HOW MUCH FLEXIBILITY NEEDS TO BE PROVIDED BY HYDROGEN POWER PLANTS

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BUSINESS AREAS

Value creation in five business areas

TRADING & SALES

Gas import and wholesale for inexpensive and reliable supply of public utilities and industrial customers.

588 bn kWh
Gas send-out

TRANSPORT

Operation of the critical gas infrastructure at the level of transmission network as the basis for secure energy transport.

7,700 km
Transmission network

STORAGE

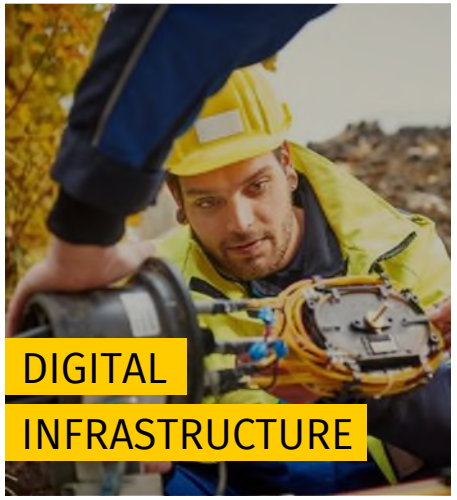
Gas held in four underground storage facilities as a pillar of supply security.

2.2 bn m^3
Storage capacity

BIOGAS

Regional production of biogas and biomethane in eastern and northern Germany as a contribution to decarbonisation.

40
Biogas Plants



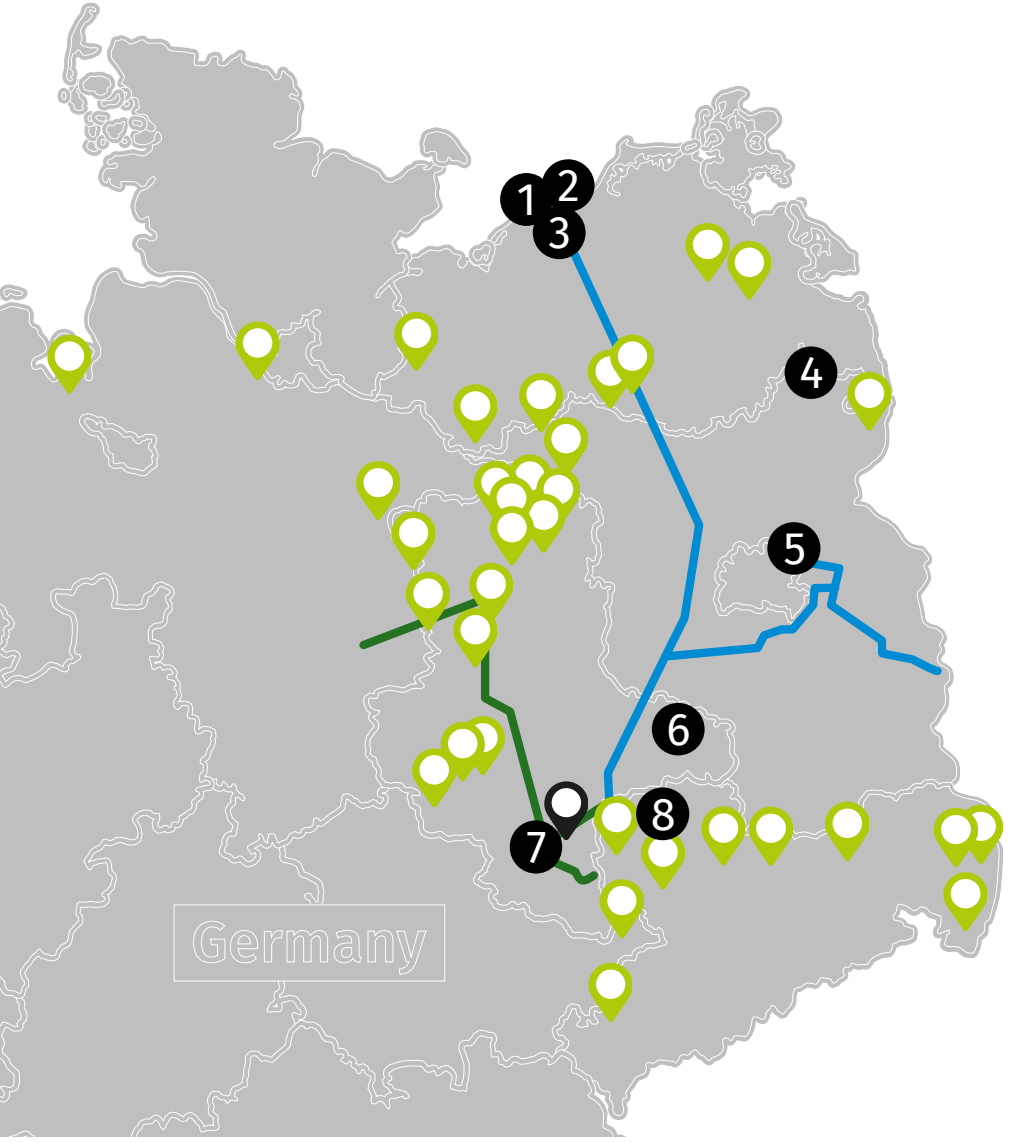
DIGITAL INFRASTRUCTURE

Broadband expansion with fibre-optic infrastructure as a basis for highper-formance communication today and in the future.

5
FTTx-Projects

GREEN GAS PROJECTS

Excerpt of the current project overview



1 **Project Chile**
Import of green ammonia

2 **H2GE Rostock**
Production of blue H_2

3 **Project AZAN**
Cracker for the generation of H_2 from ammonia

4 **H_2 separation**
Increasing the proportion of hydrogen in the natural gas grid

5 **BioVia**
Liquefaction plant for bio-LNG

6 **GreenRoot**
Electrolysis on an industrial scale for green H_2

7 **Bad Lauchstädt Energy Park**
Sand box of the energy transition

GO! Green Octopus Speicher
Large-scale storage of H_2

8 **BioHydroGen**
H_2 production from raw biogas

CapTransCO2
Feasibility study for CCU/CCS

IPCEI Transport Projects

(Important Project of Common European Interest)

- Green Octopus Central Germany – 305 km
- doing hydrogen – 616 km

Companies involved in the project

- VNG AG
- ONTRAS
- VNG Handel & Vertrieb
- VNG Gasspeicher
- BALANCE Erneuerbare Energien GmbH

Locations

Locations of biogas plants of BALANCE Erneuerbare Energien GmbH

As of: June 2023

VNG

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GEFÖRDERT VOM

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Leitprojekt **TransHyDE**

POWER PLANT STRATEGY 2024

- German government published power strategy in February 2024
- 10 GW H2-ready power plants, 100% hydrogen, latest by 2040
- 500 MW hydrogen power plants
- 2028 capacity market mechanism

Source: B. Welter pixabay

RESEARCH QUESTION

How much capacity of hydrogen power plants is needed in the future to ensure the security of supply for a carbon-neutral power system based on intermittent RES?

Table 1: Expected demand on total gas power plant capacity in GW_{el} in Germany in 2026, 2030 and beyond

	Publication	2030	2035	2045
Natural gas power plants				
	EWI (2022, pp. 75, 77)	26 - 30	-	-
Hydrogen power plants				
	EWI (2022, pp. 75, 77)	7 - 11	-	-
	AGORA, 2022, p.26	4 - 6	-	-
	BMWK, 2022	9	15-41	38-67
Gas power plants*				
	Ariadne, 2021	43		
	BDI, 2021	49 – 74	-	85-88
	DENA, 2021, p.21	47	-	59
	AGORA, 2021, p. 39	43	55	71
	AGORA, 2022, p.26	-	60	-

*no specification about natural gas and/or hydrogen

METHODOLOGY

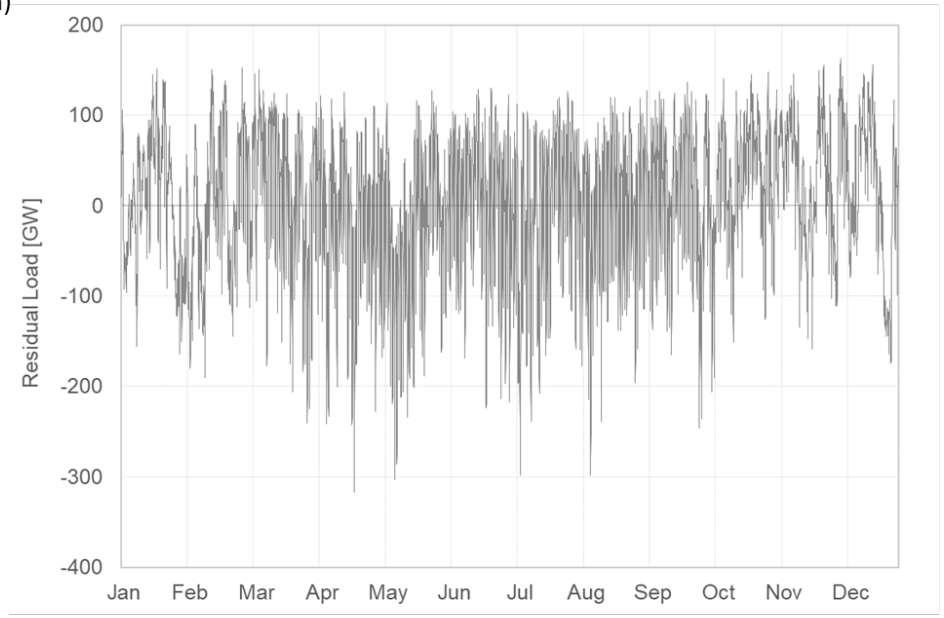
Focusing on Residual load and ELTRAMOD

- Focus on the power sector, using the network development plan 2022, scenario B

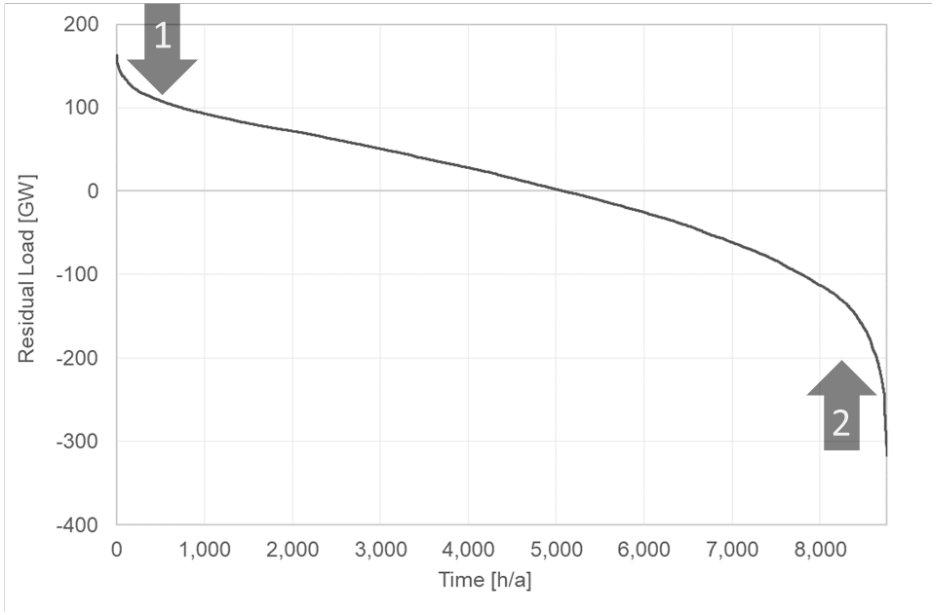
- **Residual load** for inflexible demand without additional flexibility measures in a climate-neutrality scenario for Germany 2035
  - 157 GW wind onshore, 74 GW offshore, 414 GW photovoltaic, 23 GW other renewables
  - Gas power plants → model results
  - Sector coupling technologies → scenarios

- **ELTRAMOD** (Electricity Transshipment Model) is a bottom-up linear optimization model created specifically to assess technological dispatch within the European electricity market. (Zöphel C. (2022), Eising, Hobbie, Möst (2020), Anke et al. (2020), Hobbie, Schmidt, Möst (2018), Ladwig (2018)

a)

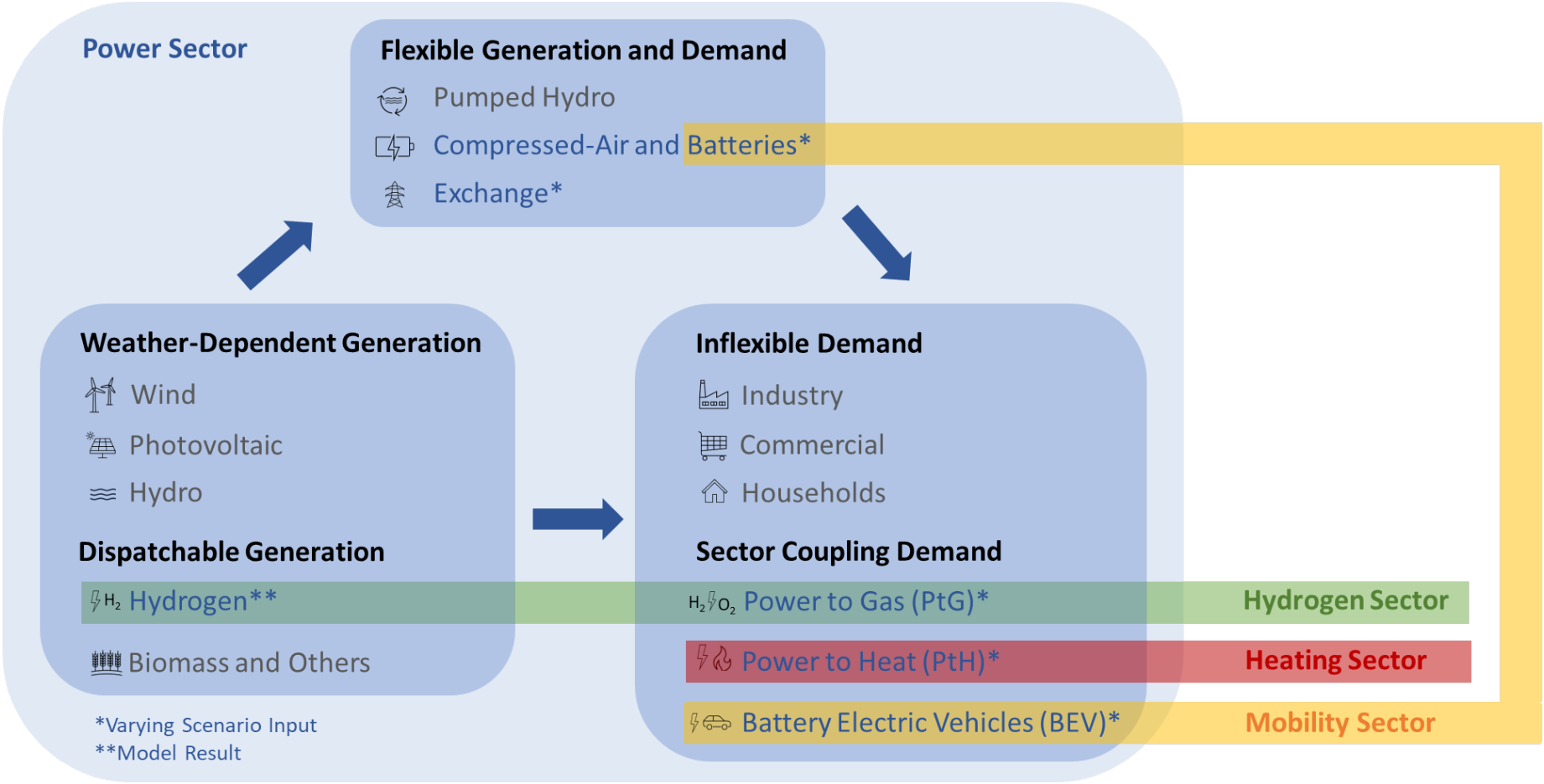


b)



SCENARIO FRAMEWORK

Modelling sector-coupling and storage technologies

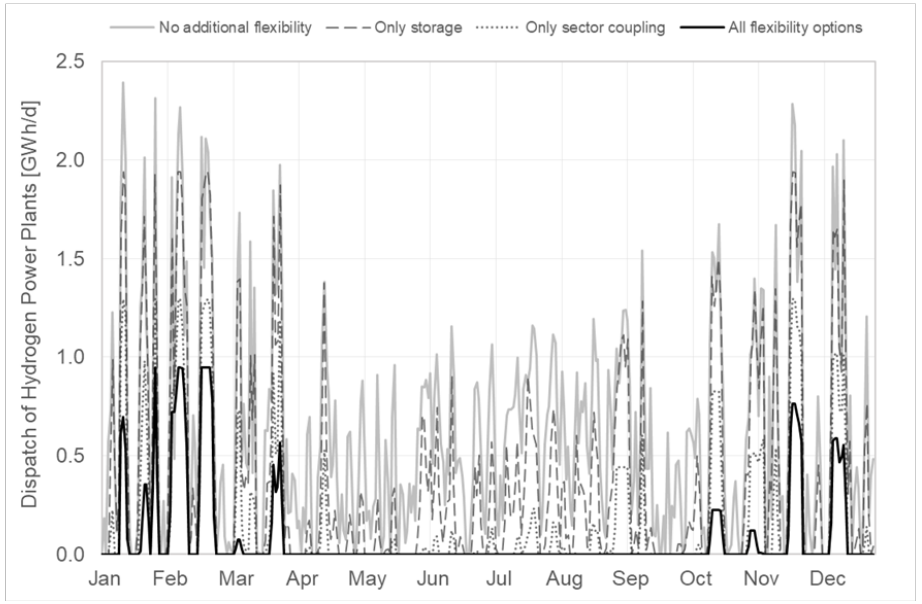


RESULTS – 1/3

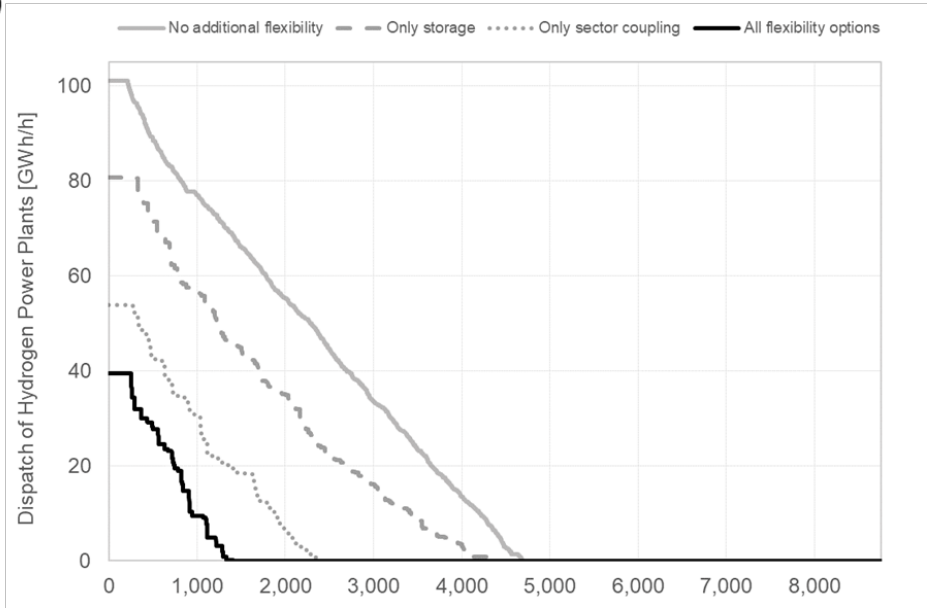
Dispatch results for H2 power plants mainly during wintertime

- Scenario “no additional flexibilities” and “all flexibilities”
- **No additional flexibility** – 100 GW hydrogen power plants are needed
- **All flexibilities** – 40 GW
- <u>Discussion:</u>
  - How many full load hours for power plants?
  - Which power plant technology? CCGT or OCGT

a)



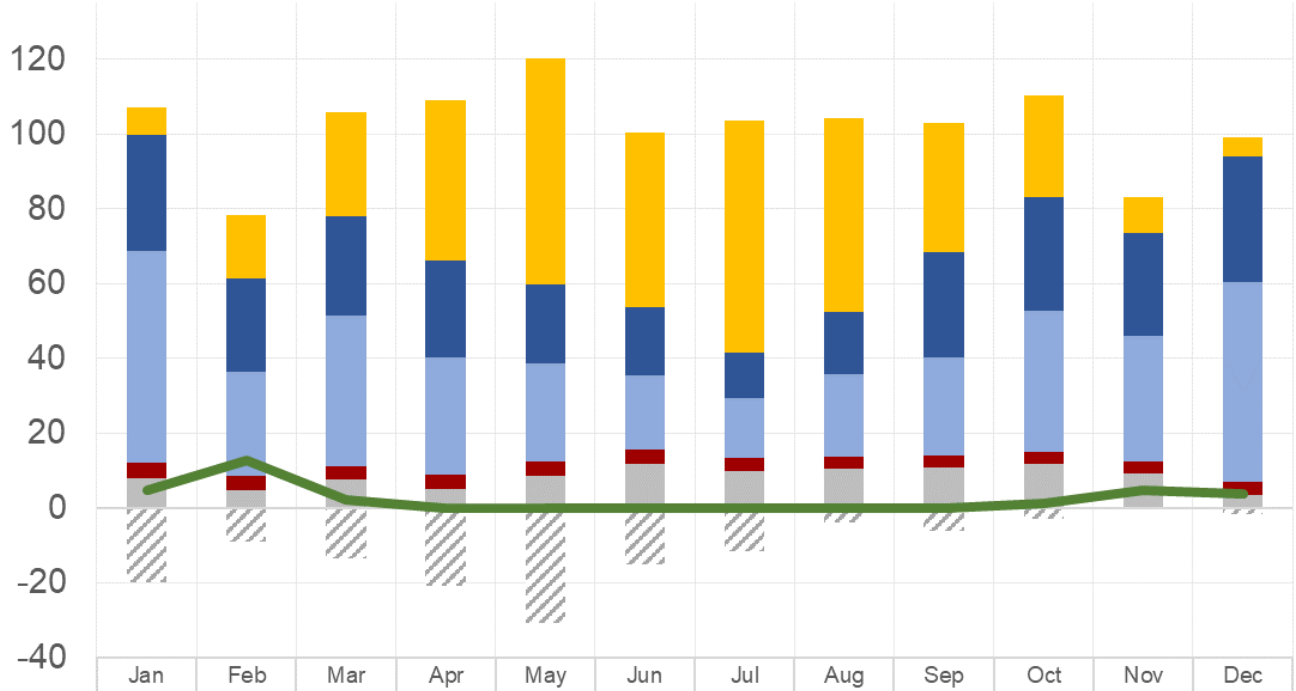
b)



RESULTS – 2/3

Monthly energy balance in scenario “all flexibilities” in TWh shows interplay between imports and RES

- Large curtailment although imports
- Imports are modelled exogenously
- <u>Discussion:</u>
- Will Germany become an import or transit country of electricity?
- What’s the impact on the demand of back up capacities?

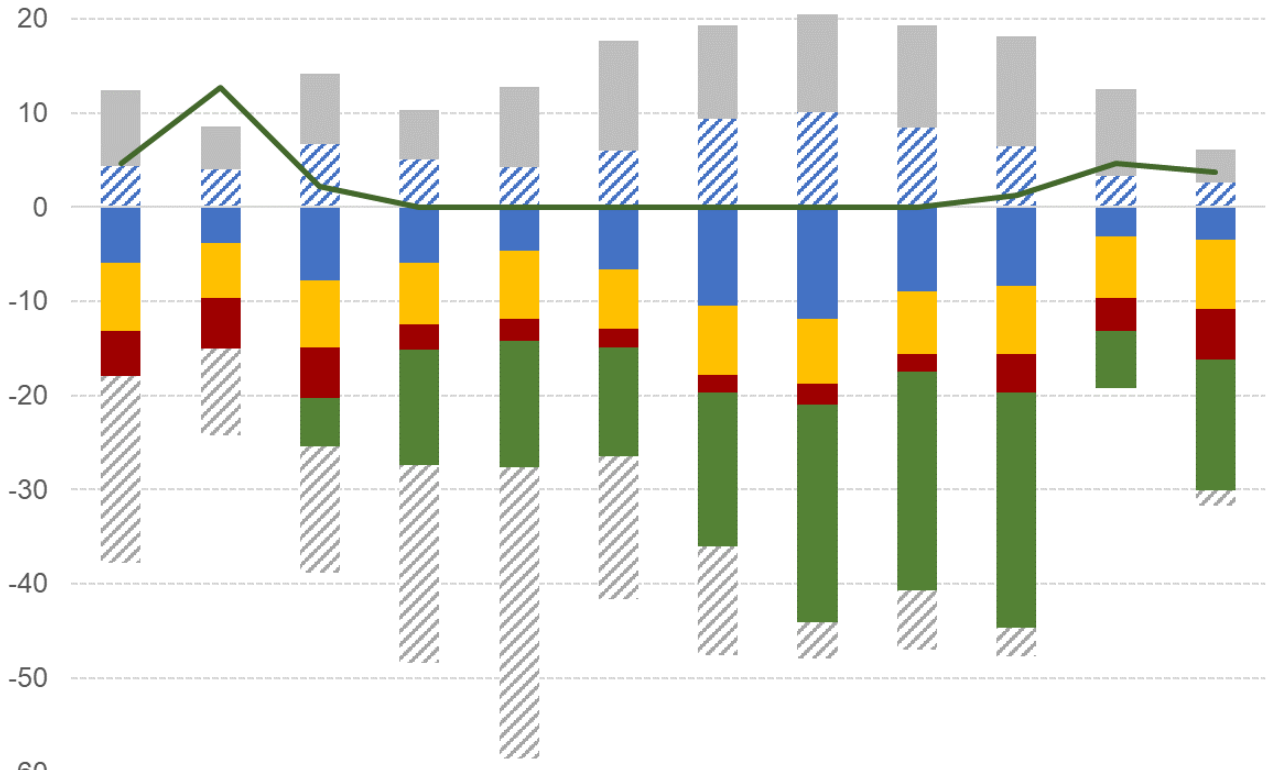


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PV	7.6	16.8	27.9	42.7	60.6	46.7	62.1	51.8	34.8	27.2	9.8	5.1
Offshore	30.9	25.2	26.4	26.0	21.3	18.4	12.1	16.9	28.0	30.3	27.3	33.5
Onshore	56.8	27.8	40.4	31.5	26.1	19.9	16.1	22.1	26.4	37.9	33.7	53.5
Other RES	4.0	3.8	3.5	3.6	4.0	3.8	3.4	3.2	3.1	3.1	3.3	3.3
Curtailed RES	-19.8	-9.2	-13.5	-21.0	-30.9	-15.2	-11.5	-3.8	-6.3	-3.0	0.0	-1.6
Net exchange	8.0	4.6	7.6	5.2	8.5	11.7	10.0	10.3	10.9	11.7	9.2	3.6
H2 power plants	4.7	12.6	2.2	0.0	0.0	0.0	0.0	0.0	0.0	1.3	4.7	3.7

RESULTS – 3/3

Dispatch of flexibility options

- Battery electric vehicles (BEV) are in favor (3.2h storage capacity)
- Hydrogen storages are filled during the beginning of the year – no PtG in
- <u>Discussion:</u>
- Impact of different weather years (the model uses 2018)



	1	2	3	4	5	6	7	8	9	10	11	12
Curtailed RES	-19.8	-9.2	-13.5	-21.0	-30.9	-15.2	-11.5	-3.8	-6.3	-3.0	0.0	-1.6
PtG dispatch	0.0	0.0	-5.1	-12.2	-13.5	-11.6	-16.4	-23.1	-23.2	-25.1	-6.0	-13.9
PtH dispatch	-4.8	-5.4	-5.4	-2.8	-2.2	-1.9	-1.9	-2.2	-1.9	-4.0	-3.5	-5.4
BEV smart charge	-7.3	-5.8	-7.2	-6.5	-7.3	-6.4	-7.3	-6.9	-6.6	-7.3	-6.5	-7.3
Net exchange	8.0	4.6	7.6	5.2	8.5	11.7	10.0	10.3	10.9	11.7	9.2	3.6
All storage charge	-5.9	-3.8	-7.8	-5.9	-4.7	-6.6	-10.4	-11.9	-9.0	-8.3	-3.1	-3.5
All storage discharge	4.4	4.0	6.6	5.1	4.2	5.9	9.3	10.1	8.4	6.4	3.3	2.5
H2 power plants	4.7	12.6	2.2	0.0	0.0	0.0	0.0	0.0	0.0	1.3	4.7	3.7

SUMMARY AND CONCLUSION

- A carbon-neutral power plant system needs back-up capacities, but how much?
- **Power plant strategy** incentivizes **10.5 GW**, a capacity mechanism is planned (by 2028)
- Based on our results, **at least 40 GW of hydrogen power plants** are needed for Germany in 2035, if all flexibility options are considered.
- Each flexibility option has a different impact on the capacity needs for hydrogen power plants, if no additional flexibility options are considered, 100 GW are needed
- Flexibility option on the **demand side reduces** the need for hydrogen power plant capacity **up to 22 GW**; the individual impacts of each flexibility cannot be cumulated as they have an interplay.
- Because of the portfolio effect **sector coupling** and **hydrogen power plants** must be considered jointly.

MANY THANKS FOR YOUR ATTENTION

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