SI)	800	[31;38]	[-150;-120]	0	[-85000;-70000]	[30;36]	[-32;-27]	0	[-340000;-280000]	[350;430]	[-2800;-2300]	0	[-170000;-140000]	[220;270]	[-1200;-1000]	0	[-140000;-110000]	1	3	Negligeable or less than 15km	25-50km	
3.10	Cluster Israel - Cyprus – Greece between Hadera and Attica region [currently known as the Euro Asia Interconnector] including the following PCIs:																						
	3.10.1 Interconnection between Hadera (IL) and Vasilikos (CY)		[530;640]	0	[3400000;4100000] MWh	[1400000;1700000]	[530;650]	0	[3600000;4400000] MWh	[1400000;1700000]	[330;410]	0	[3500000;4200000] MWh	[1200000;1400000]	[310;380]	0	[3500000;4300000] MWh	[1100000;1400000]	2	3	NA	NA	
	3.10.2 Interconnection between Vasilikos (CY) and Korakia, Crete (EL)		[530;640]	0	[3400000;4100000] MWh	[1400000;1700000]	[530;650]	0	[3600000;4400000] MWh	[1400000;1700000]	[330;410]	0	[3500000;4200000] MWh	[1200000;1400000]	[310;380]	0	[3500000;4300000] MWh	[1100000;1400000]	2	3	NA	NA	
	3.10.3 Internal line between Korakia, Crete and Attica region (EL)	900	[240;290]	0	[1500000;1800000] MWh	[630000;770000]	[240;290]	0	[1600000;2000000] MWh	[620000;760000]	[150;180]	0	[1600000;1900000] MWh	[530000;640000]	[140;170]	0	[1600000;1900000] MWh	[500000;610000]	2	3	NA	NA	
3.11	Cluster Czech Republic internal lines to increase capacity at North-Western and Southern borders including the following PCIs:																						
	3.11.1 Internal line between Vernerov and Vitkov (CZ)	500	[250;310]	[-2100;-2500]	[200000;250000] MWh	[-220000;-260000]	[270;330]	[-1800;-2100]	[200000;240000] MWh	[-260000;-320000]	[1400;1700]	[-7900;-9500]	[210000;260000] MWh	[-340000;-580000]	[1200;1500]	[-7000;-8600]	[210000;260000] MWh	[-280000;-300000]	2	3	NA	NA	
	3.11.2 Internal line between Vitkov and Prestice (CZ)	500	[250;310]	[-2100;-2500]	[200000;250000] MWh	[-220000;-260000]	[270;330]	[-1800;-2100]	[200000;240000] MWh	[-260000;-320000]	[1400;1700]	[-7900;-9500]	[210000;260000] MWh	[-340000;-580000]	[1200;1500]	[-7000;-8600]	[210000;260000] MWh	[-280000;-300000]	2	3	Negligeable or less than 15km	Negligeable or less than 15km	
	3.11.3 Internal line between Prestice and Kocin (CZ)	500	[250;310]	[-2100;-2500]	[200000;250000] MWh	[-220000;-260000]	[270;330]	[-1800;-2100]	[200000;240000] MWh	[-260000;-320000]	[1400;1700]	[-7900;-9500]	[210000;260000] MWh	[-340000;-580000]	[1200;1500]	[-7000;-8600]	[210000;260000] MWh	[-260000;-320000]	2	3	NA	NA	
	3.11.4 Internal line between Kocin and Mirovka (CZ)	500	[250;310]	[-2100;-2500]	[200000;250000] MWh	[-220000;-260000]	[270;330]	[-1800;-2100]	[200000;240000] MWh	[-260000;-320000]	[1400;1700]	[-7900;-9500]	[210000;260000] MWh	[-340000;-580000]	[1200;1500]	[-7000;-	[210000;260000] MWh	[-260000;-320000]	2	3	Negligeable or less than 15km	Negligeable or less	

		all visions	Vision 1				Vision 2				Vision 3				Vision 4				all visions				
No	Definition	GTC / investment	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	B6 - Resilience	B7 - Flexibility	S1 - "environmental impact"	S2 - "social impact"	Comments
																8600]						than 15km	
	3.11.5 Internal line between Mirovka and Cebin (CZ)	100	[50;61]	[-510;-420]	[41000;50000] MWh	[-53000;-43000]	[54;66]	[-430;-350]	[40000;48000] MWh	[-63000;-52000]	[280;340]	[-1900;-1600]	[42000;52000] MWh	[-100000;-82000]	[250;310]	[-1700;-1400]	[42000;52000] MWh	[-64000;-52000]	2	2	NA	Negligeable or less than 15km	
3.12	PCI internal line in Germany between Lauchstädt and Meitingen to increase capacity at Eastern borders	3583	[100;130]	[-460;-380]	[930000;1100000] MWh	[-1300000;-1000000]	[94;110]	[32;39]	[900000;1100000] MWh	[-1300000;-1100000]	[410;500]	[-2200;-1800]	[2600000;3200000] MWh	[-1600000;-1300000]	[600;740]	[-3600;-3000]	[4100000;5000000] MWh	[-1900000;-1600000]	5	5	NA	NA	
3.13	PCI internal line in Germany between Halle/Saale and Schweinfurt to increase capacity in the North-South Corridor East	3583	[100;130]	[-460;-380]	[930000;1100000] MWh	[-1300000;-1000000]	[94;110]	[32;39]	[900000;1100000] MWh	[-1300000;-1100000]	[410;500]	[-2200;-1800]	[2600000;3200000] MWh	[-1600000;-1300000]	[600;740]	[-3600;-3000]	[4100000;5000000] MWh	[-1900000;-1600000]	5	5	15-50km	Negligeable or less than 15km	
3.14	Cluster Germany – Poland between Eisenhűttenstadt and Plewiska [currently known as the GerPol Power Bridge project] including the following PCIs:																						
	3.14.1 Interconnection between Eisenhűttenstadt (DE) and Plewiska (PL)	800	[37;45]	[400;490]	0	[-93000;-76000]	[36;44]	[-650;-530]	0	[-86000;-70000]	[53;65]	[-43;-36]	0	[-410000;-340000]	[52;64]	[47;57]	0	[-480000;-400000]	1	4	Negligeable or less than 15km	Negligeable or less than 15km	
	3.14.2 Internal line between Krajnik and Baczyna (PL)	400	[18;23]	[200;250]	0	[-46000;-38000]	[18;22]	[-330;-270]	0	[-43000;-35000]	[27;33]	[-22;-18]	0	[-210000;-170000]	[26;32]	[23;28]	0	[-240000;-200000]	1	3	NA	NA	
	3.14.3 Internal line between Mikułowa and Świebodzice (PL)	400	[18;23]	[200;250]	0	[-46000;-38000]	[18;22]	[-330;-270]	0	[-43000;-35000]	[27;33]	[-22;-18]	0	[-210000;-170000]	[26;32]	[23;28]	0	[-240000;-200000]	1	3	Negligeable or less than 15km	Negligeable or less than 15km	
3.15	Cluster Germany – Poland between Vierraden and Krajnik including the following PCIs:																						
	3.15.1 Interconnection between Vierraden (DE) and Krajnik (PL)	1500	[250;300]	[2000;2400]	0	[-60000;-49000]	[240;300]	[2800;3400]	0	[-49000;-40000]	[75;92]	[1300;1600]	0	[-140000;-110000]	[270;330]	[50;61]	0	[-190000;-150000]	2	3	15-50km	Negligeable or less than 15km	

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		all visions	Vision 1				Vision 2				Vision 3				Vision 4				all visions				
No	Definition	GTC / investment	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/ yr	RES	Losses MWh/yr	B6 - Resilience	B7 - Flexibility	S1 - "environmental impact"	S2 - "social impact"	Comments
	3.15.2 Coordinated installation and operation of phase shifting transformers on the interconnection lines between Krajnik (PL) – Vierraden (DE) and Mikulowa (PL) – Hagenwerder (DE)	1500	[250;300]	[2000;2400]	0	[-60000;-49000]	[240;300]	[2800;3400]	0	[-49000;-40000]	[75;92]	[1300;1600]	0	[-140000;-110000]	[270;330]	[50;61]	0	[-190000;-150000]	2	3	NA	NA	
3.16	Cluster Hungary - Slovakia between Gőnyű and Gabčikovo including the following PCIs:																						
	3.16.1 Interconnection between Gőnyű (HU) and Gabčikovo (SK)	1000	[15;18]	[220;270]	0	[-91000;-74000]	[12;15]	[270;330]	0	[-120000;-95000]	[17;20]	[35;43]	0	[2600;3200]	[35;43]	[-140;-110]	0	[-2400;-2000]	1	3	Negligeable or less than 15km	Negligeable or less than 15km	
	3.16.2 Internal line between Velký Ďur and Gabčikovo (SK)	150	[2;3]	[33;40]	0	[-13600;-11100]	[1,9;2,3]	[40;49]	0	[-17500;-14300]	[2,5;3]	[5;6]	0	[-400;500]	[5,5;6,5]	[-21;-17]	0	[-400;-300]	1	3	Negligeable or less than 15km	Negligeable or less than 15km	
	3.16.3 Extension of Győr substation (HU)	200	[3;3.6]	[43;53]	0	[-18000;-15000]	[2.5;3]	[53;65]	0	[-23000;-19000]	[3.4;4.1]	[7;8.5]	0	[520;630]	[7.1;8.7]	[-28;-23]	0	[-490;-400]	1	2	NA	NA	
3.17	PCI Hungary - Slovakia interconnection between Sajóvánka (HU) and Rimavská Sobota (SK)	800	[12;15]	[170;210]	0	[-72000;-59000]	[10;12]	[210;260]	0	[-93000;-76000]	[13;16]	[28;34]	0	[2100;2500]	[28;35]	[-110;-92]	0	[-2000;-1600]	0	0	NA	Negligeable or less than 15km	
3.18	Cluster Hungary - Slovakia between Kisvárda area and Velké Kapušany including the following PCIs:																						
	3.18.1 Interconnection between Kisvárda area (HU) and Velké Kapušany (SK)	550	[2;2.4]	[-40;-32]	0	[-20000;-16000]	[2.6;3.2]	[64;78]	0	[-33000;-27000]	[9.2;11]	[-12;-9.9]	0	[-43000;-35000]	[19;23]	[-68;-55]	0	[-18000;-15000]	1	3	Negligeable or less than 15km	Negligeable or less than 15km	
	3.18.2 Internal line between Lemešany and Velké Kapušany (SK)	50	[0,18;0,22]	[-3,5;-3]	0	[-1800;-1500]	[0,2;0,3]	[-7;-6]	0	[-3000;-2500]	[0,9;1]	[-1;-0,9]	0	[-4000;-3000]	[1,8;2]	[-6;-5]	0	[-1700;-1400]	1	3	Negligeable or less than 15km	Negligeable or less than 15km	
3.19	Cluster Italy - Montenegro between																						

		all visions	Vision 1				Vision 2				Vision 3				Vision 4				all visions				
No	Definition	GTC / investment	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/ yr	RES	Losses MWh/yr	B6 - Resilience	B7 - Flexibility	S1 - "environmental impact"	S2 - "social impact"	Comments
	Villanova and Lastva including the following PCIs:																						
	3.19.1 Interconnection between Villanova (IT) and Lastva (ME)	1000	[140;170]	[1400;1700]	[13000;15000] MWh	[-18000;-14000]	[110;130]	[1100;1300]	0	[-18000;-14000]	[290;360]	[-650;-530]	[330000;410000] MWh	[1800;2200]	[290;350]	[-1700;-1400]	[990000;1200000] MWh	[3600;4400]	1	3	Negligeable or less than 15km	Negligeable or less than 15km	
	3.19.2 Internal line between Fano and Teramo (IT)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	The investment is not assessed as it has been reconsidered taking into account the actual feasibility conditions according to the National Development Plan. Therefore at the moment no implementation activities are planned in the next years.
	3.19.3 Internal line between Foggia and Villanova (IT)	600	[180;210]	[-1500;-1200]	[2200000;2700000] MWh	[-79000;-65000]	[170;200]	[-1400;-1200]	[2100000;2500000] MWh	[-79000;-65000]	[220;270]	[-1700;-1400]	[2400000;3000000] MWh	[-63000;-52000]	[220;270]	[-1700;-1400]	[2500000;3000000] MWh	[-130000;-110000]	1	2	Negligeable or less than 15km	Negligeable or less than 15km	
3.20	Cluster Italy – Slovenia between West Udine and Okroglo including the following PCIs:																						
	3.20.1 Interconnection between West Udine (IT) and Okroglo (SI)	800	[23;28]	[220;270]	0	[-110000;-90000]	[49;60]	[-260;-210]	0	[-140000;-120000]	[15;18]	0	0	[-41000;-33000]	[18;23]	0	0	[-260000;-220000]	1	4	15-50km	Negligeable or less than 15km	
	3.20.2 Internal line between West Udine and Redipuglia (IT)	600	[18;21]	[170;200]	0	[-83000;-68000]	[37;45]	[-190;-160]	0	[-110000;-86000]	[11;14]	0	0	[-31000;-25000]	[14;17]	0	0	[-200000;-160000]	1	3	Negligeable or less than 15km	Negligeable or less than 15km	
3.21	PCI Italy – Slovenia interconnection between Salgareda (IT) and Divača -	800	[22;27]	[220;270]	0	[1800;2200]	[49;60]	[-230;-190]	0	[900;1100]	[15;18]	0	0	[3600;4400]	[19;24]	0	0	0	1	3	NA	NA	

		all visions	Vision 1				Vision 2				Vision 3				Vision 4				all visions				
No	Definition	GTC / investment	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	B6 - Resilience	B7 - Flexibility	S1 - "environmental impact"	S2 - "social impact"	Comments
	Bericevo region (SI)																						
3.22	Cluster Romania – Serbia between Resita and Pancevo including the following PCIs:																						
	3.22.1 Interconnection between Resita (RO) and Pancevo (RS)	350	[83;100]	[590;720]	[430;520] MW	[-45000;-37000]	[32;39]	[330;410]	[430;520] MW	[-78000;-64000]	[8.5;10]	[-180;-150]	[430;520] MW	[-100000;-85000]	[90;110]	[-160;-130]	[430;520] MW	[-160000;-130000]	2	4	NA	Negligeable or less than 15km	
	3.22.2 Internal line between Portile de Fier and Resita (RO)	287	[68;83]	[480;590]	[350;430] MW	[-37000;-31000]	[26;32]	[270;340]	[350;430] MW	[-64000;-52000]	[7;8.6]	[-150;-120]	[350;430] MW	[-85000;-70000]	[74;90]	[-130;-110]	[350;430] MW	[-130000;-110000]	2	3	15-50km	Negligeable or less than 15km	
	3.22.3 Internal line between Resita and Timisoara/Sacalaz (RO)	180	[43;52]	[300;370]	[220;270] MW	[-23000;-19000]	[16;20]	[170;210]	[220;270] MW	[-40000;-33000]	[4.4;5.4]	[-93;-76]	[220;270] MW	[-53000;-44000]	[46;56]	[-82;-67]	[220;270] MW	[-84000;-68000]	2	3	NA	Negligeable or less than 15km	
	3.22.4 Internal line between Arad and Timisoara/Sacalaz (RO)	180	[43;52]	[300;370]	[220;270] MW	[-23000;-19000]	[16;20]	[170;210]	[220;270] MW	[-40000;-33000]	[4.4;5.4]	[-93;-76]	[220;270] MW	[-53000;-44000]	[46;56]	[-82;-67]	[220;270] MW	[-84000;-68000]	2	3	NA	Negligeable or less than 15km	
4.1	PCI Denmark – Germany interconnection between Ishőj/Bjæverskov (DK) and Bentwisch/Gűstrow (DE) via offshore windparks Kriegers Flak (DK) and Baltic 2 (DE) [currently known as Kriegers Flak Combined Grid Solution]	400	[19;24]	[-130;-110]	[54000;66000] MWh	[-62000;-51000]	[7;8]	[-4;-3]	[9000;11000] MWh	[-62000;-50000]	[10;13]	[-390;-320]	[18000;22000] MWh	[4500;5500]	[36;44]	[-760;-620]	[18000;22000] MWh	[4500;5500]	3	3	15-50km	Negligeable or less than 15km	
4.2	Cluster Estonia – Latvia between Kilingi-Nõmme and Riga [currently known as 3rd interconnection] including the following PCIs:																						
	4.2.1 Interconnection between Kilingi-Nõmme (EE) and Riga CHP2 substation (LV)	500	[6.8;8.3]	[76;93]	[30000;37000] MWh	[44000;54000]	[9;11]	[6;7.3]	[30000;37000] MWh	[76000;93000]	[0.75;0.92]	[-8.3;-6.8]	[7500;9200] MWh	[-920;-750]	[6.8;8.3]	[-27;-22]	[9000;11000] MWh	[9000;11000]	4	4	more than 100km	Negligeable or less than 15km	
	4.2.2 Internal line between Harku and Sindi (EE)	250	[3.4;4.1]	[38;46]	[15000;18000] MWh	[22000;27000]	[4.5;5.5]	[3;3.7]	[15000;18000] MWh	[38000;46000]	[0.38;0.46]	[-4.1;-3.4]	[3800;4600] MWh	[-460;-380]	[3.4;4.1]	[-13;-11]	[4500;5500] MWh	[4500;5500]	3	3	15-50km	Negligeable or less	

		all visions	Vision 1				Vision 2				Vision 3				Vision 4				all visions				
No	Definition	GTC / investment	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/yr	RES	Losses MWh/yr	SEW Meuros /yr	CO2 kT/ yr	RES	Losses MWh/yr	B6 - Resilience	B7 - Flexibility	S1 - "environmental impact"	S2 - "social impact "	Comments
																						than 15km	
4.3	PCI Estonia / Latvia / Lithuania synchronous interconnection with the Continental European networks	600	[26;31]	[-340;-280]	0	0	[12;15]	[86;110]	0	0	[34;41]	[-2600;-2100]	0	0	[120;140]	[-2000;-1700]	[54000;66000] MWh	0	2	4	NA	NA	
4.4	Cluster Latvia - Sweden capacity increase [currently known as the NordBalt project] including the following PCIs:																						
	4.4.1 Internal line between Ventspils, Tume and Imanta (LV)	150	[3.5;4.2]	[-19;-16]	[3900;4700] MWh	[60000;73000]	[7.5;9.2]	[240;290]	[3900;4700] MWh	[68000;83000]	[2.1;2.6]	[-140;-110]	[23000;28000] MWh	[30000;37000]	[38;46]	[-300;-250]	[23000;28000] MWh	[75000;92000]	3	2	15-50km	Negligeable or less than 15km	
	4.4.2 Internal line between Ekhyddan and Nybro/Hemsjö (SE)	700	0	0	0	[-23000;-19000]	0	0	0	[61000;75000]	0	0	0	[83000;100000]	0	0	0	[11000;13000]	4	3	Negligeable or less than 15km	Negligeable or less than 15km	This PCI is not assessed on vision 1 and 2, low RES scenarios.
4.5	Cluster Lithuania – Poland between Alytus (LT) and Elk (PL) including the following PCIs:																						
	4.5.1 LT part of interconnection between Alytus (LT) and LT/PL border	400	[32;40]	[-230;-190]	[43000;53000] MWh	[130000;160000]	[42;51]	[600;730]	[7200;8800] MWh	[160000;190000]	[19;23]	[-1600;-1300]	[7200;8800] MWh	[-870000;-710000]	[130;160]	[-2000;-1600]	[7200;8800] MWh	[-880000;-720000]	4	5	15-50km	Negligeable or less than 15km	
	4.5.2 Internal line between Stanisławów and Olsztyn Mątki (PL)	500	[18;23]	[-180;-140]	[9000;11000] MWh	[95000;120000]	[16;20]	[150;180]	[9000;11000] MWh	[85000;100000]	[18;22]	[-960;-780]	[14000;17000] MWh	[-330000;-270000]	[76;92]	[-1100;-890]	[14000;17000] MWh	[-150000;-120000]	0	3	Negligeable or less than 15km	Negligeable or less than 15km	
	4.5.3 Internal line between Kozienice and Siedlce Ujrzanów (PL)	300	[11;14]	[-110;-87]	[5400;6600] MWh	[57000;70000]	[9.7;12]	[87;110]	[5400;6600] MWh	[51000;62000]	[11;13]	[-570;-470]	[8100;9900] MWh	[-200000;-160000]	[45;55]	[-650;-530]	[8100;9900] MWh	[-88000;-72000]	0	3	Negligeable or less than 15km	Negligeable or less than 15km	
	4.5.4 Internal line between Płock and Olsztyn Mątki (PL)	100	[3.7;4.5]	[-35;-29]	[1800;2200] MWh	[19000;23000]	[3.2;4]	[29;36]	[1800;2200] MWh	[17000;21000]	[3.6;4.4]	[-190;-160]	[2700;3300] MWh	[-67000;-55000]	[15;18]	[-220;-180]	[2700;3300] MWh	[-29000;-24000]	0	3	NA	NA	

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1.3 Storage projects

Complying with Regulation EC 347/2013, ENTSO-E proposed to PCIs storage promoters to assess their projects according to the CBA methodology.

Caveats

- This section displays the assessment of storage projects, when their promoters sent the input data to ENTSO-E. Eventually, some are indeed listed as PCIs; some are not. Conversely, when PCIs promoters have not sent any data to ENTSO-E, no assessment can be displayed. Hence, the following PCIs are not assessed:
  - Cluster of PCIs 1.11 (with 1.11.1 PCI hydro-pumped storage in North West Ireland and 1.11.3 PCI hydro-pumped (seawater) storage in Ireland - Glinsk);
  - PCI 2.19 hydro-pumped storage in Austria - Obervermuntwerk II, Vorarlberg province;
  - PCI 3.25 battery storage systems in Central South Italy;
  - PCI 3.26 hydro-pumped storage in Poland - Mloty.

  And conversely, 2 non-PCIs projects – Izis (battery in Hungary), Pfaffenboden (pump storage in Austria) – are assessed.
- The economic benefits of projects in the SEW focus on the “energy only” part of the total economic benefits. **The SEW must be completed with an appraisal of the “capacity” part of the benefits (i.e. the availability of net power generating capacity) and the “flexibility” part of the benefits (i.e. the capability of adapt quickly the power output to the system needs).** “Flexibility” issues relate to real time phenomena that the 60-minute quantum used in the TYNDP market studies and steady state load flows in networks studies fails to capture:
  - Expanding wide area market modelling with a resolution beneath one hour to address close to real time phenomena is challenging with respect to computations capabilities and would rather involve complementary tools
  - Moreover common definitions of such close to real time benefits among all stakholders must be first agreed upon.
- **The SEW presented in the TYNDP 2014 is thus a conservative assessment of the economic benefits**. This remark is valid both for transmission and storage projects, but is all the more important for storage projects that the investment costs are larger. **Profitability of storage projects can never be concluded upon with the present assessment**.
- The definition of technical resilience and flexibility (B6 and B7) for storage projects also only partially capture their benefits. Presently the application of assessment rules result in quite low numbers compared to intuitive expectations. They must be revised with the involvement of stakeholders for the TYNDP 2016.
- S1 and S2 indicators must be re-defined for storage and the final release of the TYNDP will bear for storage projects "NA" (instead of "less than 15 km"; the latter does indeed not reflect the environmental impact of storage projects).
-

Project index	Project description	GTC (MW)	S1	S2	b6 technical resilience	b7 flexibility	scenario	SoS (MWh/yr)	SEW (Meuros/yr)	RES avoided spillage (MWh/yr)	Losses variation (MWh/yr)	CO2 emissions variation (kT/yr)
108	Grid integration of 1000MW Hydro Pumped Storage Tarnita.	1000	NA	NA	3	3	Scenario Vision 1 - 2030	-	[9;12]	[35000;43000]	[-47000;-39000]	[400;490]
							Scenario Vision 2 - 2030	-	[4;5]	[9900;12000]	[-21000;-17000]	[250;310]
							Scenario Vision 3 - 2030	-	[3;4]	[19000;23000]	[-200000;-170000]	[-46;-37]
							Scenario Vision 4 - 2030	-	[94;120]	[660000;800000]	[51000;62000]	[-550;-450]
211	Muuga HPSPP is a 500 MW Hydro Pump-Storage Power plant that locates at Estonian North coast	500	NA	NA	2	2	Scenario Vision 1 - 2030	-	[1;2]	0	[8100;9900]	[27;33]
							Scenario Vision 2 - 2030	-	[4;5]	[36000;44000]	[18000;22000]	[60;73]
							Scenario Vision 3 - 2030	-	[2;3]	[18000;22000]	[55000;67000]	[14;17]
							Scenario Vision 4 - 2030	-	[17;20]	[45000;55000]	[68000;84000]	[-41;-34]
212	Installation of 5th 225MW unit in Kruonis pump storage power plant	225	NA	NA	2	2	Scenario Vision 1 - 2030	-	0	0	[4500;5500]	[8;9]
							Scenario Vision 2 - 2030	-	[3;4]	0	[3600;4400]	[21;26]
							Scenario Vision 3 - 2030	-	0	0	[14000;18000]	[9;11]
							Scenario Vision 4 - 2030	-	[8;9]	[18000;22000]	[18000;22000]	[-12;-9]
215	Li-ion battery based energy storage unit. Project promoter: Tisza Power Ltd.	225	NA	NA	0	1	Scenario Vision 1 - 2030	-	0	0	[-1600;2600]	[15;18]
							Scenario Vision 2 - 2030	-	0	0	[-1600;2600]	[13;16]
							Scenario Vision 3 - 2030	-	0	0	[-11000;12000]	0
							Scenario Vision 4 - 2030	-	[0;1]	0	[-8200;9200]	[-5;-4]
217	Pumped Storage Complex with two independent upper reservoirs: Agios Georgios & Pyrgos	590	NA	NA	2	3	Scenario Vision 1 - 2030	-	[1;2]	[34;41]	0	[49;60]
							Scenario Vision 2 - 2030	-	[3;4]	[6200;7600]	0	[62;75]
							Scenario Vision 3 - 2030	-	[3;4]	[1600;1900]	0	[17;20]
							Scenario Vision 4 - 2030	-	[10;13]	[21000;26000]	0	[-36;-29]
218	Hydro-pumped storage in Bulgaria - Yadenitsa	860	NA	NA	1	2	Scenario Vision 1 - 2030	-	[3;4]	[49;60]	0	[72;89]
							Scenario Vision 2 - 2030	-	[4;5]	[9000;11000]	0	[90;110]

Project index	Project description	GTC (MW)	S1	S2	b6 technical resilience	b7 flexibility	scenario	SoS (MWh/yr)	SEW (Meuros/yr)	RES avoided spillage (MWh/yr)	Losses variation (MWh/yr)	CO2 emissions variation (kT/yr)
							Scenario Vision 3 - 2030	-	[5;6]	[2300;2800]	0	[24;29]
							Scenario Vision 4 - 2030	-	[15;18]	[31000;38000]	0	[-52;-43]
221	Storage faciliy at Larne in Northern Ireland. Project consists of both storage and generation facilities.	268	NA	NA	2	2	Scenario Vision 1 - 2030	-	[0;10]	[27000;33000]	0	[-44;-36]
							Scenario Vision 2 - 2030	-	0	[14000;17000]	0	[-27;-22]
							Scenario Vision 3 - 2030	-	[0;10]	[90000;110000]	0	[-71;-58]
							Scenario Vision 4 - 2030	-	[0;10]	[81000;99000]	0	[-38;-31]
222[34]	Extension of the pump storage powerplant Kaunertal	900	NA	NA	2	3	Scenario Vision 1 - 2030	-	[48;58]	0	[-44000;-36000]	[-450;-370]
							Scenario Vision 2 - 2030	-	[47;57]	0	[-54000;-44000]	[-410;-340]
							Scenario Vision 3 - 2030	-	[81;99]	[1350;1650]	[-61000;-50000]	[-345;-280]
							Scenario Vision 4 - 2030	-	[79;97]	[12960;15480]]	[-58000;-48000]	[-240;-300]
223	capacity increase of hydro-pumped storage in Austria - Limberg III, Salzburg	480	NA	NA	2	3	Scenario Vision 1 - 2030	-	[0;1]	[73;90]	[-25000;-20000]	[29;36]
							Scenario Vision 2 - 2030	-	[0;1]	[130;160]	[-29000;-23000]	[52;63]
							Scenario Vision 3 - 2030	-	[1;2]	[1800;2200]	[-33000;-27000]	[7;8]
							Scenario Vision 4 - 2030	-	[3;4]	[9900;12000]	[-32000;-26000]	[7;8]
224	hydro-pumped storage in Austria	313	NA	NA	2	3	Scenario Vision 1 - 2030	-	[0;1]	[0;1]	[-14000;-12000]	[44;53]
							Scenario Vision 2 - 2030	-	[1;2]	[83;100]	[-19000;-15000]	[33;40]
							Scenario Vision 3 - 2030	-	[0;1]	[1100;1300]	[-21000;-17000]	[8;9]
							Scenario Vision 4 - 2030	-	[2;3]	[5900;7200]	[-20000;-16000]	[2;3]

[34] The assessment of the Storage 222 has been updated after submission of the report to ACER, to correct a misprint of its GTC and of the RES indicators for Visions 2 and 3.

Project index	Project description	GTC (MW)	S1	S2	b6 technical resilience	b7 flexibility	scenario	SoS (MWh/yr)	SEW (Meuros/yr)	RES avoided spillage (MWh/yr)	Losses variation (MWh/yr)	CO2 emissions variation (kT/yr)
226	hydro-pumped storage in Germany - Riedl	300	NA	NA	1	3	Scenario Vision 1 - 2030	-	[0;1]	[73;90]	[-6400;-5200]	[37;46]
							Scenario Vision 2 - 2030	-	[1;2]	[84;100]	[-7700;-6300]	[44;53]
							Scenario Vision 3 - 2030	-	[0;1]	[1100;1400]	[-8500;-6900]	[8;9]
							Scenario Vision 4 - 2030	-	[2;3]	[5500;6700]	[-8300;-6800]	[2;3]

1.4 Smart Grid PCIs

Smart grid PCIs are not assessed according to the Cost Benefit Analysis rules applied for the TYNDP 2014 and here only mentioned, complying with Article 3.6 of Reg. EU 347/2013.

10.1. North Atlantic Green Zone Project (Ireland, UK / Northern Ireland): Lower wind curtailment by implementing communication infrastructure, enhance grid control and establishing (cross-border) protocols for Demand Side Management
10.2. Green-Me (France, Italy): Enhance RES integration by implementing automation, control and monitoring systems in HV and HV/MV substations, advanced communicating with the renewable generators and storage in primary substations

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2 Appendix 2 - Governance of TYNDP

2.1 Legal requirements for TYNDP (EC 714/2009 and EU 347/2013)

2.1.1 Regulation EC 714/2009

The key requirements of the 3rd Package, especially Regulation EC 714/2009, that forms the legislative driver for the "2012 Ten Year Network Development Plan" suite of documents (the "TYNDP 2012 package") are under:

- **Art 8.3 (b) of Regulation**

ENTSO-E shall adopt a non-binding Community-wide 10 year network development plan, including a European generation adequacy outlook, every two years.

- **Art 8.4**

The European generation adequacy outlook shall cover the overall adequacy of the electricity system to supply current and projected demands for electricity for the next five-year period as well as for the period between five and 15 years from the date of the outlook. The European generation adequacy outlook shall build on national generation adequacy outlooks prepared by each individual transmission operator.

- **Art 8.10**

ENTSO-E shall adopt and publish a network development plan every two years.

The network development plan shall include the modelling of the integrated network, scenario development, a European generation adequacy outlook and an assessment of the resilience of the system.

The network development plan shall:

- Build on national investment plans, taking into account regional plans, and if appropriate Community aspects of network planning, including the guidelines for trans-European energy networks; it shall be subject to a cost benefit analysis established as set out in Article 11 of the regulation EU No 347/2013.
- Build on the reasonable needs of different system users and integrate long-term commitments from investors referred to in Article 8 (tendering procedures), article 13 (ISO) and article 22 (network development) of the Directive;
- Identify investment gaps, notably with respect to cross-border capacities. A review of barriers to the increase of cross-border capacities arising from different approval procedures or practices may be annexed to the network development plan.

2.1.2 Regulation EU 347/2013

- **Art 3.6**

Projects of common interest included on the Union list pursuant to paragraph 4 of this Article shall become an integral part of the relevant national 10-year network development plans under Article 22 of Directives 2009/72/EC and 2009/73/EC and other national infrastructure plans concerned, as appropriate. Those projects shall be conferred the highest possible priority within each of those plans.

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- **Art 11.1**

The European Network of Transmission System Operators (ENTSO) for Electricity shall publish and submit to Member States, the Commission and the Agency their respective methodologies, including on network and market modelling, for a harmonised energy system-wide cost-benefit analysis at Union level for projects of common interest falling under the categories set out in Annex II.1(a) to (d) and Annex II.2. Those methodologies shall be applied for the preparation of each subsequent 10-year network development plan developed by the ENTSO for Electricity or the ENTSO for Gas pursuant to Article 8 of Regulation (EC) No 714/2009 and Article 8 of Regulation (EC) No 715/2009. The methodologies shall be drawn up in line with the principles laid down in Annex V and be consistent with the rules and indicators set out in Annex IV. Prior to submitting their respective methodologies, the ENTSO for Electricity shall conduct an extensive consultation process involving at least the organisations representing all relevant stakeholders — and, if deemed appropriate, the stakeholders themselves — national regulatory authorities and other national authorities.

2.2 ENTSO-E organisation for TYNDP

The European Network of Transmission System Operators for Electricity (ENTSO-E) was established on a voluntary basis on 19 December 2008 and became operational on 1 July 2009, in anticipation of the entry in to force of the 3rd Package on 3 March 2011.

Today, 41 TSOs from 34 European countries are members of ENTSO-E. The working structure of the association consists of Working and Regional Groups, coordinated by three Committees (System Development, System Operations and Markets), supervised by a management Board and the Assembly of ENTSO-E, and supported by the Secretariat, the Legal and Regulatory Group, and Expert Groups.

The main purposes of ENTSO-E are:

- to pursue the co-operation of the European TSOs both on the pan-European and regional level; and
- to have an active and important role in the European rule setting process in compliance with EU legislation.

Country	Company	North Sea	Baltic Sea	CCE	CSE	CCS	CSW
Austria	Austrian Power Grid AG						
	Vorarlberger Übertragungsnetz GmbH						
Belgium	Elia System Operator SA						
Bosnia and Herzegovina	Nezavisni operator sustava u Bosni i Hercegovini						
Bulgaria	Electroenergien Sistemen Operator EAD						
Croatia	Croatian Transmission System Operator Ltd.						
Cyprus	Cyprus Transmission System Operator						
Czech Republic	ČEPS a.s.						
Denmark	Energinet.dk						
Estonia	Elering AS						
Finland	Fingrid OyJ						
France	Réseau de Transport d'Electricité						
FYR of Macedonia	Macedonian Transmission System Operator AD						

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Germany	50Hertz Transmission GmbH		■	■			
	Amprion GmbH	■				■	
	TransnetBW GmbH	■				■	
	TenneT TSO GmbH	■		■		■	
Greece	Independent Power Transmission Operator S.A.				■		
Hungary	MAVIR Magyar Villamosenergia-ipari Átviteli Rendszerirányító Zártkörűen Működő Részvénytársaság			■	■		
Iceland	Landsnet hf						
Ireland	EirGrid plc	■					
Italy	Terna - Rete Elettrica Nazionale SpA				■	■	
Latvia	AS Augstsprieguma tīkls		■				
Lithuania	Litgrid AB		■				
Luxembourg	Creos Luxembourg S.A.	■					
Montenegro	Crnogorski elektroprenosni sistem AD				■		
Netherlands	TenneT TSO B.V.	■					
Norway	Statnett SF	■	■				
Poland	PSE Operator S.A.		■	■			
Portugal	Rede Eléctrica Nacional, S.A.						■
Romania	C.N. Transelectrica S.A.			■	■		
Serbia	JP Elektromreža Srbije				■		
Slovak Republic	Slovenska elektrizacna prenosova sustava, a.s.			■			
Slovenia	ELES, d.o.o.			■	■	■	
Spain	Red Eléctrica de España: S.A.						■
Sweden	Svenska Kraftnät		■				
Switzerland	Swissgrid ag					■	
United Kingdom	National Grid Electricity Transmission plc	■					
	Scottish Hydro Electric Transmission plc	■					
	Scottish Power Transmission plc	■					
	System Operator for Northern Ireland Ltd	■					

Figure 2-1: ENTSO-E countries and member TSOs

For more information, please refer to www.ENTSO-E.eu.

3 Appendix 3 - Cost Benefit Analysis methodology

The Cost Benefits Analysis methodology used is embedded in the TYNDP 2014 report for reference, to facilitate the readers understanding of the TYNDP 2014 methodologies as being use for the assessment of projects.

Nevertheless, the CBA methodology was not being consulted in the frame of this present TYNDP 2014, but in a separate process..

More information on the CBA methodology can be accessed here: https://www.entsoe.eu/

ENTSO-E Guideline for Cost Benefit Analysis of Grid Development Projects

14 November 2013

Notice
This document reflects the work done by ENTSO-E in compliance with Regulation (EC) 347/2013.

This document takes into account the comments received by ENTSO-E during the public consultation of the "Guideline for Cost Benefit Analysis of Grid Development Projects – Update 12 June 2013". This consultation was organised between 03 July and 15 September 2013 in an open and transparent manner, in compliance with Article 11 of Regulation (EC) 347/2013. Furthermore; it includes the outcome of an extensive consultation process through bilateral meetings with stakeholder organization, continuous interactions with a Long Term Network Development Stakeholder Group, several public workshops and direct interactions with ACER, the European Commission and Member States held between January 2012 and September 2013.

This document is now called "ENTSO-E Guideline for Cost Benefit Analysis of Grid Development Projects" and is submitted to Member States, the European Commission and ACER for their reasoned opinion pursuant to Article 11 of Regulation (EC) 347/2013.

Contents

1 INTRODUCTION AND SCOPE

1.1 TRANSMISSION SYSTEM PLANNING

The move to a more diverse power generation portfolio due to the rapid development of renewable energy sources and the liberalisation of the European electricity market has resulted in more and more interdependent power flows across Europe, with large and correlated variations. Therefore, transmission system design must look beyond traditional (often national) TSO boundaries, and move towards regional and European solutions. Close co-operation of ENTSO-E member companies responsible for the future development of the European transmission system is required to achieve coherent and coordinated planning that is necessary for such solutions to materialize. The main objective of transmission system planning is to ensure the development of an adequate transmission system which, with respect to mid and long term time horizons:

- Enables safe system operation;
- Enables a high level of security of supply;
- Contributes to a sustainable energy supply;
- Facilitates grid access to all market participants;
- Contributes to internal market integration, facilitates competition, and harmonisation;
- Contributes to energy efficiency of the system.

In this process certain key rules have to be kept in mind, in particular:

- Requirements and general regulations of the liberalised European power and electricity market set by relevant EU legislation;
- EU policies and targets;
- National legislation and regulatory framework;
- Security of people and infrastructure;
- Environmental policies and constraints;
- Transparency in procedures applied;
- Economic efficiency.

The planning criteria to which transmission systems are designed are generally specified in transmission planning documents. Such criteria have been developed for application by individual TSOs taking into account the above mentioned factors, as well as specific conditions of the network to which they relate. Within the framework of the pan-European Ten Year Network Development Plan (TYNDP), ENTSO-E has developed common Guidelines for

Grid Development (Annex 3 of TYNDP 2012). Thus, suitable methodologies have been adopted for future development projects and common investment assessments have been developed.

Furthermore, the EU Regulation 347/2013 requests ENTSO-E to establish a "methodology, including on network and market modelling, for a harmonised energy system-wide cost-benefit analysis at Union-wide level for projects of common interest" (Art. 11).

This document constitutes an update of ENTSO-E's Guidelines for Grid Development, aiming at compliance with the requirements of the EU Regulation, and ensuring a common framework for multi-criteria cost benefit analysis for candidate projects of common interest (PCI) and other projects falling within the scope below (TYNDP projects).

1.2 SCOPE OF THE DOCUMENT

This document describes the common principles and procedures, including network and market modelling methodologies, to be used when performing combined multi-criteria and cost benefit analysis in view of elaborating Regional Investment Plans and the Community-wide Ten Year Network Development Plan (TYNDP), as ratified by EU Regulation 714/2009 of the 3rd Legislative Package. Following the EU Regulation on guidelines for trans-European energy infrastructure (347/2013), it will also serve as a basis for a harmonised assessment at Union Level for Projects of Common Interest (PCI).

Typically, three categories of development transmission projects can be distinguished:

- Those that only affect transfer capabilities between individual TSOs. These projects will be evaluated according to the criteria in this document.
- Those that affect both transfer capabilities between TSOs and the internal capability of one or more TSOs' network. These projects will meet the criteria of this document and of the affected TSOs' internal standards.
- Those that only affect an internal national network and do not influence interconnection capability. These do not fall within the scope of this code, and are developed according to the TSO's internal standard.

When planning the future power system, new transmission assets are one of a possible number of system solutions. Other possible solutions include storage, generation and/or demand side management. The scope of this methodology is planning future transmission. However the regulation also requires ENTSO-E to consider storage in the cost benefit methodology. The principles of taking storage into account in the methodology are therefore described in annex 6.

This CBA guideline sets out ENTSO-E's criteria for the assessment of costs and benefits of a transmission project, all stemming from European policies of market integration, security of supply and sustainability. It describes the approach both for identifying transmission projects and for measuring each of the cost and benefit indicators. In order to ensure a full assessment of all transmission benefits, some of the indicators are monetized (inner ring of Figure 1), while others are measured through physical units such as tons or kWh (outer ring of Figure 1).

This set of common European-wide indicators will form a complete and solid basis, both for project evaluation within the TYNDP, and coherent project portfolio development for the PCI selection process[35].

Figure 1: Scope of cost benefit analysis (source: THINK project)

1.3 CONTENT OF THE DOCUMENT

Transmission system development focuses on the long-term preparation and scheduling of reinforcements and extensions to the existing transmission grid. This document describes each phase of the development planning process as well as the planning criteria and methodology adopted by ENTSO-E.

The first phase of the planning process consists of the definition of scenarios, which represent a coherent, comprehensive and internally consistent description of a plausible future. The aim of scenario analysis is to depict uncertainties on future system developments on both the production and demand sides. In order to incorporate these uncertainties in the planning process, a number of planning cases are built, taking into account forecasted future demand level and location, dispatch and location of generating units, power exchange patterns, as well as planned transmission assets. This phase is detailed in Chapter 2.

[35] It should be noted that he TYNDP will not contain any ranking of projects. Indeed, as stated by the EU Regulation 347/2013 (art4.2.4), « each Group shall determine its assessment method on the basis of the aggregated contribution to the criteria […] this assessment shall lead to a ranking of projects for internal use of the Group. Neither the regional list nor the Union list shall contain any ranking, nor shall the ranking be used for any subsequent purpose »

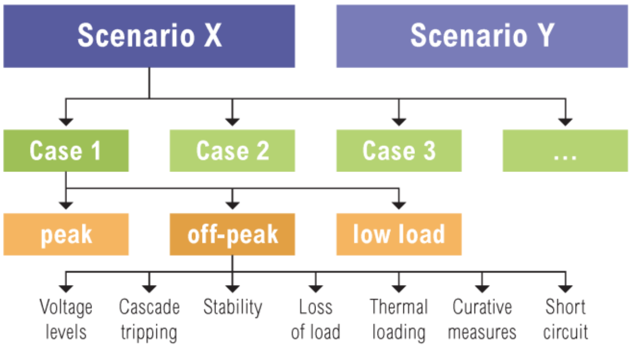


Figure 2: Scenarios and planning cases

Chapter 3 describes the multi-criteria cost-benefit analysis framework adopted for project assessment, complying with the EU Regulation 347/2013.

The cost benefit impact assessment criteria adopted in this document reflect each transmission project's added value for society. Hence, economic and social viability are displayed in terms of increased capacity for trading of energy and balancing services between bidding areas (market integration), sustainability (RES integration, CO2 variation) and security of supply (secure system operation). The indicators also reflect the effects of the project in terms of costs and environmental viability. They are calculated through an iteration of market and network studies. It should be noted that some benefits are partly or fully internalised within other benefits, such as CO2 avoidance and renewable energy integration via socio-economic welfare, while others remain completely non-monetised, such as security of supply[36].

"Network stress tests" are performed on each planning case and follow specific technical planning criteria developed by ENTSO-E on the basis of long term engineering practice (see Figures 2 and 3). The criteria cover both the kind of contingencies[37] chosen as "proxies" for hundreds of other events that could happen to the grid, and the adequacy criteria relevant for assessing overall behaviour of the transmission system. The behaviour of the grid when simulating the contingencies indicates the "health" and robustness of the system. A power system that fails one of these tests is considered "unhealthy" and steps must be taken so that the system will respond successfully under the tested conditions. Several planning cases are thus assessed in order to identify how robust the various reinforcements are. This process is developed in Chapter 4.

[36] Annex 4 provide an overview of issues around monetisation of security of supply and Values of Lost Load (VOLL) available in Europe
[37] A contingency is the loss of one or several elements of the power transmission system

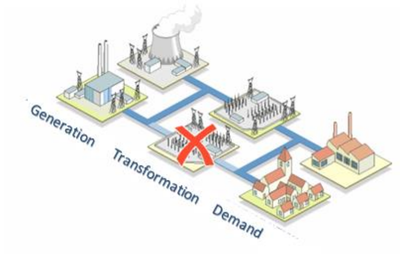


Figure 3: N-1 principle

The whole process is continually evolving, so it is the intention that this document will reviewed periodically in line with prudent planning practice and further editions of the TYNDP or upon request, as foreseen by Article 11 of the EU Regulation 347/2013.

2 SCENARIOS AND PLANNING CASES

Planning scenarios are defined to represent future developments of the energy system. The essence of scenario analysis is to come up with plausible pictures of the future. Scenarios are means to approach the uncertainties and the interaction between these uncertainties. Planning cases represent the scenarios.

Multi-criteria cost benefit analysis of candidate projects of European interest is based on ENTSO-E's System Outlook and Adequacy Forecast (SO&AF), which aim to provide stakeholders in the European electricity market with an overview of generation, demand and their adequacy in different scenarios for the future ENTSO-E power system, with a focus on the power balance, margins, energy indicators and the generation mix. The scenarios are elaborated after formally consulting Member States and the organisations representing all relevant stakeholders.

2.1 Scope of scenarios

Scenarios shall at least represent the Union's electricity system level and be adapted in more detail at a regional level. They shall reflect European Union and national legislations in force at the date of analysis.

2.2 Content of scenarios

Planning scenarios are a coherent, comprehensive and internally consistent description of a plausible future (in general composed of several **time horizons**) built on the imagined interaction of **economic key parameters** (including economic growth, fuel prices, CO2 prices, etc.). A planning scenario is characterized by a **generation portfolio** (power installation forecast, type of generation, etc.), a **demand forecast** (impact of efficiency measures, rate of growth, shape of demand curve, etc.), and **exchange patterns** with the systems outside the studied region. A scenario may be based on trends and/or local specificities (bottom-up scenarios) or energy policy targets and/or global optimisation (top-down scenarios).

Figure 4: Structure of the ENTSO-E Regions

As it can take more than 10 years to build new transmission infrastructure, the objective is to construct scenarios that look beyond the coming 10 years. However, when looking so far ahead, it becomes increasingly difficult to define what a 'plausible' scenario entails. Therefore, as illustrated in Figure 5, the objective of the scenarios is to construct contrasting future developments that differ enough from each other to capture a realistic range of possible future pathways that result in different challenges for the grid.

2.2.1 Time horizons.

The scenarios will be representative of at least two time horizons based on the following:

- Long-term horizon (typically 10 to 20 years). Long-term analyses will be systematically assessed and should be based on common ENTSO-E scenarios.
- Mid-term horizon (typically 5 to 10 years). Mid-term analyses should be based on a forecast for this time horizon. ENTSO-E's Regional groups and project

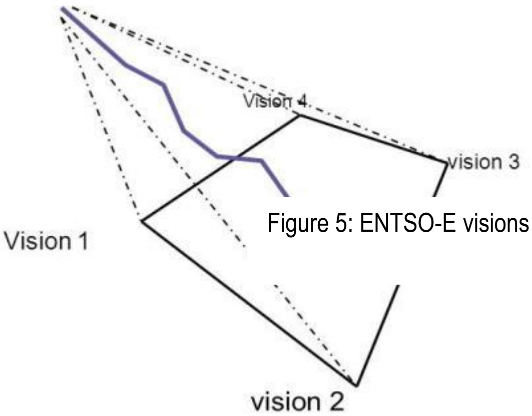


Figure 5: ENTSO-E visions

promoters will have to consider whether a new analysis has to be made or analysis from last TYNDP (i.e former long term analysis) can be re-used.

- Very long-term horizon (typically 30 to 40 years). Analysis or qualitative considerations could be based on the ENTSO-E 2050-reports.
- Horizons which are not covered by separate data sets will be described through interpolation techniques.

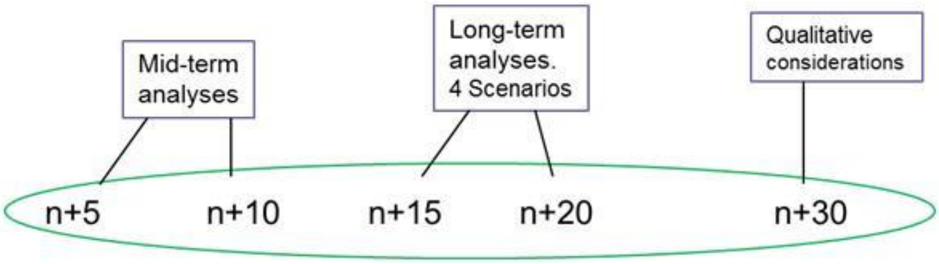


Figure 6: Time Horizons

As shown in Figure 6, the scenarios developed in a long-term perspective may be used as a bridge between mid-term horizon and very long term horizons (+30 or 40). The aim of the n+20 perspective should be that the pathway realized in the future falls within the range described by the scenarios with a high level of certainty.

2.2.2 Bottom-up and Top-down approach

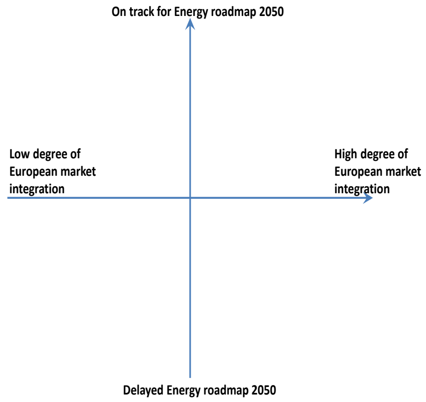
Until the preparation of the TYNDP 2010, the classic way of constructing generation and load scenarios within ENTSO-E (for the identification of grid investment needs) was mainly based on a bottom-up approach. Load and generation prognoses were collected from each TSO and mathematically summarized. Hence, the basis of the analysis was more or less national.

A new methodology was introduced by ENTSO-E in the TYNDP 2012. An EU 2020 scenario was constructed using a top-down approach, in which the load and generation evolution was constructed for all countries in a way that was compliant and coherent with the same macro-economic and political view of the future. For the EU 2020 scenario this meant that the forecasted load and generation assumptions had to be coherent with the EU 3x20 targets. Therefore, the load and RES generation in the EU 2020 scenario was derived from the NREAPs for EU countries. The top-down approach thus uses a common European basis.

Summarized, the scenarios used in cost-benefit analyses could be both top-down and bottom-up. One top-down scenario should be defined as the reference scenario. This scenario should be the one that best reflects the official European energy politics and goals. Thus, except when explicitly indicated, all key parameters listed below will be coherent at a European level with the economic background provided by the reference scenario.

'Zoom ENTSO-E: 2030 Visions for TYNDP 2014
For the coming TYNDP, the scenarios are developed around axes describing implementation of renewables and describing market integration.

The first axis (Y-axis) is related to the EU commitment to reducing greenhouse gas emissions to 80-95% below 1990 levels by 2050, according to the **Energy roadmap 2050**. The objective is not to question this commitment but to check the impact of a delay in the realization of this commitment on grid development needs by 2030. The two selected outcomes are viewed to be extreme enough to result in very different flow patterns on the grid. The first selected outcome is a state where Europe is **on track** to realize the set objective of energy decarbonisation by 2050. The second selected outcome is a state where Europe faces a **serious delay** in the realization of the energy 2020 goals and likely delays on the route to decarbonisation by 2050.



The second axis (X-axis) relates to the degree of **European market integration**. This can be done in a **strong European framework or a context of a high degree of European integration** in which national policies will be more effective, but not preventing Member States developing the options which are most appropriate to their circumstances, or in a **loose European framework or a context of a low degree of European integration** that lack a common European scenario for the future energy system that results in parallel national schemes. The strong European framework should also include a well-functioning and integrated electricity market, where competition ensures efficient dispatch at the lowest possible costs on a European level. On the other hand, a loose European framework results in less market integration and poor cross-border competition.

2.2.3 Reference and sensitivity scenarios

European wide reference scenarios analysis will serve as basis for the project assessment at regional level. There will always be a compromise between robustness (driver for analysing a large number of scenarios) and workload (driver for reducing the number of scenarios analysed). The number of scenarios that is used should be large enough for transmission planners to get a complete picture of the effects that a project may have under different possible future conditions. However, it is also important that the calculations under each scenario are performed in a sufficiently detailed and accurate manner. This is a trade off that must be made in each iteration of the TYNDP, but nonetheless we expect that, over time, experience and increasing computing power will allow the Regional Groups to continuously improve the robustness of the analysis without sacrificing quality.

The contents of the scenarios are updated in every iteration of the TYNDP process, so the values that are used for the calculations correspond with current future visions. The methodology does not specify or recommend how these values should be chosen.

Reference scenarios

Primary analyses should be based on common ENTSO-E scenarios, which are developed during the TYNDP process. ENTSO-E shall state the order in which the scenarios have to be analysed.

At least two scenarios should be analysed, for instance in order to take into account regional differences or to ensure robustness to different evolutions of the system.

Sensitivity scenarios

Secondary and optional analyses could be done on the other long-term scenarios. If these scenarios are not fully analysed, their effect on the different projects should be qualitatively considered. The other scenarios used for sensitivity analysis can be top-down scenarios or bottom-up.

2.3 TECHNICAL AND ECONOMIC KEY PARAMETERS

2.3.1 ECONOMIC KEY PARAMETERS

Fuel costs will be based on reference values established by international institutes such as the IEA, if possible at the study horizon taken into account. The economic key parameters include, but are not limited to, the following list:

Economic parameter	Level of coherence
Economic growth	European
Coal cost	
Oil cost	
Gas cost	
Lignite cost	
Nuclear cost	
CO2 cost	
Biomass cost	

2.3.2 TECHNICAL KEY PARAMETERS

Technical key parameters include, but are not limited to, the following list:

Technical parameter	Level of coherence
Efficiency rate	New plants : European

	Old plants : National
Availability	European
CO_2 emission rate	European
SO_2 emission rate	European
NO_x emission rate	European
Reserve power	European
Must-run units	European
Share of non dispatchable generation	European
Inter-temporal parameters of machines (such as minimum up- and down-time, ramping and start-up costs)	European

2.3.3 Scenarios for generation

Scenarios for generation will include generation capacities (assumptions on existing and new capacities as well as decommissioning), efficiency rate, flexiblity, must-run obligations and location (market) of at least the following generation types:

Generation capacity	**Level of coherence**
Biomass	European
Coal	
Gas	
Oil	
Lignite	
Nuclear	
Wind	
Photovoltaic	
Geothermal	
Concentrated solar	

Marine energies	
CHP	
Hydro	
Storage	
Capacity equipped for capturing carbon dioxide	

2.3.4 Scenarios for demand

Scenarios for demand will take into account at least the following items:

Demand factors	**Level of coherence**
Economic growth	European
Evolution of demand per sector	
Load management	
Sensitivity to temperature	
Fuel shift	
Evolution of climate-related extreme weather events	
Evolution of population	National

2.3.5 Exchange patterns[38]

Exchange patterns outside the modelled area will be taken into account in the following way:

Exhange pattern	**Level of coherence**
Fixed flows between the region and the outside countries	European

[38] All off shore wind farm generation is allocated to a Member state, and hence, flows between countries are not variable depending on allocations of off shore wind farms.

2.4 FROM SCENARIOS TO PLANNING CASES

The identification of the grid development needs related to a particular scenario is a complex resource and time-consuming process. The output of market analysis (generation dispatch, power and energy balances, periods of constraint) is used as an input for load flow analysis to choose the most representative planning cases (points in time) to be studied. The results are compared and the transmission adequacy is further measured allowing the iterative process of identifying the required reinforcement projects for supporting the bulk flow patterns identified in the market study.

Thus, this is not a unidirectional process, but a process with several feedback loops that could change assumptions (such as reserve, flexibility and sustainability of generation). Hence, it is important to keep the number of scenarios and cases that are fully calculated and therefore need to be quantified, limited, and to assess the impact of possible different pathways through sensitivity analysis.
The use of these scenarios for long-term grid development will lead to the identification of new flexible infrastructure development needs that are able to cope with a range of possible future energy challenges outlined in the scenarios.

2.4.1 SELECTION OF PLANNING CASES

Market-based assessment aims to perform an economic optimisation of the generation dispatch in each node of an interconnected system, for every hour of the year, using a simplified representation of the grid. This may be a DC load flow approximation with a small number of nodes and branches, or be as simple as one node per area and one branch across each boundary (all generation and load data are aggregated to this single node). This approach assumes that there are no internal constraints within a country/region, and limited grid transfer capability (GTC[39]) between them, generally without impedance description. Market studies have the advantage of clearly highlighting the structural rather than incidental bottlenecks. They take into account several constraints such as flexibility and availability of thermal units, hydro conditions, wind and solar profiles, load profile and uncertainties.

Network analysis, on the other hand, uses a simplified representation of generation and demand profiles, but includes a detailed representation of the grid. Planning cases for network analysis[40] are selected i.a. based on the following considerations:

- outputs from market studies, such as system dispatch, frequency and magnitude of constraints;
- regional considerations, such as wind and solar profiles or cold/heat spell;
- (when available) results of pan-European power transfer distribution factor (PTDF[41]) analysis.

Network studies have the advantage of taking into account internal congestion on the network (including loop flows). They contribute to assessing the GTC and its increase enabled by transmission projects. This output of the network studies can be retrofitted in market studies to assess the improvements brought by the enhanced grid.

[39] GTC is not only set by the transmission capacities of cross-border lines but also by the ratings of so-called “critical” domestic components (see 3.3)
[40] Ideally, all 8760 hours should be assessed in a load flow. However, no tool is able to perform this in an efficient way on a wide perimeter today.
[41] The PTDF analysis show the linear impact of a power transfer. It represents the relative change in the power flow on a particular line due to an injection and withdrawal of power.

Market studies and network studies are thus complementary. They are articulated in a two-step, iterative process in order to ensure consistency and efficiency (every concern being properly addressed with the appropriate modelling). An iteration of both methods is therefore recommended.

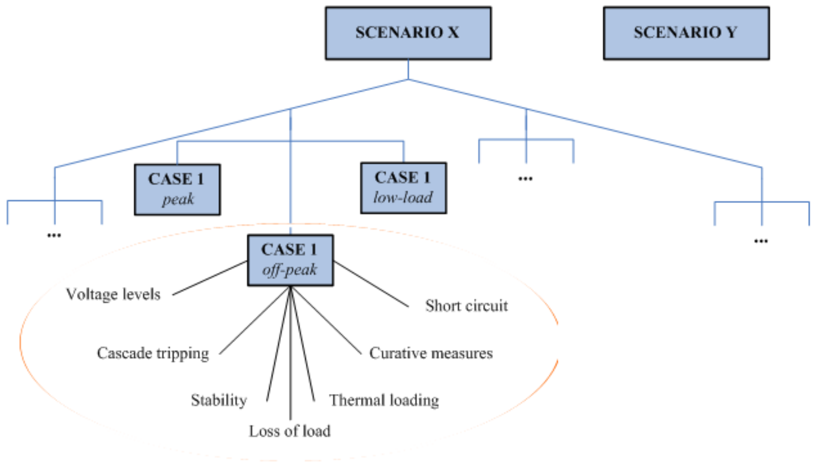


Figure 7: Scenarios and planning cases

2.4.2 Scope of planning cases

Each selected scenario is assessed by analysing the cases that represent it (see Fig. 7). These cases are defined by the TSOs involved in each study, taking into account regional and national particularities.

The following are the more important issues that have to be taken into account when building detailed cases for planning studies:

- Demand, generation and power exchange forecasts in different time horizons, and specific sets of network facilities are to be considered.
- Demand and generation fluctuate during the day and throughout the year.
- Weather is a factor that not only influences demand and (increasingly) generation, but also the technical capabilities of the transmission network.

2.4.3 Content of a planning case

A planning case represents a particular situation that may occur within the framework specified by a scenario, featuring:

- One specific point-in-time (e.g. winter / summer, peak hours / low demand conditions, year), with its corresponding demand and environmental conditions;
- A particular realisation of random phenomena, generally linked to climatic conditions (such as wind conditions, hydro inflows, temperature, etc.) or availability of plants (forced and planned);

- The corresponding dispatch (coming from a market simulator or a merit order) of all generating units (and international flows);
- Detailed location of generation and demand;
- Power exchange forecasts with regions neighbouring the studied region;
- Assumption on grid development.

When building representative planning cases, the following issues should be considered taking into account the results from market analysis:

- Estimated main power exchanges with external systems.
- Seasonal variation (e.g. winter/summer).
- Demand variation (e.g. peak/valley).
- Weather variation (e.g. wind, temperature, precipitations, sun, tides).

All transmission assets that are included in existing mid-term plans[42] will be dealt with in the corresponding case taking into account the forecasted commissioning and decommissioning dates.

The uncertainty in the commissioning date of some future assets could nevertheless require a conservative approach when building the planning cases, taking into account:

- State of permitting procedure (permits already obtained and permits that are pending).
- Existence of local objection to the construction of the infrastructure.
- Manufacturing and construction deadlines.

A case without one or some reinforcements foreseen, as well as cases including less conservative approaches, could be analysed.

To check the actual role of a grid element, and thus compare different strategies (e.g. refurbishment of the asset vs. dismantling and building a new asset), it may be considered as absent in the planning case.

2.5 MULTI-CASE ANALYSIS

System planning studies are often based on deterministic analysis, in which several representative planning cases are taken into account. Additionally, studies based on a probabilistic approach may be carried out. This approach aims to assess the likelihood of risks of grid operation throughout the year and to determine the uncertainties that characterise it. The objective is to cover many transmission system states throughout the year taking into account many cases. Thus it is possible to:

- Detect 'critical system states' that are not detected by other means.
- Estimate the probability of occurrence of each case that is assessed, facilitating the priority evaluation of the needed new assets.

[42] All new projects for which a final investment decision has been taken and that are due to be commissioned by the end of year n+5 (see Annex V, point 1a of EU Regulation 347/2013.)

The basic idea of probabilistic methods is based on creating multiple cases depending on the variation of certain variables (that are uncertain). Many uncertainties can lead to building multiple cases: demand, generation availability, renewable production, exchange patterns, availability of network components, etc. The general method consists of the following steps:

1. Definition of variables to be considered (for example: demand).
2. Definition of values to be considered for each of the variables and estimation of the probability of occurrence. In case a variable with many possible values is considered (for example: network unavailability), the amount of different possible combinations could justify the use of a random approach method.
3. Building the required planning cases. The number of cases depends on the number of variables and the number of different values for each of these.
4. Each case is analysed separately.
5. Assessment of the results. Depending on the amount of cases, a probabilistic approach could be needed to assess the results. A priority list of actions could result from this assessment.

If the variables used to build multiple cases are estimated in a pure probabilistic way, a statistical tool is needed for the assessment. In this case, besides helping to make a priority list of the actions needed in a development plan and identifying critical cases not known to be critical in advance, the probabilistic approach allows forecasting the Expected Energy Not Supplied (EENS) and Loss Of Load Expectation (LOLE) and congestion costs. The probabilistic assessment of other variables, like short-circuit current, could also be very useful for planning decisions.

3 Project assessment: combined cost benefit and multi-criteria analysis

The goal of project assessment is to characterise the impact of transmission projects, both in terms of added value for society (increase of capacity for trading of energy and balancing services between bidding areas, RES integration, increased security of supply, …) as well as in terms of costs.

ENTSO-E has the role to define a robust and consistent methodology. Thus ENTSO-E has defined this multi-criteria CBA, which compares the contribution of a project to the different indicators on a consistent basis. A robust assessment of transmission projects, especially in a meshed system, is a very complex matter. Additional lines give more transmission capacity to the market and hence allow an optimisation of the generation portfolio, which leads to an increase of Social-Economic Welfare[43] over Europe. Further benefits such as Security of Supply or improvements of the flexibility also have to be taken into due account. These technical aspects are hardly monetisable.

The multi-criteria approach shows the characteristics of a project and gives sufficient information to the decision makers. A fully monetised approach would entail one single monetary value, but because all results of the CBA are very dependent on the scenarios and horizons, this would lead to a perceived exactness that does not exist.

Furthermore this is the reason, why the costs are not compared with the monetised benefits, but are instead given as information.

The present chapter establishes an operative methodology for project identification and for characterisation of the impact of individual investments or “projects” (clusters of candidate investments[44]), falling into the scope described below.

The methodology will be used both for common project appraisals carried out for the TYNDP and for individual project appraisals undertaken by TSOs or project promoters.

3.1 Project identification

If transmission weaknesses are identified and the standards described in chapter 4 are not met, then reinforcement of the grid is planned. These measures can include, but are not limited to, the following:

- Reinforcement of overhead circuits to increase their capacity (e.g. increased distance to ground, replacement of circuits).
- Duplication of cables to increase rating.

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[43] Socio-economic welfare (SEW) is characterised by the ability of a power system to reduce congestion and thus provide an adequate GTC so that electricity markets can trade power in an economically efficient manner (see also p. 22)

[44] For more details about clustering of investments, see chapter 3.2.

- Replacement of network equipment or reinforcement of substations (e.g. based on short-circuit rating).
- Extension and construction of substations.
- Installation of reactive-power compensation equipment (e.g. capacitor banks).
- Addition of network equipment to control the active power flow (e.g. phase shifter, series compensation devices).
- Additional transformer capacities.
- Construction of new circuits (overhead and cable), DC or AC.

For the avoidance of doubt, the following varieties of solution to transmission weaknesses are not expected to be appraised by these Guidelines – i.e. they are out-of-scope:

- Relocation of Generation: the location of generation, as set out in planning cases, is a given[45]
- Assumption of new demand-side services and electricity storage devices: demand-side services and storage are not considered as solutions to transmission weaknesses, since existing and future volume of these means of flexibility are modelled within background scenarios consulted upon with stakeholders.
- Generator Inter-trips: in this context, the treatment of system-to-generator inter-trips is ambivalent. On the one hand, system-to-generator inter-trips are recommended to mitigate emergency situations like out-of-range contingencies[46]. On the other hand, system-to-generator inter-trips are not normally proposed by most TSOs as primary solutions to transmission weaknesses, and should not be regarded as a structural measure to cope with transmission weaknesses and cannot substitute any grid reinforcement.

3.2 CLUSTERING OF INVESTMENTS

A project is defined as a cluster of investment items that have to be realised in total to achieve a desired effect. Therefore, a project consists of one or a set of various investments. An investment should be included only if the project without this investment does not achieve the desired effect (complementary investments[47]).

The clustering of a group of investments (see illustration in Fig.8) is recommended by EC[48] when:

- They are located in the same area or along the same transport corridor;
- They achieve a common measurable goal;

[45] TSOs, while having a role in informing the market and public authorities about system weaknesses, cannot choose to relocate, decommission or build generation.
[46] ENTSO-E : Technical background and recommendations for defence plans in the Continental Europe synchronous area (https://www.entsoe.eu/resources/publications/system-operations/)
[47] Competitive projects should not be clustered.
[48] European Commission Guide to Cost-Benefit analysis of investment projects, July 2008., p. 20

- They belong to a general plan for that area or corridor;

Basically, a group of investments should be clustered if the investments (lines, substations …) comply with the conditions recommended by EC:

1. They achieve a common measurable goal. For instance, they are required to develop the grid transfer capability (GTC) increase associated with the project (see 3.3).
2. They are located in the same area of the project or along the same transmission corridor, and they belong to a general plan for that area or corridor.

The first condition derives from the goal of project assessment through the benefit categories set out in Chapter 3.3. In fact, the assessment of main benefits is directly related to the evaluation of the increase of GTC associated with the investment: security of supply, socio-economic welfare, RES integration and variation of CO2 emissions.

The influence of the investment on the increase of GTC must be substantial; otherwise it should not be a part of the cluster. Hence, if the influence is lower than 20%, the investment will not be considered as a part of the project.

The calculation is done in the following way (using the TOOT or PINT method as specified in section 3.6.4):

First of all, the calculation of the GTC increase provided by the main investment (1) (such as an interconnector) is made obtaining ΔGTC_1. Then, taking into account the scenarios which include investment 1, a new investment (2) (such as an internal transmission line) is added, obtaining ΔGTC_2. If $\Delta GTC_2 > 0.20\ \Delta GTC_1$, investment 2 can be clustered. Then, taking into account the scenarios with investment 1 included, a new investment (3) is added and ΔGTC_3 is obtained. If $\Delta GTC_3 > 0.20\ \Delta GTC_1$ investment 3 can be clustered. The process ends when all candidate investments have been analysed. The ΔGTC must be reported for each investment.

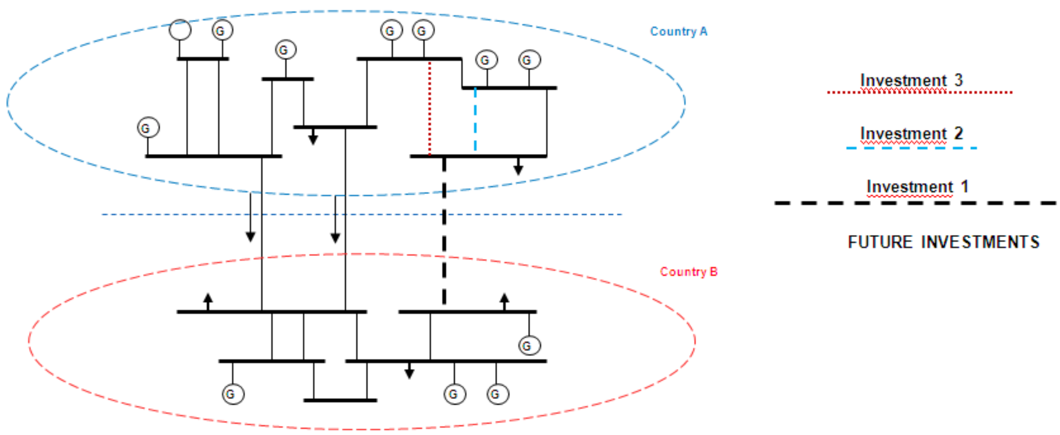

Figure 8: Clustering of investments

It is possible for a project to be limited to a single investment item only. An investment item can also contribute to two projects whose drivers are different, in which case its cost and benefits should only be counted in the main project.

Specific cases:

- Two or more investments can be a clustered, if they are in series and/or almost completely dependent on each other. Indeed two such investments should be clustered, if the GTC increase on commissioning either investment individually is less than 50% of the GTC increase on commissioning both investments together.
- An example of investments completely dependent on each other (one is a precondition of the other) would for instance be a reactive shunt device needed to avoid voltage upper limit violations due to the addition of the new investment or a converter station association with a HVDC cable.
- One cannot cluster investments which commission more than 5 years apart[49].

3.3 ASSESSMENT FRAMEWORK

The assessment framework is a combined cost-benefit and multi-criteria assessment[50], complying with Article 11 and Annexes IV and V of the EU Regulation 347/2013. The criteria set out in this document have thus been selected on the following basis:

- They enable an appreciation of project benefits in terms of EU network objectives:
    - ensure the development of a single European grid to permit the EU climate policy and sustainability objectives (RES, energy efficiency, CO2);
    - guarantee security of supply;
    - complete the internal energy market, especially through a contribution to increased socio-economic welfare ;
    - ensure technical resilience of the system,
- They provide a measurement of project costs and feasibility (especially environmental and social viability).
- The indicators used are as simple and robust as possible. This leads to simplified methodologies for some indicators.

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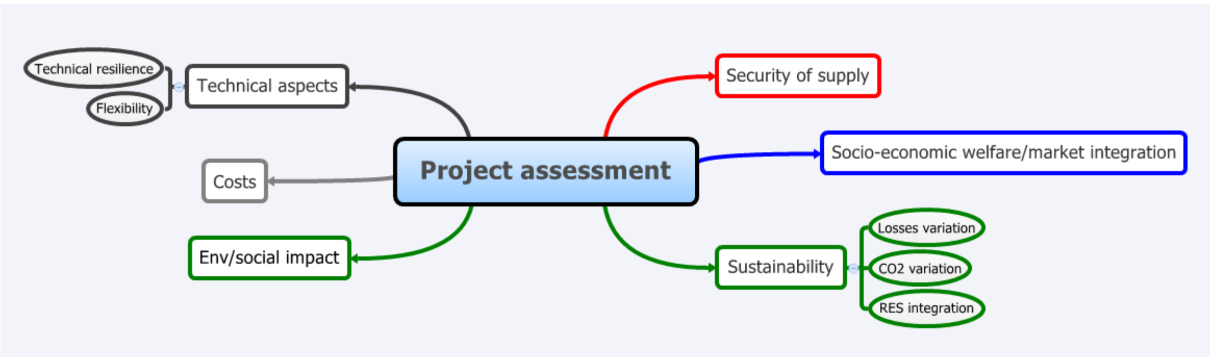

[49] In the case of integrated offshore grids of complicated timescales, this '5 year rule' may need to be relaxed, according to the circumstances of that cluster.
[50] More details on multi-criteria assessment versus cost-benefit analysis are provided in Annex 2.

Figure 9 shows the main categories that group the indicators used to assess the impact of projects.

Figure 9. Main categories of the project assessment methodology

Some projects will provide all the benefit categories, whereas other projects will only contribute significantly to one or two of them. Other benefits, such as benefits for competition[51], also exist. These are more difficult to model, and will not be explicitly taken into account.

The **Benefit Categories** are defined as follows:

B1. Improved security of supply[52] (SoS) is the ability of a power system to provide an adequate and secure supply of electricity under ordinary conditions[53].

B2. Socio-economic welfare (SEW)[54] or market integration is characterised by the ability of a power system to reduce congestion and thus provide an adequate GTC so that electricity markets can trade power in an economically efficient manner[55].

B3. RES integration: Support to RES integration is defined as the ability of the system to allow the connection of new RES plants and unlock existing and future "green" generation, while minimising curtailments[56].

B4. Variation in losses in the transmission grid is the characterisation of the evolution of thermal losses in the power system. It is an indicator of energy efficiency[57] and is correlated with SEW.

B5. Variation in CO_2 emissions is the characterisation of the evolution of CO_2 emissions in the power system. It is a consequence of B3 (unlock of generation with lower carbon content)[58].

B6. Technical resilience/system safety is the ability of the system to withstand increasingly extreme system conditions (exceptional contingencies)[59].

[51] Some definitions of a market benefit include an aspect of facilitating competition in the generation of electricity. These Guidelines are unable to well-define any metric solely relating to facilitation of competition. If transmission reinforcement has minimised congestion, that has facilitated competition in generation to the greatest extent possible. For further developments, see Annex 1.
[52] Adequacy measures the ability of a power system to supply demand in full, at the current state of network availability; the power system can be said to be in an N-0 state. Security measures the ability of a power system to meet demand in full and to continue to do so under all credible contingencies of single transmission faults; such a system is said to be N-1 secure.
[53] This category covers criteria 2b of Annex IV of the EU Regulation 347/2013, namely "secure system operation and interoperability".
[54] The reduction of congestions is an indicator of social and economic welfare assuming equitable distribution of benefits under the goal of the European Union to develop an integrated market (perfect market assumption).
[55] This category contributes to the criteria 'market integration" set out in Article 4, 2a and to criteria 6b of Annex V, namely "evolution of future generation costs".
[56] This category corresponds to the criterion 2a of Article 4, namely "sustainability", and covers criteria 2b of Annex IV.
[57] This category contributes to the criterion 6b of Annex V, namely "transmission losses over the technical lifecycle of the project".
[58] This category contributes to the criterion « sustainability » set out in Article 4, 2b and to criteria 6b of Annex V, namely " greenhouse gas emissions"
[59] This category contributes to the criterion "interoperability and secure system operation" set out in Article 4, 2b and to criteria 2d of Annex IV, as well as to criteria 6b of Annex V, namely "system resilience" (EU Regulation 347/2013).

B7. Flexibility is the ability of the proposed reinforcement to be adequate in different possible future development paths or scenarios, including trade of balancing services[60].

The **project costs[61]** are defined as follows:

C1. Total project expenditures are based on prices used within each TSO and rough estimates on project consistency (e.g. km of lines). Environmental costs can vary significantly between TSOs.

The **Project impact on society** is defined as follows:

S.1. Environmental impact characterises the project impact as assessed through preliminary studies, and aims at giving a measure of the environmental sensitivity associated with the project.

S.2. Social impact characterises the project impact on the (local) population that is affected by the project as assessed through preliminary studies, and aims at giving a measure of the social sensitivity associated with the project.

These two indicators refer to the remaining impacts, after potential mitigation measures defined when the projects definition becomes more precise.

The Grid Transfer Capability (GTC) is defined as follows:

The GTC reflects the ability of the grid to transport electricity across a boundary, i.e. from one bidding area (area within a country or a TSO) to another, or at any other relevant cross-section of the same transmission corridor having the effect of increasing this cross-border GTC. However, GTC variation may also be within a country, increasing security of supply or generation accommodation capacity over an internal boundary. In this way, as illustrated in Fig 10 below, three different categories of Grid Transfer Capability have been considered:

[60] This category contributes to the criterion "interoperability and secure system operation" set out in Article 4, 2b , and to and to criteria 2d of Annex IV, as well as to criteria 6e of Annex V, namely "operational flexibility" (idem note 26).
[61] Project costs, as all other monetised values, are pre-tax.

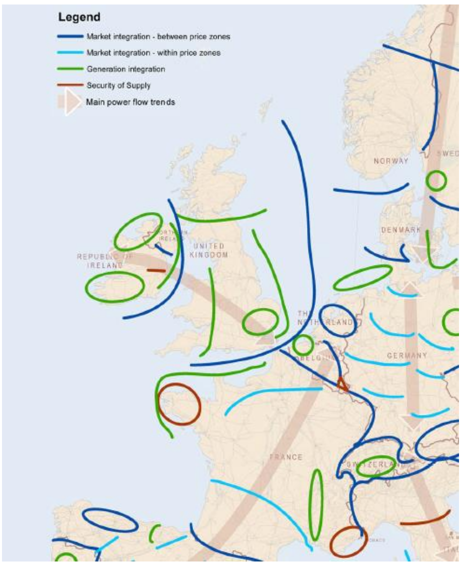

Figure 10: Illustration of GTC boundaries (source: TYNDP 2012)

Generation accommodation capability is the capability used for the accommodation of both new and existing generation. It allows the increase of generation in the exporting area and the decrease of generation in the importing area. The variations of generation follow the merit order established by the market until the marginal costs of border areas converge or the safety rules as explained in chapter 4 are no longer respected.

Security of supply capability is the capacity that is necessary for avoiding load shedding in a specific area when ordinary contingencies are simulated.

Exchange capability between bidding areas is the maximum GTC that can be designated to commercial exchanges.

The GTC depends on the considered state of consumption, generation and exchange, as well as the topology and availability of the grid, and accounts for safety rules described in chapter 4. The Grid Transfer Capability is oriented, which means that across a boundary there may be two different values. A boundary may be fixed (e.g. a border between states or bidding areas), or vary from one horizon or scenario to another. Grid projects provide an increase of GTC that can be expressed in MW.

The GTC value that is displayed and used as a basis for benefit calculation must be valid at least 30 % of the time. The variation of GTC over the year may be given as a range in MW (max, min).
A project with a GTC increase of at least 500 MW compared to the situation without commissioning of the project is deemed to have a significant cross-border impact.

Assessment summary table

The collated assessment findings are shown diagrammatically in the form of an assessment table, including the seven categories of benefits mentioned above, as well as two “impact” indicators (costs and socio-environmental impact). In addition, a “neutral” characterisation of the project is provided through an assessment of the GTC directional increase and the impact on the level of electricity interconnection relative to installed generation capacity[62] (see chapter 3.4 below). GTC is to be labelled as cross-border or internal for each project[63]. Internal or cross border GTCs are not additive.

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[62] The COM (2001) 775 establishes that “all Member States should achieve a level of electricity interconnection equivalent to at least 10% of their installed generation capacity”. This goal was confirmed at the European Council of March 2002 in Barcelona and chosen as an indicator the EU Regulation 347/2013 (annex IV 2.a) The interconnection ratio is obtained as the sum of importing GTCs/total installed generation capacity

[63] In the case of an investment that delivers both a cross-border GTC and an internal GTC, and then the rule is that the cross-border GTC takes precedence if it is greater than 0.5 of the internal GTC. For example, say an investment delivers an internal GTC of 500MW. If this investment also delivers 200MW of cross-border GTC, it is labelled 'internal GTC'; if it delivers 300MW of cross-border GTC, it is labelled 'cross-border GTC

Light green is systematically used for mild effects, green for benefits with medium effects and dark green for those having a strong impact. Thresholds for each category are given in euros when this is deemed possible, and in physical units or KPIs in the other cases. Indeed, some effects of the project, whilst relevant, cannot be monetised in a homogenous and reliable way throughout Europe. For transmission projects, some externalities (such as security of supply) are essential in decision-making, and it is important to place them appropriately. As illustrated in Fig. 11, the assessment table this is done through a quantitative assessment (when available) associated if needed with a colour code that will convey the required message to those studying it.

At least two scenarios will be used for cost benefit analysis (see chapter 2.2). Generally, the results of the reference scenario will be displayed in the table. The results of other scenarios and sensitivity analysis may populate the assessment summary table as intervals.

Internal Grid Transfer Capability Increase	Cross-border Grid Transfer Capability Increase	Contribution to 10% Intercon-nection	Social and Economic Welfare [€]	Security of Supply [MWh]	RES Integration [MWh]	CO_2 emissions variation [kt]	Losses variation [€]	Technical Resilience (++/--)	Flexibility (++/--)	Costs [€]	Environmental Impact	Social Impact
MW Generation and/or MW Demand	MW A to B and/or MW B to A	%									Km	Km

Figure 11. Example of assessment summary table

3.4 Grid Transfer Capability calculation

The identification of exchange limits (GTC) among bidding areas is obtained starting from stressed network situations that are suitable for highlighting the contributions of the reinforcement. A common grid model is used to assess the future grid transfer capability and behaviour with the planned projects, and the resilience in stressed grid situations, taking into account the security criteria described in chapter 4. The delta GTC value (allowed by the reinforcement) takes into account congestions on the grid (observed in grid studies), both inside and between bidding areas. It represents the GTC variation obtained by the whole project (including the clustered internal reinforcement if needed; see 3.2).

For those countries that have not reached the minimum interconnection ratio of 10%, each project must report the contribution to reach this minimum threshold.

3.5 Cost and environmental liability assessment

C.1. Total project expenditure

For each project, costs and uncertainty ranges have to be estimated. The following items should be taken into account:

- Expected cost for materials and assembly costs (such as masts/ basement/ wires/ cables/ substations/ protection and control systems);

- Expected costs for temporary solutions which are necessary to realise a project (e.g. a new overhead line has to be built in an existing route, and a temporary circuit has to be installed during the construction period);
- Expected environmental and consenting costs (such as environmental costs avoided, mitigated or compensated under existing legal provisions[64], cost of planning procedures, and dismantling costs at the end of the life time);
- Expected costs for devices that have to be replaced within the given period (regard of life-cycles) ;
- Dismantling costs at the end of life of the equipment.
- Maintenance costs and costs of the technical life cycle.

For transmission projects, time horizon is generally shorter than the technical life of the assets. Transmission assets have a technical lifetime up to 80 years, but uncertainty regarding the evolution of generation and consumption at such horizons is so large that no meaningful cost-benefit analysis can be performed. An appropriate residual value will therefore be included in the end year, using the standard economic depreciation formula used by each TSO or project promoter.

As far as environmental costs are concerned, only the costs of measures taken to mitigate the impacts are considered here. Some impacts may remain after these measures, which are then included in the indicators S1 and S2 that are discussed hereunder. This split ensures that all measurable costs are taken into account, and that there is no double-accounting between these indicators.

Indicative colours are assigned as follows:

Light green: total expenditures higher than 1 000 M€

Green: total expenditures between 300 M€ and 1 000 M€

Dark green: total expenditures lower than 300 M€

S.1. Environmental impact

Environmental impact characterises the local impact of the project on nature and biodiversity as assessed through preliminary studies. It is expressed in terms of the number of kilometres an overhead line or underground/submarine cable that (may) run through environmentally 'sensitive' (as defined in Annex 7) areas. This indicator only takes into account the residual impact or a project, i.e. the portion of impact that is not fully accounted for under C.1. The assessment method is described in Annex 7.

S.2 Social impact

[64] These costs vary from one TSO to another because of different legal provisions. They may include mitigation costs for avian collisions of overhead lines, landscape integration of power stations or impact on water and soils for cables, compensation costs for land use or visual impact etc…

Social impact characterises the project impact on the (local) population, as assessed through preliminary studies. It is expressed in terms of the number of kilometres an overhead line or underground/submarine cable that (may) run through socially 'sensitive' (as defined in Annex 7) areas. This indicator only takes into account the residual impact or a project, i.e. the portion of impact that is not fully accounted for under C.1. The assessment method is described in Annex 7.

3.6 BOUNDARY CONDITIONS AND MAIN PARAMETERS OF BENEFIT ASSESSMENT

3.6.1 GEOGRAPHICAL SCOPE

The rationale behind system modelling is to use very detailed information within the studied area, and a decreasing level of detail when deviating from the studied area. The geographical scope of the analysis is an ENTSO-E Region at minimum, including its closest neighbours. In any case, the study area shall cover all Member States and third countries on whose territory the project shall be built, all directly neighbouring Member States and all other Member States significantly impacted by the project[65]. Finally, in order to take into account the interaction of the pan-European modelled system, exchange conditions will be fixed using hourly steps, based on a global market simulation[66].

Project appraisal is based hence on analyses of the global (European) increase of welfare[67]. This means that the goal is to bring up the projects which are the best for the European power system.

3.6.2 TIME FRAME

The results of cost benefit analysis depend on the chosen period of study. The period of analysis starts with the commissioning date and extends to a time frame covering the study horizons. It is generally recommended to study two horizons, one midterm and one long term (see chapter 2). To evaluate projects on a common basis, benefits should be aggregated across years as follows:

- For years from year of commission (start of benefits) to midterm (if any), extend midterm benefits backwards.
- For years between midterm and long term, linearly interpolate benefits between the midterm and long term values.
- For years beyond long term horizon (if any), maintain benefits at long term value.

All costs and benefits are discounted to the present, and expressed in the price base of that year.

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[65] Annex V, §10 Regulation (EU) 347/2013

[66] Within ENTSO-E, this global simulation would be based on a pan-European market data base.

[67] Some benefits (socio-economic welfare, CO_2…) may also be disaggregated on a smaller geographical scale, like a member state or a TSO area. This is mainly useful in the perspective of cost allocation, and should be calculated on a case by case basis, taking into account the larger variability of results across scenarios when calculating benefits related to smaller areas. In any cost allocation, due regard should be paid to compensation moneys paid under ITC (which is article 13 of Regulation 714 (see also Annex 1 for caveats on Market Power and cost allocation).

3.6.3 DISCOUNT RATE

The purpose of using a discount rate is to convert future monetary benefits and costs into their present value, so that they can be meaningfully used for comparison and evaluation purposes. The discount rate reflects the time value of money as well as the risk linked to future costs and benefits.
The discount rate can be calculated as a real or a nominal rate. However, this choice must be consistent with the valuation of costs and benefits: real prices implies real rates, nominal prices imply nominal rate. Real prices must take into account specific deviation from inflation for costs and benefits.
Both costs and benefits have to be discounted to the present.

To fix the social discount rate, one has to consider:

- A lower bound (the return of the planned investment should yield at least an opportunity cost higher than):
  - The risk free rate (which can be a mean of governmental bond of countries financing the project, or the cost of debt of project promoters if available), and/or
  - Gross Domestic Product (GDP) growth rate[68] (which can be a mean of expected future growth rates in the countries financing the project).
- A higher bound: the return of the planned investment should yield an opportunity cost below the highest cost of debt observed in the countries financing the project.

Moreover, for comparison purposes and simplicity, each Regional Group should choose a unique social discount rate for the projects in the region[69]. A single discount rate must be used for each project. The discount rate for interconnectors will therefore generally be different from the regulatory rate of return of transmission assets for each TSO.
No discount rate will be applied for non-monetary benefits: these cases will use values obtained for the reference long term horizon. Values for the midterm horizon will be used for robustness analysis.

3.6.4 BENEFIT ANALYSIS

Two possible ways for project evaluation can be adopted:

- the **Take Out One at the Time (TOOT)** methodology, that consists of excluding investment items (line, substation, PST or other transmission network device) or complete projects from the forecasted network structure on a one-by-one basis and to evaluate the load flows over the lines with and without the examined network reinforcement (a new line, a new substation, a new PST, ..);
- the **Put IN one at the Time (PINT)** methodology, that considers each new network investment/project (line, substation, PST or other transmission network device) on the given network structure one-by-one and evaluates the load flows over the lines with and without the examined network reinforcement.

The TOOT method provides an estimation of benefits for each project, as if it was the last to be commissioned. In fact, the TOOT method evaluates each new development investment/project into the whole forecasted network. The advantage of this analysis is that it immediately appreciates every benefit brought by each investment item,

[68] As set in the top-down Reference scenarios.
[69] Ranking of project will indeed only be carried out at a Regional level, for internal purposes (Regulation (EU) 347/2013 Art. 4.2.4 op.cit).

without considering the order of investments. All benefits are considered in a precautionary way, in fact each evaluated project is considered into an “already developed” environment, in which are present all programmed development projects and are reported conditions in which the new investment shall operate. Hence, this method allows analyses and evaluations at TYNDP level, considering the whole TYNDP vision and every network evolution.

However, it should be noted that strictly competitive projects assessment, i.e. projects delivering the same service to the grid, may need several steps :

- TOOT approach : if the benefit is significant, then all the projects are useful.
- But poor benefits in this first TOOT assessment does not necessarily mean that none of the projects should be undertaken. Indeed one should take the reference network without ALL competing projects, and adding them one by one. This will allow to define the right level of development to reach in this part of the grid.

This conclusion will apply to ANY of the competitive projects. The assessment will not conclude which one should be preferred, but how much of this kind of project is useful.

The TOOT methodology is recommended for cost-benefit analysis of a transmission plan such as the TYNDP, whereas the PINT methodology is recommended for individual project assessments outside the TYNDP process. The TYNDP network is then considered as the reference grid.

For all the analyses third-party projects are to be assessed in the same way as projects between TSOs.

3.7 METHODOLOGY FOR EACH BENEFIT INDICATOR

According to Regulation EC 347/2013, the present CBA Guideline establishes an operative network and market methodology for project identification and for characterisation of the impact of projects. The methodology includes all the elements described both in Article 11 and the Annexes IV and V of the above-mentioned Regulation.

3.7.1 B1. SECURITY OF SUPPLY

Introduction

Security of Supply is the ability of a power system to provide an adequate and secure supply of electricity in ordinary conditions, in a specific area. The assessment must be performed for a geographically delineated area (see Fig. 12) with an annual electricity demand of at least 3 TWh[70]. The boundary of the area may consist of the nodes of a quasi-radial sub-system or semi-isolated area (e.g. with a single 400 kV injection). Two examples are provided below (project indicated in orange[71]).

[70] This value is seen as a significant threshold for electricity consumption for smart grids in the EU Regulation 347/2013 (Annex IV, 1e)

[71] One should take notice that although the definition of a 'delimited geographical area' that is made subject to Security of Supply calculation may be considered an arbitrary exercise, the indicator score (see below) is determined proportionally to the size of the area (i.e. its annual electricity demand). In order to be scored the same, a larger geographic area thus requires a larger absolute improvement in Security of Supply compared to a smaller area.

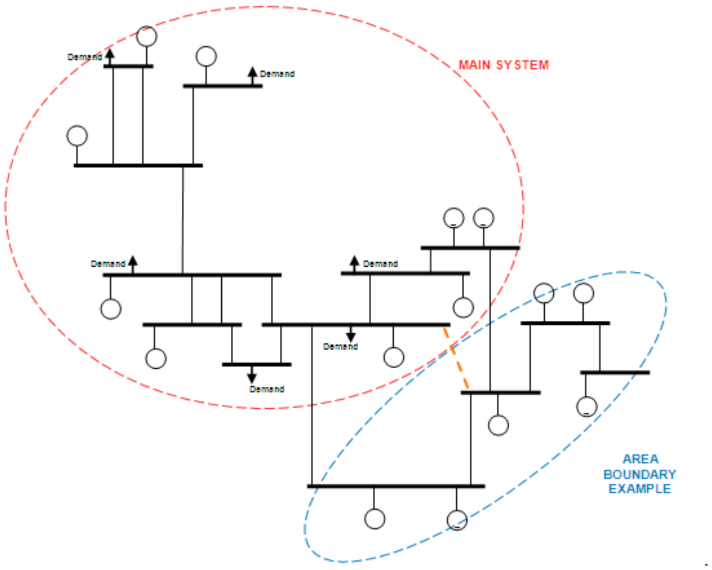

Figure 12: Illustration of delimited area for security of supply calculations

The criterion measures the improvement to security of supply (generation or network adequacy) brought about by a transmission project. It is calculated as the difference between the cases with and without the project, with the defined indicator being either Expected Energy Not Supplied (EENS) or the Loss of Load Expectancy (LOLE).

Methodology

Depending on the issue at stake, market or network models are used for the assessment calculations. When dealing with generation adequacy issues the market models are used to determine the contribution of a project to deliver power that was generated somewhere in the system to this specific area. Network models, on the other hand, are preferred for network adequacy issues, i.e. to determine the contribution of a project to network robustness (risk of network failures leading to lost load). The benefit evaluation methodology from Section 3.6.4 is used in both cases.

For network studies, performance assessment is based on the technical criteria defined in Chapter 4. Analysis of representative cases without the project may, for example, identify risk of loss of load for ordinary contingencies. The EENS indicator will then show whether the inclusion of the project triggers a significant improvement of security of supply (see scale below).

The market-based analysis relies on the same system tests, but with a simplified network representation. This assessment examines the likelihood of risks to the security of supply across an entire year in a wide range of stochastic scenarios regarding load and generation, and therefore may determine the probability of a critical system state. As such, this analysis will yield an Expected Energy Not Supplied (EENS) measure in MWh/year or a Loss of Load Expectancy (LOLE) in hours/year. Similar to the network based analysis, the inclusion of the project will identify the contribution that the project makes to either the EENS or LOLE indicators.

Both kinds of indicators may be used for the project assessment, depending on the issues at stake in the area. However, the method that is used must be reported (see table below).

Monetisation

In theory, the unreliability cost could be obtained using the EENS index and the unit interruption cost (i.e. Value of Lost Load; VOLL). In reality, however, the monetisation of system unreliability and security of supply using VOLL cannot be performed uniformly on a Union-wide basis. There is a large variation in the value that different customers place on their supply[72] and this variation can differ greatly across the Union, as it depends largely on regional and sectorial composition and the role of the electricity in the economy[73]. Additional factors such as time, duration and number of interruptions over a period also influence VOLL. The CEER has set out European guidelines[74] in the domain of nationwide studies on estimation of costs due to electricity interruptions and voltage disturbances, recommending that "*National Regulatory Authorities should perform nationwide cost-estimation studies regarding electricity interruptions and voltage disturbances*[75]*".*

Given the high variability and complexity of the VOLL, calculating project benefit using market-based assessment will only provide indicative results which cannot be monetised on a Union-wide basis. VOLL will therefore not be used as a basis for comparative EENS or LOLE calculations.

Parameter	Source of calculation[76]	Basic unit of measure	Monetary measure (externality or market-based?)	Level of coherence
Loss Of Load Expectancy (LOLE)	Market studies (Generation adequacy)	Hours or MWh	Value of Lost Load	National
Expected Energy Not Supplied (ENS)	Network studies (network adequacy/secure system operation)	MWh	Value of Lost Load	National

Indicative colours are assigned as follows:

- Light green: the project has no measurable impact on security of supply;
- Green: the project increases the security of supply for an area of annual energy demand greater than 3 TWh by more than 0.001% of annual consumption[77];
- Dark green: the project increases the security of supply for an area of annual energy demand greater than 3 TWh by more than 0.01% of annual consumption[78].

[72] The University of Bath, in the framework of the European project CASES ("WP5 Report (1) on National and EU level estimates of energy supply externalities") states that "it is safe to conclude that VOLL figures [in 2030] lay in a range of 4-40 $/kWh for developed countries" (estimation based on a literature review).
[73] Cf. CIGRE study, 2001.
[74] Guidelines of Good Practice on Estimation of Costs due to Electricity Interruptions and Voltage Disturbances, CEER, December 2010
[75] However, this has not been done everywhere. Hence, there is no full set of available and comparable national VOLLs across Europe.
[76] Cf Annex IV, 2c.
[77] For an area with an annual consumption of 3 TWh this would equal 30 MWh/yr (6 minutes of average demand).
[78] For an area with an annual consumption of 3 TWh this would equal 300 MWh/yr (60 minutes of average demand).

3.7.2 B2. SOCIO-ECONOMIC WELFARE

Introduction

A project that increases GTC between two bidding areas allows generators in the lower-priced area to export power to the higher-priced (import) area, as shown below in Fig 13. The new transmission capacity reduces the total cost of electricity supply. Therefore, a transmission project can increase socio- economic welfare.

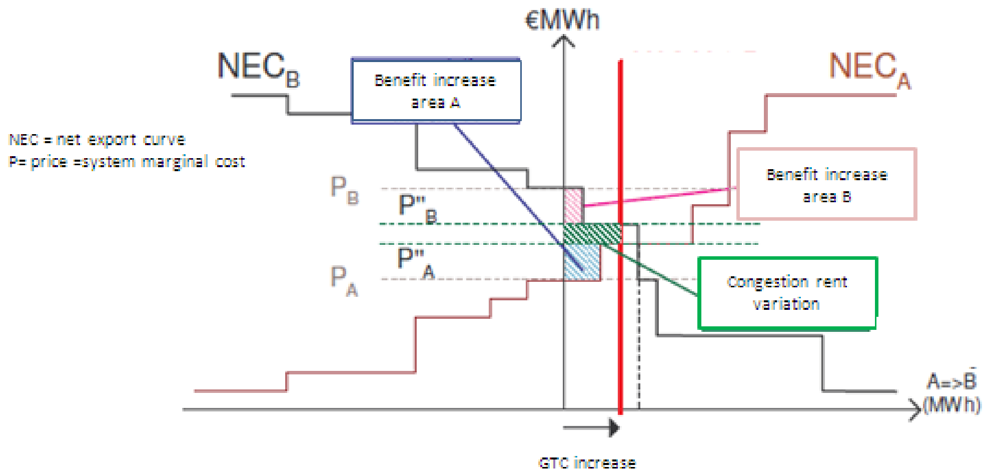

Figure 13: Illustration of benefits due to GTC increase between two bidding areas

In this chapter we consider a perfect market with the following assumptions:

- Equal access to information by market participants
- No barriers to enter or exit
- No market power

In general, two different approaches can be used for calculating the increased benefit from socio- economic welfare:

- The generation cost approach, which compares the generation costs with and without the project for the different bidding areas.
- The total surplus approach, which compares the producer and consumer surpluses for both bidding areas, as well as the congestion rent between them, with and without the project[79].

If demand is considered inelastic to price, both methods will yield the same result. If demand is considered as elastic, modelling becomes more complex. The choice of assumptions on demand elasticity and methodology of calculation of benefit from socio-economic welfare is left to ENTSO-E's regional groups.

[79] More details about how to calculate surplus are provided in Annex 3

Most of the European countries are presently considered to have price inelastic demand. However, there are various developments that appear to cause a more elastic demand-side.

Both the development of smart grids and smart metering, as well as a growing flexibility needs from the changing production technologies (more renewables, less thermal and nuclear) are drivers towards a more price-elastic demand.

There are two ways of taking into account greater flexibility of demand when assessing socio-economic welfare, the choice of the method being decided within ENSTO-E's regional groups:

1) The demand that will have to be supplied by generation is estimated through various scenarios, reshaping the demand curve (in comparison with present curves) to model the future introduction of smart grids, electric vehicles...etc. The demand response will not be exactly demand elasticity at each hour, but a movement of energy consumption from hours of (potential) high prices to hours of (potential) low prices. The generation costs to supply a known demand are minimised through the generation cost approach. This assumption simplifies the complexity of the models, in that demand can be treated as a time series of loads that 'has to be met', while at the same time considering different scenarios of demand side management.
2) Introduce hypotheses on level of price elasticity of demand. Again, two methods are possible:
    a. Using the generation cost approach, price elasticity could be taken into account via the modelling of curtailment as generators. The "willingness to pay" would then for instance be established at very high levels for domestic consumers, and at lower levels for a part of industrial demand.
    b. Using the total surplus method, the modelling of demand flexibility would need to be based on a quantification of the link between price and demand for each hour, allowing a correct representation of demand response in each area.

Generation cost approach[80]

The socio-economic welfare benefit is calculated from the reduction in total generation costs associated with the GTC variation created by the project. There are three aspects to this benefit.

a. By reducing network bottlenecks that restrict the access of generation to the full European market, a project can reduce costs of generation restrictions, both within and between bidding areas.

b. A project can contribute to reduced costs by providing a direct system connection to new, relatively low cost, generation. In the case of connection of renewables, this is directly expressed by Benefit Category B3 'RES Integration'. In other cases, the direct connection figures will be available in the background scenarios.

c. A project can also facilitate increased competition between generators, reducing the price of electricity to final consumers. Our methods do not consider market power (see annex 1), and as a result our expression of socio-economic welfare is the reduction in generation costs under (a).

[80] It is acknowledged that transmission expansions have an influence on generation investment. Instead of estimating the consequences of projects for new generation investment in each individual TYNDP, this effect is dealt with by the dynamic nature of the TYNDP process in which successive publications include developments in generation capacity as the basis for their adapted scenarios.

An economic optimisation is undertaken to determine the optimal dispatch cost of generation, with and without the project. The benefit for each case is calculated from:

Benefit (for each hour) = Generation costs without the project – Generation costs with the project

The socio-economic welfare can be calculated for internal constraints by considering virtual smaller bidding areas (with different market prices) separated by the congested internal boundary inside an official bidding area.

The total benefit for the horizon is calculated by summarising the benefit for all the hours of the year, which is done through market studies.

Total surplus approach

The socio-economic welfare benefit is calculated by adding the producer surplus, the consumer surplus and the congestion rents for all price areas as shown in Fig 14. The total surplus approach consists of the following three items:

a. By reducing network bottlenecks, the total generation cost will be economically optimized. This is reflected in the sum of the producer surpluses.
b. By reducing network bottlenecks that restrict the access of import from low-price areas, the total consumption cost will be decreased. This is reflected in the sum of the consumer surpluses.
c. Finally, reducing network bottlenecks will lead to a change in total congestion rent for the TSOs.

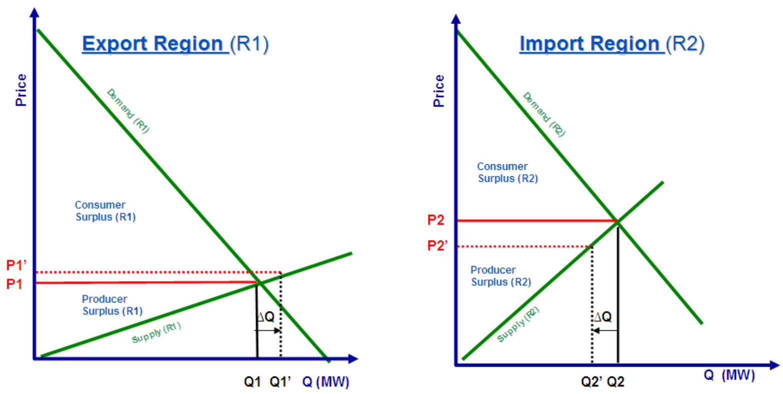

Figure 14: Example of a new project increasing GTC between an export and an import region.

An economic optimisation is undertaken to determine the total sum of the producer surplus, the consumer surplus and the change of congestion rent, with and without the project. The benefit for each case is calculated by:

Benefit (for each hour) = Total surplus with the project – Total surplus without the project

The total benefit for the horizon is calculated by summarizing the benefit for all the hours of the year, which is done through market studies.

Parameter	Source of calculation[81]	Basic unit of measure	Monetary measure (externality or market-based?)	Level of coherence of monetary measure
Reduced generation costs/ additional overall welfare	Market studies (optimisation of generation portfolios across boundaries)	€	idem	European
Internal dispatch costs	Network studies (optimisation of generation dispatch within a boundary considering grid constraints)	€	idem	National

Indicative colours are assigned as follows:

Light green : the project has an annual benefit < € 30 million

Green: the project has an annual benefit between € 30 and € 100 million

Dark green: the project has an annual benefit > or = to € 100 million

3.7.3 B3. RES INTEGRATION[82]

Introduction

The integration of both existing and planned RES is facilitated by:

1. Connection of RES generation to the main system,
2. Increasing the GTC between an area with excess RES generation to other areas, in order to facilitate higher level of RES penetration.

This indicator intends provides a standalone value associated with additional RES available for the system. It measures the reduction of renewable generation curtailment in MWh (avoided spillage) and the additional amount of RES generation that is connected by the project. An explicit distinction is thus made between RES integration projects related to (1) the direct connection of RES to the main system and (2) projects that increase GTC in the main system itself.

Methodology

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[81] Cf Annex IV, 2a.

[82] Calculating the impact of RES in absolute figures (MW) facilitates the comparison of projects throughout Europe when considering the sole aspect of RES integration. Relative numbers (i.e the contribution of a project compared to the objectives of the NREA) can easily be calculated ex-post for analysis at a national level.

Although both types of projects can lead to the same indicator scores, they are calculated on the basis of different measurement units. Direct connection (1) is expressed in $MW_{RES\text{-}connected}$ (without regard to actual avoided spillage), whereas the GTC-based indicator (2) is expressed as the avoided curtailment (in MWh) due to (a reduction of) congestion in the main system. Avoided spillage is extracted from the studies for indicator B2. Connected RES is derived from network studies, and only calculated for specific RES integration projects. Both kinds of indicators may be used for the project assessment, provided that the method used is reported (see table below). In both cases, the basis of calculation is the amount of RES foreseen in the scenario or planning case.

Monetisation

Any monetisation of this indicator will be reported by B2. The benefits of RES in terms of CO2 reduction will be reported by B5.

Parameter	**Source of calculation**	**Basic unit of measure**	**Monetary measure (externality or market-based?)**	**Level of coherence of monetary measure**
Connected RES	Market or network studies	MW	None	European
Avoided RES spillage	Market or network studies	MWh	Included in generation cost savings (B2)	European

Indicative colours are assigned as follows:

White: the project has a neutral effect on the capability of integrating RES, i.e. allows less than 100 MW of direct RES connection or increases RES generation by less than 50 GWh.

Light green: the project allows direct connection of RES production between 100 and 500 MW or permits an increase in RES generation between 50 GWh and 300 GWh.

Dark green: the project allows direct connection of RES production greater than 500 MW or increases RES generation by more than 300 GWh.

3.7.4 B4. VARIATION IN LOSSES (ENERGY EFFICIENCY)

Introduction

The energy efficiency benefit of a project is measured through the reduction of thermal losses in the system. At constant transit levels, network development generally decreases losses, thus increasing energy efficiency. Specific projects may also lead to a better load flow pattern when they decrease the distance between production and consumption. Increasing the voltage level and the use of more efficient conductors also reduce losses. It must be noted, however, that the main driver for transmission projects is currently the higher need for transit over long distances, which increases losses.

Methodology

Variation in losses can be calculated by a combination of market and network simulation tools. The losses in the system are quantified for each planning case (covering seasonal variations) on the basis of network simulation. This is done both with and without the project, while taking into account the change of dispatch that may occur by means of market simulation. The variation in losses is then calculated as the difference between both values, which can be monetised (see below).

Monetisation

Monetisation of losses is based on forecasted marginal costs in the studied horizon. These marginal costs are derived from market studies, which must ensure that input parameters are coherent with the parameters and assumptions indicated in chapter 2.

Parameter	Source of calculation[83]	Basic unit of measure	Monetary measure (externality or market-based?)	Level of coherence of monetary measure
Losses	Network studies	MWh	€/year (market-based)	European

Indicative colours are assigned as follows:

- Red: the project increases the volume of losses on the grid
- White: the project decreases losses in some situations and increases them in others
- Light green: the project decreases the volume of losses on the grid.

3.7.5 B5. Variation in CO2 emissions

Introduction

By relieving congestion, reinforcements may enable low-carbon generation to generate more electricity, thus replacing conventional plants with higher carbon emissions. Considering the specific emissions of CO2 for each power plant and the annual production of each plant, the annual emissions at power plant level and perimeter level can be calculated and the standard emission rate established (see chapter 2).

Methodology

Generation dispatch and unit commitment used for calculation of socio-economic welfare benefit with and without the project is used to calculate the CO2 impact, taking into account standard emission rates.

Monetisation

[83] Cf Annex IV, 2c.

The monetisation of CO2 is based on forecasted CO2 prices for electricity in the studied horizon. The price is derived from official sources such as the IEA for the studied perimeter (see chapter 2). As the cost of CO2 is already included (internalised) in generation costs (B2), the indicator only displays the benefit in tons in order to avoid double accounting.

However, it is possible that the prices of CO2 included in the generation costs (B2) under-state the full long-term societal value of CO2. Accordingly, a sensitivity analysis (see chapter 3.8) could be performed for this indicator B5, under which CO2 is valued at a long-term societal price. To perform this sensitivity without double-counting against B2:

- Derive the delta volume of CO2, as above.
- Consider the CO2 price internalised in B2.
- Adopt a long-term societal price of CO2.
- Multiply the volume of (a) by the difference in prices (c) minus (b). This represents the monetisation of this sensitivity of an increased value of CO2[84].

Parameter	**Source of calculation**	**Basic unit of measure**	**Monetary measure**	**Level of coherence**
CO2	Market and network studies (substitution effect)	tons	CO2 price derived from generation costs (internalised in B2)	European

Indicative colours are assigned as follows:

White: the project has no positive effect on CO2 emissions[85]

Green: the project reduces CO2 emissions by < 500 kt/year [86]

Dark green: the project reduces CO2 emissions by > 500 kt/yea

[84] Note: for this sensitivity to B5, one does not adjust the merit order and the dispatch for B2 for the higher Carbon price. If one were to perform that exercise, that would represent a full re-run of indicator B2, against the different data assumption of a higher forecast carbon price included in the generation background and merit order.

[85] In the rare case of an investment that increases CO2 emissions, above a trigger level of 100 kT_CO2 /year, an exceptional colouring of red should be applied.

[86] The 500 kt limit is considered as a significant threshold for CO2 monitoring in the Commission Decision of 18 July 2007 on monitoring and reporting guidelines pursuant to Directive 2003/87/EC

3.7.6 B6. Technical resilience/system safety margin

Introduction

Making provision for resilience while planning transmission systems, contributes to system security during contingencies and extreme scenarios. This improves a project's ability to deal with the uncertainties in relation to the final development and operation of future transmission systems. Factoring resilience into projects will impact positively on future efficiencies and on ensuring security of supply in the European Union.

A quantitative summation of the technical resilience and system safety margins of a project is performed by scoring a number of key performance indicators (KPI) and aggregating these to provide the total score of the project.

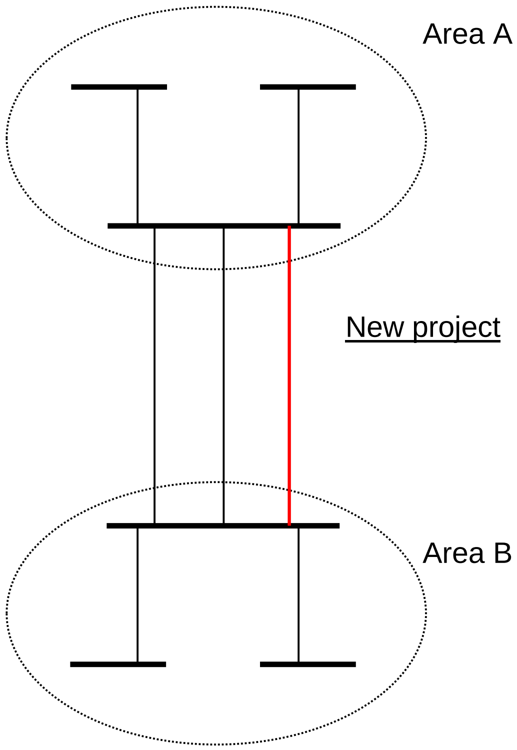
KPI	**Score** **(either ++/+/0)**
Able to meet the recommendation R.1 (failures combined with maintenance) set out in chapter 4 (as applicable)	
Able to meet the recommendation R.2 (steady state criteria) set out in chapter 4 (as applicable)	
Able to meet the recommendation R.3 (voltage collapse criteria) set out in chapter 4 (as applicable)	

A Union-wide list of projects of common interest will be of a wide type and range. Given this high degree of variability and the complexity of assessing the contribution of a project to resilience, the technical resilience benefit will be based on professional power engineering judgement rather than only an algorithmic calculation.

More specifically, the KPI score will be determined by experts from the regional groups, on the basis of demonstrable results from grid studies that are performed using detailed network models of the area under consideration. The KPI may therefore be supported by additional studies which demonstrate this benefit. The general rule is as follows:

The assessment of each KPI will be undertaken in TOOT for planning cases that are representative of the relevant year (see chapter 2). If a particular project contributes positively in the assessment of at least one KPI then it should score at least a single '+'. If the project does not completely meet the recommendations of a particular KPI then it cannot score a '++'.

Methodology



Based on the analysed new project's ability to comply with failures combined with maintenance (n-1 during maintenance) (R.1), the analysed project should be evaluated with a score that varies between a score of 0, a single or double '+'. (0/+/++).

Based on the analysed new project's ability to comply with steady state criteria in case of exceptional contingencies (R.2), the analysed project should be evaluated with a KPI that varies between a score of 0, a single or double '+'. (0/+/++).

Based on the analysed new project's ability to cope with voltage collapse criteria (R.3), the analysed project should be evaluated with a KPI that varies between a score of 0, a single or double '+'. (0/+/++).

Scores for all KPIs are added.

Indicative colours are assigned as follows:

- White: the score of KPIs is 0
- Green: the score of KPIs is < or = 3+
- Dark green: the score of KPIs is > 3

3.7.7 B7. Robustness/flexibility

Introduction

The robustness of a transmission project is defined as the ability to ensure that the needs of the system are met in a future scenario that differs from present projections (sensitivity scenarios concerning input data set[87]). The provision and accommodation of operational flexibility, which is needed for the day-to-day running of the transmission system, must also be acknowledged. The robustness and flexibility of a project will ensure that future assets can be fully utilised in the longer term because the uncertainties related to development and transmission needs on a Union-wide basis are dealt with adequately. Moreover, special emphasis is given to the ability to facilitate the sharing of balancing services, as we suppose that there will be a growing need for this in the coming years.

A qualitative summation of the robustness and flexibility of a project is performed using TOOT by scoring a number of key performance indicators and aggregating these to obtain the total impact of the project.

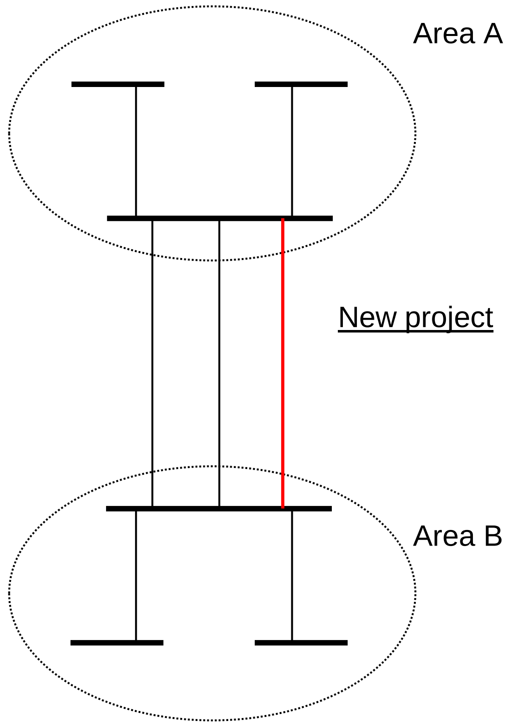
KPI	**Score** **(either ++/+/0)**
Ability to comply with all cases analysed using a probabilistic, multi-scenario approach as set out in chapter 2 (as applicable)	
Ability to comply with all cases analysed taking out some of the foreseen reinforcements as set out in chapter 2 (as applicable)	
Ability to facilitate sharing of balancing services on wider geographical areas, including between synchronous areas	

Given the highly variable and complex nature of each project, and the prohibitive number of possible future developments on a Union-wide scale, it is infeasible to accurately calculate or monetise the performance of each project with respect to flexibility. The benefits are therefore defined by a tabulated scoring system (outlined above) which is completed by professional power engineering judgement rather than by algorithmic calculation.

Scores for each KPI are added to the table and are summated to give an overall score for the project. Each KPI can be given a score of 0, '+', or '++'. The methodology for the scoring of each KPI is outlined below.

[87] See chapter 2 for definition of a sensitivity scenario.

Methodology



Based on the analysed new project's ability to comply with important sensitivities, the analysed project should be evaluated with a KPI that varies between a score of 0, a single or double '+'. (0/+/++).

Based on the analysed new project's ability to comply with commissioning delays and local objection to the construction of the infrastructure, the analysed project should be evaluated with a KPI that varies between a score of 0, a single or double '+'. (0/+/++).

Based on the analysed new project's ability to share balancing services in a wider geographical area (including between synchronous areas), the analyzed project should be evaluated with a KPI that varies between a score of 0, a single or double '+'. (0/+/++).

Scores for all KPIs are added.

Indicative colours are assigned as follows:

White: the score of KPIs is 0

Green: the score of KPIs is < or = 3+

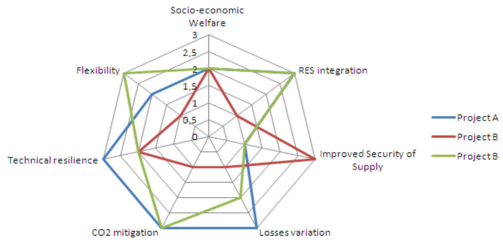
Dark green: the score of KPIs is > 3+

3.8 OVERALL ASSESSMENT AND SENSITIVITY ANALYSIS

3.8.1 OVERALL ASSESSMENT

The overall assessment is displayed as a multi-criteria matrix in the TYNDP, as shown in chapter 3.3. All indicators are quantified. Costs, socio-economic welfare and variation of losses are displayed in Euros. The other indicators are displayed through the most relevant units ensuring both a coherent measure all over Europe and an opposable value, while avoiding double accounting in Euros. Indeed, some benefits like CO2 and RES are already internalised in socio-economic welfare.

Furthermore, each indicator is qualified on a multiple level colour scale, expressing negative, neutral, minor positive, medium positive or high positive impact. This scale allows displaying the results in various formats, such as the "classical" colour code or radar formats as shown below in Fig. 15.



Criteria	Project assessment									
	Grid Transfer Capability Increase	Socio-economic Welfare	RES integration	Improved Security of Supply	Losses variation	CO2 mitigation	Technical resilience	Flexibility	Social and environmental Impact	Project costs
	MW	M€/year	MWh/year	MWh/year	M€	Mt				M€
Project A	1000	150	500			0,5	+++	++		650
Project B	500	30		3000	20		++			25
Project C	800	225	3000		10	1	++	+++		150

Figure 15: illustration of overall assessment

3.8.2 SENSITIVITY ANALYSIS

Transmission network planners face an increasing number of uncertainties. At the macroeconomic level, future evolution of the volume and the type of generation, trends in demand growth, energy prices and exchange patterns between bidding areas are uncertain, and greatly influence the need for transmission capacity. At the level of the study area, generation location and availability, as well as network evolution and availability, also have a major impact on network structure and location. The cost benefit methodology addresses these uncertainties in several ways:

- Benefit indicators are generally expected values, i.e. values obtained through a range of planning cases[88].
- Projects are assessed in at least two carefully considered macro-economic scenarios;
- The robustness of each project against variation of different scenarios or cases is assessed through indicator B7.

[88] With probabilistic market tools, the expected values may even be the results of hundreds of scenarios.

Additional sensitivity analysis (varying selected key assumptions whilst fixing all of the other assumptions) may be carried out, and the following parameters could for instance be considered for sensitivity analysis:

- Demand forecast;
- Fuel costs and RES value;
- CO2 price;
- Discount rate;
- Commissioning date.

The results may be reported as ranges in addition to the reference value.

4 TECHNICAL CRITERIA FOR PLANNING

Technical methods and criteria are defined to be used when assessing the planning scenarios, in order to identify future problems and determine the required development of the transmission grid. These assessments take into account the outcomes from the scenarios analysis.

The general methodology implies:

Grid analysis:

- Investigation of base case topology (all network elements available).
- Different type of events (failures of network elements, loss of generation, …) are considered depending on their probability of occurrence.

Evaluation of results:

- Evaluation of consequences by checking the main technical indicators:
    - Cascade tripping.
    - Thermal limits.
    - Voltages.
    - Loss of demand
    - Loss of generation
    - Short circuit levels
    - Stability conditions.
    - Angular difference.
- Acceptable consequences can depend on the probability of occurrence of the event.

Currently deterministic criteria are used in the planning of the grid.

4.1 DEFINITIONS[89]

D.1. **Base Case for network analysis.** Data used for analysis are mainly determined by the planning cases. For any relevant point in time, the expected state of the whole system, "with all network equipment available", forms the basis for the analysis ("Base case analysis").

D.2. **Contingencies**. A contingency is the loss of one or several elements of the power transmission system. A differentiation is made between ordinary, exceptional and out-of-range contingencies. The wide range of climatic conditions and the size and strength of different networks within ENTSO-E mean that the frequency and consequences of contingencies vary among TSOs. As a result, the definitions of ordinary and exceptional contingencies can differ between TSOs. The standard allows

[89] For all definitions, see also ENTSO-E's draft Operational Security Network Code (https://www.entsoe.eu/resources/network-codes/operational-security/)

for some variation in the categorisation of contingencies, based on their likelihood and impact within a specific TSO network.

- An ordinary contingency is the (not unusual) loss of one of the following elements:
  - Generator.
  - Transmission circuit (overhead, underground or mixed).
  - A single transmission transformer or two transformers connected to the same bay.
  - Shunt device (i.e. capacitors, reactors, etc.).
  - Single DC circuit.
  - Network equipment for load flow control (phase shifter, FACTS …).
  - A line with two or more circuits on the same towers if a TSO considers this appropriate and includes this contingency in its normal system planning
- An exceptional contingency is the (unusual) loss of one of the following elements:
  - A line with two or more circuits on the same towers if a TSO considers this appropriate and does not include this contingency in its normal system planning
  - A single bus-bar.
  - A common mode failure with the loss of more than one generating unit or plant.
  - A common mode failure with the loss of more than one DC link.
- An out-of-range contingency includes the (very unusual) loss of one of the following:
  - Two lines independently and simultaneously.
  - A total substation with more than one bus-bar.
  - Loss of more than one generation unit independently.

D.3. **N-1 criterion for grid planning.** The N-1 security criterion is satisfied if the network is within acceptable limits for expected transmission and supply situations as defined by the planning cases, following a temporary (or permanent) outage of one of the elements of the ordinary contingency list (see D2 and chapter 4.2.2).

4.2 COMMON CRITERIA

4.2.1 STUDIES TO BE PERFORMED

C.1. **Load flow analysis**

- **Examination of ordinary contingencies.** N-1 criterion is systematically assessed taking into account each single ordinary contingency of one of the elements mentioned above.

- **Examination of exceptional contingencies.** Exceptional contingencies are assessed in order to prevent serious interruption of supply within a wide-spread area. This kind of assessment is done for specific cases based on the probability of occurrence and/or based on the severity of the consequences.
- **Examination of out-of-range contingencies.** Out-of-range contingencies are very rarely assessed at the planning stage. Their consequences are minimised through Defence Plans.

C.2. **Short circuit** analysis. Maximum and minimum symmetrical and single-phase short-circuit currents are evaluated according to the IEC 60 909, in every bus of the transmission network

C.3. **Voltage collapse.** Analysis of cases with a further demand increase by a certain percentage above the peak demand value is undertaken. The resulting voltage profile, reactive power reserves, and transformer tap positions are calculated.

C.4. **Stability analysis.** Transient simulations and other detailed analysis oriented to identifying possible instability shall be performed only in cases where problems with stability can be expected, based on TSO knowledge.

4.2.2 Criteria for assessing consequences

C.5. **Steady state criteria**

- **Cascade tripping.** A single contingency must not result in any cascade tripping that may lead to a serious interruption of supply within a wide-spread area (e.g. further tripping due to system protection schemes after the tripping of the primarily failed element).
- **Maximum permissible thermal load.** The base case and the case of failure must not result in an excess of the permitted rating of the network equipment. Taking into account duration, short term overload capability can be considered, but only assuming that the overloads can be eliminated by operational countermeasures within the defined time interval, and do not cause a threat to safe operation.
- **Maximum and minimum voltage levels.** The base case and the case of failure shall not result in a voltage collapse, nor in a permanent shortfall of the minimum voltage level of the transmission grid, which are needed to ensure acceptable voltage levels in the sub-transmission grid. The base case and the case of failure shall not result in an excess of the maximum admissible voltage level of the transmission grids defined by equipment ratings and national regulation, taking into account duration.

C.6. **Maximum loss of load or generation** should not exceed the active power frequency response available for each synchronous area.

C.7. **Short circuit criteria.** The rating of equipment shall not be exceeded to be able to withstand both the initial symmetrical and single-phase short-circuit current (e.g. the make rating) when energising on to a fault and the short circuit current at the point of arc extinction (e.g. the break rating). Minimum short-circuit currents must be assessed in particular in bus-bars where a HVDC installation is connected in order to check that it works properly.

C.8. **Voltage collapse criteria.** The reactive power output of generators and compensation equipment in the area should not exceed their continuous rating, taking into account transformer tap ranges. In addition the generator terminal voltage shall not exceed its admissible range.

C.9. **Stability criteria.** Taking into account the definitions and classifications of stability phenomena[90], the objective of stability analysis is the rotor angle stability, frequency stability and voltage stability in case of ordinary contingencies (see section 3.1), i.e. incidents which are specifically foreseen in the planning and operation of the system..

- **Transient stability.** Any 3-phase short circuits successfully cleared shall not result in the loss of the rotor angle and the disconnection of the generation unit (unless the protection scheme requires the disconnection of a generation unit from the grid).

- **Small Disturbance Angle Stability**. Possible phase swinging and power oscillations (e.g. triggered by switching operation) in the transmission grid shall not result in poorly damped or even un-damped power oscillations.
- **Voltage security**. Ordinary contingencies (including loss of reactive power in-feed) must not lead to violation of the admissible voltage range that is specified by the respective TSO (generally 0.95 p.u. – 1.05 p.u.

4.2.3 Best Practice

R1. **Load flow analysis. Failures combined with maintenance.** Certain combinations of possible failures and non-availabilities of transmission elements may be considered in some occasions. Maintenance related non-availability of one element combined with a failure of another one may be assessed. Such investigations are done by the TSO based on the probability of occurrence and/or based on the severity of the consequences, and are of particular relevance for network equipment that may be unavailable for a considerable period of time due to a failure, maintenance, overhaul (for instance cables or transformers) or during major constructions.

R2. **Steady state analysis.** Acceptable consequences depend on the type of event that is assessed. In the case of exceptional contingencies, acceptable consequences can be defined regarding the scale of the incident, and include loss of demand. Angular differences should be assessed to ensure that circuit breakers can re-close without imposing unacceptable step changes on local generators.

R3. **Voltage Collapse analysis:** The aim of voltage collapse analysis is to give some confidence that there is sufficient margin to the point of system collapse in the analysed case to allow for some uncertainty in future levels of demand and generation.

End note.
System development tools are continuingly evolving, and it is the intention that this document will be reviewed periodically in line with prudent planning practice and further editions of the TYNDP.

[90] Definition and Classification of Power System Stability, IEEE/CIGRE Joint Task Force, June 2003

5 ANNEX 1: IMPACT ON MARKET POWER

Context

The Regulation (EU) No 347/2013project requires that the CBA takes into account the impact of the infrastructure on market power in the Member States. This paper analyses this indicator and its limits, as well as the necessary methodology to construct it.

Basics on methodology

Market power is the ability to alter prices away from competitive levels. **It is important to point out that this ability is potential**: a market player can have market power without using it. Only when it is actually used, market power has negative consequences on socio-economic welfare, by reducing the overall economic surplus to the benefit of a single market player. Taking into account market power in a CBA therefore requires three steps:

- To define carefully which asset(s)/(remedies) will be assessed. The calculus of the index will be made with and without this object, and the difference on this two calculus will be the outcome of the CBA
- To define the market on which the index will be applied: geographic extension, how to take into account interconnections and market coupling, treatment of regulated market segments, market products to consider.
- To define a market power index, which requires choosing an index among existing possibilities such as Residual Supply Index (RSI) or Herfindahl-Hirschman Index (HHI). Each of these has its advantages and disadvantages ;

All of these choices affect the results of a market power analysis, i.e. the perceived market power is highly dependent on how it is defined.

Limits of market power indicators

First, it must be highlighted that **the calculation of all these indexes requires confidential data as input**. Thus, a balance has to be found between the necessary confidentiality of these data and the need for transparency that is required for CBA, as this is a necessary condition to obtain EU permitting and financial assistance.

Furthermore, monetisation of this market power index requires that the impact of a change in the market power index on socio-economic welfare is estimated. This requires that one is able to model the functioning of a future market under the hypothesis of imperfect competition, despite the fact that the validity of such a model is virtually impossible to prove. The inevitable model assumptions can radically change the results.

The results of a CBA in terms of market power can therefore only be qualitative, and its use as a reference for cost allocation would raise many objections.

A CBA study is classically performed by evaluating the impact of a project during its whole life cycle. This requires to make a complete set of hypothesis on the future, for instance on the evolution of the level of consumption. Unfortunately, **market power evolution cannot be modelled**, as it is dependent on individual and regulatory decisions. Market structure could change dramatically in the future, for instance as the result of a merger. A solution to this issue could be to assess the impact of the infrastructure on the observed situation only. However, it should be noted that evaluating market power in a different hypothesis framework from the other aspects of the CBA would imply that the results are not consistent, and should not be compared.

Building infrastructures may have a positive impact on market power issues, but it is not the only solution. One should note that **an infrastructure project takes more time to complete is more costly than a decision affecting regulation/competition**. In case a market power issue is identified in a Member State, the national regulator should undertake relevant actions to force market players to respect the rules, rather than trying to solve the problem by expanding the infrastructure. Indeed, regulatory solutions are much more adapted to such an issue.

The instability of market power compared to the other aspects of a CBA has a crucial impact on its relevance as part of a decision making process. Dealing with generator ownership structures 10 or 20 years from now adds a highly uncertain dimension to the evaluation of European benefits of a given asset. Taking the impact of infrastructure capacity on market power into account in a CBA can heavily affect the identification of priority projects. Moreover, a change in the market structure can completely change the decision of building a particular infrastructure. **This is all the more important considering that there are other, faster ways to solve market power issues: through regulation**. By the time a project is completed, it is very likely that the market power issue has already been tackled by the regulator, and the infrastructure will not bring any benefit on this aspect. **Taking market power into account in a CBA can thus lead to sub-optimal decisions**.

Conclusion

The impact of future assets on current market power (which is generally positive) is an important indication, but this short-term vision cannot be used in the assessment of an investment decision which is, by definition, a long-term commitment;

National markets have already begun to merge, through market coupling, and a reporting of benefits on market power by Member States is already outdated.

6 Annex 2: Multi-criteria analysis vs cost benefit analysis

Goals of any project assessment method

- Transparency : the assessment method must provide transparency in its main assumptions, parameters and values
- Completeness : all relevant indicators (representing EU energy policy, as outlined by the criteria specified in annexes IV and V of the draft Regulation) should be included in the assessment framework,
- Credibility/opposability : if a criterion is weighted, the unit value must stem from an external and credible source (international or European reference)
- Coherence: if a criterion is weighted, the unit value must be coherent within the area under consideration (Europe or Regional Group).

The limits of a « pure » cost benefit analysis

- A single criterion provides less information (and is less transparent) then a multi-criteria balance sheet. Moreover, it is not well adapted in the case of a multi-actor governance, such as the one foreseen by the Regulation (EU) No 347/2013, where the actors will need information on each of the criteria in order to take common decisions.
- A « pure « CBA cannot cover all criteria specified in annexes IV and V of the Regulation (EU) No 347/2013, since some of the benefits are difficult to monetise.
    - This is the case for High Impact / Low Probability events such as « disaster and climate resilience » (multiplying low probabilities and very high consequences have little meaning) ;
    - Other benefits, such as, "operational flexibility », have no opposable monetary value today (they qualify robustness and flexibility rather than a quantifiable economic value) ;
    - Some benefits have opposable values at a national level, but no common value exists in Europe. This is case with, for instance, the value of lost load, which depends on the structure of consumption in each country (tertiary sector versus industry, importance of electricity in the economy etc…)
    - Some benefits (e.g. CO2) are already internalised (e.g in socio-economic welfare). Displaying a value in tons provides additional information and prevents double accounting.

As stated in the EC Guide to Cost Benefit Analysis (2008): "In contrast to CBA, which focuses on a unique criterion (the maximisation of socio-economic welfare), Multi Criteria Analysis is a tool for dealing with a set of different objectives that cannot be aggregated through shadow prices and welfare weights, as in standard CBA" ; "Multi-criteria analysis, i.e. multi-objective analysis, can be helpful when some objectives are intractable in other ways and should be seen as a complement to CBA ».

This is why ENTSO-E favours a combined multi-criteria and cost benefit analysis that is well adapted to the proposed governance and allows an evaluation based on the most robust indicators, including monetary values if an opposable and coherent unit value exists on a Europe-wide level. This approach allows for a homogenous assessment of projects on all criteria (e.g MWh RES is the priority of the region is RES integration).

7 ANNEX 3: TOTAL SURPLUS ANALYSIS

A project with a GTC variation between two bidding areas with a price difference will allow generators in the low price bidding area to supply load in the high price bidding area.

In a perfect market, the market price is determined at the intersection of the demand and supply curves.

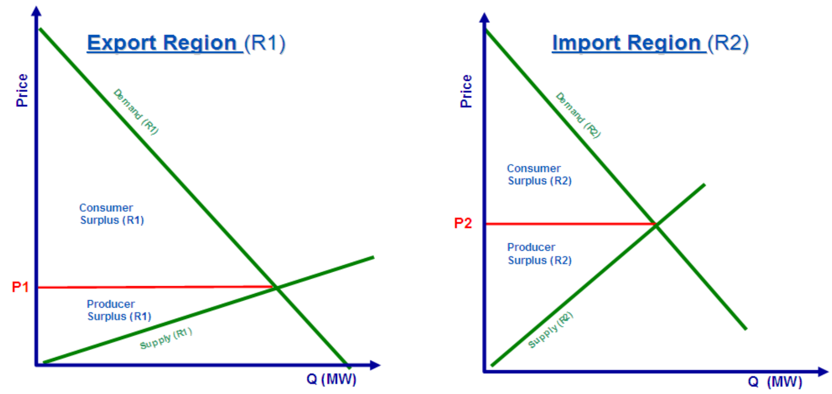


Figure 3.1: Example of an export region (left) and an import region (right) with no (or congested) interconnection capacity (elastic demand)

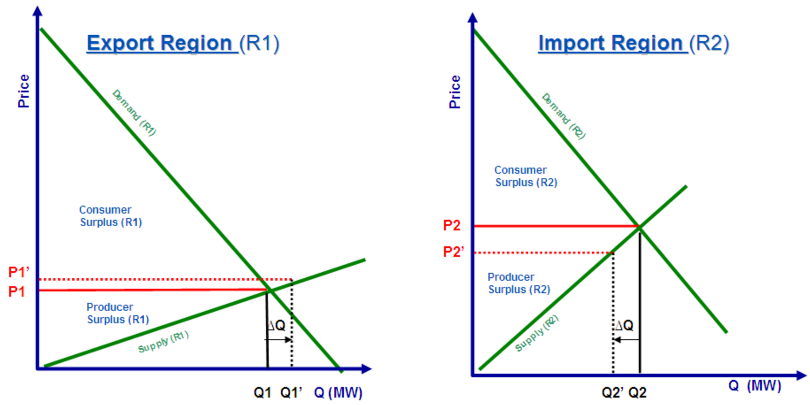


Figure 3.2: Example of an export region and an import region, with a new project increasing the GTC between the two regions (elastic demand)

The new project will change the price of both bidding areas. This will lead to a change in consumer and producer surplus in both the export and import area. Furthermore, the TSO revenues will reflect the change in total congestion rents on all links between the export and import areas.

The benefit of the project can be measured through the change in socio-economic welfare. The change in welfare is calculated by:

Change in welfare = change in consumer surplus + change in producer surplus + change in total congestion rents

The total benefit for the horizon is calculated by summing the benefit for all hours of the year.

Inelasticity of demand

In the case of the electricity market, short-term demand can be considered as inelastic, since customers do not respond directly to real-time market prices (no willingness-to-pay-value is available).

The change in **consumer surplus**[91] can be calculated as follows:

For inelastic demand: change in **consumer surplus** = change in prices multiplied by demand

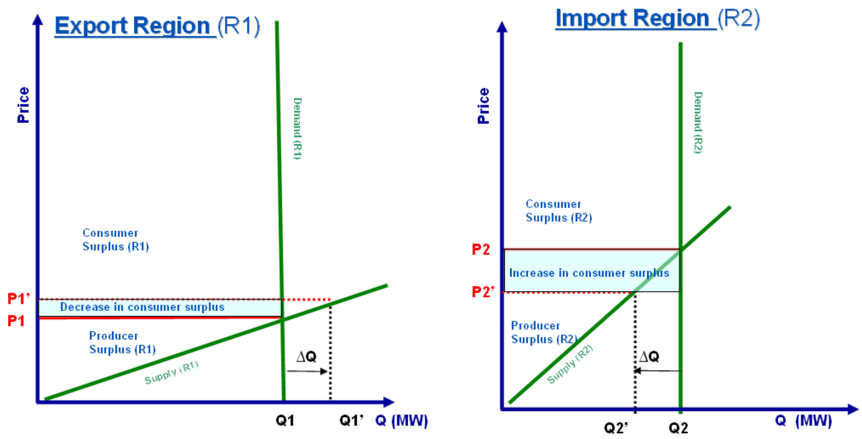


Figure 3.3: Change in consumer surplus

The change in **producer surplus** can be calculated as follows:

Change in **producer surplus** = generation revenues[92] – generation costs

[91] When demand is considered as inelastic, the consumer surplus cannot be calculated in an absolute way (it is infinite). However, the variation in consumer surplus as a result of the new project can be calculated nonetheless. It equals the sum for every hour of the year of :(marginal cost of the area x total consumption of the area)$_{\text{with the project}}$ – marginal cost of the area x total consumption of the area)$_{\text{without the project}}$

[92] Generation revenues equal: (marginal cost of the area x total production of the area).

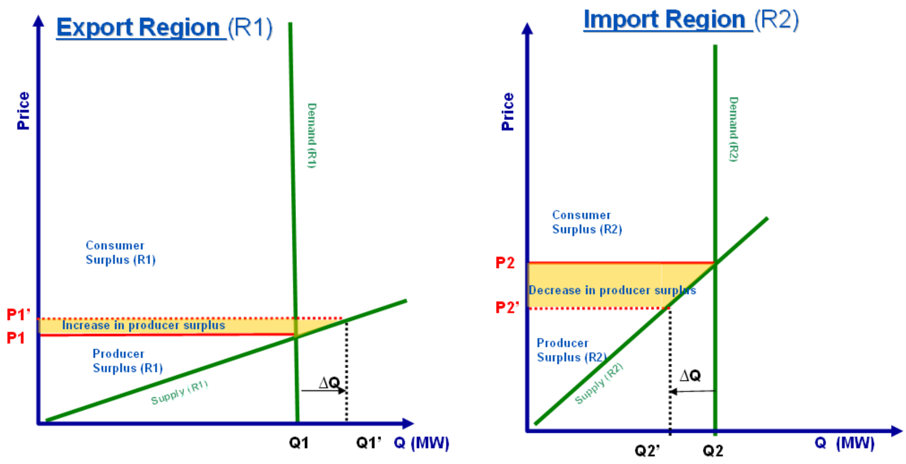


Figure 3.4: Change in producer surplus

The congestion rents with the project can be calculated by the price difference between the importing and the exporting area, multiplied by the additional power traded by the new link[93].

The change in **total congestion rent** can be calculated as follows:

Change in **total congestion rent** = change of congestion rents on all links between import and export area

8 ANNEX 4: VALUE OF LOST LOAD

The value of lost load (VoLL) is a measure of the cost of unserved energy (the energy that would have been supplied if there had been no outage) for consumers. It is generally normalised in €/kWh. It is an externality, since there is no market for security of supply.
Transmission reinforcements contribute to the improvement of security and quality of electricity supply, reducing the probability and gravity of outages, and thus the costs for consumers.
According to economic theory, there is an optimal level expressing the consumer's willingness to pay for security of supply. The level of VOLL should reflect the real cost of outages for consumers, hence providing an accurate basis for investment decisions. A too high level of VOLL would lead to over-investment; conversely, if the value were too low, it would lead to an inadequate security of supply. The VOLL should allow striking the right balance between transmission reinforcements (which have a cost, reflected in the tariff) and outage costs.

The Value of Lost Load is different from one country to another, essentially because of differences in sectorial composition of electricity consumption (share of industry, service sector etc…), level of dependency on electricity in the economy and seasons. It reflects the mean value of an outage per kWh (long interruptions) or kW (voltage dips, short interruptions), appropriately weighted to yield a composite value for the overall sector or nation considered.

[93] In a practical way, it's calculated as the absolute value of (Marginal cost of Export Area – Marginal cost of Import Area) x flows on the interconnector

The CEER has set out European guidelines[94] for nationwide studies on estimation of costs due to electricity interruptions and voltage disturbances, recommending that "*National Regulatory Authorities should perform nationwide cost-estimation studies regarding electricity interruptions and voltage disturbances".* Applying these guidelines throughout Europe would help establishing correct levels of VOLL, enabling comparable and consistent project assessments all over Europe. However, this is not yet the case, and a R&D program would be a pre-condition for adopting VOLL for consistent TYNDP or PIC assessments.

The table below gives an overview of current values in Europe, with an indication of the methodology used. The methodologies are not always reported in an exact manner; hence no direct comparison of values is possible, nor does this presentation entail that ENTSO-E endorse any of the values below.

Country	**VOLL (€/kWh)**	**Date**	**Used in planning?**	**Method/reference**	**Reference**
Austria (E control)	WTP: Industry 13,2, Households, 5,3 Direct worth: Households: 73,5 Industry : 203,93	2009	No	R&D for incentive regulation, Surveys using both WTP and Direct Worth	(4)
France (RTE)	26. Sectorial values for large industry, small industry, service sector, infrastructures, households and agriculture available	2011	Yes (mean value)	CEER: surveys for transmission planning using WTP, Direct Worth and case studies.	(12)
Great Britain	19,75	2012	No	Incentive regulation, initial value proposed by Ofgem	(13)
Ireland	Households : 68 Industry : 8	2005	No	R&D, production function approach	(6)

[94] Guidelines of Good Practice on Estimation of Costs due to Electricity Interruptions and Voltage Disturbances, CEER, December 2010. Other reports have also established such guidelines, such as CIGRE (2001) and EPRI (

	Mean : 40				
Italy (AEEG)	10,8 (Households) 21,6 (Business)[95]	2003	No	Surveys for incentive regulation, using both WTP and Direct Worth (SINTEF)	(3) & (5)
Netherlands (Tennet)	Households 16,4 Industry : 6,0 Mean : 8,6	2003	No	R&D, production function approach	(7)
Norway (NVE)	Industry: 10,4 Service sector: 15,4 Agriculture: 2,2 Public sector: 2 Large industry: 2,1	2008	Yes (sectorial values)	Surveys for incentive regulation, using both WTP and Direct Worth (SINTEF)	(9) and (10)
Portugal (ERSE)	1,5	2011	Yes (mean value)	Portuguese Tariff Code	(14)
Spain	6,35	2008	No	R&D, production function approach	(8)
Sweden	Households 0,2 Agriculture 0,9 Public sector 26,6 Service sector 19,8 Industry 7,1	2006	No	R&D, WTP, conjoint analysis	(11)

References:

1) CIGRE Task Force 38.06.01: "Methods to consider customer interruption costs in power system analysis". Technical Brochure, August 2001

2) Guidelines of Good Practice on Estimation of Costs due to Electricity Interruptions and Voltage Disturbances, CEER, December 2010

3) "The use of customer outage cost surveys in policy decision-making: the Italian experience in regulating quality of electricity supply", A. BERTAZZI and L. LO SCHIAVO

4) « Economic Valuation of Electrical Service Reliability in Austria – A Choice Experiment Approach », Markus Bliem, IHSK, 2009

[95] The value for Transmission could rise to 40€/kWh (5th CEER Benchmarking Report on the Quality of Electricity Supply, 2011)

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5) « 5th CEER Benchmarking Report on the Quality of Electricity Supply », 2011

6) « Security of Supply in Ireland », Sustainable Energy Ireland, 2007

7) "The value of security of supply", Nooij/Koopmans/Bijvoet, SEO, 2005

8) « The costs of electricity interruptions in Spain. Are we sending the right signals? », Pedro Linares, Luis Rey, Alcoa Foundation, 2012

9) FASIT, KILE-satser, 2011

10) « Customer Costs Related to Interruptions and Voltage Problems: Methodology and Results, G. Kjölle" (SINTEF) IEEE TRANSACTIONS ON POWER SYSTEMS, 2008

11) « Kostnader av elavbrott: En studie av svenska elkunder ». Carlsson, Fredrik & Martinsson, Peter, Elforsk rapport nr 06:15, (2006),

12) "Quelle valeur attribuer à la qualité de l'électricité" ? RTE, 2011

13) Desktop review and analysis of information on Value of Lost Load for RIIO-ED1 and associated work, Reckon, May 2012

14) PARÂMETROS DE REGULAÇÃO PARA O PERÍODO 2012 A 2014, ERSE, 2011

9 ANNEX 5: ASSESSMENT OF ANCILLARY SERVICES

Exchange and sharing of ancillary services, in particular balancing resources, is crucial both to increase RES integration and to enhance the efficient use of available generation capacities. However, today, there is a great diversity of

arrangements for ancillary services throughout Europe[96]. Common rules for cross border exchanges of such services are foreseen within the future Network Code on Electricity Balancing. In the absence of such a code, any homogenous assessment of the value of transmission for exchange of ancillary services remains difficult.
Some principles established by ACER's Framework Guidelines on Balancing Services provide a possible **scope** for cost benefit analysis of ancillary services:

- Frequency containment reserves97 are shared and commonly activated in synchronous areas through the reliability margin foreseen for that purpose. These margins may be included in SEW calculations, and could lead to double-counting.
- The Network Code on Electricity Balancing shall set all necessary features to facilitate the development of cross-border exchanges of balancing energy and stipulate that these are made possible on every border, in the limits defined by Network Code on Load Frequency Control and Reserves concerning abroad procurement of Ancillary Services such as frequency restoration reserves (FRR) and replacement reserves (RR). However, reservation of cross-border capacity for the purpose of balancing energy from FRR and RR is generally forbidden, except for cases where TSOs can demonstrate that such reservation would result in increased overall social welfare.

Generally, increase of cross border capacities between bidding zones through grid development would therefore only lead to additional value in terms of balancing energy from frequency restoration reserves and replacement reserves ("Reserves") during non-congested hours. Moreover, the value could only be monetised in certain **conditions**, described below.

Many transmission projects, especially new interconnectors between or within coordinated markets, can provide the benefit of good liquidity of Reserves, provided only that the sending market has spare Reserve capacity being held. The technical capability of an interconnector to deliver Reserves, at various timescales should be carefully evaluated, considering both the technical characteristics of the interconnector and the technical definitions of Reserve products in the markets. If at least one of the interconnected markets has market-based approach in balancing services, such that a price of balancing services can be sensibly projected over a forecast horizon, then a question of monetisation of a balancing services benefit arises.

If these conditions are fulfilled, the following guidance could be given:

- If the transmission project lies entirely within one control area, which has a market-based approach in balancing services, then the benefit of that project, in terms of permitting greater access to market of Reserve services should be assessed using forecast prices of Reserve within the control area. We note that such prices are normally low – it is unusual to have Reserve sources significantly limited by transmission, such that differential prices of Reserves are released by extra transmission.

[96] See for instance ENTSO-E's survey on *Ancillary Services Procurement and Electricity Balancing Market Design* https://www.entsoe.eu/resources/network-codes/electricity-balancing/.

[97] *Frequency containment reserves* are operating *reserves* necessary for constant containment of frequency deviations (in order to constantly maintain the power balance in the whole synchronously interconnected system. This category typically includes operating *reserves* with the activation time up to 30 seconds. Operating *reserves* of this category are usually activated automatically.

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- If the transmission project interconnects two control areas, both of which have a market-based approach in balancing services and similar Reserve products, then the Reserve benefits of that project should be assessed using forecast prices of Reserve within each bidding zone. Note the benefits are two-way; for example, if the interconnectors is floating at one hour, then it can let Reserve from control area A contribute to the requirement in control area B and simultaneously let Reserve from control area B contribute into control area A. But of course, if the interconnector is flowing fully from A to B at that hour, then no Reserve benefit in control area B can be also claimed ; in general, the Reserve benefit will be lower than the Trading benefit evaluated under SEW (benefit B2).
- If the transmission project interconnects one control area A, which has a market-based approach in balancing services, with a second control area B which does not, or Reserve products are very dissimilar, then great care should be exercised in attempting to quantify any Reserve benefit. Obviously, zero benefit can be claimed for delivery of Reserves from control area A into control area B if control area B does not have a marked based approach in balancing services. A Reserve benefit can only be claimed, if it is thought likely to be able to establish the holding of a Reserve service in control area B able to meet the technical requirements of Reserve in control area A. Further, a prudent forecast should be made of the price of holding the Reserve in control area B, and this forecast deducted from the forecasted Reserve price in control area A. If in doubt, it should be assumed that the price of holding in control area B exceeds the value in control area A, such that zero Reserve benefit is claimed.
- Finally, if the transmission project interconnects two control areas which have no market-based approach in balancing services, then obviously, zero benefit can be claimed for delivery of Reserves into either market.

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10 ANNEX 6: ASSESSMENT OF STORAGE

The principles and procedures described in this document, for combined Multi-criteria and Cost Benefit Analysis, may be used for the evaluation of centralised[98] storage devices on transmission system. These Multi-criteria and Cost Benefit Analysis is applicable both to storage systems planned by TSOs and both by private promoters, even if a distinction on different roles and operation uses between these two types must be done. In fact the possibility to install storage plants on the transmission network by TSO is strictly connected to improve and preserve system security and guarantee cheapness of network operation without affecting internal market mechanisms and influence any market behaviour.

The location of storage plants is decisive to the service storage will provide. Therefore, before carrying out the CBA, an assessment of the maximum power of the storage device at different points of time (for the injection and withdrawal of electricity to/from the grid) taking into account local grid capacity, should be undertaken, in the same way as the GTC is calculated for transmission.

Business models for storage are often categorised by the nature of the main target service, distinguishing between a deregulated-driven business model (income from activities in electricity markets), and a regulated-driven business model (income from regulated services). The CBA will not account for these differences[99]. As for transmission, it will yield monetised benefits of storage using a perfect market assumption (including perfect foresight), and account for non-monetised benefits using the most relevant physical indicators.

The characterisation of the impact of storage projects can be evaluated in terms of added value for society as improvement of security of supply, increase of capacity for trading of energy and balancing services between bidding areas, RES integration, variation of losses and CO_2 emission, resilience and flexibility. The remainder of this annex will describe the assessment of storage in the same way the CBA indicators were applied in the main document

B1. Security of supply: Energy storage may improve security of supply by smoothening the load pattern ("peak shaving") : increasing off-peak load (storing the energy during periods of low energy demand) and lowering peak load (dropping it during highest demand periods). Market studies will account for the value provided at the level of a European Region (specific cases of very large storage devices). These global analysis will be completed by Network studies, enabling to assess this service in regional networks, not respresented in market studies. Both will be measured as variations in EENS or LOLE.

B2. Socio-economic welfare: The impact of storage on socio-economic welfare is the main claimed benefit of large-scale storage. In fact the use of storage systems on the network can generate opportunities in terms of generation portfolio optimisation (arbitrage) and congestion solutions that imply cost savings on users of whole transmission system. Market studies will be able to assess this value based on an hourly resolution, which is consistent with current market models. Indeed, storage can take advantage of the differences in hourly peak and off-peak electricity prices by storing

[98] At least 225 MW and 250 GWh/year as defined by the published EC Regulation (EU) No 347/2013

[99] It should be noted the following the regulatory systems, the owners of storage will not be likely to capture the full value of storage. Hence, in some countries, a TSO owner will not be able to capture any arbitrage value, whereas a private owner will not be able to capture any system service value.

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electricity at times when prices are low, and then offering it back to the system when the price of energy is greater, hence increasing socio-economic welfare.

B3. RES integration: Storage devices provide resources for the electricity system in order to manage RES generation and in particular to deal with intermittent generation sources. As for transmission, this service will be measured by avoided spillage, using market studies or network studies, and its economic value is internalised in socio-economic welfare.

B4. Variation in losses: Depending on the location, the technology and the services provided by storage may increase or decrease losses in the system. This effect is measured by network studies.

B5. Variation in CO_2 emissions: As for transmission, the CO_2 indicator is directly derived from the ability of the storage device to impact generation portfolio optimisation. Its economic value is internalised in socio-economic welfare.

B6. Technical resilience/system safety: Electricity storage systems can be employed to control power fluctuations and to improve management of large incidents occurring on power transmission structures, providing voltage support or frequency regulation. As for transmission, specific studies or expert assessments will help evaluating these effects.

B7. Flexibility: As for transmission, the ability of storage to provide value for society across various scenarios may be assessed. Moreover, storage can provide balancing services[100] as an alternative or complement to energy arbitrage.

Storage also has costs and environmental impact. The same indicators as in the main document will be used.

C.1. Total project expenditure of storage includes investment costs, costs of operation and maintenance during the project lifecycle as well as environmental costs (compensations, dismantling costs etc.).

S.1. Environmental impact: The environmental impact of a storage project is different from transmission, and highly dependent on technology. The assessment must take into account national legal provisions regarding environmental impact assessment and mitigation measures.

S.2. Social impact: The social impact of a storage project is different from transmission, and highly dependent on technology. The assessment must take into account national legal provisions regarding social impact assessment and mitigation measures.The CBA of storage will use the same boundary conditions, parameters, overall assessment and sensitivity analysis techniques as the CBA for transmission. In particular, the TOOT methodology implies that the assessment will be carried out including all storage projects outlined in the TYNDP, taking out one storage project at the time in order to assess it benefits.

The methodology performed shall be used for storage project appraisals carried out for the TYNDP and for individual storage project appraisals undertaken by TSOs or project promoters.

[100] See annex 5

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11 ANNEX 7: ENVIRONMENTAL AND SOCIAL IMPACT

A stated in chapter 1, the main objective of transmission system planning is to ensure the development of an adequate transmission system which:

- Enables safe system operation;
- Enables a high level of security of supply;
- Contributes to a sustainable energy supply;
- Facilitates grid access for all market participants;
- Contributes to internal market integration, facilitates competition, and harmonisation;
- Contributes to improving the energy efficiency of the system.

The TYNDP highlights the way transmission projects of European Significance contribute to the EU's overall sustainability goals, such as CO_2 reduction or integration of renewable energy sources (RES). On a local level, these projects may also impact other EU sustainability objectives, such as the EU Biodiversity Strategy (COM 2011 244) and landscape protection policies (European Landscape Convention). Moreover, new infrastructure needs to be carefully implemented though appropriate public participation at different stages of the project, taking into account the goals of the Aarhus Convention (1998) and the measures foreseen by the Regulation on Guidelines for trans-European energy infrastructure (EU n° 347-2013).

As a rule, the first measure to deal with the potential negative social and environmental effects of a project is to avoid causing the impact (e.g. through routing decisions) wherever possible. Steps are also taken to minimise impacts through mitigation measures, and in some instances compensatory measures, such as wildlife habitat creation, may be a legal requirement. When project planning is in a sufficiently advanced stage, the cost of such measures can be estimated accurately, and they are incorporated in the total project costs (listed under indicator C.1).

Since it is not always possible to (fully) mitigate certain negative effects, the indicators 'social impact' and 'environmental impact' are used to:

- indicate where potential impacts have not yet been internalized i.e. where additional expenditures may be necessary to avoid, mitigate and/or compensate for impacts, but where these cannot yet be estimated with enough accuracy for the costs to be included in indicator C.1.
- indicate the *residual* social and environmental effects of projects, i.e. effects which may not be fully mitigated in final project design, and cannot be objectively monetised;

Particularly in the early stages of a project, it may not be clear whether certain impacts can and will eventually be mitigated. Such potential impacts are included and labelled as *potential impacts*. In subsequent iterations of the TYNDP they may either disappear if they are mitigated or compensated for, or lose the status of *potential* impact (and thus become *residual*) if it becomes clear that the impact will eventually not be mitigated or compensated for.

When insufficient information is available to indicate the (potential) impacts of a project, this will be made clear in the presentation of project impacts in a manner that 'no information' cannot be confused with 'no impact'.

In its report on *Strategic Environmental Assessment for Power Developments,* the International Council on Large Electric Systems (CIGRÉ, 2011) provides an extensive overview of factors that are relevant for performing Strategic Environmental Assessment (SEA) on transmission systems. Most indicators in this report were already covered by ENTSO-E's cost-benefit analysis methodology, either implicitly via the additional cost their mitigation creates for a project, or explicitly in the form of a separate indicator (e.g. CO_2 emissions). Three aspects ('biodiversity', 'landscape', and 'social integration of infrastructure'), however, could not be quantified objectively and clearly via an indicator or through monetisation. Previously, these were addressed in the TYNDP by an expert assessment of the risk of delays to projects, based on the likelihood of protests and objections to their social and environmental impacts. Particularly for projects that are in an early stage of development, this approach improves assessment transparency as it provides a quantitative basis for the indicator score.

To provide a meaningful yet simple and quantifiable measure for these impacts, the new methodology improves on this indicator by giving an estimate of the number of kilometres of a new overhead line (OHL), underground cable (UGC) or submarine cable (SMC) that might have to be located in an area that is sensitive for its nature or biodiversity (environmental impact), or its landscape or social value (social impact) (for a definition of "sensitive": see below).

When first identifying the need for additional transmission capacity between two areas, one may have a general idea about the areas that will be connected, while more detailed information on, for instance, the exact route of such an expansion is still lacking, since routing decisions are not taken until a later stage. In the early stages of a project it is often thus difficult to say anything concrete about the social and environmental consequences of a project, let alone determine the cost of mitigation measures to counter such effects. The quantification on these indicators will thus be presented in the form of a range, of which the 'bandwidth' tends to decrease as information increases as the project progresses in time. In the very early stages of development, it is possible that the indicators are left blank in the TYNDP and are only scored in a successive version of the TYNDP when some preliminary studies have been done and there is at least some information available to base such scoring upon. A strength of this type of measure is that it can be applied at rather early stages of a project, when the environmental and social impact of projects is generally not very clear and mitigation measures cannot yet be defined. In subsequent iterations of the TYNDP, as route planning advances and specification of mitigation measures becomes clearer, the costs will be internalised in 'project costs' (C.1), or indicated as 'residual' impacts.

Once one has a global idea of the alternative routes that can be used, a range with minimum and maximum values for this indicator can be established. These indicators will be presented in the TYNDP along with the other indicators as specified in ENTSO-E's CBA methodology, with a link to further information. The scores for social and environmental impact will not be presented in the TYNDP by means of a colour code. These impacts are highly project specific and it is difficult to express these completely, objectively, and uniformly on the basis of a single indicator. This consideration led to the use of "number of kilometres" as a measure to provide information about projects in a uniform manner, while respecting the complexity of the underlying factors that make up the indicators. Attaching a colour code purely on the basis of the notion "number of kilometres" would imply that a "final verdict" had been passed regarding social and environmental sensitivity of the project, which would not be right since the number of kilometres a line crosses through a sensitive area is only one aspect of a project's true social and environmental impact.

Considering that translating the project score to a colour code would make the indicator appear to be simpler and more objective than it actually is, and would undermine its main intention, which is to provide full information to decision makers and the public, scoring is carried out in the following manner:

Assessment system for residual environmental impact

- Stage: Indicate the stage of project development. This is an important indication for the extent to which environmental impact can be measured at a particular moment.
- Basic notion: # of km that might have to run “in” sensitive areas. An area can be sensitive to (nearby) infrastructure because of the potential effects this infrastructure will have on nature and biodiversity[101]
- Type of sensitivity: Define why this area is considered sensitive.

Example:

Project	Stage	Impact Potentially crosses environmentally sensitive area (nb of km)	Typology of sensitivity	Link to further information
A	Planned	Yes (a. 50 to 75 km; b. 30 to 40 km)	a. Birds Directive; b. Habitats Directive	e.g. Big Hill SPA www….
B	Design & permitting	No		www….
C	Planned	Yes (20 km)	Habitats Directive	www….
D	Under consideration	N.A	N.A	www….

Assessment system for residual social impact

- Stage: Indicate the stage of project development. This is an important indication for the extent to which social impact can be measured at a particular moment.
- Basic notion: # of km “in” sensitive area. An area can be sensitive to (nearby) infrastructure if it is densely populated or protected for its landscape value.
- Type of sensitivity: Define why this area is considered sensitive.

101 The EC has formulated its headline target for 2020 that “Halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, and restoring them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss.”

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Example:

Project	Stage	Impact Crosses dense area (nb of km)	Sensitivity Typology of sensitivity	Link to further information
A	Design & permitting	Yes (20 to 40km)	Dense area	www.…
A	Planned	Yes (100 km)	European Landscape Convention:	www…
B	Planned	No	Submarine cable	www.…
C	Under construction	Yes (50 km)	Dense area, OHL	www.…

Definitions:

This section provides an overview of impacts that may qualify an area as environmentally or socially 'sensitive'.

Environmental impact

- Sensitivity regarding biodiversity:
  - Land protected under the following Directives or International Laws:
    - Habitats Directive (92/43)
    - Birds Directive (2009/147)
    - RAMSAR site
    - IUCN key biodiversity areas
    - Other areas protected by national law
  - Land within national parks and areas of outstanding natural beauty
  - Land with cultural significance

Social impact

- Sensitivity regarding population density:
  - Land that is close to densely populated areas (as defined by national legislation). As a general guidance, a dense area should an area where population density is superior to the national mean.
  - Land that is near to schools, day-care centres, or similar facilities
- Sensitivity regarding landscape: protected under the following Directives or International Laws:
  - World heritage
  - Other areas protected by national law

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4 Appendix 4 - Technologies – outlook, perspectives

4.1 Introduction

As we can observe changes in electricity markets requirements, power demand shape, power sources distribution or other external constraints, Transmission System Operators need to anticipate their future needs and participate actively in the research and development of new technologies. For the same reasons, TSOs constantly consider the panel of available technologies and strive to make the best use of them, including technologies considered as unconventional rather than new as their lack of use does not offer the extensive experience shared by conventional technologies.

The technologies employed to date in the transmission grids are efficient, reliable, well-engineered and are widely available for transferring energy in high-voltage grids.

The evolution of technologies depends on several factors. As a matter of fact, documents such as the European "Smart Grids Vision" formulate a demand pull on technology which is fully experienced by TSOs through their deep involvement in R&D projects. The liberalisation of the European electricity market, the massive integration of renewable generation in the system as well as environmental, social and economic constraints constitute the major drivers of this demand pull.

On the other hand, the power industry offers a variety of new and emerging technologies for the evolution of power systems, as observed in many available studies and recently compiled by the "Realisegrid" European co-funded project.

Of course, the present appendix is not bound to give a comprehensive description of all the research done regarding grid operation and development. Moreover, as some projects are considered as demonstration projects rather than network development projects, they do not appear at the TYNDP level.

Therefore, the reader is invited to refer to the ENTSO-E R&D Plan, which describes a plan of around €790 million over ten years.

Research fields that are included in the R&D plan and subsequently in R&D projects managed by ENTSO-E members – and therefore monitored by ENTSO-E – include the following:

- architecture and planning tools for the pan-European network,
- tools to prove the efficiency of technology aimed at increasing both the flexibility and the security of the operation of transmission systems,
- new tools based on simulation technologies that will give rise to new market design options.

In this respect, this appendix only presents a brief illustration of the researched fields to illustrate how transmission projects presented in the "Foreseen Investments on the European Grid" chapter take advantage of the best available technologies to meet present and future grid development challenges.

In the present selection of innovative and unconventional technologies, each technology has its own advantages and drawbacks, which have to be considered and assessed in the context of a given project. As ENTSO-E considers it particularly difficult and delicate to assess a technology in a global way and, apart from given local needs and constraints, the current document does not provide any quantitative assessment or any comparison between the examined technologies.

Indeed, each project is different and therefore inherits different levels of benefits from new technologies. Although some new technologies have been granted a lot of publicity, there is no universal solution for transmission networks so far.

Each project has to be studied with its own characteristics and an assessment of the best fitting technologies.

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4.2 Overview of available or promising technologies today

This section deals with edge technologies as well as with unconventional technologies, i.e. known technologies that have not been widely used for various reasons. Essentially, technologies can be sorted into four categories depending on their maturity:

- Some are *mature*, even though they might not be largely implemented, i.e. they have already proved their general applicability, have been fully developed, tested, their operation within the existing meshed grid has proved reliable and introducing new items is not a technological challenge. DC connections between synchronous and asynchronous areas and Phase Shifting Transformers (PSTs) are examples of such mature technologies.
- Some are *in the large scale testing phase*, i.e. they have been fully developed (laboratory devices work) but their insertion into the existing meshed grid is still being, or to be, tested in order to check they can be reliably operated along with other equipment in all likely situations. For instance, Real Time Thermal Rating (RTTR), and low sag conductors have reached this level of maturity.
- Some are *in the development phase*, i.e. no feasibility questions remain, but some resources are needed to engineer some still missing elements (e.g. some operating IT, some forms of Flexible AC Transmission System – FACTS).
- Some are *in the research phase*, i.e. some key-issue have not yet been solved and hence feasibility is not demonstrated. Typically, distributed storage solutions are today no alternative solution to transmission grid development as their capability regarding power as energy issues is about 100 or 1000 times too small compared to transmission grid requirements. The implementation of superconductors and nanotechnologies is also still being researched with no practical application yet.

This section presents an overview of selected new transmission technologies that have the potential for large scale integration in the transmission grid in Europe in the future.

4.2.1 Transmission technologies (overhead lines and cables)

High Temperature Conductors (HTCs) are able to withstand higher operating temperatures, thus carrying a higher amount of power compared to conventional conductors. However, as the losses depend on the square of the transmitted current, operating at higher rates generates significantly more losses.

HTCs can enhance transmission capacity without impacting the negotiated right-of-way, ideally with minor modifications of transmission towers (mostly clamps and mountings), but this is not always the case. Although existing lines are used, in some countries such projects have to go through the impact assessment procedure again, especially when expected currents are higher due to the increased magnetic field level.

HTCs encompass a broad family of very different technologies in terms of potential for transmission capacity and investment costs level. This explains the diverging viewpoints observed between equipment manufacturers and TSOs: the appropriate selection of a conductor will follow an in-depth analysis of the power system including operational and climatic conditions, fatigue and safety issues as well as the overall investment costs. Gains in capacity can reach 30% for the most used HT Conductors.

HTC costs are generally higher (in some cases much higher) than conventional ACSR (Aluminium Conductor, Steel Reinforced) conductors. Investment cost figures need to be tuned by considering electrical losses, potential structure reinforcement, and installation and maintenance costs. The assessment of performance over the whole life-time through a better understanding of reconductored lines (models, endurance testing and the level of electrical losses) is essential to further extend HTC use.

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Among the studied technologies, *High Temperature Superconducting (HTS) cables* are the ones which are the farthest away from commercial applications. Some optimistic experts believe the first applications of HTS will be before 2020 thanks to a second generation of materials (Yttrium Barium Copper Oxide, YBCO) and advanced deposition technologies, starting at the distribution system level. However, the majority of manufacturers are much more prudent with regards to their use in transmission systems and do not consider any significant application before at least 2030. The costs and size of the cryogenic refrigeration units will remain a major obstacle. Field tests experimentations within very specific situations (short distance, dense urban area, DC applications) will contribute to the further development of the HTS technology blocks.

Illustration: illustrating the above mentioned difficulties, the choice of HTC has been made for several projects of the TYNDP: the 260 km long 400 kV overhead line between France and Italy, the 80 km 400 kv double circuit line between Belgium and France, the ongoing upgrade of a 220 kV line in Poland , in Belgium Horta-Mercator and Gramme-Van Eyck.

The ***High Voltage Direct Current (HVDC)*** technology has proven its reliability and attractiveness for long distance power transmission, long submarine cable links and the interconnection of asynchronous systems. HVDC cables begin to be used also for large on-shore transmission projects.

The most recent technology, the self-commutated Voltage Source Converter (VSC), is more flexible than the more conventional line-commutated Current Source Converter (CSC) since it allows active and reactive power to be controlled independently.

HVDC key benefits are, in terms of increased transmission capacity, compared to conventional HVAC for the same asset size and power flow controllability, which in turn can enhance the stability of the link and of its surrounding environment.

Although the investment costs of a VSC-HVDC converter station are higher than those of an AC substation, the overall investment costs of a DC transmission link can be lower than those of a corresponding AC interconnection if a certain transmission distance is reached (i.e. “break-even” distance). This break-even distance strongly depends on the specific project parameters: it is typically between 100 and 130 km for offshore submarine cable connections, while for onshore applications the break-even distance between an AC and DC OHL is usually in the order of 700 km. Nevertheless, other constraints then have to be taken into account.

Typical applications of VSC-HVDC include active control of flows, interconnection of offshore wind farms, black start functionalities and multi-terminal DC applications. This technology is a key component of future European grid architectures as we can already observe in the TYNDP.

Voltage levels of DC underground and subsea cables will continue to increase considerably. By doing so, and with circuit breakers and switchgear equipment gaining market experience, meshed HVDC networks will become possible.

Illustration: around 45 HVDC projects representing some 10 000 km of lines (up to 800 km for the UK –NO interconnector), mostly undersea and located in north, west, central and south Europe, are described in the TYNDP 2014. Nevertheless, some cables are to be installed onshore, e.g. in France between Haute Normandie and the south of Paris.

Real-Time Thermal Rating (RTTR) – monitored cables/overhead lines, or ***Dynamic Line Rating*** – is on its way to become a mature technology based on the real time control of the thermal rating of an overhead line or a cable. It aims at maximising the capability of a transmission line/cable while respecting design margins, thus reducing potential congestion problems. Its further development will be facilitated by solving some practical integration challenges: integration with other tools, interoperability with protection equipment settings, coordination of RTTR monitored links, communication with SCADA and use of RTTR output values at a dispatch level.

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The combined use of RTTR measurements with weather forecasting might significantly increase the value of RTTR for network operations; this could become an interesting option for TSOs to achieve higher transmission capacity ratings safely and reliably for existing systems at relatively low investment costs (when compared to the investment needed for new transmission links). The challenge here consists of developing more reliable and precise wind forecasts.

Illustration: Real-Time Thermal Rating Projects do not explicitly appear as such in the TYNDP list as they are not considered by TSOs as necessarily directly related to the development of the European transmission grid.

Underground and submarine XLPE (Cross-Linked Poly-Ethene) cables present a potential for transmission. Such cables for HVDC applications are being used increasingly. For HVAC XLPE cables, however, notwithstanding the recent technological progress, the further deployment and consequent cost reduction, the cost barrier (when compared to conventional solutions) is still high and is expected to remain so due to the intrinsic higher complexity and installation constraints of this technology.

Despite this, the cost barrier might be reduced when all the benefits stemming from this technology are considered, such as the consideration of losses during the whole life-time, the duration of authorisation procedures in some countries, visual impacts, etc.

Nevertheless, these underground assets represent a specific risk for operation that has to be carefully analysed: on the one hand this technology is less exposed to external events, but on the other hand it causes long outages when damaged.

Illustration: some above mentioned HVDC projects consider the use of or will use XLPE cables.

Gas Insulated Line (GIL) is a proven yet not widespread technology mostly used in short length installations (exploiting tunnels, bridges, or other existing infrastructures). It allows a much higher amount of power to be carried through a single line than conventional solutions and XLPE cables. Yet, it faces strong environmental concerns in terms of SF6 emissions, which are more than 20 000 times more harmful than CO2 emissions concerning the greenhouse effect, with a cost ratio over conventional solutions that remains high. GIL deployment is likely to continue within niche applications valorising existing nonelectrical infrastructures; much will also depend on the successful implementation of GILs in planned projects at the European level. The first GIL pilot projects as a part of European Grid were commissioned in 2011. 1.9km, Kelsterbach, Germany) will deliver the first experiences in operation soon.

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4.2.2 Substations

Phase Shifting Transformers (PSTs) are a mature technology, implemented by TSOs in Europe to control active power through preventive or curative strategies. PSTs do not increase the capacity of the line themselves, but if some lines are overloaded while capacity is still available on others parallel to them optimising the transits with PSTs can increase the overall grid capacity. In the future, the focus will be on enabling issues: the development of shared PST models by TSOs and standards should facilitate PST integration in transmission systems. In parallel, the development of cross-border power trade and the integration of renewable generation will increase the need for such a technology, possibly operated by power electronics and enhanced by coordinated control protocols implemented within inter-TSO coordination centres.

Illustration: a dozen Phase Shifting Transformers are to be installed in Europe in the coming 10 years, for example in Zandvliet (4th PST on the Belgian north border).

Fault Current Limiters (FCLs) comprise technologies with different degrees of maturity. When addressing new concepts (High Temperature Superconducting FCL, solid-state FCL, hybrid FCL), technology challenges still have to be confronted before a commercial exploitation (especially for High Temperature Superconducting FCLs). The implementation of joint testing facilities by TSOs at the EU level would help the converging of design types and materials, cost reduction and standards and might speed-up the technology take-up for certain niche applications in Europe.

Illustration: such a technology is considered as possible assistance for operations, but does not appear as full part of the TYNDP list of investments.

Flexible Alternating Current Transmission System (FACTS) equipment is a family of power electronics-based devices able to enhance AC system controllability and stability and increase power transfer capability.

FACTS devices can be classified according to their shunt, series or combined types of connection. Shunt type devices present relevant features for reactive power compensation and voltage control, while series devices offer key advantages for active power flow control and transient stability enhancement.

Costs, complexity and reliability issues nowadays represent the main barriers to the integration of these promising technologies from the TSOs' perspective. Up to the present, shunt devices (like the SVC, Static VAR Compensator) have been the most widespread and mature FACTS technologies. Further FACTS penetration will depend on the technology providers' ability to overcome these barriers thanks to more standardisation, interoperability and economies of scale.

Key technology challenges are related to power electronic topologies and the exploration of new types of semiconductors replacing silicon. More user-friendly interfaces and proof of performance through field testing will contribute to improved confidence among TSOs in these new technologies. Like other active equipment (HVDC (VSC) and PST), FACTS will be crucial for the future integration of RES into the European system while also delivering full benefits when subject to a coordinated control in combination with Wide Area Measurement Systems (WAMS).

Illustration: such a technology is considered as a possible help in operations, but does not appear specifically under this name in the TYNDP list of investments. Nevertheless, some TYNDP projects involve banks of capacitors include SVC.

4.2.3 Operating strategies

Wide Area Monitoring System (WAMS) is an information platform with monitoring purposes. Based on *Phasor Measurements Units (PMUs)*, WAMS allow transmission system conditions to be monitored over large areas in view of detecting and further counteracting grid instabilities. This early warning system contributes to increased system reliability by avoiding the spreading of large area disturbances and optimises the use of assets. However, some critical R&D challenges exist in signal accuracy and reliability, communication architectures and data processing.

Standards for data processing, large scale demonstrations possibly in combination with other active equipment, will be needed to estimate the benefits brought by WAMS. There are a lot of on-going projects and investments involving synchrophasors. Currently, one of the CE TSOs WAM data concentrators has links to 22 PMUs from nine TSOs.

Illustration: such a technology is considered as possibly useful in operations, but does not appear as a full part of the TYNDP list of investments.

Electric Storage: although not generally operated by TSOs, electricity storage solutions could have a significant impact on transmission planning and operations. Storage solutions (centralised ones like hydro pumping or decentralised ones like batteries in cars, if and when electric cars are deployed extensively) can provide TSOs with new options to cope with variable power flows.

Storage could help maximise electricity system stability in case of any sudden drop/surge due to the variability of most RES generation plants. It could also support CO2 emission abatement targets either during off-peak periods by avoiding electricity spillage or during peak periods in the case of a generation mix that is highly fossil fuel dependent.

Historically, storage is related to technologies like Pumped Hydro and Compressed Air Energy Storage, whereas other storage technologies do not clearly address large scale system issues. Despite this, there are still technical and mostly regulatory issues to be faced. In terms of regulatory issues, open questions are related to which players (private market operators contributing to system optimisation or regulated operators) shall own and manage storage facilities. Implementing large scale demonstrations of storage solutions at the European level appears to be a necessary step to validate both storage benefits based on full scale studies and the potential asset ownership options for storage regulations.

Illustration: currently, there are around 15 projects among Europe which are limited to the connection of hydro pump power plants, mainly in Switzerland, Austria, Romania, Spain and Portugal. As for storage demonstration projects, the TWENTIES project involving several ENTSO-E members responding to the ENERGY 2009.7.1.1 call (the optimisation of the electricity grid with large scale renewables and storage) can be quoted, as well as the Almacena project in Spain.

4.3 Conclusion

As already mentioned, European TSOs are supporting the development of the above-mentioned new technologies by testing new products supplied by manufacturers and testing new technologies, thus influencing the improvement of the most relevant technologies. In fact TSOs are frontrunners in all these advances in new technologies, while carefully choosing the most promising ones.

Some of the technologies are still in a premature state and a large scale integration of these technologies in the transmission grid is not possible due to reliability constraints. As the TSOs have the responsibility for the whole electrical system in their control zone, precaution is needed with respect to the introduction of new technologies.

As a matter of fact, none of the examined technologies are a universal solution. Each project has to be considered in a dedicated study assessing the best fitting technologies.

For that reason, some technologies play a real role in the European TSOs' transmission projects in the next 10 years while some other technologies do not appear as their level of maturity and reliability are not yet satisfactory within this timeframe.

Moreover, as some projects are considered as demonstrations rather than network development projects, they do not appear at the TYNDP level. The ENTSO-E R&D Plan provides a larger and exhaustive approach of projects involving new technologies, and for that reason the reader is invited to refer to this document in order to get more detailed information regarding new technologies.

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5 Appendix 5 - Dynamic Studies – Relevance and Challenges to secure the energy transition

A strong development in electricity system infrastructure and the integration of Renewable Energy Sources (RES) has been seen across Europe in recent years and is expected to continue.

In order to meet the targets for RES, the low carbon future of Europe and the effective implementation of the internal electricity market whilst also maintaining a secure system operation, an adequate analysis of the stability conditions of the power system following large and small disturbances, on a short- and long-term basis, is becoming more and more relevant. In part this is due to the fact that the increasing levels of non-synchronously connected RES, distributed generation and long distance bulk power-flows directly impact and put added emphasis on the system's dynamic performance.

The transmission system steady-state capacity objective is often a central driver in network development but the emerging challenges call for new and more encompassing ways to analyse problems and find solutions, namely from the power system stability point of view, to accommodate targets and challenges in a secure, efficient and reliable way.

The successful transition towards the future power system targets will require not only the necessary transmission system reinforcements but also new procedures and rules for the market and operation, as well as adequate technical capabilities for generators, demand users and HVDC connections (the expected implementation of the network codes following Regulation (EC) 714/2009).

To illustrate how the emerging challenges fit in power system stability analysis in a comprehensive approach that necessarily includes TYNDP plans, the following chapters present a brief description of the different dynamic phenomena, relevant associated studies and the inherent methods and modelling challenges that are being faced.

5.1 Power system stability analysis

Power system stability refers to the ability of a power system to remain intact and settle at a new equilibrium following a physical disturbance. Figure 5-1 The figure below illustrates the “power system stability tree”. Stability is typically divided into three aspects: rotor angle stability, frequency stability and voltage stability. In a synchronous system these three aspects tend to interact, however at any given time and depending on system conditions any one may become dominant.

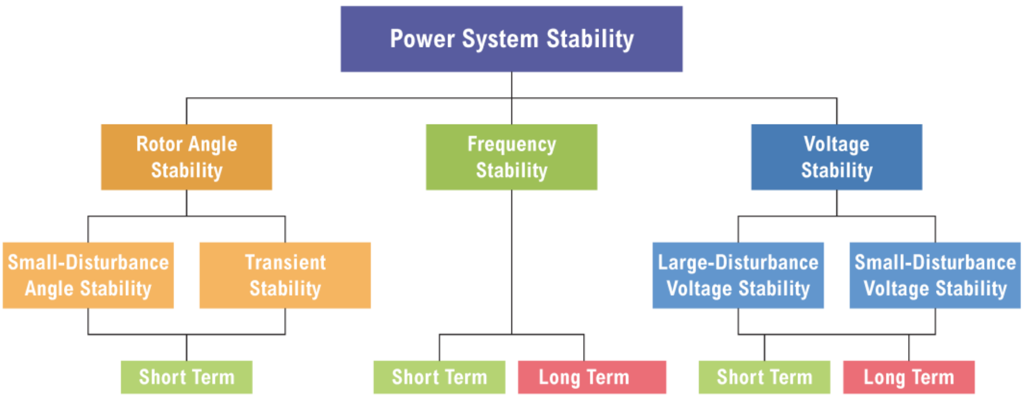

Figure 5-1 IEEE/CIGRÉ Classification of power system stability

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Rotor angle stability has usually been the focus of stability analysis, but in the new system paradigm frequency and voltage related stability phenomena have also become a central aspect.

Rotor angle stability is dependent on the torque balance and can be further divided into two categories:

- **Small disturbance angle stability** is concerned with the ability of the power system to maintain synchronous operation under small disturbances such as switching events. Small disturbance angle instability generally arises due to the lack of damping torque supplied by the synchronous generators that results in low frequency power oscillations in the range of 0.1-3Hz.
- **Transient stability** describes the ability of the power system or groups of generators to maintain synchronous operation during large disturbances (e.g. a short circuit fault or a loss of in-feed). For example, during a fault, the mechanical input power of the affected generator or group of generators is much higher than the electrical output power, causing these machines to speed up and lose synchronism with the system if the fault is not cleared quickly enough.

Frequency stability is dependent on the balance between active power supplied by generation and the power drawn by loads within a synchronous area. Frequency stability characterises the ability of the system to maintain frequency within prescribed limits in order to prevent loads and generators from disconnecting from the system following a loss of in-feed or other incidents on the system.

Frequency stability is closely related to system inertia, i.e. the amount of energy stored in the rotating mass of the synchronous generators. During a disturbance, this power is extracted from/drawn into this energy storage; this in turn determines frequency deviations. The lower the system inertia (and therefore the stored energy), the steeper the frequency deviation will be, e.g. in case of a generation or load outage. Other important aspects related to frequency stability are the different dependencies of active power and frequency (i.e. the frequency sensitivity of generators, loads and, as a last resort measure, load shedding schemes).

Voltage stability describes the ability of the power system to maintain steady voltages on all buses of the system following a disturbance. Voltage stability is related to the reactive power balance both locally and across the system. In transmission grids, voltage instability is usually observed at a regional level. A possible outcome of voltage instability is the loss of load in an area or the tripping of transmission lines and other elements by their protective systems leading to cascading outages.

Based on the above stability phenomena, the impact of the future system paradigm can be summarised as follows, including both challenges and solutions:

- Displacement of conventional generation in favour of non-synchronously connected RES; this directly affects the system in terms of all power system stability phenomena, given that there is a reduction of system inertia, a reduction of reactive reserves from synchronous generation and a reduction in the number of voltage and power system stabiliser devices.
- Emergence of converter based generators; this will put emphasis on concerns related to frequency and voltage control capabilities, not the loss of synchronism in these generators. Reduction of short-circuit power also raises the difficulty of assessing system strength.
- Long distance AC bulk power flows; this will put emphasis on voltage stability issues and will further stress the reduction of reactive reserves from synchronous generation.
- Technical functions necessary for stable system operation that today are provided by large synchronous generators will be delivered by the new players and will be significantly based on the provisions established by the Grid connection Network Codes.
- New capabilities, devices and solutions such as Demand Side Response, FACTS and HVDC connections; this will provide significant changes to network dynamic performance.
- Market decisions leading to highly fluctuating allocation of generation; this will also affect regional system dynamics.

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The relevance of these aspects varies from one synchronous area to another and from one TSO to another depending on factors such as generation mix and network architecture. For this reason, the priority and detail at which the stability phenomena need to be analysed also varies.

5.2 Stability studies: main drivers and scope

Stability studies covering the aforementioned aspects of system stability already represent a common and frequent tool for network planning and operation across Europe.

Numerous studies have also been performed in recent years focusing on different network phenomena, the scope of analysis and objectives. Depending on the particular objectives and phenomena under investigation, stability studies have required analysis ranging from the TSO level up to the synchronous area level.

5.2.1 Synchronous area level

Examples of drivers that require synchronous area level studies are expansions a synchronous areas or the assessment of the impact of the substantial shift from synchronous to non-synchronous generators. Phenomena associated with these studies are **transient**, **small signal** and **frequency stability**.

Frequency stability phenomena are of particular interest for smaller, if compared to Continental Europe, synchronous areas. However, in a context of high RES penetration, it may become significant even for larger systems in specific situations. For large interconnected power systems a frequency stability study is also commonly associated with conditions following the splitting of systems into islands (e.g. the 4th November 2006 UCTE split).

Some relevant examples of wide area studies performed in the past are: “Inter-Area Oscillations in the UCTE/CENTREL Power System”; “Synchronous Interconnection of the IPS/UPS with UCTE”; “Turkey Interconnection to Continental European Synchronous Area”; and the “European Wind Integration Study (EWIS)”.

5.2.2 Regional/bilateral level

At the regional/bilateral level an important driver is the development and reinforcement of interconnections of different regions within the same synchronous area. Given the importance of electrical interconnections within Europe, there are currently about fifty projects being developed to enhance existing interconnections in accordance with directives from the European Union.

In particular, HVDC interconnections will be a challenging issue in the following years. The stability studies carried out in the context of such projects, in order to assess the general dynamic performance of the HVDC controls, are usually transient stability to assess for example voltage support controls of the HVDC link, and small signal stability studies to assess for example the power oscillation damping control of the HVDC link. An example of a project for which such stability studies have been performed is INELFE (Electrical Interconnection between France and Spain), with a VSC based HVDC link.

Phenomena associated with these studies are **transient**, **small signal** and **voltage stability**.

5.2.3 Local/TSO level

Some examples of drivers for local/TSO level studies are:

- In case of heavily loaded networks, and/or large imports, long-term voltage stability studies are often necessary to assess the risk of voltage collapse phenomena.
- Transient stability studies are often necessary to assess the impact on the power system of a given set of disturbances and to check power system stability margins.
- Other studies can be performed at the TSO level if necessary. Examples are the connection process of a generator or a demand facility whose dynamic performance may have an impact on the overall

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system security or more specific studies aiming to improve the stability of single machines (local mode oscillations).

Phenomena associated with these studies are essentially **transient** and **voltage stability**.

Since voltage stability studies investigate longer term effects (a few seconds to minutes), they are subject to the specific objectives of the studies and modelling (secondary voltage control if it exists, on-load tap changers, etc.). As the consequences are related to the voltage profile, they could be considered as local, and be handled at the TSO level or the regional when involving two large areas of different TSOs exchanging energy. In both cases, an appropriate representation of the neighbouring TSOs' voltage sources is required, such as in France where voltage collapse is watched particularly closely in the north and south west in cases of high consumption.

5.3 Modelling challenges

Besides the well-known increased challenges in dynamic analysis, both from the modelling and required computational resources points of view, when compared to steady-state analysis further relevant challenges can be highlighted.

- The penetration of RES connected via power electronics is growing continuously. Power electronics exhibit different characteristics compared to conventional generating units. Their dynamics are determined by controls, even in the sub-transient time frame. For that reason simulation models are generally manufacturer specific. For large scale power system stability studies, however, standard models are necessary. Moreover, different types of models might be needed depending on whether local or remote impacts of RES are analysed.
- Generating units are to a significant extent connected to the distribution system, i.e. the adequate representation of distribution systems is gaining an increasing importance. In this case, the modelling process is considerably different from transmission-connected generation. Aggregated information and methods for aggregation are needed. As a consequence, DSO network modelling requires the involvement of DSOs and close cooperation between TSOs and DSOs.
- Modelling of loads has also become increasingly important either due to their effect on frequency and voltage or their demand side response capabilities.
- At this time the significance of HVDC links is also increasing. Here as well important standardisation work is urgently needed to develop standard models for large scale power system stability analysis.
- Studying the stability phenomena described in the outline of this document is sufficient for power systems that are dominated or at least significantly impacted by conventional generating units. Once a power system is dominated by power electronics, e.g. for offshore wind-farm connections, the interaction of controls and control instabilities becomes an issue as well, which can open the analysis for areas such as electromagnetic transients.

The level of detail of the dynamic model to be used depends on the type of study. For a transient stability and voltage stability study, a detailed model of the TSOs/regions plus a dynamic equivalent of the rest of the system is sufficient. In a frequency stability or small signal stability study, even if it is performed on a regional level, the complete model of the synchronous area is generally deemed necessary since both involve the entire synchronous area. However, the models needed for such studies are specific to each phenomenon. This stresses the importance of cooperation, quality models and standardisation:

- Cooperation between TSOs is required to build a reliable dynamic model of the zone under investigation and relevant equivalents.

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- Given many existing confidentiality arrangements concerning the dynamic models of the generators and of some specific loads, alternatives that meet a good balance between the accuracy of the model and the generic purpose of the model need to be considered and studied.
- The use of standard models requires manufacturers to parameterise these models accordingly and to make them available to power plant operators and TSOs. In that respect appropriate conditions have to be set out to facilitate the exchange of the necessary data between the involved parties.

5.4 Conclusion

Maintaining system security in the European interconnected electrical power system is the superordinate objective of the European TSOs. The previous chapters of this document show the different aspects of stability and explained how a loss of stability may affect the security of supply of the whole interconnected system.

Today, TSOs perform stability analysis covering the current needs in response to relevant impacts on system security. The classification of stability and the focus of various stability studies being performed by the TSOs have been described in this document.

The foreseen future development of the European electricity market and the decarbonisation of electric power generation is expected to lead to higher power transfers in the transmission system and to a significant change of the generation pattern. Although the system steady-state capacity objective will generally remain the central driver in network development, system dynamic performance will have an increasing impact. To identify evolving risks and initiate risk mitigation measures in time, the evaluation of dynamic system performance using appropriate power system stability studies has become more relevant.

Depending on the aspect of stability focused on during a study, different levels of analysis and detail are appropriate. Similar to studies requiring adequate information from both the network and its connected users, various dynamic studies also require an adequate exchange of information between TSOs. This information covers data, methodologies and assumptions. While for some phenomena national studies may still give the most adequate perspective, others that require wider observation may be performed in co-operation in the framework of ENTSO-E, e.g. in regional groups. Such an approach allows the European TSOs to address all future challenges in an efficient way.

Furthermore, TYNDP as a central part in the development of the European system will continuously evolve to take into account the relevant aspects of prudent planning practice.

Thus, all stakeholders including TSOs, DSOs, consumers, conventional and renewable generation units need to co-operate to maintaining system stability after normative and exceptional contingencies. This cooperation includes not only exchanges of data and models to perform necessary dynamic studies but also contributions to measures designed to increase system stability. This effort should allow the aforementioned European goals to be maximised in an efficient manner both from the technical and economic perspective.

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6 Appendix 6 - Long-term development of the pan-European Electricity Highways System for 2050

Renewable electricity sources are rapidly expanding in Europe, like in other parts of the world. Electricity is expected to be transported over longer and longer distances, and therefore across national borders, in order to be delivered where consumption needs arise. A pan-European network is required to enable more power exchanges between Transmission System Operators (TSOs), whilst also taking care of different generation and consumption profiles and integrating wind energy from the North Sea, solar energy from North Africa and biomass from eastern countries. Such a long distance and meshed transmission network at the pan-European level gives birth to the innovative concept of an “Electricity Highway System” (EHS).

After defining a comprehensive set of boundary conditions which set the planning study limits, the developed methodology generates candidate grid architectures which are able to meet the challenges of electricity markets between 2020 and 2050; the implemented scenario-based planning approach takes into account technological, financial/economic, environmental and socio-political issues in order to propose sustainable and efficient grid architectures for Europe up to 2050.

One challenge is to define a grid model with an appropriate level of description of the pan-European grid, taking into account the geographical dispersion of generation and demand and the transmission network evolution from 2020 to 2050. A generation clustering technique to describe the pan-European grid is developed in order to model this complex meshed network. The scenario simulations are then performed on a pan-European grid model: grid architecture options are proposed, capable of alleviating the detected overloads in 2050 and implementing a modular grid development plan between 2020 and 2050. A portfolio of candidate grid architectures is then selected, taking into account the technologies and solutions such as AC interconnections, DC interconnections, hybrid AC/DC interconnections, or power electronics to better control flows over long distances.

In order to assess the candidate grid architectures, a new cost benefit methodology is elaborated to compare the new transmission investments using a socio-economic impact analysis involving the costs, the risks and the benefits for society and stakeholders. This analysis of the pan-European grid architectures will encompass each of the scenarios with the aim of ranking them according to the above mentioned cost benefit assessment.

This chapter explains the methodology developed by the project in order to provide the scenarios, the tentative grid models and the methodology developed to provide the candidate grid architectures for 2050.

6.1 Introduction

ENTSO-E has identified the main elements enabling transmission system operators (TSOs) to keep up with the objectives of the EC to accelerate the designing and planning the future energy system looking at the 2050 horizon. The time horizon of the framework covers the period after the Ten-Year Network Development Plan (TYNDP), i.e. post 2030.

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A long-distance and meshed transmission network at the pan-European level introduces the opportunity for the innovative concept of “electricity highways” as shown in the figure below. The development of such novel infrastructures requires new top-down planning approaches over longer time frames, with the development of scenarios. This enables the system to cope with intrinsic uncertainties linked to the evolution of generation, demand and exchanges with neighbouring regions, and also the progress of technology solutions. ENTSO-E provides the TYNDP, which already includes a methodology for a pan-European network and offers visibility within a 10-year horizon. The methodology useful in the longer term must take into account more scenarios as the evolution of generation, demand and exchange with neighbouring regions are uncertain. The methodology must also design different technical solutions for the development of the electricity highways (e.g. VHAC, DC, mix, bulk power transmission means, etc.). The set of the most relevant scenarios with different ways to reach the 2050 targets establishes the Modular Plan towards 2050.

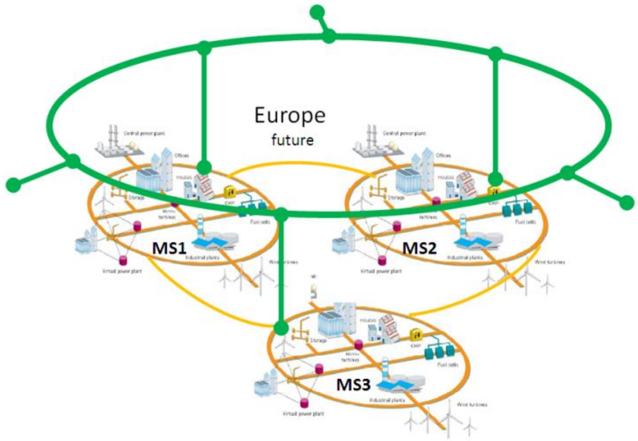

Figure 6-16-2 Electricity Highways System concept

With the objective of reducing Green House Gas (GHG) emissions to 80%-95% below 1990 levels by 2050, the European Union has analysed the implications for the energy sector in the Energy Roadmap 2050, in which how this goal can be achieved is investigated taking into account different scenarios.

In this perspective of very ambitious targets for GHG emissions reduction, the Renewable Energy Sources should represent the main part of the energy mix in Europe and be developed in different locations, often far away from major consumption sites. Electricity should be transported over longer distances, across national borders, to be delivered where the consumption needs arise. Such a long-distance and meshed transmission network at the pan-European level introduces the opportunity or the innovative concept of an ‘Electricity Highways System’ (EHS).

In response to the ENERGY.2012.7.2.1 call of the 7th Framework Programme (FP7) of the European Commission, a consortium of 28 partners involving a wide spectrum of stakeholders launched the "e-Highway2050" project in September 2012. The project aims to deliver a top-down methodology to support the planning of a pan-European EHS capable of meeting European needs for electricity transmission between 2020 and 2050. The final results of the project should be published by the end of 2015.

This chapter presents the first results of the e-Highway 2050 project, focusing on the scenario building and on the construction of the grid architecture, which are key issues of the project.

6.2 Objectives of the project

The project develops methods and tools to support the planning of an Electricity Highways System, based on various future power system scenarios including back-up and balancing generation as well as storage capacities, and develops options for a pan-European grid architecture under different scenarios, taking into account the benefits, costs and risks for each of them. The newly developed top-down methodology, which addresses the transition planning between 2020, 2030, 2040 and 2050, is built around five main steps (see Figure below):

1. the development and application of an approach to design different long-term energy generation, exchange and consumption scenarios, based on macro-economic data;
2. power localisation using the assumptions about generation mix exchanges and consumption for each scenario at the country and cluster level;
3. the network simulation in order to identify the possible weak points of the transmission grid in case there is no reinforcement;
4. the identification of optimised grid architecture in 2050, involving the foreseen generation and demand profiles, while taking into account storage, demand-side management and transmission technologies available by 2050;
5. the development of implementation routes from 2020 to 2050 for the pan-European transmission system, covering each of the studied scenarios and being optimised by taking into account social welfare, environmental constraints, as well as grid operations and governance issues.

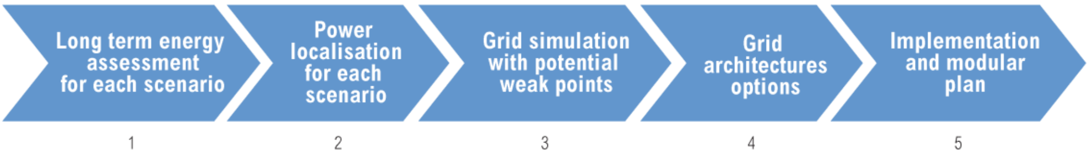

Figure 6-4 The five main steps of e-Highway2050 project

6.3 The development of scenarios

The scenario development work is based on the assumption that GHG emissions should be reduced between 80-95% by 2050 compared to the estimated 1990 levels. This is a major policy assumption set at the European Union level to shape a challenging 2050 horizon.

The scenario building process in e-Highway2050 consists of seven main steps (see Figure 3).

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1. The approach starts by defining a number of uncertainties that will influence the future developments but cannot be controlled by the decision makers, as well as technical and non-technical options that can be chosen by the decision makers. Boundary Conditions are specified (with upper and lower limit values) for the different uncertainties and options.

Example: in the technology domain, the development of electricity transmission system is an uncertainty); on the contrary, the development of distributed generation is an option.

In the economic domain, the GDP growth is an uncertainty, as is the demography.

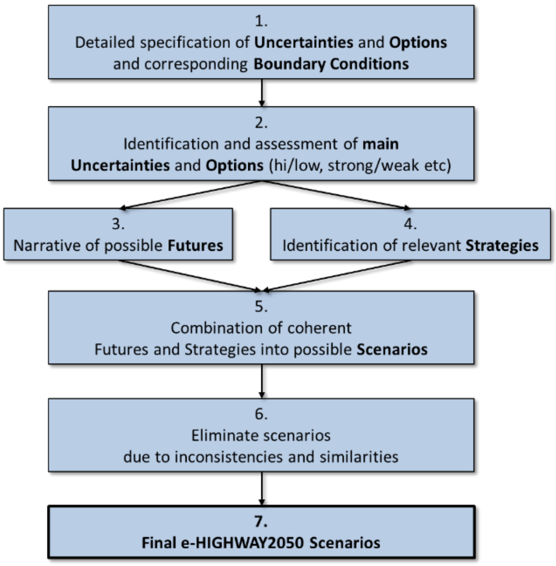

Figure 6-5 the scenario building process

2. To limit the possible combinations to a tractable number, the main Uncertainties and Options are selected, for which the boundaries are specified in the form of numerical values (min, max, average).
3. The main Uncertainties are combined into possible Futures that are narrated in a verbal way.

In the project, five futures were set up: Green Globe, Green EU, EU-Market, Big is beautiful, Small things matter. They take into account energy and climate possible policies as well as assumptions on technological development and economic and socio-political perceptions.

4. In parallel, the main Options are combined into relevant Strategies for the EHS implementation in different possible Futures.

In the project, six strategies were developed (Market led, Large scale RES, Local solutions, 100% RES, Carbon free CCS and nuclear, and No nuclear), the main differences being the level of deployment for centralised/decentralised generation, the source of RES electricity, nuclear and fossil fuels, as well as the level of imports/exports with countries outside EU28.

5. A combination of a Future and a Strategy is a possible Scenario. Multiple scenarios are then generated by trying several different strategies within the same future, or by testing one strategy in many possible futures.
6. The resulting number of Scenarios (= Futures x Strategies) from Step 5 is too large for the amount of analyses to be carried out for each scenario in the work packages of e-Highway2050. Thus, an extra step is performed to reduce the number of possible scenarios. First, a more detailed check for inconsistencies is performed between the different Uncertainties, between the different Options and between the Uncertainties and Options. Second, we assess how each scenario is assumed to impact on the development of EHS in terms of Generation, Demand and Exchange (G/D/E). Scenarios that have a similar impact on G/D/E developments can be combined into one scenario. This reduction process aims to select the most challenging scenarios from the point of view of grid development and the implementation of EHS.
7. Finally, after a detailed process of evaluation, selection and elimination, a set of agreed e-Highway2050 scenarios is proposed.

A thorough scanning of uncertainties and options has been performed according to their ranking in decreasing order of importance. The main criteria used during this ranking process include:

- an e-Highway2050 scenario is relevant when it challenges the entire existing European electricity system, not just the grid;
- the selected e-Highway2050 scenarios should substantially differ from each other in coherence with the identified boundary conditions;
- some of the e-Highway2050 scenarios should challenge the electricity system in a way which differs from the current state of affairs.

Finally, the seven-step filtering process leads to the five following scenarios:

- S1- Big and market,
- S2- Large fossil fuel with CCS and nuclear,
- S3- Large scale RES & no emission,
- S4- 100% RES,
- S5- Small and local.

It must be pointed out that the e-Highway2050 project does not recommend or prefer one or more scenarios when compared to others and does not conclude that one scenario is more likely to happen.

6.4 The European network modelling

The next step of the methodology aims to define the installed capacities in relation to the estimated overall electricity demand for 2050 and conduct a grid development process to determine the grid infrastructures in 2050. The grid development process mainly consists of generation scheduling and unit commitment optimisation, as well as load flow analysis at the nodal level.
Simulations of the EU transmission network taking into account the 10000 electrical nodes are not tractable for the project and therefore a clustering approach has been introduced in order to reduce the level of description of the grid.

The geographical clustering process is performed to split Europe and its countries into smaller parts relevant for system modelling. The basis for this analysis has been the Nomenclature of Territorial Units for Statistics (NUTS3 regions) which is set by Eurostat. The clustering is based on real system characteristics in order to represent the underlying transmission system appropriately and it had to be ensured that the chosen clusters were valid for all scenarios. This has enabled the creation of clusters that combine all possible development paths and do not differ between scenarios, allowing a comprehensive comparison of different architectures in the results of the different energy scenarios presented in the previous chapter.

The criteria used are:

- population,
- potential of RES generation,
- land use - availability of the areas,
- installed generation capacity (thermal and hydro),
- network density (degree of meshing and grid constraints),
- assignment of RES priority areas.

In the first round, an algorithm is applied considering the first four criteria (measureable criteria). The optimisation is designed to join together the incremental NUTS-regions in a way that homogenous clusters are reached.

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In the second round, the network density is taken into account for the optimisation of the clusters.

Then, the clusters are used for the definition of transmission equivalents. The starting point is the existing transmission system, including the grid reinforcements already planned for the next decade. This whole picture is provided by the Ten Year Network Development Plan. This basis for grid reduction ensured that the European grid model is based on the most accurate information about the available transmission system.

The determination of transmission equivalents, enabling scheduled unit commitment optimisation and grid analysis, leads to two main indicators. A transmission equivalent is characterised by its thermal capacity and impedance; the latter describes the load flow distribution within the network. Equivalent lines are only introduced between adjacent clusters sharing at least one interconnection line in reality.

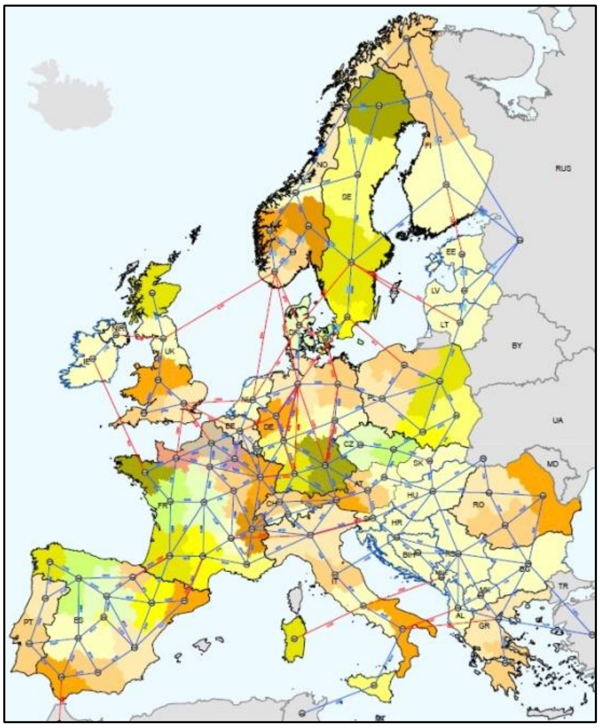

Figure 6-6 pan-European Grid Model.

The methodology chosen to determine the thermal capacity of the transmission equivalent has been derived from the European Network TSO-E (ENTSO-E) methodology to assess the Net Transfer Capacity (NTC) value between two neighbouring countries.

The purpose of Z-equivalents in the grid model is to estimate the load flows of the reduced system in comparison to the real flows on the borders between clusters. The methodology used searches for an optimal impedance matrix that minimises the mean to Root Mean Square Error (RMSE) for the difference between the initial flows of the nodal and the reduced network for each transmission equivalent.

The final pan-European cluster model, as a result of the clustering and grid reduction, is shown in Figure 4.

6.5 Localisation of generation and load

After the development of the European grid model the scenario quantification process is performed, meaning generation and demand localisation. For each scenario and cluster, the installed capacities of the different generation technologies, the demand values and exchanges with neighbouring countries (outside the EU28) must be identified. In this respect, a top-down quantification approach is applied where installed capacities and demand are quantified in three steps.

As a first step, the quantification is performed at macro-area level, gathering together several countries (e.g. Northern-Europe consists of Norway, Sweden and Finland). The determined values for macro-areas are then broken down to the country-level (second step). In step 3, the country level values are distributed across the clusters.

Macro-area level (step 1): a “pre-conditioning” is performed, which sets the volumes for each macro-zone of annual energy generation, the demand and the corresponding installed capacities at the macro-area level. Then, a market simulator is launched using the input of the previous step. This process takes into account the variability and stochasticity of both renewable generation and demand by performing system adequacy analyses for the operation of the power system on an hourly basis, relying on a simplified merit-order algorithm and without consideration of internal grid constrains (copper plate).

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Country level (step 2): a first-order distribution of the generation, demand and exchange figures per country is given within each "macro-area" for each scenario. The following questions are then addressed: "What does the top-down quantification mean for each country?"; "How do different country trends/polices affect the top-down quantification?". This step includes techno-economic and policy aspects explicitly, which control and affect the distribution of Generation /Demand /Exchange figures from the macro-area to country level.

Cluster level (step 3): generation, demand and exchange figures defined at the country level are distributed into individual clusters.
In this last step there is no evaluation of the system adequacy or overall fulfilment of the Green House Gas targets. It is assumed that the determined values verify both constraints (system adequacy and emission targets).

The next step in the overall analyses of the e-Highway2050 is to develop an overlay transmission system capable of providing exchange capacities, allowing free power flows to reach these targets.

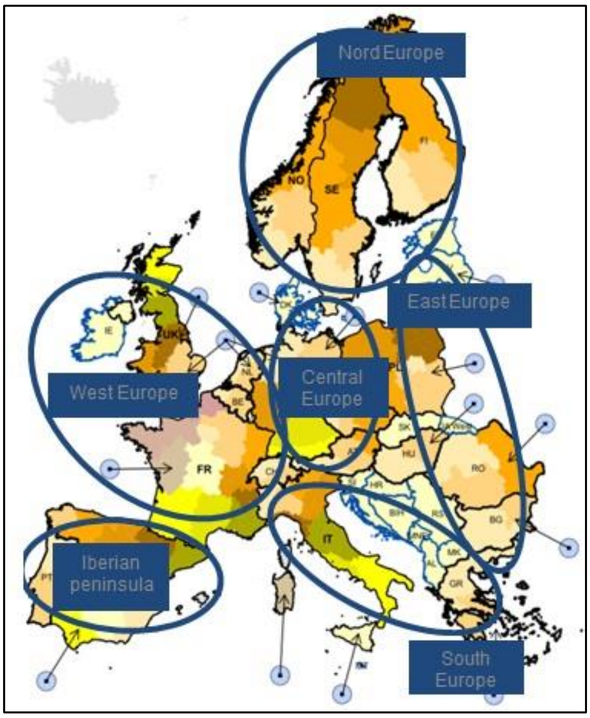

Figure 6-86 Macro-Areas – Countries – Clusters.

6.6 The technology assessment of the grid architecture

After the power localisation (G/D/E) for each scenario, at the country and cluster level, the objective is to identify the possible weak points, the congestion points in the transmission grid, in case there is no reinforcement.

The next step of the overall methodology aims at identifying grid architectures in 2050, solving the congestions. In this respect, a portfolio of technologies (generation, storage, transmission, and demand) has been selected according to their impact on transmission networks with regard to planning issues by 2050. For generation, storage and transmission technologies, the portfolio has been constructed based upon expert views.

For demand-side technologies, a specific methodology has been proposed on the basis of the technology changes criticality induced by the future demand-side, impacting the transmission system in 2050. The proposed approach has been designed in two successive steps: firstly, a selection of end-uses based on the assessment of their criticality and, secondly, for each of the retained end-uses technologies which are the driving factor of the criticality have been identified.

As a consequence, the database is organised, according to the technologies, which are listed as follows:

- *generation and storage technologies*: hydropower; PV; concentrated solar power; wind power; geothermal; gas turbines; hard coal and lignite with or without CCS (Carbon Capture and Storage); nuclear power; biomass and biogas; pumped-hydro; CAES (Compressed Air Energy Storage); electrochemical storage.
- *demand-side technologies*: electric vehicles; heat pumps; lighting (Light Emitting Diodes and Organic LED).

- *passive transmission technologies*: high voltage (HV)AC and DC cables (submarine and underground); HVAC and DC overhead lines; high temperature conductors; combination of HVAC/HVDC transmission solutions; gas insulated lines; superconductors.
- *active transmission technologies*: converters for HVDC (CSC and VSC); FACTS (shunt and series); phase shift transformers and transformers with tap changers; protection and control at substation and at system level.

Apart from the data gathering process, two major difficulties have been addressed: uncertainties and contextualisation.

- Uncertainties refer to the intervals of confidence of the values for given variables. For example, the value of a given variable in 2050 cannot be determined with a probability of 1, i.e. 2100 MW (if one considers for instance the maximum power for a VSC station in 2050); it should instead be 2100 MW (+/- 10%) or [2080-2265] MW (it may vary within a min max interval). The increasing uncertainty over time has been a major difficulty when assessing numerical values for several data types, such as costs or technical performances.
- Contextualisation refers to the different values that might be taken by a variable depending on the e-Highway2050 scenario. For example, in the scenario *100% RES*, with a high penetration of large scale renewables at 2050, one can expect that the installation costs of a VSC substation might be different from the ones in a scenario where renewables reach a lower penetration level and the thermal electricity generation is roughly at the same level as today (*Large fossil & nuclear*). In the latter, one could expect that the installation costs of a VSC station would be higher than in the former.

The key assumption of the approach is that the main driver for contextualisation is the penetration rate of the considered technology (the cumulative number of units at a given time). It is indeed assumed that the cost and performance trends of a technology by 2050 are directly correlated to its level of deployment. A generic methodology has been developed for all technologies, and the successive steps are displayed as follows in the particular case of electric vehicles (EVs) for the sake of clarity:

1. an overall qualitative assessment is made which reflects for the given scenario the deployment level of EVs on a three degree scale (Low, Medium, High);
2. in parallel, a subset of key technology variables describing EVs is selected, for example the penetration level (number of units by 2050), performances (driving range) and costs (battery and vehicle),);
3. from the value ranges attached to the selected key technology variables, the minimum, average and maximum values are extracted;
4. by combining the scenario assessments made during step 1 and the EV value tables built at step 3, specific values are allocated to the subset of EV variables (key technology variables) according to each given scenario (mapping of the minimum, average, maximum values with the Low, Medium, High scale depending on the type of variable).

The table below displays the results of data contextualisation for BEVs (Battery EVs). Each scenario corresponds to a given penetration rate (High, Medium, Low) according to the analysis described above. The values of specific variables for each scenario are displayed.

Table 6-1 data contextualisation for Battery Electric Vehicles

Variables	unit	2013	2050		
Penetration level	-	-	low	medium	high
Number of units	Million	0.05	52	104,5	157

Driving range	km	150	250	450	650
Battery cost	€/kWh	450	250	195	140
Consumption	kWh/km	0,16	0,1	0,095	0,09
Battery capacity	kWh	24	25	42,75	58,5

As an example, this means that for a scenario where the penetration of BEVs is Low, it is expected that the battery costs (250 €/kWh) will be higher than in a scenario where the penetration of BEVs is High (140 €/kWh), because of the economies of scale, the higher investment in R&D, etc. when more vehicles are produced.

6.7 The socio-economic impact

After defining different alternative grid architectures for 2050, the objective is to rank them according to their cost efficiency. In this respect a Cost Benefit Analysis (CBA) methodology is developed. It includes a full range of technical-economic aspects. In a following phase, this methodology will be used in order to assess the best investment path till 2050 ("pan-European modular plan") for each of the five selected project scenarios. This assessment constitutes the ultimate goal of the e-Highway2050 project.

The basic idea of the CBA is to scan all aspects that make up the costs and benefits of a new grid infrastructure with a particular focus on long distance trans-national transmission infrastructures like electricity highways. These components can be grouped into four categories, as shown in the figure:

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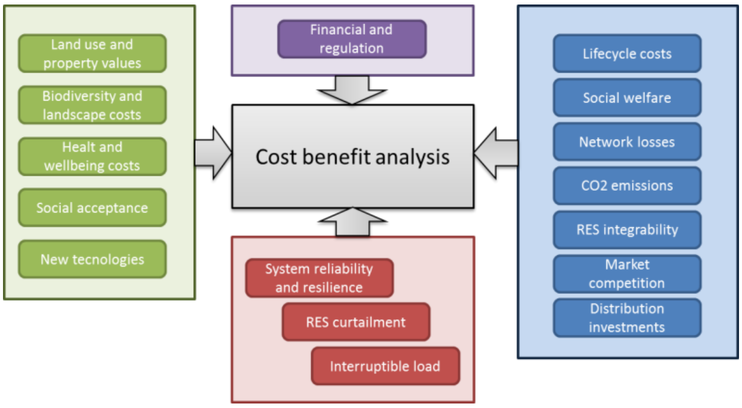
- **Economic profitability analysis:** this includes all the main aspects that have a direct economic impact on the system, such as lifecycle costs, benefits for social welfare, costs of network losses, benefits of RES integration and CO2 emission reduction, as well as innovative contributions related to the impact of market power and synergies with the distribution of network investments.



- **Socio – environmental and technological issues**: this deals with social and environmental costs tied with the development of the infrastructure under examination and extra benefits provided by new technologies. This includes: right of way compensation costs, possible extra costs for the deployment of new infrastructures in sensible areas close to inhabited centres, and project approval delays due to social opposition. Moreover, the impact of new technologies in terms of flexibility of operation is further investigated.
- **Security of supply**: this deals with aspects tied to system security: costs for service interruption and for RES curtailments, system resilience (in terms of capacity to withstand possible unforeseen events that are not included in the reference scenarios). The main indicators included in this topic are system reliability, system resilience, interruptible load costs and RES curtailment compensation (if any).
- **Financial and regulatory aspects**: this deals with the different costs (directly affecting the Net Present Value calculation) that different grid expansion initiatives could be subject to due to the different levels of risk and to the different regulatory regimes allowing investment recovery. The main drivers investigated refer to network ownership, regulation, financing and risks.

Particular attention is devoted to obtain an exhaustive list of non-overlapping cost/benefit factors. All these elements are quantified in monetary terms and can simply be added up in order to obtain a scoring parameter able to compare alternative grid architectures. Most of the elements described are directly accounted for in the CBA, while others are considered for further sensitivity analyses aimed at adding further elements to the analysis.

In order to account for uncertainties tied with the scenario realisation, an additional parameter characterising the specific grid architecture has been introduced: the flexibility of a transmission alternative is defined as the ability to preserve its effectiveness for the system against possible changes in the scenario realisation. A set of investments is flexible if it keeps high standards in the cost benefit analysis whatever the scenario realisation during the target year, thus resulting in a good choice for all defined scenarios. Flexibility is implemented in the CBA as an extra sensitivity parameter.

Finally, an extra sensitivity analysis can be performed by assessing the variability of the scoring result obtained within a single scenario, according to the relative importance (weight) attributed to the different factors of the CBA. To simplify the analysis, this sensitivity analysis is carried out considering the relative weighting among the three groups of costs/benefits: already presented:

- economical profitability
- socio–environmental and technological aspects
- security of supply and system resilience. This distinction broadly reflects the distinction among the three pillars of the EC energy policy (markets integration, RES integration and security of supply).

6.8 Conclusion

The e-Highway2050 project has been launched to define which transmission grid should be developed from the perspective of a decarbonised energy mix by 2050, as expected in Europe. The final results will be provided by the end of 2015.

The first period of the project has focused on the definition of the scenarios, the modelling to apply for the system simulation, and the method to define the grid architecture for 2050. In this respect, a clustering technique to describe the pan-European grid has been developed in order to model the complex meshed network. Grid architecture options are proposed, capable of alleviating the detected overloads in 2050, and a portfolio of candidate grid architectures is selected, taking into account the available technologies and solutions such as AC interconnections, DC interconnections, hybrid AC/DC interconnections, or power electronics to better control flows over long distances.

In order to assess the candidate grid architectures, a new cost benefit methodology is utilised to compare the new transmission investments using a socio-economic impact analysis involving the costs, the risks and the benefits for society and stakeholders.

The next steps will concern the description of the path to follow in order to implement a modular grid development plan from 2020 to 2050.

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7 Appendix 7 - Best practices to mitigate the environmental impacts of projects

The following tables summarise the potential impacts in each discipline and the measures used in general in order to mitigate them. Nevertheless it is always convenient to study each project case-by-case, for the potential impacts and define the measures that can be taken to limit or avoid them.

Table 7-1 Summary table of best practice to mitigate the environmental impacts of high voltage overhead transmission lines

Discipline	Possible effect	Mitigating measures
Soils	• Soil compaction • Erosion and slopes • Soil loss • Contamination by casting tank cleaning	• De-compacting and adapting areas post construction • Routing: avoid areas of high slope • Timing of works to prevent impacts on sensitive soil types • Restoration of natural spaces and areas affected by works (laying coconut netting, hydro sowing and planting) • Designing specific locations for concrete mixing
Ground/land use	• Limited taking of space	• Positioning of towers, compensation for loss of land/loss of income, (design of towers)
Water	• Pollution due to construction related machinery accidents • Damage to water courses • Sedimentation	• Provision of spillage containment facilities during construction • Temporary groundwater control during construction phase • Protection of watercourses • Installation of silt control measures
Air and Climate	• Dust emissions due to construction activities • Increased emissions from construction vehicles	• Dust containment using water spraying
Noise	• Construction noise • Corona effect • Aeolian noise	• Routing to avoid densely populated areas where possible • Technical measures • Distance to houses
EMF	• EMF exposure	• Raised clearance (height of pylons, compact line design (compaction) and conductor arrangements (optimal phasing, phase splitting) • Distance to houses
Biodiversity	• Impacts to sites of high nature value • Removal/ damage to natural and semi natural habitats • Disturbance of breeding species	• Routing to avoid Natura 2000 sites and sites of high nature value • Marking and protecting adjacent habitat, utilising helicopters in very sensitive habitats, limiting access tracks to existing tracks / establishing dedicated access • Species relocation • Limit activities during breeding season

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	• Collision with birds • Limiting the height of forest in transition zone • Traffic incidents with wildlife • Increased risk of illegal hunting with opening of access and security corridor	• Undergrounding cables in sensitive areas for birds" (as it may entail drawbacks for other species) • Set markers/ bird diverters to earth wires in corresponding sections • Nesting deterrents • Biotrope management in transition zone, selective cutting • Establish fire prevention plans and emergency plans for fire in susceptible areas • Limit speed of vehicles • Prevent access in areas where a possible increase in illegal hunting is a risk
Visual impact	• Impact on landscape in open space	• Adequate routing • Bundling with existing linear infrastructure • Landscape development (trees) • Camouflage the towers • Dark wires (avoid illumination and reflection from new wires) • Positioning and design of towers
Cultural Heritage	• Disturbance of archaeological potential	• Routing to avoid all known sites or areas of high cultural heritage potential • Archaeological monitoring during construction • Protection of any adjacent features • Notification to the responsible authority

Table 7-2 Summary table of best practices to mitigate environmental impacts of Underground Cables

Discipline	Possible effect	Mitigating measures
Ground, geology, land use	8 Soil disturbance, heating, 9 Changes to land use	• Design to limit soil heating near the surface • Forced cooling • Construction: keep topsoil and subsoil separated • Construction: depth of cables to avoid loss of land use
Water	10 Pollution 11 Sedimentation 12 Changes to flow regimes/ watercourse diversions Impacts on ground water	• Adequate route design to limit the number of river crossing necessary • Robust water pollution measures are required including protecting of watercourses during the construction phase and restoration post construction • Limit the number of water course diversions • Installation of settlement ponds and siltation traps to prevent siltation
Noise	No noise production	Restricted to station
EMF	EMF exposure	• Design cable layout, avoid neighbouring of junction chambers

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Light, radiation and EMF	Heat	• Design cable layout to keep EMF under limits (distance between conductors), depth (the deeper it is, the less capacity) • Design to limit soil heating near the surface • DC statistic magnetic fields
Biodiversity	Habitat removal/ damage Disturbance of fauna species Permanent effects on habitats	• Routing: avoid sensitive habitats where it is difficult to restore cables (e.g. forest, bog, water dependant habitats) • Construction: keep topsoil and subsoil separated, horizontal directional drilling under important habitats (e.g. rivers) • Restrict works to avoid sensitive breeding seasons for protected species • Habitat restoration post construction
Archaeology/ Cultural Heritage	Permanent effect on archaeological features	• Routing: avoid known sites of archaeological importance or potential • Supervision during construction • Archaeological excavation and preservation in situ where artefacts are encountered

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8 Appendix 8 - Abbreviations

AC	Alternating Current
ACER	Agency for the Cooperation of Energy Regulators
CCS	Carbon Capture and Storage
CHP	Combined Heat and Power Generation
DC	Direct Current
EIP	Energy Infrastructure Package
ELF	Extremely Low Frequency
EMF	Electromagnetic Field
ETS	Emission Trading System
ENTSO-E	European Network of Transmission System Operators for Electricity (see § A2.1)
FACTS	Flexible AC Transmission System
FLM	Flexible Line Management
GTC	Grid Transfer Capability (see § A2.6)
HTLS	High Temperature Low Sag Conductors
HV	High Voltage
HVAC	High Voltage AC
HVDC	High Voltage DC
KPI	Key Performance Indicator
IEM	Internal Energy Market LCC Line Commutated Converter
LOLE	Loss of Load Expectation
NGC	Net Generation Capacity
NRA	National Regulatory Authority
NREAP	National Renewable Energy Action Plan
NTC	Net Transfer Capacity
OHL	Overhead Line
PEMD	Pan European Market Database
PCI	Project of Common Interest (see EIP)
PST	Phase Shifting Transformer
RAC	Reliable Available Capacity
RC	Remaining Capacity
RES	Renewable Energy Sources
RG BS	Regional Group Baltic Sea
RG CCE	Regional Group Continental Central East
RG CCS	Regional Group Continental Central South
RG CSE	Regional Group Continental South East
RG CSW	Regional Group Continental South West
RG NS	Regional Group North Sea
SEW	Social and Economic Welfare
SOAF	Scenario Outlook & Adequacy Forecast
SoS	Security of Supply
TEN-E	Trans-European Energy Networks
TSO	Transmission System Operator
VOLL	Value of Lost Load
VSC	Voltage Source Converter