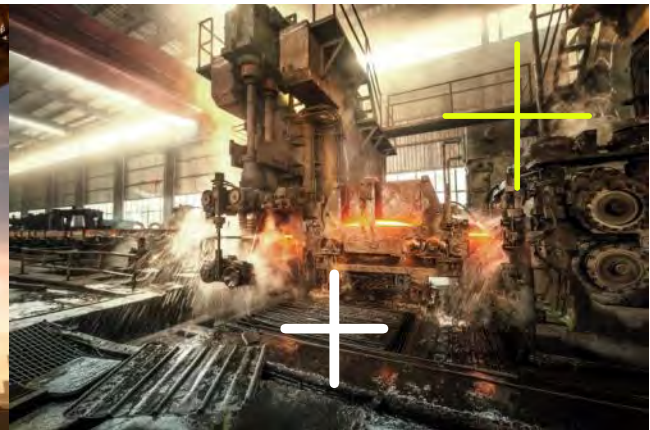




Hydrogen Technologies Overview

EMTF Monthly Speaker Series



September 1, 2021



Agenda

- Introduction to Hatch
- Hydrogen Technologies Overview
- Hydrogen Industry Today
- Industry Forecast and Costs



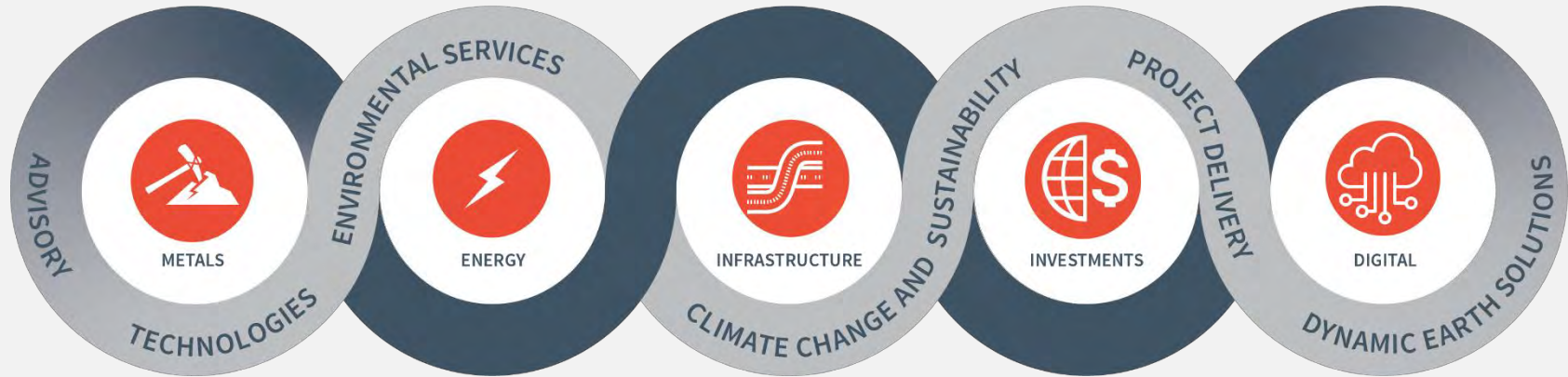
Agenda

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Hydrogen production and use opportunities

Across all parts of our business



9,000 professionals

Thinking globally, acting locally

NORTH AMERICA

Canada
Baie-Comeau
Calgary
Edmonton
Fredericton
Halifax
Kitimat
Markham
Mississauga (GDC)
Montreal (GDC)
Niagara Falls
Port Elgin
Regina
Saguenay
Saint John
Saskatoon
Sorel-Tracy

St. John's
Sudbury
Sydney
Thunder Bay
Trail
Vancouver
Winnipeg

Pittsburgh
Salem
Salt Lake City
Scottsdale
Seattle
State College
Tampa

SOUTH AMERICA

Belo Horizonte
Calama
Santiago (GDC)
Medellin
Sao Luis
Lima

AFRICA/EUROPE/ME

Cape Town
Durban
East London
Johannesburg (GDC)
Port Elizabeth
Secunda
Moscow
St. Petersburg

Gaborone
London
Manchester
Dorking
Muscat
Jubail
Abu Dhabi
Delhi

AUSTRALIA/ASIA

Beijing
Shanghai
Shenyang
Jakarta
Newcastle
Adelaide
Brisbane (GDC)
Melbourne
Perth
Wollongong



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The Many Colours of Hydrogen

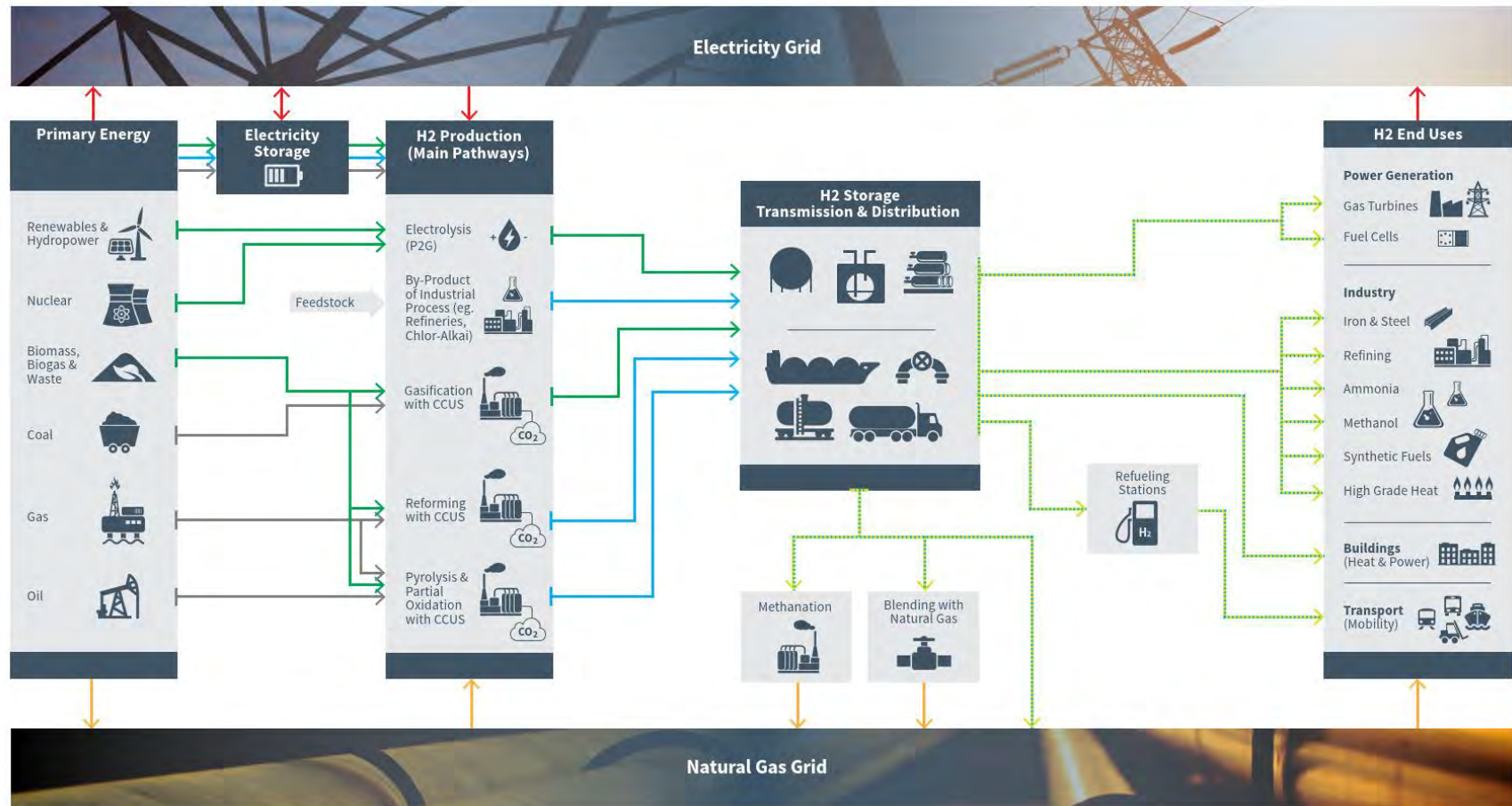
Lowering carbon content



Black	From naphtha or other petroleum products via partial oxidation
Brown	From coal via gasification
Grey	From natural gas via steam-methane reforming (SMR)
Blue	From natural gas via steam-methane reforming paired with carbon capture and storage (CCS)
Green	From water and renewable / carbon free power via electrolysis
Turquoise	From natural gas via molten metal pyrolysis

- Canada is agnostic of pathway as long as the hydrogen is clean. We are actively working through our codes and standards work and international work to establish a low carbon intensity standard
- Let's start by using similar terminology such as **clean hydrogen** or **low cost, low carbon** or **low carbon intensity hydrogen** or **hydrogen with carbon abatement**

Hydrogen Value Chain

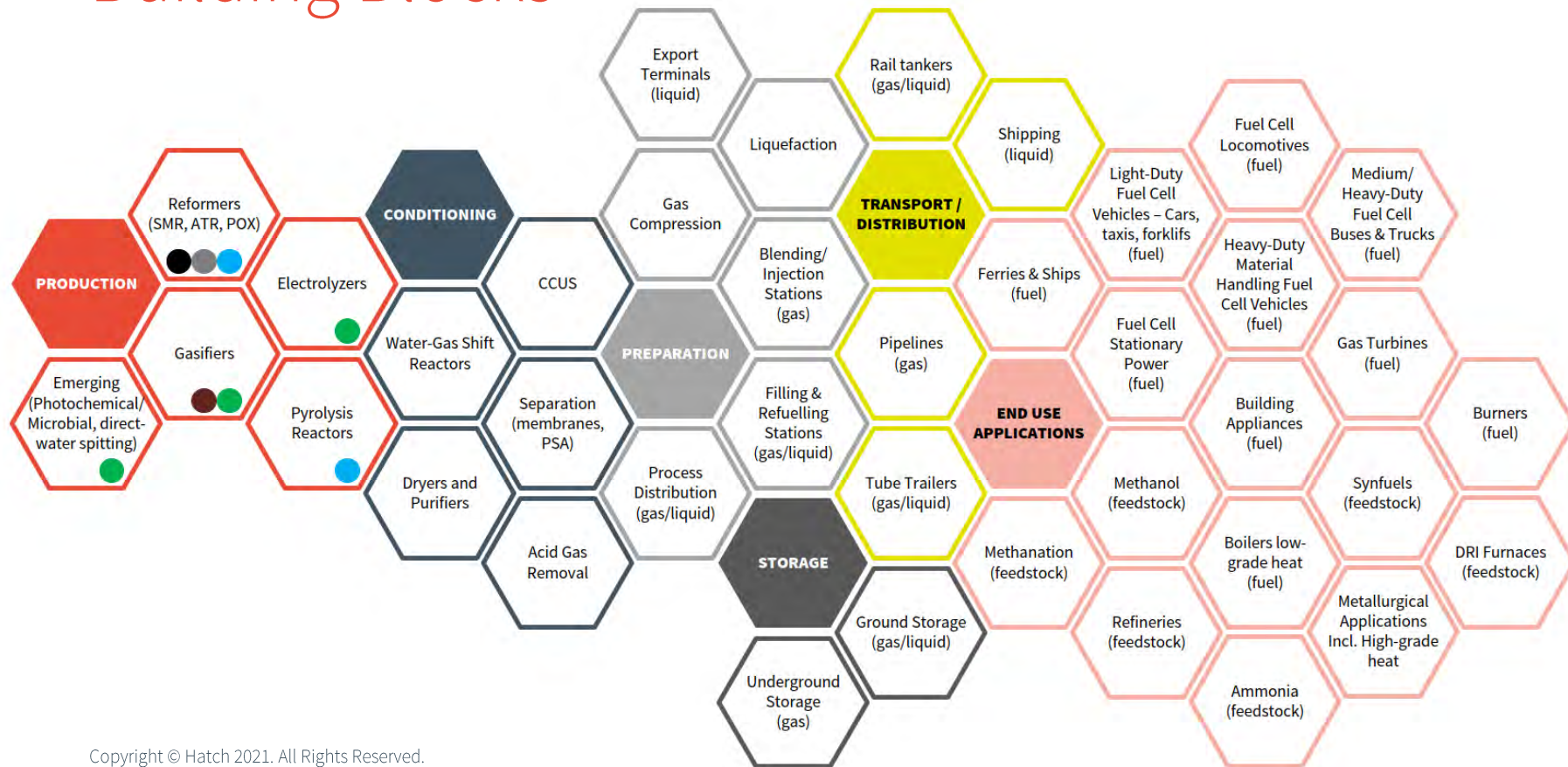


Neutral/negative carbon hydrogen production
 Low carbon hydrogen production
 High carbon hydrogen production

Hydrogen
 Natural gas
 Electricity

Rev B - 04Dec20

Building Blocks



Hydrogen electrolyzer vendor landscape

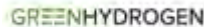
Alkaline Electrolyzers



Alkaline and Proton Exchange Membrane (PEM) Electrolyzers



PEM Electrolyzers



Other electrolyzers



Electrolyzer examples



Siemens PEM Electrolyzer
(Source: Siemens)



Cummins PEM Electrolyzer
(Source: Cummins)



Thyssenkrupp Alkaline Electrolyzer
(Source: Thyssenkrupp)



NEL Alkaline Electrolyzer
(Source: pv-magazine)

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H2 electrolyzer facilities examples



6 MW H2 Production + TT filling & NG Blending in Germany
(Source: gettyimages)



10 MW H2 Production + 20 MW Solar Farm in Japan
(Source: rechargenews.com)



1.2 MW H2 Production + TT Filling in Denmark
(Source: Air Liquide)



20 MW PEM H2 Production Expansion in Quebec
(Source: Air Liquide)

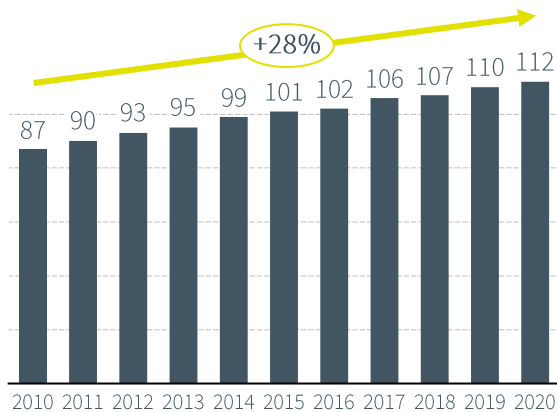


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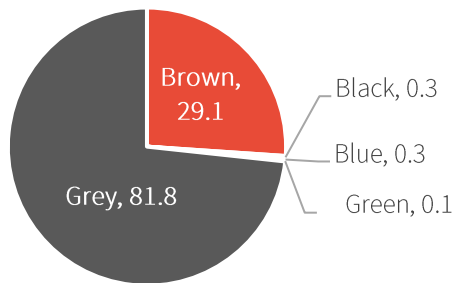
Current hydrogen market

Hydrogen Historical Demand, Mt



Source: IEA

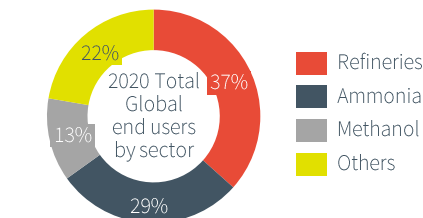
Hydrogen Production Methods



Source: IEA

2020 Hydrogen Source, (Mt)

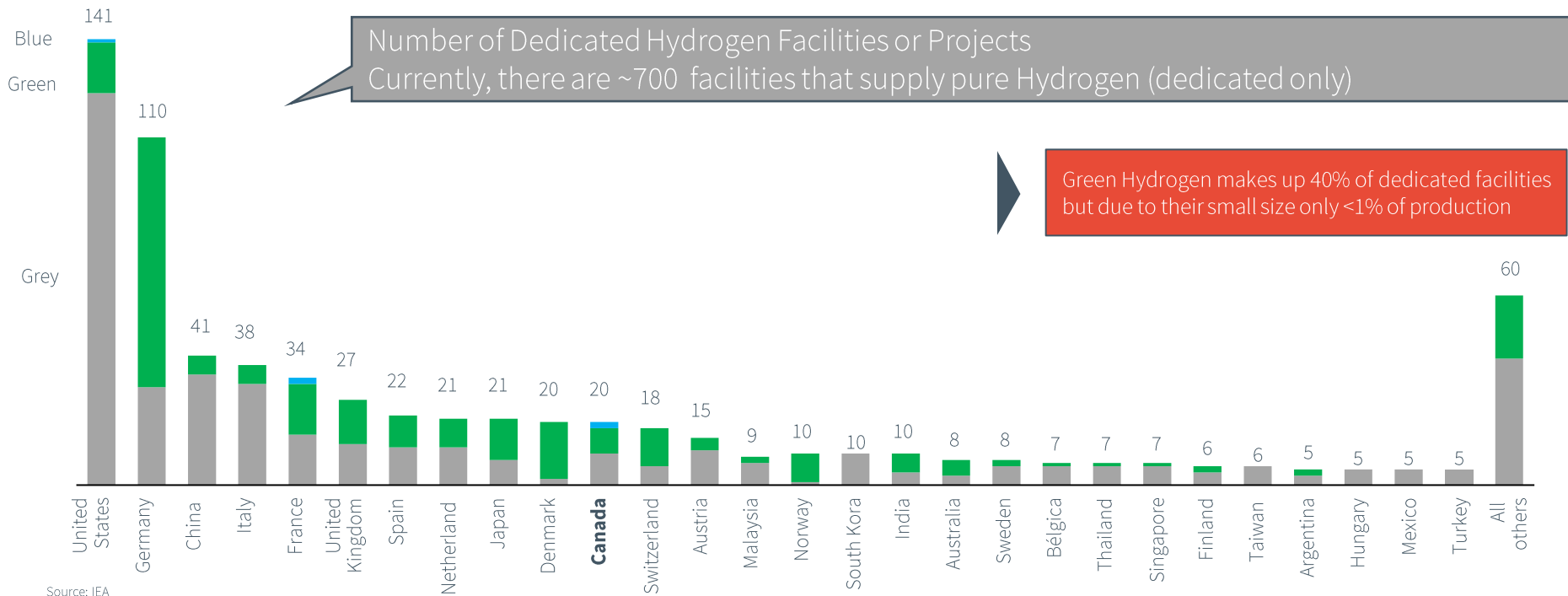
Hydrogen End Uses



Source: IEA

Black	From naphtha or other petroleum products via partial oxidation
Brown	From coal via gasification
Grey	From natural gas via steam-methane reforming (SMR)
Blue	From natural gas via steam-methane reforming paired with carbon capture and storage (CCS)
Green	From water and renewable / carbon free power via electrolysis
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Global hydrogen facilities



Source: IEA

The figure shows facilities that produce pure hydrogen from either hydrocarbons or from electrolyzers. Facilities that self produce hydrogen are not represented.



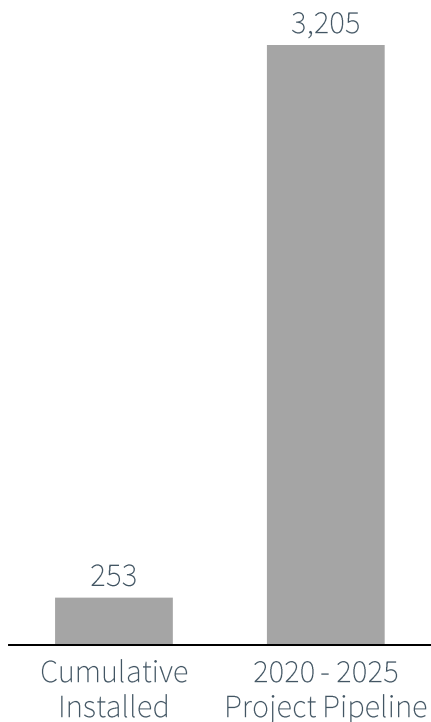
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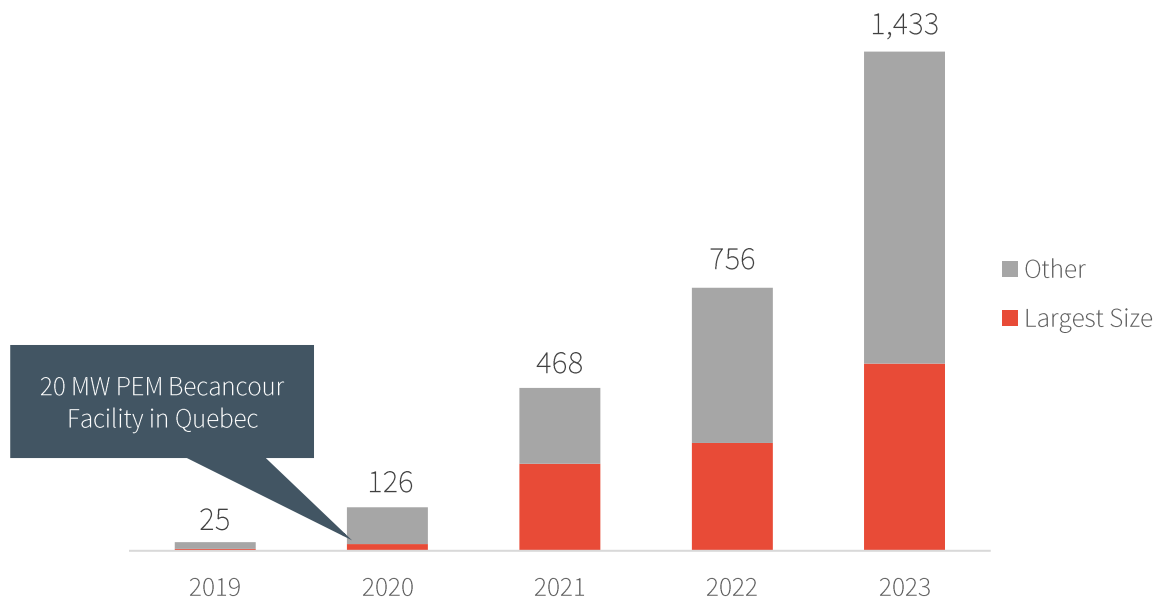
Green hydrogen project announcements

Cumulative installed capacity and project pipeline, MW)



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Project Announcements by year, MW

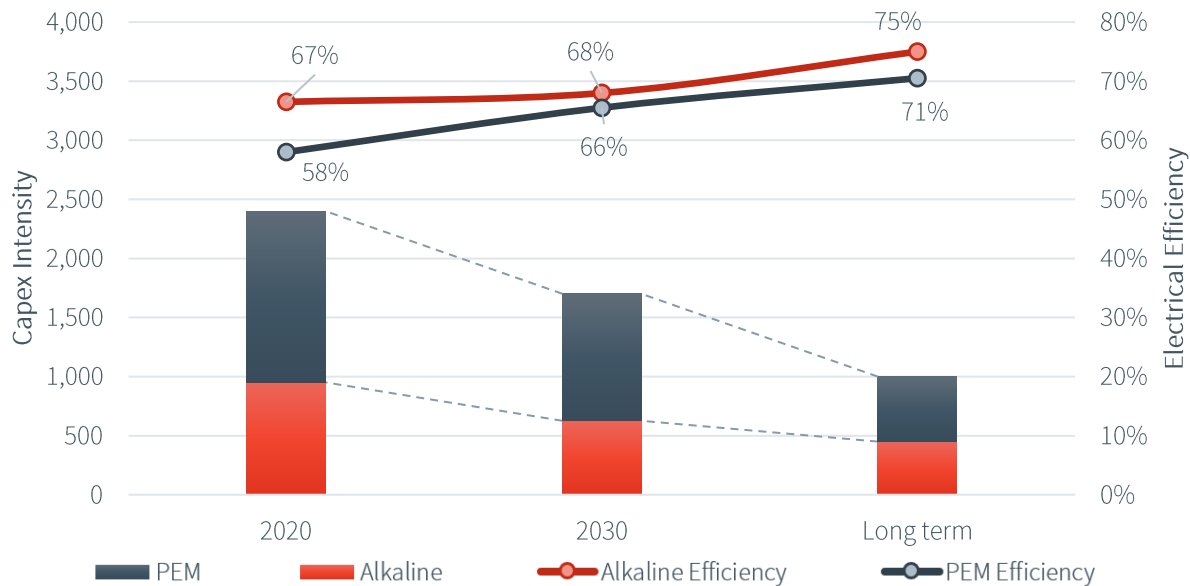


5 MW = ~ 100 kg of H₂/h

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Capital intensity for electrolyzers is expected to decrease

Electrolyzers: CAPEX Intensity, USD/kWe and Electrical Efficiency, %LHV



LHV = lower heating value

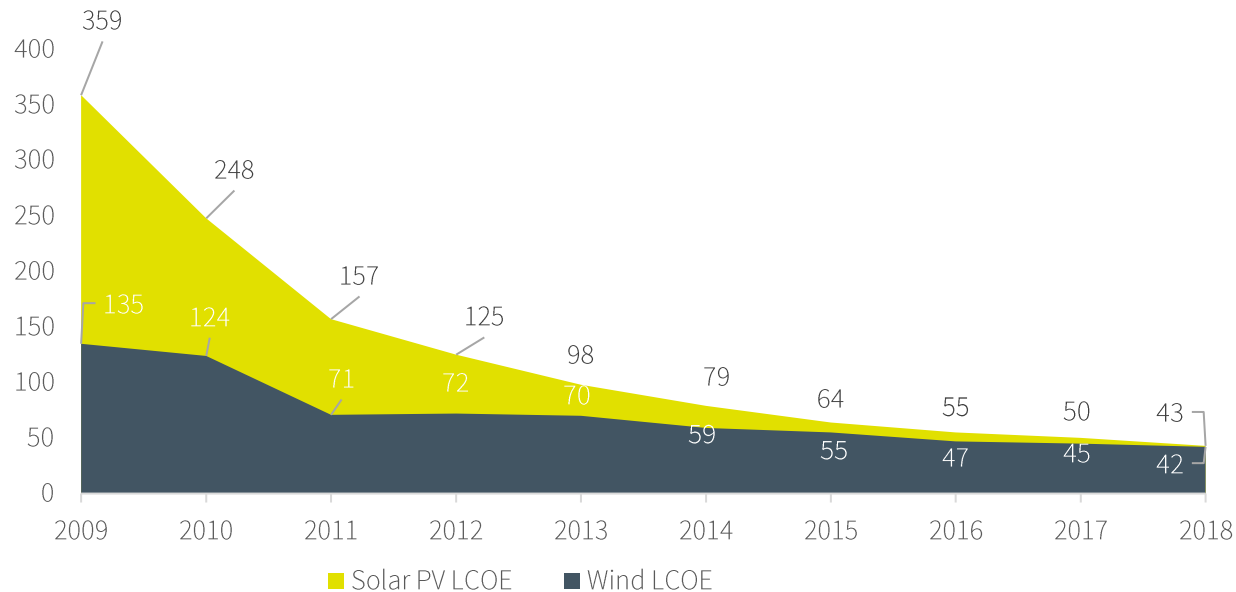
Source: Buttler and Spliethoff, Agora Energiewende and Frontier Economics Schmidt et al., Element Energy, 2018.

- Current CAPEX Intensity:
 - 950 USD/kW (Alkaline).
 - 1,450 USD/kW (PEM).
- Cost reductions will be influenced by:
 - Technologies.
 - Economies of scale in the manufacturing processes.

For alkaline and PEM systems CAPEX are estimated to decrease by up to 20% and 40%, respectively, in the long term

As renewable energy costs continue to drop, Green Hydrogen becomes more competitive

Unsubsidized levelized cost of energy, USD/MWh



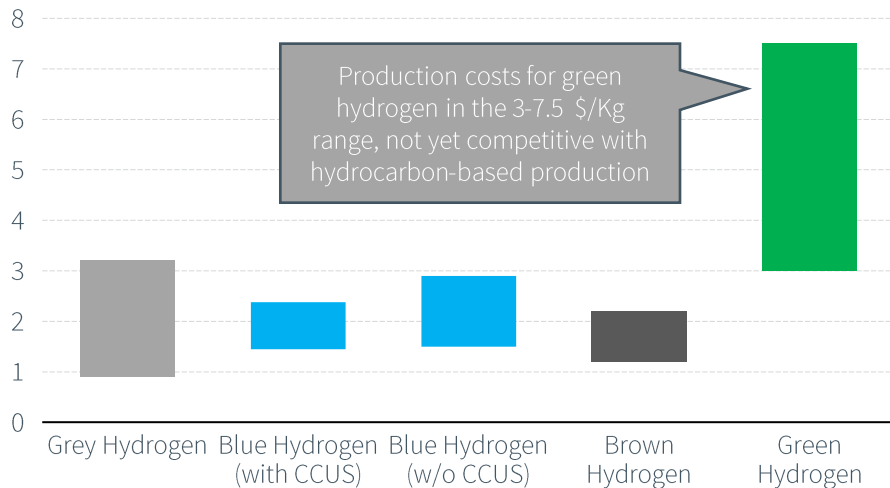
Source: Lazard

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- Cost of wind and solar energies have dropped by 69% and 88% respectively in the last decade.
- Green hydrogen is expected to follow the same trend, as electrical power is around 50-80% of the total cost of hydrogen.

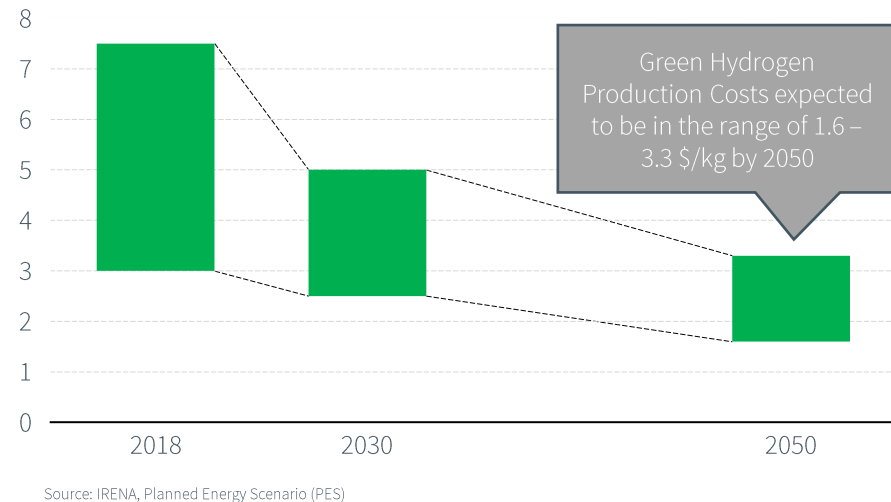
Hydrogen production cost forecast

Current Production Costs, USD/kg



Production costs for green hydrogen are not currently competitive

Green Hydrogen Projected Costs, USD/kg



Projections based on the expectation that renewable energy costs drop further (LCOE of solar PV and onshore wind are expected to fall by 71% and 58% respectively by 2050).



Thank you

For more information, please contact:

Sujin Wren

Direct: +1 416 525 2335

sujin.wren@hatch.com

www.hatch.com

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