Siemens Energy

Power2X and sector coupling

August 2020

Siemens Energy is a registered trademark licensed by Siemens AG.
Restricted
© Siemens Energy Austria GmbH, 2020

Power2X and sector coupling

Alexander Peschl

August 2020

Siemens Energy is a registered trademark licensed by Siemens AG.
© Siemens Energy Austria GmbH, 2020
Restricted

Disclaimer

This document has been prepared in respect of Siemens Energy AG (together with its subsidiaries, “**Siemens Energy**”), under which the majority of the energy business of Siemens Aktiengesellschaft (together with its subsidiaries, “**Siemens**”) will be bundled. It is intended to admit the shares in Siemens Energy to trading on the regulated market of the Frankfurt Stock Exchange. This document does not constitute or form part of any offer or invitation to sell or issue, or any solicitation of any offer to purchase or subscribe for, any shares or other securities of Siemens or Siemens Energy in any jurisdiction.

This document contains statements relating to the future business and financial performance and future events or developments involving Siemens and Siemens Energy that may constitute forward-looking statements. These statements may be identified by words such as “expect,” “look forward to”, “anticipate”, “intend”, “plan”, “believe”, “seek”, “estimate”, “will”, “project” or words of similar meaning. Such statements are based on the current expectations and certain assumptions, of which many are beyond Siemens’ and Siemens Energy’s control. These are subject to a number of risks and uncertainties. Should one or more of these risks or uncertainties materialize, should decisions, assessments or requirements of regulatory authorities deviate from our expectations, or should underlying expectations not occur or assumptions prove incorrect, actual results, performance or achievements of Siemens or Siemens Energy may (negatively or positively) vary materially from those described explicitly or implicitly in the relevant forward-looking statement. Neither Siemens nor Siemens Energy intend, nor assume any obligation, to update or revise these forward-looking statements in light of developments which differ from those anticipated.

The information and opinions contained in this document are provided as at the date of this presentation and are subject to change without notice. They do not purport to contain all information that may be required to evaluate Siemens or Siemens Energy and have not been verified independently. Historical financial or operative information contained in this document has been taken or derived from Siemens’ financial statements, accounting records or management reporting. The combined financial statements for Siemens Energy are currently being prepared. These may deviate substantially from the information included in this document. The information in this document is of a preliminary and abbreviated nature and may be subject to updating, revision and amendment, and such information may change materially. In addition, the historical financial and operative information included in this document does not necessarily fully reflect changes that will occur when Siemens Energy operates as a separate group of companies. Accordingly, such information is not necessarily indicative for the future consolidated results of operations, financial position or cash flows of the prospective Siemens Energy business on a stand-alone basis.

This document includes – in the applicable financial reporting framework not clearly defined – supplemental financial measures that are or may be alternative performance measures (non-GAAP-measures). These supplemental financial measures should not be viewed in isolation or as alternatives to measures of Siemens’ or Siemens Energy’s net assets and financial positions or results of operations as presented in accordance with the applicable financial reporting framework in its consolidated financial statements and combined financial statements, respectively. Other companies that report or describe similarly titled alternative performance measures may calculate them differently. Due to rounding, numbers presented throughout this and other documents may not add up precisely to the totals provided and percentages may not precisely reflect the absolute figures.

This document contains forecasts, statistics, data and other information relating to markets, market sizes, market shares, market positions and other industry data on Siemens’ or Siemens Energy’s business and markets (together the “**market data**”) provided by third party sources as interpreted by us. This market data is, in part, derived from published research and additional market studies prepared primarily as a research tool and reflects estimates of market conditions based on research methodologies including primary research, secondary sources and econometric modelling, which may not be representative.

© Siemens Energy Austria GmbH, 2020

Leveraging Siemens Energy capabilities – our competence along the PtX value chain

SIEMENS energy

Planning & Consulting | Financing | Components and Equipment: Renewable Power | Grid Connection | Electrolysis | PtL-/PtG-Equipment | CO_2 / N_2 Supply | Synthesis

Solution provider for Power-to-liquids (i.e. Methanol)

– One face to the customer
– Overall system design
– Integration of Siemens products and technology & products from external partners

Wind Park

– Onshore wind
– Offshore wind

Ext/Siem.-Gamesa

Photovoltaics

– Solar Fields/ Storage Systems
– External Sourcing

Power Grid

– Transmission
– Distribution
– Substations
– Transformers
– Power cable systems

Electrolysis

PEM technology

(Silyzer 300)

Machinery

– Compressors
– Storage systems
– Water treatment
– Elec. equipment,
– Mech. equipment
– Turbines/engines (back up power)

CO_2 Capture

– Capture from flue gas (PostCap)
– DAC

N2 Supply

– Air separation: external

Synthesis

– Partnering
  - CH3OH
  - CH4
  - NH3
– Own concepts
– Novel, flexible methanol reactor concept in R&D stage

BoP

Focus Power-to-H2

DAC: direct air capture: under development; no Siemens activities CCU: Carbon Capture and Utilization

typical share in value addition

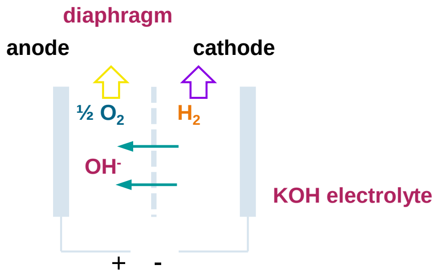
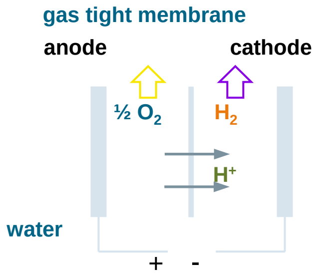
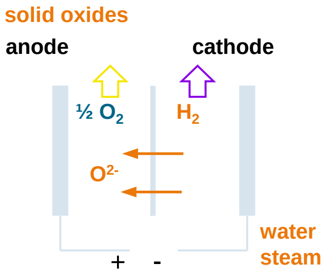
Siemens Energy portfolio/ capabilities

If required to be developed with external partner(s)

© Siemens Energy Austria GmbH, 2020

There are three considerable technologies of water electrolysis

SIEMENS energy

	Alkaline Electrolysis	PEM Electrolysis	High temperature
			
Electrolyte	KOH[3]	Polymer membrane	Ceramic membrane
Circulated medium	KOH[3]	Water	Steam
Operational temperature[1]	60 - 90 ºC	RT[4] - 80 ºC	700 - 900 ºC
Technical maturity[1]	Industrially mature	Commercially available	Lab/ demo
Field experience[1]	🟢	🟢	🔴
Cold-start capability[2]	🟡	🟢	🔴
Intermittent operation[2]	🟡	🟢	🟡
Scalability to multi Mega Watt[2]	🟢	🟢	🟡
Reverse (fuel cell) mode[1]	🔴	🔴	🟢

Source: [1] Fraunhofer [2] IndWede; [3] KOH: Potassium hydroxide : [4] room temperature

🟢 Existing/ available 🟡 In development/ limited 🔴 Not possible, not available

© Siemens Energy Austria GmbH, 2020

We convert green power into green hydrogen –

Our H_2 Electrolyzer portfolio scales up by factor 10 every 4 – 5 years

SIEMENS energy

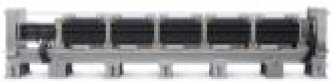
0,1 MW | 1 MW | 10 MW | 100 MW | 1000 MW

2011

Silyzer 100
Lab-scale demo
~4.500 OH[1],
~150k Nm^3 of H_2

2015

Silyzer 200
~86.500 op.h
~7.3 mio Nm^3 of H_2



Siemens equips world's largest Power-to-Gas plants with PEM electrolyzers

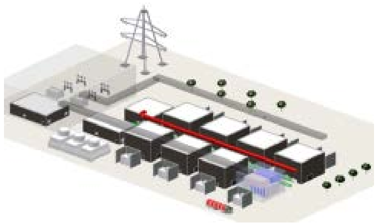
2018

Silyzer 300

Siemens builds world's largest PEM cell

… 2023

Next generation
Under development



… 2028+

First investigations in **cooperation with chemical industry**

Standardized and efficient systems at industrial scale are a precondition for broad application in all sectors.

[1] Operating Hours; Data OH & Nm^3 as of Dec. 2019; Source: NEB Next[2]

© Siemens Energy Austria GmbH, 2020

Green H_2 market expected to grow from small size today to GW ranges due to increased decarbonization efforts

SIEMENS energy

H_2 electrolyzer market potential: Market drivers and potential developments

Key market drivers

Regulatory support to promote H_2 and other renewable based energy forms

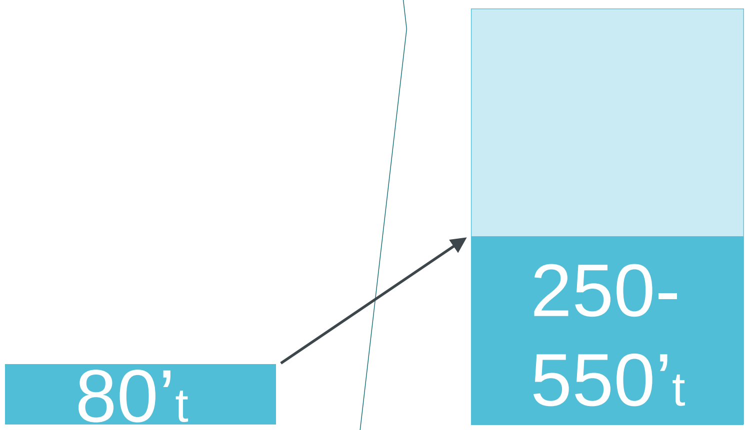
Decarbonization self commitments of **players**

Economic pressure due to e.g., increase in **CO_2 price**

Hydrogen market by 2050 – Tripling with shift to green hydrogen and commercial markets

Today | **2050**

Energy source for H_2 production



Exemplary top down use cases	Installed electrolyzer capacity required
Mobility	
H2 direct use	
– H2 supply for up to 100k fuel cell heavy trucks	**20 GW**
E-fuels	
– 1% substitution of rail & road transport fuel in EU	**15 GW**
Industry (Deep dive)	
– 50% H2 based decarbonization of 30% of key players with self commitment in steel industry	**6 GW** [2]
Energy	
– 3% substitution of natural gas in EU & North AM (e.g., blending in gas distribution grid)	**47 GW**

[1] Based on market reports and regulatory support for hydrogen in Europe | [2] Thyssen Krupp Europe, POSCO, Salzgitter, Arcelor Mittal Europe, Tata Steel, voestalpine, SSAB

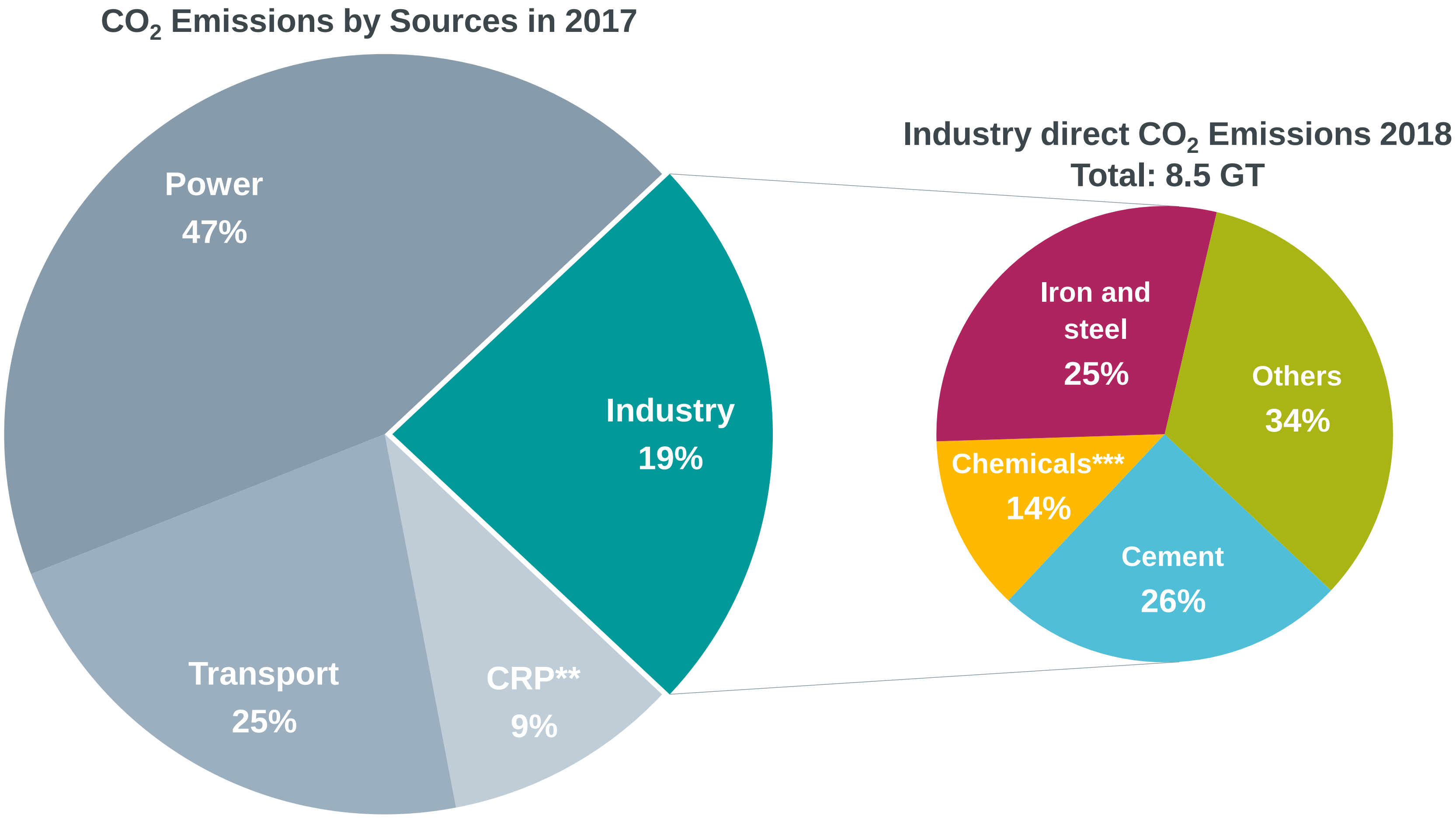
Source: Siemens Energy top down H2 market potential estimation, IEA report, market reports: Hydrogen Council (2017), IHS Autonomy & Rivalry (2019) FMI (2019), GIA (2016), Certifhy (2015)

© Siemens Energy Austria GmbH, 2020

Steel is one of three main hard-to-abate industries

SIEMENS energy

- Global crude steel production increased by 3% in 2019 to reach 1 870 Mt – and it continues to increase
- Direct emissions from global steel production* represents ~8% of the global total



* including power consumption **Commercial, Residential and Public; ***Chemicals incl. Chemicals and petrochemicals

Sources: Annual CO2 emissions from fuel combustion 2019 (IEA, Nov 2019), Global crude steel output increases by 3.4% in 2019 (World Steel Association, Jan 27, 2020), “Tracking Industry 2020” (IEA, June 2020)

© Siemens Energy Austria GmbH, 2020

DRI is needed, as the use of scrap metal, RE and CCS will not be enough for sufficient CO_2 reduction in the steel industry

SIEMENS energy

Overview of CO_2 emissions in a steel plant and green alternative technologies

	Technology	Evaluation	Preparation of raw materials (coking, sintering)	Hot blast furnace (Ore → Iron)	Basis oxygen furnace (Iron → Steel)	Casting	Processing of steel (e.g. rolling)
Status Quo	**Hot blast furnace** (CO_2 emiss.)	✗ Traditional method with high CO_2 emissions	~26%	~54%	~5%	~3%	~12%
Green alternatives	**DRI H2 / CNG**	✓ Innovative method enabling high CO_2 abatement	✓	✓			
Green alternatives	**Scrap metal**	! Already used today, max additions 50%	✓	✓			
Green alternatives	**CCS**	! Viewed as problematic in EU; limited capacity	✓	✓	✓		
Green alternatives	**Renewable electricity**	! Limited supply of cheap RE, competi. with other use cases			✓ Powering an arch furnace	✓ For heating	✓ For heating and electric motors

✓ Only option for full decarb ✗ No decarb. possible ! No full decarb. possible ✓ Possible decarb technology

Note: Assuming that CCU is applicable at this large scale
Source: Siemens Energy

© Siemens Energy Austria GmbH, 2020

H2FUTURE – a European Flagship project for generation and use of green hydrogen

H2FUTURE

SIEMENS energy

6 MW

Power demand based on Silyzer 300

1.200 Nm³

of green hydrogen per hour

Project

- Partner: VERBUND (coordination), voestalpine, Austrian Power Grid (APG), TNO, K1-MET
- Country: Austria
- Installed: 2019
- Product: Silyzer 300

Use cases

- Hydrogen for the steel making process
- Supply grid services

Challenge

- Potential for “breakthrough” steelmaking technologies which replace carbon by green hydrogen as basis for further upscaling to industrial dimensions
- Installation and integration into an existing coke oven gas pipeline at the steel plant
- High electrolysis system efficiency of 80%

Solutions

- Operation of a 12-module array Silyzer 300
- Highly dynamic power consumption – enabling grid services
- State-of-the-art process control technology based on SIMATIC PCS 7

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 735503. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovative programme and Hydrogen Europe and NERGHY.

Siemens Energy is a registered trademark licensed by Siemens AG.

© Siemens Energy Austria GmbH, 2020

Hydrogen production cost depend on site and technology specific drivers

SIEMENS energy

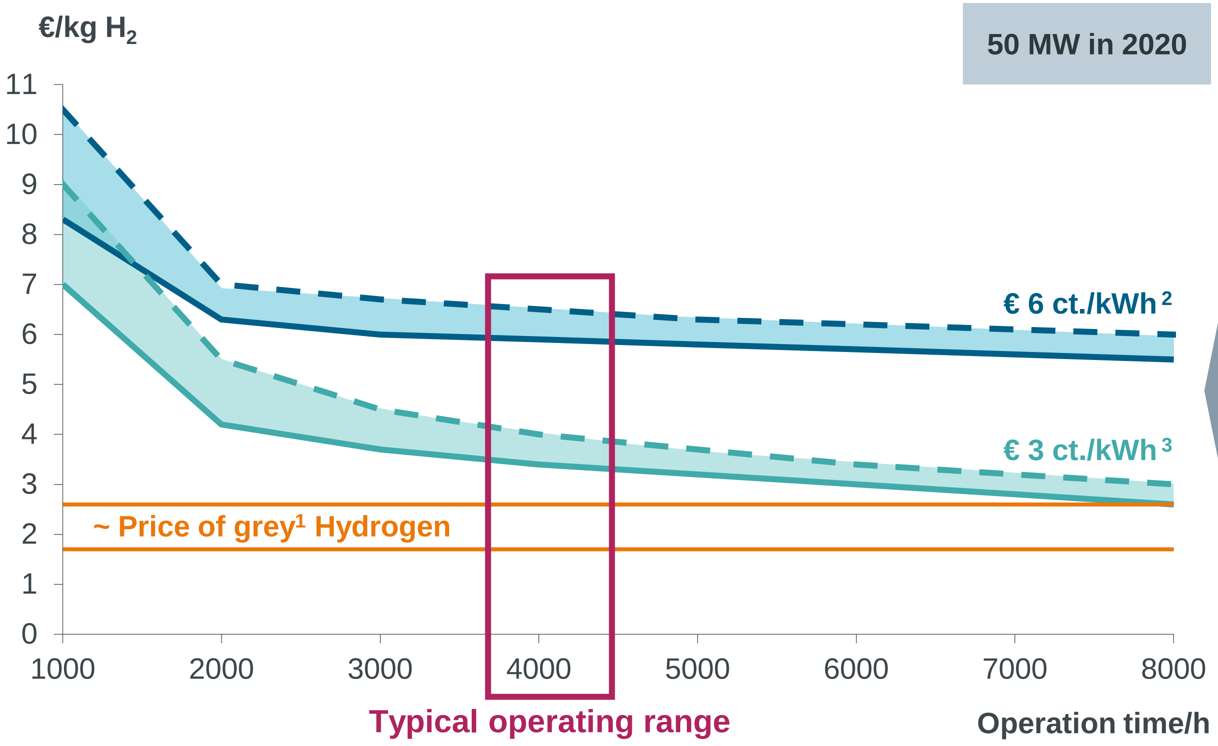
Drivers for Hydrogen production cost

Site specific drivers

Electricity price

Operation time

H_2 production cost per operation time



With compression to 100 bar and DeOxo — W/o compression and DeOxo

Technology specific drivers

Efficiency

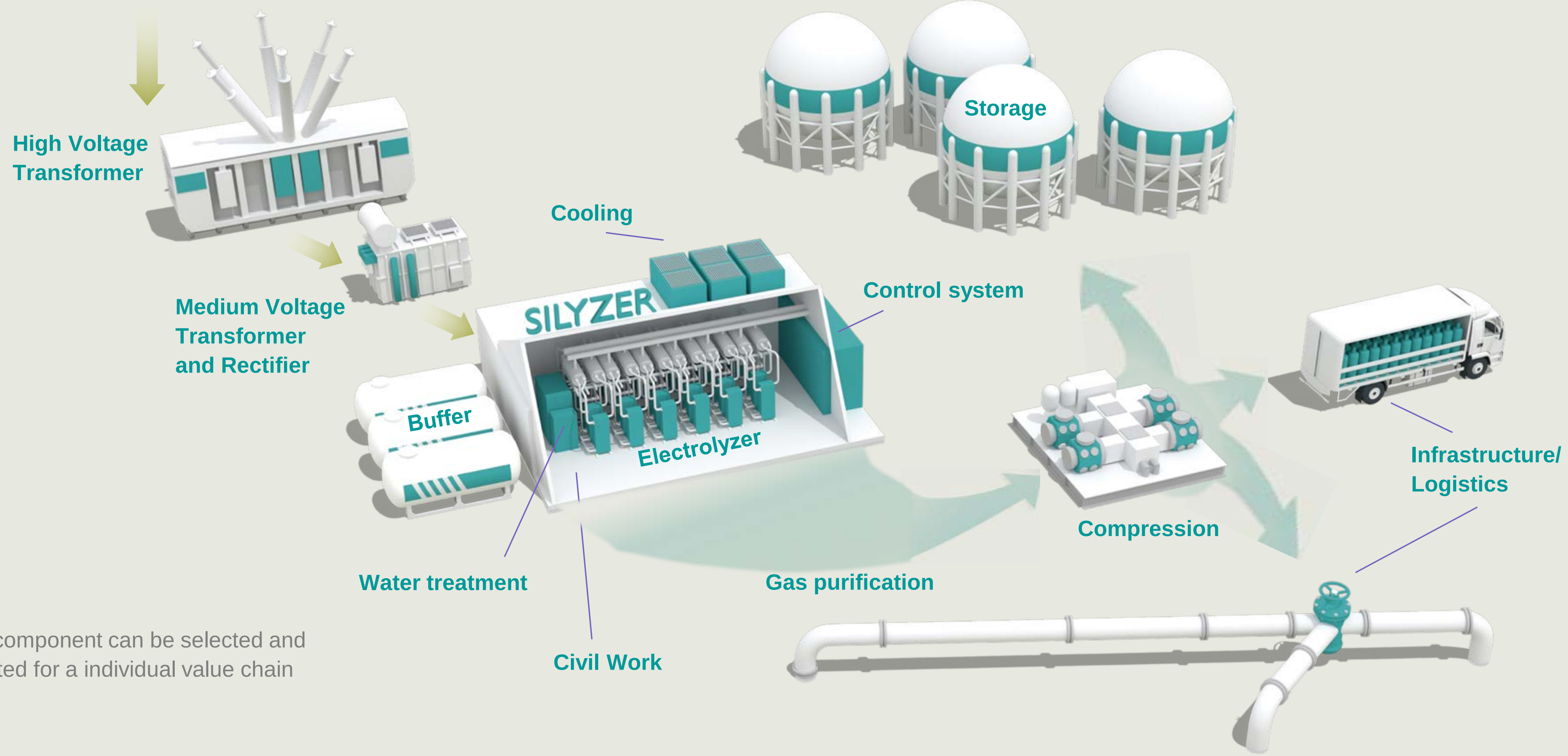
CAPEX

Maintenance cost

[1] Grey H2: Hydrogen produced by conventional methods as steam methane reforming
[2] € 6 ct./kWh: E.g., on shore wind (4-6ct./kWh) or PV in Germany
[3] € 3 ct./kWh: Reachable in renewable intense regions like Nordics (Hydro Power), Patagonia (Wind), UAE (PV)

© Siemens Energy Austria GmbH, 2020

Hydrogen generation - more than just an electrolyzer



Each component can be selected and extracted for a individual value chain