Introduction to H2@Scale

2017 DOE Hydrogen and Fuel Cells Program Review

Bryan Pivovar (PI)

June 9, 2017

This presentation does not contain any proprietary, confidential, or otherwise restricted information
27 September 2016 / GENEVA - A new WHO air quality model confirms that 92% of the world’s population lives in places where air quality levels exceed WHO limits.

More than half US population lives amid dangerous air pollution, report warns

https://www.theguardian.com/environment/2016/apr/20/dangerous-air-pollution-us-population-report
Energy System Challenge

• Multi-sector requirements
  o Transportation
    o Industrial
    o Grid

How do we supply all these services in the most beneficial manner?
Changing Landscape - RPS

29 States + Washington DC + 3 territories have a Renewable Portfolio Standard
(8 states and 1 territories have renewable portfolio goals)

- Renewable portfolio standard
- Renewable portfolio goal

Extra credit for solar or customer-sited renewables
† Includes non-renewable alternative resources
Renewable Energy Impacts

Source: (Arun Majumdar) 1. DOE EERE Sunshot Q1’15 Report, 2. DOE EERE Wind Report, 2015

Denholm et al. 2008
Renewable Energy Impacts

Nuclear Plants at Risk by 2030, or Recently Retired (GW) ¹

1. Source: U.S. DOE Quadrennial Energy Review, 01/2017

7 of 10 announced retirements in 2016 attributed to market conditions.¹

Actual cost of electricity production by nuclear plants in the United States

Market Impacts of a Nuclear Power Plant Closure
What constitutes “a pace and scale that matters” for our efforts to transform clean energy systems?

Note: % VRE in 2015

% Variable Renewable Energy (of annual energy)

System Size (GW)

Actual Operating System
Modeled System

DOE 2050 Goals
35% Wind (404 GW)
19% PV (632 GW)

Alaska Village
Lanai
Maui
Denmark*
Ireland
CA 50%
WWSIS
ERGIS
REF
CA* Germany*
Cont. USA

* Part of a larger synchronous AC power system

Credit: B. Kroposki, NREL

NATIONAL RENEWABLE ENERGY LABORATORY

WWSIS = Western Wind and Solar Integration study
ERGIS = Eastern Renewable Generation Integration Study
REF = Renewable Electricity Futures Study
• Dwight D. Eisenhower

"If you can't solve a problem, enlarge it"
Conceptual H2@Scale Energy System*

*Illustrative example, not comprehensive
H2@Scale Vision

• **Attributes**
  - Large-scale, clean, energy-carrying intermediates for use across energy sectors
  - Increased penetration of variable renewable power and nuclear generation
  - Expanded thermal generation (nuclear, CSP, geothermal) through hybridization
  - Increased H2 from methane (carbon capture/use potential)

• **Benefits**
  - Increased energy sector jobs (GDP impact)
  - Manufacturing competitiveness (low energy costs)
  - Enhanced energy security (reduced imports, system flexibility/resiliency)
  - Enhanced national security (domestic production (metals), local resources)
  - Improved air(water) quality via reduced emissions (criteria pollutants, GHGs)
  - Decreased energy system water requirements.

Getting **all** these benefits in a single energy system significantly enhances value.
Conceptual H$_2$ at Scale Energy System*

- Intermittent integration
- R&D Advances

- **Fuel Cell R&D has decreased projected costs by 80%**

- **1 kg H$_2$ ≈ 1 gallon of gasoline equivalent (gge)**
H2@Scale has moved beyond this National Lab team to include DOE offices, and other stakeholders.

DOE - FCTO: Neha Rustagi, John Stevens, Fred Joseck, Eric Miller, Jason Marcinkoski, Dave Peterson, James Kast, Leah Fisher; NE: Carl Sink
Stakeholder Groups - Workshops - Roadmaps

- Nuclear
- Wind
- **Solar**
- Fossil
- Grid/Utilities
- Regulators
- Electrolysis
- Industrial Gas
- Auto OEMs/supply chain
- Fuels Production (Big Oil, Biomass)
- **Metals/Steel**
- Ammonia
- Analysis
- Investors

Blue: High engagement and support
Green: Engaged with interest/support
Orange: Limited engagement
Black: Little engagement

H2@Scale Workshop Report available at
http://www.nrel.gov/docs/fy17osti/68244.pdf
Key Current/Next Steps

**FY16-FY17**
- H2@Scale Workshop to obtain feedback that guided roadmap development
- Preliminary analysis to determine technical potential of hydrogen supply and demand

**FY17-FY18**
- H2@Scale Workshop to solicit feedback on draft RD&D roadmap, and identify regional and near-term opportunities to advance H2@Scale
- H2@Scale Roadmap identifying and prioritizing RD&D needs
- Analysis to assess potential supply and demand of H2@Scale under future market scenarios

**June 10, 2017**
- Review session at FCTO’s Annual Merit Review to obtain feedback on technoeconomic analysis, and roadmap
Future Impact

The Great Barrier Reef’s catastrophic coral bleaching, in one map

Mysterious Whale Swarms Perplexing Scientists
"Super-groups" of up to 200 humpback whales—a normally solitary species—are gathering off South Africa.

Images:
Technical Backup Slides
Key H2@Scale Events - Timeline

- **2015**
  - Jan: Precursor to H2@Scale focused on Hybrid Energy Systems
  - June: Initial development of H2@Scale Vision and value proposition. Championed through Transportation Working group.
  - Aug-Dec: 1st Meeting of what would become H2@Scale National Lab team

- **2016**
  - Jan-Mar: H2@Scale development through NL CRO Working Group and through DOE program offices.
  - Apr: 1st HTAC Briefing
  - May-Oct: National Lab Chief Research Officer Meetings
  - Nov: Big Idea Summit
  - Dec-Apr: Engagement with various (industry) stakeholder groups.

- **2017**
  - May: H2 at Scale Workshop

H2@Scale webinar available at [http://energy.gov/eere/fuelcells/downloads/h2-scale-potential-opportunity-webinar](http://energy.gov/eere/fuelcells/downloads/h2-scale-potential-opportunity-webinar)
What is needed to achieve \( \text{H}_2 \) at Scale?

<table>
<thead>
<tr>
<th>Development of low cost, durable, and intermittent ( \text{H}_2 ) generation.</th>
<th>Development of thermally integrated, low cost, durable, and variable ( \text{H}_2 ) generation.</th>
<th>Development of safe, reliable, and economic storage and distribution systems.</th>
</tr>
</thead>
</table>

\( \text{H}_2 \) as game-changing energy carrier, revolutionizing energy sectors.

### Analysis

| Foundational Science |
| Future Electrical Grid |
Value Proposition Development

- Trying to build off/follow in tracks of others