SUSTAINABLE AND COMPETITIVE ENERGY SUPPLY: THE ROLE OF EFFICIENCY AND INNOVATION

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OUTLINE

- Drivers for innovation in O&G Industry
- Roles of O&G Stakeholders
- Innovations Focus for Producers under Energy Transition pathways

Challenges Facing O&G Industry: Drivers of innovation

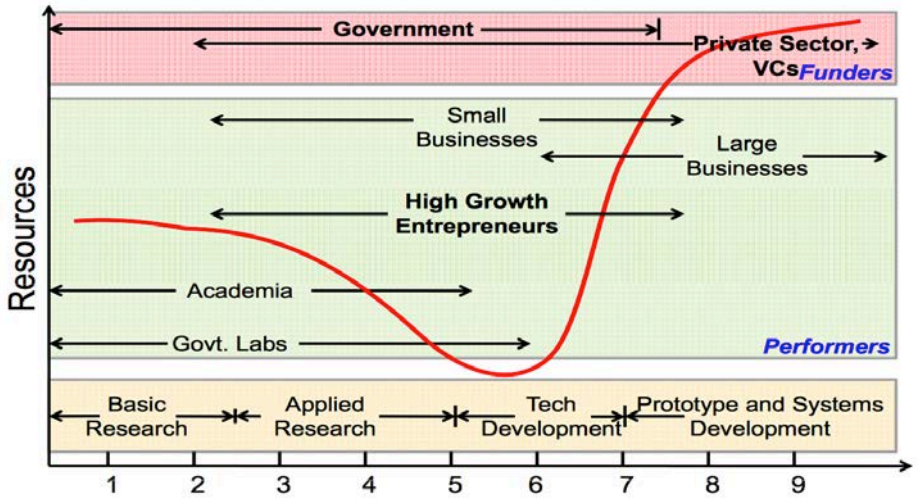
- **Minimize Costs to Remain Competitive:**
  - Optimize economic value from O&G and continue to mitigate potential of major reduction in demand for O&G (e.g. SDS scenario)
  - Potentially new business models and products that represent new revenue streams
- **Environmental Issues:**
  - Take measures towards addressing the Climate change challenge (Paris Agreement) and fostering low carbon footprint,
    - Low hanging fruit for decarbonizing energy systems:
      - Energy conservation
      - Improving Energy Efficiency
      - Renewables (solar and hydrogen)
    - Development of new, more complex / disruptive innovative tech. e.g. CCUS and CDR, Hydrogen economy
- **Improving performance to ensure the valorization of assets:**
  - Aim to achieve close to 100% reliability (i.e. no unplanned shutdowns, secure industrial assets, etc.)
  - Using digital and automated solutions to enhance economics of current assets (4th IA)

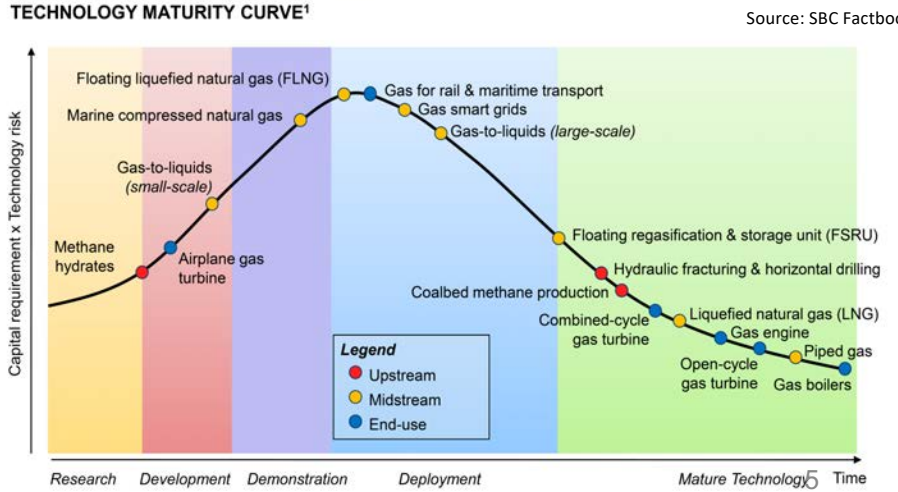
Long-term success involves continued innovation and research, as well as collaboration across the sector

Roles of O&G Stakeholders in innovation to address challenges

Innovation, R&D and Technology Valley of Death

- The **primary role of R&D in innovation:**
  - To develop technology, evolutionary and revolutionary, to maintain growth, respond to a need or address a challenge
- The **role of Government, Industry, Academia, others:**
  - Roles varied over time, economic conditions, sectors and category of business, with government funding focused on basic & national mission-oriented RD
- **Technology Valley of Death:**
  - Challenges and roles across the bridge to success; Example from Natural Gas technologies
- **O&G, including Petrochemicals, is technology intensive:**
  - Leadership & nature of RD & innovation landscape changing within the industry



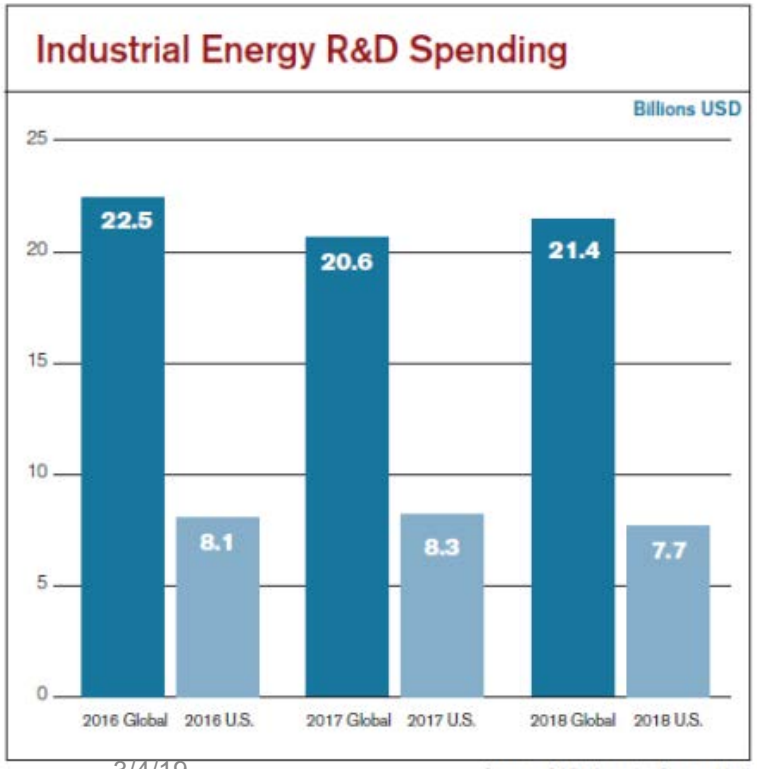


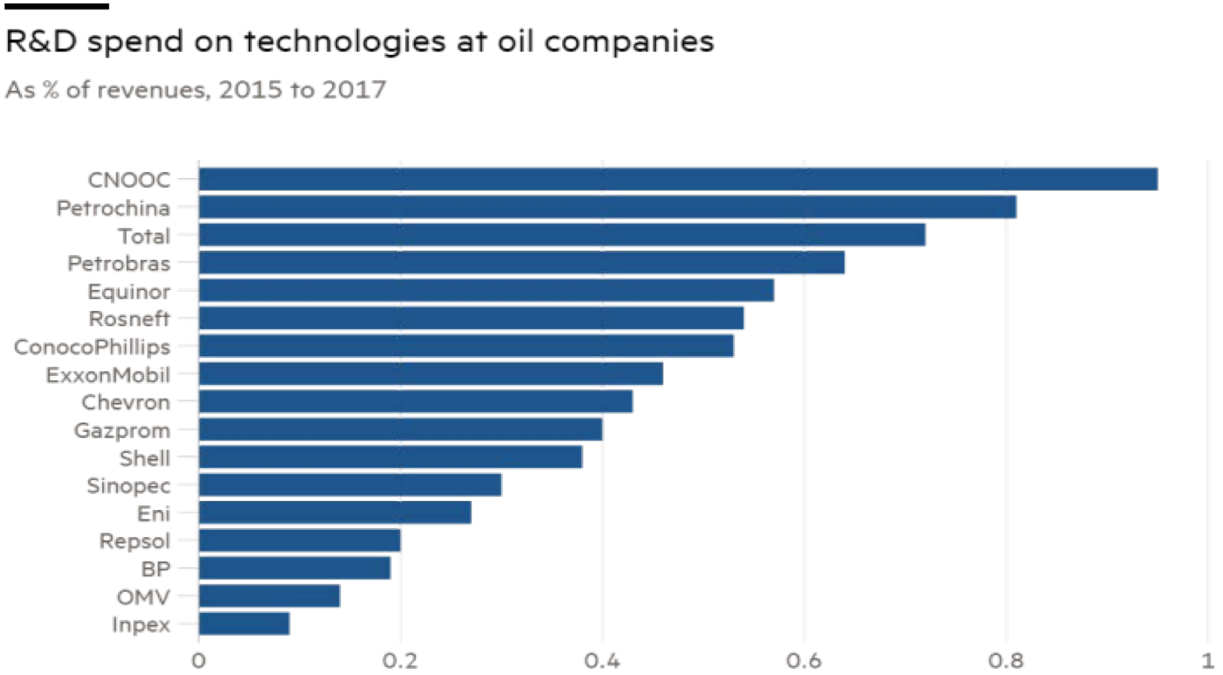
Source: SBC Factbook NG

R&D in O&G

- O&G: a mature industry: benefited immensely from steady & cycles of technology development covering exploration for and deployment of resources, extraction, processing, storage & delivery

- O&G is technology intensive: yet historically it ranks low in terms of R&D investment, but leadership & nature of R&D & innovation landscape changing within the industry (Service companies invested ~ 2%)

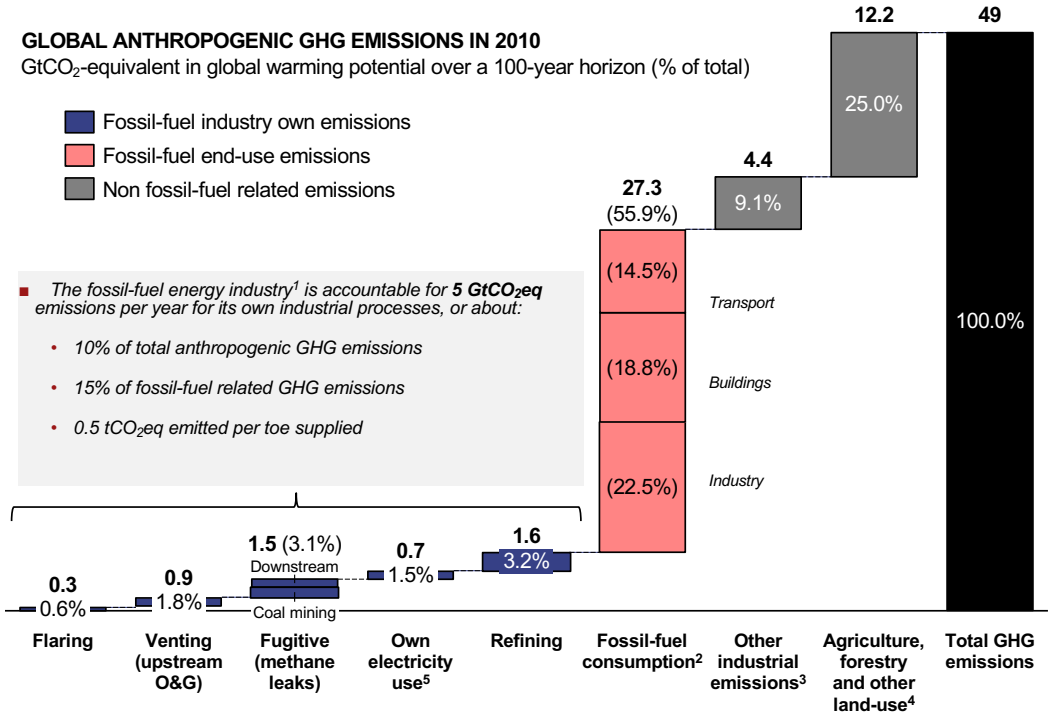


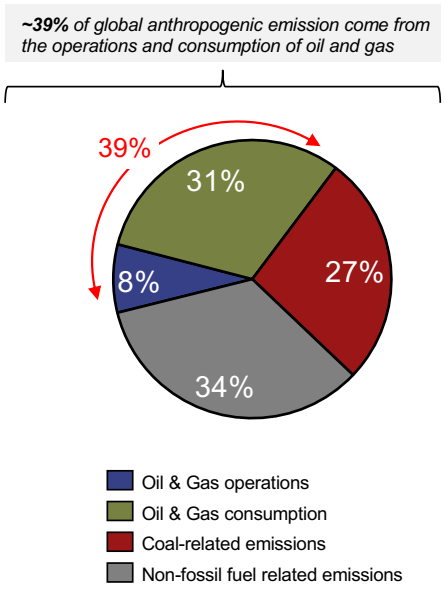


Source: R&D Magazine Survey 2017; Financial Times

Innovations Focus for Producers under Energy Transition Pathways

Whilst GHG emissions related to O&G mostly come from end-use combustion, there is a need to manage GHG emitted from upstream activities





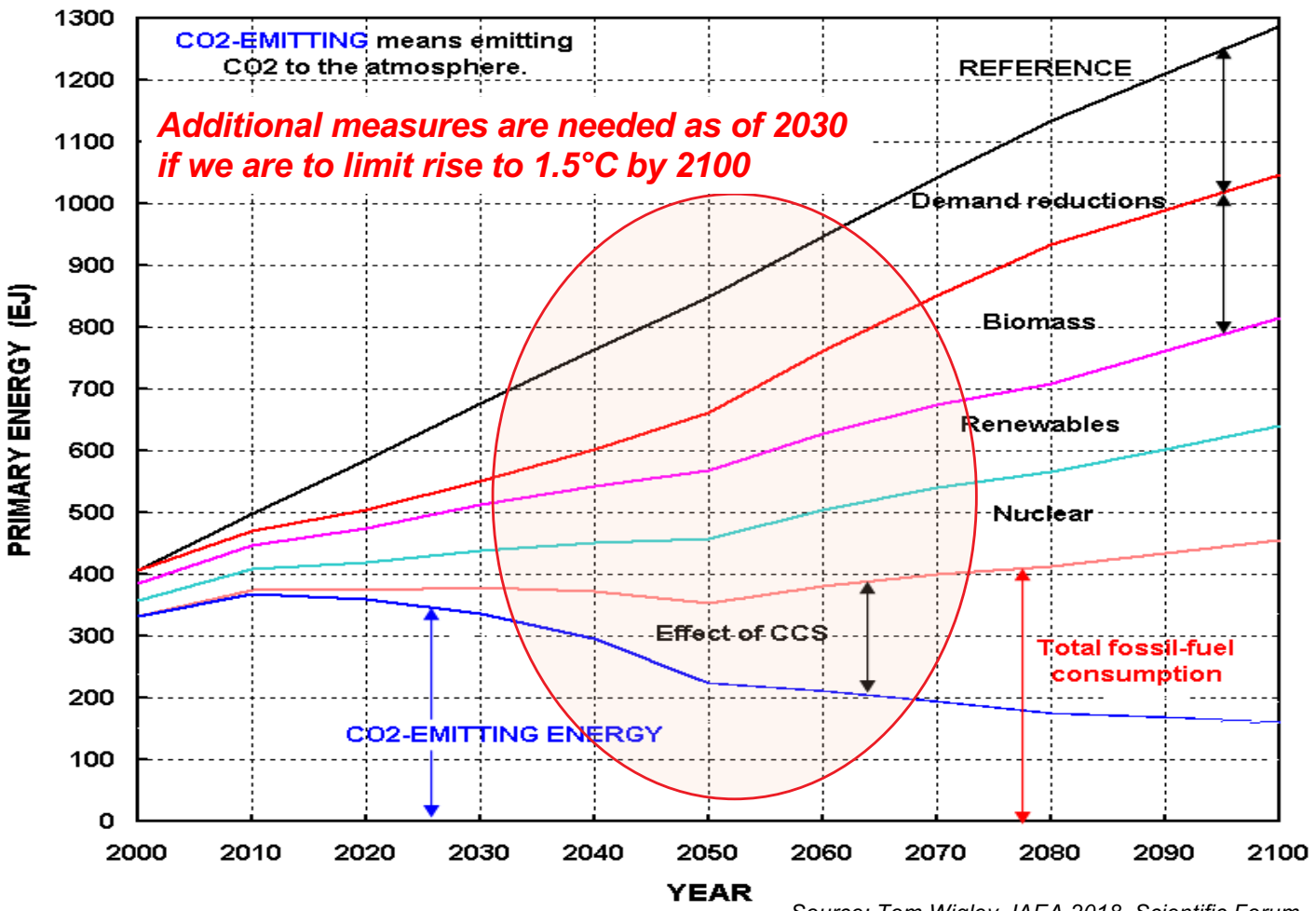
Notes: 1 Exploration, production, transport, refining and distribution oil, gas and coal. 2 CO2 emission from fossil fuel combustion and other oxidation processes in chemical or metal plants. Excludes emissions from diesel generator used to produce fossil-fuel, that are included in "own electricity use" 3 Non fossil-fuel related emissions such as process CO2 cement or other GHG emissions from landfills, chemical production, steel etc 4 Includes methane and N2O emissions from agriculture, CO2 sources and sinks from afforestation and reforestation etc… Excludes energy-related CO2 emissions for agriculture machines, which are accounted under "fossil-fuel combustion". 5 Mostly from on-site diesel engines for production facilities. Excludes transportation fuel used for trucks etc…
Sources: IPCC (2014) "AR5-WGIII"; Carbon Dioxide Information Analysis (CDIAC); and IEA (2015) "World Energy Outlook"; A.T. Kearney Energy Transition Institute

According to recent UN (IPCC), more action is needed quickly to limit T rise from GW to 1.5°C by 2100 rather than 2°C

All plausible scenarios to meet the 2°C target show that all sources and technologies must contribute and more is needed if we aim at 1.5°C limit.

- **Efficiency & Re is low hanging fruit; contribute most 2050**
- **Room to double engine efficiency, introduce EV/Re.**
- **Biomass, nuclear and clean fossil fuels (with CCUS, DAC, CDR) contribute increasingly, but development & investment needed for all on equal footing.**
- **Planes and trucks powered by hydrogen will be a crucial part of efforts to cut carbon emissions to required levels consistent with the desired limit of 1.5 °C to 2 °C.**

A Typical Scenario that would meet the 2°C Target



Source: Tom Wigley, IAEA 2018 Scientific Forum,

O&G Producers' Strategies to Address Emissions for Domestic & Export Markets

- **Short-term:**
  - Reduce excessive high p/c energy demand and limit growth rates: Continue/accelerate subsidy reforms.
  - Continue decarbonization of energy systems through more Re and increased investments in E&P for natural gas as a cleaner substitute for domestic power
- **Long term (2040 and beyond):**
  - CDR technologies, including DAC, to offset CO2 (blockchain verified) from exported O&G, need to be developed
  - More R&D needed to mitigate potential challenges
- **Medium to long-term, aim for deeper decarbonization:**
  - Focus on reducing CO2 emissions from power using CCUS (with EOR first).
  - Develop and deploy O&G sourced hydrogen with CCUS.
  - Remaining carbon captured and sequestered underground: reducing more than 90% of CO_2 emissions.
  - Lead the way to the scale-up of carbon free oil made using carbon-free sources of electricity to convert water and CO_2 to hydrocarbons for use in equipment that is difficult to electrify.
  - Continue to focus on R&D and deployment of new technologies to advance CCUS, including policy making

DAC technologies are being developed and could be available commercially soon in case time runs out

- **Direct Air Capture ("DAC")** systems are an emerging class of technologies capable of separating carbon dioxide (CO_2) directly from ambient air at large scale

Carbon Engineering, Canada

Succeeded in using captured CO_2 to synthesize a mix of petrol and diesel

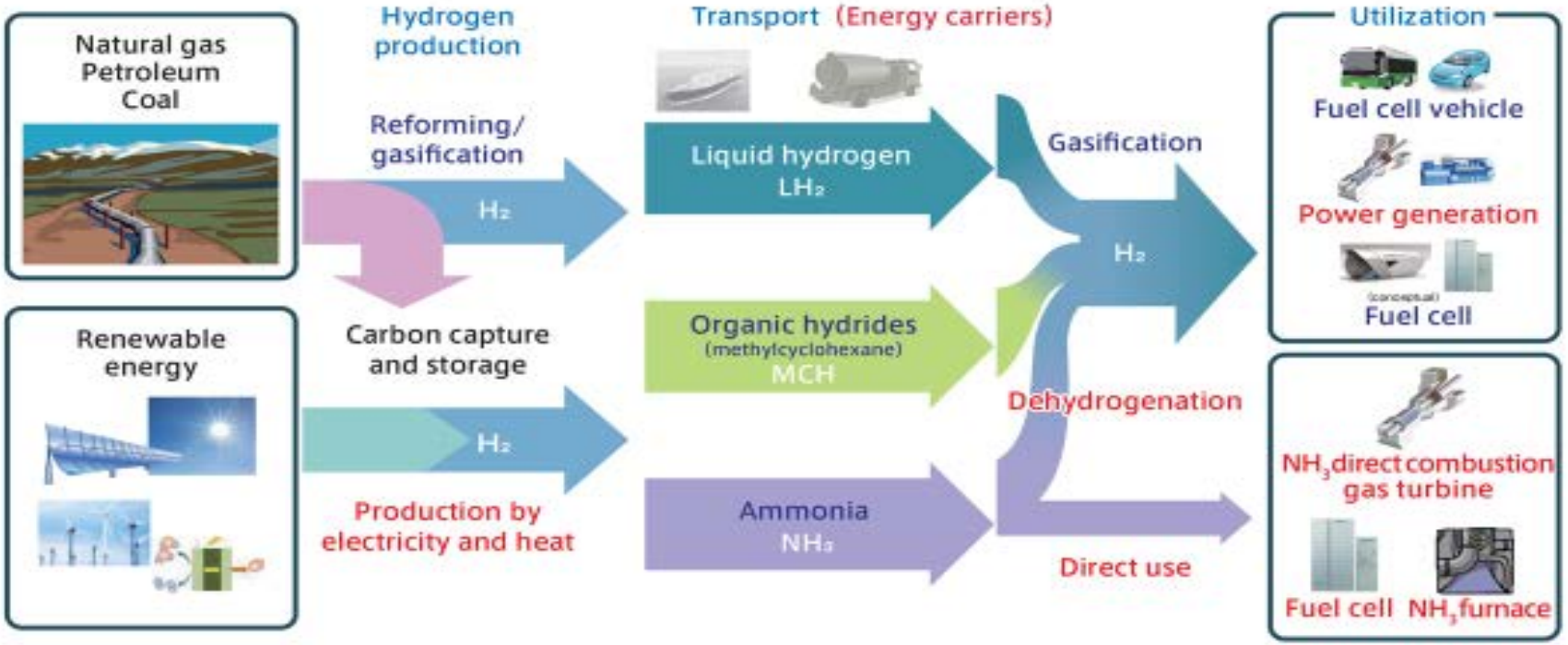
Climeworks, Switzerland

Raised USD 30.8 million to commercialize carbon dioxide removal technology

- In 2011, the American Physical Society (APS) study estimated the costs of DAC at 780 \$/t-CO_2-avoided and 550 \$/t-CO_2-captured
- Carbon Engineering cost projections range is 107–249 \$/t-CO_2

Sources: carbonengineering.com; climeworks.com

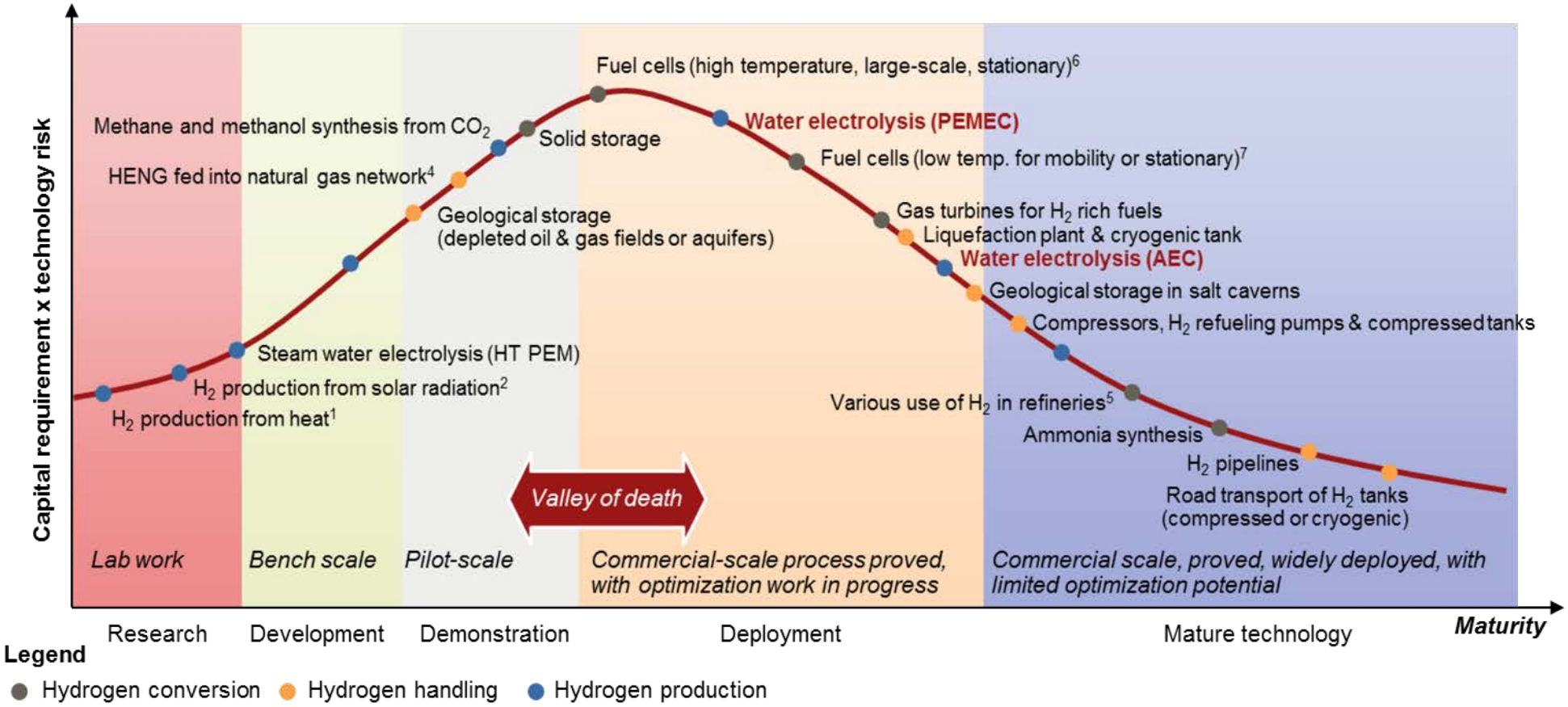
Strategy of Energy Carriers ~Development of CO_2 free hydrogen value chain~



- Hydrogen can be produced from various energy sources and can be utilized for electricity as well as fuel (Potential to reduce CO_2 emission significantly)
- Hydrogen has a difficulty in transportation, because it is low Btu gaseous form. It is essential to develop viable mass-transportation methods and related technologies (energy carrier) and make hydrogen to be affordable energy source.

Source: Adopted from Cross-ministerial Strategic Innovation Promotion Program (SIP)_Energy Carriers_2016

Several H2 technologies are emerging



Thank You

Mission Innovation Clean Energy R&D Focus Areas

	AUSTRALIA	BRAZIL	CANADA	CHILE	CHINA	DENMARK	EUROPEAN UNION	FINLAND	FRANCE	GERMANY	INDIA	INDONESIA	ITALY	JAPAN	KINGDOM OF SAUDI ARABIA	MEXICO	NETHERLANDS	NORWAY	REPUBLIC OF KOREA	SWEDEN	UNITED ARAB EMIRATES	UNITED KINGDOM	UNITED STATES
INDUSTRY & BUILDINGS	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
VEHICLES & OTHER TRANSPORTATION	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●		●	●	●	●			●
BIO-BASED FUELS & ENERGY	●	●	●			●	●	●	●	●	●	●	●			●	●	●	●	●	●	●	●	●
SOLAR, WIND & OTHER RENEWABLES	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
NUCLEAR ENERGY	●	●	●		●											●			●		●	●	●	●
HYDROGEN & FUEL CELLS	●	●	●		●	●	●	●	●	●	●			●	●	●	●	●	●			●	●	●
CLEANER FOSSIL ENERGY		●	●		●	●		●		●	●	●			●		●		●					●
CO_2 CAPTURE, UTILIZATION & STORAGE	●	●	●		●	●	●		●	●	●	●		●	●	●	●	●	●		●	●	●	●
ELECTRICTY GRID	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●
ENERGY STORAGE	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
BASIC ENERGY RESEARCH	●		●			●	●		●	●	●	●	●	●	●		●	●		●	●			●

Indicators are for key areas of R&D investment, but do not imply a comprehensive representation of a country's full R&D portfolio.

Source: IEA