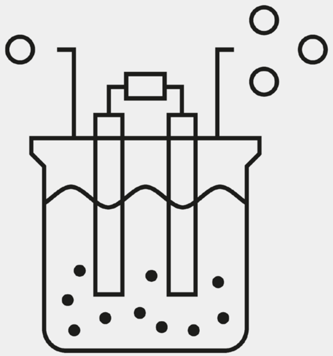
WASSERSTOFF KOMPASS

Electrolysis in Germany

Power, political goals and projected demand for 2030

Berlin, 21 July 2022

Water electrolysis

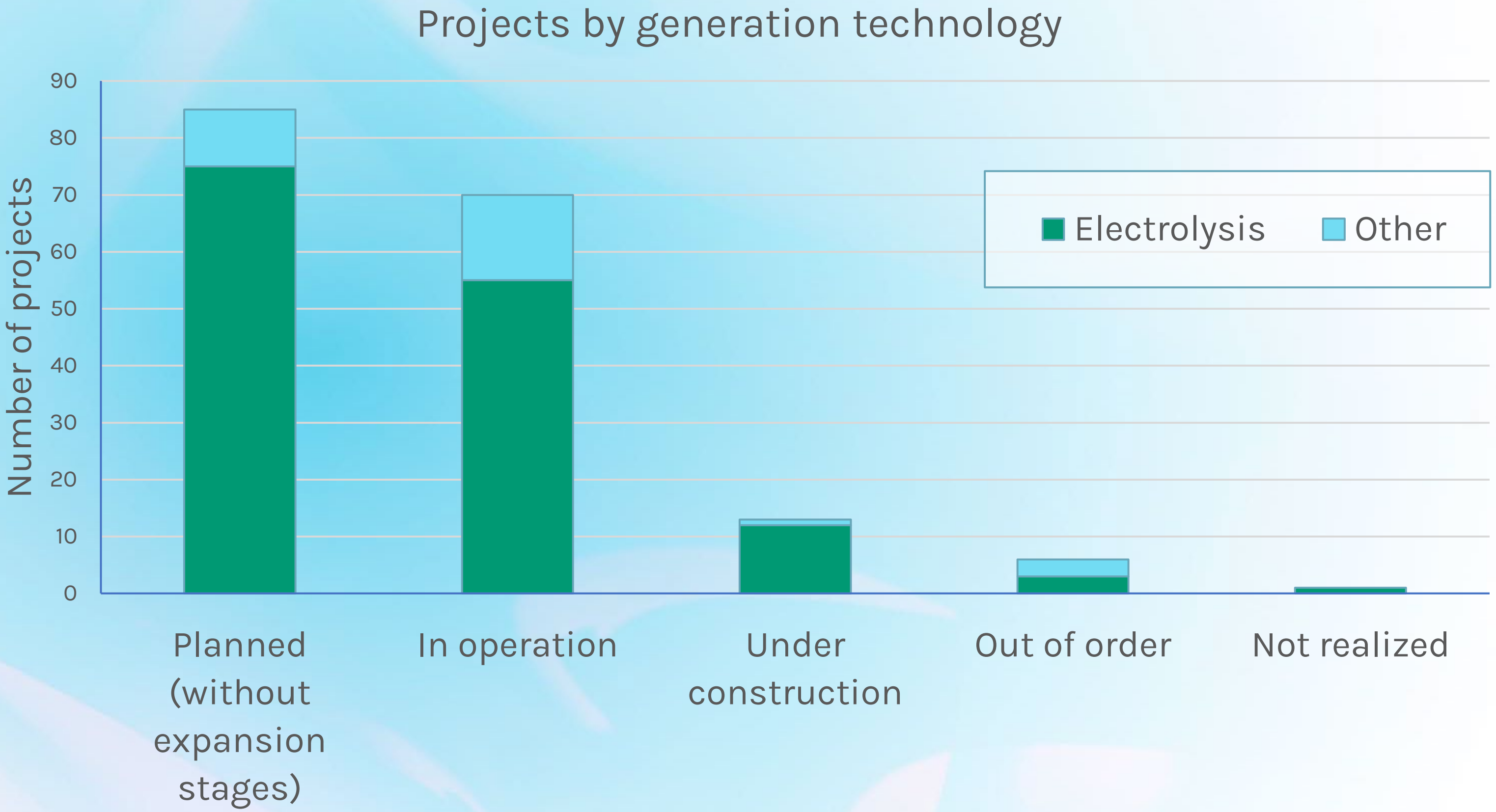


- In water electrolysis, water is electrochemically split into hydrogen and oxygen:
  - $2H_2O \rightleftharpoons 2H_2 + O_2$
- Water electroysis can be a climate-friendly technology to generate hydrogen. However, the CO_2 intensity of this method largely depends on the electricity mix used.
- About 10 kg of H_2O are needed to produce 1 kg of H_2.
- There are different technologies for water electrolysis:
  - Alkaline electrolysis (A-EL)
  - Proton exchange membrane electrolysis (PEM-EL)
  - Solid oxide electrolysis (SOEC-EL)
  - Anion exchange membrane electrolysis (AEM-EL)

Water electrolysis

Projects in Germany

The Wasserstoff-Kompass project maintains a database of hydrogen production projects.
The majority of the publicly announced projects in Germany use water electrolysis to generate hydrogen.



Quantities and capacities 1/3

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- Required hydrogen **quantities** are often stated in terawatt hours (TWh). This is a unit of energy referring to the amount of energy which can be obtained from a given amount of hydrogen by oxidation (e.g. in a fuel cell).
  A measure of this amount of energy is the lower heating value, which is 33.3 kWh/kg for hydrogen. This means that 33.3 kWh of energy (electricity and heat) can be obtained from 1 kg of hydrogen in a fuel cell if water is produced as vapour.

  - 1 kWh = 1,000 Wh
  - 1 TWh = 1,000,000,000 kWh = 1,000,000,000,000 Wh

- Hydrogen is produced in facilities that are described by their **power**. It indicates how much hydrogen can be generated per second or how much electricital power is required per second for hydrogen generation. The unit of power is watt (W) or gigawatt (GW). In context with electrolysis, **capacity** is often used synonymously with power.

  - 1 GW = 1,000 MW = 1,000,000 kW = 1,000,000,000 W

Quantities and capacities 2/3

- Since the production of hydrogen, for example, also generates heat, not all of the energy is used to produce hydrogen - the efficiency is less than 100 %.

- Here we assume an efficiency of 70 % for water electrolysis. Currently, this is a rather optimistic value and reflects our expectation that technologies will become more efficient over the next few years. An efficiency of 70 % means that 70 % of the deployed electrical energy is actually stored as hydrogen.

- Therefore it is important to distinguish electrolyser capacity referring to electrical power consumption from electrolyser capacity referring to hydrogen production. Capacity usually refers to electrical power consumption.

  - $\text{power}_{H_2} = \text{power}_{\text{electricity}} \times \text{efficieny}$

  - Example: A facility with 70 % efficiency, which uses 1 GW electrical power, has a hydrogen production capacity of 0.7 GW = 700 MW.

Quantities and capacities 3/3

In order to calculate how much hydrogen can be produced in a facility during a certain period of time (e.g. one year), the **hydrogen production capacity must be multiplied by the operation time**.

- The amount of hydrogen produced in a facility which is operated 4,000 hours a year under full load (a year has 8760 hours) results from

$$\text{amount of hydrogen} = \text{power}_{H_2} \times 4{,}000\ \text{h}$$

- For the facility in the example above, which uses 1 GW electrical power, this results in an annual production of hydrogen of

$$\text{amount of hydrogen} = 0.7\ \text{GW} \times 4{,}000\ \text{h} = 2{,}800\ \text{GWh} = 2.8\ \text{TWh}$$

Electrolysis capacities 2030

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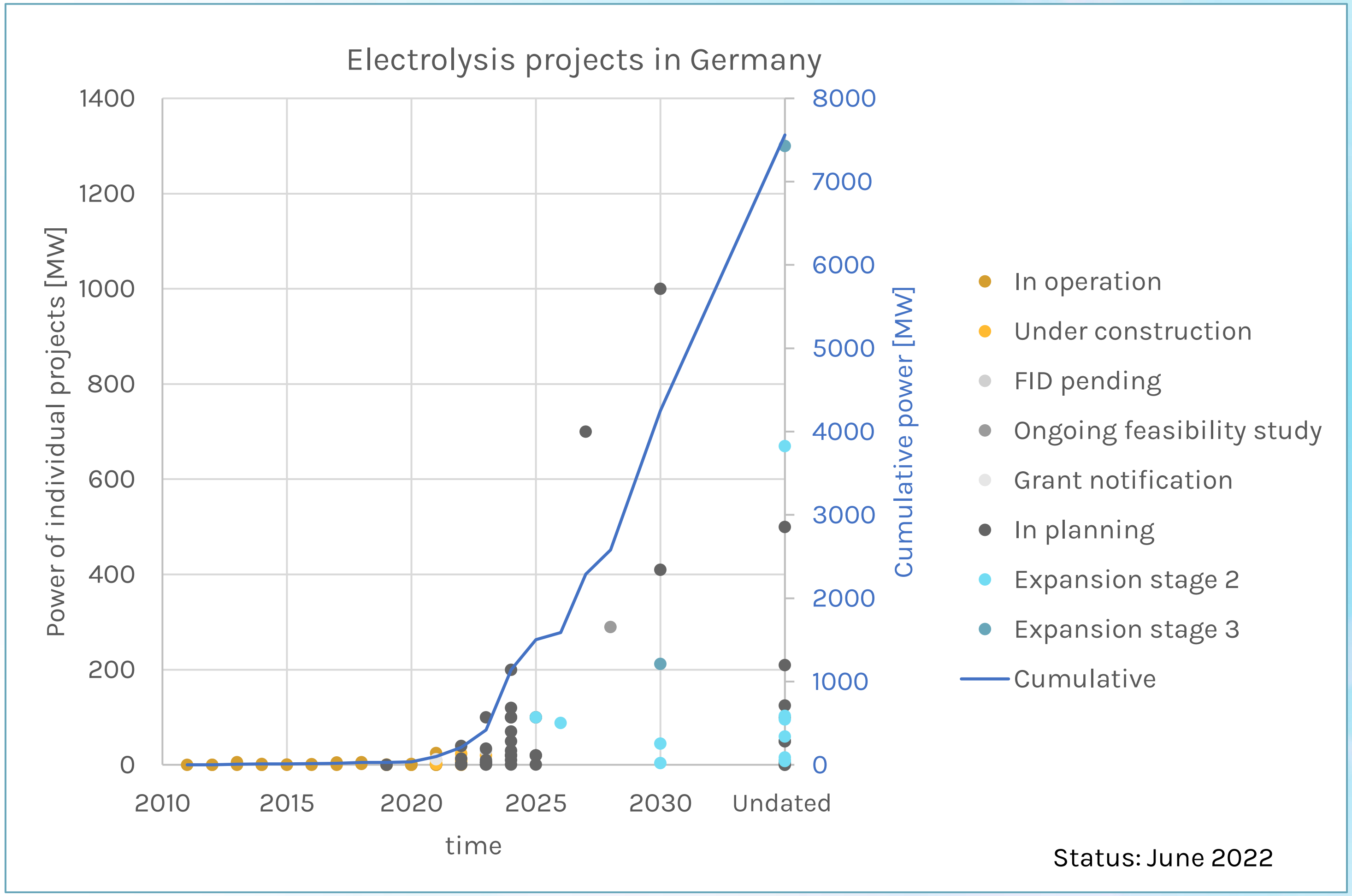
Projected hydrogen production projects

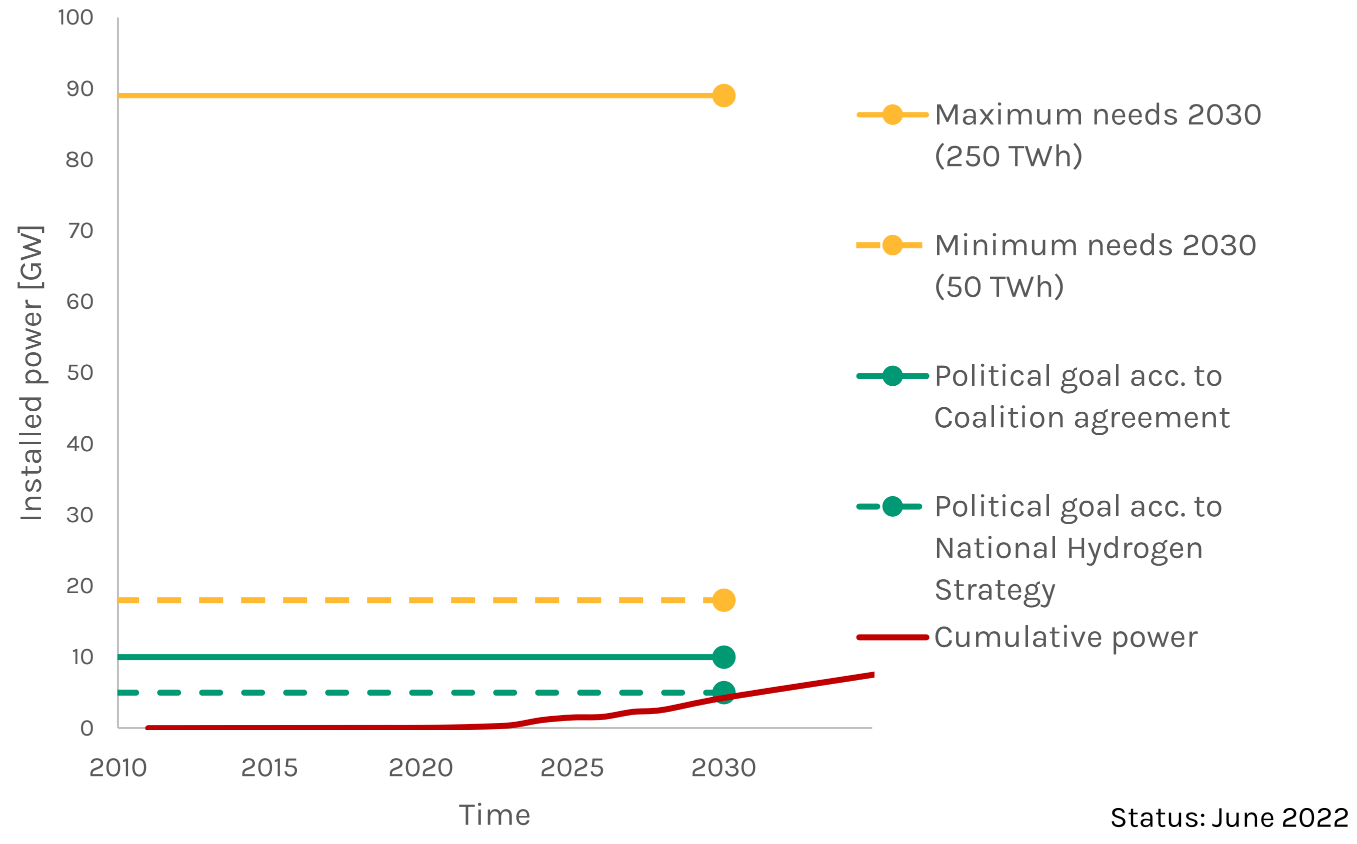


The electrolysis projects are displayed according to the scheduled time of commissioning (x-axis) and power (y-axis). Only projects with known power are mapped.

The cumulative power of all included projects is shown as a line and plotted on the right-hand axis.

Electrolysis capacities 2030

Comparison with needs assessments and political goals



The previously shown cumulative electric power required for elecytrolysis is plotted in red.

- Assumptions for calculating the necessary electric power:
  - 4000 full load hours
  - 70 % electrolysis efficiency

- Own needs assessments[1]:
  - Minimum needs 2030: ~ 50 TWh
  - Maximum needs 2030: ~ 250 TWh

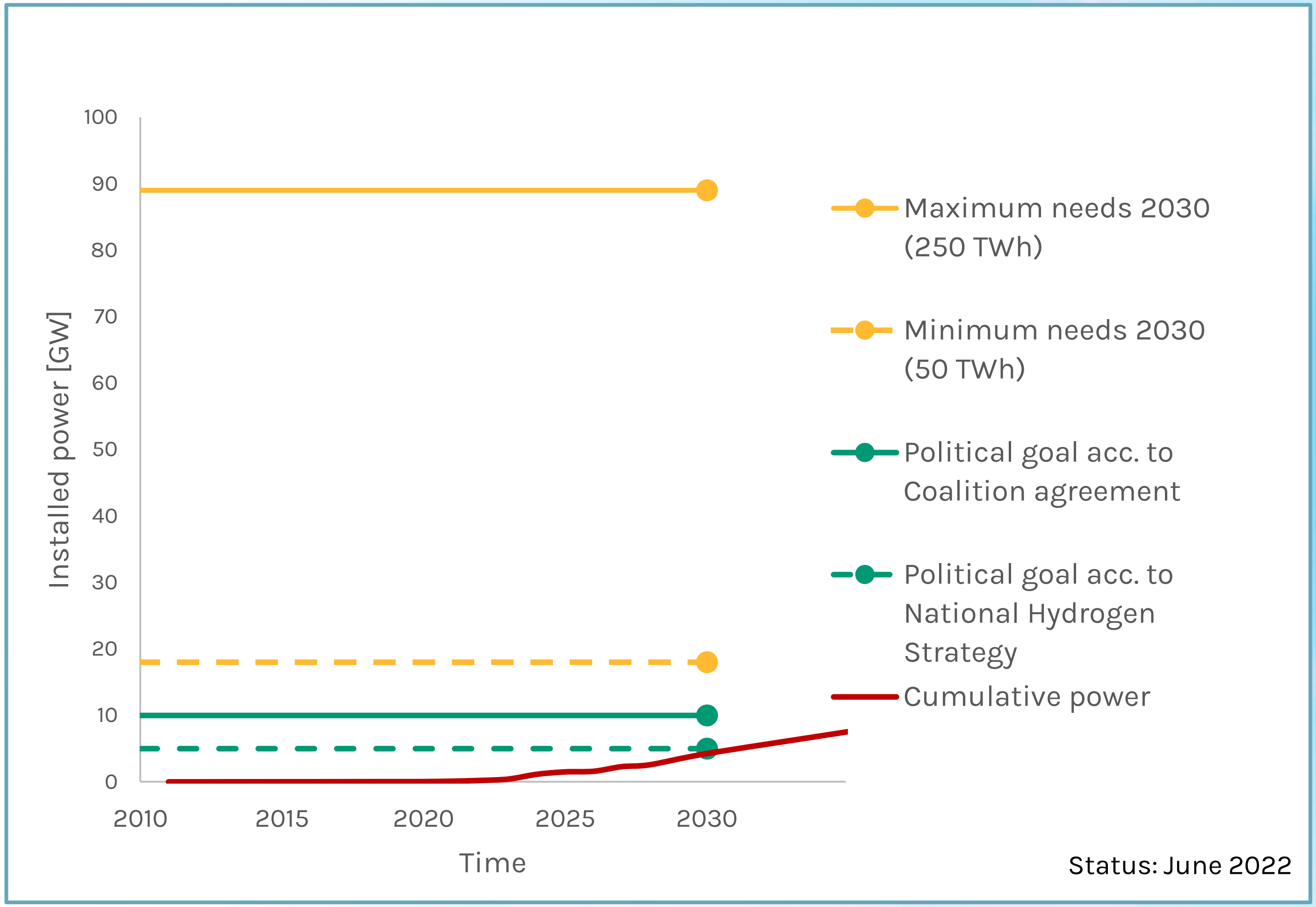
➢ Large gap between expected electrolysis power and requirements for 2030

➢ Must be covered by other sources e.g. imports

[1] to be published

Electrolysis capacities 2030

Comparison with needs assessments and political goals



Political objectives according to …

- National Hydrogen Strategy 5 GW
- Coalition agreeement 10 GW

Projected electric power consumption for electrolysis (including upscaling)

- In 2030 4.3 GW
- Including undated projects 7.6 GW

Required electrolysis capacity to cover demand

- Minimum: 50 TWh 18 GW
- Maximum: 250 TWh 89 GW

Contact

WASSERSTOFF KOMPASS

Contact persons:

Michaela Löffler

loeffler.m@acatech.de

Dr. Andrea Lübcke

luebcke@acatech.de

www.wasserstoff-kompass.de

acatech – National Academy of Science and Engineering

Headquarter

Karolinenplatz 4

80333 Munich/Germany

Berlin Office

Pariser Platz 4a

10117 Berlin/Germany

T +49 (0)30/2 06 30 96-0

F +49 (0)30/2 06 30 96-11

info@acatech.de

www.acatech.de

DECHEMA Gesellschaft für Chemische Technik und Biotechnologie e.V.

Theodor-Heuss-Allee 25

2560486 Frankfurt am Main

T +49 (0)69 75 64-0

info@dechema.de

www.dechema.de

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