Decarbonization and the potential of Green H_2

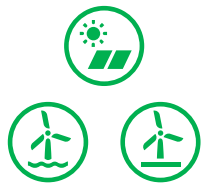
Dr. Francis O'Sullivan

MIT Climate Symposium
February 2020

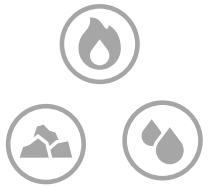
H_2 has the potential to be an energy vector for delivering carbon-free solutions across a wide array of difficult to abate applications

Energy Sources

Carbon-free electricity



Fossil energy sources



H_2 Production Pathways

- **Electrolysis**
  - Alkaline
  - PEM
- **Reforming**
  - SMR
  - ATR
- **Gasification**
  - Coal
  - Biomass

With and without CCS to produce grey or blue H_2

H_2 & H_2-derived Products

- **Gaseous H_2**
- **H_2-based fuels & feedstocks**

Carbon carriers:
Synthetic CH_4
Methanol

Non-carbon carriers:
Ammonia

H_2 and its associated products provide significant storage and distribution flexibility

End Use Sectors

Industry
- Refining
- Chemical feedstocks
- Heat
- Iron & steel

Power sector
- Generation
- Longer-term storage

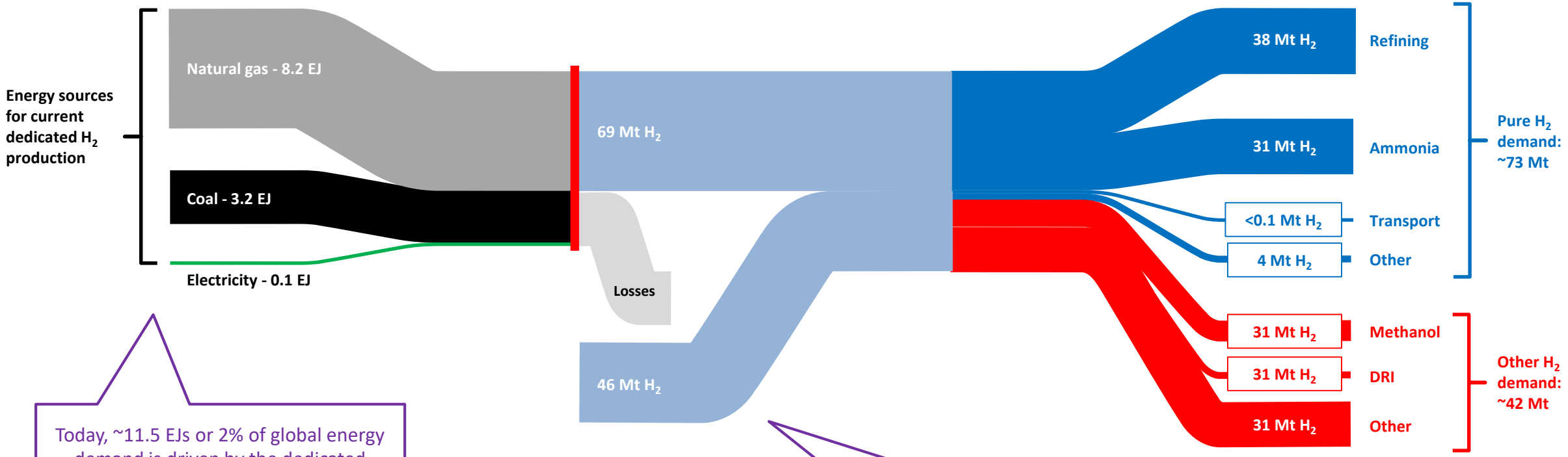
Transportation
- Light & heavy duty ground transport
- Shipping
- Aviation

Buildings
- Space heating

At the same time, the contemporary H_2 sector itself is a major source of energy demand and CO_2 emissions that requires decarbonization

The contemporary hydrogen value chain

Input sources and consuming sectors



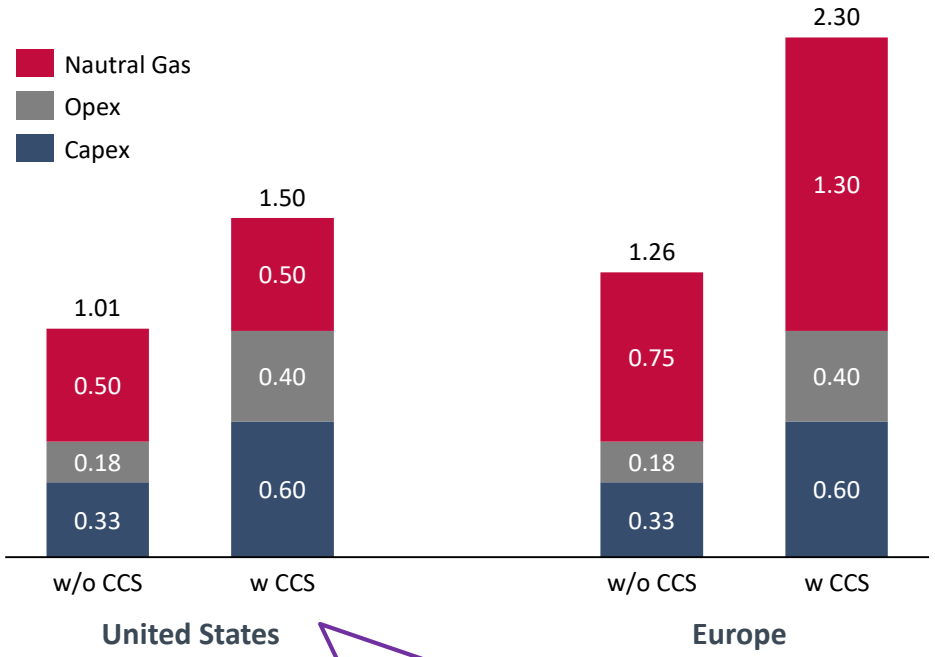
Today, ~11.5 EJs or 2% of global energy demand is driven by the dedicated production of H_2

In 2018 the production of H_2 resulted in 830 $MtCO_2$ or ~2.5% of total energy and industry related CO_2 emissions

Sources. IEA, IPCC

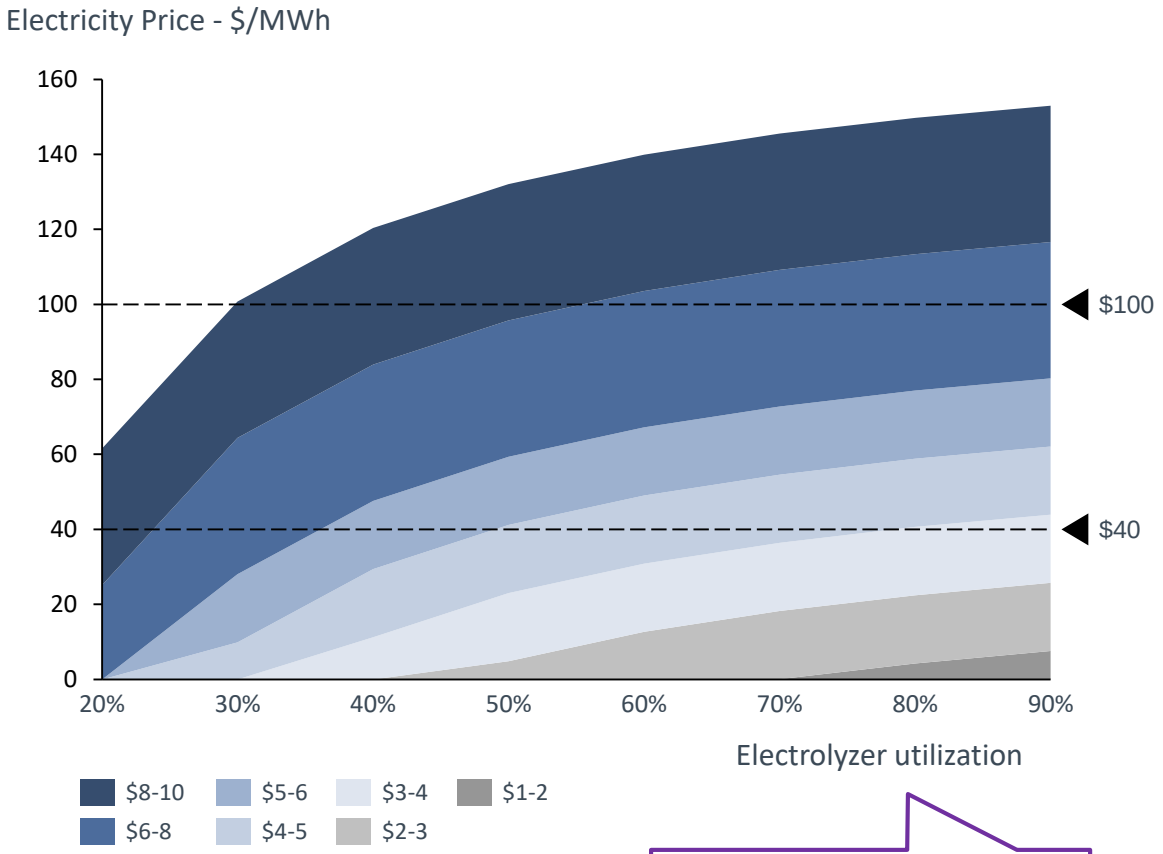
Low-carbon H_2 via SMR w CCS costs $1.50-2.30/kg today – Green H_2 costs vary but production in the $3.5-5/kg range is possible with current electrolyzers

Range of contemporary SMR-based H_2 production costs[1]
$/Kg



Current cost-effectiveness of SMR further enhanced by near record low US natural gas prices

H2 cost isobands for contemporary PEM electrolyzer across power price and utilization ranges

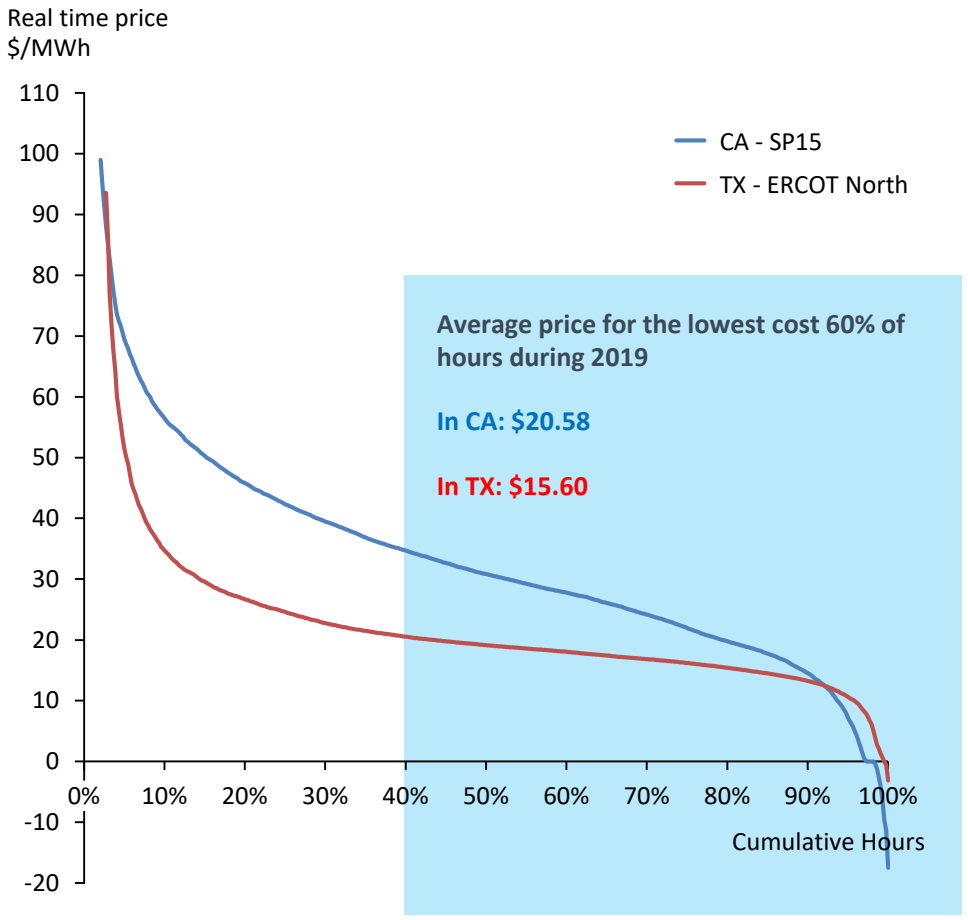


With today's electrolyzer costs maximizing utilization is important

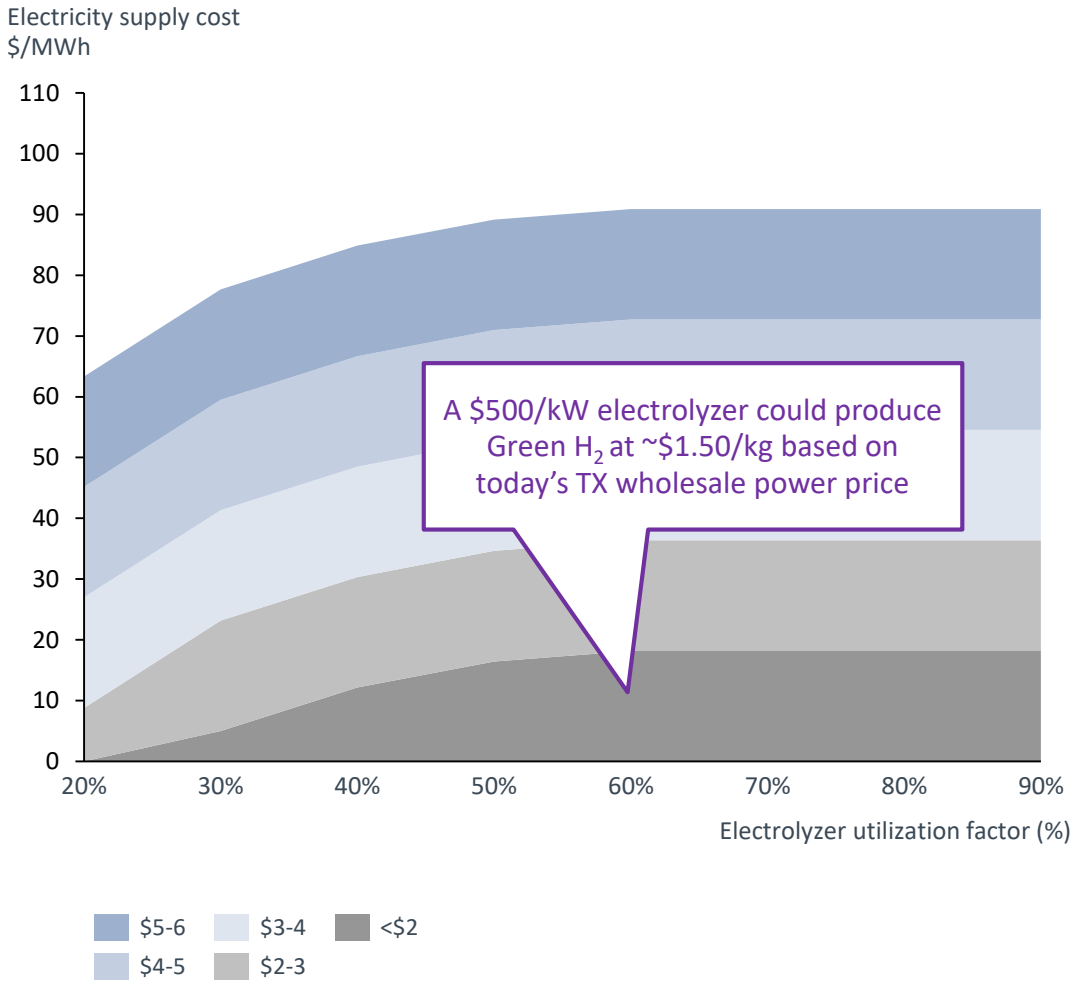
1 Assuming on 2019 US and European hub natural gas prices
Sources. IEA, Internal analysis

Scaling demand is driving down electrolyzer costs with $400-500/kW system CAPEX projected by 2030 – At these CAPEX levels the economics of Green H_2 will pivot on the cost of electricity

2019 electricity price duration curves for CA and TX[1]



H_2 cost isobands for a $500/kW electrolyzer



Sources. CAISO, ERCOT, Internal analysis

Low-cost Green H_2 production itself is only one piece of the jigsaw – For H_2 to really play a part in economy-wide deep decarbonization hurdles around its storage and transmission must also be addressed

Indicative H_2 storage cost ranges for various time-scales and technologies
$/kg H_2

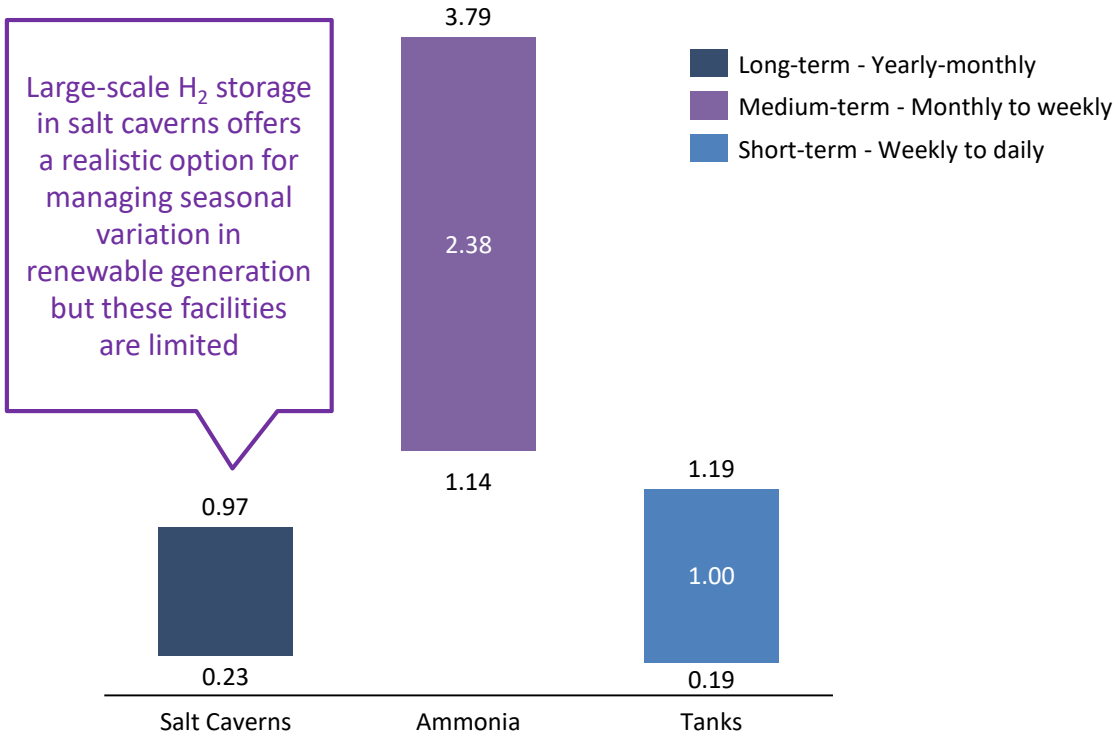
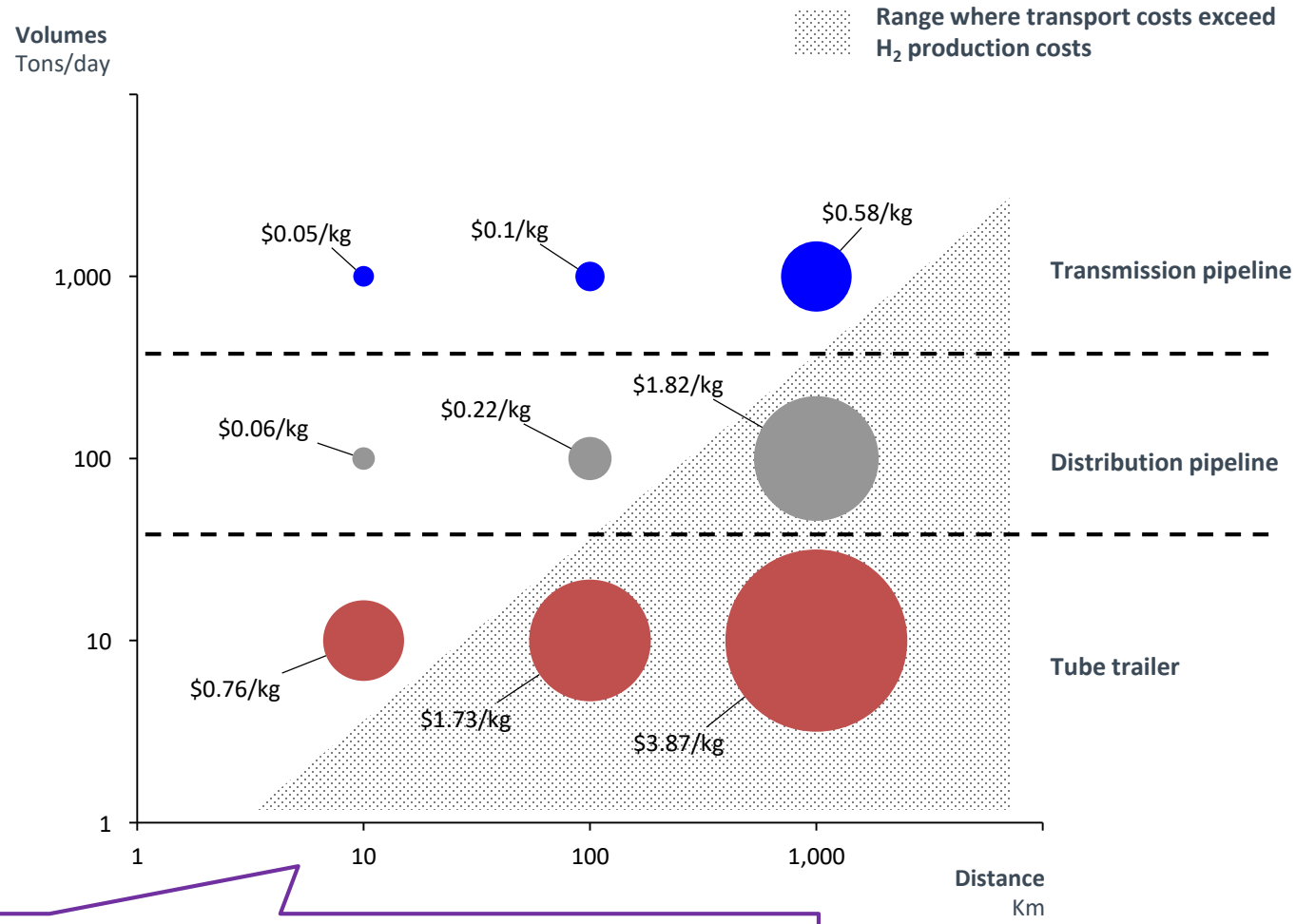


Illustration of variation in H_2 transport costs by mode based on volume and distance



H_2 transmission and distribution pipelines are cost effective but lower volume distribution is prohibitively expensive

Sources. BNEF

H_2 has real potential, but unlocking it to aid deep decarbonization will require progress across each of the three dimensions that shape the energy sector

1 Technology development and systems analysis

- Enhancing technical performance and better understanding of where and how H_2 fits into a decarbonizing energy system

2 Policy and regulatory design

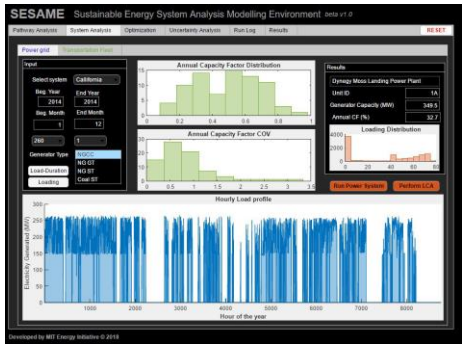
- Putting in place policies that align with the realities of where H_2 makes sense
- Ensuring that the broad regulatory frameworks that govern energy allow H_2 to access the market

3 Commercial innovation and market scaling

- Near-term focus on opportunities where H_2 can deliver commercially
- Look to innovative financing structures to de-risk H_2 and accelerate market scaling

SESAME

Sustainable Energy System Analysis and Modelling Environment



EPPA

Emissions Prediction and Policy Analysis Model