FUTURE FUELS CRC

Enabling the decarbonisation of Australia's energy networks

RP1.1-02B: Transport and storage option for future fuels

With the ongoing development of Australia's hydrogen industry, there is a need to better understand the different transport options available. This project has developed mathematical models that provide a comparison between transport options – mainly whether the energy to produce hydrogen should be delivered as molecules or electrons.

An Excel-based tool was developed early in the project to quickly compare investment costs and levelised cost of energy transportation of different energy transport infrastructure options, namely, gas pipelines and electricity transmission lines. The gas pipeline option was further divided into three options for the three different energy carriers: hydrogen, synthetic natural gas (methane), or a hydrogen-methane blend. Electricity transmission line options consist of either high-voltage direct current (HVDC) or high-voltage alternating current (HVAC) transmission lines.

Following this, a more detailed mathematical model was developed. This model includes relevant infrastructure as per other models in the literature, including:

- HVDC,
- HVAC,
- Reactive power plants,
- Battery energy storage systems (BESS), and
- Hydrogen pipelines and compressors.

The new model also incorporates the essential nonlinearities that directly influence optimal infrastructure investment decisions, including:

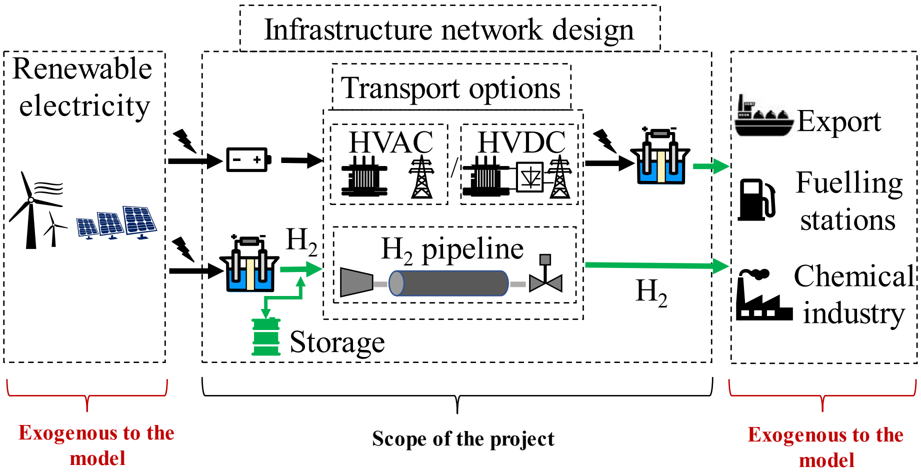
- Voltage drops due to impedances in HVAC and HVDC transmission lines;
- Losses in HVDC converter stations;
- Reactive power flow;
- Pressure drops in pipelines;
- Linepack; and
- Non-linear withdrawal and injection rates of underground hydrogen storage (UHS) systems.

The model adopts a high temporal resolution that aligns with the resolution used by AEMO's 2022 ISP to be able to match the forecast variable renewable energy (VRE) traces used by AEMO. This allows the variability of renewable generation and the ability of storage technologies to buffer this variability and their impact to be included in the optimal investment decision.

The mathematical model was illustrated using a point-to-point analysis using a single corridor. The model calculated the optimal infrastructure decision based on the supply capacity (ranging from 169 to 6,080 MW), the corridor length (25 to 800 km) and the storage duration between 0 and 8 hours. For a single corridor, the findings of the model suggest that:

- Under steady state throughput, where no storage is required, hydrogen pipelines are more cost effective than their electricity counterparts across all the capacities and distances considered.
- Where one hour of storage was required, the optimal infrastructure is heavily influenced by the cost of BESS relative to the cost of electrolysers. In particular, electricity transmission lines and BESS are chosen for distances shorter than 100 km.
- Where 2 hours or more of storage is required, then hydrogen pipelines are more cost effective than their electricity counterparts over most distances and capacities. This is due to an increase in pipeline size (to provide storage) and an increase in electrolyser capacity being outweighed by a larger increase in cost due to the additional investment in BESS over most to the distances. The only exception was in the case for a capacity of 6,080 MW and distance less than 25 km.

The model was expanded to consider the infrastructure across a whole network connecting renewable energy zones with hydrogen demand centres, and to include the role of energy storage via either UHS or BESS.



To demonstrate the model, hydrogen demands were set in line with the hydrogen volumes of the 2022 AEMO Integrated System Plan (ISP) – in the hydrogen superpower scenario – for the years 2027, 2032 and 2037. Key findings of the model suggest that:

- Only pipelines are deemed as the optimal energy transport infrastructure across all the considered planning stages. This is predominantly due to the high variability of RES, which requires in some cases more than 8 hours of storage to buffer this variability. Linepack storage is cheaper in the model than BESS.
- Investing in UHS in the form of depleted gas fields in specific locations in Australia can significantly decrease the total investment cost of transport and storage infrastructure.

A further modification of the model demonstrated how investment decisions could be optimised by comparing single year solutions that were locked, and subsequently expanded to meet future demand with multi-stage planning to enable cheaper future expansions by making long-term forward-thinking investments. The multi-stage model can capture the option value of building larger pipelines in the early years in anticipation for uncertainty in RES in future years that may call for larger storage requirements. For the considered case study, the model showed that the multi-stage planning approach is AUD4.75 Bn cheaper (13 per cent) than the solution found using an incremental approach.

This project only considers new energy infrastructure, and the results may change when the existing gas and electricity infrastructure is included.

The developed models were tested with hydrogen demand scenarios as per 2022 AEMO's ISP Hydrogen Superpower scenario. Industry-led scenarios can be developed to help inform decision making for new hydrogen infrastructure. The technical reports for this project are available from the project's webpage on the Future Fuels CRC website: https://www.futurefuelscrc.com/project/rp1-1-02b-transport-and-storage-options-for-future-fuels/

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