Hydrogen Enabling Renewables Working Group

Working Group Summary Report and Close-Out Plan

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Purpose

Examine the various ways in which hydrogen might serve as an enabler for high penetrations *(>50% nationally, or regionally, on an energy basis – See appendix)* of variable renewable energy in the United States.

Summarize the opportunities and challenges of using hydrogen as an enabler for renewables in "white paper(s)" for DOE executive management.

Potential Applications

- Energy storage
- Supplement to Natural Gas System
- Energy transmission & distribution
- Improved renewable resource utilization via vehicle fuel production

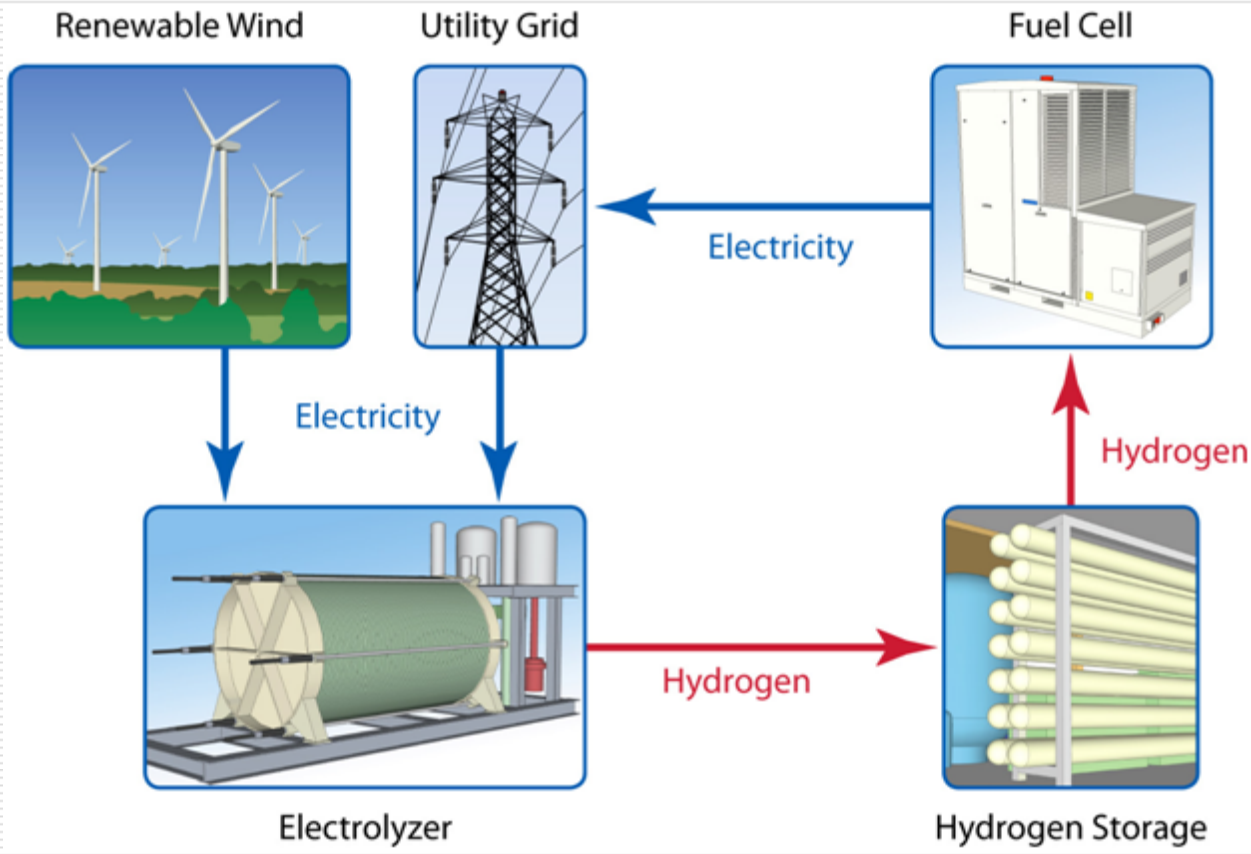
Initial Focus Area

- **Grid energy storage application**
  - Integration of variable renewable resources (ramp rate controls, time shifting from off-peak to on-peak, reserve margins, etc.)
  - Reduction of variable renewable energy curtailments due to baseload bottoming and/or transmission and distribution system constraints
- **Basis**
  - Analysis of this application can be leveraged in the analysis of other applications
  - DOE interest in energy storage for integrating renewables

Energy Storage Modeling

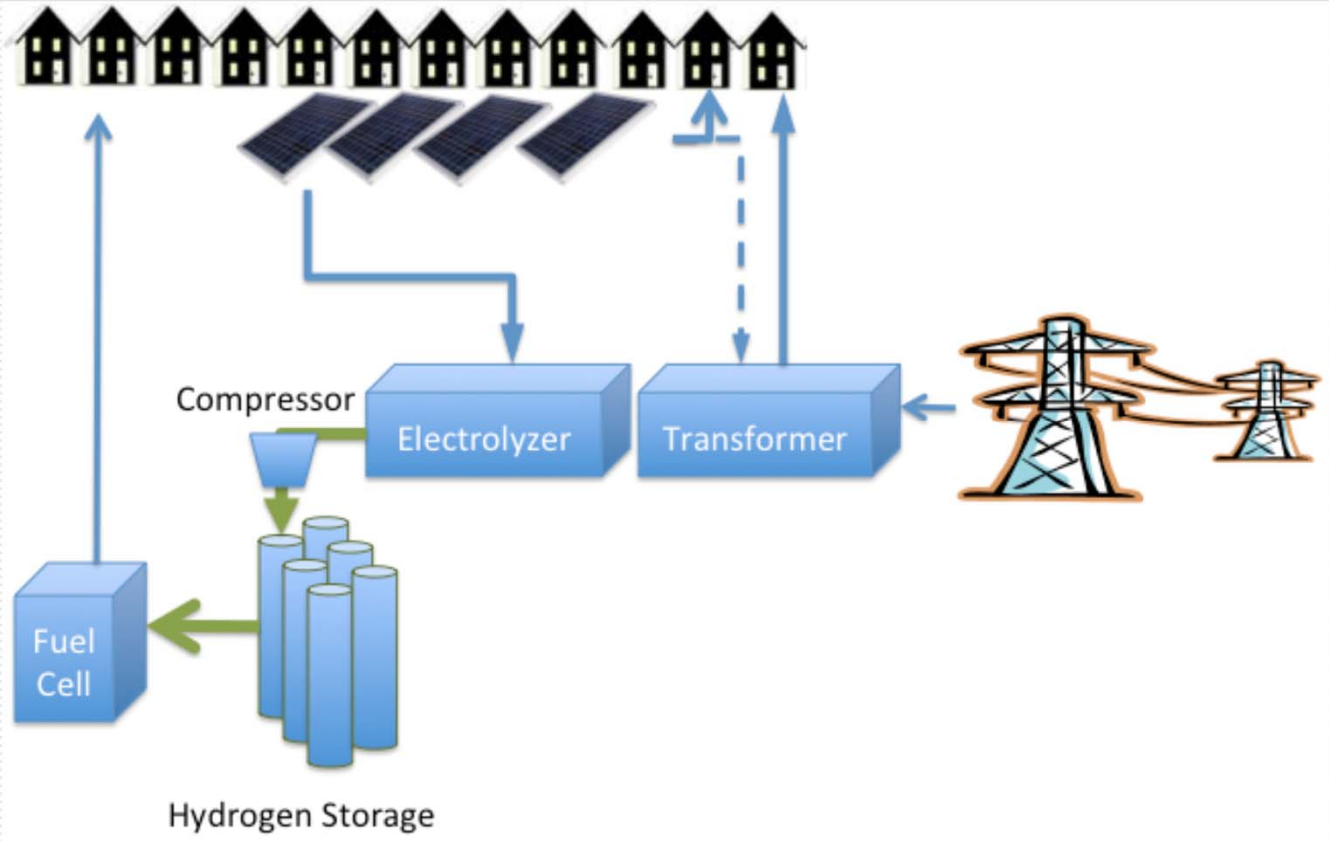
- **Simple Model: Sandy Thomas (Consultant)**
  - Direct comparison of energy storage technologies
  - Identified competitive opportunities
- **Community Energy Model: Darlene Steward (NREL)**
  - Explored potential for small scale hydrogen energy storage to support grid and hydrogen vehicles
  - Compared results to comparable/competitive energy storage system supporting grid and electric vehicles

"Simple Model"



C.E. "Sandy" Thomas - Consultant

"Community Energy" Model



Darlene Steward - NREL

Other Approaches

- Near the end of the of the Working Group's efforts, new information was being discussed about approaches to storing renewable energy as hydrogen in the nation's existing natural gas system.
- In Europe there are now more than twenty so called "power-to-gas" hydrogen energy storage demonstration projects which have been launched in the last 18 months – more than any other technology platform for utility scale storage.
- Though the Working Group did not delve into this hydrogen storage pathway in significant detail, the concept is intriguing to several of its members and could possibly have applications for the U.S.

Overall Conclusions

- As the nation's renewable generating capacity (solar and wind) expands to deliver a significant fraction of the total electric energy generated (somewhere greater than 30 percent on an energy basis nationally), both short and long term energy storage will likely be very desirable, if not required.
- Under the Working Group's scenario, it was assumed that environmental policies would likely be in place influencing grid economics to maximize the use of renewable energy, such that using curtailment as a means to maintain grid stability would be much a much more costly control measure than it is today.
- If that is the case, there would conceivably be economic benefits to storing weeks or more of otherwise curtailed renewable energy during peak output periods in high penetration renewable regions for use during periods when renewable energy output is low.
- Hydrogen technology, as shown by the "Simple Model" analysis, has the most economical and greatest storage capacity for absorbing and re-purposing energy generated from renewable generation when compared to batteries, compressed air energy storage, and pumped hydro storage solutions, when the storage requirement is in terms of weeks or longer.
- Although results do not show a clear advantage for hydrogen energy storage load leveling or vehicle refueling at smaller scales, the economics could become competitive with larger systems (on the order of 15,000-kW peak capacity PV systems).
- Continuing assessment of the economic viability of hydrogen production as a renewable energy storage pathway should be a high priority for DOE and the renewable/electric industry, working in partnership.

Recommendations

Energy Storage for Wind Integration:

- ☐ Determine if there are national policies being considered that would significantly increase renewable penetrations as a means to reduce greenhouse gas emissions.
- ☐ Conduct system analyses including and excluding long-term storage using policy scenarios identified, and from these analyses, estimate the value of hydrogen energy storage to the overall system under those scenarios.
- ☐ Determine what value the government could assign to otherwise curtailed renewables to make multi-day/week scale hydrogen (and other) energy storage economical.

Recommendations

Community Energy for Load Leveling and Vehicle Fueling:

- Conduct sensitivity analyses to determine what conditions are necessary for a hydrogen system to compete with electric battery system for fueling FCV and EV vehicles, respectively, with solar PV energy.
- Determine the community scale at which hydrogen storage competes with battery storage for solar PV load leveling and vehicle fueling.

Recommendations

Other Approaches

- Consider investigating potential U.S. applications for "power-to-gas" energy storage systems
- If deemed to have potential, initiate a dynamic economic study (potentially led by EPRI and supported by the relevant teams at DOE and NREL) to evaluate the system wide and integrative benefits of such hydrogen storage system for U.S. markets.

Closeout Process

- Seek approval from HTAC of Summary Report, including conclusions and recommendations, pending HTAC review of final white papers and agreement that they support the Summary Report approved
- Finalize white papers to address recent quality review comments from team members
- Transmit final white papers to HTAC, requesting member comments
- Conduct an HTAC webinar or teleconference to seek final agreement or delegate final responsibility to Working Group lead and white paper authors to determine that the white papers support the Summary Report approved today
- Re-submit Summary Report with final white papers to HTAC when complete

Many Thanks!!!

- **Sandy Thomas** – Architect and driver of the Simple Model (on personal time!)
- **Darlene Steward** – Hydrogen energy storage subject matter expert and lead for grounding our work in reality
- **HTAC and other Non-HTAC Members** – experts and thought leaders

Bob Shaw
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Daryl Wilson
Fred Joseck
Monterey Gardiner
George Sverdrup
Jason Marcinkoski
Levi Thompson
Harol Koyama
Maurice Kaya
Peter Bond
Rob Friedland
Todd Ramsden

Appendix

Characteristics of a future US combined electric grid and transportation sector powered with >50% renewables

- Large amounts of variable off-peak renewable energy "spillage"
- Renewables used to power both grid and transportation sectors would count toward total energy produced (denominator) and total renewable energy produced (numerator)
- Reductions in the cost of renewable energy versus traditional energy sources due to high volume production and technological advances
- Baseload power plants with lower turndown capabilities and better load following performance
- Large wind resources will not be near large load centers, requiring significant transmission investments
- Environmental concerns and transmission constraints will limit large scale central solar facilities. This will influence more distributed scale solar, using existing urban and suburban open spaces, including paved lots. This resource will be interconnected to the distribution grids, and will produce more power than is used by the facilities associated with the solar resource.
- Distributed energy such as stationary fuel cells may be more economical and more efficient (both from energy conversion and CO2 perspectives) than utility scale thermal resources.