Navigating the Roadmap for Clean, Secure and Efficient Energy Innovation

SET-Nav
Strategic Energy Roadmap

REGIONAL WORKSHOP

Pathways analysis results for the electricity network development

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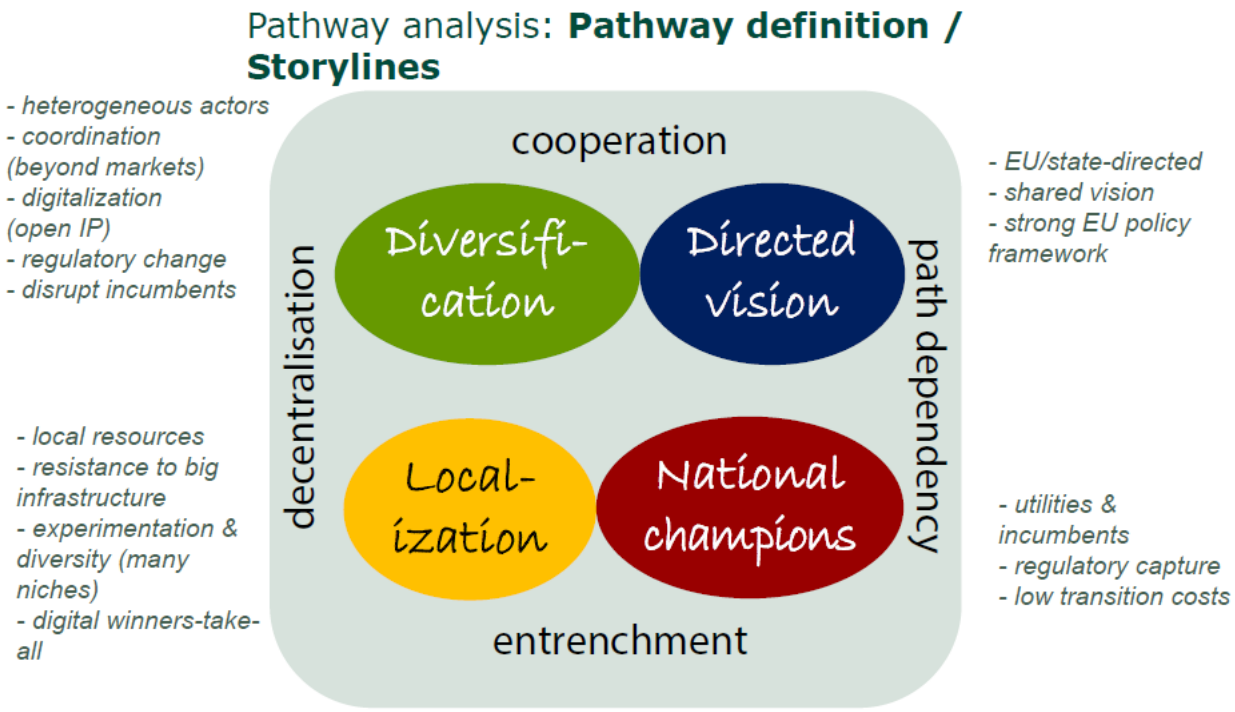
Introduction: The network that will support the energy transition

Grids are the backbone of the power system:

- Transmission capacity is necessary to integrate large-scale renewable projects (Directed Vision)
- It can provide support for the increasing amounts of renewable penetration (Diversification).
- Increasing the connection capacity is essential to support large cross-border flows (Directed Vision).
- Network investments might be necessary also to reduce market power (National Champions).
- Moreover, new capacity is needed to relieve recurrent congestions, reduce system losses or improve stability issues.



TWO MODELS FOR AN INTEGRATED PERSPECTIVE: **ENERTILE**

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enertile

- Enertile is an **energy-system optimization model** developed at the Fraunhofer ISI Institute for System and Innovation Research
- It **focuses on the power sector** but includes others (heating/cooling, transport)
- It has a **high technical and temporal resolution**
- Includes conventional generation, renewables, CHP or DSM
- The **potential for RES** is calculated at a very **detailed (grid) level**

Zonal level. Nodes indicated as dots.

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TWO MODELS FOR AN INTEGRATED PERSPECTIVE: **TEPES**

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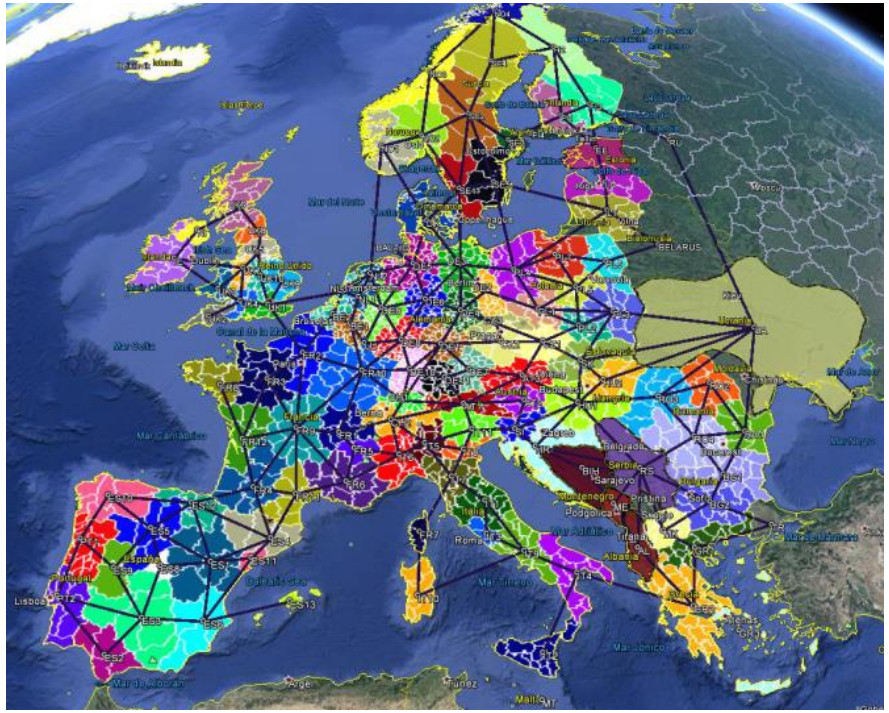
- TEPES performs **power transmission expansion planning** for large-scale systems, developed at Comillas Pontifical University.
- It considers a detailed description of the grid (around 250 nodes, linearized power flows with ohmic losses) and around 80 time snapshots to represent the yearly system operation.
- The model identifies the **main optimal transmission corridors to reinforce**.
- TEPES is dynamic and stochastic (in demand, RES, etc.)
- **Candidate lines** are **proposed by the model** and include HVDC and PSTs.
- Returns detailed grid costs and operation, nodal prices, …



Detailed transmission grid

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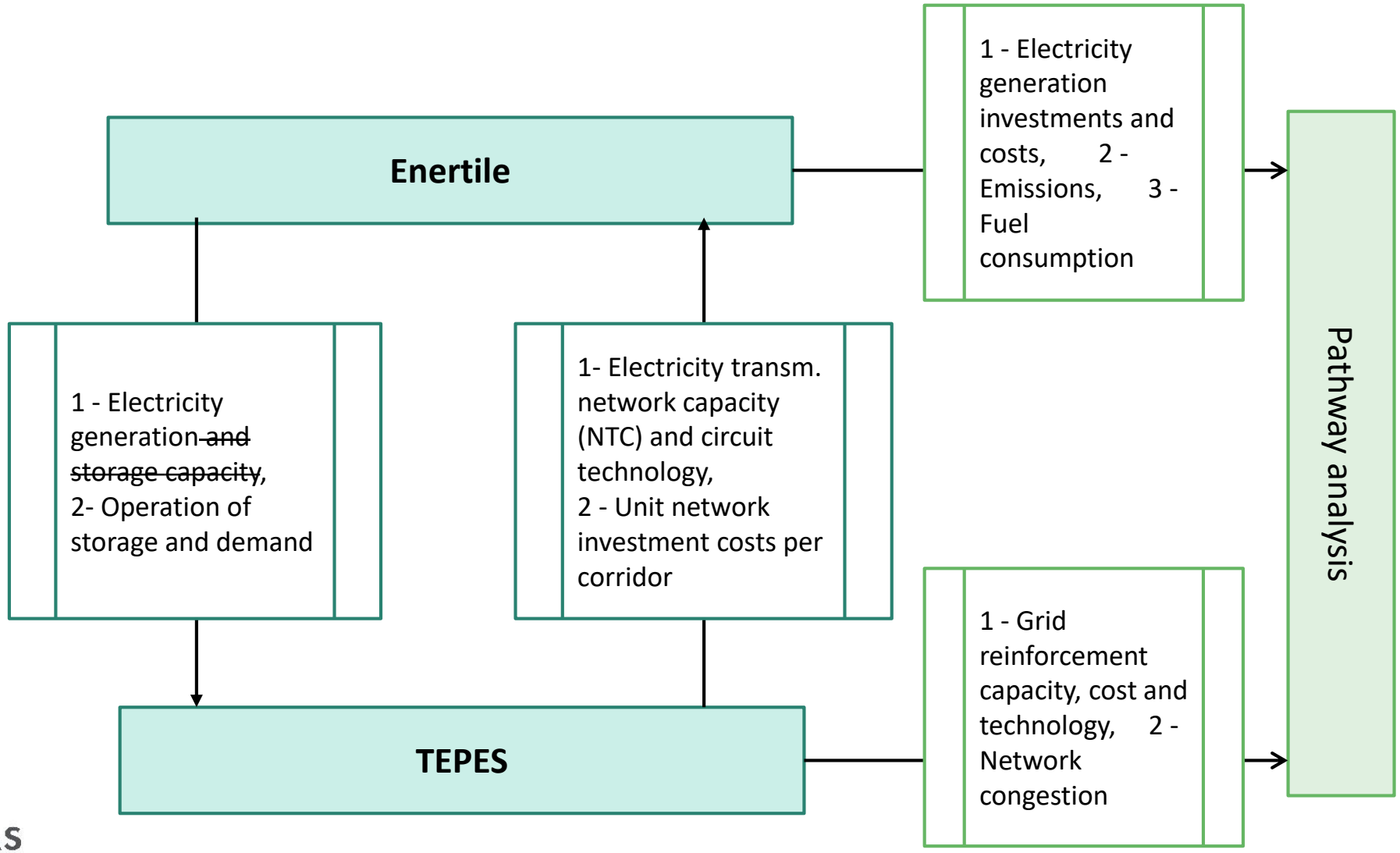
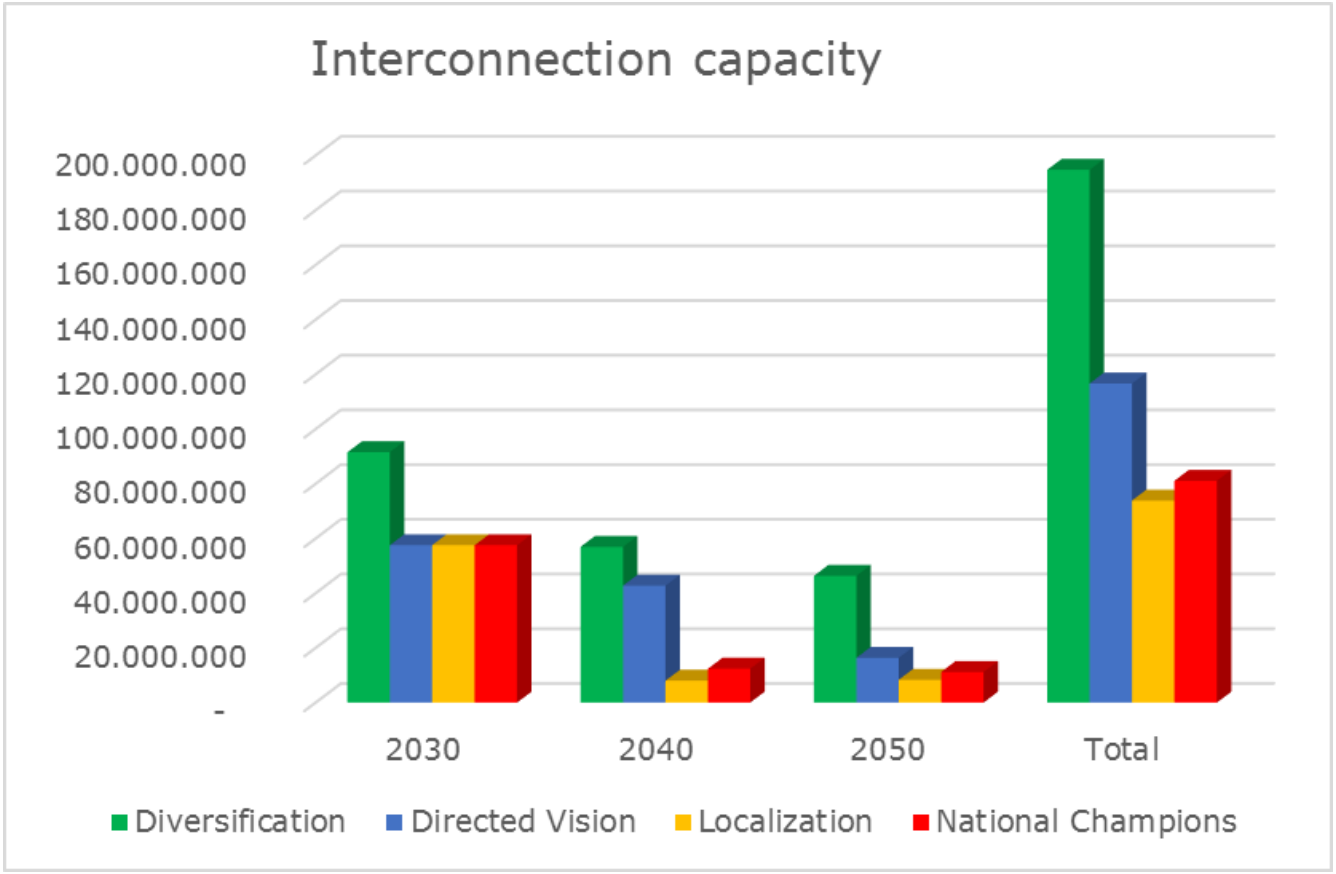
Model Interactions



OVERALL PRELIMINARY RESULTS (CAPACITY)

- *Diversification* has the greatest need for network investments, which arise from the need to provide backup for the renewable generation.
- The *directed vision* pathway follows at a considerably lower cost. This has to do with integrating the new large renewable plants.
- The *Localization* and *National Champions* pathways still present considerable needs for transmission upgrades, although they are less than half the necessary in the diversification pathway.
- The time dynamics are very different in the different pathways.

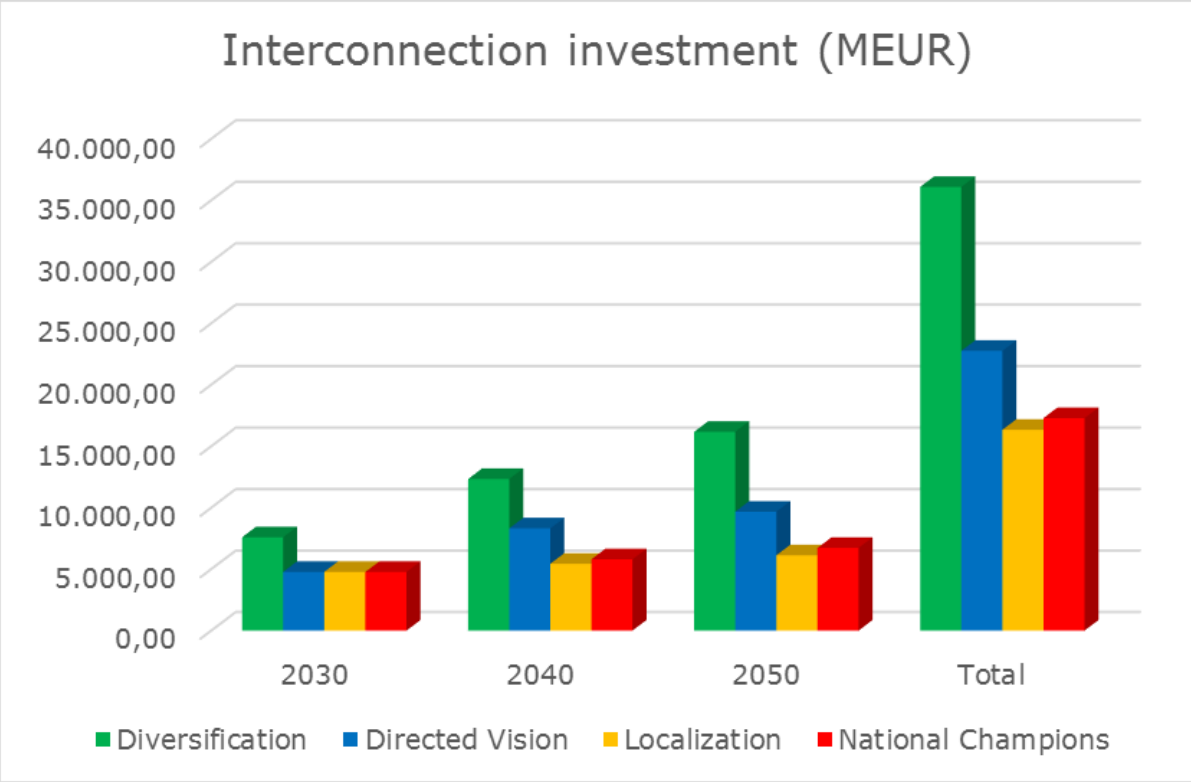


Interconnection capacity represents the sum of the capacities of all the lines of the system (MW)

Preliminary results

OVERALL PRELIMINARY RESULTS (COST)

- The *Diversification* pathway is the most expensive in terms of network costs, and the three others are quite similar.
- Investment increases with time in all the pathways.
- This effect is more relevant in the case of the *Diversification* pathway, which has the highest associated cost.
- This makes it easier to dynamically adapt to the development of the system.



DIVERSIFICATION

- Substantial investment is needed to provide backing capacity.
- Extensive capacity enhancements are needed between Spain and France.
- A more interconnected central Europe is needed, with Germany increasing the connection to many of its neighbors.
- The interconnection between the UK and Continental Europe is increased.
- Some capacity is installed in the Nordic Region –the storage of Europe- and to interconnect it to Central Europe.

	Diversification
DE_0	147.792,99
FR_0	131.608,41
PL_0	78.496,99
UK_0	48.247,00
ES_0	47.282,99
DK_0	40.748,00
IT_0	39.477,42
NO_0	34.567,00
SE_0	32.942,00
BE_0	32.431,00
CH_0	26.666,00

ES_0	FR_0	40.895,99
DE_0	PL_0	38.001,99
DE_0	FR_0	27.510,00
DE_0	DK_0	25.749,00
LT_0	PL_0	23.718,00
FR_0	IT_0	22.813,42
FR_0	UK_0	21.287,00
NO_0	SE_0	16.307,00
DE_0	NL_0	13.386,00
BE_0	UK_0	12.100,00
DK_0	NO_0	10.900,00

DIRECTED VISION

- There is a great need for capacity in Central Europe and between Central Europe and the periphery.
- Investments are more spread tan in 'Diversification'
- The countries with the most investment are France, Germany, Denmark, the UK, Italy and Spain.

	Directed Vision
FR_0	84.033,00
DE_0	71.971,96
DK_0	34.561,67
UK_0	29.765,10
IT_0	27.372,48
ES_0	26.524,30
PL_0	24.127,80
CH_0	22.501,65
BE_0	21.160,22
NO_0	19.662,36

CH_0	FR_0	21.857,49
AT_0	IT_0	21.526,75
FI_0	SE_0	15.055,41
NO_0	UK_0	13.456,71
AT_0	CH_0	9.564,18
CH_0	IT_0	9.201,65
AT_0	HU_0	7.502,40
DE_0	PL_0	7.500,00
CH_0	DE_0	7.500,00
FR_0	IT_0	6.191,99
DE_0	NL_0	6.000,00
HR_0	SI_0	6.000,00

LOCALISATION

- There is a great need for capacity in Central Europe.
- Additional investments are needed in the UK and in the Nordic countries.
- The countries with the most investment are Germany, France, Switzerland, Italy and Austria.
- Substantial investment might be needed at the intra-country and distribution levels.

	Localisation
DE_0	51.670,72
FR_0	38.129,96
CH_0	22.099,98
IT_0	18.194,98
AT_0	18.005,98
SE_0	16.119,98
UK_0	15.859,98
NL_0	14.039,99
NO_0	13.968,99
BE_0	13.493,99
PL_0	12.713,99
DK_0	11.491,99
ES_0	10.700,00

DE_0	PL_0	9.749,99
CH_0	DE_0	9.749,99
NO_0	UK_0	8.969,99
DE_0	NL_0	7.799,99
HR_0	SI_0	7.799,99
NO_0	SE_0	7.279,99
CZ_0	PL_0	7.279,99
AT_0	IT_0	6.499,99
FI_0	SE_0	5.915,99
LT_0	LV_0	5.388,99
CZ_0	AT_0	5.388,99
CH_0	FR_0	5.199,99

National Champions

- Network investment is the least of the four pathways
- Germany, France, Switzerland and the UK dominate the need for investment.
- The largest capacity increase would happen between Norway and the UK.

	National Champions
DE_0	53.724,99
FR_0	46.927,98
CH_0	20.900,00
UK_0	19.519,99
SE_0	17.831,19
IT_0	17.536,79
NO_0	17.192,99
PL_0	15.647,99
AT_0	15.057,88
BE_0	14.568,00
DK_0	14.143,99
NL_0	13.740,00
ES_0	12.200,00

NO_0	UK_0	11.040,00
AT_0	IT_0	8.000,00
DE_0	PL_0	7.500,00
CH_0	DE_0	7.500,00
NO_0	SE_0	7.280,00
CZ_0	PL_0	7.280,00
FI_0	SE_0	7.280,00
LT_0	LV_0	6.633,00
CZ_0	AT_0	6.633,00
CH_0	FR_0	6.400,00
DE_0	NL_0	6.000,00
HR_0	SI_0	6.000,00

RESULTS

- Significant investment in the transmission network will be needed.
- In particular, situations with a high level of DER or centralized renewables will need a much higher level of development.
- Central Europe must increase its interconnections in all cases.
- France and Spain must increase their interconnection in all cases.
- The UK and Norway must increase their interconnection in all cases both to each other and to the Continent.

POLICY TAKEAWAYS

- In the Pathways 'Diversification' and 'Directed Vision', significant coordination efforts take place at European level, and the most promising energy resources are to be exploited at length using appropriate technologies regardless of their geographical distribution. 'Localization' and 'National Champions' have smaller needs due to lower cross-border flows.
- Even in those scenarios, or pathways, where RES generation is well spread across Europe, transmission capacity should play a relevant role in balancing excesses and deficits of electricity production in different areas within Europe. This is due to the chronological unbalance of RES production.
- The integration of large volumes of Distributed Energy Resources (DER), that are prominent in the pathway Diversification, will result in very relevant changes of the flows in distribution grids, potentially leading to the need to undertake relevant upgrades in these grids.
- New transmission technologies will be very relevant (in some scenarios, around 50% of the new capacity is built using HVDC lines). R&D investment in new technologies could result in improved solutions.
- Policies aimed at increasing RES penetration or the development or storage should be complemented by network developments.

POLICY TAKEAWAYS

- Achieving the construction of large new pan-European transmission developments, as in 'Diversification' and 'Directed Vision', requires addressing three main challenges:
  - 1) implementing an appropriate institutional framework for the governance of the development of the cross-border network.
  - 2) allocating the cost of the cross-border network investment projects in an efficient way that is perceived as fair by the national authorities.
  - 3) putting in place the appropriate conditions for these projects to attract funds at a reasonable cost.
- Planning should be in the hands of entities of a European scope that have executive powers.
  - National authorities looking after their own interests should not have the ability to block the construction of such facilities.
  - Some progress has been made (ACER, ENTSO-e, PCIs) but this is still insufficient.
- Cost should be allocated proportionally to benefits.
- Financing instruments should be made available.
- Distribution needs will be very high in some cases (i.e. Localization), and DSO compensations should account for the increasing need for coordination.

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Thank you

Network Investment Amounts and Costs

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3.2% of Op. Costs

18.6% of Op. Costs

42.1% of Op. Costs

	[MW]	2030 (Ann. Inc. Invt: 2 MM€)		2040 (Ann. Inc. & Accu. Invt: 6.4MM€; 8.4MM€)		2050 (Ann. Inc. & Accu. Invt: 5.1MM€; 13.6MM€)	
		Capacity increment	Final capacity	Capacity increment	Final capacity	Capacity increment	Final capacity
PL	AT	2000	2000	2000	4000	5000	9000
DE_N	BE	1941	2941	2046	4988	3012	8000
GB_S	BE	8000	9000	2000	11000	1000	12000
PL	CZ	0	1800	815	2615	5965	8580
FR_N	DE_S	4576	6999	5424	12423	1000	13423
IT_N	DE_S	6000	6000	0	6000	0	6000
PL	DE_S	0	0	4000	4000	6000	10000
DK	DE_N	0	3000	18172	21172	4161	25333
FR_N	DE_N	2000	2577	6898	9475	4102	13577
NL	DE_N	3596	7555	3944	11498	2098	13596
PL	DE_N	5351	8215	7943	16158	10222	26381
SE_S	DE_N	0	600	4000	4600	2000	6600
GB_S	DE_N	3000	3000	11000	14000	0	14000
NO	DK	0	1600	6000	7600	3000	10600
FR_S	ES	11433	15433	8343	23776	565	24341
FR_N	ES	6000	6000	5000	11000	5000	16000
IT_N	FR_S	0	0	6000	6000	1000	7000
FR_S	FR_N	9584	18684	8396	27079	5631	32710
IT_N	FR_N	0	3103	0	3103	11026	14129
GB_S	FR_N	0	3000	11988	14988	3000	17988
PL	HU	0	0	6000	6000	4000	10000
NL	IE	0	0	2000	2000	5000	7000
PL	LT	0	1751	13111	14862	9841	24703
PL	LV	0	0	0	0	7000	7000
SE_S	NL	0	0	0	0	6000	6000
SE_S	NO	6199	10199	301	10500	2750	13250
SK	PL	0	600	2000	2600	4000	6600
SE_S	SE_N	1294	6294	3114	9407	5778	15186
GB_S	GB_N	5000	11800	26603	38403	397	38800

TAKEAWAYS

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- Transmission development costs are limited compared to other costs in the 2030 horizon but end up being relatively significant in the 2050 one
  - 465 GW of accumulated investments in the 2020-2050 period
- Transmission investments are focused on:
  - The connection of peripheral countries, mainly Spain, the UK, and the Baltic counties, to central Europe.
  - Connections of Germany to the neighboring countries
  - North-South internal corridors in France and the UK
  - Internal corridors in general within the Scandinavian peninsula
- North-South internal corridor in Germany is not reinforced because it has been previously
  - Strongest corridor in Europe in the 2020 horizon

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