Tecnologie attuali e future per la produzione di idrogeno *green*

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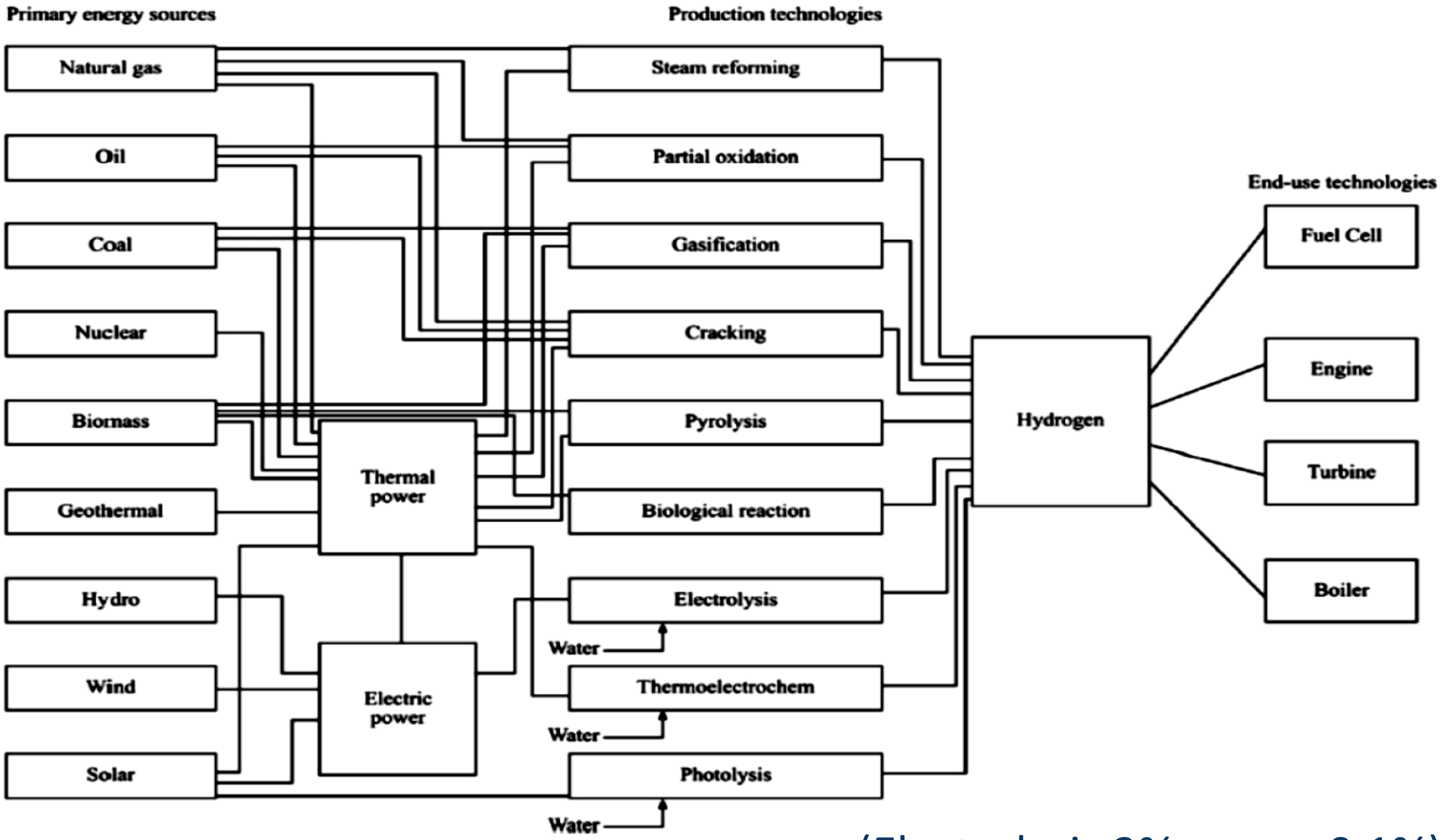
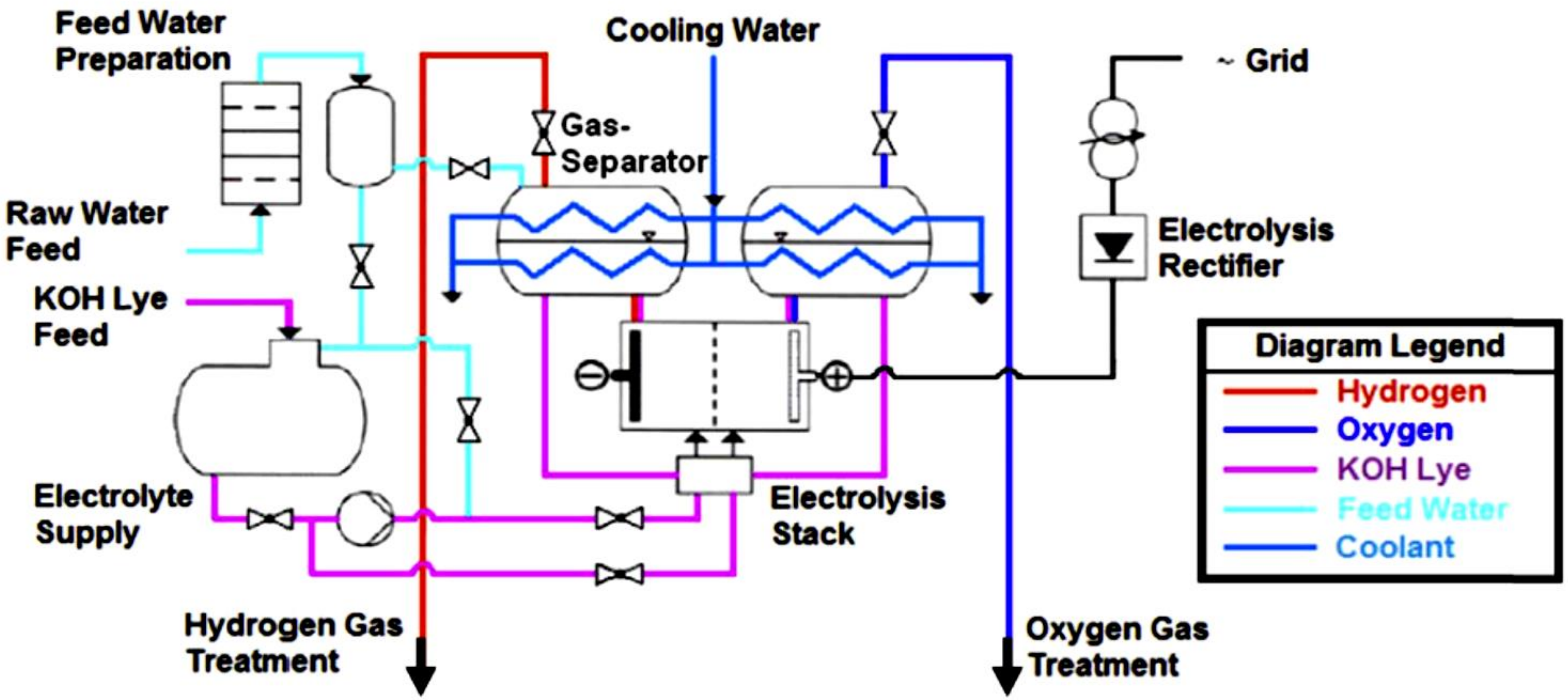
Roma 9/10/2020

Hydrogen production systems (500 bn m^3/year)



(Electrolysis 3%, green 0,1%)

Alkaline Electrolysers (commercial, eff 65-70%, <30 bar, 70-75°C)

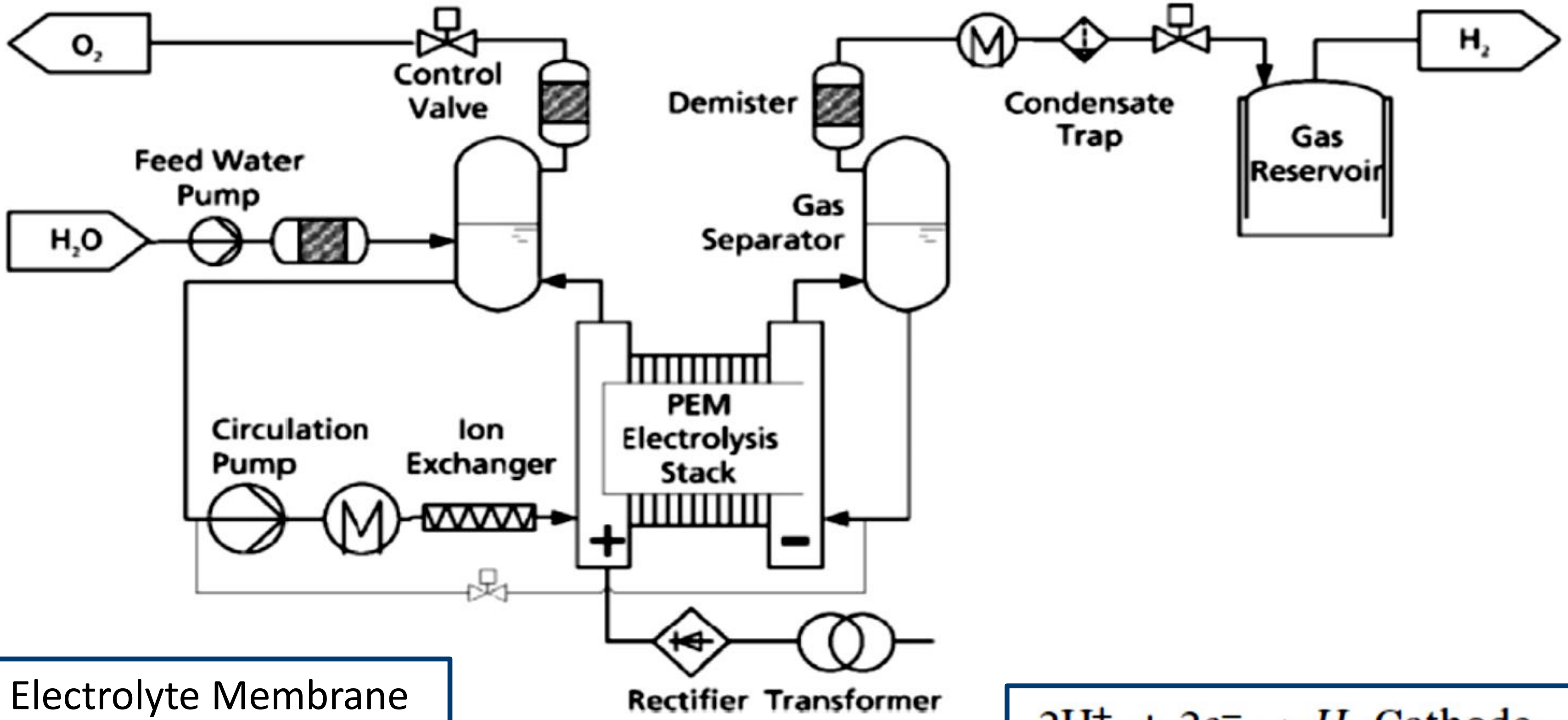


$$2H_2O + 2e^- \rightarrow H_2 + 2OH^- \text{ Cathode}$$

$$2OH^- \rightarrow \frac{1}{2}O_2 + H_2O + 2e^- \text{ Anode}$$

Alkaline Electrolysers not suitable for electricity dispatching, because of high transients

PEM Electrolysers (first applications since 1990, eff 70-78%, 10 bar, 60-80°C)



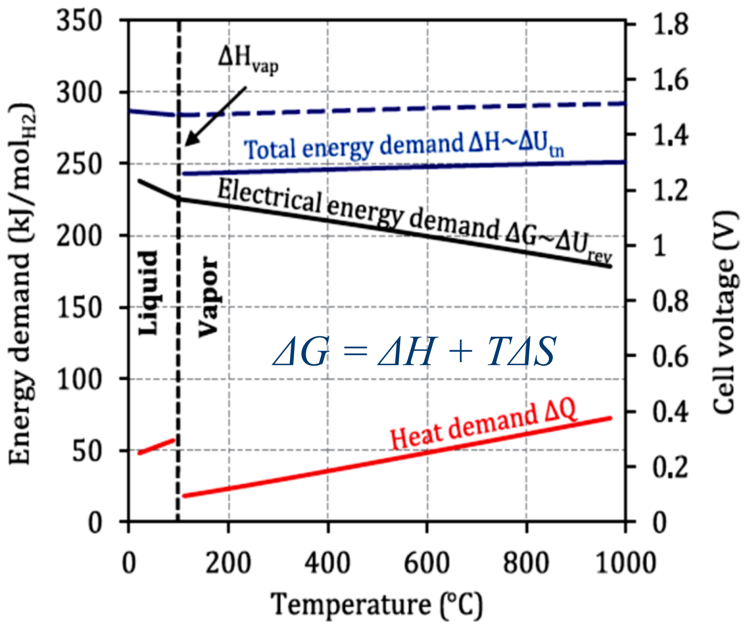
Polymer Electrolyte Membrane
or
Proton Exchange Membrane
Under study now AEM Anionic Exchange Membrane

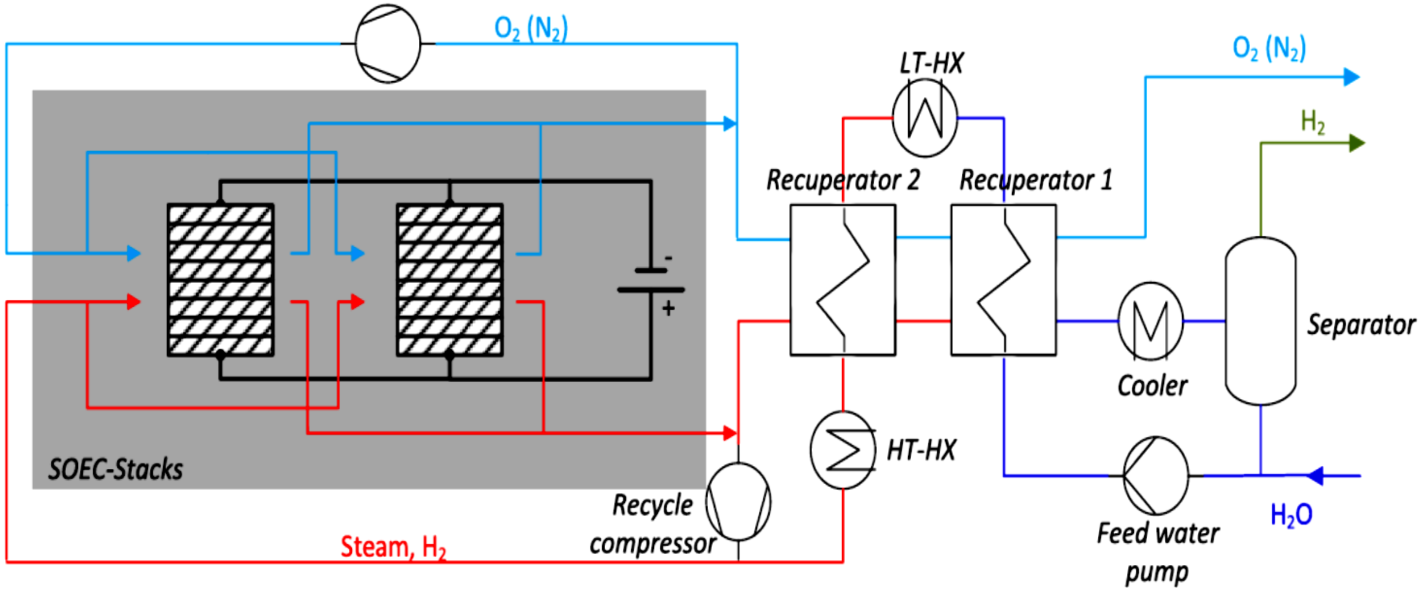
$$2H^+ + 2e^- \rightarrow H_2 \text{ Cathode}$$

$$H_2O \rightarrow \frac{1}{2}O_2 + 2H^+ + 2e^- \text{Anode}$$

PEM higher current density, efficiencies and modulation capacity, but higher costs, low pressure, membrane technology

Solid Oxides Electrolysers





- No complete info (Germany leader, TRL7, 50-100 mc/h)
- Costs approx (6.000-10.000 €/kWe)
- Highest efficiency (3,6 kWh/nm3)
- Potential application of co-electrolysis: Water vapour together with CO2 splitting for synt methane production into the stack
- SOFC reverse avoiding thermal fatigue

$$H_2O + 2e^- \rightarrow H_2 + O^{2-} \text{ Cathode}$$

$$O^{2-} \rightarrow \frac{1}{2}O_2 + 2e^- \text{Anode}$$

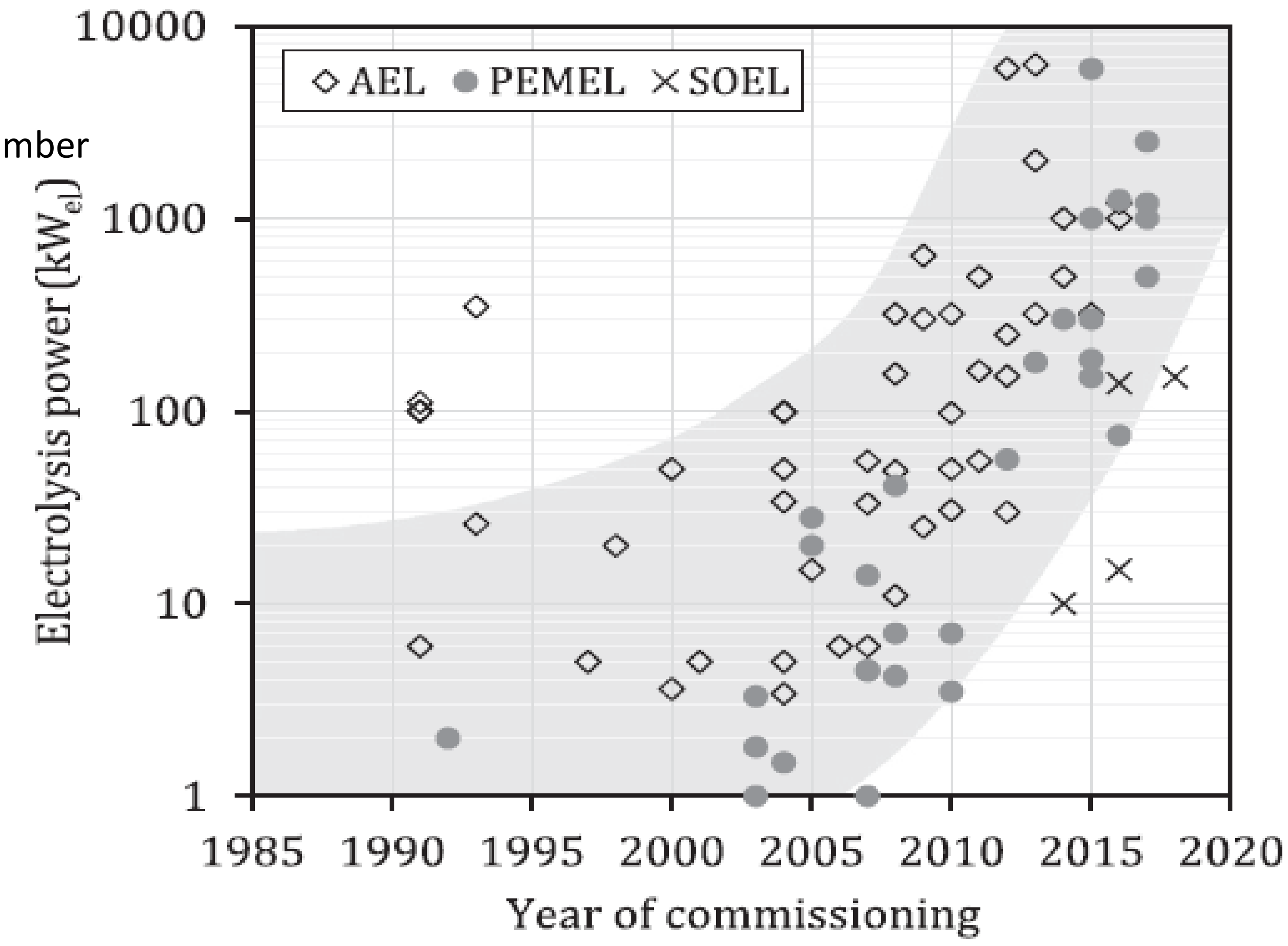
Technologies deployment

Key Drivers

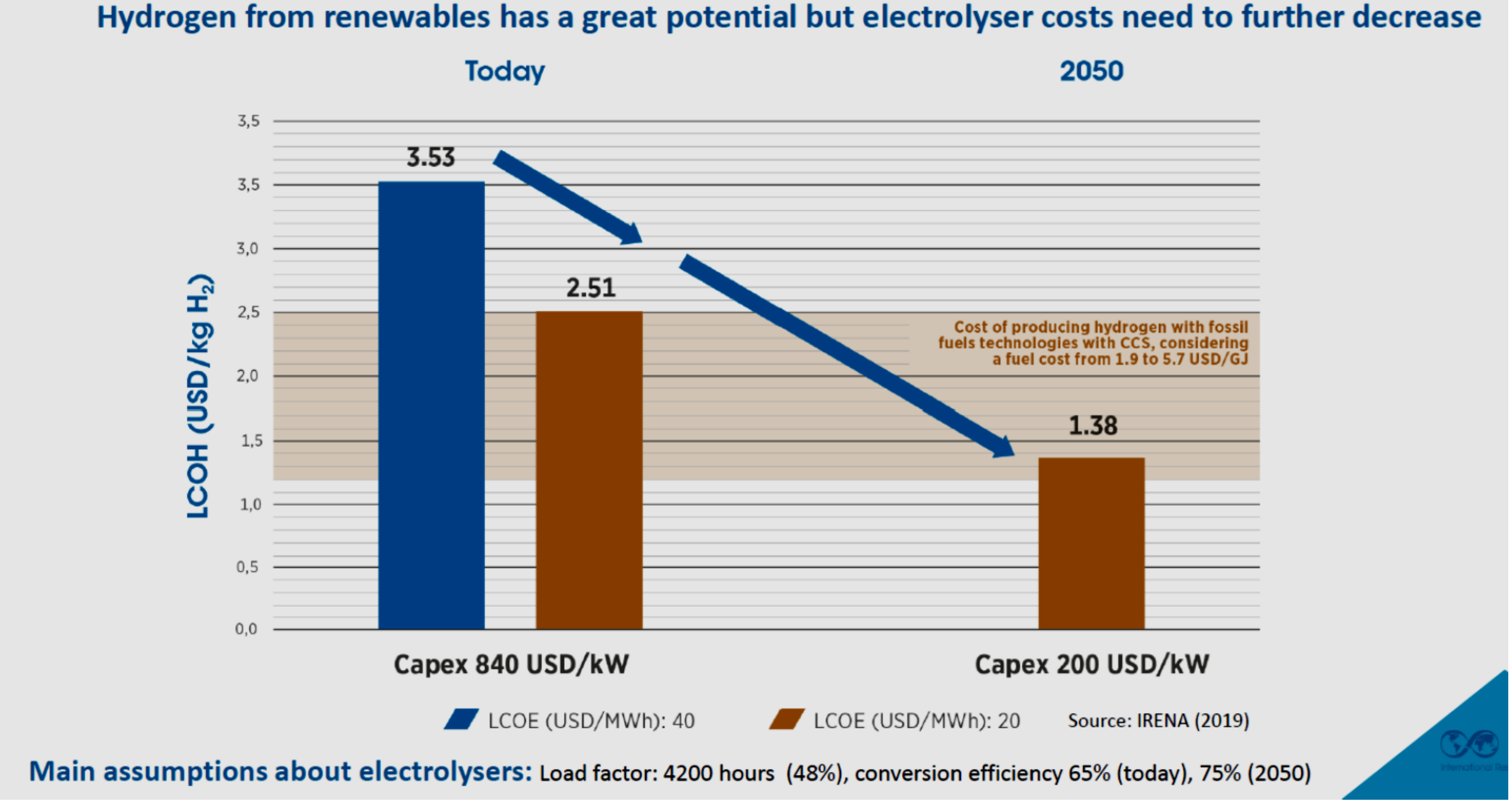
- **Renewable costs** continue to fall
- System **integration challenges**
- Electrolyser projects rapidly growing in size and number
- Electrolyser **cost is projected to halve**

Main Focus

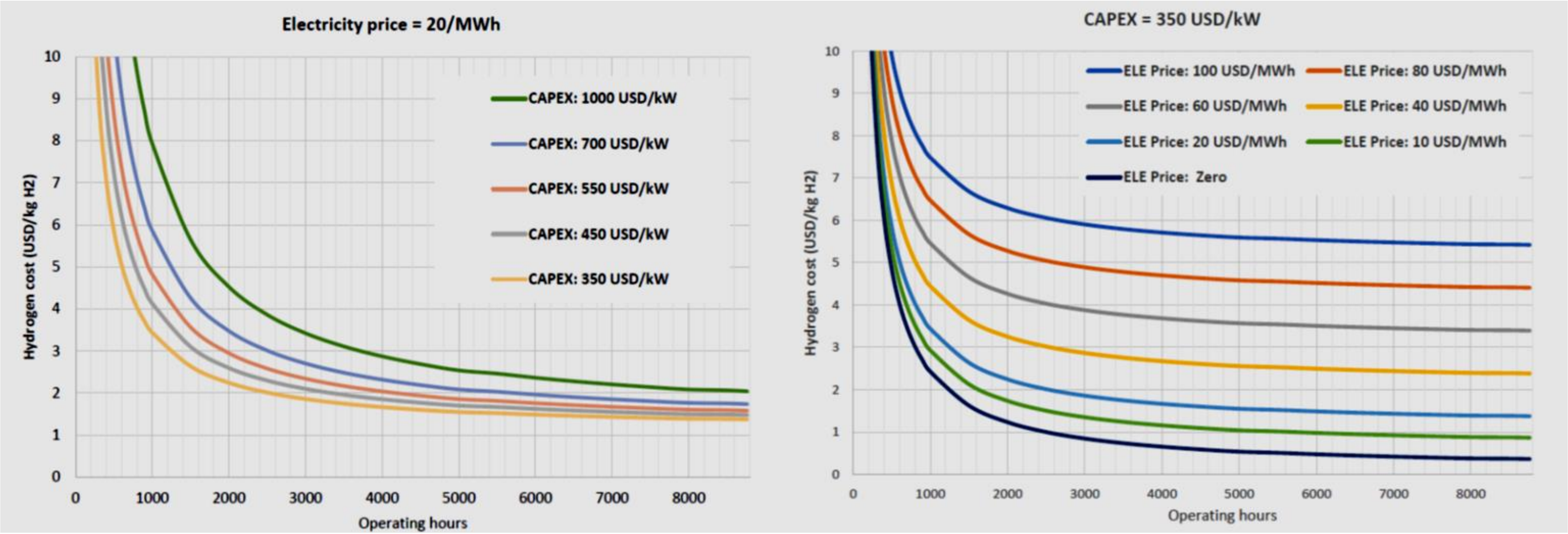
- Project cost and equipment **cost trends**
- **Efficiency and lifetime**
- Compressor and on-site storage linkages with operation and **capabilities to provide flexibility**
- Potential of **technological innovation**



2 MW PEM Hydrogen production costs (Irena 2019)



Hydrogen production costs: renewable electricity prices, CAPEX of electrolysers and operating hours

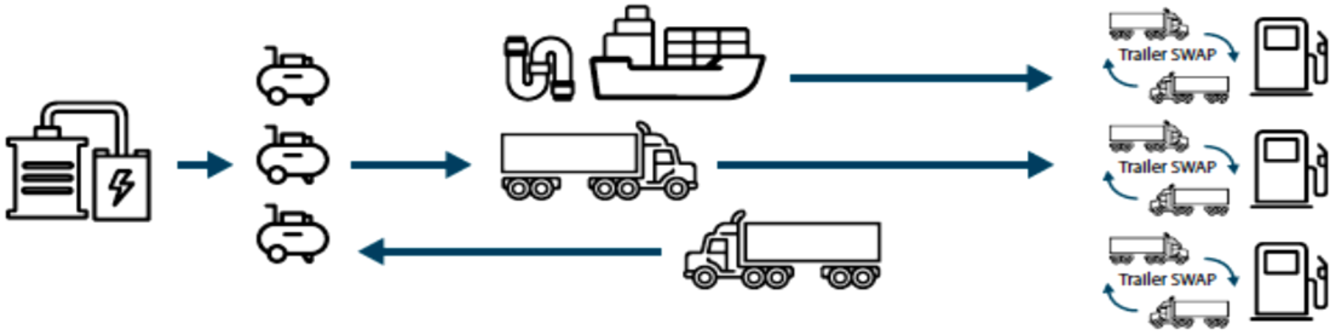


Source: IRENA 2019

Hydrogen from renewables has a great potential but Electrolysers costs need to further decrese

CAPEX, **electricity price** and **operating hours** are the main drivers for determinig the GREEN-H2 production costs

Cumulative supply chain target costs for hydrogen in transport (Irena, 2016)



	H_2 production	H_2 compression	H_2 logistics	H_2 distribution
Cumulated supply chain cost – current estimate	5–6 $/kg	$$	$$	13–16 $/kg
Cumulated supply chain costs – targets (Europe)	1–3 $/kg	$	$	3–7 $/kg

Based on HINICIO (2016), present costs estimate at the pump from US DOE (2018). However Japan current estimate is 10 USD/kg. Target prices for production: IRENA analysis. Target prices at the pump of 3 USD/kg for Japan, 5 for US and 6–7 for Europe. See text for references.)

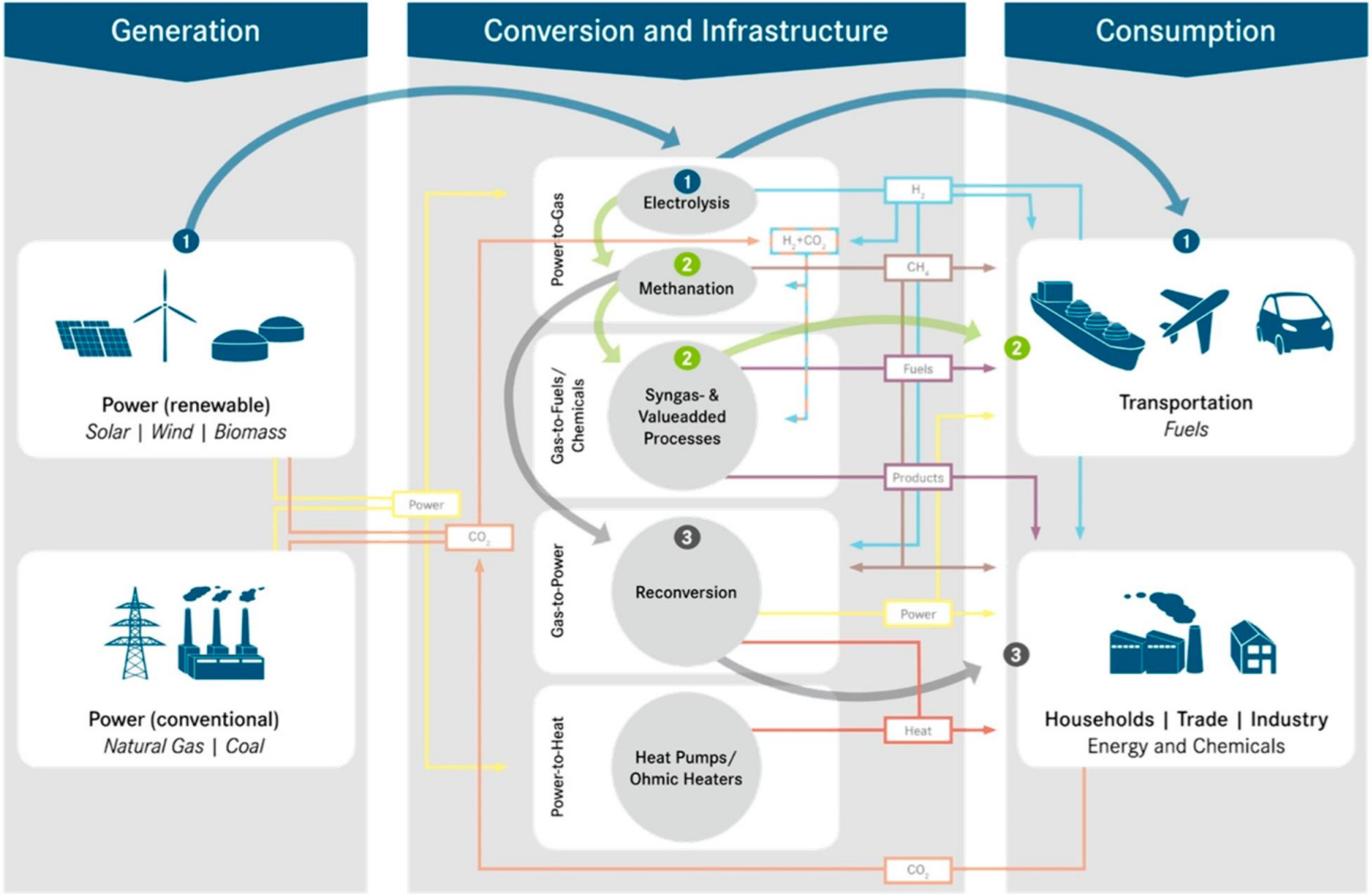
Source: IRENA 2019

The experience of Sapienza University of Rome Lab towards *Smart Energy Systems* which include hydrogen

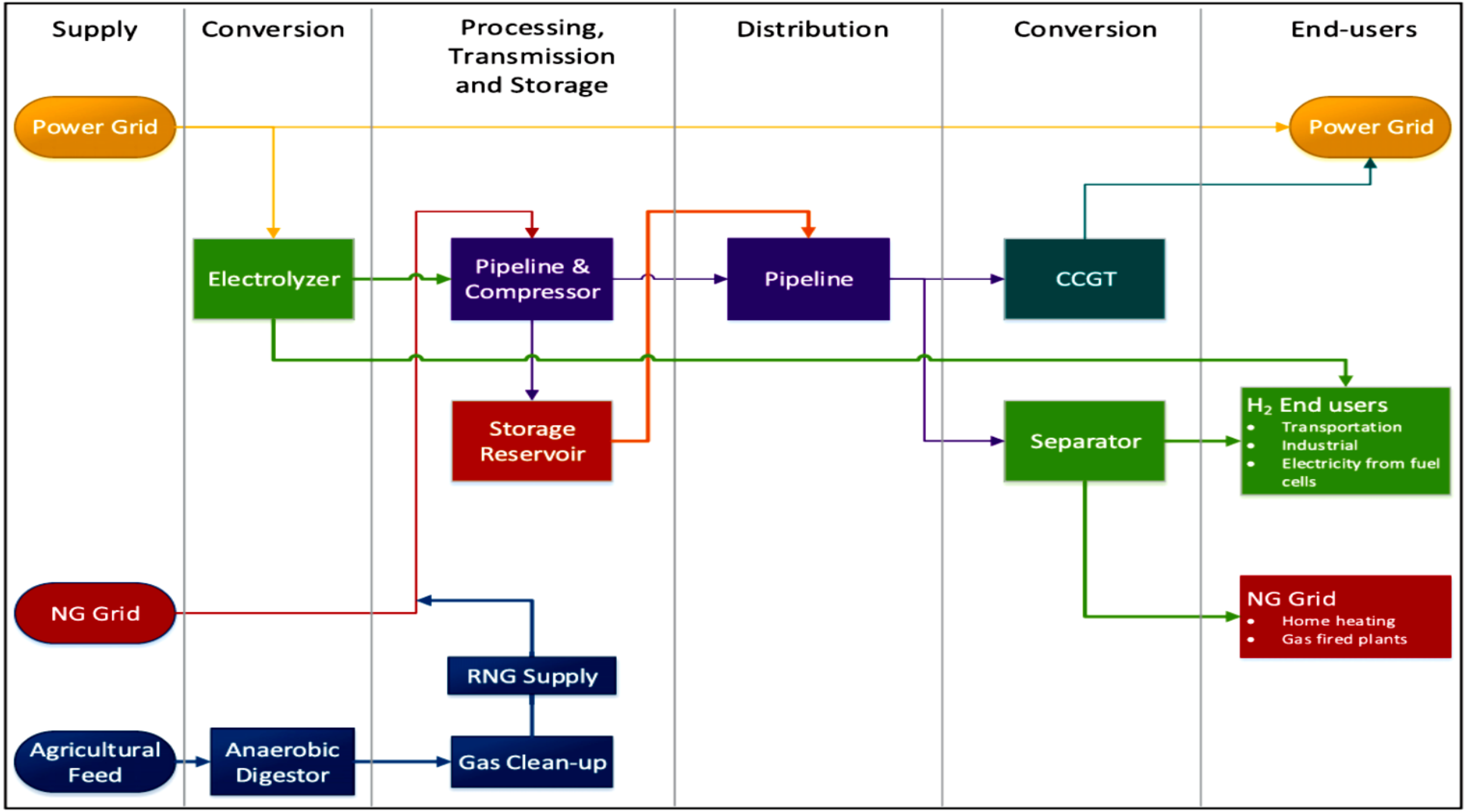
- Power-to-gas H2 for transport and building sectors, hydrogen injected into the natural gas grid or hydrogen with CO2 and convert to bio-methane (Sabatier), or using the output gas of a wood gas generator or a biogas plant, and mixed with the hydrogen to upgrade the quality of the biogas.
- Renewable electrofuels using electrolysis based on electricity from fluctuating renewable energy sources
- Grid and storages options. By combining the electricity, thermal and transport sectors, the grids and the storages in these sectors can improve the energy system flexibility and compensate for the lack of flexibility from RES
- Short and long term storage options in an effective penetration of renewables energy systems and so are the infrastructure and grids that enable such storage

Different application for Power – to – X (Irena 2019)

Power-to-X is an umbrella term for a number of conversion, storage and reconversion pathways that use surplus electric power from renewable energy, typically solar and wind. **"X" stands for the type of energy into which the electricity surplus is being converted.**



P2G logical scheme



Why investigating on H_2NG blends as the most handy-forward P2G application

H_2 is a carbon free fuel (vector)

- High adiabatic flame temperature
- Laminar speed burning 8 times faster than NG one
- Zero carbon emissions
- Water emissions only
- High NO_x production with air combustion
- Energy intensive production process and high costs

H_2NG use to achieve lower CO_2 and NO_x emissions

- Owing to the higher H/C ratio. the CO and CO_2 values deriving from H_2NG burning are lower than any other gaseous fuel
- Lower NOx emissions than NG in ultra lean combustion conditions
- Environmentally-friendly fuel if the hydrogen production carbon footprint is close to zero.

H_2NG as one of the Power to Gas (P2G) options for electrical energy storage

- To mitigate troubles and inefficiencies related to the electricity time-shift and to renewable capacity firming *(i.e. NG pipeline injection. artificial Hydrocarbons synthesis)*

H_2NG burning can increases ICE mechanical efficiency

- Application for sustainable mobility and static power generation as well
- Increase of combustion efficiency due to faster burning speed
- The espansion stroke is characterized by lower energy losses (toward adiabatic one)

Grazie

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