



Necessary Conditions for Hydrogen Energy Storage Projects to Succeed in North America

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Hydrogenics is a world leader in water electrolysis products and hydrogen fuel cell power systems

Onsite Generation Electrolyzers



Industrial Hydrogen



Hydrogen Fueling

Power Systems Fuel Cell Modules



Stand-by Power



Mobility Power

Energy Storage



Power-to-Gas

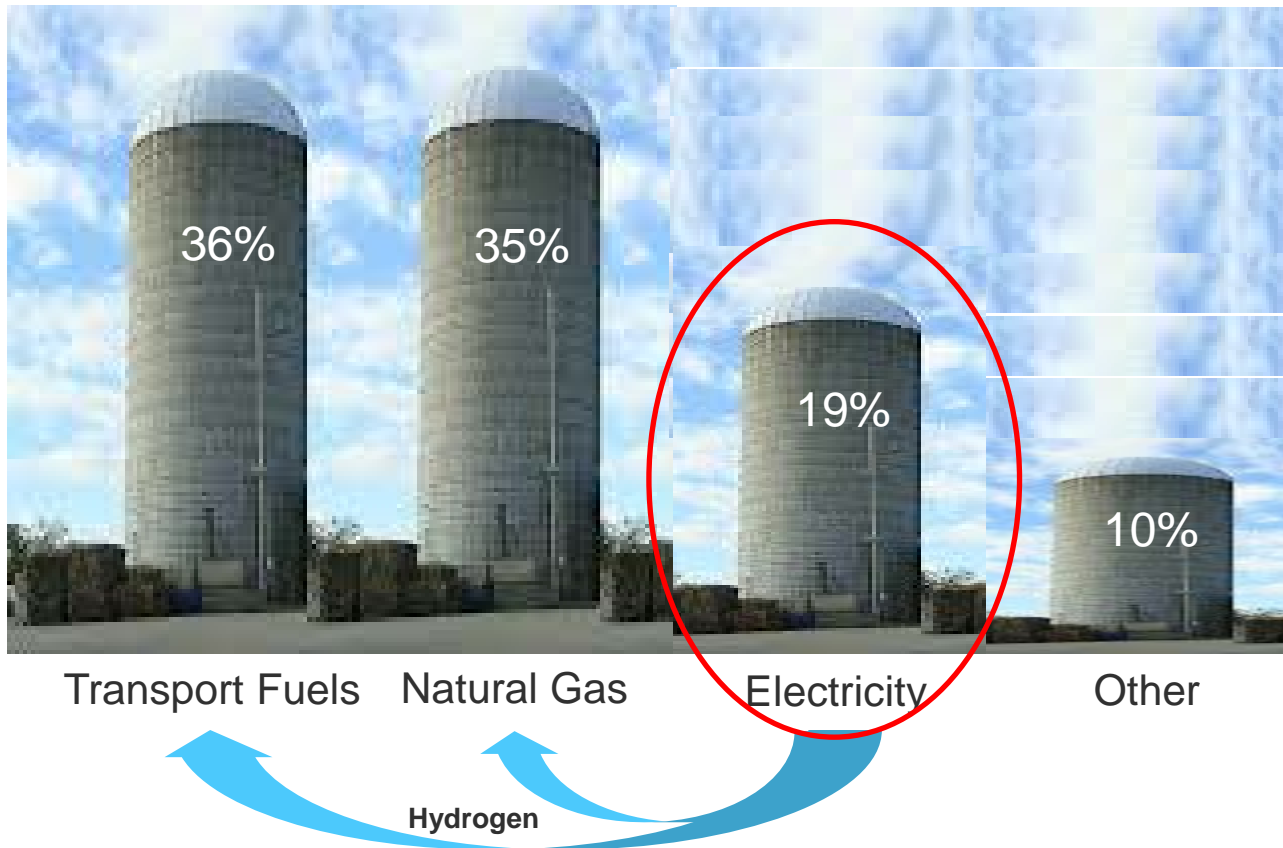
The potential for renewable electricity is unparalleled, but one reaches the point of diminishing returns at higher penetrations



- Germany
 - 550 TWh annual demand
 - Renewable generation 24% in 2012
 - Significant transmission constraints results in 30% wind power curtailment
- California
 - 275 TWh annual demand
 - Renewable generation now 20%
 - CAISO solar duck emerging in 2015
 - At 33% RPS will be well past tipping point for need of seasonal storage
- Ontario
 - 140 TWh annual demand
 - 3½% renewable generation, but frequent periods of surplus baseload nuclear generation

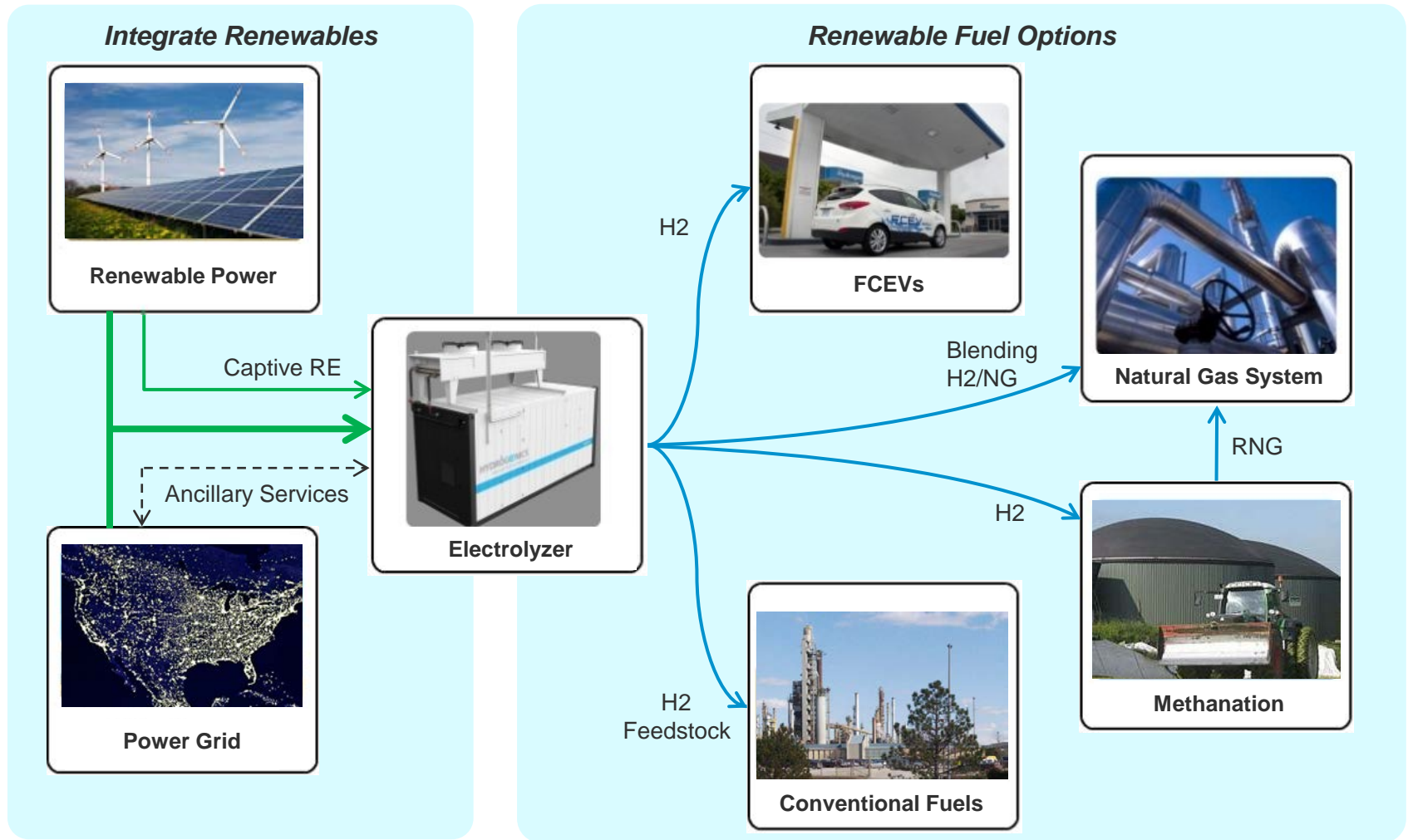
Hydrogen provides the means to significantly increase the use of renewable energy across the entire energy demand spectrum

End-Use Energy Demand



Hydrogen Energy Storage using electrolysis provides the link

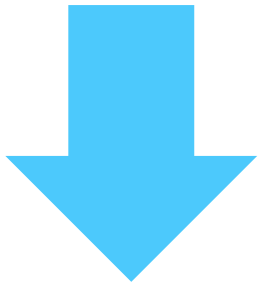
HES (Power-to-Gas) Solution



There are five key economic drivers which will impact the business case for commercial Power-to-Gas project developers

Economic Drivers

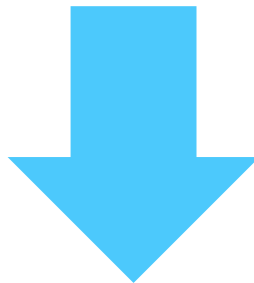
Operating Cost



Price of Electricity

Same challenges as other bulk energy storage solutions

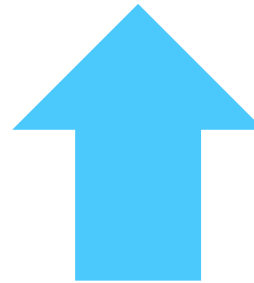
Capital



Equipment Capex

Initial volume production will result in large cost reductions

Multiple Revenue Streams



Ancillary Service(s)

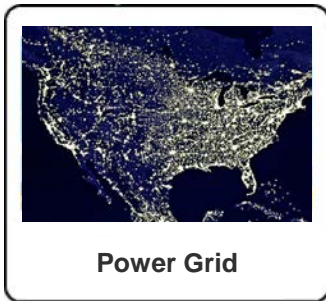


H2 Energy Produced



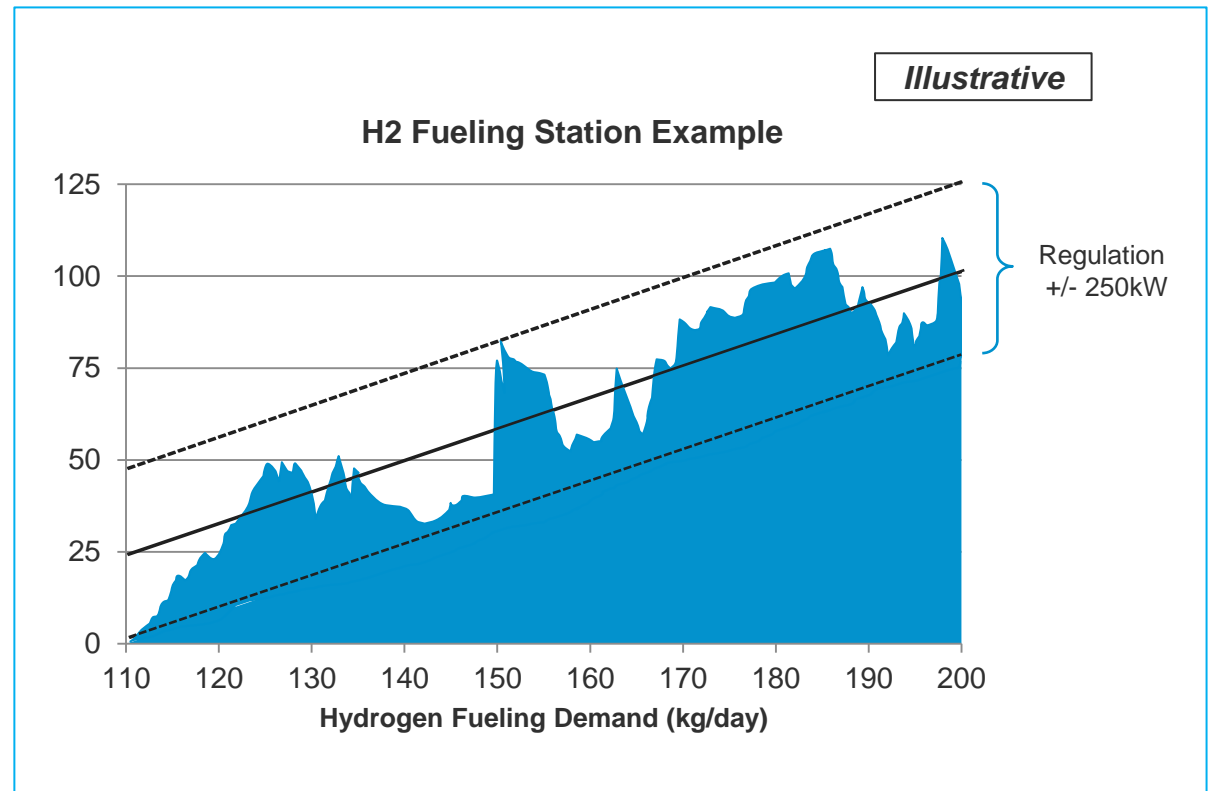
Credit for Renewable Fuel

The fast, dynamic response of electrolyzers adds value to ISOs and will allow HES developers to participate in ancillary service markets



ISO Ancillary Service(s)

- Regulation
- Ramping
- Demand Response
- Voltage Support



North American gas interoperability standards needed to inject hydrogen into the Natural Gas grid

Hydrogen Energy Produced



Sell H2 Energy	✓	• Not eligible	✓	✓
Development Status	• Commercial for small scale H2 fueling stations	• GTI and GERG research	• Biogas methanation technology at pre-commercial stage	• Early stage evaluation by refiners

Only one option would qualify under renewable fuel credits today

Renewable Fuel Credit



California LCFS Credit	<ul style="list-style-type: none"> No current path 	<ul style="list-style-type: none"> Not eligible 	✓	<ul style="list-style-type: none"> Not eligible
US Renewable Fuel Standard RIN	<ul style="list-style-type: none"> Not eligible 	<ul style="list-style-type: none"> Not eligible 	✓	<ul style="list-style-type: none"> Not eligible
CEC H2 Fueling Infrastructure PON	<ul style="list-style-type: none"> Qualifies for 100% station procurement 	Not applicable		

LCFS mandates oil companies to achieve carbon intensity reduction of 10% by 2020

Preliminary estimates indicate that renewable fuel credits would provide important incentive

- Low carbon fuel standard credits trading at \$50/ton would be worth about \$1.25/kg (100% RH2)
- RIN credit at \$7/MMBTU would be worth about \$0.75/kg

It's time to broaden the Renewable Fuel Standards tent

- 1) Include hydrogen in the federal RFS2 Renewable Fuel Standard
 - US EPA has established pathways for biodiesel and RNG
 - New pathways for renewable hydrogen as clean fuel, blended with natural gas and used (or credit) for refining conventional transport fuels

- 2) In California, allow RECs for electrolysis into the LCFS
 - Large, liquid markets will drive participation
 - New demand for RECs will stabilize prices and help support further renewable generation development

- 3) In Canada, expand biofuel blending mandate to include renewable hydrogen used in refining
 - 5% ethanol in gasoline
 - 2% biodiesel fuel and heating distillate oil

The first necessary condition is to launch Power-to-Gas (HES) pilot projects in North America

- Technology
 - MW Scale pilots
 - Working labs needed to mitigate power costs
- Ancillary Services demonstration
- Applications
 - FCEV H2 fueling (with ancillary services)
 - Direct injection into NG Grid
 - Biogas methanation
 - Renewable H2 for refining
 - Offshore wind (captive RE)
- Standards and Codes
 - H2 Interoperability with Natural Gas
 - Renewable Fuel Standards
- Contracting and Markets



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