Is Renewable Energy with Energy Storage a "Disruptive" Technology?

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Joel M. Rinebold

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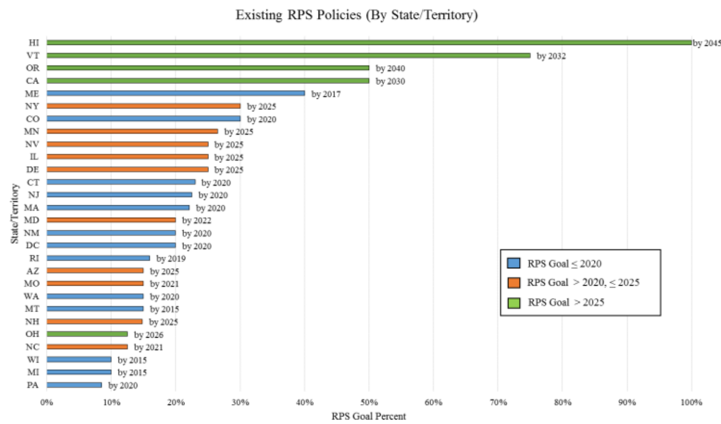
Renewable energy from solar and wind resources is getting attention from utilities, end users, and government. This attention is well justified in that renewable energy technology is becoming cost effective when compared to on-site conventional energy systems, and can provide an element of improved reliability that is increasingly important to maintain power after storm related grid outages. The technology, once considered "disruptive" to conventional baseload, fossil fueled, power plants tied to end users by long distance transmission lines and local distribution wires, is becoming accepted by consumers and supported by government with incentives to provide reliable distributed power without emissions and use of fossil fuels.

This technological advancement is however not complete and the transformation to renewable sustainability continues to evolve. In fact, it could be argued that renewable energy is just beginning to become the technology of choice. The barrier to a more rapid transformation is cost effective "energy storage" and how to make intermittent renewable resources work directly for consumers and for utilities powering up the grid when the sun does not shine and wind does not blow.

Currently, there are approximately 85,000 megawatts of intermittent renewable wind and solar resources in the US compared to an overall capacity to meet load of over 1,167,000 megawatts.[1] These renewable power facilities emit essentially no air emissions and use only sunlight and wind as fuel, but are available only during limited times ranging from 15 to 40 percent of the day. Even without the ability to follow demand and be dispatched for consumer use, this lower level of market penetration presents little concern that the grid can provide the backup power or storage with ease and without excessive cost to the consumer. However, as the amount of renewables

[1] U.S. Energy Information Administration (EIA); "Table 4.3. Existing Capacity by Energy Source 2015 (Megawatts;" https://www.eia.gov/electricity/annual/html/epa_04_03.html; October 17,2017.

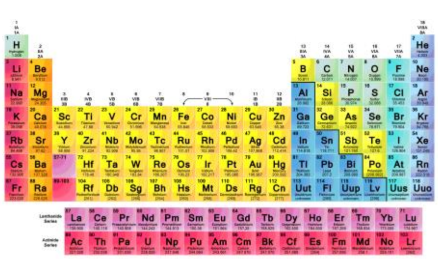
increases, the grid will be increasingly burdened with the provision of backup power that is only used when the renewables are not providing power. For the grid utilities and independent system operators, this presents a potential imbalance of redundant resources needed to meet consumer demand when intermittent generation does not run. Notwithstanding the overall public value for low emission renewable power, this imbalance is costly, technically inefficient, and must be reconciled with energy storage tied to the intermittent resources to effectively provide 24/7 dispatchable power as the consumer demands.



Energy storage is nothing new and has been provided by hydroelectric pumped storage facilities, electrochemical batteries, flywheels, and capacitor banks. All of these technologies are commercially available, and in certain circumstances, can be cost effective. However, these energy storage technologies will need to be ramped up to keep pace with the rapid deployment of intermittent solar and wind power that is projected to be added to the grid.

The deployment of intermittent renewables is expected to increase, partially due to government incentives and partially due to market acceptance of successful energy technologies. With state policies that provide incentives for renewables, some states may in a relatively short time have the majority of their power produced by renewables (NY 50% by 2030, CA 50% by 2030, VT 75% by 2032, HI 100% by 2045). With these higher levels of renewable energy penetration energy storage coupled with conservation and demand response will be necessary for 1) technical reasons to meet consumer demand, and 2) economic reasons for equitable allocation of costs.[2]

Lithium ion batteries are becoming widely accepted as the electrochemical energy storage technology of choice. Indeed, they have high power density, can be readily discharged and recharged on a daily basis, and can be cost effective for storage. However, hydrogen and hydrogen rich products provide another option for physical energy storage.



Are We Entering the Global Hydrogen Economy?

Hydrogen (element number one) is abundant in many natural compounds, and when present as a gaseous element

[2] Database of State Incentives for Renewables & Efficiency (DSIRE); "Renewable Portfolio Standard Policies:" http://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2017/03/Renewable-Portfolio-Standards.pdf; February 2017.

is lighter than air. If released, hydrogen will rise and dissipate without toxic effects. Hydrogen is currently used commercially for food production, metals manufacturing, industrial cooling, electric generation, and in the petrochemical industry to reformulate fuels. Hydrogen is typically separated from other elements to form pure hydrogen through electrolysis of water (H2O) or steam reformation of natural gas (CH4); however, hydrogen can be sourced from many hydrogen rich compounds, such as ammonia. Pure hydrogen is best characterized as an energy carrier, similar to electricity that can produce power without harmful air emissions, and can also be stored like conventional fuels, such as propane and natural gas. Consequently, gaseous and liquefied hydrogen (and hydrogen rich compounds such as ammonia) are being considered for energy storage when coupled with intermittent renewable energy, including wind and solar generation, and use with fuel cell technology to produce electricity, heat, and power.

Fuel cell and electrochemical technologies that can produce hydrogen for energy storage and use hydrogen to produce electricity have been in development in the Northeast US for space missions, stationary power, and transportation applications since the 1950s. The technology currently in use has been developed, tested, and refined consistent with an array of technical codes and standards to insure safety, durability, and reliability. The technology for stationary power, fuel cell zero emission vehicles (FCEV), and hydrogen production/refueling is now in commercial use in the US, including California and the Northeast states, Republic of Korea (South Korea), Japan, and Europe. As consumers and government demand cost effective energy that is clean, reliable, and available when needed, hydrogen is anticipated to become a widespread energy carrier for stationary power, transportation, and energy storage.

The pathways for the production of hydrogen are reliable and can be sustainable with high economic value. Many technologies to produce, store, and use hydrogen are proven, and represent opportunities for global economic development.

Is there a Structure to Produce and Market Hydrogen Technology?

Substantial portions of the global supply chain for hydrogen and fuel cell industries exist in the Northeast US. Key findings from a recent economic analysis of the hydrogen fuel cell industry in the Northeast US suggest that the hydrogen and fuel cell supply chain has a significant bearing on the region's economy, contributing over $1.4 billion in revenue and investment; more than

6,550 direct, indirect and induced jobs; and labor income of approximately $620 million. [3] This supply chain cluster in the Northeast US is concentrated in the New York, Connecticut, and Massachusetts region with industry companies involved in research, development, and manufacture of hydrogen production technology, transportation equipment, and electric generators for stationary power.

The geographic cluster of hydrogen and fuel cell original equipment manufacturers (OEM) and supply chain companies in the Northeast appears as a regional "Silicon Valley" for the advanced energy industry with all of the hallmarks of a global leader. This cluster provides benefits to its companies, suppliers, and workers in the entire region. The proximity of the OEMs and supply chain companies in this cluster has provided a competitive advantage for research, design, development, manufacturing, and export of commercial products to national and international markets. This cluster of hydrogen and fuel cell companies also provides an opportunity for the US to more fully utilize its renewable energy industry using hydrogen and fuel cells for transportation, energy storage, and power supply at consumer sites. Such applications continue to make the Northeast US a showcase for renewable energy while reducing greenhouse gas (GHG) emissions as new jobs are created and energy reliability is increased.[3]

The development of the OEM base and supply chain cluster has been supported by government policy for environmental protection, reliable energy, and economic development. These policy incentives include provisions for the following: [4]

- State/Regional Hydrogen and Fuel Cell Development Plans
- Mandatory Renewable Portfolio Standards (RPS)
- Net Metering
- Public Benefits Fund
- Performance Based Power Purchase
- Utility Ownership/Investment
- State Grants/Loans
- Microgrid Development for Reliability
- Property/Sales Tax Incentives
- Property-Assessed Clean Energy (PACE) Financing
- One Stop Regulatory Approval
- Identified Regulatory "Point" Person
- State/Regional Hydrogen Fleet Deployment Plans

[3] "2017 Economic Impact of the Northeast Hydrogen Energy and Fuel Cell Industry;" NEESC; September 2017.
[4] NEESC / H_2USA; "2017 Northeast Regional Hydrogen Economy Fuel Cell Electric Vehicle (FCEV) Fleet Deployment Plan" http://h2usa.org/sites/default/files/2017_Regional_H2_Fleet.pdf; April 2017, and NEESC "2015 Hydrogen & Fuel Cell Development Plan for CT, ME, NY, NH, VT, RI, MA, and NJ;" http://neesc.org/publications/2015_roadmaps/; January 2015.

- Zero Emission Vehicle (ZEV) and Fuel Cell Vehicle / H_2 Infrastructure Investments
- ZEV Purchase Target for Government Fleets
- Purchase Incentives and "Point-of-Purchase" ZEV Rebates
- Fuel/Tax Incentives
- Public/Private Infrastructure Partnership
- Fuel Efficiency Standards (Private/State Fleets)
- Renewable H_2 RECs
- HOV Lanes and Parking Incentives

The emergence of the Northeast US hydrogen fuel cell cluster has been mirrored in other global locations including South Korea. For example, the supply chain cluster in South Korea is concentrated in the Seoul area, with hydrogen and fuel cell companies in both the transportation and stationary power sectors. South Korea is home to at least 279 companies that are part of this growing hydrogen and fuel cell industry. These companies include developers of membrane stacks, balance of plant (BOP), test technology, catalysts, and other equipment.[5] Global companies include Doosan Fuel Cell, Hyundai, FuelCell Energy Inc. / Posco Energy, LG Corp. / Rolls-Royce Fuel Cell Systems, GE / GS Caltex Corp, Air Liquide, and Linde.[6] The majority of these companies have a global presence and do business worldwide. To date, these companies have installed over 220 MW of fuel cell technologies and deployed more than 100 fuel cell electric vehicles (FCEV) with at least 10 hydrogen refueling stations in South Korea. In order to expand the deployment of new and renewable energy, South Korea state-owned power generation companies (GENCOs) and independent power producers (IPPs) that generate over 500MW are required to generate at least 10 percent of their electricity from renewable energies by 2023.[7] Additionally, South Korea seeks to expand the market for FCEVs by providing incentives for clean energy technologies to help ensure there are more than 9,000 FCEV on the road by 2020 and 630,000 by 2030.

While these hydrogen fuel cell clusters in the Northeast US and South Korea are fully capable to function independently, a collaborative between the two clusters and their global companies in

[5]Korea Hydrogen Industry Association (KHIA); Hee Chun Lim; "The Status and Future Prospect for the Hydrogen and Fuel Cell Industry in Korea'". http://www.iphe.net/docs/Meetings/SC26/Workshop/Session2/IPHE%20Forum%20Gwangju%20Session%202%20Infrastructure%20-%20KHIA.pdf; November 2, 2016.
[6] H2-international; "South Korea Invests in Fuel Cells;" https://www.h2-international.com/2016/09/06/south-korea-invests-in-fuel-cells/; September 6, 2017.
[7] Export.gov; "Korea – Energy New and Renewable;" https://www.export.gov/article?id=Korea-Energy-New-and-Renewable; June 18, 2017.

an open and competitive manner could help to expedite research, manufacturing, and the economy of scale to needed drive down costs and increase international market penetration. [8]

Conclusion

Renewable energy with energy storage is no longer considered disruptive, but is often favored by consumers over large baseload fossil fueled generation facilities. The barriers are cost, adequate storage to meet peak demands, and interconnection on the grid. The pathways include commercially available technologies with market opportunities to improve the deployment of intermittent renewable energy resources. The growth of this market has ushered in the hydrogen economy which will rely on hydrogen as an energy carrier for energy transmission, storage, and production of electricity for stationary and motive power needs. As manufacturing clusters emerge to produce the technology to support this market, there will be an increasingly important value for global industries to collaborate in an open and competitive manner to accelerate research, engage in advanced manufacturing, develop supporting government policy, and improve the economy of scale for increased market use and global penetration of advanced energy technology.

[8] Such collaboration would require attention to avoid collusion and violation of anti-trust provisions. For example, all collaborative meetings in the Northeast Electrochemical Energy Storage Cluster are held in an open and competitive forum in compliance with strict anti-trust guidelines.