Strategy Recommendation for Encouraging Hydrogen Economy

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Introduction

Carbon based fuels, through their extraction and consumption, are the most extensive and intensive cause of environmental degradation. Renewable forms of energy such as solar and wind have made great strides forward but are hampered by their intermittent nature and lack of cost effective storage options.

Storage in the form of batteries is making great strides forward to be cost competitive but the production of batteries still relies on significant natural resource extraction and there are many physical limitations to their efficacy. Another promising energy storage method is Hydrogen.

Hydrogen, as an energy carrier, has three times the energy density as fossil fuels. Additionally, when its energy is released through combustion or in a fuel cell, the only byproducts are water and heat.

Unfortunately, the vast majority of hydrogen is produced through steam reformation of methane and therefore tied to fossil fuels. There are many renewable alternative methods of hydrogen production such as electrolysis, or biomass gasification but they are prohibitively expensive or not scalable. New material advances in production and storage are bringing the hydrogen horizon within sight.

Objectives

We assessed technological advances in all facets of the hydrogen economy as well as economic, political, safety, and public perception factors to answer the following questions:

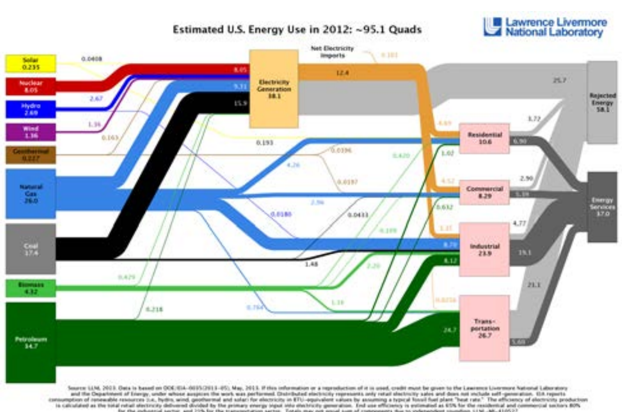
1) Is Hydrogen a viable alternative to our current energy system?
2) If so, should it be developed and what is the best strategy?

Methods

We analyzed the major energy use scenarios to determine where and how hydrogen could be implemented. These scenarios were utility scale, industrial scale, residential scale, and transportation.

Our strategy was very heavily influenced by political feasibility, infrastructure logistics, other renewable markets, and public safety.

We also formed a quantitative model that analyzed the energy efficiency, cost, and lifetime of different pathways with a hydrogen integrated system.

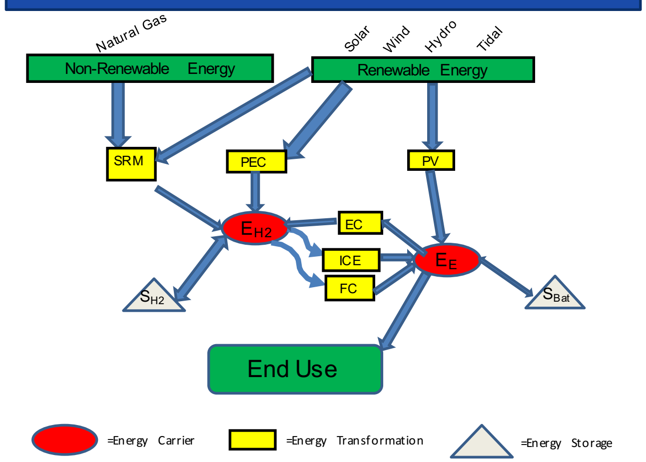


Preliminary Findings

After conducting our research surveying the current state of hydrogen energy, we have come up with several initial findings to incorporate as we continue our analysis. These will help guide us through the latter stages of our research and, ideally, shape our final recommendations and strategies.

1. Hydrogen research goals and applications focus primarily on transportation scenarios instead of other options, such as utility-scale power production. Hydrogen as a fuel for transportation does not appear to be viable because of the massive infrastructure and logistical hurdles that need to be overcome to support hydrogen vehicles on a significant scale.
2. Out of the three primary production technologies- steam reformation, photoelectrocatalysis, and standard electrocatalysis- steam reformation produces 90% of commercial hydrogen and has appeal as a cost-effective and mature method of mass hydrogen production when compared to the other two technologies.
3. Research and new material development in both PEC and EC is promising; however, they do not appear to be ideal for implementing hydrogen into the energy system for the near future.
4. While a carbon-free energy system is desired, hydrogen energy systems which incorporate fossil fuel use may still benefit from avoided emissions and a higher cost-effectiveness, thus being an attractive option for commercial implementation.

Pathways to Integrated Hydrogen System



(P)EC= (Photoelectro) Electrocatalysis PV= Photovoltaic FC= Fuel Cell
ICE= Internal Combustion Engine S_{H2}= Hydrogen Storage S_{Bat}= Electrical Battery (Lithium-Ion)

Above is our pathways model we constructed in order to better visualize the layout of our analysis and to provide a convenient way of envisioning potential energy systems incorporating hydrogen. In the model, hydrogen is produced from various sources of input energy, where it can then be stored or transformed into electricity. This electricity can, in turn, be stored, converted back to hydrogen, or consumed for final end use. While this model represents a simplified view of an energy system, it provides a convenient method rapidly assessing the viability of hydrogen's incorporation into the existing power production framework.

Example Energy Pathway

Natural Gas →(SMR) E_{H2} →(Compressed Gas) S_{H2} → E_{H2} →(FC) E_E →(Residential) End Use

Takeaways

During our research process and model analysis we learned a great deal about the feasibility of differing pathways for the production, storage, distribution, and end-use of hydrogen.

Here are the major takeaways from our work:

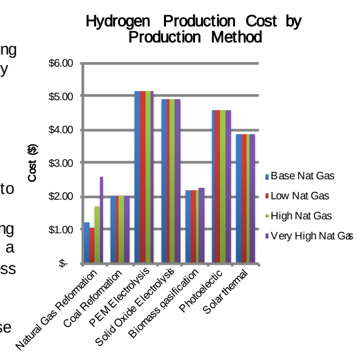
1. Research for the use of hydrogen in transportation is abundant, but there is significantly less research directed towards hydrogen storage on the grid. Yet, due to the lack of distribution infrastructure, transportation is only reasonable in the short-term for fleet-based vehicles (such as city buses and delivery vehicles) that refuel at a central depot
2. Due to the large-scale needs for centralized production, storage, and application of hydrogen, implementation of hydrogen as a method of energy storage is much more likely to be realized on a distributed scale in the short-term
3. In the short-term, steam reformation produces more hydrogen at lower costs than electrolysis and alternative production methods based
4. Photoelectric Catalysis is not feasible in the short-term. In the long-term it is feasible if improvements are made in the capital costs of materials, the processes efficiency, and the scale at which it is able to produce hydrogen

These takeaways lead into our recommendations for how to best utilize hydrogen's potential as an energy carrier.

Recommendations

Our initial research and findings led these specific recommendations:

1. Industry should consider investing in hydrogen storage over battery storage
2. Government should incentivize hydrgoen production, storage, and end-use in the electricity sector
3. Steam reformation of methane to produce hydrogen should be used as a complement to existing electricity generation, providing a cost-effective way to store excess electricity
4. Further investment in hydrogen production, storage, and end-use will increase hydrogen's viability as an essential component of a reliable energy network



Future Work

We hope our research can support future investigations into the technologies, policies, and strategies needed to complete the integration of hydrogen generation and storage into the global energy system.

In the short term, we encourage further research in three main areas:

1. Compare the lifecycle efficiencies among the hydrogen pathways in our model
2. Evaluate potential government policies and financial incentives that encourage hydrogen storage over battery storage
3. Project the impact of new materials advancements on the cost effectiveness of hydrogen generation and storage

Over time, we expect hydrogen storage to be seen more as a electricity generation storage solution rather than as a transportation fuel. This will raise new questions about the costs and benefits of a hydrogen-integrated energy system.