IRENA INNOVATION WEEK 2018

# Hydrogen from Renewable Power

## Technology outlook for the energy transition


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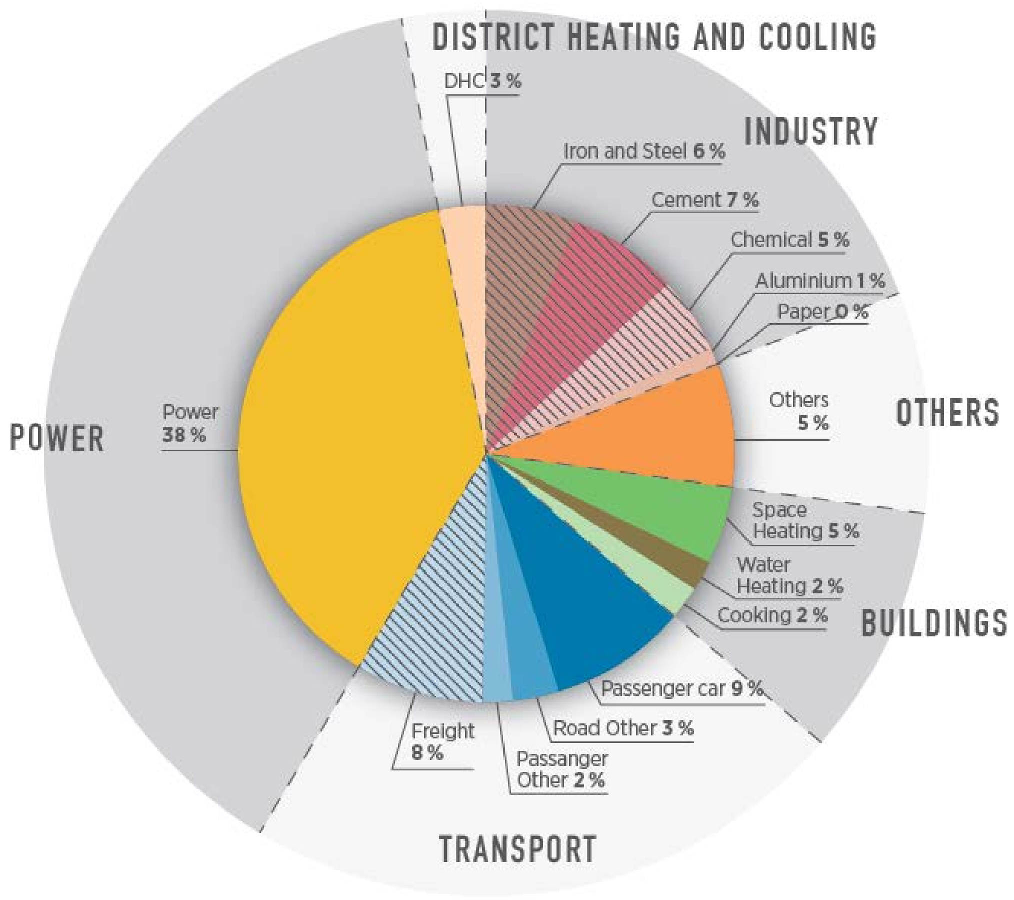
# Context: the Global Energy Transformation

- Paris Agreement: Average global temperature to **“well below 2 degrees”**

- Presently, **no economically viable options** to decarbonize one third of energy-related emissions (mostly from the energy-intensive industry sectors and freight transport).

- **Hydrogen could be the “missing link”**: supply renewable energy to sectors for which electrification is otherwise difficult, such as transport, industry and processes that require high-grade heat



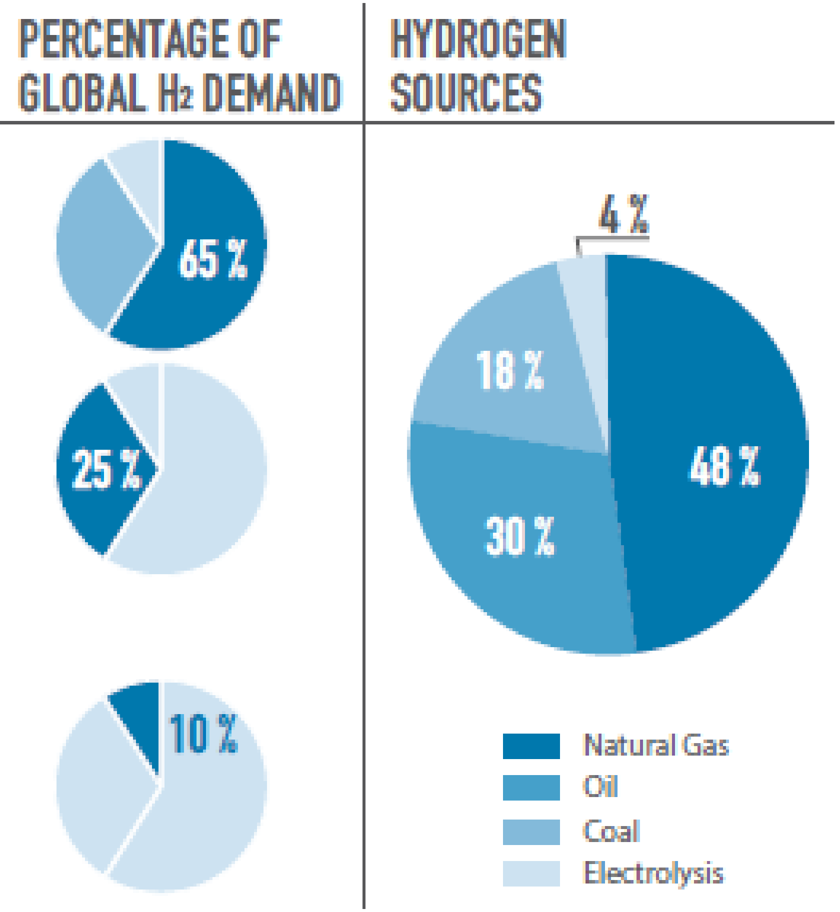
# Hydrogen today

Hydrogen is used at scale as **a feedstock** in industry

- Global demand (2015): **8 exajoules (EJ)**
  - Largest consumers: **Ammonia and Oil Refineries**
  - **Lower share:** iron and steel, glass, electronics, chemicals and bulk chemicals
- Current hydrogen production **is almost entirely fossil-fuel based**
- Around **4%** by electrolysis

| INDUSTRY SECTOR | KEY APPLICATIONS |
|---|---|
| CHEMICAL | • Ammonia<br>• Polymers<br>• Resins |
| REFINING | • Hydrocracking<br>• Hydrotreating |
| IRON & STEEL | • Annealing<br>• Blanketing gas<br>• Forming gas |
| GENERAL INDUSTRY | • Semiconductor<br>• Propellant fuel<br>• Glass production<br>• Hydrogenation of fats<br>• Cooling of generators |



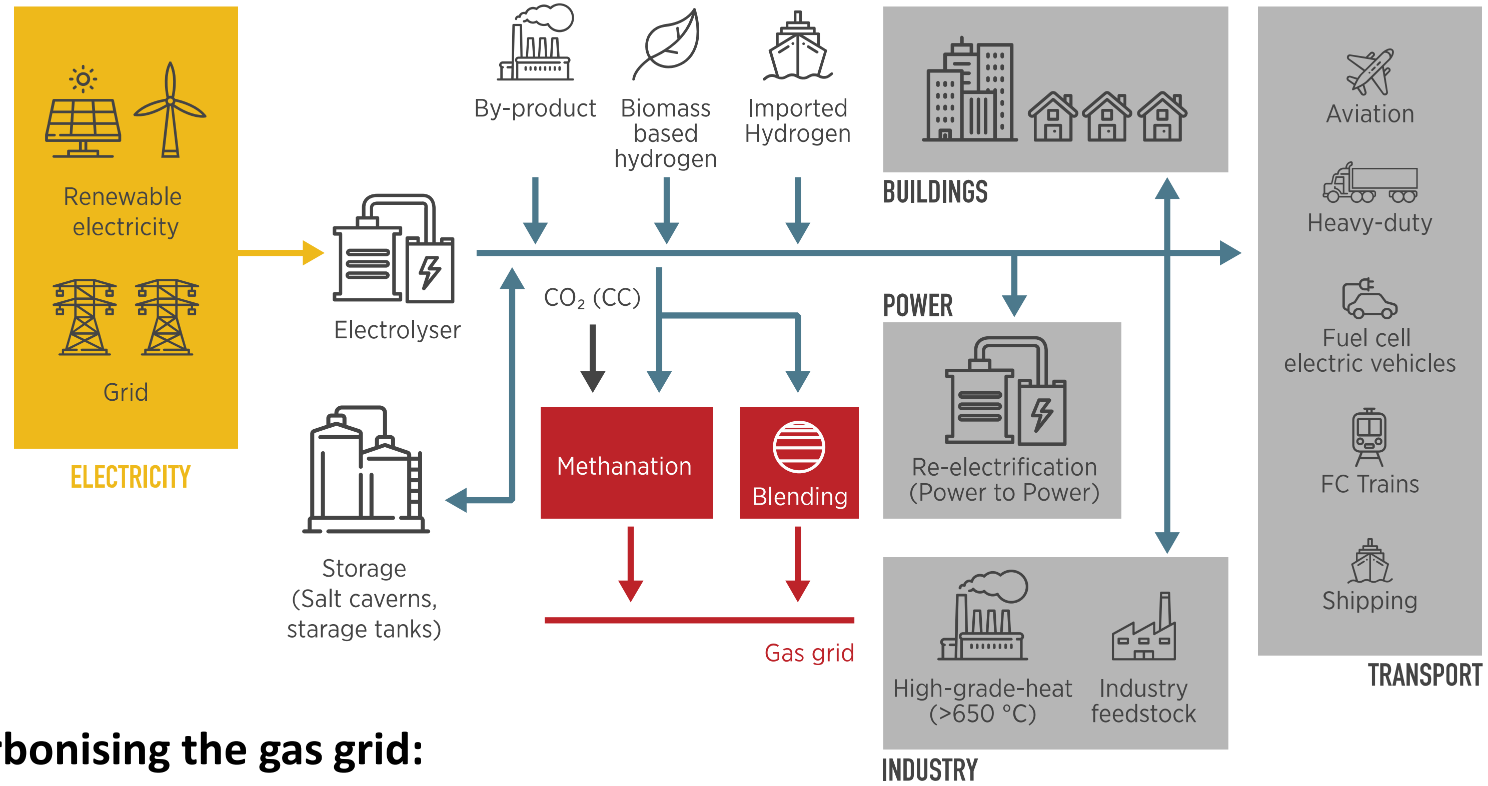


# Hydrogen in the energy transition

## Hydrogen and electricity, as energy carriers, are complementary in a world dominated by renewable energy

**Decarbonising Transport:**

- **Fuel cells**
  - FCEVs are complementary to BEVs in decarbonising road transport
  - Technical maturity within the next 5-15 years
  - Suitable for road, rail and maritime
- **Drop-in synthetic liquid fuels**
  - Complementary to biofuels
  - Mainly aviation




**Decarbonising Industry:**

- Replace fossil-fuel based feedstocks
- Applications in iron&steel, petrochemical, refining
- Potential in high-temperature processes

**Decarbonising the gas grid:**

- Capture low electricity prices on the market
- Provide seasonal storage for solar and wind
- Provide grid services from electrolysers

# Hydrogen Pathways

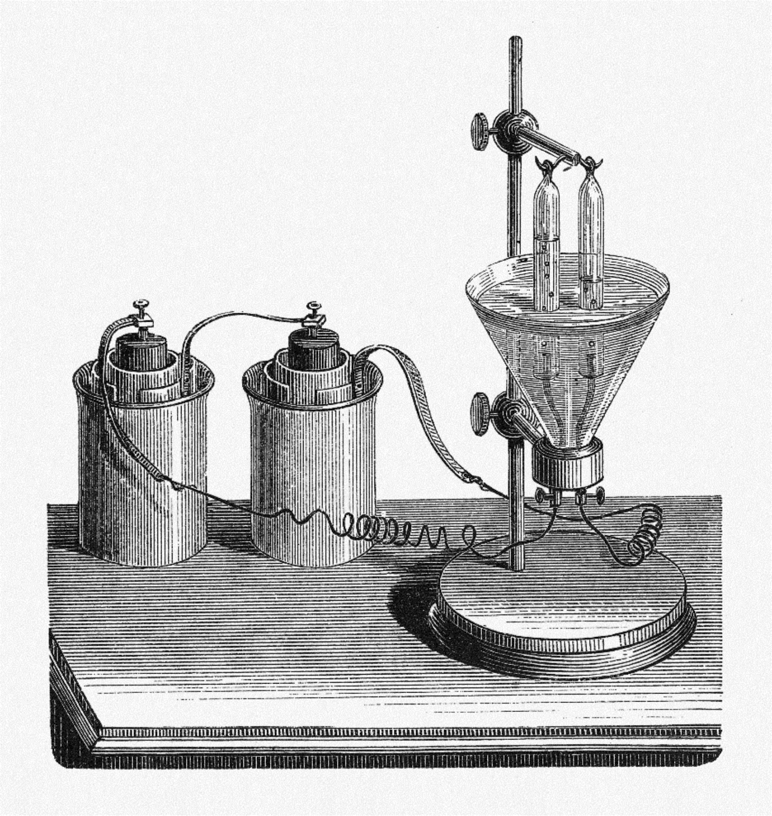
- **Short-term:**
  - o Electrolyser operators need sufficient guaranteed take-off of hydrogen production for mobility or industrial demand

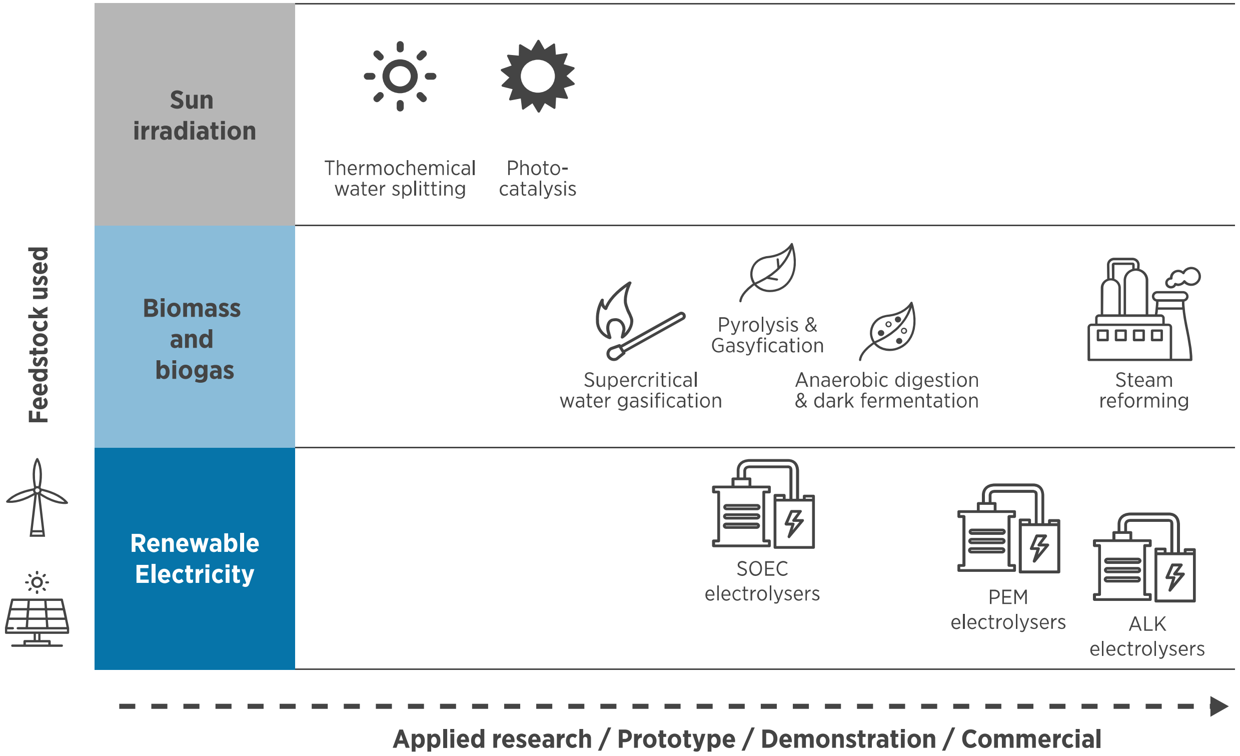
- **Medium-term:**
  - o Additional revenue streams from ancillary services market for PEM electrolysers
  - o Injection into the gas grid
    - \+ Run at high load factors
    - \- May not have enough hours in a year with low-enough prices in electricity markets

- **Long term**
  - o Carrier for linking the best renewable resources from remote locations to the global energy market
  - o On-site production for energy intensive industry from electricity grid with high shares of renewables

# Green hydrogen production pathways

- **Most established**
  - Water electrolysis
  - Steam reforming of biomethane/biogas with/without CCS and CCU
- **Less mature**
  - Biomass gasification and pyrolysis
  - Thermochemical water splitting
  - Photo-catalysis
  - Supercritical water gasification of biomass
  - Combined dark fermentation and anaerobic digestion





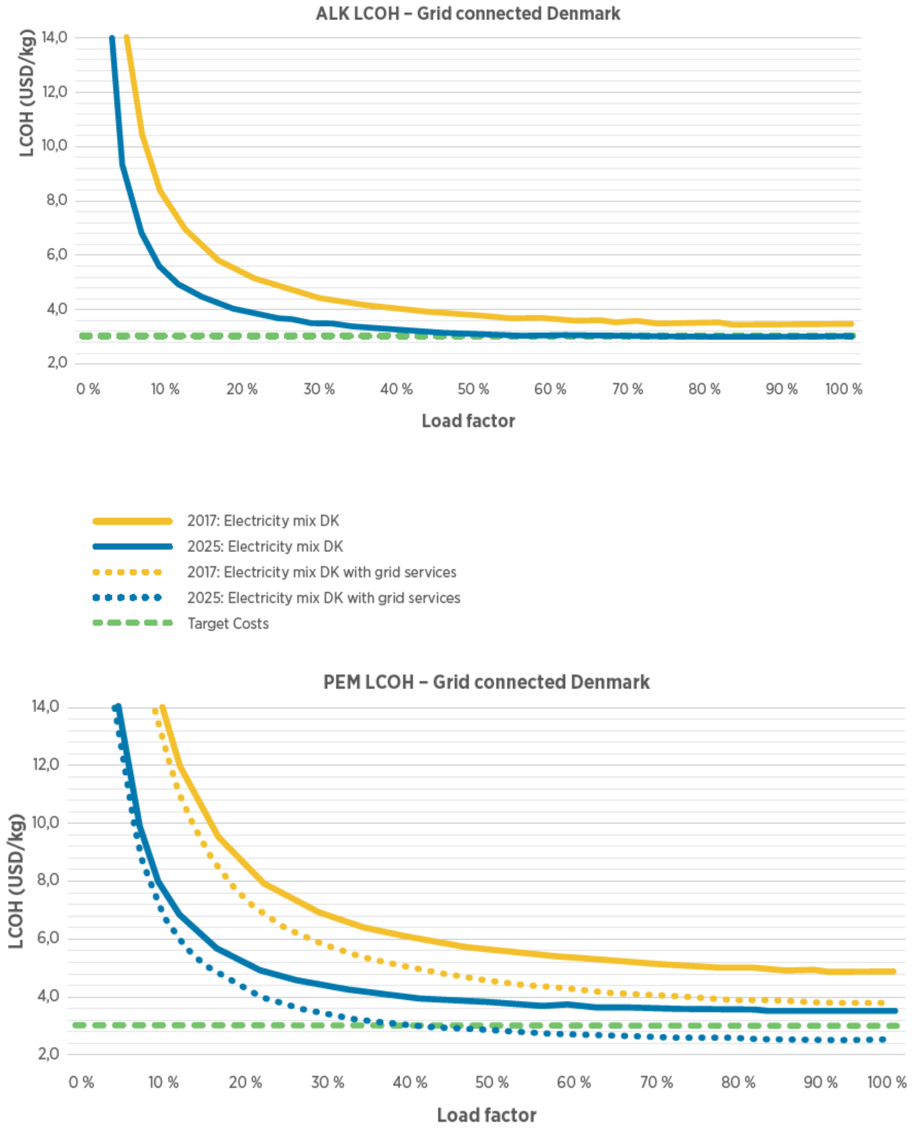
# Hydrogen production via electrolysis – grid connected

- **Alkaline**
  - **Mature**
  - Lower Capex
  - Lifetime is twice as PEM
  - Less flexible
  - Mostly active as buyer in **day-ahead market**

- **Proton Exchange Membrane (PEM)**
  - **Approaching commercial stage**
  - Higher Capex
  - Lifetime is shorter
  - Can provide ancillary services
  - Can **follow real time** prices in intra-day and balancing markets

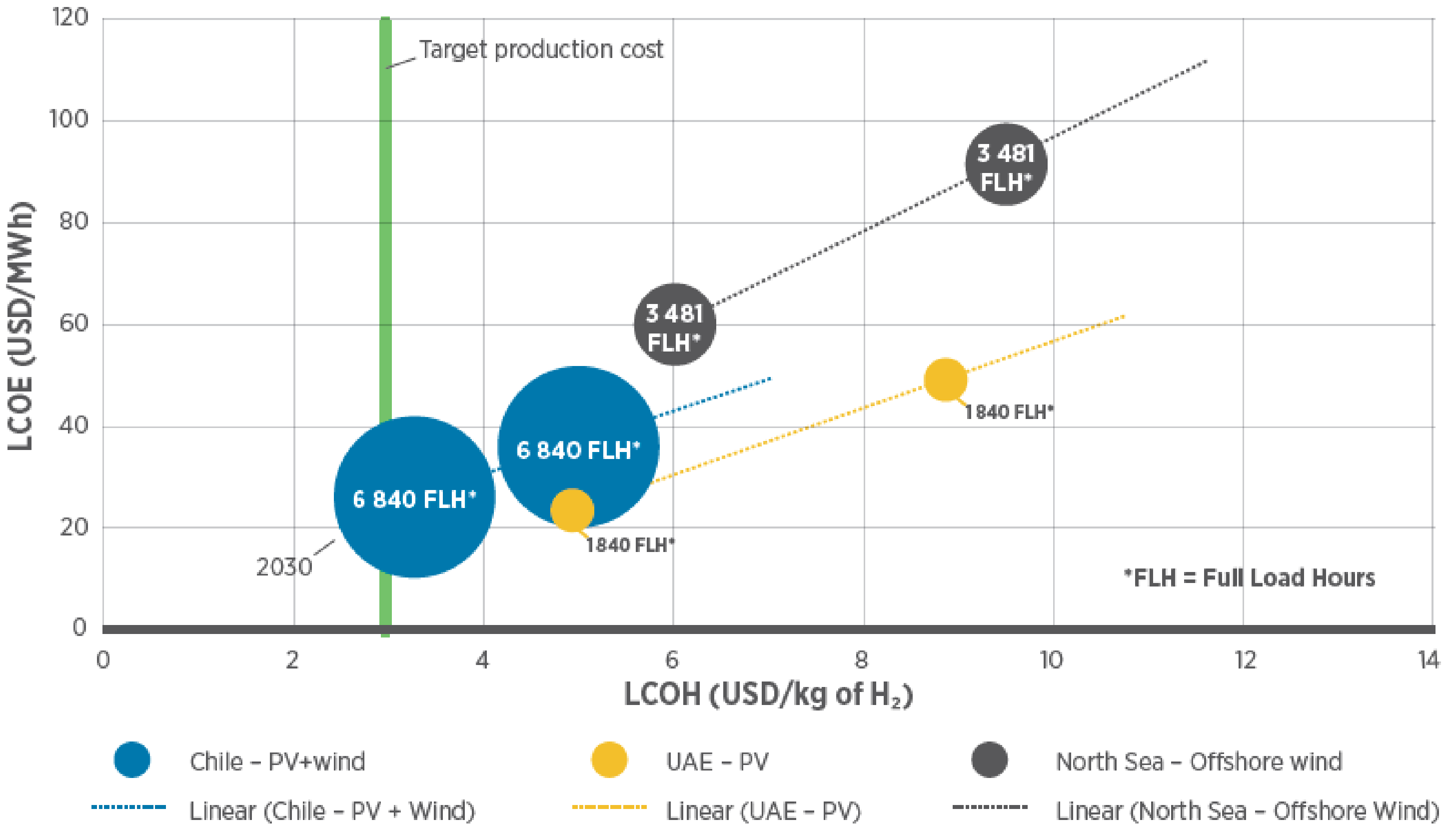
**Connected to the grid (ALK or PEM)**

- Low load factors yield a high LCOH
- At higher load factors, electricity prices are the determining factor in the LCOH



# Hydrogen production via electrolysis – off-grid solar and wind

- Requires **PEM** flexibility to be able to **follow variations** in VRE generation
- Possible to **access lowest-cost electricity** from best **renewable** resources, avoid grid cost
- **Low** capacity factor for electrolysers is a significant **challenge**
- Cost reductions in solar, wind and electrolysers will increase competitiveness over time
- Guaranteed to be 100% RE
- **Requires supply chain** to transport H2 to demand, or relocate demand/manufacturing (e.g. as happened in the past for aluminum)
- Production cost:
    - **Current**: 5–6 $/kg - **Target**: 1–3 $/kg

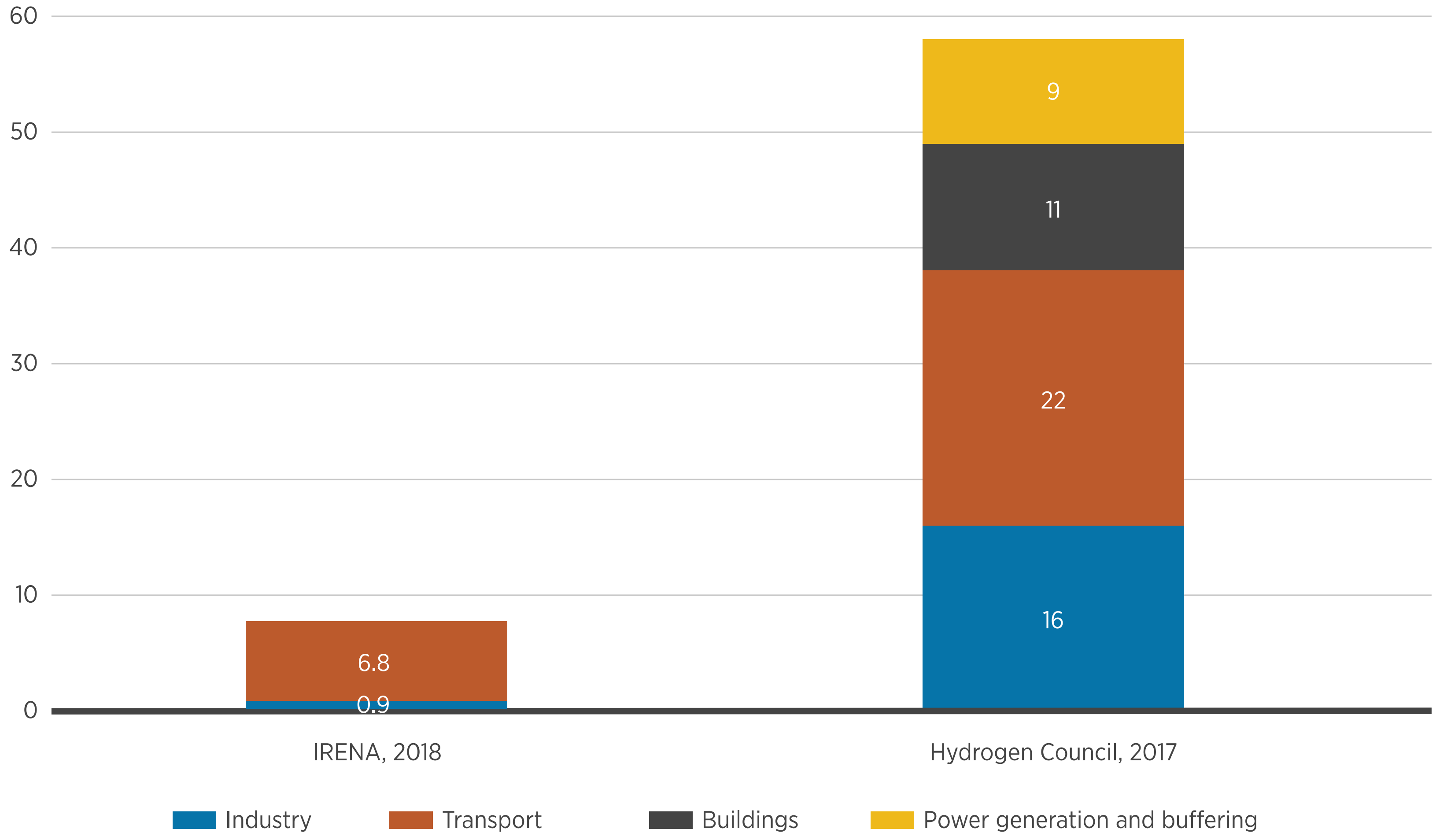



** Bubble size proportional to load factor of electrolyser, depending on full load hours of VRE*

# Hydrogen potential by 2050

**Global Potential by 2050**

- ***Technical*** *potential* is significant
- ***Economic*** *potential* will depend on cost reductions and competition with other options, with **estimates in the order of 10-100 EJ**
- Switching current feedstocks from fossil fuels to RE has a **potential of 10 EJ today** *(chart excludes feedstocks)*



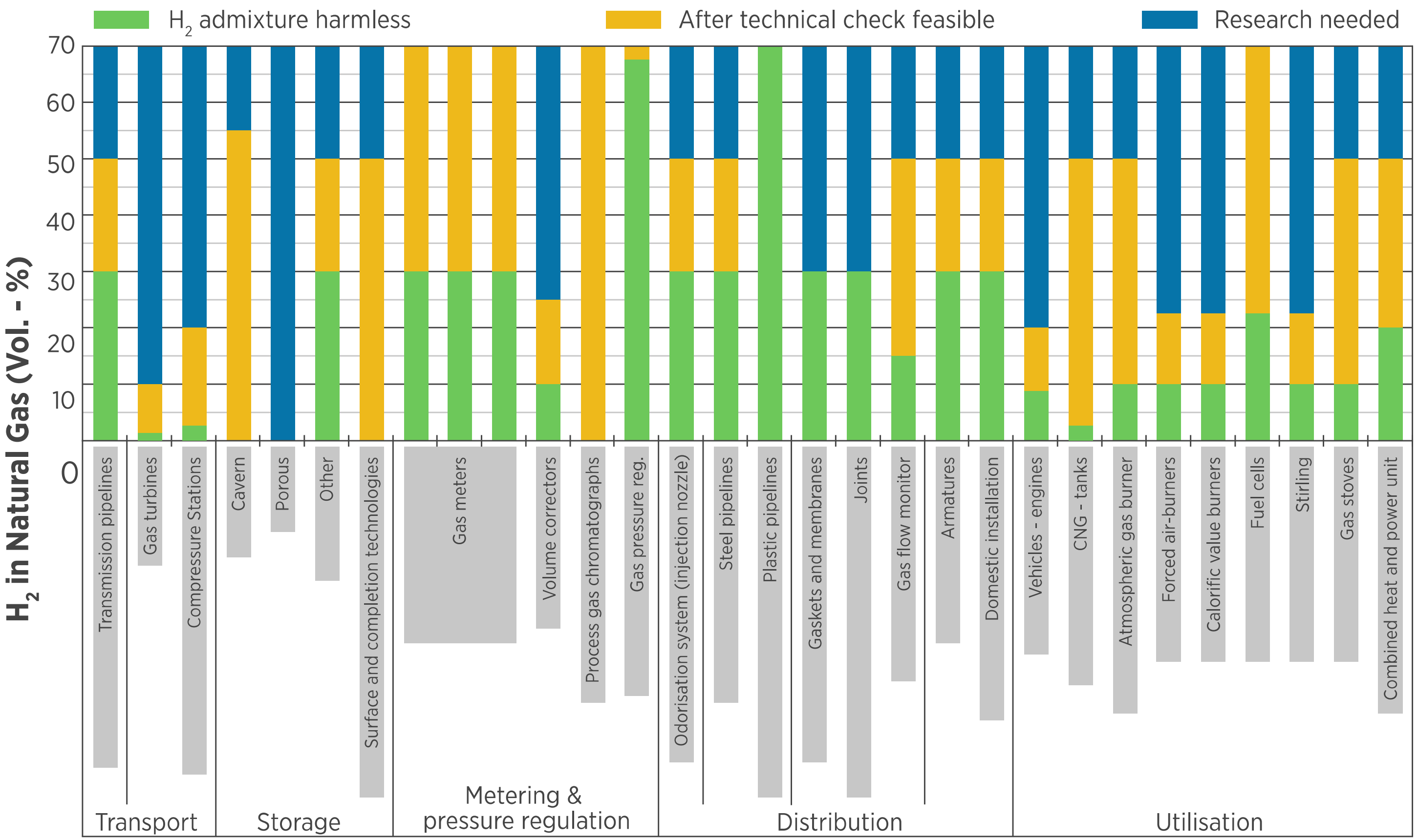
# Decarbonizing the gas grid

**Short-term:** Injection could support early-stage hydrogen infrastructure development and economies of scale

- **Up to 10-20%** blend: minor Investments
- **Greater than 20%:** significant changes in Infrastructure and end-use applications

**In the long-term:** Store large amounts of renewables, while decarbonizing gas

- **Large capacity of gas network** EU natural gas grid stores around 1200 TWh of energy
- **Enable further deployment of solar and wind** into continental power grids where renewable resources are close to gas grid
- **Possible creation of a global market** tapping into best remote/off-grid renewable resources

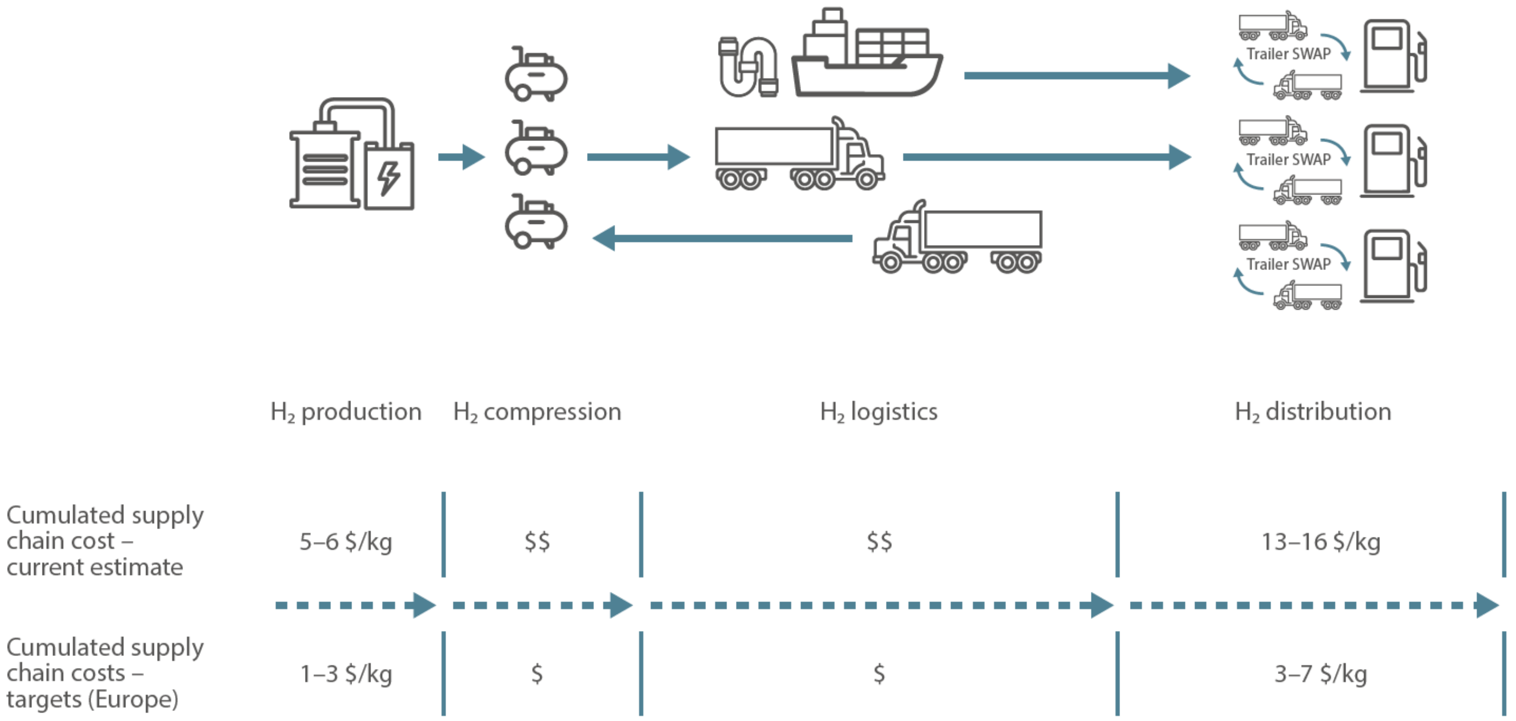


# Deploying the hydrogen supply chain

- Achieving economies of scale for hydrogen production is key
- Beyond a certain consumption threshold, on-site production is the only viable production option
- Investment in large-scale production capacities can only be justified today if a large portion of the production is sold through long term contracts

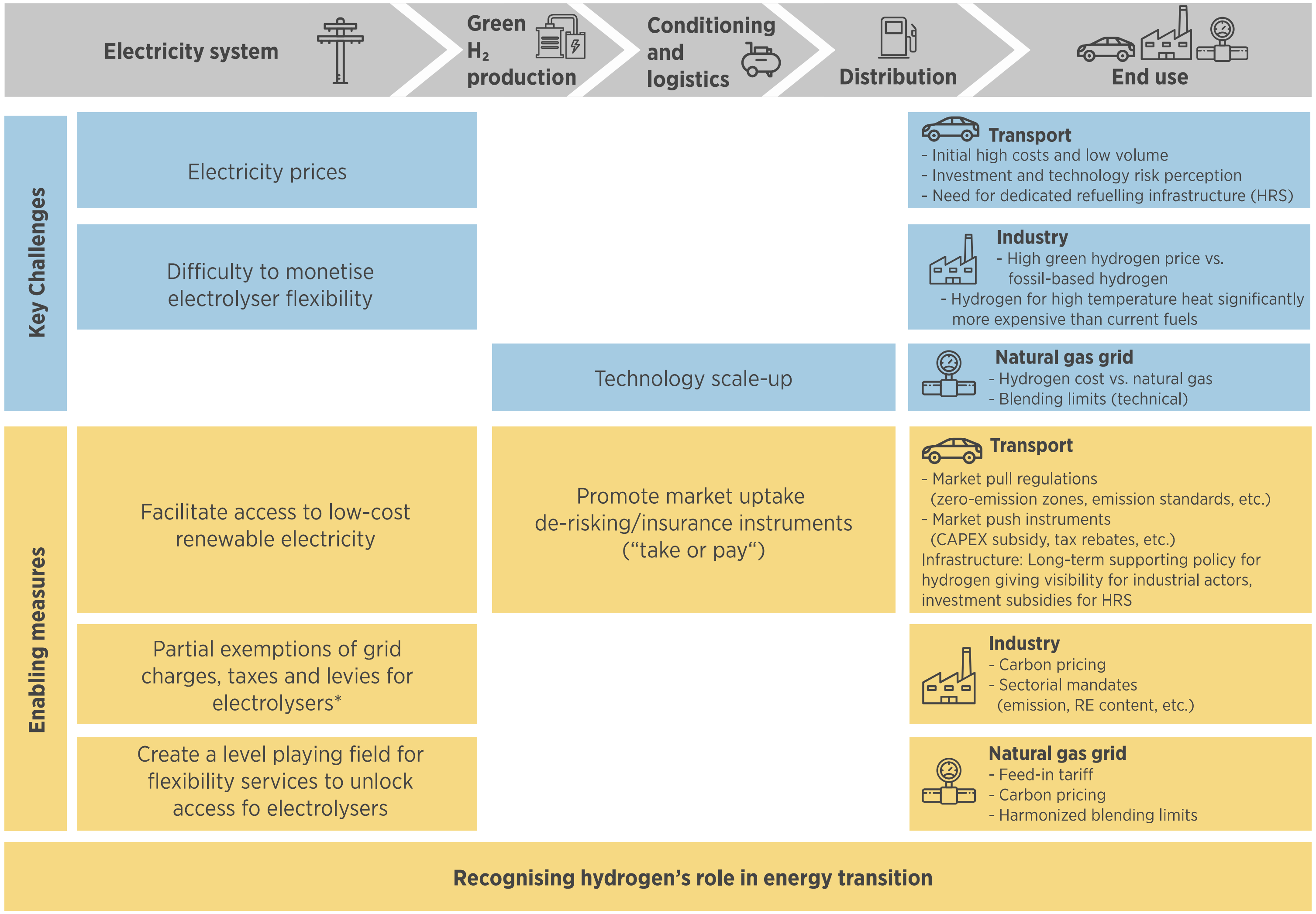
**The historic deployment pattern could serve as a blueprint for future investments in the hydrogen supply chain**

- Start with investments focused on multi-megawatt capacities for large consumers
- Second phase, new production facilities can be leveraged to become “semi-centralized” or “centralized” supplying smaller local consumers
- Regions with best renewable resources can export hydrogen globally (e.g. see current LNG market growth)



# Recommendations for policy makers

- **Technology is ready, costs need to decrease significantly**
- **Initial efforts**
  - Large-scale applications with limited investment requirements to **trigger cost reductions through scale**
  - Large industry (refineries, chemicals facilities, etc) and heavy-duty transport, difficult to decarbonize without hydrogen from renewables
- **Necessary conditions for scale-up**
  - **Stable and supportive policy framework** to encourage investments
  - Instruments aimed at final consumers can **trigger demand** and **justify** investment in infrastructure



# Thank you!