e-HIGHWAY 2050

Modular Development Plan of the Pan-European Transmission System 2050

Contract number	308908	**Instrument**	Collaborative Project
Start date	1st of September 2012	**Duration**	40 months
WP 4	**Modular development and operations**		
D 4.4	**Modular development plan from 2020 to 2050**		

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Project co-funded by the European Commission within the Seventh Framework Programme		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Document information

General purpose

This document constitutes the final version for Deliverable 'D4.4 – Modular development plan from 2020 to 2050'.
It uses:

- TYNDP ENTSO-e scenarios and grid architectures for 2020 and 2030.
- Results from D4.3 regarding scenarios and the grid architectures for 2040.
- Results from D2.3 regarding scenarios and the grid architectures for 2050.

Acknowledgements

The dataset provided by ENTSO-e regarding the starting grid and the visions.
The work performed by TU Berlin for the assessment of 2040.
The work performed by WP1 and WP2 regarding scenarios and the grid architectures for 2050.
The help from RTE, BRUNEL and TRANSELECTRICA related to the country profile.

Change status

Revision	Date	Changes description	Authors
V1.0	2015-11-12	First version – Generation, Demand and Storage	R. Pestana
V1.1	2015-11-23	Grid architectures for 2040 and 2050	R. Pestana
V1.2	2015-11-27	Comments from RTE Cost Benefits analysis	N.Grisey R. Pestana
V1.3	2015-12-31	Comments from IPE, SWISSGRID, SINTEF, PSE, SVENSKA Executive Summary, Introduction and Conclusion Country profile	R. Pestana

EXECUTIVE SUMMARY

This report presents the main findings of the e-Highway2050 project regarding the expected scenarios and the grid reinforcement for 2040 and 2050 (summarizing deliverables 2.1, 2.3 and 4.3) and compares them to available datasets from today to 2030.

This report is structured in three sections;

- The first describes the demand, generation and storage expected from 2020 to 2050 in each decade, with values of installed capacity (MW) and values in energy (GWh).
- The second section indicates the necessary grid reinforcements for 2040 and 2050. We assume that all the expected grid foreseen by the TYNDP 2014 dataset for the year 2030 is granted.
- The last section assesses the cost benefit analysis, comparing the yearly cost of the reinforcement's grid with the benefit of build it, since it reduces the Energy Not Supplied, the renewable energy spillage, CO_2 emissions, etc. Only a simplified CBA is presented in this report, the exhaustive one is described in deliverable 6.3.

Finally, in appendix, synthesis of the generation, demand and grid per country are provided from today to 2050.

The five boundary scenarios for 2050 show a significant spread of yearly electrical demand expectations from 3.2 to 5.2 PWh (Peta Watt hour). Assumption on the energy efficiency, DSM and EV increases the uncertainties of the expected load. The peak power in Europe can vary from 537 to 900 GW, and the total install generation capacity is from 1,336 to 2,120 GW. High penetration of RES will require that the total installed generation capacity largely exceeds the peak load.

The grid reinforcements expected for 2030 were taken from the dataset of 2014 from the TYNDP team of ENTSO-e. They are not re-assessed by the e-HIGHWAY 2050 project but considered as a starting point. Since the project has identified 5 scenarios for 2050, there are five alternative grids for 2050, more adjusted to the expected future but still with common elements. For 2040 we were able to provide a minimal common grid for all 5 scenarios, composed of minimal regret investments.

The main grid reinforcements is not just to connect the additional generation to the grid, but to minimize the Energy Not Supply, the spillage of renewable energy and the CO2 emissions. By accounting this benefits and cost of the grid, we can evaluate the cost-benefit analysis of the grid investments. Even with a low value for ENS in the range of 200 €/MWh the profitability is positive for all 5 scenarios in 2040 and 2050.

Disclaimer

The accuracy of the results illustrated in this report depends strongly on the used input data and the used methodology. Real future developments that deviate from the assumptions made in the scenarios, especially the generation mix, might lead to other propositions of grid reinforcements.

Given the time horizon of this study (2050) and the size of the playfield, a zonal approach (clustering) was chosen for the main studies. Consequently the granularity of the results presented here is not as accurate as in a study that would tackle a closer time horizon and use a full grid model (TYNDP for instance, where detailed consistency of projects is given). The clustering approach enables focusing on transmission needs between clusters, only, thus does not reveal needs for intra-cluster reinforcements. Another consequence is that the priority has been set on the detection of major electric energy transportation issue. That is to say long distance and large capacity reinforcements (often greater than 2GW) and does not assess if smaller reinforcements would prove necessary.

The analyses in this task pursue a conservative approach to assess new transmission corridors. Only corridors that are required and beneficial even under difficult circumstances are suggested. The definition of the initial grid transmission capacities (GTC) within the cluster model has been taken from deliverable 2.2. Here an approach focusing on the thermal capacities between clusters was applied. Since this does not give credit to operational issues of the grid, defined GTCs tend to be higher than on could expect in daily grid operation. Therefore the given architectures per scenario present the minimum required grid reinforcements in each scenario. Beyond those, further reinforcements can be required and beneficial. The starting grid, assumed in the analysis, builds on a full realization of the TYNDP 2014 projects. Without their realization, the proposed reinforcements would be different.

It should be kept in mind that the generation capacities were defined following a top-down approach that ensures a European consistency; in particular there are no excessive extra generation capacities to secure independent national system adequacy. To realize such objectives, a very strong collaboration between countries is required in some scenarios. This coordinated development may differ from the combination of national development plans or from ENTSO-e's Ten Years Network Development Plan visions. Only grid solutions have been implemented to solve the identified issues. Other solutions like more storage or more generation were not considered.

The architectures proposed hereafter can be understood as additional capacity requirements that are required beyond the grid expansion plan that has been issued in ENTSO-e's Ten Years Network Development Plan 2014 (TYNDP '14). Some of these projects set already a basis for a future e-Highway system as they are comparable in use, capacity and distance, e.g. the HVDC corridors in Germany and southwest France and from UK to continental Europe.

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Abbreviations

CCS	Carbon capture and storage
CSP	Concentrated solar power
DSM	Demand side management
ENS	Energy not supplied
ENTSO-E	European Network of Transmission System Operators for Electricity
LOLD	Loss of load duration
PSP	Pumped Storage Plant
PV	Photovoltaics
RES	Renewable energy source
RoR	Run-of-the-river
TR	Transmission capacity Requirement
TYNDP	Ten Year Network Development Plan

1. Introduction

The objective of this report is to present the main findings of the project regarding the expected scenarios and the grid reinforcement for 2040 and 2050.

Initially the scope of the work was expected to cover 2020 and 2030, but since ENTSO-e has provided a good starting grid and visions for that time period by the TYNDP - *Ten Year Network Development Plan* team, it is considered as the best assessment from the European TSO's and not re-assessed under the e-Highway2050 project.

The e-HIGHWAY 2050 project started in September 2012, and the interaction with the TYNDP team covered two planning stages;

- The 2014 dataset from TYNDP were used by WP2 as a 2030 starting grid for the 2050 grid assessment,
- The 2016 draft dataset of the 2030 visions from TYNDP were used by the task 4.3 for the 2040 scenario assessment.

The five scenarios used to represent the 2050 future are boundary conditions for generation and demand, not the most likely future. If the European reinforced grid can deal with it, any expected future is feasible.

This report is structured in three sections;

- The first will describe the demand, generation and storage expected from 2020 to 2050 in each decade, with values of installed capacity (MW) and values in energy (GWh),
- The second section will indicate the necessary grid reinforcements for 2040 and 2050. We assume that all the expected grid foreseen by the TYNDP 2014 dataset for the year 2030 is granted,
- The last section will assess the cost benefit analysis, comparing the yearly cost of the reinforcement's grid with the benefit of build it, since it reduces the Energy Not Supplied, the renewable energy spillage, CO_2 emissions, etc.

The detailed information, the models and the assumption taken is available on the several deliverables of WP2 and WP4, with the contribution of WP1 (Boundary Conditions) and WP3 (Technology portfolio).

2. Demand, generation and storage from 2020 to 2050

ENTSO-E provided the demand dataset for 2020 (Expected Progress) and 2030 with 4 visions.

Based on the 5 scenarios proposed by the project for 2050, the best path to link the 2030 vision to the 2050 scenarios was identified, and the same 5 scenarios were also proposed for 2040 (see D4.3).

Since the work for 2040 was done in the summer of 2015, the draft dataset from TYNDP 2016 from ENTSOE was used.

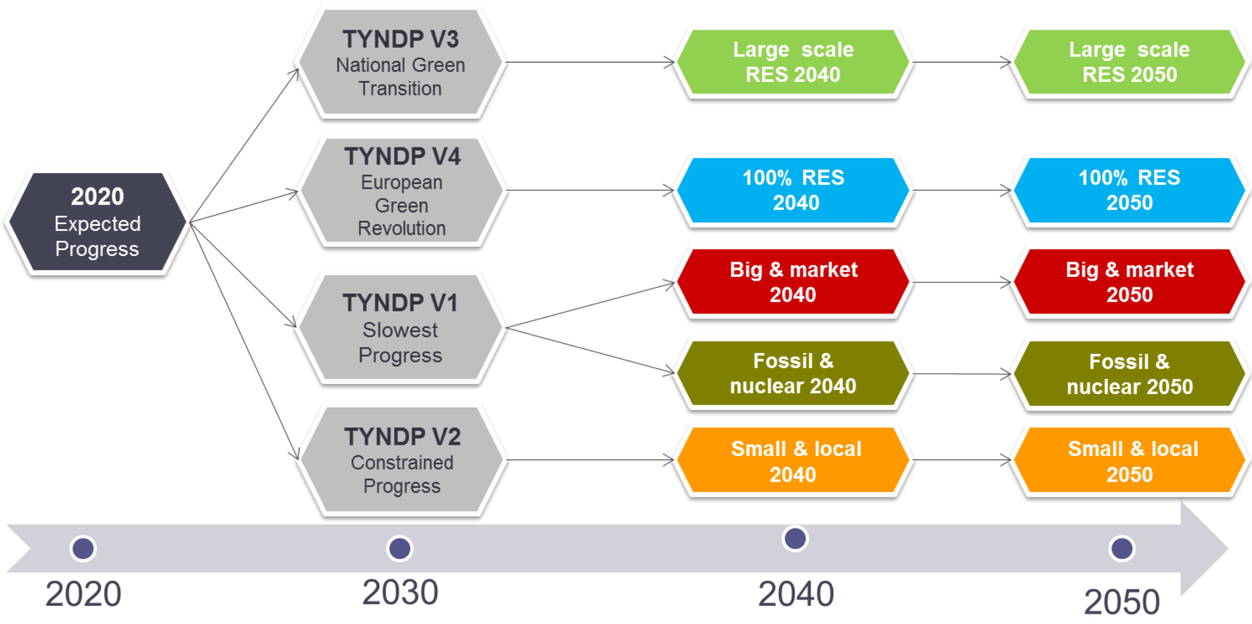


Figure 1: Linking 2030 visions to 2050 scenarios

2.1. Demand from 2020 to 2050

The latest statistics from ENTSO-E show that the total demand for Europe in 2014 was 3,310.4 TWh [1].

For clarification the ENTSO-E statistics include Iceland and Cyprus and exclude Albania since it doesn't belong to ENTSO-E. In the e-HIGHWAY2050 project, Albania is included but Iceland and Cyprus are excluded since there is no physical interconnection with the European market.

Table 1: Energy Demand in TWh from 2020 to 2050

Scenario	2020	2030	2040	2050	Scenario
Expected Progress	3,393				
National Green Transition		3,429	4,318	5,196	Large Scale RES
European Green Revolution		3,681	3,984	4,277	100% RES
Slowest Progress		3,496	3,894	4,281	Big & Market
			4,106	4,705	Fossil & Nuclear
Constrained Progress		3,309	3,253	3,187	Small & Local

Only in the 2030 vision of Constrained Progress and 2040 & 2050 Small and Local, demand decreases over time. All other visions and scenarios show an increase. The figure below represents the data from table 1, with corresponding colours.

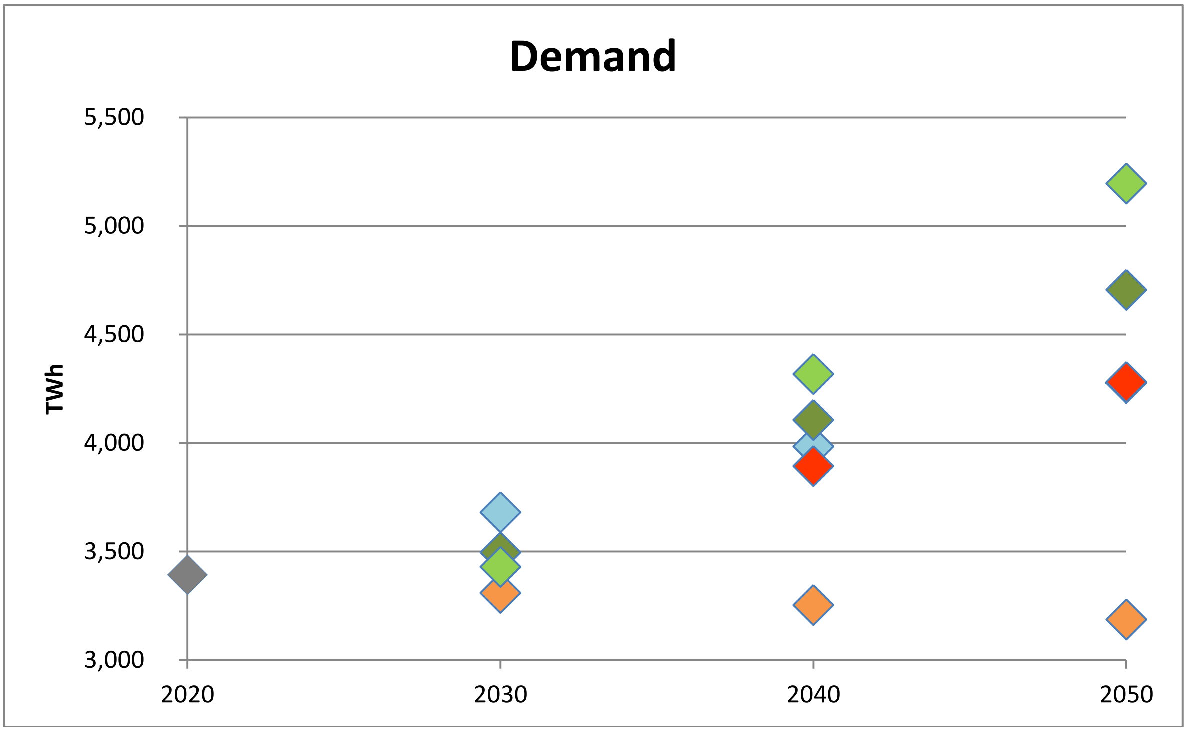


Figure 2: Energy Demand from 2020 to 2050

Country data for the years 2030, 2040 and 2050 by vision/scenario is provided in the annex together with the 2014 data.

Lowest and highest peak

In the table below lowest and highest peak demand for energy consumption is presented. In 2014 the lowest and highest peak was 228,758 MW and 518,894 MW respectably.

Table 2: Lowest and Highest peak demand without DSM in 2050

Scenario	*Large Scale RES*		*100% RES*		*Big & Market*		*Fossil & Nuclear*		*Small & Local*	
Load	*Lowest*	*Highest*	*Lowest*	*Highest*	*Lowest*	*Highest*	*Lowest*	*Highest*	*Lowest*	*Highest*
	MW	*MW*	*MW*	*MW*	*MW*	*MW*	*MW*	*MW*	*MW*	*MW*
Europe	384,923	899,823	324,452	720,101	327,598	727,766	359,416	809,879	243,891	536,637

2.2. Generation from 2020 to 2050

2.2.1. Installed capacity

The next tables show the overall expected installed capacities in Europe, detailed information by country is provided in the annex. The data is divided by generation type, namely Wind, Solar, Biomass, Hydro, Fossil and Nuclear. The installed capacity for North Sea is related to off-shore wind and the North Africa is related to solar. This data is presented in a separate table.

Generation for 2020 and 2030

Table 3: Installed generation capacity in Europe by type for 2020 and 2030

	Type Gen	Wind	Solar	Biomass	Hydro	Fossil	Nuclear	Σ Total
Year	Scenario	MW	MW	MW	MW	MW	MW	MW
2020	Expected Progress	199,580	121,710	54,343	219,619	390,039	124,372	1,109,663
2030	Slowest Progress	239,440	149,640	51,722	230,276	368,500	108,285	1,147,863
2030	Constrained Progress	242,397	150,838	51,017	230,276	356,764	108,285	1,139,577
2030	National Green Transition	352,170	225,060	74,865	253,249	374,834	80,097	1,360,275
2030	European Green Revolution	379,048	241,390	74,865	258,766	366,476	80,097	1,400,642

Generation for 2040 and 2050

Table 4: Installed generation capacity in Europe by type for 2040 and 2050

	Type Gen	Wind	Solar	Biomass	Hydro	Fossil	Nuclear	Σ Total
Year	Scenario	MW	MW	MW	MW	MW	MW	MW
2040	Large Scale RES	507,089	240,807	72,500	316,221	218,800	118,400	1,473,817
2040	100% RES	544,445	466,628	129,500	336,334	150,400	40,000	1,667,307
2040	Big & Market	325,042	220,135	57,750	241,128	274,600	112,000	1,230,655
2040	Fossil & Nuclear	237,636	172,371	52,250	244,506	323,200	139,200	1,169,164
2040	Small & Local	298,589	367,831	79,750	244,506	167,000	78,400	1,236,075
2050	Large Scale RES	709,744	256,315	69,750	376,569	267,850	157,200	1,837,429
2050	100% RES	759,878	691,519	184,000	411,118	73,250	0	2,119,765
2050	Big & Market	436,301	290,283	63,250	250,422	298,100	116,200	1,454,556

2050	**Fossil & Nuclear**	261,790	195,020	52,500	257,179	401,000	169,000	1,336,490
2050	**Small & Local**	372,873	583,900	107,750	257,179	126,650	48,000	1,496,351

*except the North Sea region

In the 100% RES scenario for 2050 there is no nuclear, but since the majority of the renewable generation is variable, the total installed capacity exceeds 2 TW.

Generation in North Sea, Africa and Middle East

The off-shore wind in the North Sea is distributed in 11 clusters, linked to 8 countries, that is illustrated in the next figure.

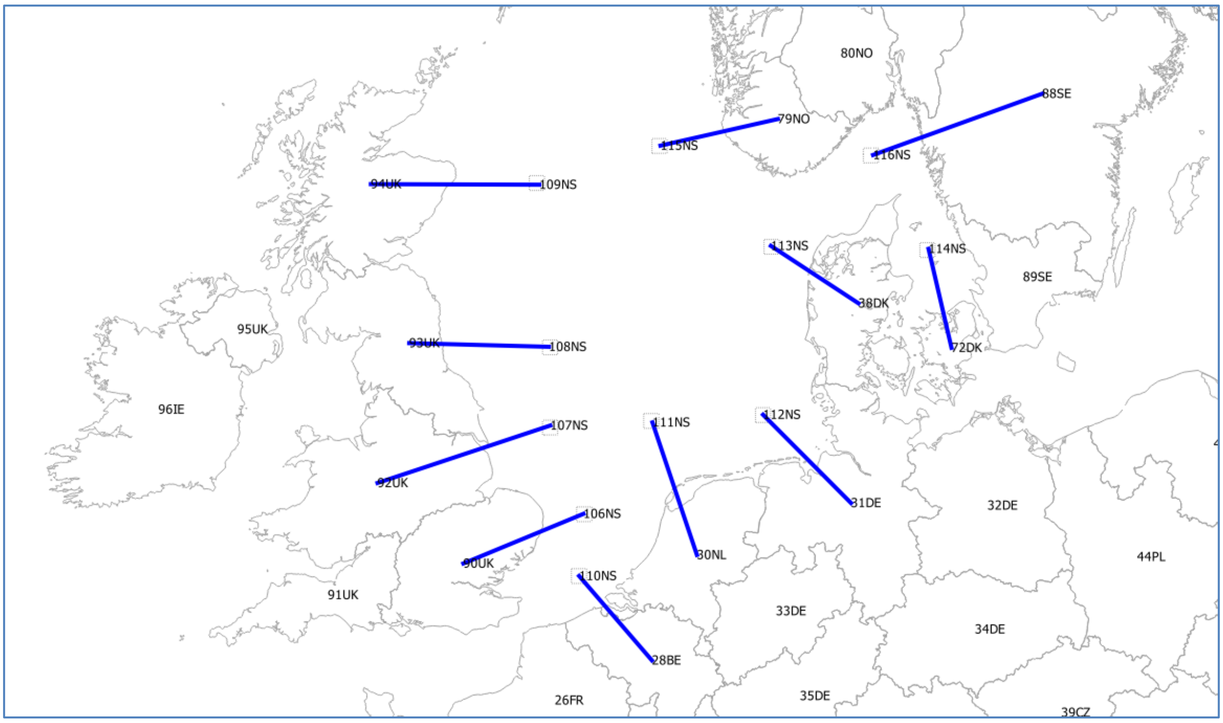


Figure 3: North Sea links

The total install capacity in the NS varies from 15 GW to 115 GW in 2050 depending of the scenario.

Table 5: Installed generation capacity of off-shore wind in North Sea for 2040 and 2050

Year	2040	2050
Scenario	**MW**	**MW**
Large Scale RES	76,249	103,725
100% RES	82,995	114,900
Big & Market	50,925	75,988

Fossil & Nuclear	34,027	42,000
Small & Local	16,606	14,880

Table 6: Installed generation capacity of Solar in Africa and Middle East for 2040

Scenario	*Large Scale RES*		*100% RES*		*Big & Market*		*Fossil & Nuclear*		*Small & Local*	
Type Gen.	*PV*	*CSP*	*PV*	*CSP*	*PV*	*CSP*	*PV*	*CSP*	*PV*	*CSP*
Country	*MW*	*MW*	*MW*	*MW*	*MW*	*MW*	*MW*	*MW*	*MW*	*MW*
MA	5,533	12,867	1,933	4,533	667	1,533	0	0	467	1,067
DZ	10,467	24,400	3,667	8,533	1,200	2,867	0	0	867	2,067
TN	1,733	4,067	600	1,400	200	467	0	0	133	333
LY	5,000	11,733	1,733	4,133	600	1,400	0	0	400	1,000
MI	533	1,267	200	467	67	133	0	0	67	133
Sum	**23,267**	**54,333**	**8,133**	**19,067**	**2,733**	**6,400**	**0**	**0**	**1,933**	**4,600**

The solar resources are Photovoltaics (PV) and Concentrated Solar Plant (CSP).

Table 7: Installed generation capacity of Solar in Africa and Middle East for 2050

Scenario	*Large Scale RES*		*100% RES*		*Big & Market*		*Fossil & Nuclear*		*Small & Local*	
Type Gen.	*PV*	*CSP*	*PV*	*CSP*	*PV*	*CSP*	*PV*	*CSP*	*PV*	*CSP*
Country	*MW*	*MW*	*MW*	*MW*	*MW*	*MW*	*MW*	*MW*	*MW*	*MW*
MA	8,300	19,300	2,900	6,800	1,000	2,300	0	0	700	1,600
DZ	15,700	36,600	5,500	12,800	1,800	4,300	0	0	1,300	3,100
TN	2,600	6,100	900	2,100	300	700	0	0	200	500
LY	7,500	17,600	2,600	6,200	900	2,100	0	0	600	1,500
MI	800	1,900	300	700	100	200	0	0	100	200
Sum	**34,900**	**81,500**	**12,200**	**28,600**	**4,100**	**9,600**	**0**	**0**	**2,900**	**6,900**

The above presented values are the expected solar resources used to export to Europe only, the total installed capacity for each country should be higher. The full demand and generation portfolio of the Northern African and Middle Eastern countries could not be modelled in the e-Highway2050 study and thus a simplified approach was chosen: only some solar generation is modelled. Indeed, it is expected that the solar plants will represent the main source of exports towards Europe, as their generation is highly concentrated during some hours and it will be challenge to consume all of it locally.

2.2.2. Energy Production

The next table shows the expected electrical energy production in Europe after grid reinforcements, detailed information by country is provided in the annex. The data is divided by generation type, namely Wind, Solar, Biomass, Hydro, Fossil and Nuclear. The energy production for North Sea is related to off-shore wind and North Africa for solar. This data is presented in a separate table.

Generation for 2020 and 2030

Table 8: Energy production in Europe by type for 2020 and 2030

	Type Gen	Wind	Solar	Biomass	Hydro	Fossil	Nuclear	Σ Total
Year	Scenario	GWh	GWh	GWh	GWh	GWh	GWh	GWh
2020	Expected Progress	446,322	156,839	252,836	582,485	1,133,424	868,156	3,440,062
2030	Slowest Progress	536,885	198,030	241,016	581,140	1,200,501	763,791	3,521,363
2030	Constrained Progress	565,158	204,222	232,268	557,839	998,102	756,582	3,314,171
2030	National Green Transition	830,990	306,102	319,397	604,485	875,113	542,260	3,478,347
2030	European Green Revolution	915,354	336,365	334,215	602,396	977,482	552,418	3,718,230

Generation for 2040 and 2050

For the expected grid, the energy production by type is showed in the next tables.

Table 9: Energy production in Europe by type for 2040 and 2050

	Type Gen	Wind	Solar	Biomass	Hydro	Fossil	Nuclear	Σ Total
Year	Scenario	GWh	GWh	GWh	GWh	GWh	GWh	GWh
2040	Large Scale RES	1,207,104	317,525	303,653	744,067	522,488	791,712	3,886,550
2040	100% RES	1,270,404	606,547	649,070	764,972	206,363	215,352	3,712,708
2040	Big & Market	785,510	286,999	329,135	539,259	943,723	788,493	3,673,119
2040	Fossil & Nuclear	566,866	215,119	324,275	552,276	1,327,998	985,209	3,971,743
2040	Small & Local	671,954	455,062	539,949	549,435	426,012	549,034	3,191,445
2050	Large Scale RES	1,659,844	349,804	298,481	852,146	307,175	1,030,110	4,497,560
2050	100% RES	1,773,906	892,085	454,115	890,175	13,096	0	4,023,378
2050	Big & Market	1,077,993	390,776	333,132	551,800	802,383	801,951	3,958,035
2050	Fossil & Nuclear	646,410	251,806	322,664	570,880	1,545,390	1,197,247	4,534,397
2050	Small & Local	843,012	721,449	593,442	574,756	135,406	313,261	3,181,325

Generation in North Sea, Africa and Middle East

Table 10: Energy production of off-shore wind in North Sea for 2040 and 2050

Year	2040	2050
Scenario	GWh	GWh
Large Scale RES	308,634	424,089
100% RES	332,500	464,353
Big & Market	204,353	308,499
Fossil & Nuclear	134,001	167,592
Small & Local	65,253	57,703

Table 11: Energy production of Solar in Africa and Middle East for 2040

Scenario	Large Scale RES	100% RES	Big & Market	Fossil & Nuclear	Small & Local
Country	GWh	GWh	GWh	GWh	GWh
MA	56,904	20,023	6,793	0	4,730
DZ	110,076	38,506	12,886	0	9,292
TN	18,814	6,482	2,161	0	1,528
LY	52,881	18,585	6,315	0	4,466
MI	5,850	2,161	633	0	633
Sum	**244,526**	**85,758**	**28,787**	**0**	**20,650**

Table 12: Energy production of Solar in Africa and Middle East for 2050

Scenario	Large Scale RES	100% RES	Big & Market	Fossil & Nuclear	Small & Local
Country	GWh	GWh	GWh	GWh	GWh
MA	85,357	30,035	10,189	0	7,095
DZ	165,114	57,759	19,329	0	13,939
TN	28,222	9,723	3,241	0	2,292
LY	79,322	27,877	9,472	0	6,699
MI	8,775	3,241	949	0	949
Sum	**366,788**	**128,636**	**43,181**	**0**	**30,974**

As explained before the solar generation in Africa and the Middle East given here represents only the generation available for exports to Europe. Moreover, all of it is finally not exported to Europe due to the assumed grid limitations.

2.3. Storage from 2040 to 2050

Storage is one of the technical solutions to avoid the curtailment of the variable renewable generation. This generation cannot be managed because of lack of demand or not enough transmission capacity to transfer its output from excess generation regions to regions where more expensive generation is produced.

During the project, only Hydro Pumped Storage Plant (PSP) was considered but any other storage type can be used if they are economical and environmentally acceptable. This could impact the characteristics and localisation of storage compared to the project assumptions.

The next table presents the maximum and the minimum PSP for the 5 scenarios for 2040 and 2050.

Table 13: Maximum and minimum installed hydro Pumped Store Plant among the scenarios by country in 2040 and 2050

Scenario	2040 Maximum	2040 Minimum	2050 Maximum	2050 Minimum
Country	MW	MW	MW	MW
AL	0	0	0	0
AT	10,965	7,120	10,733	6,788
BA	773	526	696	440
BE	2,379	1,256	2,308	1,308
BG	1,103	801	1,482	937
CH	6,129	5,851	5,443	5,443
CZ	1,510	1,104	1,787	1,130
DE	10,362	7,703	12,799	8,095
DK	0	0	0	0
EE	400	252	791	500
ES	12,245	8,242	13,547	8,568
FI	0	0	0	0
FR	10,405	7,021	13,420	8,488
GB	4,948	1,386	6,397	4,046
GR	3,472	1,635	2,486	1,572
HR	378	273	463	293
HU	489	307	949	600
IE	1,167	787	1,907	1,206
IT	5,207	4,043	5,344	3,380
LT	1,385	1,041	1,787	1,130
LU	1,383	1,071	1,651	1,044
LV	0	0	0	0
ME	0	0	0	0
MK	0	0	0	0
NI	0	0	0	0
NL	0	0	0	0
NO	14,482	7,388	17,291	10,936
PL	2,853	1,919	3,790	2,397
PT	5,658	3,896	5,743	3,632
RO	1,242	908	1,534	970
RS	1,105	817	974	616
SE	0	0	0	0

SI	380	310	316	200
SK	736	661	307	194
Sum	**101,155**	**66,317**	**113,943**	**73,913**

Some small decreases between 2040 and 2050 can be observed in some countries. This is due to some inconsistencies between the different datasets available and should be considered as an error margin.

2.4. RES curtailment and ENS

The generation must be equal to the demand in an isolated system, but in systems with interchange market, the generation plus the imports must be equal to the demand plus the exports.

Due to the variable infeed of renewable sources, sometimes generation is greater than the demand and curtailment is needed. This curtailment also occurs if there is no network capacity to transmit the excess generation to other regions. The Spillage Energy (SE) is the amount of generation energy that is not used.

The opposite can also occur, when the generation is less than the load, and demand must be curtailed to keep the frequency stable. Energy Not Supplied (ENS) is the amount of demand energy that is not satisfied.

The final energy equilibrium equation is:

Generation + Imports – Spillage Energy = Demand + Export – Energy Not Supplied

Network losses are not simulated due to the simplified DC load flows performed. A fixed percentage of the demand was thus assumed to account for losses and is included in the demand data presented in this report (see D2.1 for the losses ratio per country).

Storage is not explicit in the balance formula, since it was not treated has an additional demand. It was considered as “export” when the energy is stored and “import” when the energy is extracted from the storage unit.

The values below are given after the grid reinforcements.

Table 14: Energy Balance for 2040

Scenario	Generation	Imports	Spilled Energy	Demand	Exports	ENS	Gen.+Imp. -SE	Dem.+Exp. -ENS
	GWh	GWh	GWh	GWh	GWh	GWh	GWh	GWh
Large Scale RES	3,886,550	677,062	34,097	4,315,600	214,544	628	4,529,516	4,529,516
100% RES	3,712,708	531,937	50,763	4,002,644	192,359	1,121	4,193,882	4,193,882
Big & Market	3,673,119	386,796	2,877	3,894,688	162,407	57	4,057,038	4,057,038
Fossil & Nuclear	3,971,743	358,727	1,663	4,099,736	229,301	230	4,328,807	4,328,807
Small & Local	3,191,445	250,285	1,747	3,268,873	171,239	127	3,439,984	3,439,984

The scenarios with great penetration of RES will have bigger spillage energy and ENS in special case with the 100% RES scenario.

Table 15: Energy Balance for 2050

Scenario	Generation	Imports	Spilled Energy	Demand	Exports	ENS	Gen.+Imp. -SE	Dem.+Exp. -ENS
	GWh	GWh	GWh	GWh	GWh	GWh	GWh	GWh
Large Scale RES	4,497,560	1,118,541	24,920	5,193,743	397,445	6	5,591,181	5,591,181
100% RES	4,023,378	769,541	155,314	4,297,587	340,492	474	4,637,604	4,637,604
Big & Market	3,958,035	540,452	6,816	4,282,542	209,171	42	4,491,671	4,491,671
Fossil & Nuclear	4,534,397	514,843	1,559	4,698,885	348,850	55	5,047,680	5,047,680
Small & Local	3,181,325	193,177	48,726	3,202,334	123,449	7	3,325,776	3,325,776

For 2050 the amount of spilled energy is bigger than 2040 due to the higher RES generation. However, ENS is higher in 2040 as the common grid identified at 2040 was not designed to solve all the congestions. Additional grid reinforcements would be necessary to reach the same level of adequacy as in the 2050 cases.

3. Grid architectures from 2020 to 2050

The grid architecture is based on the cluster definition explained in the report *D2.2 - European cluster model of the pan-European transmission grid*.

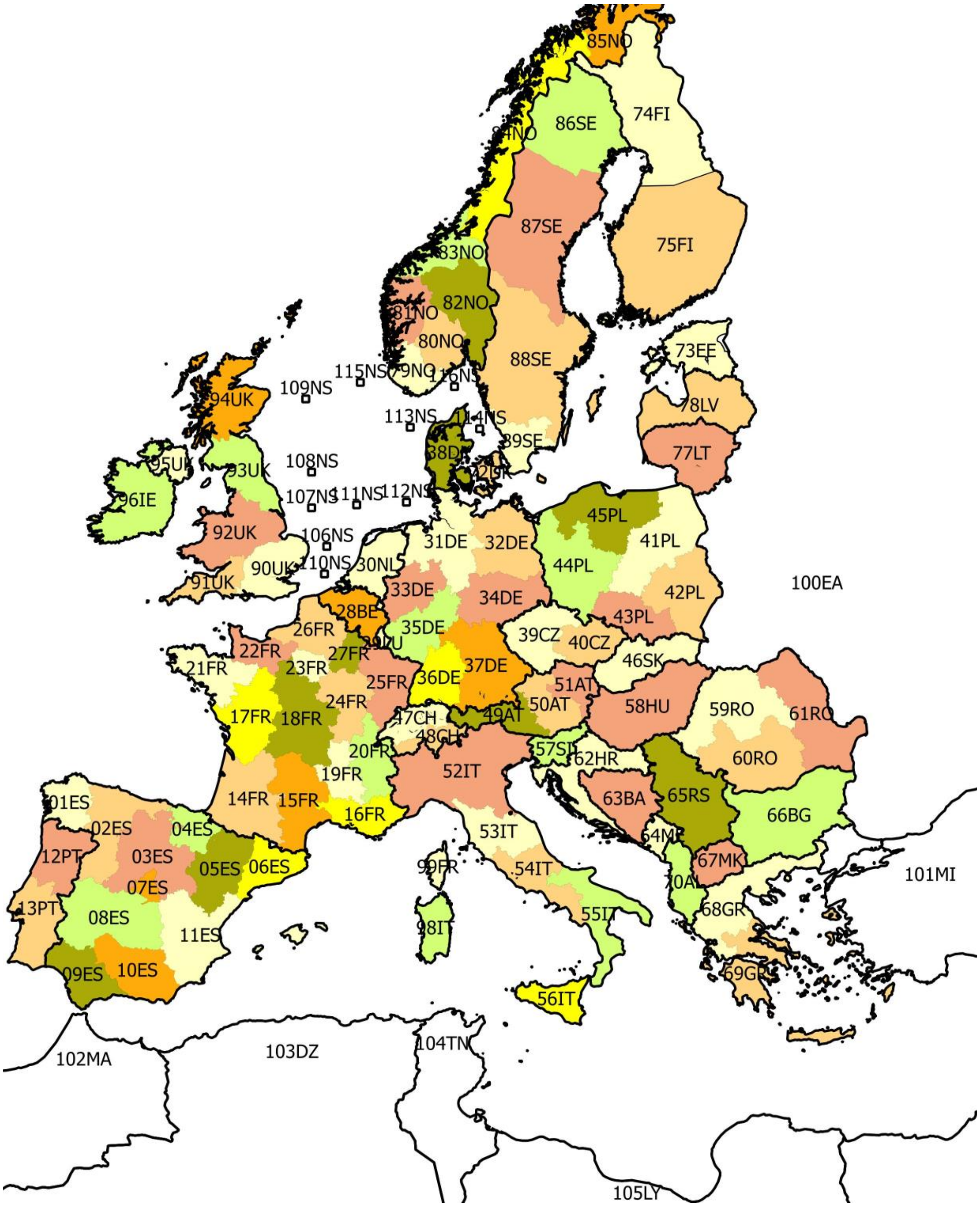


Figure 4: Cluster map

Each cluster is considered as a copper plate in terms of grid, so only the transmission capacity and distance between cluster matters.

3.1. From 2020 to 2030

The dataset for the European grid was provided by ENTSO-E in the beginning of the work in 2013, meaning that the dataset used, was the intermediate data from the TYNDP 2014 provided in 26/04/2013 which is related to 2030.

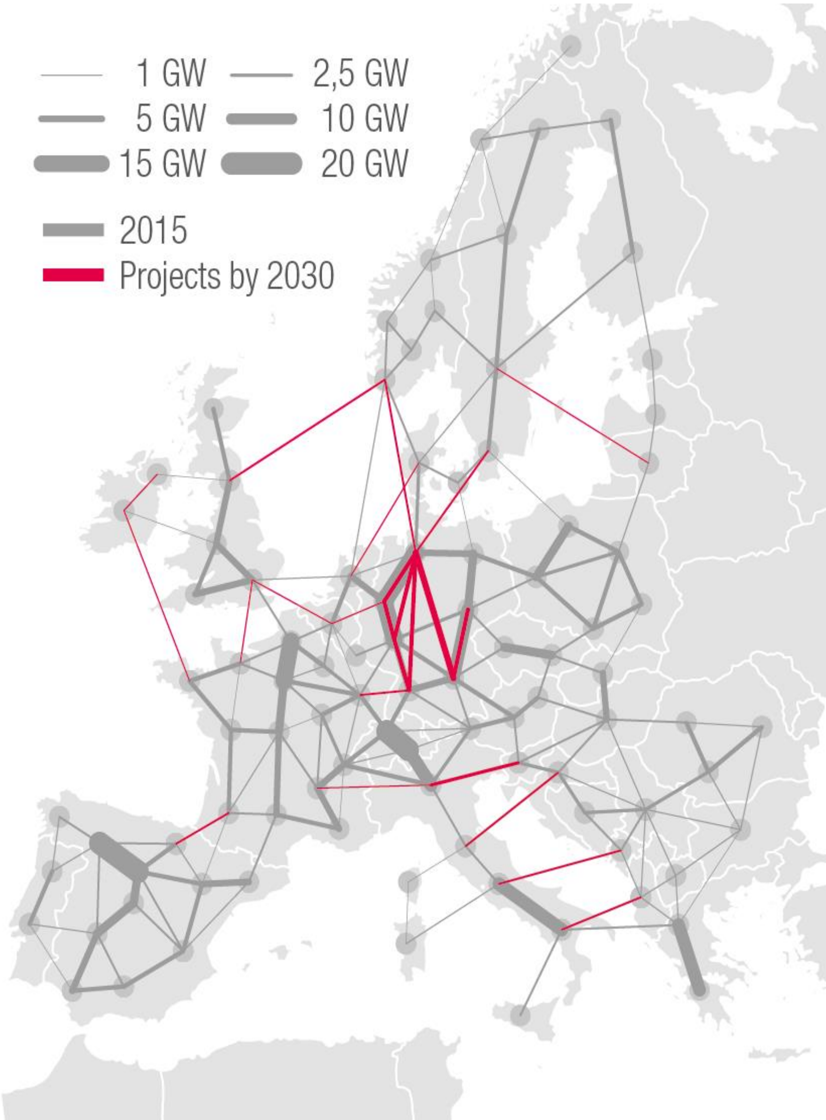


Figure 5: European Grid linking clusters in 2030

Without any further developments this 2030 network was taken as base case for the reinforcements for 2040 and 2050. Some large projects under discussion today, such as the very important links within Germany, are already included in the 2030 dataset which explains their absence as reinforcements in 2040 and 2050.

Each individual link connecting the clusters is in the *Table 38: Starting Grid for all scenarios in 2030* in the annex.

3.2. For 2040

The 2040 grid was evaluated as the intermediate step between 2030 and 2050.

After the identification of the five grid reinforcements needed to meet each scenario for 2050, it was computed the average grid for 2050.

The first proposed gird for 2040 is the 50% average of the reinforcements for 2050 and is labelled as ***common 2040 grid***.

Figure 6: European Grid for 2040 – Common (50% average)

The methodology to identify the adequacy of the 2040 grid was the same which was used to assess the 2050 grid.

Due to the fact that there are two scenarios with very high RES integration, an extended grid with 70% average of the reinforcement was also evaluated.

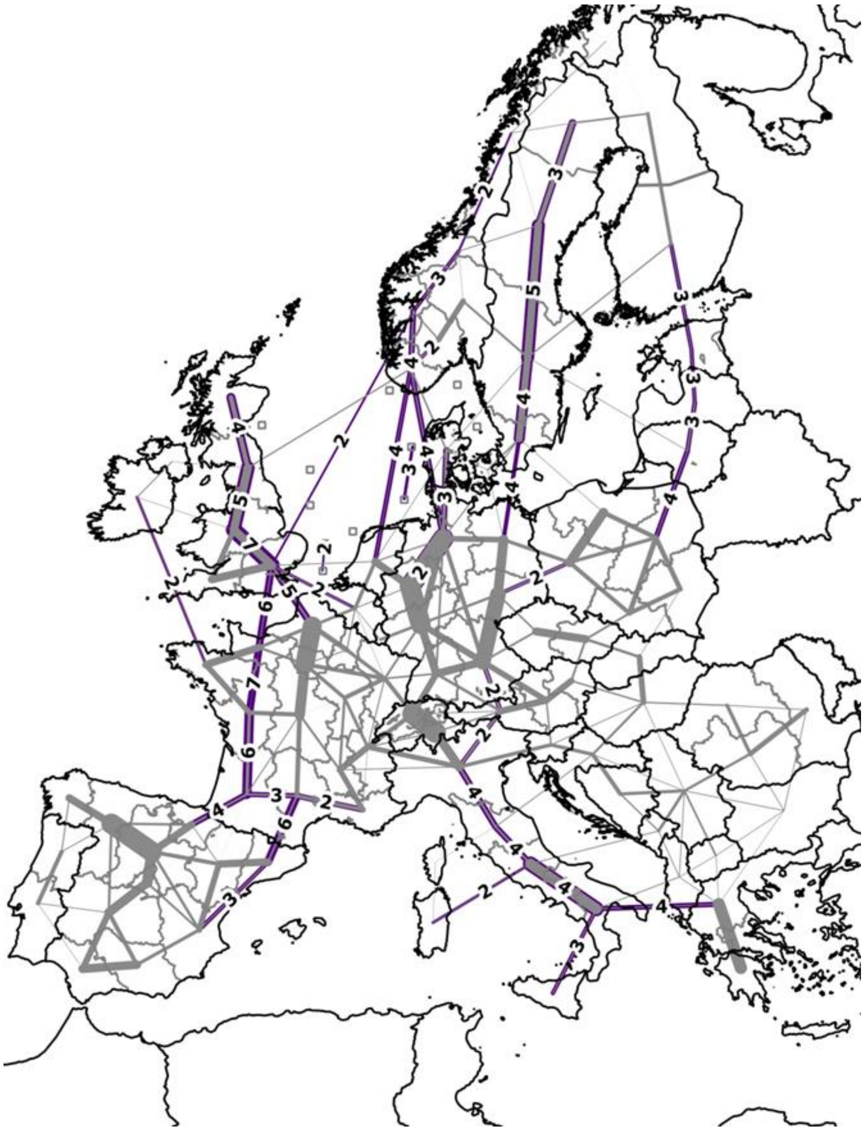


Figure 7: European Grid for 2040 – Extended (70% average)

The cost benefit analysis in the next chapter will show what is the best average for 2040 for each scenario in 2050. Anyway for 2040 it is possible to identify a common network, where there are reinforcements with no regret investments.

As the focus for 2040 was the identification of common reinforcements to all scenarios, specific reinforcements for each scenario were not defined. However, some would for sure be necessary, especially in the scenarios Large Scale RES and 100% RES, as significant volumes of RES curtailment and redispatch are unsolved with the 50% or the 70% grid model.

3.3. For 2050

The identification of the grid reinforcements for 2050 is explained in detail in the report D2.3 – System simulations analysis and overlay-grid development. The following maps and tables summarize the results for each scenario.

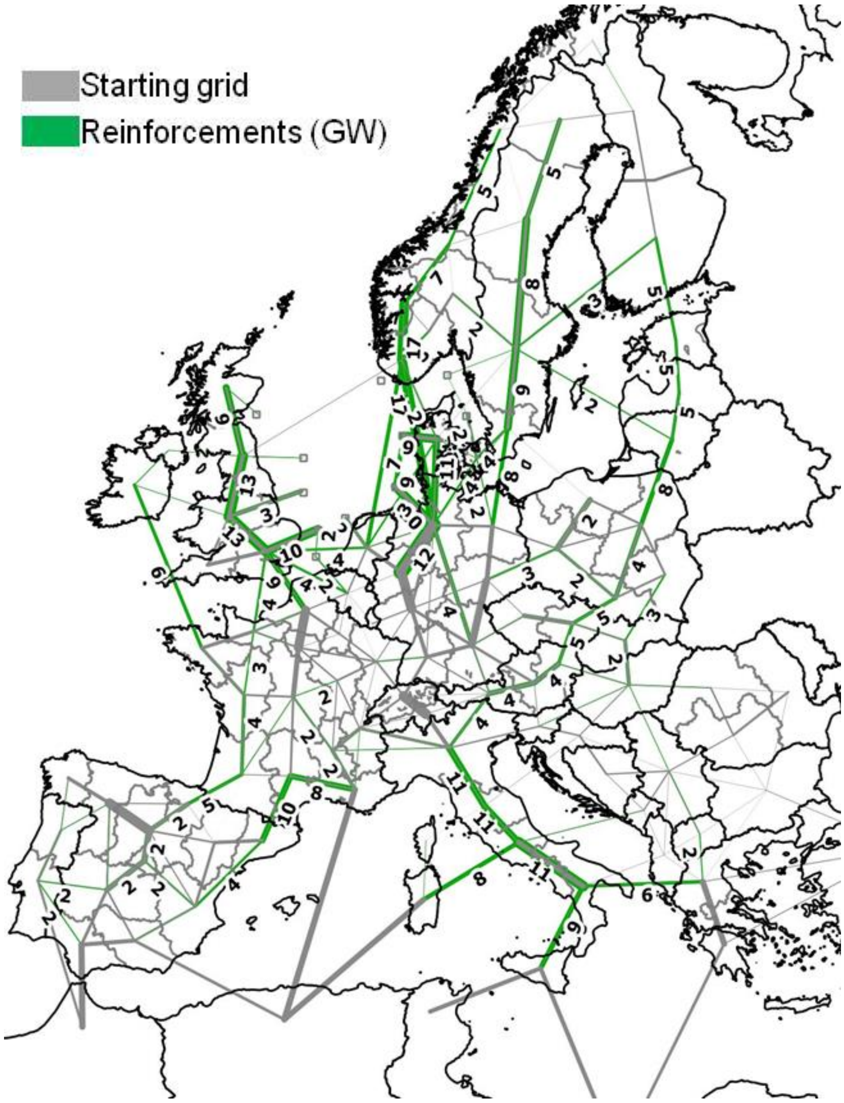


Figure 8: European Grid for 2050 – Large Scale RES

The transmission capacity between cluster are related to “thermal capacity” of the line/cable, since we are dealing with small distance and there are no stability issues between clusters.

Table 16: Length and Transmission capacity by technology for 2050 – Large Scale RES

Strategy	Total	AC OHL	DC OHL	DC Cable	DC Subsea Cable
1	451,800 MW	283,000 MW	4,000 MW	0 MW	164,800 MW
2	451,800 MW	272,000 MW	4,000 MW	11,000 MW	164,800 MW
3	451,800 MW	0 MW	0 MW	287,000 MW	164,800 MW

1	85,705 km	35,715 km	975 km	0 km	49,015 km
2	86,403 km	33,506 km	975 km	2,907 km	49,015 km
3	107,754 km	0 km	0 km	58,739 km	49,015 km

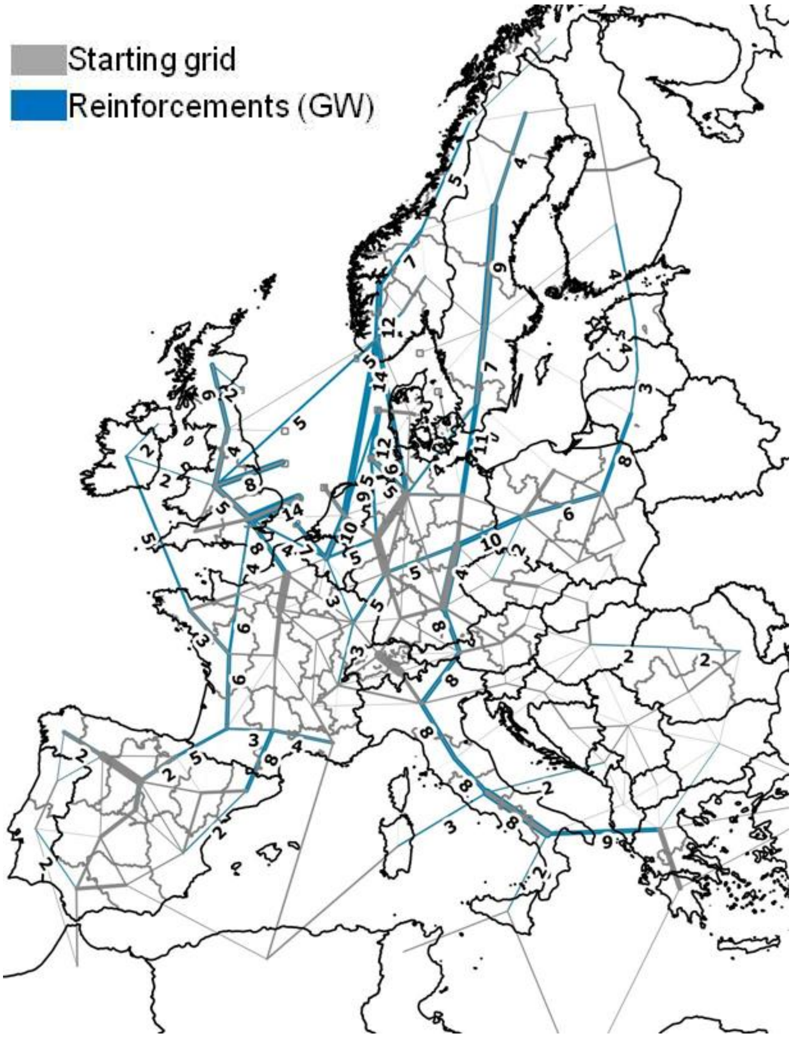


Figure 9: European Grid for 2050 – 100% RES

Table 17: Length and Transmission capacity by technology for 2050 – 100% RES

Strategy	Total	AC OHL	DC OHL	DC Cable	DC Subsea Cable
1	378,000 MW	197,000 MW	0 MW	36,000 MW	145,000 MW
2	378,000 MW	178,000 MW	0 MW	55,000 MW	145,000 MW
3	378,000 MW	0 MW	0 MW	229,000 MW	149,000 MW
1	80,004 km	23,673 km	0 km	9,658 km	46,673 km
2	78,575 km	22,103 km	0 km	11,158 km	45,314 km
3	100,798 km	0 km	0 km	54,273 km	46,525 km

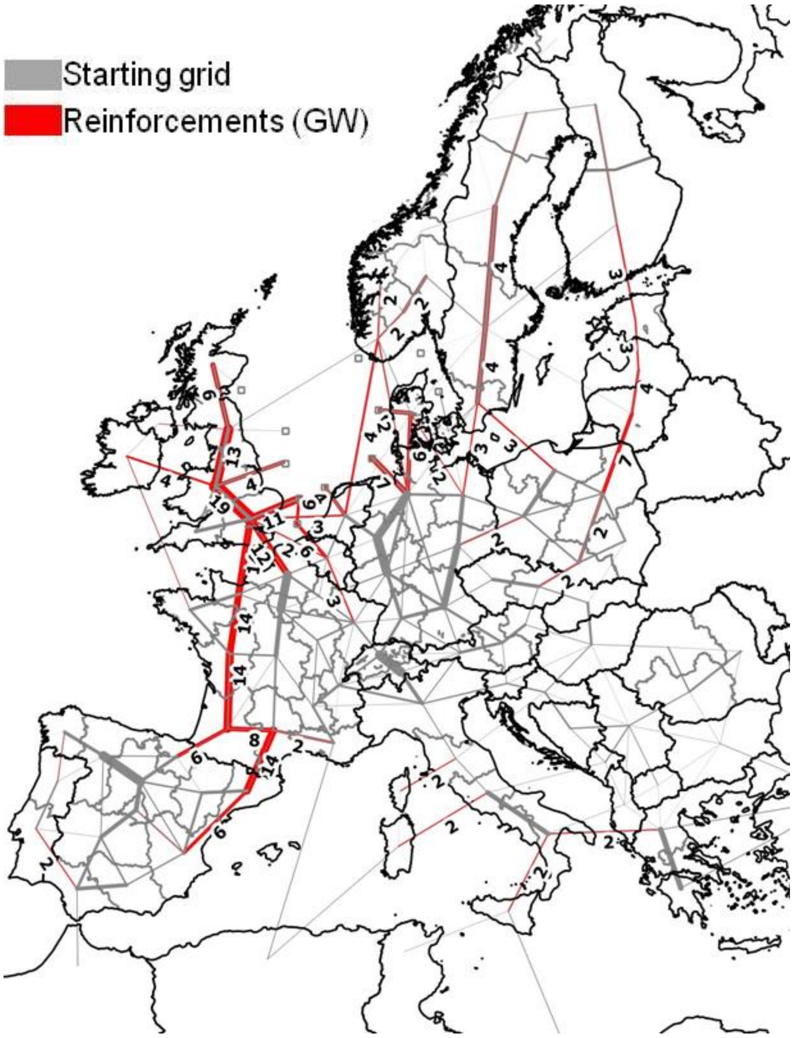


Figure 10: European Grid for 2050 – Big & Market

Table 18: Length and Transmission capacity by technology for 2050 – Big & Market

Strategy	Total	AC OHL	DC OHL	DC Cable	DC Subsea Cable
1	255,000 MW	151,000 MW	0 MW	0 MW	104,000 MW
2	255,000 MW	151,000 MW	0 MW	0 MW	104,000 MW
3	255,000 MW	0 MW	0 MW	151,000 MW	104,000 MW
1	46,668 km	17,278 km	0 km	0 km	29,390 km
2	46,668 km	17,278 km	0 km	0 km	29,390 km
3	58,305 km	0 km	0 km	28,915 km	29,390 km

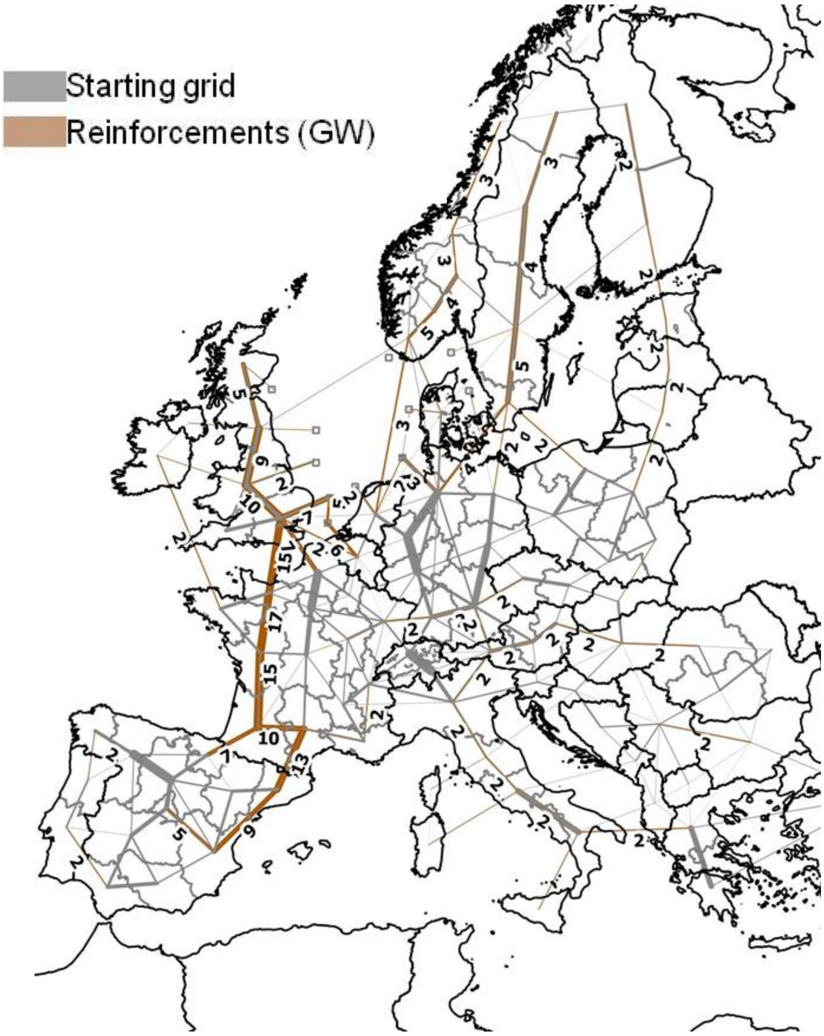


Figure 11: European Grid for 2050 – Fossil & Nuclear

Table 19: Length and Transmission capacity by technology for 2050 – Fossil & Nuclear

Strategy	Total	AC OHL	DC OHL	DC Cable	DC Subsea Cable
1	253,000 MW	173,000 MW	0 MW	0 MW	80,000 MW
2	253,000 MW	173,000 MW	0 MW	0 MW	80,000 MW
3	253,000 MW	11,000 MW	0 MW	162,000 MW	80,000 MW
1	48,624 km	23,136 km	0 km	0 km	25,488 km
2	48,624 km	23,136 km	0 km	0 km	25,488 km
3	61,084 km	2,312 km	0 km	33,706 km	25,066 km

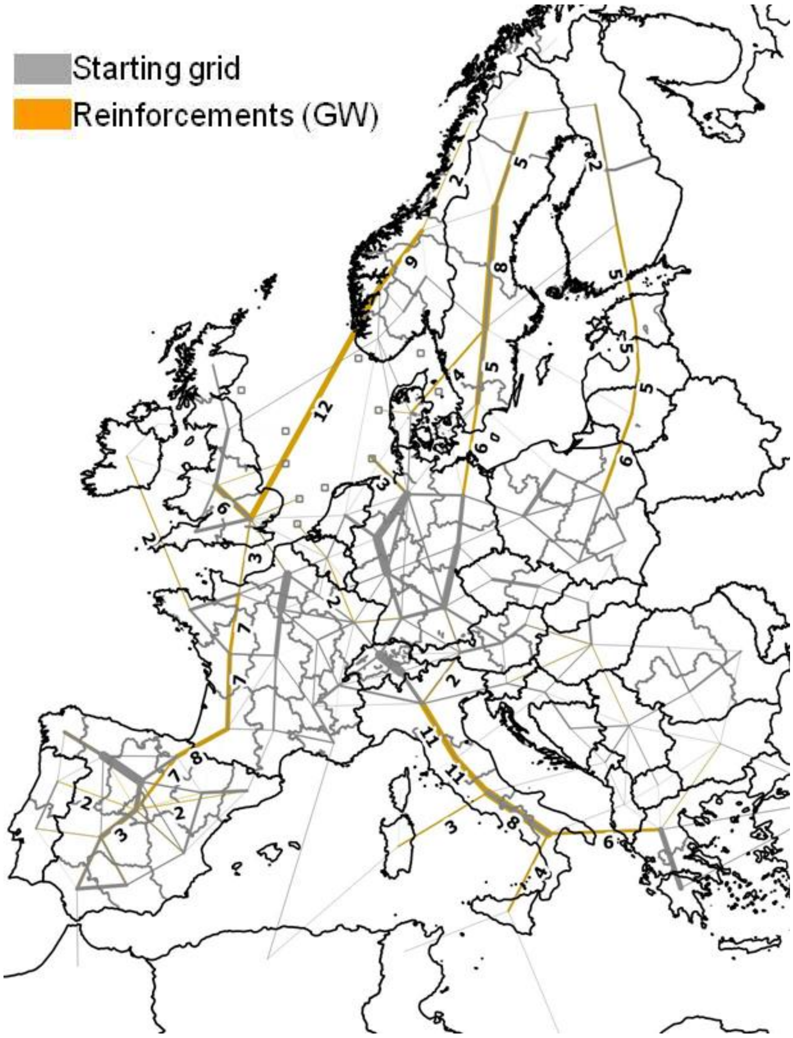


Figure 12: European Grid for 2050 – Small & Local

Table 20: Length and Transmission capacity by technology for 2050 – Small & Local

Strategy	Total	AC OHL	DC OHL	DC Cable	DC Subsea Cable
1	190,000 MW	136,000 MW	0 MW	1,000 MW	53,000 MW
2	190,000 MW	109,000 MW	0 MW	32,000 MW	49,000 MW
3	190,000 MW	9,000 MW	0 MW	128,000 MW	53,000 MW
1	47,505 km	19,850 km	0 km	860 km	26,795 km
2	48,527 km	17,554 km	0 km	6,367 km	24,606 km
3	54,281 km	1,773 km	0 km	29,425 km	23,083 km

3.4. Evolution of the grid

The next table shows the length (km) and transmission capacities (MW) from 2030 to 2050. These values refer to the 100 clusters equivalent grid model used by the project, they do not reflect the whole extent of the European network.

Table 21: Length and Transmission capacity from 2030 to 2050

Year	Length	Large Scale RES	100% RES	Big & Market	Fossil & Nuclear	Small & Local
	km	MW	MW	MW	MW	MW
2030	69,113	796,299	755,823	721,902	704,383	698,673
2040-C	11,864	101,000	101,000	101,000	101,000	101,000
2040-E	14,154	149,000	149,000	149,000	149,000	149,000
2050	44,980	451,800	378,000	255,000	253,000	190,000

To compare the effort to add all this transmission power over distance, the next table accounts the number of GW x km expected for the next decades.

Table 22: Evolution of Transmission grid in GW.km from 2030 to 2050

Year	Large Scale RES	100% RES	Big & Market	Fossil & Nuclear	Small & Local
	GW.km	GW.km	GW.km	GW.km	GW.km
2030	220,116	190,735	177,261	170,068	171,485
2040-C	33,331	33,331	33,331	33,331	33,331
2040-E	48,820	48,820	48,820	48,820	48,820
2050	137,566	122,110	71,842	70,735	67,893

This means that the effort for 2040 in the common grid is to build/reinforce 20% of the GW.km related to 2030, but the effort for 2050 is huge challenge (above 50%) of the existing grid of 2040 in the Large Scale RES or 100% RES scenarios.

The following map presents the similarities between scenarios. It shows only keeping those the corridors that have been identified for reinforcement in at least two scenarios. The map also shows the range of the size of the corridors needed to be developed, depending on the scenario considered.

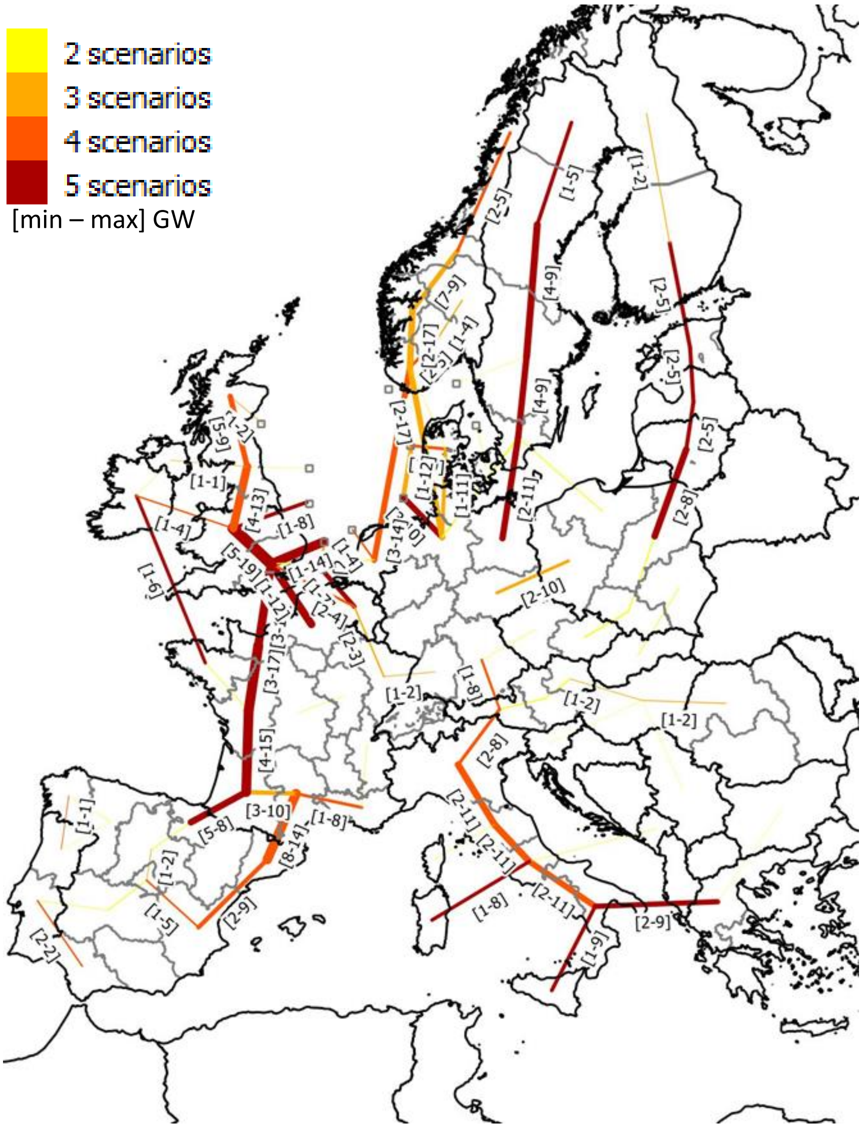


Figure 13: Common grid reinforcements for 2050

4. Cost Benefit analysis

Only a simplified cost benefit analysis is presented below, the complete CBA is presented in deliverable 6.3

4.1. Costs

The costs are related to the capital investments related to the selected grid and the yearly annuities are used to compare with the benefits.

For 2040

The selected grid for 2040 is the Common grid that represents 50% of the average reinforcements needed for 2050.

Table 23: Investment cost for 2040 – Common grid

Strategy	No. of links to be reinforced	Total Transmission requirements	Total capacity of new lines	Total investment costs	Investment annuities
	#	MW	MW	MEUR	MEUR
1	35	101,000	153,975	63,854	3,624
2	35	101,000	153,975	66,322	3,748
3	35	101,000	111,250	96,016	5,596

Since each strategy will use different technologies to achieve the same transmission requirement, the total capacity and cost will vary. Strategy 3 with more underground cables will be more expensive whilst strategy 1 with more AC OHL will be cheaper.

For 2050

We have 5 different grids based on the scenarios.

Table 24: Investment cost for 2050

Scenario	Strategy	No. of links to be reinforced	Total transmission requirements	Total capacity of new lines	Total investment costs	Investment annuities
		#	MW	MW	MEUR	MEUR
Large Scale RES	1	110	451,800	731,475	254,671	14,469
	2	110	451,800	724,500	268,752	15,246
	3	110	451,800	542,250	384,294	22,371
100% RES	1	73	378,000	446,400	244,629	13,962

	2	73	378,000	441,500	246,973	14,057
	3	73	378,000	447,500	345,012	20,055
Big & Market	1	52	255,000	395,000	137,761	7,856
	2	52	255,000	395,000	142,136	8,076
	3	52	255,000	311,875	216,268	12,599
Fossil & Nuclear	1	72	253,000	401,925	121,168	6,845
	2	72	253,000	401,925	126,656	7,121
	3	72	253,000	317,625	211,055	12,288
Small & Local	1	51	190,000	302,850	116,036	6,567
	2	51	190,000	291,800	134,981	7,665
	3	51	190,000	249,250	192,396	11,203

4.2. Benefits

The Benefits of the grid reinforcements are the reduction of the Operating Costs, Energy Not Supplied (ENS), Peak ENS, Spilled Energy (SE), and CO_2 emissions.

Operating Costs

Table 25: Operating Costs in 2040 - Benefit

Operating Costs	Large Scale RES	100% RES	Big & Market	Fossil & Nuclear	Small & Local
	MEUR	MEUR	MEUR	MEUR	MEUR
Starting	95,777	52,051	82,150	93,875	71,552
Common	77,438	39,704	76,904	89,289	67,321
Copperplate	62,583	29,524	74,420	86,634	65,465
Benefit	**18,339**	**12,347**	**5,245**	**4,586**	**4,230**
Remaining	14,854	10,180	2,484	2,655	1,856
Solved	55%	55%	68%	63%	70%

The benefit is defined as the difference between the starting grid and the proposed grid, which is the common (average 50%) grid for 2040.

Table 26: Operating Costs in 2050 - Benefit

Operating Costs	Large Scale RES	100% RES	Big & Market	Fossil & Nuclear	Small & Local
	MEUR	MEUR	MEUR	MEUR	MEUR
Starting	148,881	48,554	82,303	103,286	42,869
Proposed	70,119	9,756	59,583	92,094	33,153

Copperplate	62,288	5,587	56,357	91,530	32,632
Benefit	**78,762**	**38,798**	**22,719**	**11,192**	**9,716**
Remaining	7,831	4,168	3,226	564	522
Solved	91%	90%	88%	95%	95%

The operating cost for the copperplate is still high for the majority of the scenarios. For 2050 the proposed grid solves almost all the extra-costs that are related to the grid congestions.

Energy Not Supplied

Table 27: Energy Not Supplied in 2040 - Benefit

Energy Not Supplied	**Large Scale RES**	**100% RES**	**Big & Market**	**Fossil & Nuclear**	**Small & Local**
	GWh	**GWh**	**GWh**	**GWh**	**GWh**
Starting	9,041	10,295	1,790	2,804	1,127
Common	628	1,121	57	230	127
Copperplate	0	0	0	71	68
Benefit	8,412	9,175	1,733	2,573	1,000
Remaining	628	1,120	56	159	59
Solved	93%	89%	97%	94%	94%
	MEUR	**MEUR**	**MEUR**	**MEUR**	**MEUR**
Benefit	**1,682**	**1,835**	**347**	**515**	**200**

The ENS is valorised by the value of 200 €/MWh (plus a cost per MW given below).

NB : In WP2 and WP6, the default value for ENS was defined at 10 000€/MWh without any cost per MW. It lead to extremely high benefits of the reinforcements which were not fully realistic. That is why a different approach is chosen here, based on the cost to increase the local generating capacity (€/MW) and to generate with these additional units (€/MWh including CO2 cost).

Table 28: Energy Not Supplied in 2050 - Benefit

Energy Not Supplied	**Large Scale RES**	**100% RES**	**Big & Market**	**Fossil & Nuclear**	**Small & Local**
	GWh	**GWh**	**GWh**	**GWh**	**GWh**
Starting	23,418	50,718	11,537	6,831	4,541
Proposed	6	474	42	53	7
Copperplate	0	9	0	31	1
Benefit	23,412	50,245	11,495	6,778	4,534
Remaining	6	465	42	22	6
Solved	100%	99%	100%	100%	100%
	MEUR	**MEUR**	**MEUR**	**MEUR**	**MEUR**
Benefit	**4,682**	**10,049**	**2,299**	**1,356**	**907**

We can see that for 2050 the ENS issue is almost solved by the proposed grid.

Peak ENS

The grid reinforcements will reduce the ENS peak power. It can be considered as a reduction of the need of peak generation capacity, thus leading to a benefit for the whole system. The Peak ENS is valorised by the value of 0.05 €/MW (it corresponds to an investment of 0.7b€/GW for a typical OCGT plant with a 25 years lifespan).

Table 29: Peak ENS in 2040 - Benefit

Peak ENS	Large Scale RES	100% RES	Big & Market	Fossil & Nuclear	Small & Local
	MW	MW	MW	MW	MW
Starting	93,030	89,074	48,241	69,552	72,235
Common	70,665	72,186	39,375	60,812	50,362
Copperplate	4,785	6,156	11,767	38,959	39,179
Benefit	22,365	16,888	8,866	8,740	21,873
Remaining	65,880	66,030	27,608	21,853	11,183
Solved	25%	20%	24%	29%	66%
	MEUR	**MEUR**	**MEUR**	**MEUR**	**MEUR**
Benefit	**1,118**	**844**	**443**	**437**	**1,094**

Table 30: Peak ENS in 2050 - Benefit

Peak ENS	Large Scale RES	100% RES	Big & Market	Fossil & Nuclear	Small & Local
	MW	MW	MW	MW	MW
Starting	112,358	137,214	77,838	77,191	62,767
Proposed	21,516	*46,000*	*34,000*	24,962	*21,000*
Copperplate	0	33,772	14,558	11,694	10,846
Benefit	91,358	91,214	43,838	52,229	41,767
Remaining	21,516	12,228	19,442	13,268	10,154
Solved	81%	88%	69%	80%	80%
	MEUR	**MEUR**	**MEUR**	**MEUR**	**MEUR**
Benefit	**4,542**	**4,561**	**2,192**	**2,611**	**2,088**

Spilled Energy

Table 31: Spilled Energy in 2040 - Benefit

Spilled Energy	Large Scale RES	100% RES	Big & Market	Fossil & Nuclear	Small & Local
	GWh	GWh	GWh	GWh	GWh
Starting	236,711	241,968	21,392	6,349	13,127
Common	120,181	123,769	8,841	3,953	5,734
Copperplate	17,076	17,759	605	0	3,421
Benefit	116,529	118,199	12,551	2,395	7,392
Remaining	103,105	106,010	8,236	3,953	2,313
Solved	53%	53%	60%	38%	76%

In the scenarios with large penetration of RES, spoiling the energy cannot be avoided (there are still 17 TWh in the copperplate solution) because there is more generation than load.

The total amount of energy spillage is not only Europe (sum of each country) but it includes the North Sea, North Africa and the Middle East.

Table 32: Spilled Energy in 2040 – Europe, NS, NA & MI

Scenario	*Large Scale RES*	*100% RES*	*Big & Market*	*Fossil & Nuclear*	*Small & Local*
Country	*GWh*	*GWh*	*GWh*	*GWh*	*GWh*
Europe	34,097	50,763	2,877	1,663	1,747
NS	28,844	57,659	5,343	2,290	663
MA	4,137	3,279	92	0	592
DZ	25,921	6,721	484	0	1,141
TN	8,292	1,305	14	0	8
LY	18,805	4,035	30	0	1,583
MI	86	7	0	0	0
Sum	**120,181**	**123,769**	**8,841**	**3,953**	**5,734**

The majority of spilled energy is in the North Sea and North Africa.

Table 33: Spilled Energy in 2050 - Benefit

Spilled Energy	Large Scale RES	100% RES	Big & Market	Fossil & Nuclear	Small & Local
	GWh	GWh	GWh	GWh	GWh
Starting	608,994	772,565	205,209	41,615	107,273
Proposed	87,649	307,296	22,127	2,027	60,436
Copperplate	37,652	207,594	2,549	0	54,365
Benefit	521,345	465,268	183,082	39,588	46,837
Remaining	49,997	99,703	19,578	2,027	6,071
Solved	91%	82%	90%	95%	89%

For 2050 the spilled energy is better solved than 2040. Indeed, the 2040 grid was designed to be common to the different scenarios and not necessarily to solve all the RES curtailment or ENS. Additional reinforcements, specific to each scenario, would be necessary to reach the same level of efficiency as in the 2050 grid.

Scenario	*Large Scale RES*	*100% RES*	*Big & Market*	*Fossil & Nuclear*	*Small & Local*
Country	*GWh*	*GWh*	*GWh*	*GWh*	*GWh*
Europe	24,920	155,314	6,816	1,559	48,726
NS	24,289	117,463	12,999	468	5,930
MA	5,499	5,144	394	0	1,359
DZ	19,871	15,160	1,393	0	2,425
TN	3,730	4,746	143	0	263
LY	9,234	9,080	380	0	1,697
MI	107	391	0	0	36
Sum	**87,649**	**307,296**	**22,127**	**2,027**	**60,436**

CO_2 Emissions

Table 34: CO_2 Emissions in 2040

CO2 Emissions	Large Scale RES	100% RES	Big & Market	Fossil & Nuclear	Small & Local
	kt	kt	kt	kt	kt
Starting	239,121	112,125	185,155	165,722	166,510
Common	177,915	71,582	160,966	141,374	148,312
Copperplate	133,425	42,133	151,083	127,627	139,923
Benefit	61,206	40,543	24,189	24,348	18,198
Remaining	44,490	29,449	9,883	13,747	8,389
Solved	58%	58%	71%	64%	68%

Table 35: CO_2 Emissions in 2050

CO2 Emissions	Large Scale RES	100% RES	Big & Market	Fossil & Nuclear	Small & Local
	kt	kt	kt	kt	kt
Starting	292,418	86,442	101,330	77,683	67,589
Proposed	100,577	6,391	47,047	42,848	44,325
Copperplate	81,050	372	39,357	39,967	43,090
Benefit	191,841	80,051	54,283	34,835	23,264
Remaining	19,527	6,019	7,691	2,881	1,235
Solved	91%	93%	88%	92%	95%

There is a relevant reduction of CO_2 emission proposed for 2050 related to 2040.

In the annex the CO_2 emission by country is provided for 2050.

4.3. Profitability

The cost benefit analysis will compare the sum of the benefits with the expected cost of the investments in the grid.

For 2040

Table 36: Cost Benefit analysis for 2040

2040	Large Scale RES	100% RES	Big & Market	Fossil & Nuclear	Small & Local
	b€/year	b€/year	b€/year	b€/year	b€/year
Saving in Operating Costs	18.3	12.3	5.2	4.6	4.2
Saving in ENS Fuel and C02 Costs	1.7	1.8	0.3	0.5	0.2
Saving in ENS Peak Power	1.2	0.9	0.5	0.5	1.1
Benefits	**21.2**	**15.1**	**6.1**	**5.6**	**5.6**
Min. Annuities Inv. Cost	3.6	3.6	3.6	3.6	3.6
Max. Annuities Inv. Cost	5.6	5.6	5.6	5.6	5.6
Cost	**5.6**	**5.6**	**5.6**	**5.6**	**5.6**
Benefits - Cost	**15.6**	**9.5**	**0.5**	**0.0**	**0.0**

There is no negative profitability, but only two scenarios (Large Scale RES and 100% RES) have a profitability of a factor 2 to 3 related to cost.

For 2050

Table 37: Cost Benefit analysis for 2050

2050	Large Scale RES	100% RES	Big & Market	Fossil & Nuclear	Small & Local
	b€/year	b€/year	b€/year	b€/year	b€/year
Saving in Operating Costs	78.8	38.8	22.7	11.2	9.7
Saving in ENS Fuel and C02 Costs	4.7	10.0	2.3	1.4	0.9
Saving in ENS Peak Power	4.5	4.6	2.2	2.6	2.1
Benefits	**88.0**	**53.4**	**27.2**	**15.2**	**12.7**
Min. Annuities Inv. Cost	14.5	14.0	7.9	6.8	6.6
Max. Annuities Inv. Cost	22.4	20.1	12.6	12.3	11.2
Cost	**22.4**	**20.1**	**12.6**	**12.3**	**11.2**
Benefits - Cost	**65.6**	**33.4**	**14.6**	**2.9**	**1.5**

There is no negative profitability, but three scenarios (Large Scale RES, 100% RES and Big&Market) have a profitability of a factor 2 to 3 related to cost.

The profitability can be higher if the value of ENS used is bigger the 200 €/MWh. Some countries used values up to 40.000 €/MWh, but we avoid using so higher values to evade big expectations in revenue, since this ENS cost is the loss of productivity in the country and not the grid tariff income.

5. Conclusions

This report presented the main findings of the e-Highway2050 project regarding the expected scenarios and the grid reinforcement for 2040 and 2050 (summarizing deliverables 2.1, 2.3 and 4.3) and compared them to available datasets from today to 2030.

The five boundary scenarios for 2050 show a significant spread of yearly electrical demand expectations from 3.2 to 5.2 PWh (Peta Watt hour). Assumption on the energy efficiency, DSM and EV increases the uncertainties of the expected load. The peak power in Europe can vary from 537 to 900 GW, and the total install generation capacity is from 1,336 to 2,120 GW. High penetration of RES will require that the total installed generation capacity largely exceeds the peak load.

The grid reinforcements expected for 2030 were taken from the dataset of 2014 from the TYNDP team of ENTSO-e. They are not re-assessed by the e-HIGHWAY 2050 project but considered as a starting point. Since the project has identified 5 scenarios for 2050, there are five alternative grids for 2050, more adjusted to the expected future but still with common elements. For 2040 we were able to provide a minimal common grid for all 5 scenarios, composed of minimal regret investments.

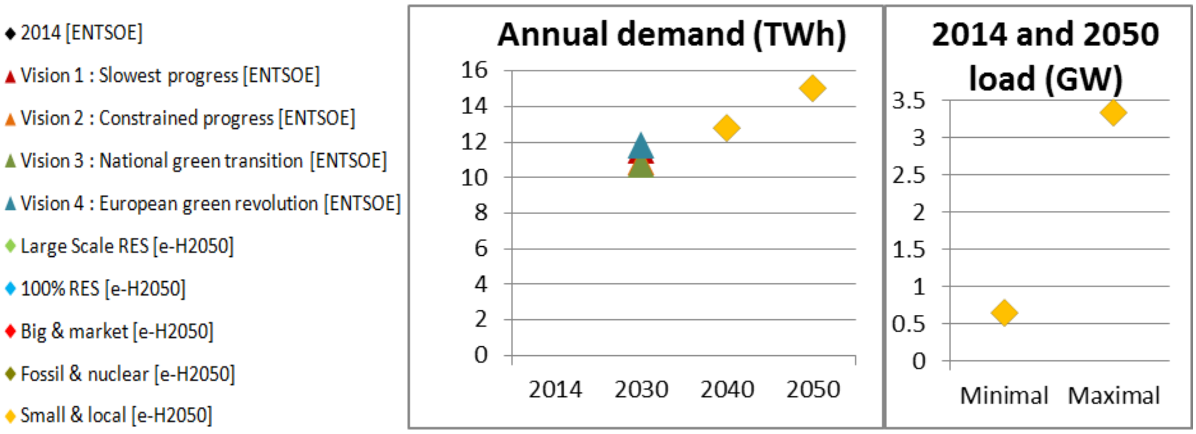
The main grid reinforcements is not just to connect the additional generation to the grid, but to minimize the Energy Not Supply, the spillage of renewable energy and the CO2 emissions. By accounting this benefits and cost of the grid, we can evaluate the cost-benefit analysis of the grid investments. Even with a low value for ENS in the range of 200 €/MWh the profitability is positive for all 5 scenarios in 2040 and 2050.

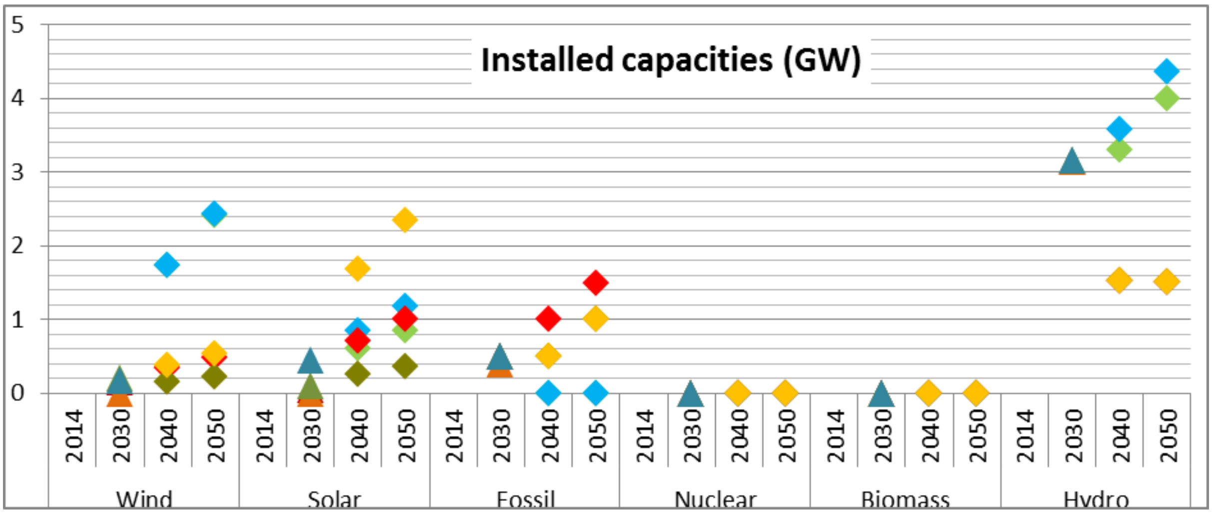
ANNEX 1 – Country Profile

Code	Country
AL	Albania
AT	Austria
BA	Bosnia-Herzegovina
BE	Belgium
BG	Bulgaria
CH	Switzerland
CZ	Czech Republic
DE	Germany
DK	Denmark
DZ	Algeria
EA	East Europe
EE	Estonia
ES	Spain
FI	Finland
FR	France
GB	Great Britain
GR	Greece
HR	Croatia
HU	Hungary
IE	Ireland
IT	Italy
LT	Lithuania
LU	Luxembourg
LV	Latvia
LY	Libya
MA	Morocco
ME	Montenegro
MI	Middle East
MK	FYR of Macedonia
NA	North Africa
NI	North Ireland
NL	Netherlands
NO	Norway
NS	North Sea
PL	Poland
PT	Portugal
RO	Romania
RS	Serbia
SE	Sweden
SI	Slovenia
SK	Slovak Republic
TN	Tunisia
UK	United Kingdom

Albania

Demand and generation (no available data from ENTSO-e for Albania)





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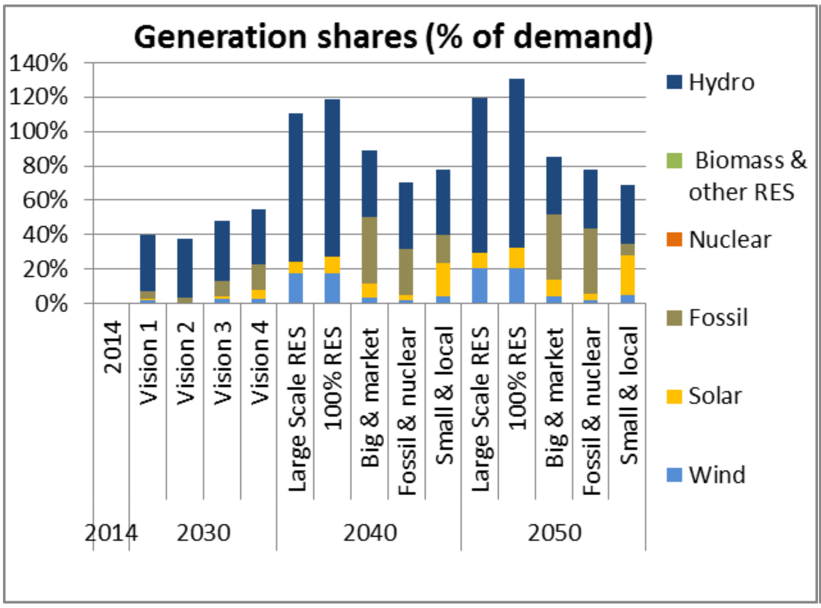
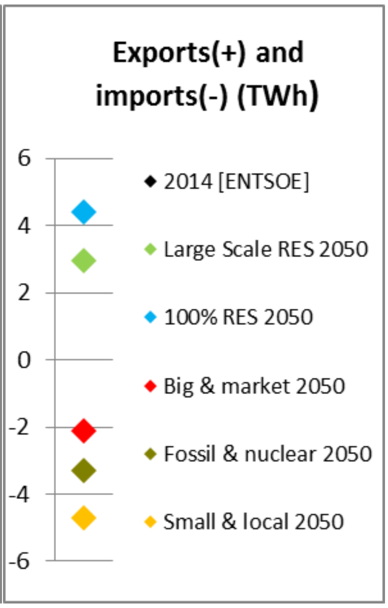
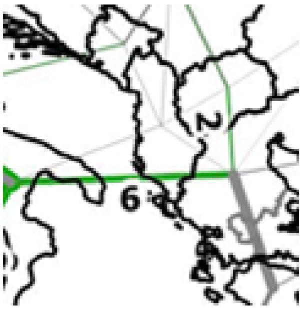




NB: Generation shares and imports/exports are here given in the case of a reinforced grid. RES curtailment is not subtracted from the generation in the left graph.

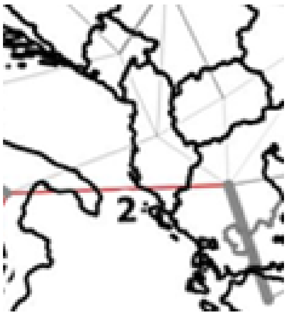
Grid reinforcements

Common 2040 grid

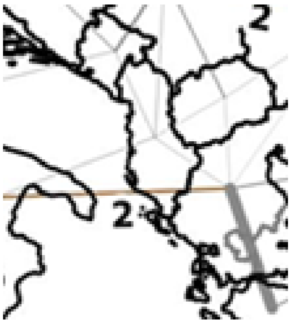


Large scale RES 2050

100% RES 2050



Big & market 2050

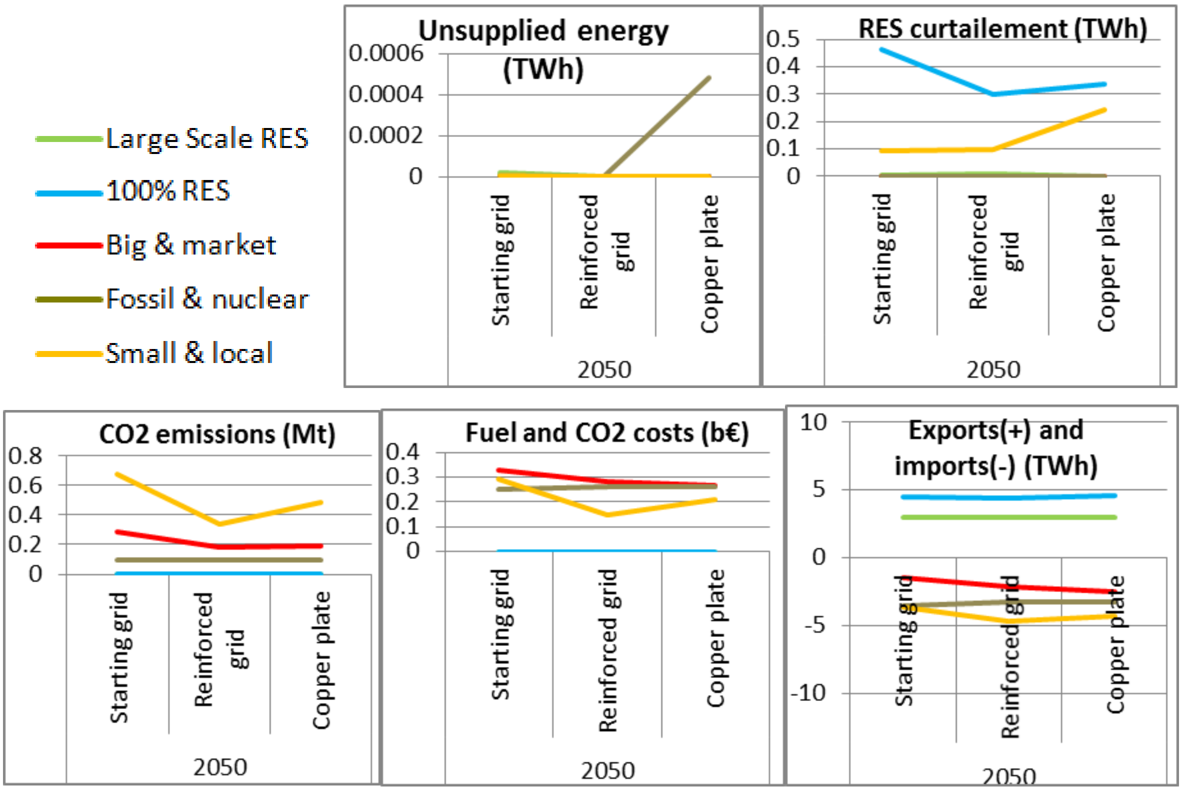


Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

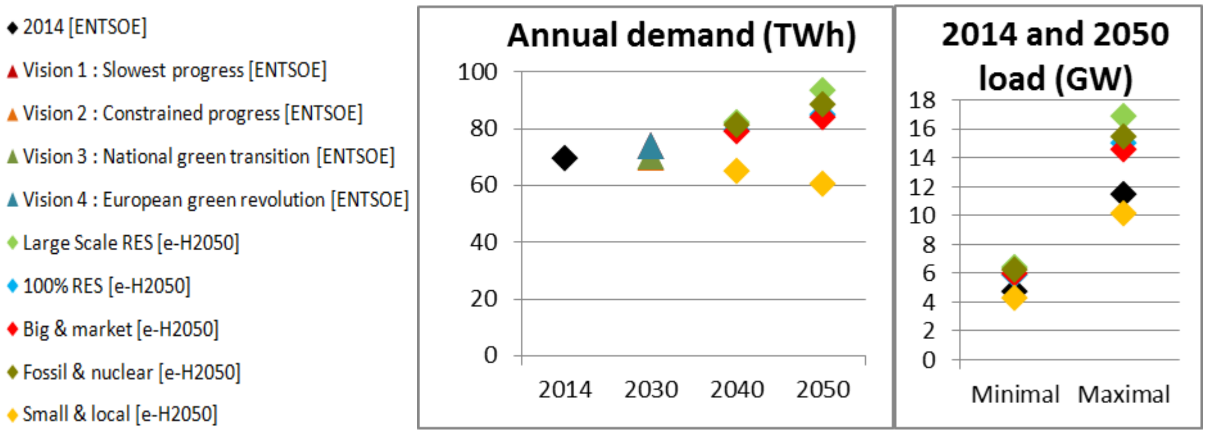
Impact of the grid reinforcements (2050)

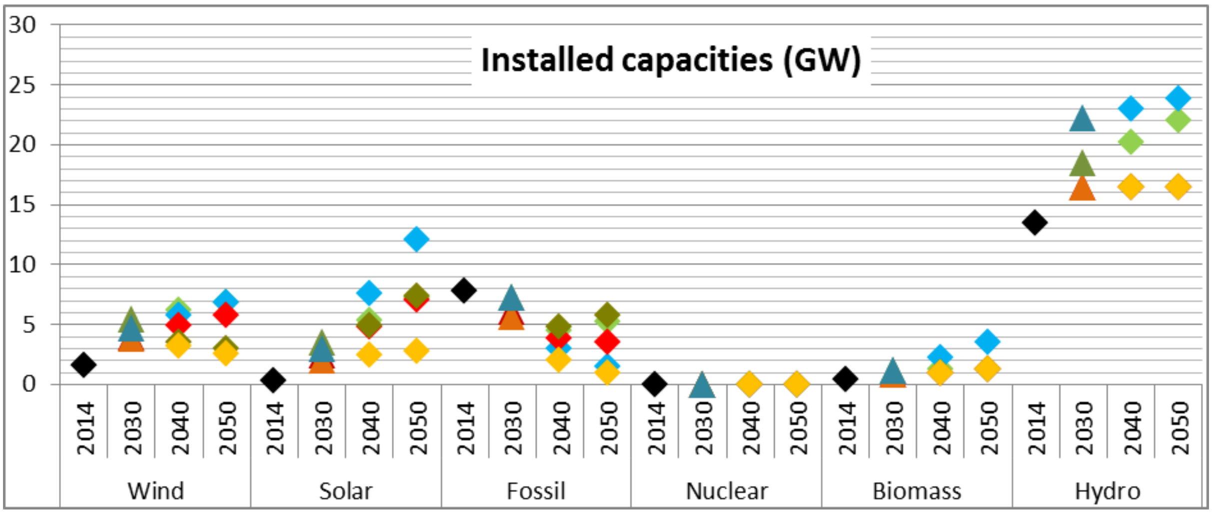


NB : The impact of the grid reinforcements can be difficult to analyse at a national level. For example, fuel and CO2 costs can increase to support more exports towards countries with more expensive generation. Also small increases of the unsupplied energy or of the RES curtailment can occur on a national level

Austria

Demand and generation





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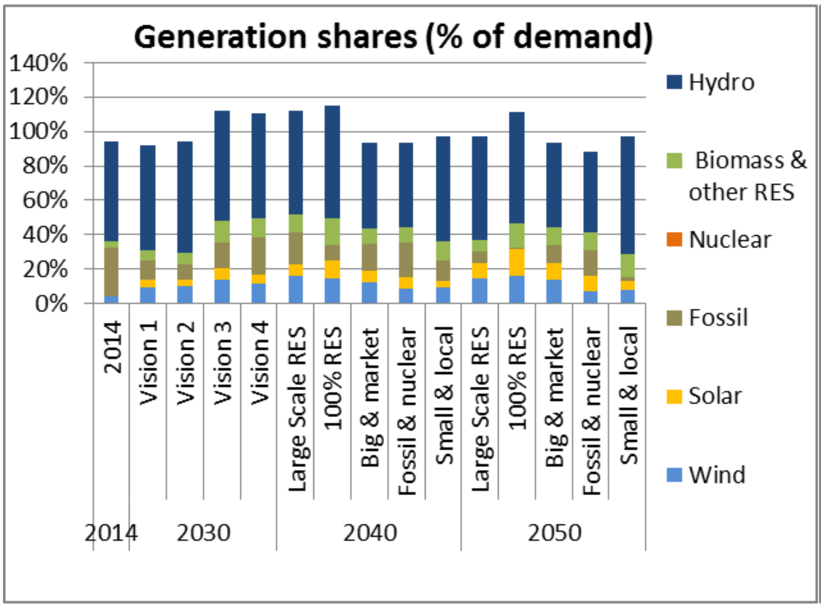

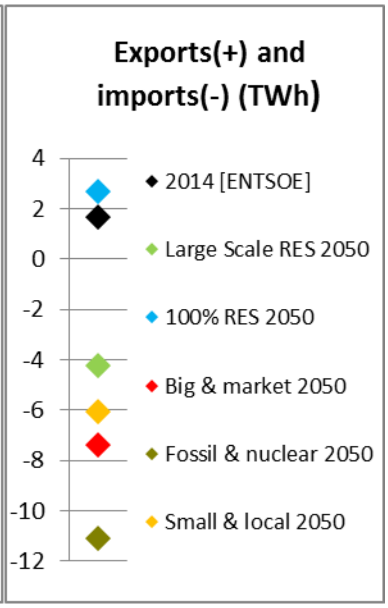

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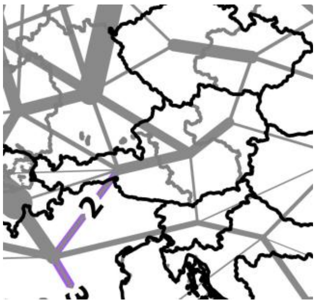
Grid reinforcements



Common 2040 grid

Large scale RES 2050

100% RES 2050

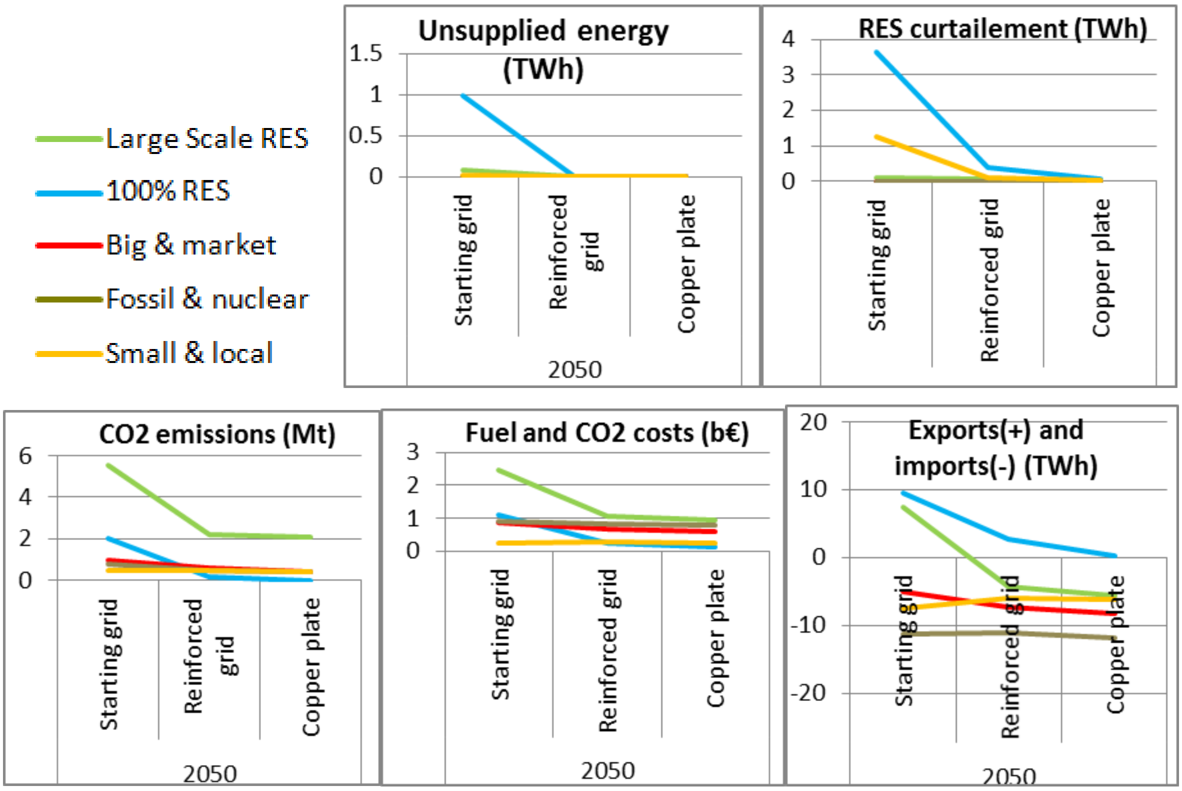
Big & market 2050

Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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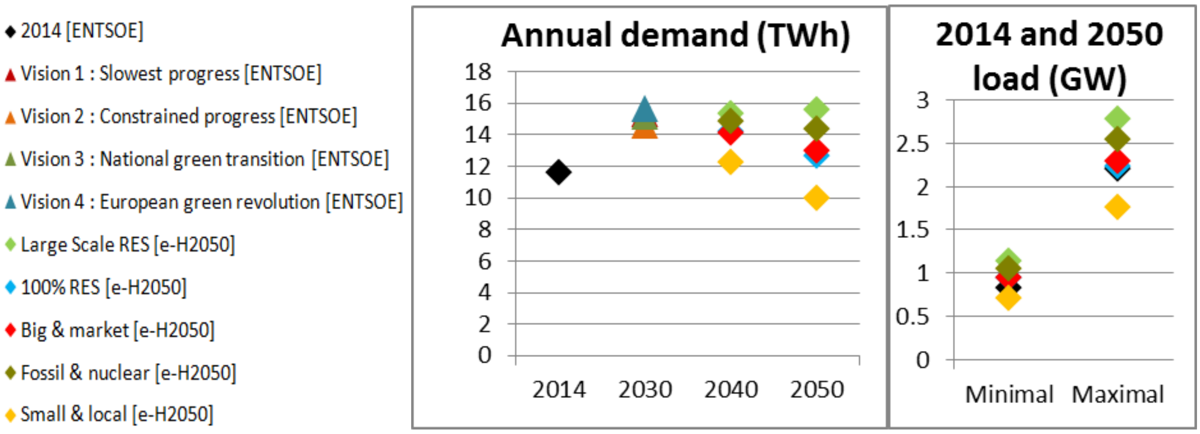
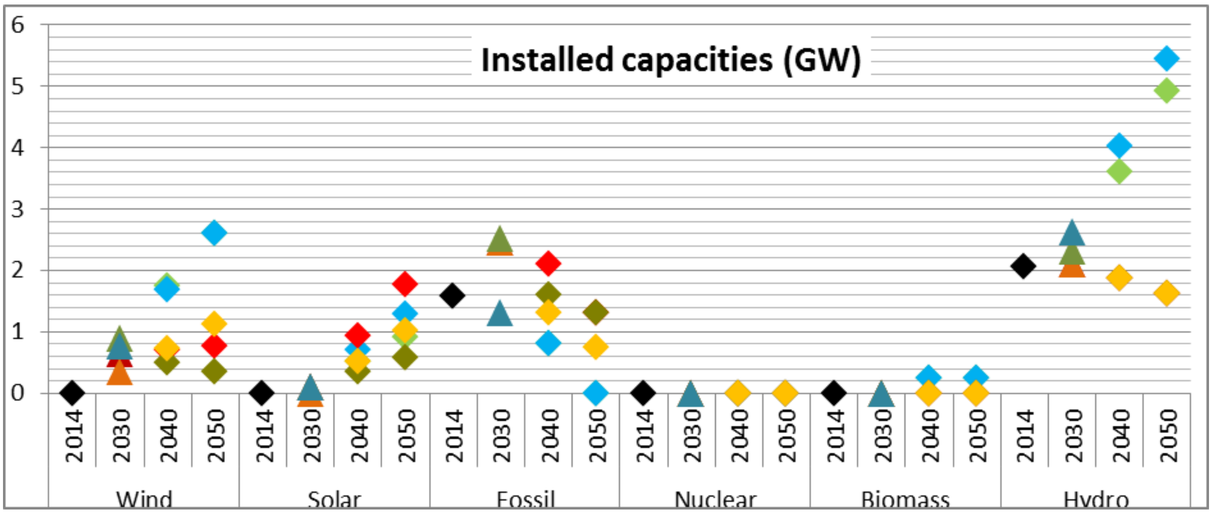
Bosnia & Herzegovina

Demand and generation





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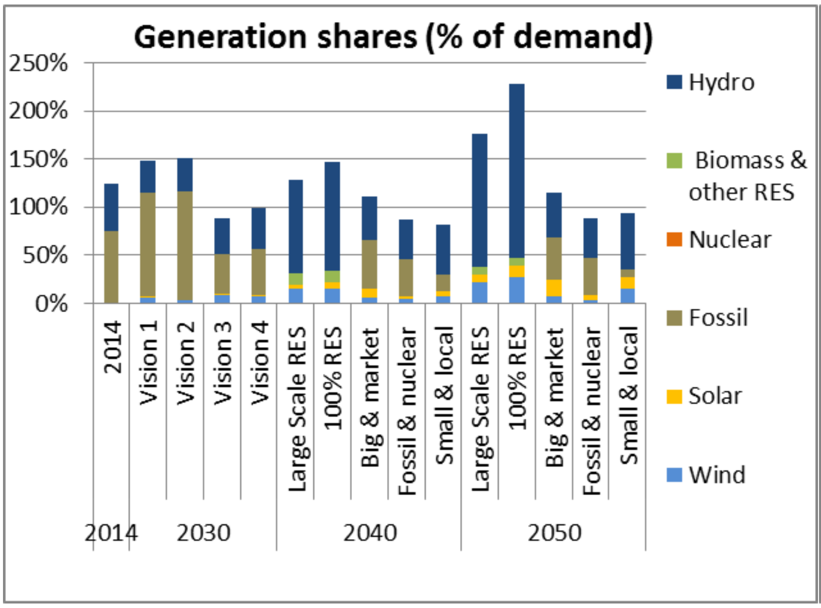

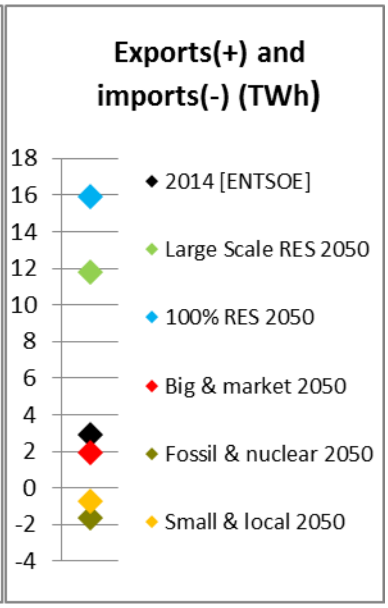

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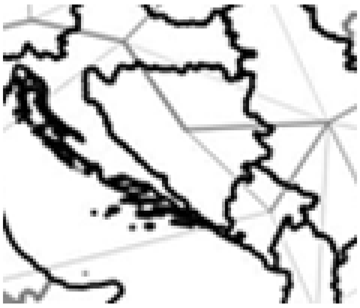
Grid reinforcements

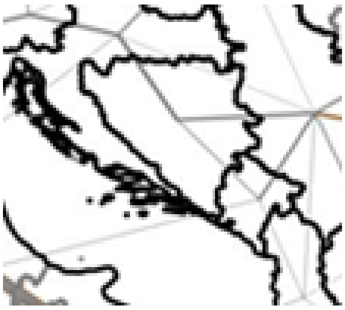
Common 2040 grid

Large scale RES 2050

100% RES 2050



Big & market 2050

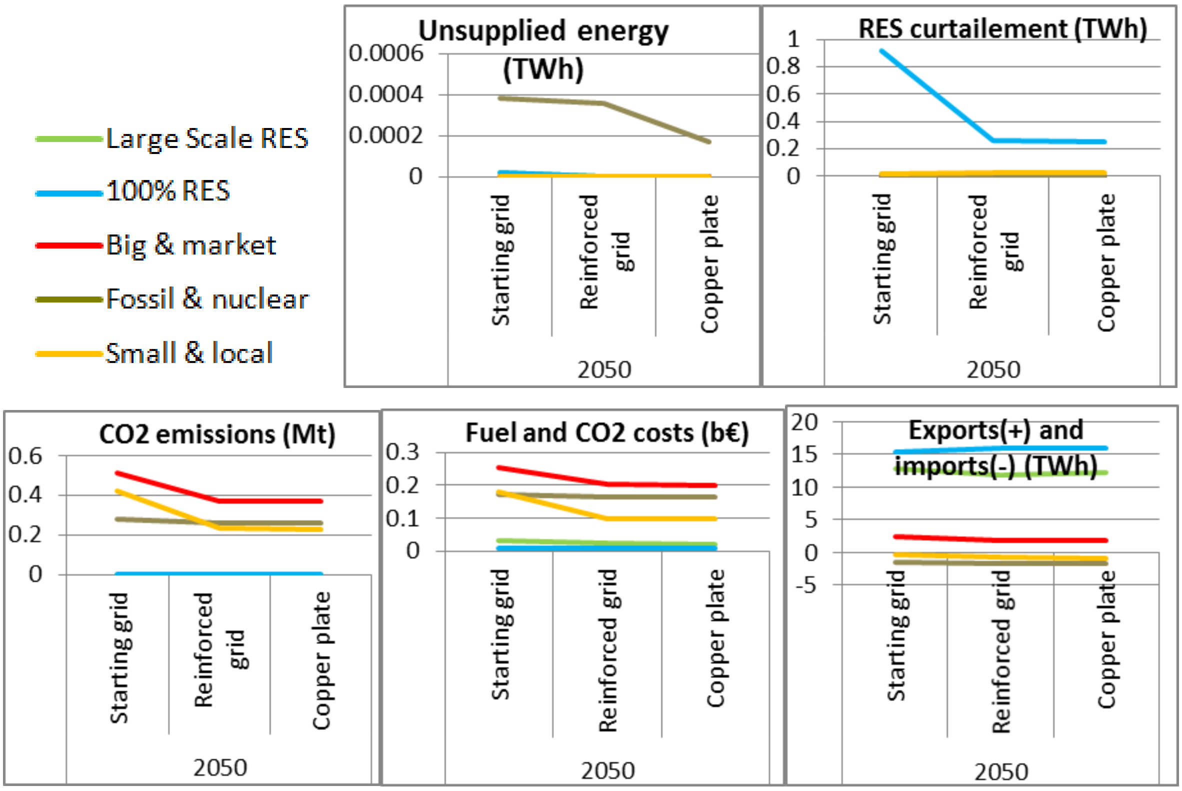


Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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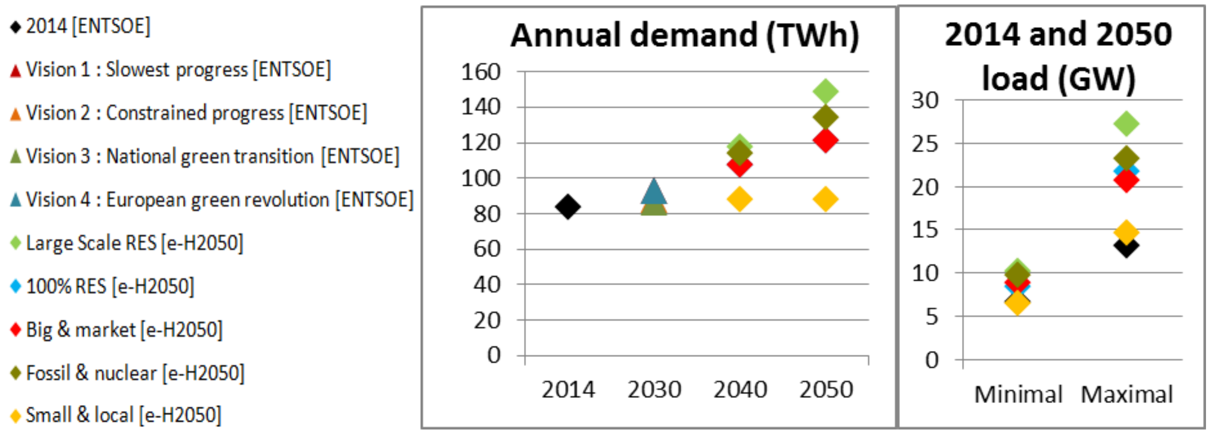
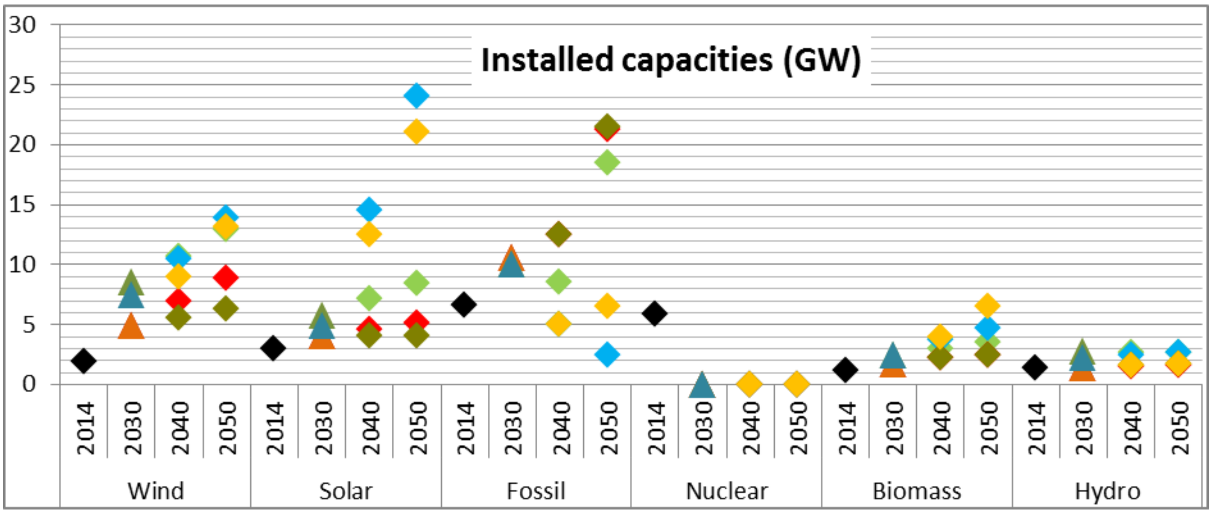
Belgium

Demand and generation





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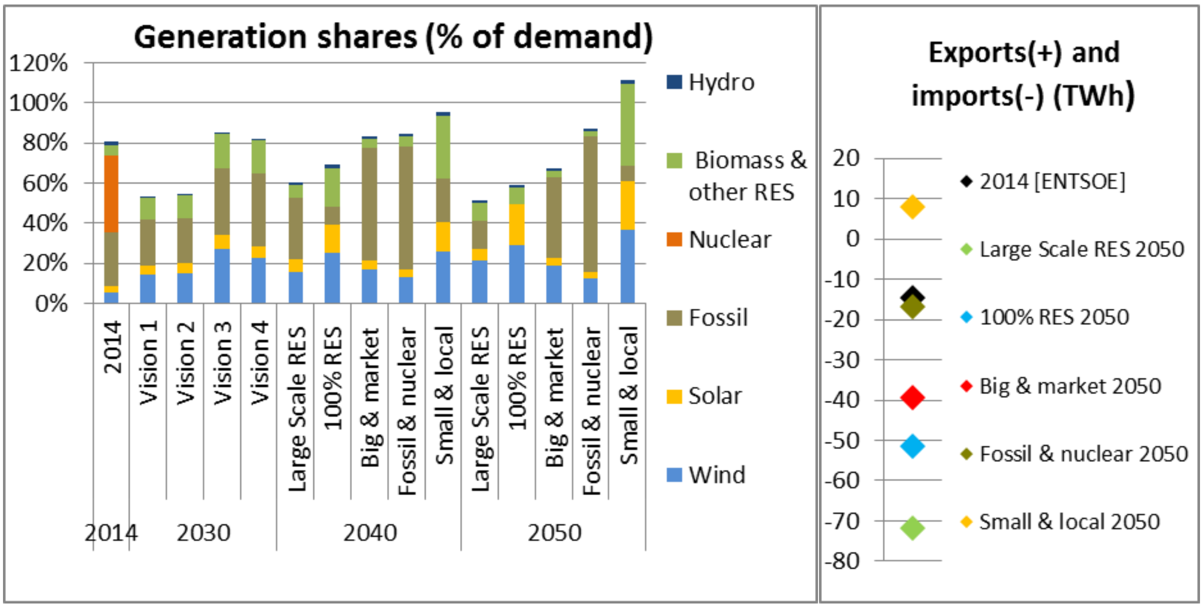

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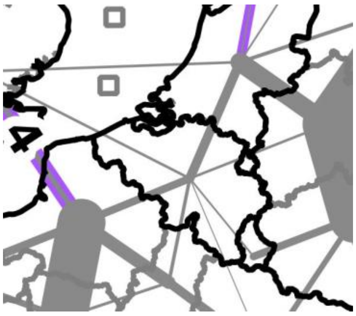
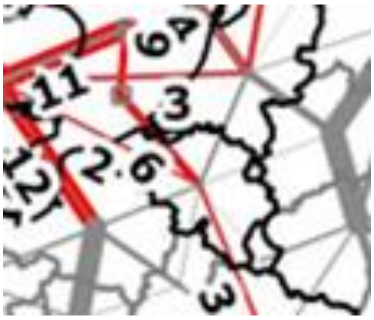
Grid reinforcements



Common 2040 grid

Large scale RES 2050

100% RES 2050



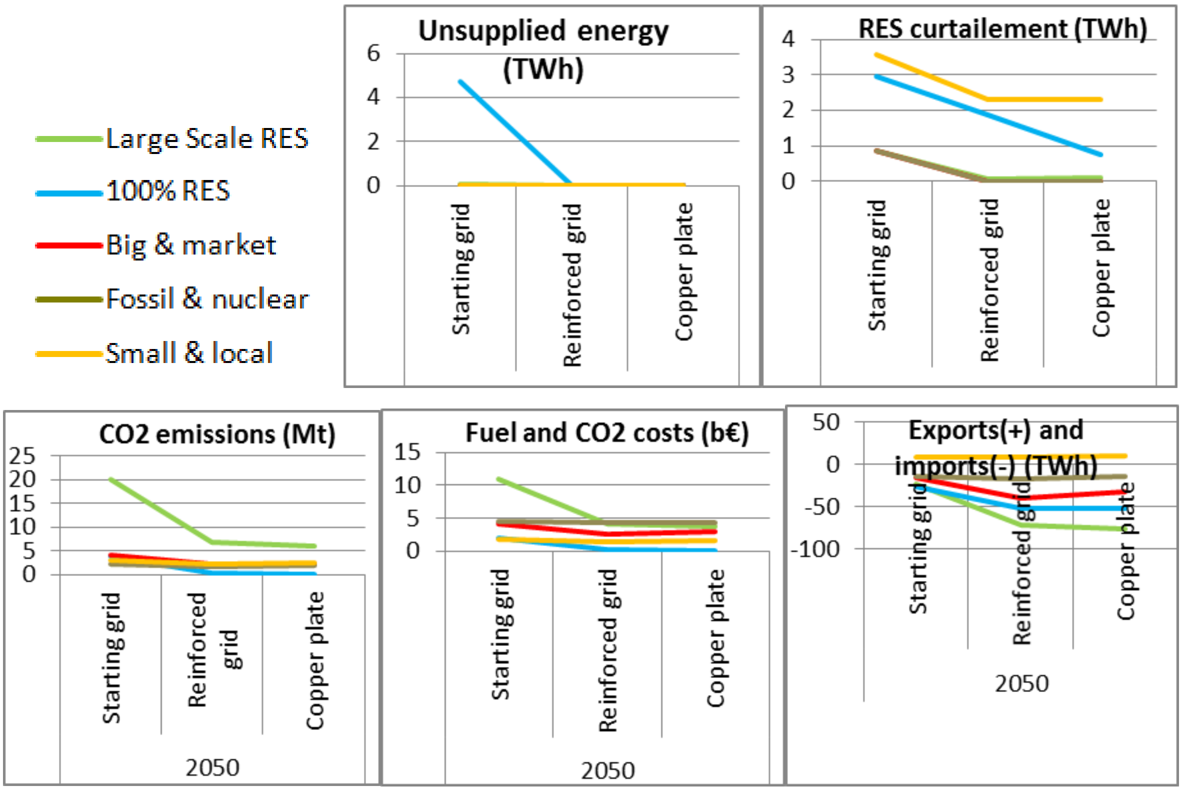
Big & market 2050

Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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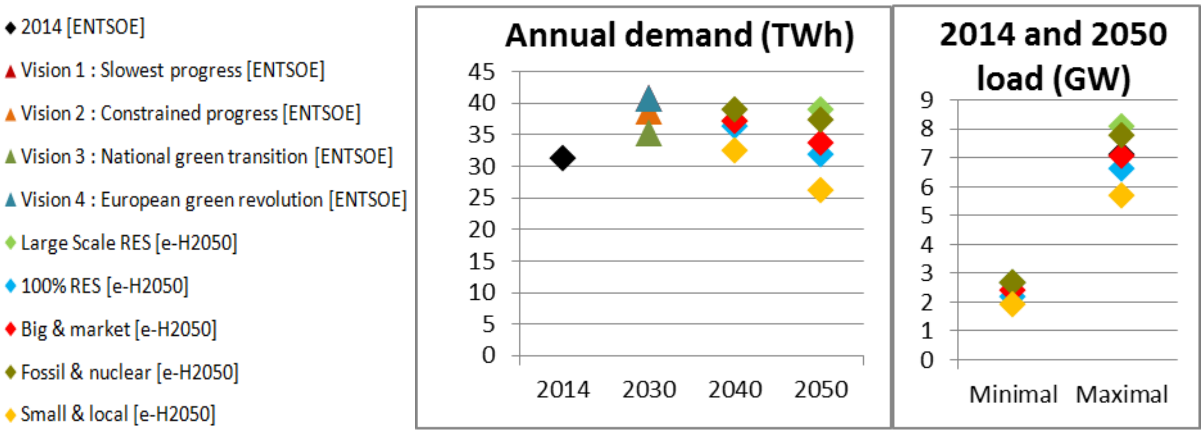
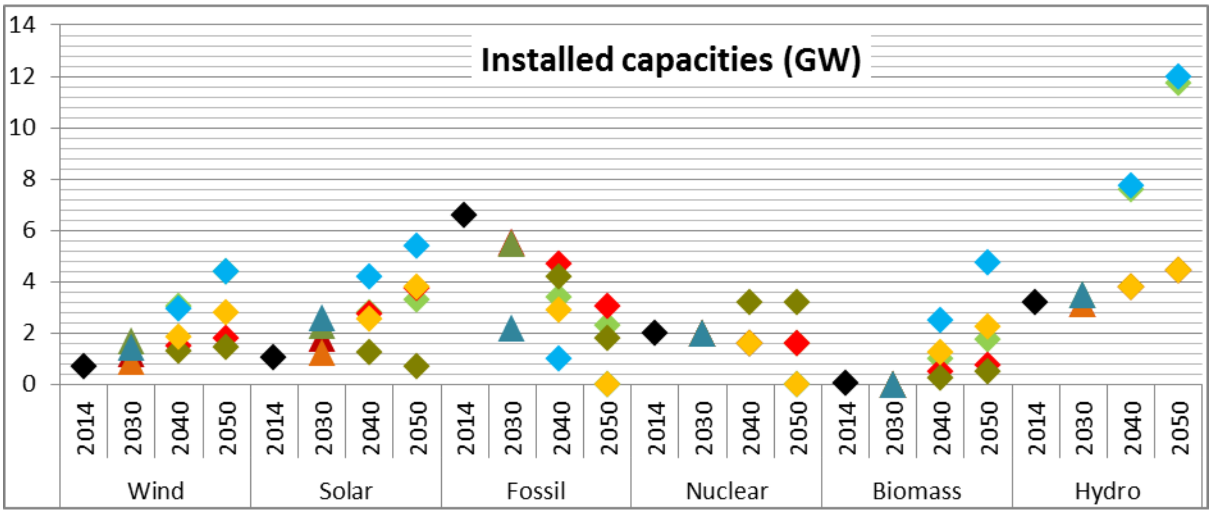
Bulgaria

Demand and generation





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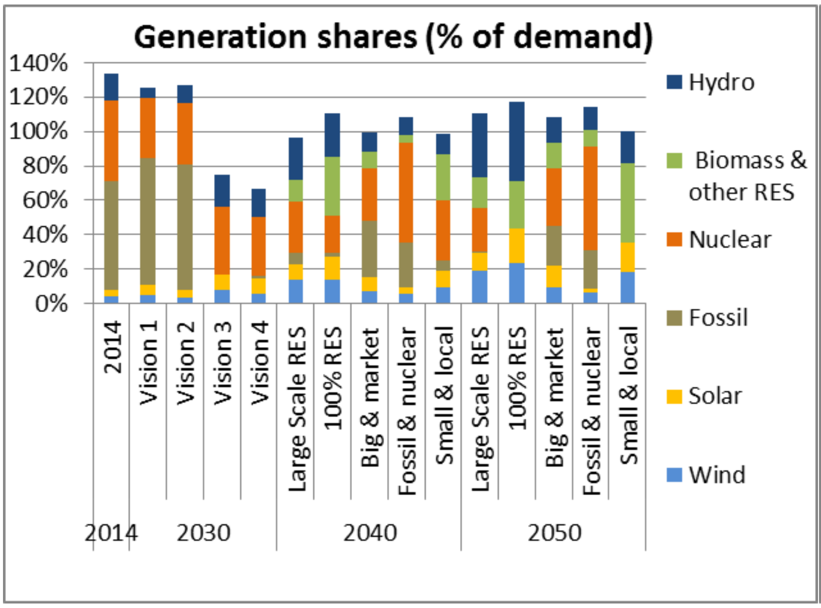

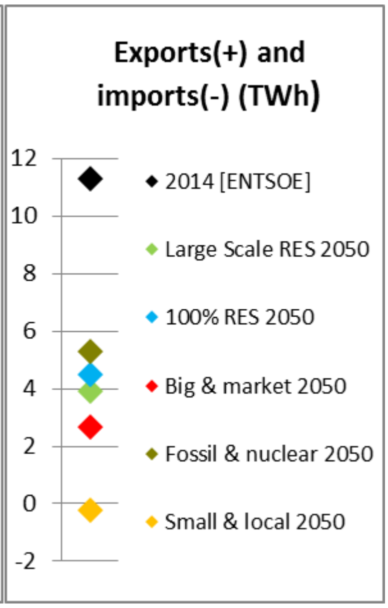

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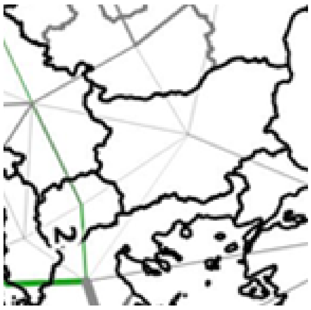
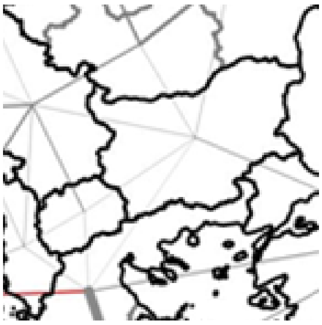
Grid reinforcements

Common 2040 grid

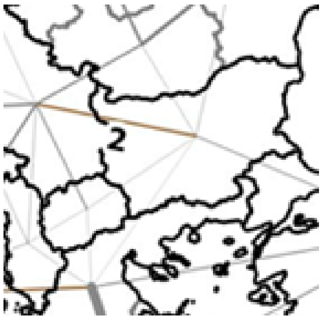


Large scale RES 2050

100% RES 2050



Big & market 2050

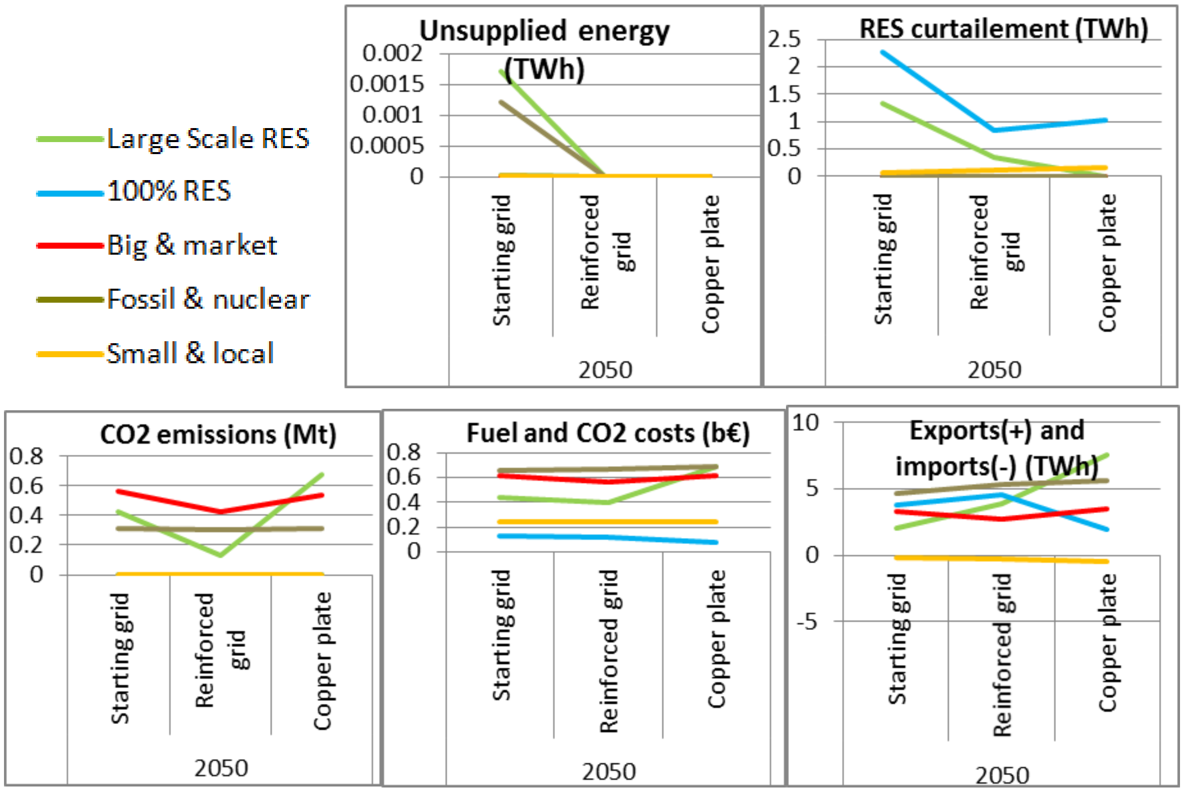


Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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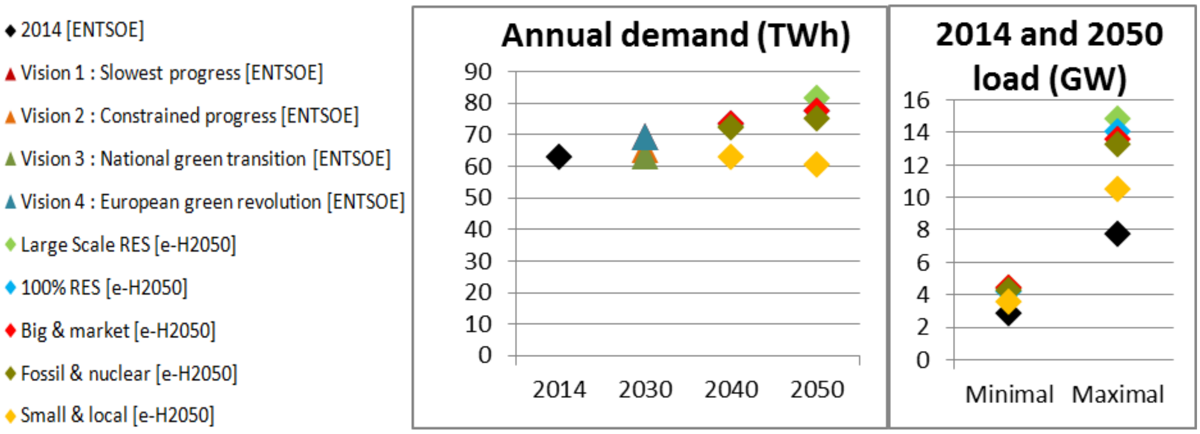
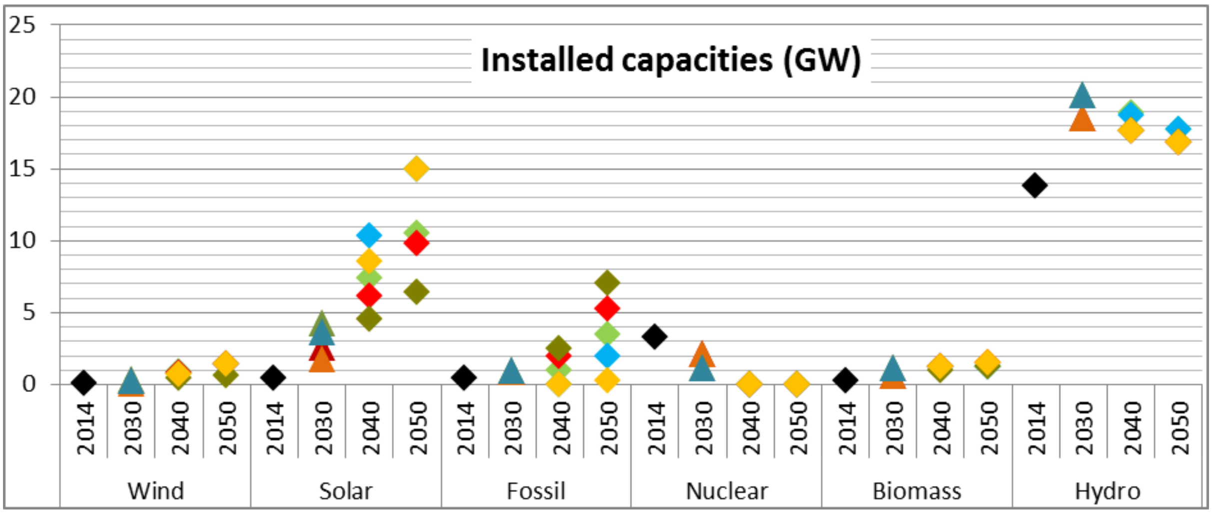
Switzerland

Demand and generation





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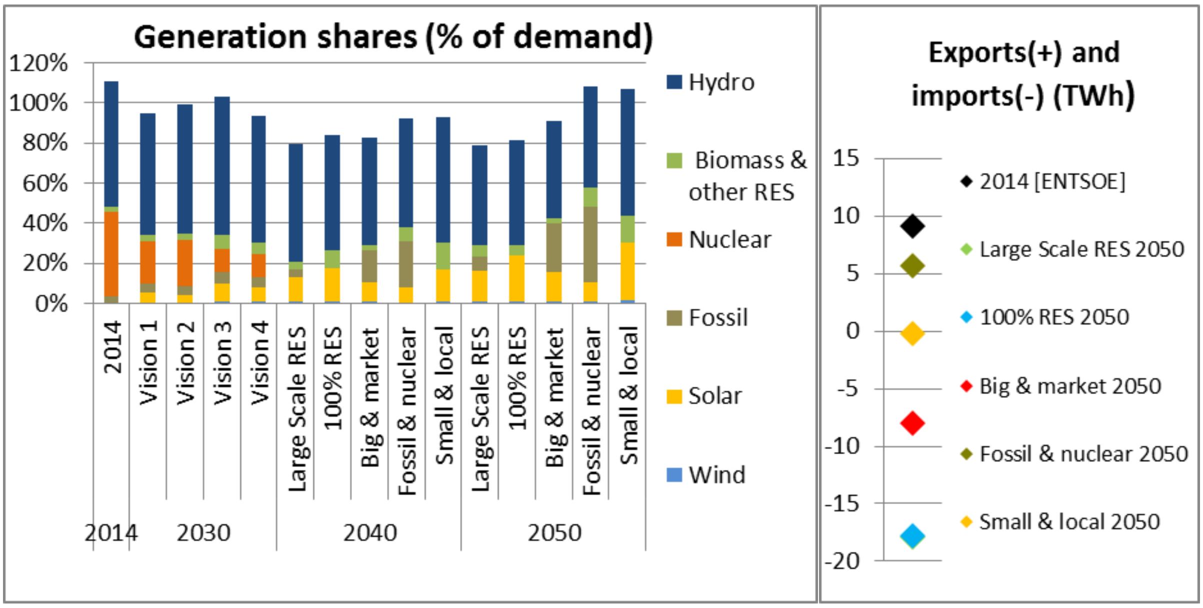

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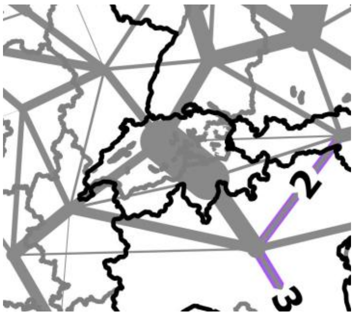
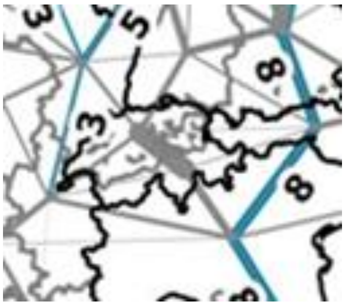
Grid reinforcements

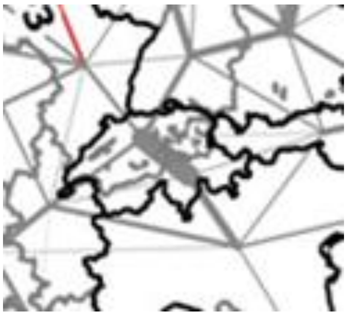


Common 2040 grid

Large scale RES 2050



100% RES 2050



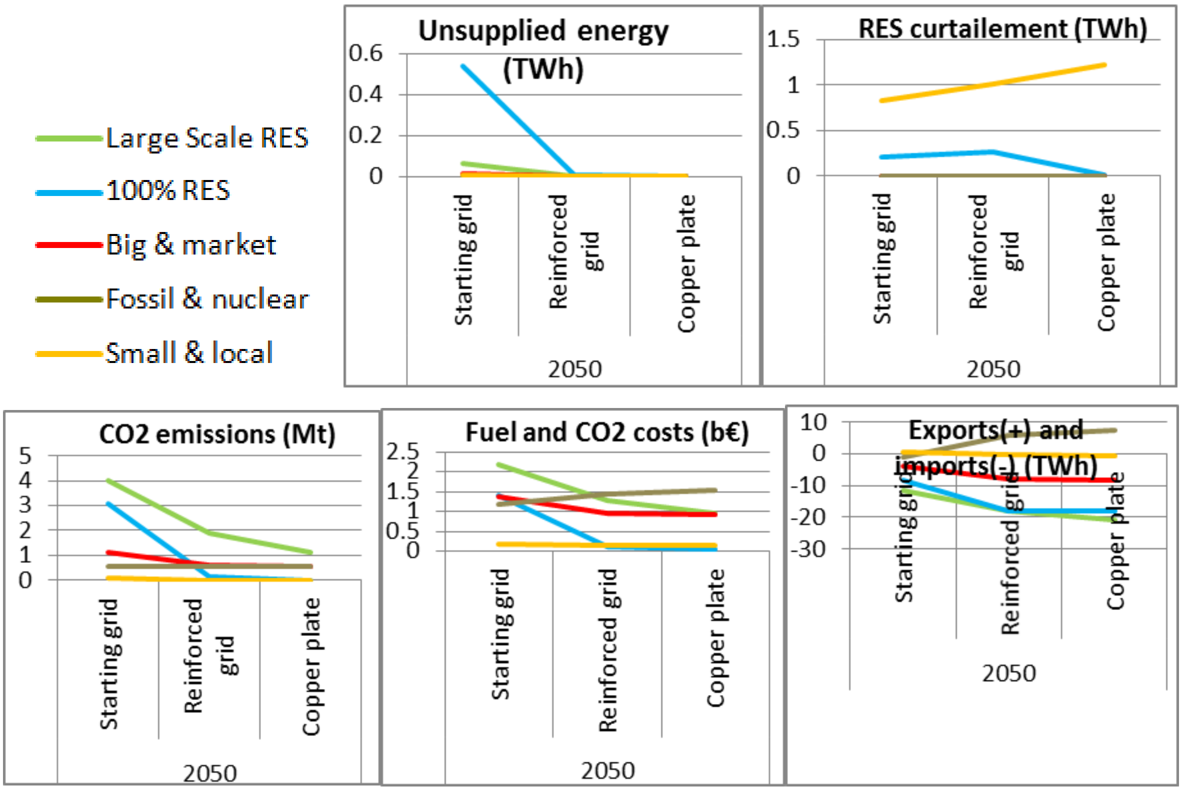
Big & market 2050

Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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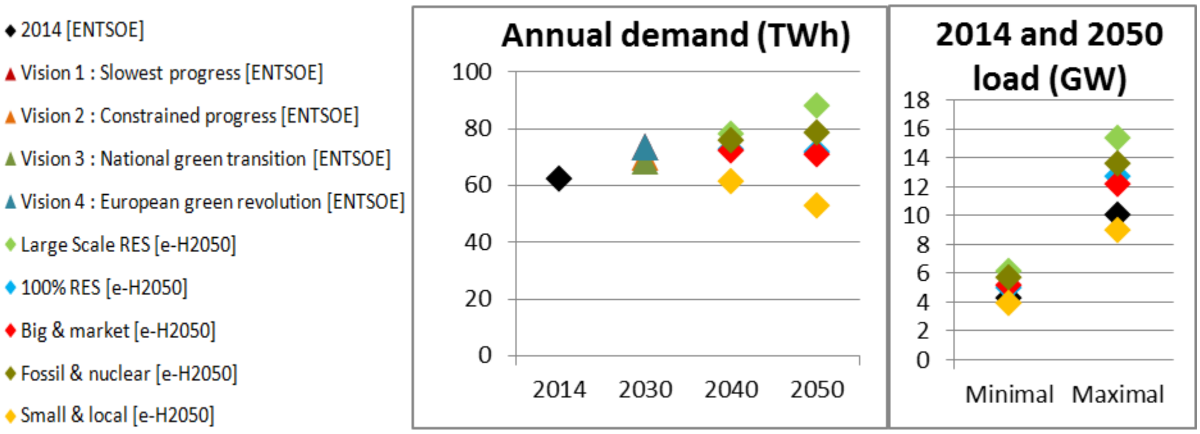
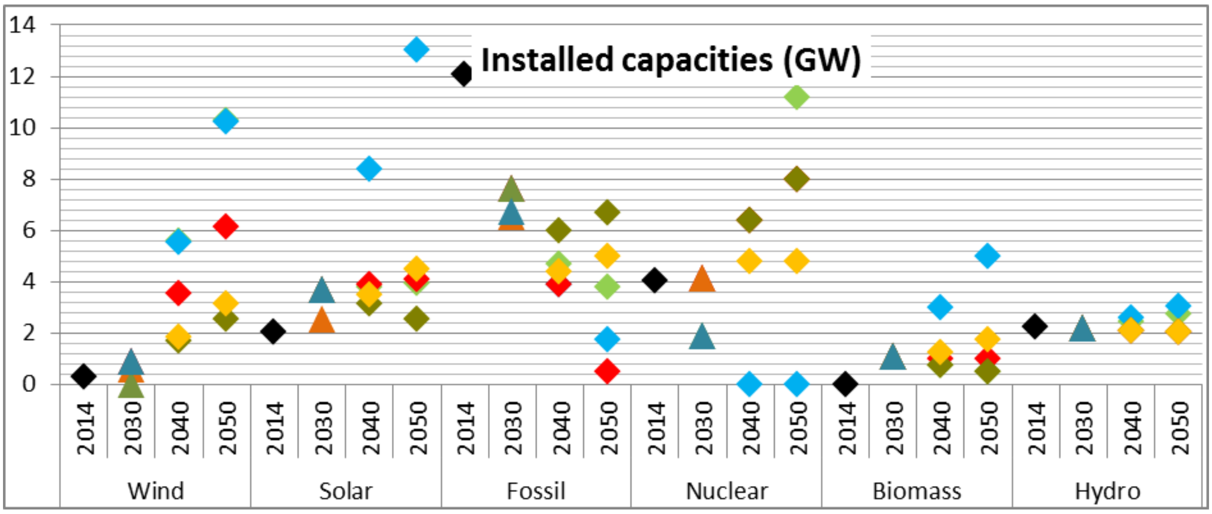
Czech Republic

Demand and generation





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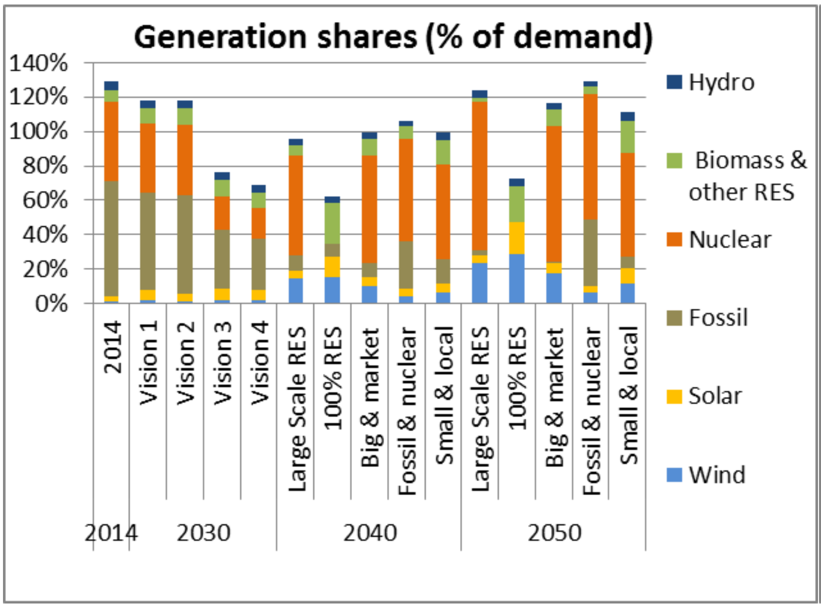

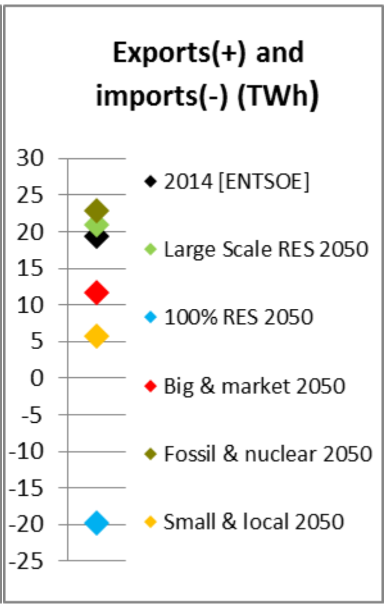

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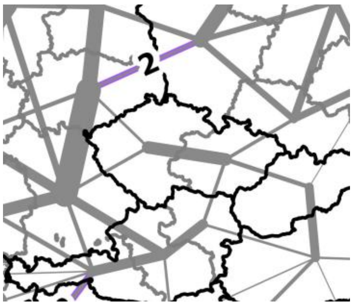
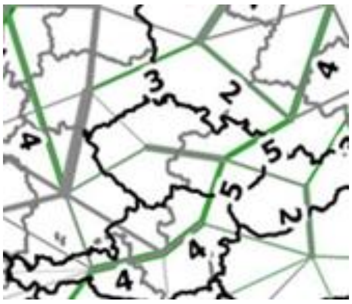
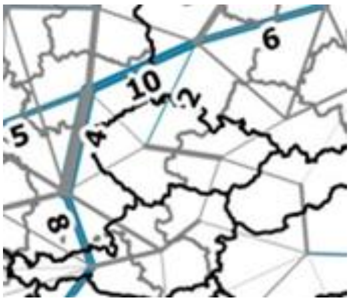
Grid reinforcements



Common 2040 grid



Large scale RES 2050



100% RES 2050

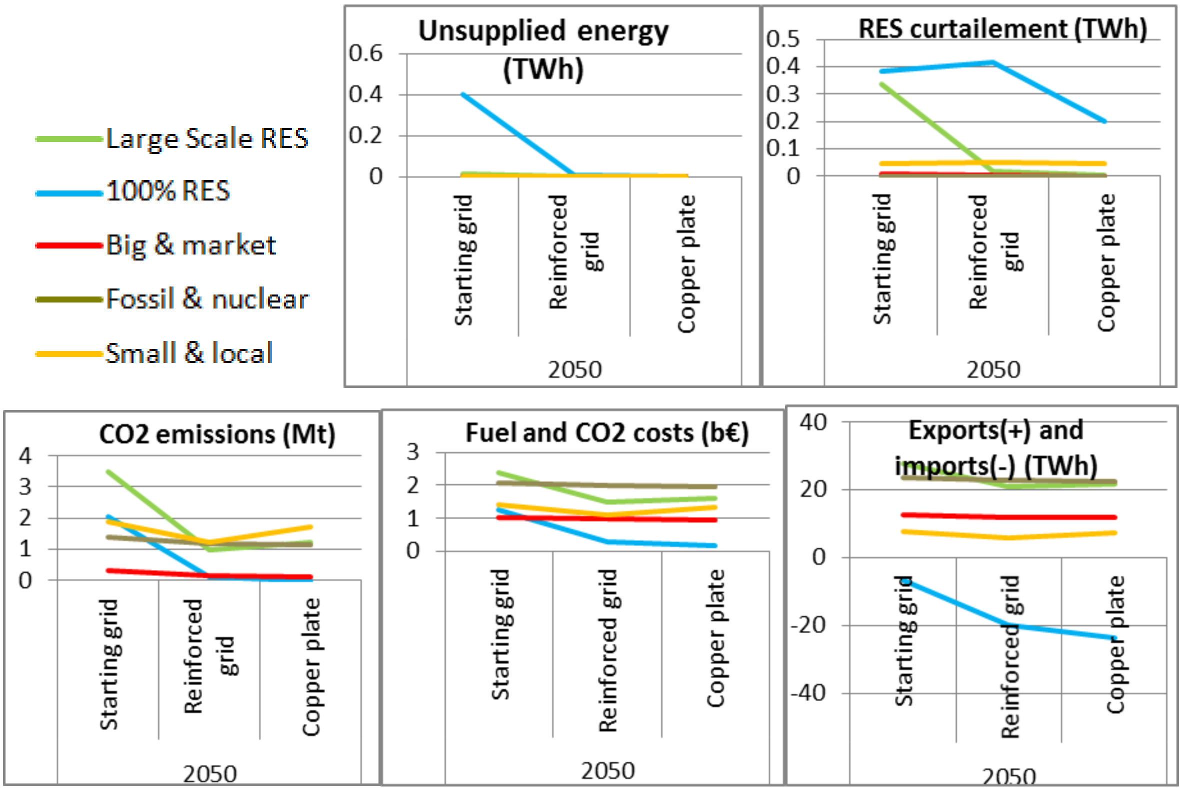
Big & market 2050

Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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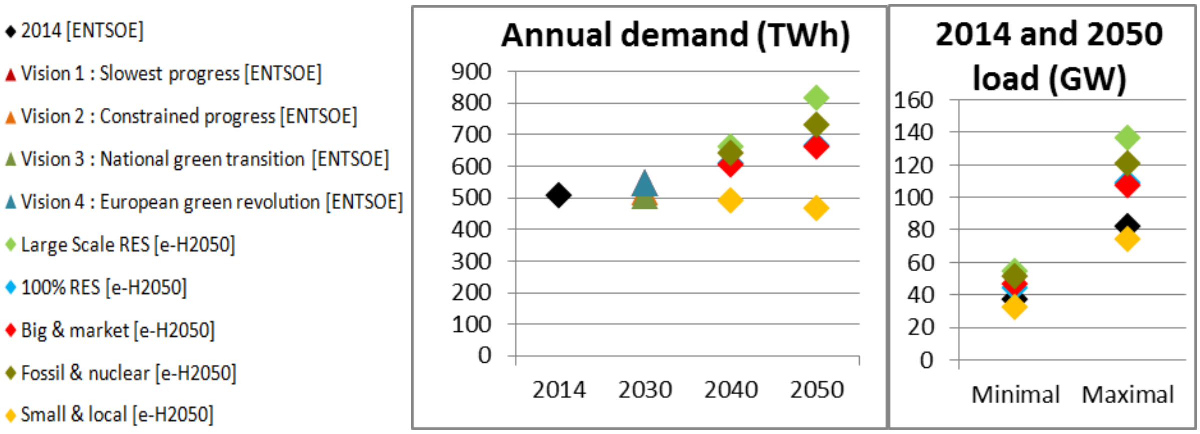
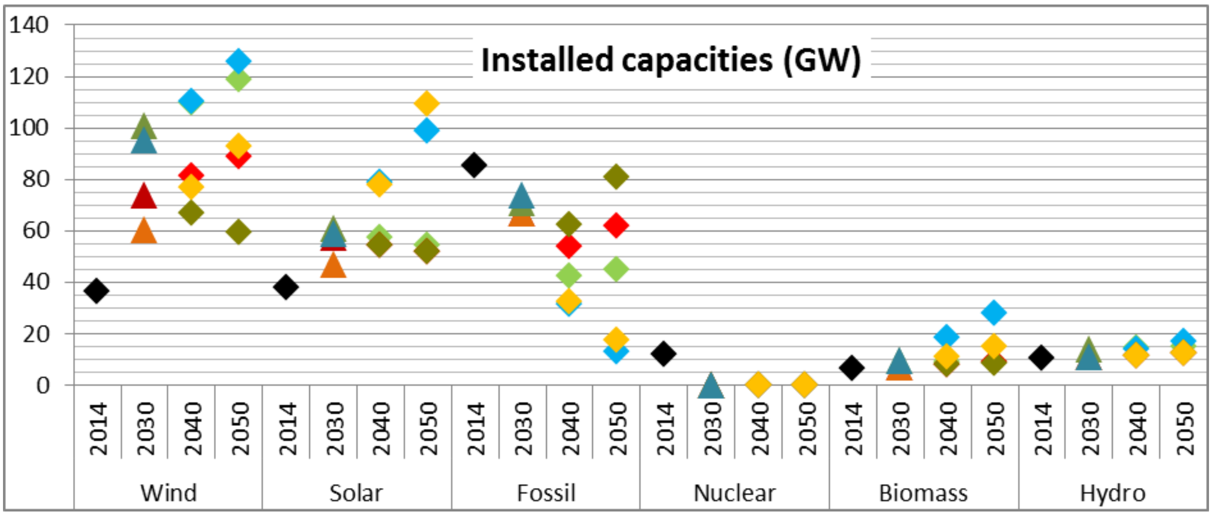
Germany

Demand and generation





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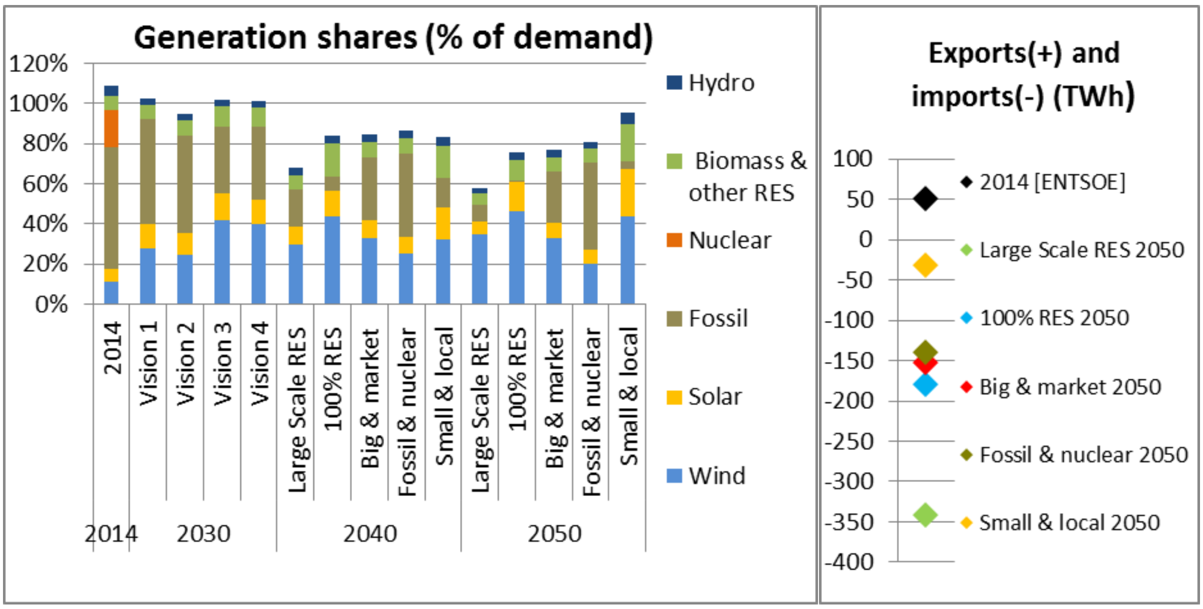

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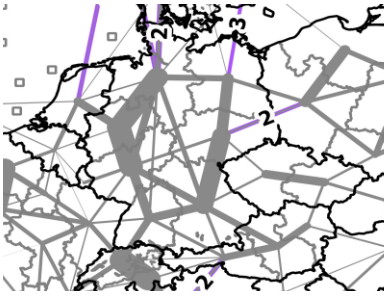
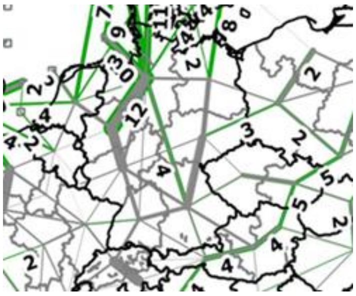
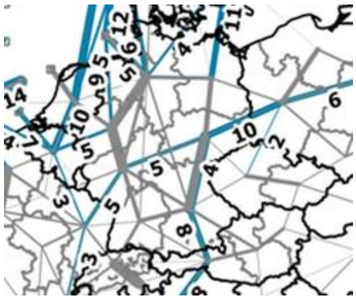
Grid reinforcements



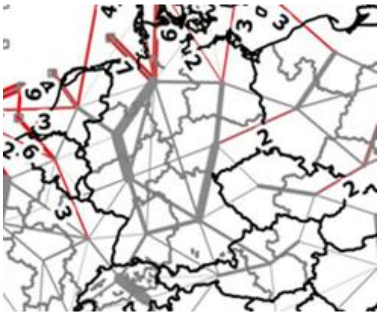
Common 2040 grid



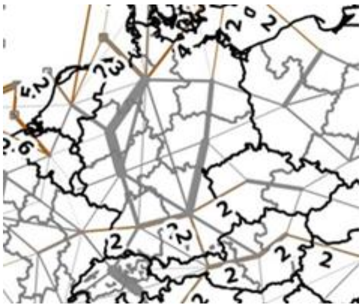
Large scale RES 2050



100% RES 2050



Big & market 2050

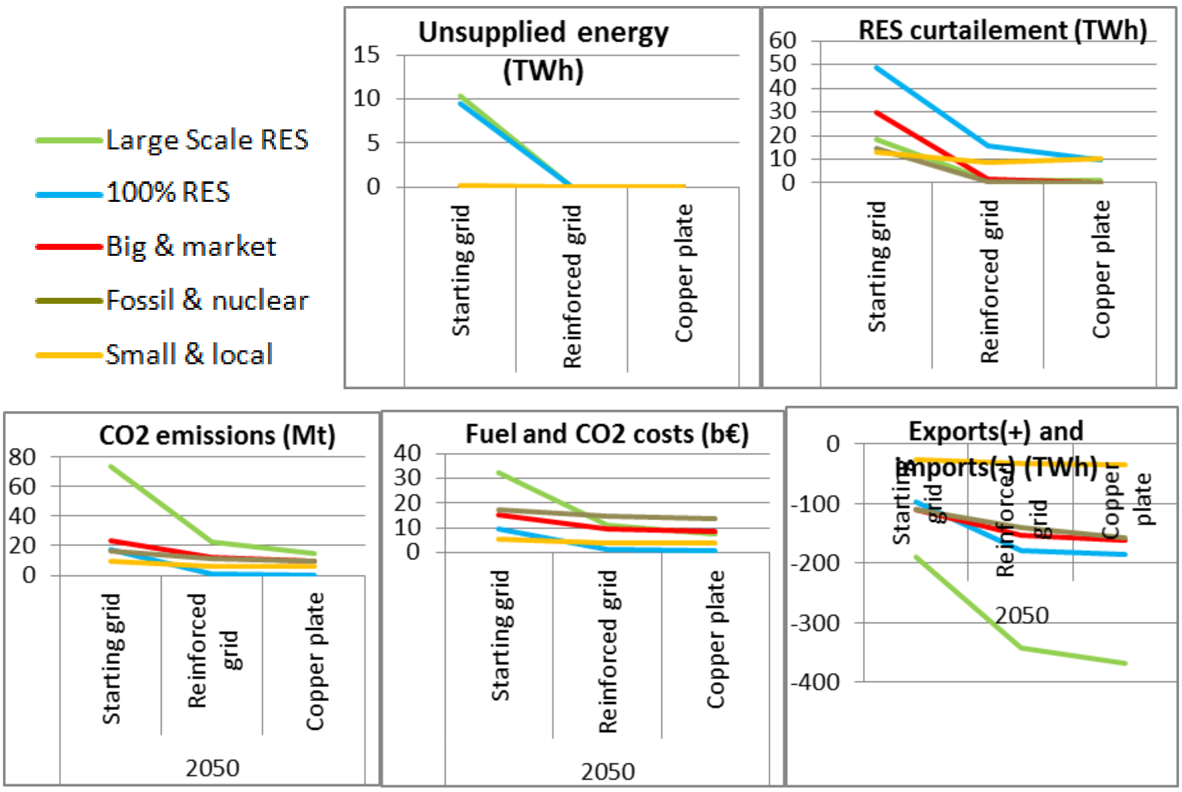


Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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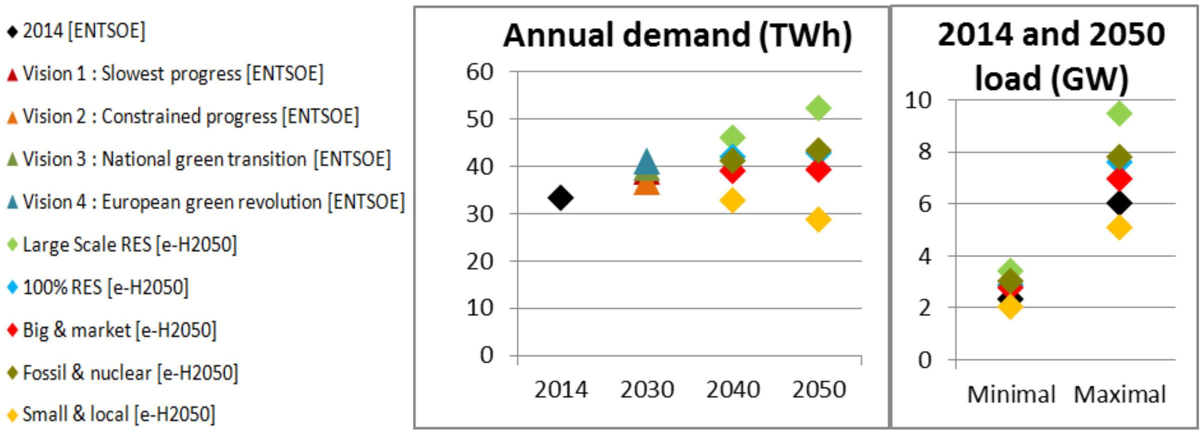
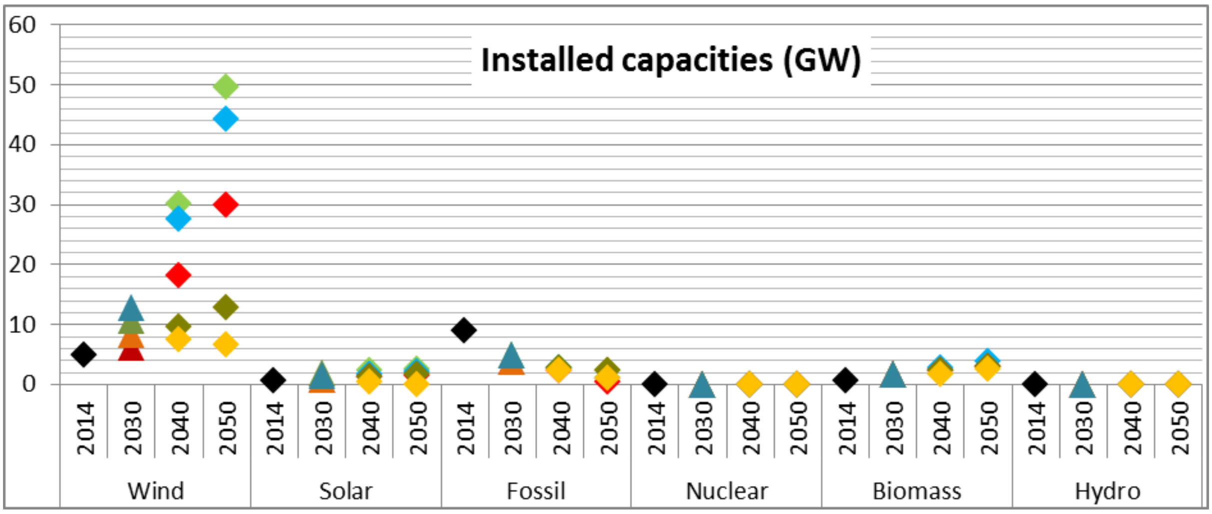
Denmark

Demand and generation





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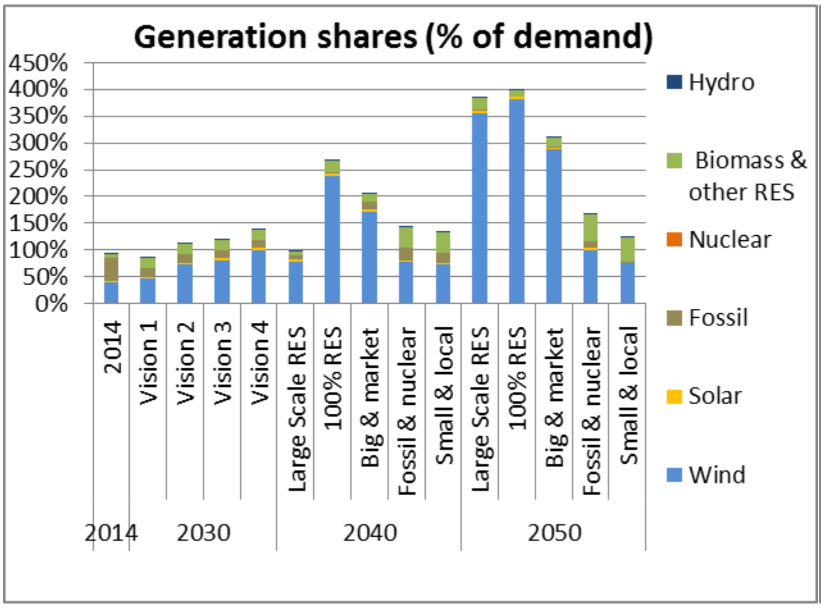

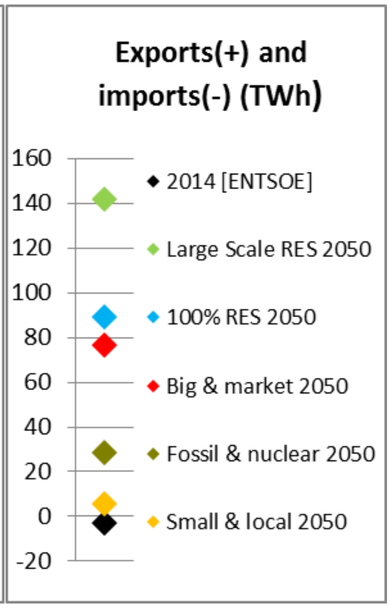

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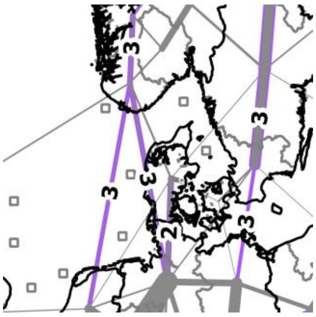
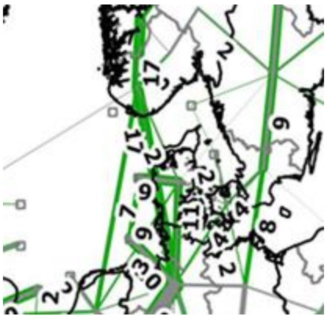
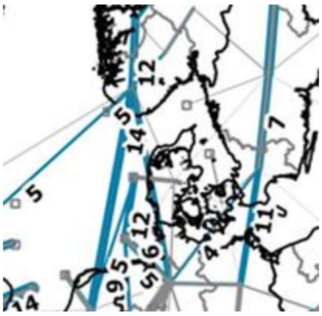
Grid reinforcements



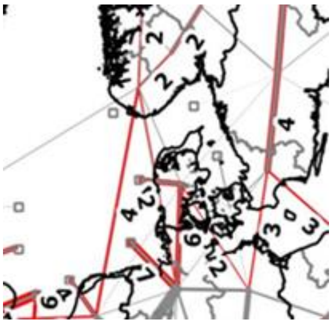
Common 2040 grid



Large scale RES 2050

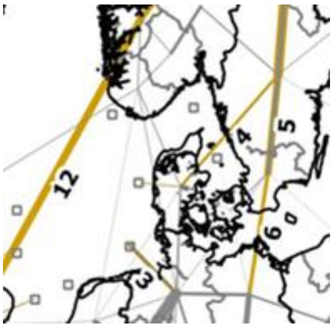


100% RES 2050



Big & market 2050

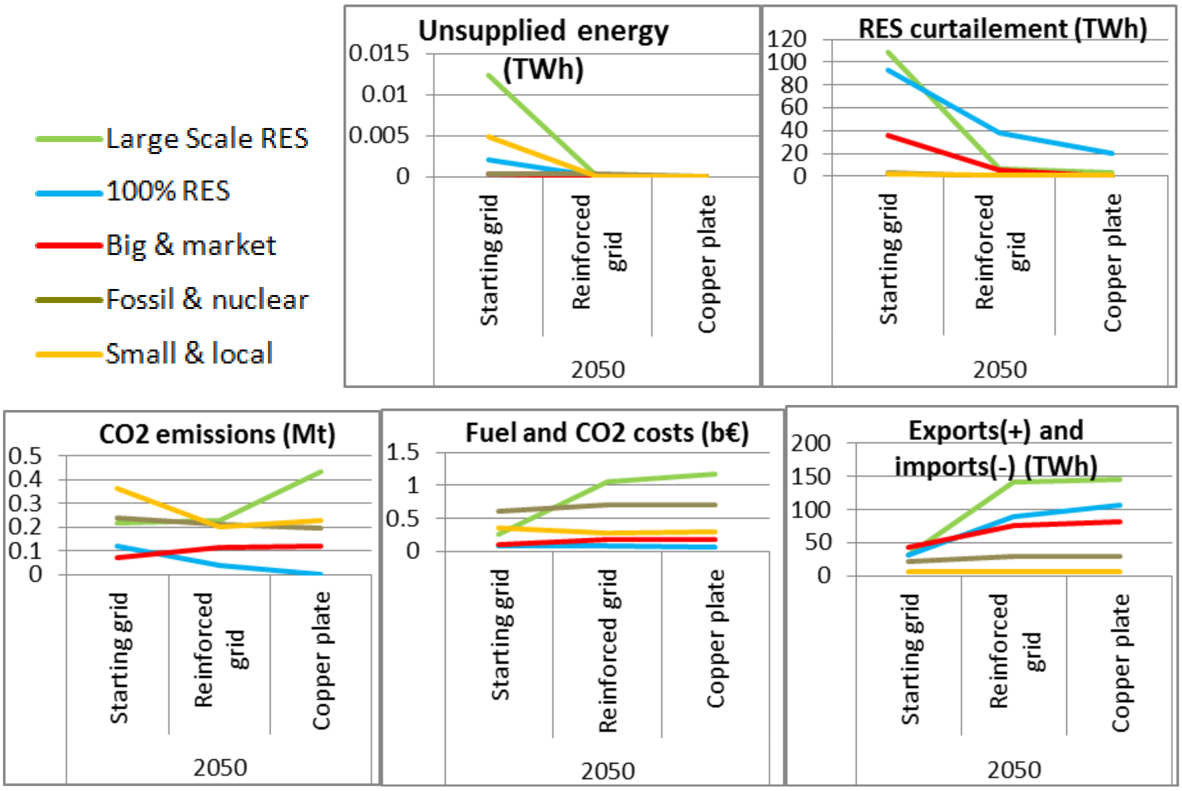
Fossil & nuclear 2050



Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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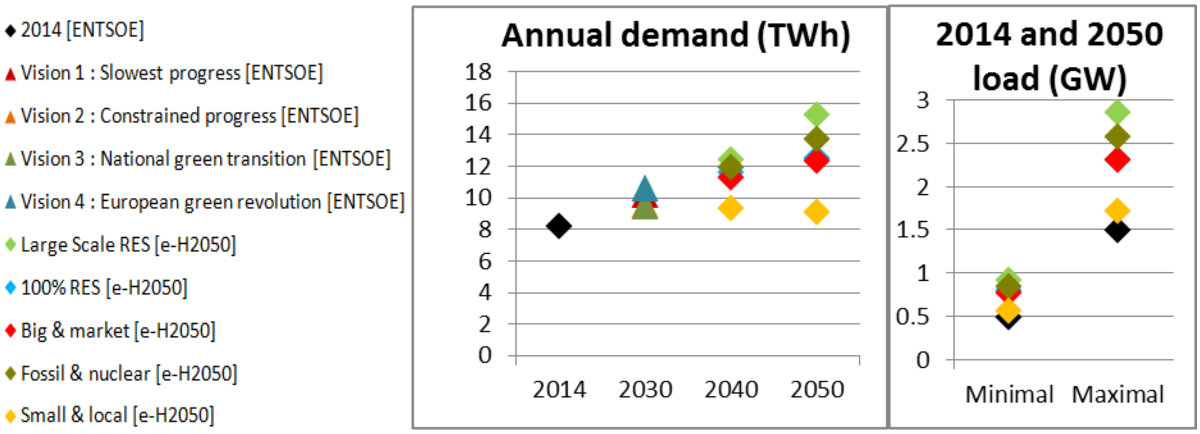
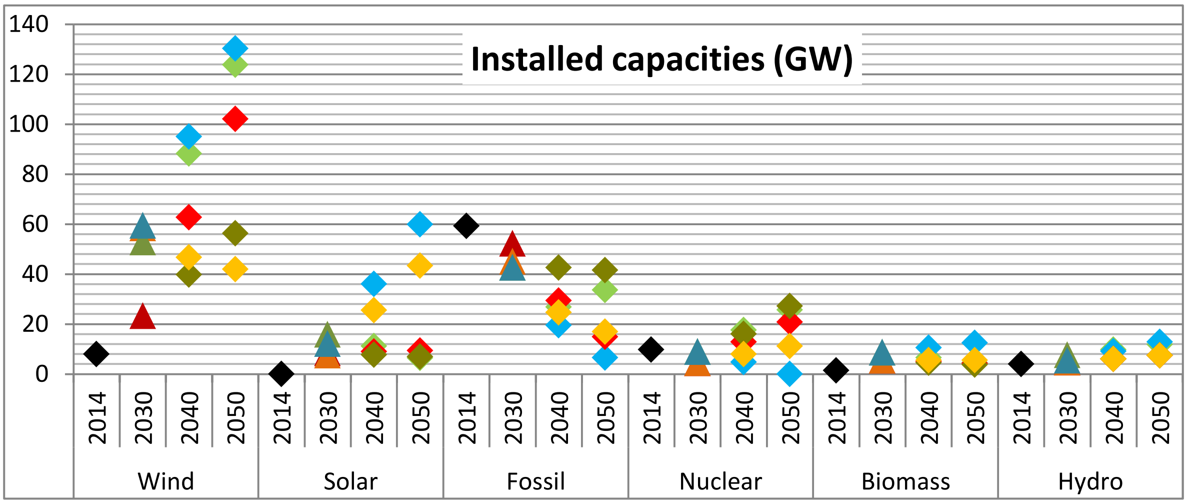
Estonia

Demand and generation





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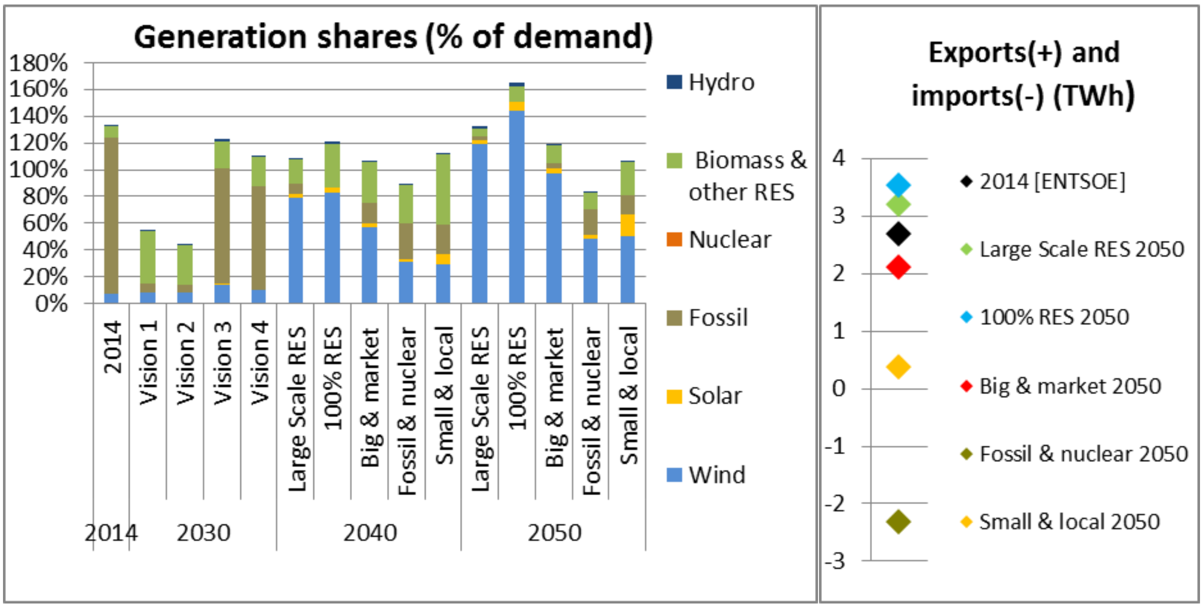

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Grid reinforcements

Common 2040 grid

Large scale RES 2050

100% RES 2050

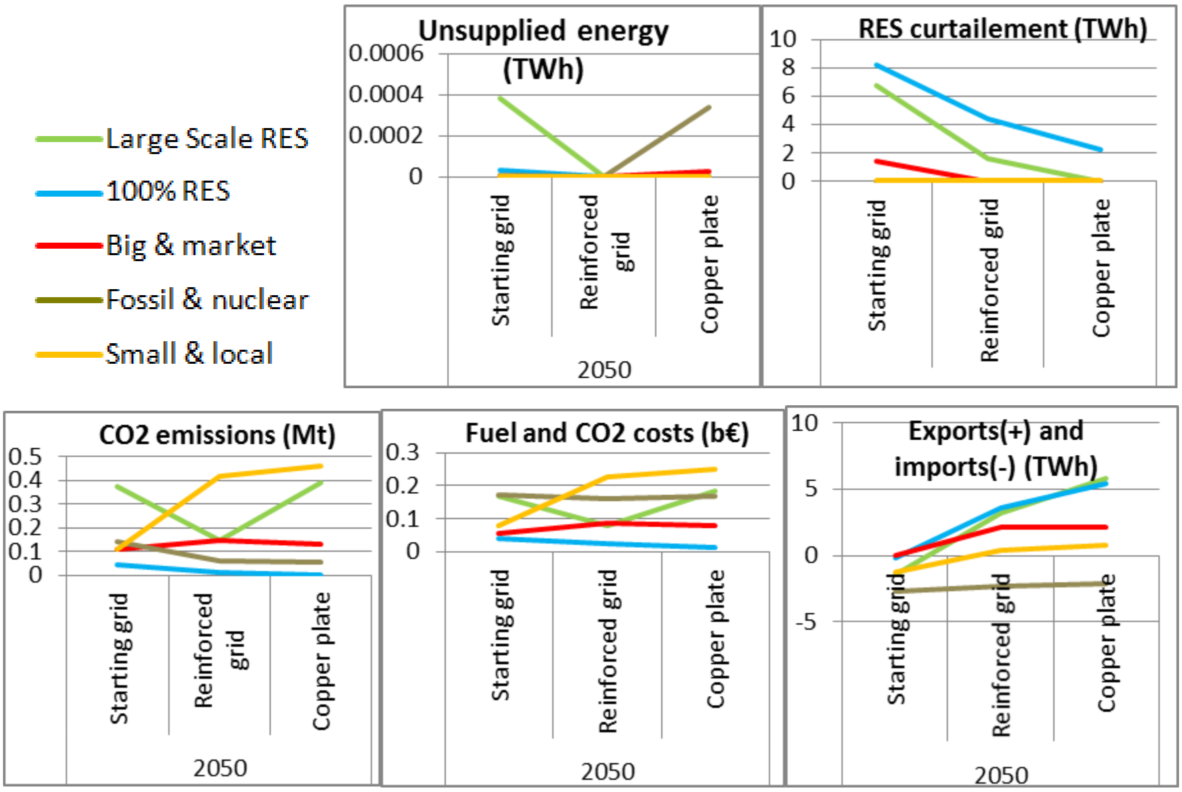
Big & market 2050

Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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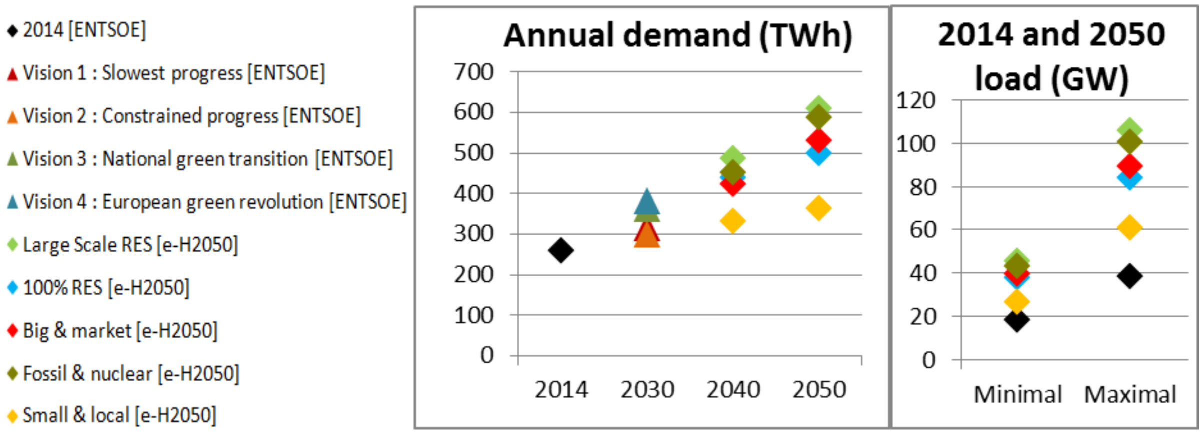
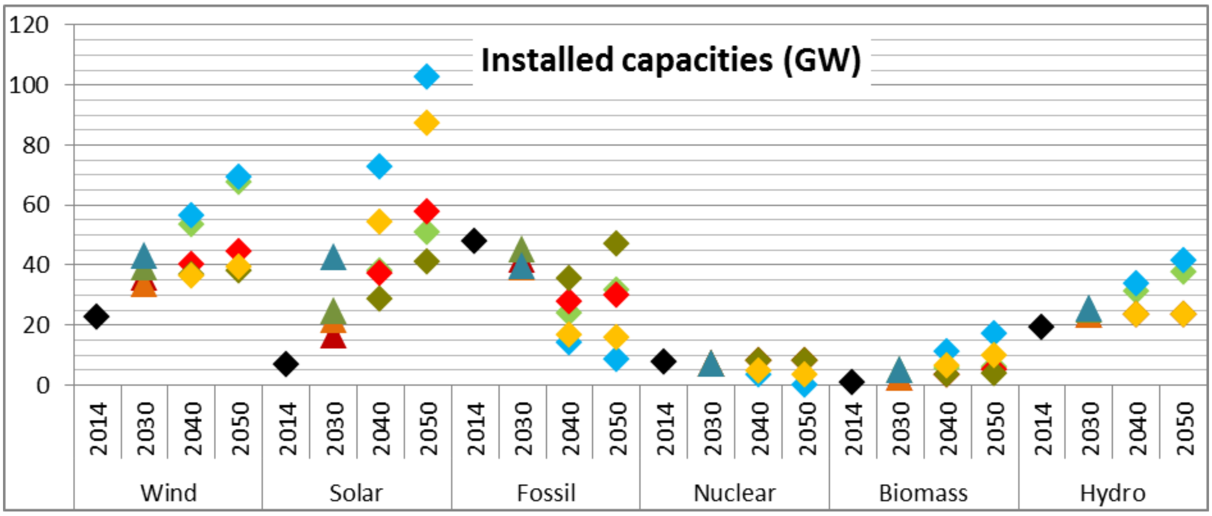
Spain

Demand and generation





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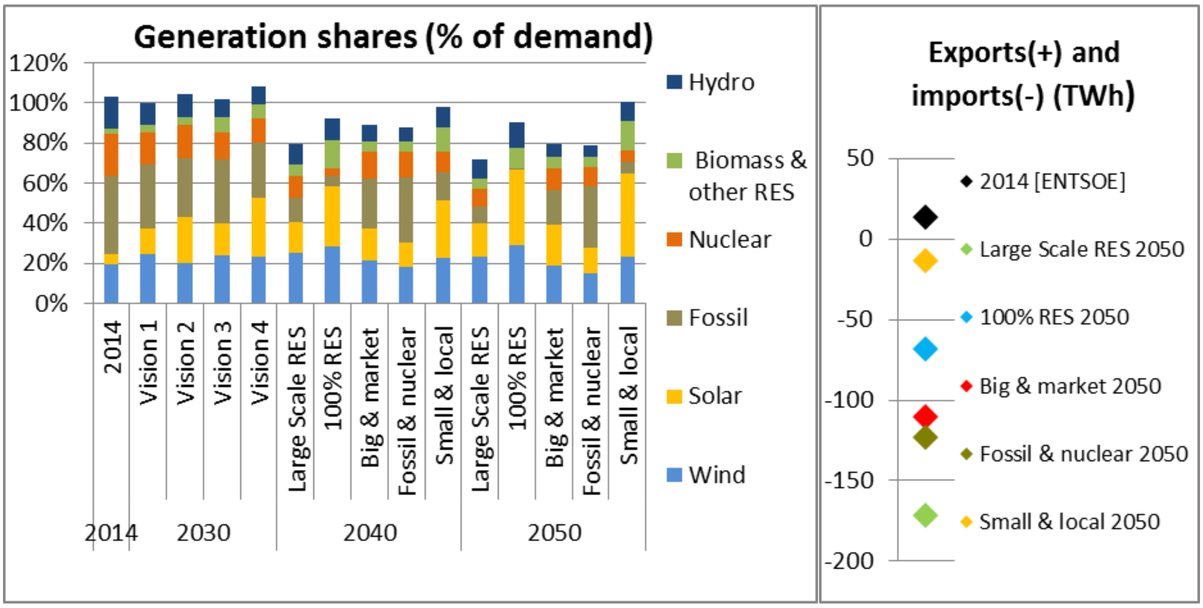

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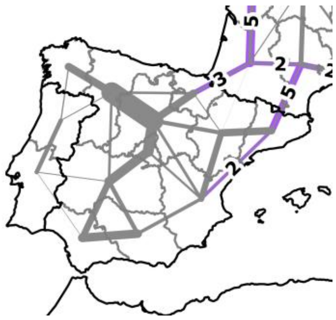
Grid reinforcements



Common 2040 grid

Large scale RES 2050

100% RES 2050

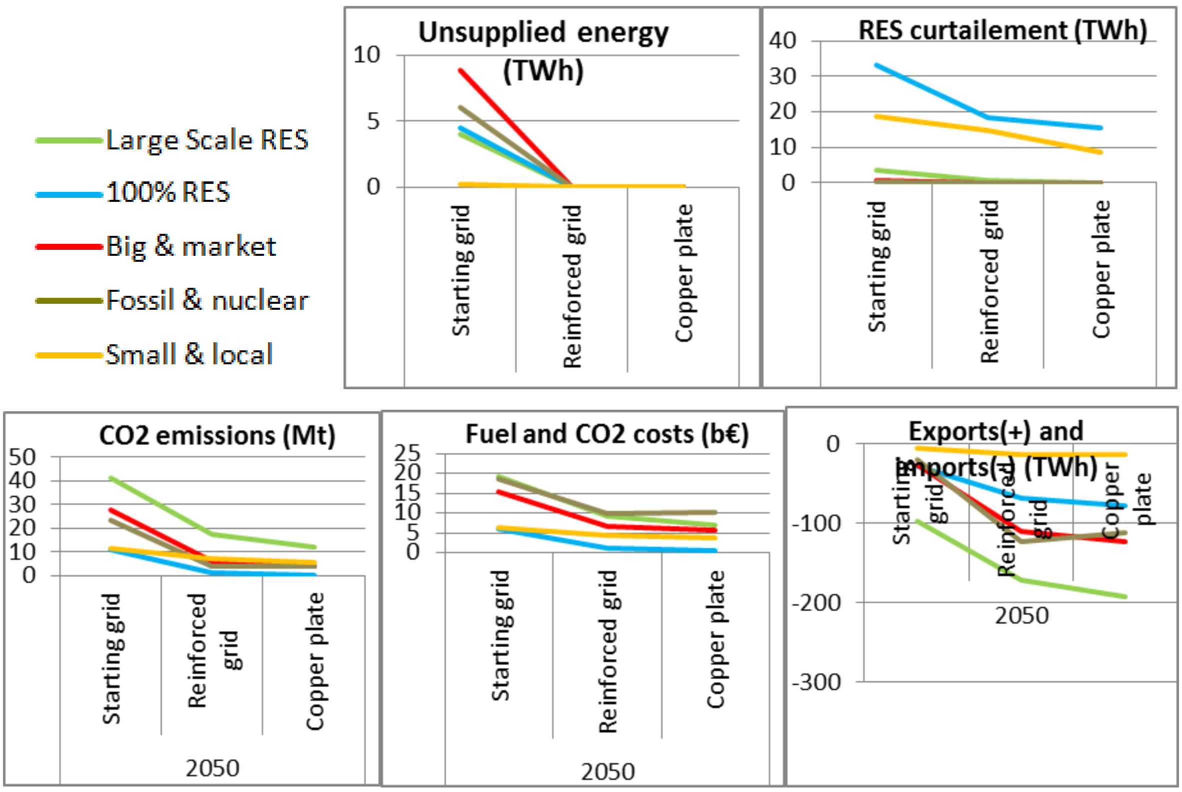
Big & market 2050

Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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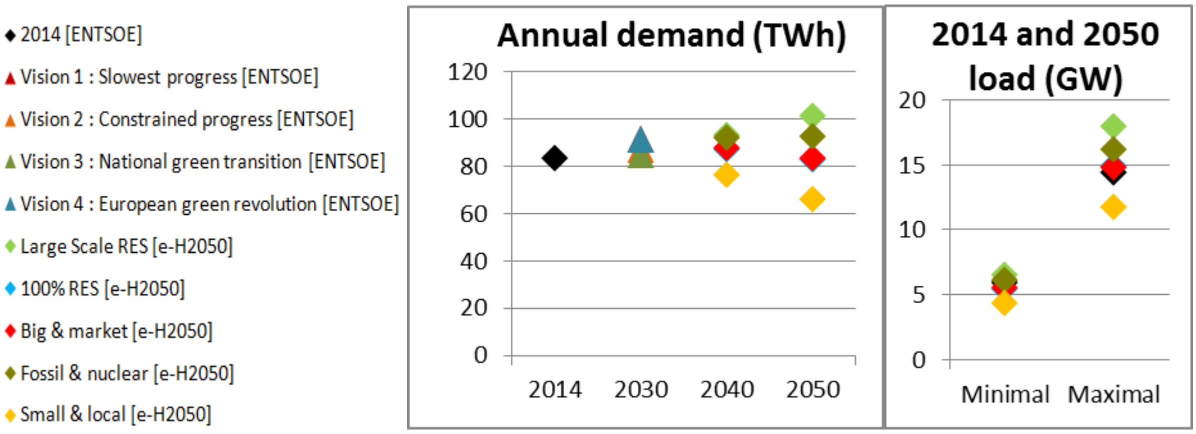
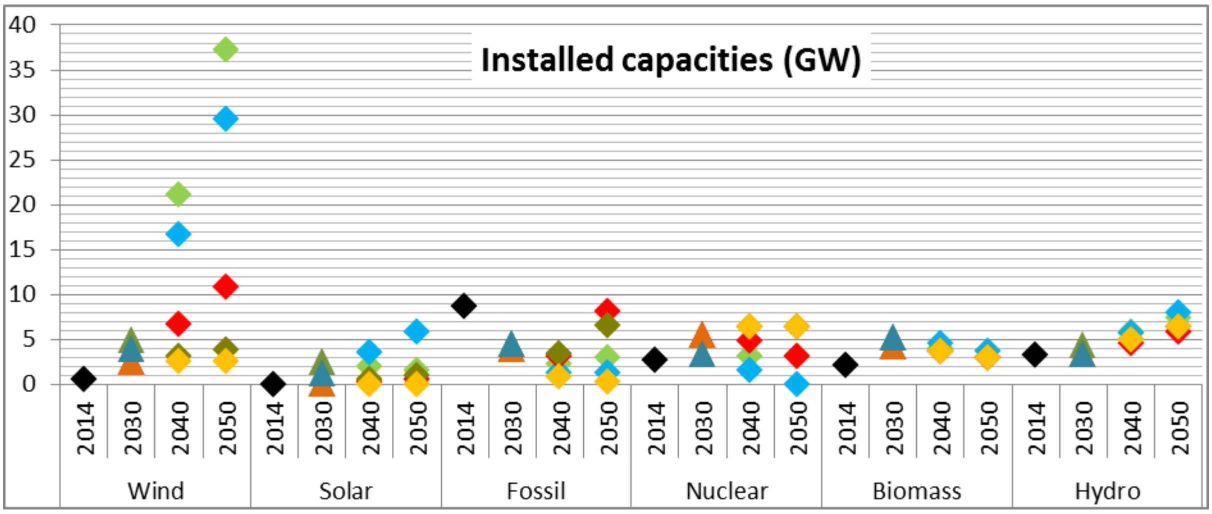
Finland

Demand and generation





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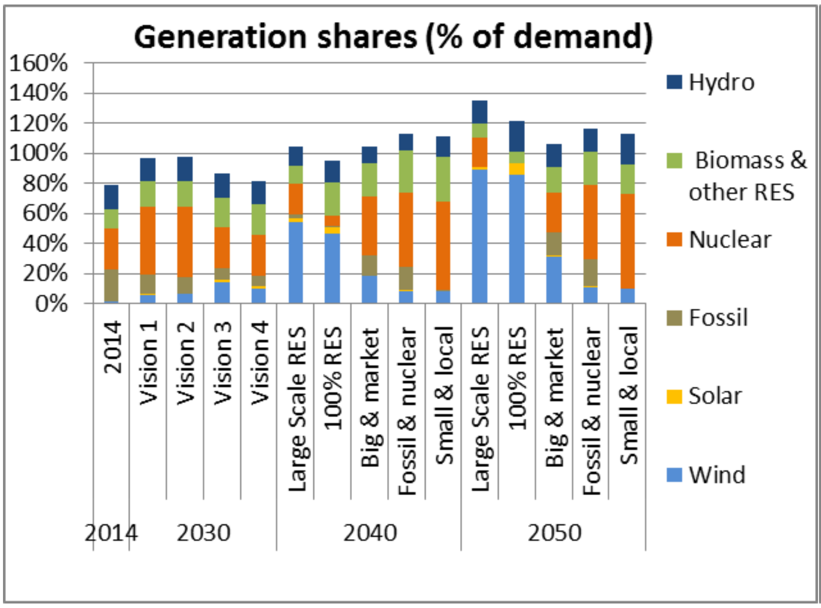

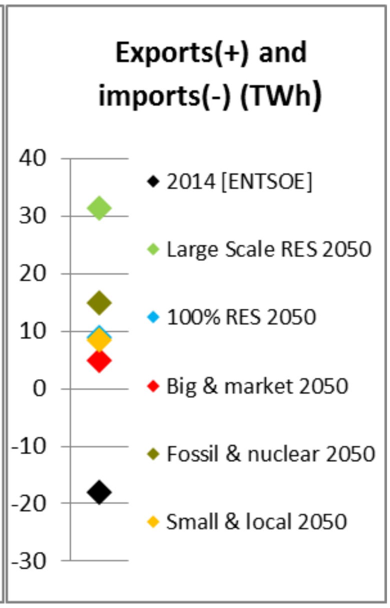

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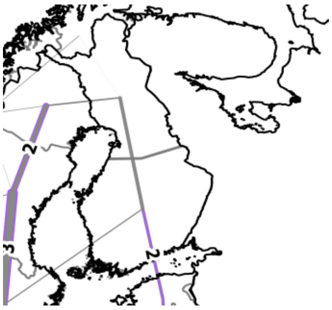
Grid reinforcements



Common 2040 grid

Large scale RES 2050

100% RES 2050

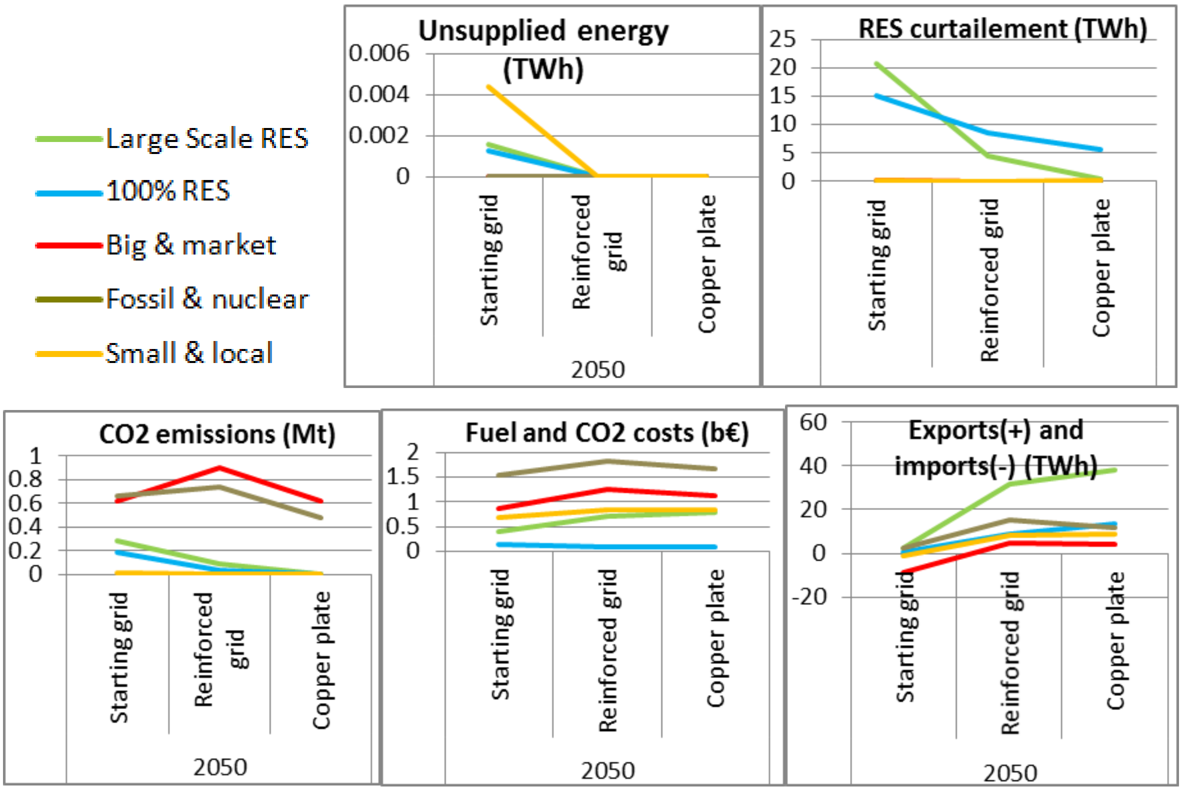
Big & market 2050

Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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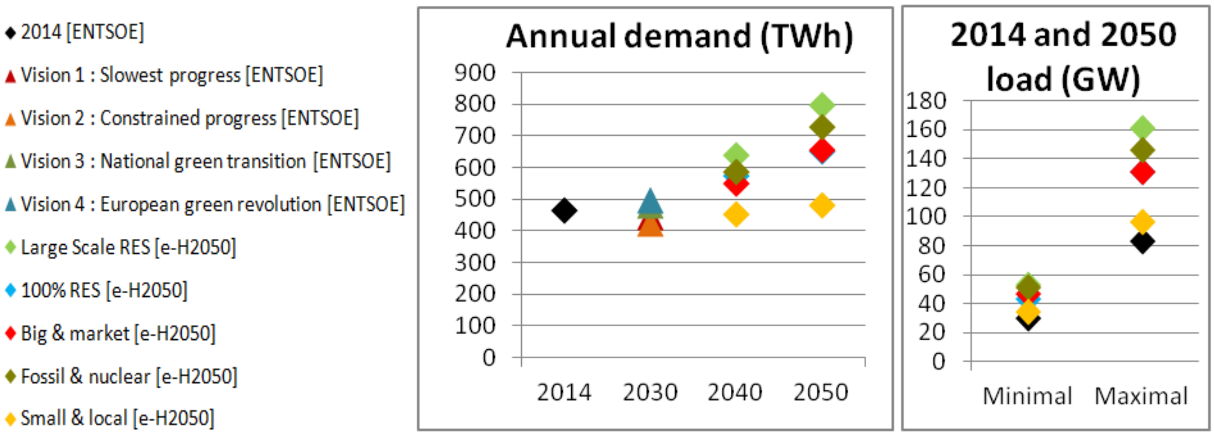
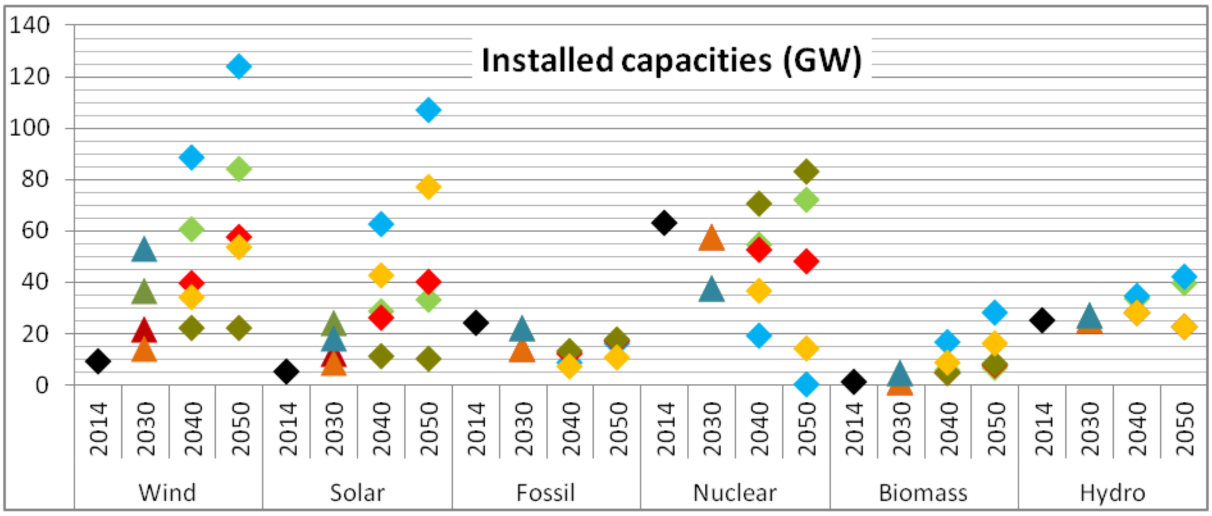
France

Demand and generation





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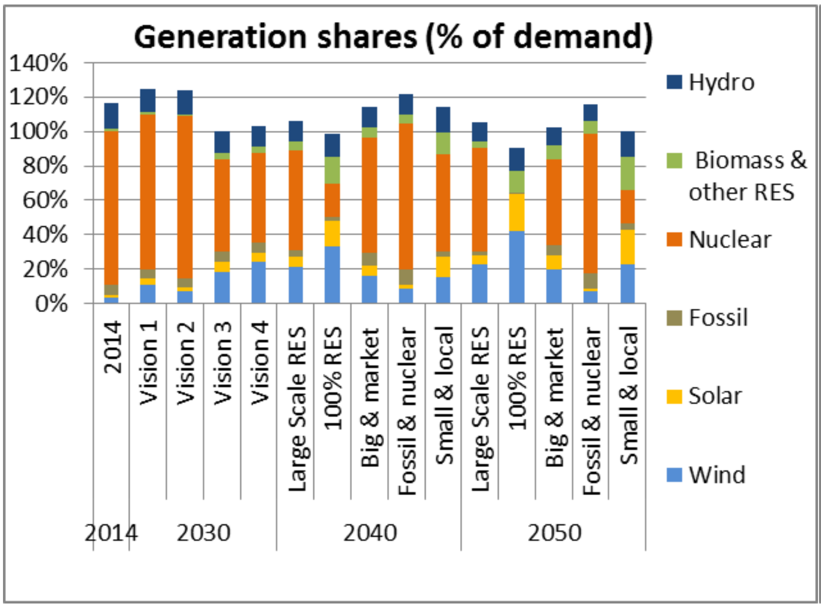

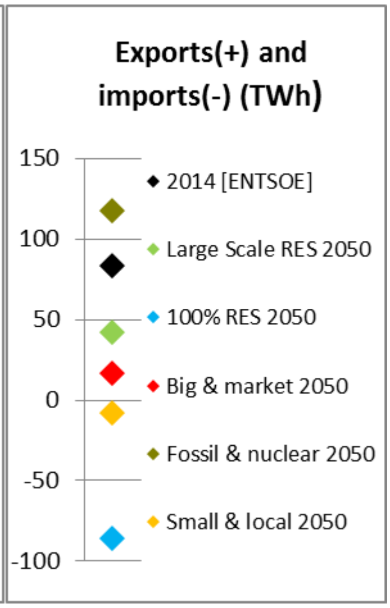

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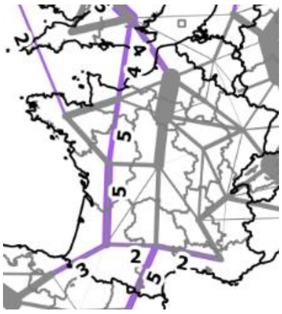
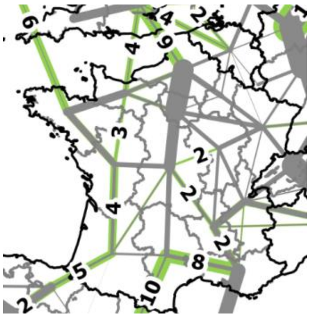
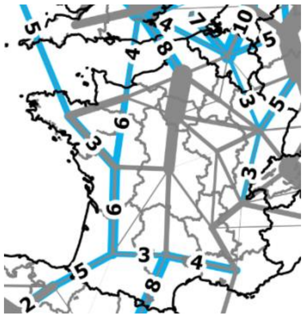
Grid reinforcements



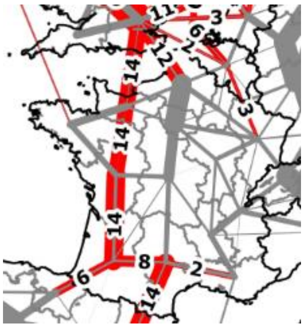
Common 2040 grid



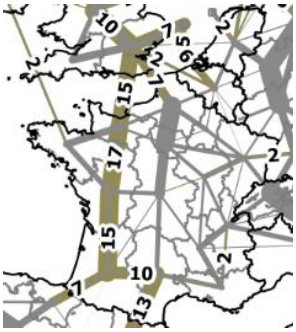
Large scale RES 2050



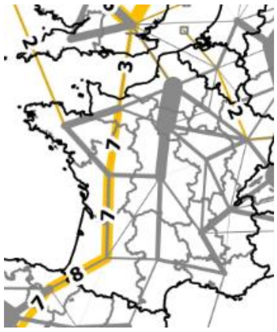
100% RES 2050



Big & market 2050



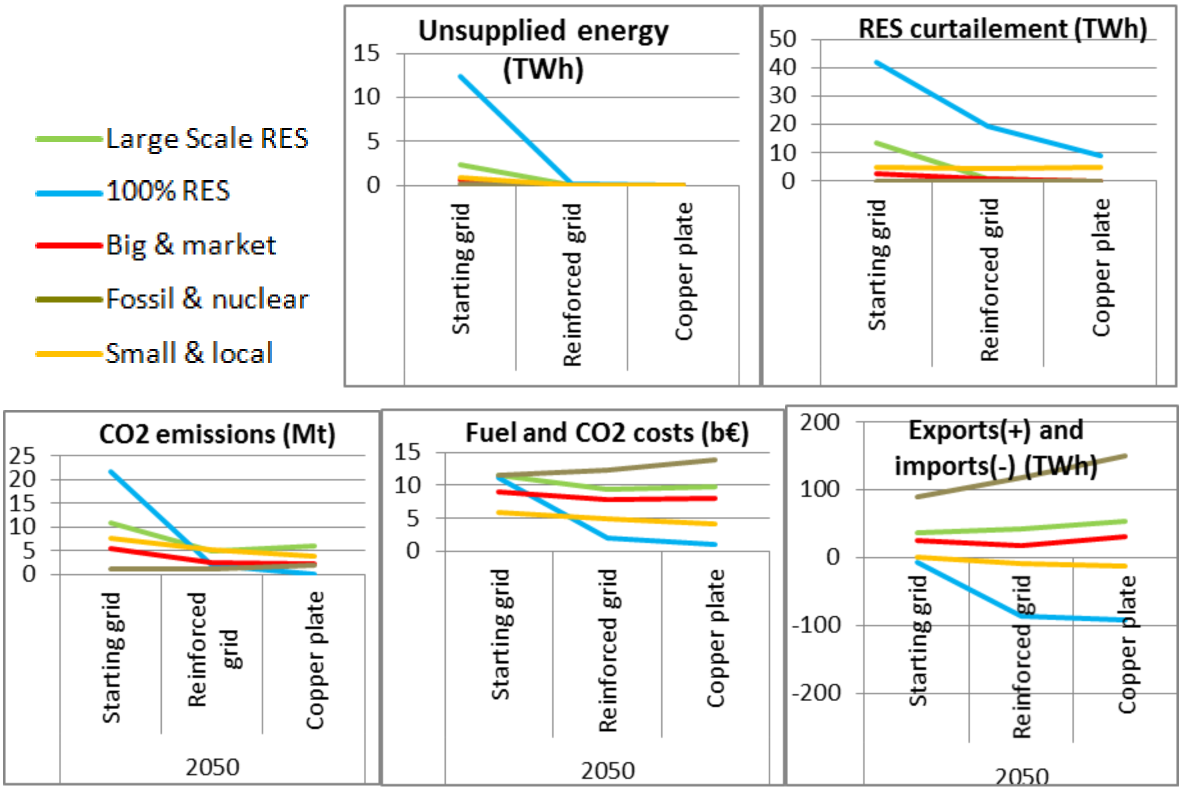
Fossil & nuclear 2050



Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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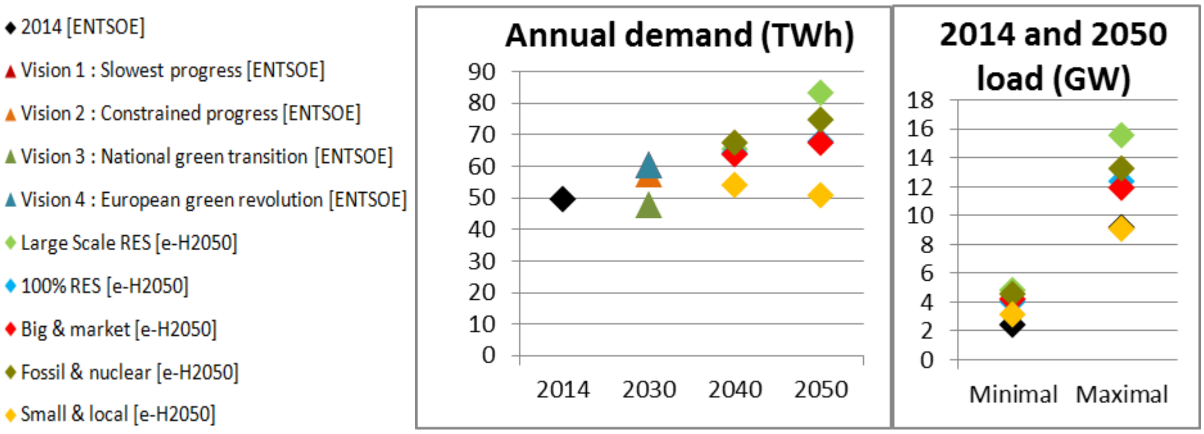
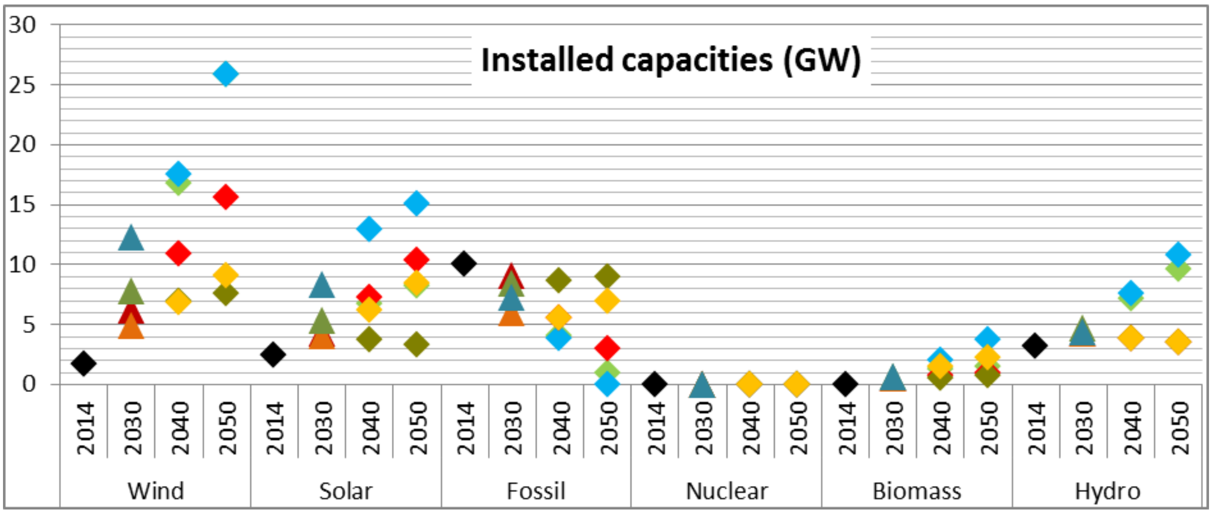
Greece

Demand and generation





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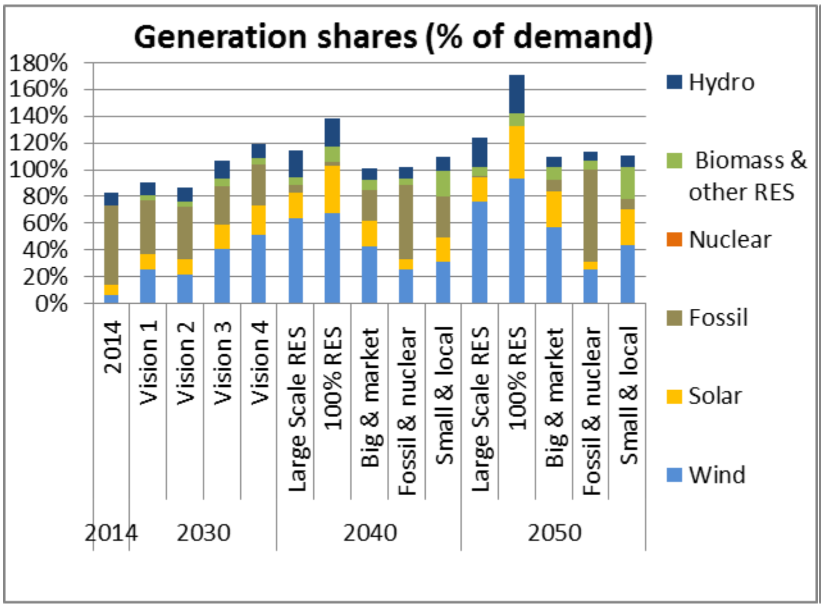

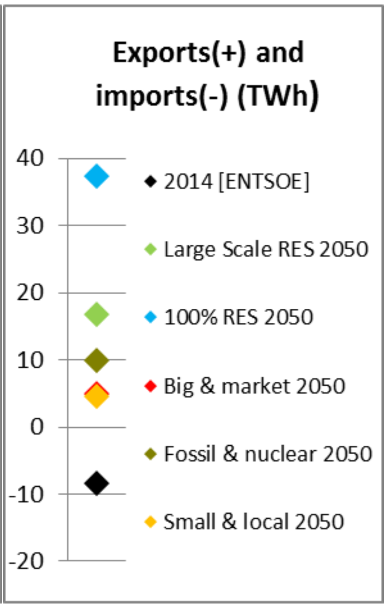

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Grid reinforcements

Common 2040 grid

Large scale RES 2050

100% RES 2050

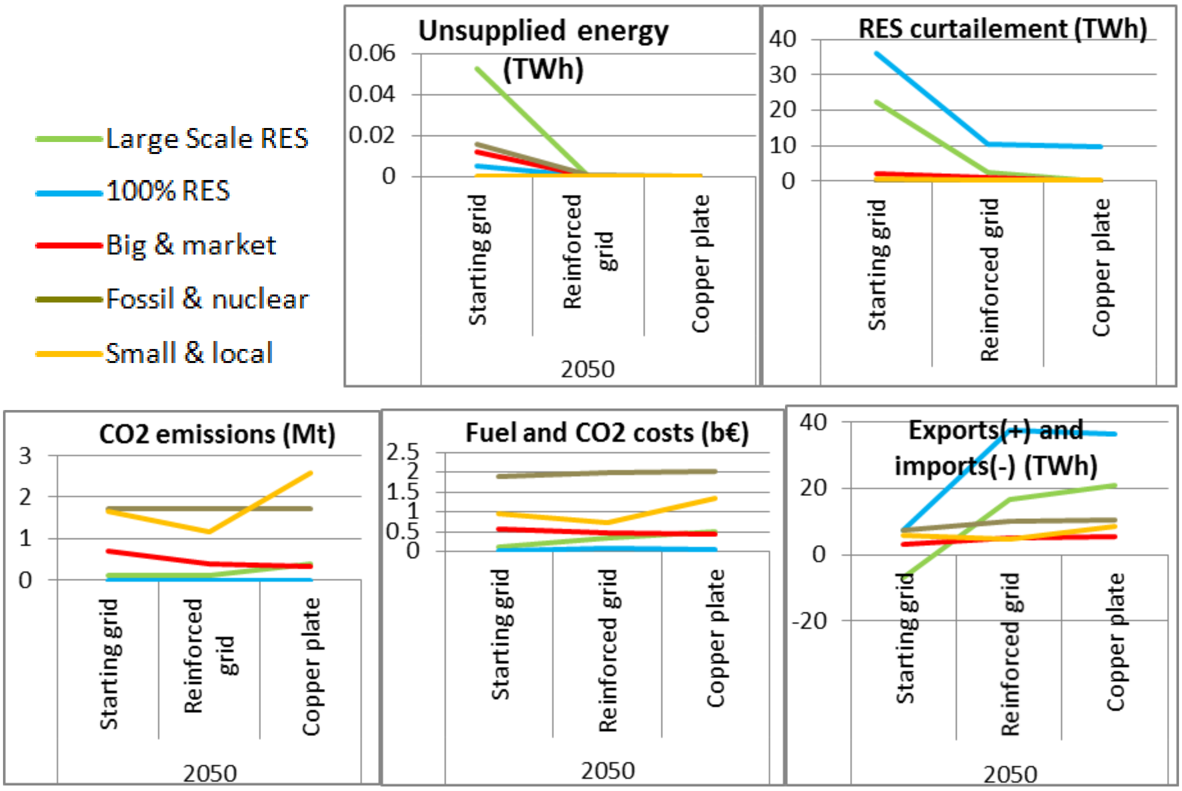
Big & market 2050

Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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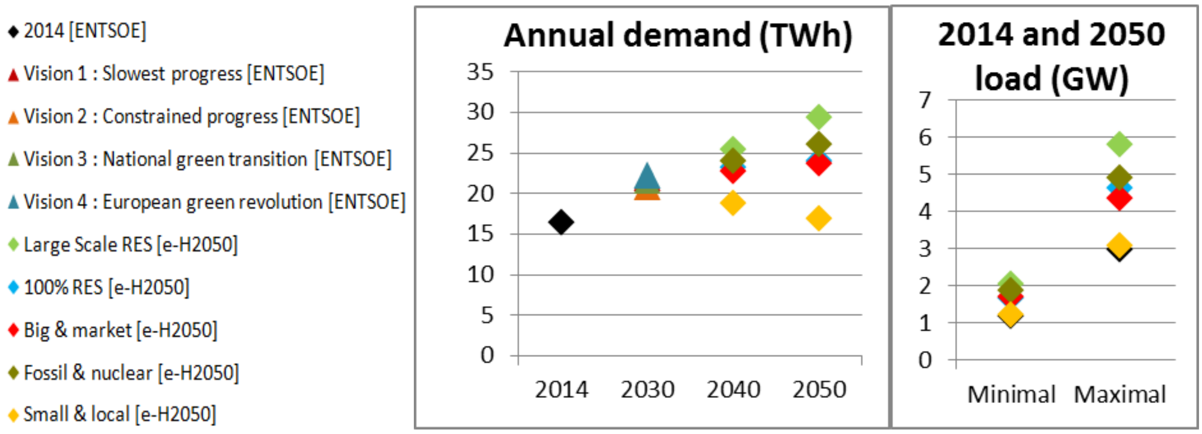
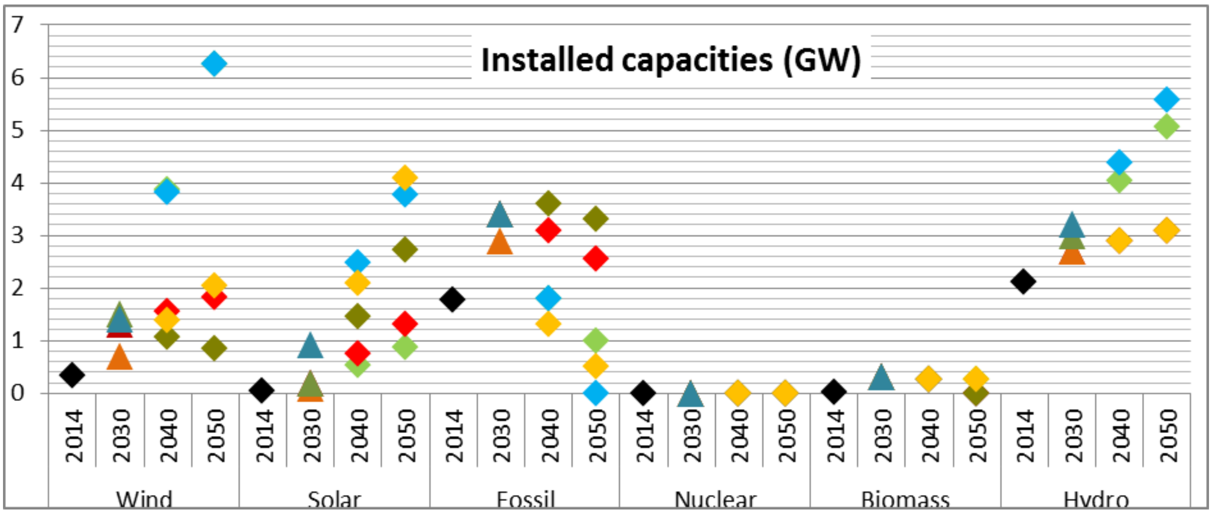
Croatia

Demand and generation





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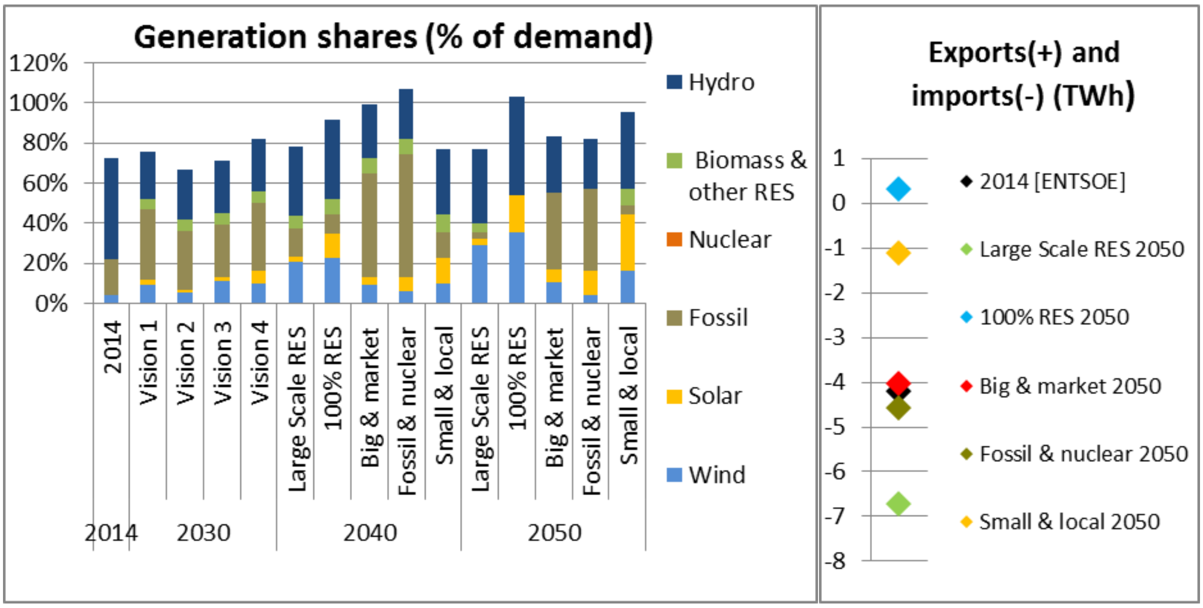

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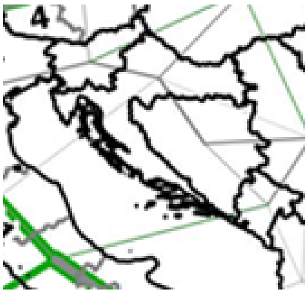
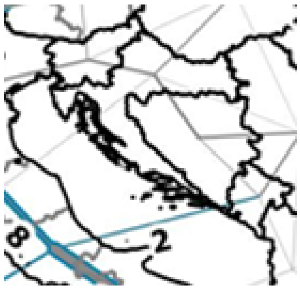
Grid reinforcements

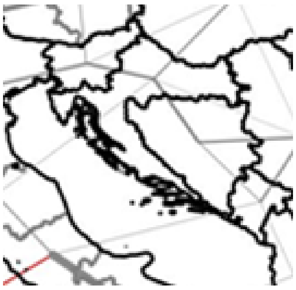
Common 2040 grid



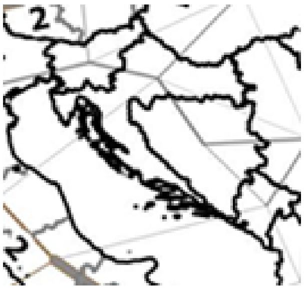
Large scale RES 2050



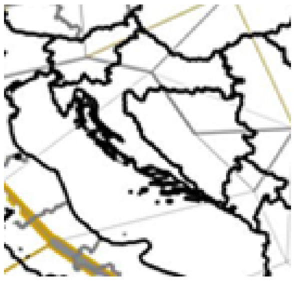
100% RES 2050



Big & market 2050



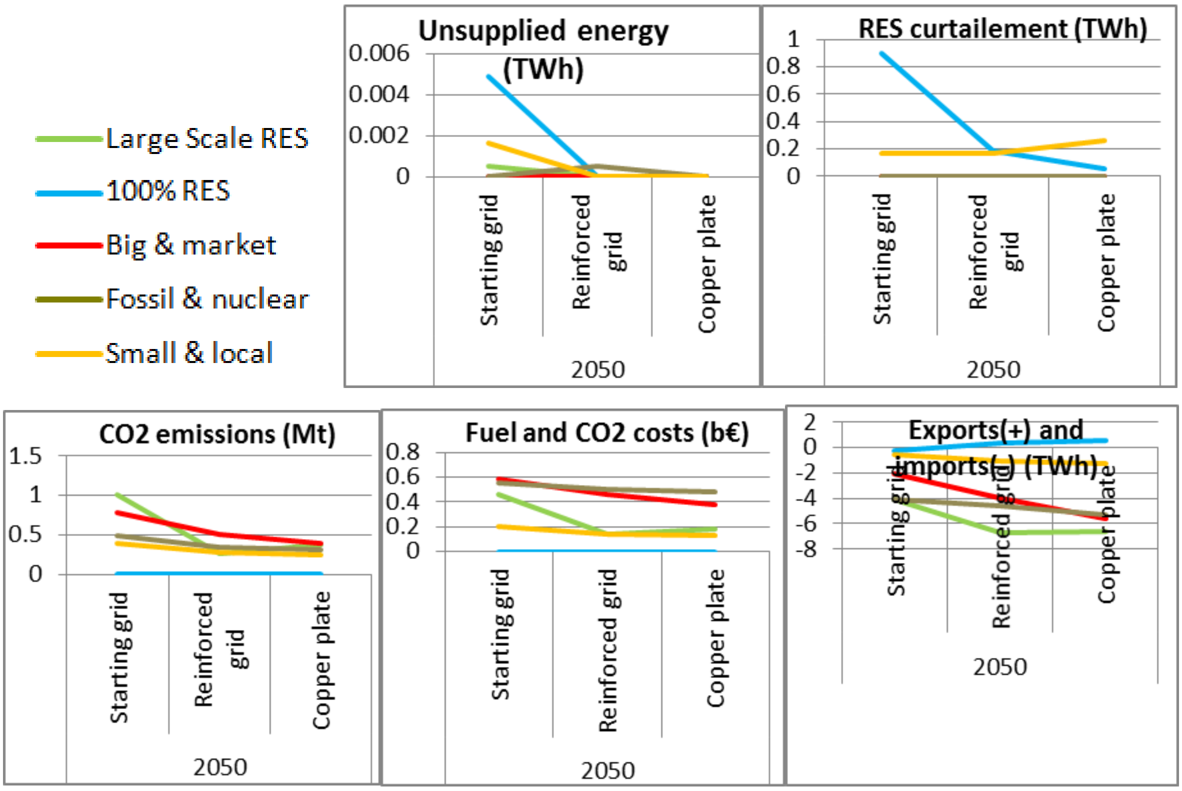
Fossil & nuclear 2050



Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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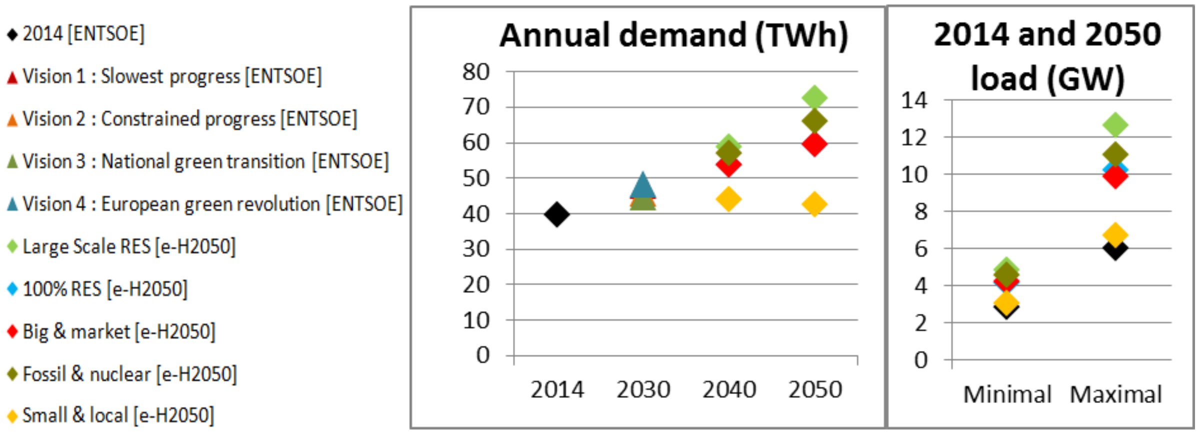
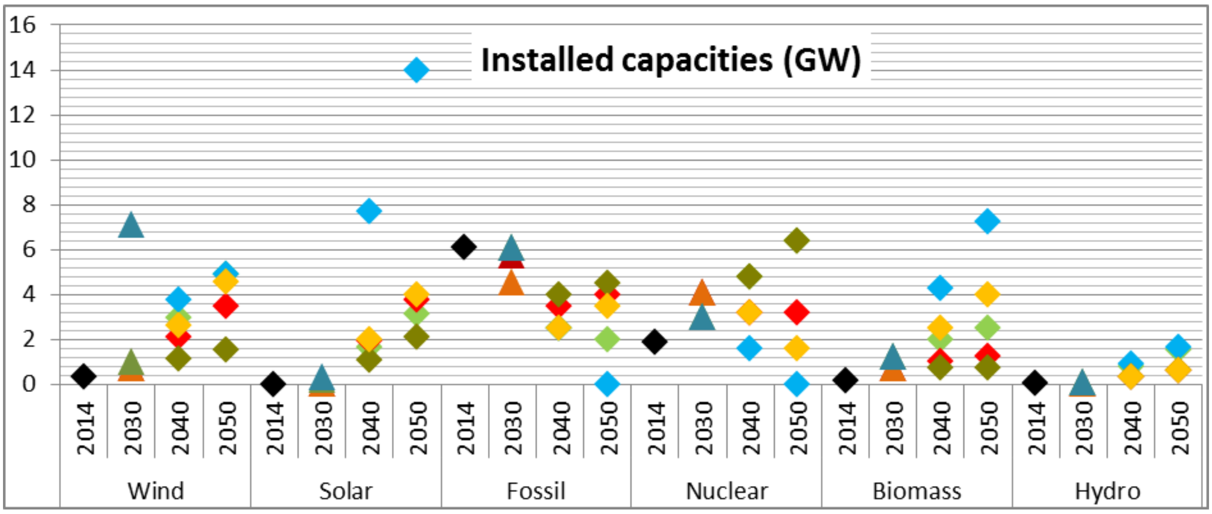
Hungary

Demand and generation





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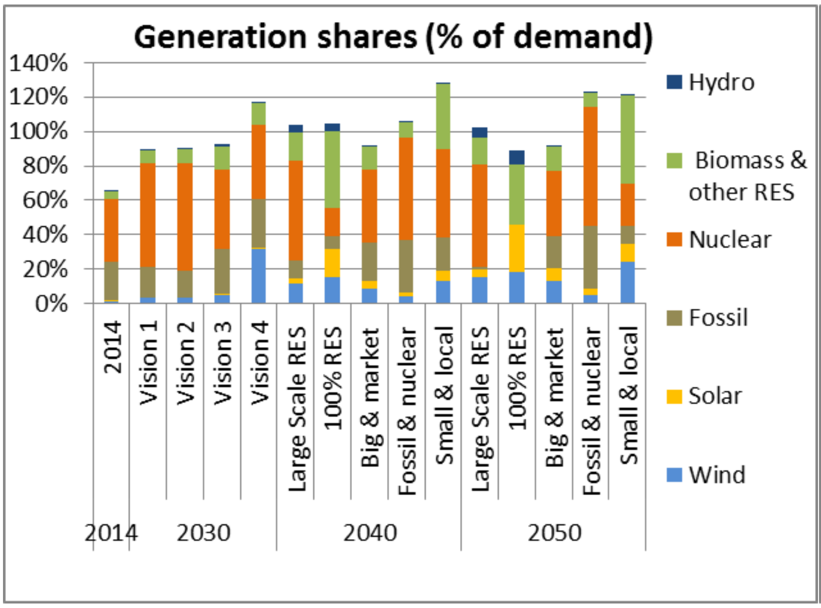

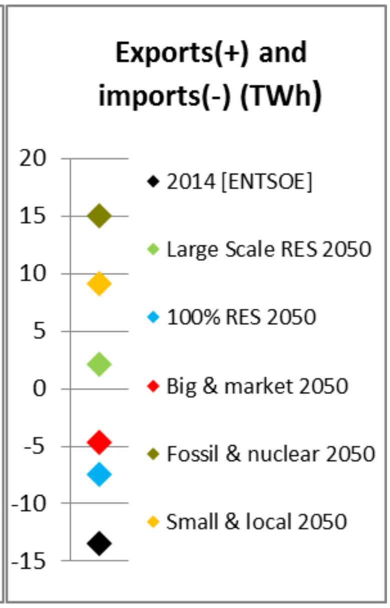

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Grid reinforcements

Common 2040 grid

Large scale RES 2050

100% RES 2050

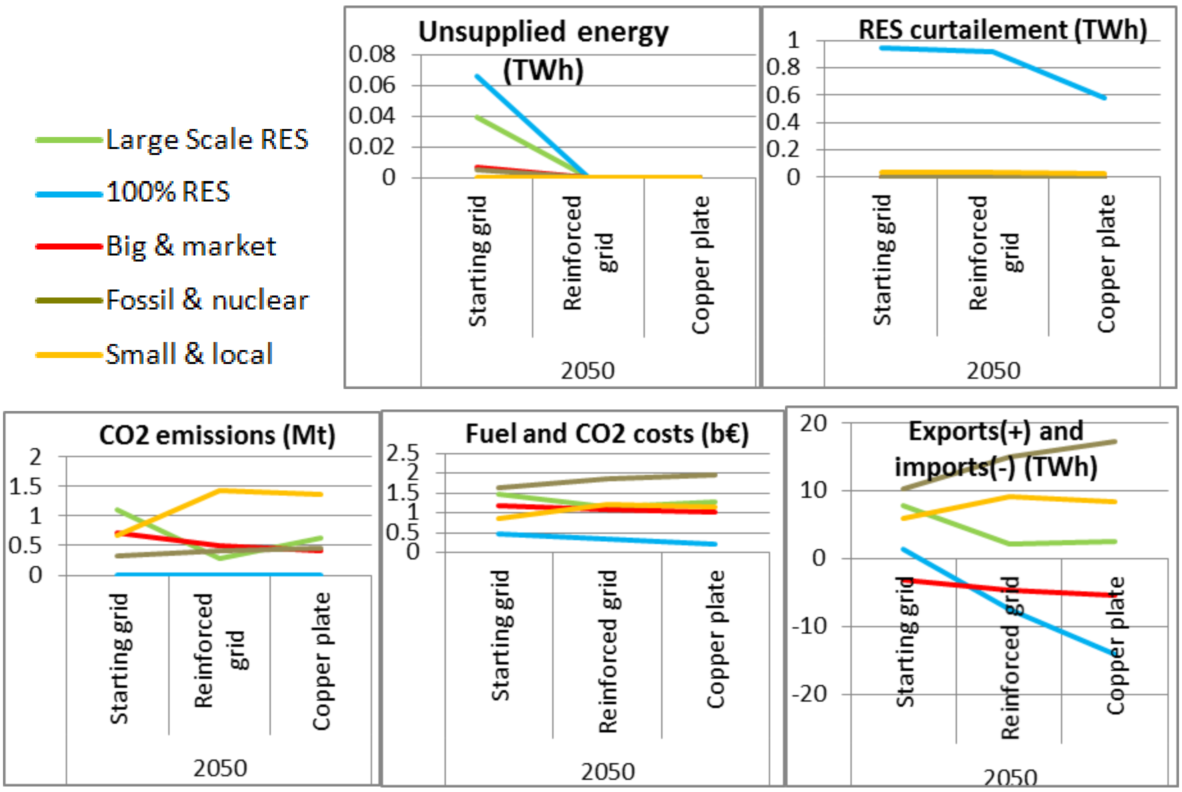
Big & market 2050

Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

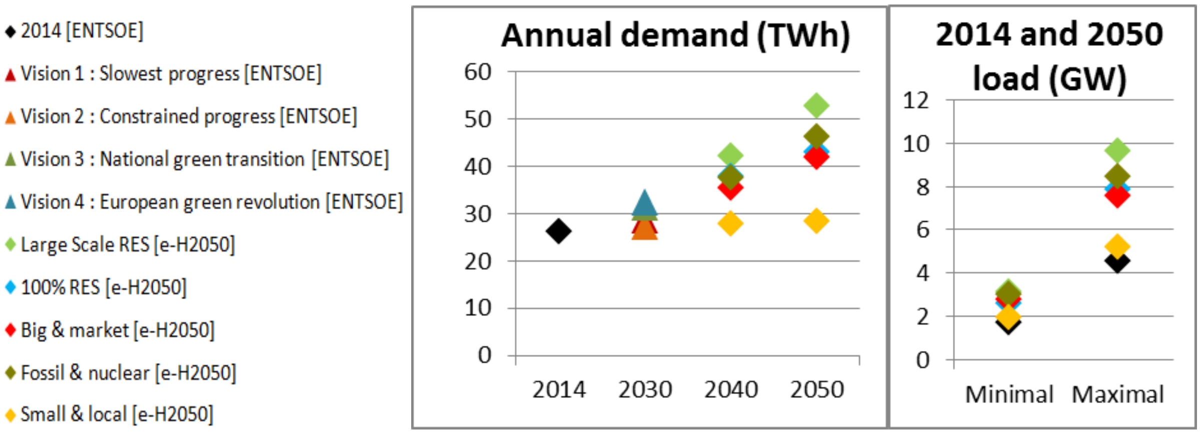
Impact of the grid reinforcements (2050)

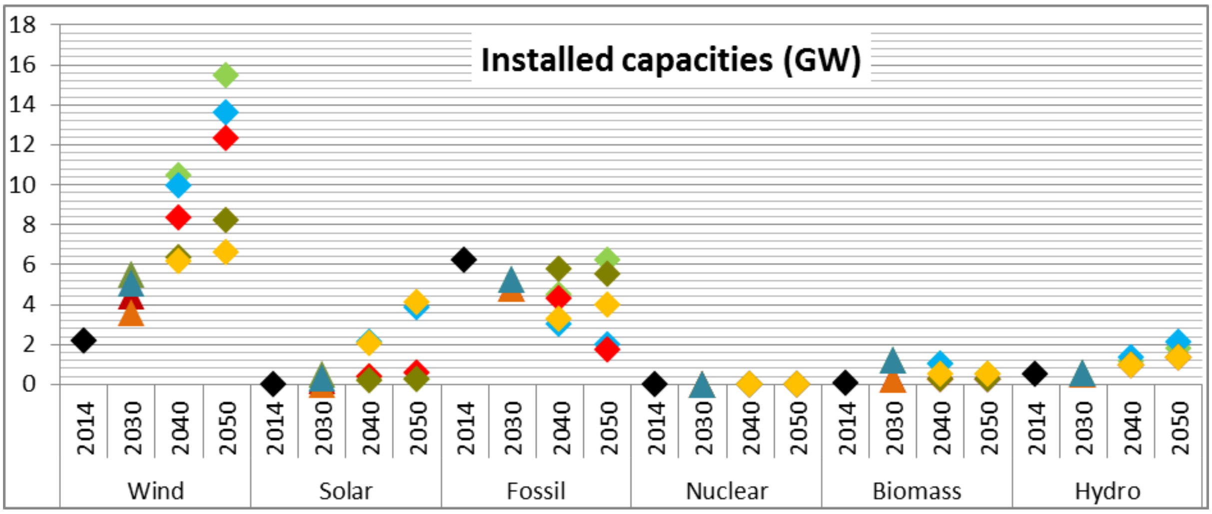


NB : The impact of the grid reinforcements can be difficult to analyse at a national level. For example, fuel and CO2 costs can increase to support more exports towards countries with more expensive generation. Also small increases of the unsupplied energy or of the RES curtailment can occur on a national level

Ireland

Demand and generation





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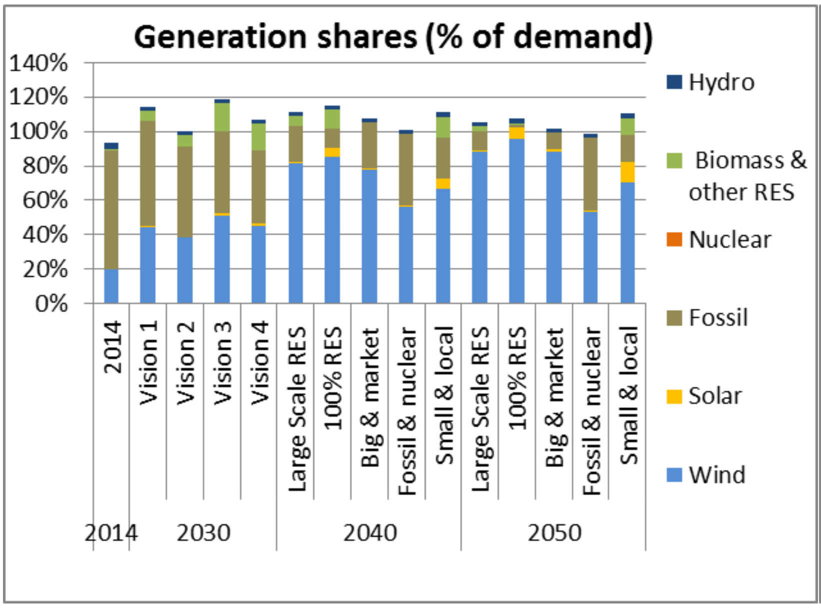
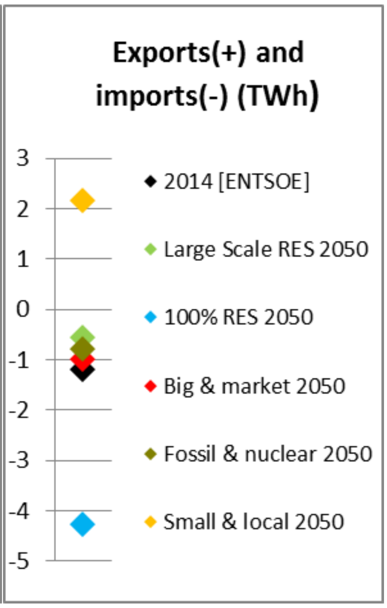
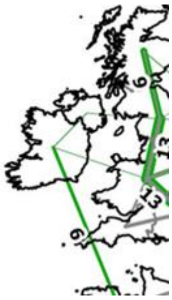




NB: Generation shares and imports/exports are here given in the case of a reinforced grid. RES curtailment is not subtracted from the generation in the left graph.

Grid reinforcements

Common 2040 grid



Large scale RES 2050

100% RES 2050

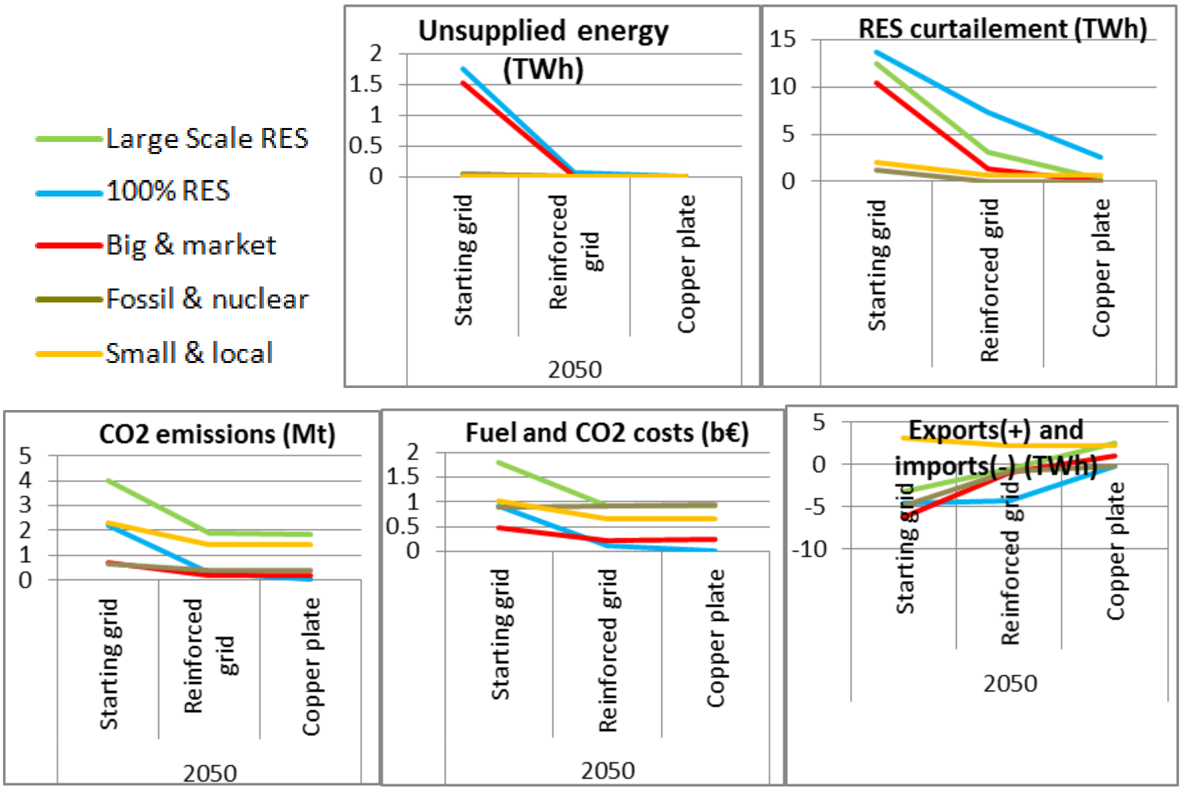
Big & market 2050

Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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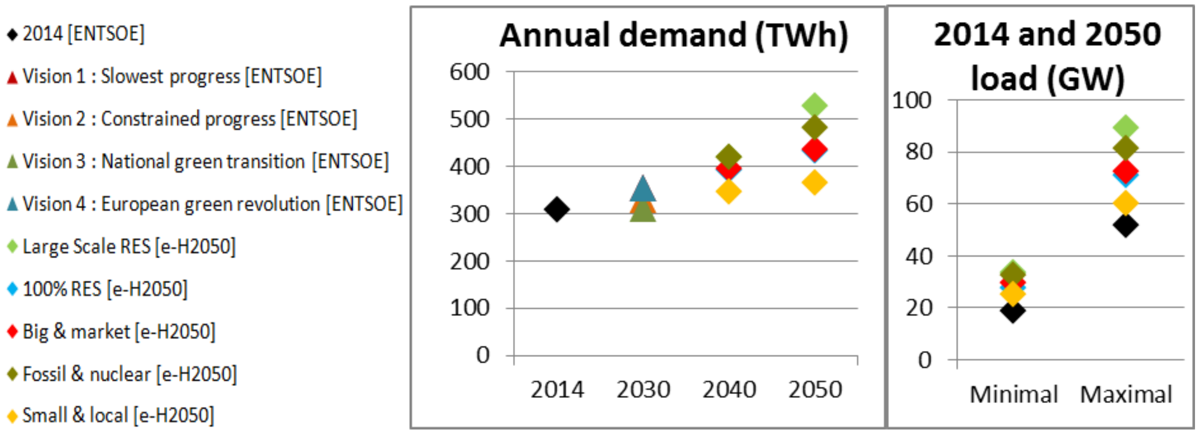
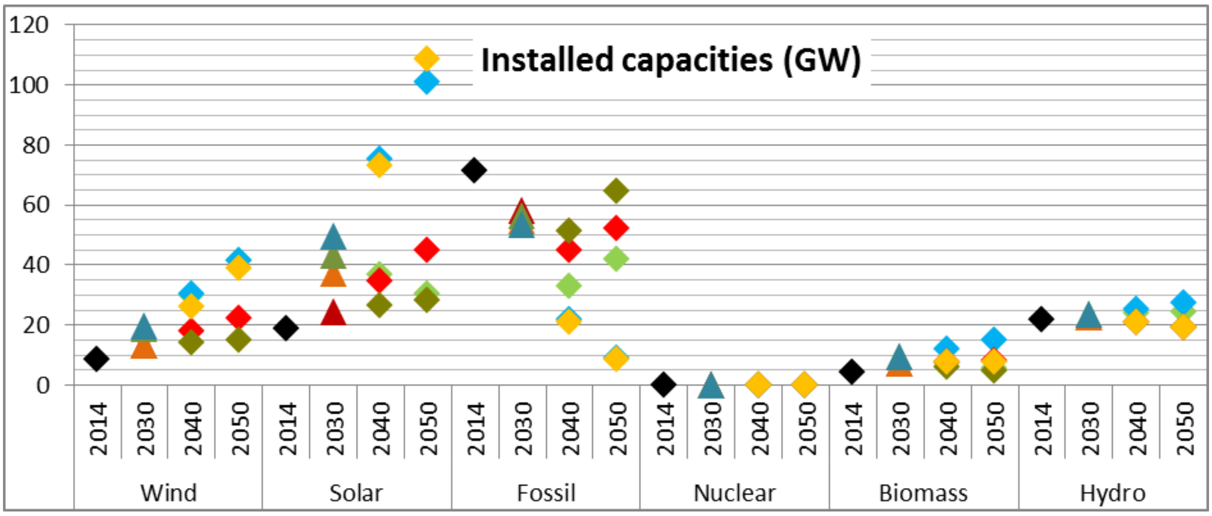
Italy

Demand and generation





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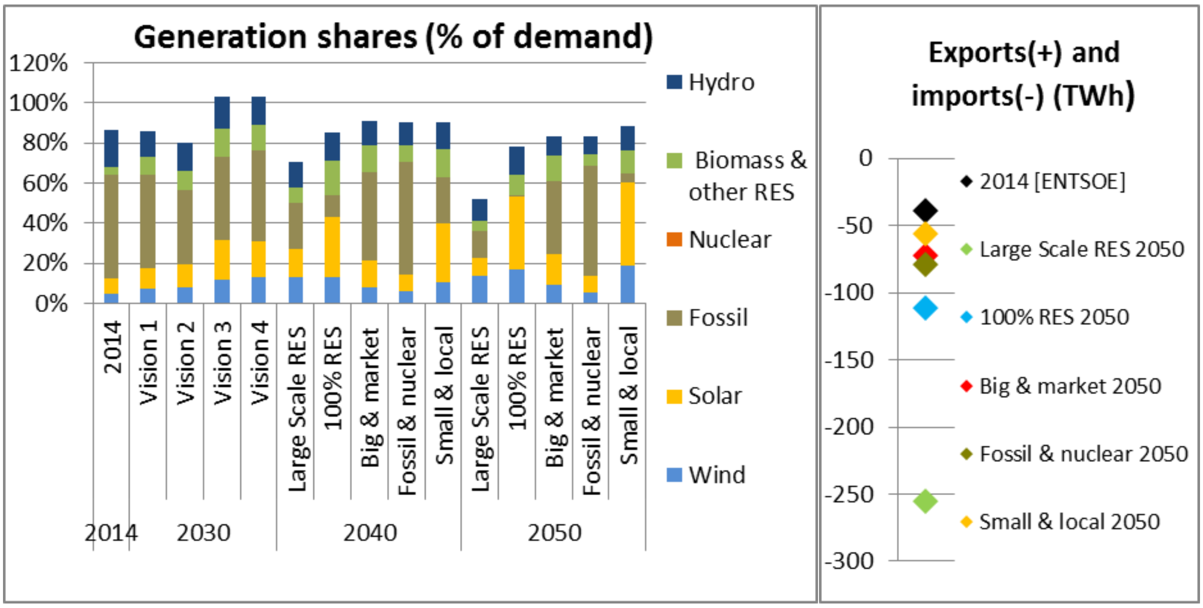

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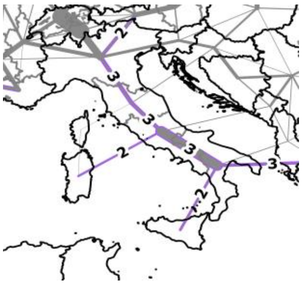
Grid reinforcements



Common 2040 grid

Large scale RES 2050

100% RES 2050

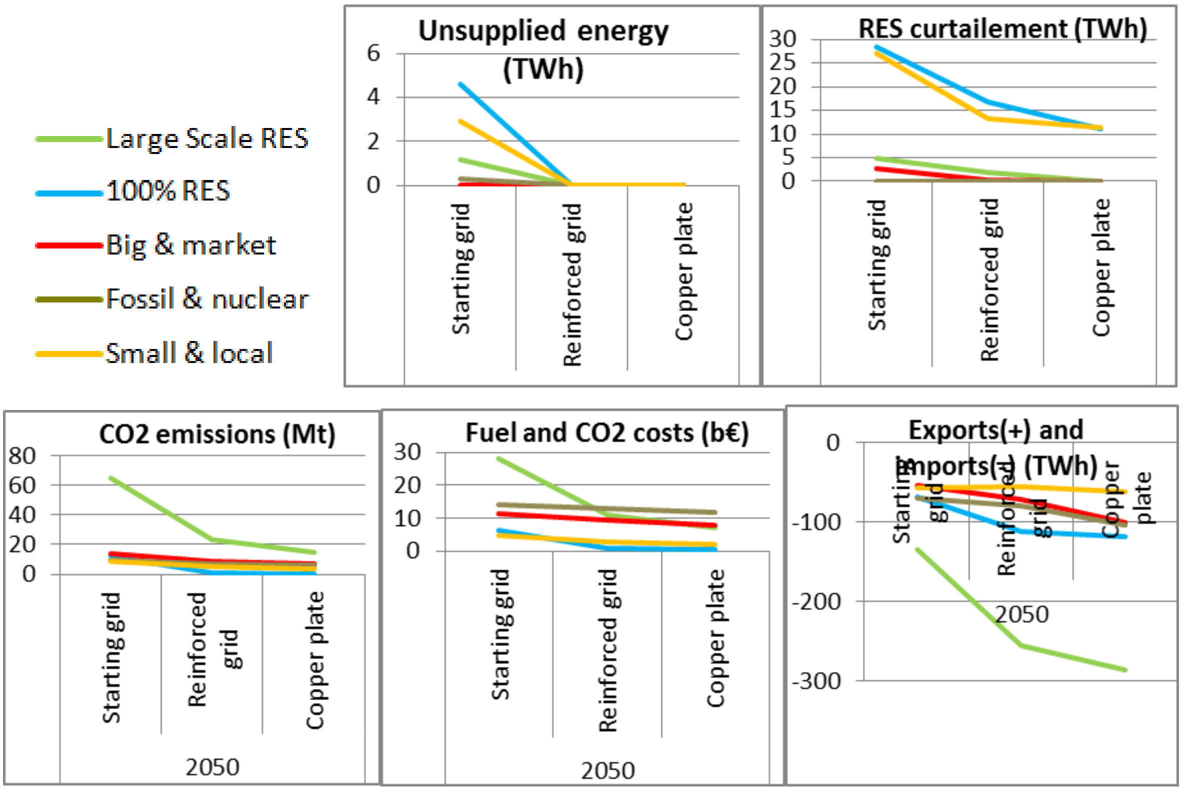
Big & market 2050

Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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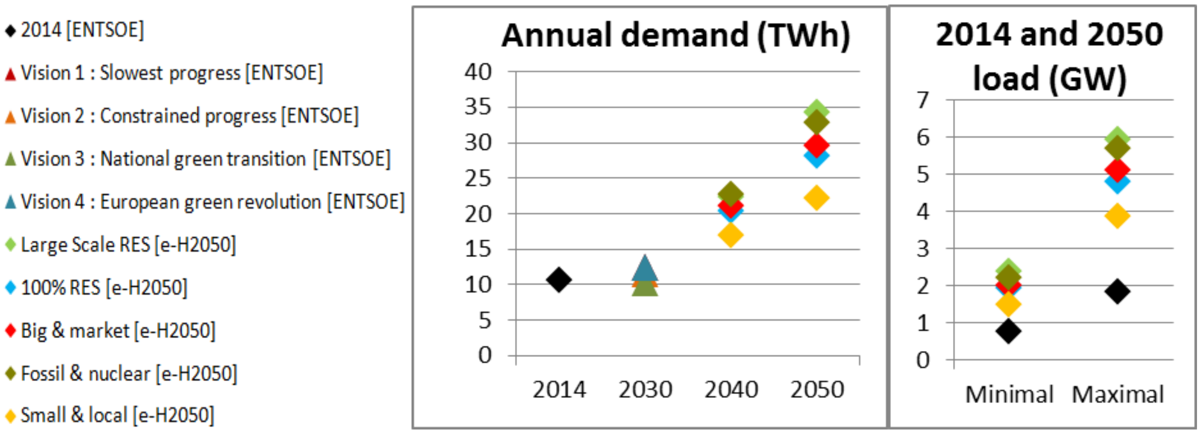
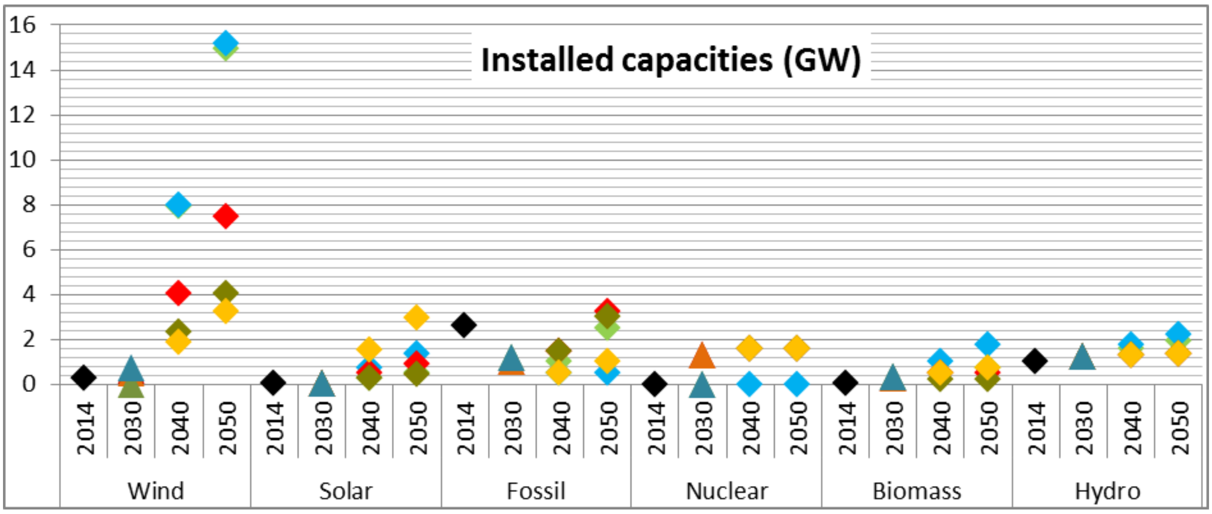
Lithuania

Demand and generation





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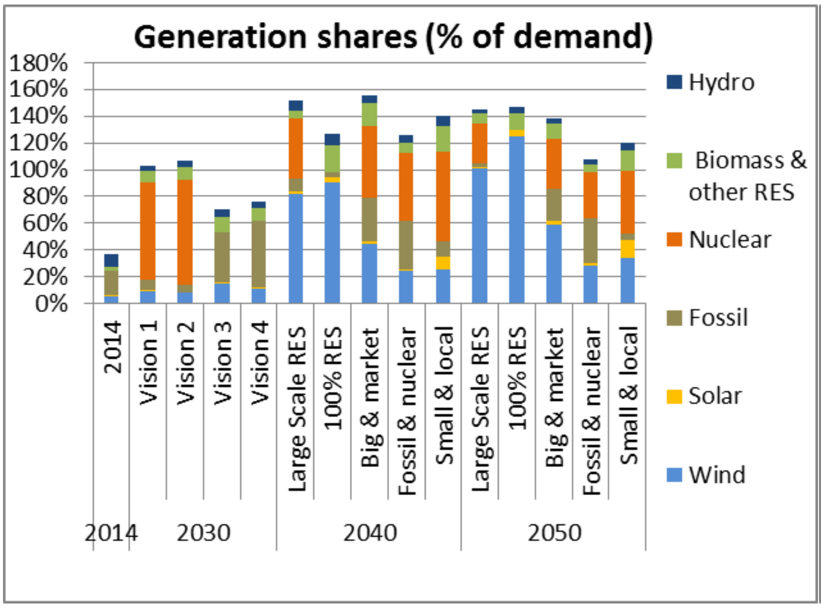

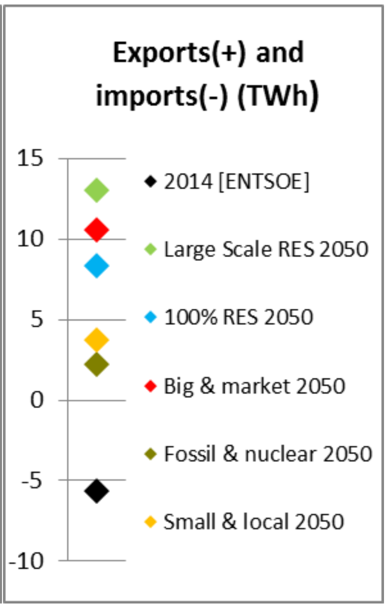

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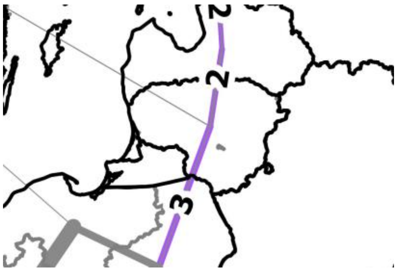
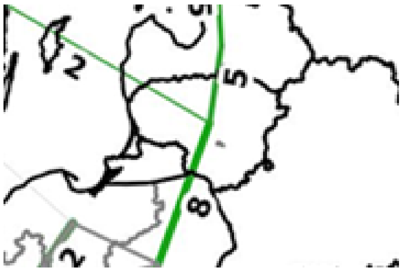
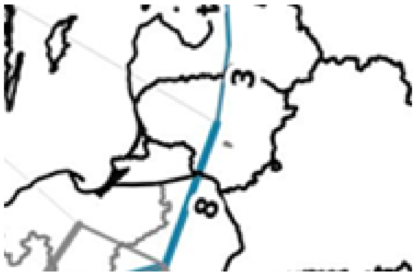
Grid reinforcements



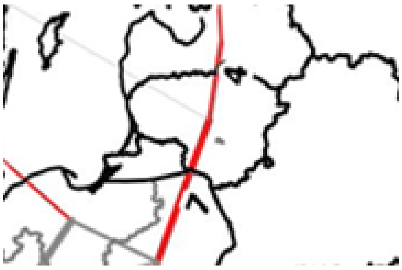
Common 2040 grid



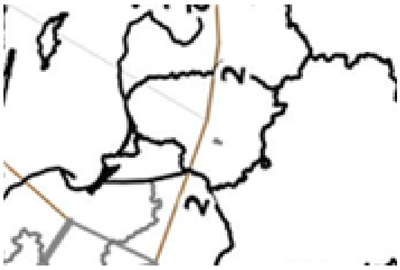
Large scale RES 2050



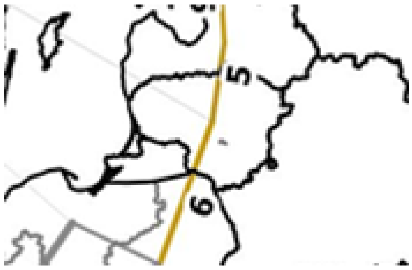
100% RES 2050



Big & market 2050



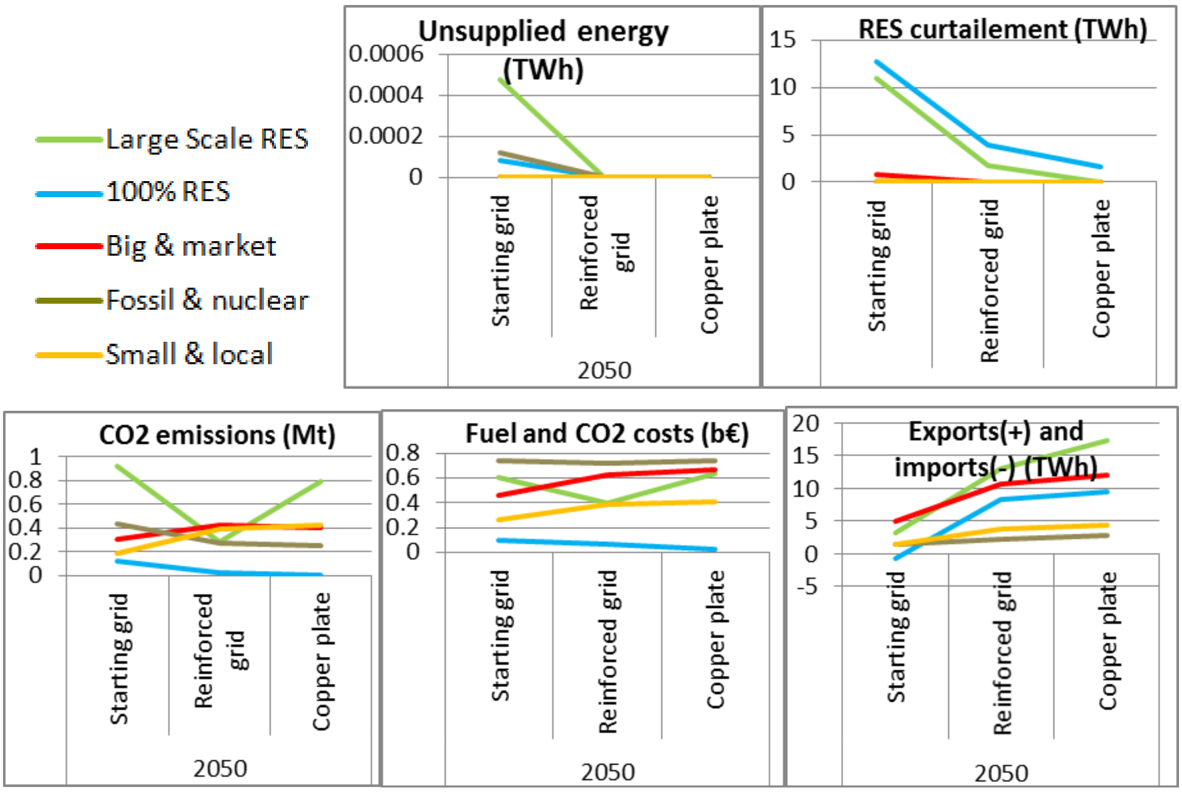
Fossil & nuclear 2050



Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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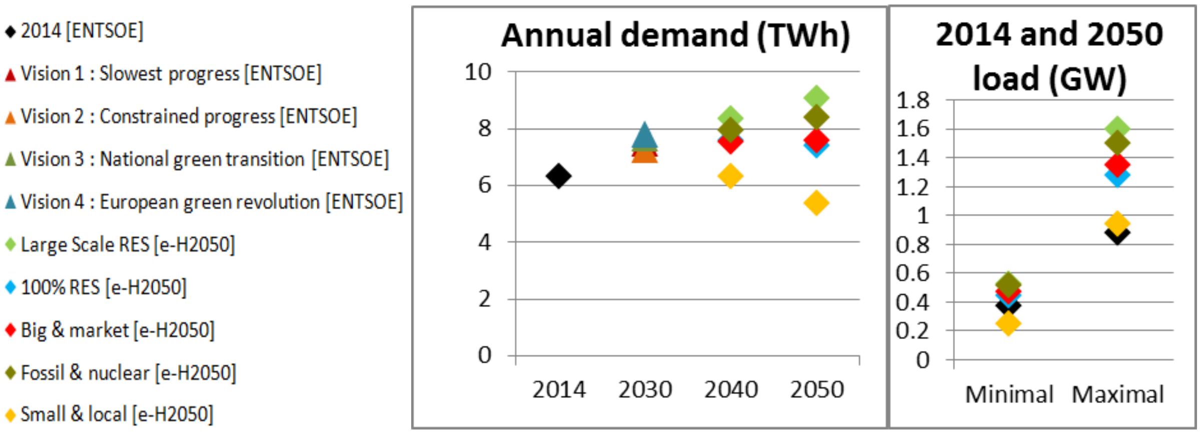
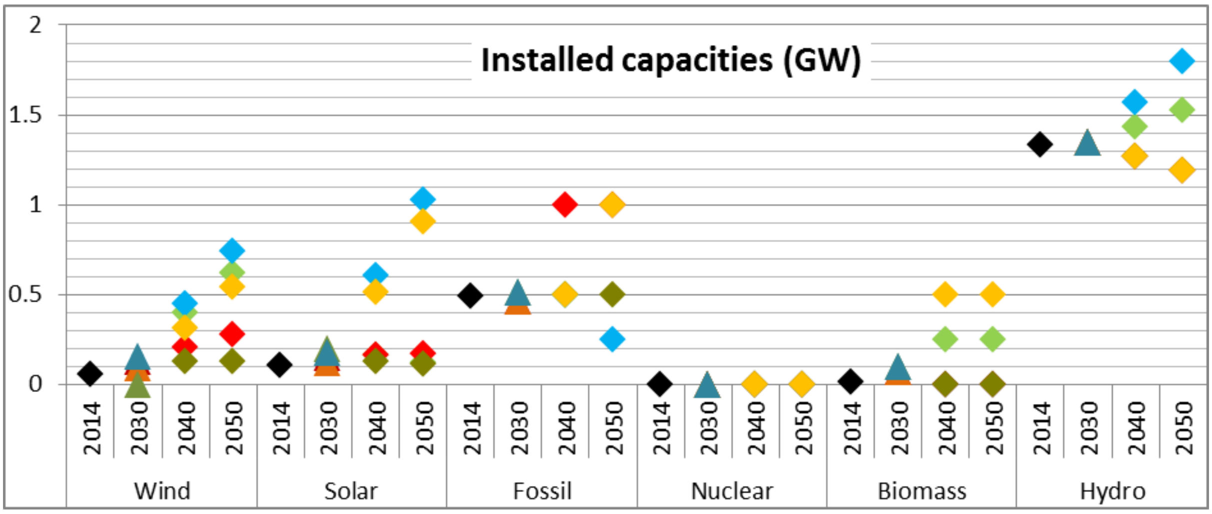
Luxembourg

Demand and generation





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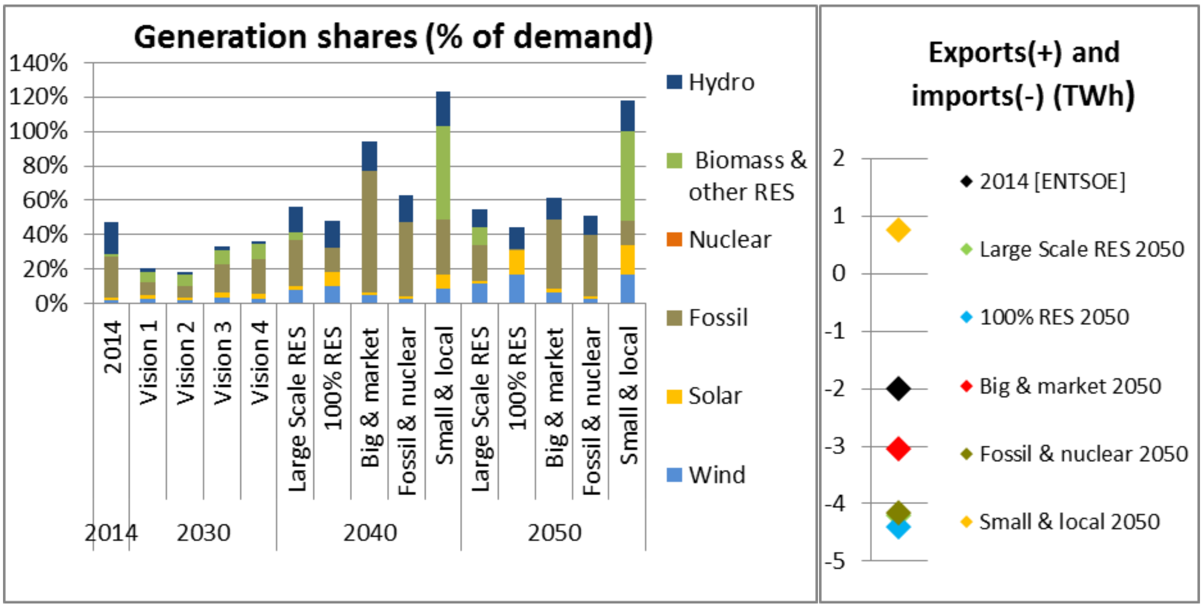

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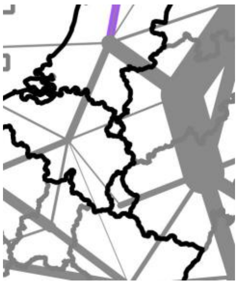
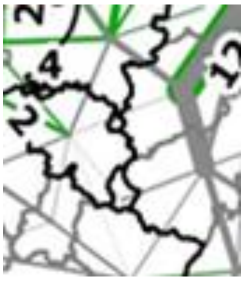
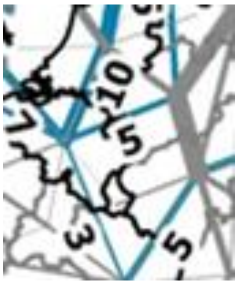
Grid reinforcements



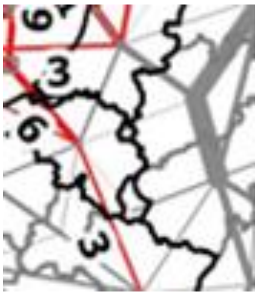
Common 2040 grid



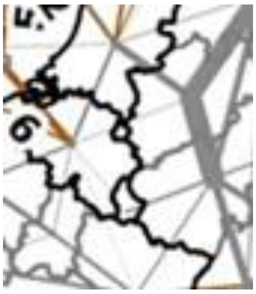
Large scale RES 2050



100% RES 2050



Big & market 2050

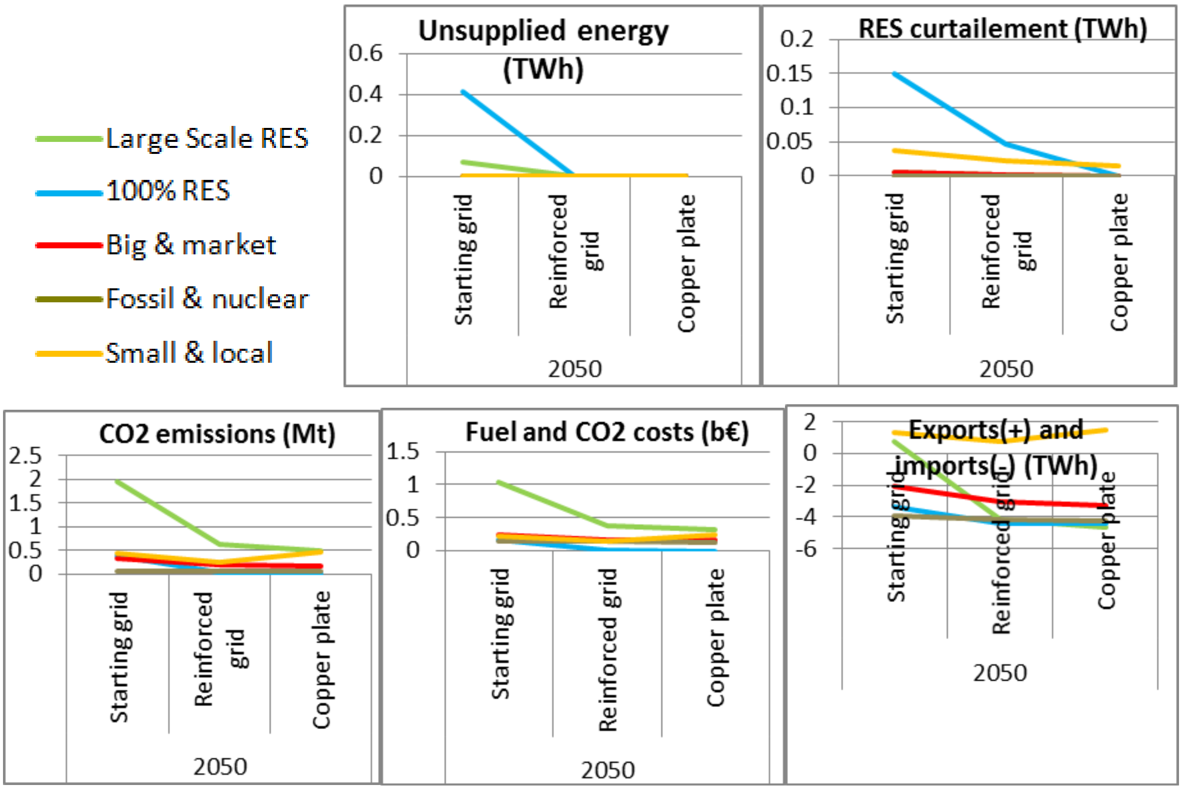


Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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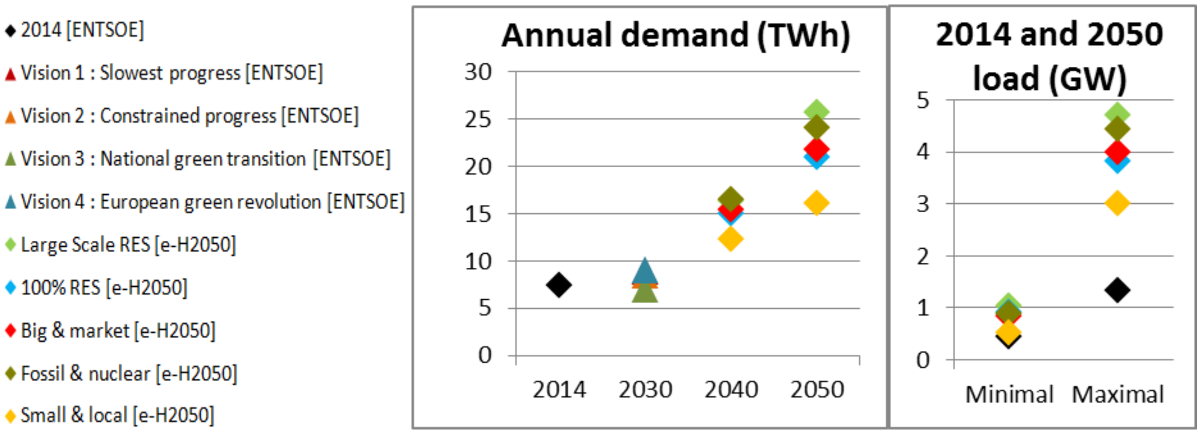
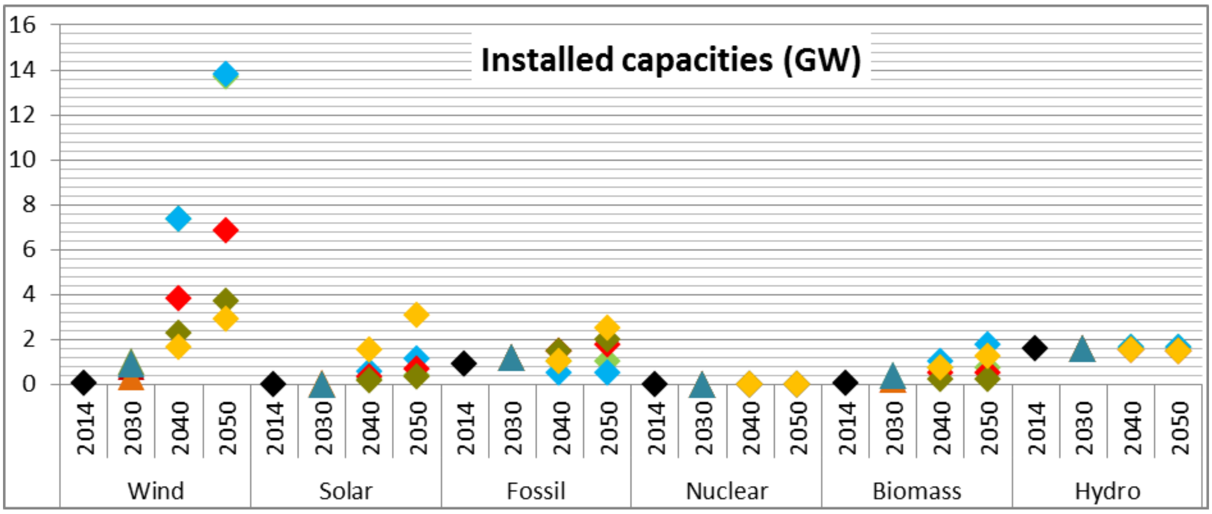
Latvia

Demand and generation





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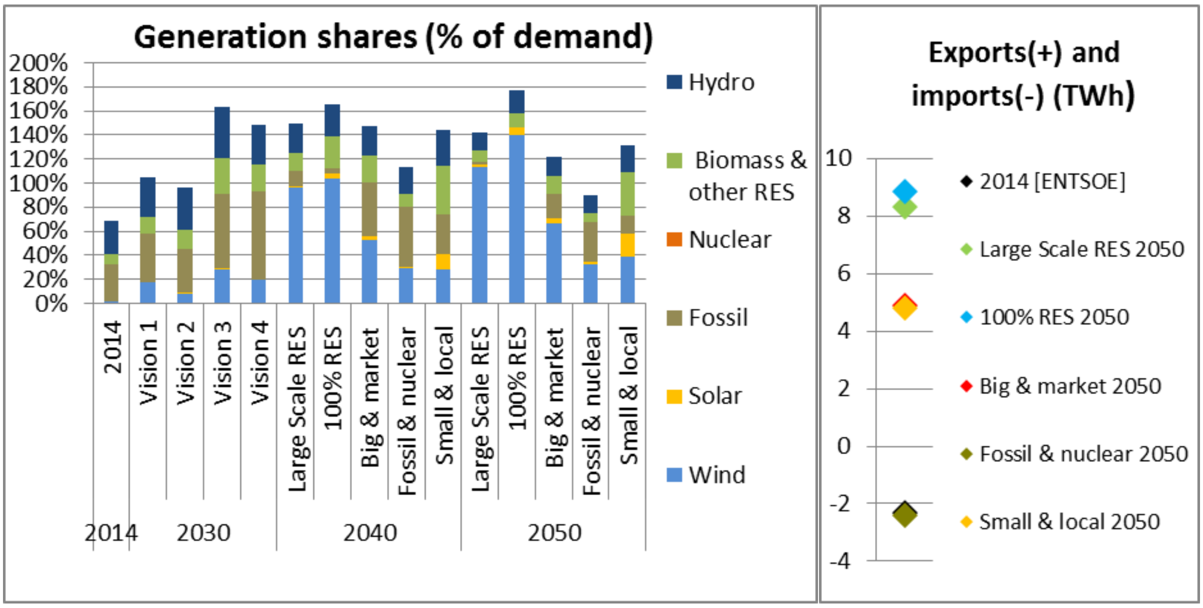

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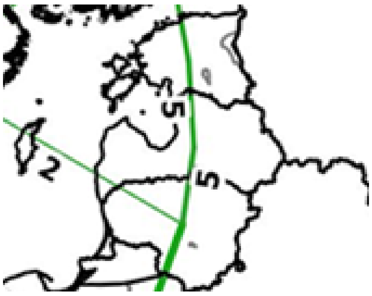
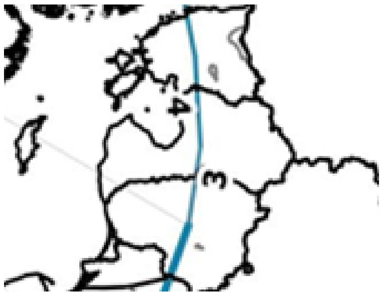
Grid reinforcements

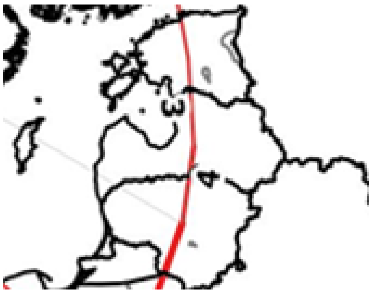
Common 2040 grid



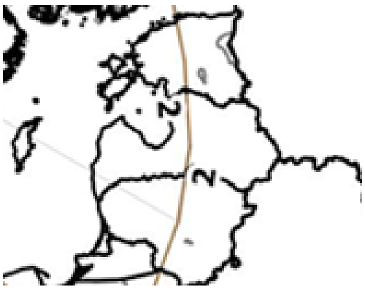
Large scale RES 2050



100% RES 2050



Big & market 2050

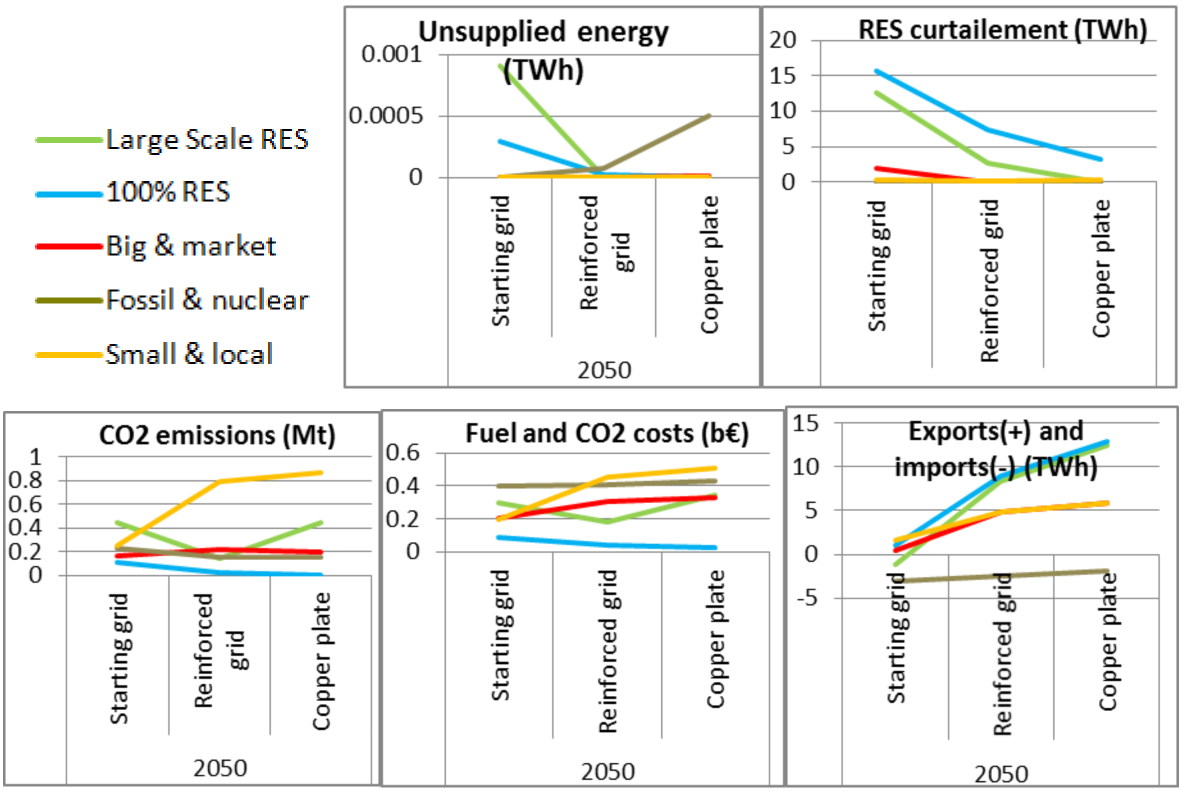


Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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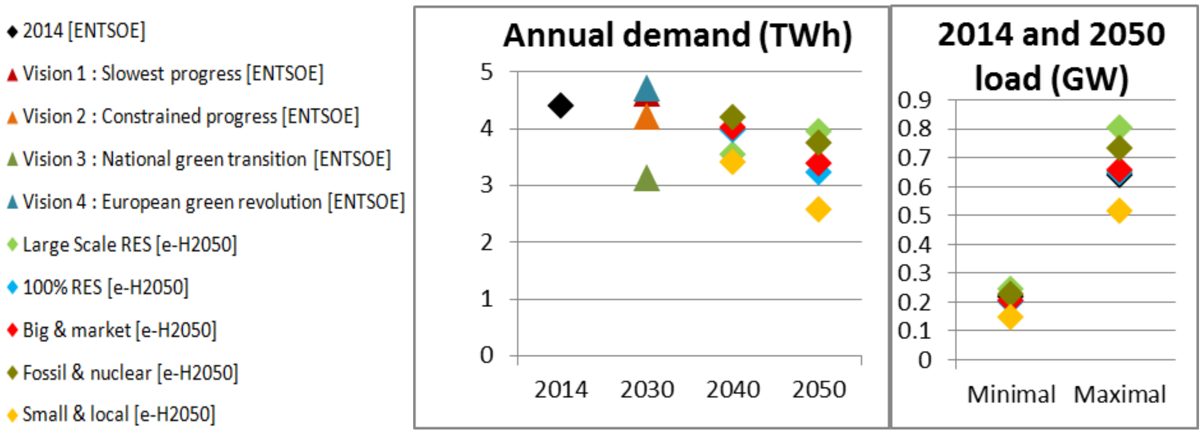
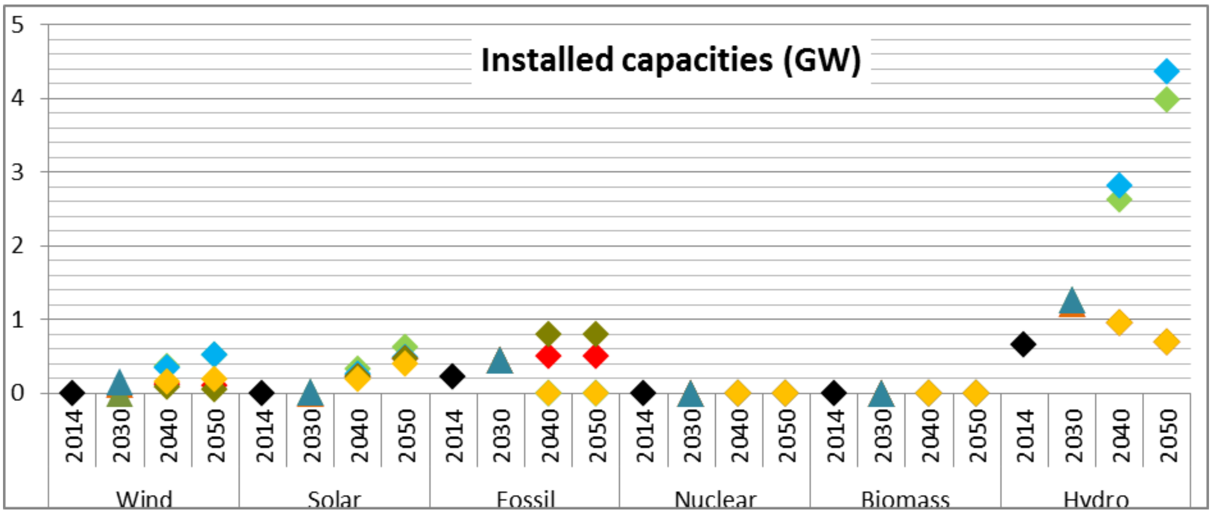
Montenegro

Demand and generation





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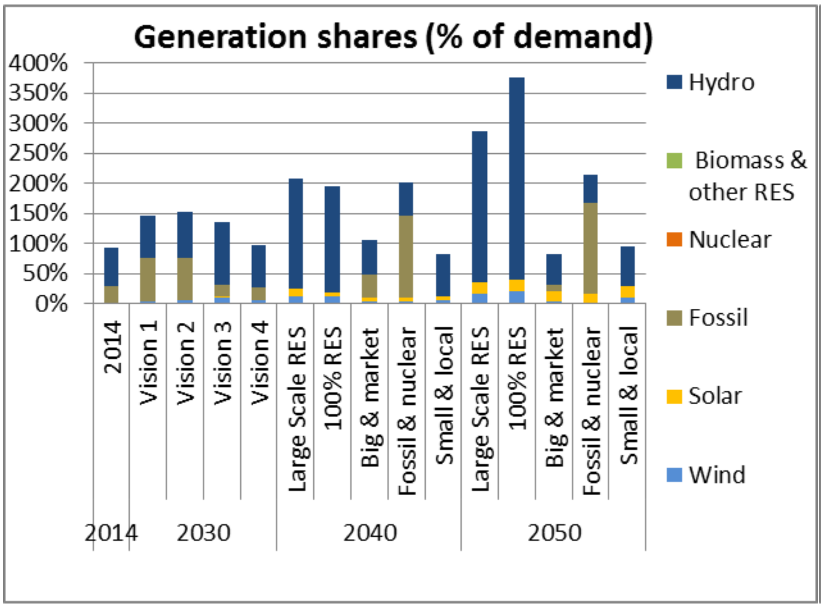

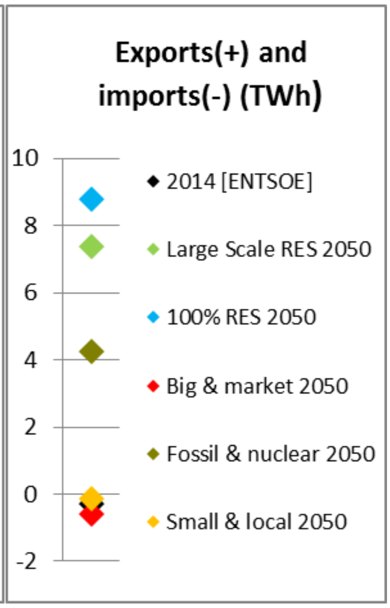

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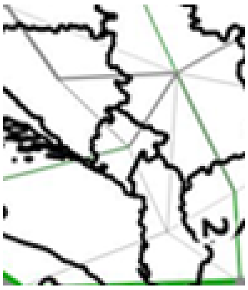
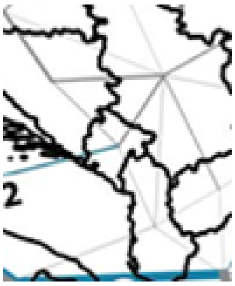
Grid reinforcements

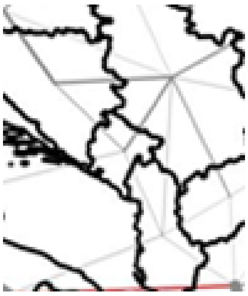
Common 2040 grid



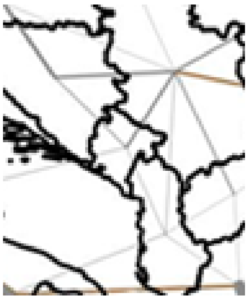
Large scale RES 2050



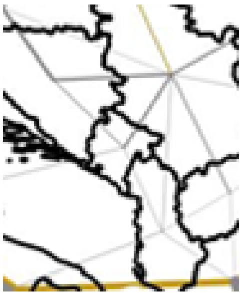
100% RES 2050



Big & market 2050



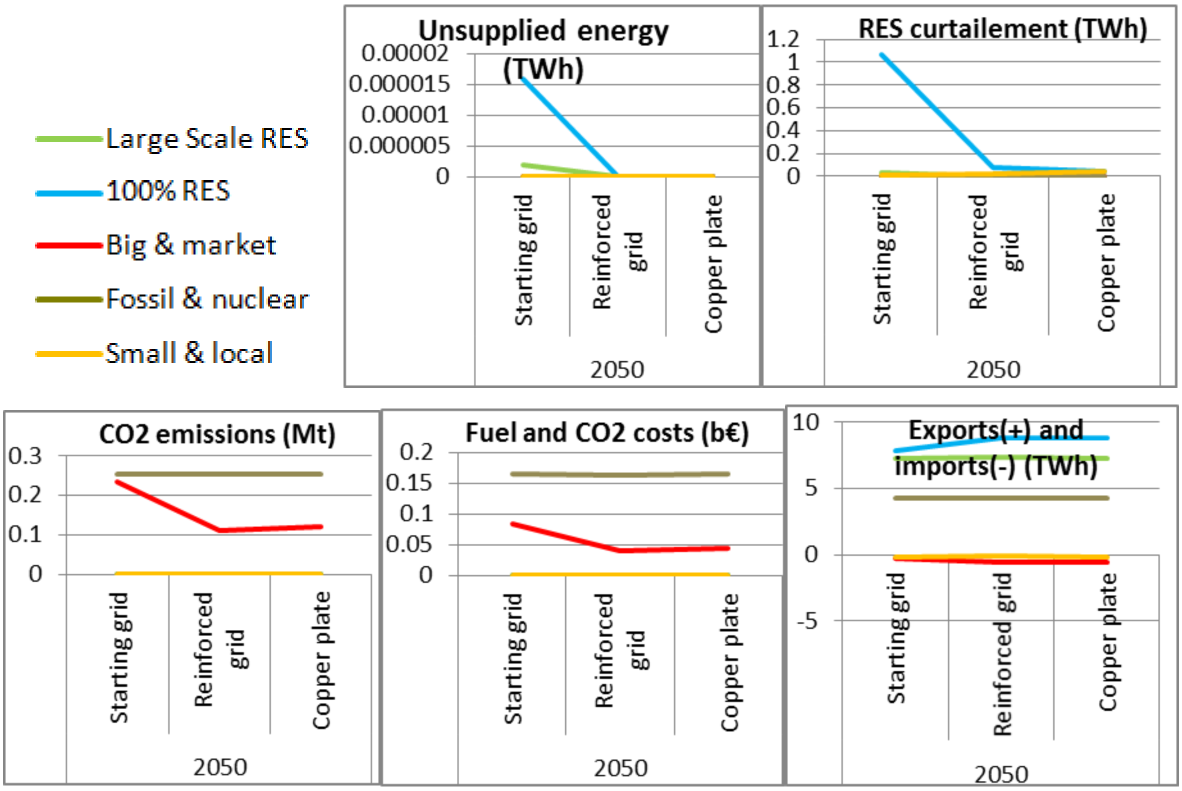
Fossil & nuclear 2050



Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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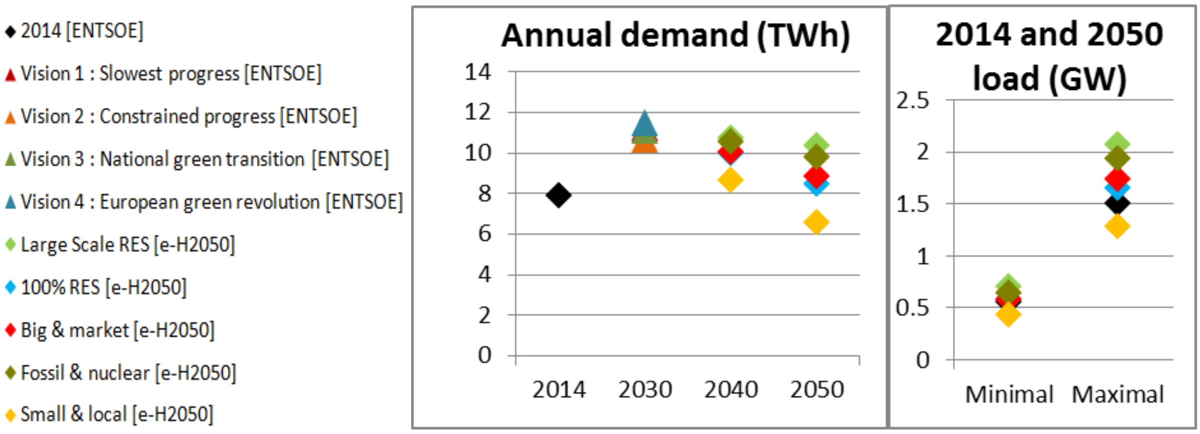
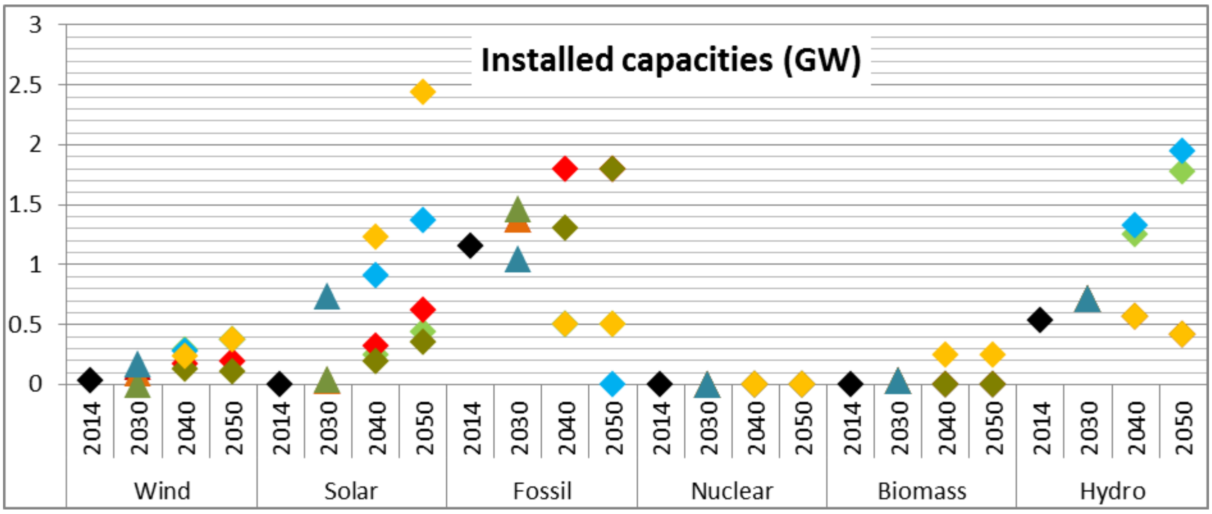
FYR of Macedonia

Demand and generation





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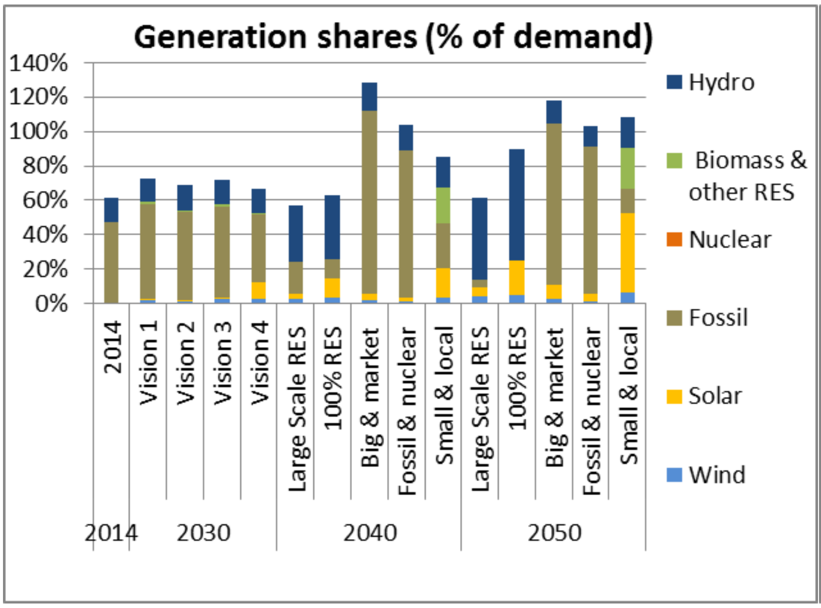

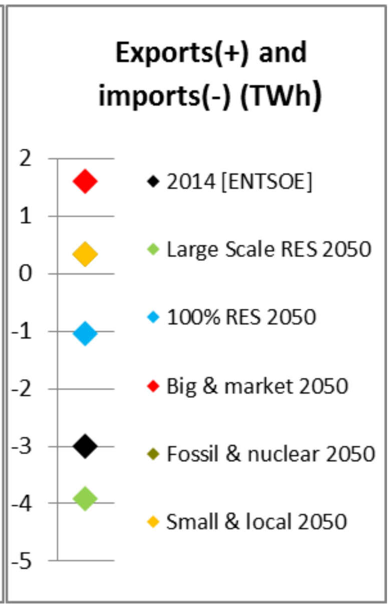

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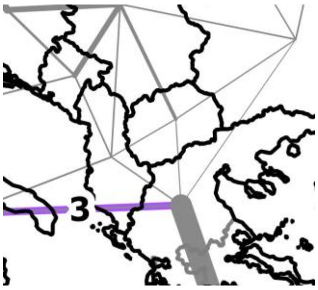
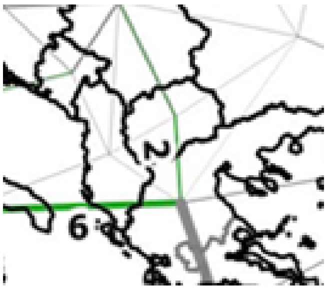
Grid reinforcements

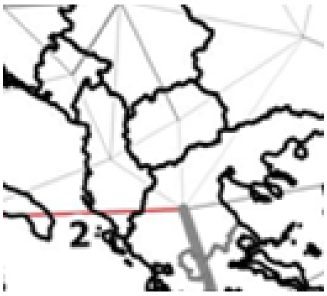


Common 2040 grid

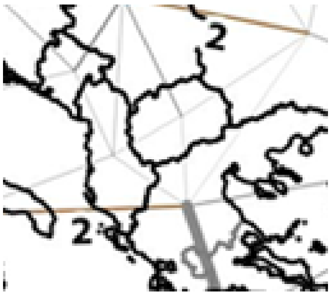


Large scale RES 2050

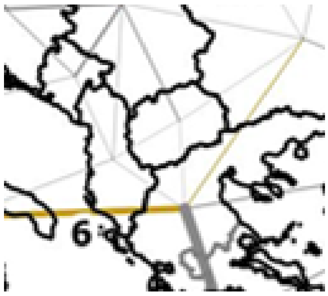
100% RES 2050



Big & market 2050



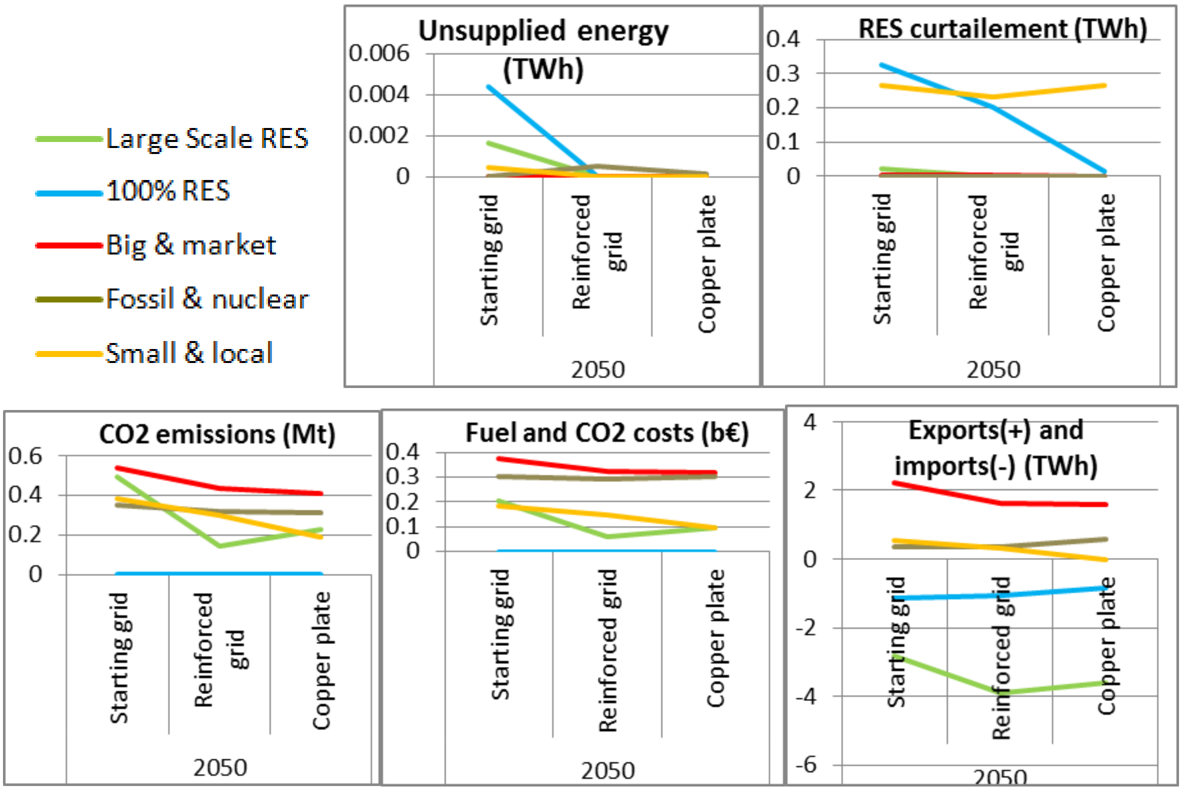
Fossil & nuclear 2050



Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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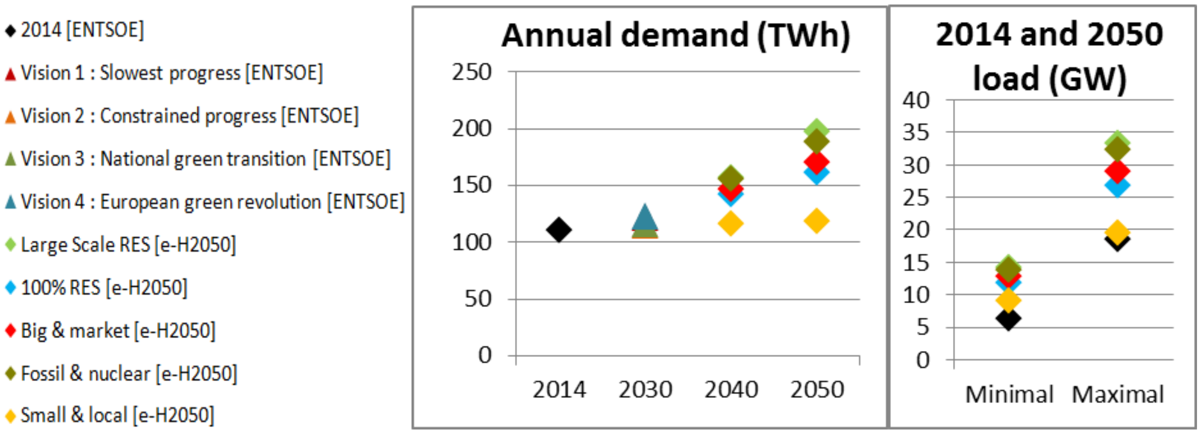
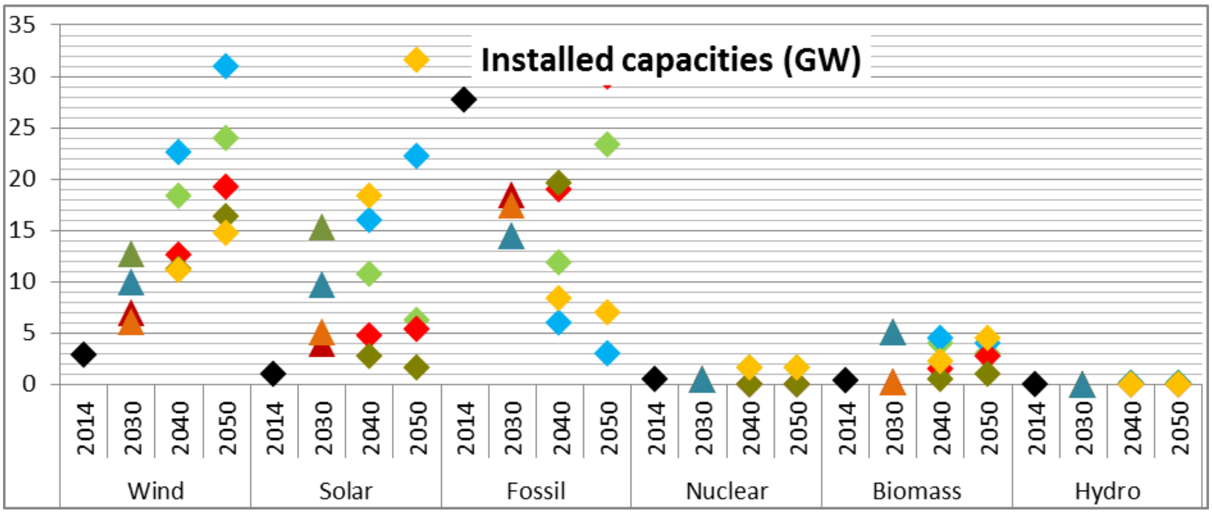
Netherlands

Demand and generation





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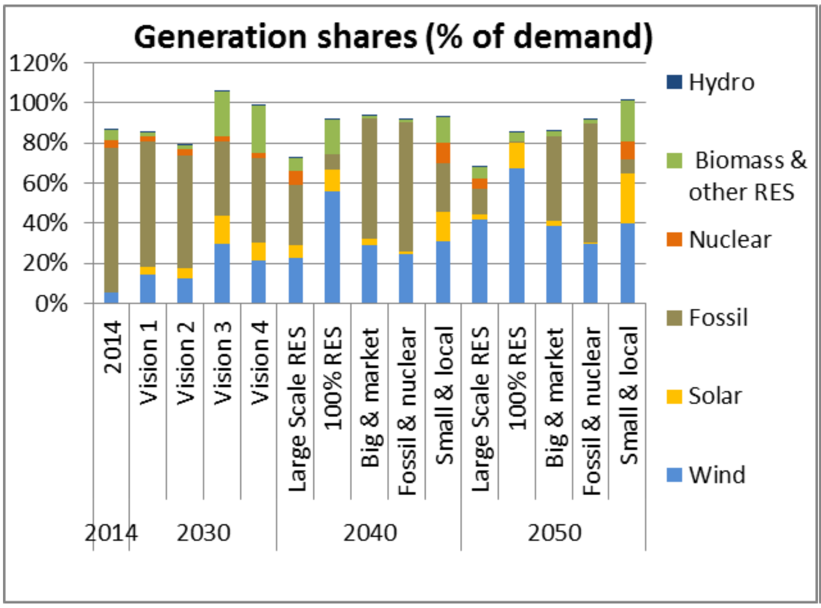

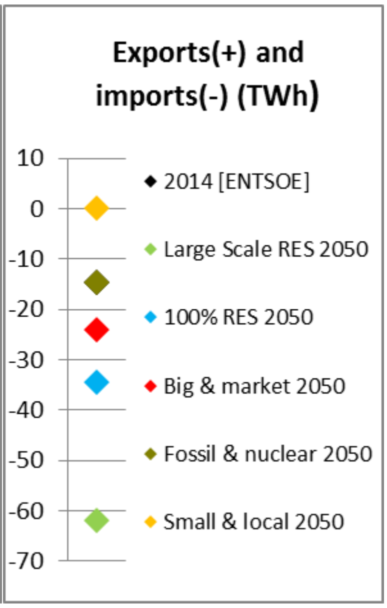

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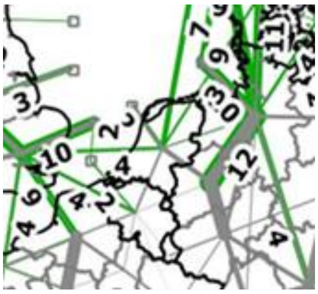
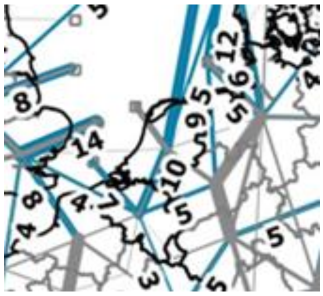
Grid reinforcements

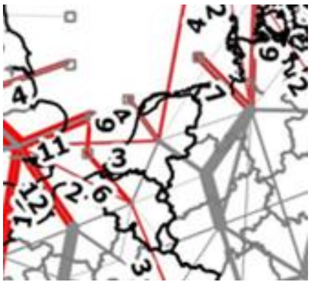
Common 2040 grid



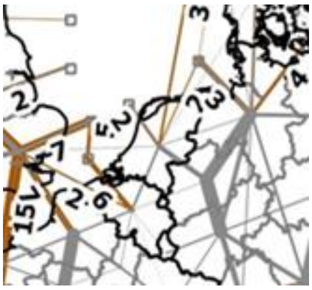
Large scale RES 2050



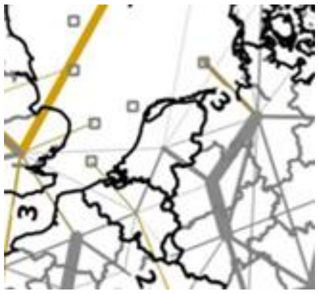
100% RES 2050



Big & market 2050



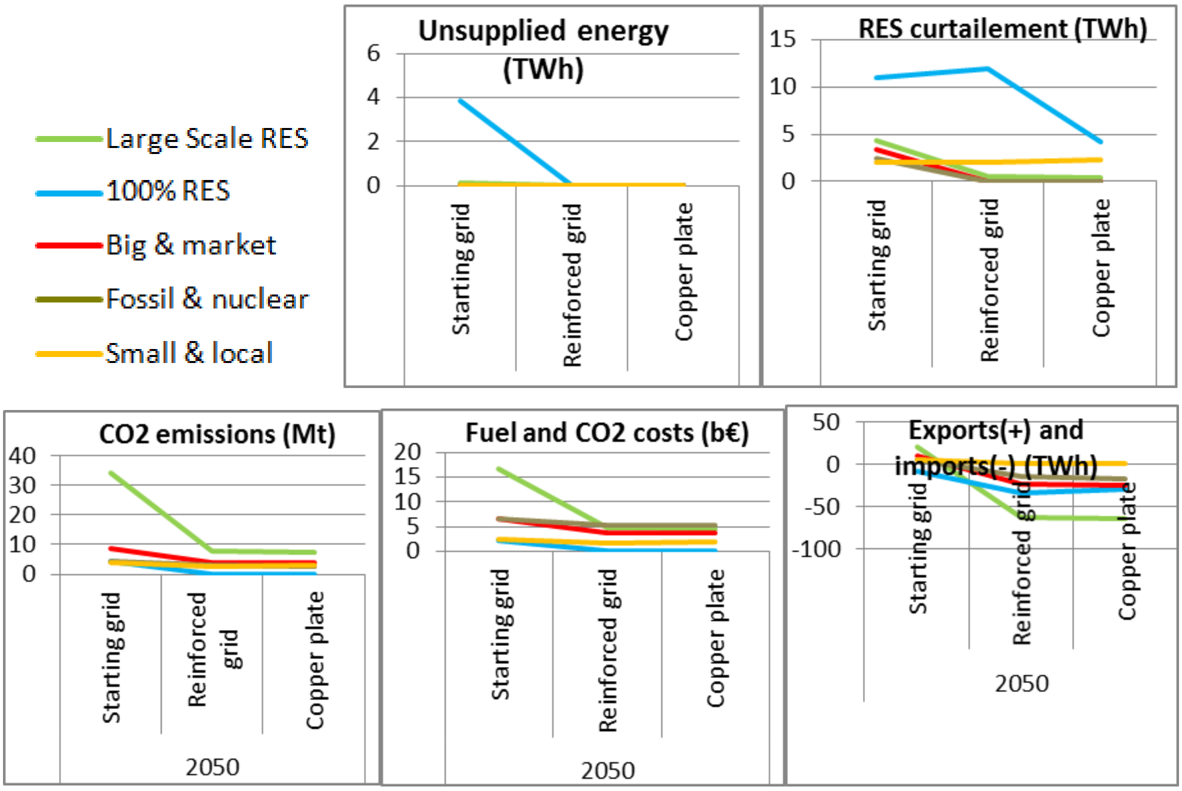
Fossil & nuclear 2050



Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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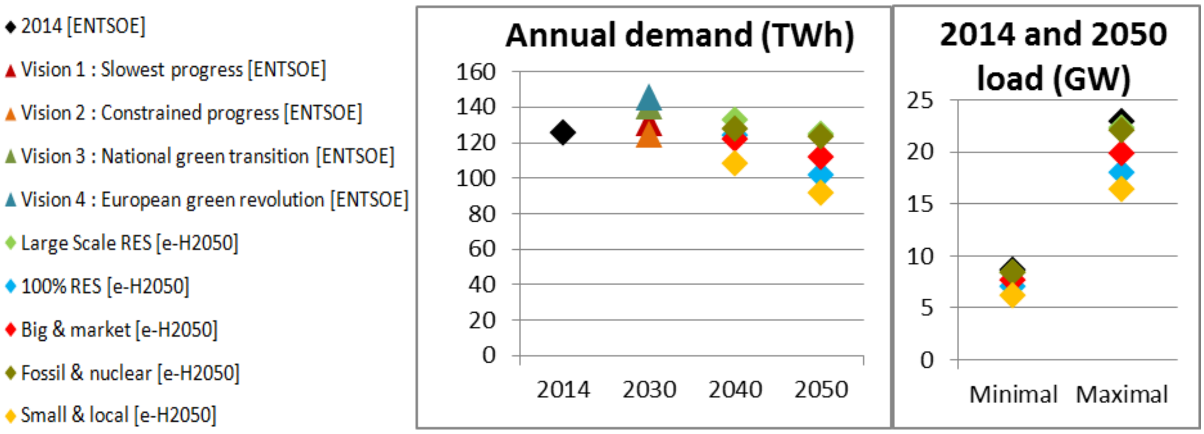
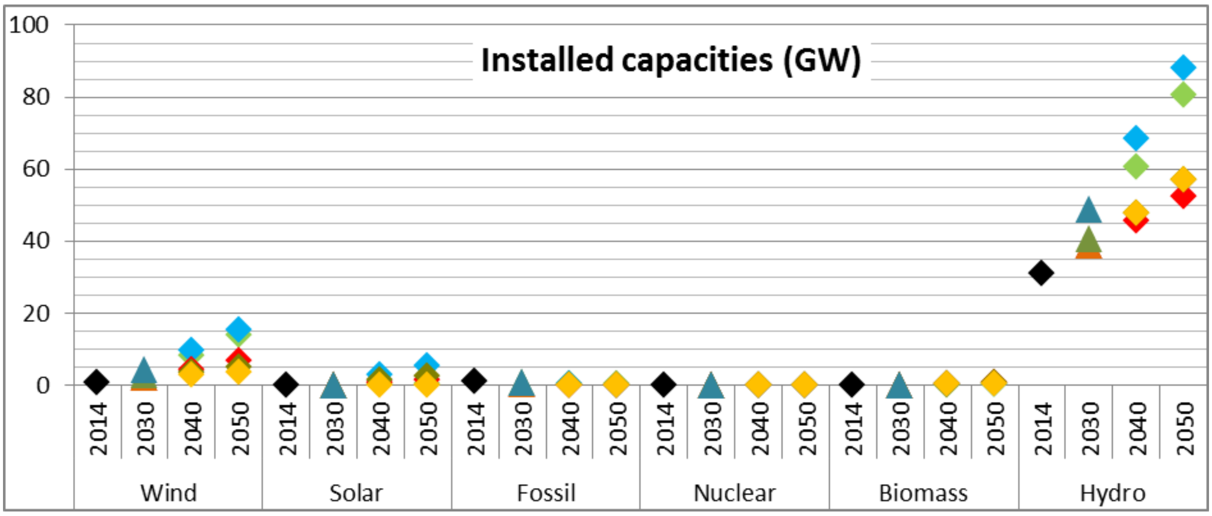
Norway

Demand and generation





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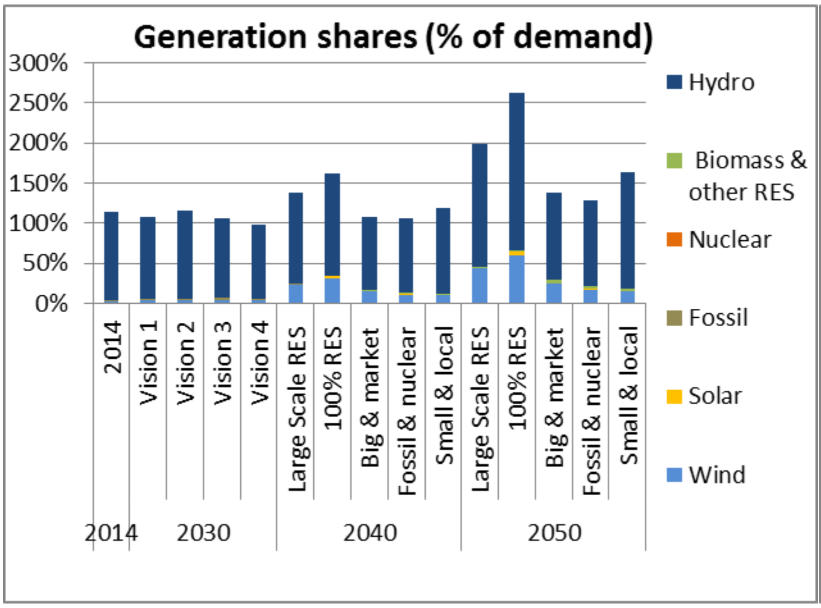

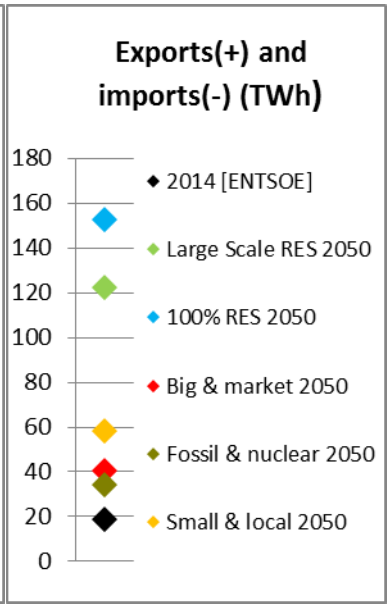

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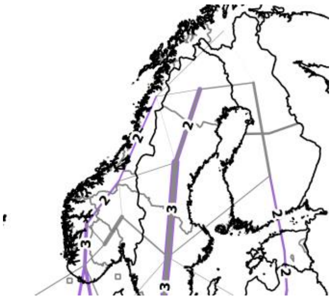
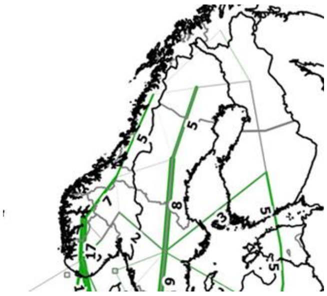
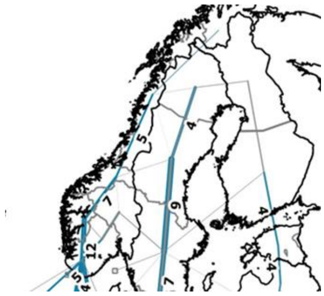
Grid reinforcements



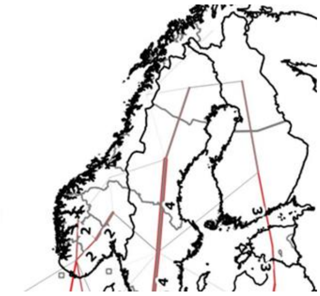
Common 2040 grid



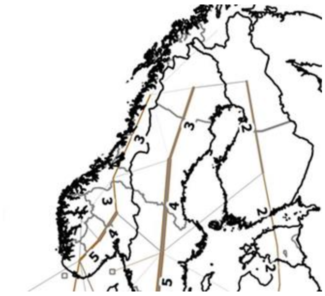
Large scale RES 2050



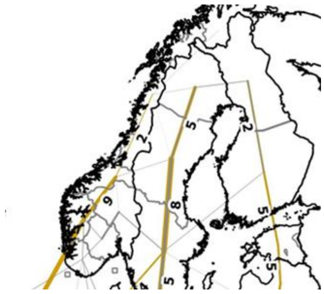
100% RES 2050



Big & market 2050



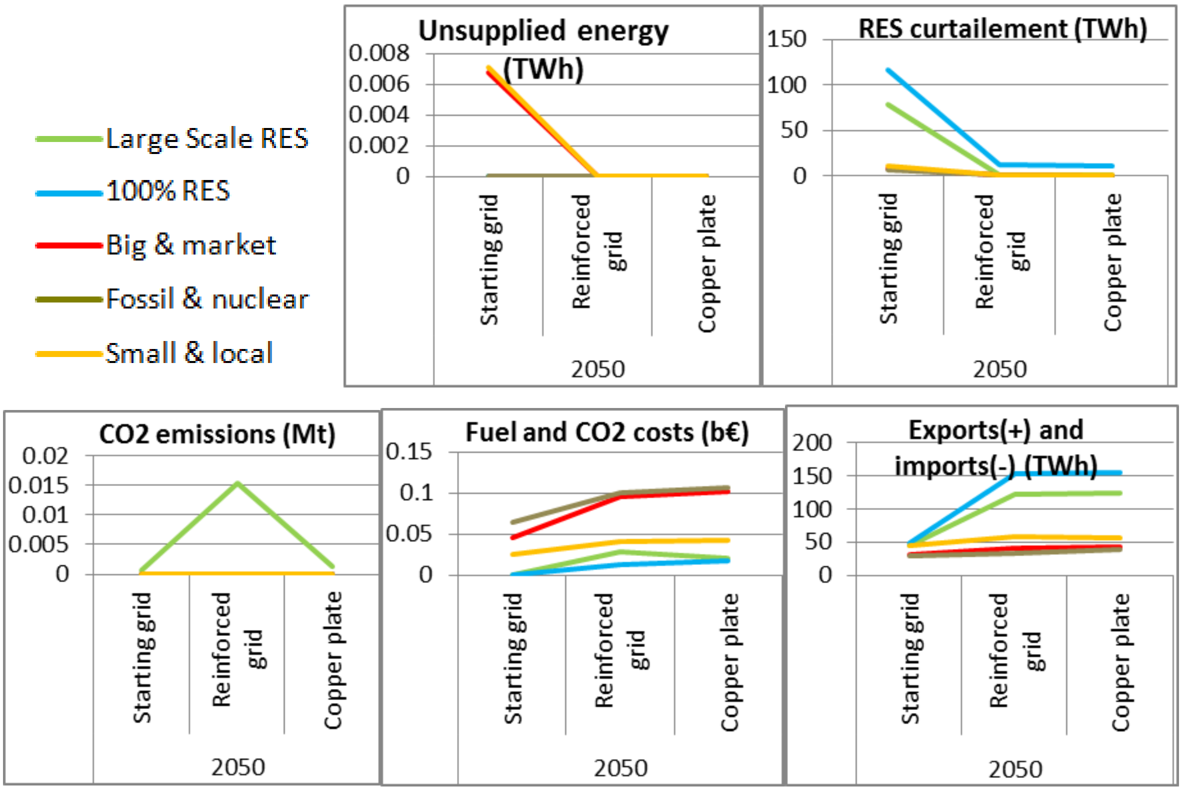
Fossil & nuclear 2050



Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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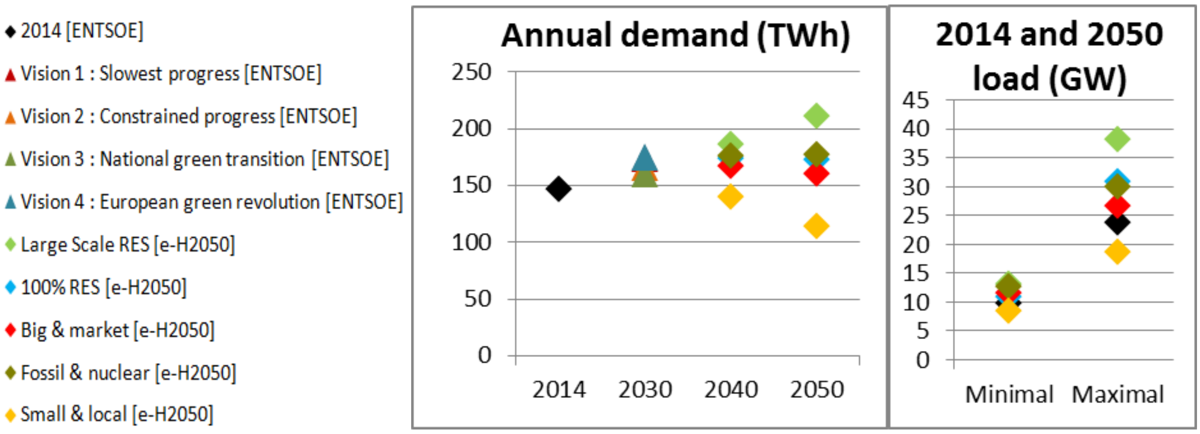
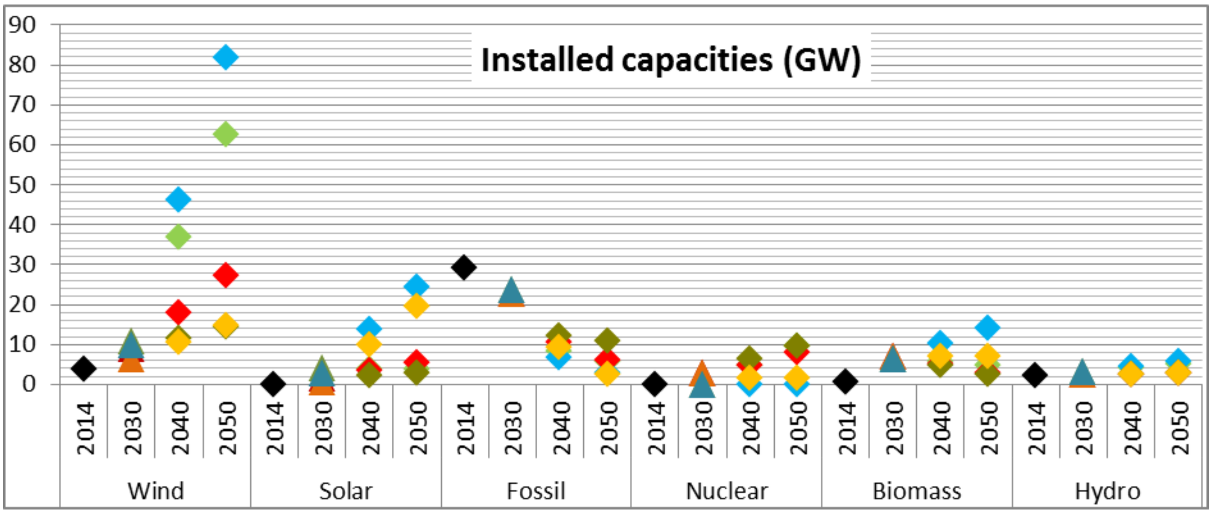
Poland

Demand and generation





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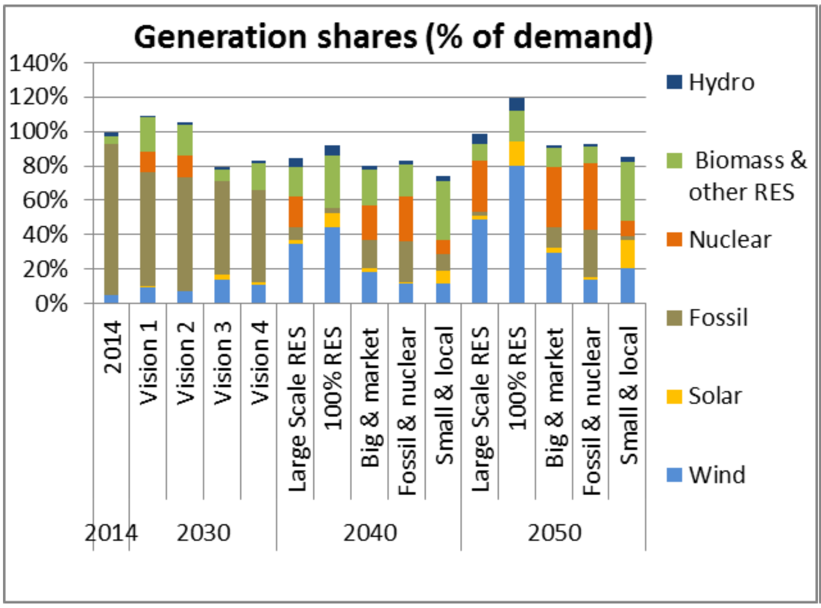

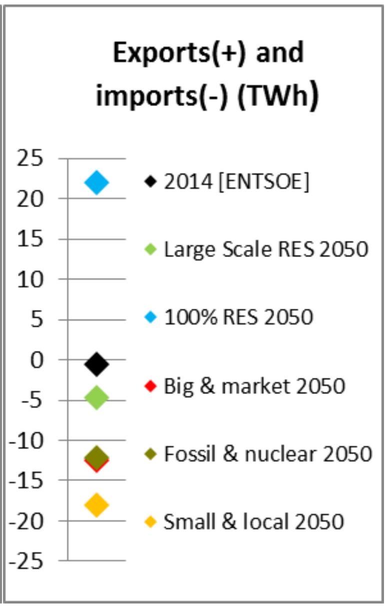

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Grid reinforcements

Common 2040 grid

Large scale RES 2050

100% RES 2050

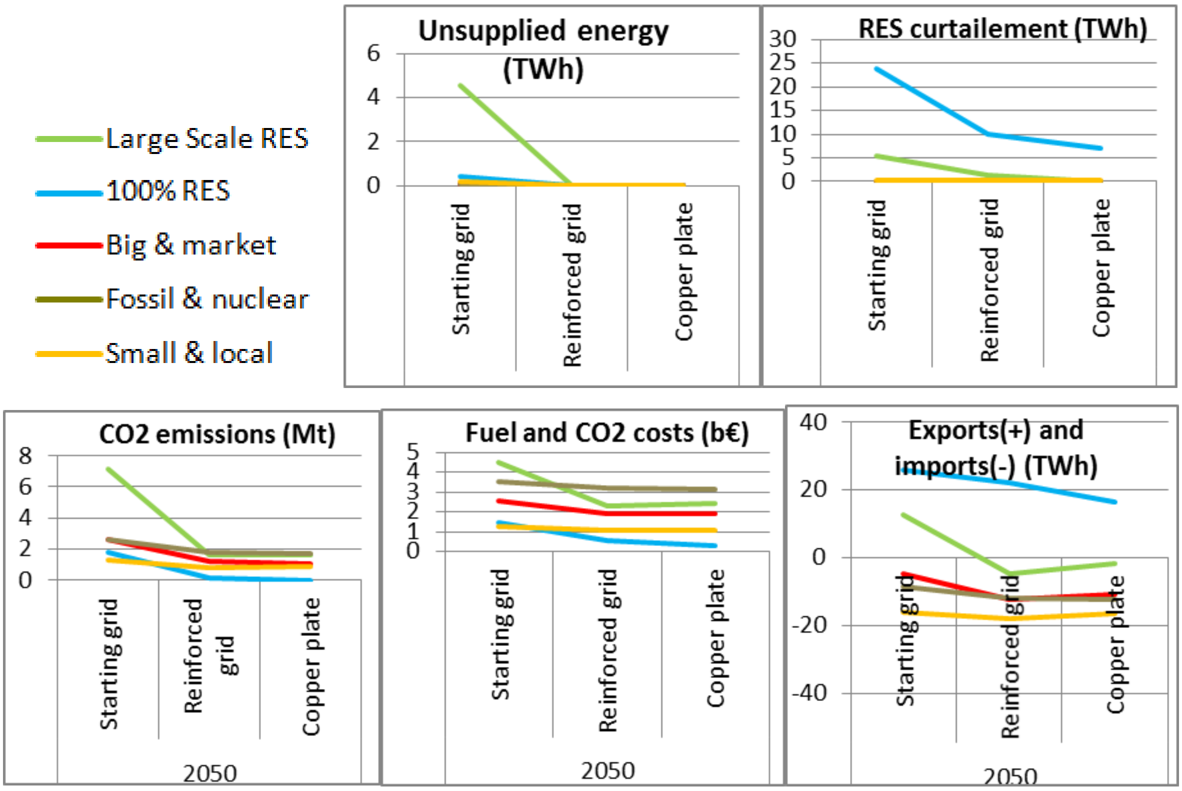
Big & market 2050

Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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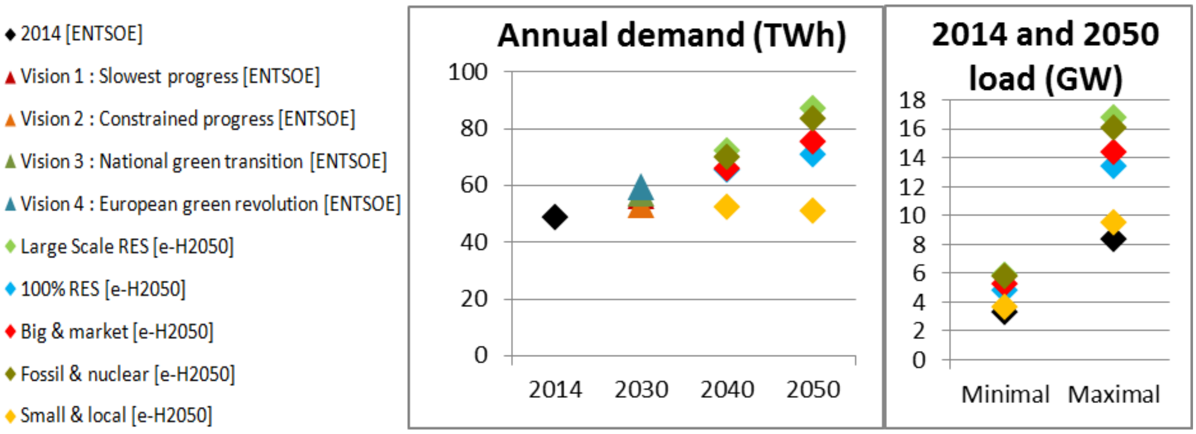
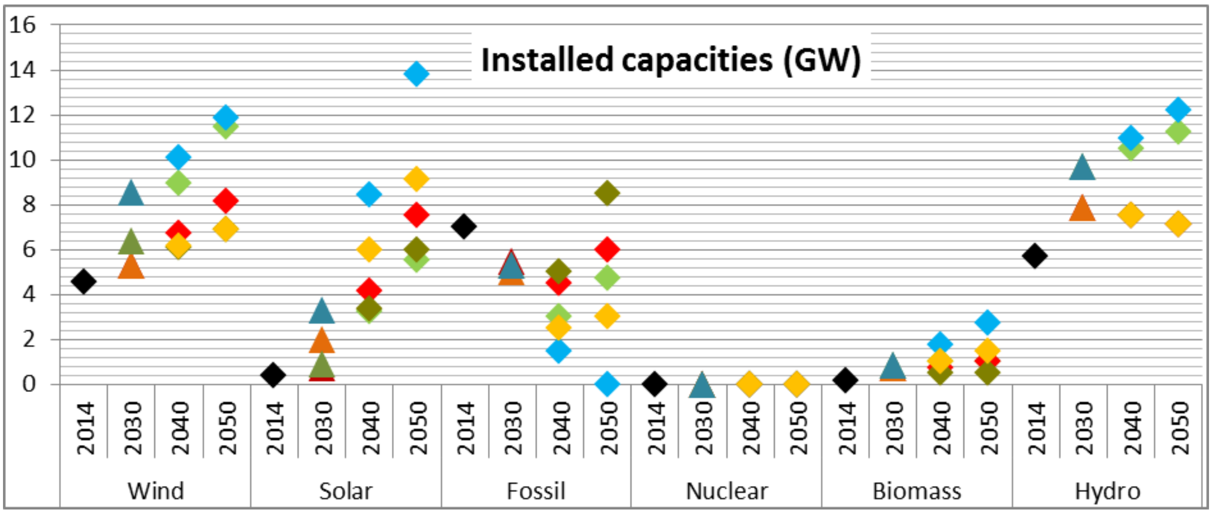
Portugal

Demand and generation





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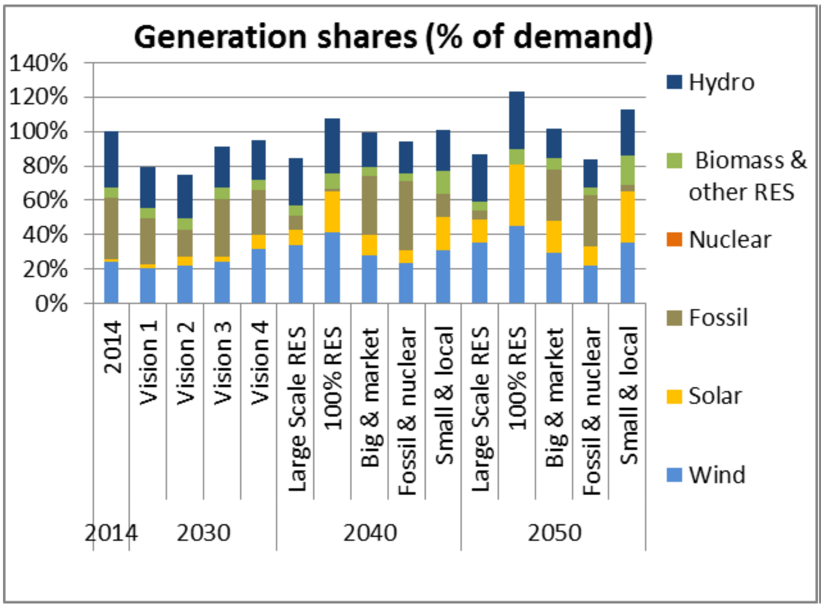

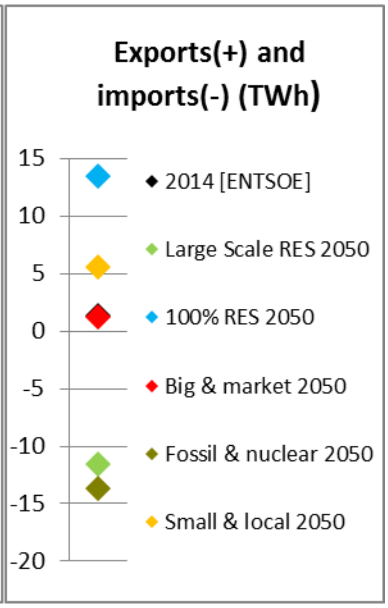

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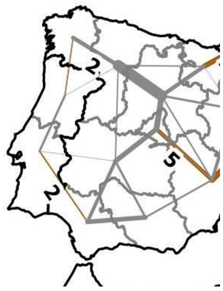
Grid reinforcements

<u>*Common 2040 grid*</u>

<u>*Large scale RES 2050*</u>

<u>*100% RES 2050*</u>

<u>*Big & market 2050*</u>

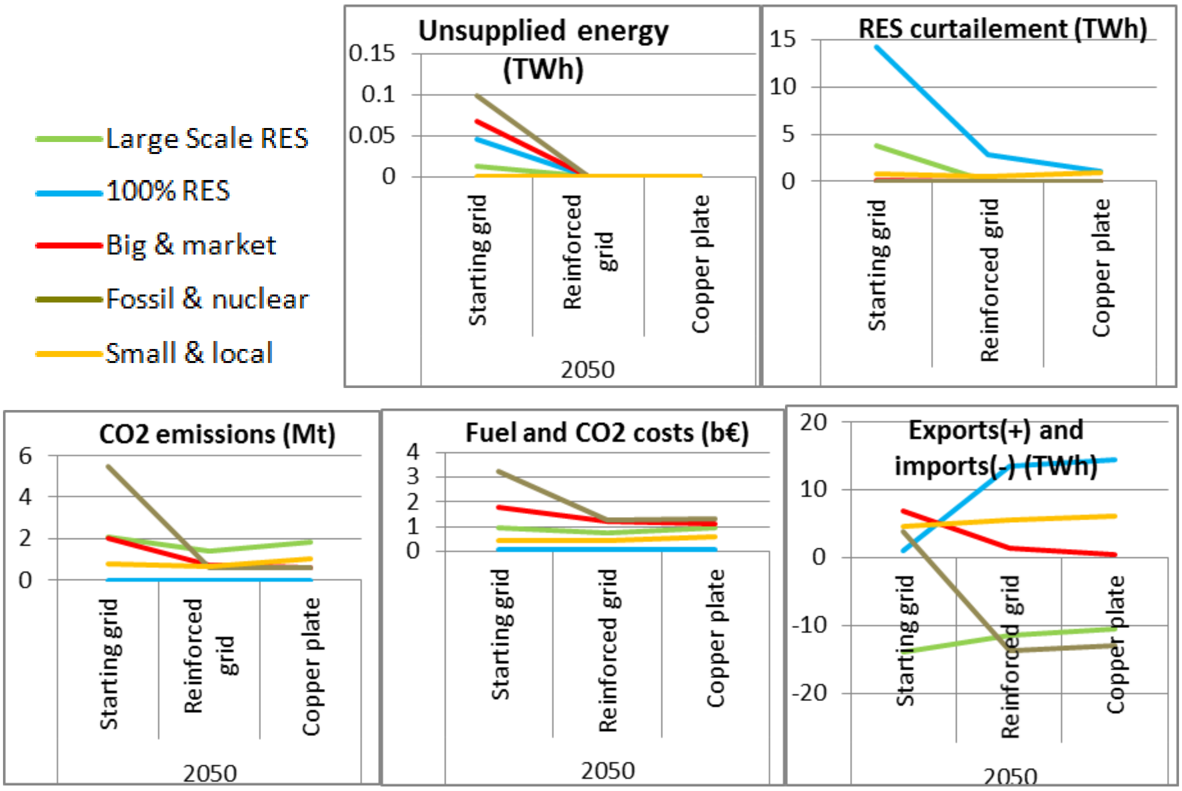


<u>*Fossil & nuclear 2050*</u>

<u>*Small & local 2050*</u>

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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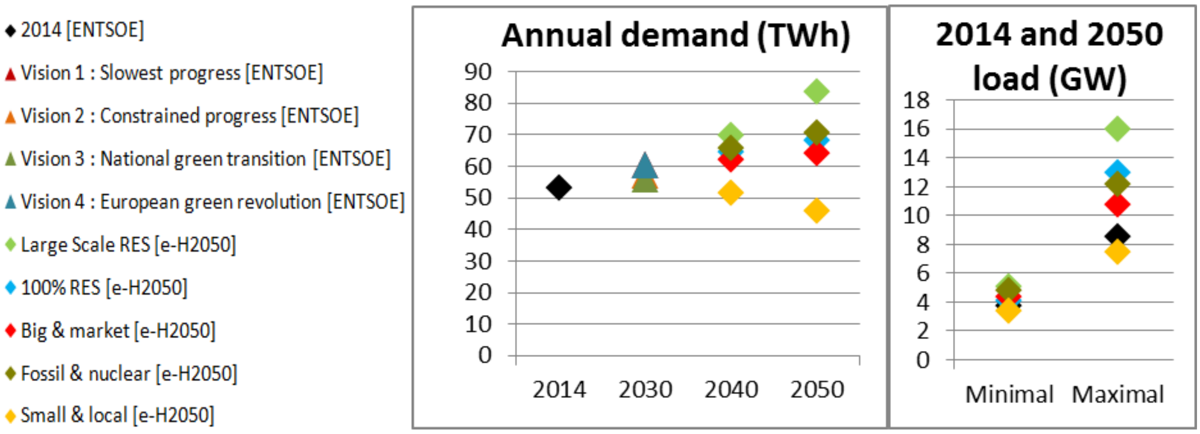
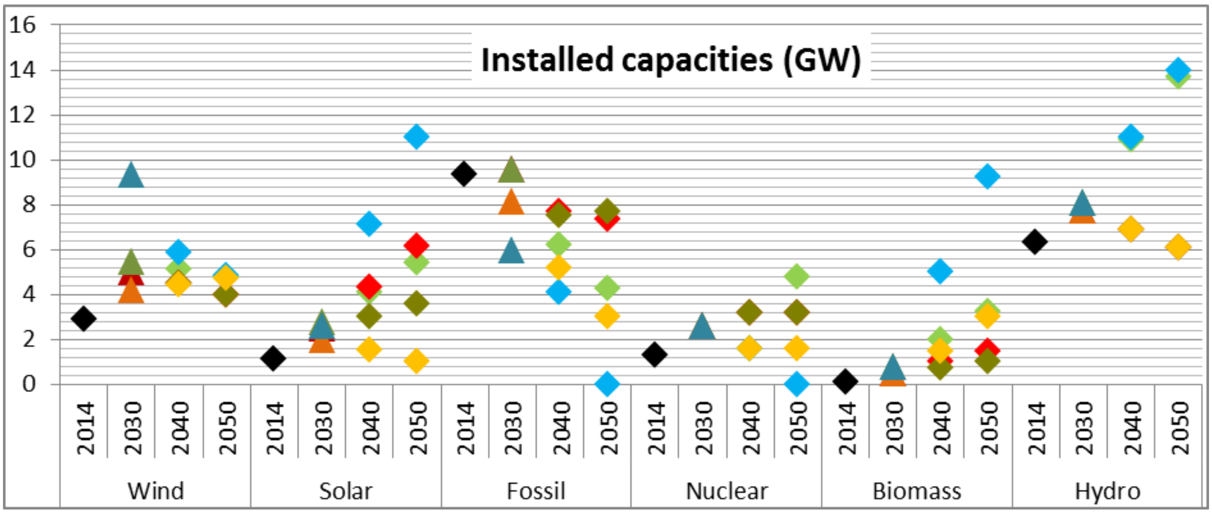
Romania

Demand and generation





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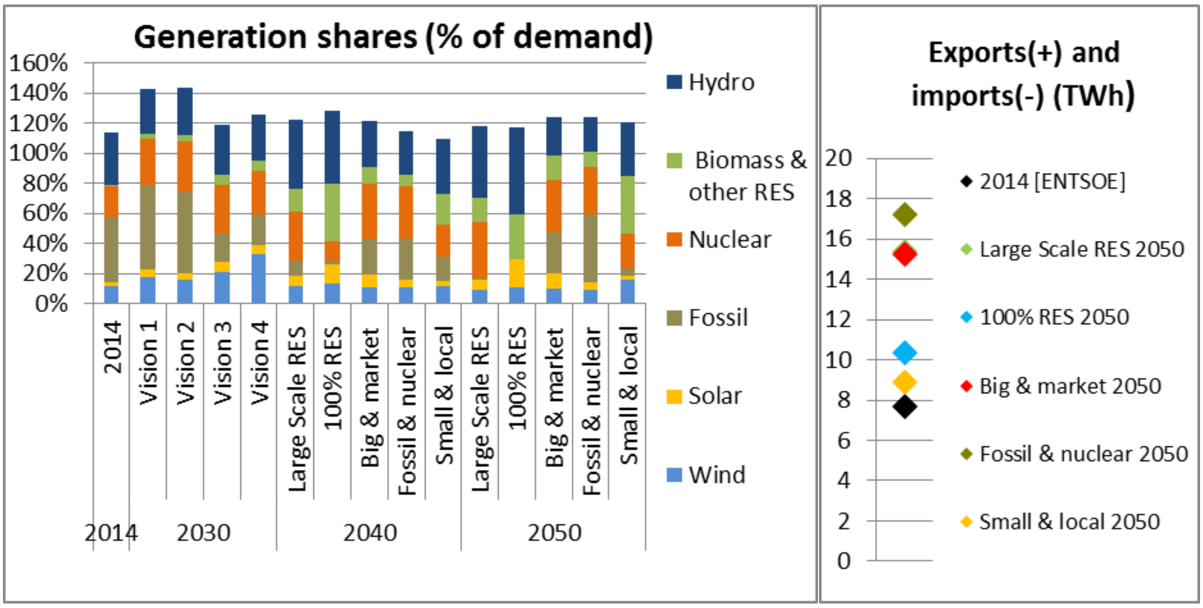

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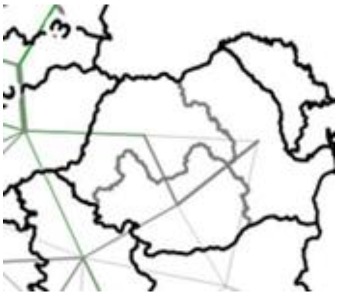
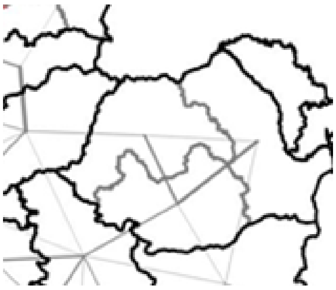
Grid reinforcements

Common 2040 grid

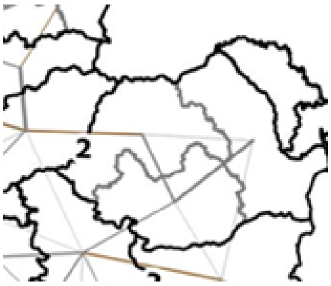


Large scale RES 2050

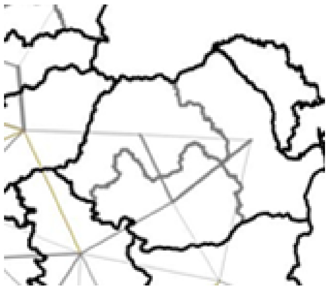
100% RES 2050



Big & market 2050



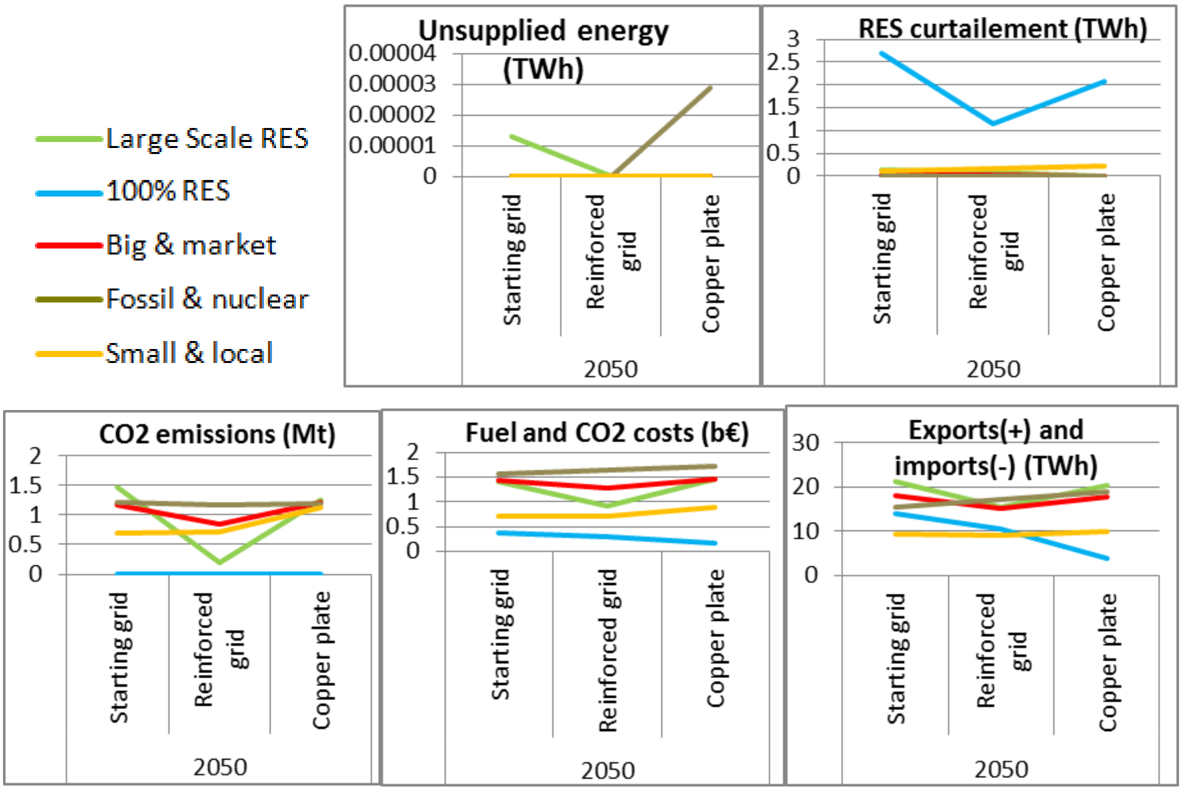
Fossil & nuclear 2050



Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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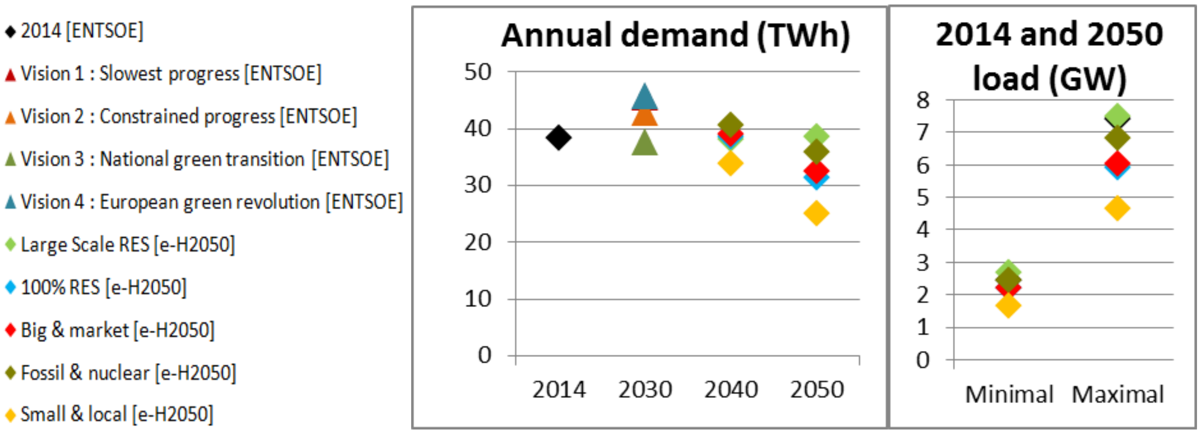
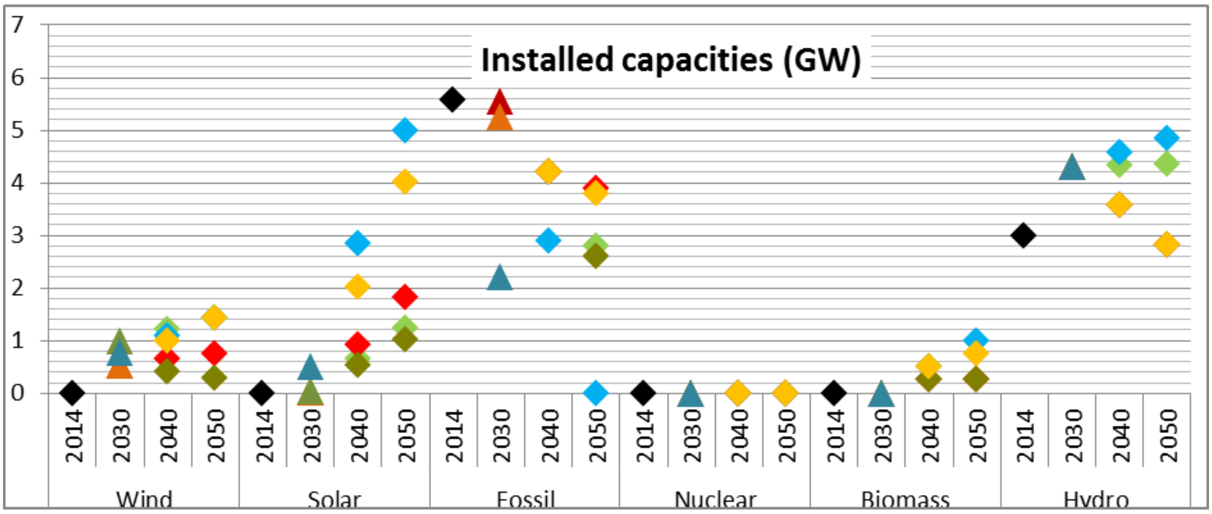
Serbia

Demand and generation





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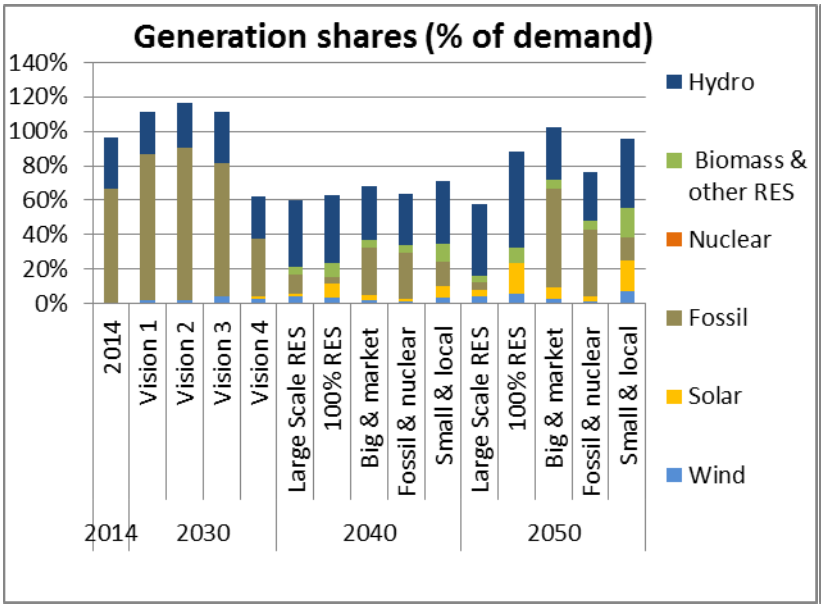

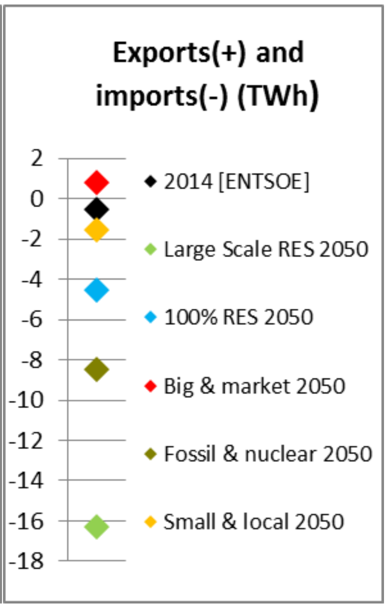

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Grid reinforcements

Common 2040 grid

Large scale RES 2050

100% RES 2050

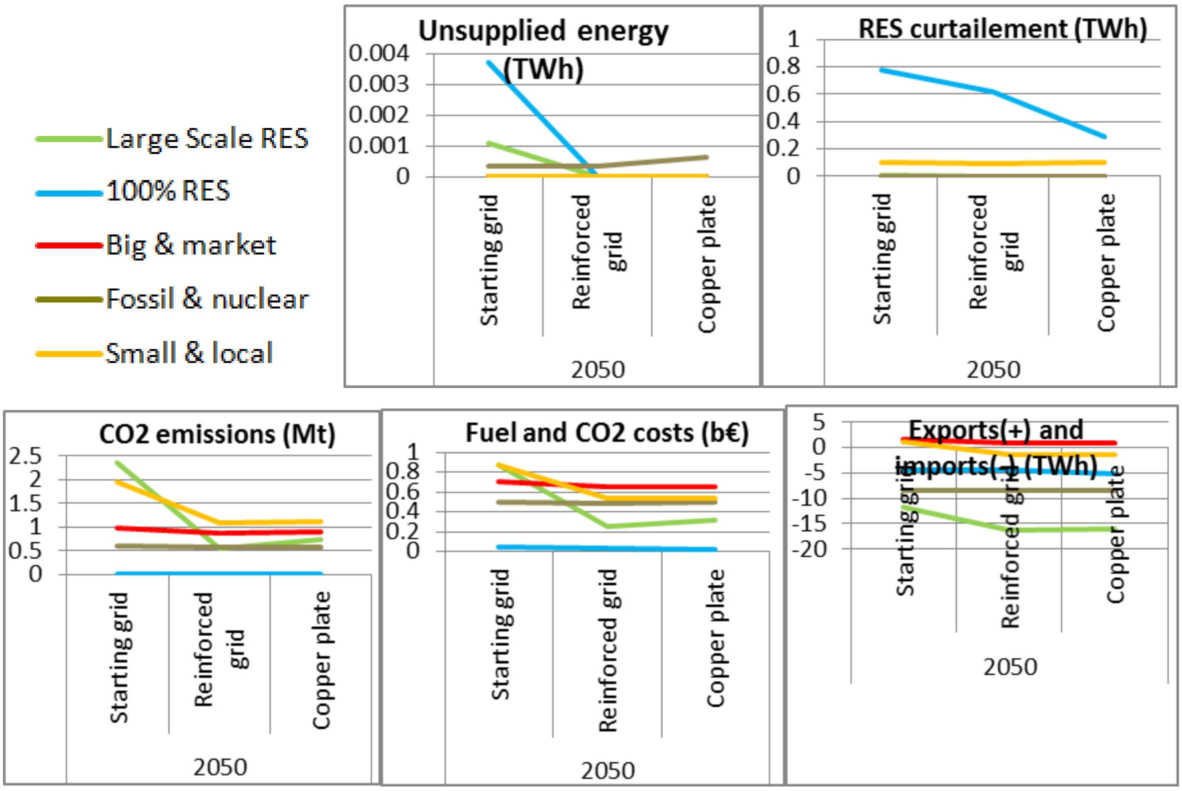
Big & market 2050

Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



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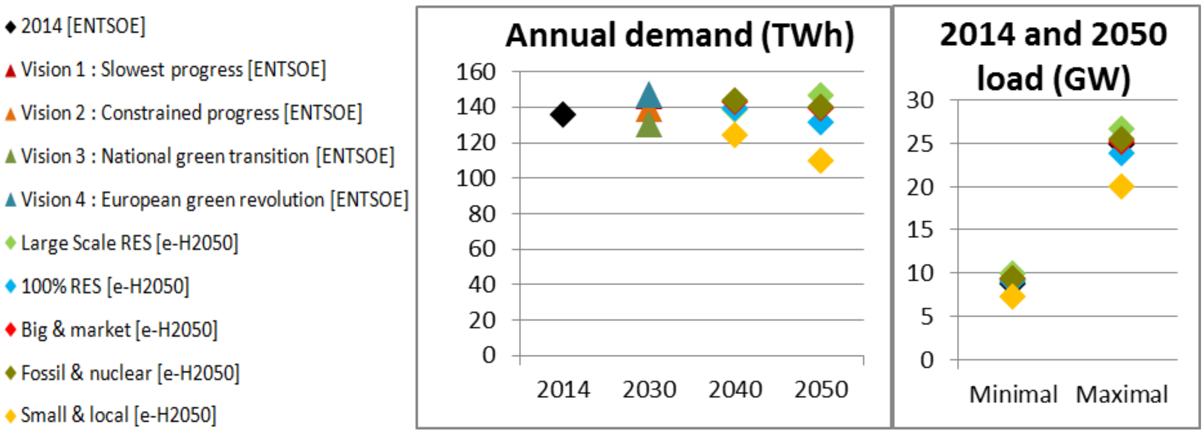
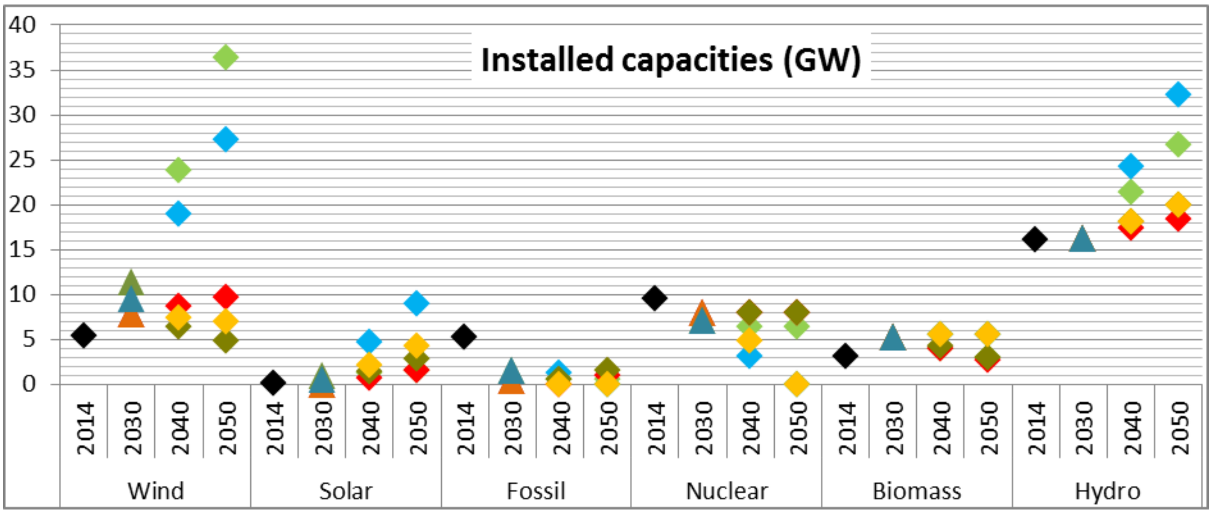
Sweden

Demand and generation





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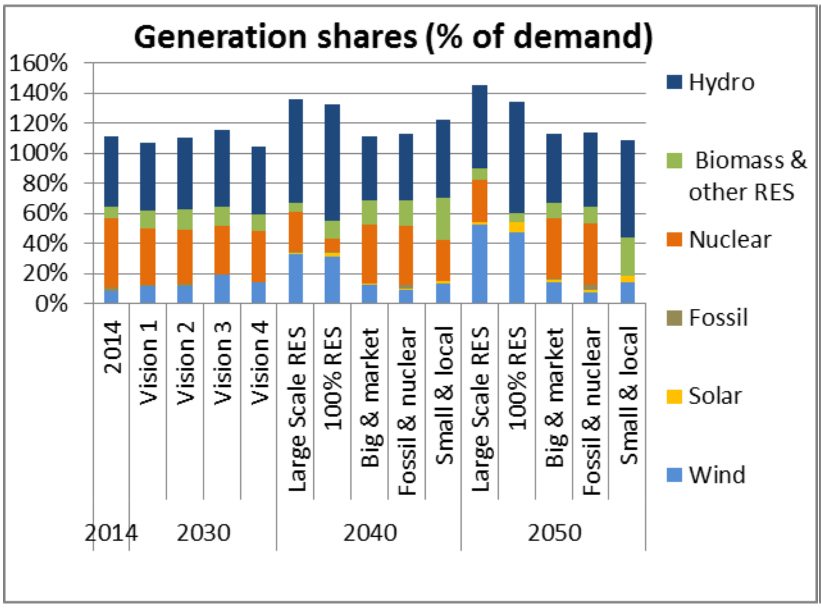

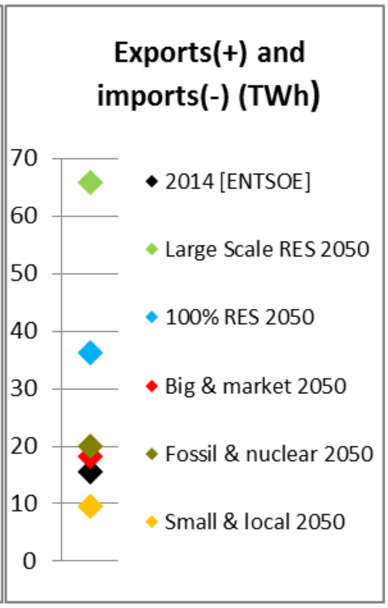

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Grid reinforcements

Common 2040 grid

Large scale RES 2050

100% RES 2050

Big & market 2050

Fossil & nuclear 2050

Small & local 2050

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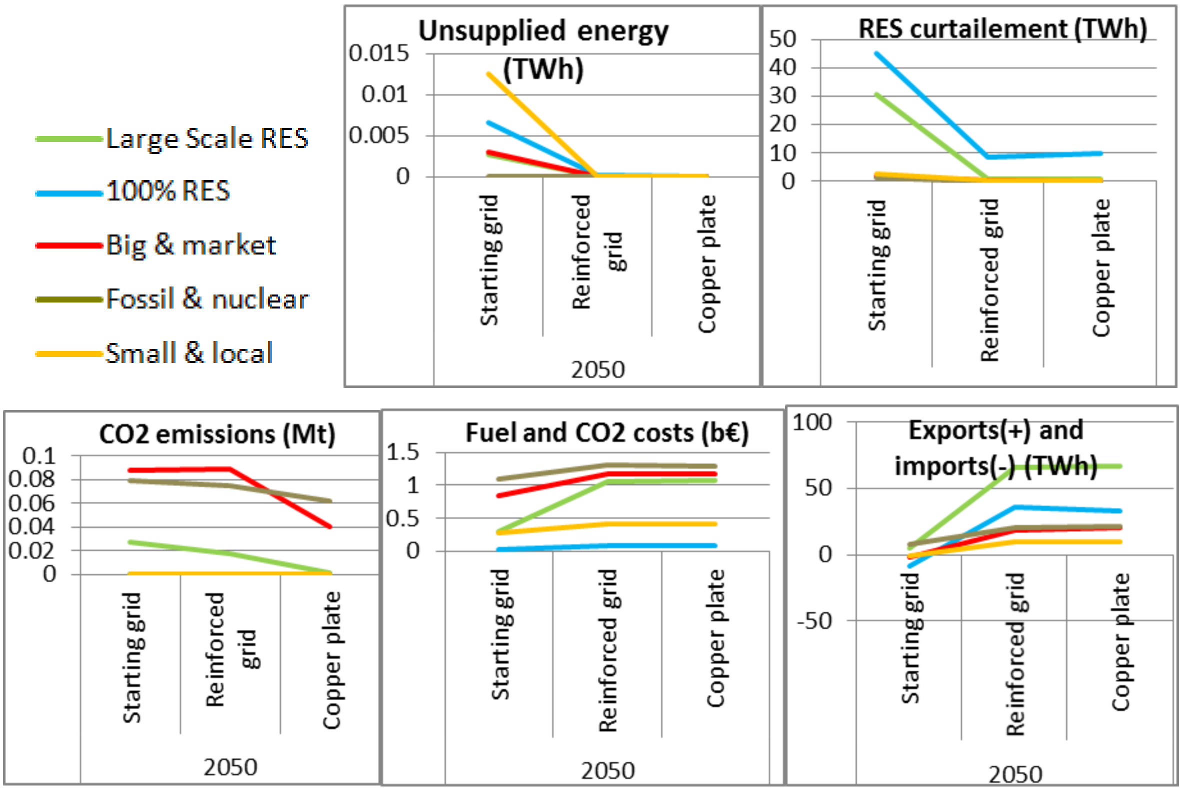
Impact of the grid reinforcements (2050)



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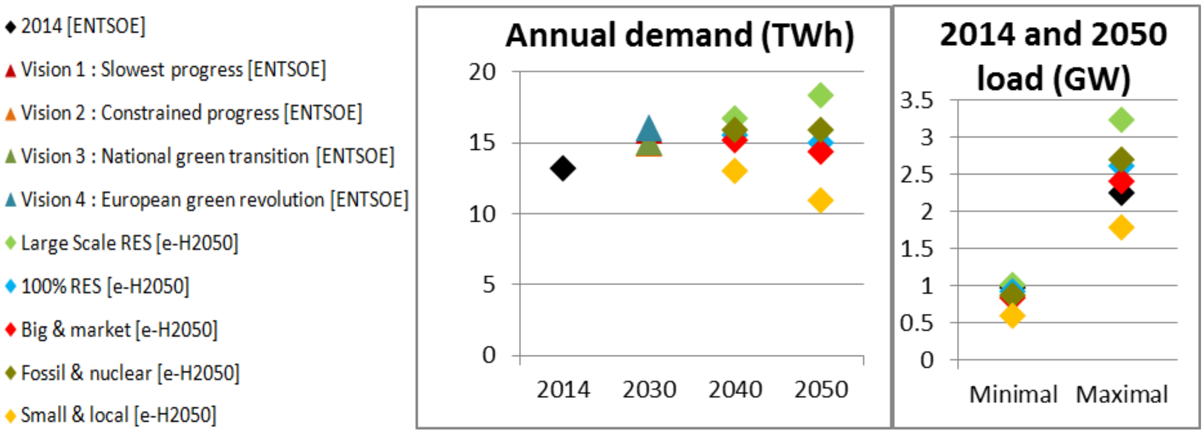
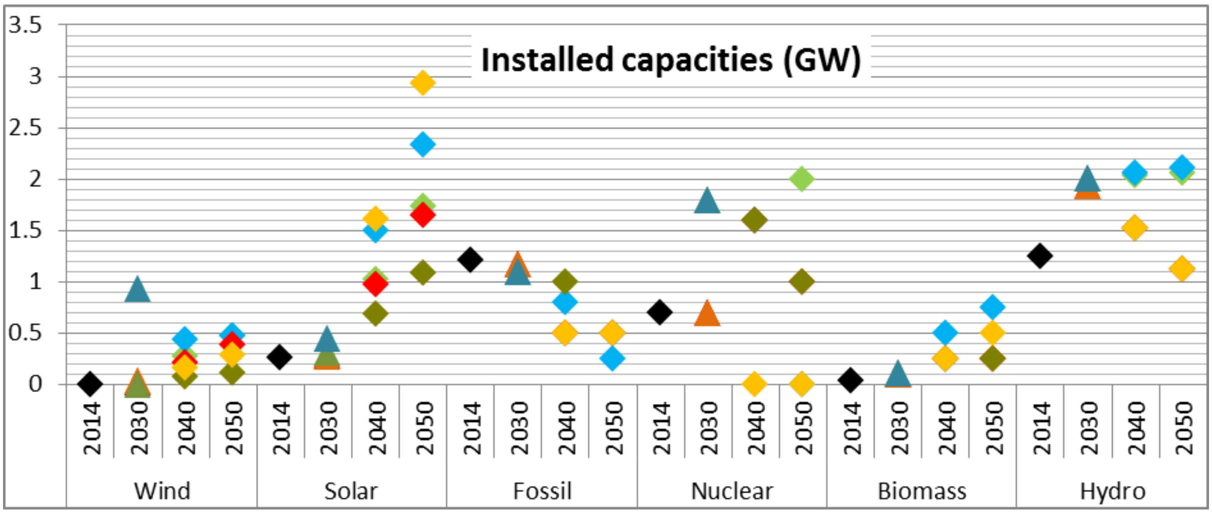
Slovenia

Demand and generation





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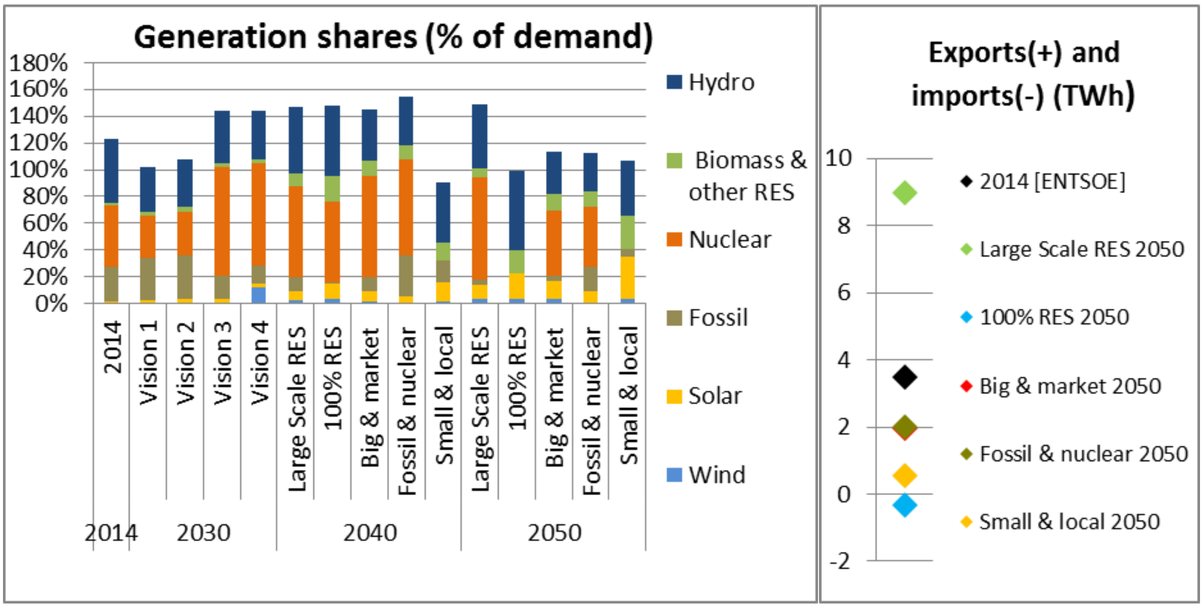

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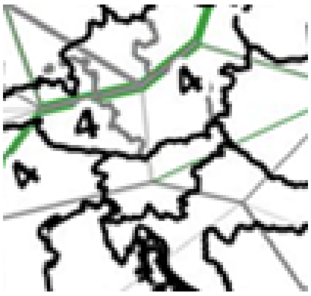
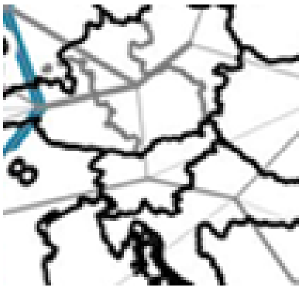
Grid reinforcements

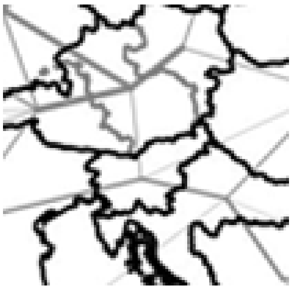
Common 2040 grid



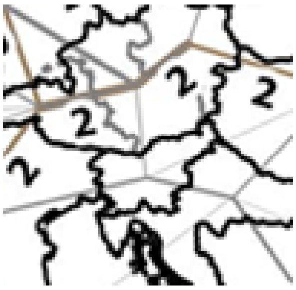
Large scale RES 2050



100% RES 2050



Big & market 2050



Fossil & nuclear 2050

Small & local 2050

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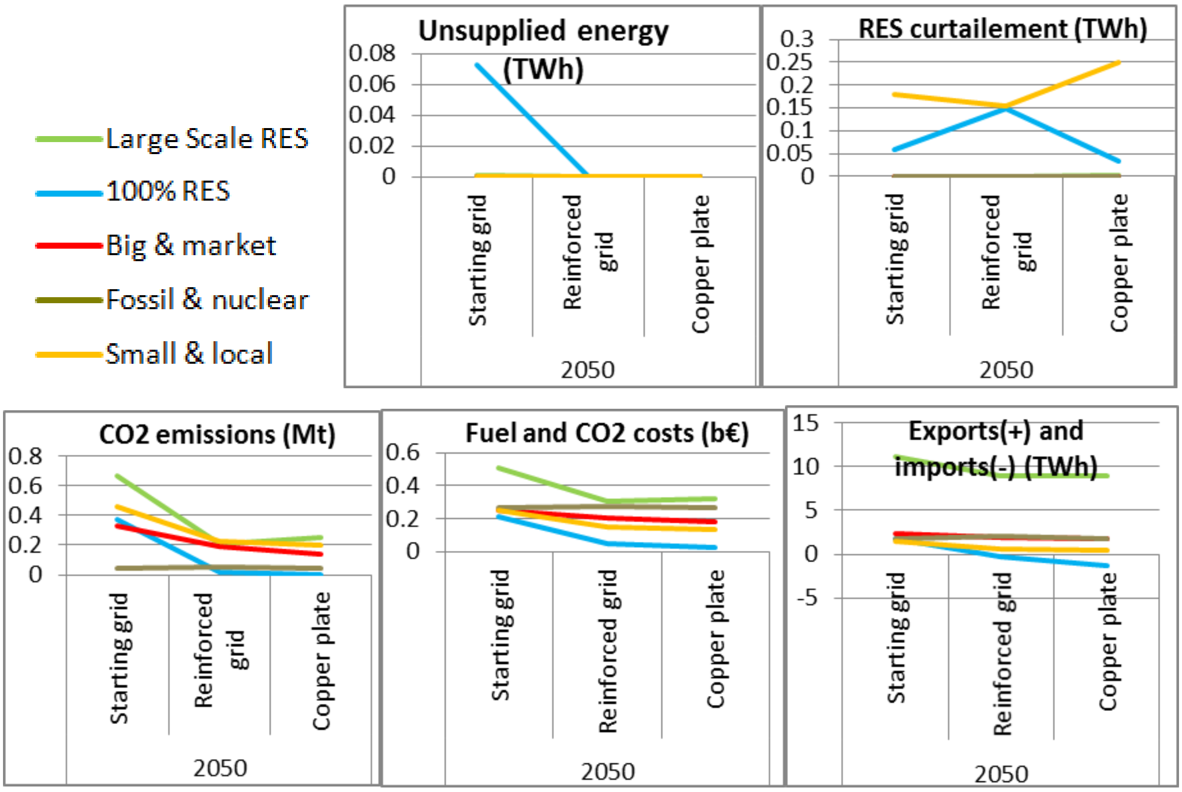
Impact of the grid reinforcements (2050)



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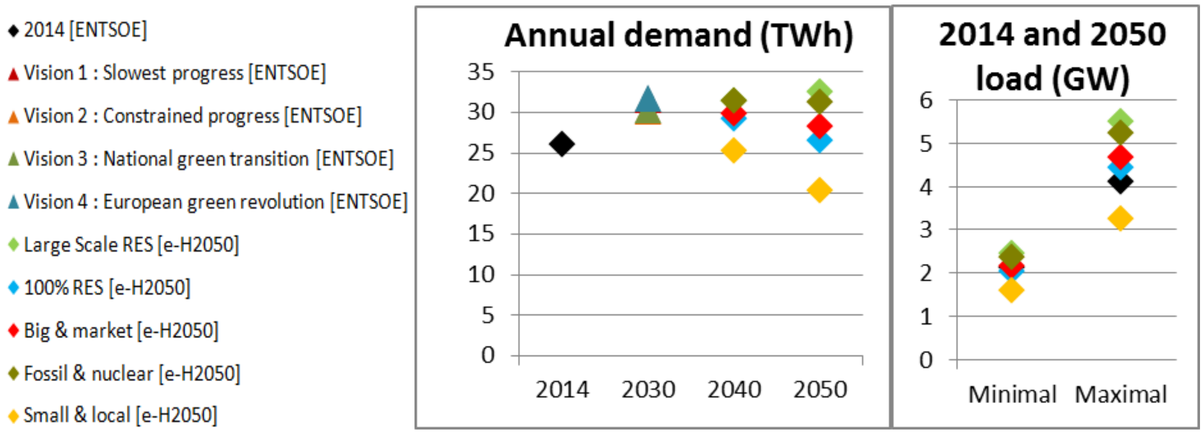
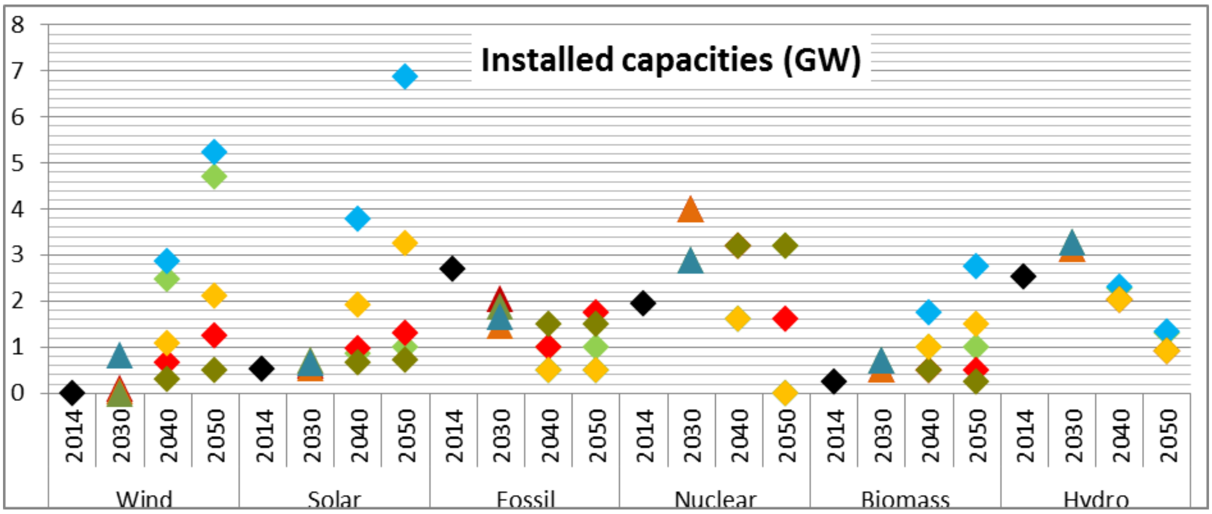
Slovak Republic

Demand and generation





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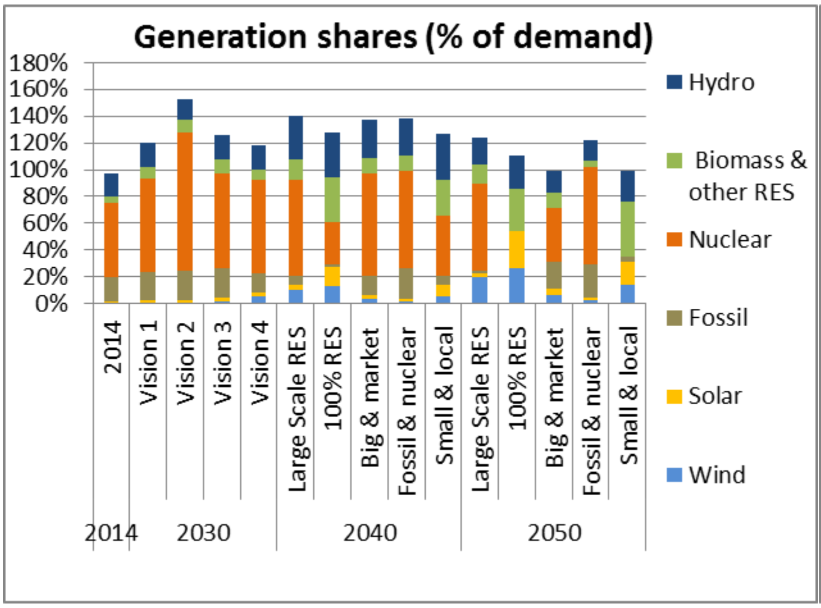
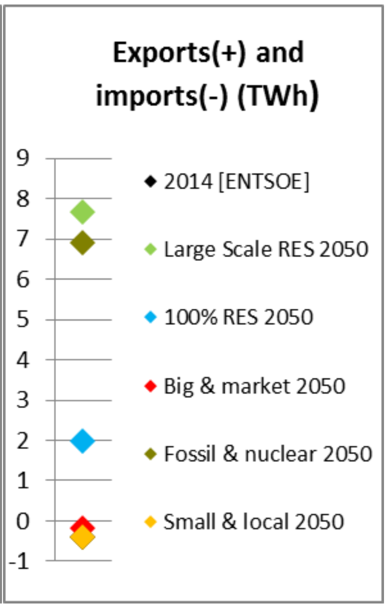
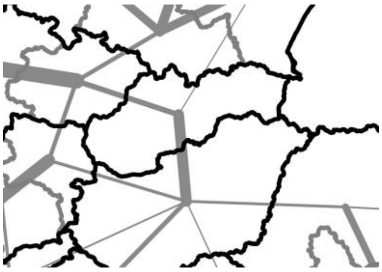


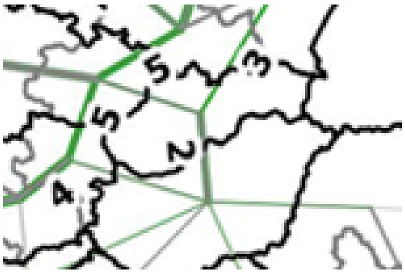


NB: Generation shares and imports/exports are here given in the case of a reinforced grid. RES curtailment is not subtracted from the generation in the left graph.

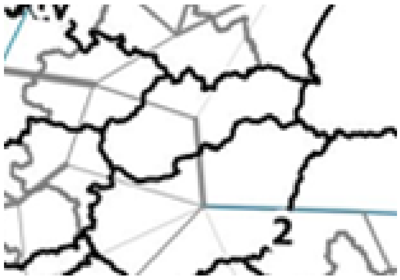
Grid reinforcements



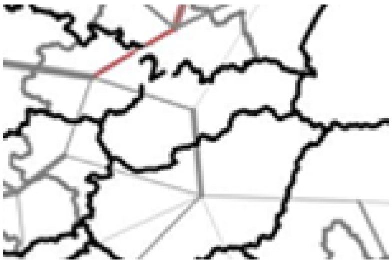
Common 2040 grid



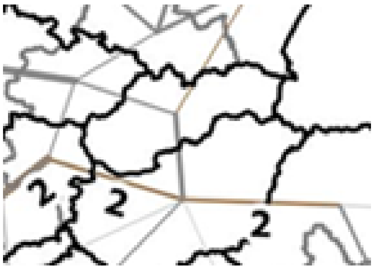
Large scale RES 2050



100% RES 2050



Big & market 2050

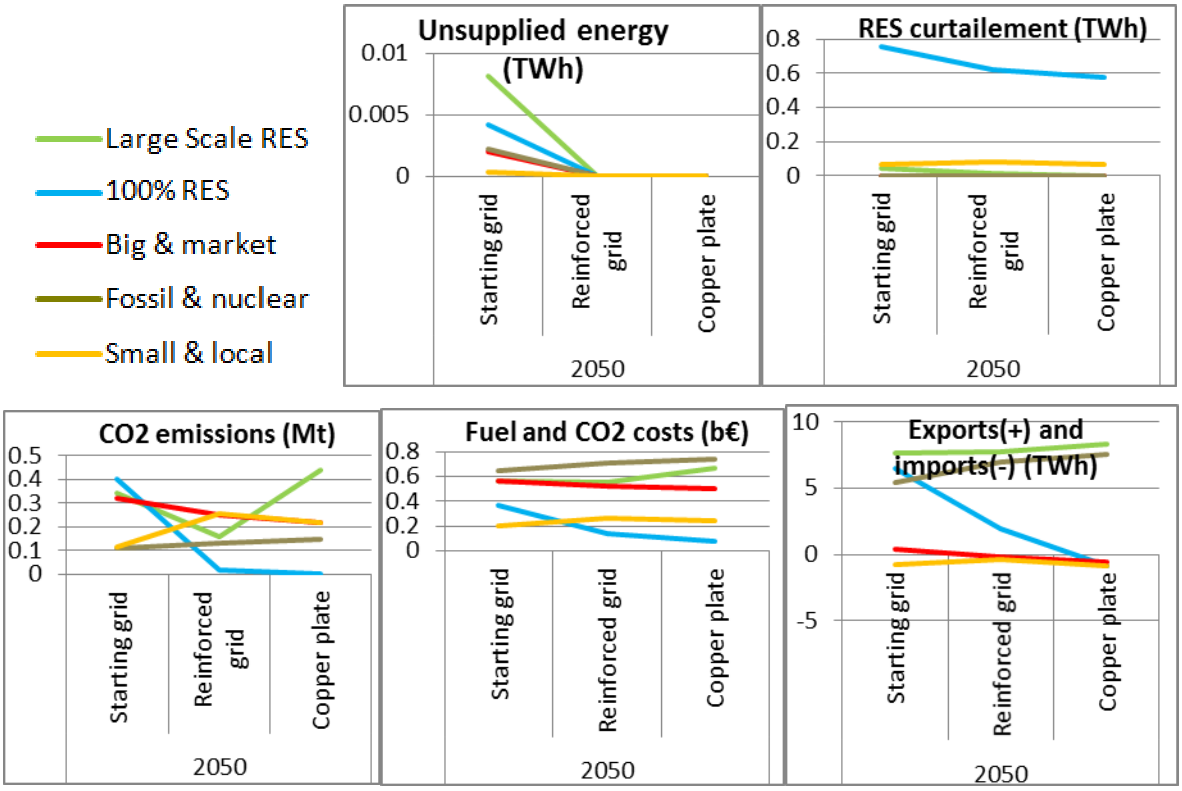


Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

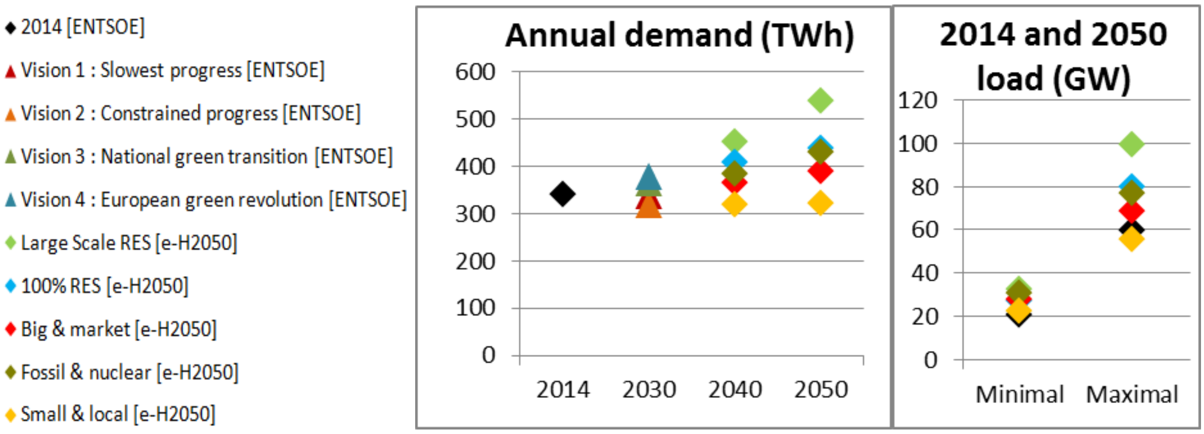
Impact of the grid reinforcements (2050)

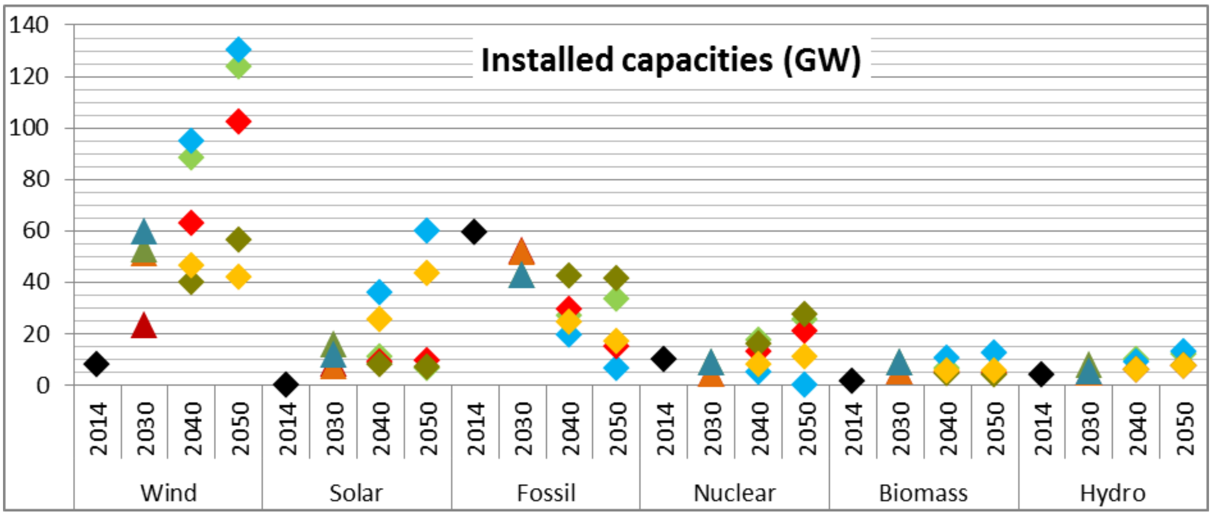


NB : The impact of the grid reinforcements can be difficult to analyse at a national level. For example, fuel and CO2 costs can increase to support more exports towards countries with more expensive generation. Also small increases of the unsupplied energy or of the RES curtailment can occur on a national level

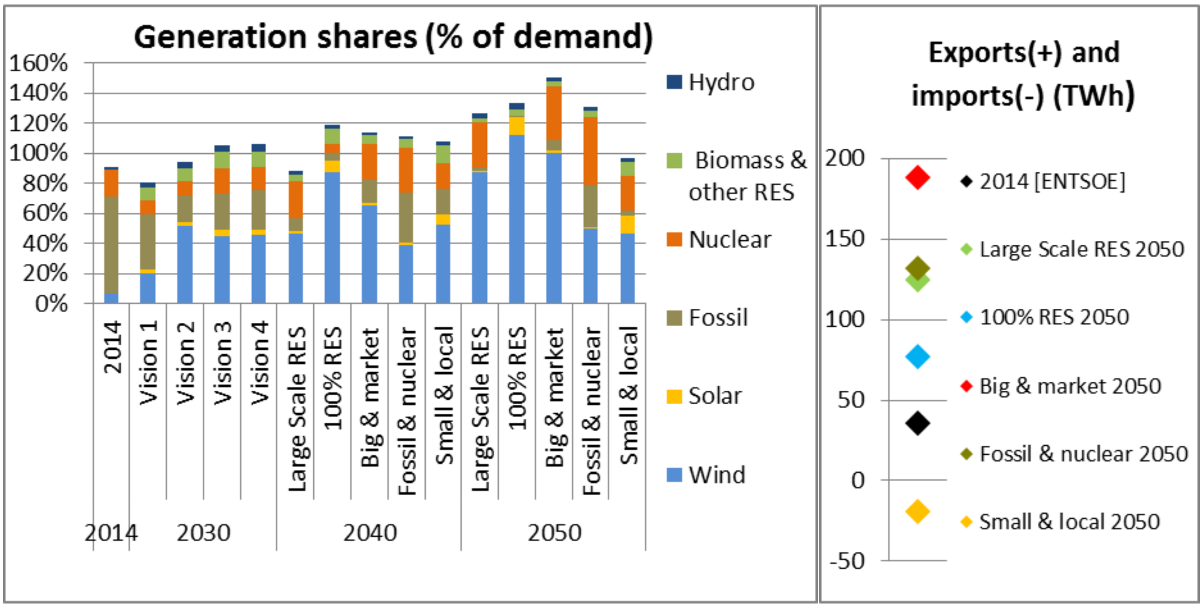
United Kingdom

Demand and generation





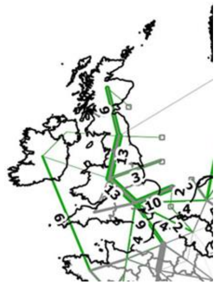
NB : Some surprising decreases of the wind or hydro capacity can be observed in some countries. This is due to some inconsistencies between the different datasets available and should be considered as an error margin.



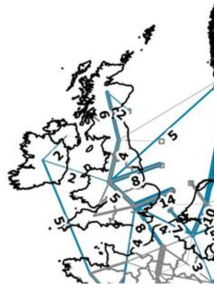
NB: Generation shares and imports/exports are here given in the case of a reinforced grid. RES curtailment is not subtracted from the generation in the left graph.

Grid reinforcements

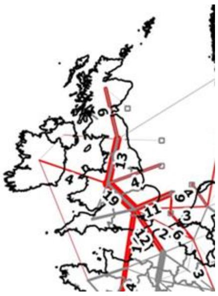
Common 2040 grid



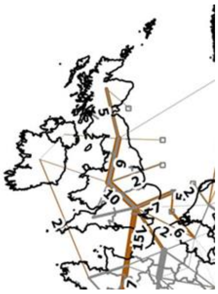
Large scale RES 2050



100% RES 2050



Big & market 2050

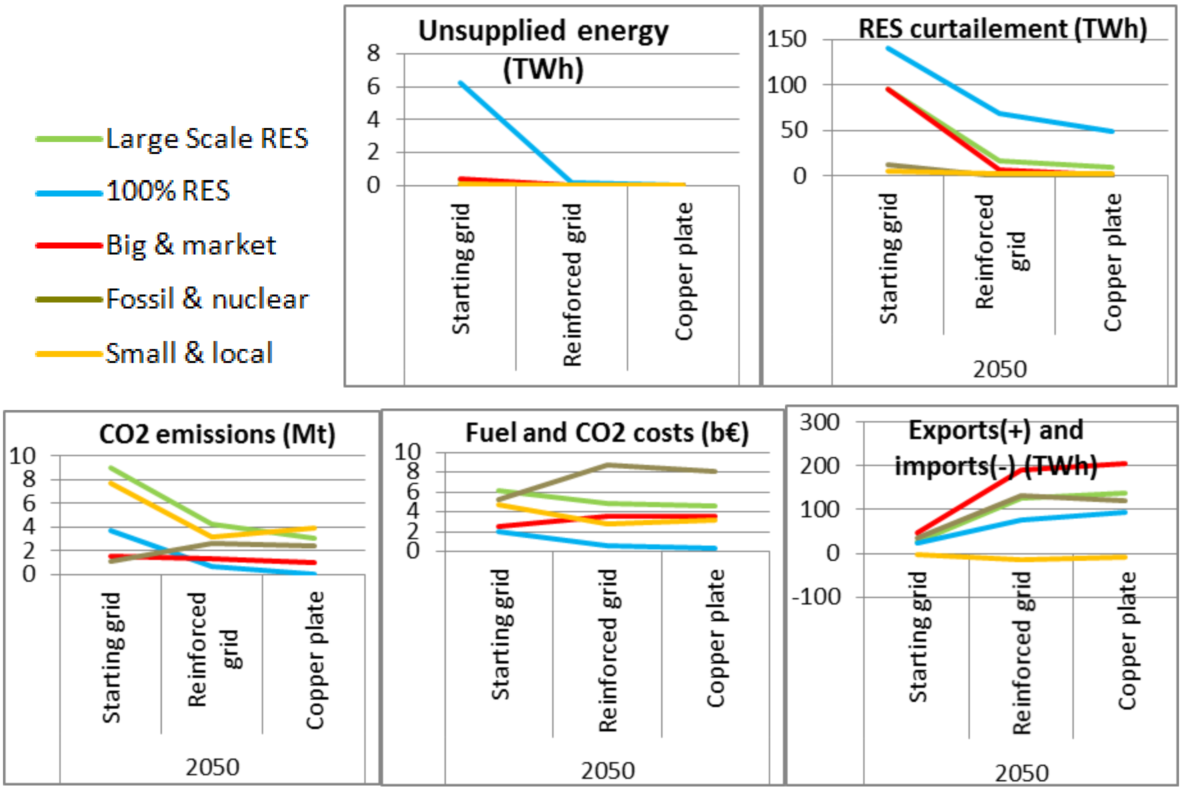


Fossil & nuclear 2050

Small & local 2050

Grey: 2030 starting grid, colours: reinforcements in GW

Impact of the grid reinforcements (2050)



NB : The impact of the grid reinforcements can be difficult to analyse at a national level. For example, fuel and CO2 costs can increase to support more exports towards countries with more expensive generation. Also small increases of the unsupplied energy or of the RES curtailment can occur on a national level

ANNEX 2 – Transmission Requirements

Table 38: Starting Grid for all scenarios in 2030

Links	Type	Length	Starting Grid (2030)				
			Large Scale RES	100% RES	Big & Market	Fossil & Nuclear	Small & Local
		km	MW	MW	MW	MW	MW
01_es - 02_es	AC	186	7,200	7,200	7,200	7,200	7,200
01_es - 12_pt	AC	204	1,200	1,200	1,200	1,200	1,200
02_es - 03_es	AC	186	19,100	19,100	19,100	19,100	19,100
02_es - 04_es	AC	302	2,400	2,400	2,400	2,400	2,400
02_es - 08_es	AC	335	2,400	2,400	2,400	2,400	2,400
02_es - 12_pt	AC	215	950	950	950	950	950
03_es - 04_es	AC	181	7,100	7,100	7,100	7,100	7,100
03_es - 05_es	AC	257	3,900	3,900	3,900	3,900	3,900
03_es - 07_es	AC	118	10,200	10,200	10,200	10,200	10,200
03_es - 11_es	AC	344	2,700	2,700	2,700	2,700	2,700
04_es - 05_es	AC	181	900	900	900	900	900
04_es - 14_fr	AC	238	2,000	2,000	2,000	2,000	2,000
05_es - 06_es	AC	185	7,000	7,000	7,000	7,000	7,000
05_es - 11_es	AC	259	5,700	5,700	5,700	5,700	5,700
05_es - 14_fr	AC	283	100	100	100	100	100
06_es - 11_es	AC	365	1,100	1,100	1,100	1,100	1,100
06_es - 15_fr	AC	272	1,800	1,800	1,800	1,800	1,800
07_es - 08_es	AC	183	8,700	8,700	8,700	8,700	8,700
07_es - 11_es	AC	265	2,100	2,100	2,100	2,100	2,100
08_es - 09_es	AC	234	6,100	6,100	6,100	6,100	6,100
08_es - 10_es	AC	223	4,000	4,000	4,000	4,000	4,000
08_es - 13_pt	AC	269	900	900	900	900	900
09_es - 10_es	AC	205	8,100	8,100	8,100	8,100	8,100
09_es - 102_ma	RoW	317	12,000	4,000	2,000	0	1,500
09_es - 13_pt	AC	299	500	500	500	500	500
10_es - 11_es	AC	269	3,200	3,200	3,200	3,200	3,200
100_ru - 73_ee	RoW	502	1,000	1,000	1,000	1,000	1,000
100_ru - 74_fi	RoW	809	70	70	70	70	70
100_ru - 75_fi	RoW	485	1,400	1,400	1,400	1,400	1,400
100_ru - 77_lt	RoW	803	1,900	1,900	1,900	1,900	1,900
100_ru - 78_lv	RoW	639	400	400	400	400	400
100_ua - 42_pl	RoW	217	1,000	1,000	1,000	1,000	1,000
100_ua - 58_hu	RoW	511	700	700	700	700	700
100_ua - 59_ro	RoW	386	700	700	700	700	700
101_mi - 66_bg	RoW	573	1,500	1,500	1,500	1,500	1,500
101_mi - 68_gr	RoW	785	2,000	2,000	2,000	2,000	2,000
101_mi - 69_gr	RoW	784	2,000	2,000	2,000	2,000	2,000
102_ma - 13_pt	RoW	590	5,000	1,500	0	0	0

103_dz - 10_es	RoW	654	6,000	2,000	0	0	0
103_dz - 16_fr	RoW	929	12,000	4,000	2,000	0	1,500
103_dz - 98_it	RoW	710	11,000	4,000	1,500	0	1,000
104_tn - 56_it	RoW	458	8,500	3,000	1,000	0	1,000
105_ly - 56_it	RoW	788	8,500	3,000	2,000	0	1,000
105_ly - 69_gr	RoW	918	6,000	2,000	0	0	0
106_ns - 90_uk	DC	217	8,000	8,000	5,000	5,000	885
107_ns - 92_uk	DC	295	6,023	5,580	4,350	2,550	443
108_ns - 93_uk	DC	231	1,004	930	725	425	74
109_ns - 94_uk	DC	162	1,004	930	725	425	74
110_ns - 28_be	DC	188	1,000	1,500	1,000	1,000	1,095
111_ns - 30_nl	DC	140	4,462	7,950	3,500	2,600	100
112_ns - 31_de	DC	210	8,000	8,000	5,000	5,000	3,800
113_ns - 38_dk	DC	128	8,000	8,000	5,000	1,500	653
114_ns - 72_dk	DC	171	3,904	3,200	2,375	500	218
115_ns - 79_no	DC	114	335	1,500	247	0	0
116_ns - 88_se	DC	286	335	1,500	247	150	100
12_pt - 13_pt	AC	214	4,000	4,000	4,000	4,000	4,000
14_fr - 15_fr	AC	189	2,000	2,000	2,000	2,000	2,000
14_fr - 17_fr	AC	308	3,000	3,000	3,000	3,000	3,000
14_fr - 18_fr	AC	360	1,100	1,100	1,100	1,100	1,100
15_fr - 16_fr	AC	254	3,500	3,500	3,500	3,500	3,500
15_fr - 18_fr	AC	306	4,500	4,500	4,500	4,500	4,500
16_fr - 19_fr	AC	173	5,200	5,200	5,200	5,200	5,200
16_fr - 20_fr	AC	237	450	450	450	450	450
17_fr - 18_fr	AC	190	4,200	4,200	4,200	4,200	4,200
17_fr - 21_fr	AC	244	5,400	5,400	5,400	5,400	5,400
17_fr - 22_fr	AC	248	250	250	250	250	250
18_fr - 19_fr	AC	257	2,200	2,200	2,200	2,200	2,200
18_fr - 23_fr	AC	191	10,000	10,000	10,000	10,000	10,000
18_fr - 24_fr	AC	181	125	125	125	125	125
19_fr - 20_fr	AC	136	6,000	6,000	6,000	6,000	6,000
19_fr - 24_fr	AC	272	2,500	2,500	2,500	2,500	2,500
19_fr - 52_it	DC	450	1,000	1,000	1,000	1,000	1,000
20_fr - 24_fr	AC	205	3,000	3,000	3,000	3,000	3,000
20_fr - 25_fr	AC	266	1,150	1,150	1,150	1,150	1,150
20_fr - 47_ch	AC	211	4,300	4,300	4,300	4,300	4,300
20_fr - 48_ch	AC	261	1,300	1,300	1,300	1,300	1,300
20_fr - 52_it	AC	353	4,800	4,800	4,800	4,800	4,800
21_fr - 22_fr	AC	211	7,000	7,000	7,000	7,000	7,000
21_fr - 96_ie	DC	682	700	700	700	700	700
22_fr - 23_fr	AC	184	2,400	2,400	2,400	2,400	2,400
22_fr - 26_fr	AC	216	3,200	3,200	3,200	3,200	3,200
22_fr - 90_uk	DC	313	1,000	1,000	1,000	1,000	1,000
23_fr - 24_fr	AC	196	3,500	3,500	3,500	3,500	3,500
23_fr - 25_fr	AC	306	4,000	4,000	4,000	4,000	4,000
23_fr - 26_fr	AC	147	17,900	17,900	17,900	17,900	17,900
23_fr - 27_fr	AC	167	1,100	1,100	1,100	1,100	1,100

24_fr - 25_fr	AC	169	4,200	4,200	4,200	4,200	4,200
25_fr - 27_fr	AC	179	3,500	3,500	3,500	3,500	3,500
25_fr - 28_be	AC	287	400	400	400	400	400
25_fr - 35_de	AC	246	2,100	2,100	2,100	2,100	2,100
25_fr - 36_de	AC	195	1,800	1,800	1,800	1,800	1,800
25_fr - 47_ch	AC	170	3,900	3,900	3,900	3,900	3,900
26_fr - 27_fr	AC	159	4,900	4,900	4,900	4,900	4,900
26_fr - 28_be	AC	175	2,900	2,900	2,900	2,900	2,900
26_fr - 90_uk	DC	275	2,000	2,000	2,000	2,000	2,000
27_fr - 28_be	AC	160	1,300	1,300	1,300	1,300	1,300
28_be - 29_lu	AC	152	700	700	700	700	700
28_be - 30_nl	AC	191	3,500	3,500	3,500	3,500	3,500
28_be - 33_de	DC	223	1,000	1,000	1,000	1,000	1,000
28_be - 90_uk	DC	353	1,000	1,000	1,000	1,000	1,000
29_lu - 35_de	AC	162	2,900	2,900	2,900	2,900	2,900
30_nl - 31_de	AC	271	1,400	1,400	1,400	1,400	1,400
30_nl - 33_de	AC	162	7,100	7,100	7,100	7,100	7,100
30_nl - 38_dk	DC	499	700	700	700	700	700
30_nl - 79_no	DC	739	700	700	700	700	700
30_nl - 90_uk	DC	390	1,000	1,000	1,000	1,000	1,000
31_de - 32_de	AC	228	5,400	5,400	5,400	5,400	5,400
31_de - 33_de	AC	219	17,330	17,330	17,330	17,330	17,330
31_de - 35_de	AC	333	6,300	6,300	6,300	6,300	6,300
31_de - 36_de	DC	510	2,000	2,000	2,000	2,000	2,000
31_de - 37_de	DC	488	4,000	4,000	4,000	4,000	4,000
31_de - 38_dk	AC	333	3,000	3,000	3,000	3,000	3,000
31_de - 79_no	DC	652	1,400	1,400	1,400	1,400	1,400
31_de - 89_se	DC	474	1,200	1,200	1,200	1,200	1,200
32_de - 34_de	AC	208	9,300	9,300	9,300	9,300	9,300
32_de - 44_pl	AC	264	3,400	3,400	3,400	3,400	3,400
32_de - 72_dk	DC	270	600	600	600	600	600
33_de - 35_de	AC	147	19,050	19,050	19,050	19,050	19,050
33_de - 36_de	DC	344	2,000	2,000	2,000	2,000	2,000
34_de - 35_de	AC	312	2,600	2,600	2,600	2,600	2,600
34_de - 37_de	AC	260	14,840	14,840	14,840	14,840	14,840
34_de - 39_cz	AC	200	1,700	1,700	1,700	1,700	1,700
34_de - 44_pl	AC	296	1,700	1,700	1,700	1,700	1,700
35_de - 36_de	AC	197	7,700	7,700	7,700	7,700	7,700
35_de - 37_de	AC	274	6,130	6,130	6,130	6,130	6,130
36_de - 37_de	AC	181	7,500	7,500	7,500	7,500	7,500
36_de - 47_ch	AC	175	6,000	6,000	6,000	6,000	6,000
36_de - 49_at	AC	281	2,800	2,800	2,800	2,800	2,800
37_de - 39_cz	AC	231	2,000	2,000	2,000	2,000	2,000
37_de - 49_at	AC	198	2,500	2,500	2,500	2,500	2,500
37_de - 50_at	AC	280	5,500	5,500	5,500	5,500	5,500
38_dk - 72_dk	DC	172	600	600	600	600	600
38_dk - 79_no	DC	335	1,700	1,700	1,700	1,700	1,700
38_dk - 88_se	DC	465	740	740	740	740	740

39_cz - 40_cz	AC	190	7,600	7,600	7,600	7,600	7,600
40_cz - 43_pl	AC	191	2,100	2,100	2,100	2,100	2,100
40_cz - 46_sk	AC	213	2,700	2,700	2,700	2,700	2,700
40_cz - 51_at	AC	166	2,100	2,100	2,100	2,100	2,100
41_pl - 42_pl	AC	215	4,700	4,700	4,700	4,700	4,700
41_pl - 43_pl	AC	302	4,900	4,900	4,900	4,900	4,900
41_pl - 44_pl	AC	338	3,400	3,400	3,400	3,400	3,400
41_pl - 45_pl	AC	219	4,400	4,400	4,400	4,400	4,400
41_pl - 77_lt	AC	349	1,000	1,000	1,000	1,000	1,000
42_pl - 43_pl	AC	212	4,300	4,300	4,300	4,300	4,300
42_pl - 46_sk	AC	298	600	600	600	600	600
43_pl - 44_pl	AC	296	4,000	4,000	4,000	4,000	4,000
44_pl - 45_pl	AC	227	8,900	8,900	8,900	8,900	8,900
45_pl - 89_se	DC	423	600	600	600	600	600
46_sk - 58_hu	AC	172	5,400	5,400	5,400	5,400	5,400
47_ch - 48_ch	AC	110	19,800	19,800	19,800	19,800	19,800
47_ch - 49_at	AC	332	900	900	900	900	900
48_ch - 49_at	AC	259	1,500	1,500	1,500	1,500	1,500
48_ch - 52_it	AC	158	8,500	8,500	8,500	8,500	8,500
49_at - 50_at	AC	177	6,300	6,300	6,300	6,300	6,300
49_at - 52_it	AC	262	2,300	2,300	2,300	2,300	2,300
50_at - 51_at	AC	119	6,100	6,100	6,100	6,100	6,100
50_at - 57_si	AC	168	1,600	1,600	1,600	1,600	1,600
51_at - 58_hu	AC	284	1,600	1,600	1,600	1,600	1,600
52_it - 53_it	AC	264	2,200	2,200	2,200	2,200	2,200
52_it - 57_si	AC	356	3,600	3,600	3,600	3,600	3,600
53_it - 54_it	AC	192	2,000	2,000	2,000	2,000	2,000
53_it - 62_hr	DC	457	1,000	1,000	1,000	1,000	1,000
53_it - 99_fr	DC	263	300	300	300	300	300
54_it - 55_it	AC	301	10,000	10,000	10,000	10,000	10,000
54_it - 64_me	DC	499	1,000	1,000	1,000	1,000	1,000
54_it - 98_it	DC	429	700	700	700	700	700
55_it - 56_it	AC	357	1,100	1,100	1,100	1,100	1,100
55_it - 68_gr	DC	463	1,000	1,000	1,000	1,000	1,000
55_it - 70_al	DC	335	1,000	1,000	1,000	1,000	1,000
57_si - 58_hu	AC	384	900	900	900	900	900
57_si - 62_hr	AC	161	3,400	3,400	3,400	3,400	3,400
58_hu - 59_ro	AC	315	1,400	1,400	1,400	1,400	1,400
58_hu - 62_hr	AC	274	2,300	2,300	2,300	2,300	2,300
58_hu - 65_rs	AC	367	700	700	700	700	700
59_ro - 60_ro	AC	203	3,500	3,500	3,500	3,500	3,500
59_ro - 61_ro	AC	300	900	900	900	900	900
60_ro - 61_ro	AC	270	4,700	4,700	4,700	4,700	4,700
60_ro - 65_rs	AC	285	2,500	2,500	2,500	2,500	2,500
60_ro - 66_bg	AC	249	800	800	800	800	800
61_ro - 66_bg	AC	390	900	900	900	900	900
62_hr - 63_ba	AC	182	4,000	4,000	4,000	4,000	4,000
62_hr - 65_rs	AC	372	700	700	700	700	700

63_ba - 64_me	AC	200	1,400	1,400	1,400	1,400	1,400
63_ba - 65_rs	AC	242	3,100	3,100	3,100	3,100	3,100
64_me - 65_rs	AC	180	2,900	2,900	2,900	2,900	2,900
64_me - 70_al	AC	190	900	900	900	900	900
65_rs - 66_bg	AC	383	900	900	900	900	900
65_rs - 67_mk	AC	272	1,900	1,900	1,900	1,900	1,900
65_rs - 70_al	AC	325	900	900	900	900	900
66_bg - 67_mk	AC	308	700	700	700	700	700
66_bg - 68_gr	AC	430	500	500	500	500	500
67_mk - 68_gr	AC	183	600	600	600	600	600
67_mk - 70_al	AC	160	700	700	700	700	700
68_gr - 69_gr	AC	254	11,600	11,600	11,600	11,600	11,600
68_gr - 70_al	AC	181	800	800	800	800	800
72_dk - 89_se	AC	168	1,700	1,700	1,700	1,700	1,700
73_ee - 75_fi	DC	404	1,000	1,000	1,000	1,000	1,000
73_ee - 78_lv	AC	204	950	950	950	950	950
74_fi - 75_fi	AC	498	3,500	3,500	3,500	3,500	3,500
74_fi - 85_no	AC	315	50	50	50	50	50
74_fi - 86_se	AC	286	1,800	1,800	1,800	1,800	1,800
75_fi - 88_se	AC	690	1,350	1,350	1,350	1,350	1,350
77_lt - 78_lv	AC	182	1,500	1,500	1,500	1,500	1,500
77_lt - 88_se	DC	698	700	700	700	700	700
79_no - 80_no	AC	152	1,500	1,500	1,500	1,500	1,500
79_no - 81_no	AC	216	1,700	1,700	1,700	1,700	1,700
79_no - 93_uk	DC	719	1,400	1,400	1,400	1,400	1,400
80_no - 81_no	AC	143	1,500	1,500	1,500	1,500	1,500
80_no - 82_no	AC	172	5,300	5,300	5,300	5,300	5,300
81_no - 83_no	AC	283	800	800	800	800	800
82_no - 83_no	AC	188	400	400	400	400	400
82_no - 88_se	AC	323	2,148	2,148	2,148	2,148	2,148
83_no - 84_no	AC	488	200	200	200	200	200
83_no - 87_se	AC	316	1,000	1,000	1,000	1,000	1,000
84_no - 85_no	AC	497	700	700	700	700	700
84_no - 86_se	AC	234	700	700	700	700	700
84_no - 87_se	AC	363	250	250	250	250	250
86_se - 87_se	AC	407	4,200	4,200	4,200	4,200	4,200
87_se - 88_se	AC	499	7,300	7,300	7,300	7,300	7,300
88_se - 89_se	AC	307	6,500	6,500	6,500	6,500	6,500
90_uk - 91_uk	AC	232	7,600	7,600	7,600	7,600	7,600
90_uk - 92_uk	AC	196	8,000	8,000	8,000	8,000	8,000
91_uk - 92_uk	AC	204	5,000	5,000	5,000	5,000	5,000
92_uk - 93_uk	AC	239	7,900	7,900	7,900	7,900	7,900
92_uk - 96_ie	DC	385	500	500	500	500	500
93_uk - 94_uk	AC	273	4,500	4,500	4,500	4,500	4,500
93_uk - 95_uk	DC	287	500	500	500	500	500
95_uk - 96_ie	AC	188	1,100	1,100	1,100	1,100	1,100
98_it - 99_fr	DC	229	400	400	400	400	400
Sum		**69,113**	**796,299**	**755,823**	**721,902**	**704,383**	**698,673**

Table 39: Transmission requirements for 2040 and all scenarios in 2050

Links	Type	Length	2040 Additional		2050 Additional Grid				
			Common grid	Extended grid	Large Scale RES	100% RES	Big & Market	Fossil & Nuclear	Small & Local
		km	MW	MW	MW	MW	MW	MW	MW
01_es - 02_es	AC	186	0	0	0	2,000	0	0	1,000
01_es - 03_es	new	372	0	0	0	0	0	2,000	0
01_es - 12_pt	AC	204	0	0	1,000	1,000	1,000	1,000	0
02_es - 07_es	new	260	0	0	0	0	0	0	1,000
02_es - 08_es	AC	335	0	0	1,000	0	0	0	0
02_es - 12_pt	AC	215	0	0	1,000	1,000	0	0	0
03_es - 04_es	AC	181	0	0	2,000	2,000	0	0	0
03_es - 07_es	AC	118	0	0	2,000	1,000	0	0	1,000
04_es - 07_es	new	276	0	0	0	0	0	0	7,000
04_es - 14_fr	AC	238	3,000	4,000	5,000	5,000	6,000	7,000	8,000
05_es - 07_es	new	280	0	0	0	0	0	0	1,000
06_es - 07_es	new	463	0	0	0	0	0	0	2,000
06_es - 11_es	AC	365	2,000	3,000	4,000	2,000	6,000	9,000	0
06_es - 15_fr	AC	272	5,000	6,000	10,000	8,000	14,000	13,000	0
07_es - 08_es	AC	183	0	0	2,000	0	0	0	3,000
07_es - 11_es	AC	265	0	0	2,000	0	1,000	5,000	1,000
07_es - 12_pt	new	343	0	0	0	0	0	0	2,000
08_es - 09_es	AC	234	0	0	0	0	0	0	1,000
08_es - 10_es	AC	223	0	0	0	0	0	0	1,000
08_es - 13_pt	AC	269	0	0	2,000	0	0	0	1,000
09_es - 13_pt	AC	299	0	0	2,000	2,000	2,000	2,000	0
10_es - 11_es	AC	269	0	0	1,000	0	0	0	0
106_ns - 110_ns	new	105	0	2,000	2,000	0	6,000	5,000	0
106_ns - 90_uk	DC	217	0	0	10,000	14,000	11,000	7,000	1,000
107_ns - 92_uk	DC	295	0	0	3,000	8,000	4,000	2,000	1,000
108_ns - 93_uk	DC	231	0	0	1,000	0	0	1,000	0
109_ns - 94_uk	DC	162	0	0	1,000	2,000	0	1,000	0
110_ns - 28_be	DC	188	0	0	2,000	7,000	6,000	6,000	1,000
111_ns - 30_nl	DC	140	0	0	2,000	1,000	4,000	2,000	0
112_ns - 113_ns	new	198	0	3,000	9,000	12,000	0	1,000	0
112_ns - 30_nl	new	261	0	0	0	0	0	2,000	0
112_ns - 31_de	DC	210	0	0	10,000	5,000	7,000	3,000	3,000
112_ns - 33_de	new	331	0	0	0	6,000	0	0	0
113_ns - 30_nl	new	455	0	0	0	5,000	0	0	0
113_ns - 38_dk	DC	128	0	0	9,000	0	4,000	1,000	1,000
114_ns - 116_ns	new	173	0	0	1,000	0	0	0	0
114_ns - 72_dk	DC	171	0	0	2,000	0	0	1,000	0
115_ns - 79_no	DC	114	0	0	0	5,000	0	0	0
116_ns - 88_se	DC	286	0	0	1,000	0	0	1,000	0
12_pt - 13_pt	AC	214	0	0	1,000	0	0	0	0
14_fr - 15_fr	AC	189	2,000	3,000	0	3,000	8,000	10,000	0
14_fr - 17_fr	AC	308	5,000	6,000	4,000	6,000	14,000	15,000	7,000

14_fr - 18_fr	AC	360	0	0	1,000	0	0	0	0
15_fr - 16_fr	AC	254	2,000	2,000	8,000	4,000	2,000	1,000	0
16_fr - 19_fr	AC	173	0	0	2,000	0	0	0	0
16_fr - 20_fr	AC	237	0	0	1,000	0	0	2,000	0
17_fr - 21_fr	AC	244	0	0	1,000	3,000	0	0	0
17_fr - 22_fr	AC	248	5,000	7,000	3,000	6,000	14,000	17,000	7,000
18_fr - 19_fr	AC	257	0	0	2,000	0	0	0	0
18_fr - 24_fr	AC	181	0	0	2,000	0	0	1,000	0
19_fr - 20_fr	AC	136	0	0	1,000	0	0	0	0
19_fr - 52_it	DC	450	0	0	1,000	0	0	0	0
20_fr - 25_fr	AC	266	0	0	0	3,000	0	0	0
20_fr - 52_it	AC	353	0	0	1,000	0	0	0	0
21_fr - 96_ie	DC	682	2,000	2,000	6,000	5,000	1,000	2,000	2,000
22_fr - 23_fr	AC	184	0	0	1,000	0	0	0	0
22_fr - 26_fr	AC	216	0	0	1,000	0	0	0	0
22_fr - 90_uk	DC	313	4,000	6,000	4,000	4,000	14,000	15,000	3,000
24_fr - 25_fr	AC	169	0	0	0	0	0	1,000	0
25_fr - 28_be	AC	287	0	0	0	3,000	3,000	0	2,000
25_fr - 35_de	AC	246	0	0	0	5,000	0	0	0
25_fr - 36_de	AC	195	0	0	1,000	0	0	2,000	1,000
26_fr - 90_uk	DC	275	4,000	5,000	9,000	8,000	12,000	7,000	1,000
28_be - 30_nl	AC	191	0	0	0	10,000	0	0	0
28_be - 33_de	DC	223	0	0	0	5,000	0	0	0
28_be - 90_uk	DC	353	0	2,000	4,000	4,000	2,000	2,000	0
30_nl - 31_de	AC	271	0	0	1,000	0	0	0	0
30_nl - 38_dk	DC	499	0	0	3,000	0	0	0	0
30_nl - 79_no	DC	739	3,000	4,000	7,000	14,000	4,000	3,000	0
30_nl - 90_uk	DC	390	0	0	4,000	0	3,000	0	0
31_de - 32_de	AC	228	0	0	0	1,000	0	0	0
31_de - 33_de	AC	219	0	2,000	12,000	0	0	0	0
31_de - 37_de	DC	488	0	0	4,000	0	0	0	0
31_de - 38_dk	AC	333	2,000	3,000	11,000	0	6,000	1,000	0
31_de - 72_dk	new	308	0	0	4,000	0	0	0	0
31_de - 79_no	DC	652	3,000	4,000	17,000	9,000	2,000	0	0
31_de - 89_se	DC	474	0	0	0	4,000	0	4,000	0
32_de - 38_dk	new	400	0	0	0	0	2,000	0	0
32_de - 72_dk	DC	270	0	0	2,000	0	0	0	0
32_de - 89_se	new	386	3,000	4,000	8,000	11,000	3,000	2,000	6,000
34_de - 35_de	AC	312	0	0	0	5,000	0	0	0
34_de - 37_de	AC	260	0	0	0	4,000	0	0	0
34_de - 44_pl	AC	296	2,000	2,000	3,000	10,000	2,000	0	0
36_de - 37_de	AC	181	0	0	0	0	0	2,000	0
37_de - 39_cz	AC	231	0	0	1,000	0	0	2,000	0
37_de - 49_at	AC	198	0	2,000	1,000	8,000	0	2,000	1,000
38_dk - 72_dk	DC	172	0	0	1,000	0	0	0	0
38_dk - 79_no	DC	335	0	0	2,000	0	0	1,000	0
38_dk - 88_se	DC	465	0	0	0	0	0	0	4,000
39_cz - 40_cz	AC	190	0	0	1,000	0	0	0	0

39_cz - 44_pl	new	289	0	0	0	2,000	0	0	0
40_cz - 43_pl	AC	191	0	0	5,000	0	2,000	0	0
40_cz - 46_sk	AC	213	0	0	1,000	0	0	0	0
40_cz - 51_at	AC	166	0	0	5,000	0	0	0	0
41_pl - 43_pl	AC	302	0	0	4,000	0	2,000	0	0
41_pl - 44_pl	AC	338	0	0	0	6,000	0	0	0
41_pl - 77_lt	AC	349	3,000	4,000	8,000	8,000	7,000	2,000	6,000
42_pl - 46_sk	AC	298	0	0	3,000	0	0	1,000	0
43_pl - 44_pl	AC	296	0	0	2,000	0	0	0	0
44_pl - 45_pl	AC	227	0	0	2,000	0	0	0	0
45_pl - 89_se	DC	423	0	0	0	0	3,000	2,000	0
46_sk - 58_hu	AC	172	0	0	2,000	0	0	0	0
49_at - 50_at	AC	177	0	0	4,000	0	0	2,000	0
49_at - 52_it	AC	262	2,000	2,000	4,000	8,000	0	2,000	2,000
50_at - 51_at	AC	119	0	0	4,000	0	0	2,000	0
51_at - 58_hu	AC	284	0	0	1,000	0	0	2,000	1,000
52_it - 53_it	AC	264	3,000	4,000	11,000	8,000	0	2,000	11,000
53_it - 54_it	AC	192	3,000	4,000	11,000	8,000	0	2,000	11,000
53_it - 99_fr	DC	263	0	0	0	0	2,000	1,000	0
54_it - 55_it	AC	301	3,000	4,000	11,000	8,000	0	2,000	8,000
54_it - 64_me	DC	499	0	0	1,000	2,000	0	0	0
54_it - 98_it	DC	429	2,000	2,000	8,000	3,000	2,000	1,000	3,000
55_it - 56_it	AC	357	2,000	3,000	9,000	2,000	2,000	1,000	4,000
55_it - 68_gr	DC	463	3,000	4,000	6,000	9,000	2,000	2,000	6,000
57_si - 58_hu	AC	384	0	0	1,000	0	0	0	1,000
58_hu - 59_ro	AC	315	0	0	1,000	2,000	0	2,000	0
58_hu - 65_rs	AC	367	0	0	1,000	0	0	0	1,000
59_ro - 61_ro	AC	300	0	0	0	2,000	0	0	0
65_rs - 66_bg	AC	383	0	0	0	0	0	2,000	0
65_rs - 67_mk	AC	272	0	0	1,000	0	0	0	0
66_bg - 68_gr	AC	430	0	0	0	1,000	0	0	1,000
67_mk - 68_gr	AC	183	0	0	2,000	0	0	0	0
72_dk - 89_se	AC	168	0	0	4,000	0	0	0	0
73_ee - 75_fi	DC	404	2,000	3,000	5,000	4,000	3,000	2,000	5,000
73_ee - 78_lv	AC	204	2,000	3,000	5,000	4,000	3,000	2,000	5,000
74_fi - 75_fi	AC	498	0	0	0	0	1,000	2,000	2,000
74_fi - 85_no	AC	315	0	0	1,000	0	0	0	0
75_fi - 88_se	AC	690	0	0	3,000	0	0	0	0
77_lt - 78_lv	AC	182	2,000	3,000	5,000	3,000	4,000	2,000	5,000
77_lt - 88_se	DC	698	0	0	2,000	0	0	0	0
79_no - 80_no	AC	152	0	2,000	3,000	4,000	2,000	5,000	0
79_no - 81_no	AC	216	3,000	4,000	17,000	12,000	2,000	0	0
79_no - 92_uk	new	902	0	0	0	5,000	0	0	0
80_no - 82_no	AC	172	0	0	0	1,000	2,000	4,000	0
81_no - 83_no	AC	283	2,000	3,000	7,000	7,000	0	0	9,000
81_no - 90_uk	new	1,066	0	2,000	0	0	0	0	12,000
82_no - 83_no	AC	188	0	0	0	0	0	3,000	0
82_no - 88_se	AC	323	0	0	2,000	0	0	0	0

83_no - 84_no	AC	488	2,000	2,000	5,000	5,000	0	3,000	2,000
84_no - 85_no	AC	497	0	0	0	1,000	0	0	0
86_se - 87_se	AC	407	2,000	3,000	5,000	4,000	1,000	3,000	5,000
87_se - 88_se	AC	499	3,000	5,000	8,000	9,000	4,000	4,000	8,000
88_se - 89_se	AC	307	3,000	4,000	9,000	7,000	4,000	5,000	5,000
90_uk - 92_uk	AC	196	5,000	7,000	13,000	5,000	19,000	10,000	6,000
92_uk - 93_uk	AC	239	4,000	5,000	13,000	4,000	13,000	9,000	0
92_uk - 96_ie	DC	385	0	0	1,000	2,000	4,000	1,000	0
93_uk - 94_uk	AC	273	3,000	4,000	9,000	6,000	6,000	5,000	0
93_uk - 95_uk	DC	287	0	0	1,000	0	1,000	1,000	0
95_uk - 96_ie	AC	188	0	0	1,000	2,000	0	0	0
98_it - 99_fr	DC	229	0	0	800	0	0	0	0
Sum		**44,980**	**101,000**	**149,000**	**451,800**	**378,000**	**255,000**	**253,000**	**190,000**

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[1] Statistical Factsheet 2014
https://www.entsoe.eu/Documents/Publications/Statistics/Factsheet/entsoe_sfs2014_web.pdf

[2] D 2.1 - Data sets of scenarios developed for 2050

[3] D 2.2 - European cluster model of the pan-European transmission grid

[4] D 2.3 - System simulations analysis and overlay-grid development

[5] D 4.3 - Data sets of scenarios and intermediate grid architectures for 2040