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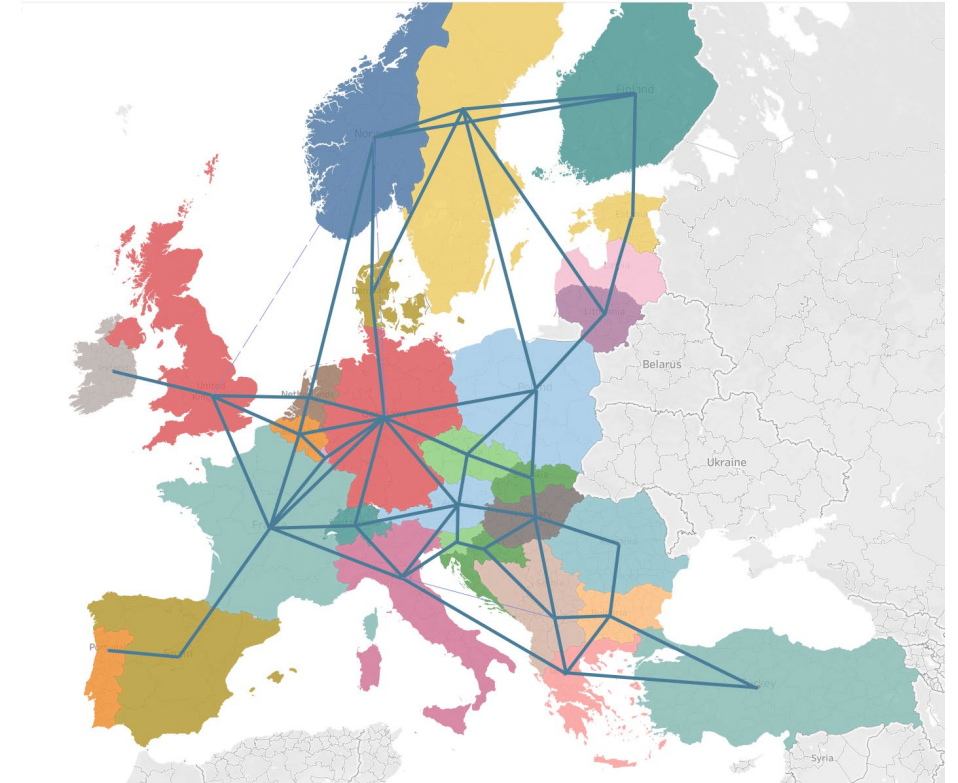
*Jonathan Hanto, Philipp Herpich, Konstantin Löffler,  
Karlo Hainsch, Nikita Moskalenko*

# Prospects of pipeline infrastructure development for hydrogen integration into the European energy system towards 2050



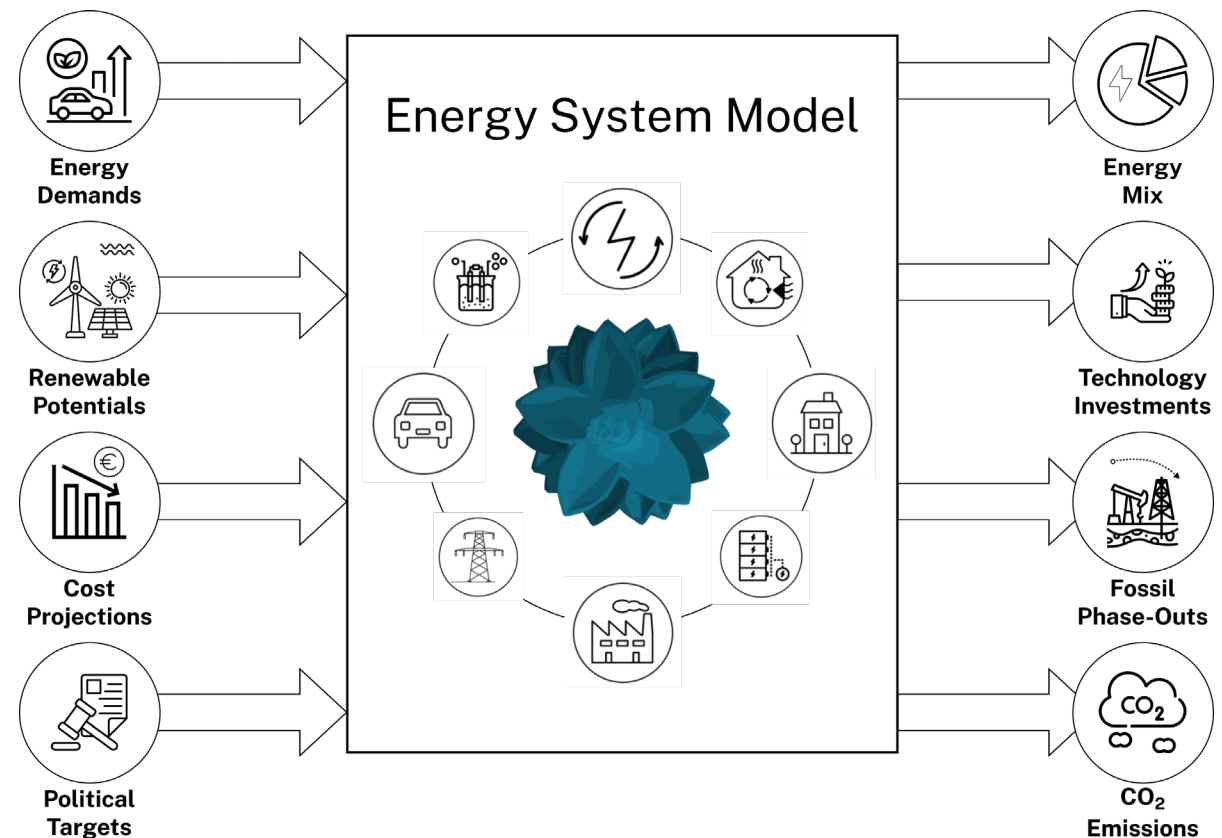
# Hydrogen Blending in ESM analyses

- What are **impacts of hydrogen blending on the European energy system** and European hydrogen trade?
- Research 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**.



# 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

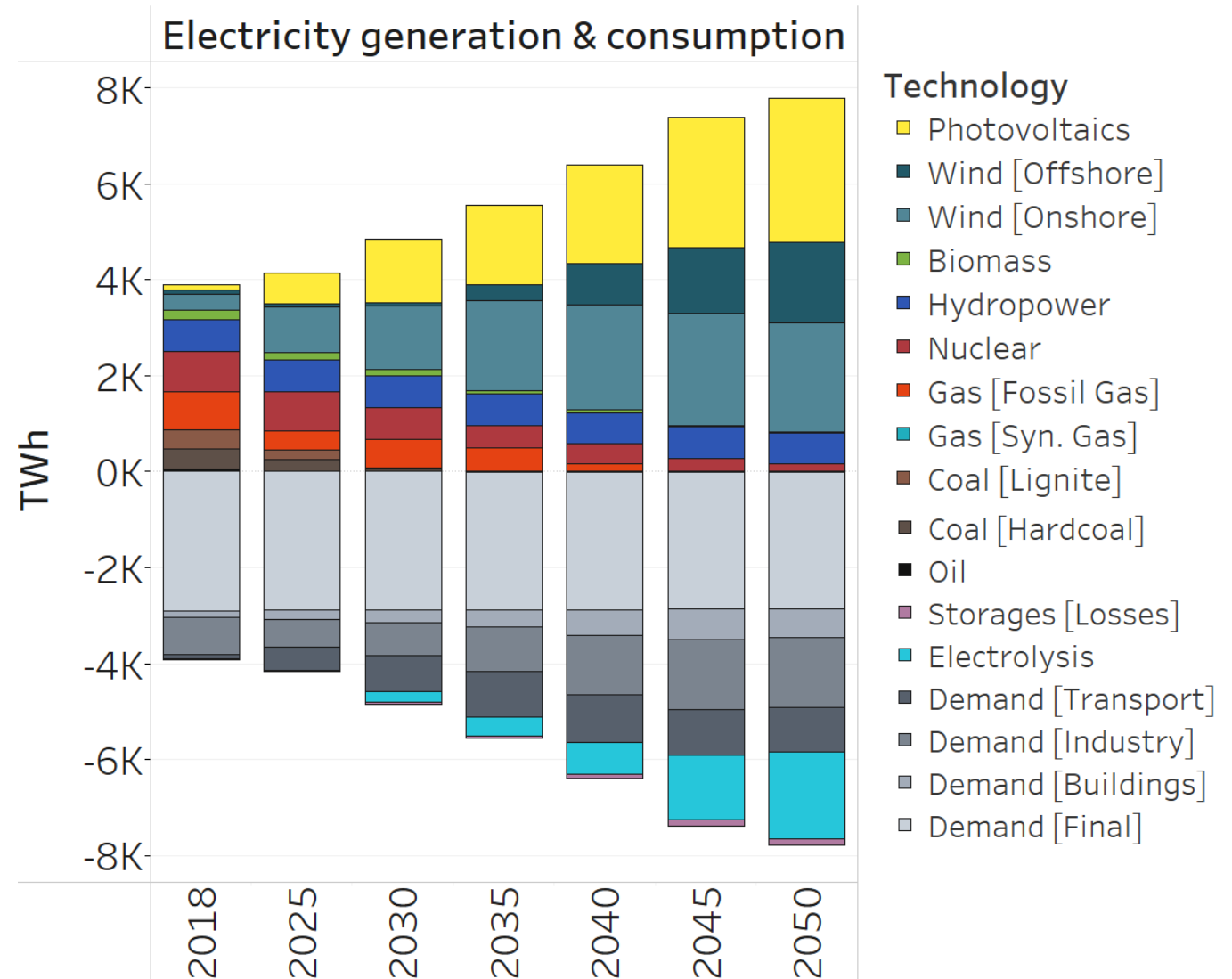


# Scenario - Gradual Development

## Gradual Development Scenario

- Ambitious reference scenario in line with a **2°C climate goal** (Net-zero 2050)
- **30 regions** (mainland EU-25, Norway, Switzerland, UK, Turkey, and an aggregated Balkan region)
- Reaches targets through **equal inclusion of societal, industry, and policy action**

[[1]][2]]

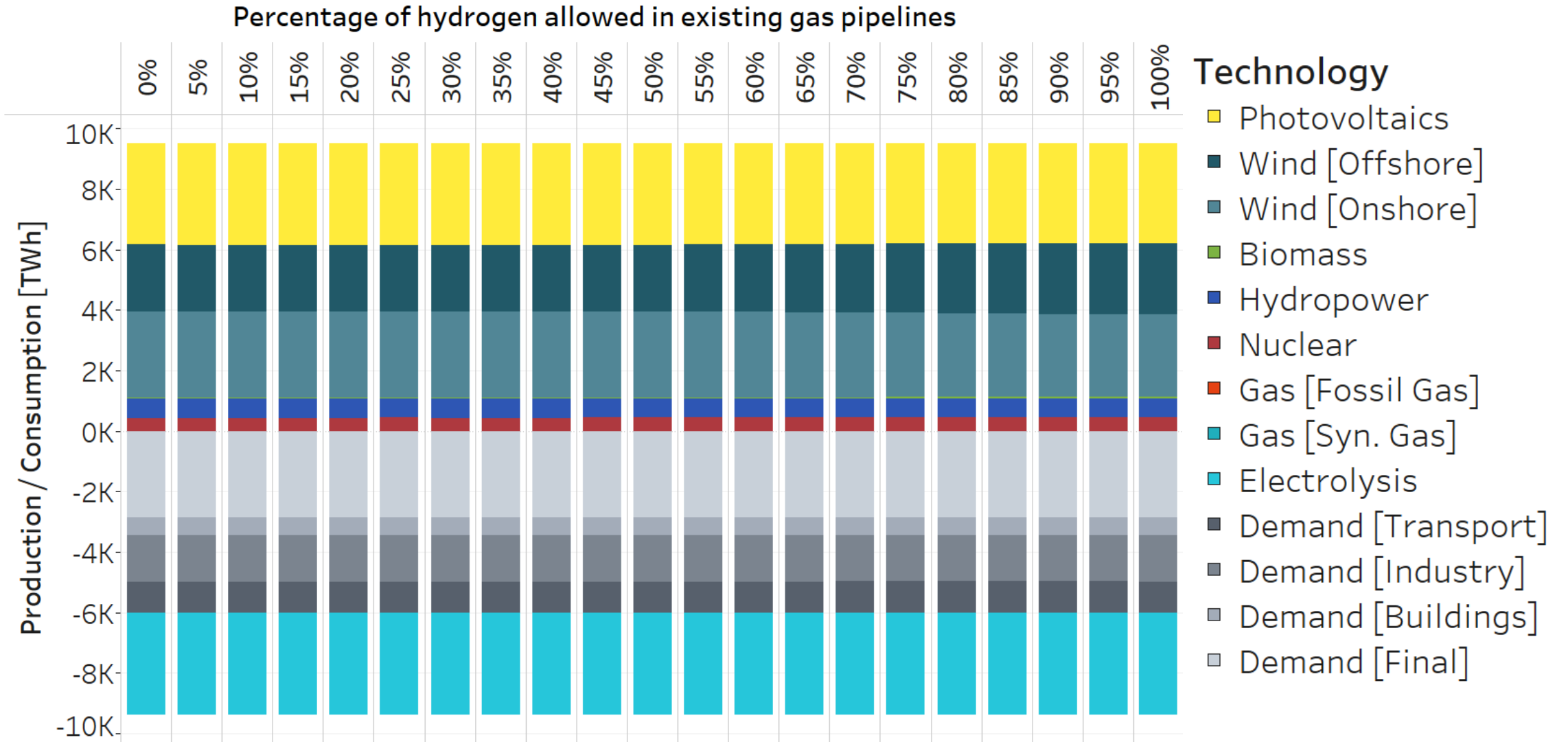


# Hydrogen blending - Model Functionality

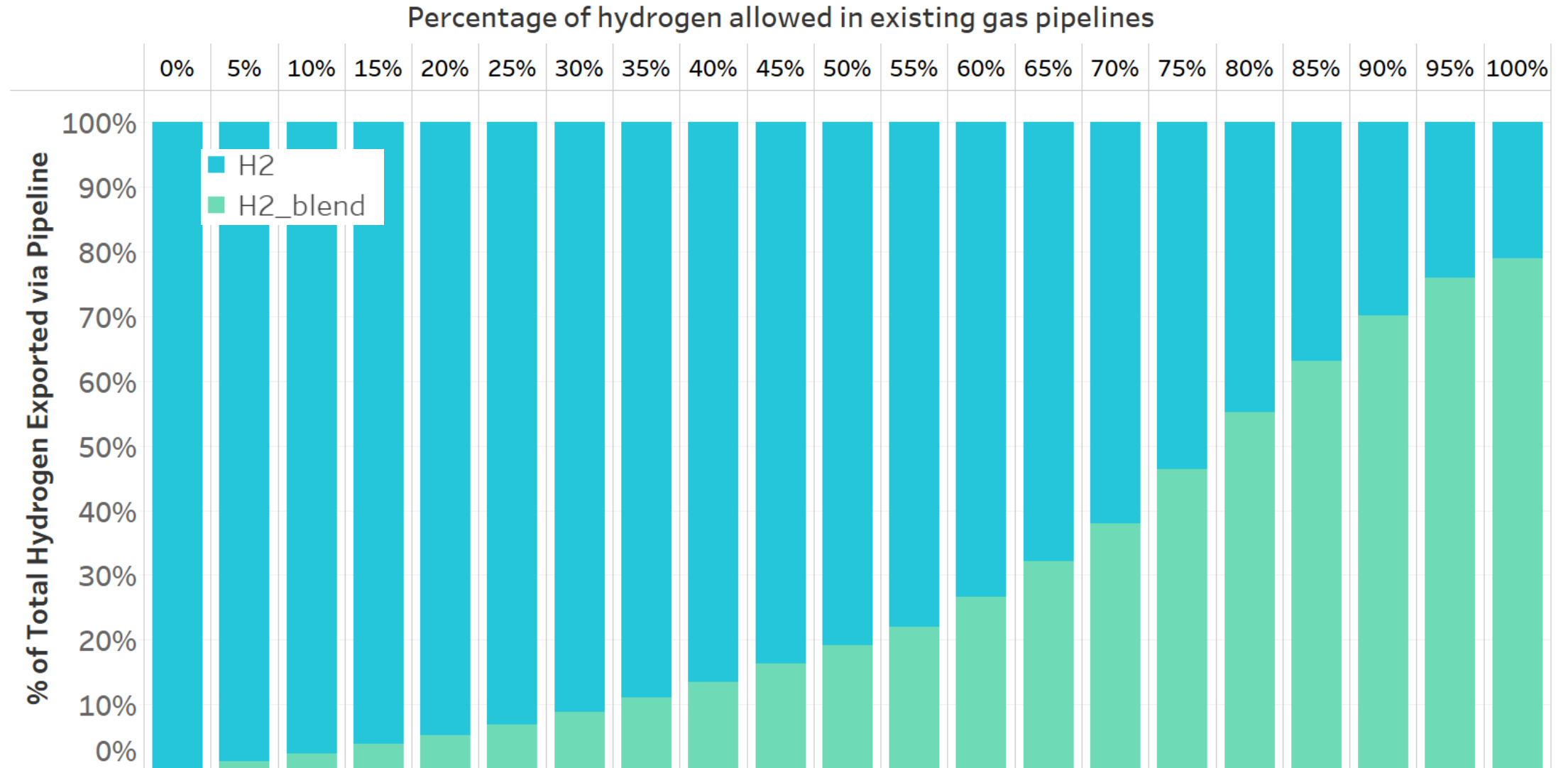
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- Improvements made to the model to represent hydrogen in a more accurate way in the energy system
- **Non-energetic Demand** for Industry, Refinery, and Ammonia [3]
- **New fuel "H2\_blend"** added to the model to achieve hydrogen blending within existing natural gas infrastructure & **Switch\_dedicated\_hydrogen\_tradecapacity** parameter introduced to **limit the share of hydrogen** in natural gas pipeline
- As the hydrogen blend in the natural gas pipeline would effect the distribution networks and ultimately consumer appliances, the **model "separates" hydrogen from gas after transport** resulting in the consumption of pure hydrogen.
- The model is allowed to add hydrogen (in volume) to the gas network in **5% increments**

# Sensitivity Results I - Electricity Generation

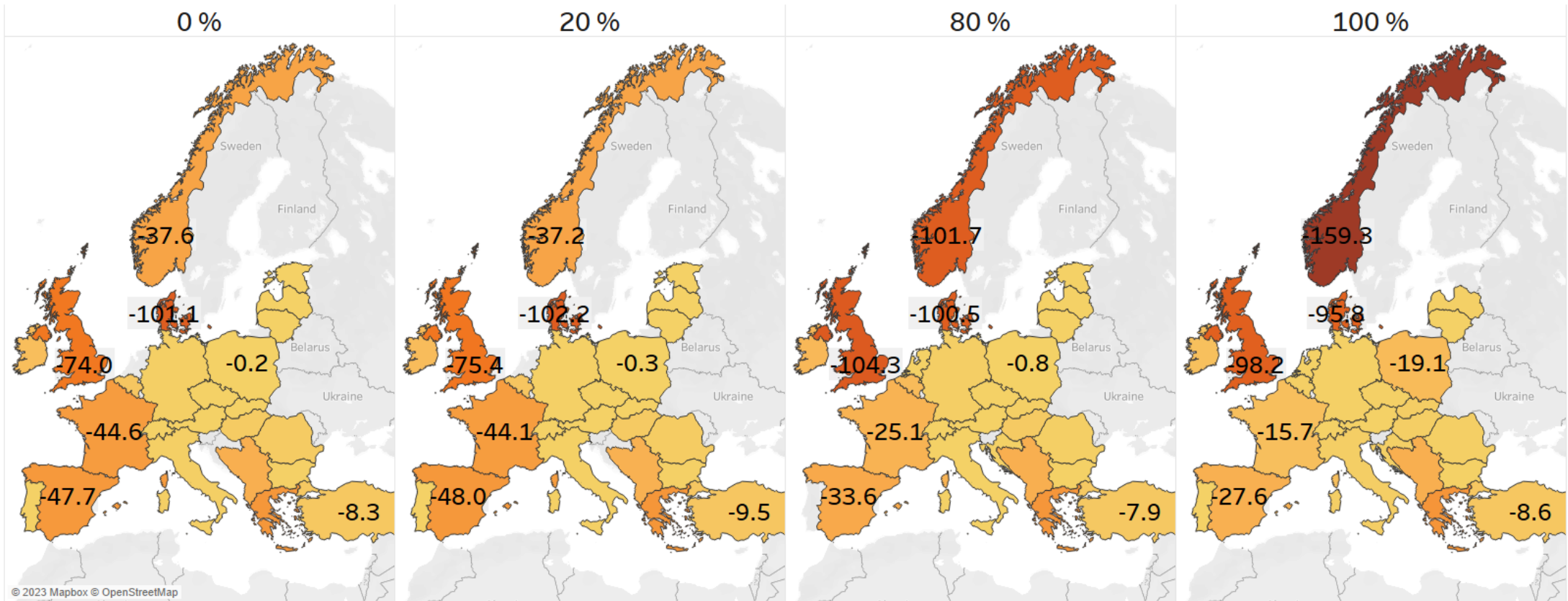


# Sensitivity Results II - H<sub>2</sub>/H<sub>2</sub>-Blending



# Sensitivity Results III - Export

Percentage of hydrogen allowed in existing gas pipelines



Hydrogen & Syn-Gas Export [TWh]

-159.3

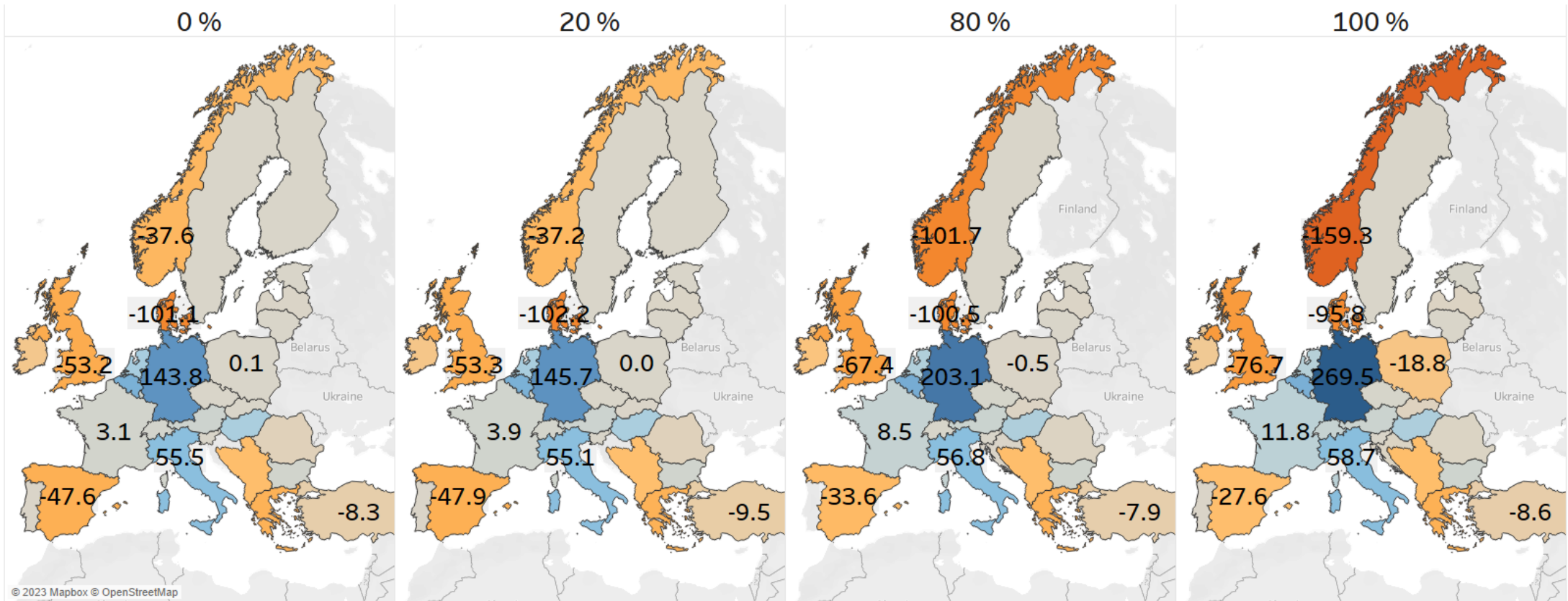


0.0



# Sensitivity Results IV - Net Trade

Percentage of hydrogen allowed in existing gas pipelines



Hydrogen & Syn-Gas Trade [TWh]

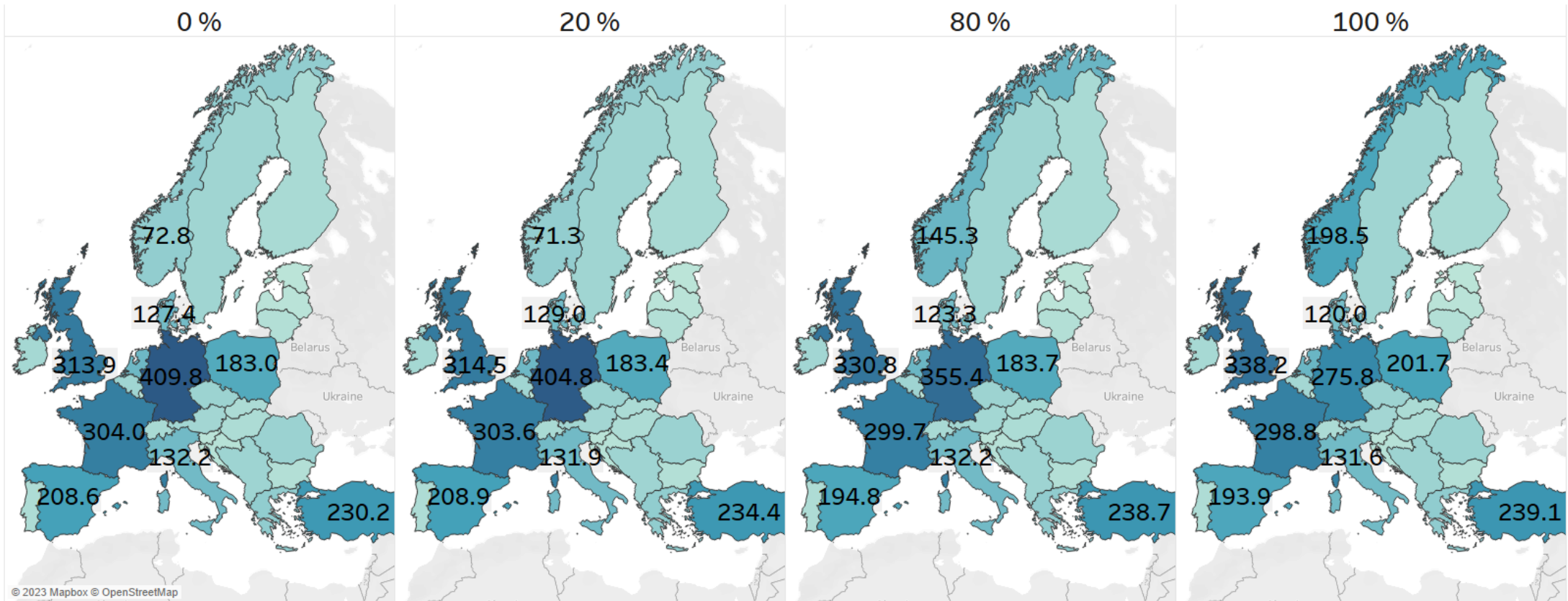
-159.3



269.5

# Sensitivity Results V - Hydrogen Generation

Percentage of hydrogen allowed in existing gas pipelines



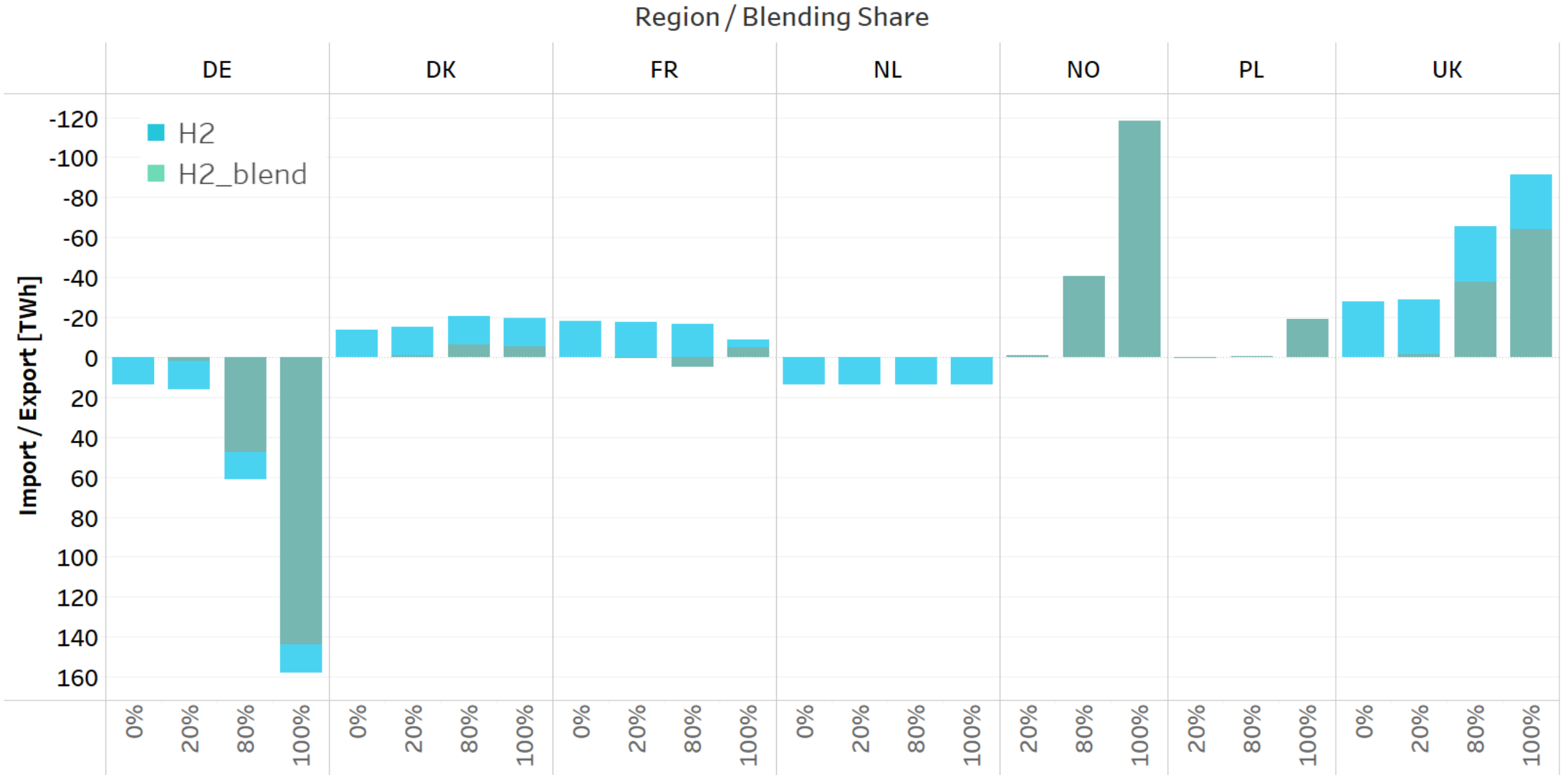
Hydrogen Production [TWh]

0.8



409.8

# Sensitivity Results VI - Country level



# Results Implications

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- The consumption of hydrogen is not limited by transportation or supply, but by its cost-effectiveness compared to other options.
- For each application, e.g. heating or transportation, there exists a cost-optimal solution such as heat pumps or BEV.
- The ability to blend hydrogen into existing natural gas pipelines in Europe affects the regional distribution of hydrogen production and trading.
- Norway & UK become the largest Exporters with rising blending shares due to existing natural-gas pipelines.
- Spain experiences the biggest decrease in production and trade.
- Slight decrease in overall system costs with rising blending shares.

# Research Outlook

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- 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.

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**Thank you for your Attention!**

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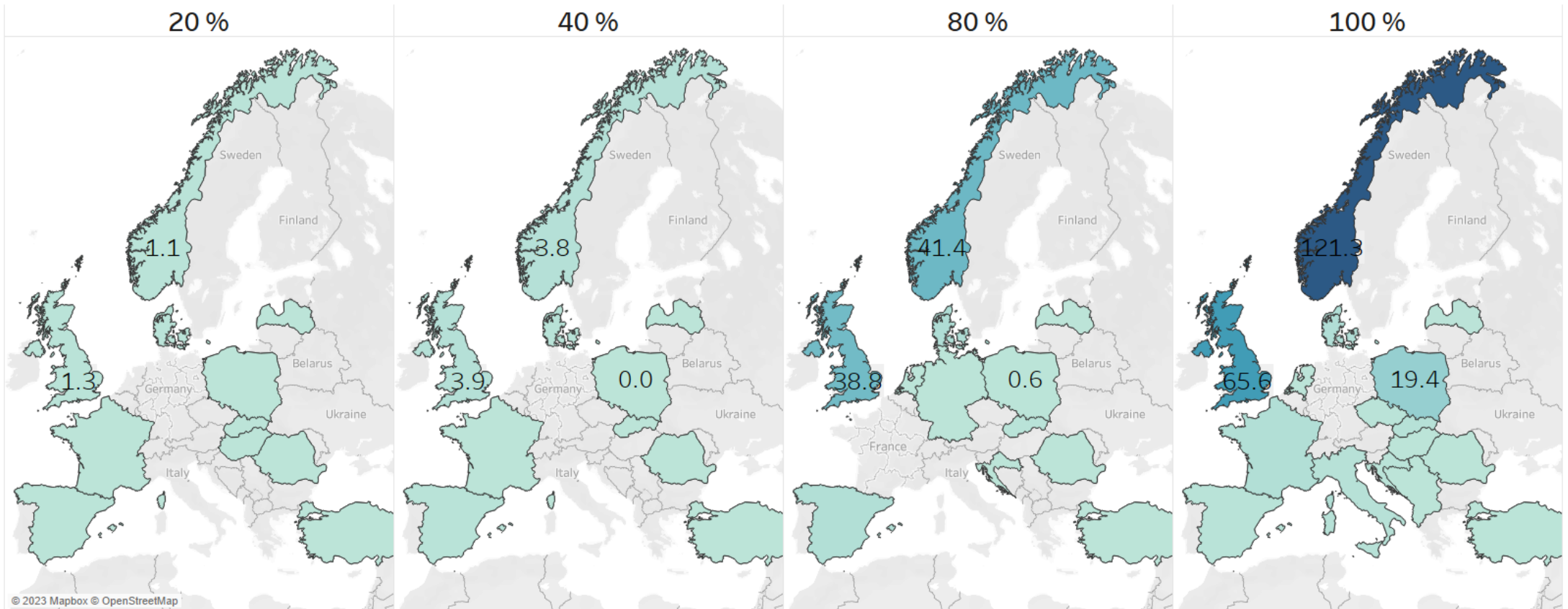
# References

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- [1] Hainsch, K., Löffler, K., Burandt, T., Auer, H., Crespo del Granado, P., Piscicella, 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>.
- [3] Fraunhofer CINES, 2023. Clean Hydrogen Deployment in the Europe-MENA Region from 2030 to 2050. URL: [https://www.cines.fraunhofer.de/content/dam/zv/cines/dokumente/Fraunhofer\\_CINES\\_Clean\\_Hydrogen\\_Deployment.pdf](https://www.cines.fraunhofer.de/content/dam/zv/cines/dokumente/Fraunhofer_CINES_Clean_Hydrogen_Deployment.pdf).

# Appendix I: H2-Blend Generation

Percentage of hydrogen allowed in existing gas pipelines

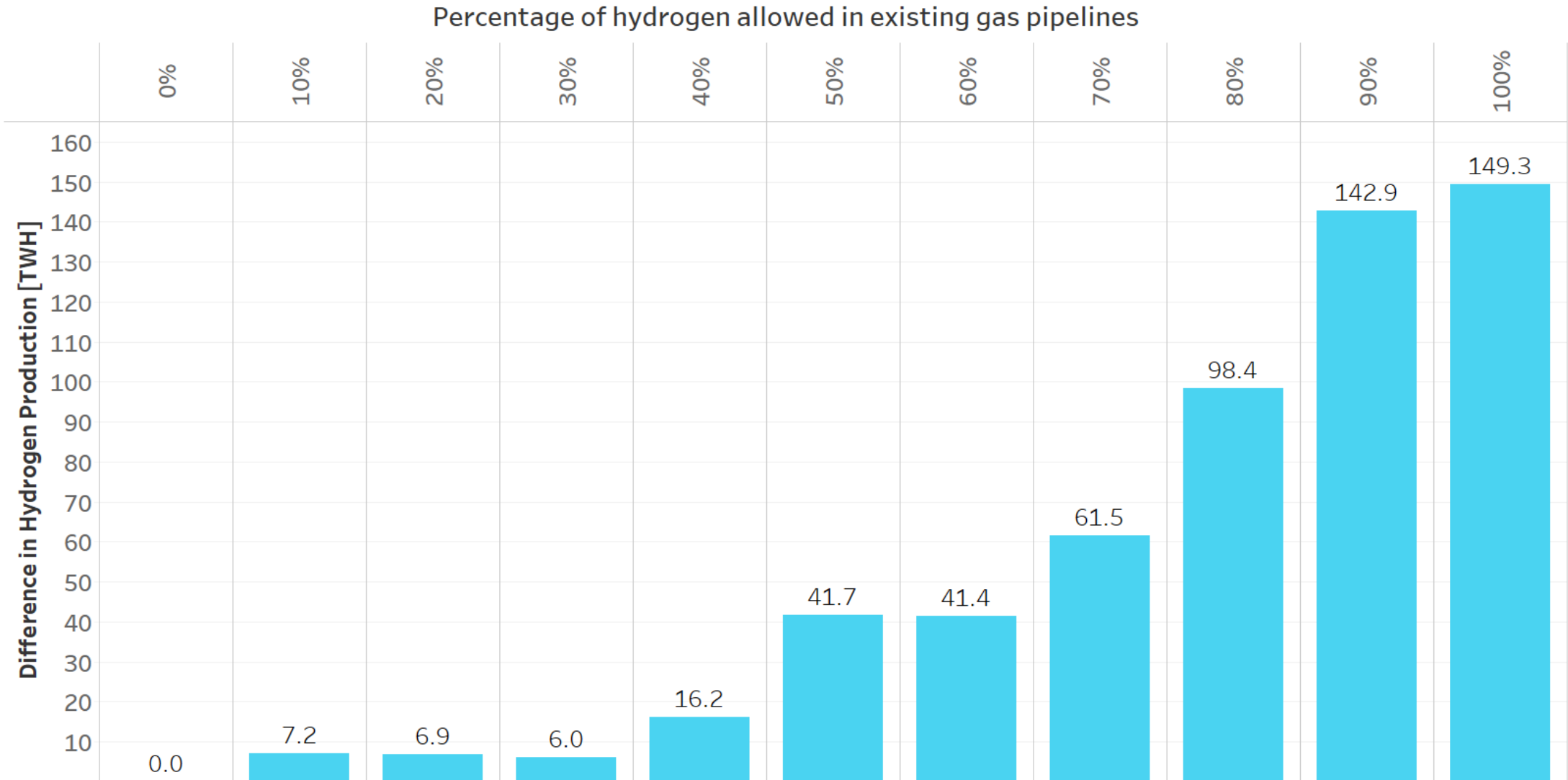


Hydrogen Blending Production [TWh]



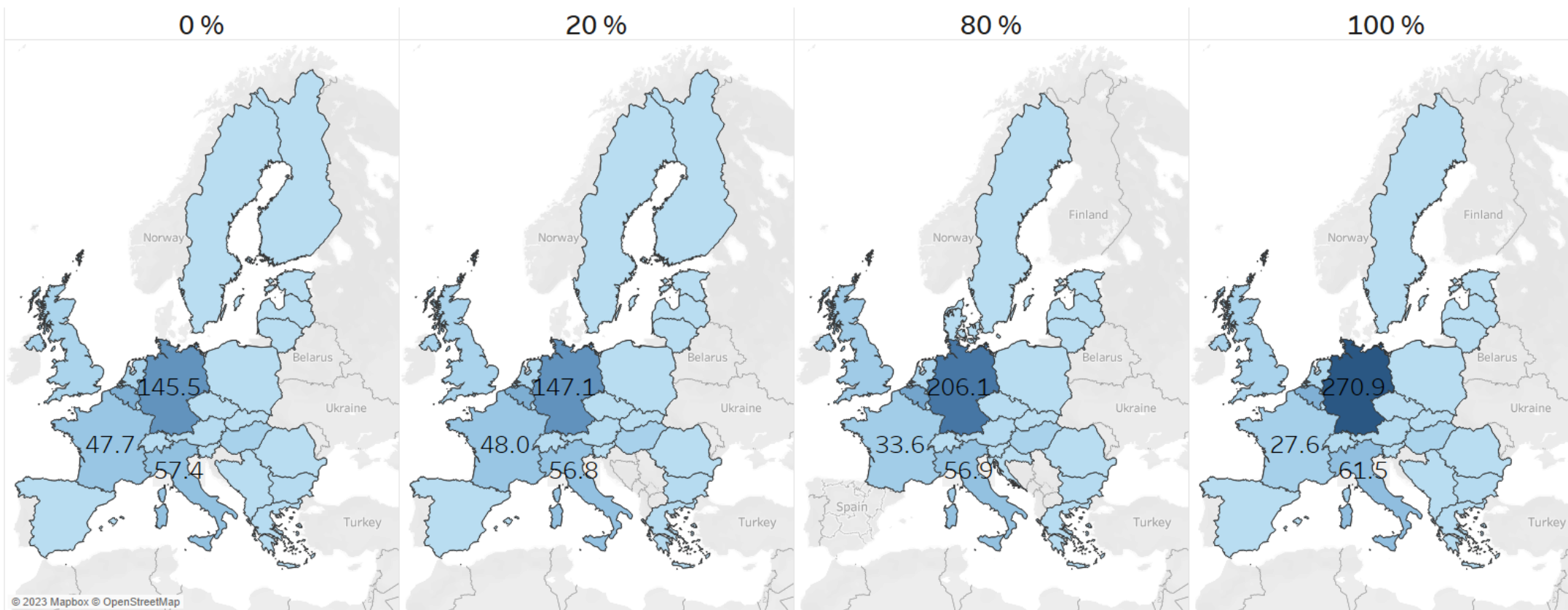


# Appendix II: Hydrogen Production in 2050



# Appendix III - Import

Percentage of hydrogen allowed in existing gas pipelines

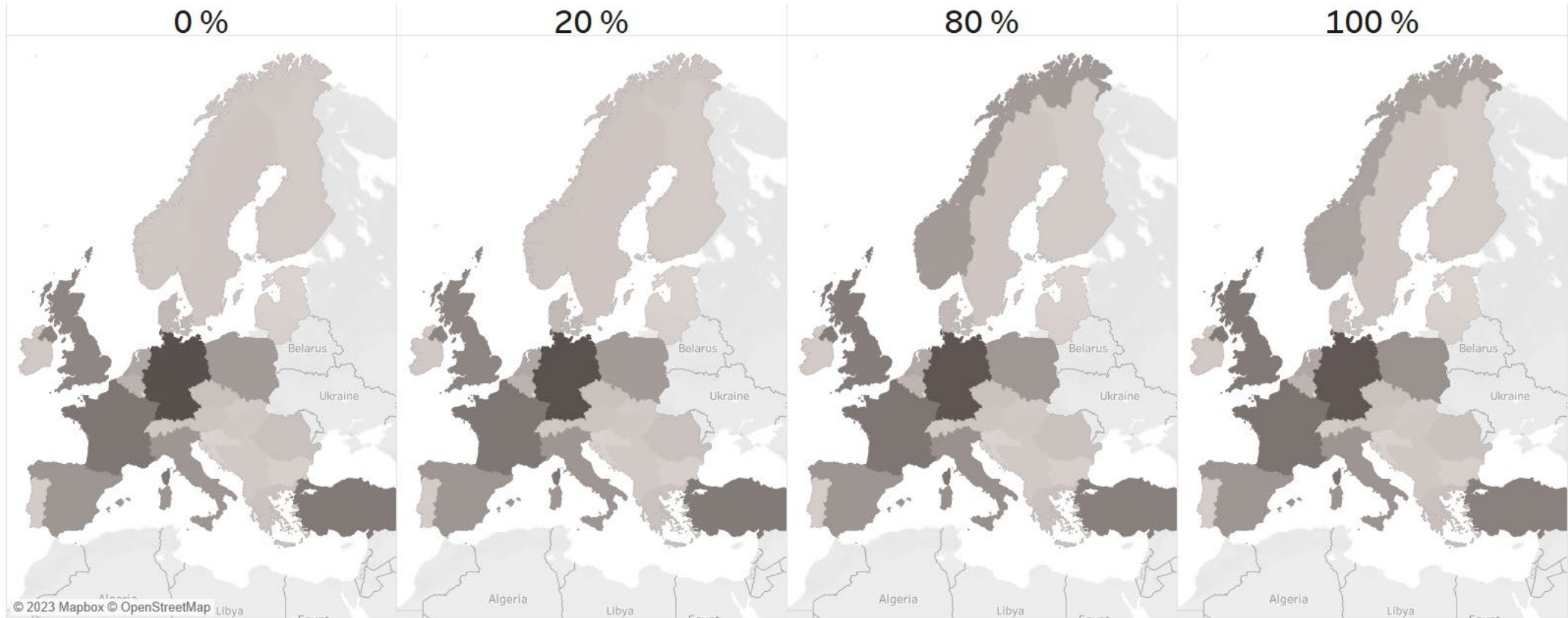


Hydrogen & Syn-Gas Imports [TWh]



# Appendix IV - Specified H2 Demand in 2050

Percentage of hydrogen allowed in existing gas pipelines



Hydrogen Demand [TWh]

4.6

601.6