Session III : Novel planning methodologies at pan-European level

Grid Development for Long Term Planning

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Objectives of grid architecture development in e-Highway 2050

To define energy scenarios and grid structure that reach EU Climate targets in 2050

- Basis is **T**en **Y**ears **N**etwork **D**evelopment **P**lan by ENTSO-e

- Definition of main transmission requirements in Europe

- Results to be understood as complete architecture for scenarios

- Identification of “no-regret” investments

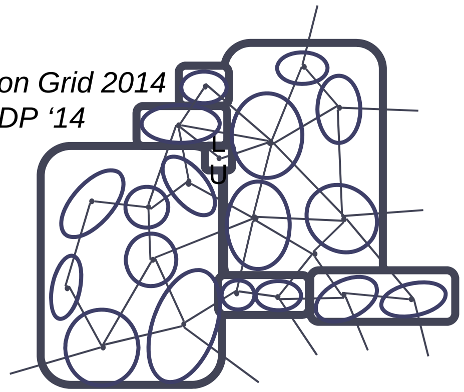
Steps of grid architecture development

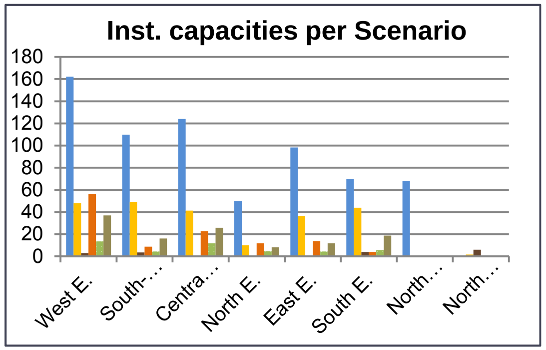
Scenario definition → European grid model / Scenarios quantification → Grid development

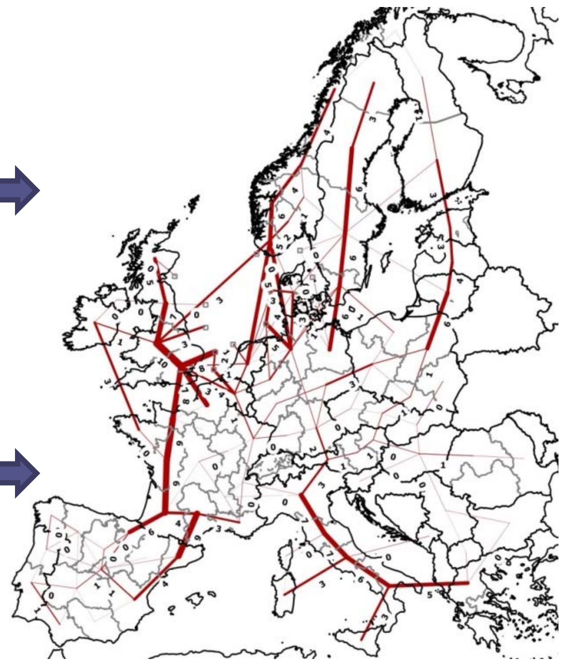
Five scenarios

- 100% RES
- Large scale RES
- Big & market
- Fossil & nuclear
- Small & local

Based on Grid 2014
+ TYNDP '14







What is the starting point for analyses?

- What is the status of available transmission system at the beginning?

Deliverable 2.2 - European Grid Model

Target of the infrastructure development is to define required bulk power transmission corridors

Objectives of work in e-Highway were to:

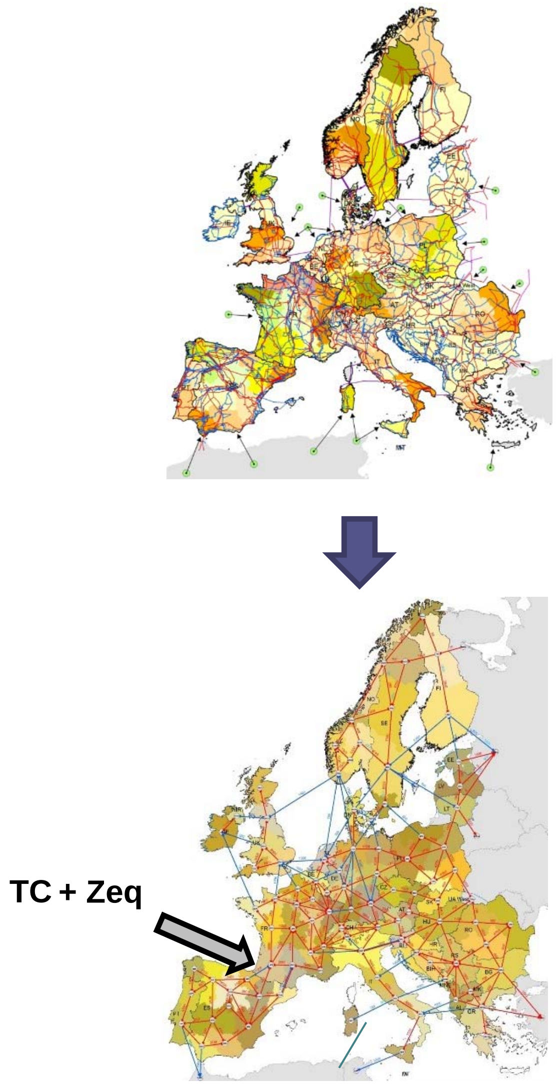
- consider high variety of possibilities for grid development
- define main transmission requirements in Europe
- identify “no-regret” investments

  → European grid model

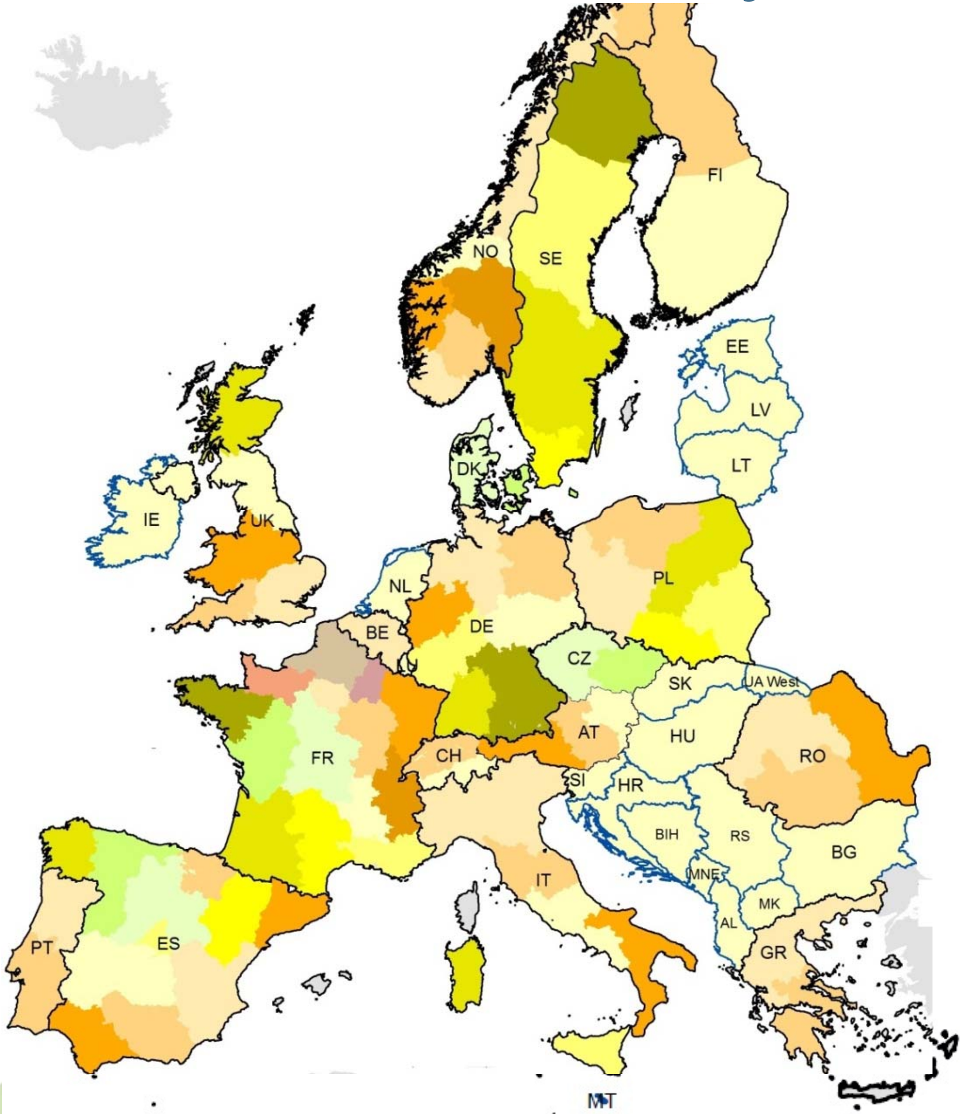
- cluster are used as smallest units for system modeling
- cluster modeled as single market node (“copperplate”)
- installed capacities and demand defined on this level

- transmission equivalents represented by:

  Transmission Capacity (TC)
  and equivalent impedance (Zeq)



Cluster model defined and consulted among the TSO Community



106 Clusters

Consultation of TSOs to apply knowledge about particular Systems

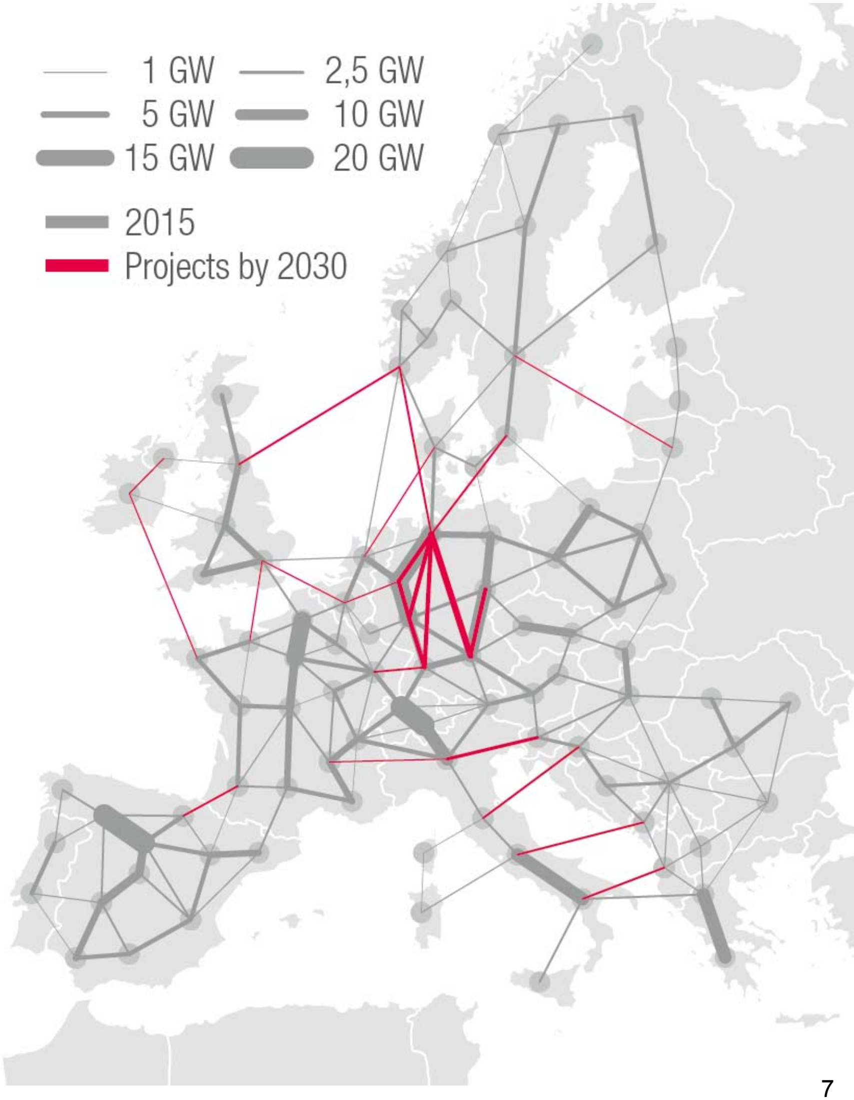
Improvement of Clusters
(Incl. Justification of Changes)

95 Clusters

Major grid reinforcement projects are already included the starting grid

Based on the TYNDP, significant grid reinforcements have already been considered in the starting grid:

- Inter and intra country connections
- Further interconnector projects
- DC cable links

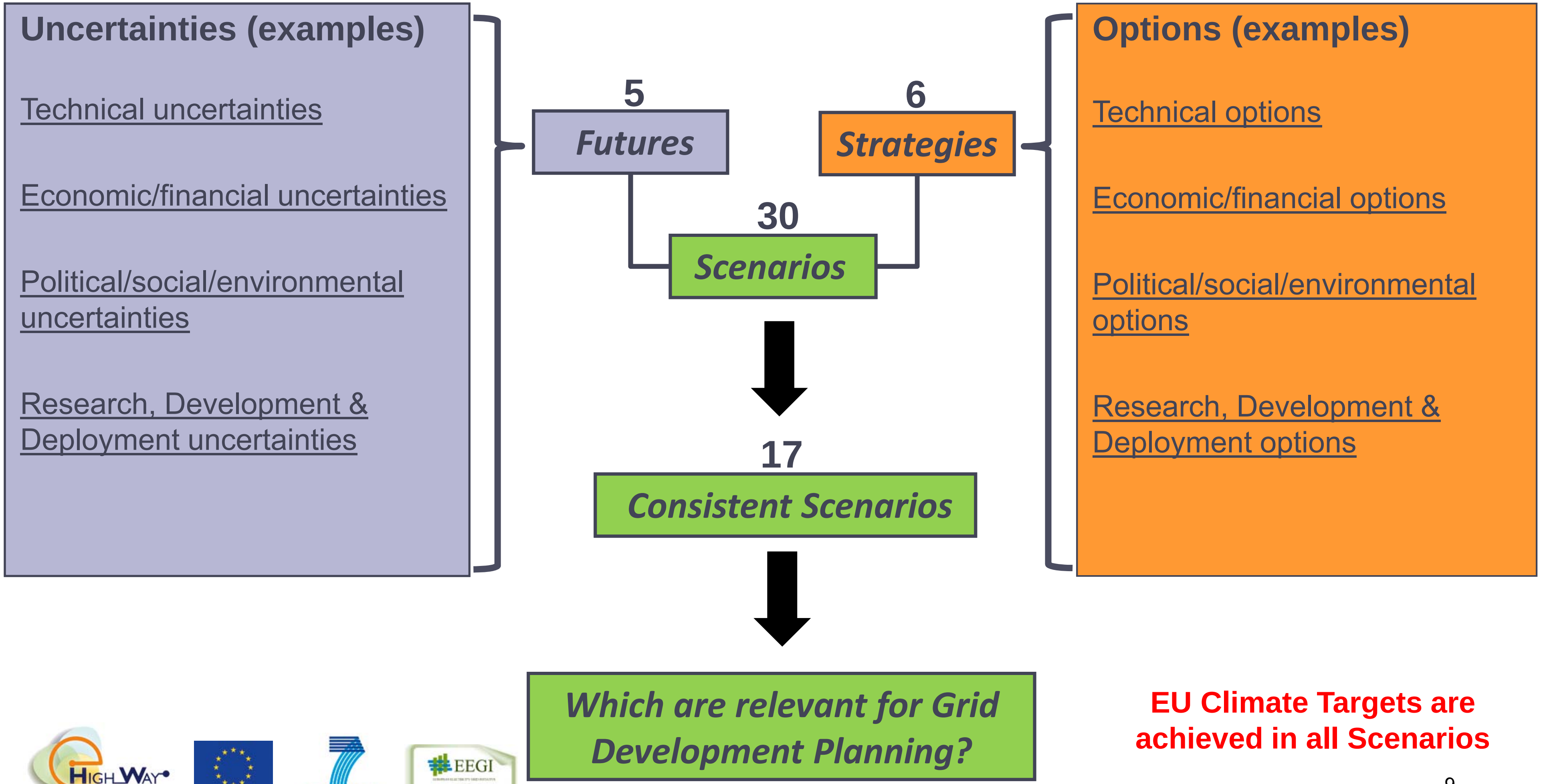


What are the energy scenarios?

- How do the energy mix and installed capacities look like?

Deliverable 2.1 - Data sets of scenarios for 2050

Scenario building methodology based on com-bination of **Futures** & corresponding **Strategies**

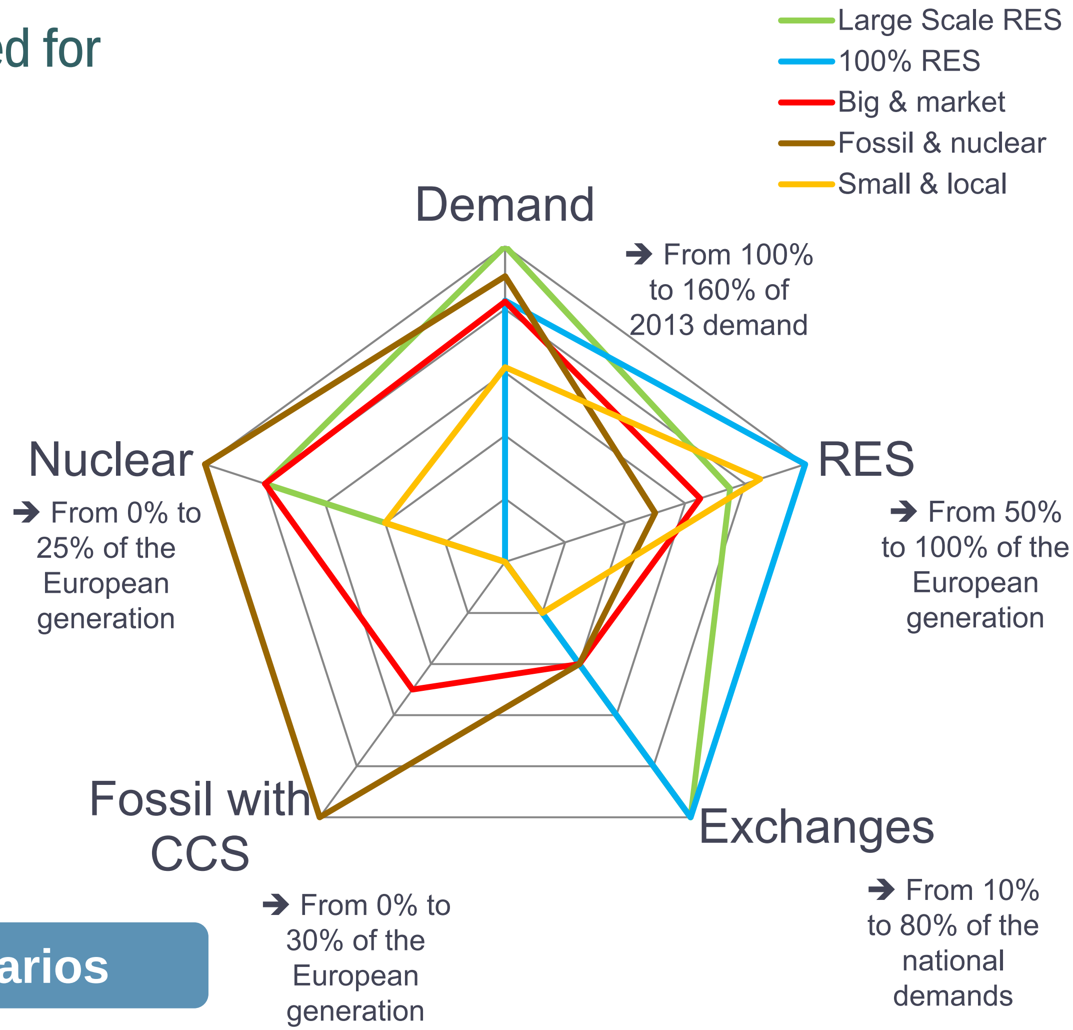


Focus on scenarios that pose a big challenge for the existing grid

Three main influences define the need for grid reinforcements :

- ▶ **Effects of generation mix**
  - Share of Fossil Fuel
  - Share of Nuclear
  - Renewables (centralized & decentralized)
  - Centralized Storage
- ▶ **Effects of demand**
  - GDP Increase
  - New Uses / Demand Shift
  - Efficiency
- ▶ **Effects of energy exchanges**
  - EU internal
  - EU external

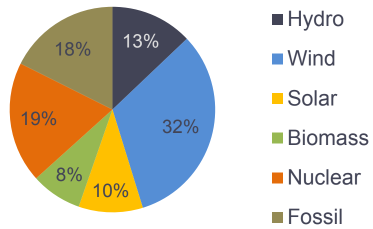
→ Selection of these five scenarios



Challenge of scenario quantification is to merge top-down and national approaches

Scenario definition:
- Energy mix
- Demand level
- Energy exchanges

Determination installed capacities on macro-area level



National policies and regulation:
- Nuclear policy
- Renewable action plans

Determination installed capacities on country-level

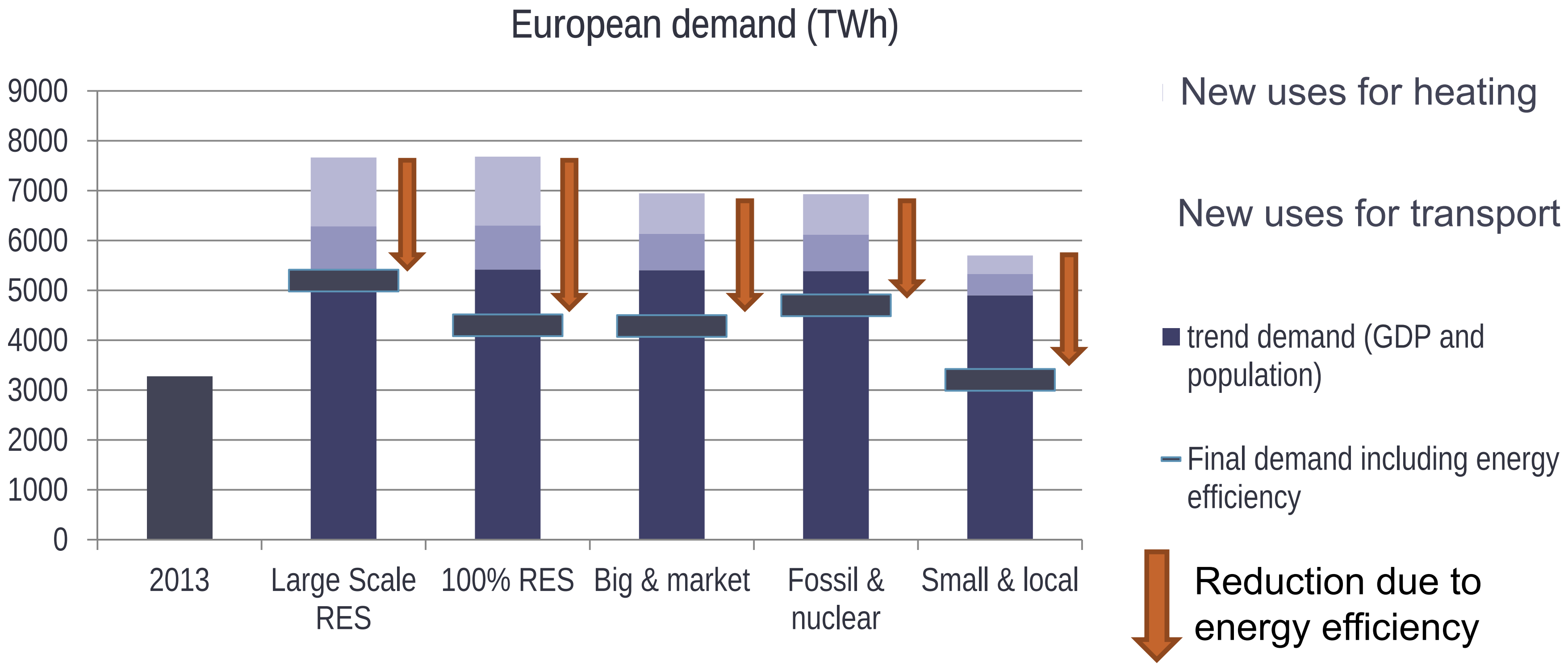
Determination installed capacities on cluster

Simulation on EU-Level

Different aspects were considered to forecast the yearly demand per scenario

For each scenario, assumptions on:

- GDP and population growth
- New uses of electricity
- Energy efficiency



Distribution of generation and exchanges in accordance with the scenario definition

- Renewable generation capacities are distributed by:
  - profitability in the different areas
  - distribution of demand

  - Depending on scenario the factors are weighted differently

- But: Installed capacities respect a maximal level of net import/export over the year in each country

	Large RES	100% RES	Big & Market	Large CCS & nuclear	Small & Local	2014*
Maximal annual energy Balance (% of the national demand)	± 80%	± 80%	± 30%	± 30%	± 10%	± ~10%

*average value in Europe – data by ENSTO-e

Final energy mixes and installed capacities in the 2050 scenarios

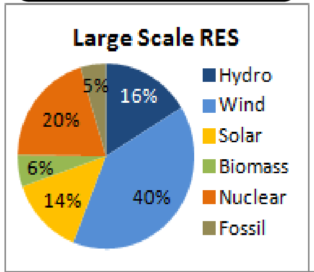
Large scale RES

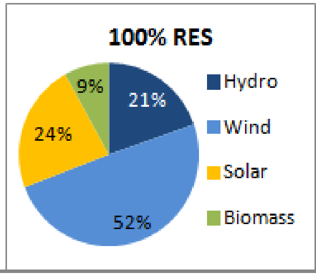
100% RES

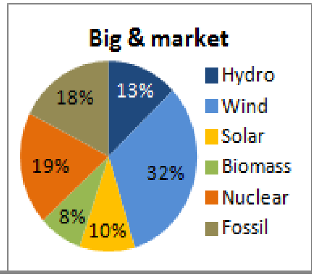
Big & market

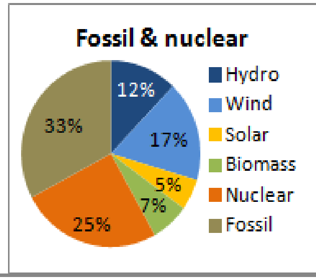
Fossil & nuclear

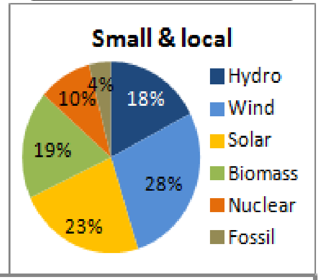
Small & local

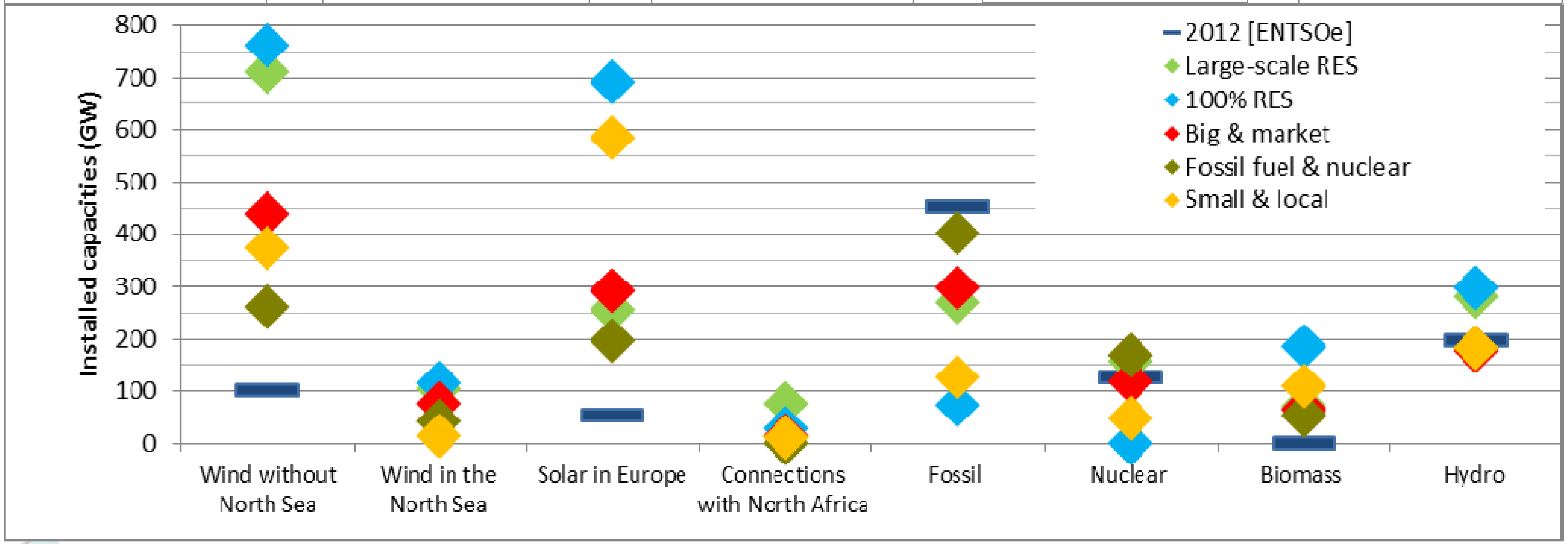










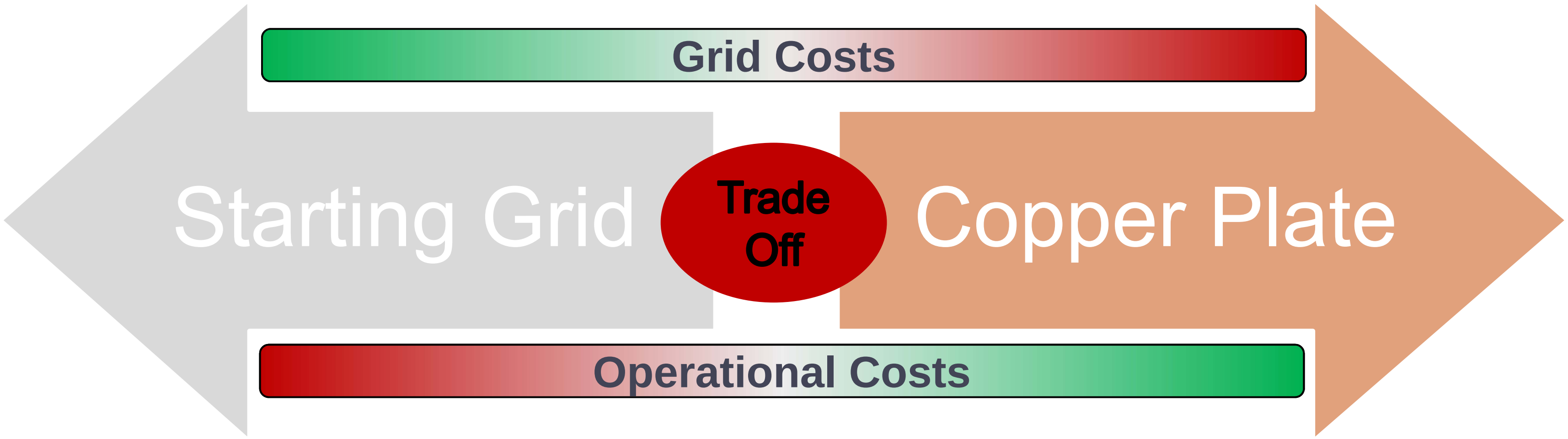


Which additional transmission grid by 2050?

- Which transmission requirements are needed to solve constraints in the starting grid

Deliverable 2.3 - Grid Development for 2050

Optimum for grid development lays in between copper plate and starting grid situation



Best case in terms of:

- Annual investment costs
- Public acceptance
- Maintenance costs

Best case in terms of:

- Operation costs
- System adequacy
- Dump-energy

System simulations

System simulations are done with Antares..

… a **stochastic tool** (Monte-Carlo scheme : Wind, Solar and load generation … weather conditions)

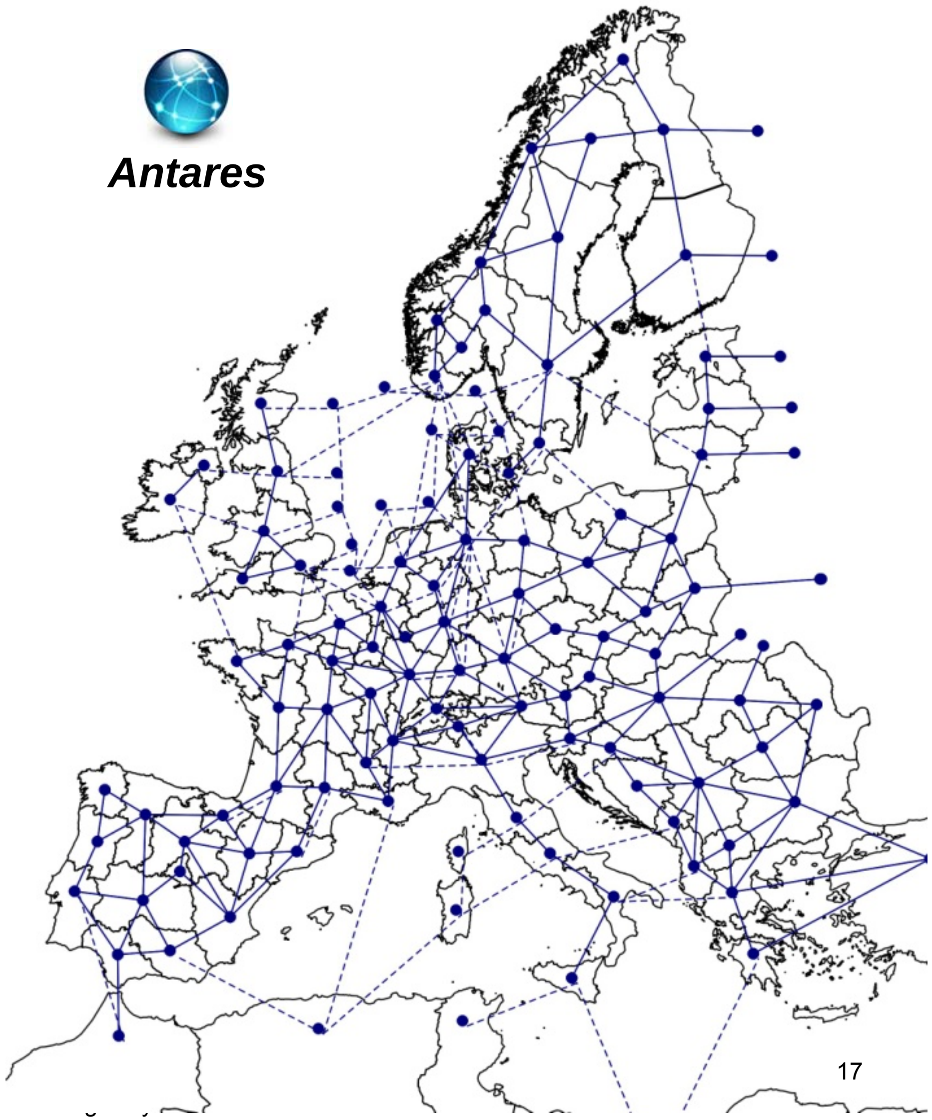
… optimize **generation of dispatchable** units (merit order) to satisfy net demand

… taking into account **grid constraints** (DC approximation : Kirchhoff laws)

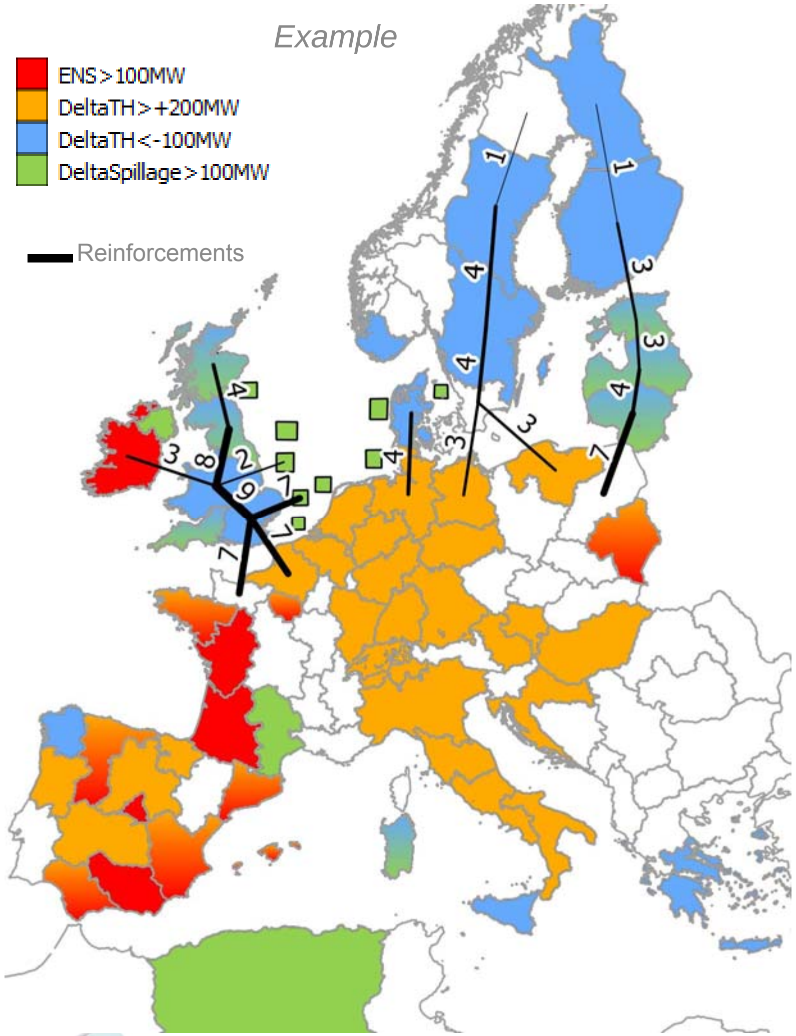
… time step resolution of **one hour …** for a period covering **one year.**

Optimization of **whole European** system in one shot (minimization of the generation cost)

Antares



Decision for grid reinforcements based on manual analyses of key-indicators



- **Identification of the in-efficiencies resulting from grid constraints :**
  - Energy not served
  - Increase of renewable spillage
  - Increase of expensive generation
  - Decrease of cheap generation

➔ **Reinforcements to solve issues**

➔ **Benefit assessment over 99 Monte-Carlo years and compared to investment cost**

- **NB : Focus is on major reinforcements, some smaller could be profitable as well**

Iterative assessment process

Constraints analysis
(Identification of Key-Indicators in European Clusters)

Proposal of reinforcements
(Introduction of additional transmission capacities)

Annual benefit assessment
(Comparison of benefits and annual investment costs)

Analysis of the remaining constraints
(Sufficient security of supply & system costs reached?)

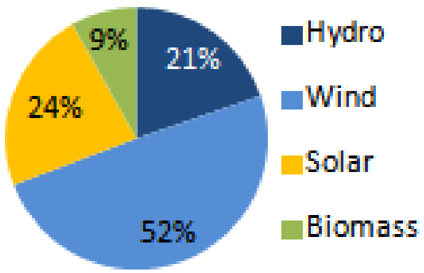
Final grid proposal for the scenario
(Set of transmission capacities to be realized)

>= 4 steps
per scenario

Energy scenario in 100% RES: high imbalances and high need for exchanges

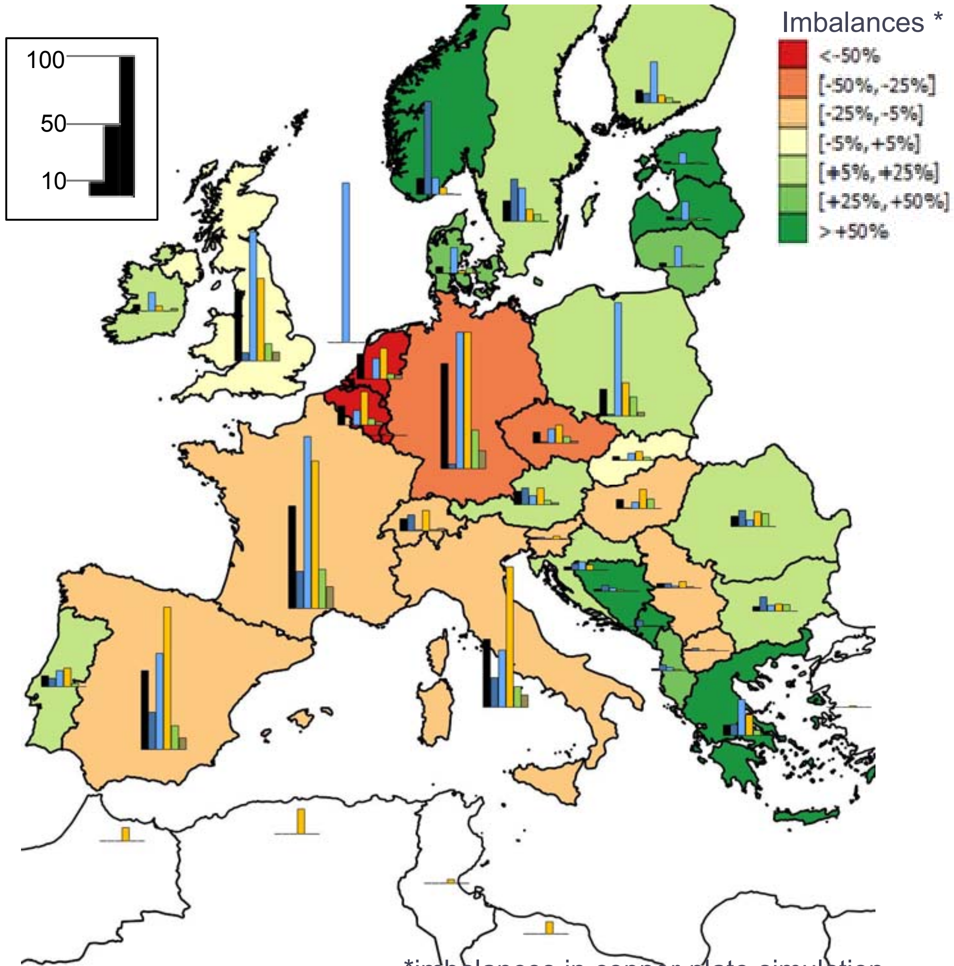
100% RES

European energy shares



- Medium/high demand : 4500TWh
- high share of non dispatchable generation
- Renewables are dominated by wind
- Peaking units included (DSM & storage)

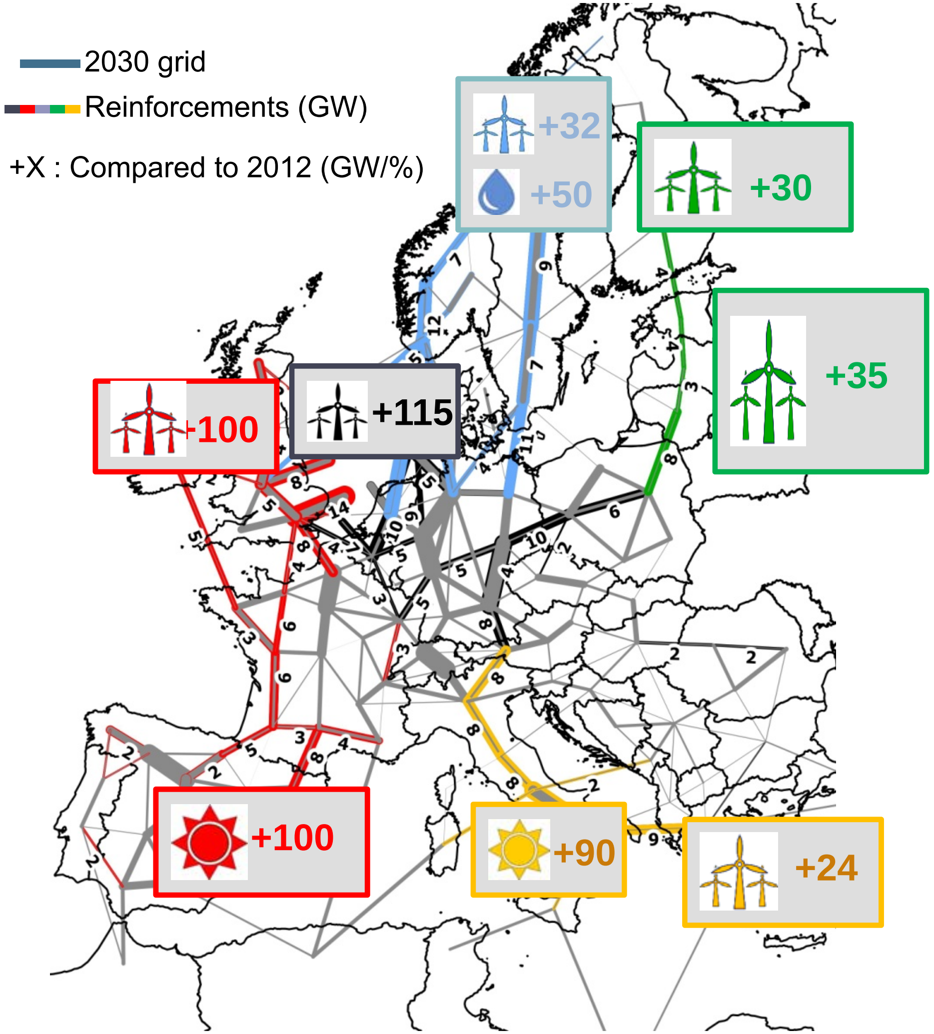
Installed capacities (GW)



*imbalances in copper-plate simulation

Overall drivers for grid development, benefits and inclusion of renewables - 100% RES

100% RES

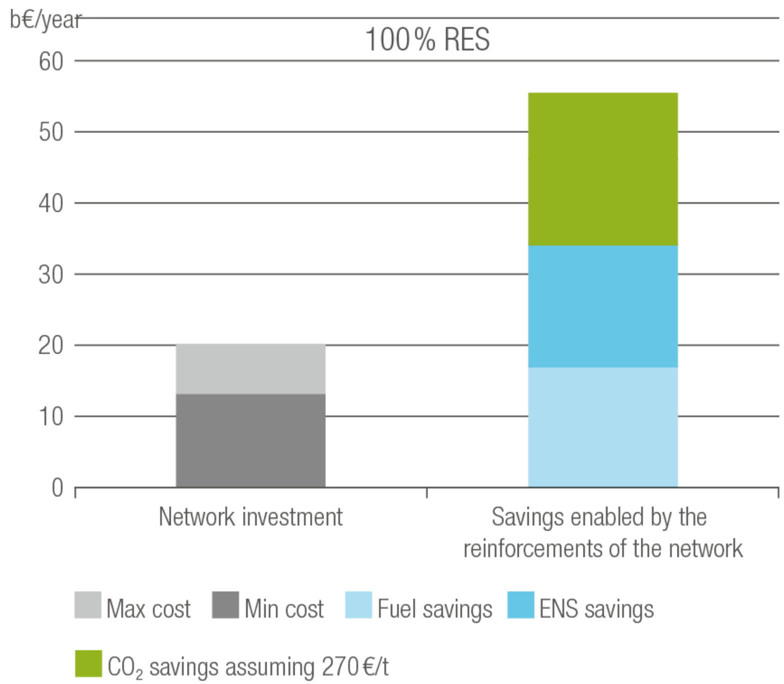


NB : only some of the key factors are displayed

Changes in System (per year):

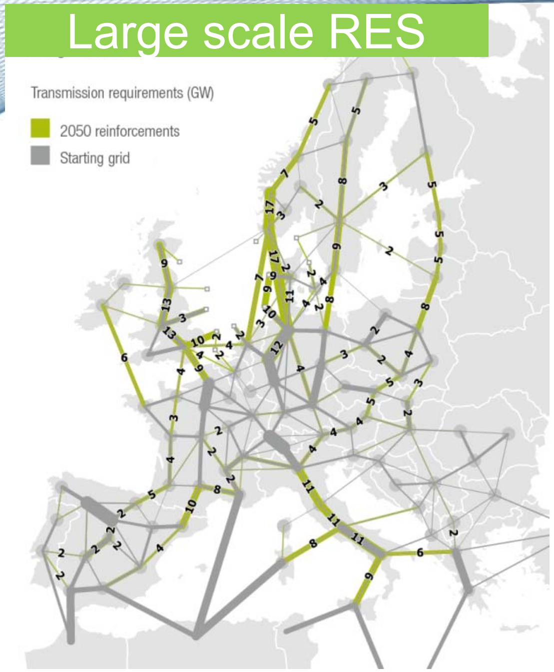
- 51 TWh of ENS avoided
- 465 TWh of spillage avoided
- 39 b€ of savings in operating costs

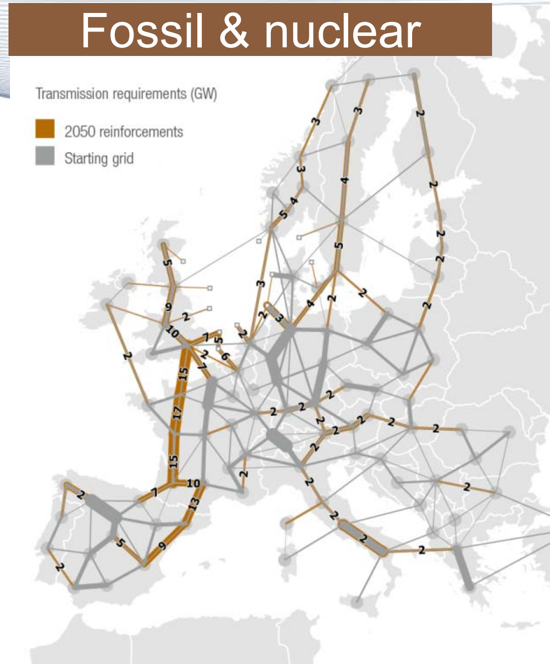
Total investment cost : 245 to 345* b€

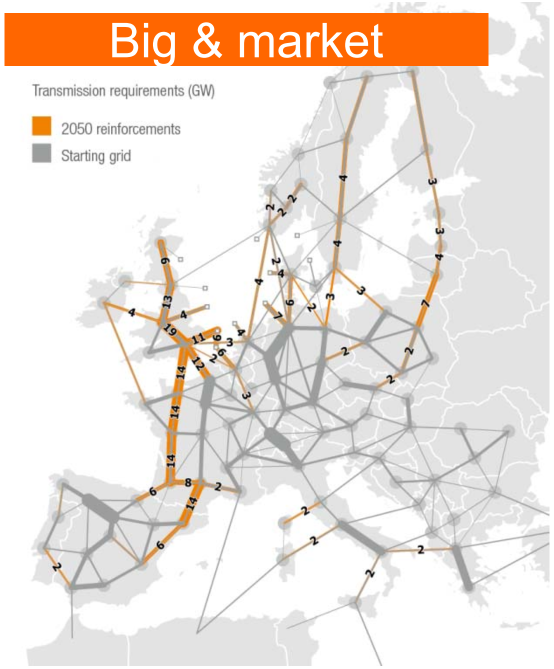


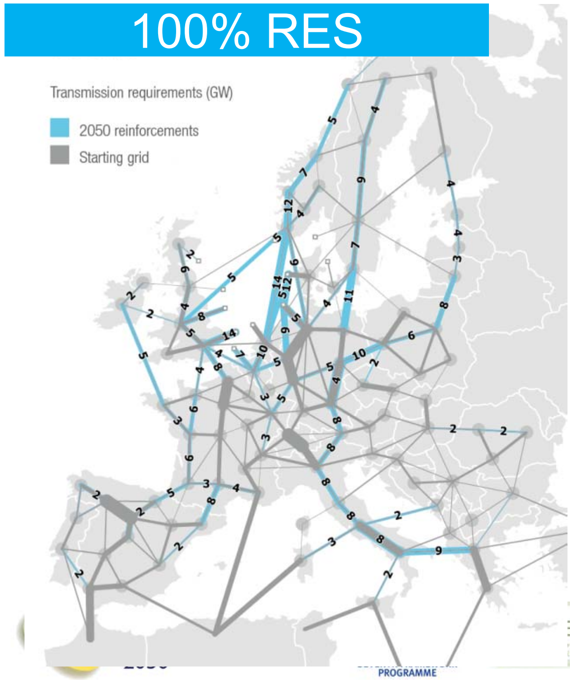
*depending on available technologies

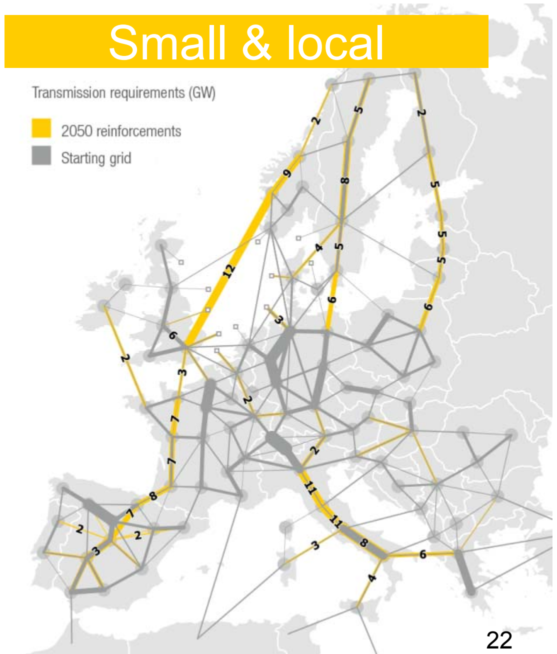
Comparison of the final architectures









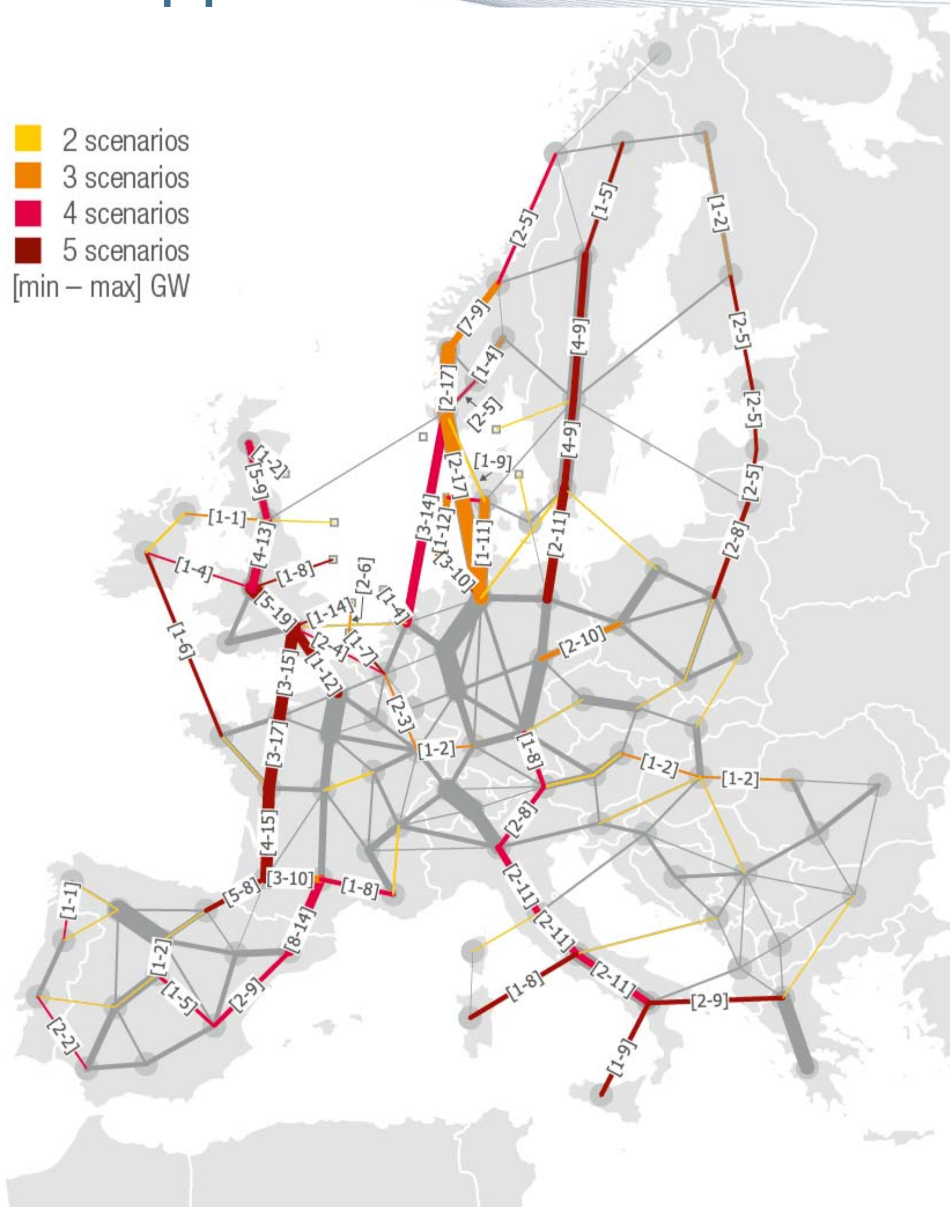


Common reinforcements that appear in two or more scenarios

- ► Displayed are all lines reinforced throughout two or more scenarios
  - Colors according to number of appearances in scenarios

- ► Reinforcement of high interest driven by RES implementation and needed exchange capacities
  - North Sea for wind integration
  - Scandinavia to central europe develop wind and storage potential
  - Connection Great Britain ↔ France ↔ Spain to distribute renewables (PV vs. Wind)

→ Need to transport energy from renewable sources thanks to North-South corridors



Conclusion

Investment in grid infrastructure is a beneficial way to support the EU energy targets for 2050

- Main advantages of the Grid are:
  - Possibility to allocate renewables in most profitable areas
  - Utilization of smoothening effects in RES-production due to geographical distribution
- Need for transmission capacity correlated with share of renewables in energy mix
  - Even the Small & local scenario requires further grid reinforcements
- Interconnection capacities between countries should be among the top priorities
  - Allowing higher exchanges between countries (usually utilized both ways)
- Planned reinforcements for 2030 are sustainable in perspective of EU 2050 climate targets

For more details see deliverables :

« *D2.1 : Data sets of scenarios for 2050* » on www.e-highway2050.eu »

« *D2.2 : European cluster model of the Pan-European transmission grid* » on www.e-highway2050.eu

« *D2.3 : System simulations analysis and overlay-grid development* » to be published very soon

Back-Up

Thank you for your attention!

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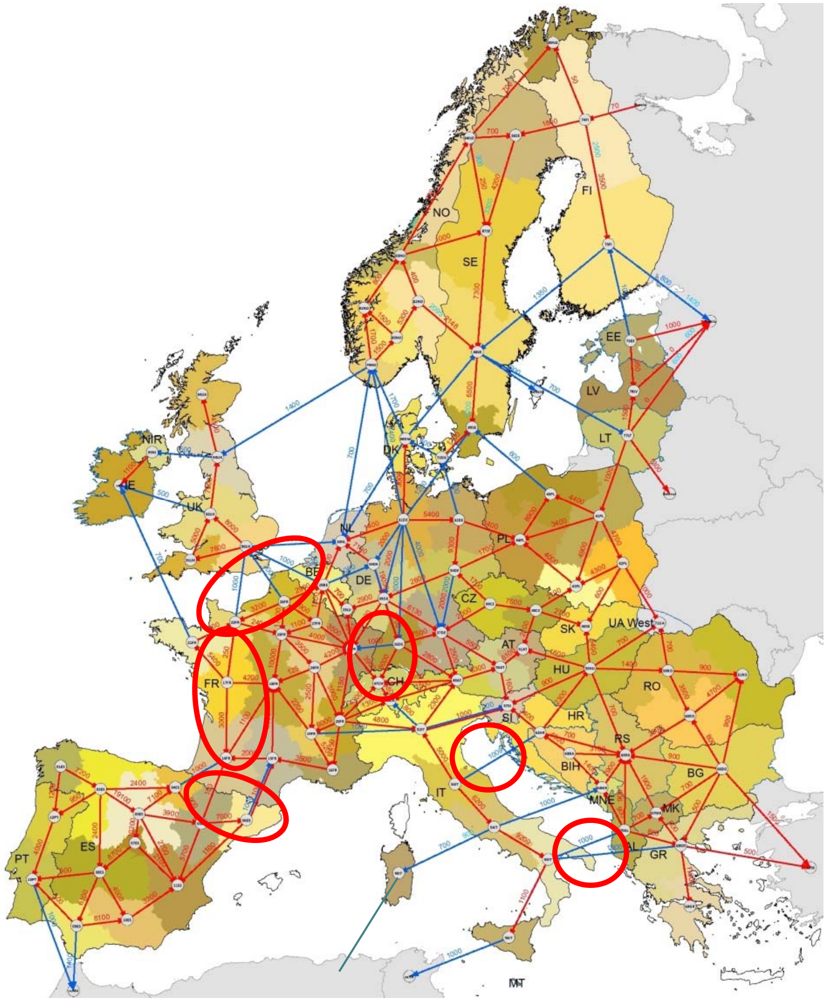
Summary of the main assumptions for grid development

- Only the inter-clusters transmission requirements are assessed
- Focus is on the major ones, some smaller could be profitable as well
- The 2030 grid from TYNDP2014 is the starting point, major projects like HVDC in Germany are thus already assumed
- The detailed routes and connection points are unknown
- Each transmission requirement could be realized through many parallel reinforcements
- For each scenario, a complete set of reinforcements for Europe is suggested, the reinforcements are not assessed independently.
- The time horizon is 2050 : the profitability of the reinforcements is not proven before.

Deviations between E-Highway Starting Grid and ENTSO-e‘s final TYNDP 2014 (based on received Feedback)

Consultation among ENTSO-e TSOs to reveal differences between e-Highway 2050 starting Grid and final TYNDP 2014.

- France to UK:
  Final TYNDP includes further DC-projects with a total capacity of 3.4 GW
- France (internal):
  Reinforcement along western part of additional 1 GW
- France to Spain:
  Final TYNDP plans an additional 1 GW
- France to Germany



Elaboration of Clustering criteria to split Europe into homogeneous clusters

Definition of criteria for clustering (measureable and non-measureable)

↓

Allocation of measureable criteria to NUTS-3 regions inside each country

↓

Mathematical optimization to identify homogeneous clusters inside countries (first step)

Methodology for setup of e-Highway2050 scenarios

- A detailed bottom-up approach is necessary to ensure transparency and efficient communication of scenario boundaries to the other WP's in e-Highway2050.
- Scenarios are constructed as a combination of **Uncertainties** (that cannot be controlled by the decision maker) and **Options** that can be chosen by the decision maker.
- A combination of *Uncertainties* create a unique **Future**
- One or more *Options* combined gives a **Strategy**
- A combination of a **Strategy** used within a **Future** is a ***Scenario***
- *Note: The e-Highway2050 scenarios are **neither predictions nor forecasts** about the future. We do not conclude that one scenario will be more likely to happen than another, nor that one scenario is more preferred or "better" than another. Rather, each e-Highway2050 scenario is **one alternative image** of how the future of European Electricity Highways (EHS) could unfold.*

Five possible Futures

Main Uncertainty	Possible Values	Future 1 Green Globe	Future 2 Green EU	Future 3 EU-Market	Future 4 Big is beautiful	Future 5 Small things matter
Energy and Climate Policy						
International Climate Agreement	Global agreement / EU alone	Global agreement	EU alone	EU alone	Global agreement	EU alone
Dependency on fossil fuels from outside Europe	High/Medium/Low	Medium	Low	Medium	Medium	Medium
Joint transnational initiatives	Difficult/Common	Common	Common	Difficult	Common	Difficult
Fuel Costs	High/Low	Low	High	High	Low	High
CO_2 cost	High/Low	High	High	Low	High	Low
Technological development						
Storage technology maturity	Small scale/Large scale/All	All tech mature	All tech mature	All tech mature	Large-scale	Small-scale
CCS maturity	Yes/No	Yes	No	Yes	Yes	No
Electrification in Transport - Heating - Industry	Residential/Large scale/All	All	All	All	Large scale (commercial, industry&freight)	Residential (Homes, person vehicles)
Economic						
Demographic change	Growth/Migration only	Growth	Growth	Migration only	Growth	Migration only
GDP growth in EU	High/Medium/Low	High	Medium	High	Medium	Low
Socio-political perceptions						
Public perceptions to RES	Positive/Indifferent	Positive	Positive	Indifferent	Indifferent	Positive
Public perceptions to Nuclear	Positive/Indifferent/Negative	Negative	Indifferent	Indifferent	Positive	Negative
Public perceptions to Shale gas	Positive/IndifferentNegative	Negative	Negative	Indifferent	Positive	Negative
Shift towards 'greener' behaviours	Major shift/Minor shift	Major	Major	Minor	Minor	Major
Assumptions - Constant Uncertainties						
RES technology / DSM technology	Mature	Mature	Mature	Mature	Mature	Mature

Six relevant Strategies

Main Options	Strategy 1 MARKET LED	Strategy 2 LARGE SCALE RES	Strategy 3 LOCAL SOLUTIONS	Strategy 4 100% RES	Strategy 5 CARBON FREE CCS & NUCLEAR	Strategy 6 NO NUCLEAR
Deployment of centralized RES	Medium	High	Low	High	Low	High
Deployment of de-centralized RES (including CHP and Biomass)	Medium	Low	High	High	Low	High
Deployment of centralized Storage	Medium	High	Low	high	Low	High
Deployment of de-centralized Storage	Medium	Low	High	High	Low	High
Deployment of nuclear plants	Medium	Medium	Low	No	High	No
Deployment of fossil fuel plants with CCS	Medium	No CCS	No CCS	No CCS	High	High
Deployment of fossil fuel plants without CCS	Medium	Low	Low	No	Low	Low
Increase of energy efficiency (include DSM and flexibility)	Medium	Low	High	High	Low	High
Increase of funds and better coordination of RDD activities (at EU level)	Medium	High	Low	High	Medium	High
Electricity imports from outside Europe	Medium	High RES (Desertec)	Medium	High RES (Desertec)	Low	Medium
Permitting framework (incl EU nature legislation)	Convergent and Strong framework	Convergent and Strong framework	Heterogeneous framework at EU level	Convergent and Strong framework	Heterogeneous framework at EU level	Convergent and Strong framework
Assumptions - Constant Option						
EU Policy for GHG reduction emissions	Strong	Strong	Strong	Strong	Strong	Strong

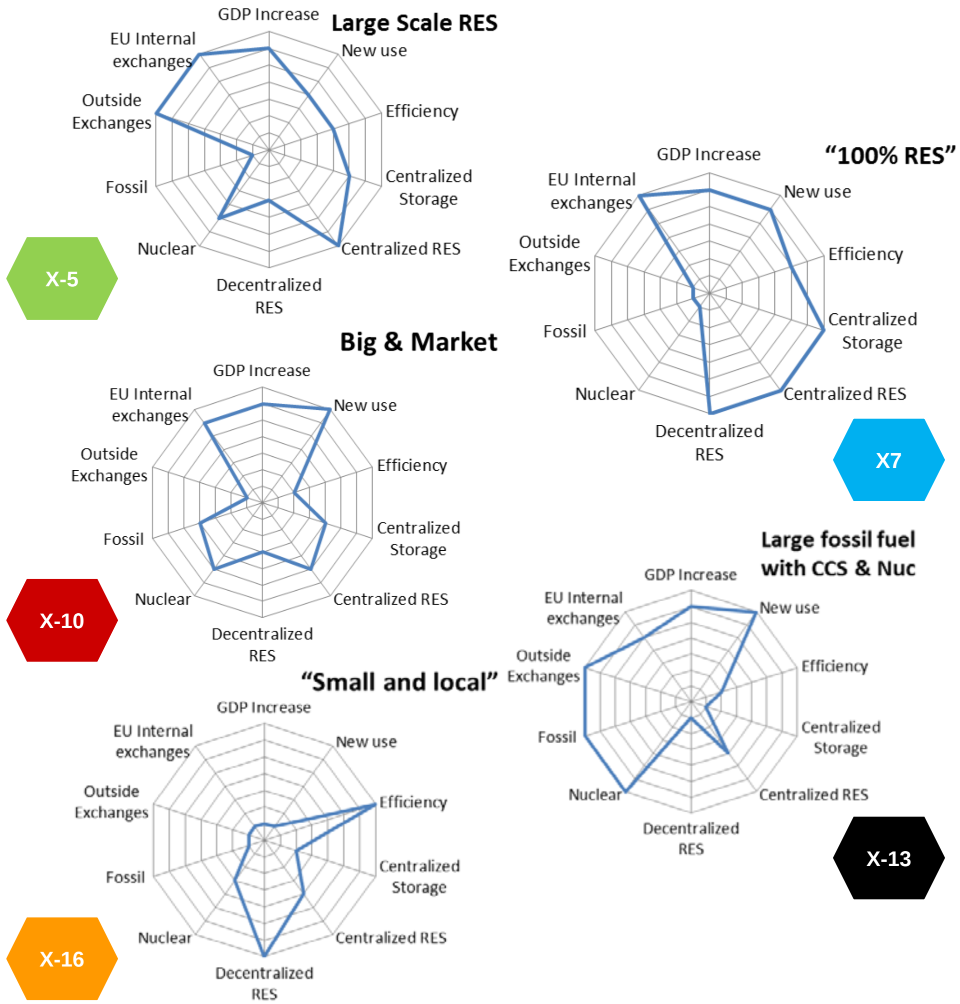
The 5 final e-Highway2050 scenarios

Criteria (options / uncertainties)	x-1	x-2	x-3	x-4	x-5	x-6	x-7	x-8	x-9	x-10	x-12	x-13	x-14	x-16	x-17
	Large Scale RES, Green Globe	Local solutions & Green globe	100% RES, Green globe	Green revolution & no nuclear	Large Scale RES & No emission	Local solutions	“100% RES”	Pure Market	local solutions & market	Big & Market	100% RES, Big EU	Big, Nuc & CCS	No nuc & Big	“Small and local”	100% RES & small
Level of centralized renewable	60%	20%	60%	40%	60%	20%	60%	30%	20%	40%	60%	30%	40%	25%	40%
	High	Low	High	M/H	High	Low	High	Medium	Low	M/H	High	L/M	M/H	Low	M/H
Level of decentralized renewable	20%	60%	40%	40%	15%	60%	40%	20%	60%	20%	40%	5%	20%	60%	60%
	M/L	High	High	High	Low	High	High	M/L	High	M/L	High	Low	M/L	High	High
Level of renewable	80%	80%	100%	80%	75%	80%	100%	50%	80%	60%	100%	35%	60%	85%	100%
Level of Fossil fuel plants with CCS	0%	0%	0%	15%	0%	0%	0%	20%	0%	15%	0%	30%	30%	0%	0%
	No	No	No	Medium	No	No	No	Medium	No	Medium	No	Yes-High	Yes-High	No	No
Level of Fossil fuel plants without CCS			0%	5%	5%		0%	10%		5%		5%		5%	
			Low	Low	Low		Low	Medium		Low		Low		Low	
Level of Fossil fuel	0%	0%	0%	20%	5%	0%	0%	30%	0%	20%	0%	35%	30%	5%	0%
Level of nuclear	20%	20%	0%	0%	20%	20%	0%	20%	20%	20%	0%	30%	0%	10%	0%
	Medium	Med	No	No	Medium	Medium	No	Medium	Medium	Medium	No	High	No	Low	No
Level of centralized storage	High	Low	High	High	High	Low	High	Medium	Low	Medium	High	Low	High	Low	High
Enabling EU international exchanges	High	Medium	High	Medium	High	Medium	High	Medium	Medium	Medium	High	Low	Medium	Medium	High
New use emerging (including DSM)	High	Low	High	High	High	Low	High	Medium	Low	Medium	High	Medium	High	Low	High
New use	High	High	High	High	High	High	High	High	High	High	High	High	High	Low	Medium
Population (demographic changes)	Growth	Growth	Growth	Growth	Growth	Growth	Growth	Migration only	Migration only	Growth	Growth	Growth	Growth	Migration only	Migration only
GDP increase	High	High	High	High	Medium	Medium	Medium	High	High	Medium	Medium	Medium	Medium	Low	Low
Energy efficiency	Low	High	High	High	Low	High	High	Medium	High	Medium	High	Low	High	High	High

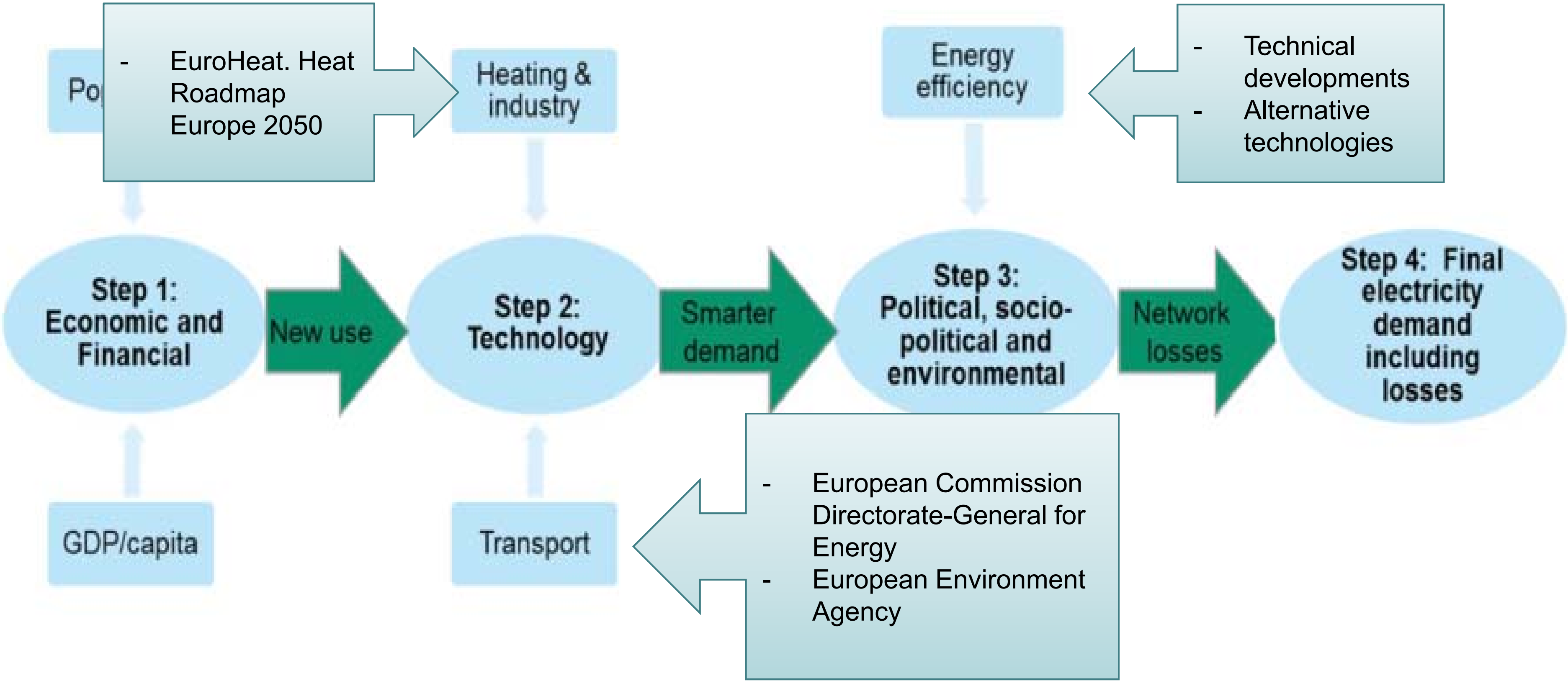
Focus on Scenarios that pose a big Challenge for the existing Grid

Three main Influences define the need for grid reinforcements

- ▶ Effects on Generation Mix
  - Share of Fossil Fuel
  - Share of Nuclear
  - Renewables (centralized & decentralized)
  - *Centralized Storage*
- ▶ Effects on Demand
  - GDP Increase
  - New Uses / Demand Shift
  - Efficiency
- ▶ Effects on Energy Exchanges
  - EU internal
  - EU external

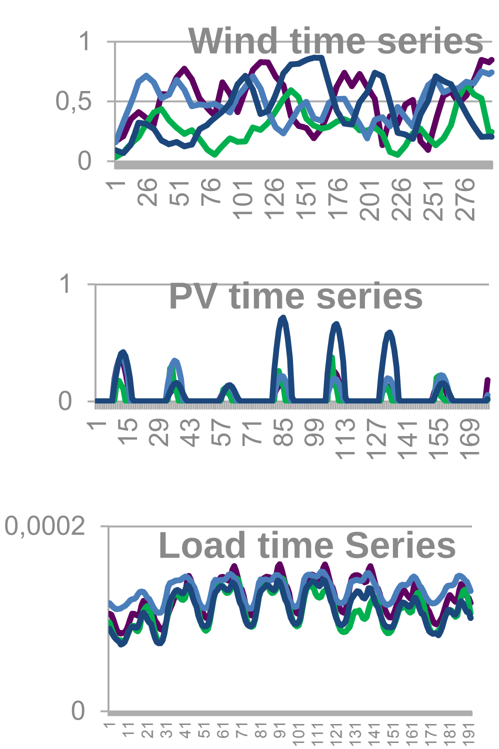


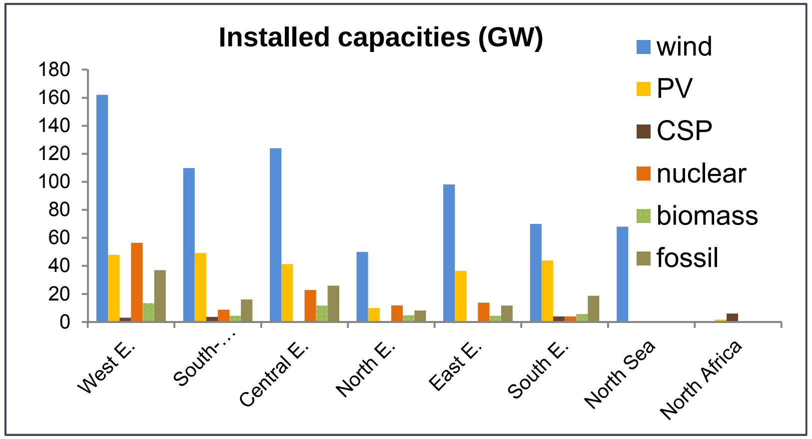
Load Forecasts considers socio-economical and technical developments towards 2050



Assessment of System Adequacy and need of extra capacities

Inputs: set of time series
(11 wind and PV and 3 load)





Hourly stochastic simulations at macro area level

Adequacy OK?
Energy mix OK?
Imbalances OK?

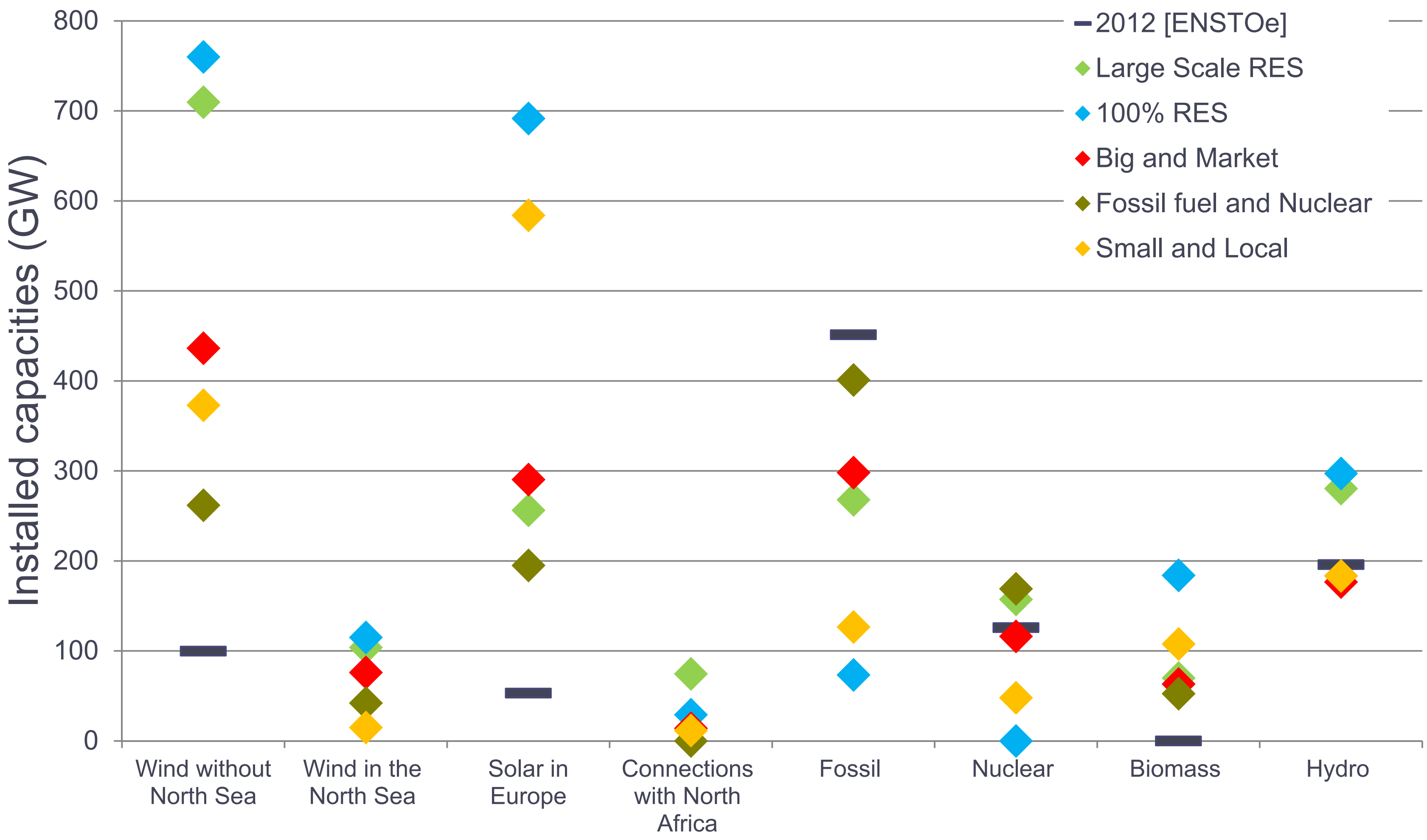
NO

Redistribution of the generation between macro areas

Final installed capacities/ final Imbalances
Incl. assessment of storage and Demand Side Management needs

	Large RES	100% RES	Big& market	Large fossil fuel	Small & local
Range of Imbalances	+/- 80%	+/- 80%	+/- 30%	+/- 30%	+/- 10%

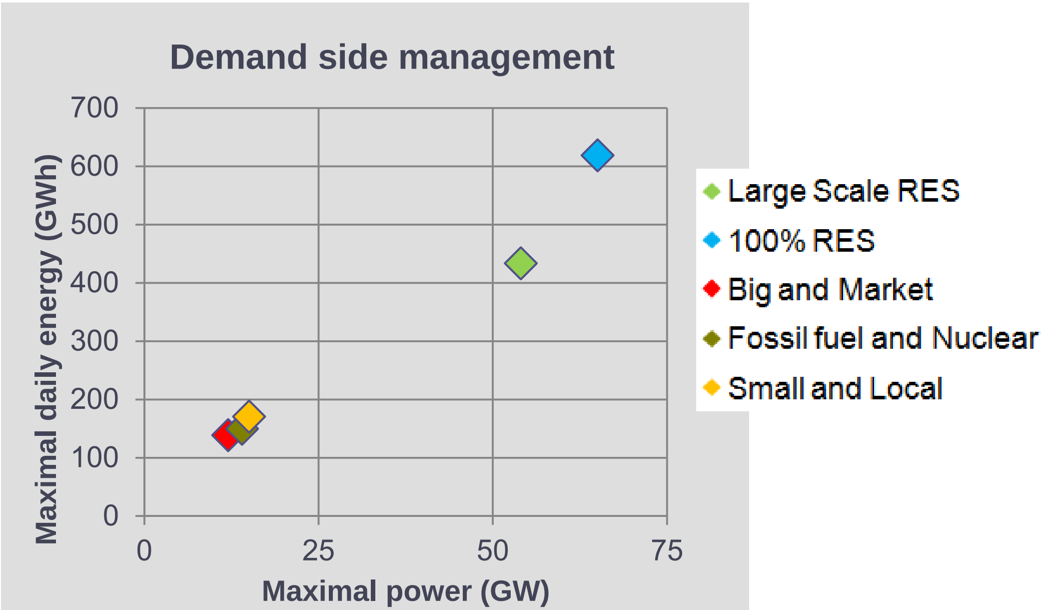
European installed capacities

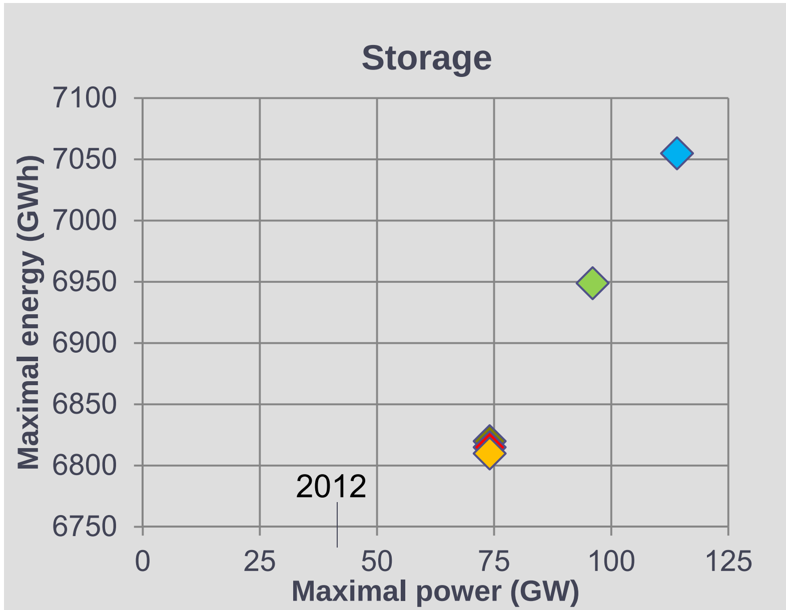


Assumptions for demand side management and storage

- Controllable load includes : a share of EV, a share of heating and a share of all the other appliances.

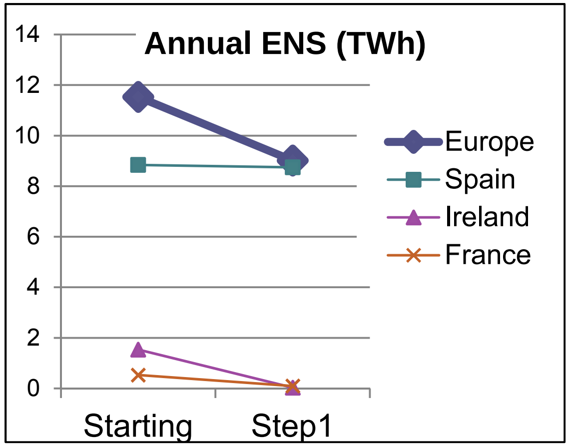
- Localization and power/energy ratio of storage follow typical Pumped Storage characteristics

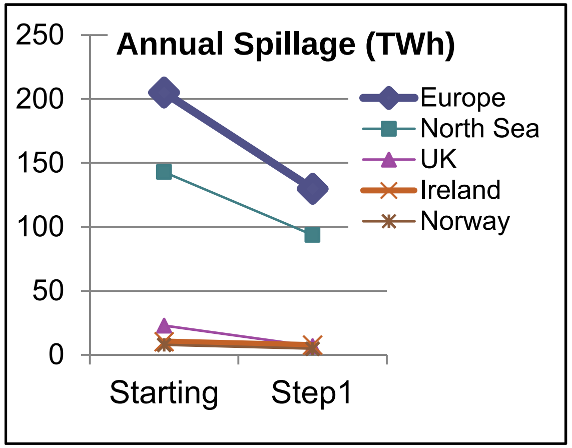


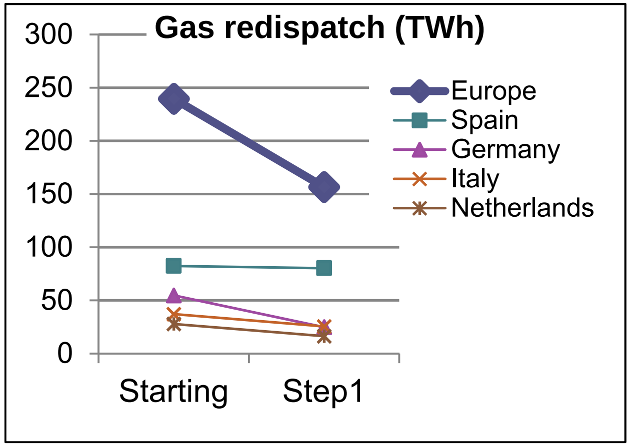


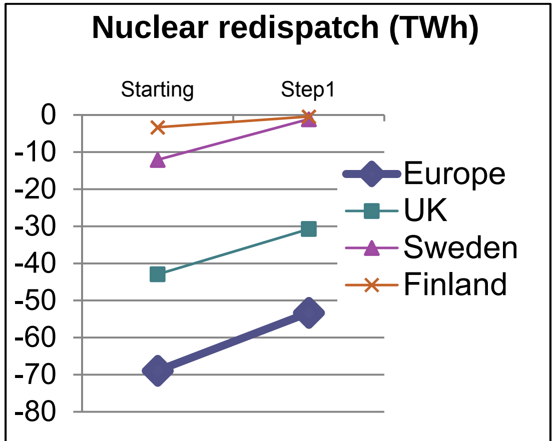
Annual benefit assessment

New system simulation (99 MC years x 8760 hours) with the chosen reinforcements are performed to assess their impact





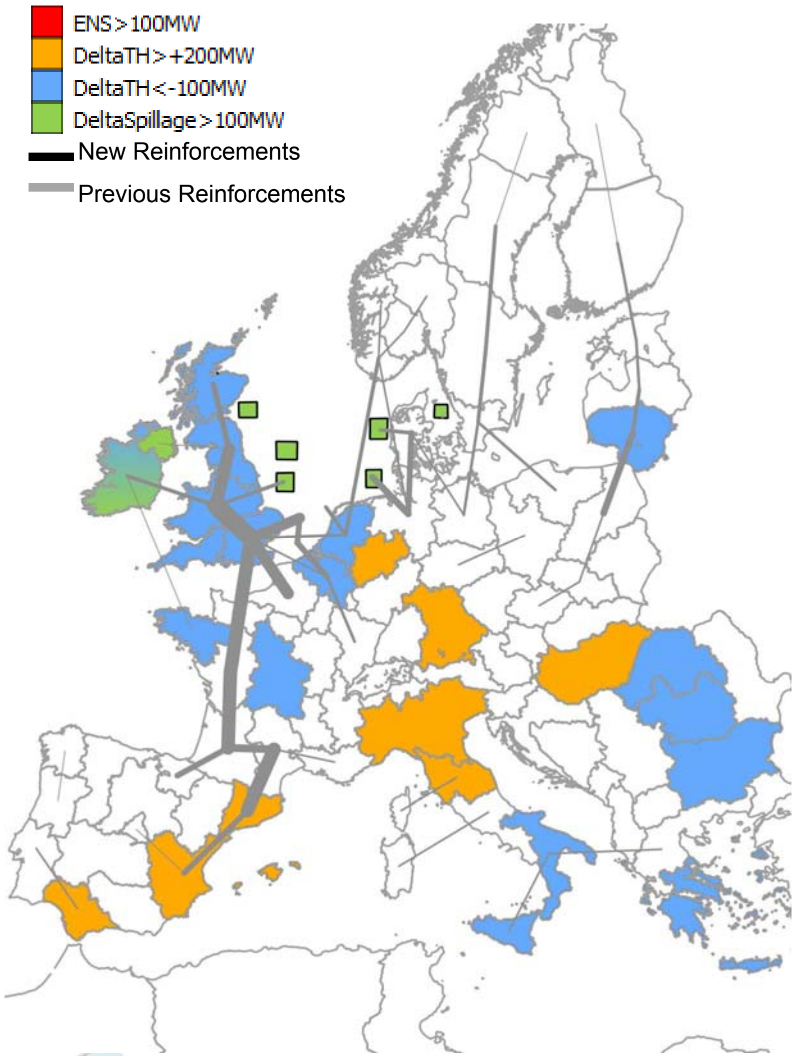




➔The cost of the tested set of reinforcements is assessed to compare it with the benefits

➔Some reinforcements can be modified if they are inefficient/over-sized (flows<<capacity, very small remaining MCV)

Analysis of the remaining constraints



➔Iterations to solve the remaining constraints

➔End of the iterations when no more significant issues (small and spread volumes of ENS/ Spillage/ Redispatch)

Scenario *Large Scale RES*

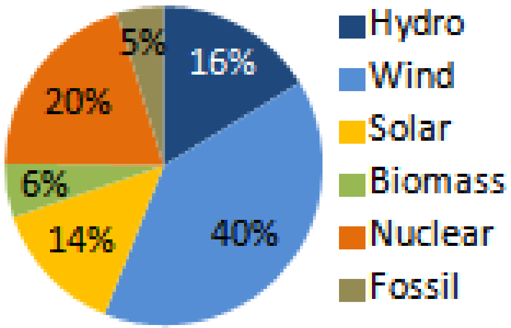
Large
scale RES

Large scale RES

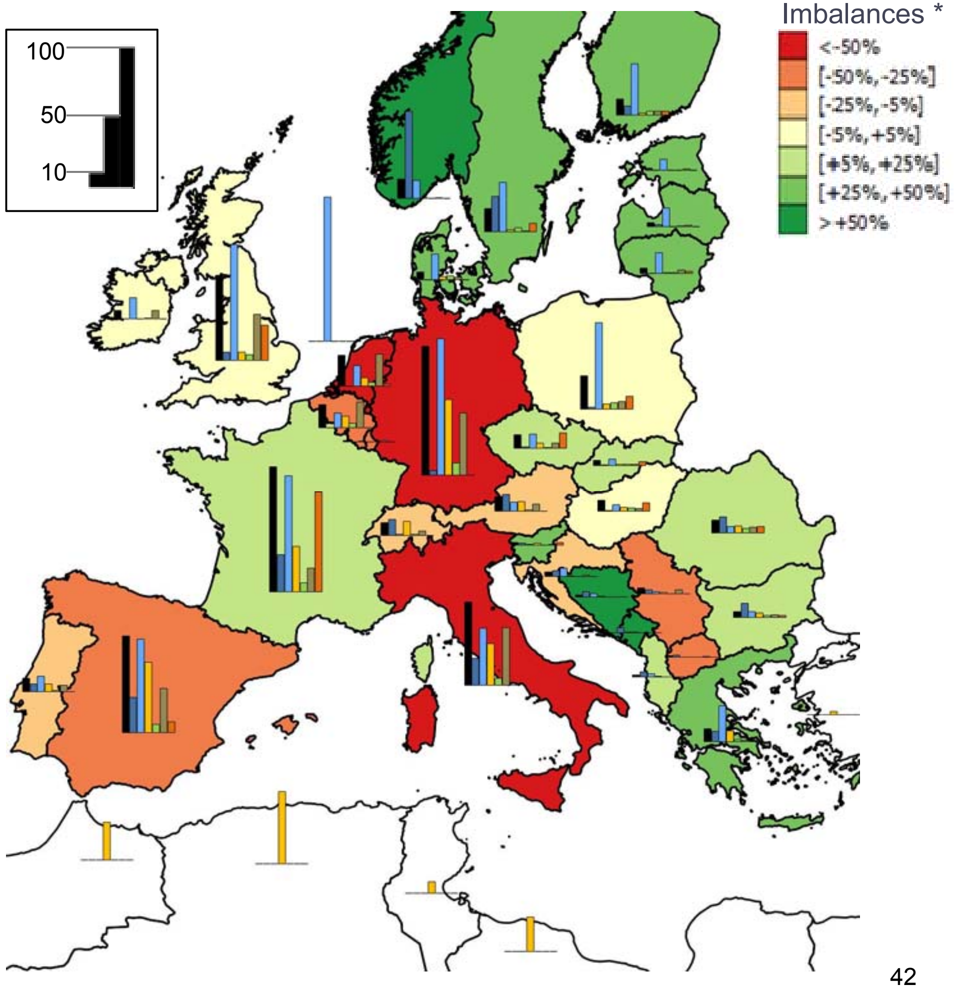
Presentation of the scenario *Large Scale RES*

- Highest demand : 5200TWh
- High participation of large scale RES, especially wind in North Sea (~105GW) and Solar in North Africa (~150GW)
- Dispatchable generation is dominated by nuclear

European energy shares



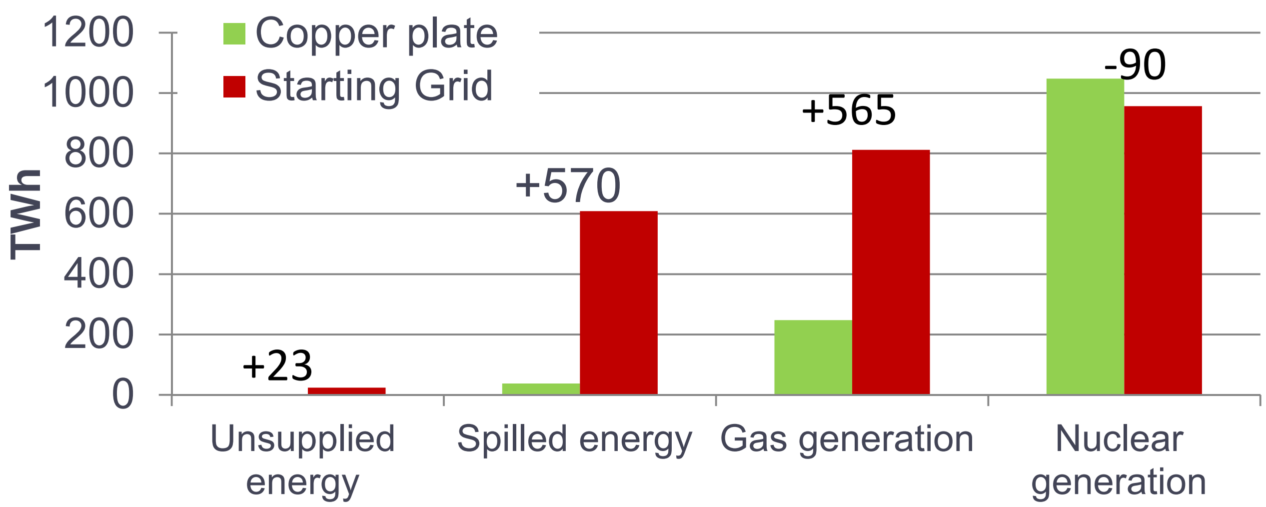
Installed capacities (GW)

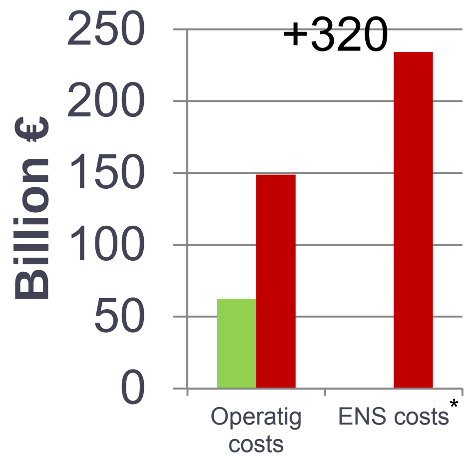


*Imbalances in copper-plate simulation

Large scale RES

Level of constraints in the Starting Grid





Unsupplied energy
- **Germany (44%)**
- Poland (19%)
- Spain (17%)

Spilled energy
- **North sea (35%)**
- North Africa (23%)
- Norway (13%)
- Sweden (5%)

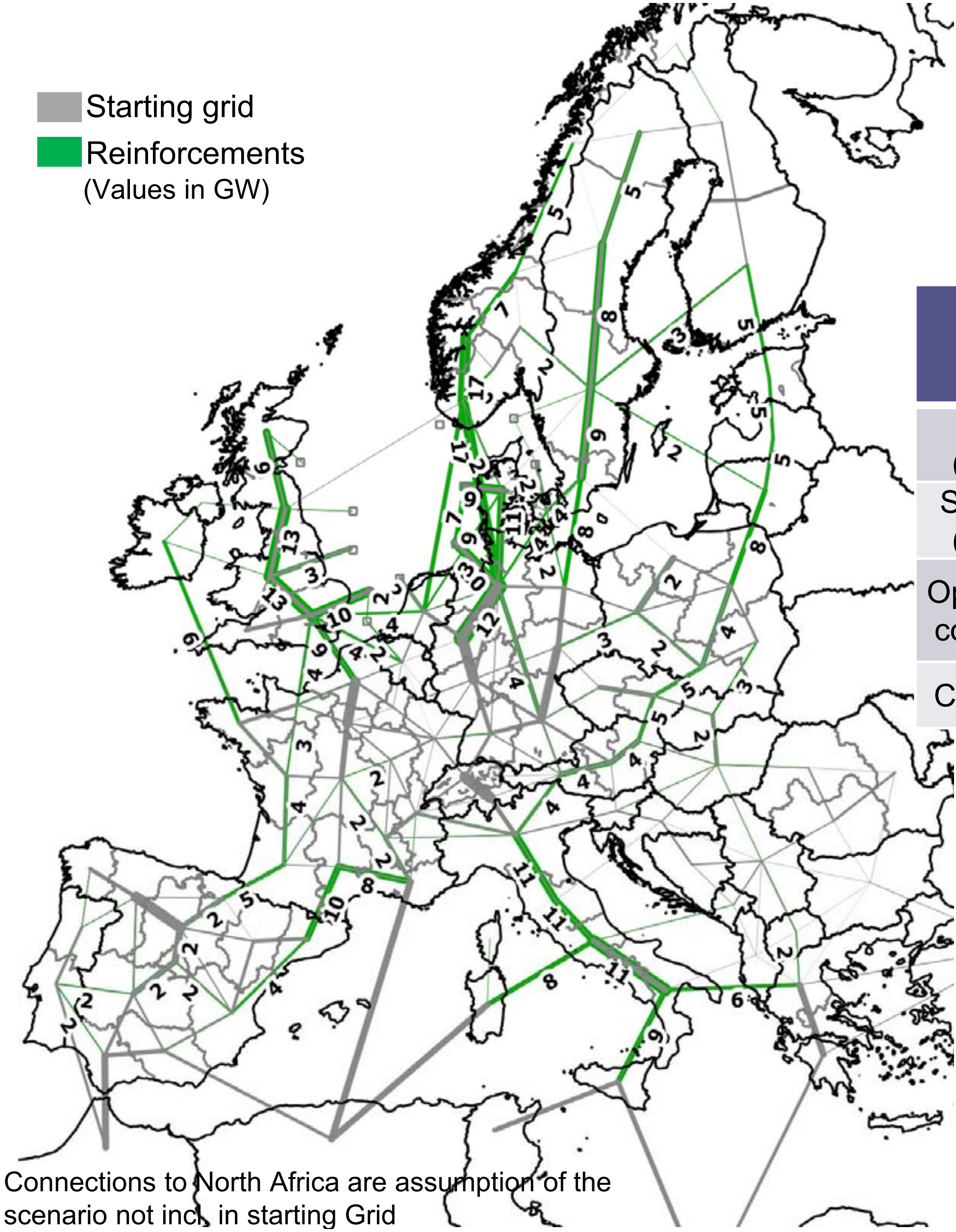
Gas generation
- **Germany (27%)**
- Italy (24%)
- Spain (14%)
- Netherlands (14%)

Nuclear generation
- **UK (38%)**
- France (26%)
- Sweden (23%)

*10,000 €/MWh & sensitivity with 1000 €/MWh

Final architecture for scenario *Large scale RES*

Large scale RES



Connections to North Africa are assumption of the scenario not incl. in starting Grid

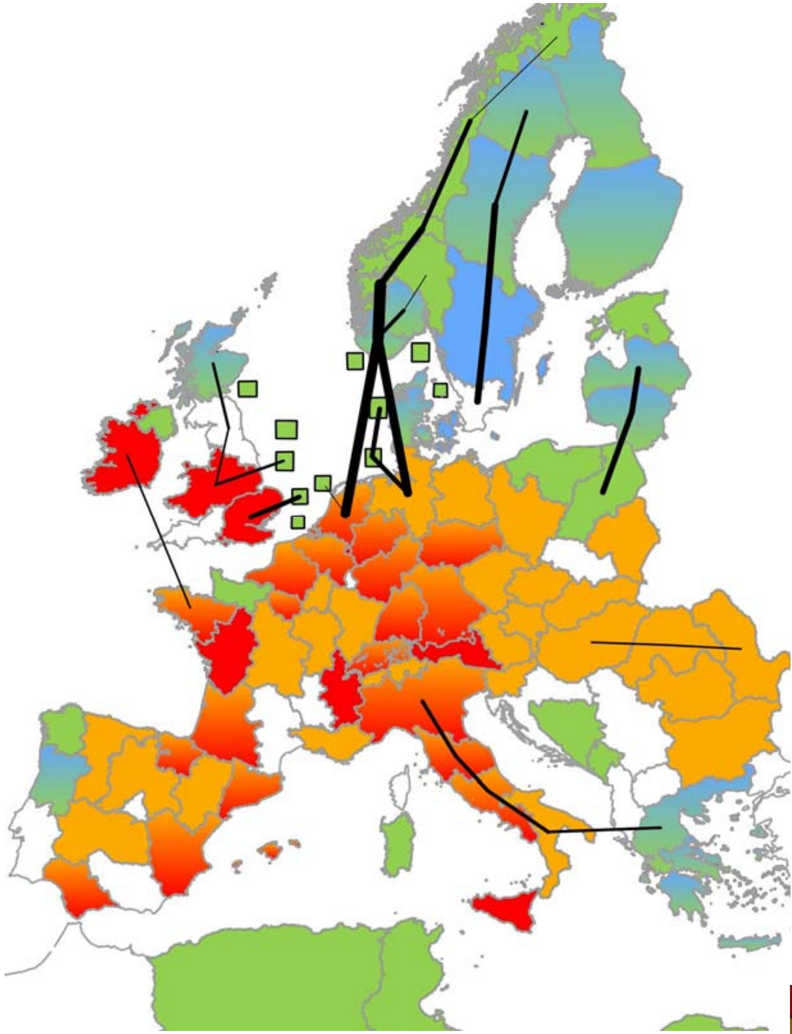
	Copper plate	Starting grid	Final grid	Savings	Financial Benefit
ENS (TWh)	0	23	0	-23	230 b€
Spillage (TWh)	38	609	88	-521	***
Operating cost (b€)	62	149	70	-79	79 b€
CO_2 (Mt)	81	292	100	-192	***

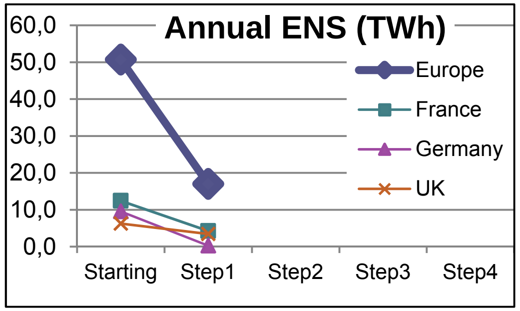
Annual benefits : 309 b€ *

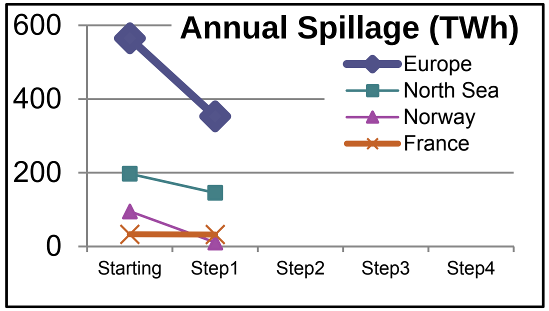
*Assuming a cost of unsupplied energy equal to 10 k€/MWh. With 1k€/MWh 102b€

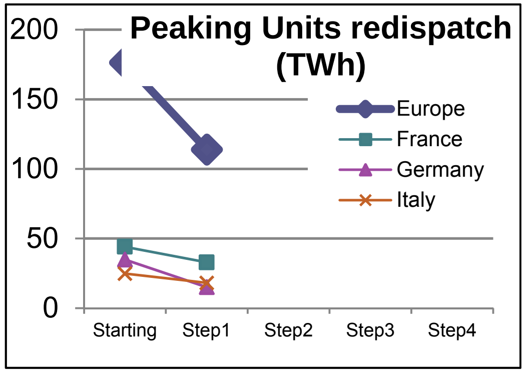
Grid Development Process – Start

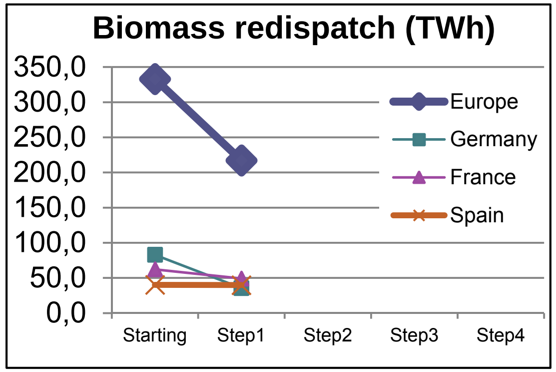
100% RES









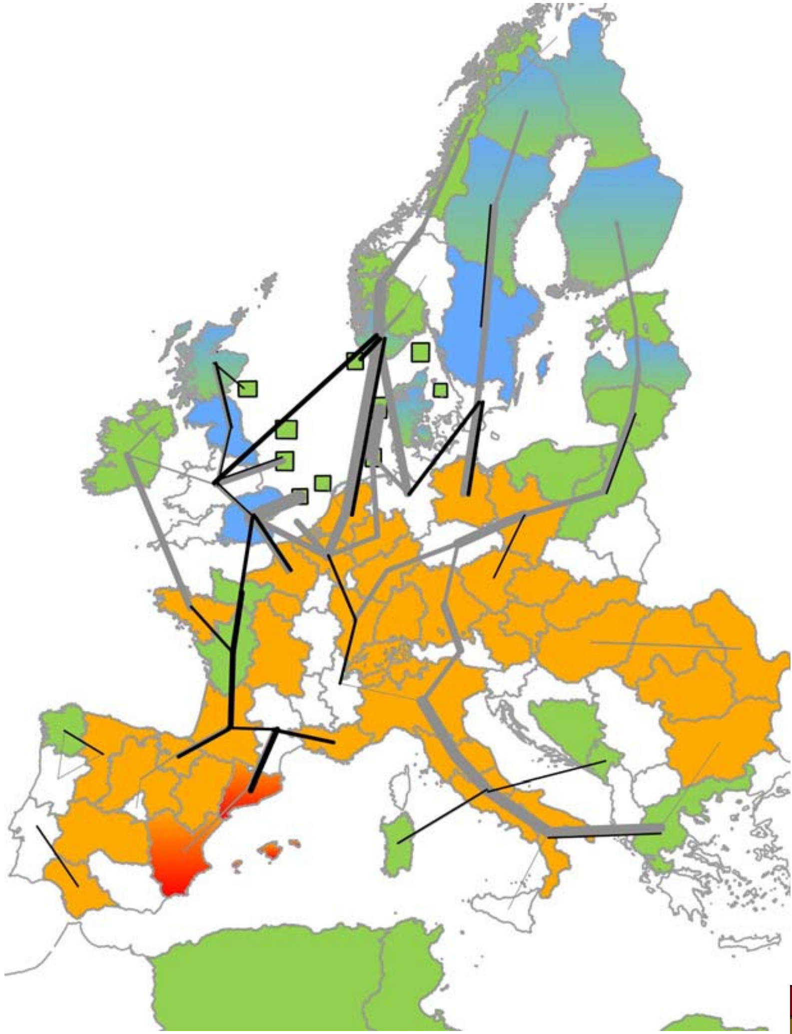


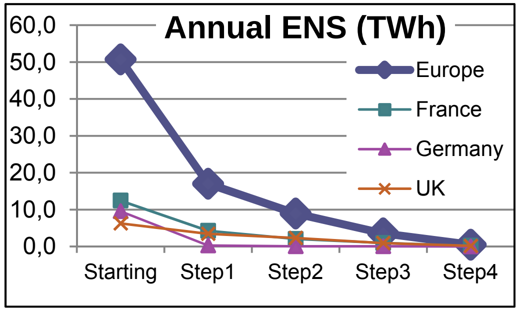
ENS>200MW
DeltaTH>+400MW
DeltaTH<-200MW
Spillage>200MW
New Reinforcements
Previous Reinforcements

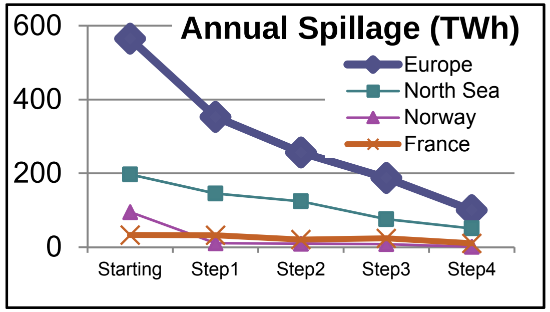
NB: other weeks and parameters are also studied

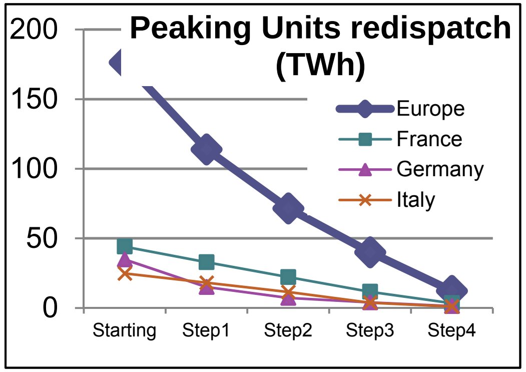
Grid Development Process – Final Step

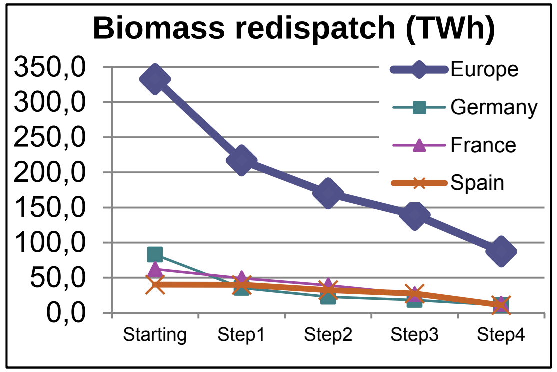
100% RES











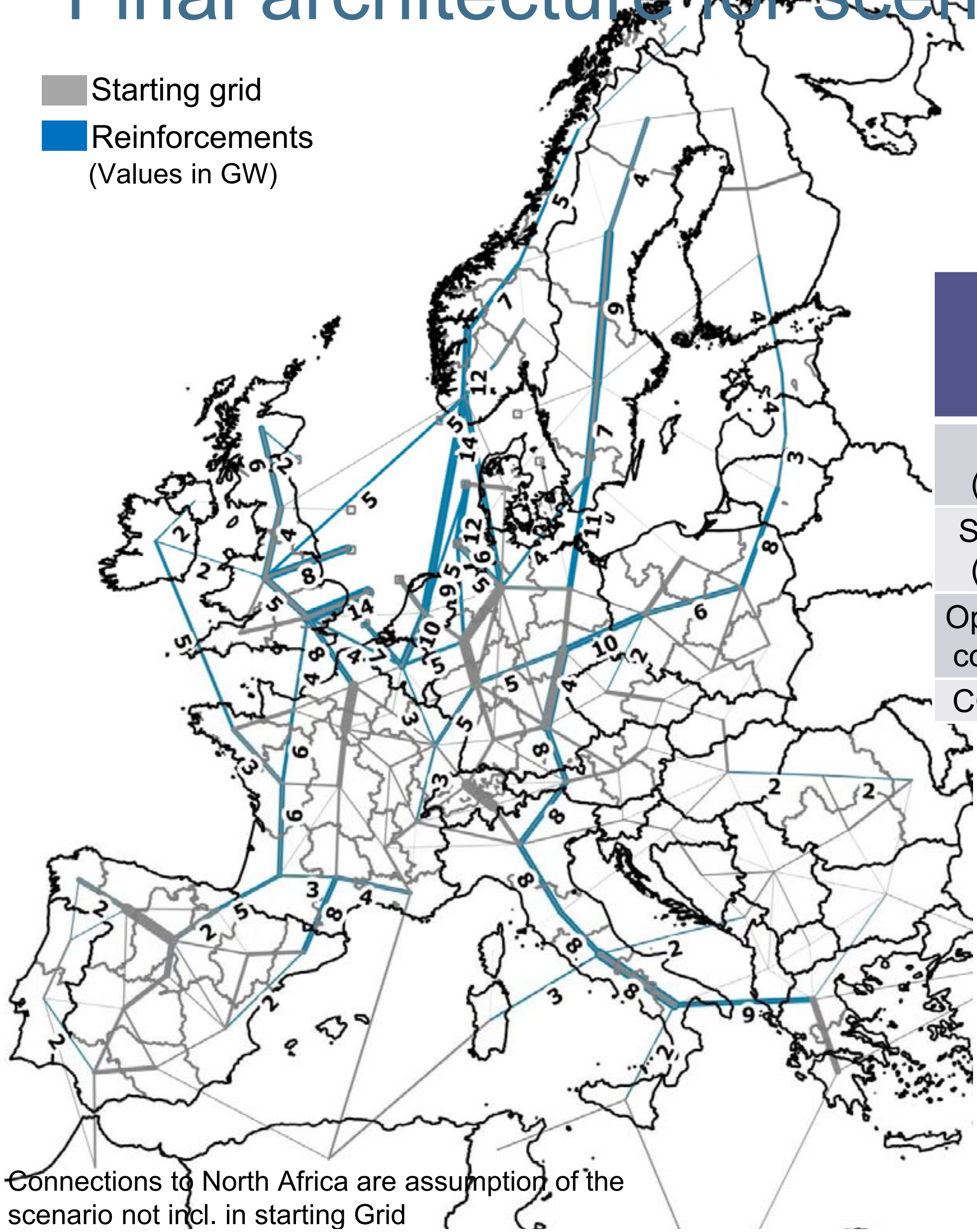
ENS>200MW
DeltaTH>+400MW
DeltaTH<-200MW
Spillage>200MW
New Reinforcements
Previous Reinforcements

NB: other weeks and parameters are also studied

100%
RES

Final architecture for scenario *Large scale RES*

Starting grid
Reinforcements
(Values in GW)



	Copper plate	Starting grid	Final grid	Savings	Financial Benefit
ENS (TWh)	0	51	0	-51	510 b€
Spillage (TWh)	208	773	308	-465	***
Operating cost (b€)	6	49	10	-39	39 b€
CO_2 (Mt)	0	86	6	-80	***

Annual benefits : 549 b€ *

Connections to North Africa are assumption of the scenario not incl. in starting Grid

*Assuming a cost of unsupplied energy equal to 10 k€/MWh. With 1k€/MWh 90b€

Scenario *Big & Market*

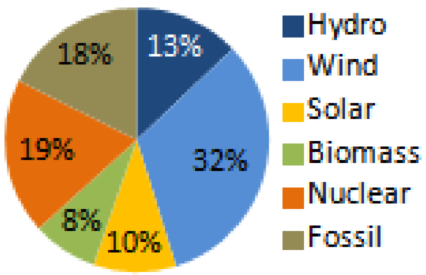
Big & market

Big & market

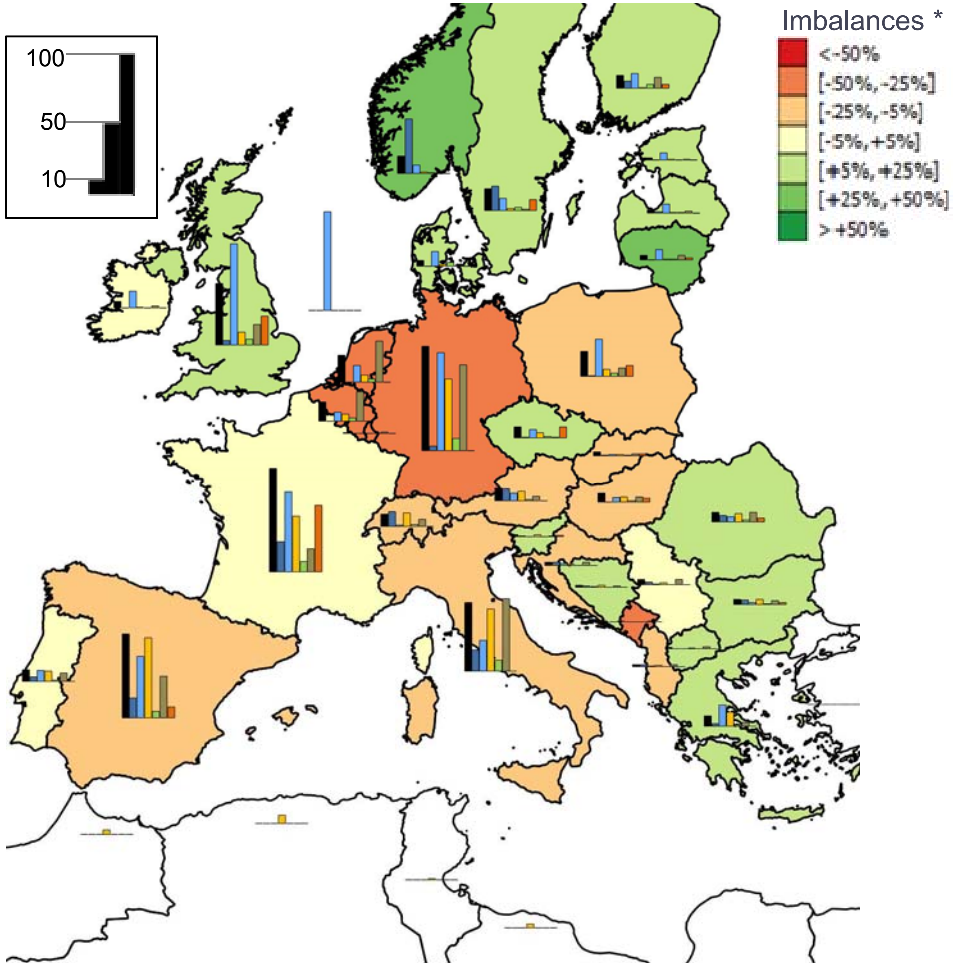
Presentation of the scenario *Big & Market*

- Medium demand : 4300TWh
- Nuclear and fossil energies are significant
- Renewables are dominated by wind especially North Sea (~ 71GW)

European energy shares



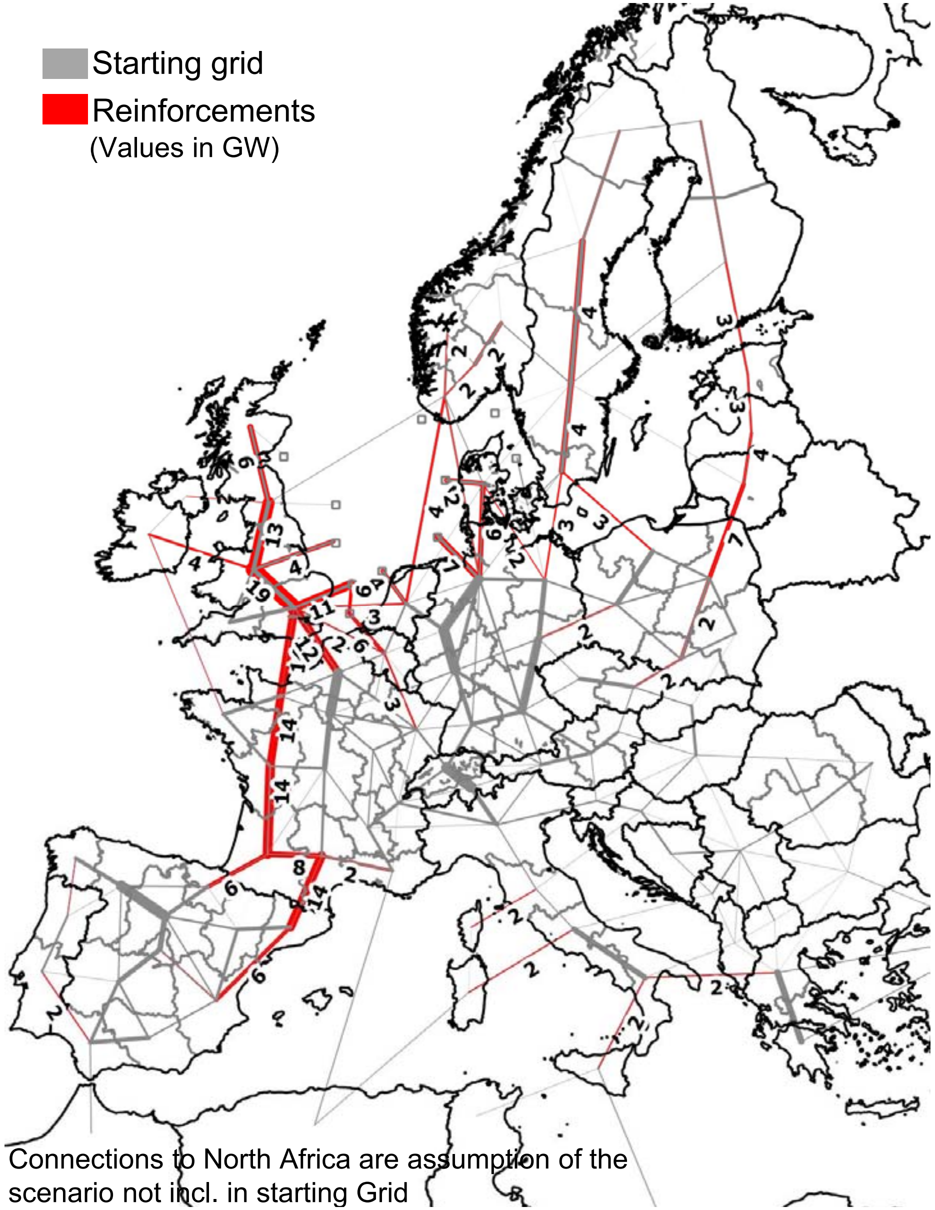
Installed capacities (GW)



*Imbalances in copper-plate simulation

Final architecture for scenario *Big & market*

Big & market



	Copper plate	Starting grid	Final grid	Savings	Financial Benefit
ENS (TWh)	0	11	0	-11	110 b€
Spillage (TWh)	3	205	22	-182	***
Operating cost (b€)	56	82	60	-22	22 b€
CO_2 (Mt)	39	101	47	-54	***

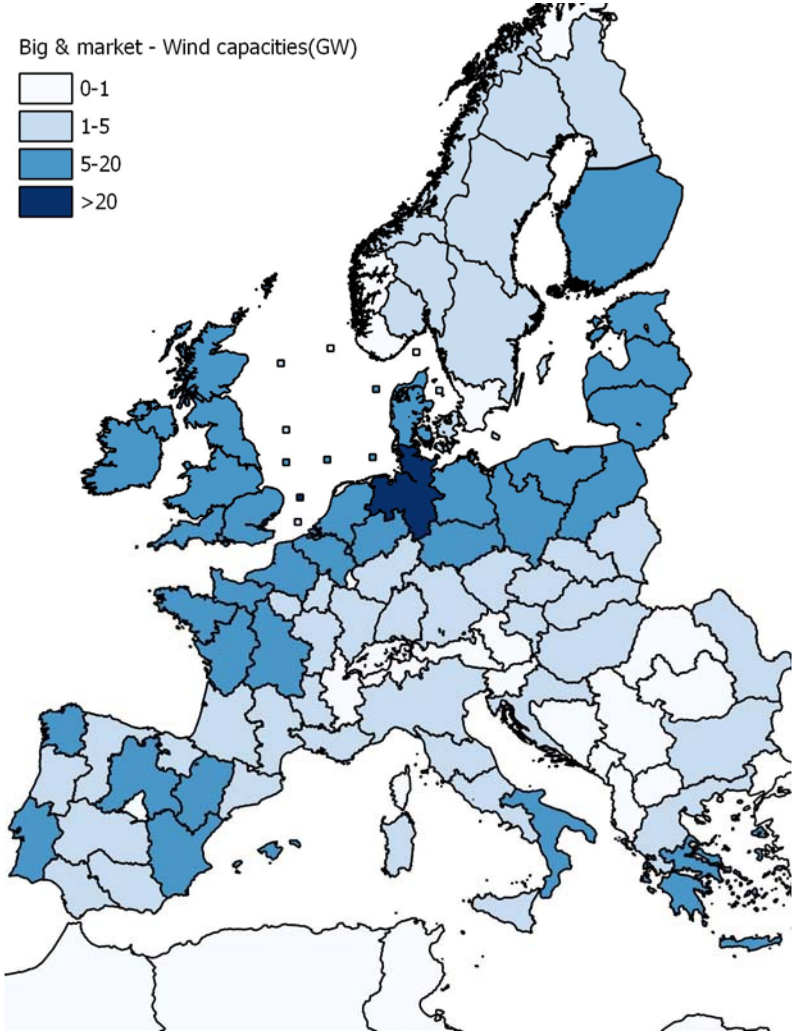
Annual benefits : 132 b€ *

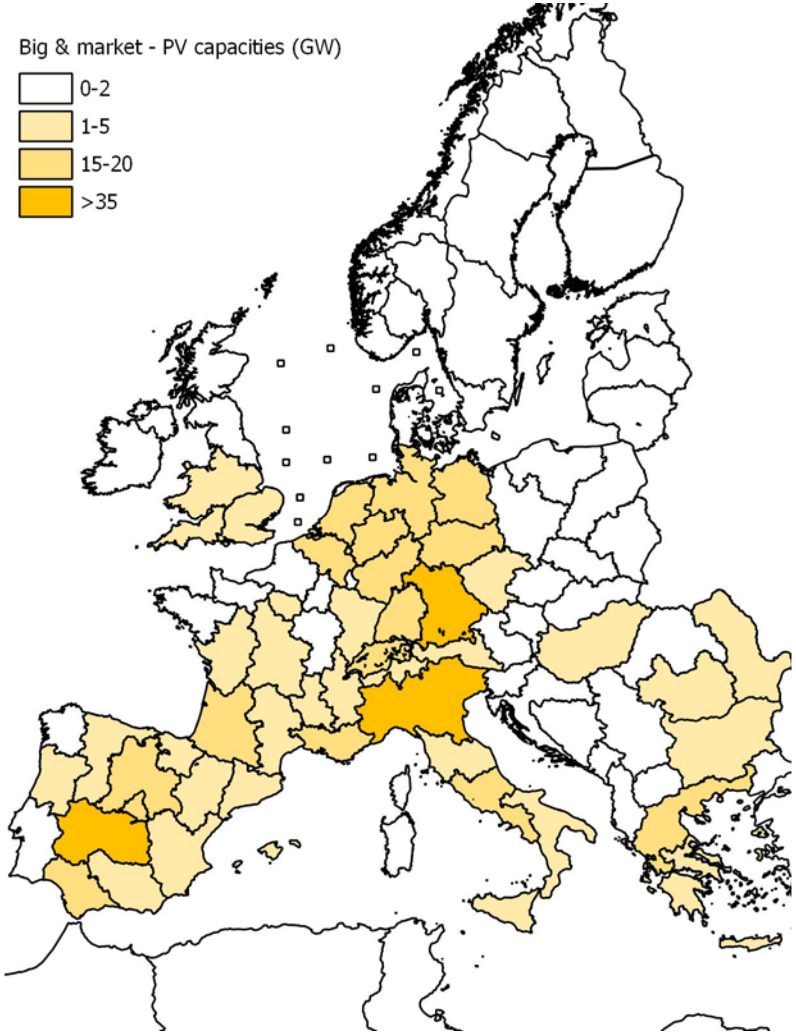
Connections to North Africa are assumption of the scenario not incl. in starting Grid

*Assuming a cost of unsupplied energy equal to 10 k€/MWh. With 1k€/MWh 33b€

Distribution of wind and solar capacities

Big & market





Scenario *Fossil & nuclear*

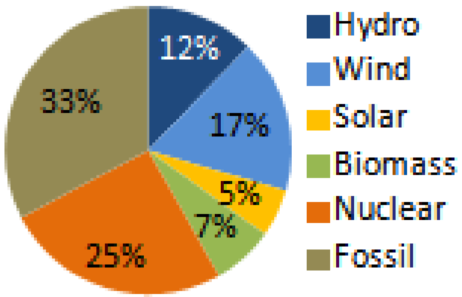
Fossil & nuclear

Fossil & nuclear

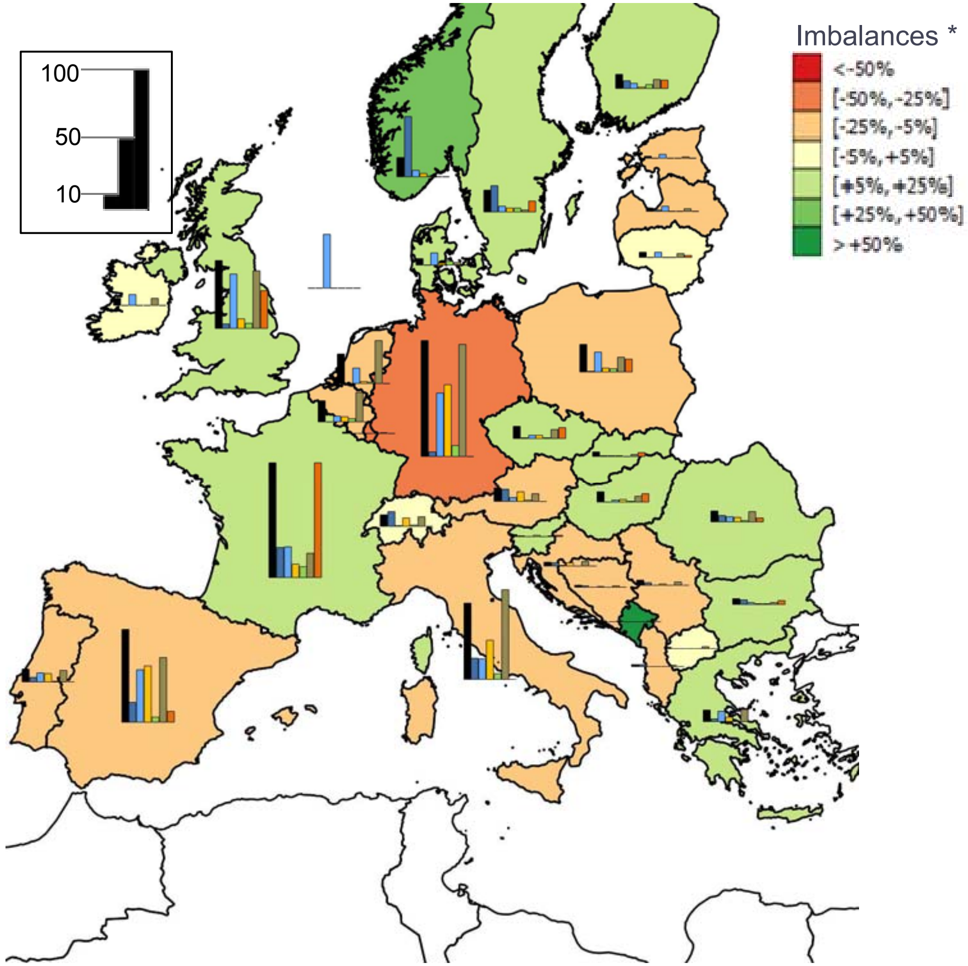
Presentation of the scenario *Fossil & nuclear*

- After X-5, second highest annual European demand: 4854 TWh
- Lowest shares of RES among all scenarios
- Nuclear and fossil fuel plants with CCS as main production
- No exchanges with North-Africa

European energy shares

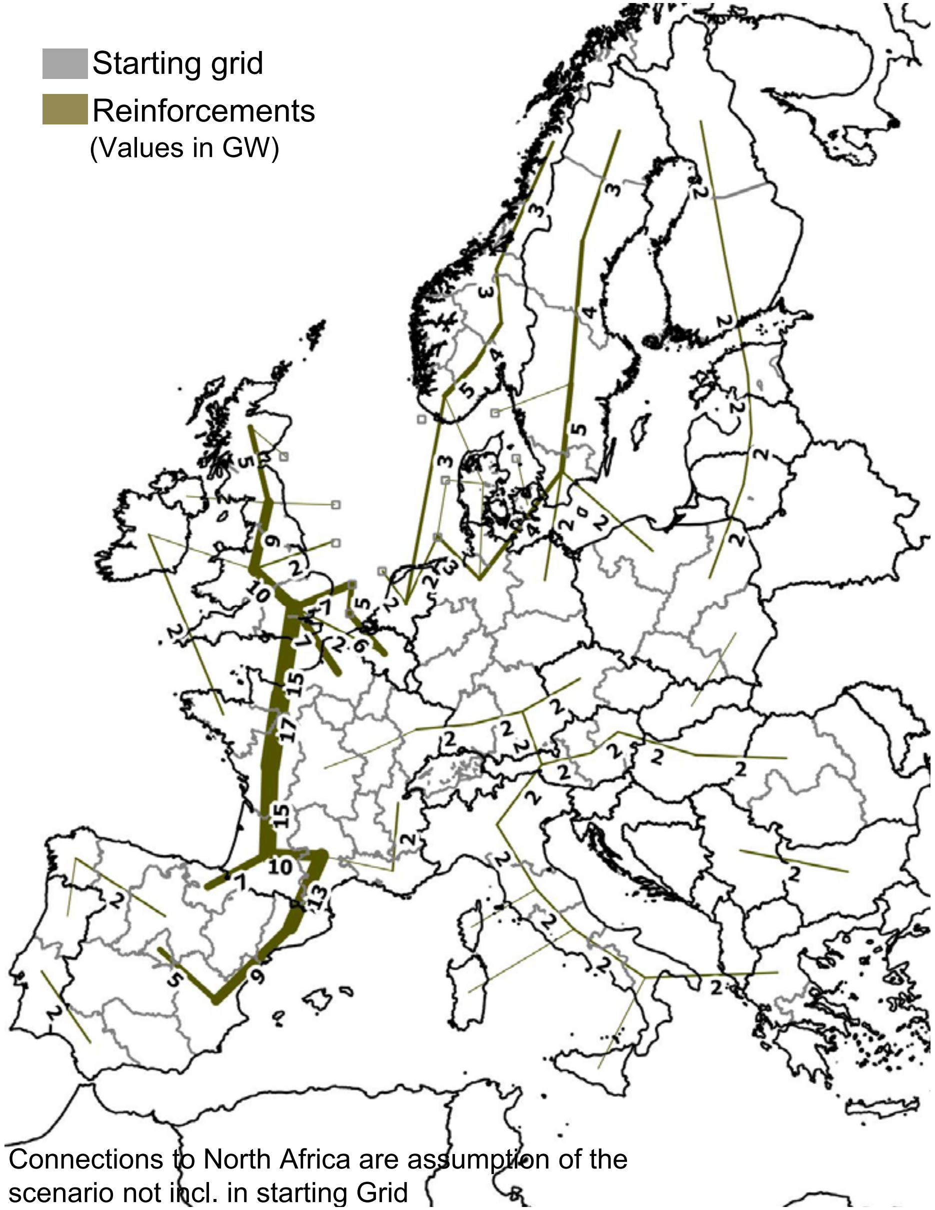


Installed capacities (GW)



Final architecture for scenario *Fossil & nuclear*

Fossil & nuclear



Connections to North Africa are assumption of the scenario not incl. in starting Grid

	Copper plate	Starting grid	Final grid	Savings	Financial Benefit
ENS (TWh)	0	7	0	-7	70 b€
Spillage (TWh)	0	42	1	-41	***
Operating cost (b€)	92	103	92	-11	11 b€
CO_2 (Mt)	40	78	42	-35	***

Annual benefits : 81 b€ *

*Assuming a cost of unsupplied energy equal to 10 k€/MWh. With 1k€/MWh 18b€

Scenario *Small & local*

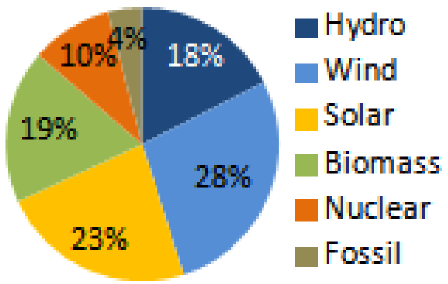
Small &
local

Small & local

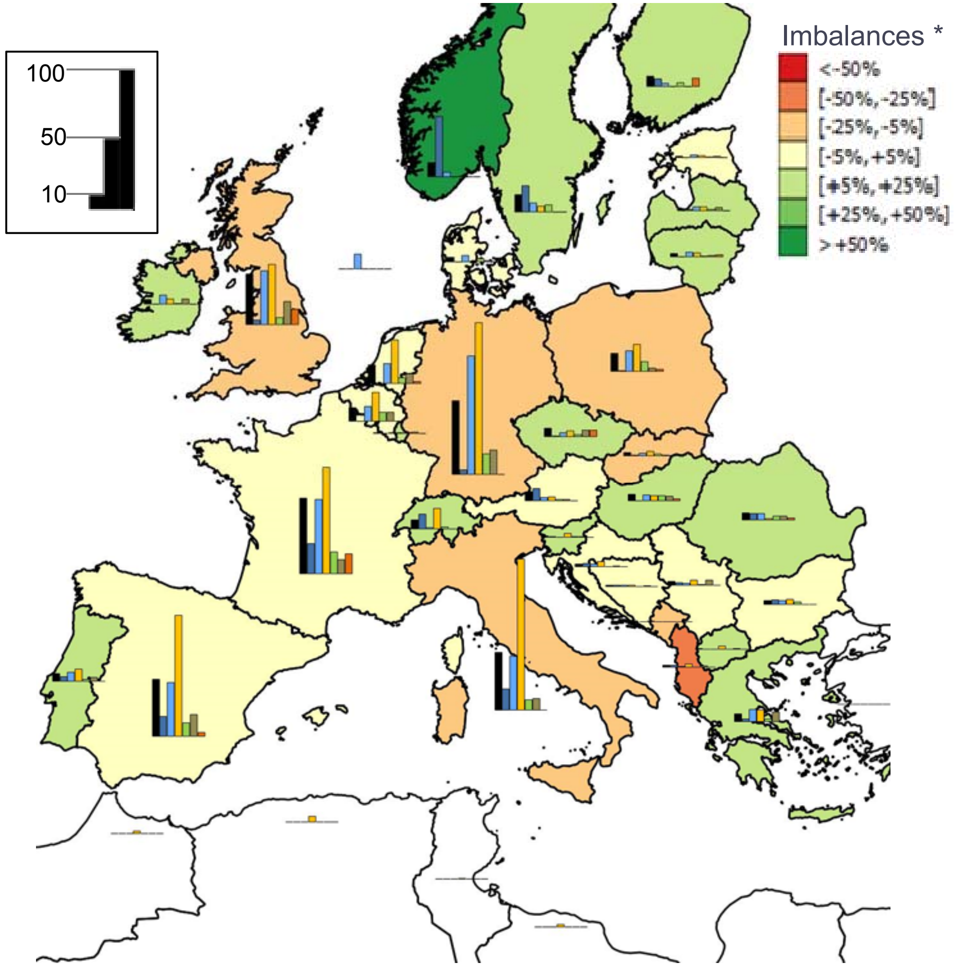
Presentation of the scenario *Small & local*

- Lowest demand: 3278 TWh
- Focus on local solutions: generation close to demand
- 85% of energy is generated from RES (mainly decentralized)

European energy shares



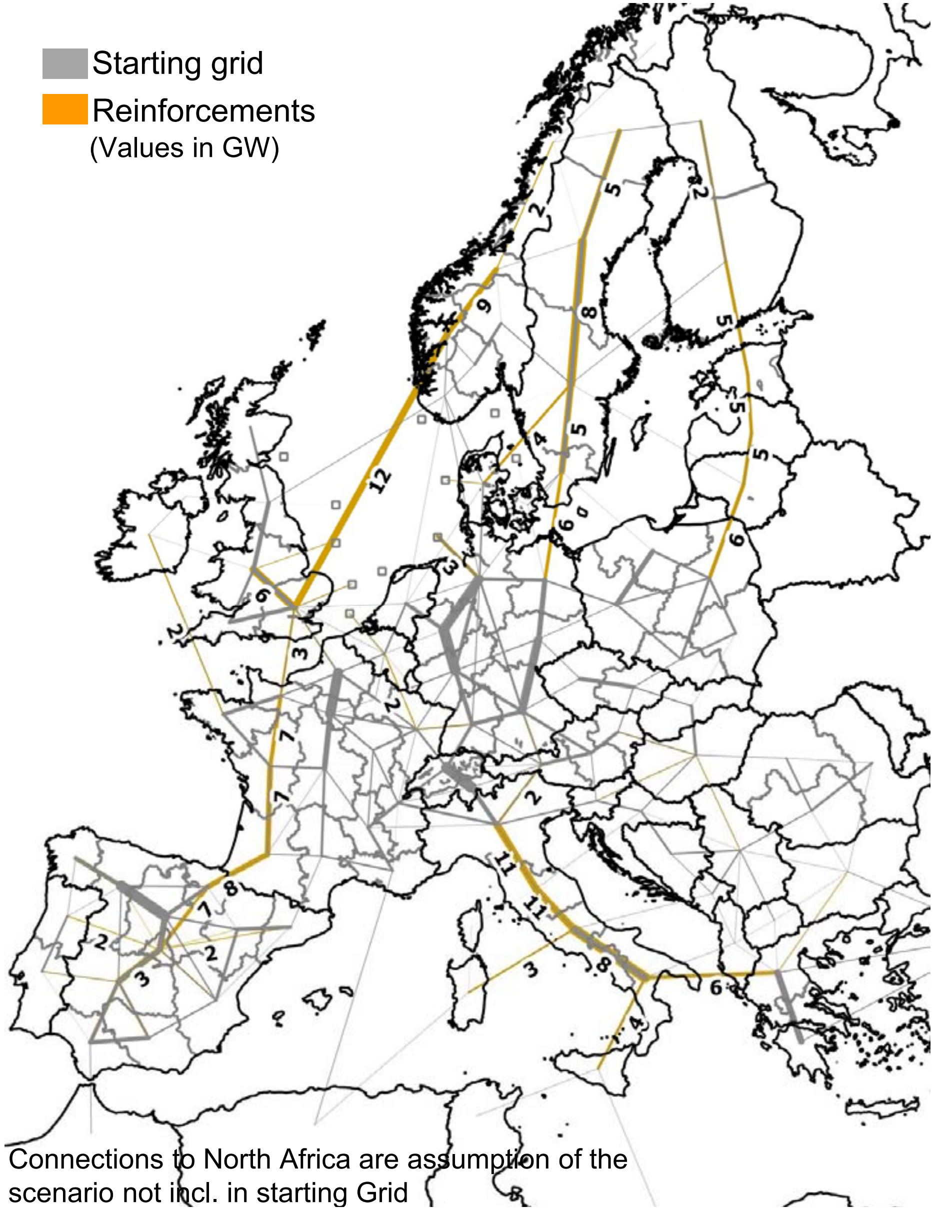
Installed capacities (GW)



*Imbalances in copper-plate simulation

Final architecture for scenario *Small & local*

Small & local



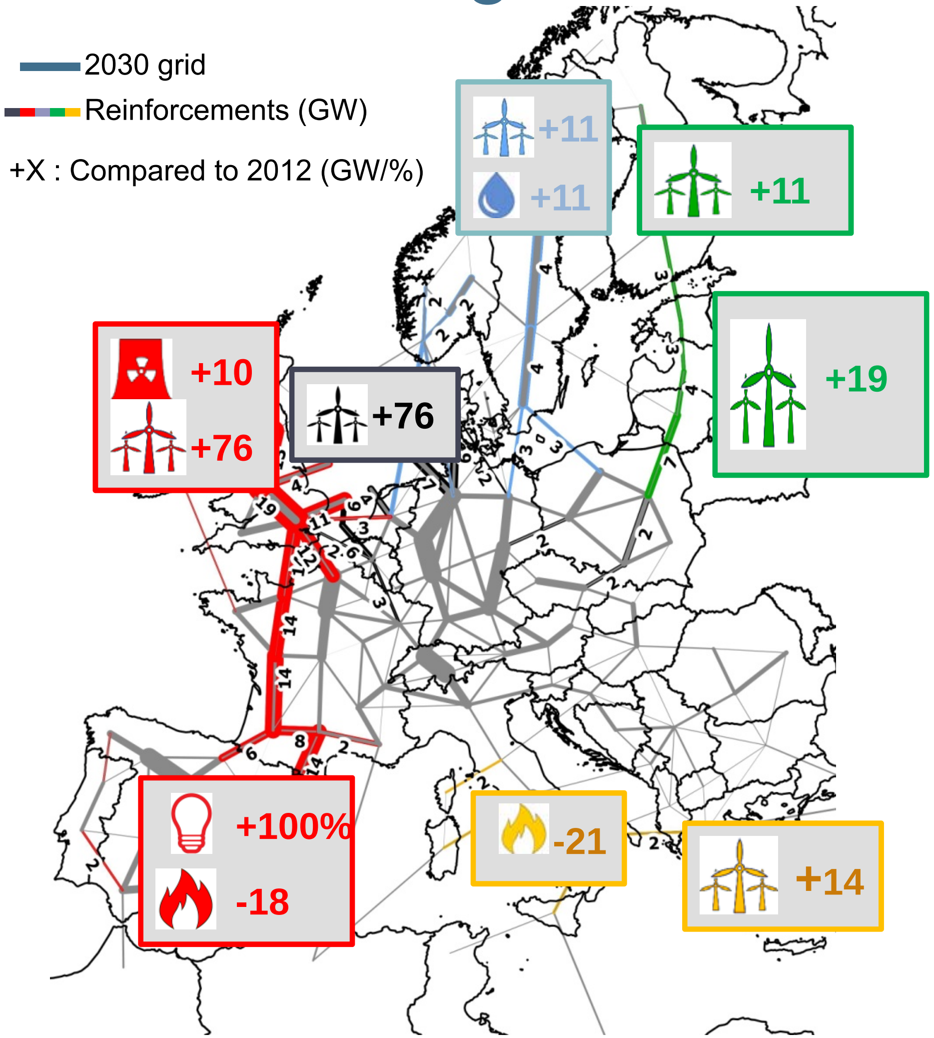
Connections to North Africa are assumption of the scenario not incl. in starting Grid

	Copper plate	Starting grid	Final grid	Savings	Financial Benefit
ENS (TWh)	0	5	0	-5	50 b€
Spillage (TWh)	54	107	60	-47	***
Operating cost (b€)	33	43	33	-10	10 b€
CO_2 (Mt)	43	68	44	-23	***

Annual benefits : 60 b€ *

*Assuming a cost of unsupplied energy equal to 10 k€/MWh. With 1k€/MWh 15b€

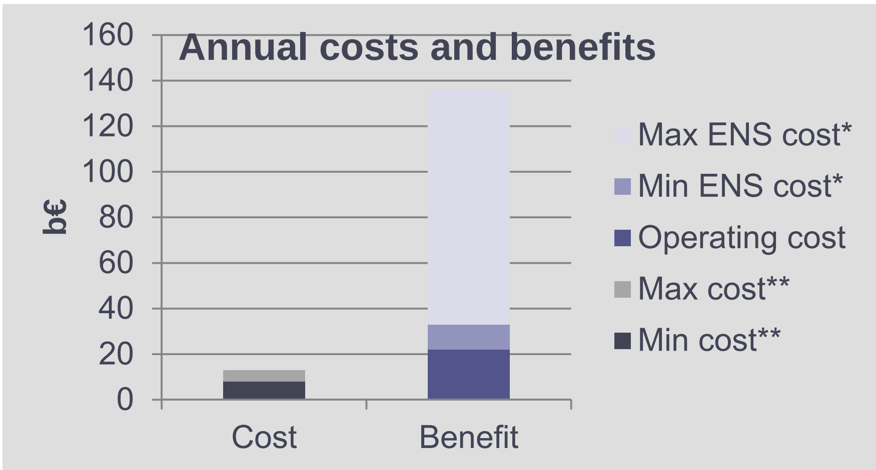
Results - Big & market



NB : only some of the key factors are displayed

Per year :
✓11 TWh of ENS avoided
✓182 TWh of spillage avoided
✓22 b€ of savings in operating costs

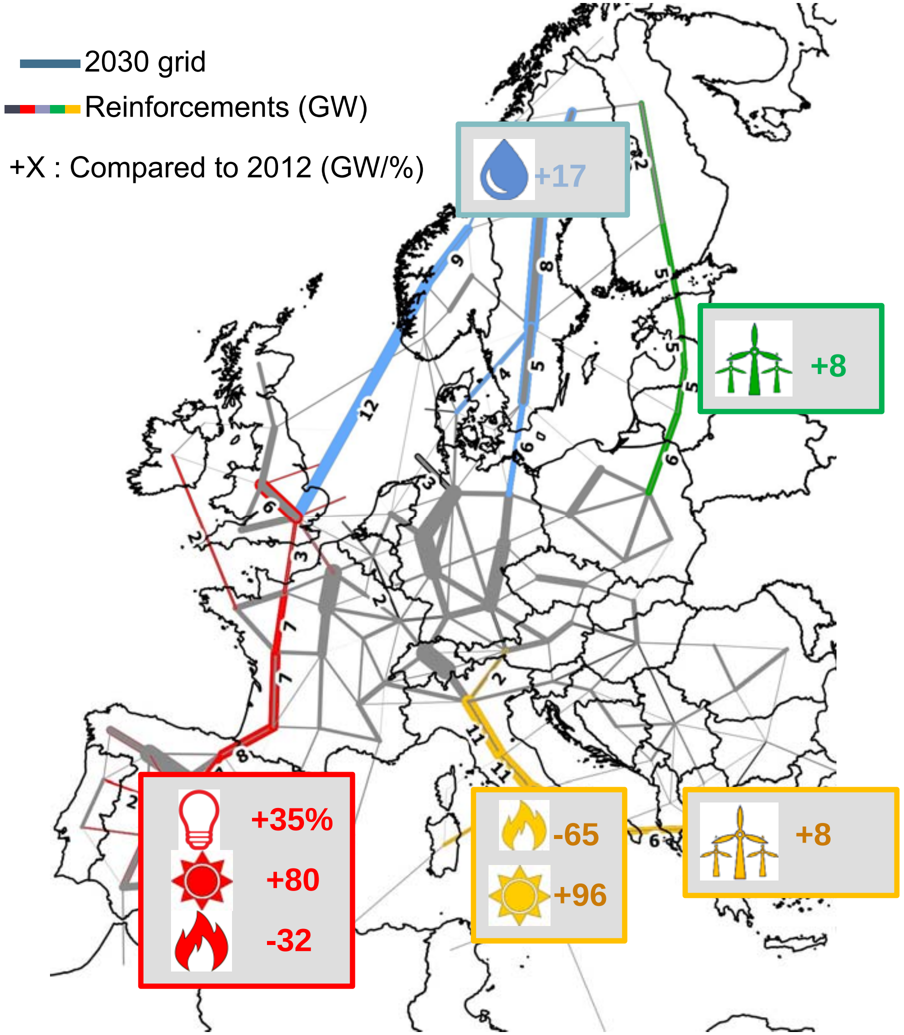
Total investment cost : 138-216** b€



** Depending on the cost of ENS : 1k€/MWh or 10k€/MWh*

** *Depending on the acceptance of over-head lines*

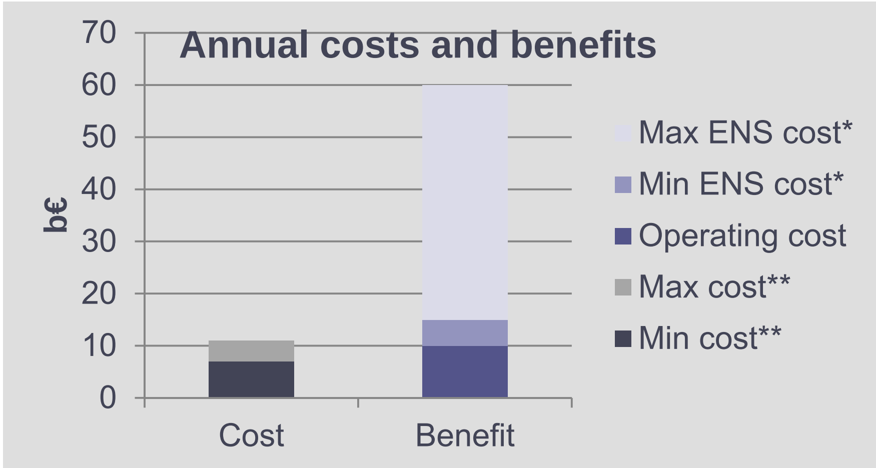
Results – Small & local



NB : only some of the key factors are displayed

Per year :
- ✓ 5 TWh of ENS avoided
- ✓47 TWh of spillage avoided
- ✓10 b€ of savings in operating costs

Total investment cost : 110-190** b€



** Depending on the cost of ENS : 1k€/MWh or 10k€/MWh*

** *Depending on the acceptance of over-head lines*

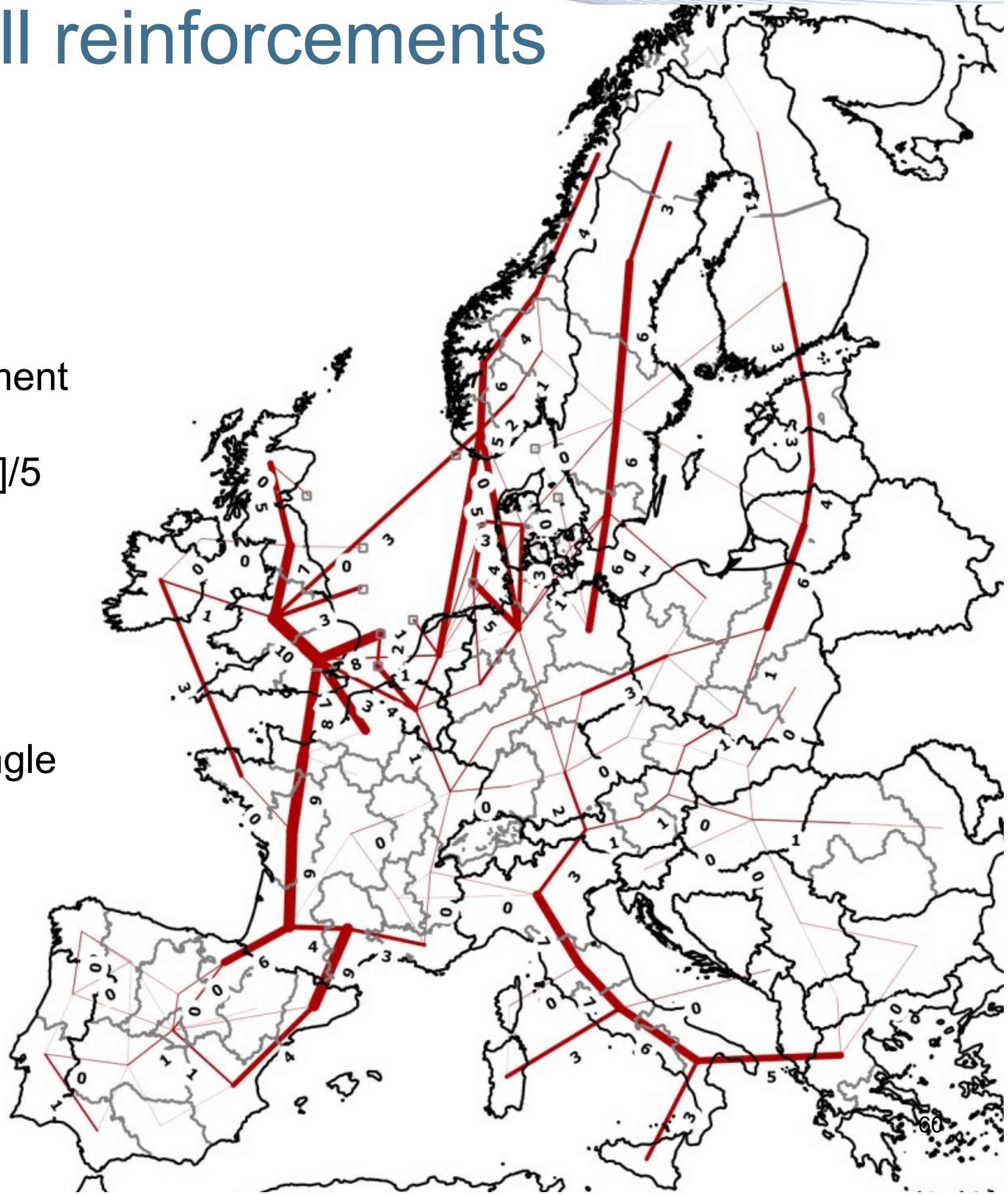
Common reinforcements
Average Capacity of all reinforcements

- Displayed are all lines reinforced throughout all five scenarios

- Widths according to average reinforcement capacity
  [Cap (X5) + Cap (X7) + … + Cap (X16)]/5

→National borders are first object for reinforcements

- Single corridors are very valuable in single scenarios

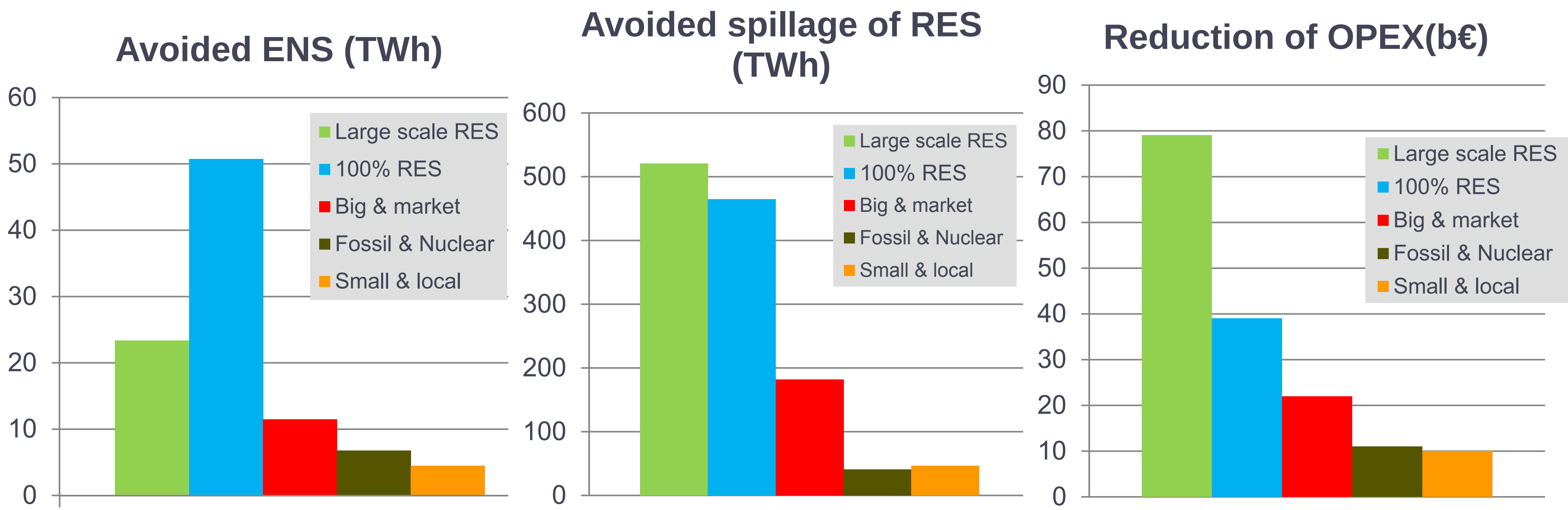


HIGHWAY 2050

SEVENTH FRAMEWORK PROGRAMME

EEGI

European annual benefits for the 5 scenarios



Benefits of the architectures are significant in all the scenarios :
- At least 10 b€ of savings on the operating cost, and up to 80b€ per year
- At least 40 TWh of spilled RES avoided, and up to 500 TWh

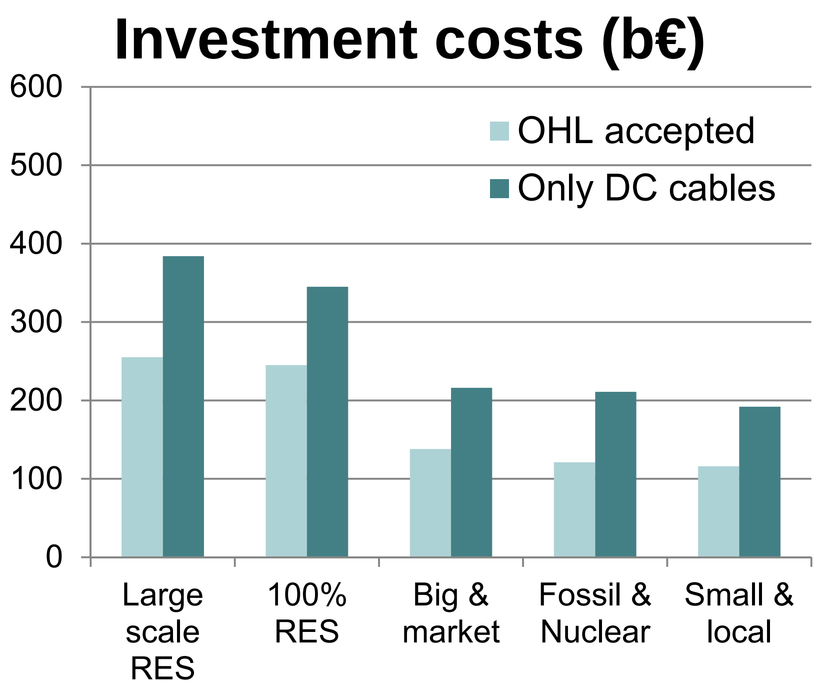
3 strategies to identify costs of possible realization

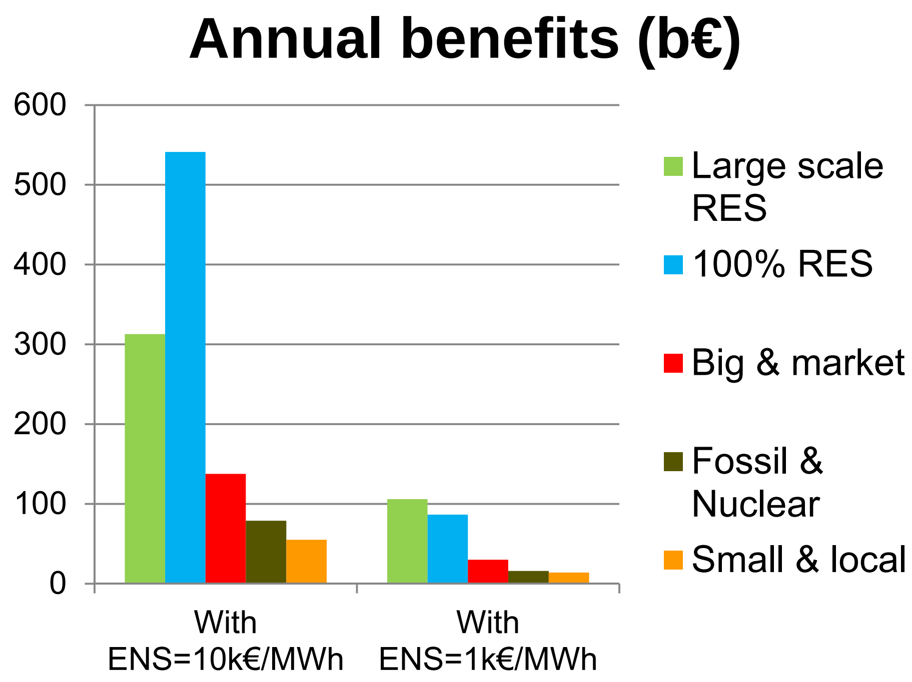
- The costs of a possible realization are dependent on implemented technologies
- Available technologies are influenced by the public acceptance of new lines
  → Three "strategies" to encompass levels of acceptability

Strategy	Social assumption	Technical description	Cables	Up-grade of OHL's	New OHL	New OHL on non existing corridors
New grid acceptance	Public acceptance for new OH Lines.	The most efficient (cost & technical) solution is selected.	X	(x)	X	X
Re-use of corridors	Public acceptance for new lines in existing infrastructure corridors.	Re-use of existing infrastructure corridors or construction of underground cable otherwise	X	(x)	X	
Status Quo	No public acceptance for new OH Lines.	Only up-grade of existing lines with same visual impact, or construction of underground cables otherwise	X	X		

→ The cost of the full architecture is calculated for each strategy

Costs of the architectures





➔ Investment costs range from 100 to 400 b€, they are compensated by the benefits

➔ Scenarios Large Scale RES and 100% RES need twice more reinforcements, but those reinforcements are extremely profitable