U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

# Overview of U.S. Department of Energy's H2@Scale Concept and RD&D Needs


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Hydrogen Technical Advisory Committee Meeting- February 2018

Washington, D.C.



# H2@Scale Stakeholder Feedback– Examples

**Attendees have ranged from 80 to over 400**
**All DOE Offices engaged:**
**EERE, FE, NE, OE, SC, ARPA-E**

**2016 Session at Intermountain Energy Summit**
**Idaho Falls, ID**

**2017 Session at Fuel Cell Seminar**
**Long Beach, CA**

**2018 at ANL**

**2017 Session at FCTO's Annual Merit Review**
**Washington, D.C.**

**2018 June 13-15, AMR**

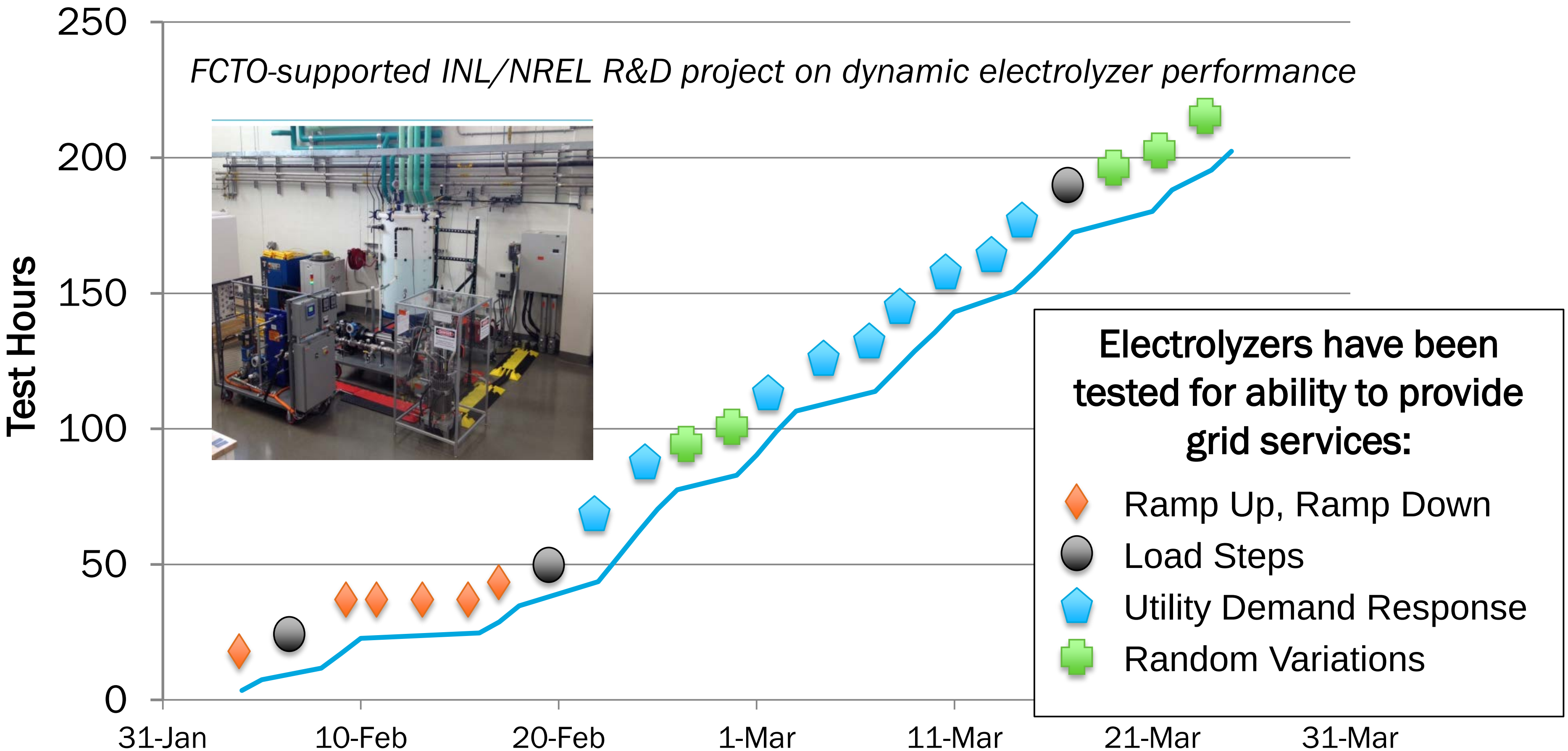
**2018 April Planned in TX Pending S1**

**2017 Workshop**
**Houston, TX**

**2016 Workshop**
**Golden, CO**

**Numerous additional presentations at events in:**
- **Utah (2017)**
- **Michigan (2017)**
- **Minnesota (2017)**
- **Germany (2017)**
- **New Mexico (2016)**

# FCTO R&D Established that Hydrogen Can Support Grid Services




**200 hours of testing established that electrolysis has potential to meet performance requirements of grid services.**

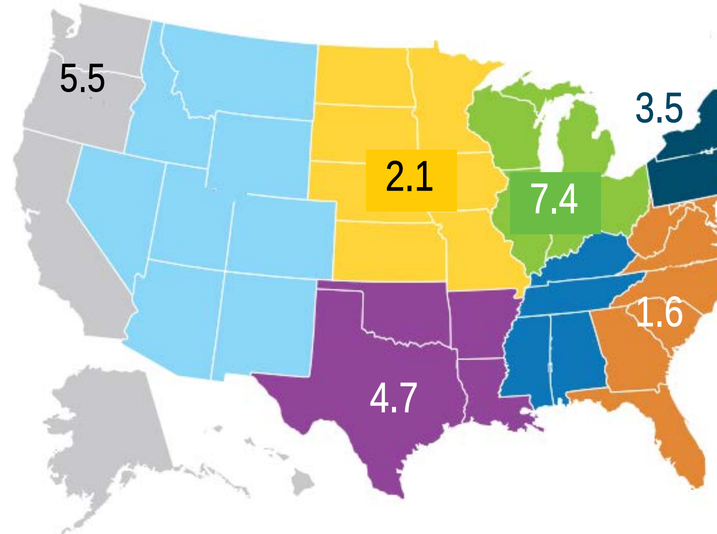
# Hydrogen Integration with Nuclear Generation

## Value Proposition

- Improve economics of fully amortized, existing reactors
- Improve economics of next generation of reactors
- Economic production of $H_2$

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

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




*7 of 10 announced retirements attributed to market conditions.*[1]

## Research Needs

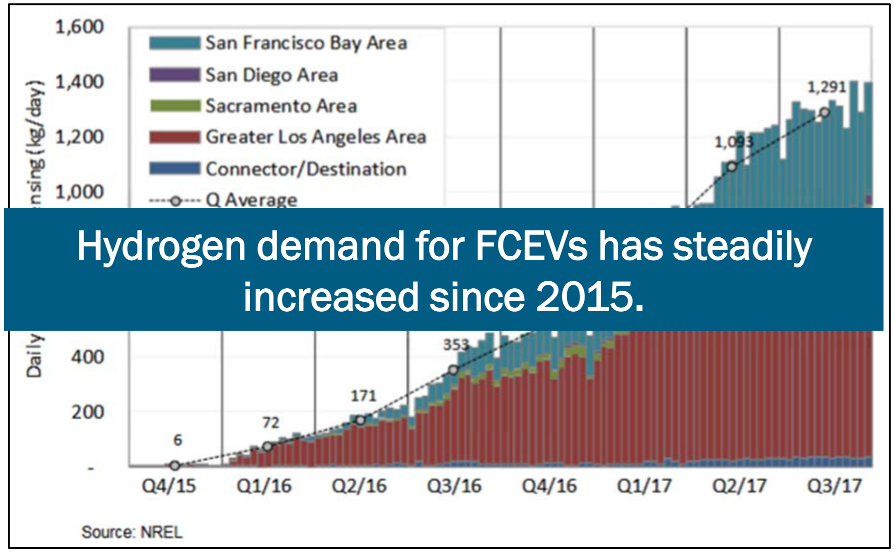
*(aligned with HydroGEN)*

- High-temperature electrolysis:
  - Elucidate degradation mechanisms
  - Develop materials for durable high current density operation
  - Evaluate load following capability
- Thermochemical:
  - Discovery of redox materials capable of efficient $H_2$ production
  - Development of high-temperature materials for thermochemical reactors

➢ Several advanced reactor types currently being studied in the U.S. (e.g. Gen IV designs) operate at 500-1,000˚C, **compatible** with high-temperature $H_2$ production.

➢ Low-temperature reactors can be integrated with $H_2$ production through heat recuperation.

# Growing Demands for Hydrogen: FCEVs



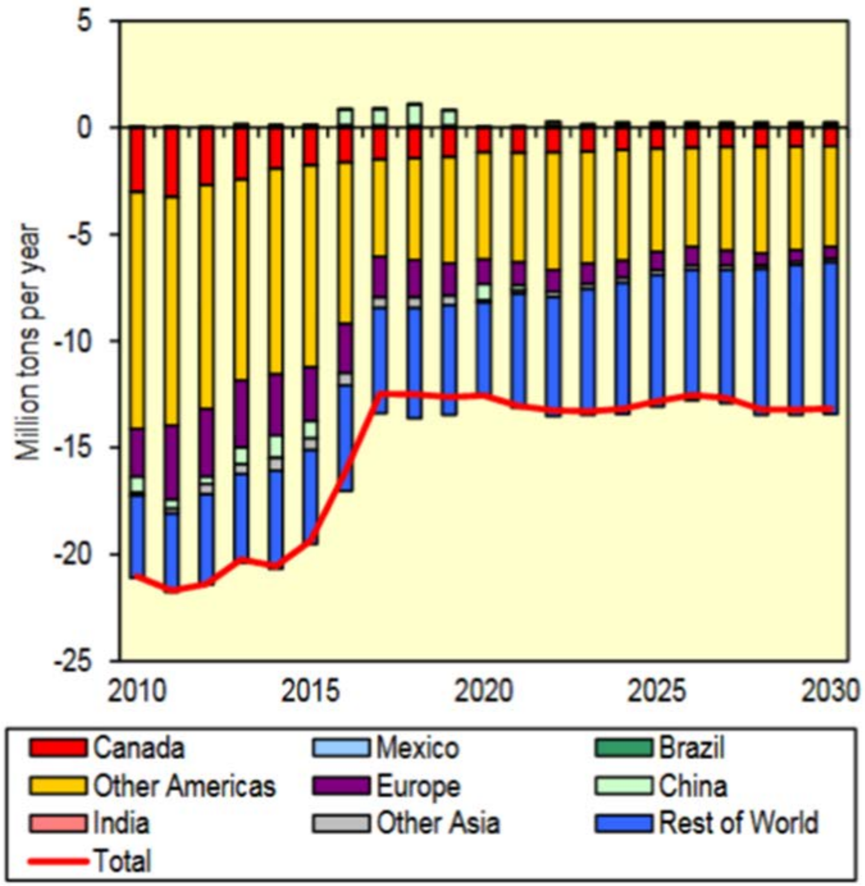


- Retail stations currently reach **80% utilization in average of 5 years.**[1]
- High-throughput hydrogen fueling stations (e.g. **1,000 kg/day**) of interest.
- **>2,000 tonnes/year of renewable hydrogen needed by 2022** to satisfy FCEV demand.[1]
- Emergence of **medium- and heavy duty fleets** would bolster demand.

1. http://www.energy.ca.gov/2017publications/CEC-600-2017-011/CEC-600-2017-011.pdf

# Growing Demands for Hydrogen: Chemicals

U.S. Net Trade Balance Methanol, Ammonia, Urea[1]
(Million tonnes/year)



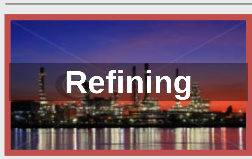

- U.S. **imports of ammonia and urea projected to decline**, and **exports of methanol projected to begin** by 2020.
- U.S. demand for nitrogenous fertilizers expected to grow by 1.5%/year by 2020.[2]
- Global methanol demand expected to grow >3.5%/year until 2026.[3]
- **Small-scale distributed methanol plants emerging** worldwide. [3]

1. https://www.americanchemistry.com/Policy/Tra0de/Fueling-Export-Growth-US-Net-Export-Trade-Forecast-for-Key-Chemistries-to-2030.pdf
2. http://www.fao.org/3/a-i6895e.pdf
3. https://cdn.ihs.com/www/Events/WPC2017/Presentations/IHSM-Nash-Globalmethanolchain-March22.pdf

# Chemicals R&D Needs: Examples

- Discovery and development of low-cost catalysts for efficient electrochemical synthesis at low temperatures and pressures.
- Bandgap materials and catalysts for photoelectrochemical synthesis technologies using sunlight.
- Development of alloys for thermochemical approaches to chemical synthesis.
- Characterization and development of catalysts for methanol synthesis under varying operating conditions (e.g. composition, temperature and pressure of feedstock gases)

# Hydrogen Infrastructure

| Industry | Key Applications | Supply Systems | Volume |
| --- | --- | --- | --- |
|  General Industrial | ■ Laboratories<br>■ Fuel Cell Applications | ■ Small on-site<br>■ Cylinders<br>■ Tube trailers<br>■ Liquid $H_2$ | Low<br><5 mmscfd |
|  Electronics | ■ Thin-film solar<br>■ Materials Processing | ■ Tube trailer<br>■ Liquid $H_2$<br>■ Small On-Site Plant | |
|  Glass | ■ Semi-Conductors<br>■ Float glass mfg<br>■ Metal Conditioning | ■ Liquid $H_2$<br>■ On-Site Plant | Medium<br>5-100 mmscfd |
|  Other | ■ Chemicals<br>■ Fuel Purification | ■ Liquid H2<br>■ On-Site Plant<br>■ Pipeline | |
|  Refining | ■ Hydro-processing<br>■ Bio-Fuels | ■ Pipeline<br>■ On-Site Plant | High<br>60-200+ mmscfd |

**Modes of hydrogen delivery depend on quantity of hydrogen demanded, stability of demand, and proximity of demand to supply.**

# Hydrogen Energy Storage is Scalable

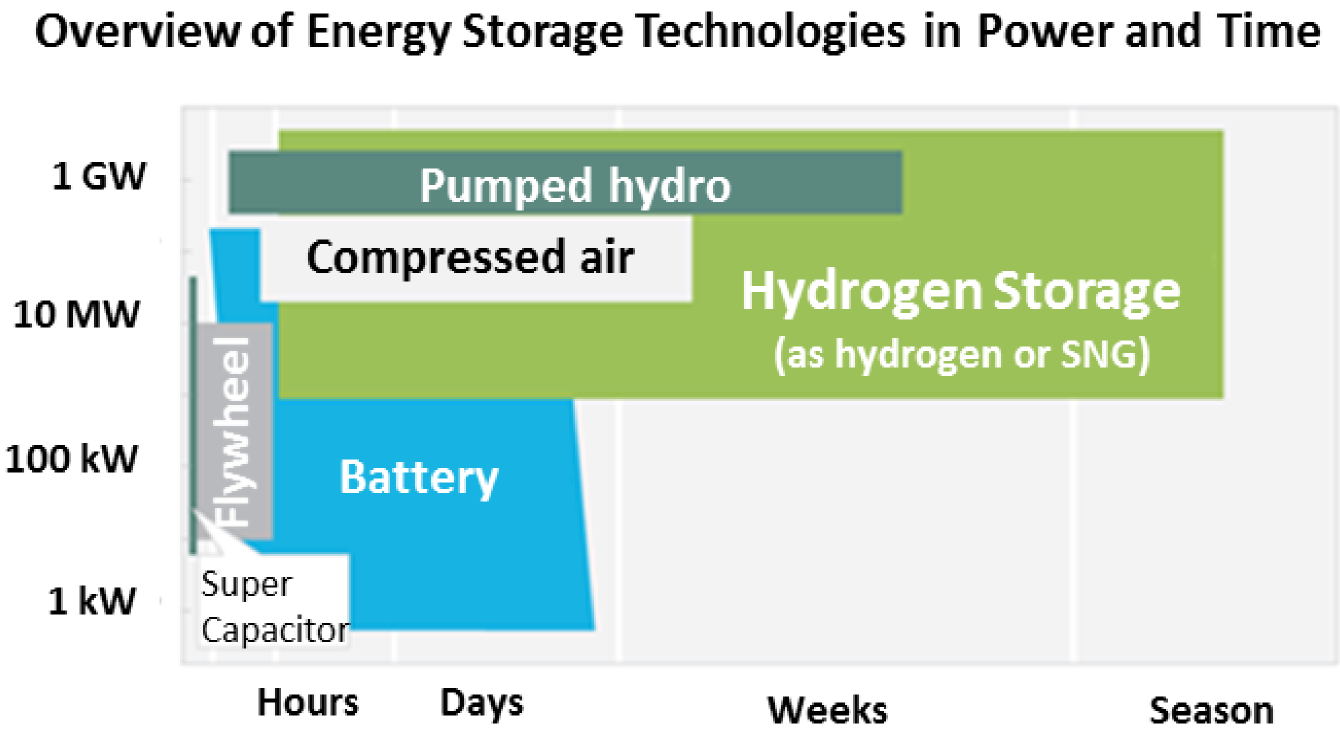



*Image: Hydrogen Council*

One Hydrogen Cavern
=
<u>~ 100 GWh energy storage</u>

**Hydrogen can be used to monetize surplus electricity from the grid, or remote, off-grid energy feedstock (e.g. solar, wind) for days to months.**

# Hydrogen Infrastructure R&D Needs: Examples

- Cross-cutting materials compatibility understanding:
  - Microstructural modeling of hydrogen induced damage of steels
  - Benchmarking polymer and steel performance in varying hydrogen environments
  - Development of novel steel alloys and polymers for reliable high-pressure, low-temperature operation.
- Scalable, efficient liquefaction technologies (e.g. caloric materials)
- Chemical carriers for low-cost, high-volume hydrogen storage and transport
- Development of innovative fueling technologies for vehicles, such as:
  - Non-mechanical compression for improved durability
  - Novel polymers, fiber reinforcements, and coatings for reliable hydrogen dispensing hoses and seals
  - Strategies to reduce setback distances with liquid hydrogen storage

# Future Work in 2018…

- Cross-office **Request for Information** (in collaboration with Solar, Wind, Water, Geothermal, Nuclear, and other DOE Offices).
- **H2@Scale RD&D Roadmap** draft release.
- **Evaluation of electrolyzer capacities required** to balance power flows and stabilize frequency disturbances under varying renewable energy penetrations.
- Evaluation of impacts of **dynamic grid integration on electrolyzer components**.
- Spatial and infrastructure assessments of **economic potential** of H2@Scale.

# Thank you!

https://energy.gov/eere/fuelcells/h2-scale