NREL
Transforming ENERGY

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Hydrogen as an energy source

Make

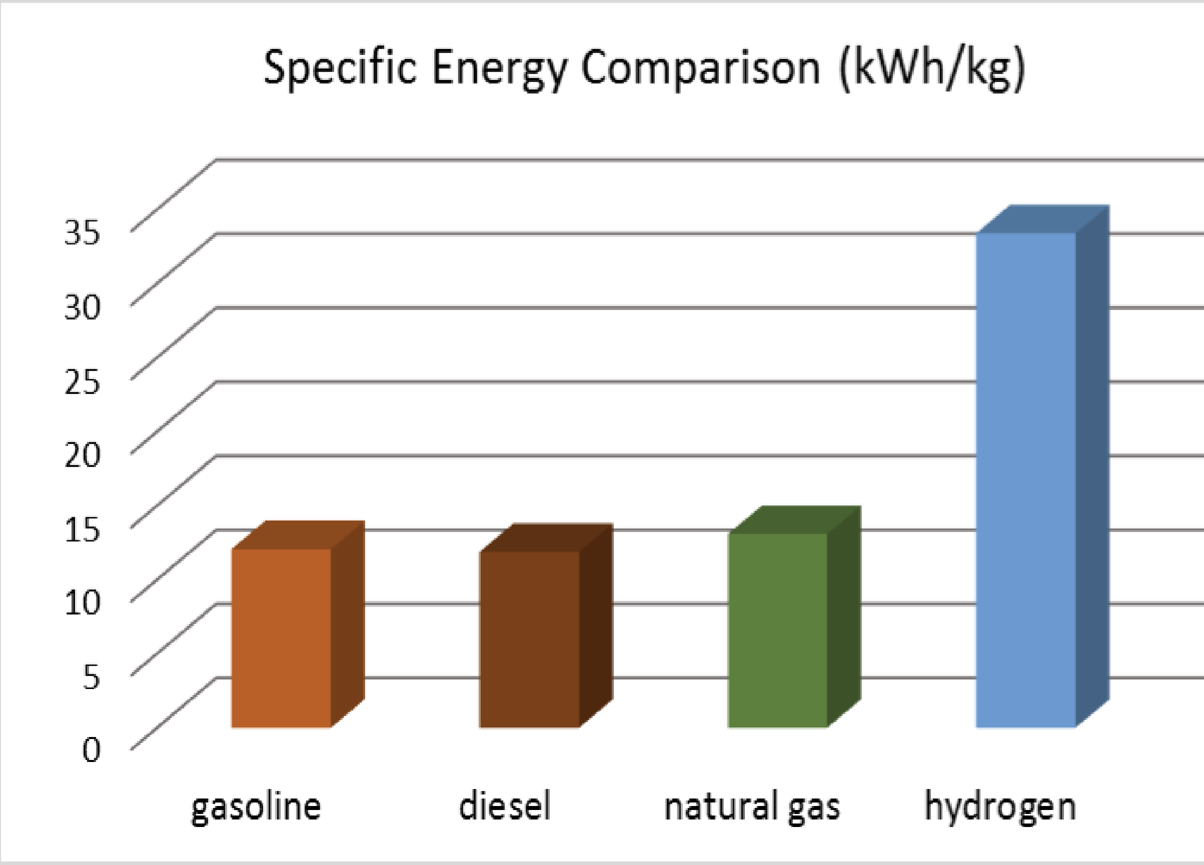
$$e^- + H_2O \longrightarrow H_2 + O_2$$

Move → **Store**

↓

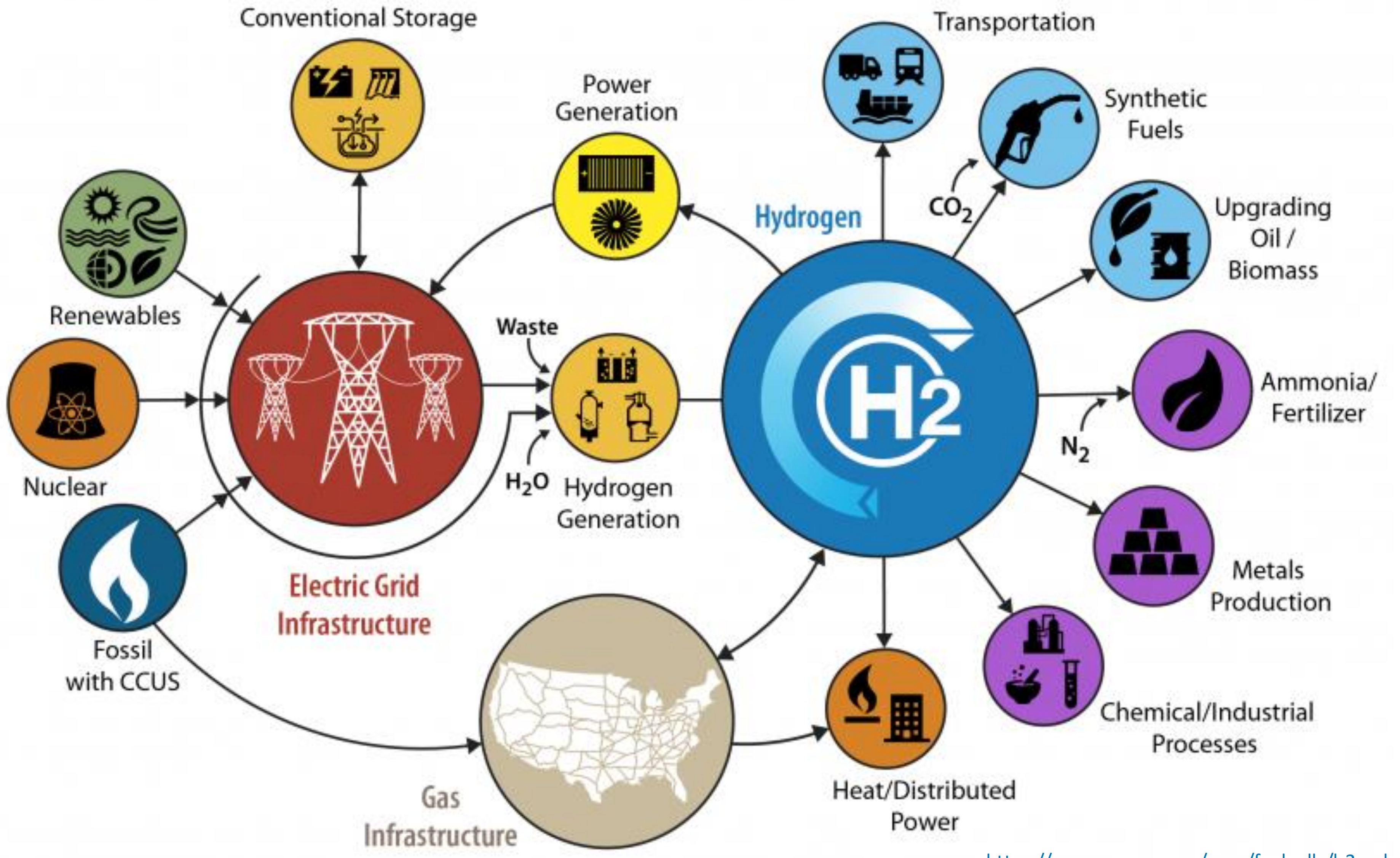
Use

$$H_2 + O_2 \longrightarrow e^- + H_2O$$



- H_2 enables electricity generation with zero emissions
- It can generate heat for industrial processes and buildings
- Hydrogen has the highest gravimetric energy density of any fuel
- H_2 is critical as feedstock for chemicals industry to enable innovations in domestic industries
- Hydrogen can be used to store surplus electricity from the grid, or remote off-grid energy feedstock (e.g. wind, solar) for days or months.
- Can be used as a responsive/complimentary fuel on for grid stability

DOE's H2@SCALE Vision



https://www.energy.gov/eere/fuelcells/h2scale

Key Hydrogen Technology Areas

Make

- Electrochemical
- Photoelectrochemical
- Biological
- Thermochemical

Move

- Pressure
- Form
- Quantity
- Mode

Store

- Materials based
- Carriers
- Bulk
- Underground

Use

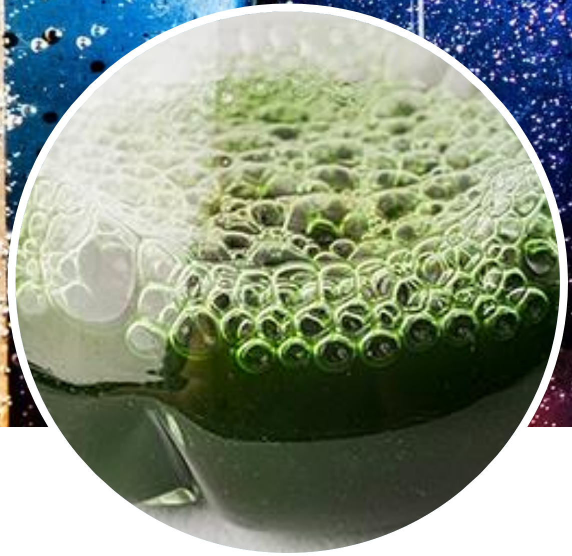
- Fuel cells
- Electrons to Molecules
- Fuel upgrading
- Combustion
- Metal reductant

Crosscuts

- System integration
- Manufacturing
- Safety
- People

***Vision:** Hydrogen will be a ubiquitous means of transporting, storing, and transforming energy at the scale necessary to enable a clean and vibrant economy*

Make



Electrochemical

Decrease cost of H_2 production, focusing on PEM & AEM; Develop membrane electrode assembly (MEA) fabrication (performance and durability focus); Benchmark catalyst, membrane, and MEA; Understand effects of contaminants/water quality; Perform single cell, stack, and system testing.

Biological

Decrease feedstock cost, increase rate, yield & durability of hydrogen production. Develop robust microbes in photobiological and fermentation processes. Develop microbial electrolysis cell (MEC) alone, and in an integrated system.

Photoelectrochemical

Decrease photoabsorber, catalyst, cell, balance of plant, and reactor design cost. Increase solar-to-hydrogen (STH) efficiency and stability; Technoeconomic analysis of different use cases; Demonstrate a feasible use case with concentrated solar irradiation.

Thermochemical

Fundamental understanding of materials that can split water efficiently and with high conversion through synthesis of high-quality materials, first principles calculations, advanced characterization, and systems modeling.

Move

Pressure

Different applications require different pressures, compression is currently limited by throughput and has frequent failures today

Form

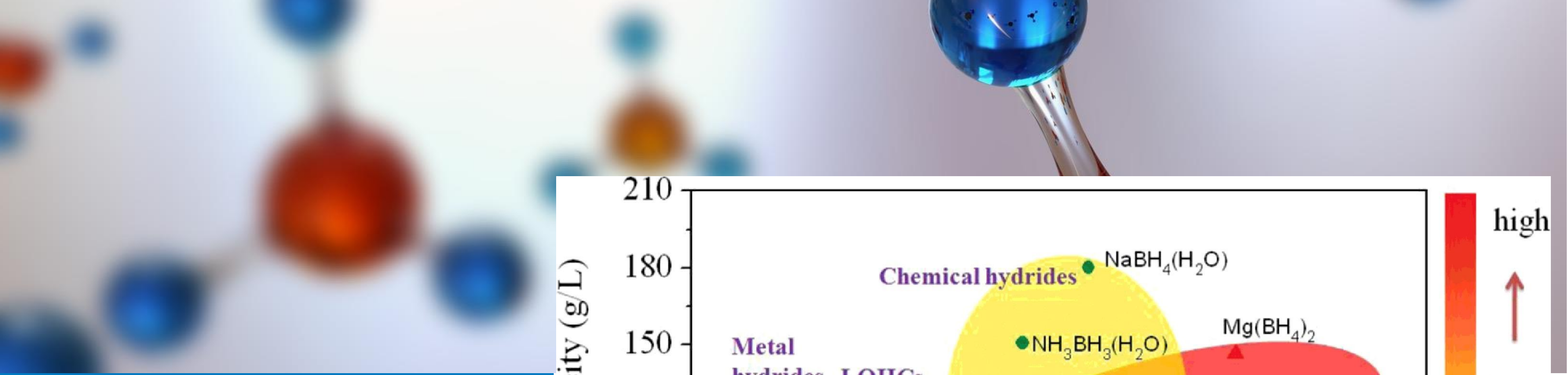
Requirements for storage density and transport dictate a need to identify highest potential phase on both production and use, and interface with multiple options

Quantity

Moving hydrogen has to accommodate sizes that vary from kg to MMT, with varying pathways (centralized and distributed) and distances. Therefore flexibility and scalability is essential.

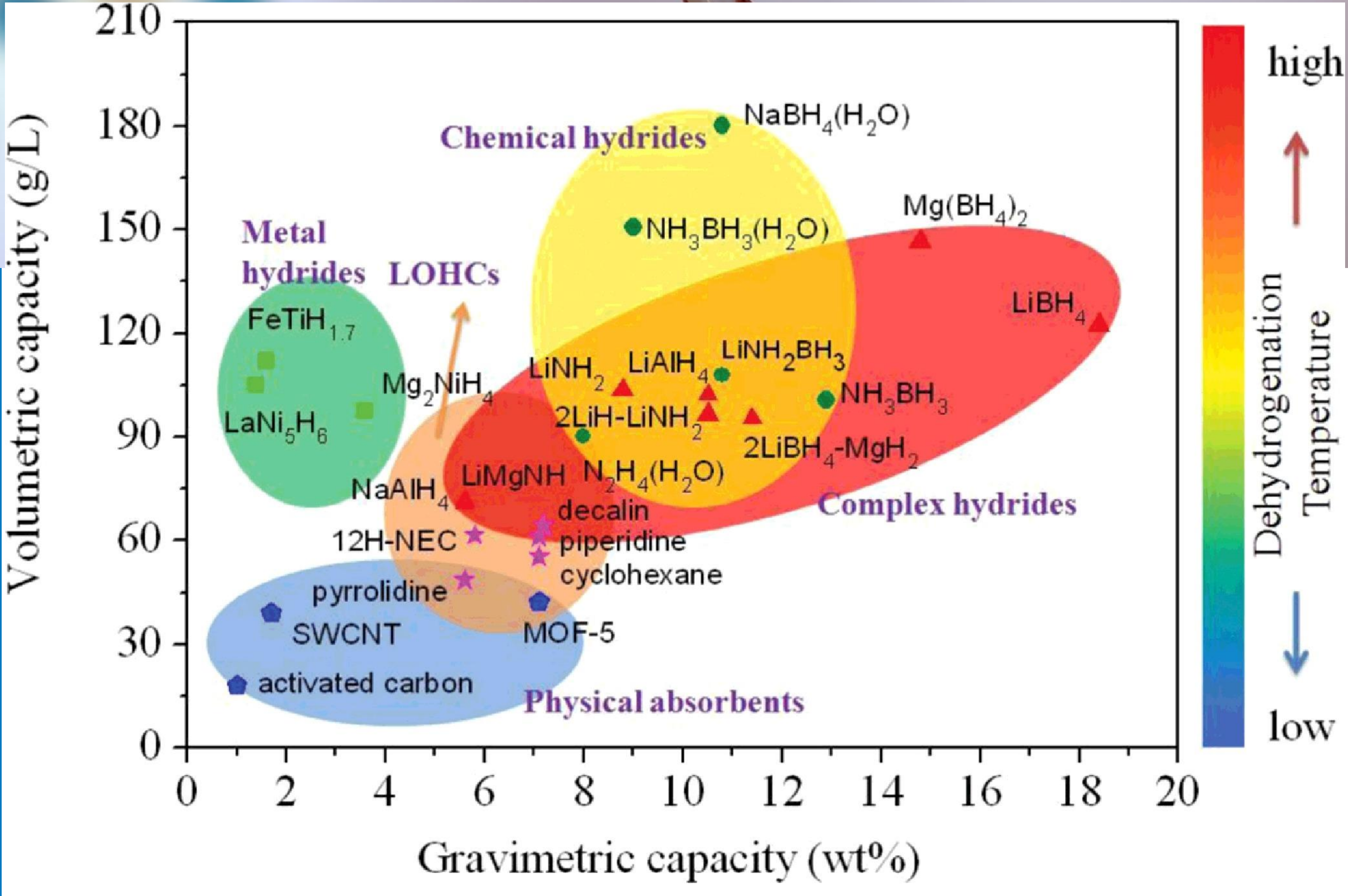
Mode

Truck, pipeline, and dispensing are hydrogen delivery forms that have to increase in capability, throughput, while reducing cost

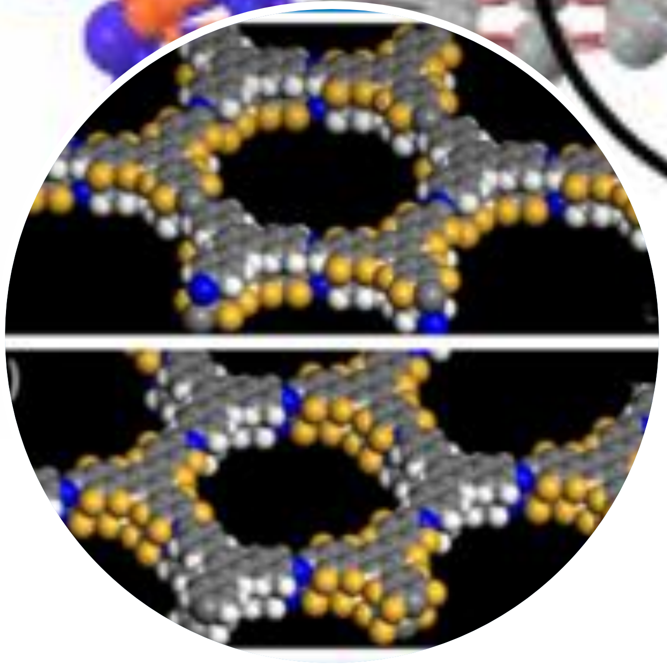


Store

H_2 Storage materials



Store

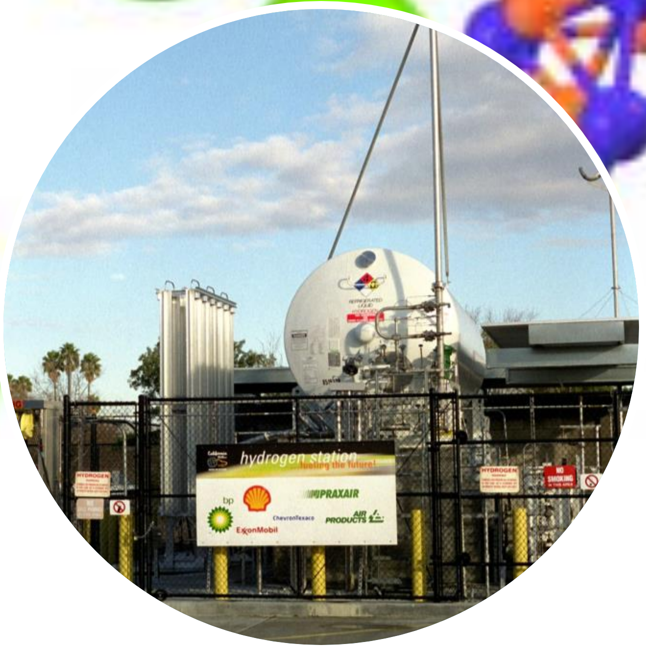


Materials

Advanced materials R&D to engineer hydrogen to material binding strength for targeted applications

Carriers

Utilize hydrogen carriers for different market applications to enable low-cost energy storage and transportation solutions through advanced R&D and market segment analysis



Bulk

Evaluate the long-term and bulk storage of materials, for different applications as well as on-demand after long-term storage. Understand the loss versus time of various processes

Use – End Applications

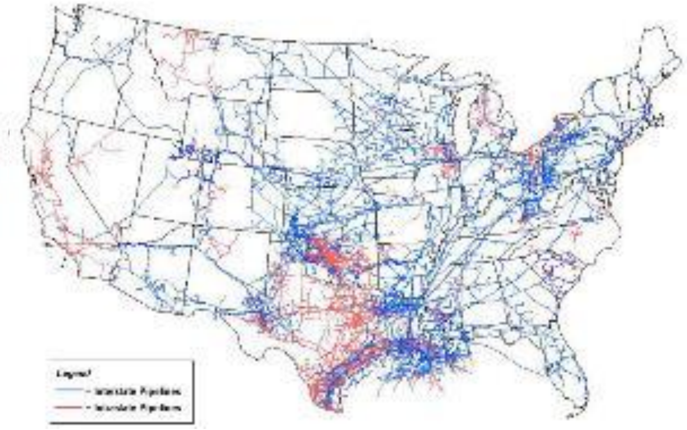
For many applications, it is critical to optimize production and storage to expected end use demand profiles

Marine propulsion, port operations and cargo transport

Medium and heavy-duty trucking

Stationary backup and prime power: Data centers as early adopters

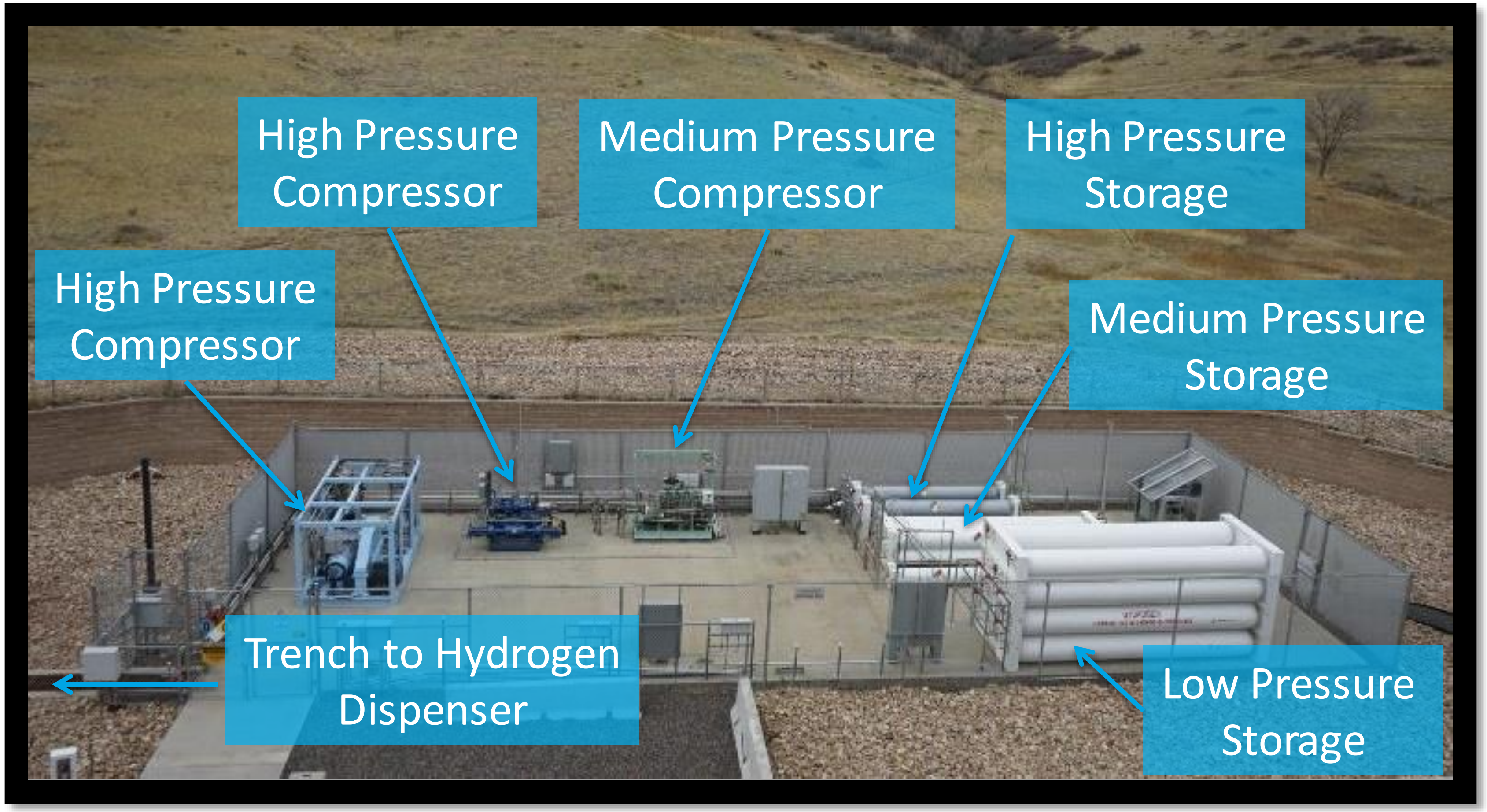
Ammonia and fertilizer production



Blending into Natural Gas

Steel Production/iron

H_2 Fueling Station – Light-duty and Heavy-duty



Images: NREL

Advanced Research on Integrated Energy Systems (ARIES)

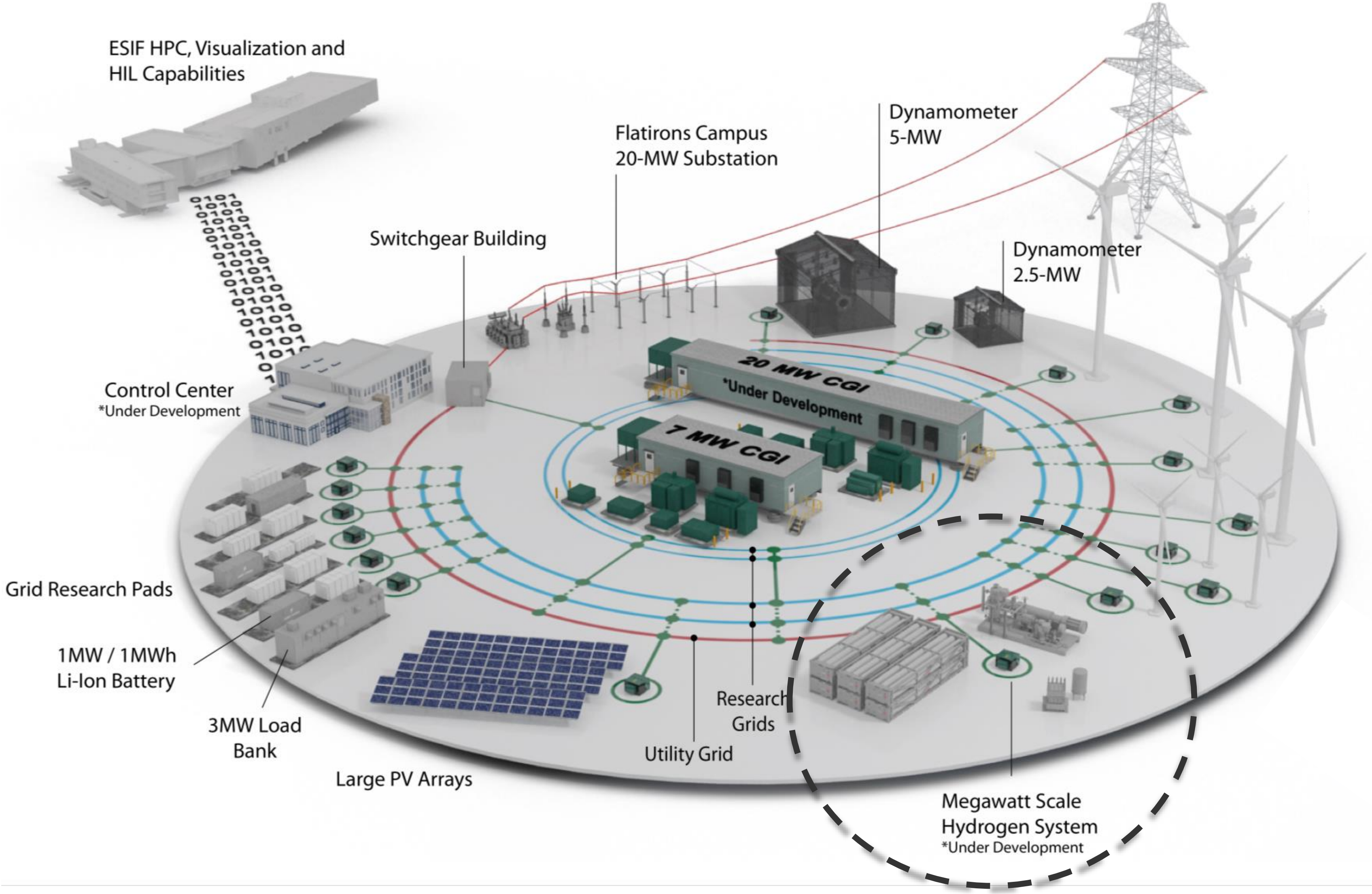
Renewably Powered

HPC Connected

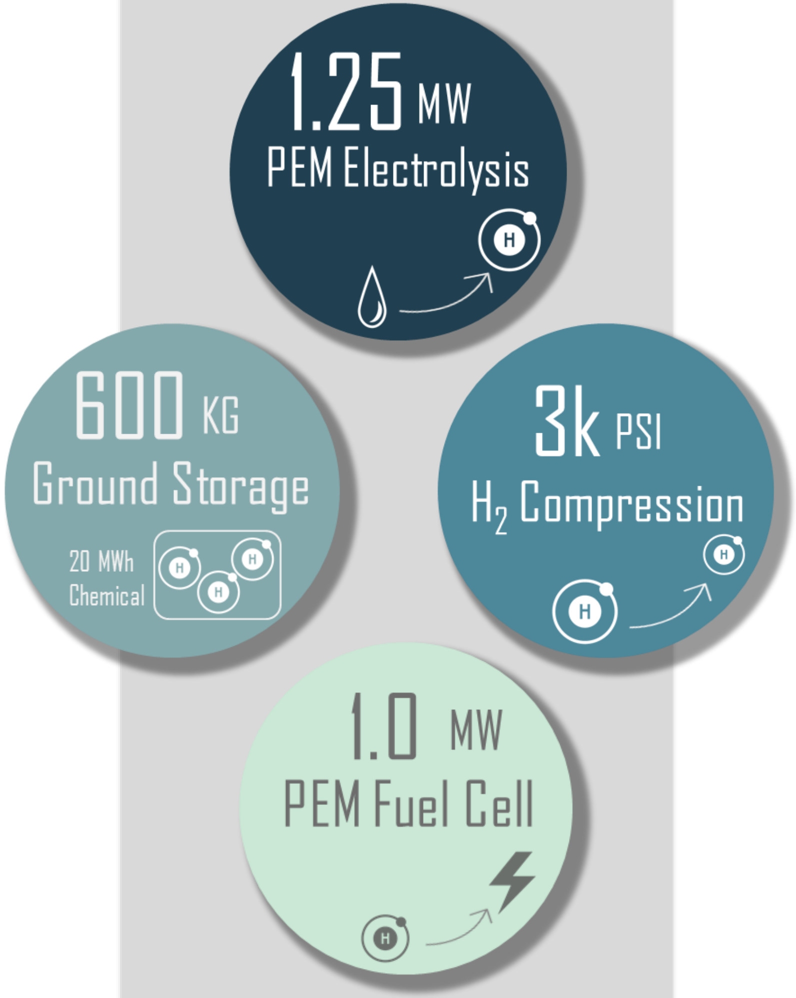
Grid, microgrid emulation

Energy Storage

Science of Scaling Hydrogen Systems



Integrated Megawatt Scale Hydrogen System



Heat Exchanger, H_2 Electrolyzer and Storage, are installed at Flatirons Campus

- The 1.25 MW PEM electrolysis system and the 3.4 MW integrated cooling system heat exchanger arrived at the Flatirons campus.
- The build-out to integrate and power the new hydrogen infrastructure will continue through the summer.
- Commissioning is planned for the end of the summer.

Installation and integration of the hydrogen infrastructure (including the hydrogen storage, electrolyzer, and heat exchanger) are integral to create dynamic hybrid energy capabilities for ARIES to study energy integration at the MW scale.

Summary

Hydrogen offers a tremendous opportunity to link **renewable energy** with difficult to **decarbonize applications**, but requires significant R&D advances in making, storing, moving and using hydrogen more effectively.

Research Challenges

- Scale up next-generation electrolysis technologies to produce carbon-free hydrogen at costs lower than fossil-based routes.
- Advance hydrogen production and use for electric grid support and energy storage to enable the shift of energy across time, sectors, and location.
- Develop advanced materials for polymer electrolyte electrolyzers and fuel cells, focusing on the emerging markets of intermittent H_2 production and heavy-duty transportation.
- Enable safe hydrogen fueling and related infrastructure for heavy-duty vehicles, reducing the cost and improving reliability.

Thank You

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