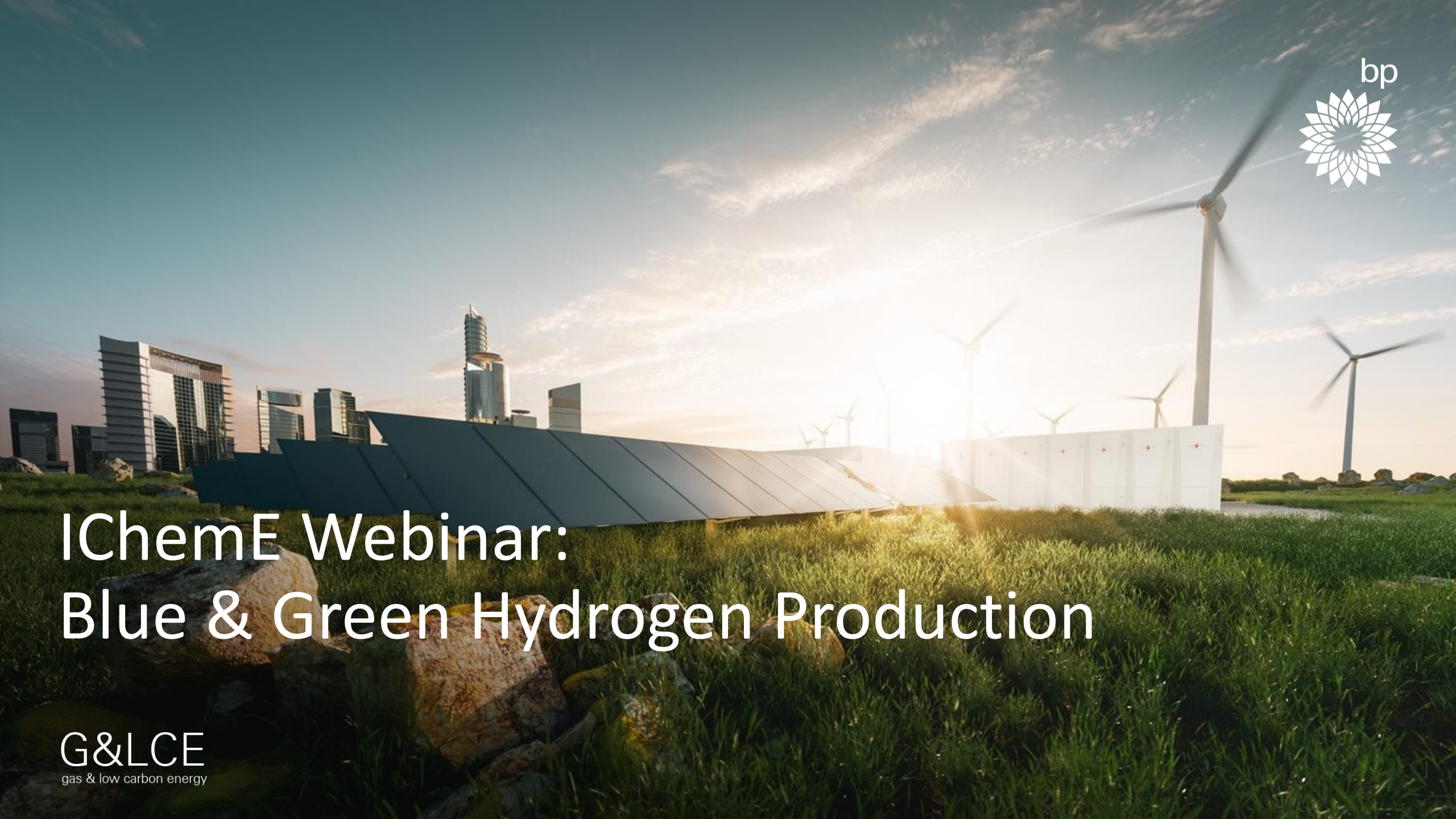


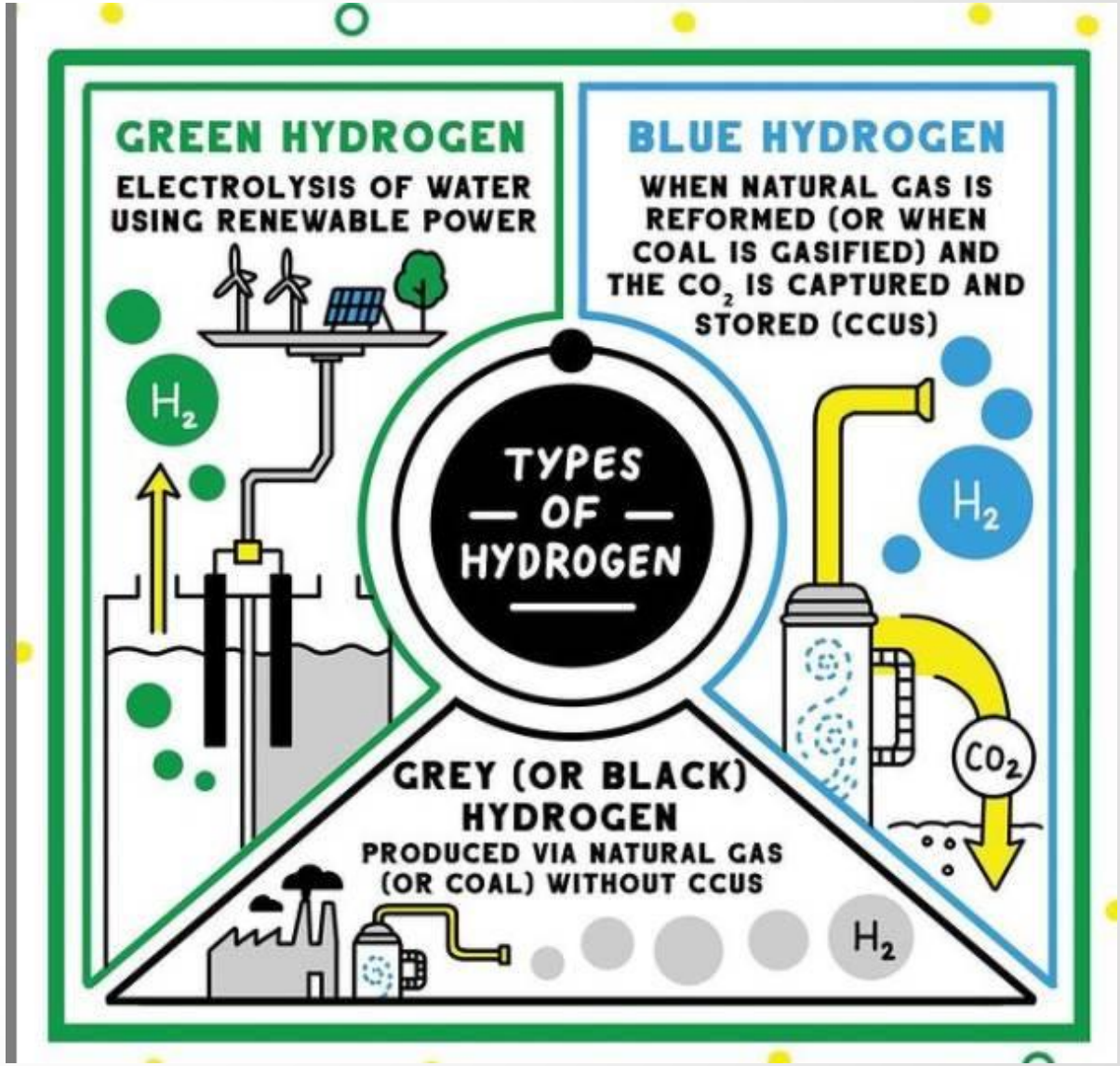
IChemE Webinar:
Blue & Green Hydrogen Production

G&LCE
gas & low carbon energy


bp
our ambition
to become a
Net Zero company
by 2050 or sooner and to help
the world reach that goal

Blue and green hydrogen

- Both blue and green hydrogen have a strategic role to play in the energy transition and policy is required to enable their full potential.
- The clean hydrogen market is relatively immature and there is a lot of uncertainty as to how the market will scale.
- Policy will be critical to support the development and growth of green and blue hydrogen.
- New gas infrastructure and equipment should be CCUS or hydrogen-compatible or ready to avoid lock-in of unabated gas.



Blue & Green Hydrogen – Scale up

"A combined scenario [of Blue and Green Hydrogen] makes best use of complementary global resources: each region can follow a different build-out path and trade with other energy-rich regions, if advantageous."

Exhibit 1: Core assumptions for selected hydrogen production pathways

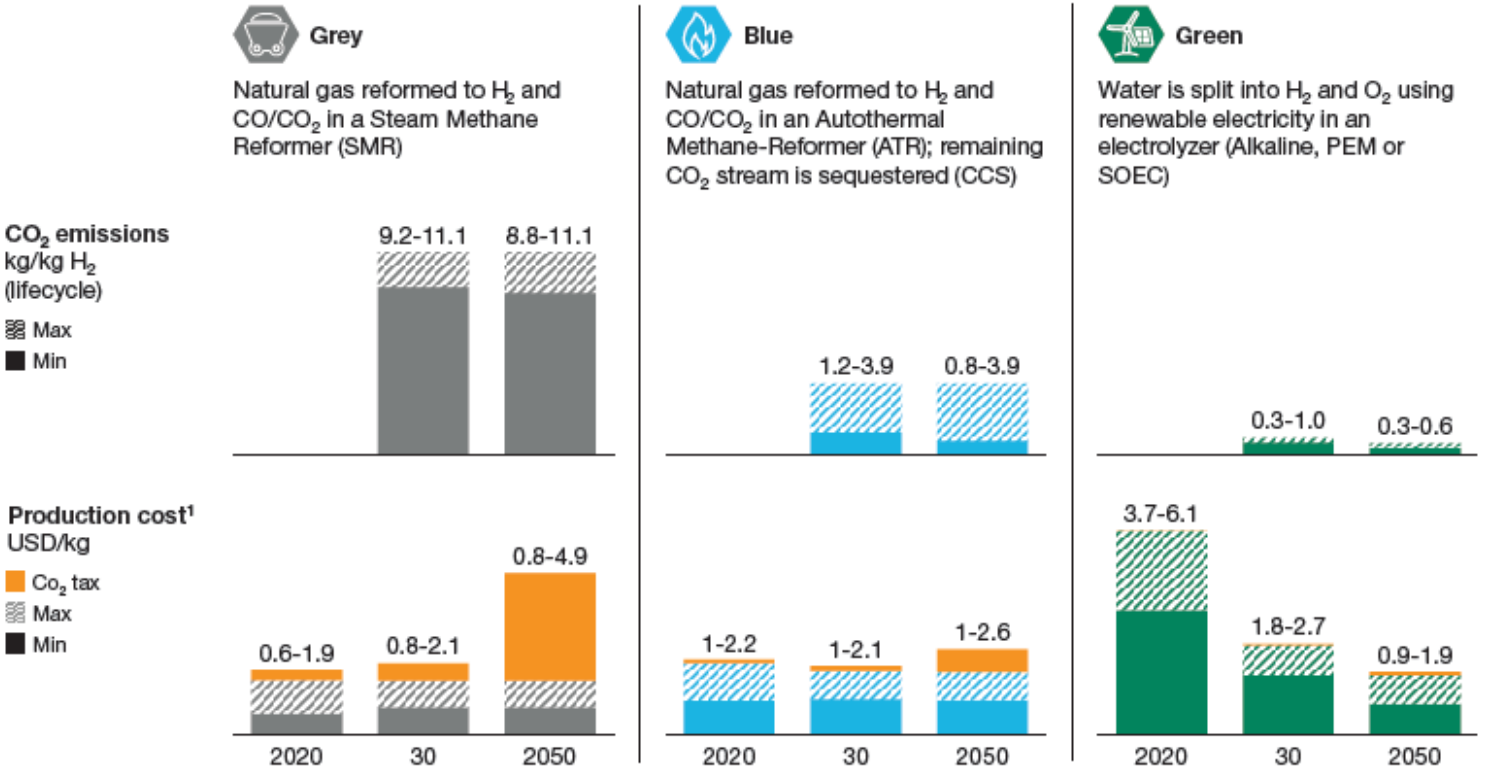
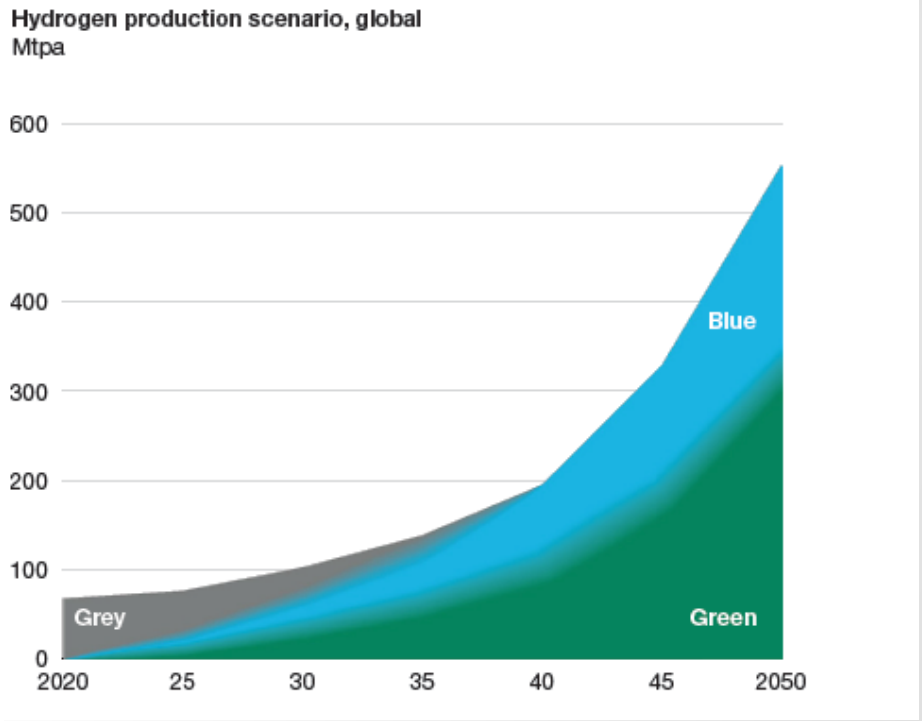


Exhibit 2: Combined scenario for decarbonized hydrogen



Source: *Hydrogen Decarbonization Pathways*, Hydrogen Council, Jan 2021

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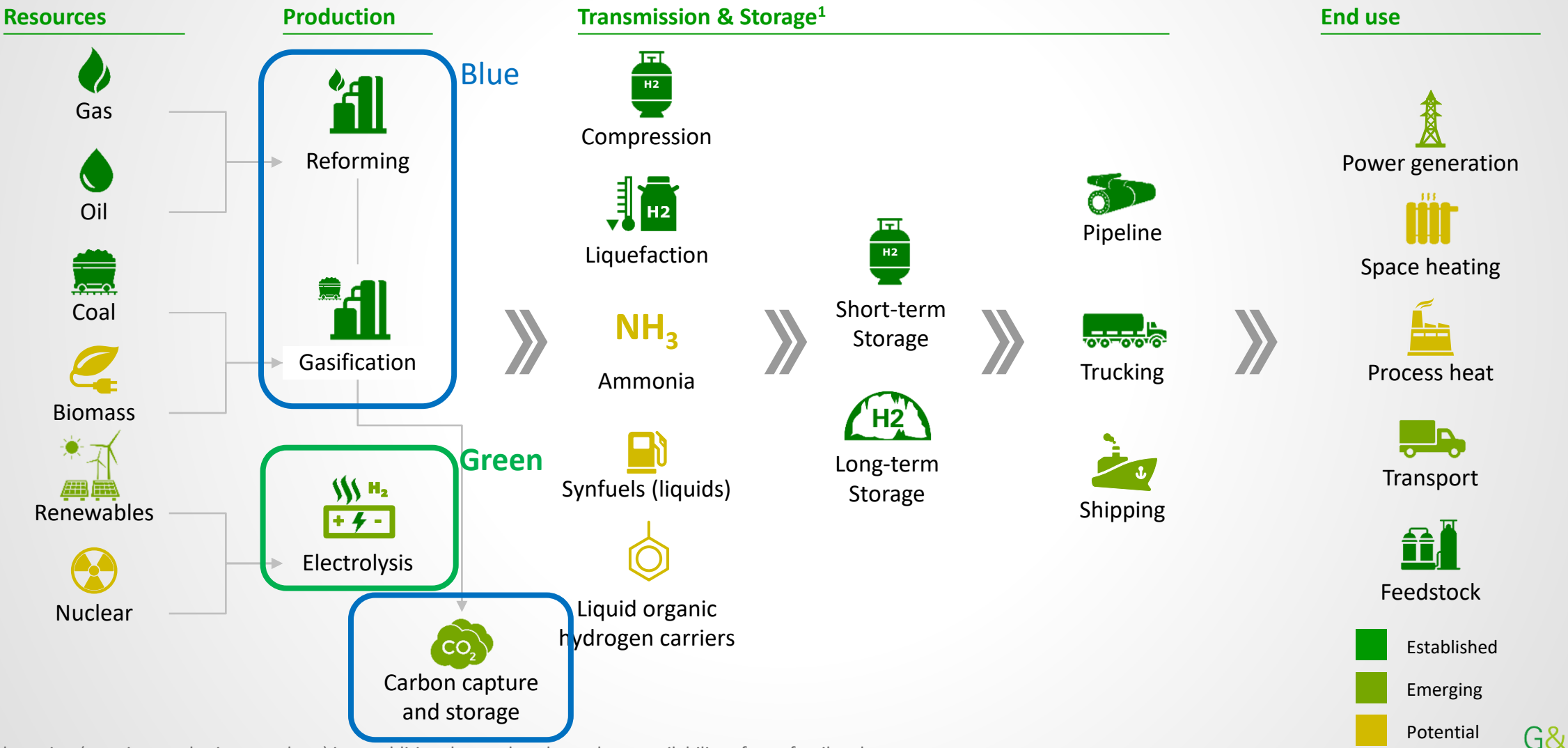
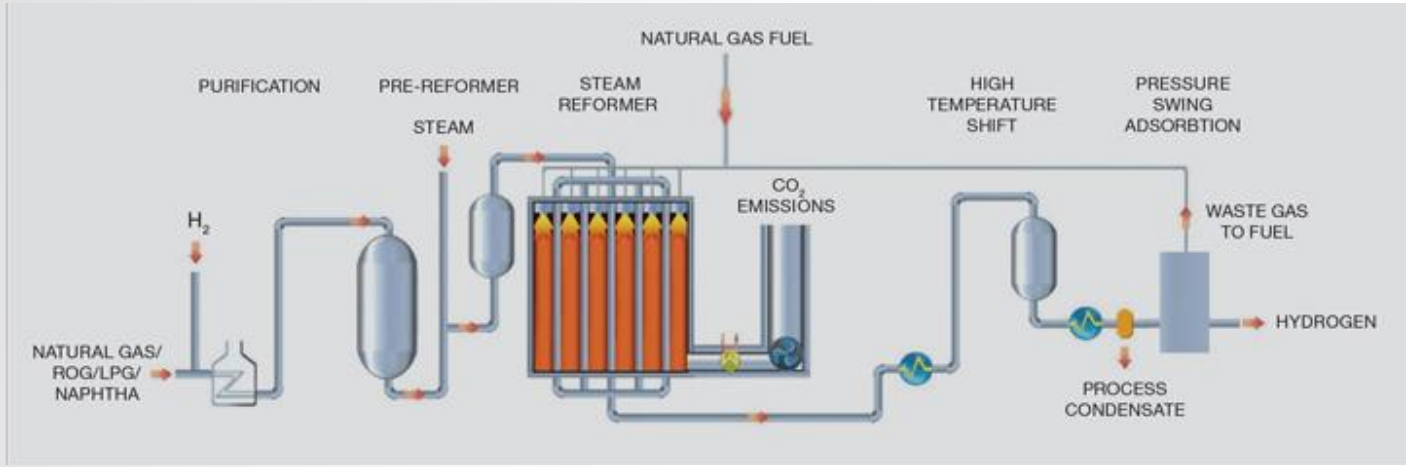
Hydrogen value chains



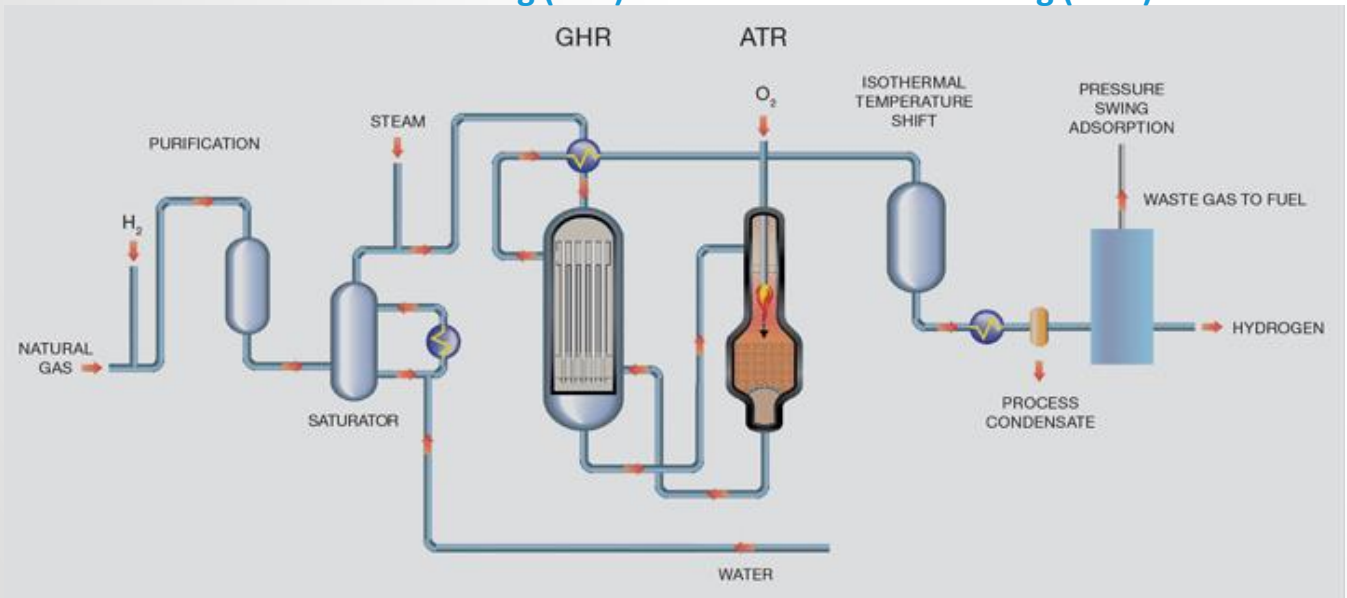
1 Methanation (creating synthetic natural gas) is an additional route but depends on availability of non-fossil carbon.

Safety in Production: Blue Hydrogen

Steam Methane Reforming (SMR)



Autothermal Reforming (ATR) and Gas-heated Reforming (GHR)



Industry Standards:

- Nothing specific to Gas Reforming. SMR, ATR and Carbon Capture (refer next slide) are mature technologies
- **ISO/TS 19883** *Safety of pressure swing adsorption systems for H2 separation and purification*

HSSE risk management focus:

- Jet Fire - Hydrogen or Natural Gas
- VCE - Hydrogen or Natural Gas
- CO2 release - asphyxiation
- Hydrogen Embrittlement

Areas for focus:

- Hazards associated with CO2 Use, Transport and Storage at scale
- Potential for less experienced operators to try reforming - need for a focused standard?

Source: *Clean Hydrogen. Part 1: Hydrogen from Natural Gas Through Cost Effective CO2 Capture*, Bill Cotton, The Chemical Engineer, Mar 2019

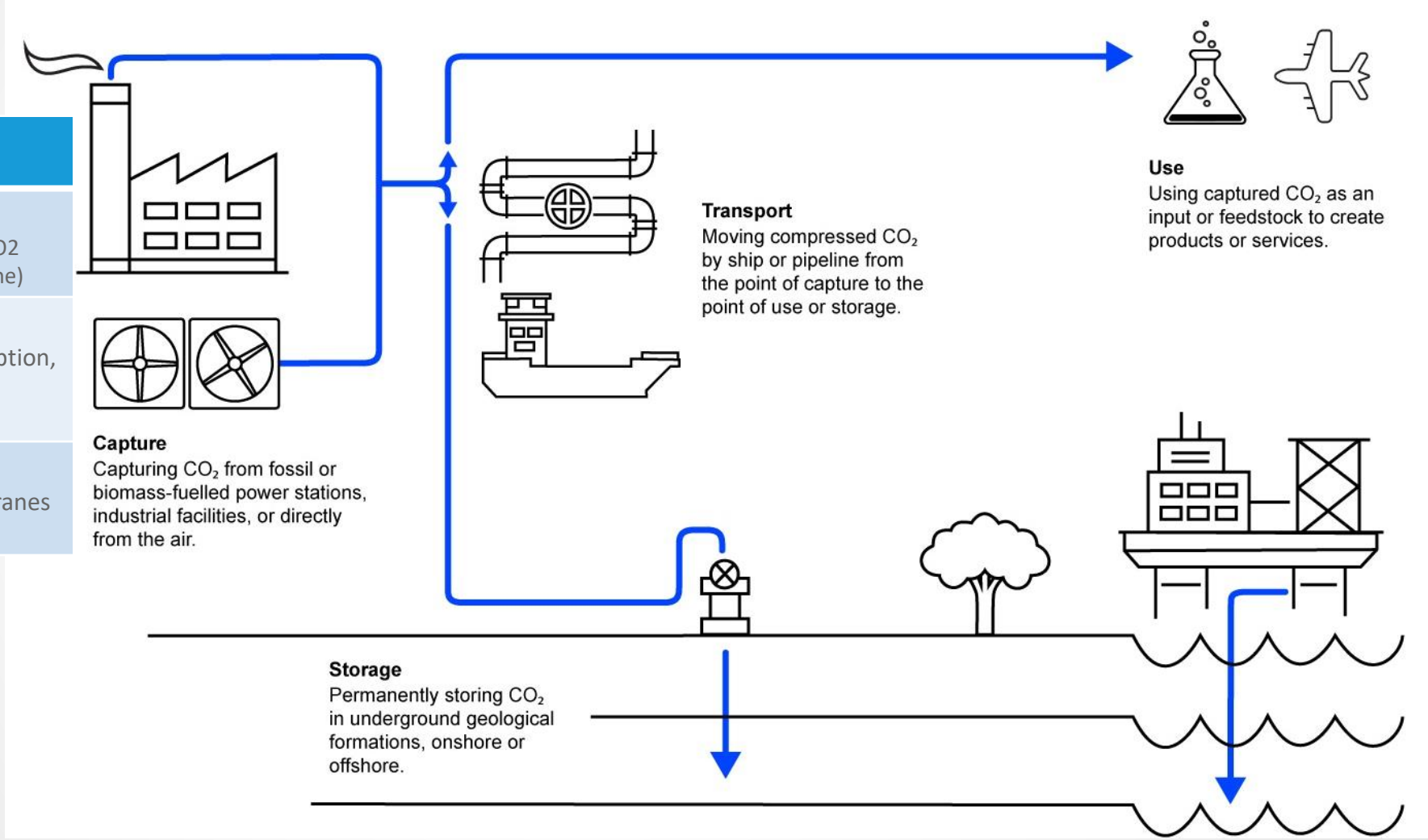
Carbon Capture, Use & Storage – An overview

CO2 Capture for Blue H2

Chemical absorption
Processes using the reaction between CO2 and a chemical solvent (e.g. ethanolamine)

Physical Separation
A range of processes based on adsorbtion, absorption, cryo separation and compression.

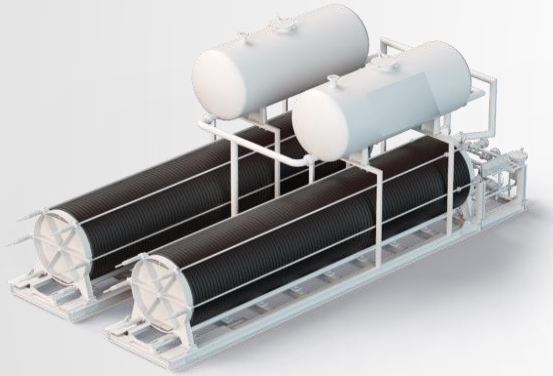
Membrane Separation
Use of polymeric or inorganic membranes with high CO2 selectivity



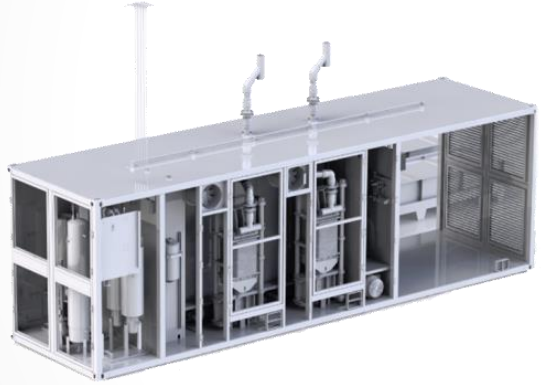
Source: *About CCUS*, IEA Technology Report, April 2021

Safety in Production: Green Hydrogen Production

- Operation consists of electrical feed/rectification, water purification, KOH supply (alkaline only), electrolysis and H2/O2 separation.
- Lower severity section of value chain - H2 produced at relatively low pressure (1 to 30 bar) and temperature



Alkaline Electrolyser



PEM Electrolyser

HSSE risk management focus:

- **Hydrogen Jet Fire**
- **Hydrogen Explosion**
- **High-Voltage Electrical**

Industry Standards:

- **ISO 22734-1** *Water electrolysis in industrial and commercial applications* **(Under review)**
- **NFPA 2** *Hydrogen Technologies Code*

Note: NFPA2 contains general requirements with reference to UL/CSA standards based on ISO standard.

Areas for focus:

- **Process safety capability** for new entrants to Green Hydrogen Industry
- **Interfaces** between packaged units
- High reliability **mitigation barriers** – gas detection, ventilation, suppression, explosion relief

Further Information

bp Resources:

Hydrogen Explainer *(links to podcasts and other resources)*

Key Hydrogen Safety organisations:

- Centre for Hydrogen Safety (AIChemE) – great source of practical safety information including h2tools.org
- HySafe - international body for sharing H2 safety research. Bi-annual International Hydrogen Safety Conference.
- Fuel Cell & Hydrogen Joint Undertaking – collaboration of EU govt, Industry and Research institutions. Long list of projects.

Information used:

- Hydrogen Council – Hydrogen Decarbonisation Pathways
- Clean Hydrogen. Part 1: Hydrogen from Natural Gas Through Cost Effective CO2 Capture - Features - The Chemical Engineer
- Carbon capture, utilisation and storage - Fuels & Technologies – IEA