

Hydrogen Enabling Renewables Working Group

Update for the HTAC
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Members

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 - ❑ Rob Friedland (Outside Member - Proton Energy Systems)
 - ❑ Maurice Kaya (Energy and Management Consultant)
 - ❑ Harol Koyama (IdaTech)
 - ❑ Frank Novachek (Xcel Energy)
 - ❑ Robert Shaw (Aretê Corporation)
 - ❑ George Sverdrup (Outside Member – National Renewable Energy Laboratory)
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 - ❑ Levi Thompson (University of Michigan)
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Purpose

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

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

Potential Applications

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

- Grid energy storage
 - 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
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Plan for Evaluating Energy Storage Application

- Identify and assimilate information needed to evaluate the viability of hydrogen energy storage to:
 - Mitigate the variability of renewable energy
 - To be competitive with other energy storage technologies, including:
 - associated infrastructure requirements and
 - the relative probability of a solution being commercially available in the next 10 years
 - Develop simple model for examining the basic economics
 - Apply model to hydrogen and other competing energy storage systems
 - Compare results
 - Identify key issues for hydrogen system competitiveness
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Identified Information Needs

- Scale of energy storage required to enable 50% penetration of renewables on an energy basis
 - Levelized cost per kWh of energy (total life-cycle normalized) from hydrogen storage systems vs. alternative storage technologies that are commercial or projected to be in a comparable time frame,
 - At various scales
 - At various hours of storage
 - Infrastructure required (and costs) for hydrogen energy storage systems that is not required for alternative energy storage systems, and visa-versa, at various geographic scales (national, regional, local, distribution feeder levels)
 - Different configurations (i.e., energy transmitted by pipe or wire?)
 - Scale of systems (i.e., number of nodes)
 - Cost of operating and maintaining each infrastructure
 - Dynamic response capabilities from hydrogen and other energy storage systems
 - Energy storage applications that may be unique to hydrogen systems that can deliver additional value as perceived by customers
 - Performance & economics data from existing renewables integration projects world-wide
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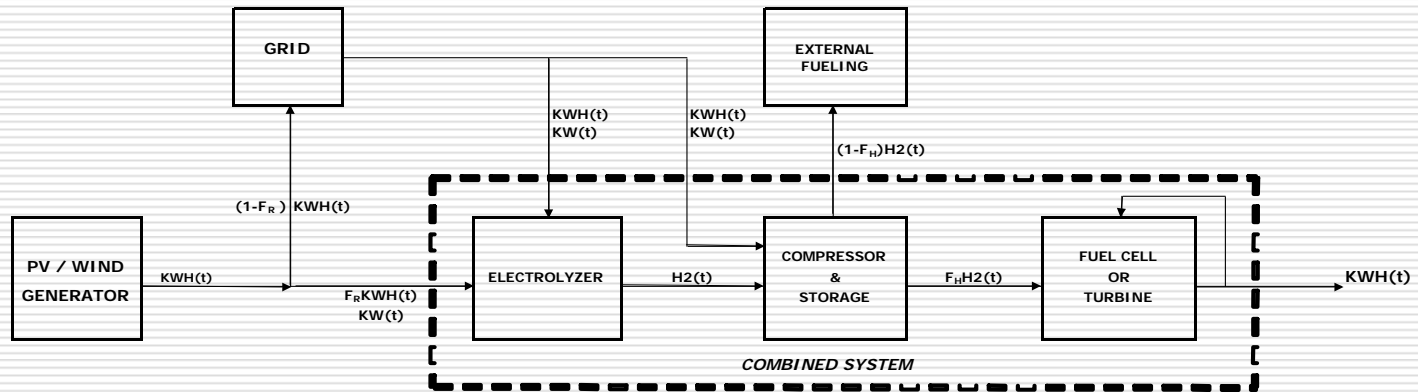
Simple Energy Storage Model Concept (DRAFT)

OUTPUT VARIABLES:

H2 PRODUCED (t)

COST/KG OF H2

COST OF POWER (€/KWH)
 •• OPERATING
 •• CAPITAL



INPUT VARIABLES:

CAPACITY: KW
 HOURS OF OUTPUT/DAY: T_o
 CONTRACT PRICE: €/KWH

COST OF GRID ENERGY: €/KWH(t)

F_R = fraction of kwh to electrolyzer

EFFICIENCY: KWH/KG
 CAPITAL COST: \$/KG
 POWER REQUIRED: KW
 OUTPUT: KG H2(t)

EFFICIENCY: KWH/KG
 CAPITAL COST: \$/KG
 POWER REQUIRED: KW
 OUTPUT: KG H2 stored (t)

F_H = fraction of H2 to fuel cell

EFFICIENCY: KWH/KG
 CAPITAL COST: \$/KW OUTPUT
 POWER REQUIRED: KW (HOTEL LOAD)
 OUTPUT: KWH (t)

COST OF CAPITAL

Assume the *Combined System* runs 24/7 with input either from the Renewable Generator or the Grid.

Note: Model could be run in hourly segments or integrated over a day, week, month, or year.

Questions for HTAC

- Does the HTAC/DOE agree with the Working Group's decision to initially focus on grid energy storage?
 - Are there other applications that the Working Group should be considering?
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