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Hydrogen Technologies and Decarbonizing the Energy System

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Low-carbon energy future

- Major reduction in carbon from energy production in all sectors
- Enhance the resiliency and reliability of the electrical grid with integrated renewable energy sources
- Integrate energy sectors (*e.g.* base power and transportation)
- Develop fully domestic, secure, sustainable energy sectors

Reduced carbon energy footprint is being legislated by the states

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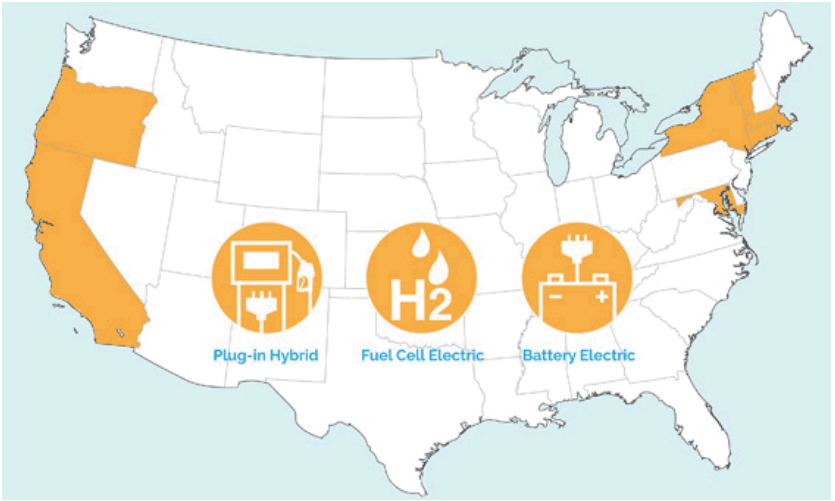
- Hawaii
  - legislated 100% RPS by 2045
- California
  - Considering 50% RPS and 50% reduction of petroleum use by 2030
  - Carbon credits for vehicle fleets
  - ZEV Action Plan:
    - 1.5 million ZEVs by 2025
- 8-state MOU
  - CA, OR, and northeastern states
  - 3.3 million ZEVs by 2025



RPS == renewable portfolio standard

Hydrogen enables robust integration of energy sectors

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H2 Transportation

Heat

Power

Gas / H2

Gas/H2 to Trans.

Trans. to Power

Heat to Gas/H2

Power to Gas/H2

Managed as an integrated energy system, hydrogen production and storage can achieve:

- sustainability (clean energy)
- resiliency
- reliability
- flexibility

H_2@Scale energy system*

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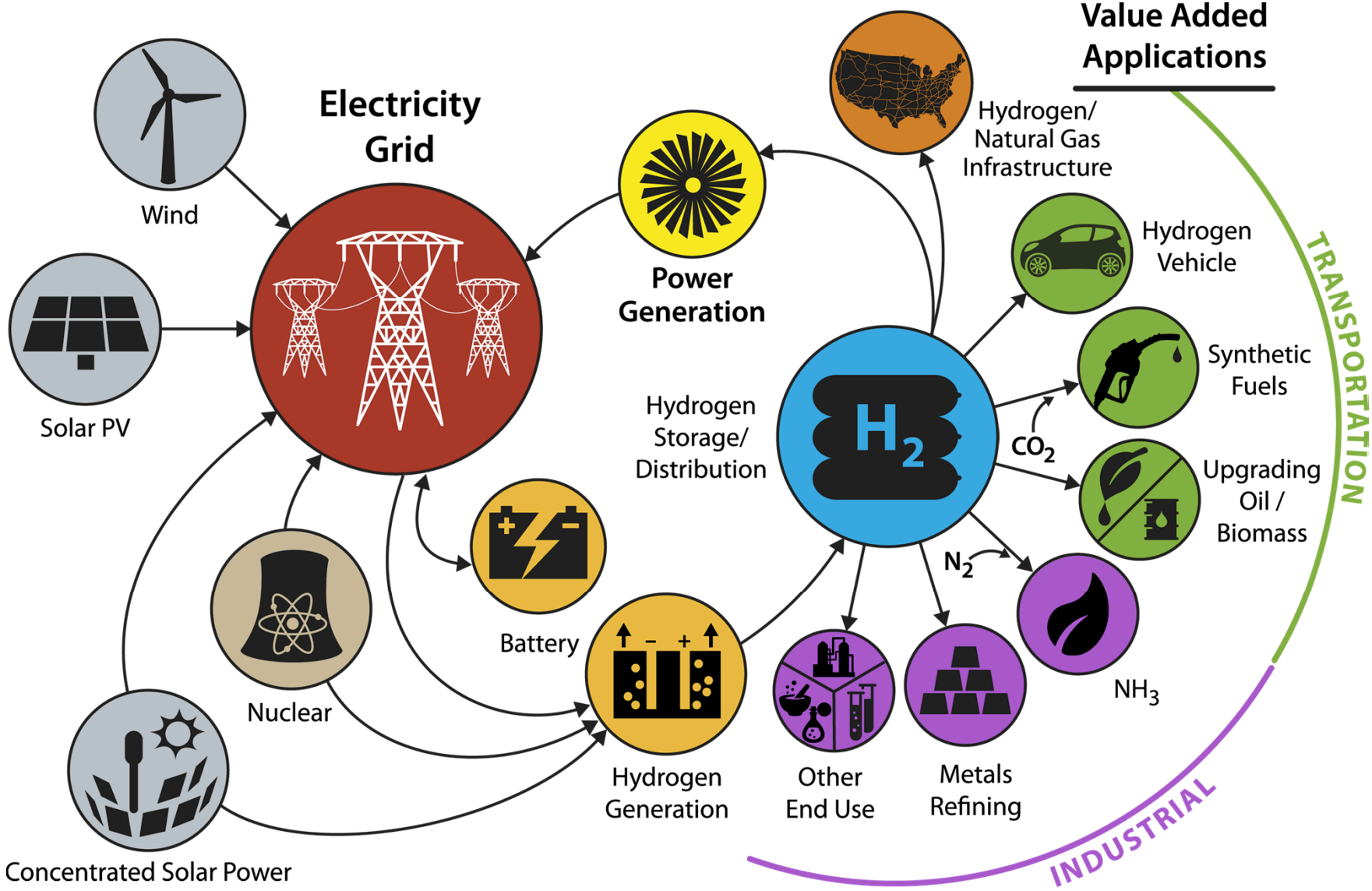

*Illustrative example, not comprehensive

Technology framework

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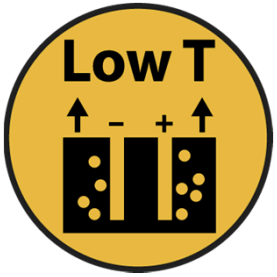
Low and High Temperature H_2 Generation



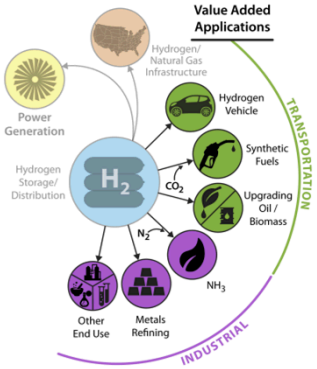
Development of **low cost, durable, and intermittent H_2** generation.

Development of **thermally integrated, low cost, durable, and variable H_2** generation.

H_2 Storage and Distribution

Development of **safe, reliable, and economic storage and distribution** systems.

H_2 Utilization



H_2 as game-changing energy carrier, revolutionizing energy sectors.

Analysis

Foundational Science

Future Electrical Grid

Production

- Low-temperature generation (hydrogen production)
  - Develop non-noble metals OER catalyst
  - Low-cost durable high-conductivity membranes
  - Alkaline membranes enabling noble metal replacement
  - Low-cost, corrosion resistant, then film metal coatings
  - Develop durable systems for intermittent operation

- High-temperature generation (hydrogen production)
  - Durable corrosion resistant conductive materials
  - Front end controls for thermal management with cyclic operation
  - Technologies for high temperature thermal storage
  - CO_2 electrochemical reduction
  - System integration

Solar thermochemical production

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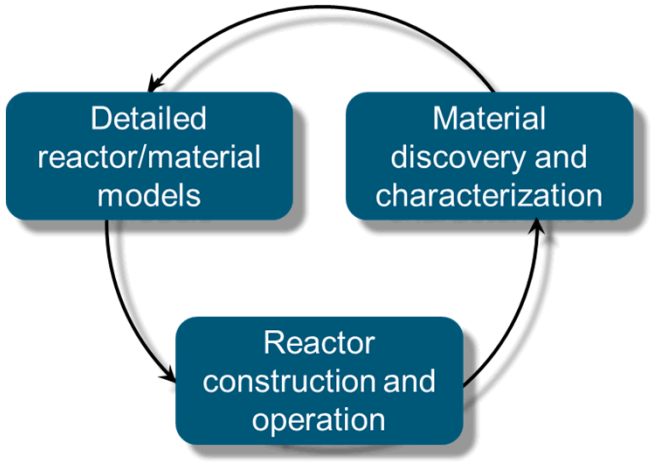
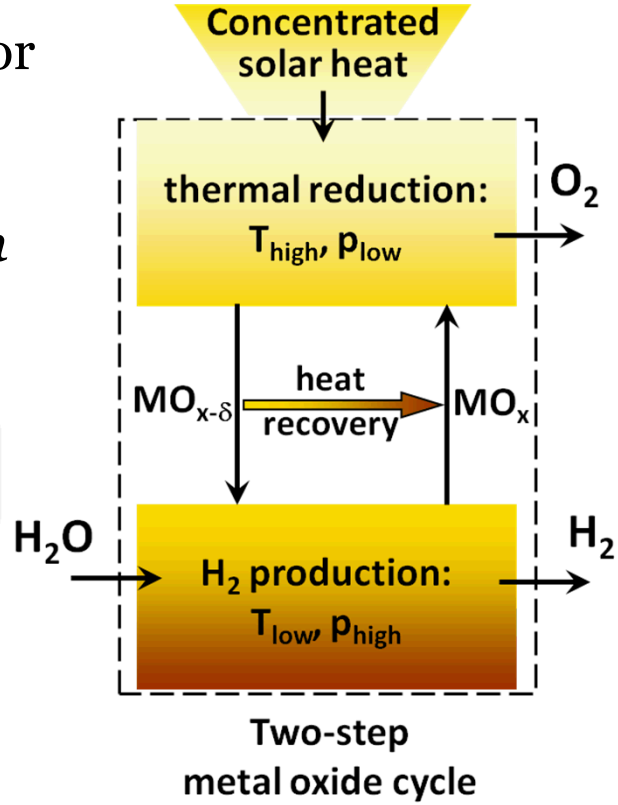
Two-step thermochemical water-splitting cycle

MW scale concentrating solar power facilities provide heat for

1. Metal oxide reduction
2. Oxidation with water ***producing hydrogen***

Source: iStock





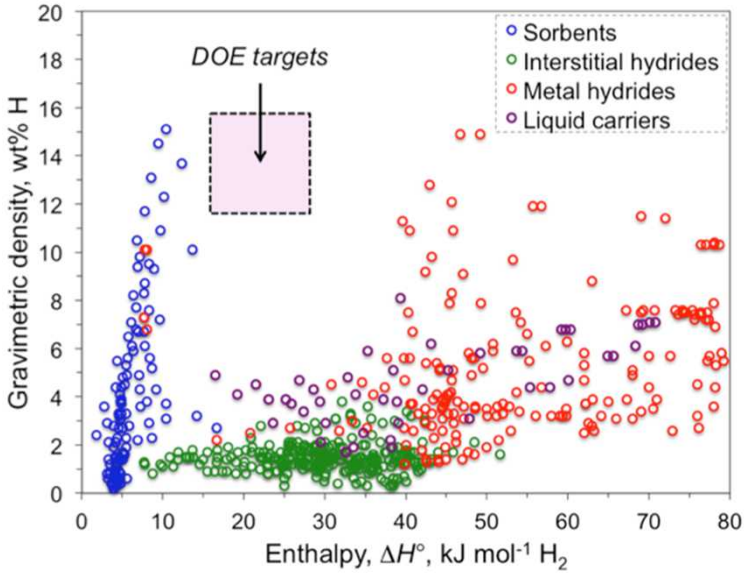
The challenge is to develop efficient and scalable solar-powered reactors up to 100,000 kg/day

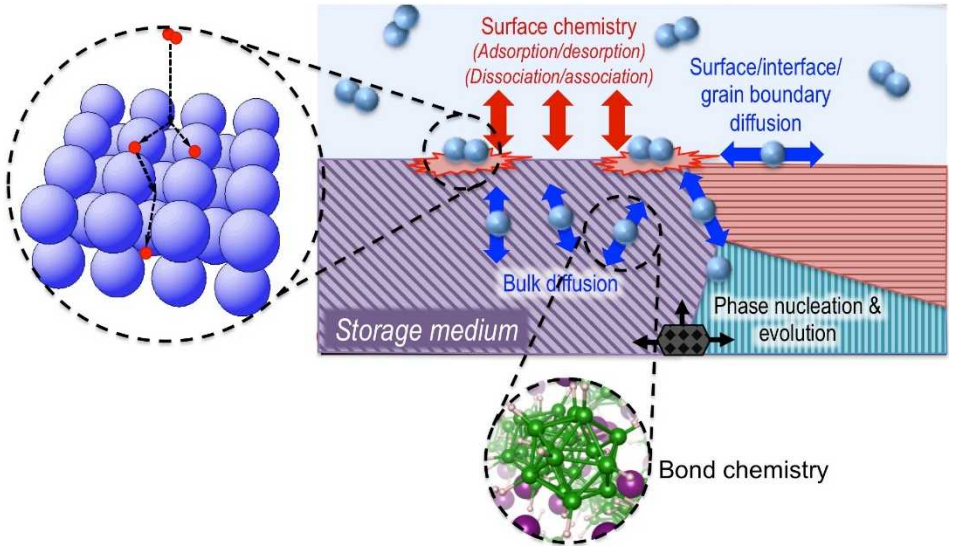
Storage and distribution

- H2 storage and distribution
  - GWh/month scale geologic storage
  - Develop novel materials and processes for chemical storage
  - Integration with renewable grid
  - Novel compression and liquefaction technologies
  - Leak detection and hydrogen purification
  - Materials compatibility

- H2 end-use
  - Process heat integration with intermittent hydrogen generation
  - New process chemistry with hydrogen as reductant
  - Ammonia production beyond Haber-Bosch
  - Hydrogen combustion

No solid-state materials meet all the DOE targets for vehicular storage





HyMARC project will address gaps in the foundational science of hydrogen storage materials:

- Reaction thermodynamics
- Solid-state diffusion
- Surface chemistry
- Phase nucleation and microstructure
- Catalysis and additive behavior

Cost effective hydrogen steel pipelines

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Goal

Identify pathways for reducing cost of steel hydrogen pipelines without compromising reliability and integrity

Demonstrated Impact

- Experimental fatigue data are used to guide the optimization of hydrogen pipeline codes and standards (*e.g.* ASME B31.12)
  - Lower pipeline costs while maintaining reliability

NIST National Institute of Standards and Technology U.S. Department of Commerce

ASME SETTING THE STANDARD

OAK RIDGE National Laboratory

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Summary

- ***Energy storage*** is an important component of a comprehensive grid modernization and zero-carbon energy future
  - Resiliency = better able to sustain and recover from adverse events such as severe weather
  - Reliability = fewer and shorter electrical power interruptions
  - Manage intermittent, renewable energy resources (e.g., solar and wind) that stress the current power grid
  - Reduce decoupling of generation and demand (exacerbating stresses) with greater penetration of intermittent renewables

- Hydrogen is a high-value chemical energy carrier
  - Transportation fuel
  - Chemical processing component
  - Auxiliary power using a fuel cell

H_2 at Scale Big Idea Teams

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Steering Committee:
Bryan Pivovar (lead, NREL), Amgad Elgowainy (ANL), Richard Boardman (INL), Adam Weber (LBNL), Rod Borup (LANL), Mark Ruth (NREL), Jamie Holladay (PNNL), Chris Moen (SNL), Don Anton (SRNL),

H2@Scale has moved beyond this National Lab team to include DOE offices, and industrial/other stakeholders.

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High T Generation:
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