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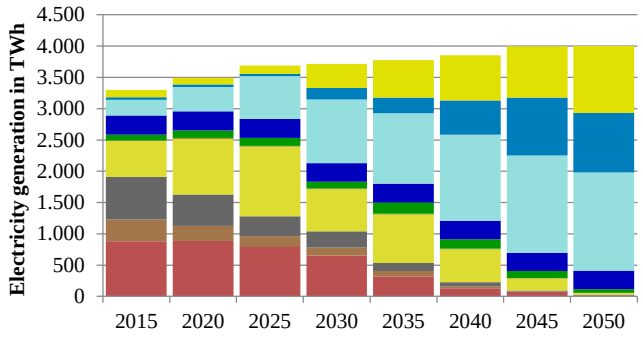
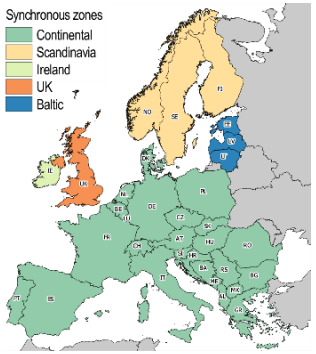
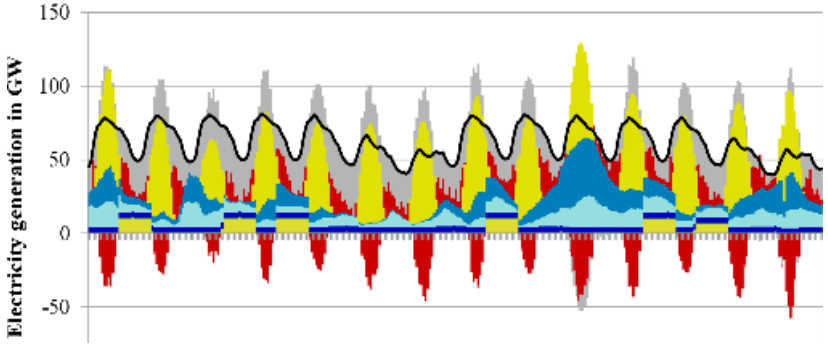
September 2017







Electricity sector transformation in Europe – Taking local idiosyncrasies into account

Clemens Gerbaulet, Hanna Brauers, Christian von Hirschhausen, Casimir Lorenz, Pao-Yu Oei

Motivation

How to achieve decarbonization in European Electricity?

European Emission reduction targets

- European Union energy and climate package:
  - 80-95% reduction of greenhouse gases by 2050 (base: 1990)
- Ratification of the Paris Agreement to limit the rise in global temperature to below 2°C

Coordination between member countries is necessary, but differing local objectives regarding

- Emissions
- Fossil fuels
- Possibly grid expansion

Cooperation taking into account is required for successful energy system transformation towards decarbonization

Hypothesis:

- **Taking into account some possible local developments does not affect the overall sector development**
- **Emission limits can still be adhered to**
- **Mostly neighboring countries are affected**

Determining cost-effective pathways in the electricity sector

dynELMOD:

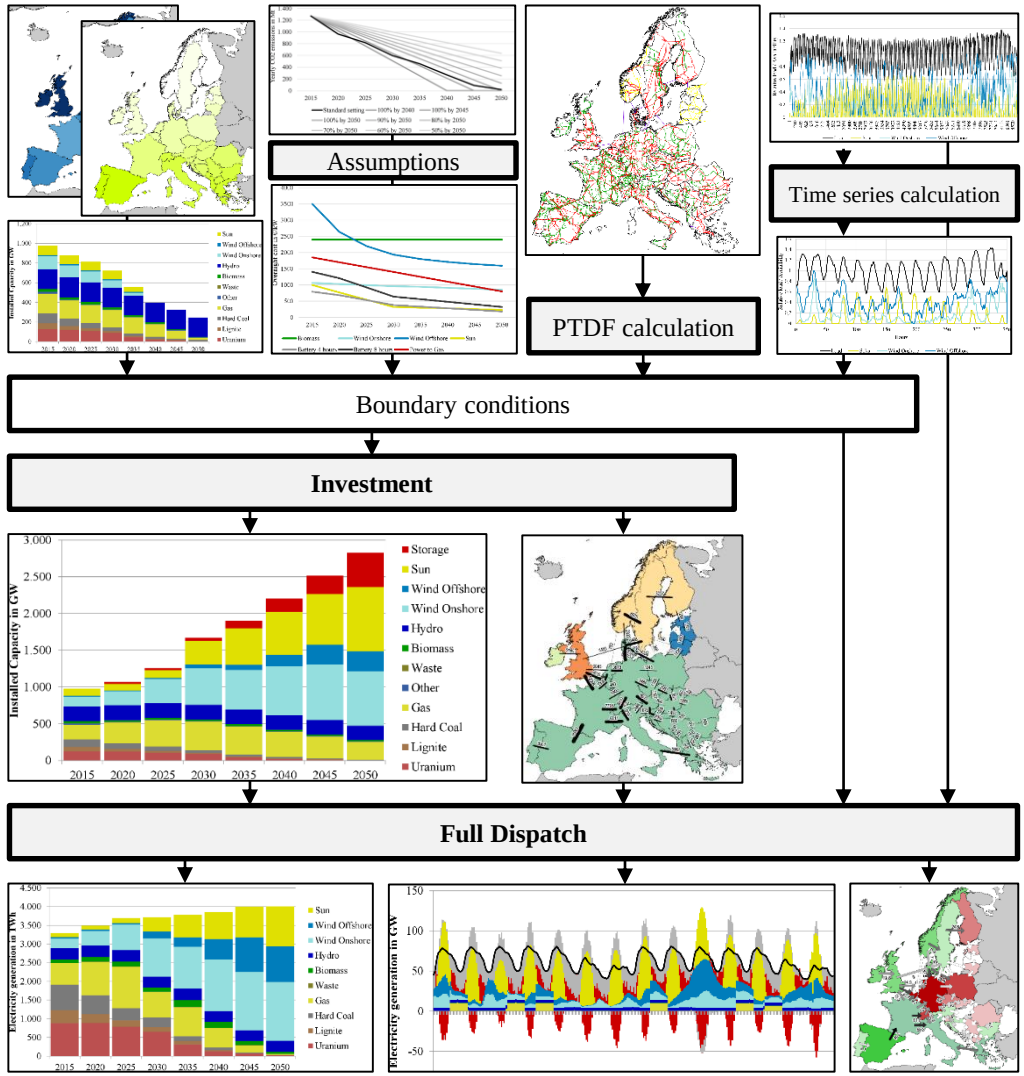
Linear program to determine cost-effective development pathways in the European electricity sector

Model:
33 European countries
31 conventional or renewable generation and storage technologies
9 investment periods, five-year steps 2020 – 2050
Good storage representation (including reservoirs, DSM)
Approximation of loop-flows in the HVAC electricity grid
CCTS and CO2 storage constraints

1. **Investment**
   - Investment into Conventional and renewable generation, cross-border capacities
   - Reduced time series used
2. **Dispatch**
   - Investment result from step 1 fixed
   - Time series with 8760 hours (validate result adequacy)

Outputs

- Investment into generation capacities, storage, transmission capacities
- Generation and storage dispatch
- Emissions by fuel
- Flows, imports, exports

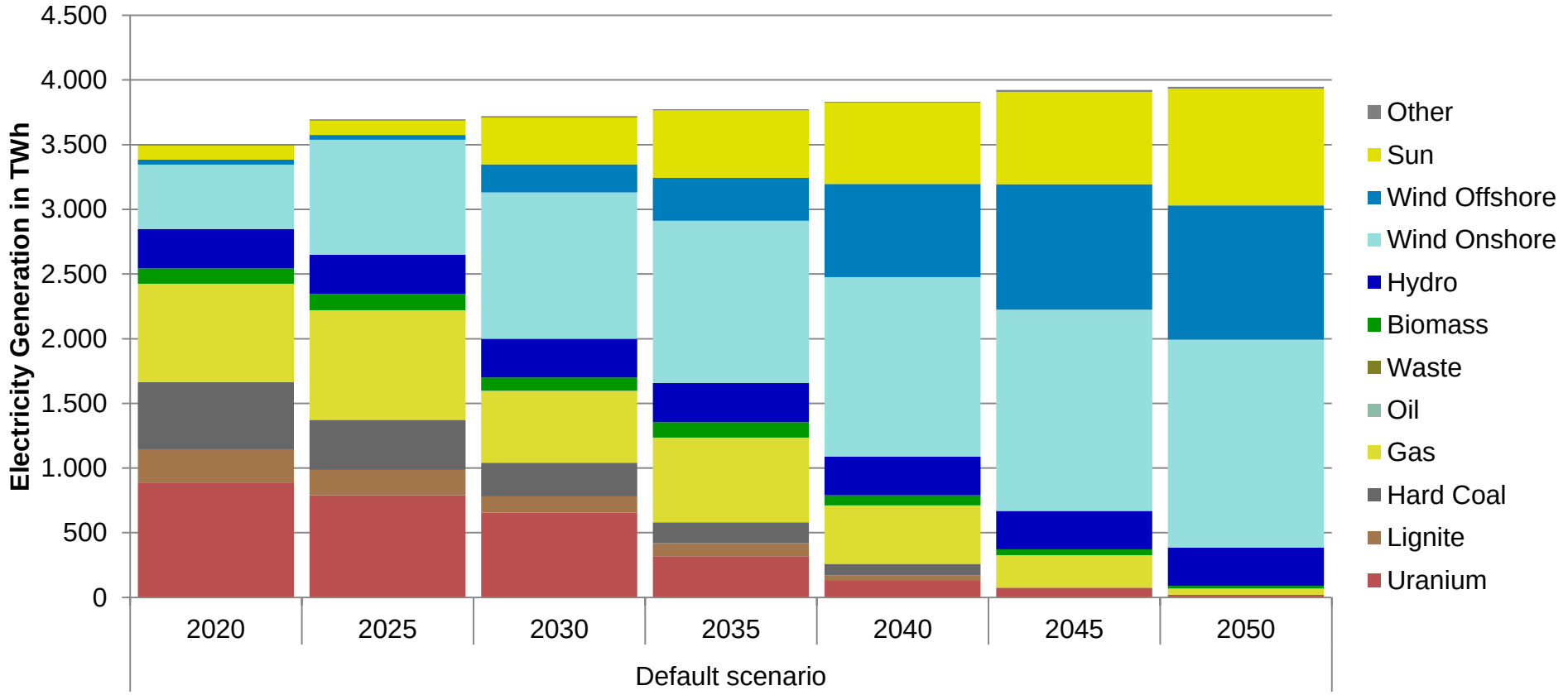


Application

Scenario	Scenario description
Default scenario	**Default scenario:** • European electricity sector development 2015 – 2050 • Default assumptions from dynELMOD, but with more detailed storage technologies • Serves as baseline for comparison
More Lignite in PL, BG, CZ	**Characteristics:** • What happens when some countries do not follow a decarbonization pathway? • What countries compensate the additional emissions? • Implemented as minimum full-load hours for lignite plants, variations 4000-7000 hours
Reduced grid extension	**Characteristics:** • What happens when renewable exporters do not export / grid does not get built? • No new grids between British Isles and Central Europe, between France and Spain
France: less nuclear 2025	**Characteristics:** • Reduce French nuclear fleet by 50% by 2025

Renewables become dominant electricity source in Europe

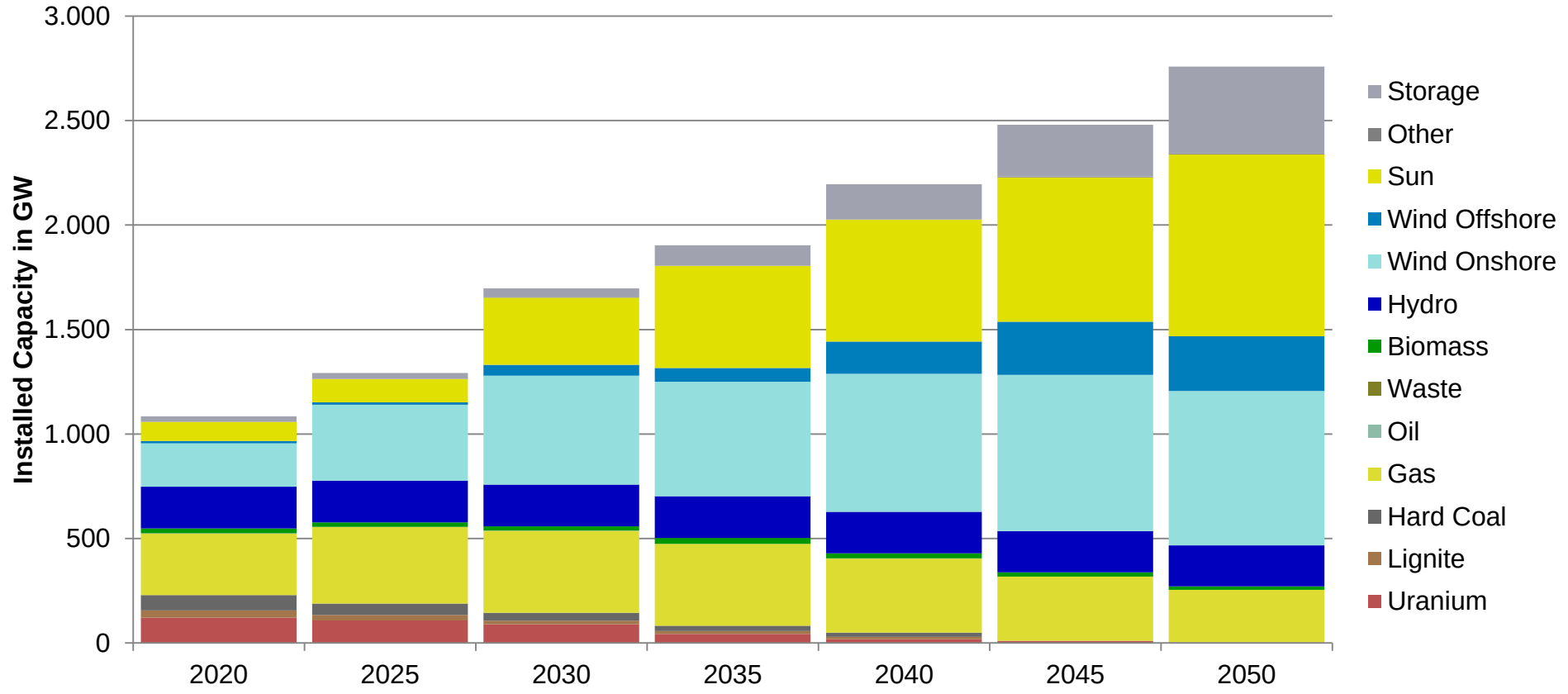
Electricity Generation in Europe 2020 – 2050



- **No new nuclear, hard coal, or lignite power plants emerge**
- **Natural gas usage reduces after 2030 to become backup technology**
- **Renewables become dominant electricity source**
- **Storage capacities (>400GW installed in Europe) balance fluctuations**

Renewables become dominant electricity source in Europe

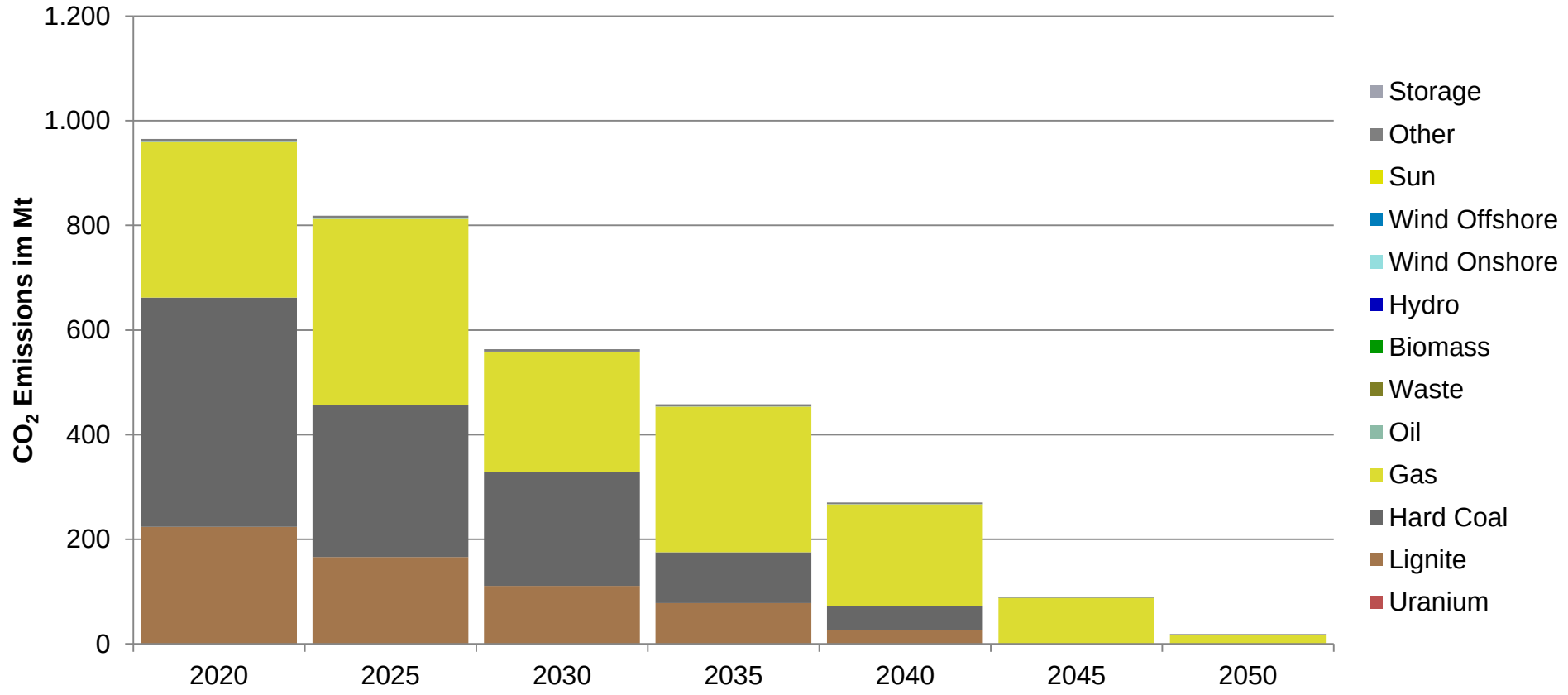
Installed Capacity in Europe 2020 – 2050



- **With high decarbonization of the electricity sector, between 250 and 400 GW electricity storage need until 2050.**
- **Mostly battery based storage, almost no new pumped storage capacities,**
- **Almost no new storage in Switzerland and Austria.**
- **Highest storage investment in UK, DE, ES, FR.**

Renewables become dominant electricity source in Europe

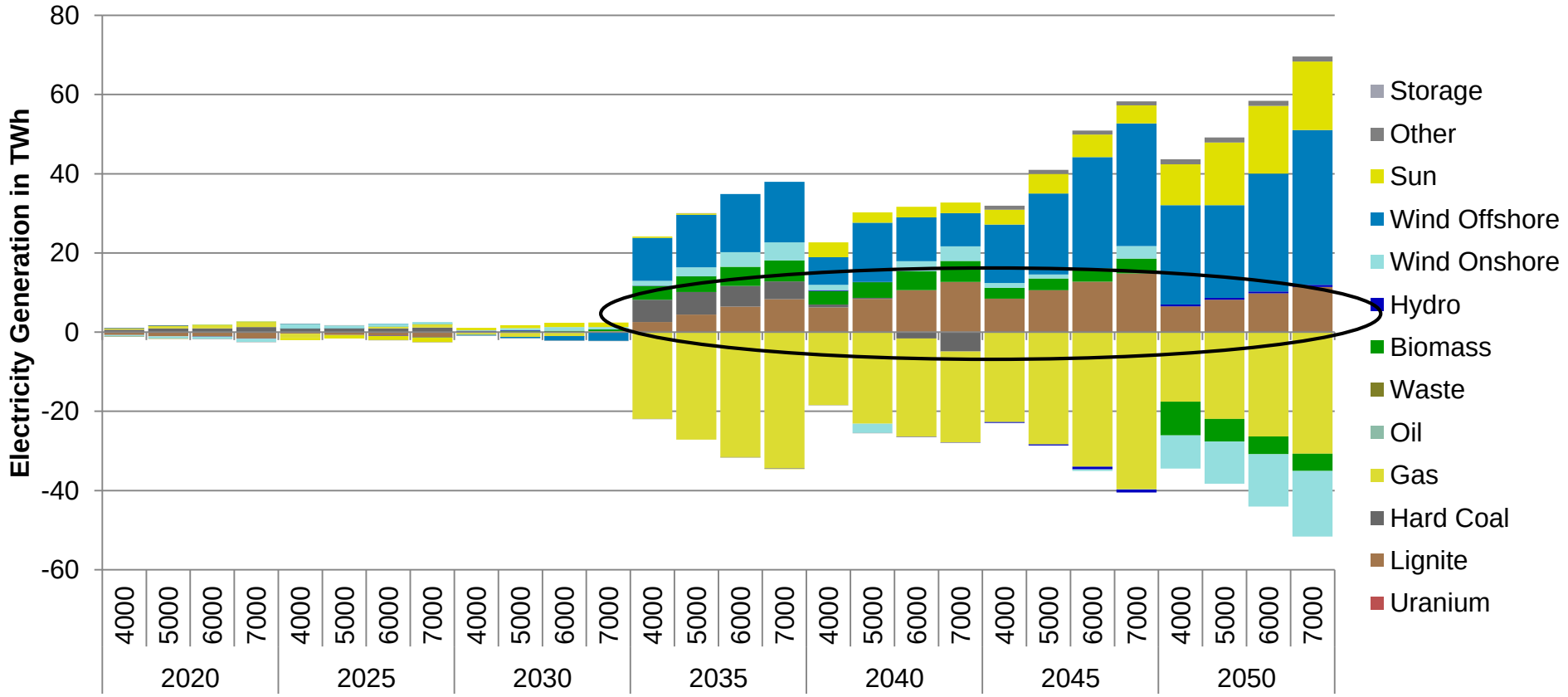
CO_2 emissions in Europe 2020 – 2050



- **Emissions follow the emission constraint imposed by the model**
- **Emissions from gas initially increase, although no new gas-fired power plants emerge**

Additional lignite leads to less gas, more RES generation

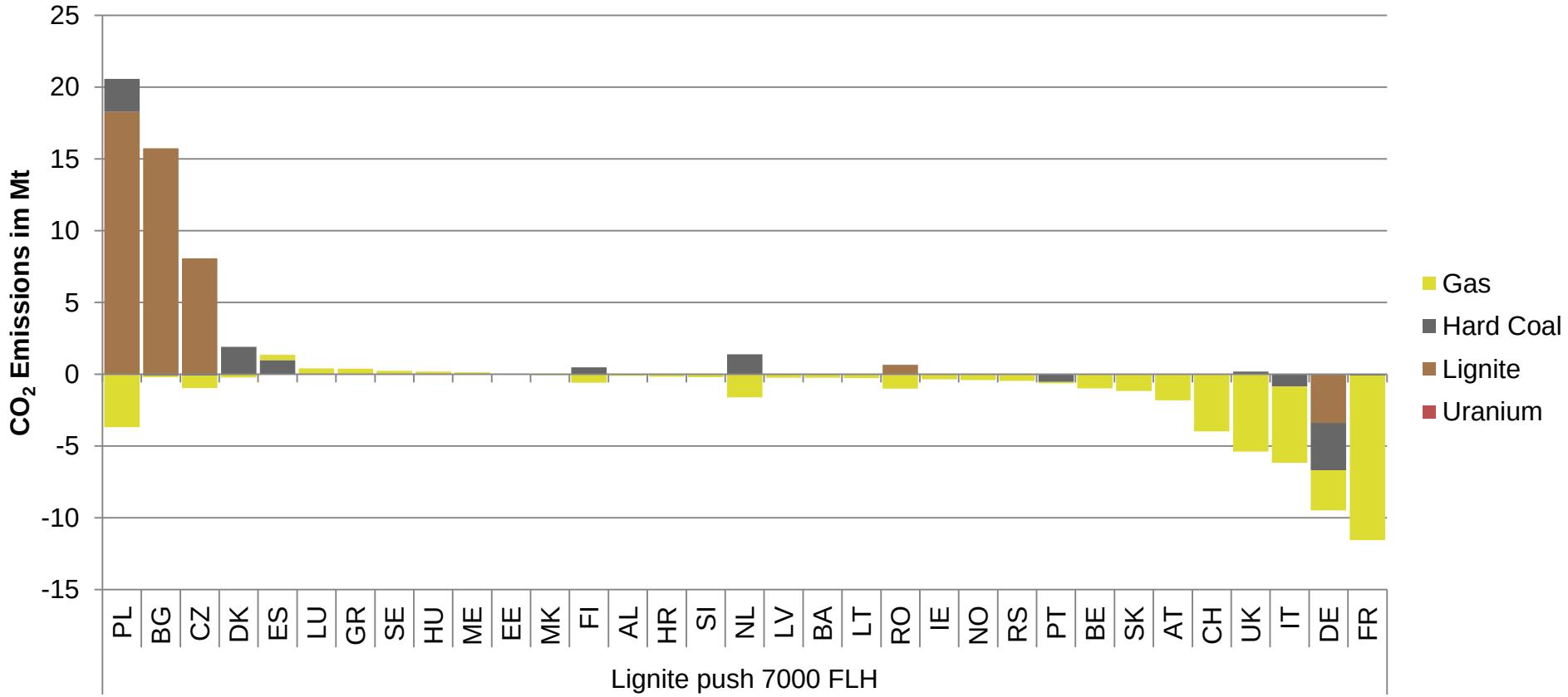
Difference in electricity generation by Lignite Full-load-hours in Europe 2020 – 2050



- **Only in 2035 the full load hour constraint changes the power plant dispatch**
- **Lignite replaces gas fueled generation**
- **Leads to additional wind and some solar generation**

Additional lignite leads to less gas, more RES generation

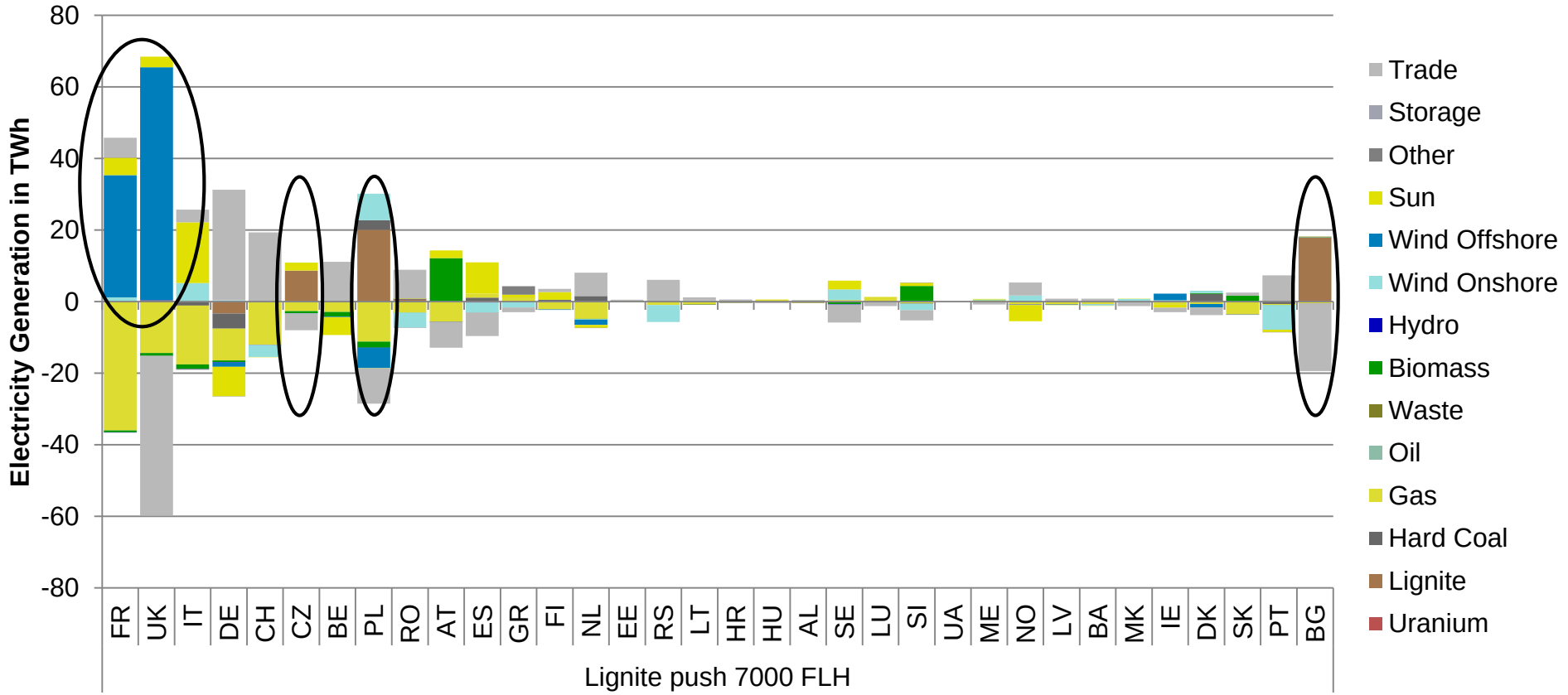
Difference Emissions by country, sum over 2020 – 2050



- **More emissions as expected in PL, BG, CZ**
- **Cost-effective to compensate in emissions in France, Germany, Italy, UK, and Switzerland**

Additional lignite leads to less gas, more RES generation

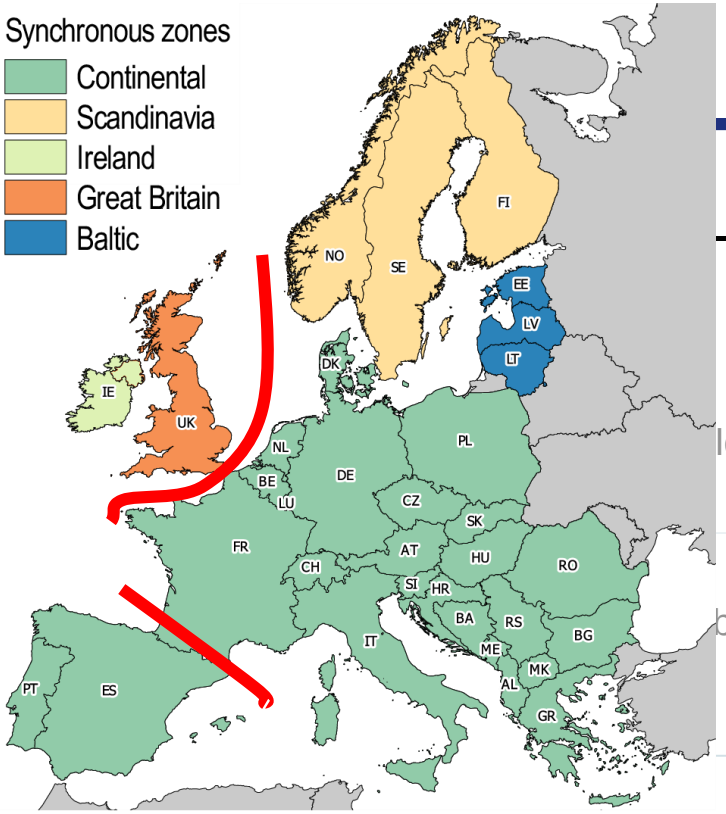
Difference electricity generation by country, sum over 2020 – 2050



- **Exports in Poland and Bulgaria increase, not in Czech republic**
- **UK increases exports, additional wind generation in France and UK**
- **More imports in DE, CH, BE, RO, NL**

Application

Scenario



Default scenario

Default scenario:
- European elec
- Default assum
- Serves as bas

led storage technologies

Lignite push in PL, BG, CZ

Characteristics:
- What happens
- Implemented a
- Variations betw

bonization pathway?

Reduced grid extension

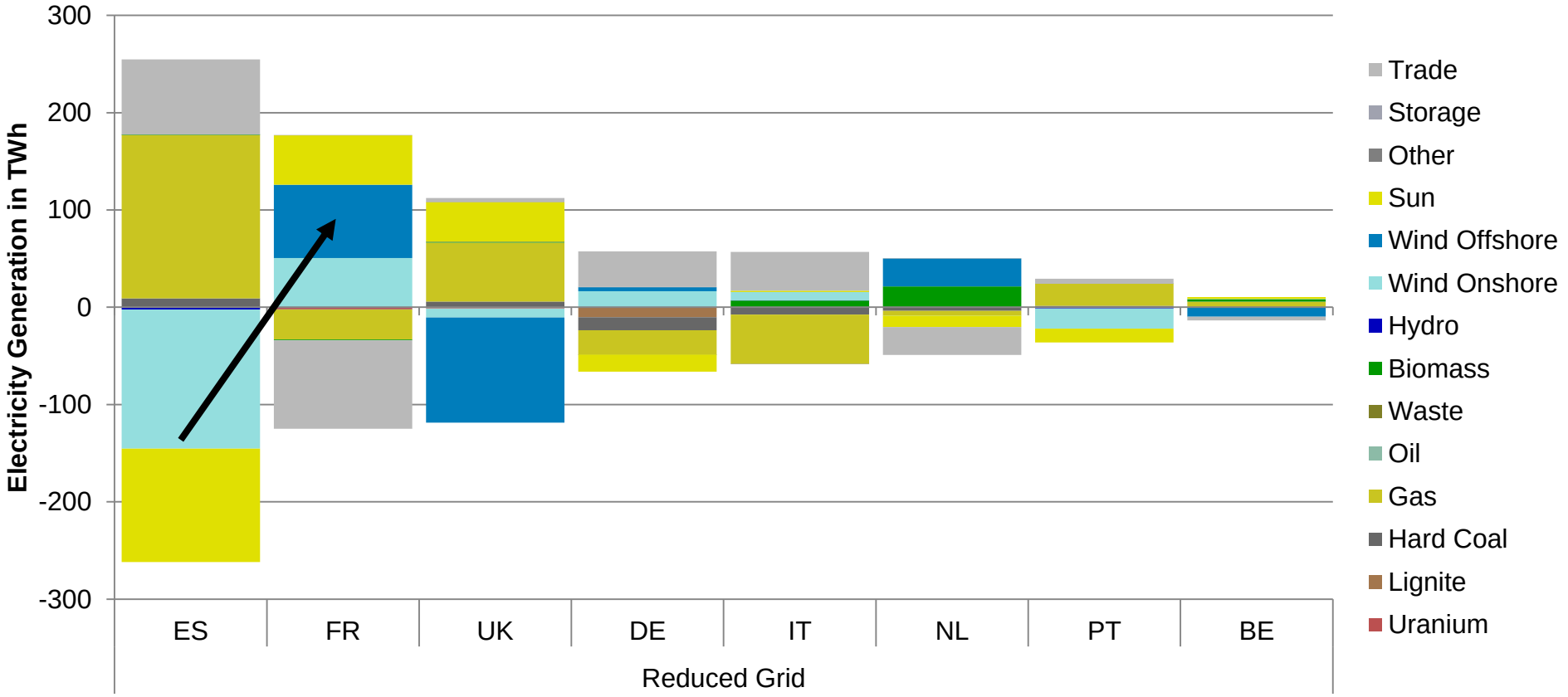
Characteristics:
- What happens when renewable exporters do not export / grid does not get built?
- No new grids between British Isles and Central Europe, between France and Spain

France: less nuclear 2025

Characteristics:
- Reduce French nuclear fleet by 50% by 2025

Reduced Grid

Difference electricity generation by country, sum over 2020 – 2050



- **Southwestern Export role shifts from Spain towards France**
- **Spain mostly affected, mostly additional gas generation**
- **The generation in UK shifts from wind towards wind and gas, more storage capacities**
- **Otherwise, the effect of reduced interconnection is smaller than expected**

Application

Scenario	Scenario description
Default scenario	**Default scenario:** • European electricity sector development 2015 – 2050 • Default assumptions from dynELMOD, but with more detailed storage technologies • Serves as baseline for comparison
Lignite push in PL, BG, CZ	**Characteristics:** • What happens when some countries do not follow a decarbonization pathway? • Implemented as minimum full-load hours for lignite plants • Variations between 4000 and 7000 hours
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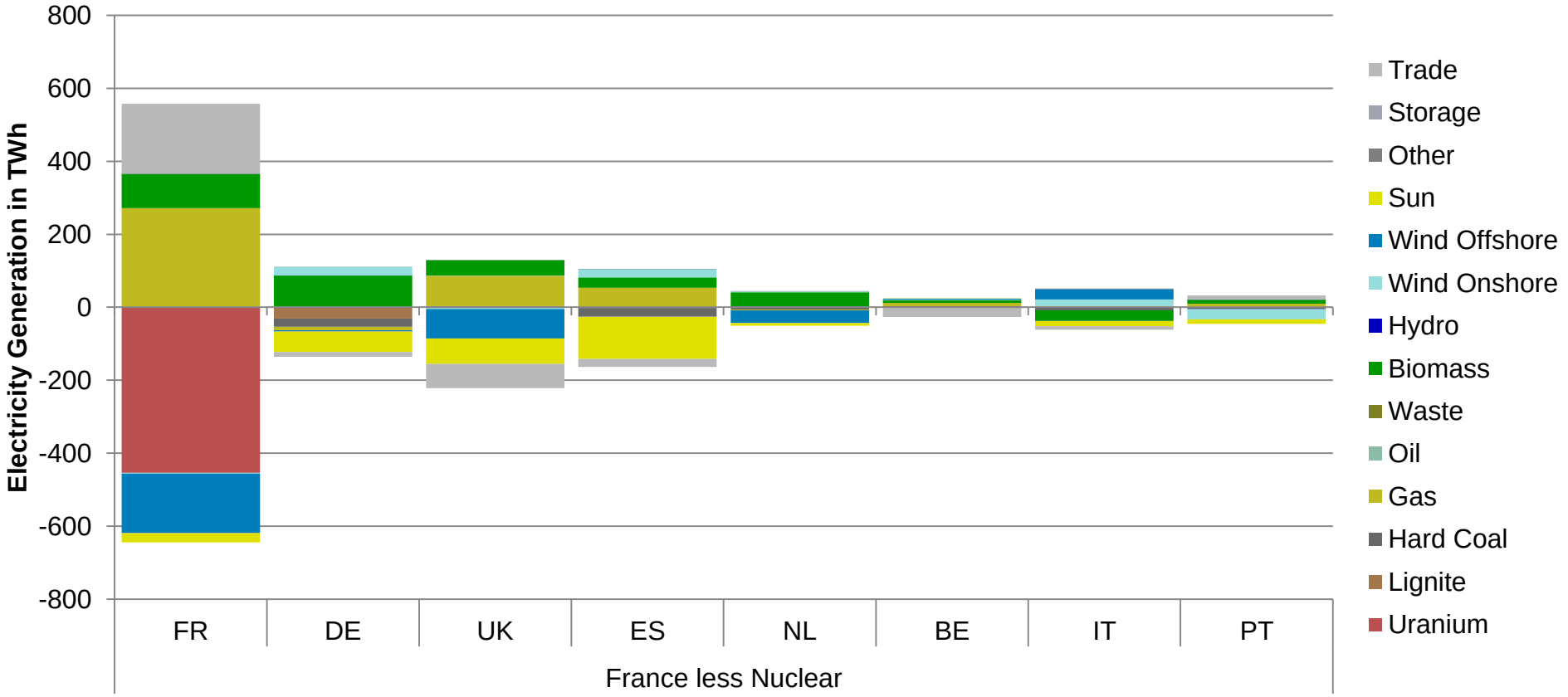
France less nuclear

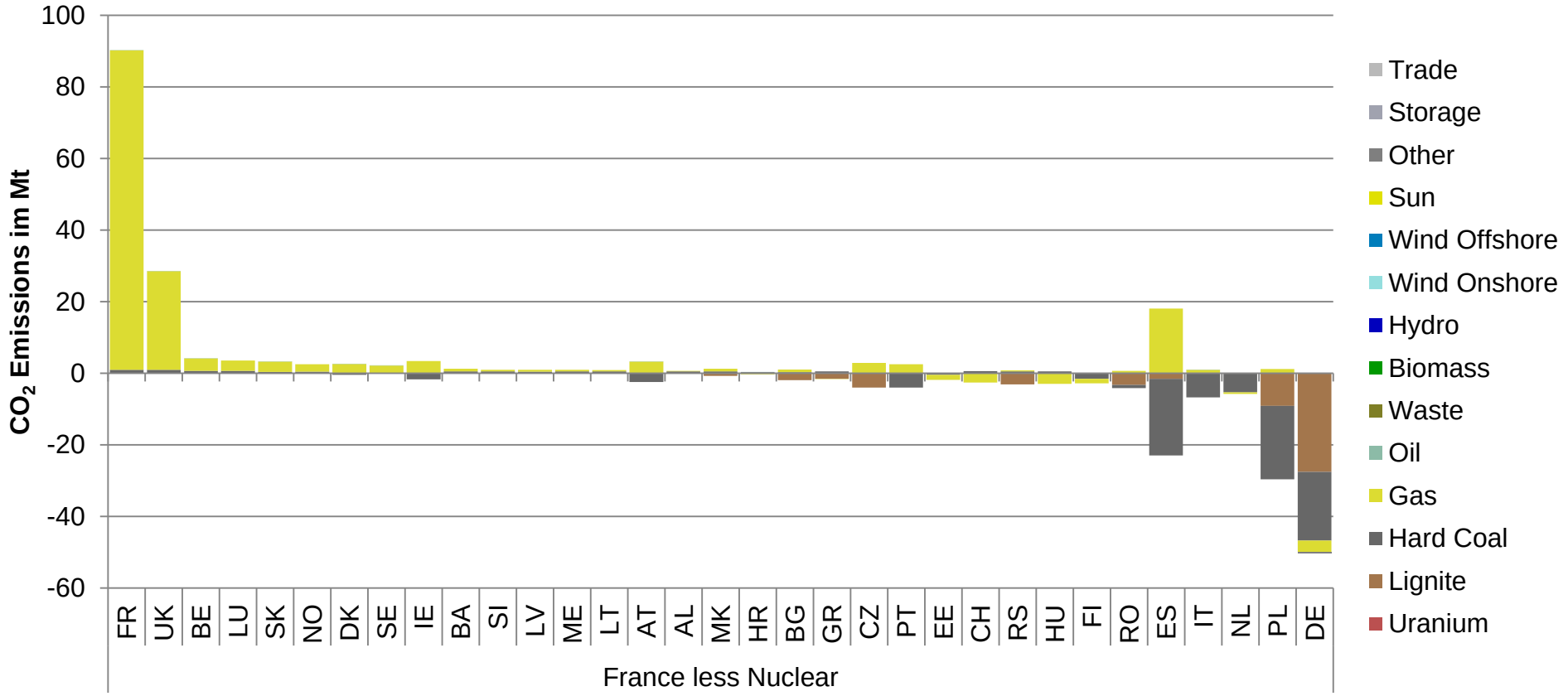
Difference electricity generation by country, sum over 2020 – 2050



- **The reduction of French nuclear in 2025 is compensated inlands, and with additional imports**
- **Gas and Biomass generation is increased in France and neighboring countries**
- **Slightly more Storage capacities across neighboring countries needed**

France less nuclear

Difference emissions by country, sum over 2020 – 2050



- **To adhere to the emission limit, some countries are affected**
- **Coal and Lignite generation is reduced in Spain, Poland, and Germany**

Conclusion

- **Overall capacity investment is stable in the scenarios, Regional differences occur**
- **These local changes do not substantially affect the overall sector development**
- **Cost differences between the scenarios are as expected relatively small**
- **The overall emission limit is not exceeded**
  - enough potential in neighboring countries is available
- **Changes can propagate “far”, e.g. lignite in the east leads to more wind in the west**

Hypothesis:

- **Taking into account some possible local developments does not affect the overall sector development** ✓
- **Emission limits can still be adhered to** ✓
- **Mostly neighboring countries are affected** ✗

- **Next:**
  - **Combination of many countries’ local preferences and its effect on overall capacity development transmission expansion**
  - **Energy autarky targets**

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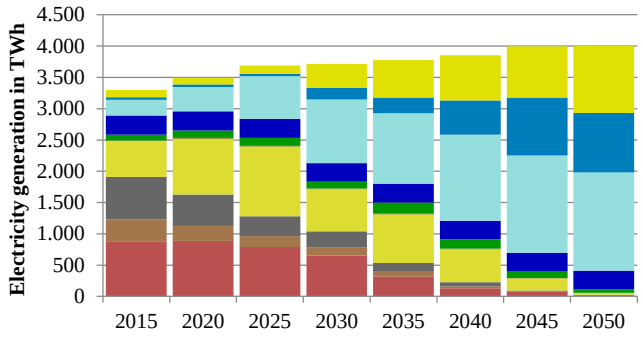

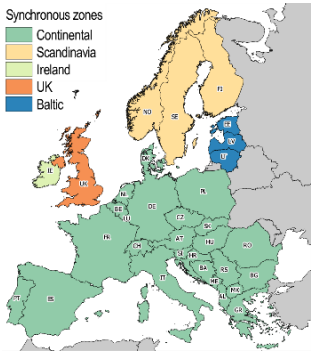

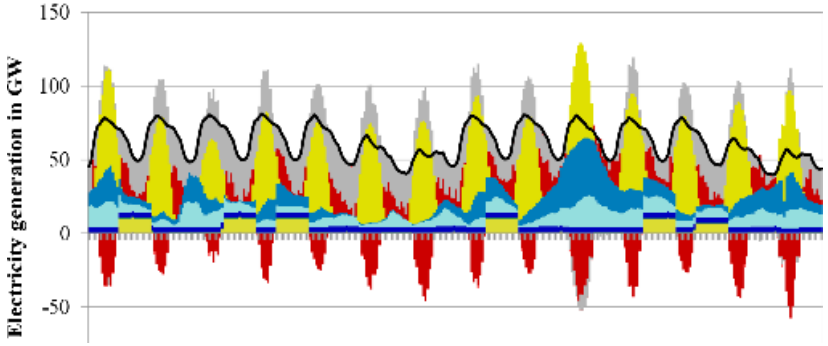

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