The Role of Power Electronics in Achieving a Sustainable H_2 Economy

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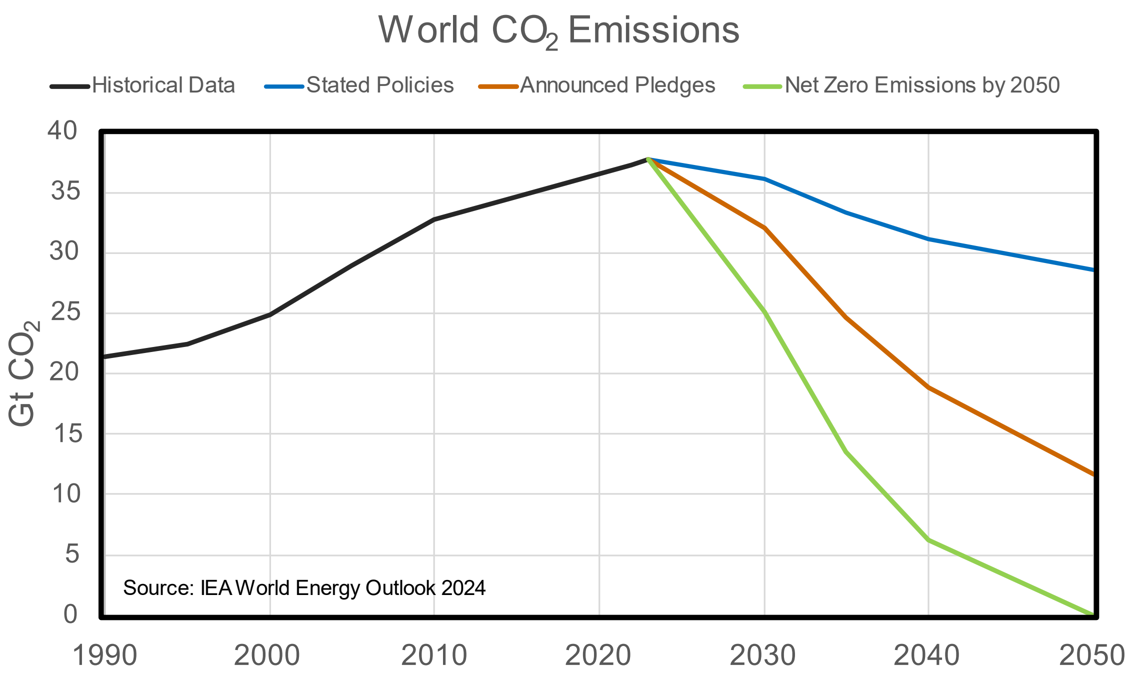
The importance of hydrogen in the energy transition

1.5°C climate pathway



Stated Policies Scenario: explores how energy systems will evolve based on concrete policies and measures in effect as of August 2024.

Announced Pledges Scenario: assumes that governments will meet all climate commitments, even if the required policies are not yet in place.

Net Zero Emissions by 2050 Scenario: pathway required to limit the global temperature rise to 1.5 °C with at least 50% probability according to the IEA.

Renewable and low-carbon **hydrogen** is crucial for meeting the Paris Agreement goals to **decarbonize hard-to-abate sectors** and reaching the **1.5°C** climate scenario.

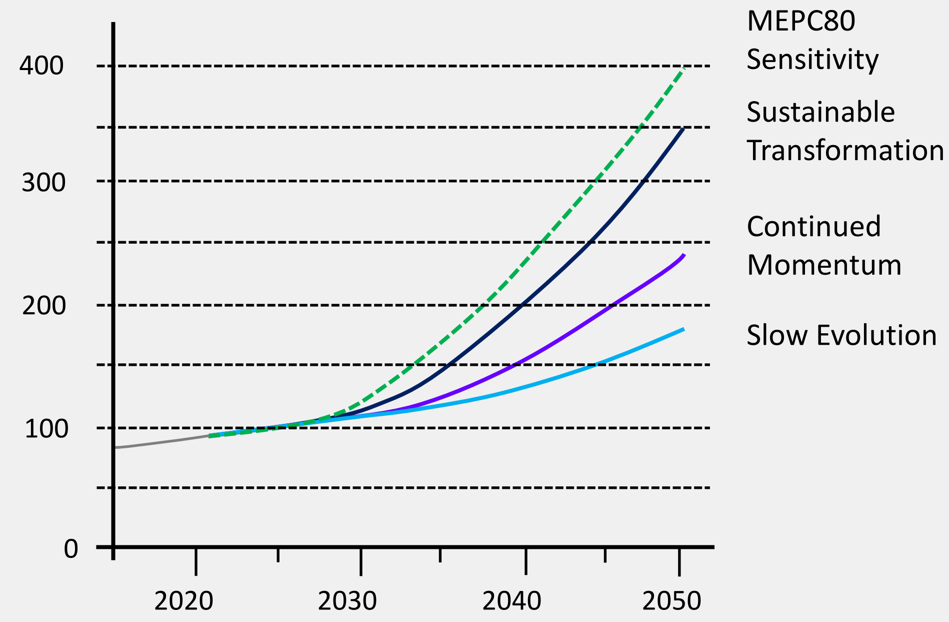
To meet the targets, hydrogen would need to meet around **15% of world energy demand** by mid-century.

Source: DNV Energy Transition Outlook 2024, IEA Global Hydrogen Review 2024

Global hydrogen demand continues to rise, inflection point in 2030

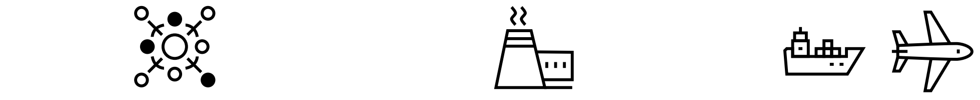
1000 GW of electrolyzer power is needed to produce ~**100M tons** of hydrogen that's already being consumed today

Global hydrogen demand by scenarios (M tons)



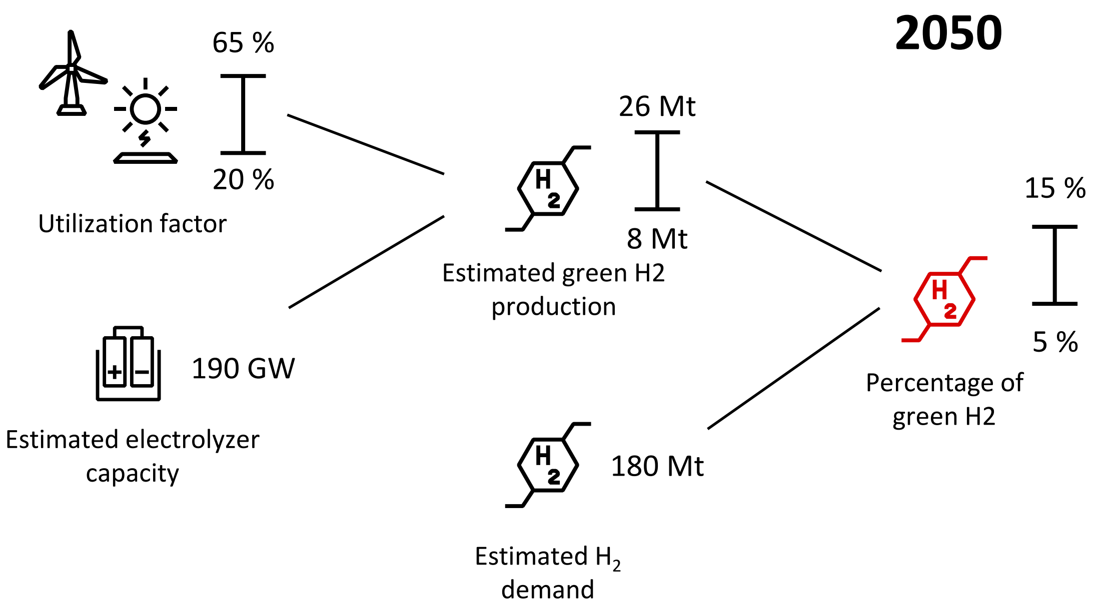
Source: Rystad energy hydrogen data cube (data extracted 2024-03-02)

Old and new potential sectors for green H_2 demand



Industrial feedstock	Industrial process heat	Long-haul transport
• **Ammonia** • **Oil refining** • **Methanol** • **Steel**	• **Furnaces** • **Cement kilns** • **Glass**	• **Marine** • **Aviation**

Estimation of future green hydrogen coverage ratio



Agenda

1. Introduction to Hydrogen Economy

2. Power Converters for Large Scale H_2 Plan Configurations

3. Digital Twin for H_2 Production Optimization

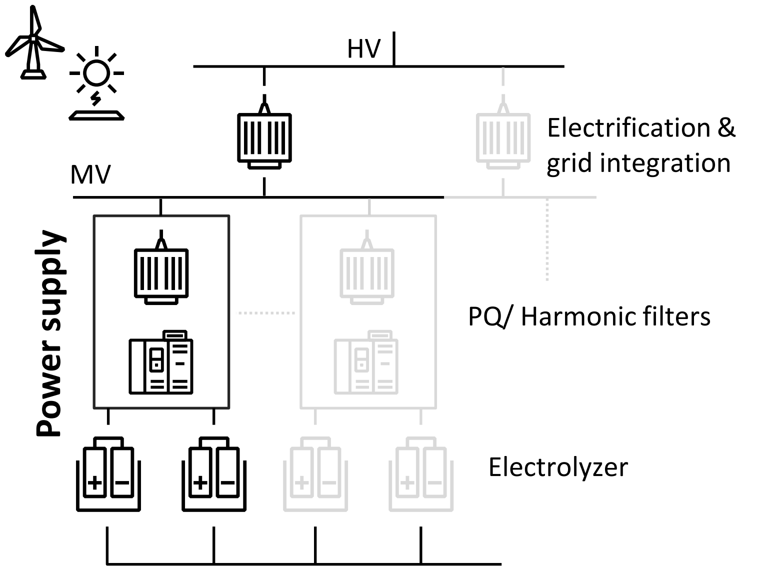
4. Reference Cases

5. Conclusions

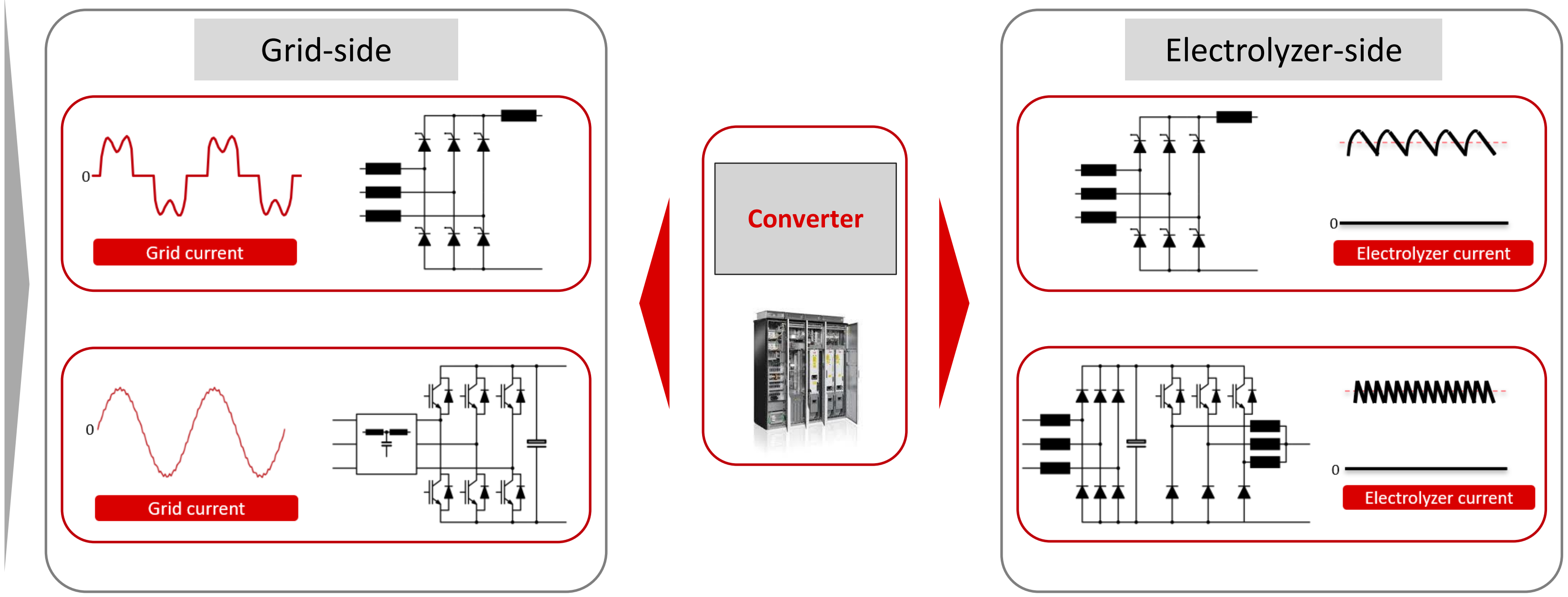
Electrolyzer power supply structure and technologies

Overview

General structure



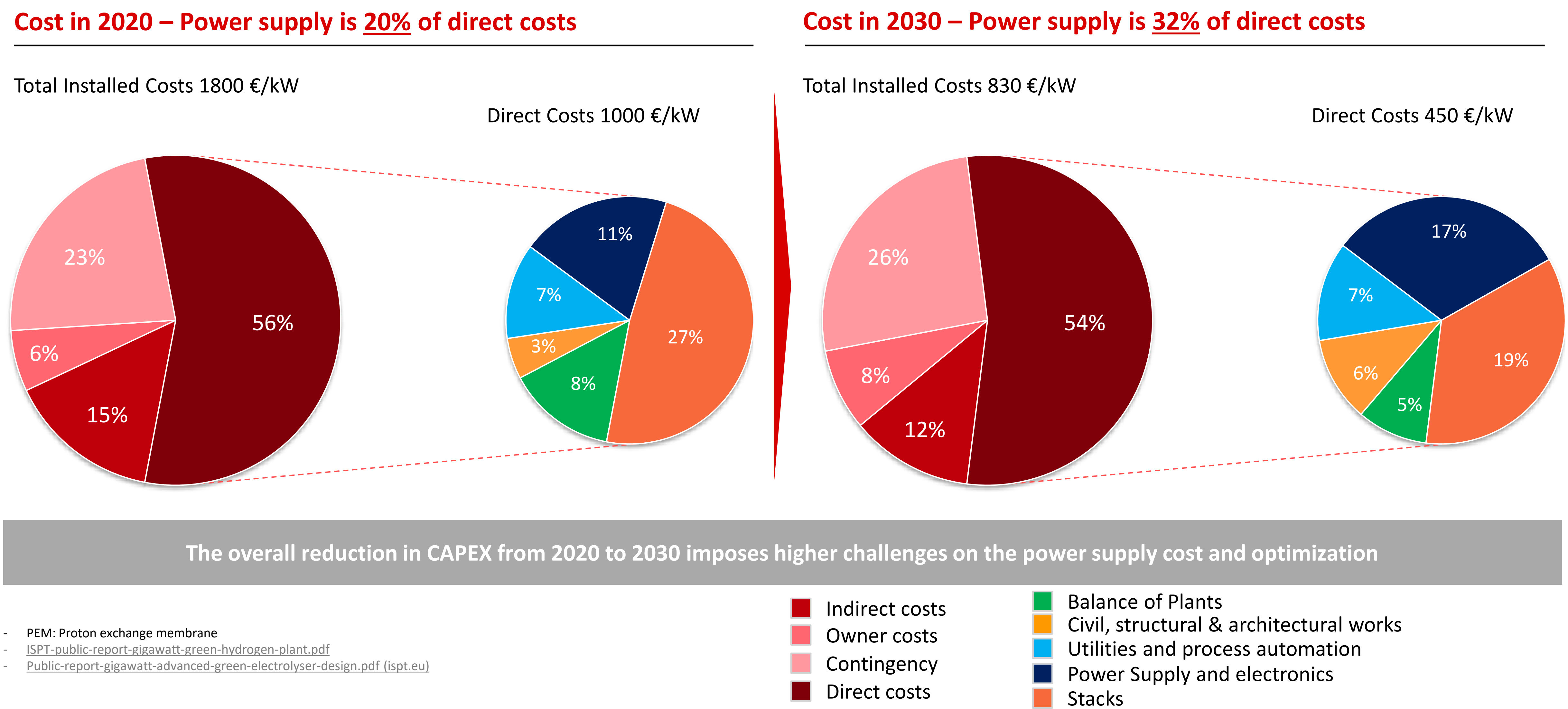
Technologies



Different transformer + converter configuration/topologies solutions

Cost breakdown of a one GW green hydrogen plant

Based on PEM technology from 2020 to 2030



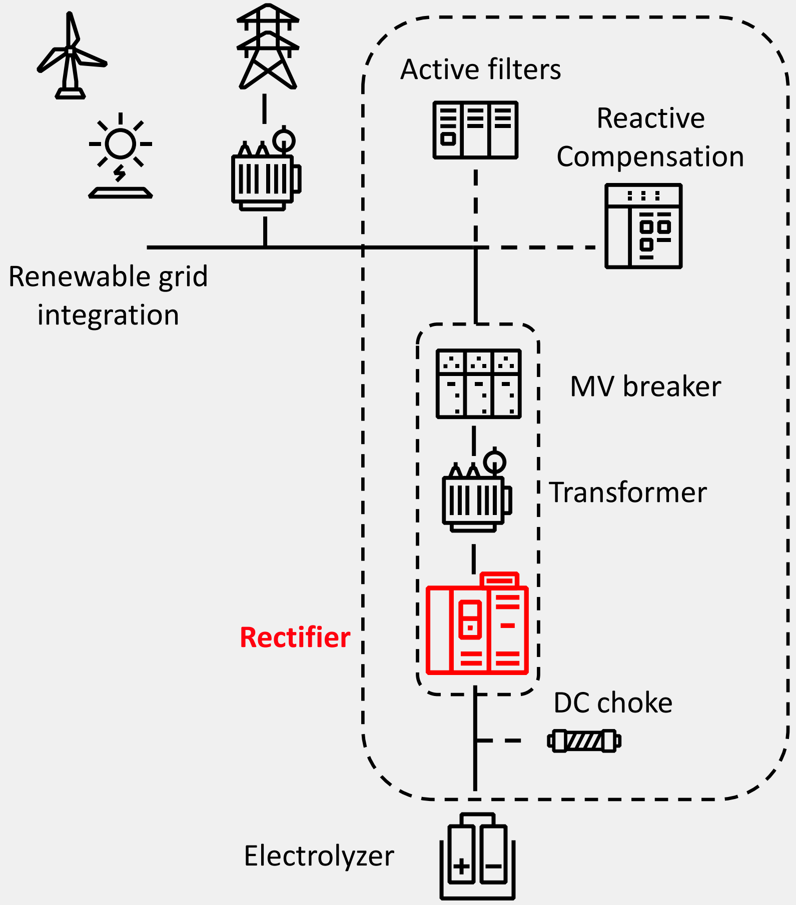
The overall reduction in CAPEX from 2020 to 2030 imposes higher challenges on the power supply cost and optimization

- PEM: Proton exchange membrane
- ISPT-public-report-gigawatt-green-hydrogen-plant.pdf
- Public-report-gigawatt-advanced-green-electrolyser-design.pdf (ispt.eu)

Power supply for hydrogen production

Typical solutions

Power supply solutions



Thyristor

- Up to 20 MW+
- Voltage DC: 10 up to 1500 V
- Air-cooled
- THDi: Rectifier and plant configuration dependent
- Power factor: 0.90 - 0.95
- Small footprint, 4500 kW/m2
- 12-, 24-pulse
- Indoor/Outdoor in container

IGBT– or Diode & DC/DC

- Up to 10 MW
- Voltage DC: 435 up to 1000 V
- Air- or water-cooled
- THDi < 3%
- Power factor: 0.99 - 1.00
- Ultra-low harmonic AC voltage
- Low to none reactive power
- Indoor/Outdoor in container

IGBT- Multi-Level

- Up to 10 MW
- Voltage DC: 850 up to 1500 V
- Air-cooled
- THDi < 3%
- Power factor: 0.99 - 1.00
- Ultra-low harmonic AC voltage
- Low to none reactive power
- Indoor/Outdoor in container

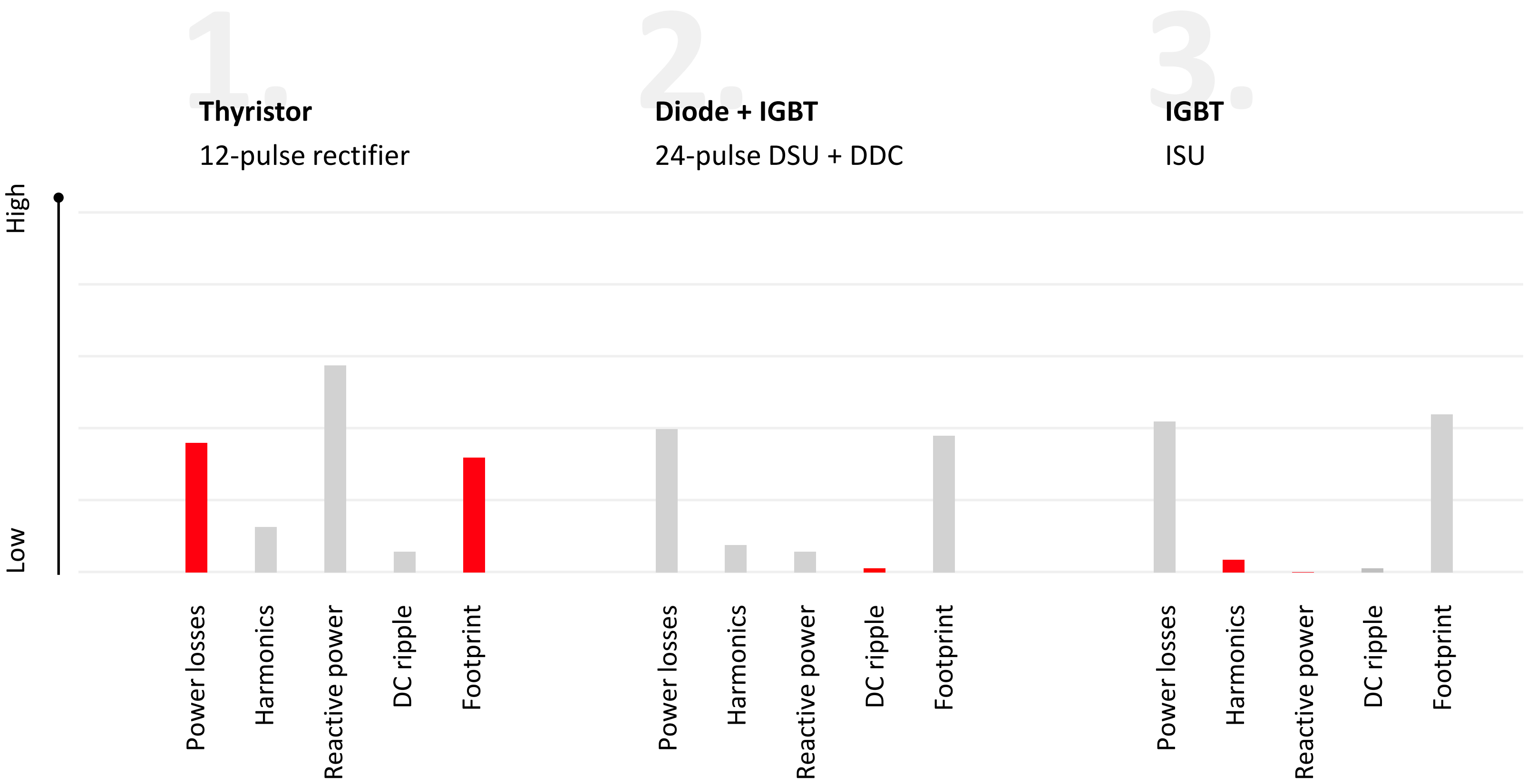
Configurable solutions meeting operational efficiency

Different solution possibilities example

Example specification

- Power: 2.5 MW
- DC Voltage: 500 V
- DC Current: 5000 A
- Rectifier efficiency > 90% @ 100% load
- Power Factor > 0.8
- THDi < 3%
- DC Ripple < 5%

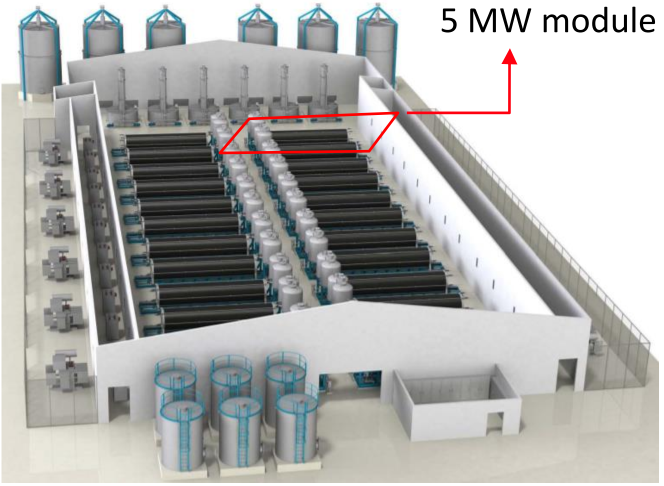
Comparison of possible solutions



Getting into giga scale - footprint

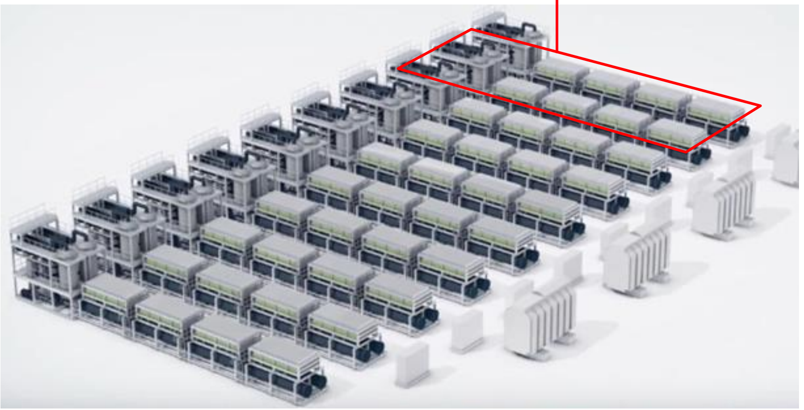
Modular, large-scale modular or pure large-scale concept

Modular concept



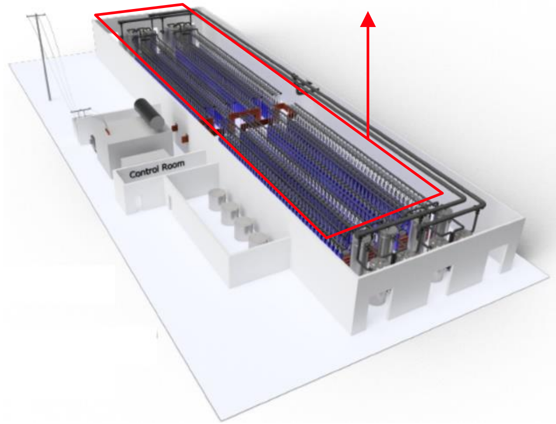
- Module rating ranges from 50 kW – 5 MW
- Connection of modules in **parallel**
- Footprint 1000 MW plant: approx. 63000 m^2
- 9 American football fields

Large-scale modular concept



- Module rating ranges from 10 MW – 20 MW
- Connection of modules in **parallel**
- Footprint 1000 MW plant: approx. 28000 m^2
- 4 American football fields

Pure large-scale concept



- Module rating ranges from 50 MW – 100 MW
- Modules are connected in **series**
- Footprint 1000 MW plant: approx. 21000 m^2
- 3 American football fields

1) https://www.capitalenergetico.cl/wp-content/uploads/2021/03/Nel-H2_Chile_r1.pdf
2) https://hydrogentechworld.com/thyssenkrupp-nucera-names-its-20-mw-alkaline-electrolysis-module-scalum
3) https://www.renewableenergymagazine.com/hydrogen/hydrogen-optimized-signs-letter-of-intent-to-20220110

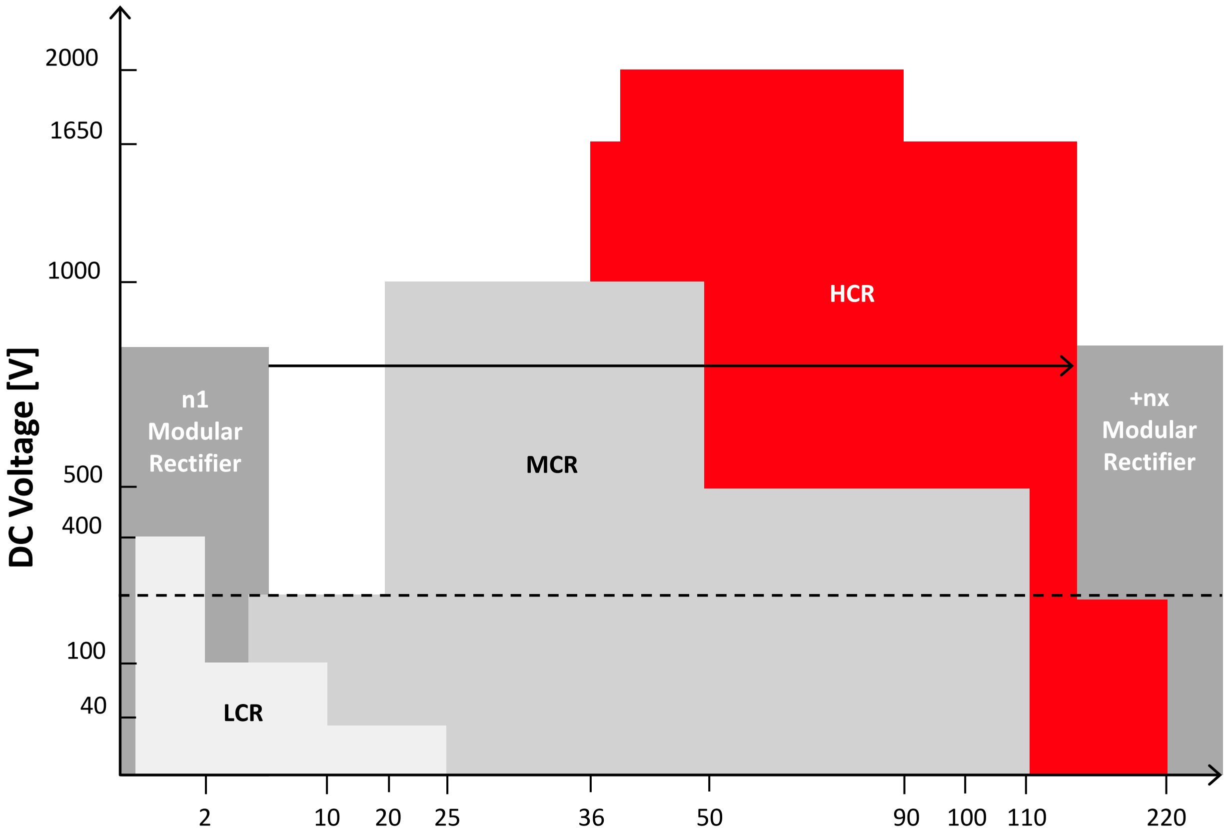
High-power supply for hydrogen production
Modular rectifier

MCR

- Diode and thyristor: 3 to 4-inch types
- 5 kA to 200 kA, up to 1,000 VDC
- De-ionized water/glycol mixture
- Applicable for 6- or 12-pulse systems
- Available for 2 to 6 semiconductor in parallel

HCR

- Diode and thyristor: 3 to 4-inch types
- Up to 2000 V and up to 220 kA
- Diode and thyristor rectifiers in DC, DSS or APR connection
- Water or water-glycol cooling
- Available for 2 to 6 semiconductors in parallel

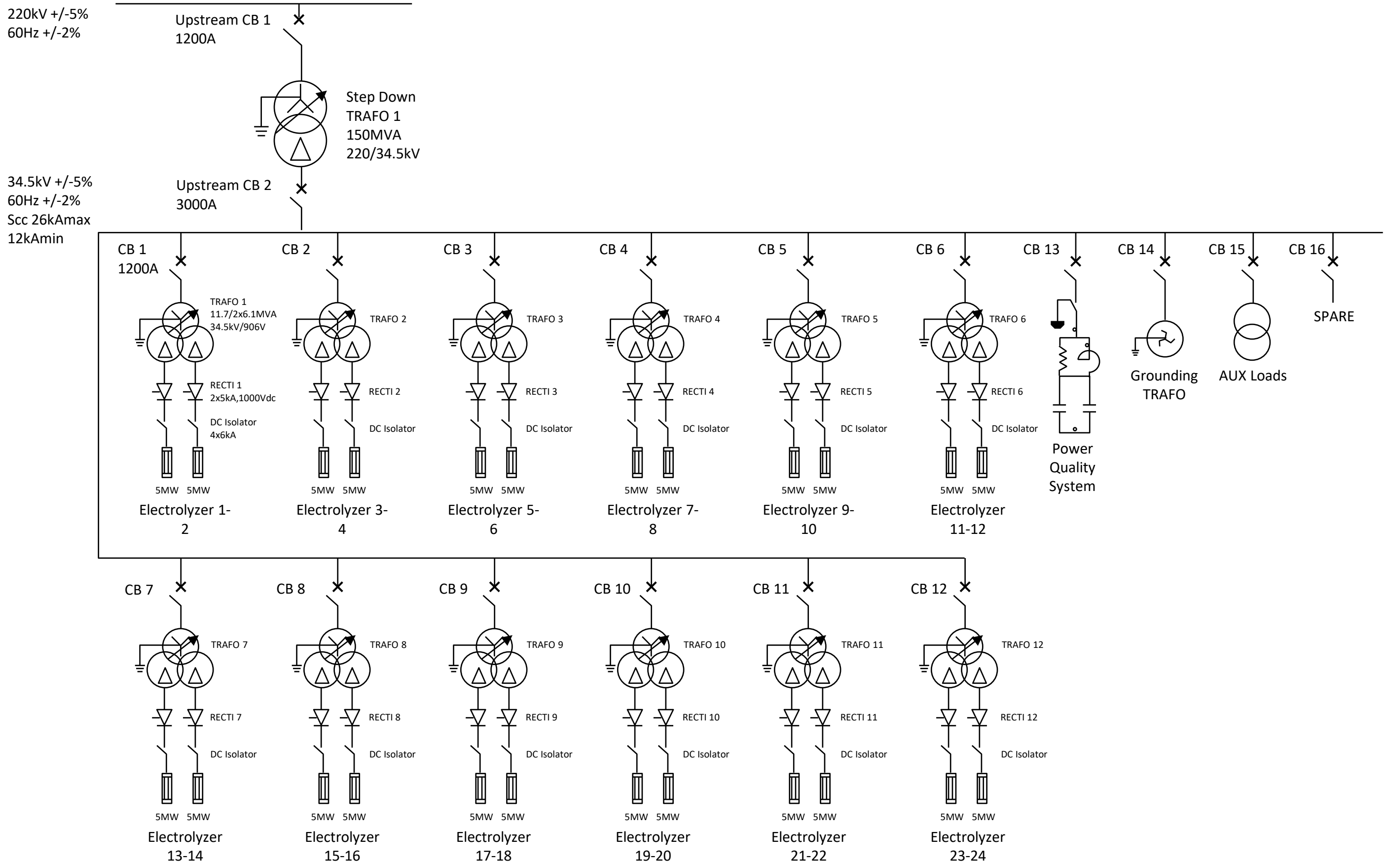


Rectifiers provide DC current in the range up to 550 kA for multiple units

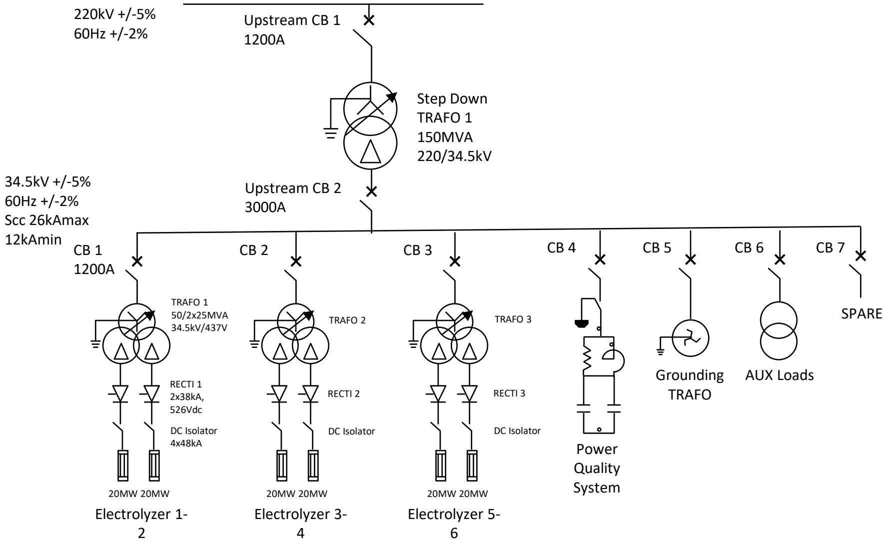
Large-scale H_2 plants – two approaches for GW plants

Comparison

120 MW Block – 24x5 MW Electrolyzer



120 MW Block – 6x20 MW Electrolyzer



Large-scale H_2 plants – two approaches for GW plants

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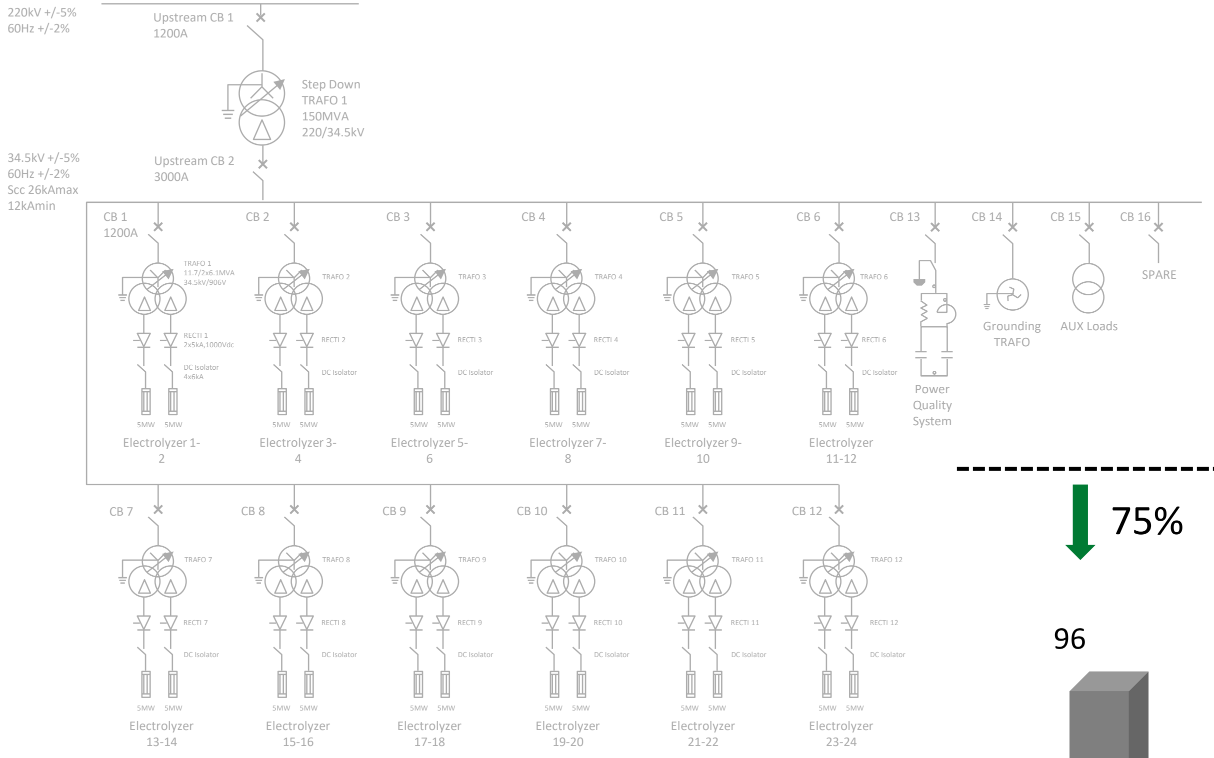

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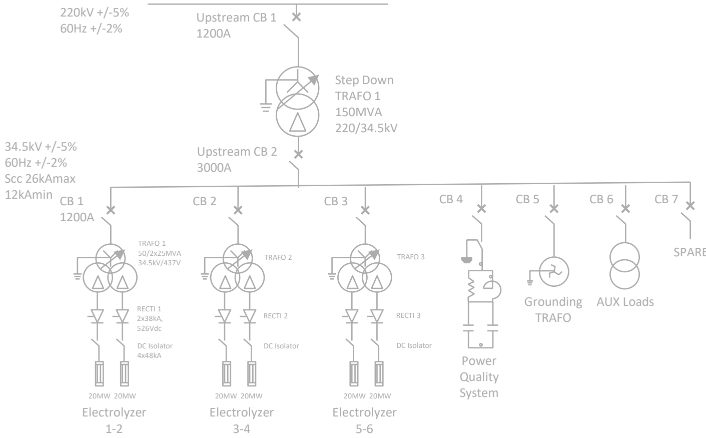
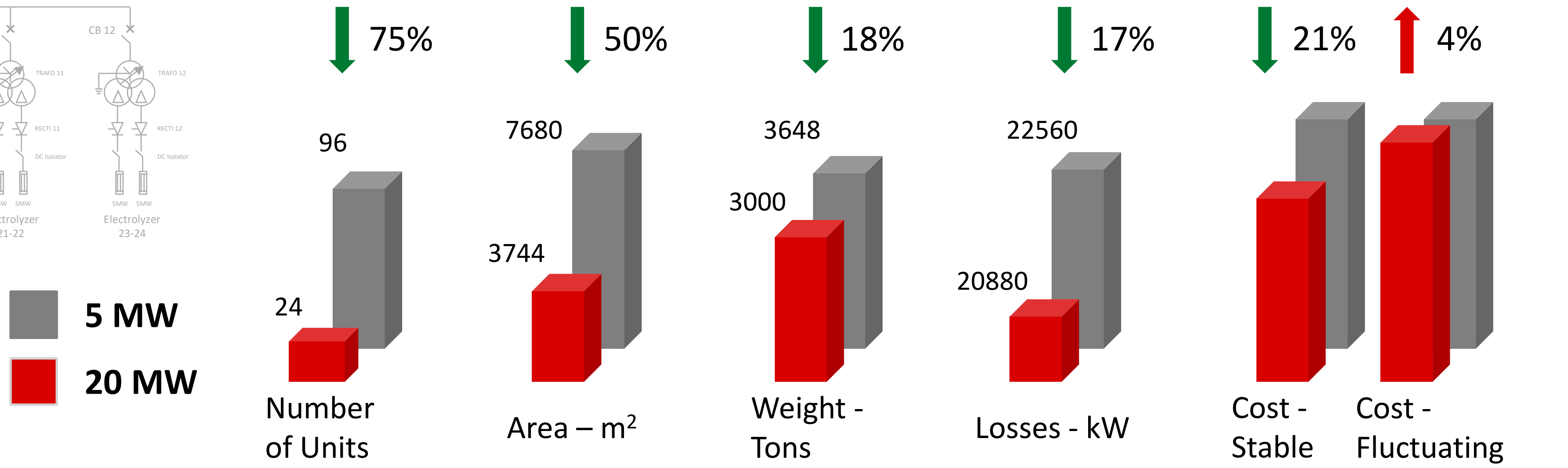


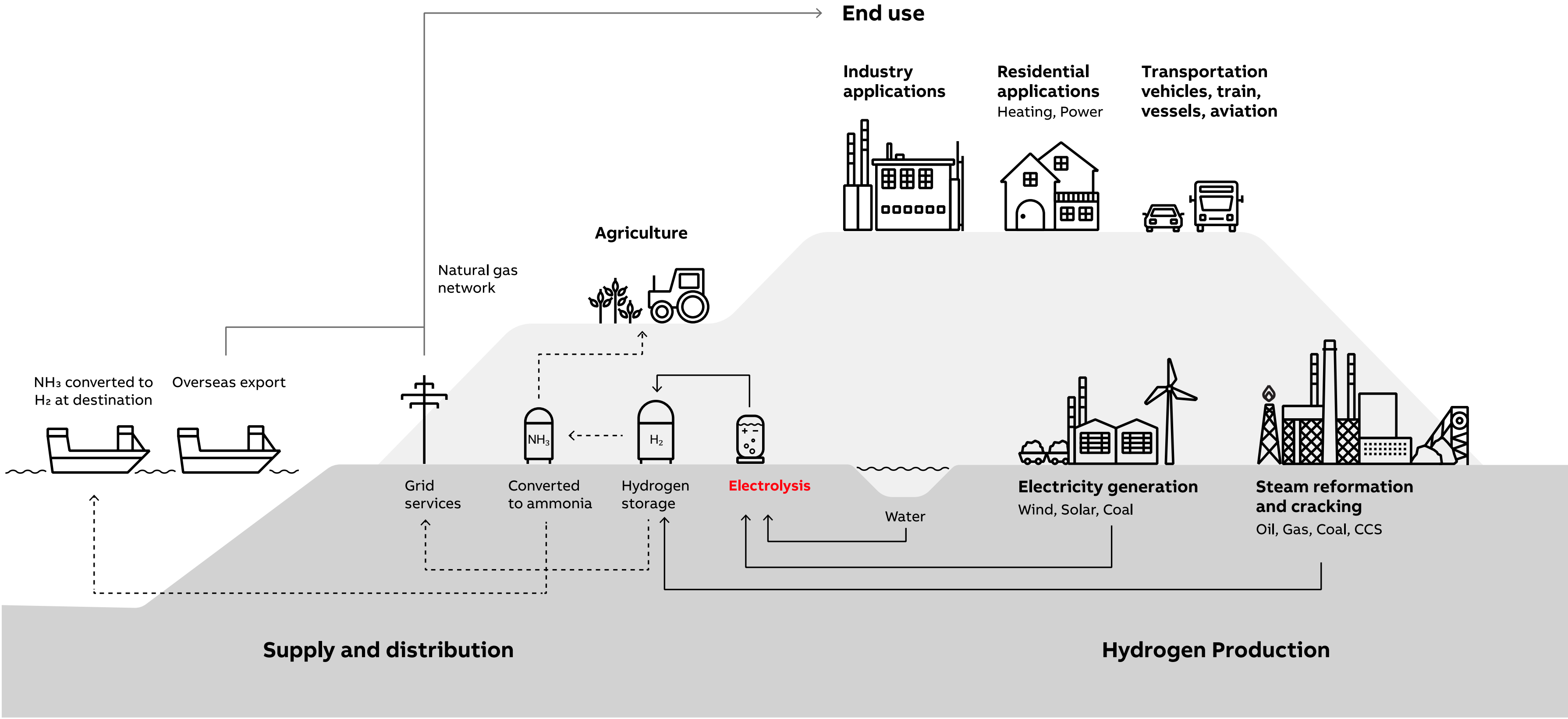


H_2 ecosystems: why combine electrification and advanced automation?

Challenges in renewable hydrogen production

Renewable Hydrogen still is an emerging industry, now with:

1. Integration of renewables and energy storage
2. Variable power generation and operational complexity
3. Integration of new designs, concepts and equipment
4. Lack of operational experience
5. Increased pressures on CAPEX and OPEX reductions



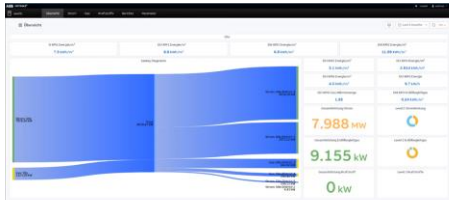
H_2 ecosystems: why combine electrification and advanced automation?

Digital twins

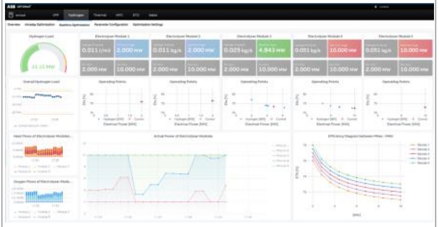
Design, Planning & System Engineering

- Evaluate alternatives
- Improve visibility
- Gain agility
- Mitigate risk

ABB OPTIMAX® Green Hydrogen Portfolio

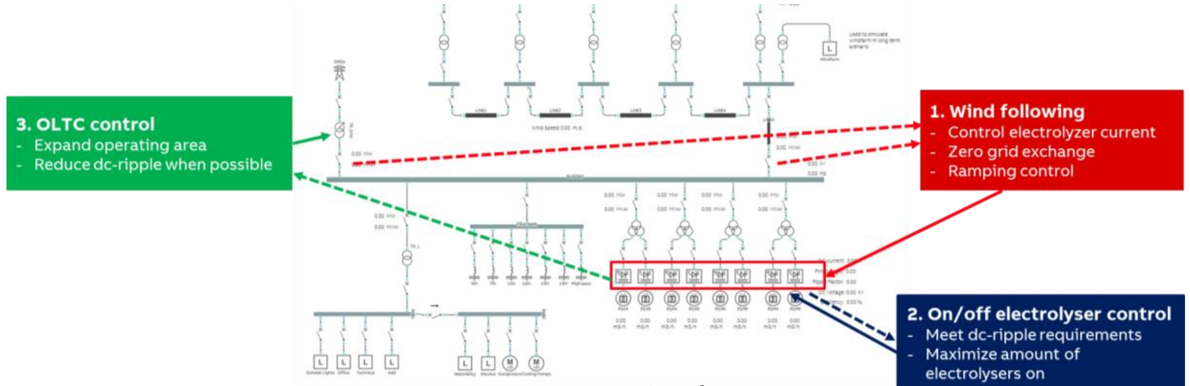


Monitoring



Real-time Optimization

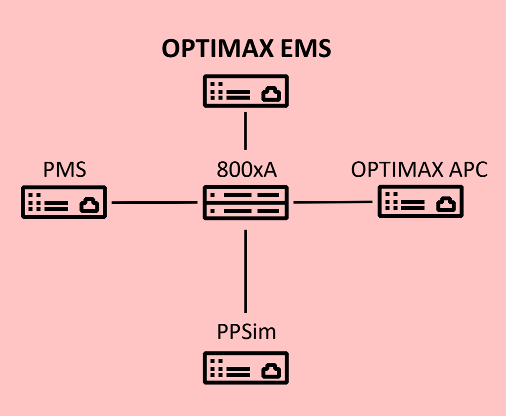
Predictive Optimization
Intra-Day Optimization



Process Power Simulator

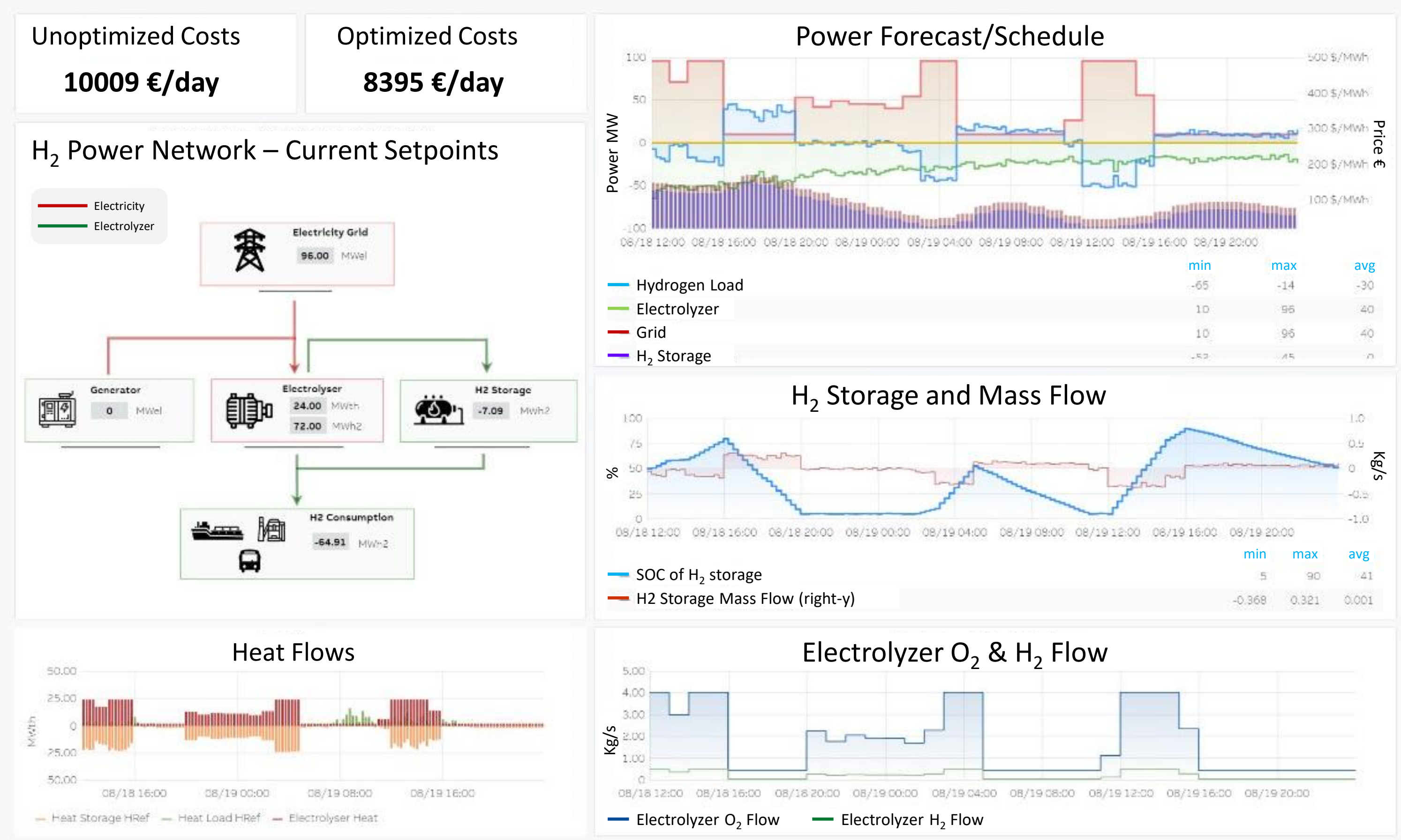
Operation & Maintenance

1. Optimize assets performance
2. Forecast of energy demand and supply, including renewables
3. Simulate and virtualize best possible energy flows and use adaptive control to achieve them



OPTIMAX® for Green Hydrogen

Importance of OPEX for levelized cost of H_2



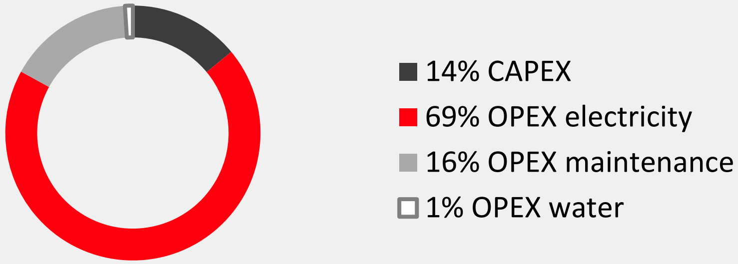
Goal: reduce production costs to less-than 2 \$/kg by 2026**

- 20% electrical lifetime OPEX

Optimal planning of the integrated circular energy system based on forecasts (renewable generation, demand and electricity price)

Enable the efficient production of renewables and their integration into the process' power supply – safely and reliably

Align times of operation with grid prices, considering process constraints

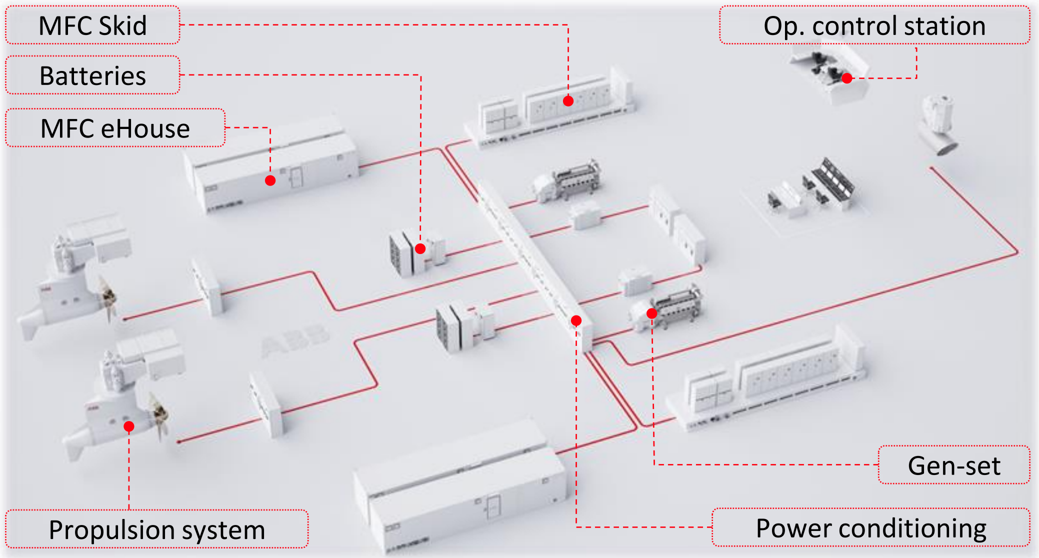


Levelized costs of green H_2 per kg

Transportation's demands to boost H_2 production

Zero-emission hydrogen fuel cell technology for large ships

- Modular power supply systems for marine use
- MV and LV power system compatible with AC and DC
- 200 kW Hydrogen proton exchange membrane (PEM) fuel cells
- Centralized Balance of Plant
- Multi-megawatt fuel cell system - 3 MW (4,000HP) of electrical power



Zulu06 flagship project

Samskip Container Vessels

MFC High Power & Skid

Maritime transportation contributes **nearly 3% of annual CO_2 emissions**, predicted **to increase to 50% by 2050**

The International Maritime Organization (IMO) has **targeted net-zero GHG emissions by 2050**

Batteries, hydrogen-fed fuel cells, and ammonia-based systems are considered to meet IMO targets

20 mtpa Hydrogen demand by **2030** increasing to **100 – 150 mtpa Hydrogen by 2050**[1)]

1) DNV GL, Hydrogen council

Conclusion

- **Power electronics in future hydrogen systems**
  - Clean hydrogen to play key role in the world's transition to a sustainable energy future
  - Hydrogen to be implemented in hard-to-decarbonize areas such as heavy industries, marine transportation, long distance trucking, and seasonal energy storage
  - Power electronics central to scaling hydrogen production – both in cost and operation performance
  - Real-time simulation, digital twins and automation solutions like ABB's OPTIMAX® for H_2 production let operators minimize expenses and navigate renewable variability with ease

- **Some opportunities to be further explored/optimized**
  - Innovative converters for electrolyzers and fuel cell integration
  - Advanced control methods to guarantee system stability, power management, and lifetime optimization

THANK YOU

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