EXPLORING THE COMPLEXITY OF THE TRANSITION TO LOW-EMISSION HYDROGEN: A DYNAMIC SIMULATION APPROACH

REZA FAZELI, THOMAS LONGDEN, AND FIONA BECK

July 2023

ZERO CARBON ENERGY FOR THE ASIA-PACIFIC

Australian National University

The ZCEAP programs

Hydrogen Fuels program »

The Hydrogen Fuels program focuses on creating the expert technical, socio-economic and geopolitical knowledge for Australia to become a leading exporter of zero-emissions hydrogen.

Renewable Metal Refining program »

This program examines the opportunity for Australia to realise a new high-value export stream in the form of renewable metal refining, with emphasis on refining of iron ore to produce 'green steel'.

Renewable Energy Systems program »

The Renewable Energy Systems program aims to understand the geopolitical, economic and technological drivers needed to ensure the successful trade in renewable electricity.

Indigenous Engagement with Renewable Energy Industries program »

This program focuses on First Nations benefit in the transition to low and zero emissions technologies in Northern Australia.

Renewable Energy Policy and Governance in Asia-Pacific Countries program »

This program focuses on policy and governance approaches best able to facilitate the adoption and use of renewable energy in Asia-Pacific countries.

Regulatory Frameworks for Renewables-based Trade and Investment program »

This program focusses on law and policy to support expansion of resilient and sustainable Indo-Pacific supply chains based on renewable energy. Key topics include certification, embedded emissions accounting, international green industrial policy, and investment treaties.

Inaugural director, Prof Ken Baldwin

Current Director, Prof Frank Jotzo

THE HYDROGEN FUELS PROJECT

ANALYSING THE TRANSITION TO THE HYDROGEN ECONOMY

- Dynamic system models probing the evolution of supply and demand under different policy settings. **Dr Reza Fazeli, Dr Tom Longden, Dr Lee White**
- Emissions implications and technoeconomic analysis of hydrogen supply chains. **Dr Reza Fazeli, Dr Tom Longden**

GOVERNANCE AND ENABLING REGULATIONS FOR HYDROGEN TRADE

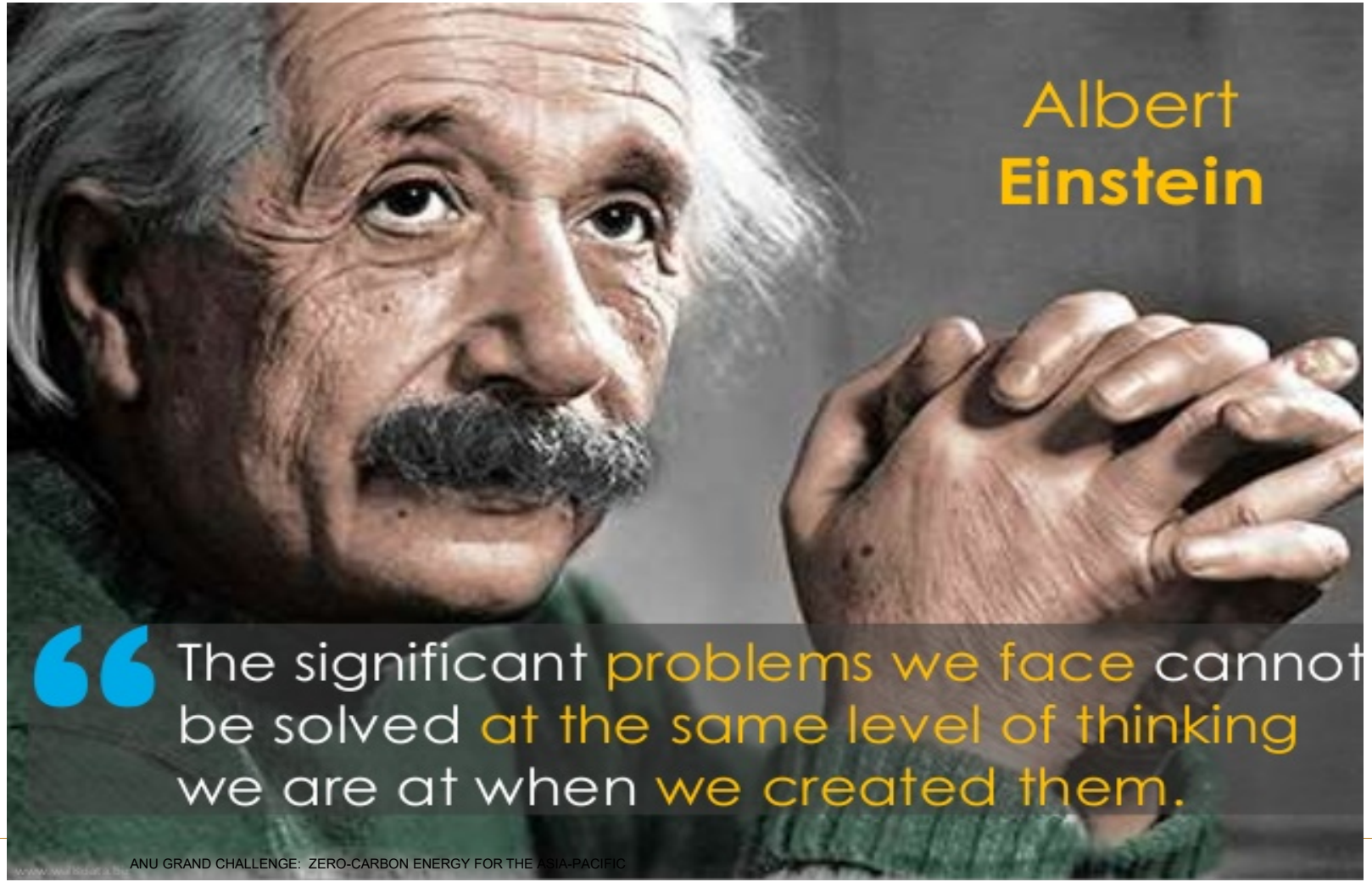
- Pioneering the definition of the key elements needed in a hydrogen certification scheme. **Dr Lee White Dr Reza Fazeli**

LARGE-SCALE STORAGE TECHNOLGIES TO ENABLE EXPORT

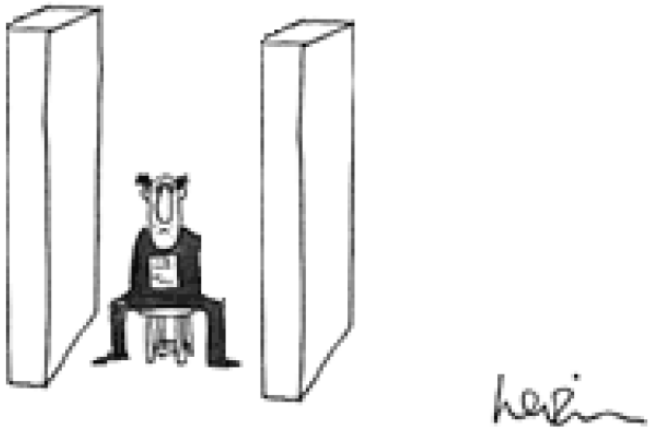
- Technological development of liquid organic hydrogen carriers: from materials discovery and development, to system analysis, and addressing legal/regulatory implementation issues. **Dr Chunguang Tang**
- Comparative technoeconomic and system analysis for storage technologies. **Dr Zainul Abdin**

DIRECT SOLAR HYDROGEN GENERATION FOR LOW COST RENEWABLE HYDROGEN

- Materials, technology development, techno-economic analysis. Team at ANU School of Engineering led by A/Prof Fiona J Beck and A/Prof Siva Karuturi

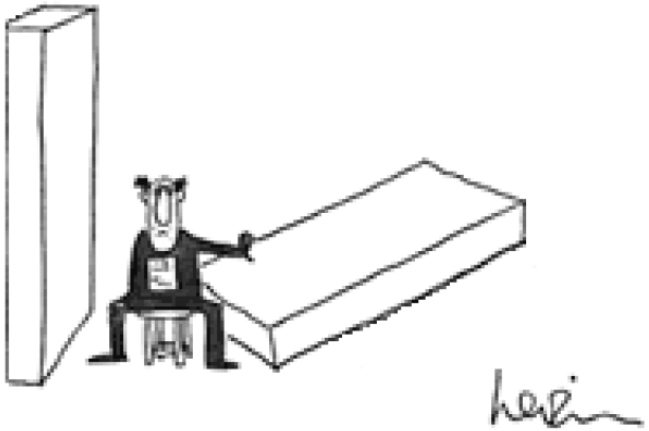

Albert
Einstein
The significant problems we face cannot be solved at the same level of thinking we are at when we created them.

Managing Complexity



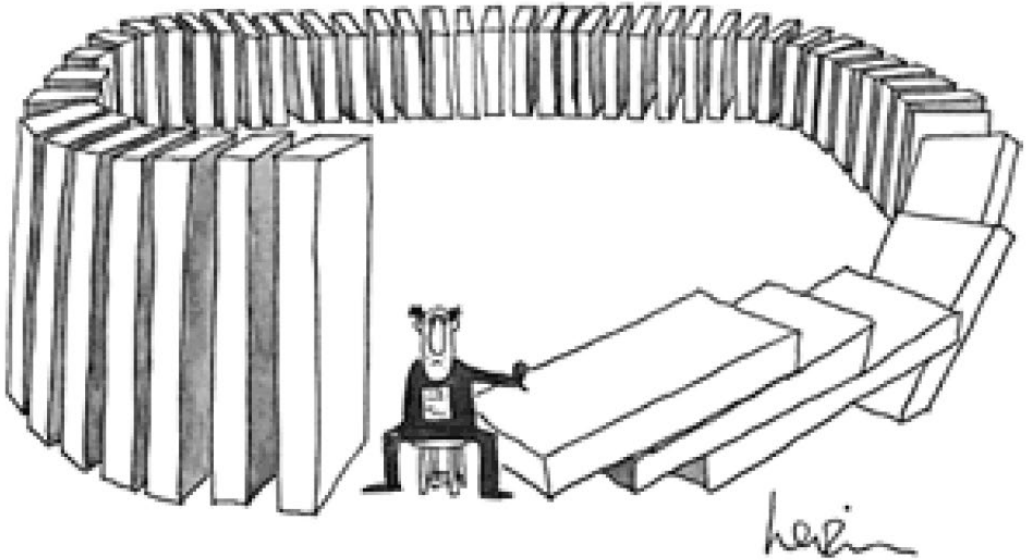
Arnie Levin, New Yorker, December 27, 1976

Managing Complexity



Arnie Levin, New Yorker, December 27, 1976

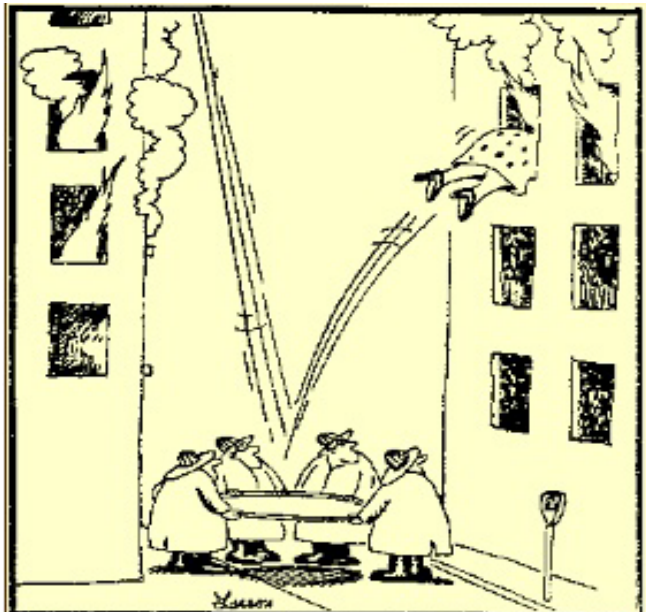
Complexity & Unintended Consequences



Arnie Levin, New Yorker, December 27, 1976

Solutions can create new problems

Policy Resistance is the tendency for interventions to be defeated by the response of the system.



Meadows, et al., 1982. Groping in the Dark: the First Decade of Global Modeling. John Wiley and Sons, Chichester

What is System Thinking?

Traditional analysis focuses on separating the elements to understand the issue,

System thinking focuses on how the components interact with each other!

HYDROGEN PRODUCTION PATHWAYS

Renewable ("green") hydrogen

RE Electricity 54 kWh

Water 9 L

Electrolysis

Hydrogen 1 kg

Oxygen 8 kg

"Blue" hydrogen

Natural gas 3.2 kg

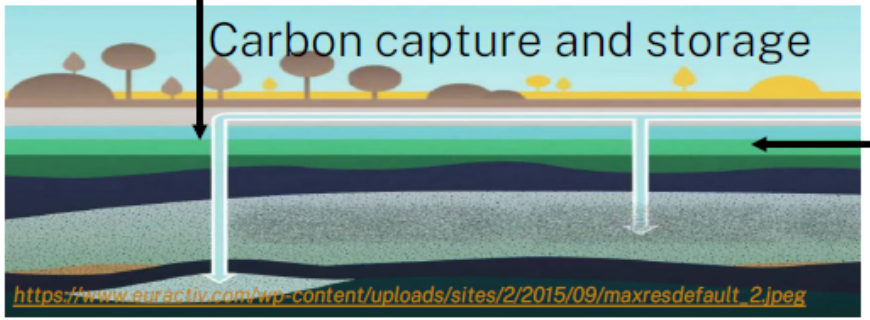
Water 7 L

Reforming

Hydrogen 1 kg

Carbon Dioxide 10 kg

Carbon capture and storage



https://www.etiactiv.com/wp-content/uploads/sites/2/2015/09/maxresdefault_2.jpeg

Gasification

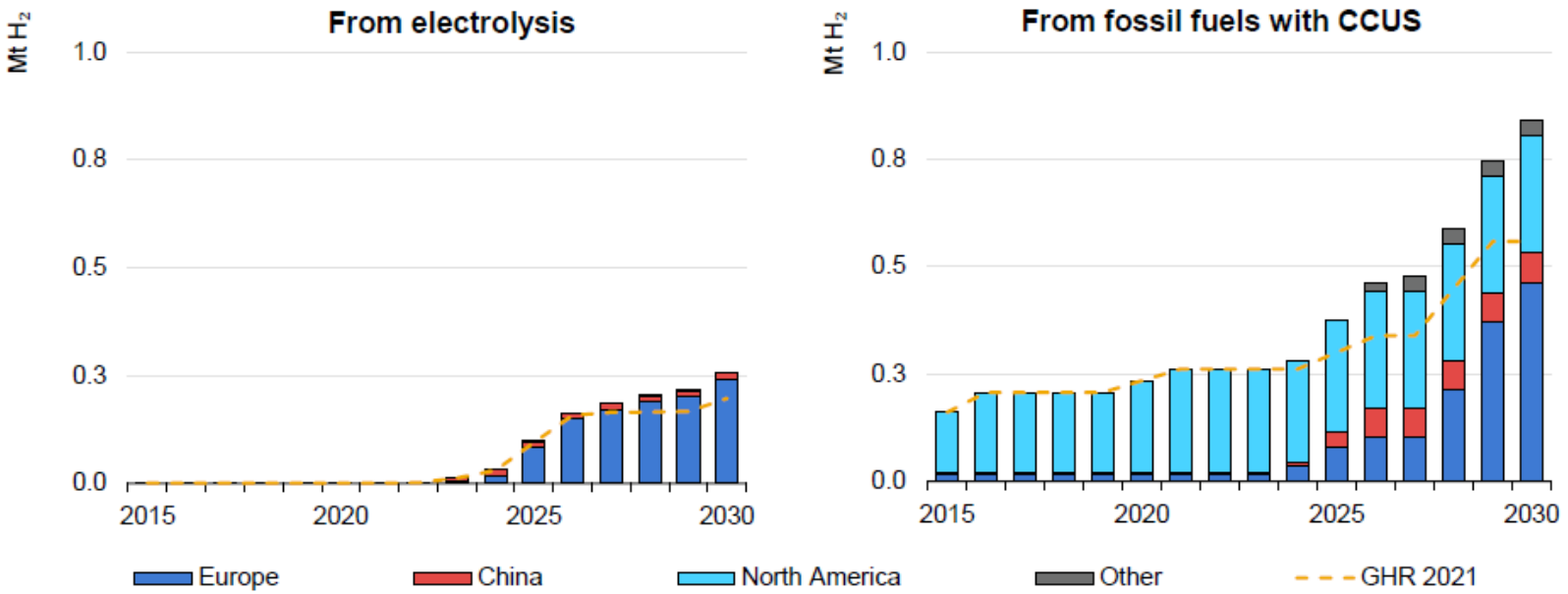
Coal 7.6 kg

Water 9 L

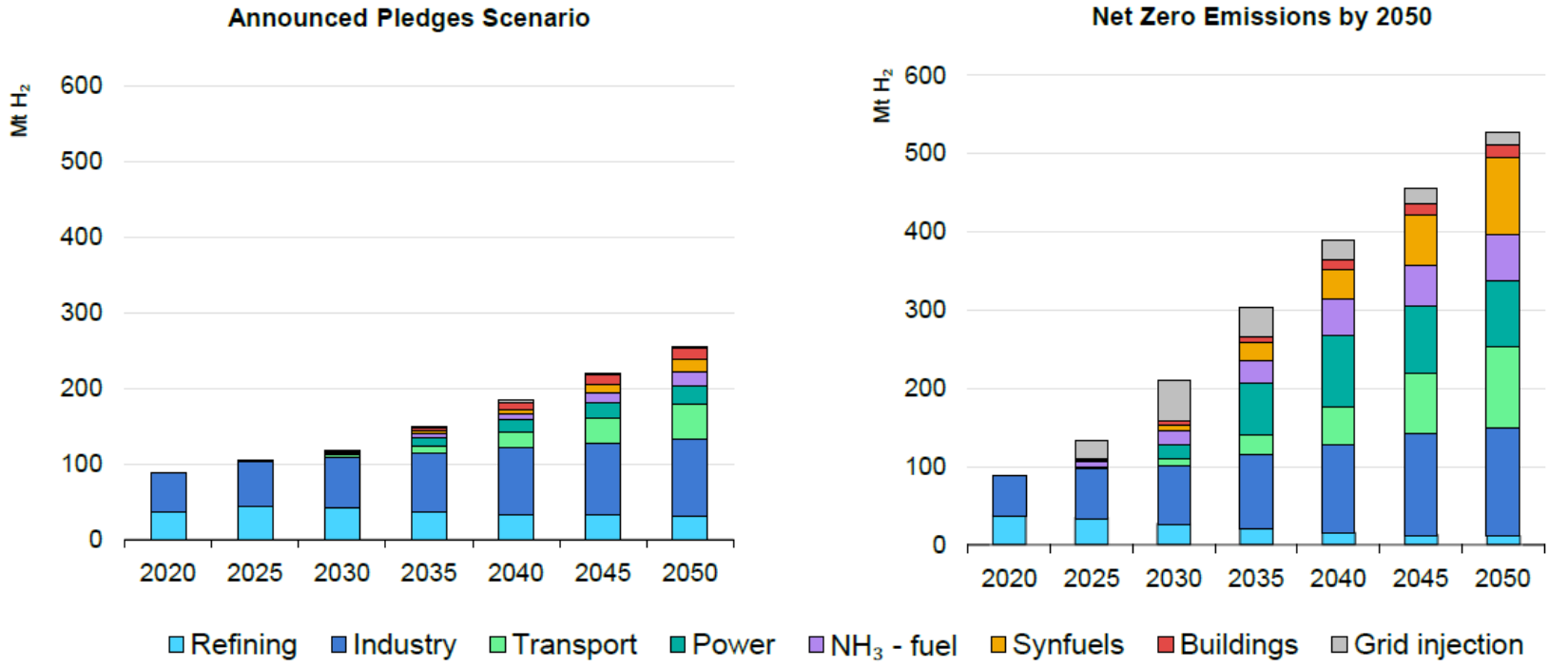
Hydrogen 1 kg

Carbon Dioxide 20 kg

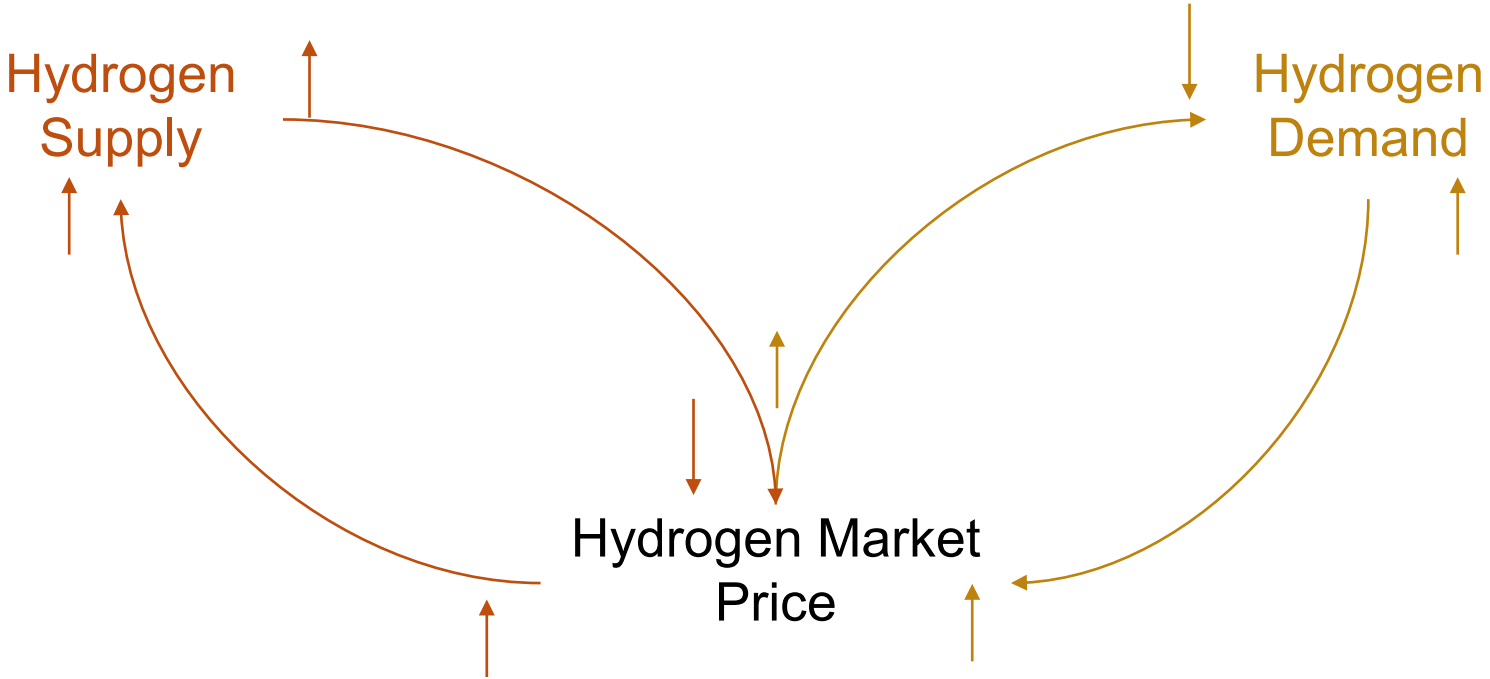
Planned production of low-emission hydrogen for refining by technology and region, 2018-2030



Hydrogen demand



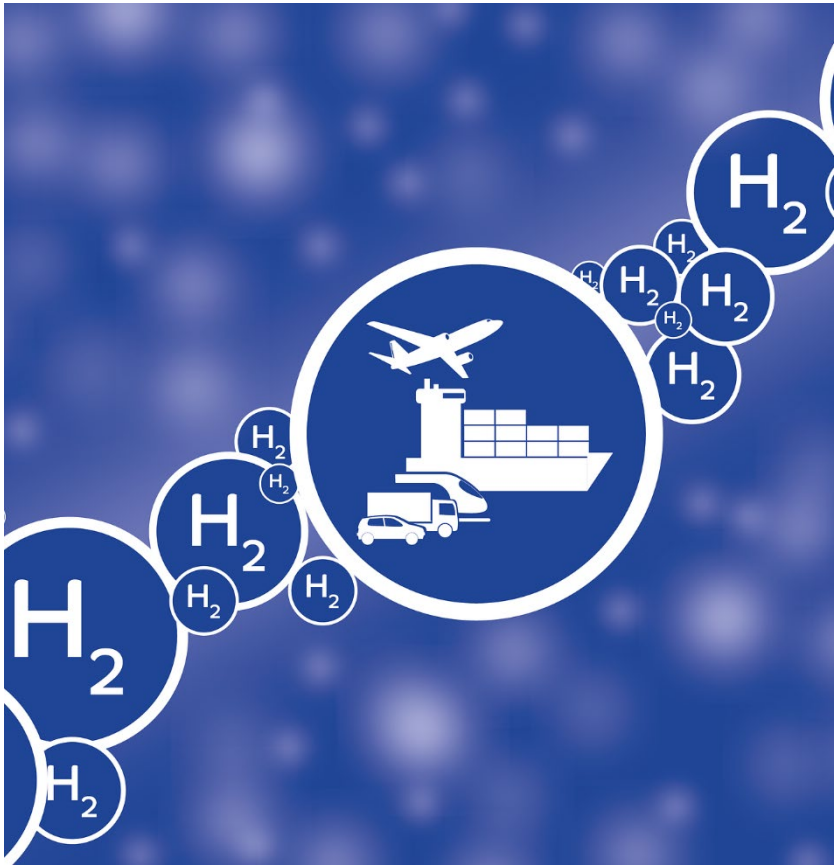
Notes: "NH_3 - fuel" refers to the use of hydrogen to produce ammonia for its use as a fuel. The use of hydrogen to produce ammonia as a feedstock in the chemical subsector is included within industry demand.


Hydrogen Supply
Hydrogen Demand
Hydrogen Market Price

Research Questions

1. How blue and green hydrogen may be deployed over the next decades?

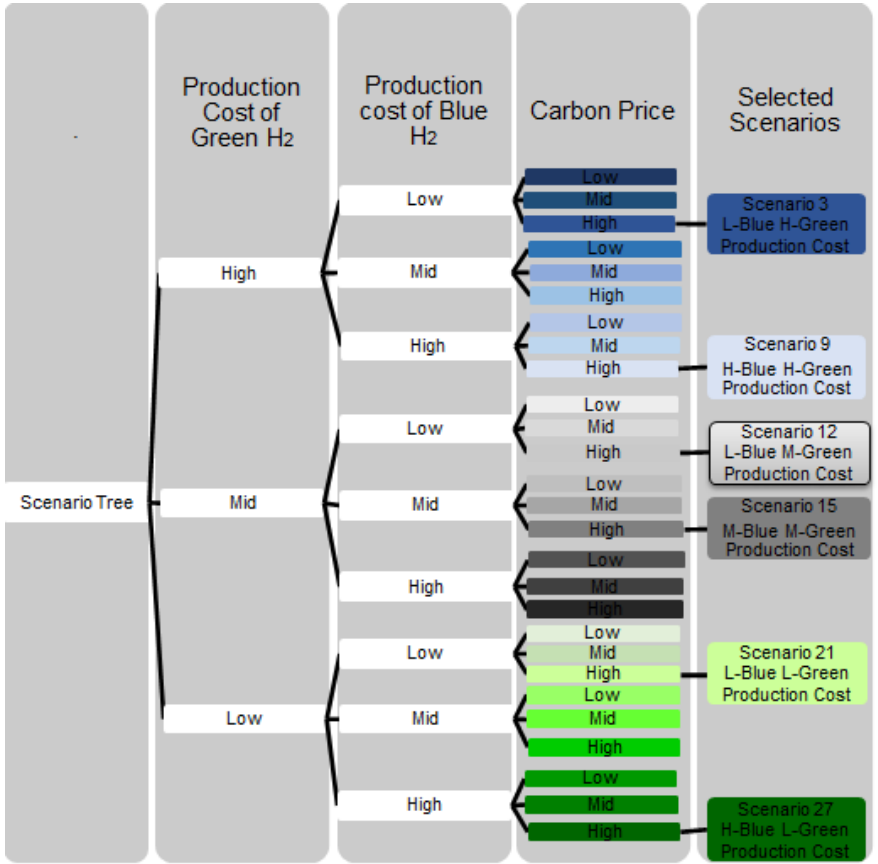
2. Under what conditions, will investment in blue hydrogen result in early retirement?



Key factors affecting Blue vs Green H_2

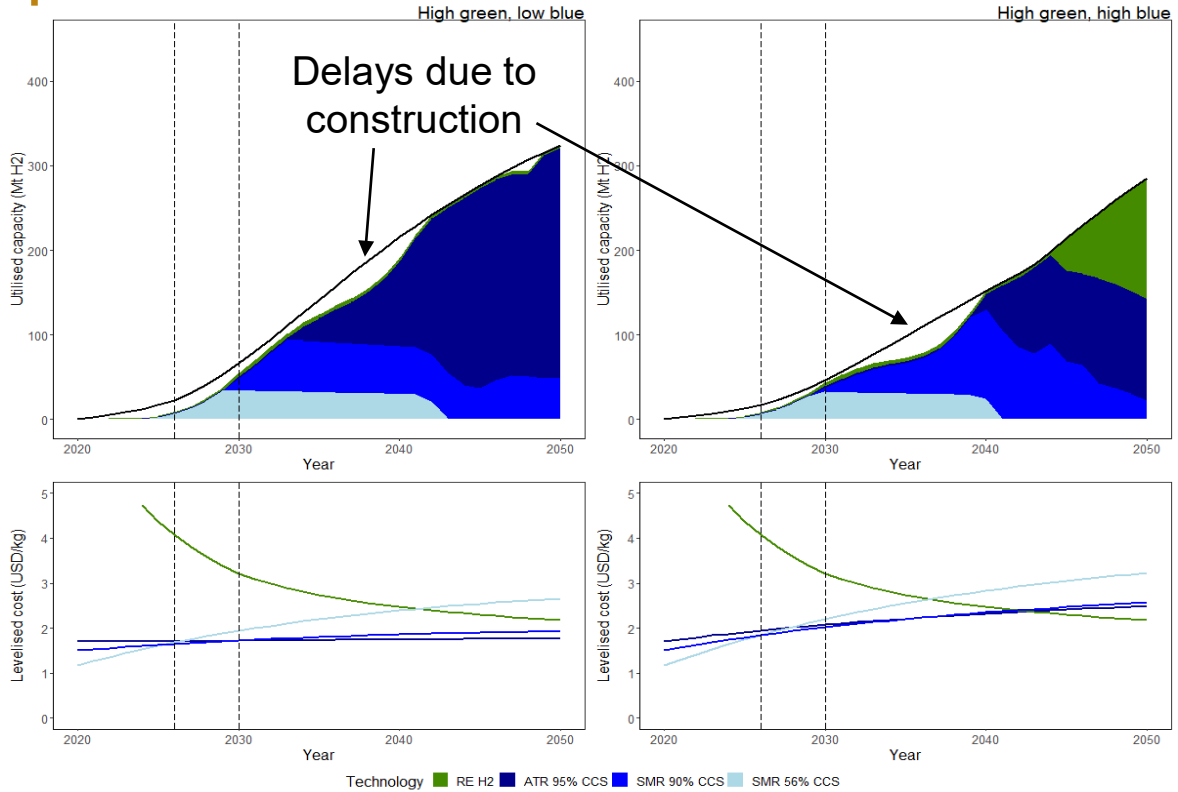
- Production Cost of Green H2
  - Electrolyser CAPEX
  - Electricity Price
  - Capacity Factor
- Production Cost of Blue H2
  - CAPEX
  - Gas Price
- Carbon Price
  - Three trajectories based on IEA WEO Scenarios

Scenario Tree



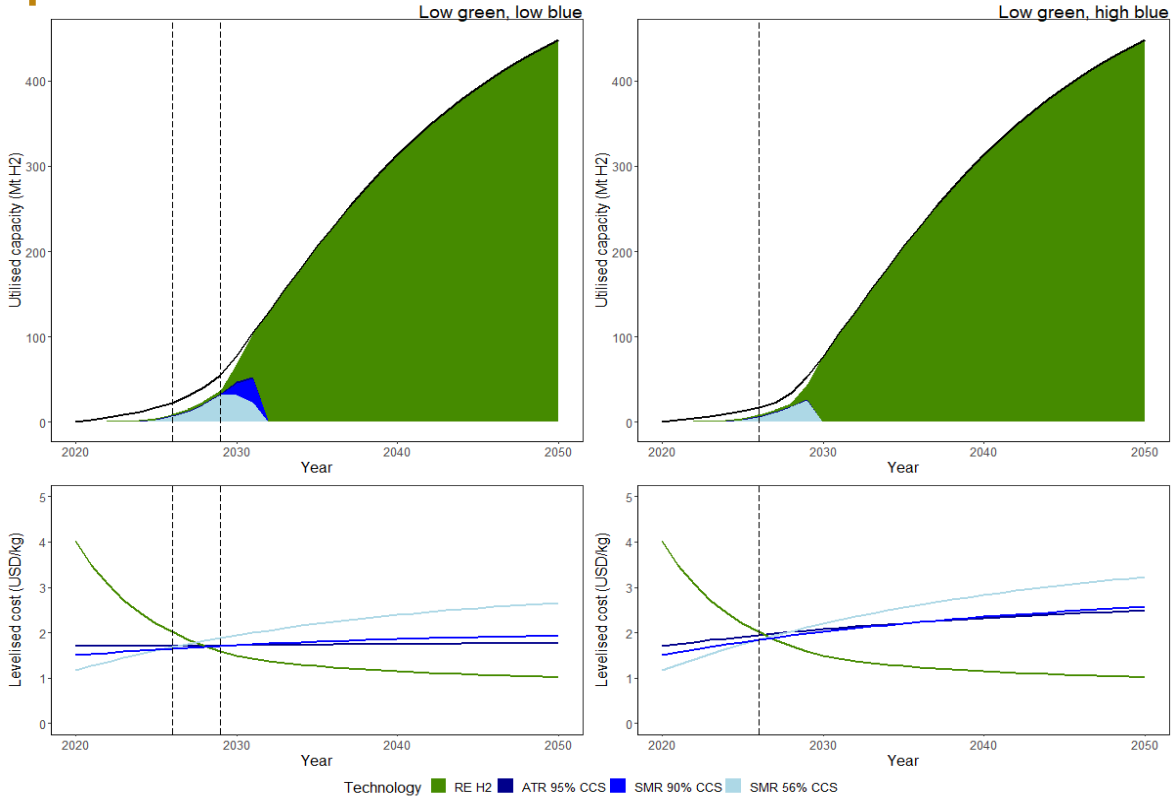
Results

Hydrogen production and LCOH

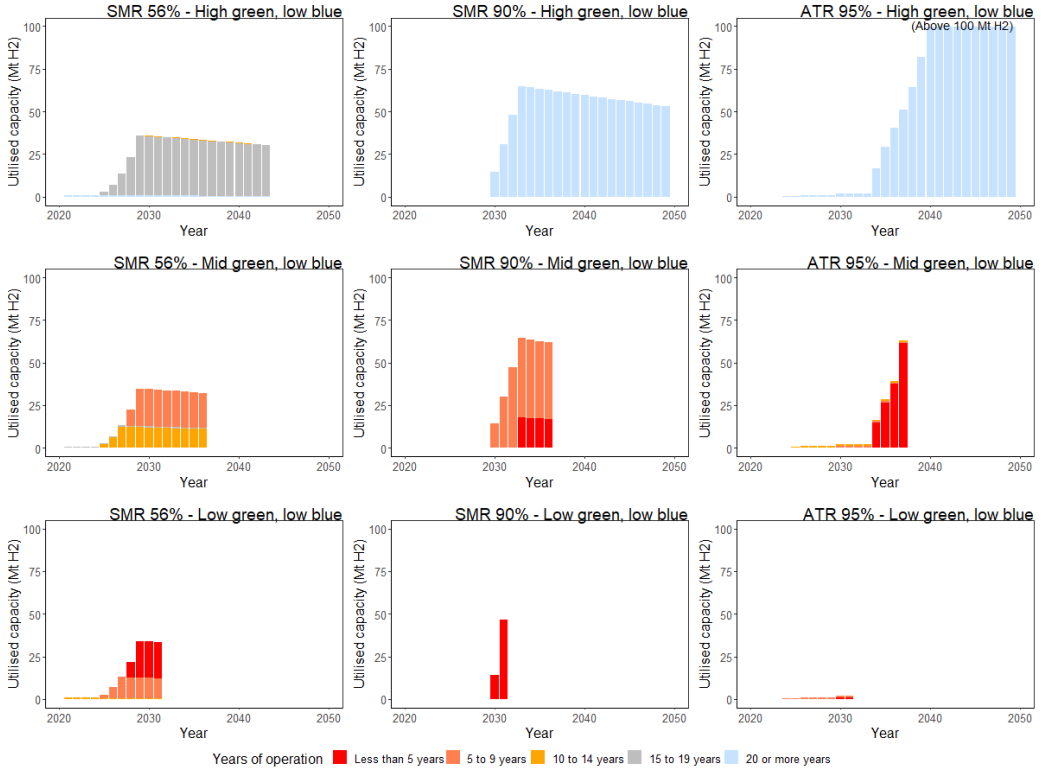


Results

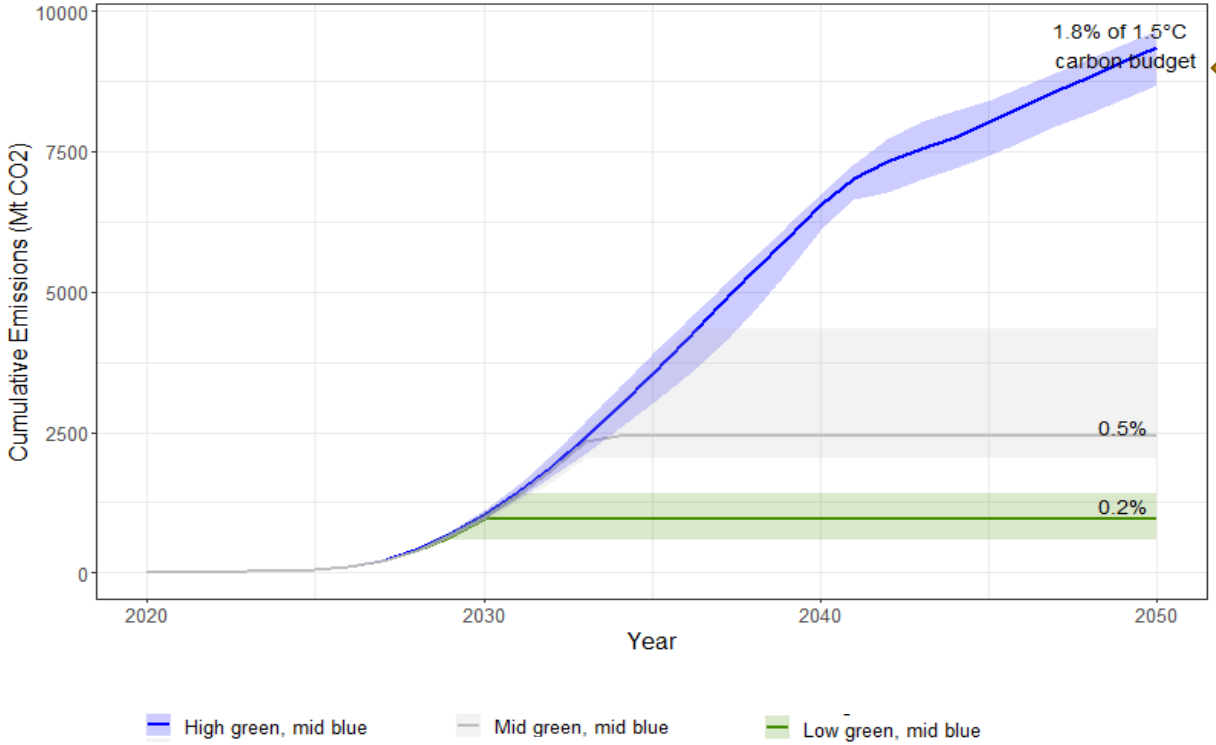
Hydrogen production and LCOH



Operational lifetime of blue hydrogen production plants



Cumulative emissions for Net Zero Scenarios

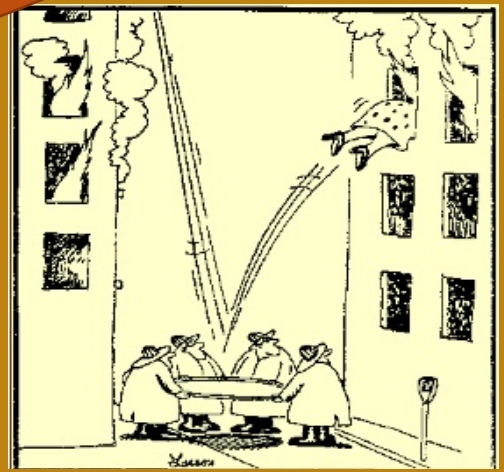


Need for policy intervention

KEY TAKEAWAY

- Understanding the impacts of uncertainti… transition is not trivial, yet very inf…
- The uncertainty around sy… the capacity factor … critical factors for tr…
- While … lue H_2 support the … ydrogen, **the risk of early … Blue H_2 technologies** is … ross the majority of scenarios.

Some solutions can create new problems.



THANK YOU

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