Understanding the risk of stranded assets for blue hydrogen production plants

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Abstract

Hydrogen can help tackle various critical energy challenges, since it offers ways to decarbonise a range of hard-to-abate sectors, including long-haul transport, chemicals, and iron and steel. However, currently hydrogen is almost entirely supplied from natural gas and coal. Thus, the hydrogen production market needs massive shift towards the capture of CO2 from hydrogen production from fossil fuels and significant supplies of renewable hydrogen from clean electricity. Establishing hydrogen supply chains on the basis of fossil fuels, as many national strategies anticipate, may be incompatible with decarbonisation targets and raise the risk of stranded assets.

Our analysis show that several key techno-economic factors can significantly affect the contribution of different hydrogen production technologies. We found that across all scenarios, there is a considerable risk for early retirement of blue hydrogen production plants. Yet, the significance of risk and the average lifetime of those plants depend heavily on how the technologies (CCS, ATR and Electrolysis) will evolved in the next few decades.

Introduction

Hydrogen can help tackle various critical energy challenges, since it offers ways to decarbonise a range of hard-to-abate sectors, including long-haul transport, chemicals, and iron and steel. However, currently hydrogen is almost entirely supplied from natural gas and coal. Thus, the hydrogen production market needs massive shift towards the capture of CO2 from hydrogen production from fossil fuels and significant supplies of renewable hydrogen from clean electricity. Yet, producing low-emission hydrogen is costly at the moment, but it’s projected that the cost of producing hydrogen from renewable electricity could fall 30% by 2030 as a result of declining costs of renewables and the scaling up of hydrogen production (Fazeli, et al 2021). Establishing hydrogen supply chains on the basis of fossil fuels, as many national strategies anticipate, may be incompatible with decarbonisation targets and raise the risk of stranded assets.

In the context of transition to low-carbon economy, stranded assets are defined as assets that have suffered unanticipated write-downs, devaluations or conversions to liabilities (Ansar et al. 2013). These assets may refer to resource reserves, infrastructure or industries that may be affected by economic, physical or political changes along a pathway of decarbonisation.

For example, the introduction of climate mitigation policies such as a global carbon tax, or the phasing out of fossil fuels’ direct and indirect subsidies, could directly affect investments’ return through portfolios’ exposure to carbon-intensive economic sectors. Such effects could induce systemic risk and result in early retirement of assets (Battiston et al., 2016a).

Computable general equilibrium models are not capable, by construction, to model the dynamics of a complex finite system such as the human-environmental coupled system characterized by non-linearity, multiple feedbacks, time delays, and the presence of nonrational and short-term thinking agents (Monasterolo et al., 2015). On the other hand, evolutionary economics approaches applied to complex systems such as system dynamics, agent based models and network analysis could contribute filling in the modelling gap and support the implementation of a new economics paradigm to rethink sustainability as a complex adaptive system, as advocated by Farmer et al. (2015) and Battiston et al., (2016b).

This study aims at 1) providing a better understanding of the dynamics of hydrogen supply development using the dynamic simulation model that captures the interactions between supply, demand and market price of hydrogen, 2) assessing whether investment in blue hydrogen in the short-term can result in a significant early retirement of blue hydrogen production plants (stranded assets).

Description of Simulation Model

A dynamic simulation model is developed to explore the risk of stranded assets for blue hydrogen production plants. Figure 1 shows main components of the model and their interactions. There are two main balancing feedback loops; B1 represents the balance of supply and demand, while B2 captures the balance of price and demand.

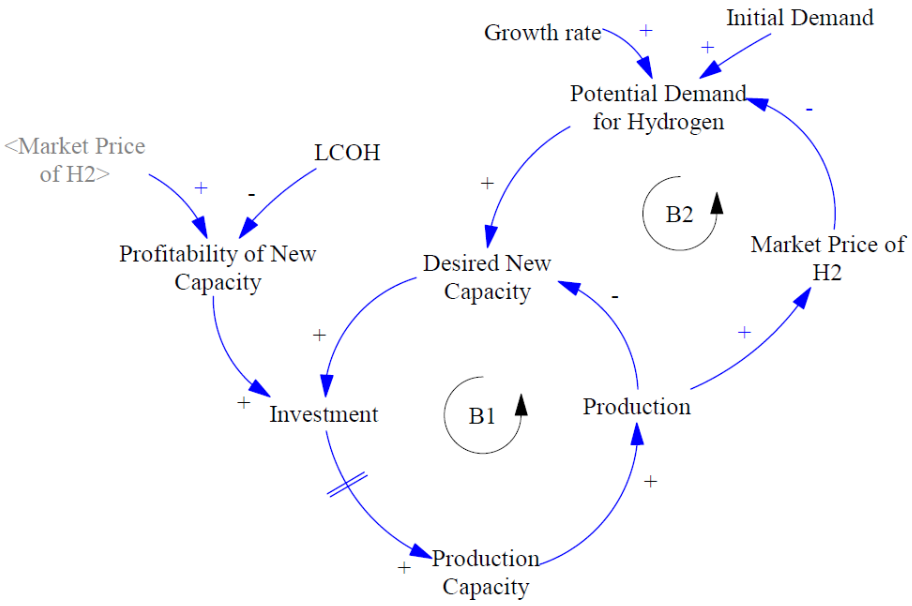

Figure 1: The dynamics of hydrogen transition model

Key equations in the Hydrogen transition model are presented here:

To estimate the potential demand for hydrogen (PD_t), we modified a Gompertz curve by removing time and replacing it with the difference between a reference price and the lowest levelised cost of low-emission hydrogen in each time period (t). Potential demand (PD) is calculated as follows:

$$PD_t = D_{t=2020} \exp\left(\ln\left(\frac{A}{D_{t=2020}}\right)\left(1 - \exp(-k[L_{t=2020} - L_t])\right)\right) \tag{1}$$

where $D_{t=2020}$ is the demand level in 2020 (87Mt), *A* is the upper asymptote of 528Mt, which was set based on a projection for Net Zero Scenario at 2050 in IEA (2020), *k* is a growth coefficient and L_t is the lowest production cost of low-emission H_2 at time *t*. The levelised cost in 2020 ($L_{t=2020}$) is the sum of \$1.57/kg (the cost of producing hydrogen using SMR with 56% CCS) and the cost of carbon with emission intensity of 12.4 Kg CO_2/Kg H_2 (SMR based H2 production).

Market Price depends on two factors; the marginal cost of the most expensive producer (marginal producer)[1] and the Demand/Supply ratio (Sterman 2000).

$$MP_t = Max\ (MC_{it}, if\ TP_{it} > 0)\ \times (\frac{Demand}{Supply})^s \qquad (2)$$

MP_t is the Market Price at time t

MC_{it} is the Marginal Cost of technology i, time t

TP_{it} is the total hydrogen production of technology i time t.

s is the sensitivity of price to the demand-supply balance

Total production (TP) is based on Installed Capacity and the operational capacity factor (α_{it}):

$$TP_{it} = \alpha_{it} IC_{it} \qquad (3)$$

The operational capacity factor (α_{it}) allows for a merit order selection of technologies where existing installed capacity is utilised based on comparative cost (LCOH).

$$\alpha_{it} = \begin{cases} \frac{ED_t - \sum_{i \neq I}^{4} TP_{it}}{TP_{it}} \quad (merit\ based) & if MC_i < MP_{t-1} \\ 0 & if\ MC_i > MP_{t-1} \end{cases} \qquad (4)$$

When a technology (*i*) becomes unprofitable, i.e. marginal cost of production is significantly greater than the market price, then the capacity factor for that technology is set to zero and the early retirement of facilities is being activated in that situation.

Scenario Analysis

Scenario Analysis is a powerful approach to explore the combined effect of a wide range of factors simultaneously. In this study, the key critical factors include the production costs of blue and green hydrogen and carbon price. We studied three scenarios, to explore different trajectories for key techno-economic factors:

- Good for Blue H2: Low CAPEX of blue H2 plants (SMR-56%CCS 1050 US$/KW at 2020, 850 US$/KW at 2050, SMR-90%CCS 1600 US$/KW at 2020, 1300 US$/KW at 2050, ATR-95%CCS 1700 US$/KW at 2020, 13500 US$/KW at 2050), low Gas Price (<8 $/GJ)
- Baseline: Mid CAPEX of SMR and ATR with CCS and electrolyser, Mid Gas and electricity Price
- Good for Green H2: Low CAPEX of electrolyser (835 US$/KW at 2020, 200 US$/KW at 2050) and Low cost of Electricity (46 AU$/MWh at 2020, 22 AU$/MWh at 2050), and high capacity factor (48%)

In all scenarios, the carbon price is set to be consistent with IEA NZE Scenario, reaching 250 US$/ton CO2 at 2050.

Preliminary results

Figures 2a-c illustrates the hydrogen production from different production technologies. We found that in the baseline scenario (Figure 2b), the SMR with 56% and 90% CCS can contribute significantly to hydrogen production until 2032, but then the green hydrogen will dominate the production, which can result in early retirement of those CCS plants.

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[1] Referred to as the market clearing price in the economics literature

On the other hand, in the “Good for Blue H2” scenario (Figure 2a), because of the low capital cost of blue hydrogen production technologies, they can continue the production of blue hydrogen until 2050, yet, SMR with 56% and 90% CCS plants are facing the risk of being stranded before 2035 and 2045, respectively.

In the “Good for green H2” scenario, due to rapid reduction in the capital cost of electrolysers and electricity, only the plants that are currently under development will continue to produce hydrogen, whereas there is a considerable uncertainty about their profitability even in their first 10 years of lifetime.

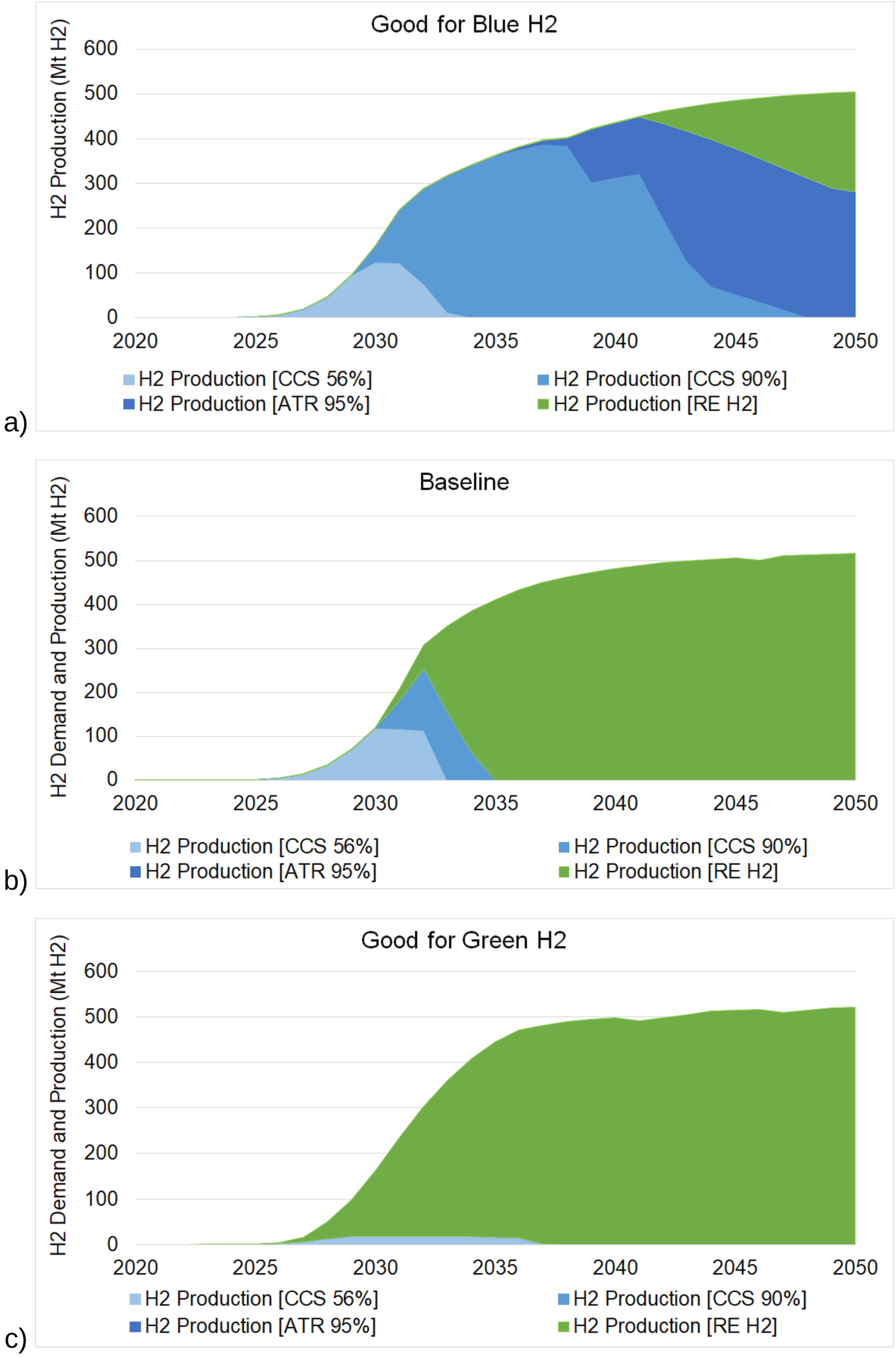

Figure 2: Hydrogen production from different technologies across three scenarios

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