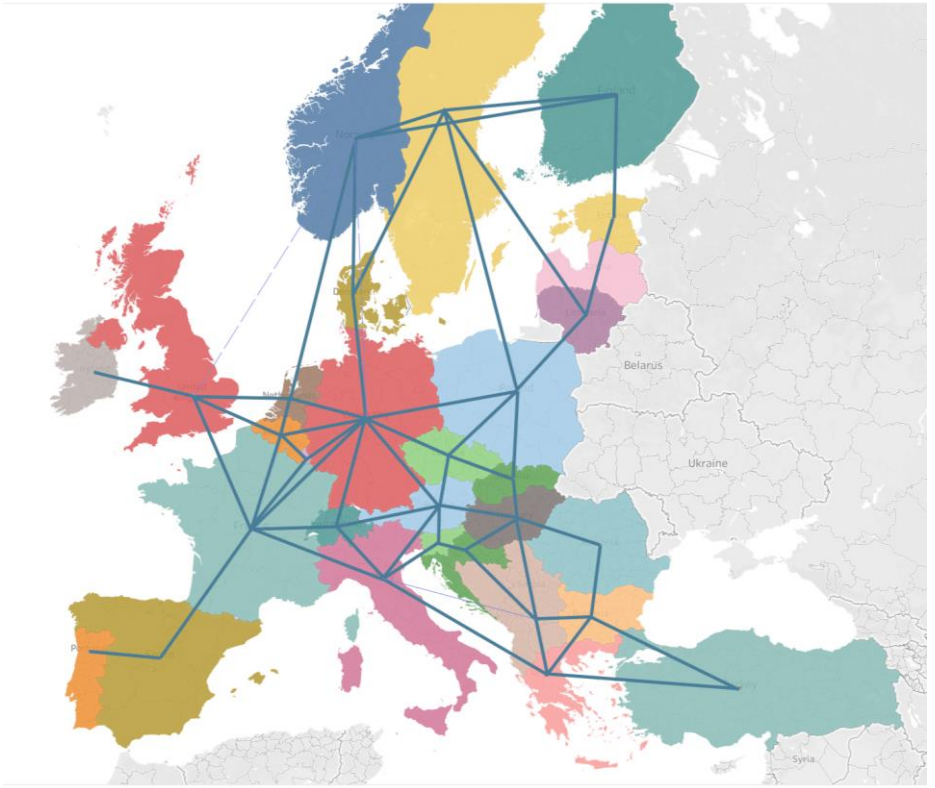
***Jonathan Hanto**, Philipp Herpich, Konstantin Löffler,*
Karlo Hainsch, Nikita Moskalenko

Exploring the role of hydrogen pipeline infrastructure in a sector-coupled European energy system towards 2050

Hydrogen Blending in ESM analyses

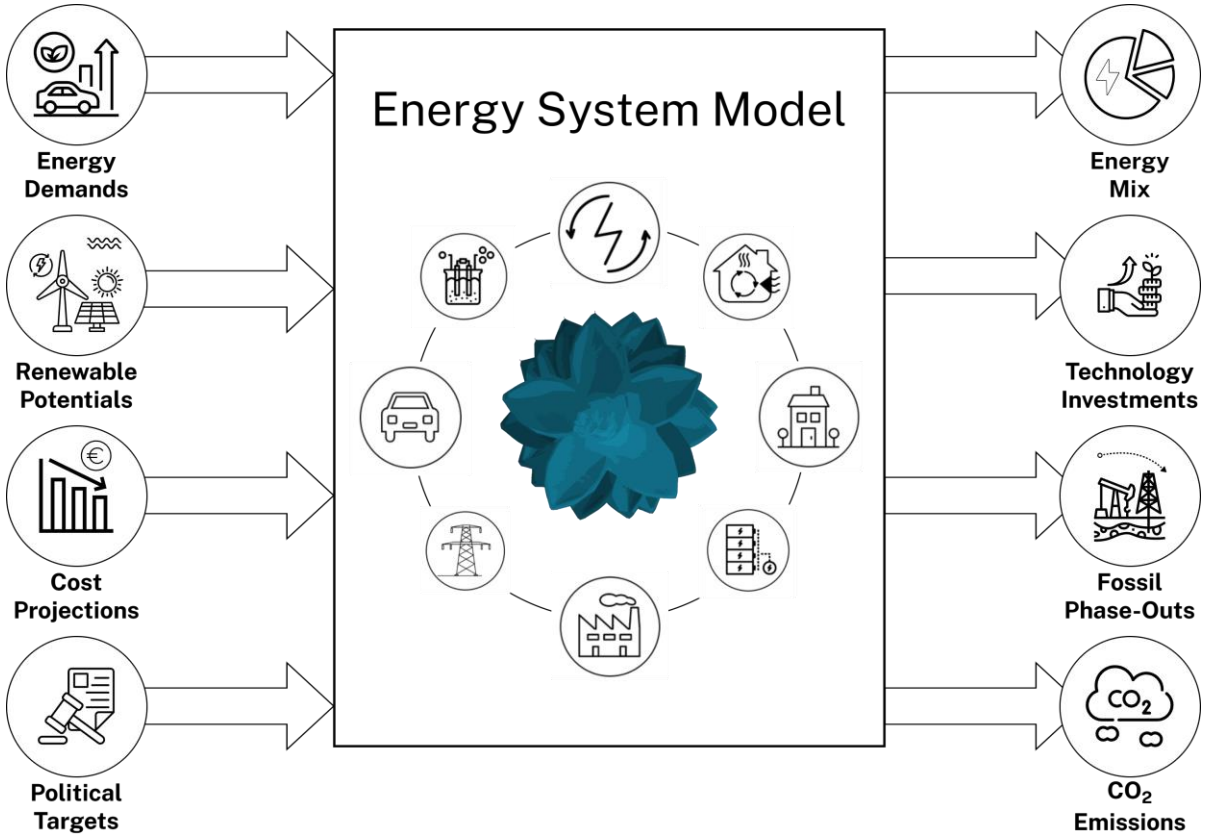
- Lack of research on **impacts of hydrogen blending on European energy system** and international trade/transmission
- Paper aims to compare impacts of injecting hydrogen into existing natural gas pipeline system at **various percentages** on European energy system until **2050**
- Uses Global Energy System Model (**GENeSYS-MOD**) to explore effects of hydrogen blending on production, transport options, and regional localization of hydrogen generation in Europe
- Study **builds on low-carbon transition pathways** for Europe developed in Horizon 2020 project openENTRANCE
- Focus of study is on **overall effects on energy system in Europe**, not techno-economic aspects of blending



The Global Energy System Model (GENeSYS-MOD) - Overview

- …is based on the Open-Source Energy Modeling System (OSeMOSYS) and enhances the framework with multiple additional features.
- …is a **linear program** which optimizes the net present value of a future energy system based on the given assumptions and bounds (cost-optimizing).
- …includes **all the main energy sectors**: Power, Buildings, Industry, and Transport
- …is **publicly available** to the community with both code and model data.

(https://git.tu-berlin.de/genesysmod/genesys-mod-public/-/releases/genesysmod3.0)

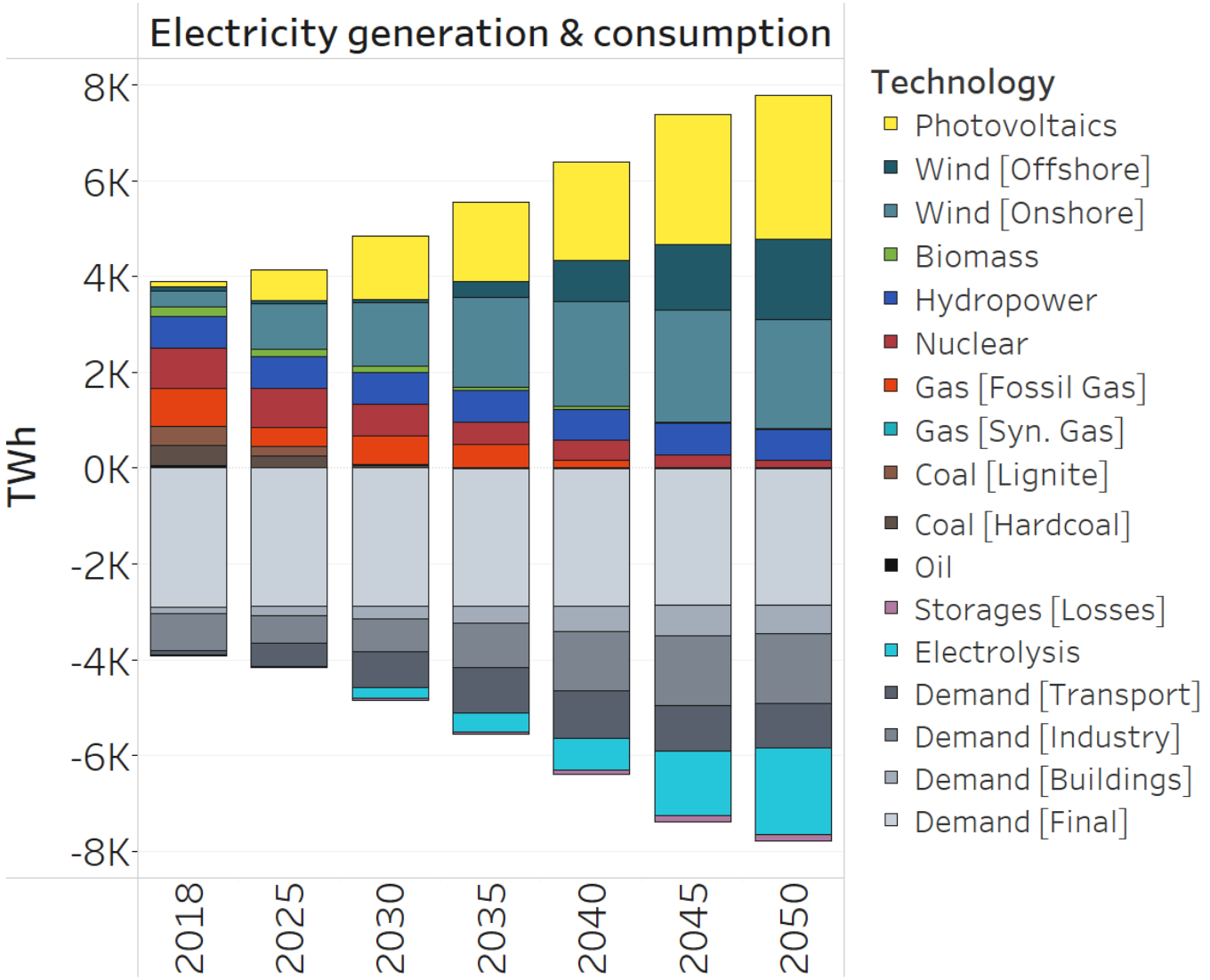


Scenario – Gradual Development

Gradual Development Scenario

- Ambitious reference scenario in line with a **2°C climate goal** (Net-zero 2050)
- Reaches targets through **equal inclusion** of **societal, industry, and policy action**
- **Carbon price** drives decarbonization
  2030 -> 76,4 M€/tCO_2
  2050 -> 355 M€/tCO_2
- **Balanced in its ambitions**, helps the model include constraints and limitations more easily

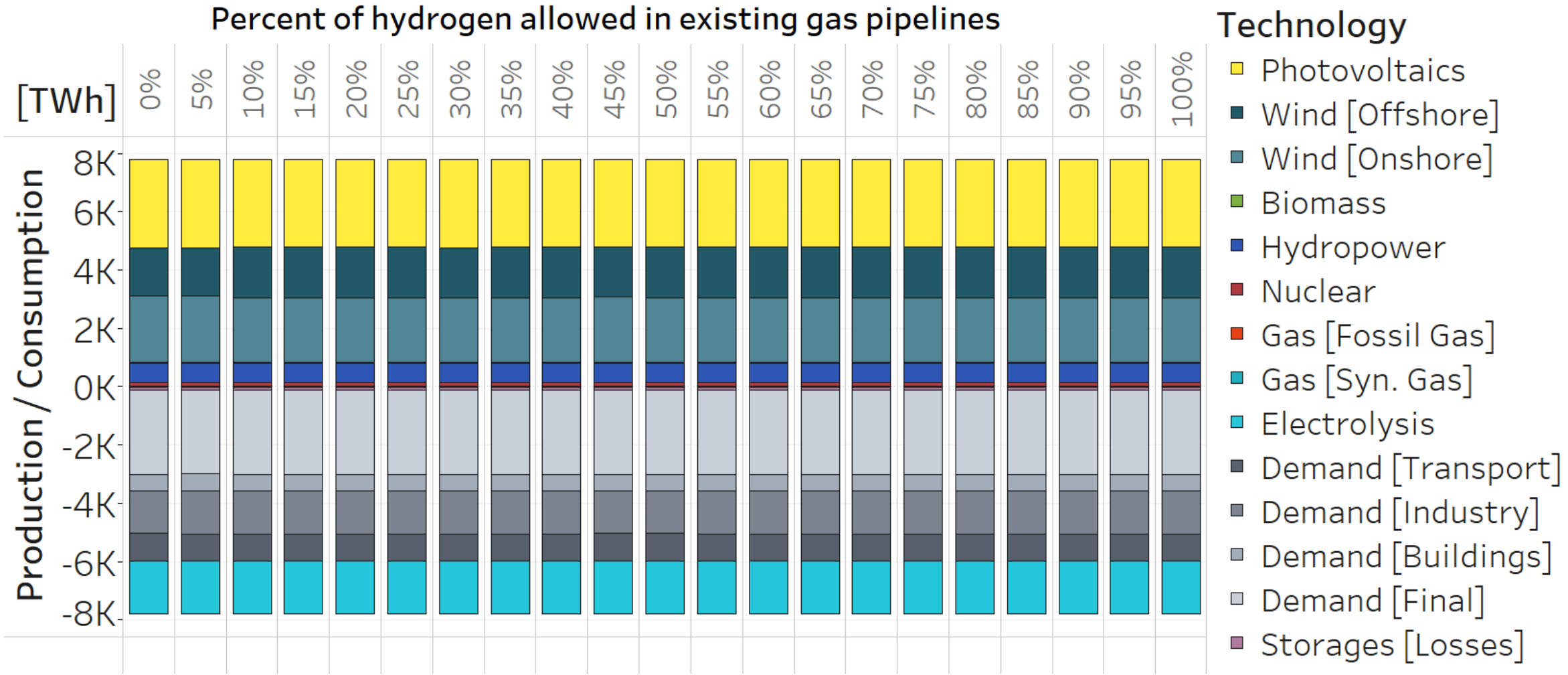
[1][2]



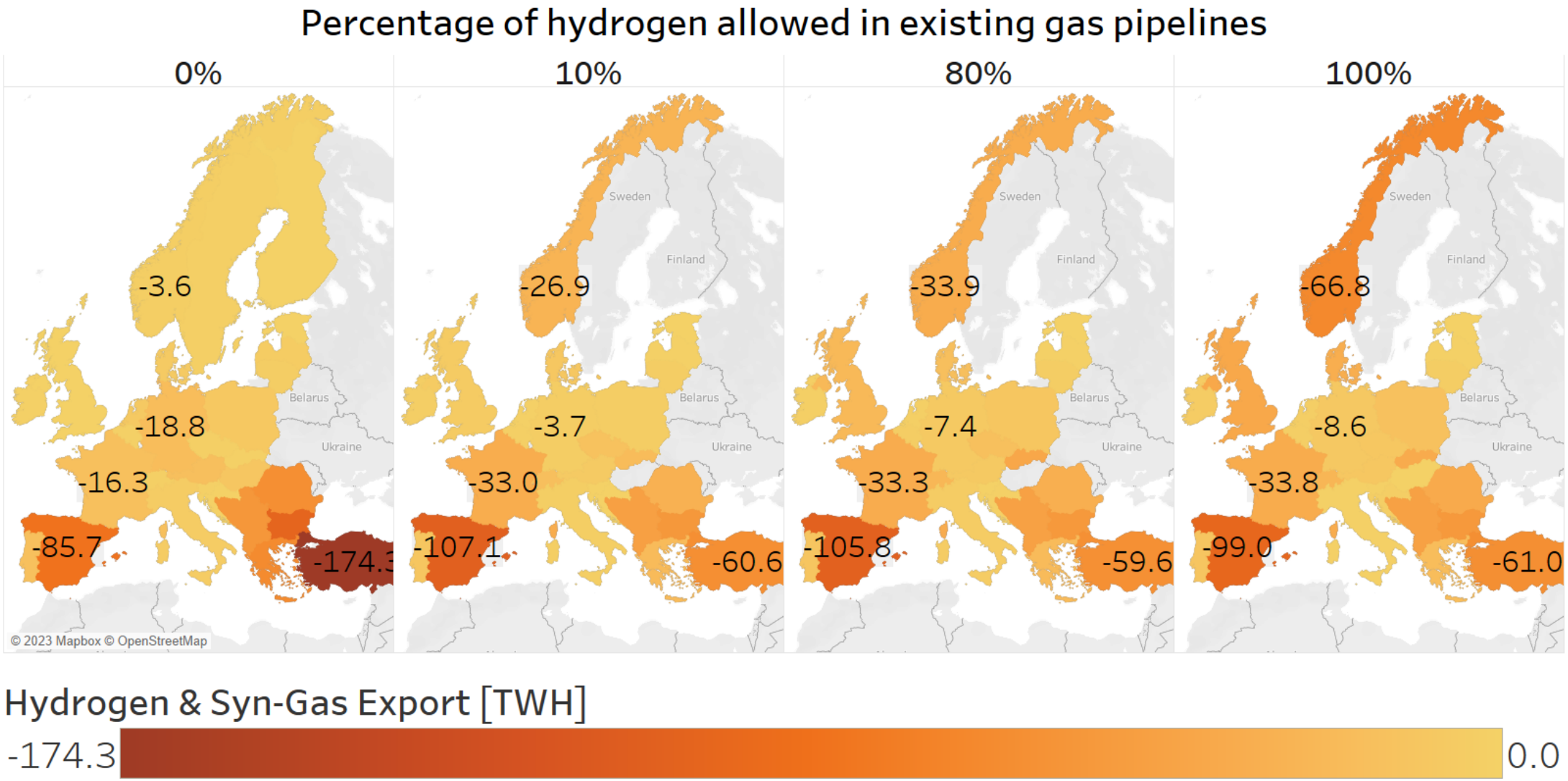
Hydrogen blending – Model Functionality

- Improvements made to the model to represent hydrogen in a more accurate way in the energy system
- **New fuel "H2_blend**" added to the model to achieve hydrogen blending within existing natural gas infrastructure & Switch_dedicated_hydrogen_tradecapacity parameter introduced to **limit the share of hydrogen** in natural gas pipeline
- **Hydrogen separated from gas** after transport for consumption of pure hydrogen
- The model is allowed to add hydrogen (in volume) to the gas network in **5% increments** utilizing the switch_dedicated_hydrogen_tradecapacity for each model run from 2018-2050.
  A model **run is performed for each possible ratio from 0%** (no hydrogen-blending allowed) to **100%** (only hydrogen in existing gas pipelines is allowed), resulting in a total of 21 model runs.
- A model run with **limitation of trade for Turkey** to deduce impact on European hydrogen production & trade

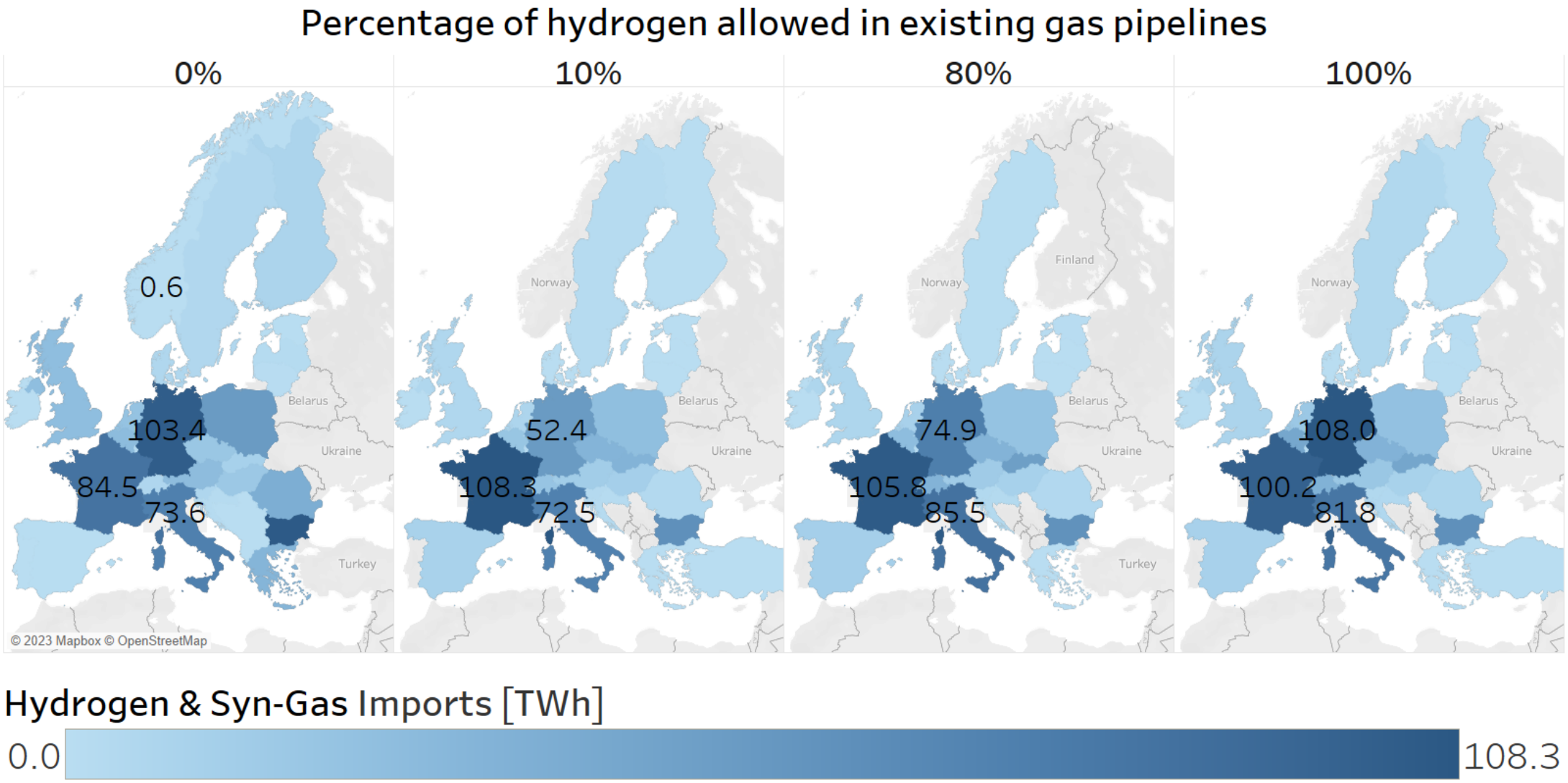
H2-Blending Sensitivity Results I – Electricity Generation



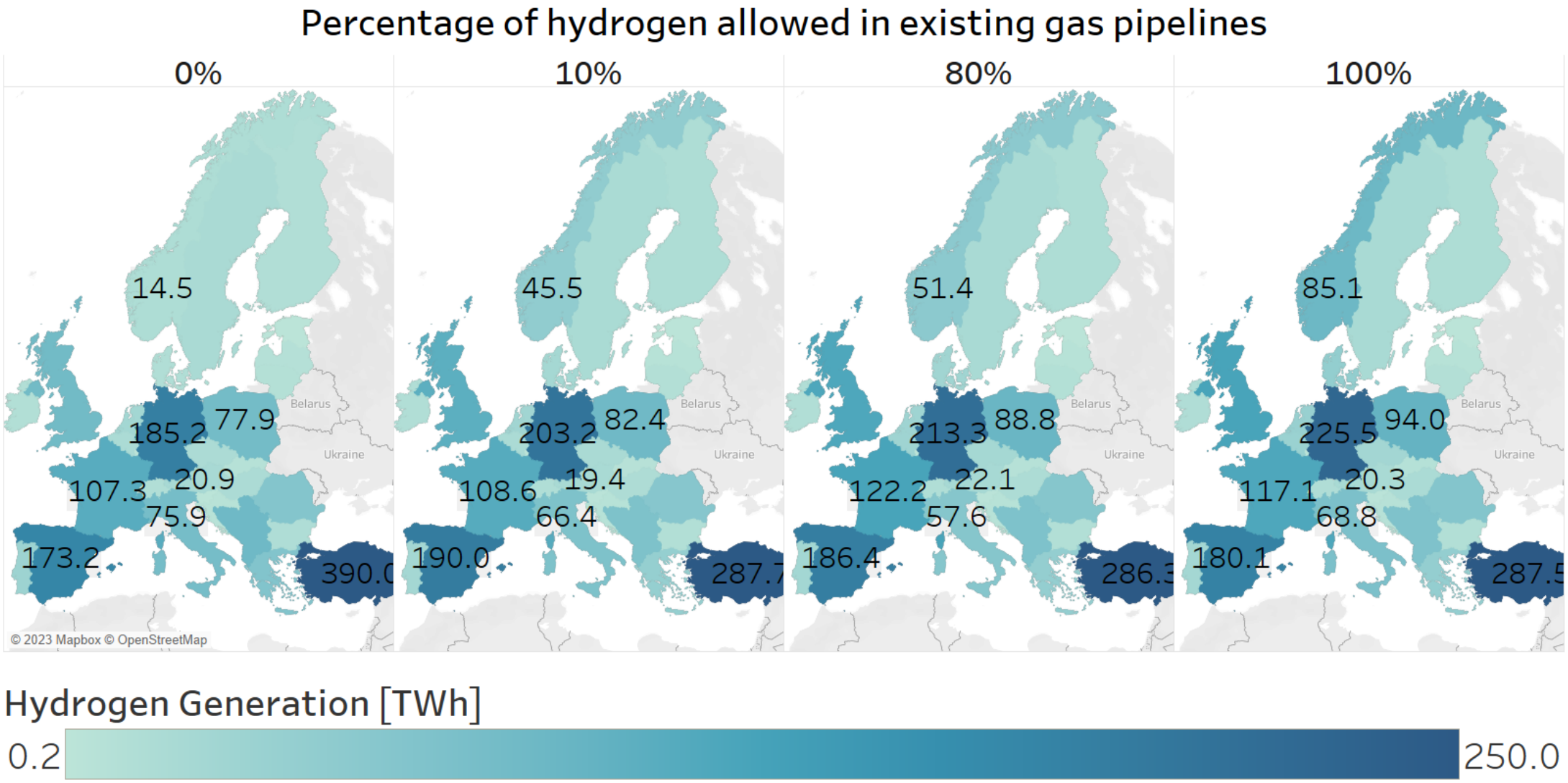
H2-Blending Sensitivity Results II - Export



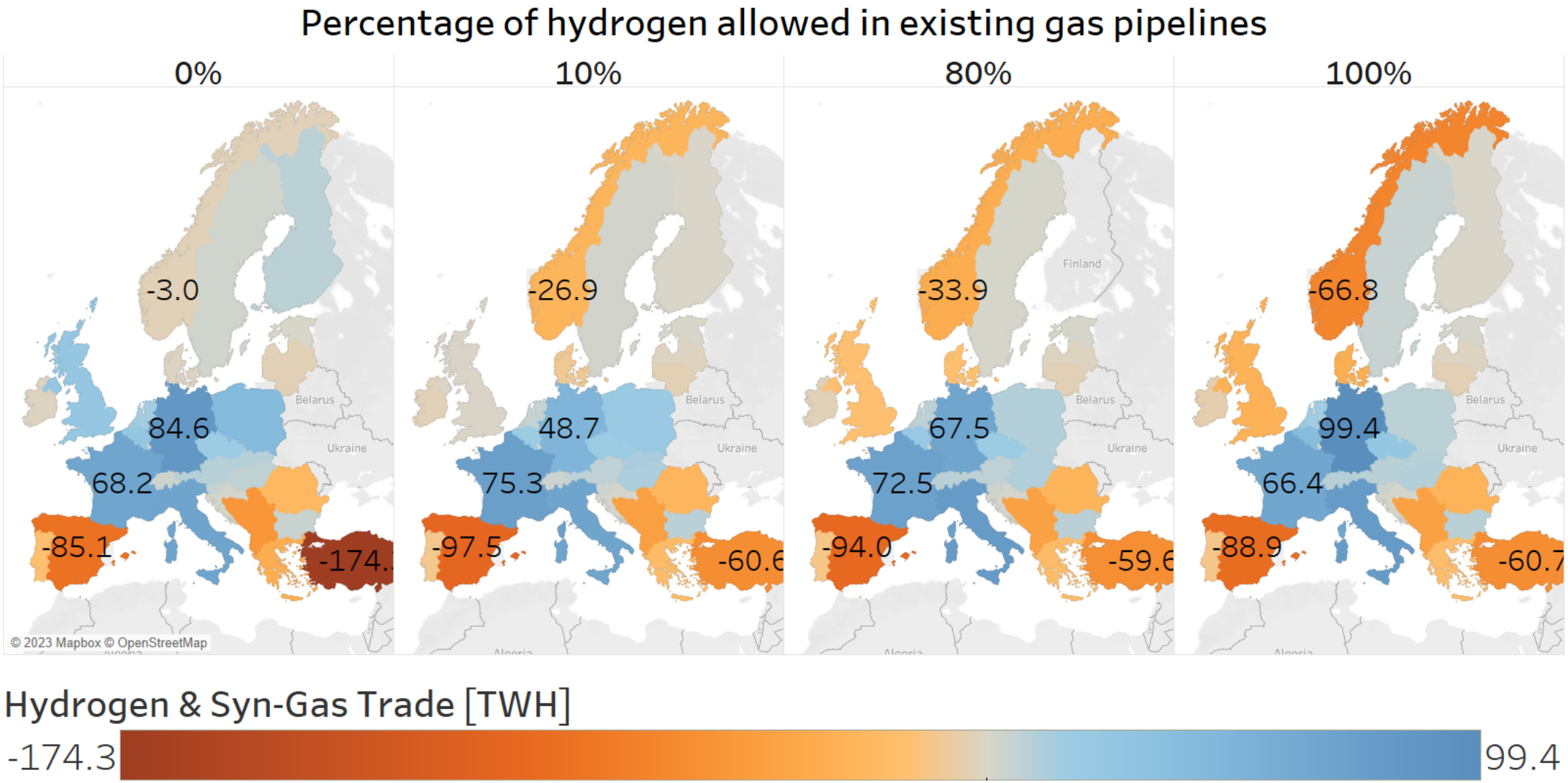
Sensitivity Results III - Import



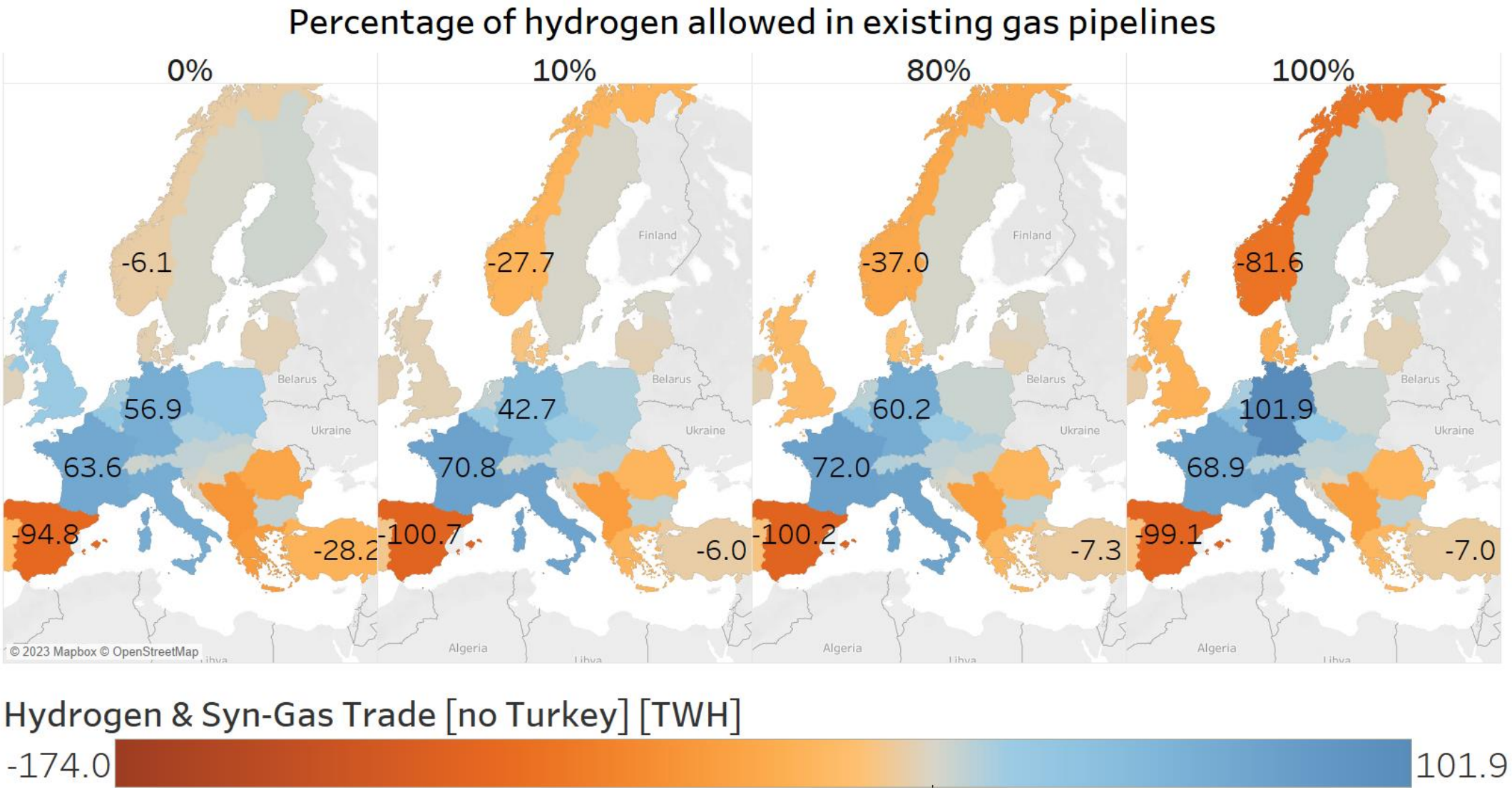
Sensitivity Results – Hydrogen Generation



Sensitivity Results VI – Trade



Sensitivity Results VI – Restricted Trade with Turkey



Results Implications

- The consumption of hydrogen is not limited by transportation or supply, but by its cost-effectiveness compared to other options. There is **already a sufficient demand** for hydrogen where it is needed.

- The ability to blend hydrogen into existing natural gas pipelines in Europe **affects the regional distribution** of hydrogen production and trading. Norway becomes the second largest hydrogen exporter after Spain. Turkey experiences the biggest decrease in production and trade.

- The **sudden changes** from 0%-5% result from **the current model setup**, where a new hydrogen grid must be built at 0% but can use the existing gas grid when blending is allowed (5-100%).

- For all the shares between 5% and 95%, the share of blending refers to the overall quantity of gases in the pipeline. Hence, the model **needs to transport natural or synthetic gas** in order to **transport the H2 within the existing natural gas grid**.

- Blending has minimal effect on hydrogen production/demand, but production location can have major impact on EU energy system. Importing hydrogen from countries like Turkey could create **new** energy **import dependency** or diversify supply and reduce dependence on a single source.

Research Outlook

- The model only **considers the transmission network** of the gas grid for the transportation of hydrogen between countries via pipeline. No representation of a distribution grid within the countries. Therefore, only effects on a country basis can be deduced.
  -> **Country level** study

- Current model setup allows hydrogen blending up to 100% without additional investments into technical devices such as valves and compressors.
  -> include **additional techno-economic** aspects

- The gas grid is only considered as a mode of transportation in the GENeSYS-MOD, but it can also serve as a gas or hydrogen storage. Considering the possibility of **hydrogen storage in the gas grid** might reduce the overall costs.

- Detailed System cost comparison, **lock-in effects**

- **Import effects** on the European Energy System & Hydrogen Trade

Thank you for your Attention!

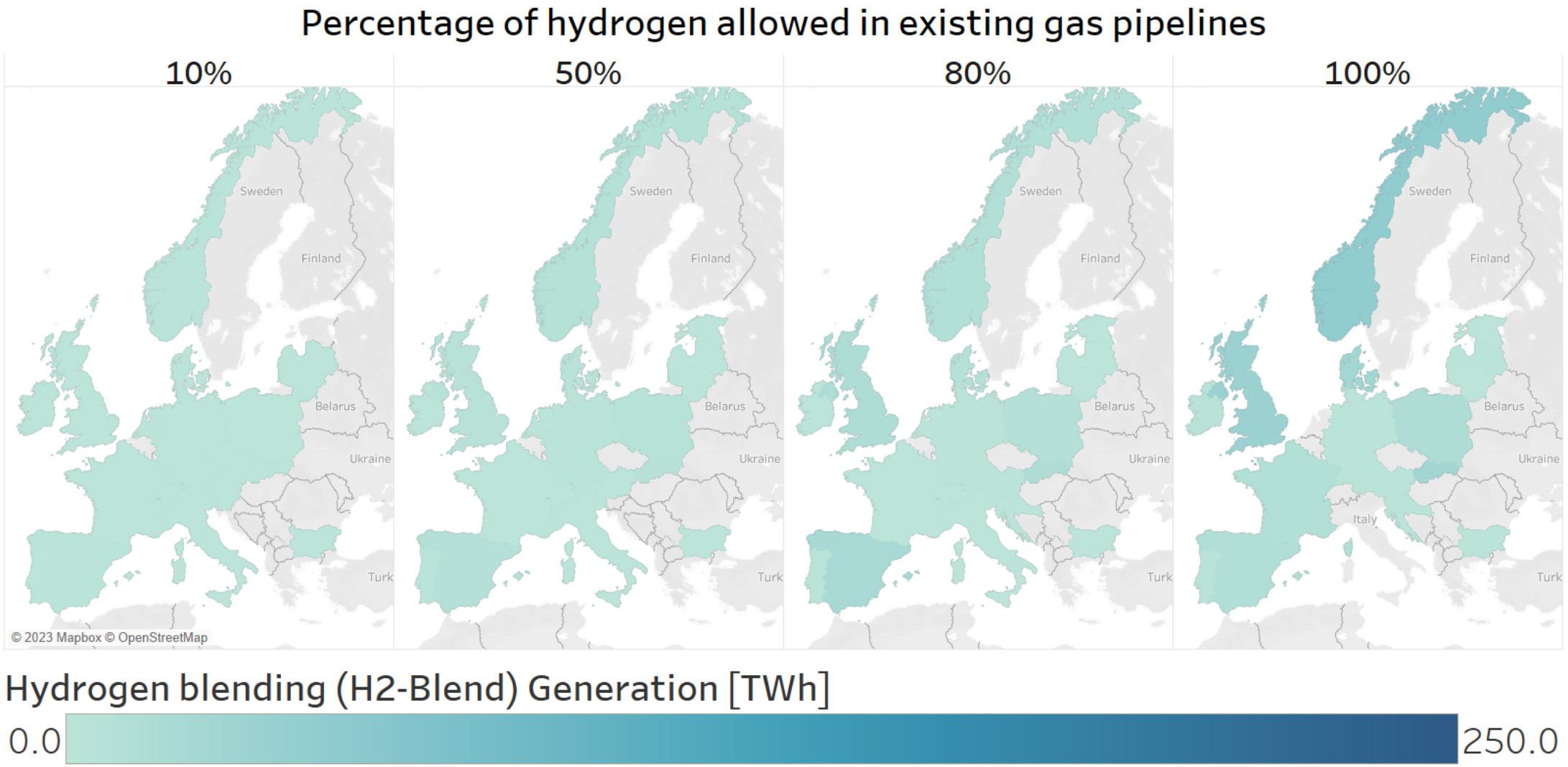
Jonathan Hanto – Research Associate
Technische Universität Berlin – joh@wip.tu-berlin.de
Europa-Universität Flensburg – jonathan.hanto@uni-flensburg.de

References

[1] Hainsch, K., Löffler, K., Burandt, T., Auer, H., Crespo del Granado, P., Pisciella, P., Zwickl-Bernhard, S., 2022. Energy transition scenarios: What policies, societal attitudes, and technology developments will realize the EU Green Deal? Energy 239, 122067. URL: https://www.sciencedirect.com/science/article/pii/S036054422102315X, doi:10.1016/j.energy.2021.122067.

[2] Auer, H., Crespo del Granado, P., Oei, P.Y., Hainsch, K., Löffler, K., Burandt, T., Huppmann, D., Grabaak, I., 2020b. Development and modelling of different decarbonization scenarios of the European energy system until 2050 as a contribution to achieving the ambitious 1.5° C climate target—establishment of open source/data modelling in the European H2020 project openENTRANCE. e & i Elektrotechnik und Informationstechnik 2020. doi:https://doi.org/10.1007/s00502-020-00832-7.

Appendix I: H2-Blend Generation



Appendix II– Production & Consumption