Optimizing the distribution of hydrogen production: Evaluation of centralized vs. decentralized approaches from an energy system perspective based on the case of Germany

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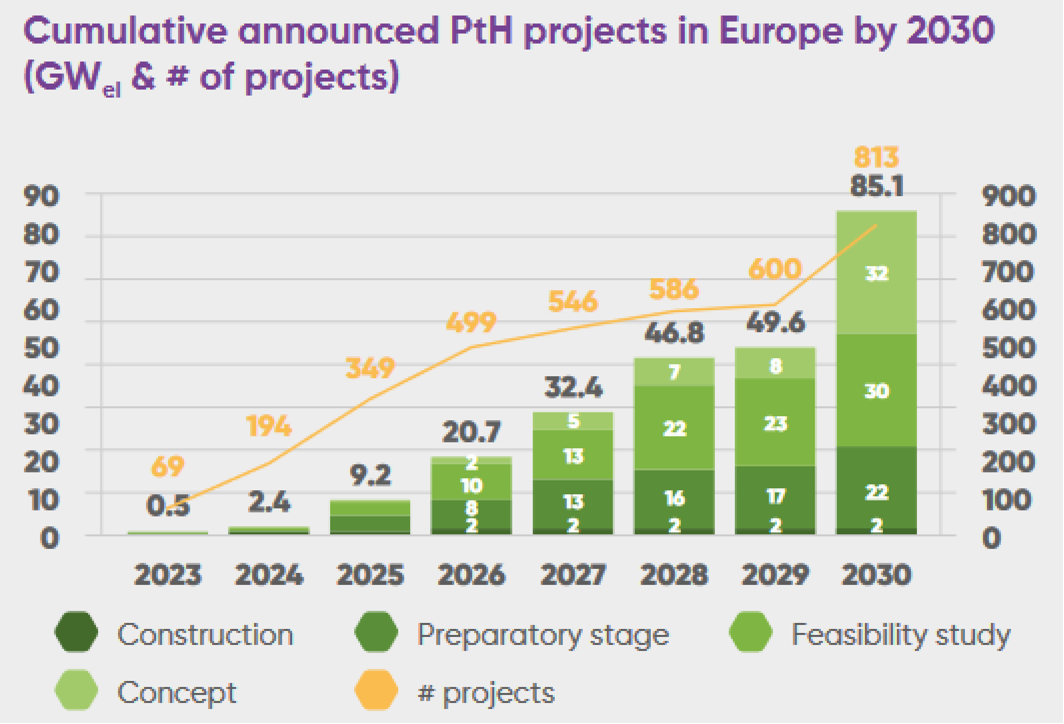
Motivation & Introduction

Green hydrogen will most likely hold a key role in the European energy system

- REPowerEU aims to produce 10Mt of hydrogen by 2030
- Countries have to plan their respective strategies regarding hydrogen infrastructure
  - Germany: 10GW by 2030
- What is the optimal production strategy?



Source: Hydrogen Europe 2023

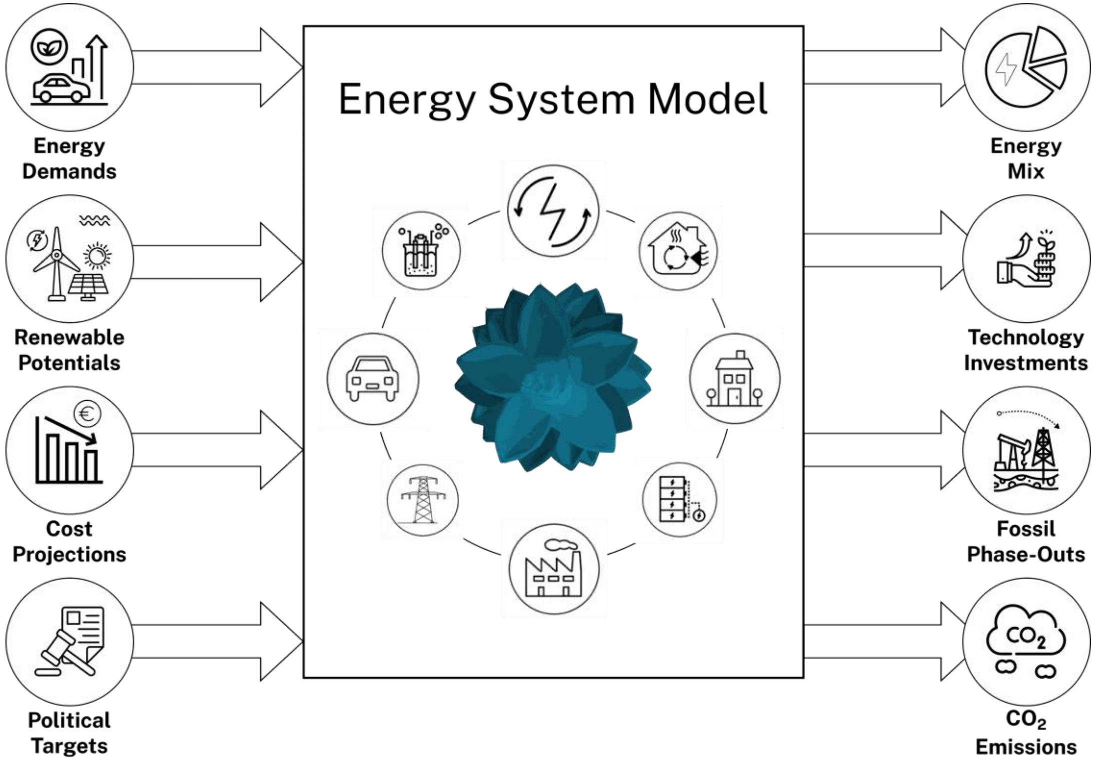
Central or decentral hydrogen production?

- Central: Have centralized production and transport hydrogen to the rest of the country
  - Makes use of high potentials of renewable energy like wind (offshore) or solar
  - Flexibility option and potential of reduced curtailment
  - However need for large scale hydrogen transport infrastructure

- Decentral: Close to demand site
  - Reduces transport costs of hydrogen
  - Waste heat can be used to increase electrolyser efficiency and support decarbonization of heating sector
  - Might need an extension of the electricity grid

Methodology: Case study of Germany

The Global Energy System Model (GENeSYS-MOD)

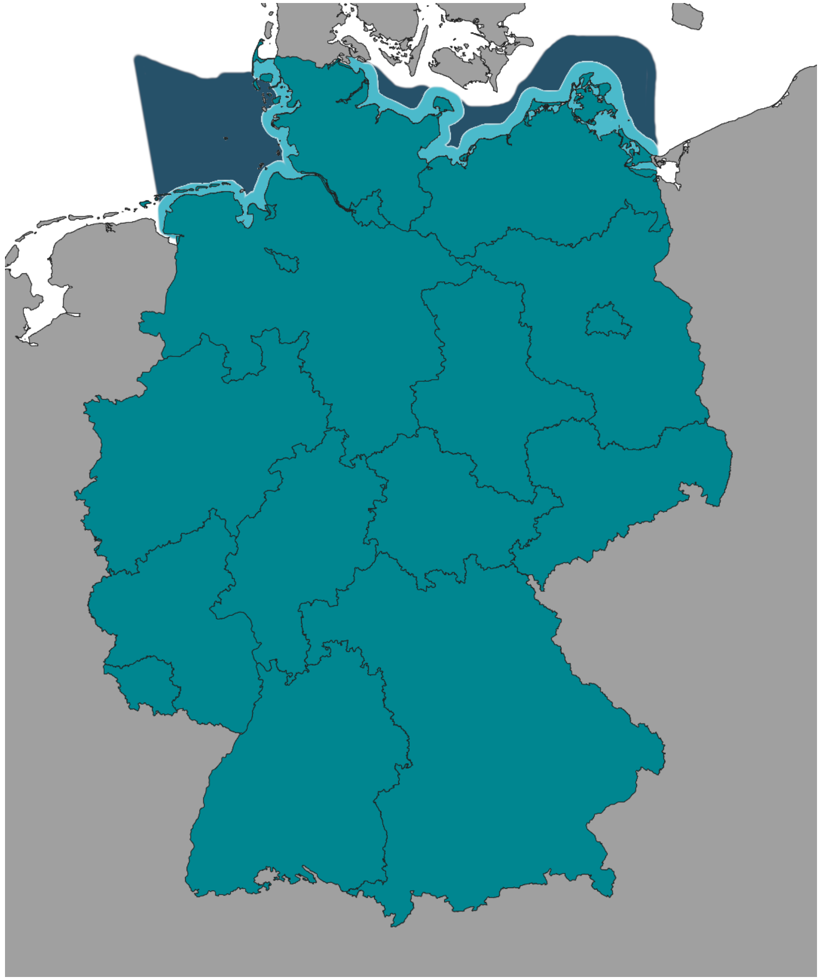


- Based on the Open-Source Energy Modeling System (OSeMOSYS)
  - Enhances the framework with multiple additional features.
- Linear program which optimizes the net present value of a future energy system based on the given assumptions and bounds (cost-optimizing).
- Includes the energy sectors electricity, building, industry, and transport and considers sector-coupling.
- Publicly available to the community with both code and model data [1]

Scenario specific model settings

Spatial and temporal resolution

- Germany disaggregated into 18 regions
- 16 Federal States
- 2 offshore zones
  - North Sea and Baltic Sea
  - Can only build offshore wind and electrolysis capacity
- Hourly time-series for renewable potentials and demands
- Reduced by time-series clustering algorithm[2]
- Results in temporal resolution of every 244th hour (35 time slices)



Scenario: Net zero 2045

A net zero carbon emission energy system by 2045

Political goals

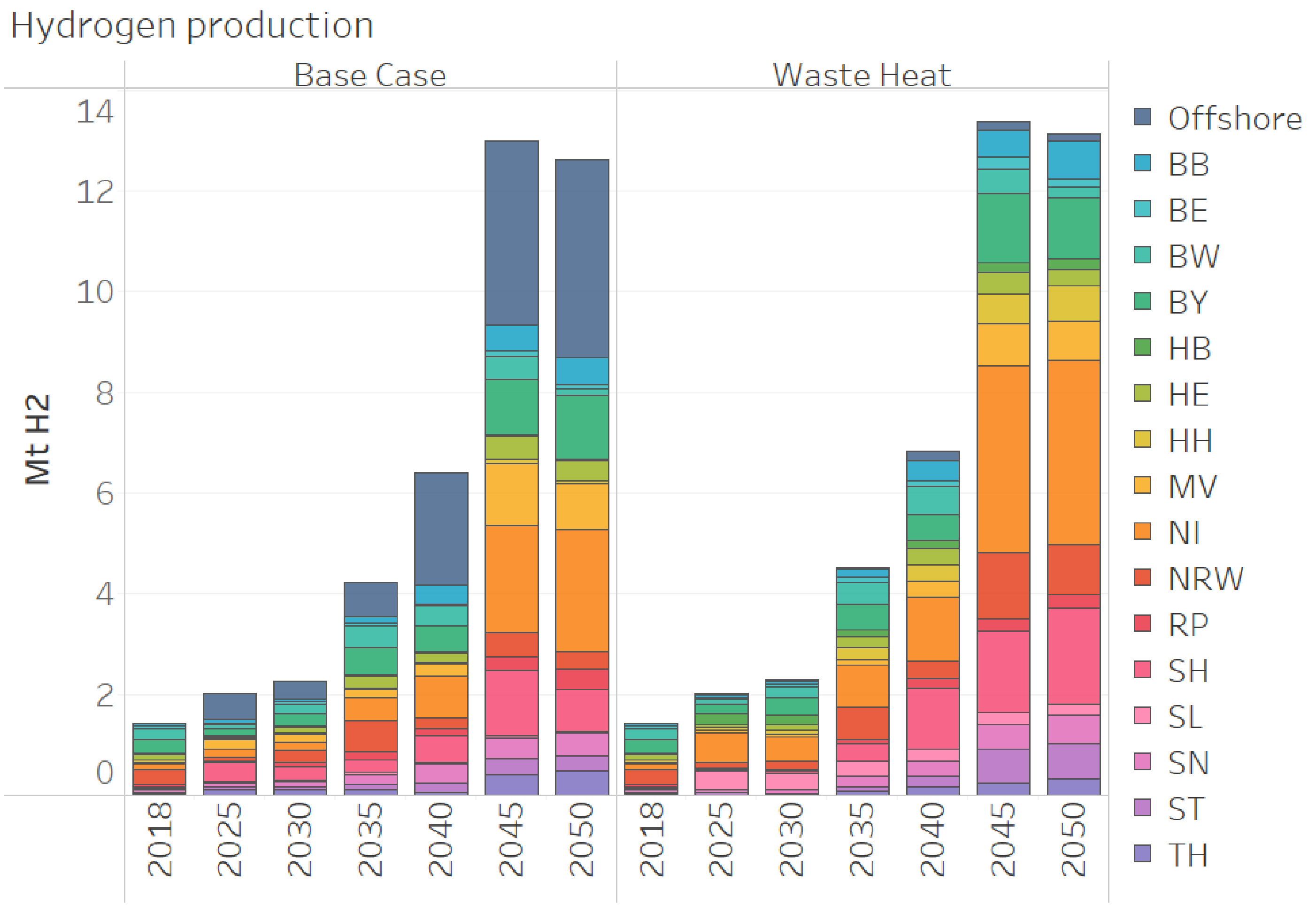
- Electricity sector will be decarbonized by 2035
  - 80% RES by 2030
- Heating sector with 50% RES by 2030
- 10 GW of electrolysis capacity by 2030
- 70 GW offshore wind capacity by 2045

Model cases

- Base Case with political goals
  - Serves as a reference
- Waste Heat Case
  - Inclusion of electrolyser waste heat usage, to maximize electrolysis efficiency
- Sensitivities regarding electrolyser capital costs and transport costs of hydrogen and electricity

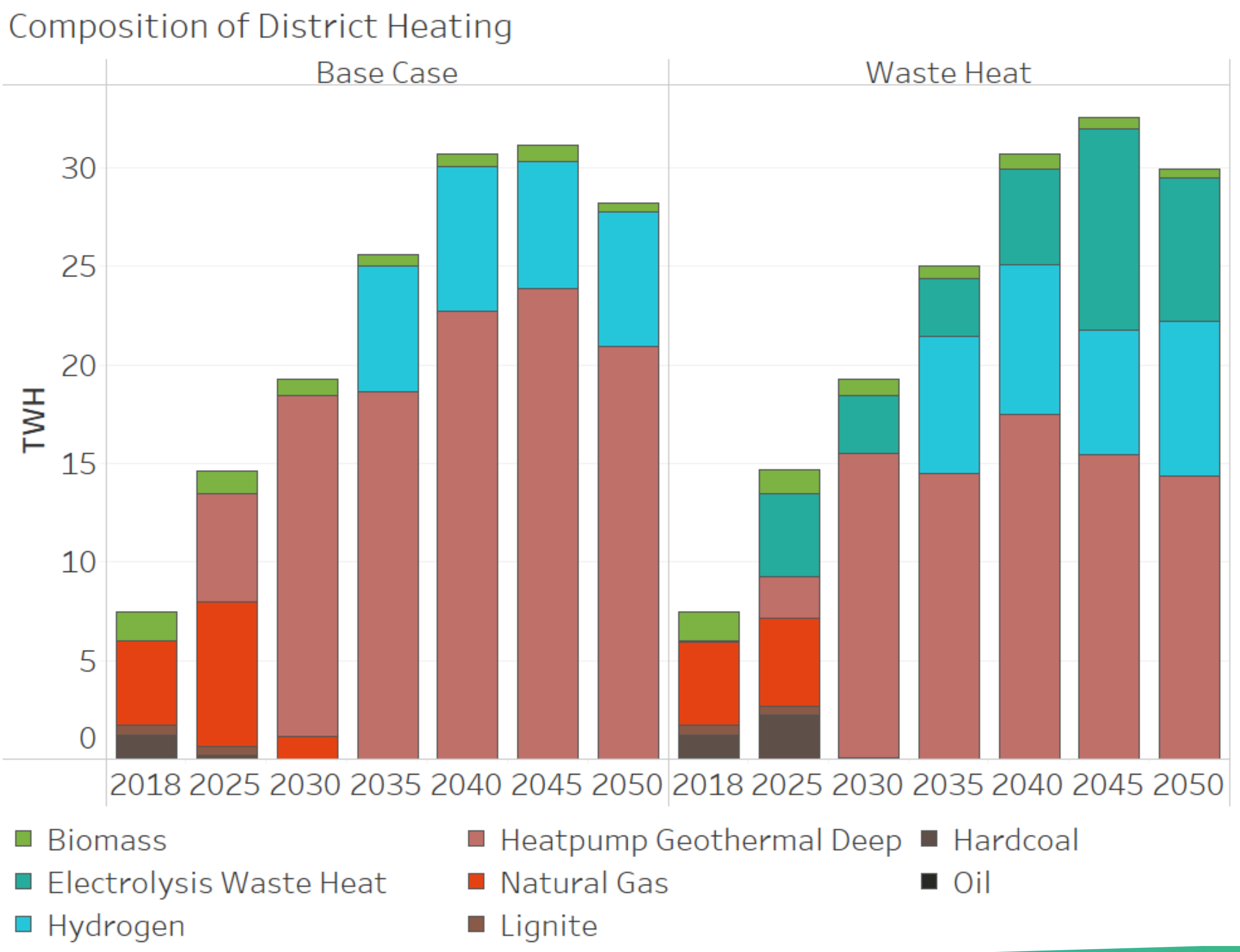
Results & Sensitivities

Inclusion of electrolysis waste heat shifts hydrogen production towards inland



- Offshore zones make up ~30% of hydrogen production in Base Case in 2050
- Shift towards inland hydrogen production with the introduction of electrolyser waste heat usage
- Hydrogen transport infrastructure reduced by 30%, in a decentral approach
  - Electricity grid expansion increased by only 4%

Electrolyser waste heat becomes a major district heat provider

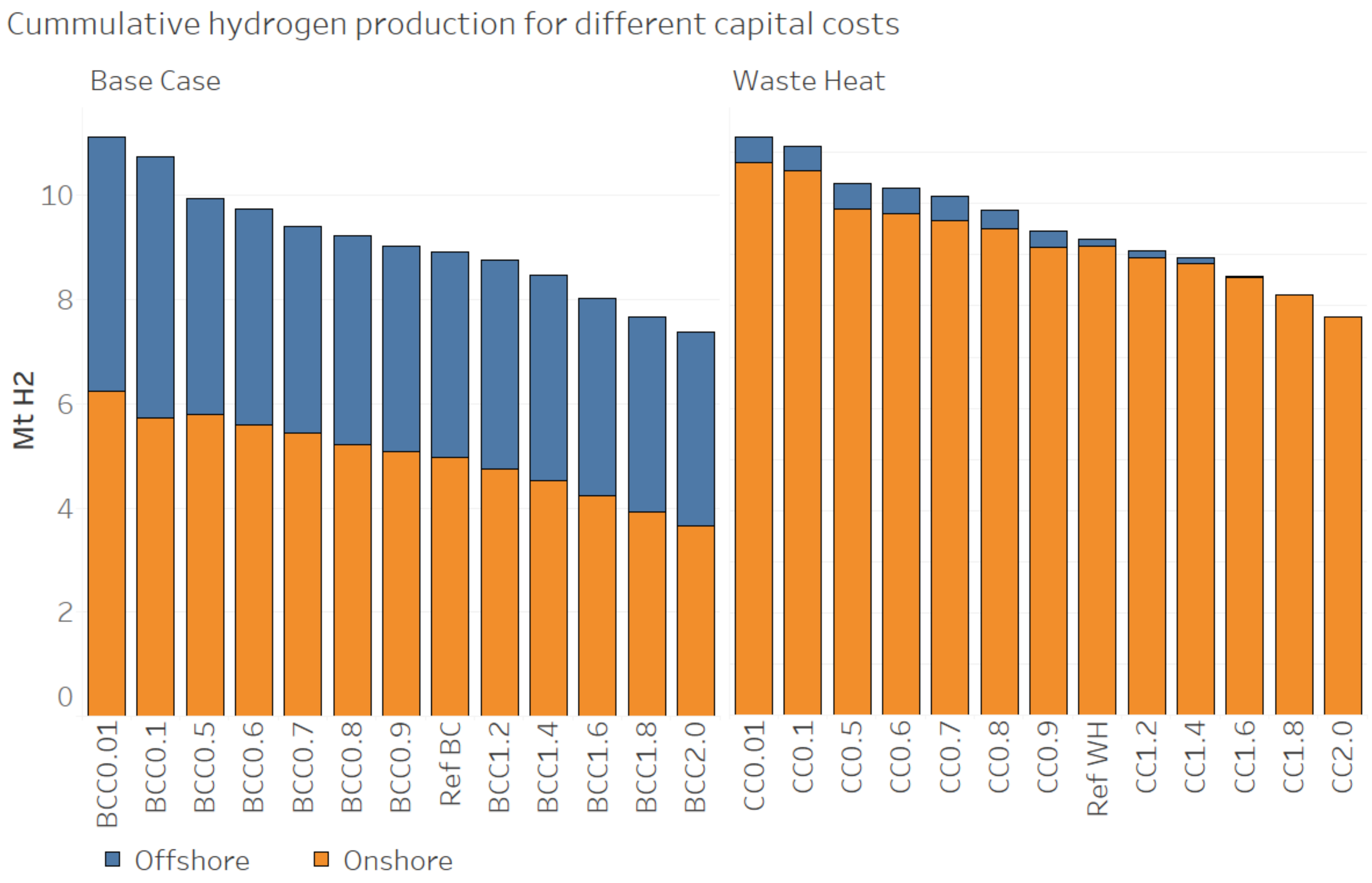


– Around 25% of district heat is provided by electrolyser waste heat

– Electrolyser waste heat replaces more expensive technologies

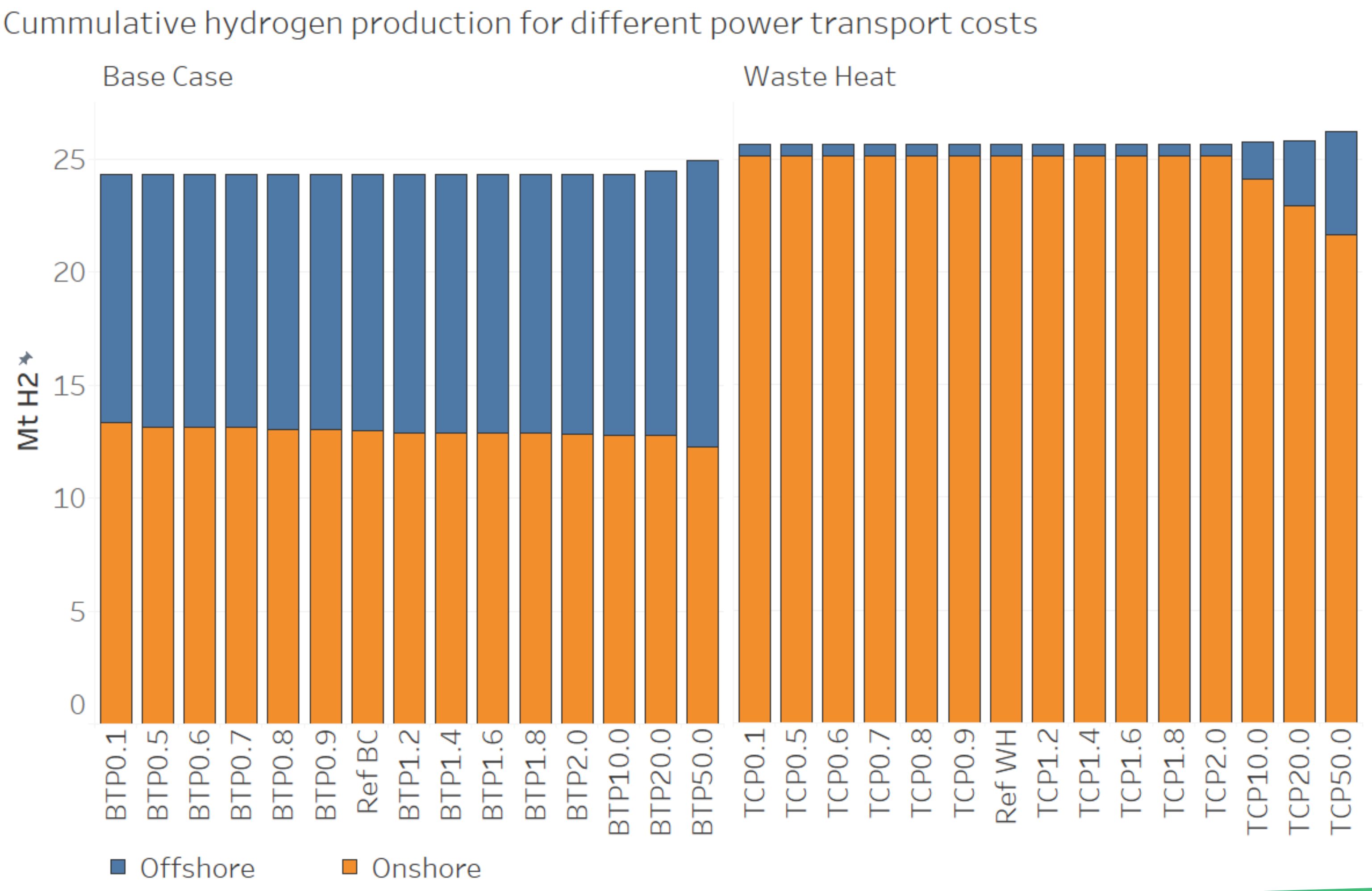
– Overall amount of district heating does not change much

Capital costs have a strong effect on hydrogen production



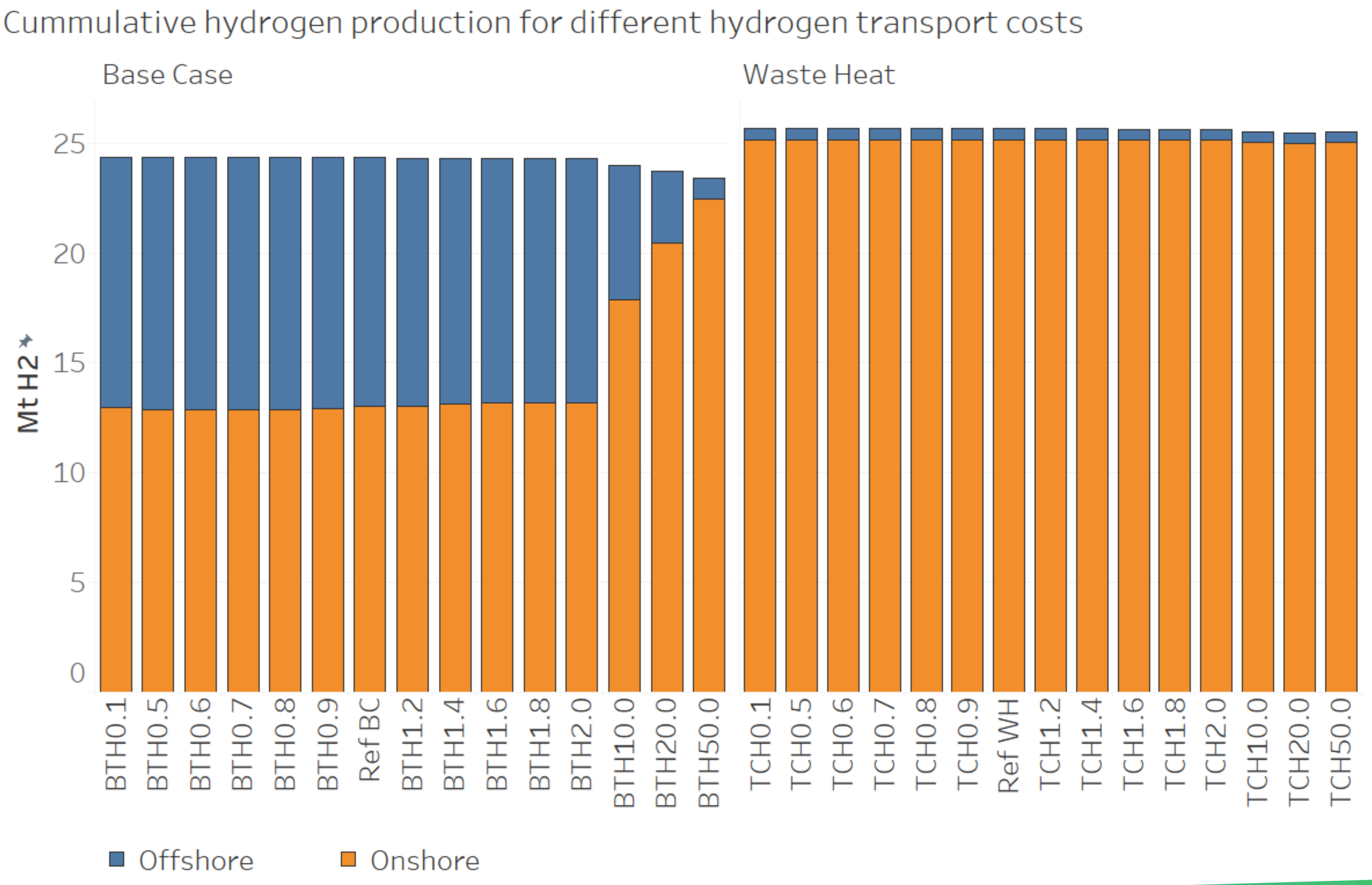
- Base Case shows increased share of offshore hydrogen production with increasing capital costs
- With use of waste heat, offshore hydrogen production is not cost-efficient enough with increasing capital costs

Costs for electricity transmission have little influence on the hydrogen production



- Change is only noticeable from an increase of factor 10 upwards in both cases
- The reason for this is the high availability of electricity supply in every region

Transportation costs for hydrogen only impact the Base Case



- With high enough transportation costs, the share of offshore hydrogen production is reduced
- Due to the close vicinity of electrolysers to the demand-site, transportation costs have no influence on the case with waste heat usage

Conclusion & Outlook

Preliminary results show a preference towards decentralized hydrogen production

- Without the use of electrolyser waste heat, high potentials of offshore wind are used to produce hydrogen in the offshore zones

- However, the introduction of waste heat usage shifts the production (almost) completely towards the inland

- Capital costs of electrolysers influence the proportion between offshore and onshore hydrogen production

- The increased efficiency of the electrolysers make them cost-optimal and inelastic regarding transport costs of hydrogen and electricity

Limitations and further research

- The spatial resolution limits the analysis of the transmission grid of electricity and hydrogen
- Water availability can limit the build up of electrolysis capacity especially in the later years
- Currently only alkaline electrolysis is used, other types as SOEC and PEM should be added
- Further insights from the results and sensitivities are to be gained

Thank you for your attention.
Questions?

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[2]: Gerbaulet, C., Lorenz, C., 2017. dynELMOD: A Dynamic Investment and Dispatch Model for the Future European Electricity Market. DIW Berlin, Data Documentation No. 88. DIW Berlin. Berlin, Germany. URL: https://www.diw.de/sixcms/detail.php?id=diw_01.c.558131.de.