HYDROGEN STORAGE FOR A NET ZERO CARBON FUTURE

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Overview

As the worldwide demand for hydrogen continues to grow, the need for hydrogen storage is expected to increase proportionally. The main driver of this demand would likely be the eventual imbalance between hydrogen production and consumption. For example, hydrogen generated through electrolysis using solar and wind power will be intermittent. Variability in wind speed and solar irradiation at different times of the day and year can significantly impact hydrogen production. As a result, hydrogen manufacturing may not coincide with peak consumption and demand may not be highly responsive to overproduction or underproduction of hydrogen. Furhemore, even hydrogen generated from fossil fuels with carbon capture, utilization, and storage (CCUS) – will be reasonably flat (linear) to provide the maximum efficiency. At the same time, this production pattern is unlikely to coincide with hydrogen demand all the time, which could be addressed through storage. Indeed, storage is already a key component of existing fossil fuel supply chains.

Moreover, in the electricity sector, hydrogen storage could serve as a means of grid balancing when overproduction and underproduction issues arise. Power-to-X technologies, which convert electrons into molecules and back, could help avoid the curtailment of renewable generation due to overgeneration or local network issues. Consequently, hydrogen storage would play a vital role in the decarbonization process by facilitating the spread of renewable energy sources through offering backup and seasonal storage options where batteries and pumped hydro have capacity or geographical limitations. This is critical because natural gas, which is commonly stored to meet seasonal energy demand, is not a carbon-free solution.

This paper evaluates the relative merits and techno-economic features of the major types of hydrogen storage options. It also discusses the main barriers to investment in hydrogen storage and highlights key features of a viable business model for hydrogen storage.

Methods

The study will involve extensive literature review and analysis of data related to the various types of hydrogen storage options, including their costs, efficiencies, and environmental impacts. Additionally, interviews with industry experts and stakeholders are conducted to gain insights into the current state of hydrogen storage technologies and the main challenges faced by potential investors.

To address the primary risks to which potential hydrogen storage investors are exposed, the study will also examine the policy and regulatory framework needed to support investment in hydrogen storage. This will involve a review of possible business models as well as an analysis of the potential impact of future policy changes on the hydrogen storage industry.

Overall, the methodology for this study includes extracting and synthesizing data to provide a thorough analysis of the relative merits and challenges associated with different types of hydrogen storage options, and the policies and regulations needed to support investment in this critical industry.

Results

Different types of hydrogen storage options have varying advantages and disadvantages. Pure hydrogen storage through compression or liquefaction is relatively mature in terms of technology and market, but it is energy-intensive, presents safety risks, or may face challenges in finding suitable storage locations. Synthetic hydrocarbons are a simpler option because they have well-developed storage infrastructure but production and dehydrogenation can be costly. Chemical hydrides like ammonia and methanol are liquid under ambient conditions, easier and cheaper to preserve, and have extensive storage infrastructure, but their production and dehydrogenation costs are still unclear. Liquid organic hydrogen carriers (LOHCs) are by-products of oil refining but their gravimetric hydrogen content may not necessarily be attractive enough in all the cases. Metal hydrides allow for solid and concentrated storage, but are heavy and have slow hydrogenation/dehydrogenation speed. Porous materials such as metal organic frameworks and carbon-based systems offer safe and stable storage, but are not widely used yet. These mean that each hydrogen storage option could potentially offer unique benefits and prospects for development in the future.

Apart from technical and technology-related challenges that influence the cost and overall business attractiveness of a particular H2 storage option, there are several barriers and uncertainties related to hydrogen preservation and the entire hydrogen value chain. These factors should be considered when designing a business model for hydrogen storage. Uncertainties regarding the demand for hydrogen, regulations, and the potentially high cost and scale of storage are just a few examples.

Conclusions

Although both small- and large-scale hydrogen storage options are likely to be important in the future, government support for large scale storage can be justified by at least two reasons. First is that large-scale storage facilities are likely to be more cost-efficient than smaller ones, as they can benefit from economies of scale in terms of equipment, infrastructure, and operation costs. Second, large-scale hydrogen storage facilities can help to accelerate the development and commercialization of hydrogen technologies by creating a market for hydrogen storage and stimulating private sector investment in the technology. The presence of a hydrogen storage market will benefit smaller and less mature technologies too over the long run.

There are various business models that could be applied to make hydrogen storage more attractive for investors by allocating risks between the government and private parties. The three main categories of business models are market-based, centrally-coordinated, and regulated. These models can be used to address different risks, such as price and volume risks, and an optimum business model would need to provide some degree of certainty with respect to both risks. However, each approach has its challenges and deficiencies, and careful consideration is needed to select the most suitable business model for a specific context.