

European Commission

# Decarbonisation of the heating and power sectors of the European Union

## 1. Background

**EU targets [2]:**

55% emissions cut by 2030

90% emissions cut by 2040

Climate neutrality by 2050

**EU strategy:**

Integrated energy system and transition to a renewable-based economy

Identifying effective decarbonisation pathways is key

## 2. Objectives

Examine decarbonisation pathways for Europe's interconnected electricity and heating sectors by 2030 and 2035 using the PyPSA-Eur [3] open-source energy system model and dataset

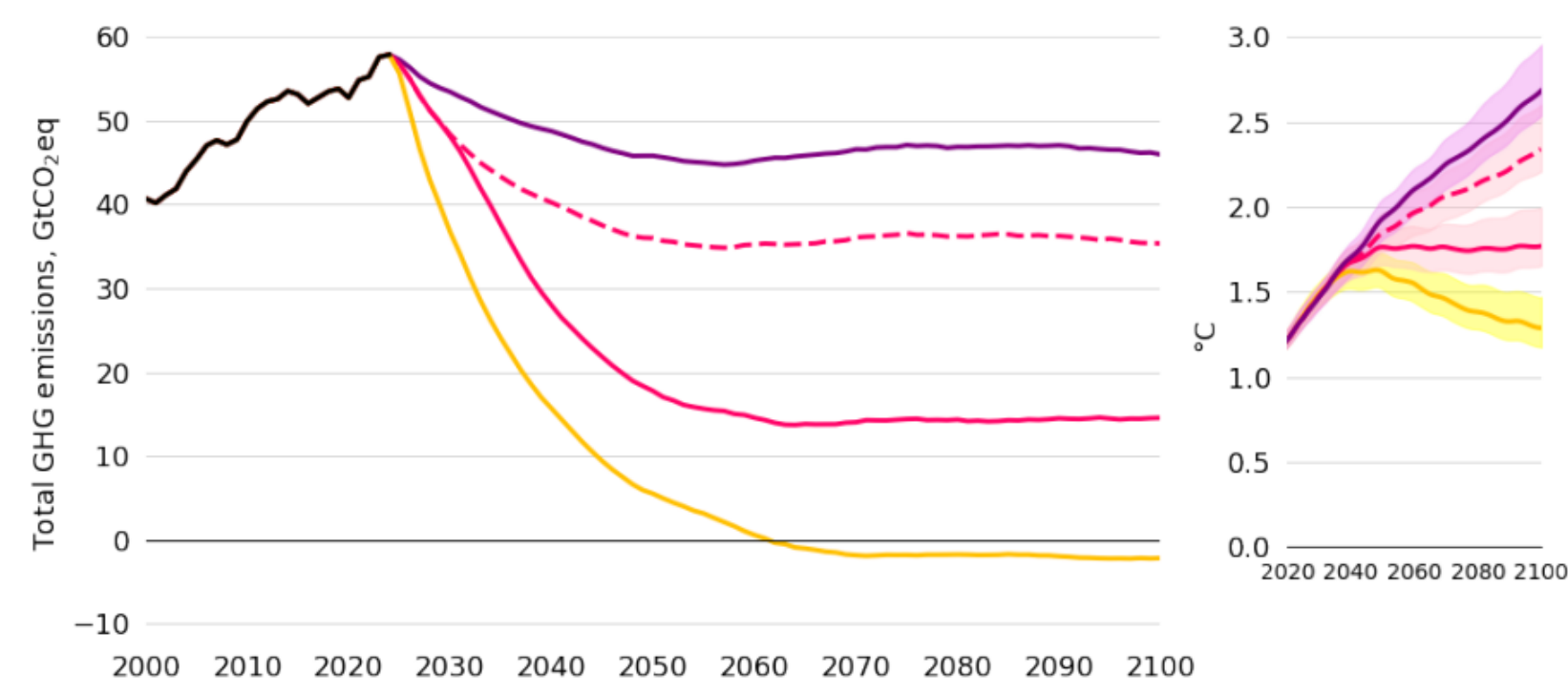


Fig. 1 Global emissions and global mean temperature change, by scenario [1]

## 3. Mathematical Model

**Components:**

Buses, Lines, Links, Stores, Carriers, Generators, Loads

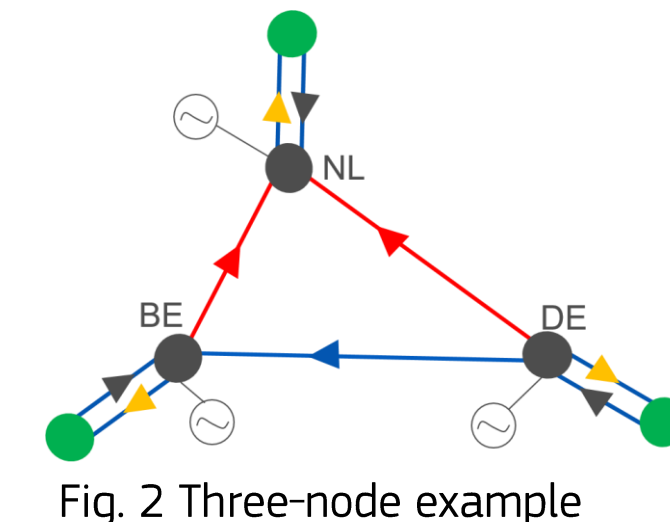


Fig. 2 Three-node example

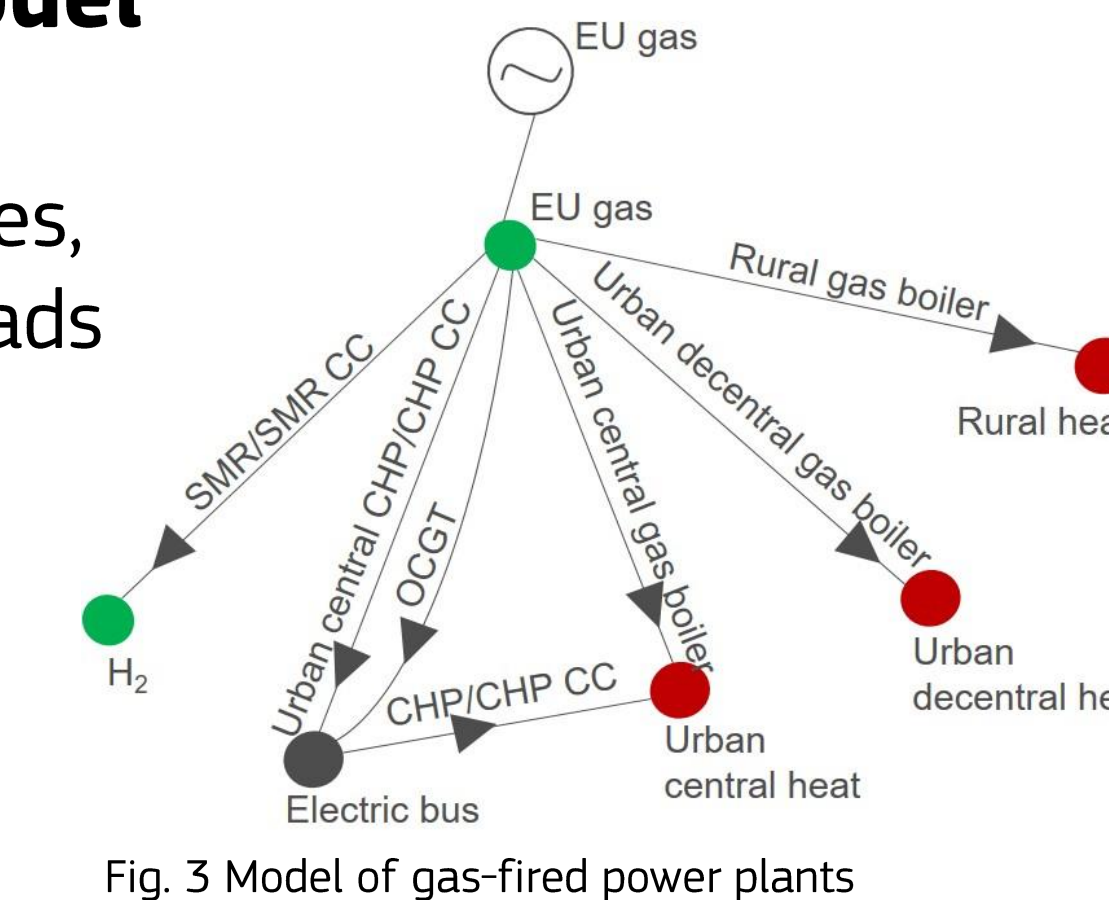


Fig. 3 Model of gas-fired power plants

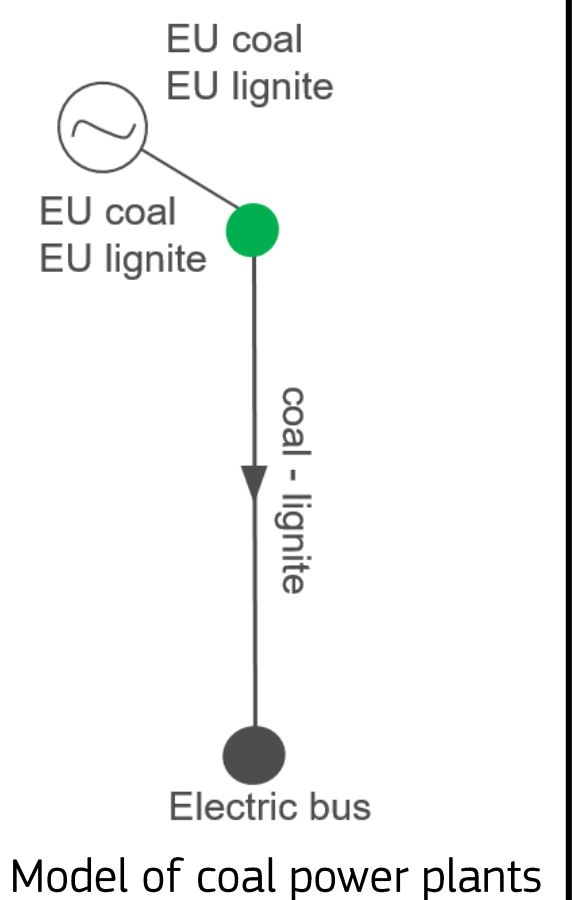


Fig. 4 Model of coal power plants

**Bounded and balance constraints:**

$$g_{BE,OCGT,t} + g_{BE,nuclear,t} - f_{BE-NL,t} - f_{BE electrolysis,t} + f_{DE-BE,t} + 0.5f_{BE fuelcells,t} = d_{BE,t}$$

$$\bar{x}_{label,t} \bar{x}_{label,t} \leq x_{label,t} \leq \bar{x}_{label,t} \bar{x}_{label,t}$$

**Objective function to optimise:**

$$\sum_{n,s} c_{n,s} \bar{g}_{n,s} + \sum_{n,s} c_{n,s} \bar{h}_{n,s} + \sum_t c_t F_t + \sum_t w_t \left[ \sum_{n,s,t} o_{n,s,t} \bar{g}_{n,s,t} + \sum_{n,s,t} o_{n,s,t} \bar{h}_{n,s,t} + \sum_{n,s,t} o_{f,t} \right] + \sum_t [suc_{n,s,t} + sdc_{n,s,t}]$$

## 4. Assumptions and Settings

Three-country model (BE, DE, NL) and EU-wide model aggregated to 39 nodes for 2030 and 2035 (climatic year 2013)

Renewable and conventional energy sources

Variable CO<sub>2</sub> targets relative to 1990 emissions

Time series segmentation (1095 time steps)

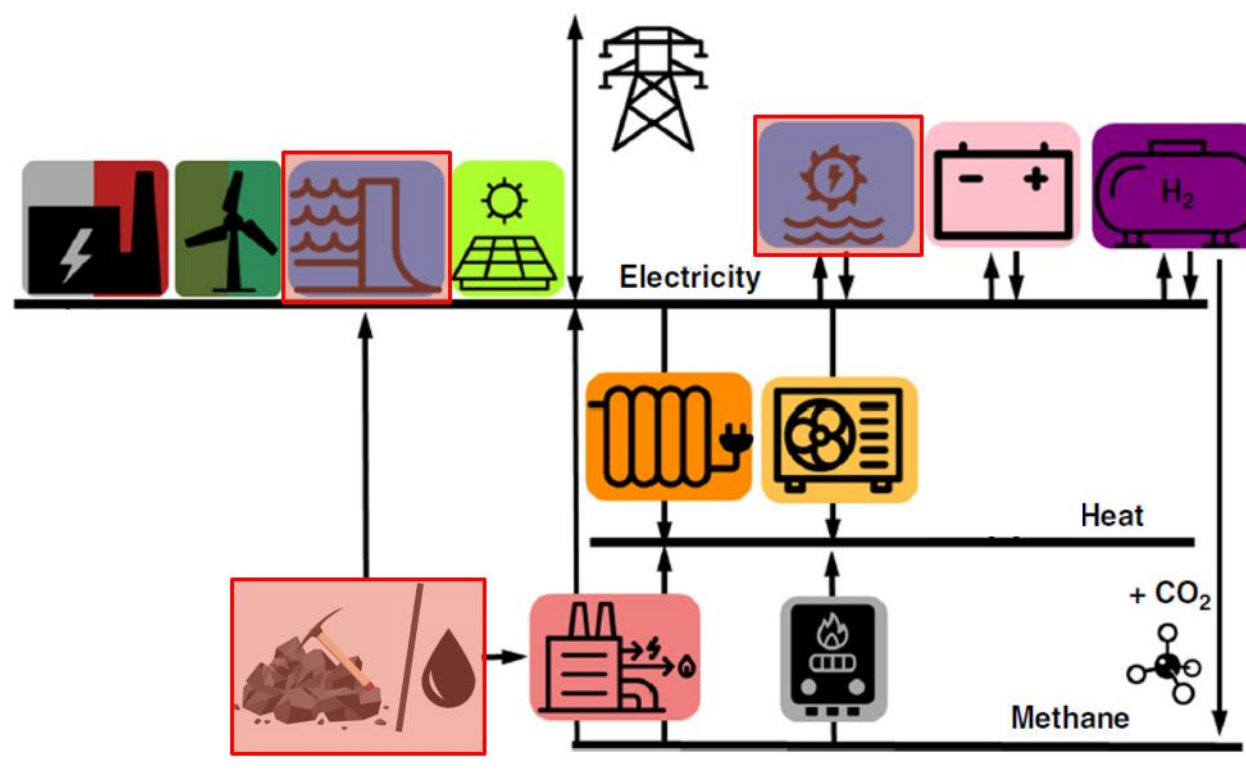


Fig. 5 Renewable and conventional energy technologies [4, modified]

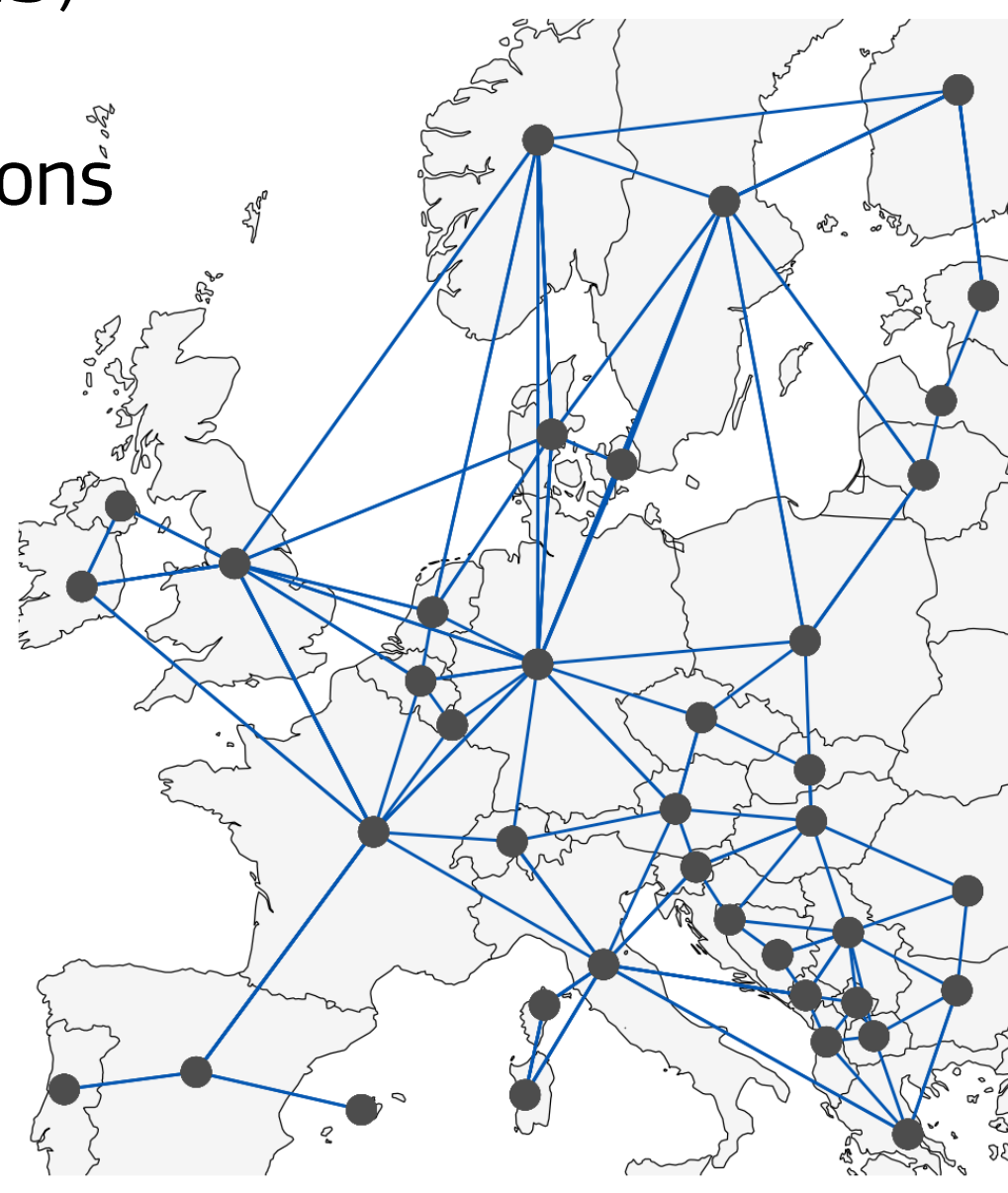


Fig. 6 EU-wide model network (simplified)

## 5. Results: technology expansion and solidarity approach

Optimisation results for a three-country study and a European-wide simulation

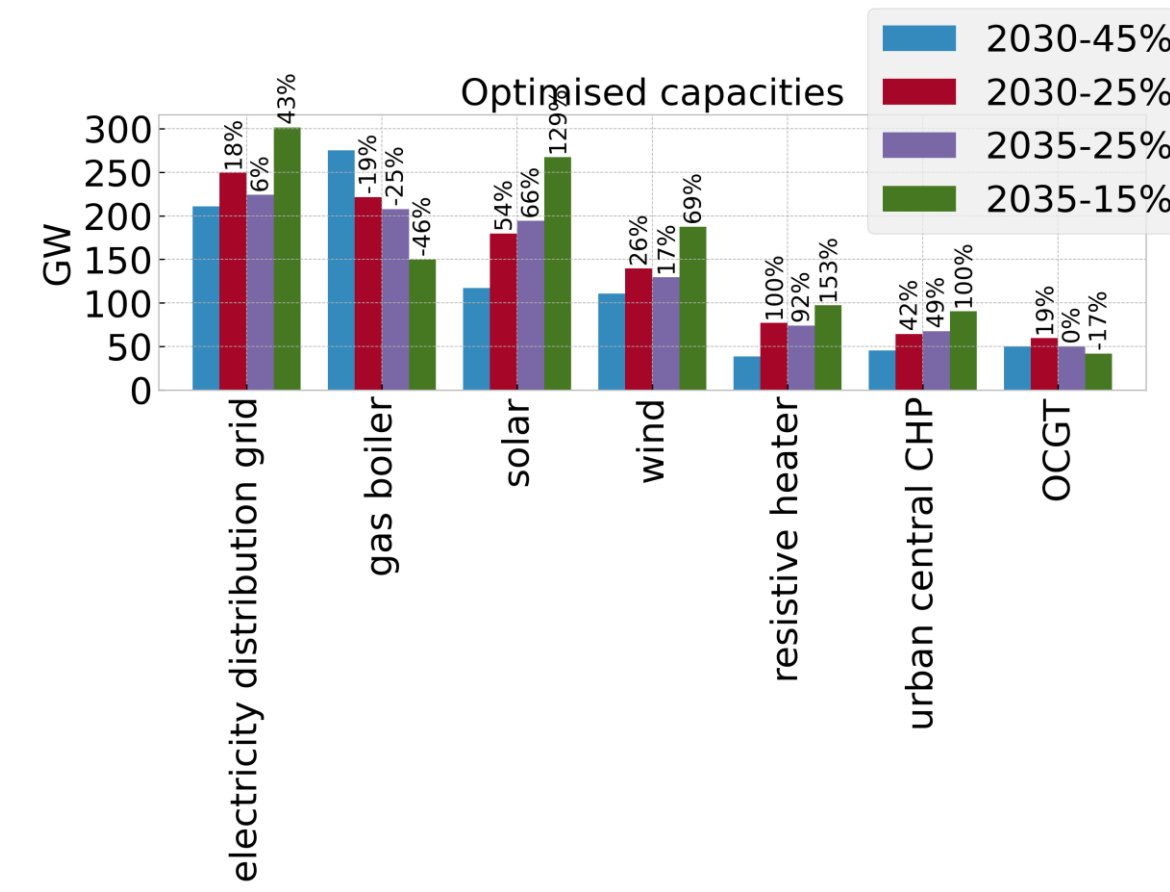


Fig. 7 Optimised capacities per scenario (three-country model)

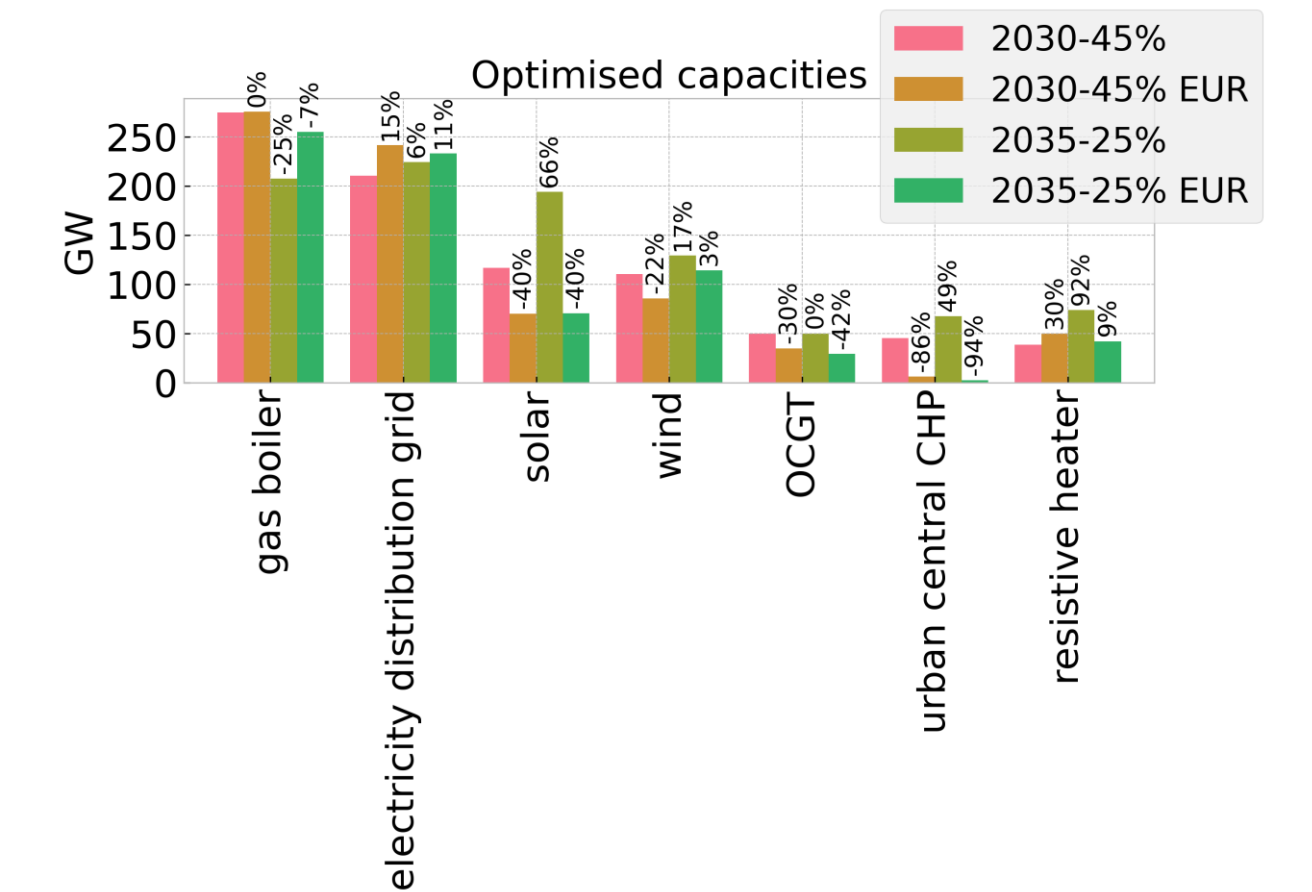


Fig. 8 Optimised capacities (three-country and EU-wide models)

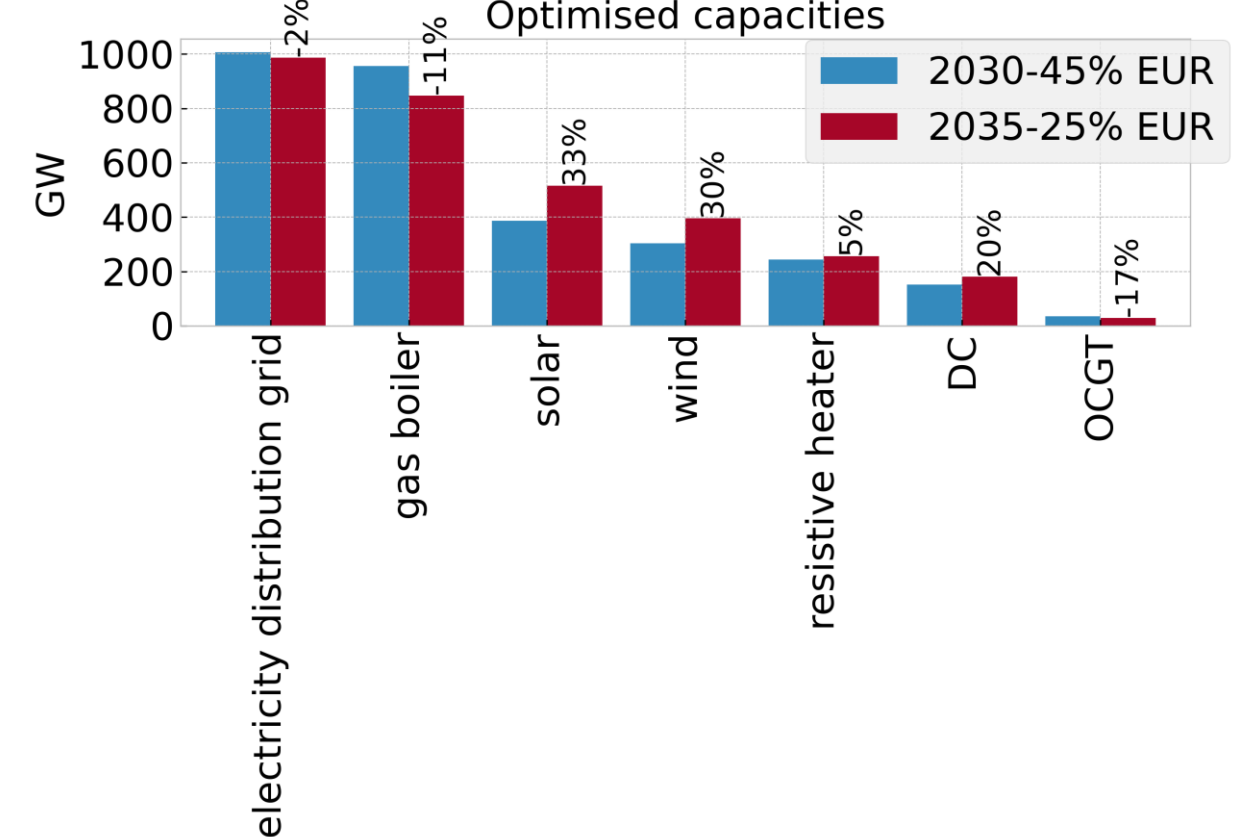


Fig. 9 Optimised capacities per scenario (EU-wide model)

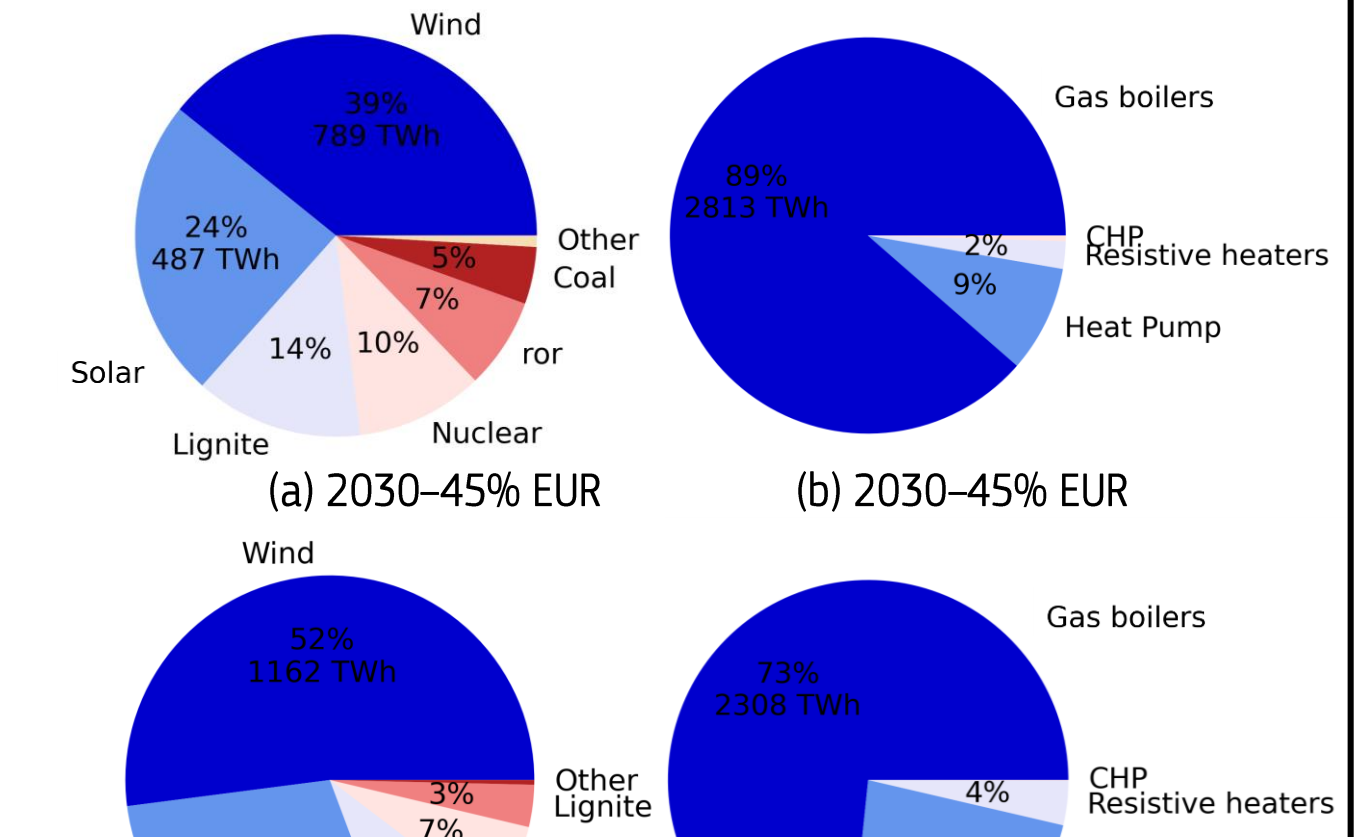


Fig. 10 Installed capacities by technology per scenario (EU-wide)

An EU-wide approach reduces the need for new technology deployments

## 6. Results: costs

Stricter CO<sub>2</sub> budgets increase system cost

Stricter CO<sub>2</sub> budgets encourage investments in offshore wind over gas in NL, while the shares of nuclear and gas remain largest in BE and DE, respectively

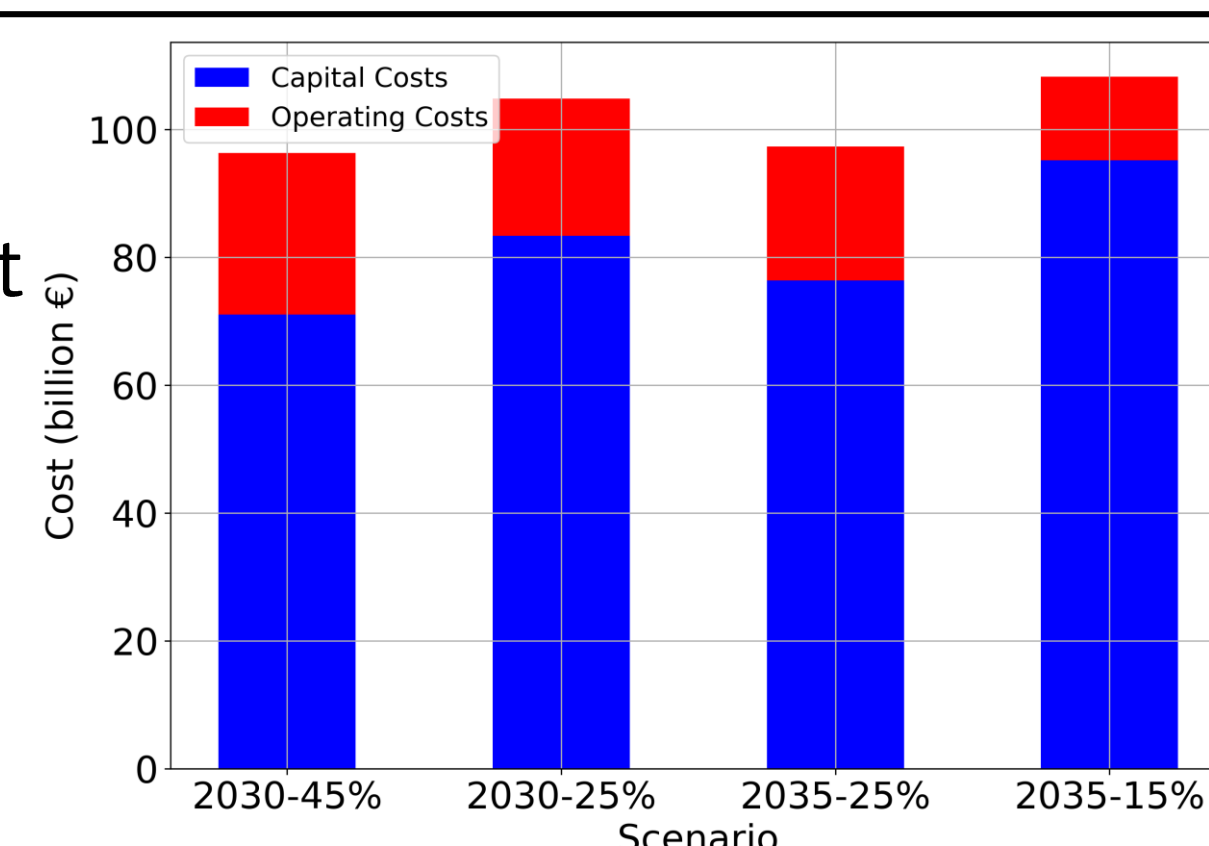


Fig. 11 Costs per scenario (three-country model)

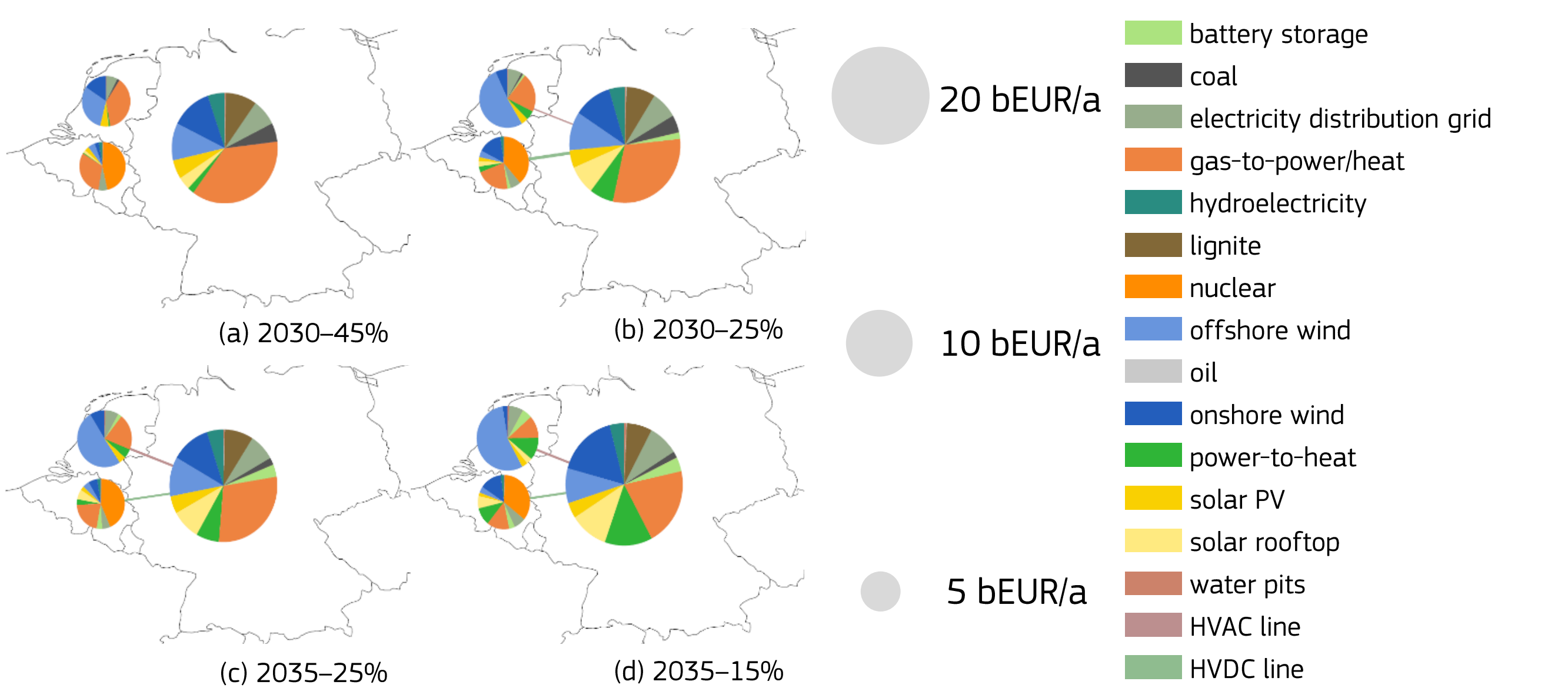


Fig. 12 Capital cost per country by technology for each scenario (three-country model)

## 7. Conclusions

1. Stricter CO<sub>2</sub> budgets reduce reliance on fossil fuels
2. Hydrogen technologies and batteries show limited development
3. System costs increase with stricter CO<sub>2</sub> limits but cooperative strategies result in lower costs
4. Low carbon budgets lead to pronounced seasonal trends in electricity demand

## References

[1] Keramidas, K., Fosse, F., Diaz Rincon, A., Dowling, P., Garaffa, R., Ordóñez, J., Russ, P., Schade, B., Schmitz, A., Soria Ramirez, A., Van Der Vorst, C. and Weitzel, M., Global Energy and Climate Outlook 2023, Publications Office of the European Union, Luxembourg, 2023. doi:10.2760/836798, JRC136265.  
 [2] European Commission, "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Securing our future Europe's 2040 climate target and path to climate neutrality by 2050 building a sustainable, just and prosperous society," 6 February 2024. [Online].  
 [3] T. Brown, J. Hoersch, F. Hofmann, F. Neumann, M. Victoria and L. Zeyen, "PyPSA-Eur Documentation," 2024. [Online].  
 [4] Victoria, M., Zhu, K., Brown, T. et al. Early decarbonisation of the European energy system pays off. *Nat Commun* **11**, 6223 (2020). <https://doi.org/10.1038/s41467-020-20015-4>

Poster presenters:  
Cecilia Rorai, Rebecca Schill

Contributors:  
Jean-François Vuillaume, Nuria Rodríguez-Gómez, Ricardo Bolado-Lavín

