Open-Source Tools for the Hydrogen and Power to X Economy

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Background and Motivation

- Renewable energy driven "Power to X" technologies are emerging as key supply pathway for clean energy and feedstocks to enable deep routed decarbonisation in hard to abate and directly electrify sectors.[1]
- To achieve global net zero targets, Power to X deployment to generate green hydrogen, synthetic fuels (methanol, ammonia, synthetic aviation fuels etc) and clean industrial commodities (ammonia, green steel etc.) are expected to account for upto ~30% of final energy consumption by 2050.[2]
- This potential is realised globally with more than 30 countries and the EU committing to roadmaps, policy, targets, incentives, technology and investments to enable offtake of Power to X. Of these key emerging projects include green hydrogen, ammonia, their export and use of hydrogen for natural gas blending and hydrogen refuelling.[3]
- Yet, while there has been a record number of projects being committed and announced, of these ~ 4 – 10% have reached Final Investment Decisions and majority are still in prefeasibility stages.[3-4]

Aims and Objectives

- Develop comprehensive frameworks to enable Power to X project design development and their subsequent economic analysis.
- Apply these frameworks to inform the development of emerging Power to X economies in Australia and globally.
- Development of and distribution of open-source tools to support the global application of the frameworks.

HySupply – Hydrogen Costing Tool

Salient Features

- Enables design, simulation and costing of Power to Hydrogen projects (**Figure 1**)
- Provides functionality to design Power to Hydrogen projects through 24 different combinations of solar/wind farms and intermediate battery storage as either dedicated standalone or grid connected configurations.
- Relies on local solar/wind electricity generation data to simulate hydrogen generation (preloaded with data for 41 different potential project locations across Australia with option to include custom data as per user requirement)
- Is built around a comprehensive costing model that then enables a levelised cost analysis with options to conduct additional business cost analysis (Return on Investment, Net Profit and Payback period)

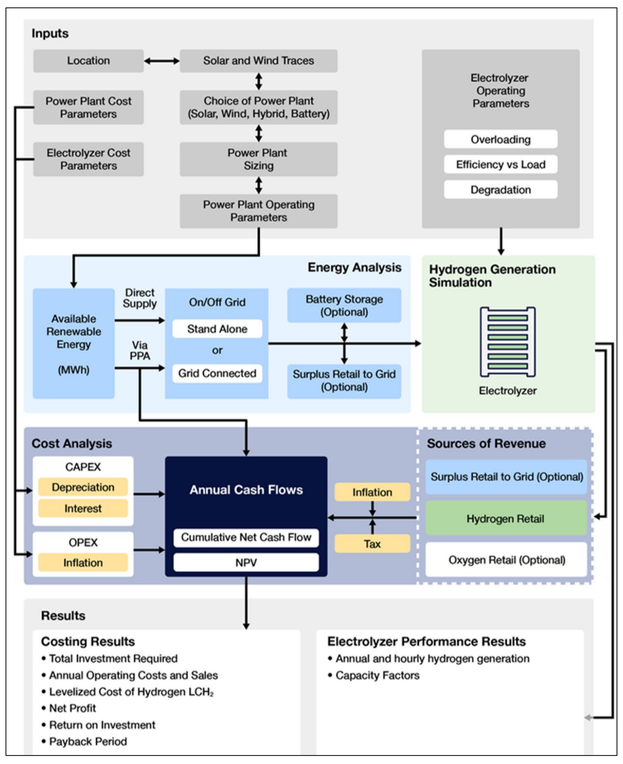

Figure 1: HySupply Hydrogen Costing Tool Framework

Key Outcomes

- Capacity factor modelling of powerplant (including battery) and electrolyser across year to visualise hydrogen generation.
- Detailed breakdown of levelised costs of hydrogen including subsequent cash flow.

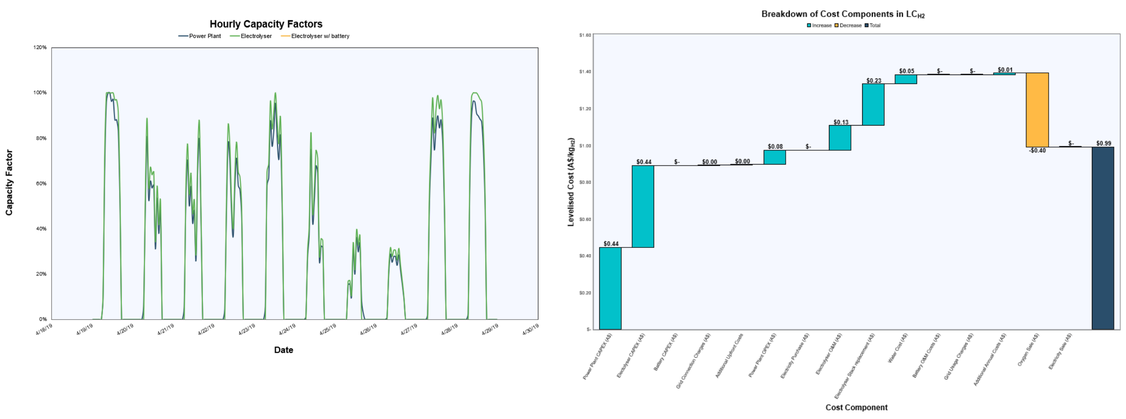

Figure 2: HySupply Hydrogen Tool Outputs

Tool Availability: The excel based tool, its user manual and walk through video are available on **GlobH2E Website**

HySupply Shipping Tool

Salient Features

- Enables roundtrip costing of hydrogen exports via different carriers (**Figure 3**).
- The carriers included are liquid hydrogen, ammonia, methanol, LSNG and LOHC)
- User can define fleet size, shipping volume and route to match their scope.

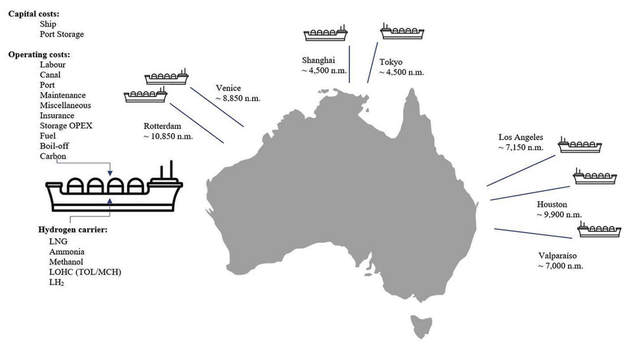

Figure 3: HySupply Shipping Tool Framework

Key Outcomes

- Tool then establishes the levelised cost of shipping based on roundtrip amount of hydrogen (A$/kg), energy delivered (A$/GJ) and carrier (A$/tonne of carrier) delivered.

Tool Availability: The excel based tool and its user manual are available on **GlobH2E Website.** In addition the tool was used for an export case study and that has been published by Johnston *et al.*[5]

HySupply – Ammonia Tool

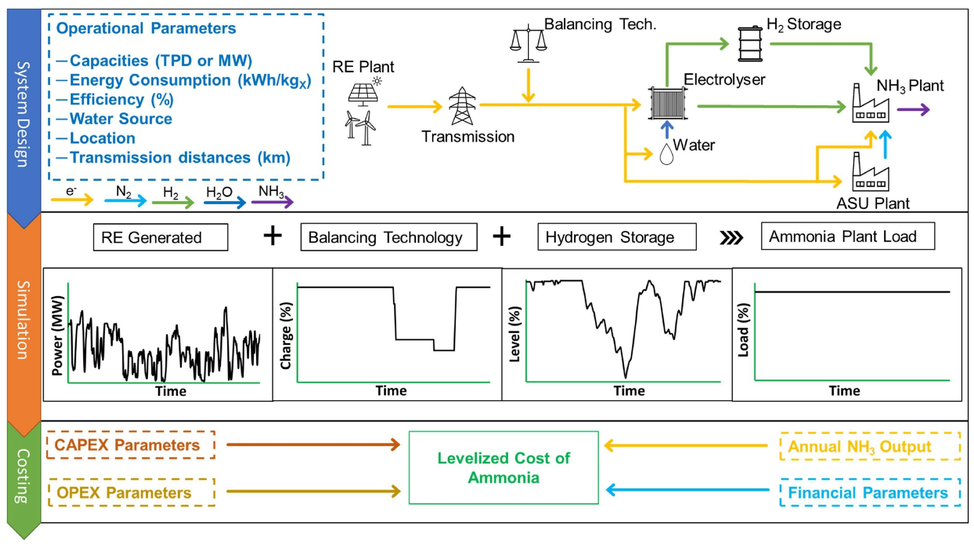

Figure 4: HySupply Ammonia Costing Tool Framework

Salient Features

- Enables design, simulation and costing of Power to Ammonia projects (**Figure 4**), by adding an additional layer of intermediate balancing of hydrogen supply and Haber Bosch process on to the HySupply Hydrogen Costing tool.
- Similar to hydrogen tool, the ammonia tool relies on solar/wind data to simulate hydrogen supply for Haber Bosch process.
- In addition, the tool integrates several types of balancing technology (battery, gas turbine and grid power) which is used to provide dispatchable power to maintain system reliability when the renewable power generation is insufficient to meet the power demand.
- Is built around a comprehensive costing model that then enables a levelised cost analysis for ammonia produced.

Key Outcomes

- Capacity factor modelling of integrated Power to Hydrogen and Haber Bosch Facility (including balancing technology and storage)
- Detailed breakdown of levelised costs of ammonia.

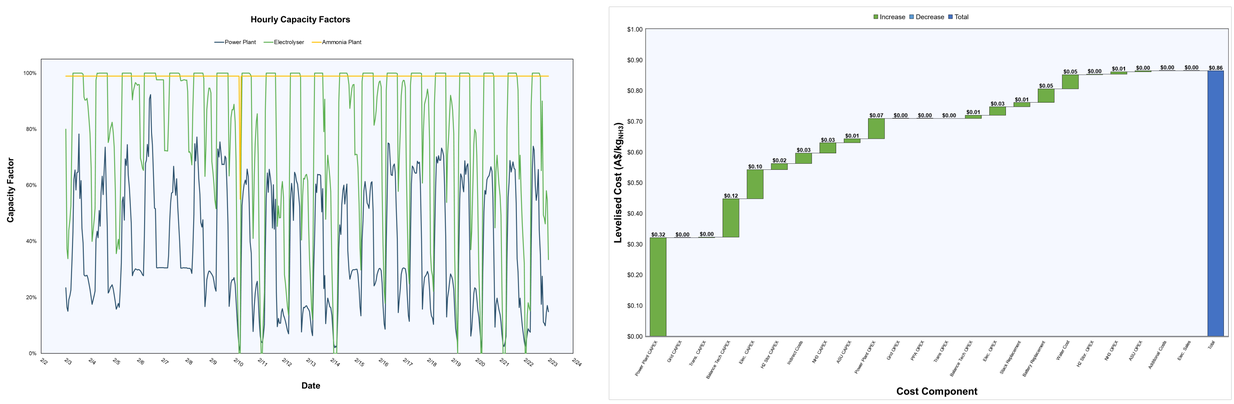

Figure 5: HySupply Ammonia Tool Outputs

Tool Availability: The excel based tool and its user manual are available on **GlobH2E Website.** In addition the tool was used for an export case study and that has been published by Shepherd *et al.*[6]

Next Steps

- In line with this theme, we are developing further similar open source tools to extend on the Power to X value chains.
- These tools and relevant publications will be shared and made available through our GlobH2E website (https://www.globh2e.org.au/)

References

1. R. Daiyan, I. MacGill, R. Amal, ACS Energy Letters. 2020, 3843.
2. IEA. Net Zero by 2050. 2021.
3. IEA. Global Hydrogen Review 2022. 2022.
4. Hydrogen Council & McKinsey and Company. Hydrogen Insights. 2022.
5. C. Johnston, M. H. A. Khan., R. Amal, R. Daiyan, I. MacGill, International Journal of Hydrogen Energy. 2022, Vol 47 (47), 20362 - 20377
6. J. Shepherd, M. H. A. Khan., R. Amal, R. Daiyan, I. MacGill, Energy Conversion and Management. 2022, Vol 274, 116413

Acknowledgements

We acknowledge the ARC Training Centre for the Global Hydrogen Economy which is funded by The Australian Government through the Australian Research Council Industrial Transformation Research Program, the Partner Organisations and the Universities for support on these projects.