Short-term effectiveness of electrolytic hydrogen production for energy system decarbonisation

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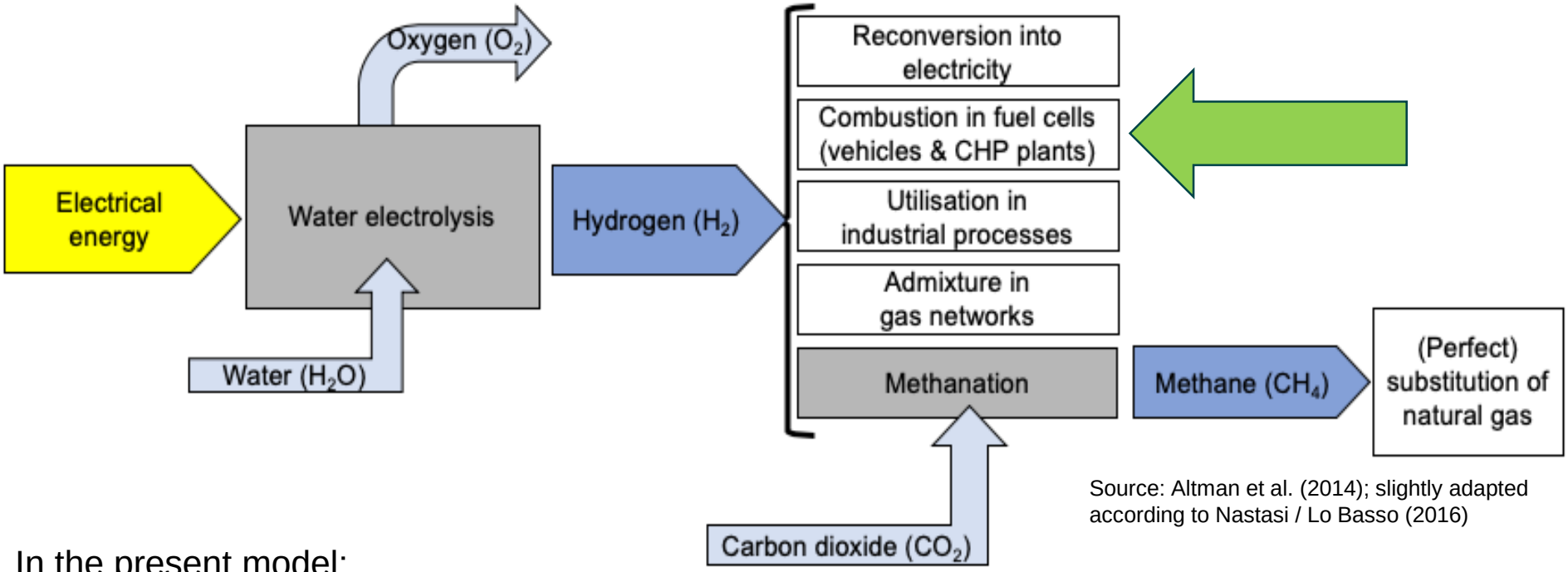
Agenda

1. Motivation & Fundamentals
2. Research Model & Research Questions
3. Materials & Methods
4. Analysis & Results
5. Summary & Conclusions

Motivation

- Energy-related CO2-emissions: ≈ 9 tons per capita and year (BMWI, 2018)
- Necessary: ≈ 2,7 tons per capita and year (Paech, 2012)
- In Germany, ≈ 96 % of CO2-emissions are energy-related (BMWI, 2017)
- Decarbonisation target achievement conflicts with federal coal phase-out plans (Heinrichs et al., 2017)
- Decarbonisation targets are not achievable without large-scale deployment - at least 80 GW until 2050 - of plants for the production of synthetic energy sources like hydrogen, methane or liquid fuels from renewable electricity (Henning / Palzer, 2015)
- Interdependence between phase-out policies & low carbon technology diffusion recognised (Rogge / Johnstone, 2017) but hardly addressed in prior research
- In what follows: Investigation on the interplay of electrolysis technology diffusion and coal-fired power plant closure from a systemic perspective

Fundamentals of water electrolysis



Source: Altman et al. (2014); slightly adapted according to Nastasi / Lo Basso (2016)

<u>In the present model:</u>

Electrolytic hydrogen production

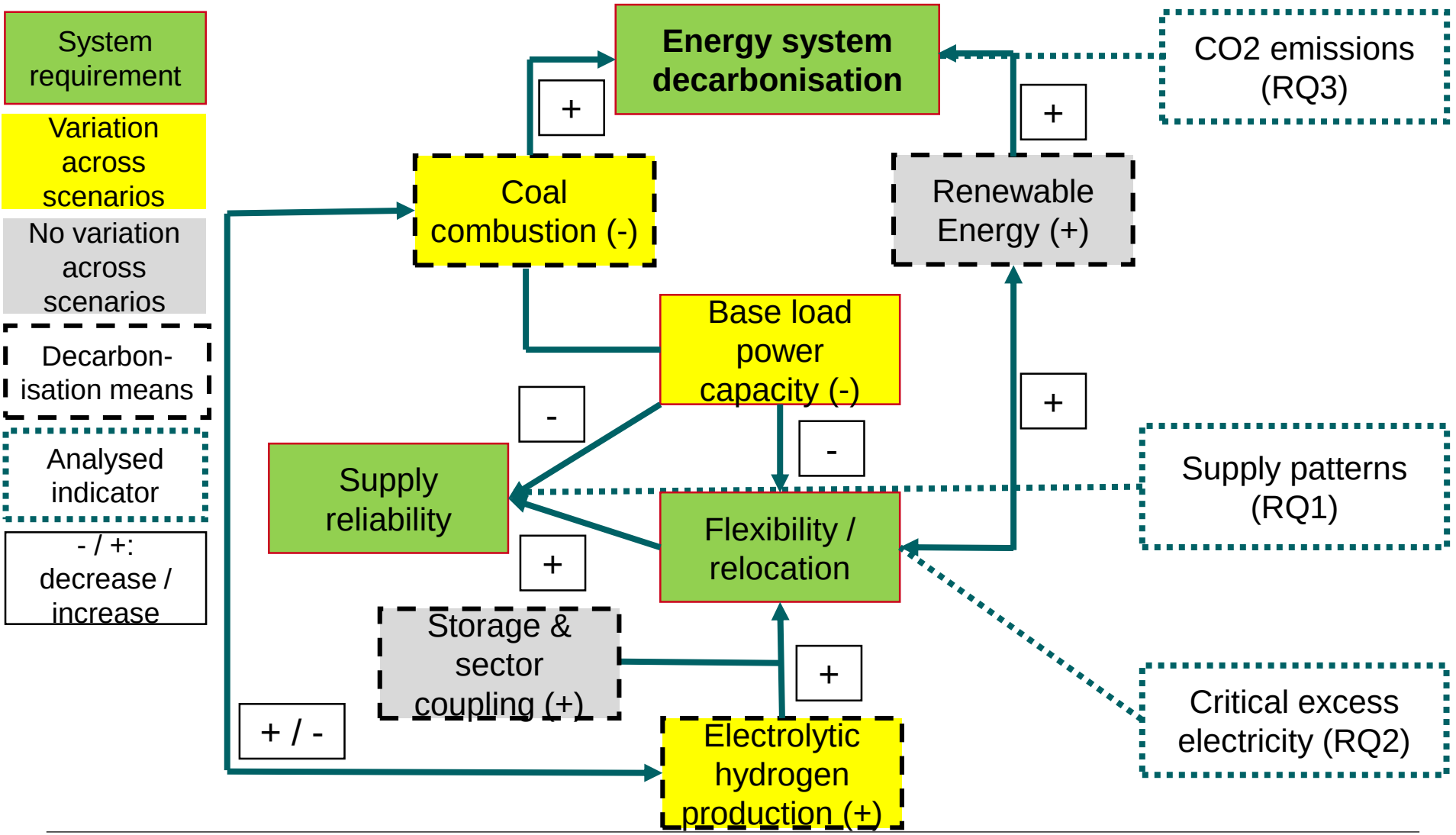
… to meet flexible hydrogen demand in the heat sector

- takes place only at times the electrolysers can be operated with excess electricity from RES

… to meet fixed hydrogen demand in the transportation sector

- potentially requires additional fossil fuel combustion processes to generate electricity for the operation of electrolysers

Research Model



Research Questions (Today's focus on RQ2 & RQ3)

How do the coal phase-out and electrolytic hydrogen production expansion shape the decarbonisation of the German energy system during the next decade?

CO2 emissions (RQ3)

Which consequences arise for the German energy system, in terms of supply reliability, if the coal phase-out is implemented according to alternative proposals of environmental associations (BUND & Greenpeace) as compared to the declared plans of federal authorities?

Supply patterns (RQ1)

To what extent does electrolytic hydrogen production enhance system flexibility?

Critical Excess Electricity (RQ2)

Modelling & Simulation with EnergyPLAN

- Deterministic bottom-up simulation tool (developed at Aalborg University)
- Simulates the operation of national energy systems on an hourly basis, including the electricity, heating, cooling, industry, and transport sectors (www.energyplan.eu)

Data Types	Input	Output
Annual data	➢ Power plant capacities ➢ Production & consumption volumes ➢ Efficiencies ➢ Emission factors …	➢ Complete energy balances ➢ CO2 emissions …
Hourly profiles	➢ Demand patterns ➢ (Intermittent RES) generation profiles …	➢ Generation & load profiles per technology ➢ Import/export profiles …

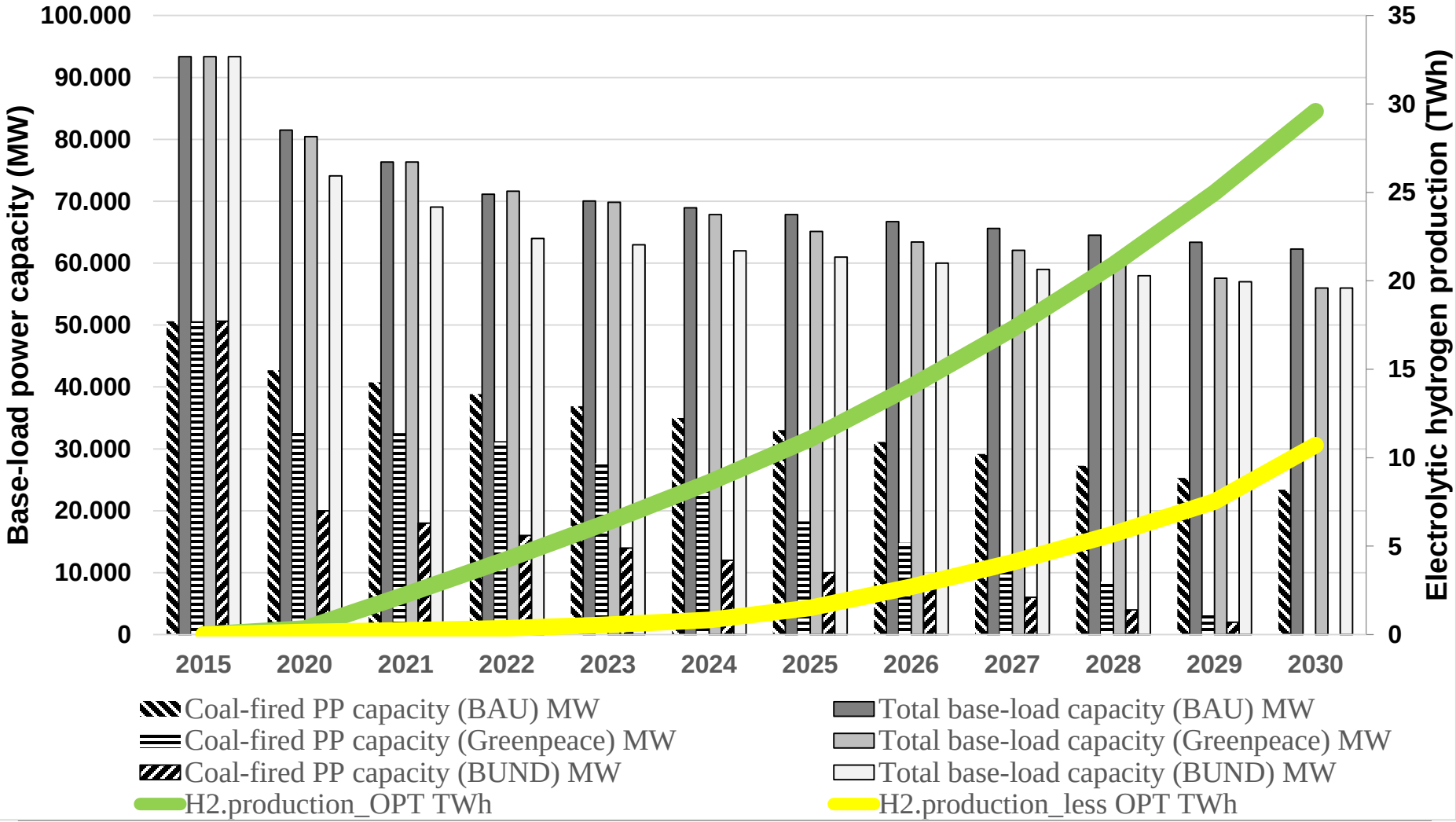
Work Steps

1. Data collection (Sources: Federal statistics, environmental associations …)
2. Model calibration
3. Pathway modelling
4. Simulation (strategy: balancing both heat and electricity demand)

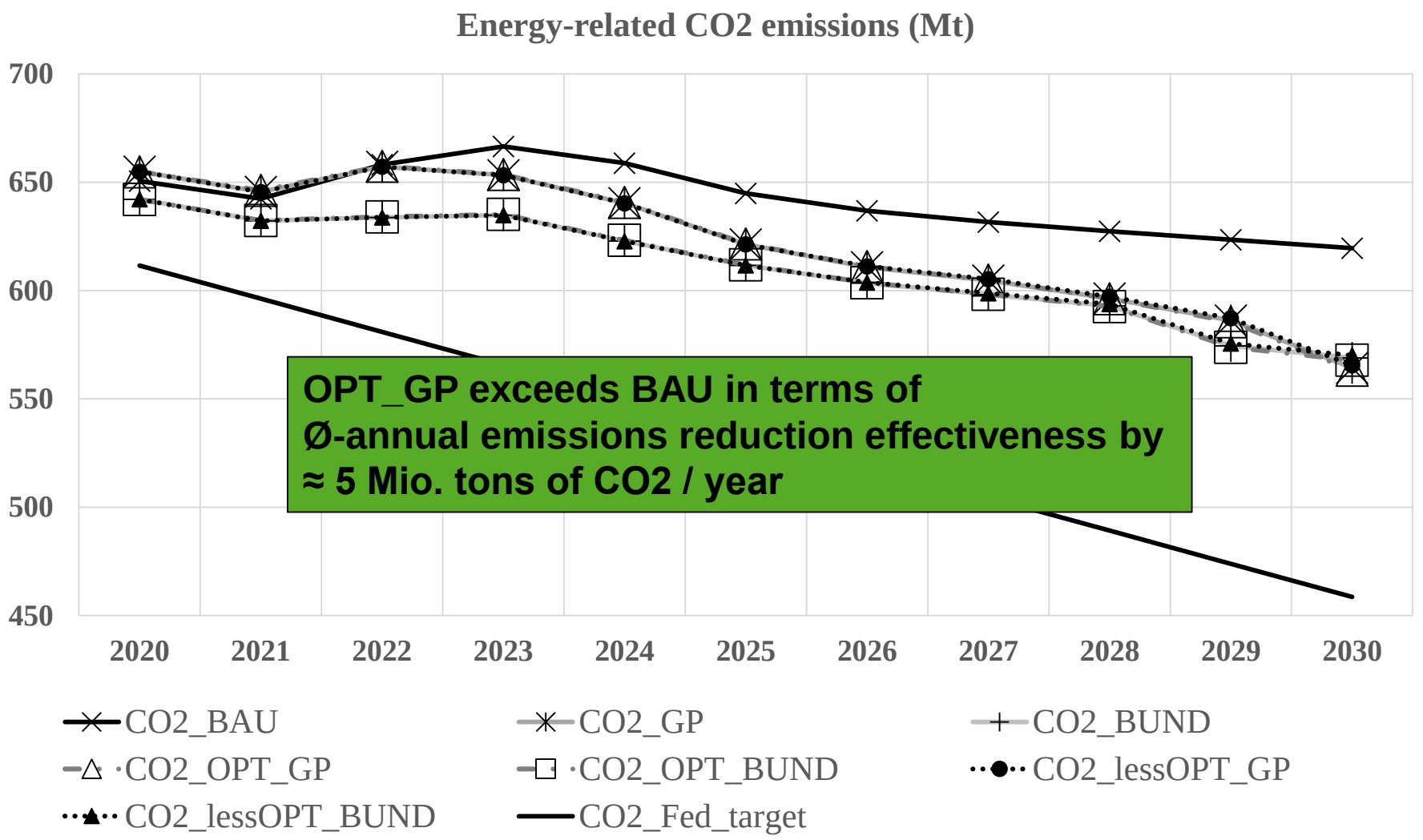
Scenario Definition

7 Scenario pathways modelled for the period 2020-2030		Electrolytic hydrogen production		
		None	Low (less optimistic)	High (optimistic)
Coal-fired power plant closures	Federal network development plan	*BAU*	-	-
	BUND	*BUND*	*lessOPT_BUND*	*OPT_BUND*
	Greenpeace (GP)	*Greenpeace*	*lessOPT_GP*	*OPT_GP*

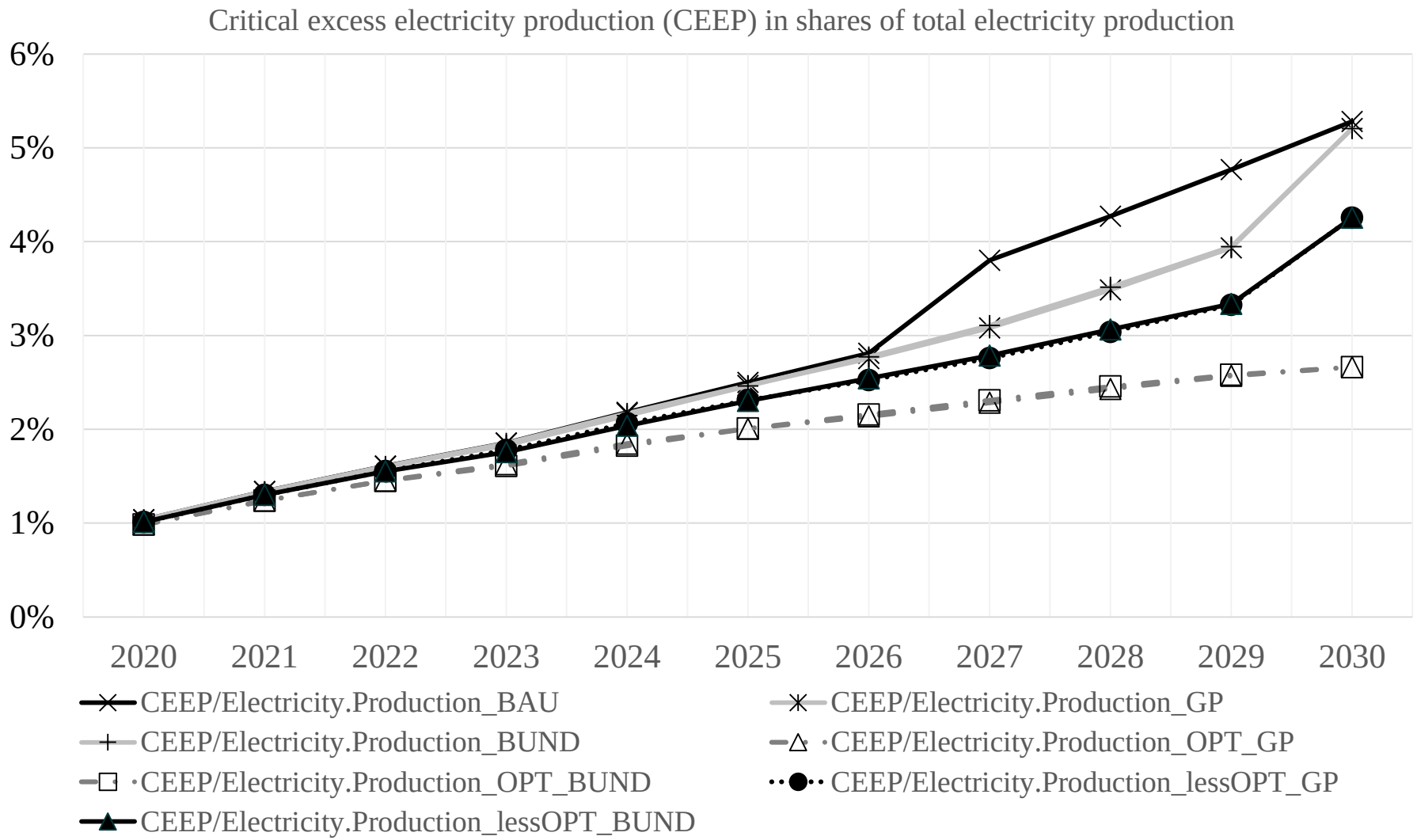
Development of power plant capacity (pillars) & electrolytic hydrogen production (lines)



Coal phase-out mainly determines decarbonisation target achievement – additional fossil fuel combustion processes triggered by fixed hydrogen demand don't increase total emissions (RQ3)



Rate of electrolytic hydrogen production mainly determines system flexibility - effectiveness of other decarbonisation measures (such as RES deployment & electrification) increases with the rate of hydrogen production (RQ2)



Summary & Conclusions

- Increasing usage of electrolysers for the absorption of excess electricity and the production of hydrogen as an enabler of system flexibility and (consequentially) decarbonisation

- Calculation of annual & hourly KPI's for the evaluation of decarbonisation measures in seven distinct pathway scenarios that vary with regard to the timing of the coal phase-out and the rate of electrolytic hydrogen production

- Results strongly support the alternative coal phase-out plans and the expansion of water electrolysis technologies but, for the achievement of federal CO2 targets, decarbonisation measures must go far beyond

- From an environmental point of view: Policy makers should support water electrolysis technology diffusion in the short-term even if this is initially associated with additional fossil-fuel combustion processes to operate the electrolysers

- Decarbonisation measures should be assessed holistically under consideration of joint effects of the underlying technology mix

Thank you for your attention!

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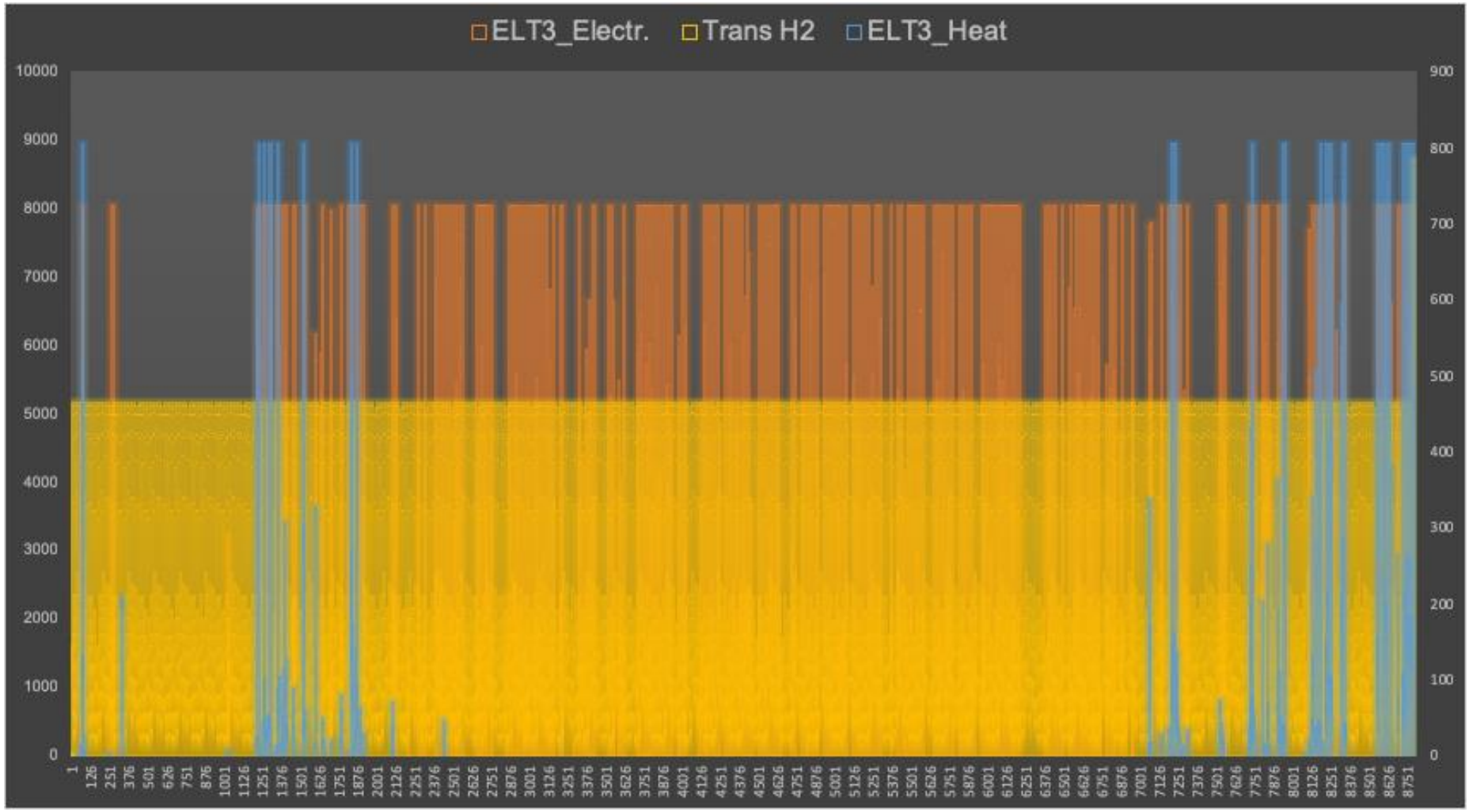
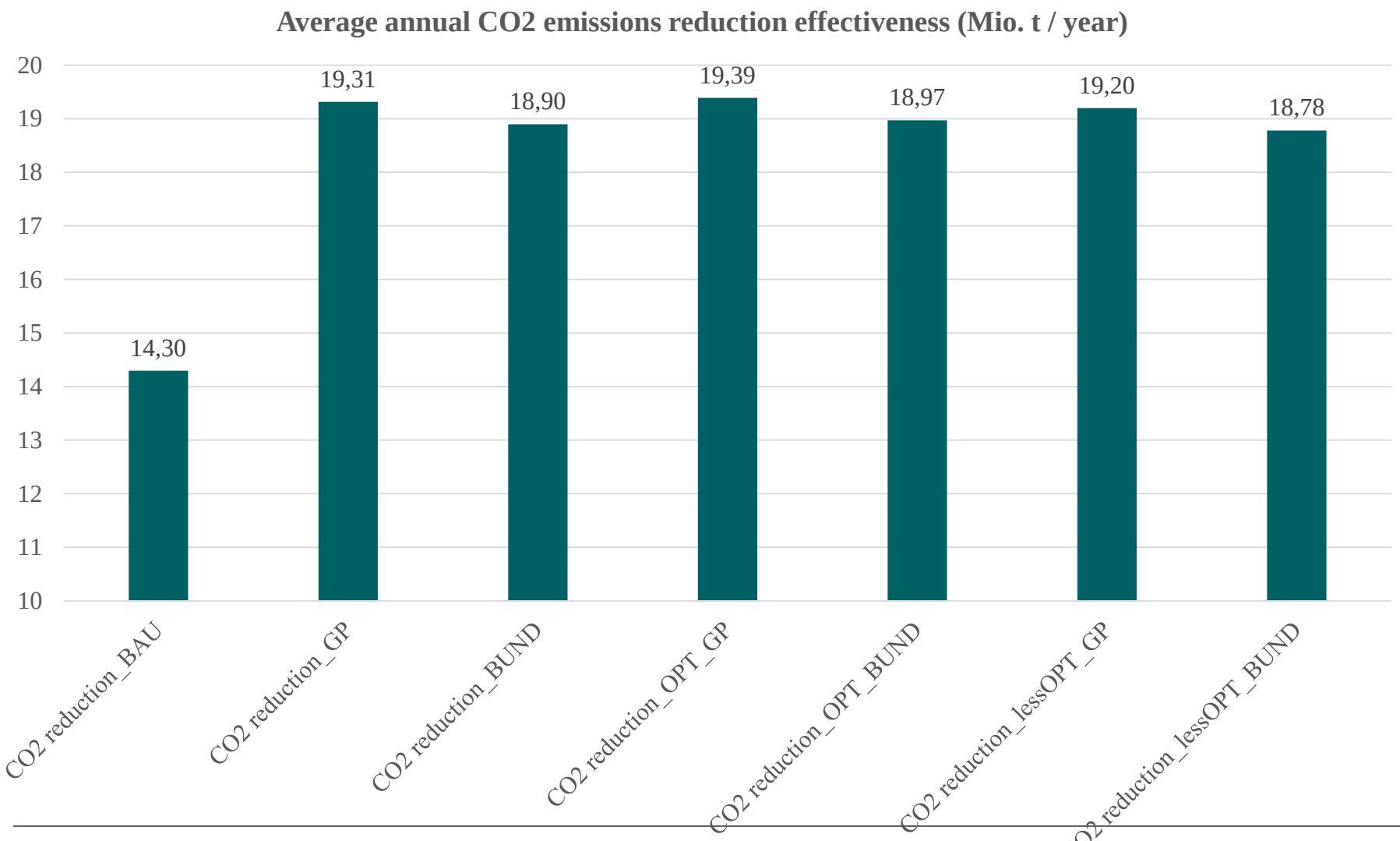
BACK-UP

Electrolytic hydrogen production (MW)

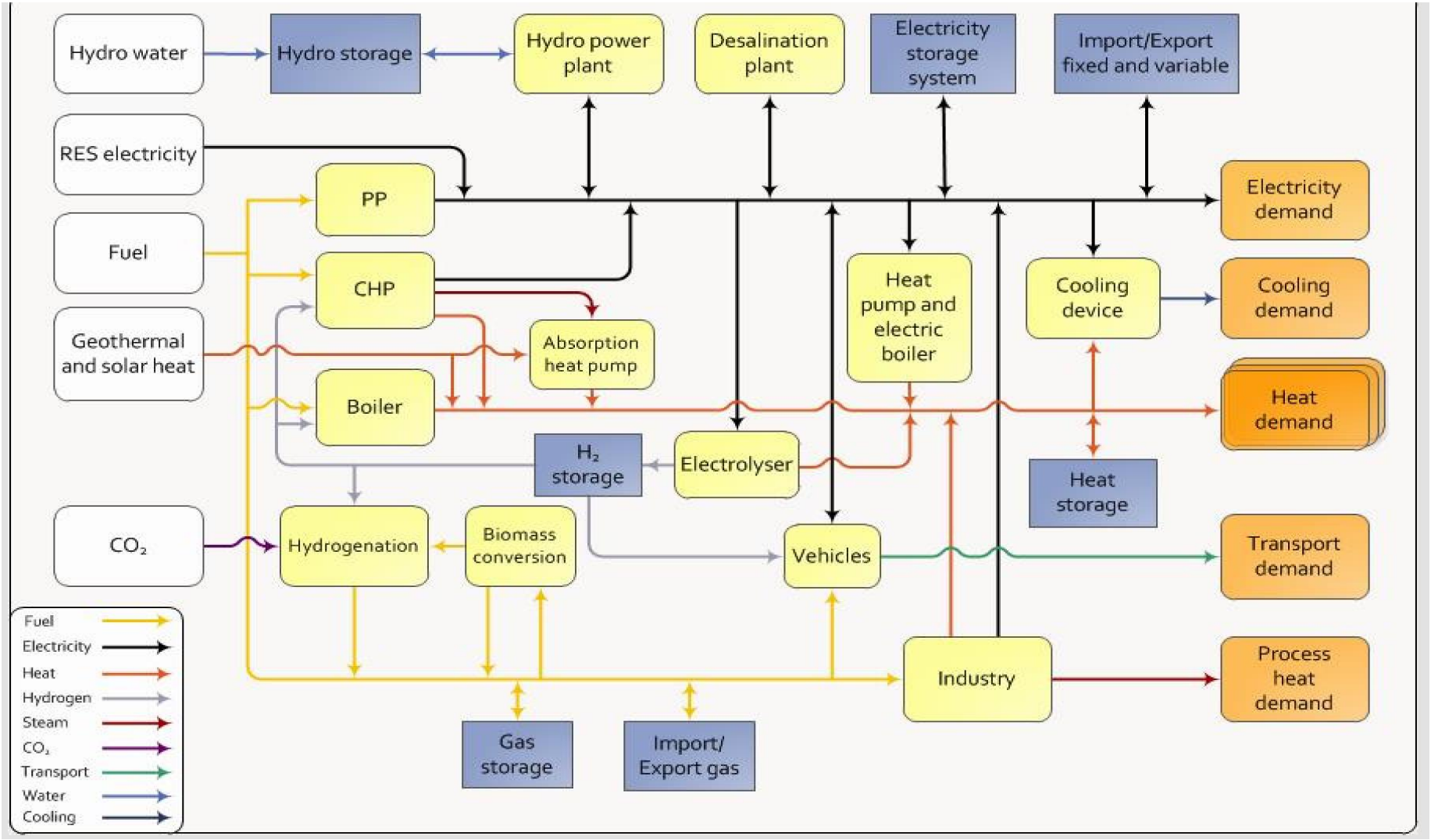


Total CO2 emissions (Mio. t)

$Effectivity\_CO2_t = Ø\ (CO2_{t+1} - CO2_t)$



Smart energy system analysis based on EnergyPLAN



Base load capacity in Germany varies in relation to the pace of coal-fired power plant closures