Elia Task Force: Workshop #2: Flexibility options in electricity consumption

Contribution of Electrolysers

24.09.2021

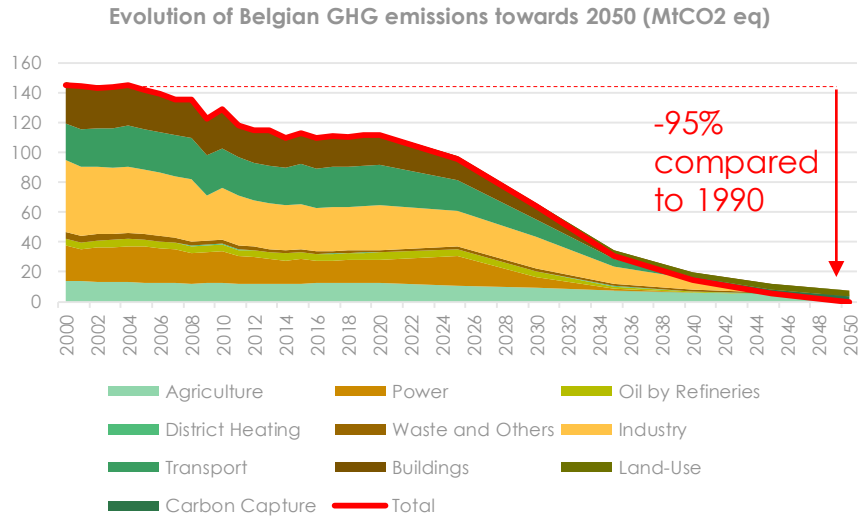
This presentation gathers a collection of references explaining what electrolysers can bring to the electric system. This is not a presentation of the Fluxys's expertise.

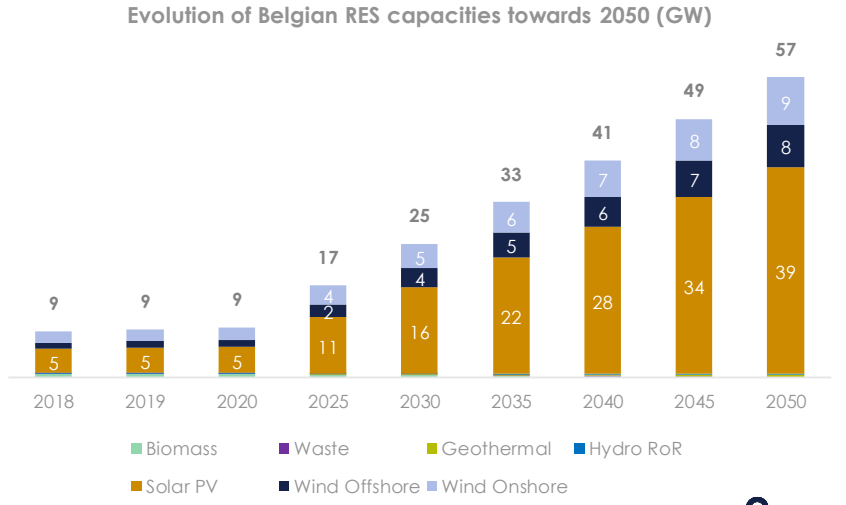
Agenda

- Context of the energy transition towards 2050
- Electrolysers' technology
- Hydrogen applications
- Electrolysers' contribution to the flexibility
- Examples of electrolysers plants
- Future electrolyser's capacities
- Conclusions

Energy systems will drastically change in the future

- **Decarbonization of the energy system**
  - Objective of **climate neutrality** in 2050 (EU Green Deal 2020)
  - Fossil fuels phase out
- **Integration of large renewables capacities**
  - Increasing **intermittency** of the electricity production
  - Increasing need for **flexibility** in the system (demand & production)
- **Green molecules will be essential**
  - To support the electric system by flexible means (short & long term flexibility)
  - To supply sectors hard to electrify





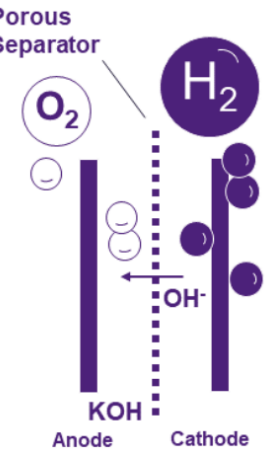
Source: Climact Core-95 scenario

What is an electrolyser?

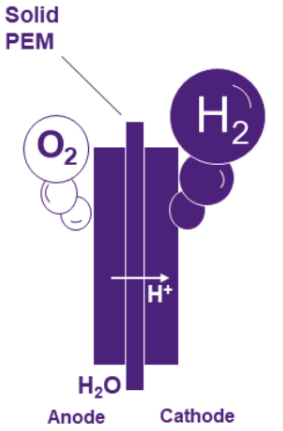
- **Electrolysis**:
  - Electrochemical reaction that splits **water** into **hydrogen** and **oxygen**, using **electricity**.
  - The electrolysis takes place in a system called **electrolyser**.
- Two main **electrolyser technologies** are today fully mature and being commercialized for the production of hydrogen:
  - **Alkaline** (ALK) electrolysers
    - » Electrolyte/Membrane: liquid solution with OH^- ions / porous membrane for OH^-
    - » Reliable proven technology being used by the industry for more than 60 years
  - **Proton Exchange Membrane** (PEM) electrolysers
    - » Electrolyte/Membrane : pure water / solid polymer membrane permeable to H^+
    - » Emerging on the market and more flexible than ALK electrolysers

Global reaction
$2\ H_2O \rightarrow 2\ H_2 + O_2$

ALK



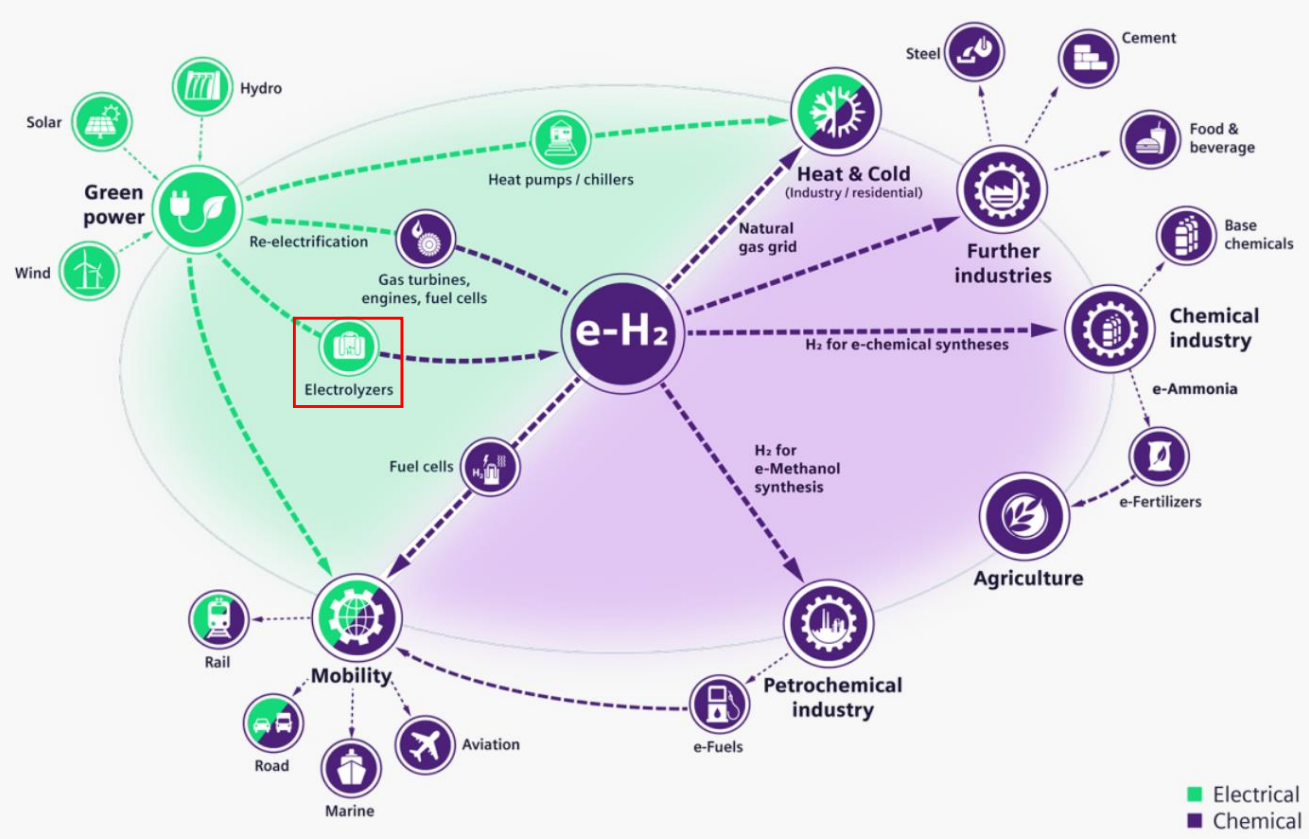
PEM



Source: Siemens

Source: Hydrogenics/Cummins 2019

Hydrogen will become a key molecule



Source: Siemens Energy Website

- **Electrolysers**
  - Will help to integrate the massive **renewables capacities** by producing **green hydrogen**.
  - Will bring **short & long term flexibility** to the system
- **Green hydrogen** will be required to **decarbonize** sectors hard to electrify e.g. :
  - In the industry sector: to replace fossil feedstock or fuels for process heating
  - In the transport sector: to be used for long distance transport (aviation SAF, shipping, road freight, …)
  - In the building sector: to be used for space heating & electricity generation (i.e. micro CHP fuel cell)

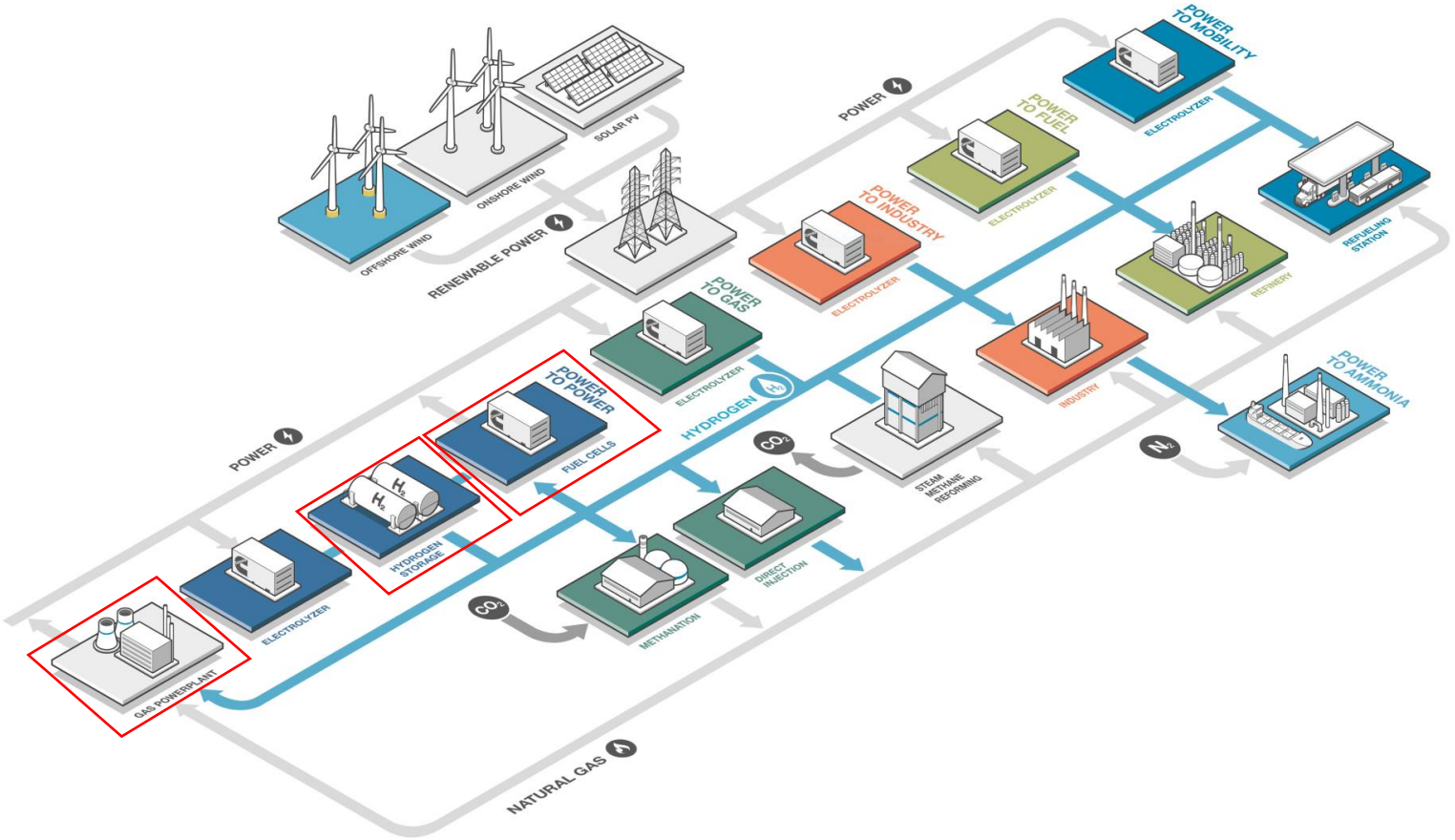
Electrolysers can help to integrate renewables and offload grids

- Trinomics for the **European Parliament**: "*Applying **power-to-gas** technologies in **periods of excess electricity** supply removes the **need for curtailment** of renewable electricity generation or the need for **additional investments in electricity** transmission, distribution or storage **infrastructure**. Improving the **integration** of the electricity and gas sectors would also allow an **optimized use of existing gas infrastructure***"

- **European Commission**: "*Hydrogen produced through electrolysis using renewable electricity can play a particularly important "nodal" role in an **integrated energy system**, where it can help integrate large shares of variable renewable generation, by **offloading grids in times of abundant supply**, and providing **long term storage** to the energy system. It can also allow local renewable electricity production to be used in a range of **additional end-use applications**.*"

Sources:
- *Trinomics for the European Parliament 2018: Sector Coupling*
- *European Commission 2020: EU Strategy for Energy System Integration*

Electrolysers can bring long term flexibility to the energy system



Source: Cummins 2021

Once hydrogen is produced based on renewable electricity, it can be:

- **Transported** in the gas infrastructure (hydrogen buffer)
- **Stored** in hydrogen storage: tanks, salt caverns for long periods (seasonal storage)
- **Converted** into methane
- **Re-converted to electricity** using fuel cells or gas powerplants (in case of "dunkelflaute" periods)

Source: IRENA 2018

Electrolysers can bring short term flexibility to the energy system (1/2)

Electrolysers can operate in **highly dynamic modes**:

- **Quick start-up** or **shut down** of the installations
- **Quick ramp-up or down** of their electric consumption

This way, electrolysers:

- Can provide **low-cost balancing services** by means of flexible load (up or down)
- Could play on **real-time balancing markets** but also day ahead or intraday markets

-> Those additional grid revenues are **improving electrolysers' business cases**

Source: WaterstofNet 2021: Greenports project

Table 2: Dynamic operation of ALK and PEM electrolysis

	ALKALINE	PEM
Load range	15–100 % nominal load	0–160 % nominal load
Start-up (warm – cold)	1–10 minutes	1 second–5 minutes
Ramp-up / ramp-down	0.2–20 %/second	100 %/second
Shutdown	1–10 minutes	Seconds

Note: Values for 2017.
Source: FCH JU (2017b).

Source: IRENA 2018

Siemens Silyzer 300 - PEM electrolyser

Silyzer 300 – PEM Module Array

Technical data

Hydrogen production:
100 – 2,000 kg per hour
Plant efficiency: > 75,5%
Startup time: < 1 minute
Dynamics: 0 – 100% in 10% / s
Minimum load: ≥ 5%
Water consumption (DI):
10 l per kg hydrogen
Hydrogen quality:
Ultra high purity 5.0

Scalable up to **100 MW** plant

Source: Siemens Data Sheet

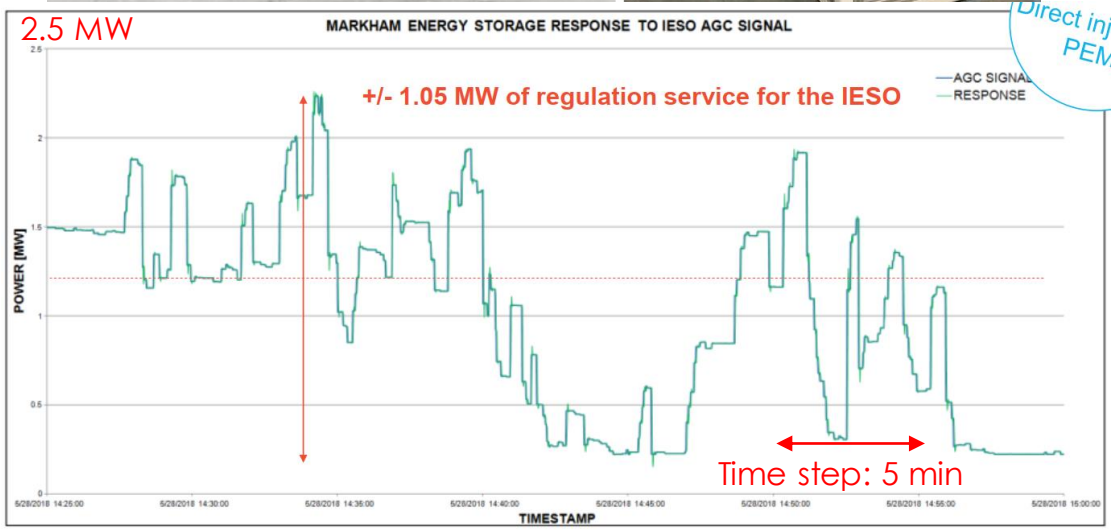
Electrolysers can bring short term flexibility to the energy system (2/2)

	Alkaline			PEM (Proton Exchange Membrane)		
						
	HySTAT®-15-10	HySTAT®-60-10	HySTAT®-100-10	HyLYZER® -500-30	HyLYZER® -1.000-30	HyLYZER® -4.000-30
Output pressure	10 barg (27 barg optional)			30 barg		
Design	Indoor/outdoor	Indoor/outdoor	Indoor/outdoor	Indoor/outdoor	Indoor	Indoor
Number of cell stacks	1	4	6	2	2	8
Nominal hydrogen flow	15 Nm³/h	60 Nm³/h	100 Nm³/h	500 Nm³/h	1.000 Nm³/h	4.000 Nm³/h
Nominal input power	80 kW	300 kW	500 kW	2.5 MW	5 MW	20 MW
AC power consumption (utilities included, at nominal capacity)	5.0 to 5.4 kWh/Nm³			≤ 5.1 kWh/Nm³	DC power consumption: 4.3 kWh/Nm³ ± 0.1 (at nameplate hydrogen flow)	
Turndown ratio	40-100%	10-100%	5-100%	5-100%	5-125%	
Hydrogen purity	99.998% O2 < 2 ppm, N2 < 12 ppm (higher purities optional)			99.998% O2 < 2 ppm, N2 < 12 ppm (higher purities optional)		
Tap water consumption	<1.4 liters / Nm³ H2			<1.4 liters / Nm³ H2		
Footprint (in containers)	1 x 20 ft	1 x 40 ft	1 x 40 ft	2 x 40 ft	(LxWxH) 8.4 x 2.3 x 3.0 m	20 x 25 m (500 m²)
Utilities (AC-DC rectifiers, reverse osmosis, cooling, instrument air, H2 dryer)	Incl.	Incl.	Incl.	Incl.	Optional	Optional

Source: Cummins 2020

Example of flexibility project: Markham Energy Storage

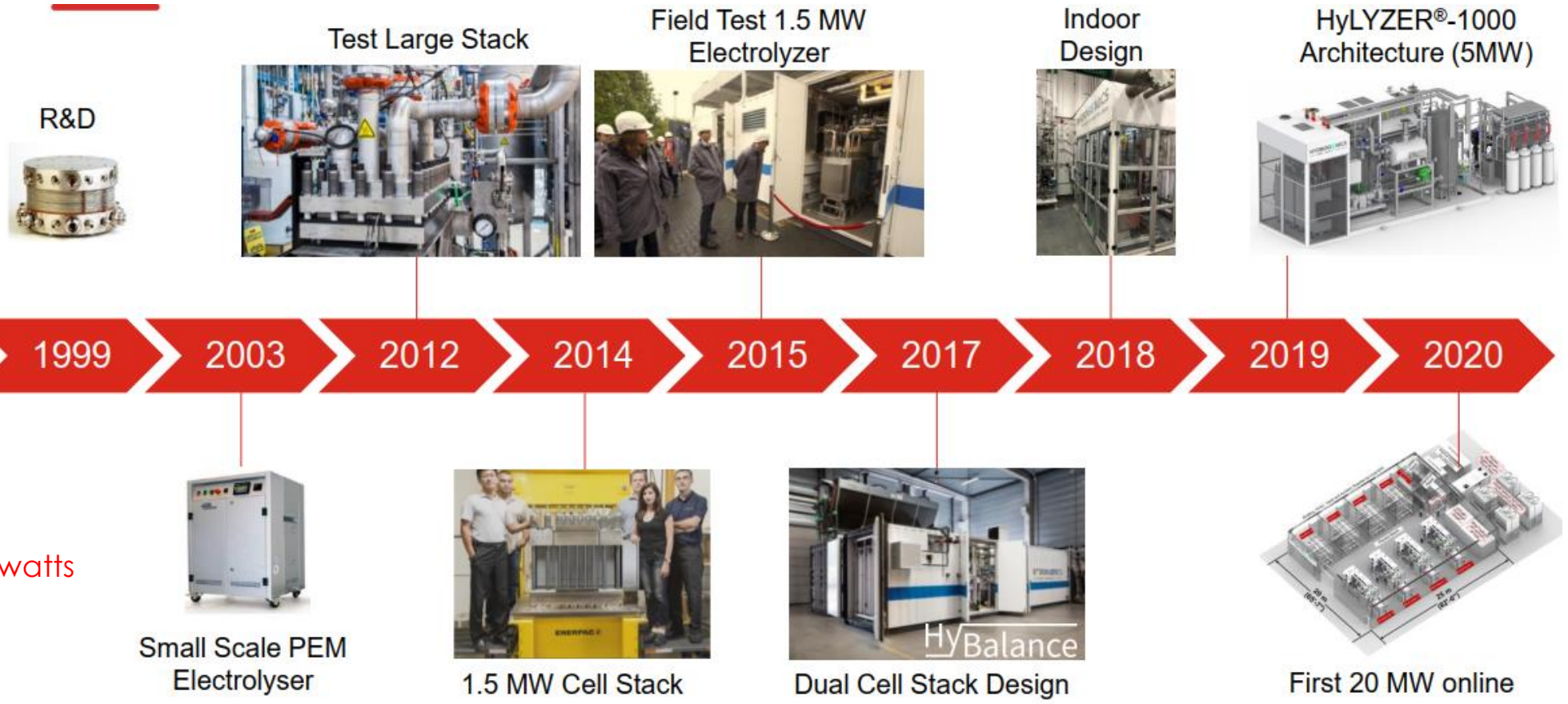
- **Energy Storage** plant in operation since **2018** in **Canada**
- Currently installed **PEM electrolyzer** capacity: **2.5MW** (designed for 5MW)
- **Short term flexibility**:
  - Secondary **Frequency Control** for IESO (Canadian TSO)
  - Plant provides +/- **1.05 MW** of **regulation service** for the IESO
  - **2 second response time, 2 MW/sec ramp rate**
- **Long term flexibility:**
  - 100 kW fuel cell with 8 MWh of onsite hydrogen storage



Source: Cummins 2020

Source: Cummins 2020

Electrolysers capacities significantly increased over the last 20 years



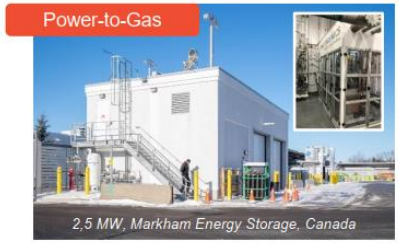
From few kilowatts

To Megawatts

Source: Cummins 2020

Large electrolysis plants are already in operation all around the world

2015 - 2019



2019

World's largest green-hydrogen plant begins operation in Austria

The 6MW facility in Linz, running Siemens electrolysers, will provide clean H2 for steel production

18 November 2019 10:57 GMT *UPDATED 19 November 2019 3:40 GMT*

2020

The Fukushima Hydrogen Energy Research Field (FH2R) uses a 20MW solar array, backed up by renewable power from the grid, to run a 10MW electrolyser at the site in Namie Town, Fukushima Prefecture.

Japan opens world's largest green-hydrogen plant near Fukushima disaster site

Partners including Toshiba say Fukushima Hydrogen Energy Research Field is most powerful electrolyser yet to link production to renewables

9 March 2020 8:57 GMT *UPDATED 9 March 2020 9:28 GMT*

2021

World's largest green-hydrogen plant inaugurated in Canada by Air Liquide

The new facility, based around a 20MW PEM electrolyser, doubles the previous record set in Fukushima, Japan

27 January 2021 12:04 GMT *UPDATED 27 January 2021 12:04 GMT*

Sources:
- *Cummins 2020*
- *Recharge News*

Electrolysers capacities will continue to grow in the future

From Megawatts → To Gigawatts

Linde to build 'world's largest electrolyser' to produce green hydrogen

Industrial gases giant to build 24MW PEM electrolyser at Leuna in Germany by the second half of 2022

13 January 2021 13:48 GMT UPDATED 13 January 2021 13:53 GMT

Energy giants Total and Engie to tap solar for France's largest green hydrogen plant

French oil major and utility plan using 100MW of PV power for 40MW electrolyser to produce H2 for further processing into renewable diesel

13 January 2021 10:09 GMT UPDATED 13 January 2021 12:45 GMT

Commissioning in 2024

Shell Starts Up 10-MW REFHYNE Hydrogen Electrolyzer, Eyes Expansion to 100 MW

02/07/2021

100 MW in 2024

Shell Energy has started up a 10-MW polymer electrolyte membrane (PEM) electrolyzer facility—one of the largest of its kind in the world—to produce green hydrogen at its Energy and Chemicals Park Rheinland refinery in Wesseling, Germany, and it says plans are underway to expand the plant's capacity to 100 MW.

Shell, Worley to develop a 200MW electrolysis plant in Rotterdam

By George Heynes on Jun 01, 2021 | Translate NEW

Shell has awarded Australia-based Worley a services contract to support the development of a new 200MW electrolysis-based hydrogen plant in Rotterdam, the Netherlands today (June 1).

The new plant will be powered by renewable energy from an offshore windfarm that is currently in development and, once complete, the green hydrogen plant will be one of the largest commercial green hydrogen production facilities in the world.

Operations will begin by 2023 and the plant is estimated to produce around 50,000 to 60,000kg of green hydrogen per day that will initially be used to decarbonise Shell's nearby refinery in Pernis, and support the industrial use of hydrogen in heavy transportation.

Sources:
- *Recharge News*
- *Power Mag / Shell*
- *H2 View*
- *S&P Platts*

COAL | ELECTRIC POWER | NATURAL GAS — 07 Dec 2020 | 14:27 UTC — London

Equinor, RWE join Dutch NorthH2 offshore wind green hydrogen project

NorthH2 is one of the largest green hydrogen projects planned anywhere in the world. It targets 1 GW of electrolysis capacity by 2027, ramping up to 4 GW by 2030 and over 10 GW by 2040.

European group aims to use 95GW of solar to push green H2 price to fossil fuel level

'HyDeal Ambition' consortium targets 67GW of electrolysis capacity before 2030 and price of €1.50/kg for green hydrogen

15 February 2021 10:14 GMT UPDATED 15 February 2021 11:14 GMT

AquaVentus project in North Sea:
- 30 MW by 2025
- 300 MW by 2028
- 10 GW by 2035

And many other projects in Australia, Chile, Asia, Middle East, …

Significant capacities could be used for flexibility purposes

- **Federal Planning Bureau** (2020 study: "Fuel for the Future") sees a significant potential for **electrolyser capacity in Belgium by 2050**:

Scenario	Installed capacity (GW)
Diversified Energy Supply	19.1
Deep Electrification	10.6

- As seen for the **Markham project** in Canada, **50% of the installed capacity** could be allocated to provide **ancillary services** to the grid.

Conclusions

Conclusions

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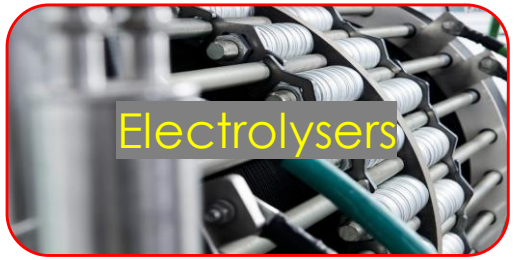

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Short term flexibility

Long term flexibility


fluxys