Innovative grid-impacting technologies for pan-European system analyses: key GridTech results on Demand Response application

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Outline

- GridTech project overview
- Technology focus and tool
- Demand Response (DR) inclusion
- Pan-European study: key assumptions and data
- Pan-European study: main scenario results with/without DR
- Discussion

About the project

Contract number:
IEE/11/017 / SI2.616364

GridTech is a project co-funded by the European Commission under the **Intelligent Energy Europe** Programme.

Duration:
May 2012 - April 2015

Full title: *Impact Assessment of New Technologies to Foster RES-Electricity Integration into the European Transmission System*

Co-funded by the Intelligent Energy Europe Programme of the European Union

About the project

GridTech's main goal:

→ Conduct a ***fully integrated assessment of new grid-impacting technologies and their implementation*** into the European electricity system.

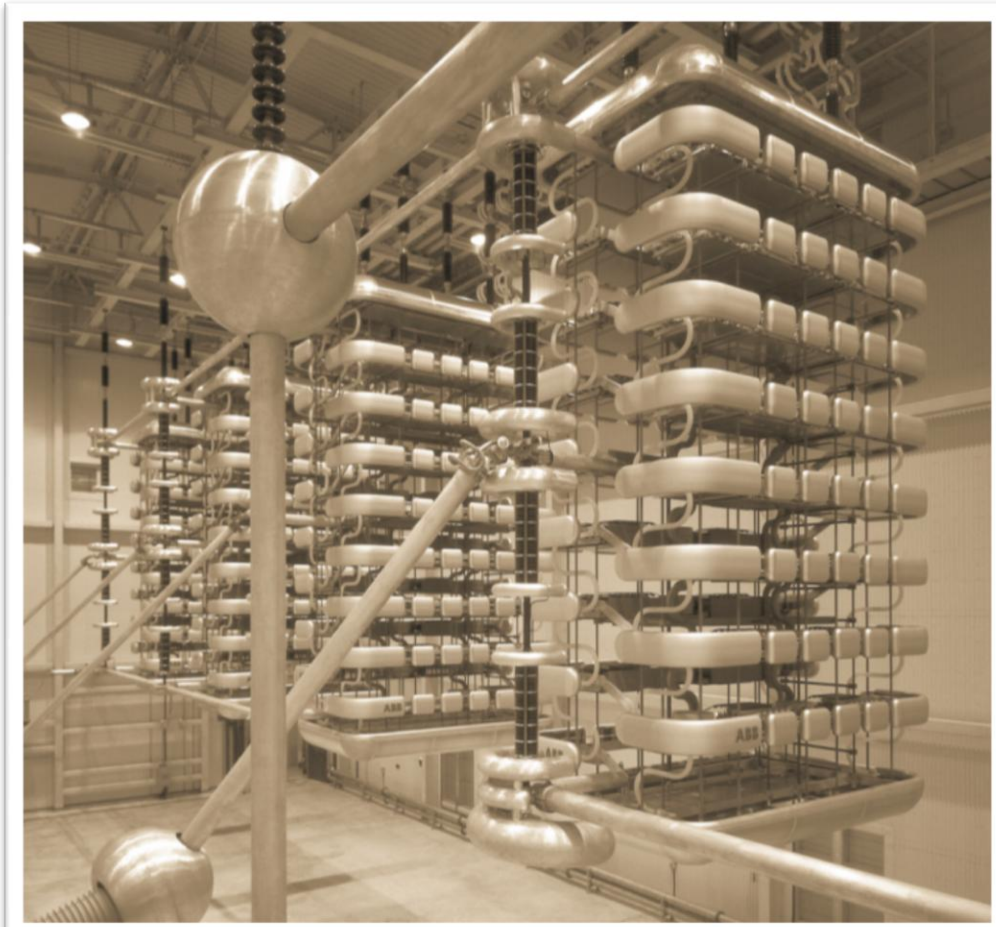
This will allow comparing different technological options, towards the exploitation of the full potential of future **electricity production from renewable energy sources (RES-E)**, with the lowest possible total electricity system cost.

Project objectives

- Assess the **non-technical barriers** for transmission expansion and market compatible renewable electricity integration in Europe.
- Develop a robust **cost-benefit analysis methodology** on investments in most suitable **new technologies fostering large-scale renewable electricity integration** into the European transmission grid.
- Apply and verify the cost-benefit analysis methodology for **investments in the transmission grid, on national and European level**.
- Achieve a common understanding among key actors and target groups on **best practise** criteria for the implementation of new technologies fostering large-scale renewable electricity and storage integration.
- Deliver tailor-made **recommendations** and **action plans**, taking into account the legal, regulatory, and market framework.

Technology focus

The analysis focuses on the most promising and innovative technologies that directly or indirectly impact on the transmission system.



Innovative grid-impacting technologies

EGT

- Onshore and offshore wind energy
- Large-scale solar technologies: Concentrated Solar Power (CSP) and Photovoltaics (PV)

Electricity generation technologies, with a focus on variable RES-E

EST

- Pumped Hydro Energy Storage
- Compressed Air Energy Storage

Bulk energy storage technologies

EDT

Demand Response Technologies/ Measures and electric vehicles

TGT

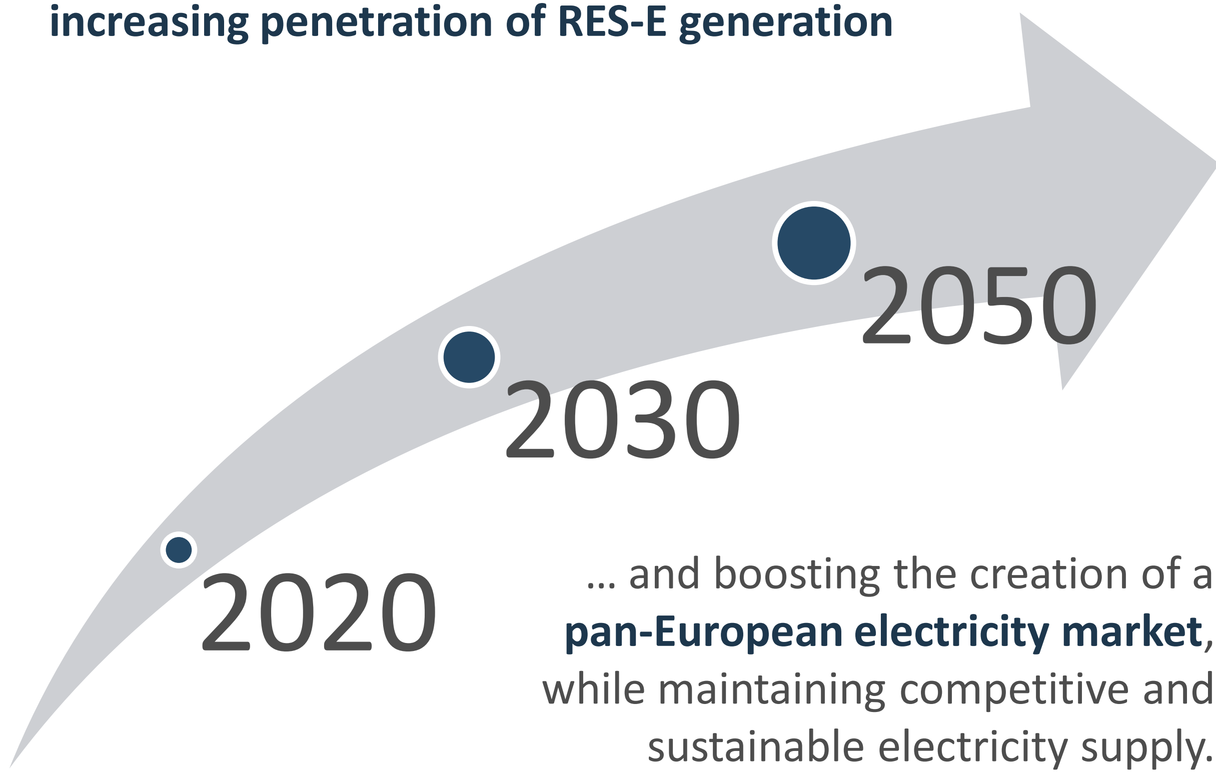
- HVDC - High Voltage Direct Current, both VSC (Voltage Source Converter)-based and CSC (Current Source Converter)-based
- FACTS - Flexible Alternating Current Transmission System
- PST - Phase Shifting Transformers
- WAMS - Wide Area Monitoring System
- DLR - Dynamic Line Rating-based OHLs
- HTLS - High Temperature Low Sag Conductor-based OHLs

Transmission technologies directed at improvements in network control and flexible electricity system operation

2020 and beyond

Within the 2020, 2030 and 2050 time horizons, the aim is to assess, among **innovative technologies**, i) **which**, ii) **where**, iii) **when**, and iv) **to which extent** they could effectively contribute to the further development of the European transmission system

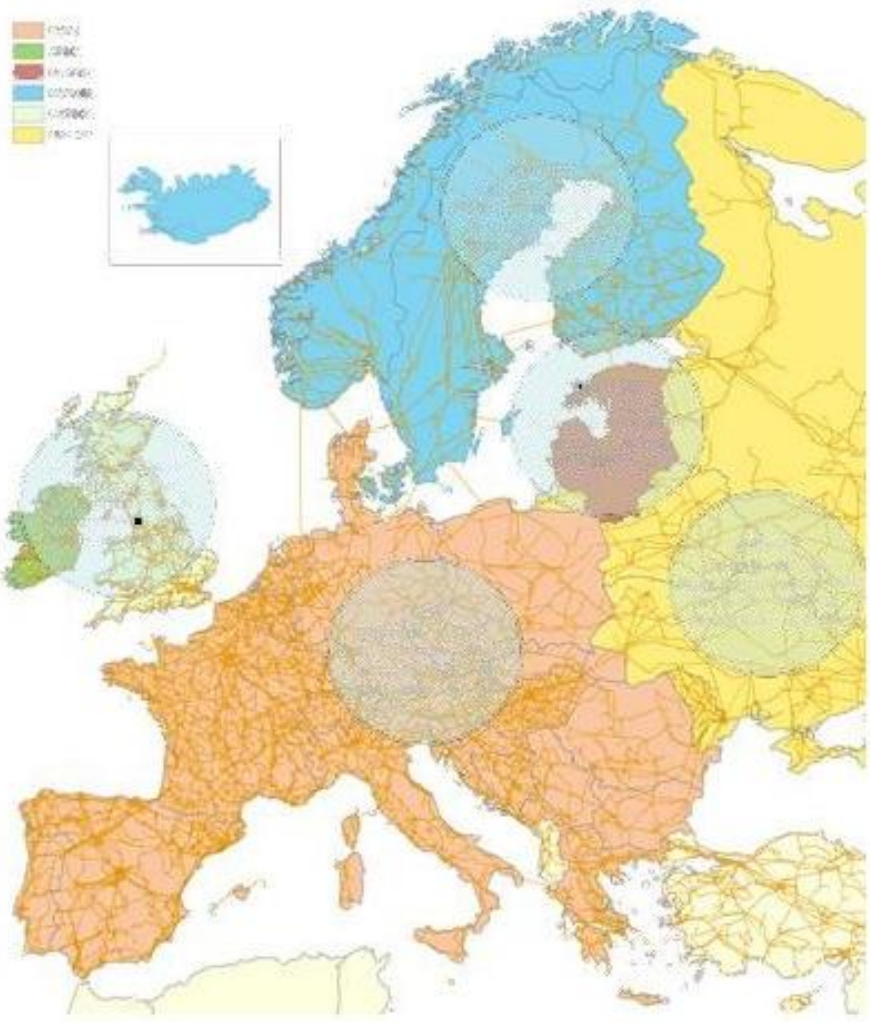
… fostering the **integration of an ever-increasing penetration of RES-E generation**



… and boosting the creation of a **pan-European electricity market**, while maintaining competitive and sustainable electricity supply.

Pan-European system

Pan-European system



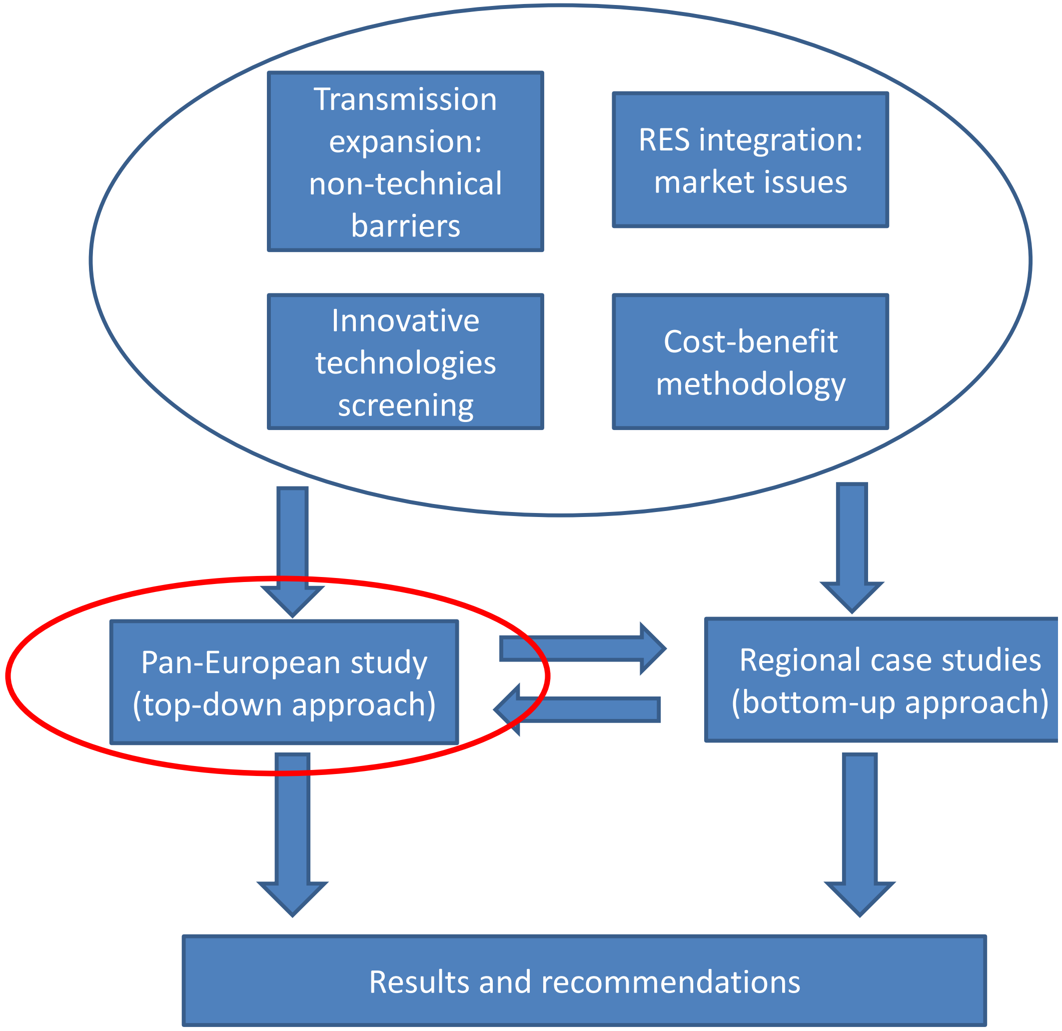
Source: JRC (2010)

Target countries

- AUSTRIA
- BULGARIA
- GERMANY
- IRELAND
- ITALY
- NETHERLANDS
- SPAIN

In addition to top-down modelling on EU30+ and taking stock from it in a consistent data input-output flow, GridTech focuses on **7 countries**, representative of the existing and future European electricity systems, **studied at 2020, 2030 and 2050 by detailed grid/zonal analyses**.

The Pan-European study in the project



Pan-European study aims and tool

The goals of the Pan-European study are threefold:

-**Setting the boundary conditions for the regional case studies in a tightly correlated manner at 2020, 2030, 2050**

-**Analyzing the 2020, 2030, 2050 Pan-European scenarios including the effects of new technologies**

-**Applying a techno-economic assessment methodology to the 2020, 2030 and 2050 Pan-European scenarios including the effects of new technologies fostering large-scale RES-E integration.**

The Pan-European study is based on a **top-down approach** by including the entire European system (**EU30+**) in the model: the tool for conducting this kind of scenarios analyses is MTSIM (Medium Term SIMulator), developed by RSE over the years.

Main features of MTSIM

MTSIM is a **medium-term simulator** of a generic **day-ahead zonal market** (DAM).

The model is devised to carry out **system-wide energy evaluations** (i.e. fuel consumption) and **emission evaluations** (CO_2 and other pollutants).

MTSIM **calculates a hourly clearing price all over the year**, by means of a DC Optimal Power Flow **minimizing the energy price**, considering variable fuels costs, environmental costs and hourly bid-up of each group (input of the model), taking account of **constraints** related to: thermal power units limits, thermal must-run units operation, thermal generation bounds, thermal power units ramping, fuel consumption, CO_2 emissions bounds, hydropower plants limits, hydro reservoirs volume limits, total power balance, inter-zonal power transit bounds, non-supplied energy (load shedding), excess energy.

The transmission network among zones is modeled by an **inter-zonal equivalent system** including both **HVAC corridors** (whose physical constraints are represented through a **PTDF matrix**) and **HVDC interconnectors**, operated independently of HVAC.

A key feature of MTSIM relates to the so-called **planning modality** **allowing to calculate the optimal dispatch** whenever **it is possible to install additional interconnection capacity** between the market zones.

Main features of MTSIM

MTSIM provides **main outputs for techno-economic assessments**:

- Hourly zonal generation dispatch
- Dispatch cost
- Inter-zonal flow transits
- Load shedding (EENS)
- RES curtailment (EIE)
- CO_2 emissions
- Hourly zonal marginal costs/prices
- Fuel consumption
- Revenues, margins and market quotas

MTSIM provides also the **possibility of including in the model innovative technologies**, such as

- HVDC
- PST/FACTS
- Storage
- DSM/DR

Pan-European study

The Pan-European study, based on **EU30+ zonal model**, endogenously includes:

- EU28 countries -> 30 systems (including 2 German zones + Northern Ireland)
- EEA countries -> 3 systems
- Western Balkans -> 5 systems
- Turkey
- additional 5-7 potential offshore islands (after 2030)

Pan-European study exogenously includes:

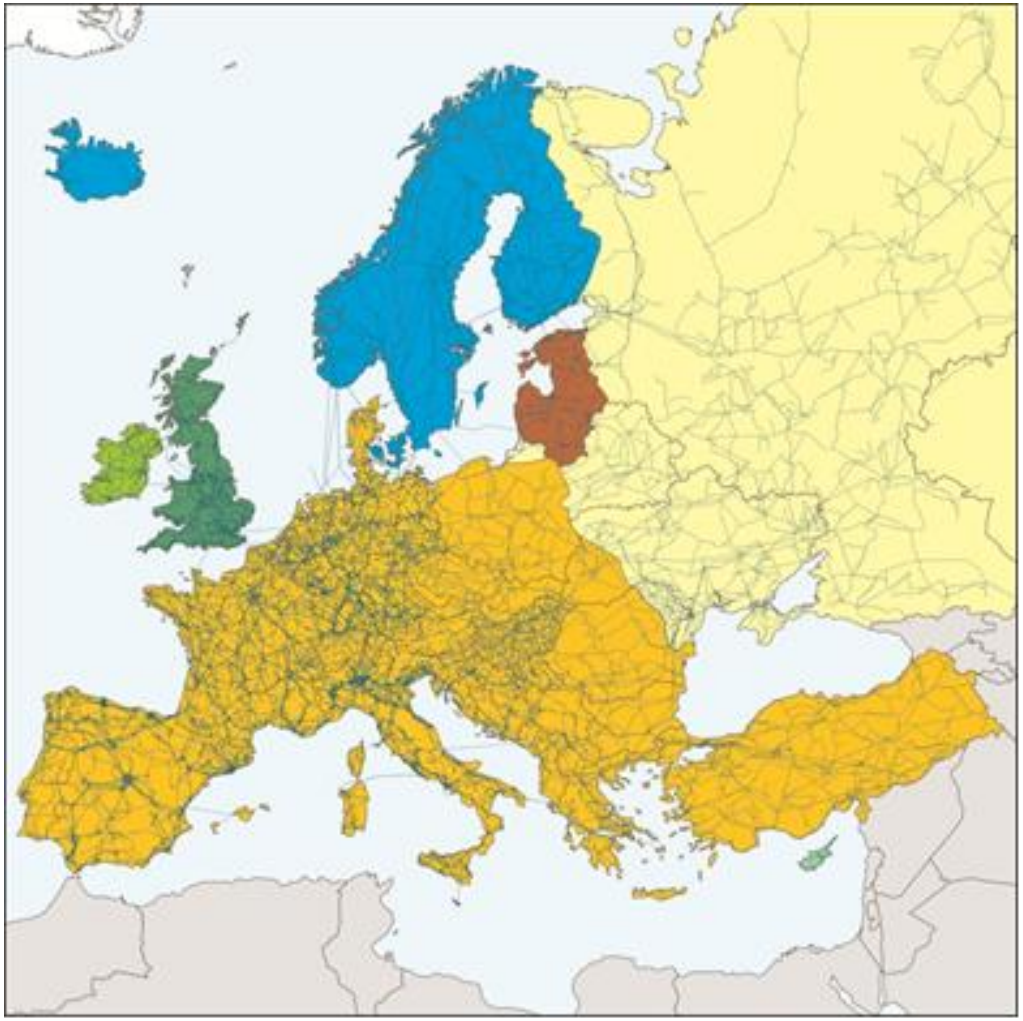
- Bordering systems of North Africa
- Bordering systems of Middle East
- Bordering systems of eastern edge (Russia, Belarus, Ukraine, Moldova)

Pan-European study

Geographic perimeter of the Pan-European study

Pan-European study

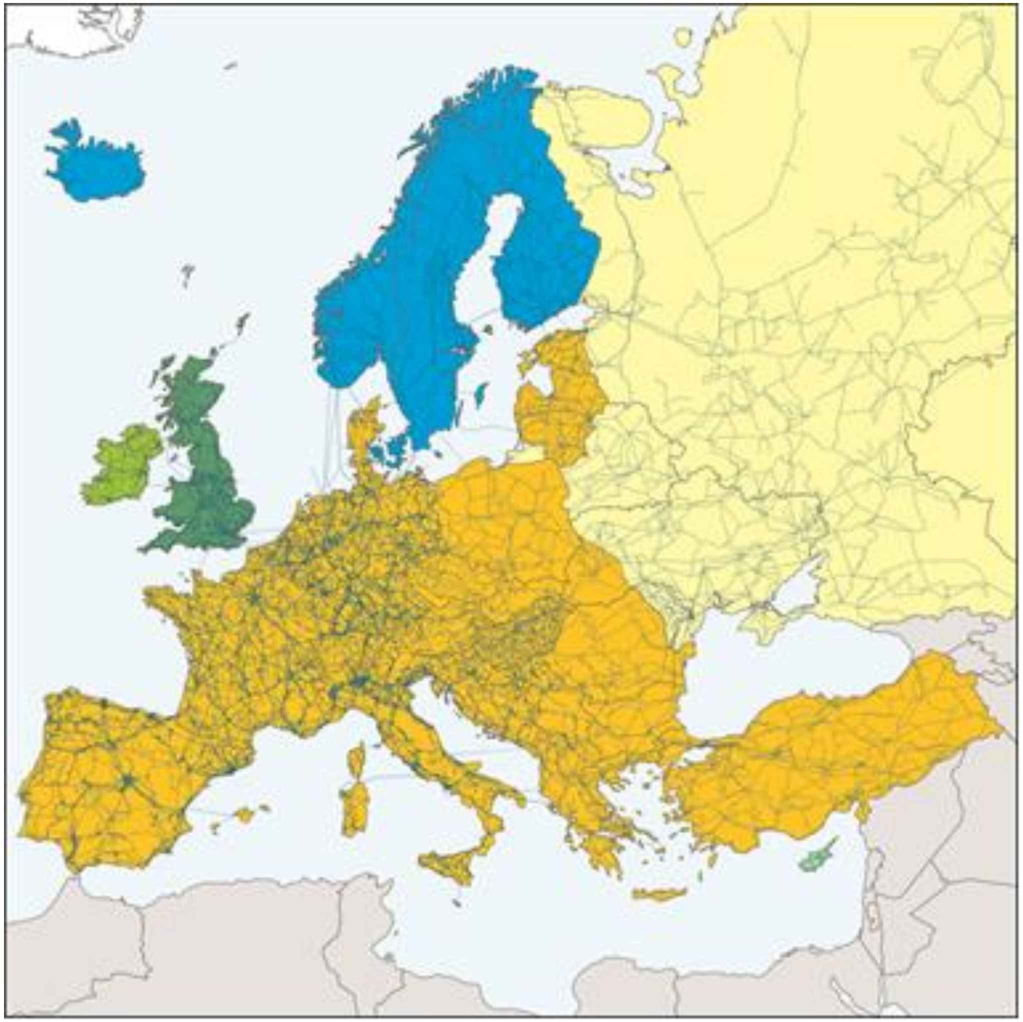
European transmission system (2020, planned)



Source: JRC-IET (based on ENTSO-E and PLATTS data)

Pan-European study

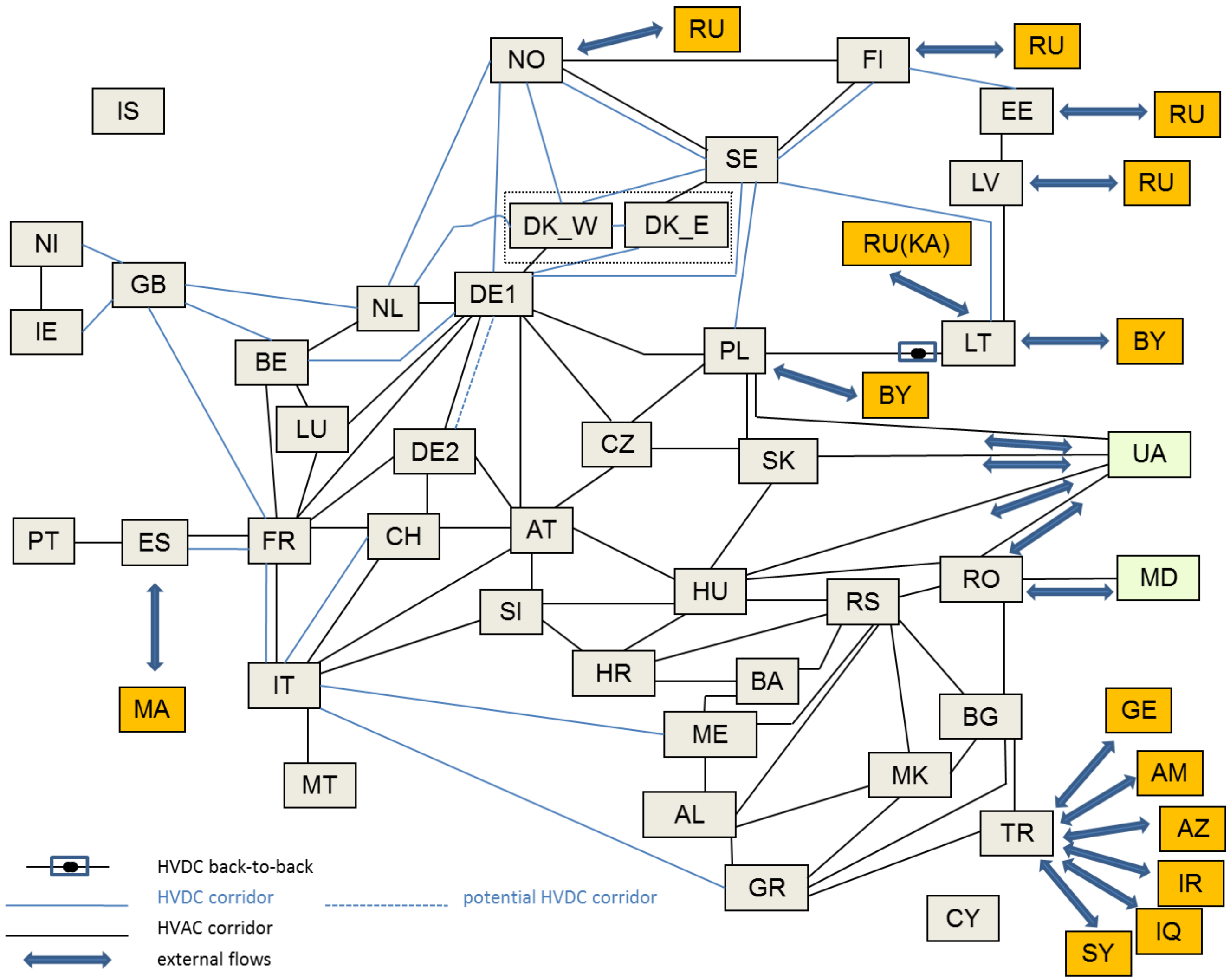
European transmission system (2030, preliminary)



Source: JRC-IET (based on ENTSO-E and PLATTS data)

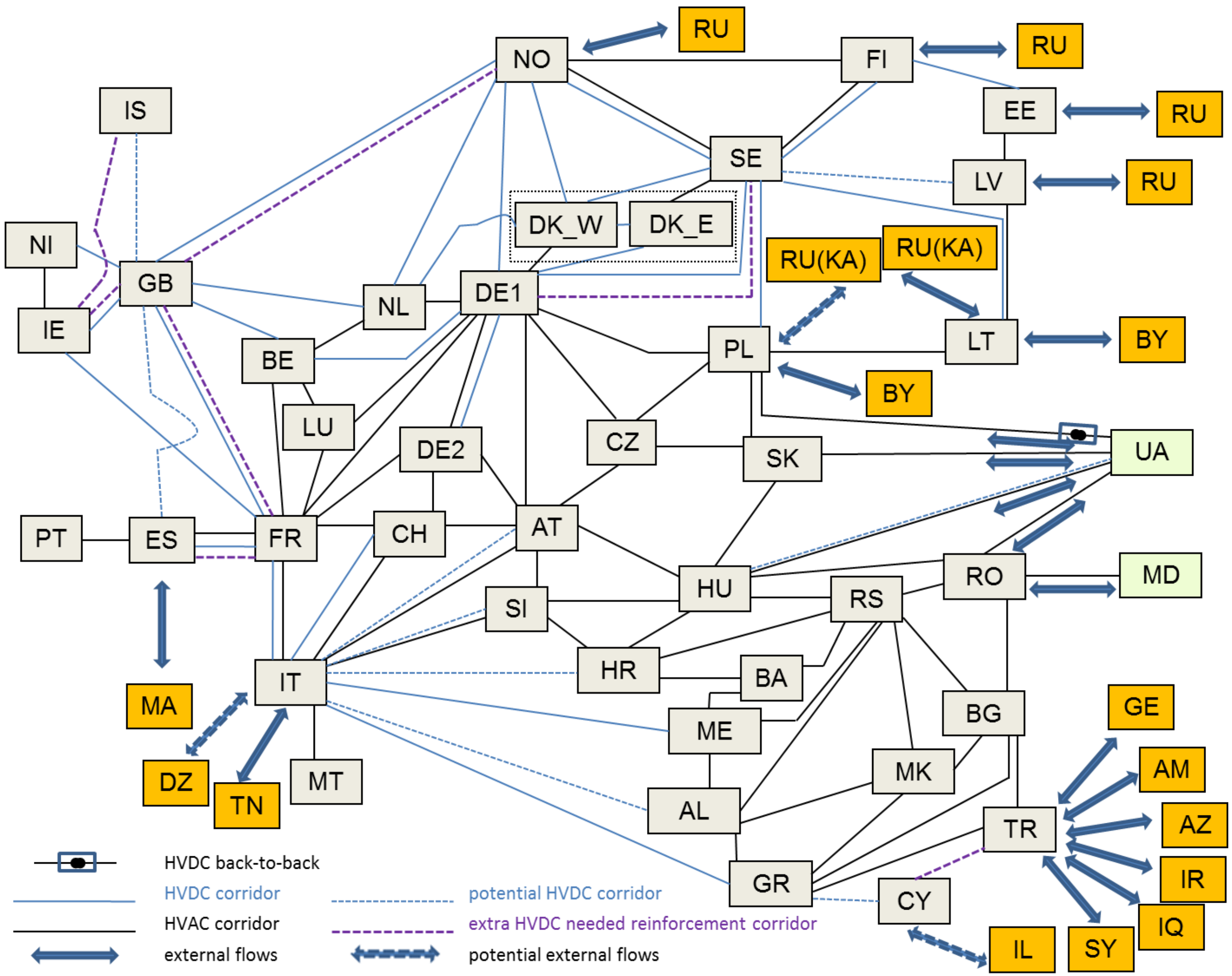
Pan-European study

Pan-European zonal model (2020, planned)



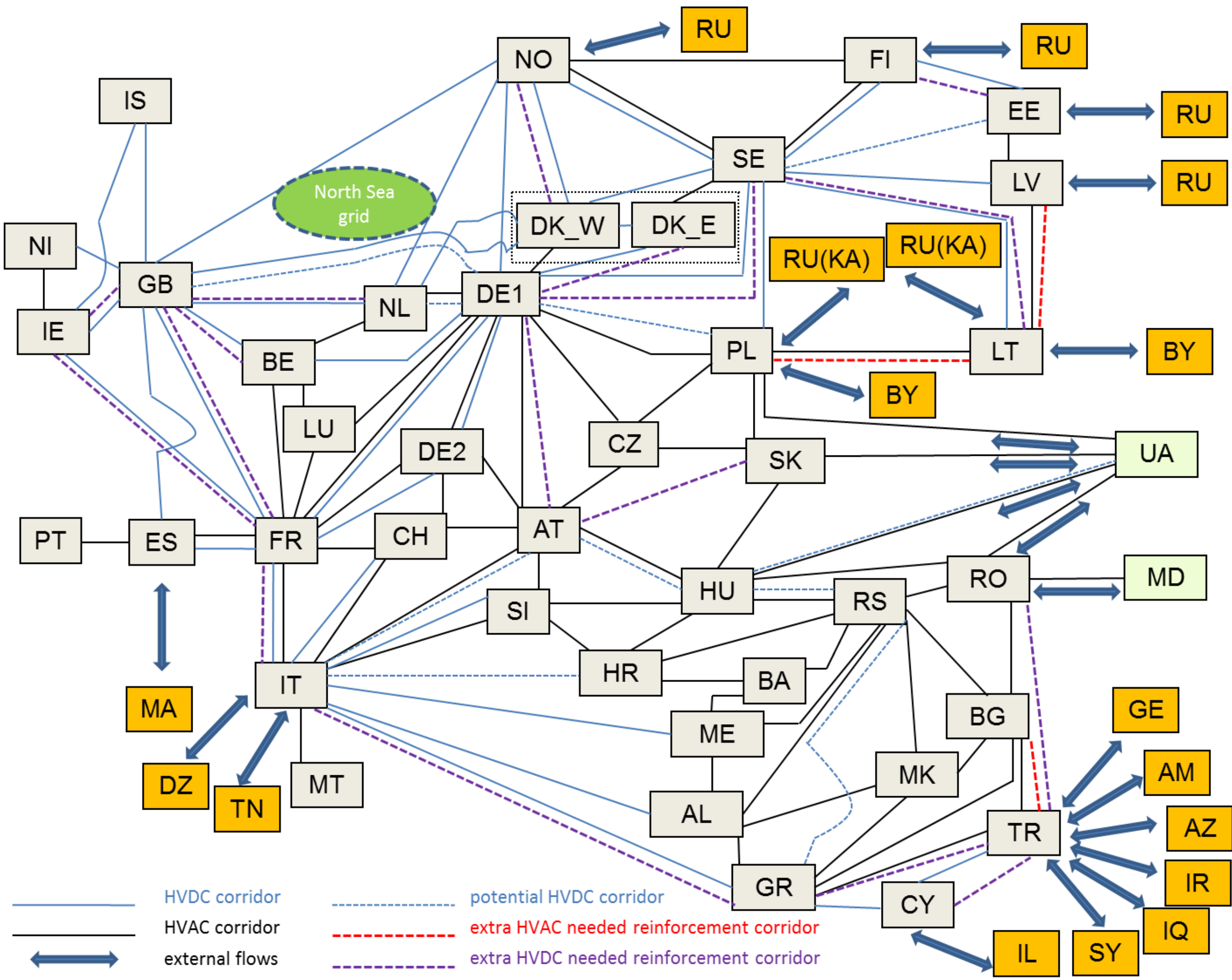
Pan-European study

Pan-European zonal model (2030, updated)

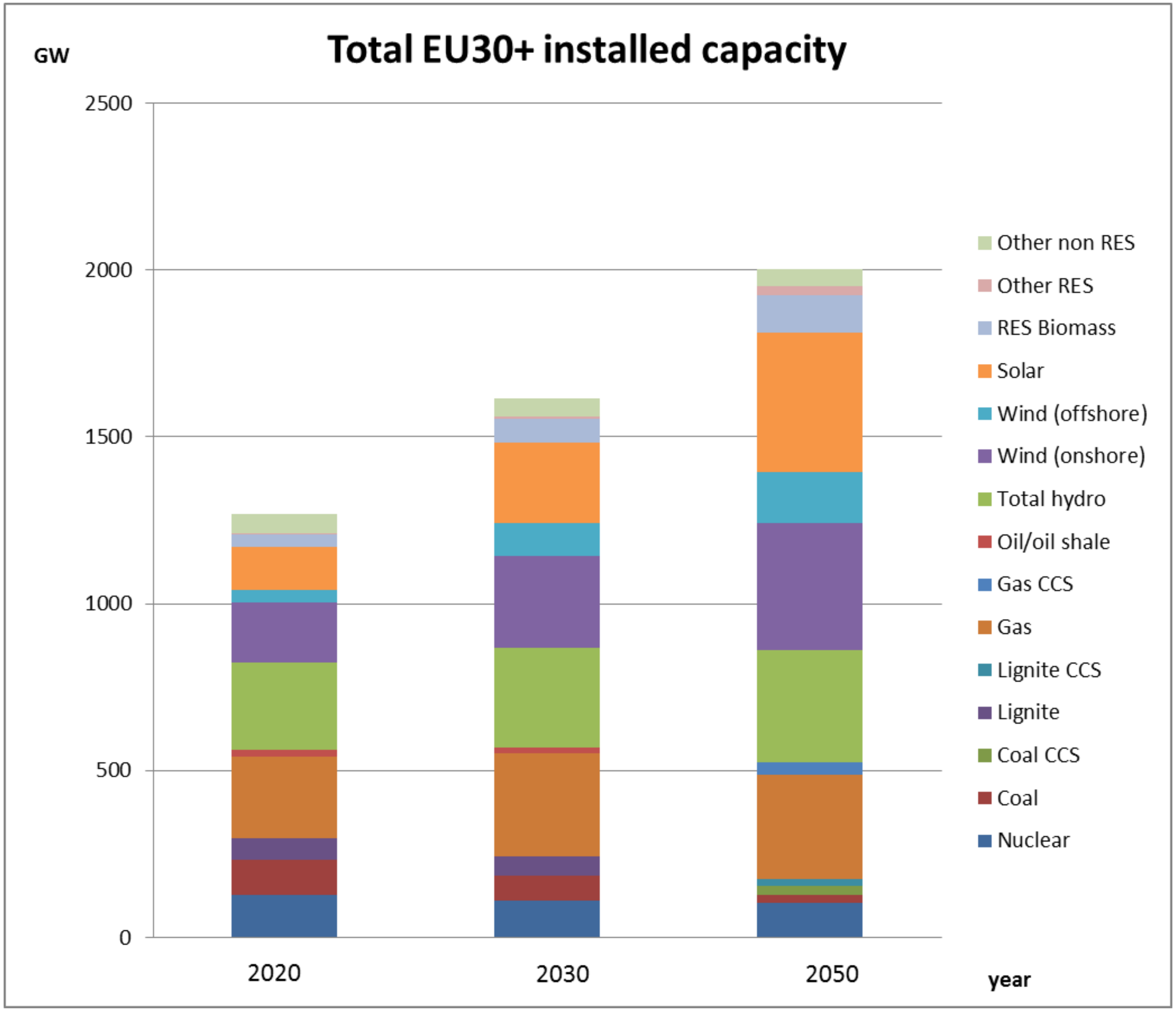


Pan-European study

Pan-European zonal model (2050, updated)



Pan-European study: baseline scenarios (S0)



Pan-European study: baseline scenarios (S0)

EU30+	2020 (GW)	2030 (GW)	2050 (GW)
Nuclear	126.9	108.6	102.1
Hard coal	105.5	76.5*	53.0*
Lignite	65.6	56.6	19.8*
Gas	245.1	311.2*	349.9*
Oil / oil shale	20.4	16.6	0
Other non RES	57.3	53.0	50.8
Total Hydro	260.7	297.0	335.1
Wind (onshore)	179.9	276.8	380.8
Wind (offshore)	37.9	96.9	154.3
Solar	126.7	243.2	416.8
RES Biomass	38.8	69.6	113.7
Other RES	2.5	8.5	26.9

*: including CCS

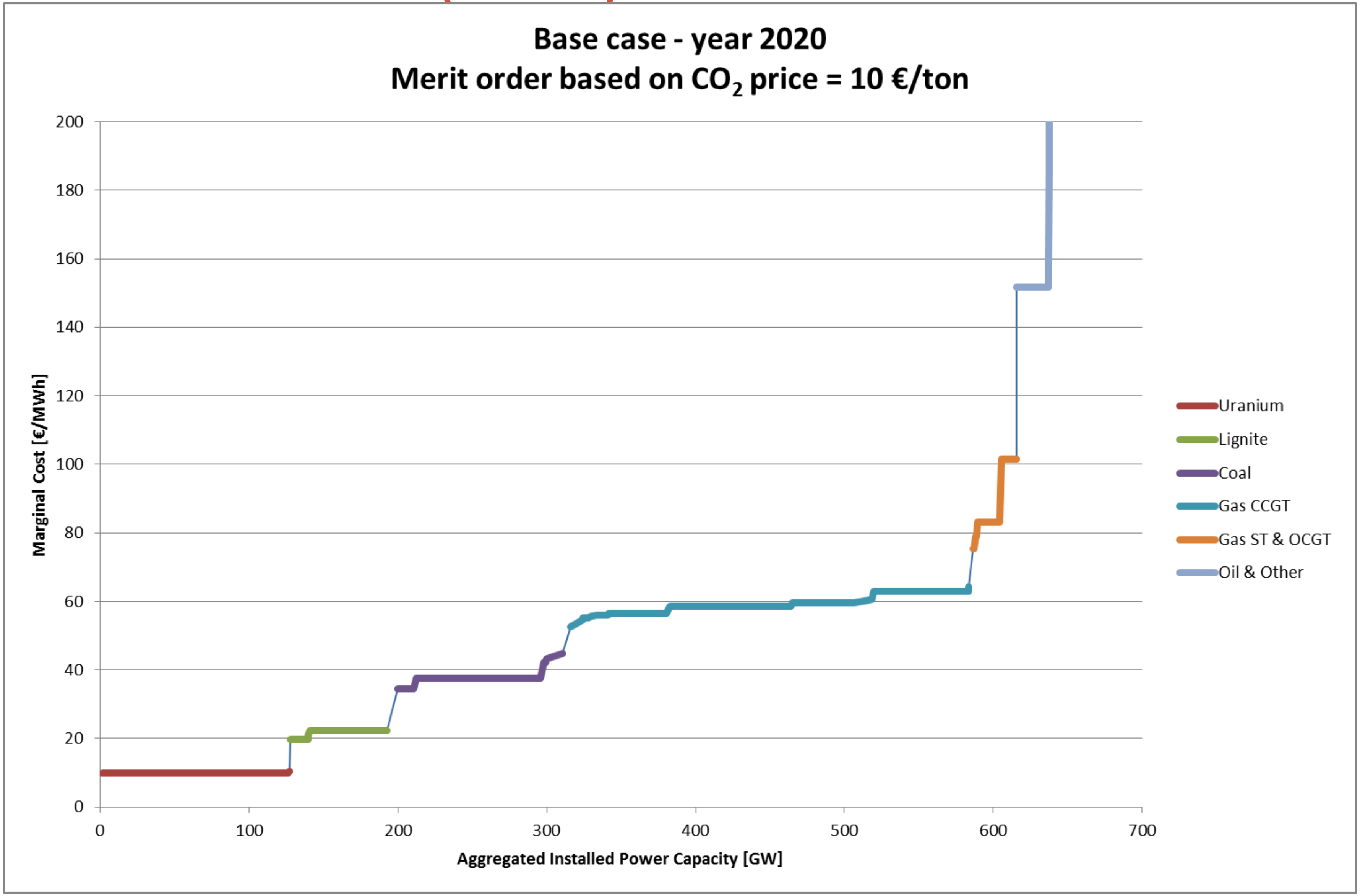
Pan-European study scenarios

% RES-E/load:

- 39% (2020)
- 49-50% (2030)
- 62-64% (2050)

Country/ zone	2020 Load demand (TWh)	2020 Load shifting	2030 Load demand (TWh)	2030 Load shifting	2050 Load demand (TWh)	2050 Load shifting
AL	10.424	1.0%	15.431	5.0%	25.28	7.0%
AT	73.67	3.5%	91.81	6.4%	90.70	10.1%
BA	14.96	3.0%	17.95	3.0%	20.10	5.0%
BE	95.40	3.1%	104.80	5.8%	115.40	9.2%
BG	41.75	0.6%	40.50	2.3%	35.52	3.6%
CH	69.17	1.0%	78.60	3.0%	85.90	6.0%
CY	8.055	0.7%	8.958	2.9%	10.41	4.6%
CZ	69.41	0.7%	82.09	2.6%	104.90	4.1%
DE1	483.49	2.8%	546.10	5.2%	563.69	8.2%
DE2	78.71	2.8%	88.90	5.2%	91.76	8.2%
DK	36.36	3.5%	44.82	6.4%	49.01	10.1%
EE	9.67	1.7%	13.19	3.9%	13.76	6.1%
ES	292.17	10.1%	364.00	10.1%	419.16	16.1%
FI	98.30	10.1%	104.40	10.1%	106.26	16.1%
FR	489.16	10.1%	516.30	10.1%	573.20	16.1%
GB	326.45	10.1%	357.02	10.1%	461.70	16.1%
GR	64.57	3.1%	87.02	5.8%	88.43	9.2%
HR	21.20	0.7%	24.00	2.6%	30.50	4.1%
HU	49.20	2.0%	51.60	3.9%	67.80	6.1%
IE	30.42	10.1%	33.34	10.1%	34.06	16.1%
IS	18.899	4.2%	24.65	4.2%	33.20	6.0%
IT	339.00	10.1%	460.45	10.1%	481.01	16.1%
LT	12.43	0.7%	17.80	2.3%	19.14	3.6%
LU	6.78	0.6%	7.33	2.3%	8.50	3.6%
LV	8.80	0.6%	9.20	2.3%	10.02	3.6%
ME	5.00	0.1%	5.97	0.1%	7.40	2.0%
MK	12.29	0.1%	14.53	0.1%	14.20	2.0%
MT	2.542	10.1%	2.81	10.1%	3.43	16.1%
NI	9.76	10.1%	12.55	10.1%	12.66	16.1%
NL	124.36	10.1%	163.01	10.1%	110.40	16.1%
NO	133.88	10.1%	148.00	10.1%	149.91	16.1%
PL	177.00	6.4%	215.00	6.4%	238.10	10.1%
PT	50.09	10.1%	63.36	10.1%	70.10	16.1%
RO	68.14	2.8%	83.56	5.2%	88.10	8.2%
RS	44.16	3.0%	48.69	5.0%	50.05	7.0%
SE	151.09	3.8%	157.95	7.0%	160.42	11.2%
SI	14.64	2.6%	19.99	5.8%	19.70	9.2%
SK	30.60	0.6%	35.63	2.3%	44.20	3.6%
TR	412.40	3.0%	610.45	10.0%	825.00	15.0%
Total	3984.40		4771.76		5333.07	

2020 S0 (base) case: merit order

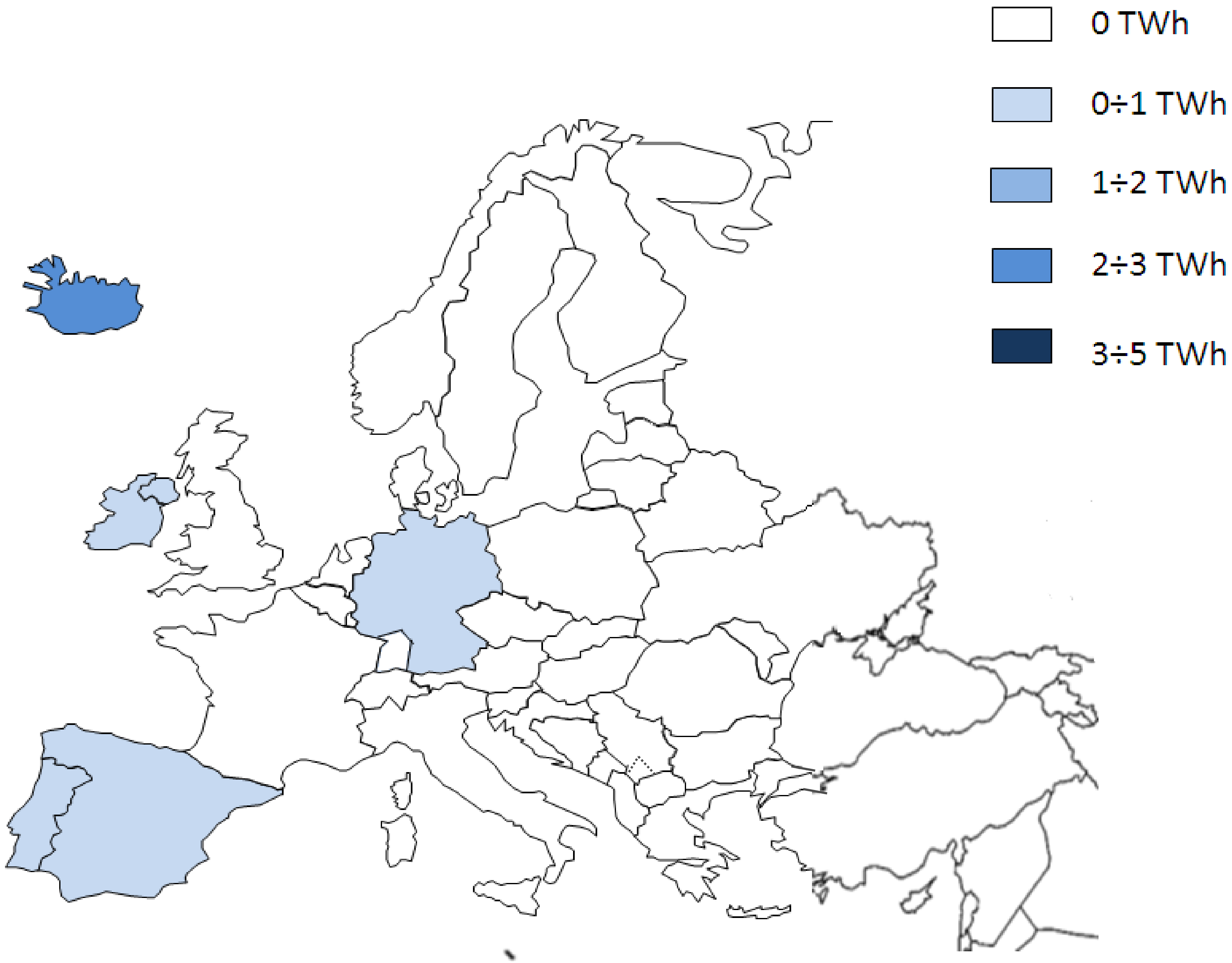


Pan-European study results (2020 S0, base)

Main outcomes:

- Load shedding is null
- RES curtailment (2.67 TWh) is mostly concentrated in IE, IS and is very limited in DE1, ES, NI, PT
- Zonal costs are changing depending on countries, RES penetration, energy mix: the highest average zonal marginal costs concern CY (above 70 €/MWh), MT and TR (about 60 €/MWh)
- HVDC corridors are rather fully utilised

2020 S0 (base) results: RES curtailment

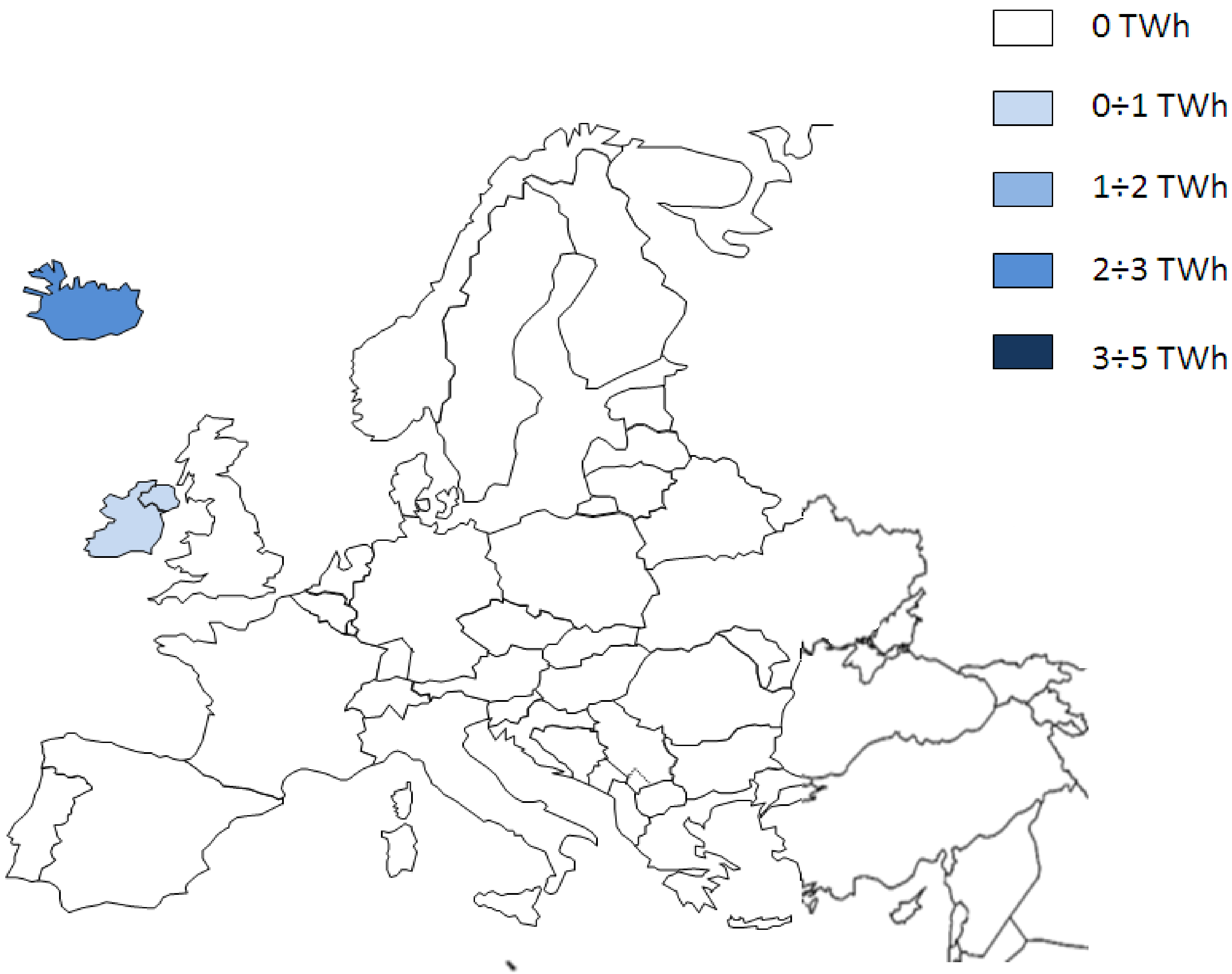


Pan-European study results (2020 S3, EDT)

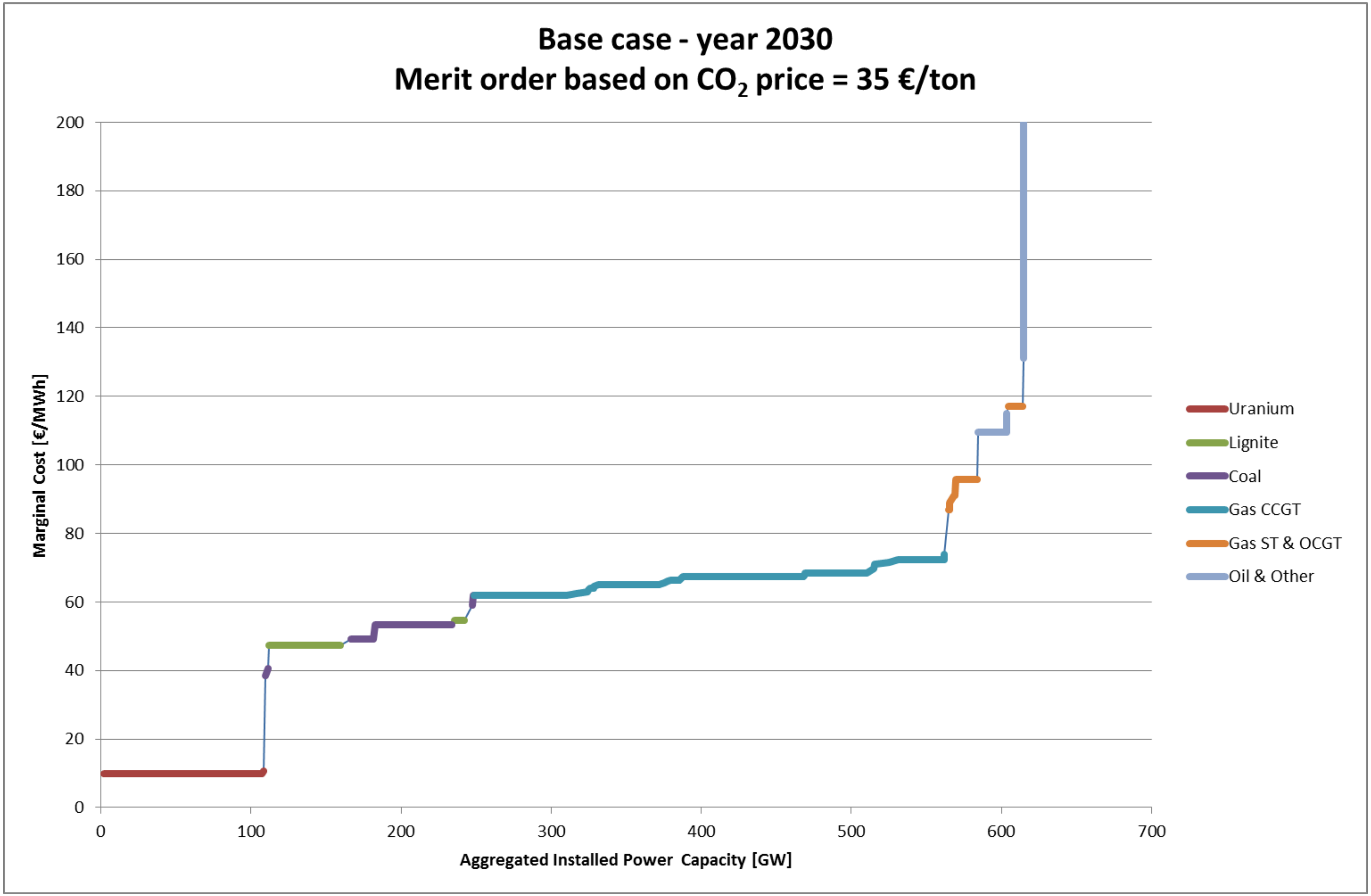
Main outcomes:

- Load shedding is null
- Dispatch cost reduction by DR amounts to 425 M€ with respect to 2020 S0
- RES curtailment is reduced by 127 GWh due to DR (load shifting) effect
- Zonal costs are changing depending on countries, RES penetration, energy mix
- Impact of DR on CO_2 emission variation is very limited (slight increase)

2020 S3 (EDT) results: RES curtailment



2030 S0 (base) case: merit order

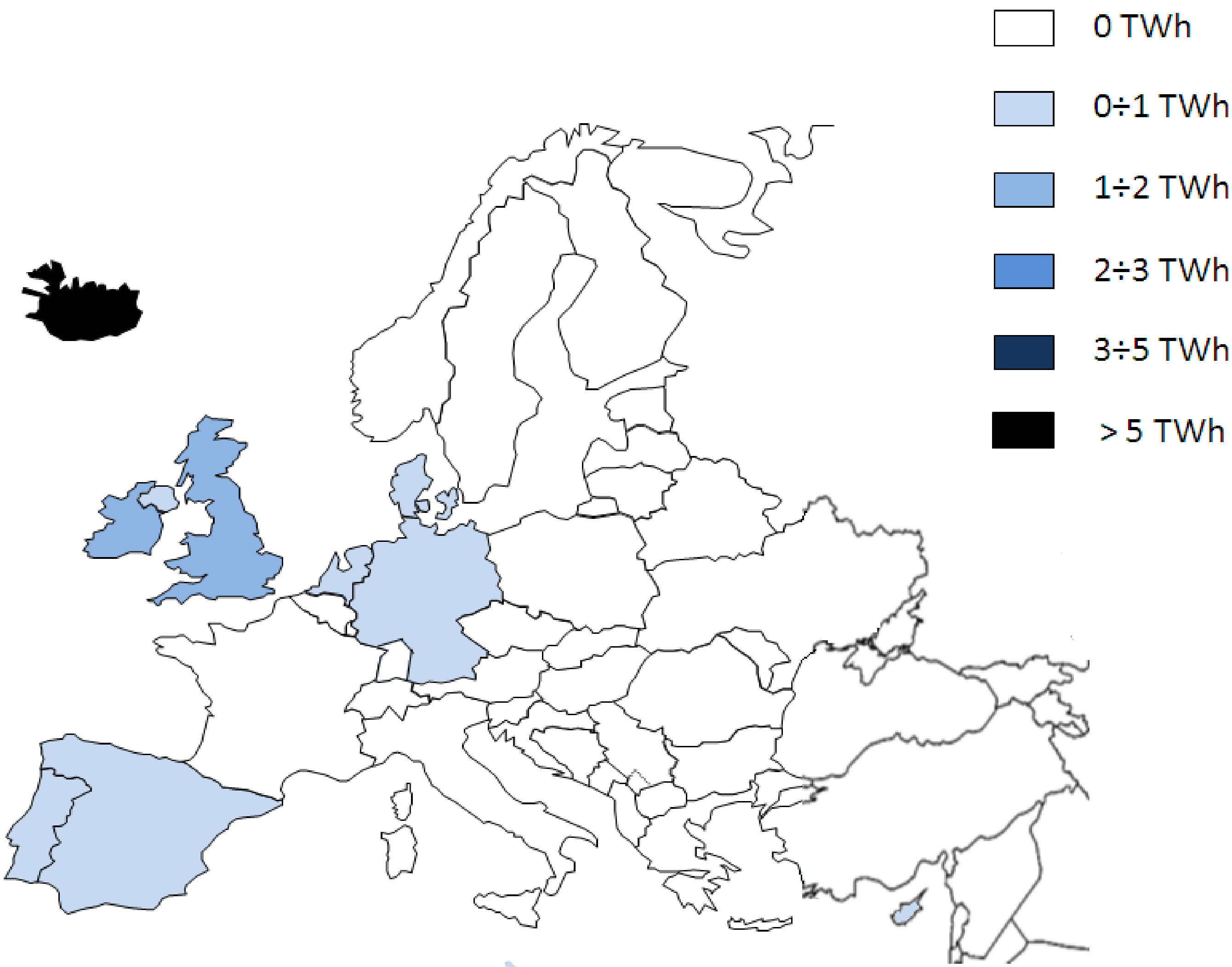


Pan-European study results (2030 S0, base)

Main (updated) outcomes:

- Load shedding is null
- RES curtailment (9.4 TWh) is rather higher than in 2020 S0: it mostly concerns CY, DE1, DK, ES, GB, IE, IS (while it is very limited in MT, NI, NL, PT)
- Zonal marginal costs are higher than in 2020
- HVDC corridors are rather fully utilised
- The system needs first reinforcements across British islands, in Balkan, Iberian and Baltic regions, on north-south Central Europe axis and around isolated zones

2030 S0 (base) results: RES curtailment

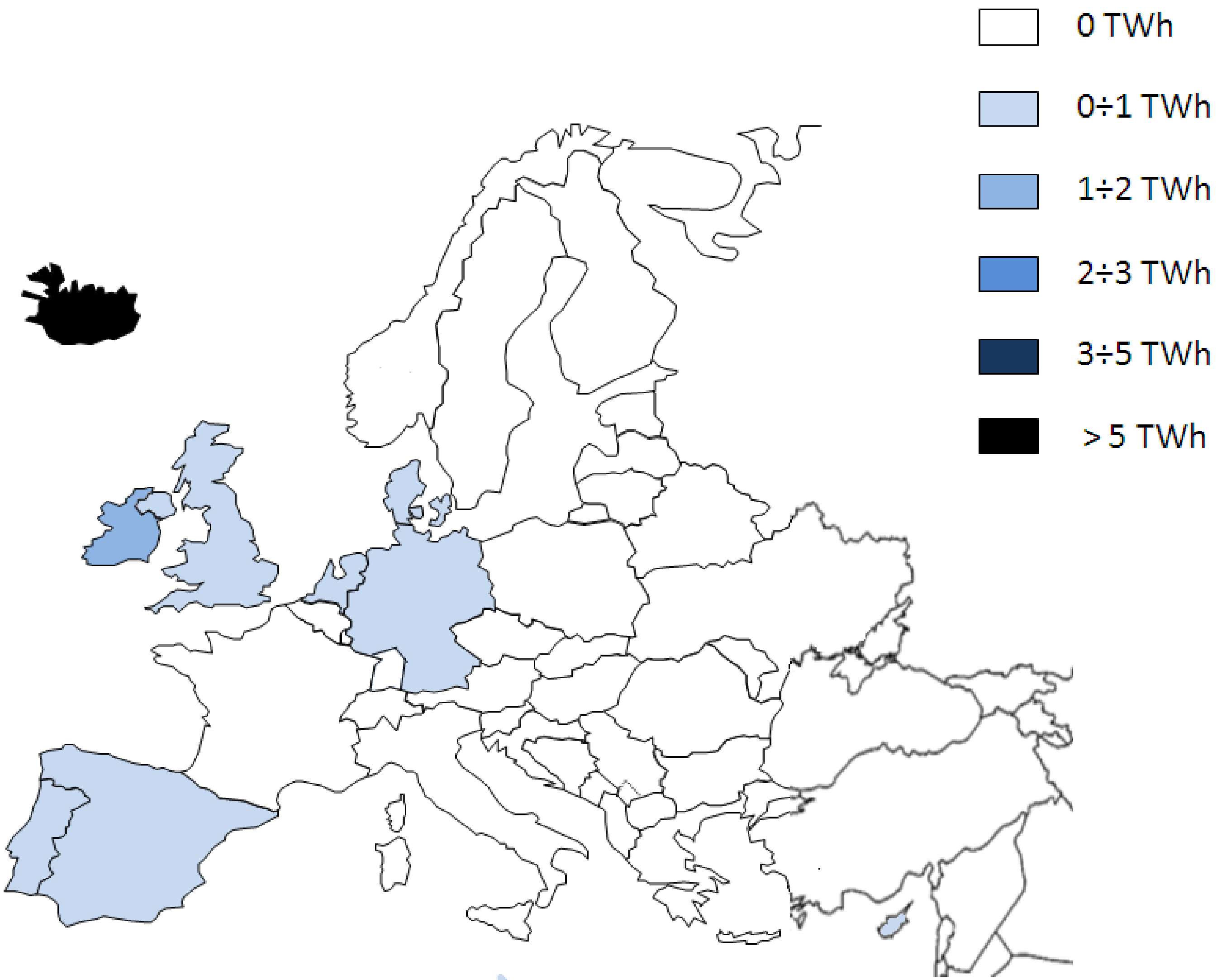


Pan-European study results (2030 S3, EDT)

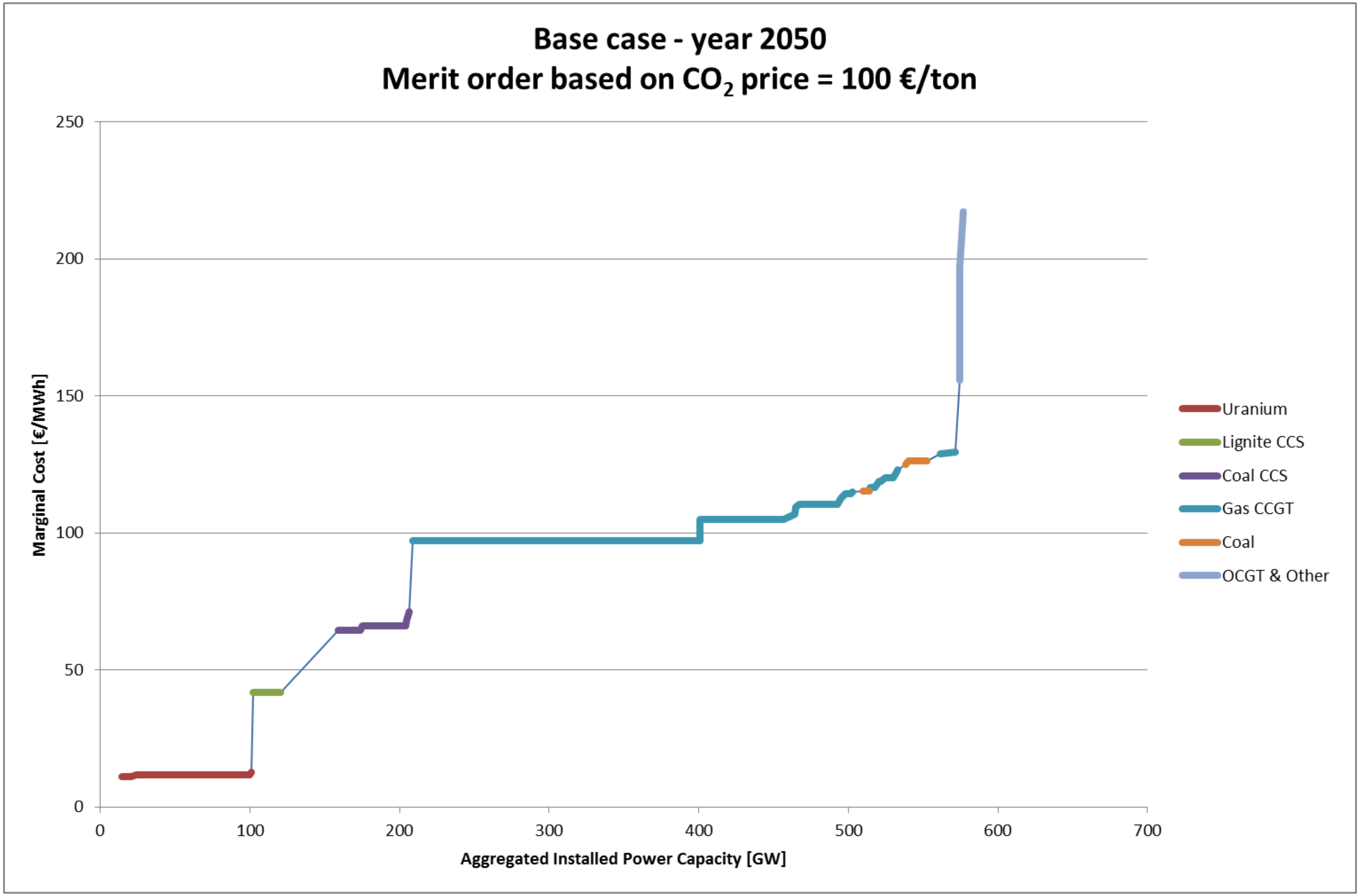
Main outcomes:

- Load shedding is null
- EDT (DR) brings higher benefits than in 2020 in terms of RES curtailment reduction (1458 GWh) and dispatch cost decrease (1.42 b€) over S0
- Zonal costs are changing depending on countries, RES penetration, energy mix
- Impact of EDT (DR) on CO_2 emissions variation is negative (CO_2 emissions increase: 8.4 $MtCO_2$ by DR)

2030 S3 (EDT) results: RES curtailment



2050 S0 (base) case: merit order

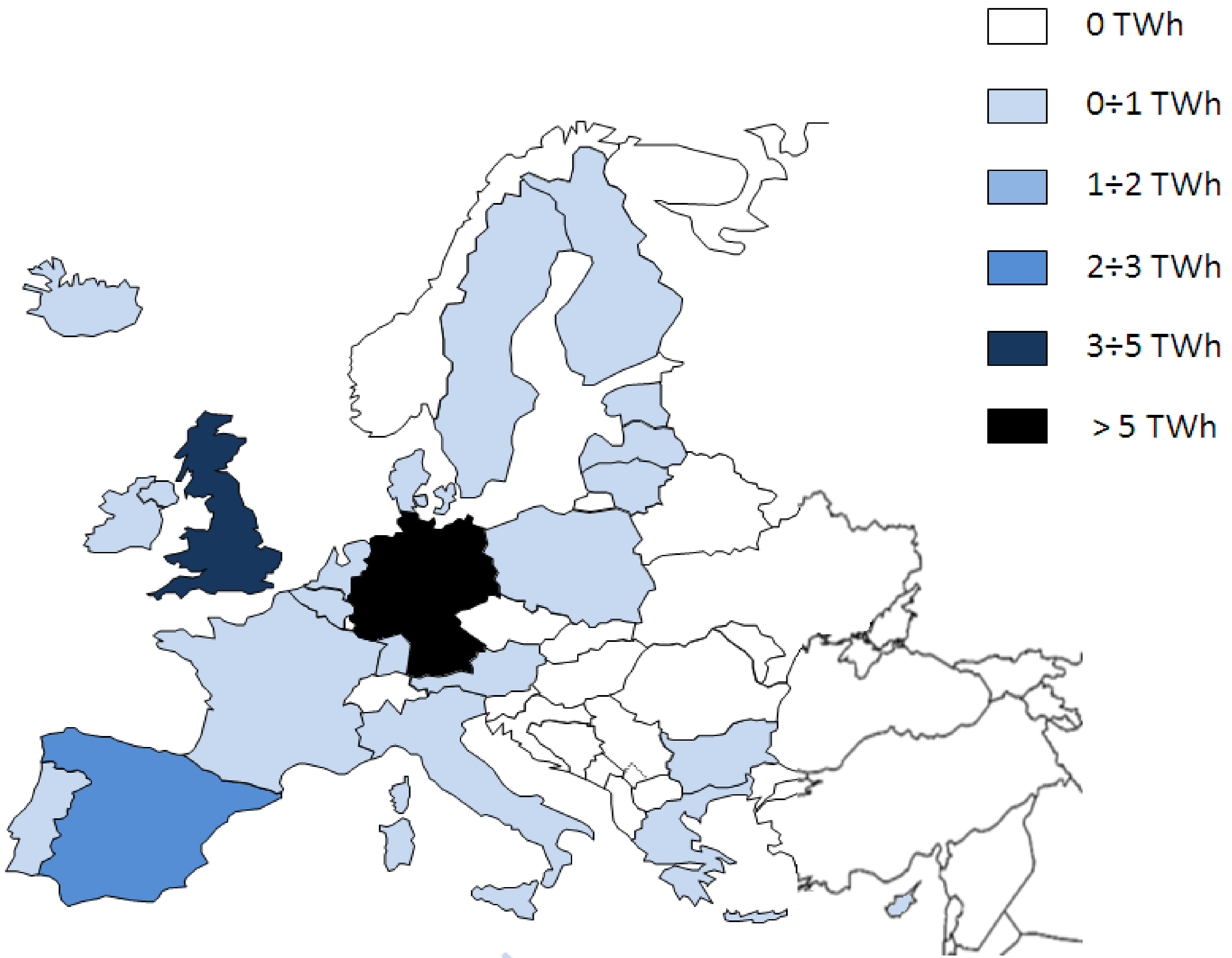


Pan-European study results (2050-1 S0, base)

Main (updated) outcomes:

- Load shedding is rather high and concerns TR (depending on TR demand projection)
- RES curtailment is higher than in 2030 (15.6 TWh) and concerns several zones: AT, BE, BG, CY, DE1, DE2, DK, EE, ES, FI, FR, GB, GR, IE, IS, IT, LT, LV, MT, NI, NL, PL, PT, SE (highest values are in DE1, GB, ES, NL, PT, DK, IE, NI, EE, FR)
- Zonal marginal costs can reach very high levels due to load sheddings (at a VOLL of 5000 €/MWh)
- HVDC corridors are rather fully utilised
- The system needs several reinforcements

2050-1 S0 (base) results: RES curtailment

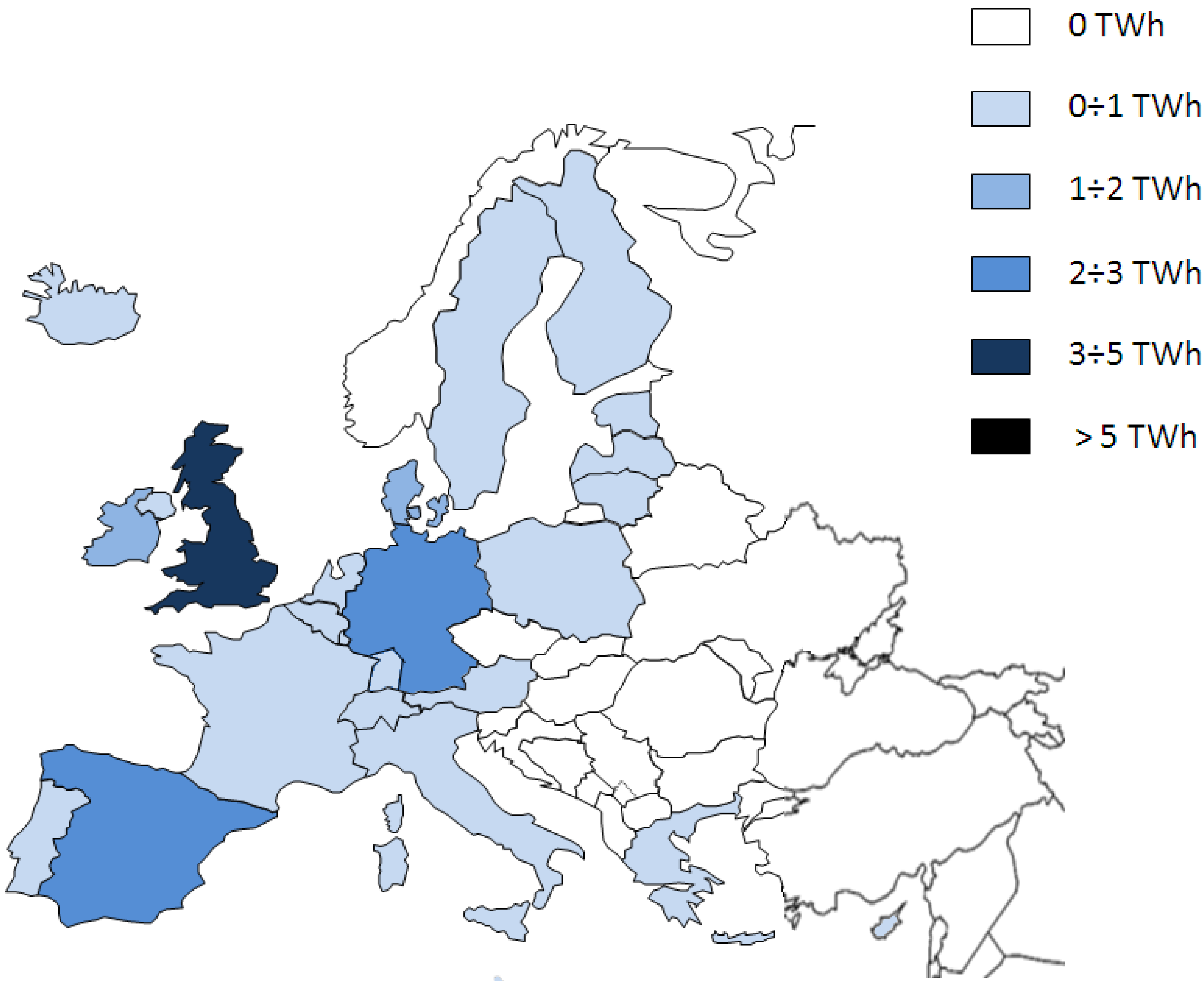


Pan-European study results (2050-2 S0, base)

Main (updated) outcomes:

- Load shedding is rather high and concerns TR (depending on TR demand projection)
- RES curtailment is 14.2 TWh (rather higher than in 2030 but lower than in 2050-1) and concerns several zones: AT, BE, CH, CY, DE1, DE2, DK, EE, ES, FI, FR, GB, GR, IE, IS, IT, LT, LU, LV, MT, NI, NL, PL, PT, SE (highest values are in GB, DE1, ES, IE, DK, NL, NI, PT, FR, EE)
- Zonal marginal costs can reach very high levels due to load sheddings (at a VOLL of 5000 €/MWh)
- HVDC corridors are rather fully utilised
- The system needs several reinforcements

2050-2 S0 (base) results: RES curtailment



Pan-European study results (2050-1 S3, EDT)

Main outcomes:

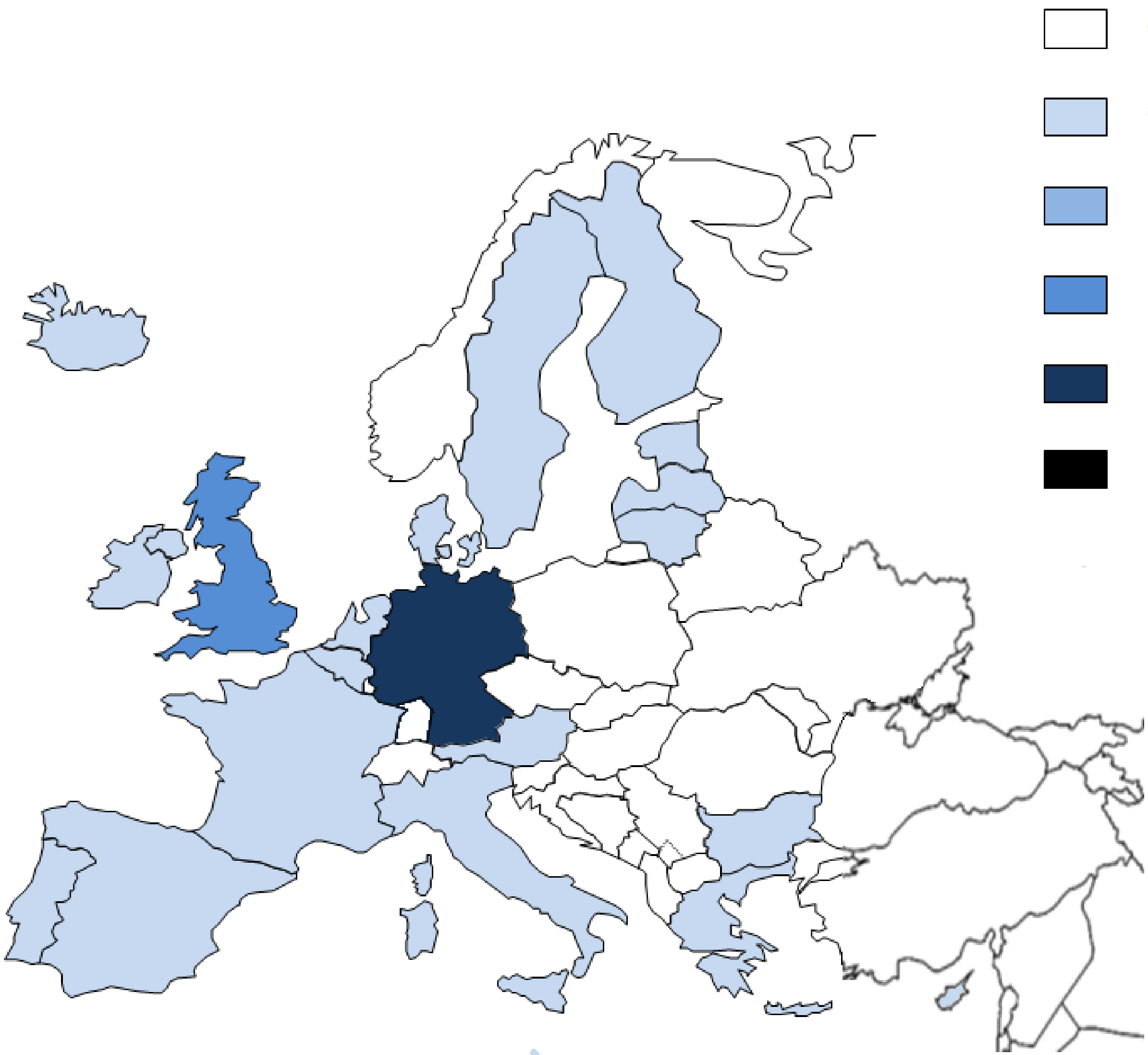
- Load shedding reduction amounts to 4.3 TWh by DR in 2050-1
- EDT (DR) brings in 2050-1 much higher benefits than in 2020 and 2030 in terms of RES curtailment reduction (6.7 TWh by DR) and dispatch cost decrease (24.5 b€ by DR) over 2050-1 S0
- Zonal costs can be high depending on RES penetration, energy mix, load sheddings
- Impact of EDT (DR) on CO_2 emissions reduction is positive in 2050-1 (6.7 $MtCO_2$ by DR)

Pan-European study results (2050-2 S3, EDT)

Main outcomes:

- Load shedding reduction amounts to 4.6 TWh (by DR) in 2050-2
- EDT (DR) brings in 2050-2 much higher benefits than in 2020 and 2030 in terms of RES curtailment reduction (6.4 TWh by DR) and dispatch cost decrease (25.6 b€ by DR) over 2050-2 S0
- Zonal costs can be high depending on RES penetration, energy mix, load sheddings
- Impact of EDT (DR) on CO_2 emissions reduction is positive in 2050-2 (6.6 $MtCO_2$ by DR)

2050-1 S3 (EDT) results: RES curtailment



2020-2030-2050 EDT (DR) -> S3

EDT (DR) benefits	2020	2030	2050-1 (with PTDF)	2050-2 (without PTDF)
Total dispatch cost reduction	425 M€	1423 M€	24530 M€	25636 M€
RES curtailment reduction	127 GWh	1458 GWh	6719 GWh	6445 GWh
CO_2 emissions reduction	-869 $ktCO_2$	-8384 $ktCO_2$	6694 $ktCO_2$	6563 $ktCO_2$
Load shedding reduction	0 GWh	0 GWh	4327 GWh	4555 GWh

Main conclusions on DR

- Large investments and system extensions are needed to foster huge RES-E integration: there are several technological options available today and in the future, while there are not solutions good for all cases/regions (much depends on local situation)
- From a society perspective, the use of DR might be very effective -> price signals to industry and customers are needed
- Storage vs. DR -> DR may be favoured over storage as it is generally cheaper and more efficient
- Flexibility, controllability and socio-environmental impact will be more and more crucial aspects to be further investigated
- Further analyses towards a full quantitative techno-economic DR assessment, taking into account DR benefits and costs, as well as comparisons with other innovative technologies, have been carried out within GridTech

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IEE GridTech project

http://www.gridtech.eu

Thanks!