LA100

The Los Angeles 100% Renewable Energy Study

The Potential Role of Hydrogen for In-Basin Generation

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Los Angeles Department of Water & Power

NREL Transforming ENERGY

LA100 Scenarios Based on Advisory Group Priorities

Each Scenario Evaluated Under Different Customer Demand Projections
(different levels of energy efficiency, electrification, and demand response)

- Moderate
- High
- Stress

SB100

Evaluated under Moderate, High, and Stress Load Electrification

- 100% clean energy by **2045**
- Only scenario with a target based on retail sales, not generation
- Only scenario that allows up to 10% of the target to be natural gas offset by renewable electricity credits
- Allows existing nuclear and upgrades to transmission

Early & No Biofuels

Evaluated under Moderate and High Load Electrification

- 100% clean energy by **2035**, 10 years sooner than other scenarios
- No natural gas generation or biofuels
- Allows existing nuclear and upgrades to transmission

Transmission Focus

Evaluated under Moderate and High Load Electrification

- 100% clean energy by **2045**
- Only scenario that builds new transmission corridors
- No natural gas or nuclear generation

Limited New Transmission

Evaluated under Moderate and High Load Electrification

- 100% clean energy by **2045**
- Only scenario that does not allow upgrades to transmission beyond currently planned projects
- No natural gas or nuclear generation

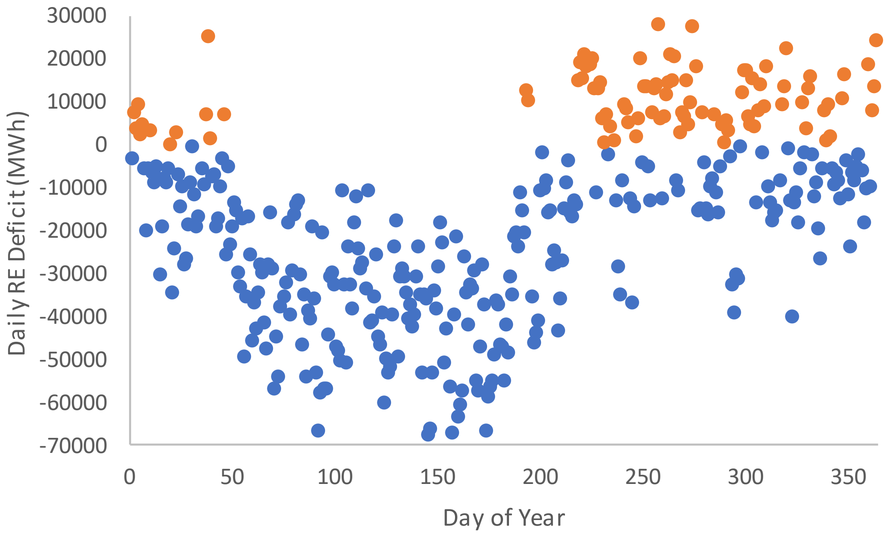
Reliability was a central focus of the study

Study examines in detail reliability during periods of very low wind and solar, extremely high demand, and unplanned events like transmission outages.

Three Supply-Side Challenges of a 100% RE System

1. When there **isn't enough** RE
2. When we cannot get it **into the basin**
3. When we cannot get it to the **right places** in basin

There are days of the year with insufficient supply of wind and solar energy

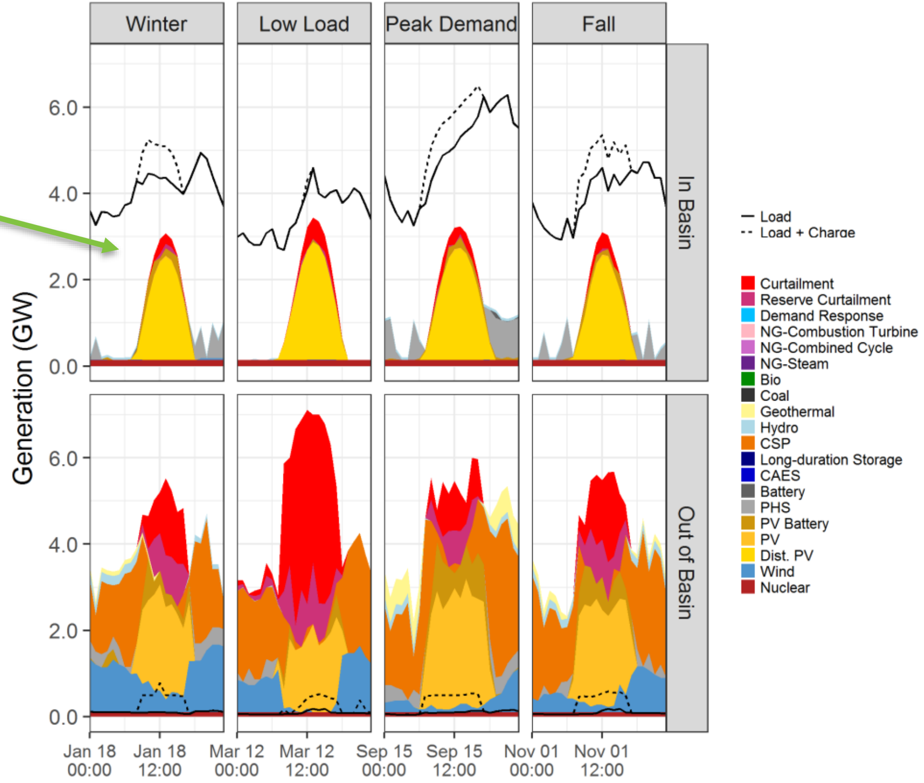


We have too much renewable energy during much of the year.

And not enough on a relatively few days

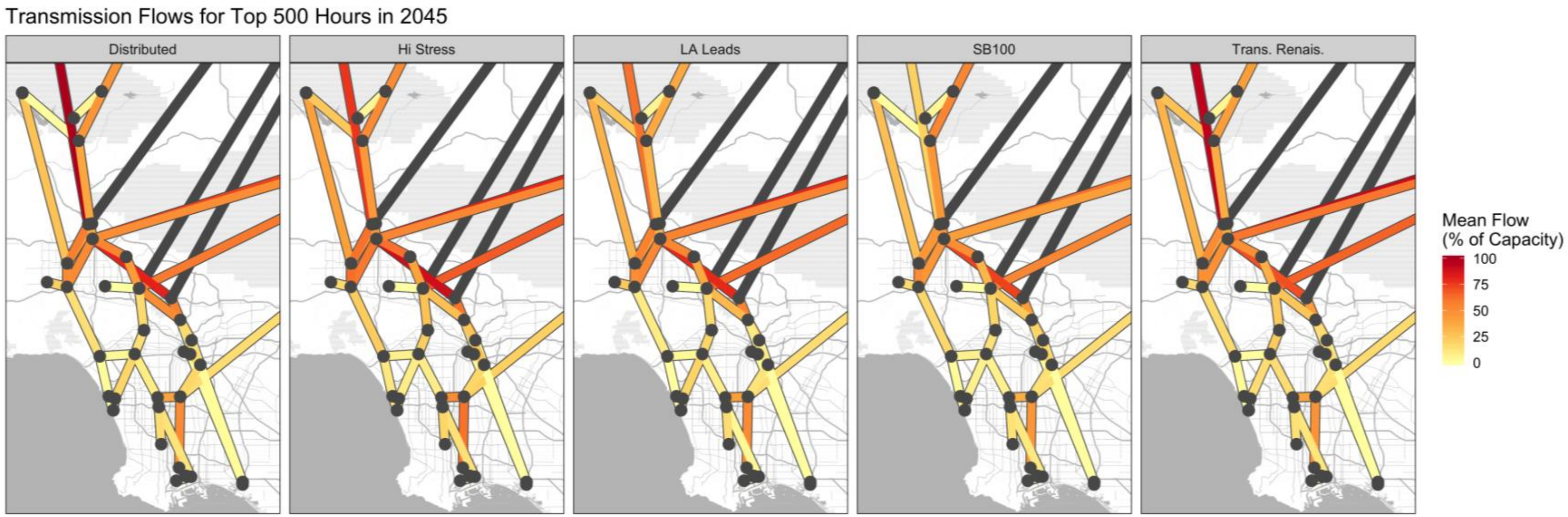
Challenge 2 – Out-of-Basin Transmission

During certain periods we are deriving a large fraction of total demand from out-of-basin resources

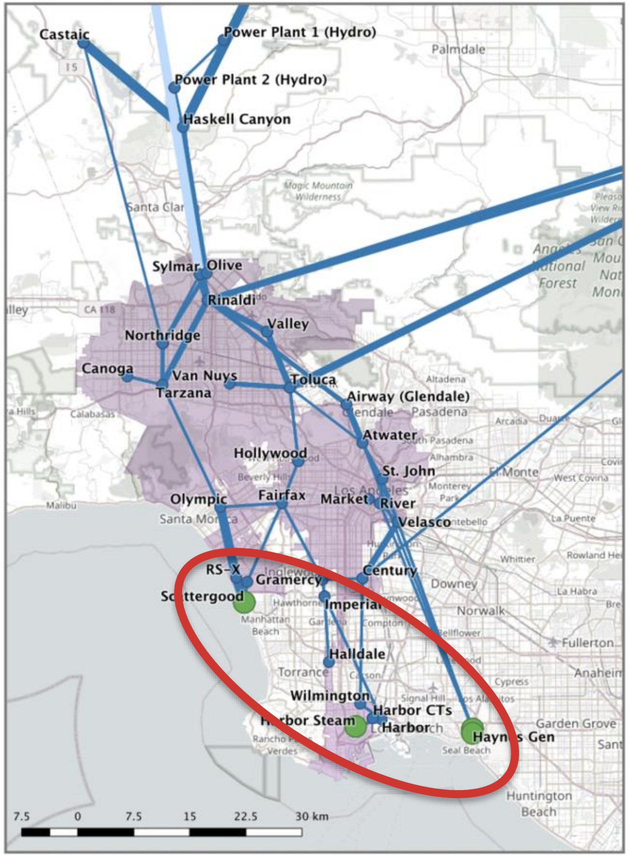


Challenge 2 – Out-of-Basin Transmission

Leading to large flows on the existing transmission networks



Challenge 3 – In-Basin Transmission



Transmission from the north

The LADWP transmission network was designed in part around power plants at specific locations in the basin.

Transmission limits/outages are currently addressed by running generators in the southern part of the system (at OTC sites)

Existing generators in the south

Key Issues for Challenges #2 & #3

Sometimes transmission **breaks**

So we have two general options:

1. **New and essentially redundant transmission**, for both the out-of-basin to in-basin pathways AND in-basin transmission pathways
2. **Something in basin** to replace out-of-basin resources for at least a few days
    - Needs to be available on the south side of the system
    - Needs to be available during periods of low solar output

Characteristics of an Ideal Solution

We likely need something in-basin that can address all three challenges

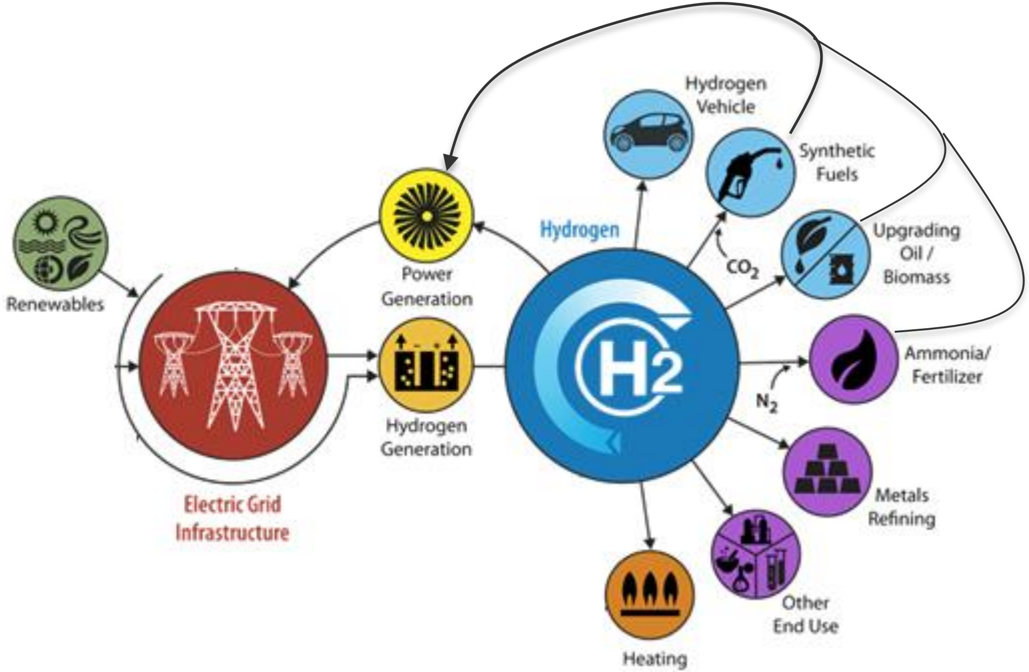
1. Can site *in basin*
   - Avoids dependencies on transmission from out of basin
2. Can site in *specific locations* in basin
   - System was designed around OTC sites, so can site there, but would like even greater flexibility
3. Can operated for *extended periods* (days or more)
4. Renewable
5. Can utilize off-peak renewables to address seasonal mismatch

Framework Solution in Three Parts

1. Producing a storable, renewably derived liquid or gaseous fuel
2. Storing and delivery
3. Converting this fuel into electricity

Renewable Electricity to Fuel

- First, use RE to split water and make hydrogen
- Then store the hydrogen and use it later to make electricity
- And/or turn the hydrogen into something else easier to store and transport
  - Natural gas (methane)
  - Ammonia
  - Liquid hydrocarbons



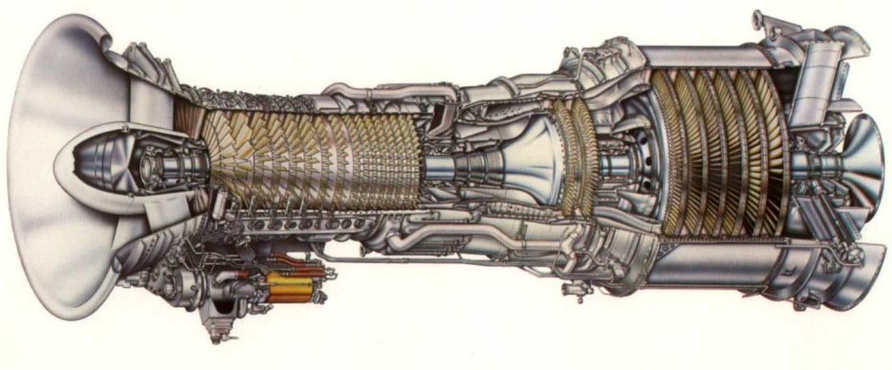
Storing and Delivery

1. Gas
   - Underground storage may be necessary
   - New pipeline infrastructure for hydrogen

2. Liquids
   - Multiple delivery and storage options

Conversion Back to Electricity: Two Options

1. Combustion



General Electric LM2500 Gas Turbine

2. Non-Combustion (Fuel Cells)

We Add In-Basin Capacity Across All Scenarios

Electrification
Efficiency
Flexible Load

Customer Rooftop Solar

Renewable Energy

Solar: + >5,700 MW
Wind: + >4,300 MW

Storage
(including coupled with solar)

+ >2,700 MW

Distribution,
Transmission

Renewably Fueled Combustion Turbines

+>2,600 MW
(in basin)

Much More

New

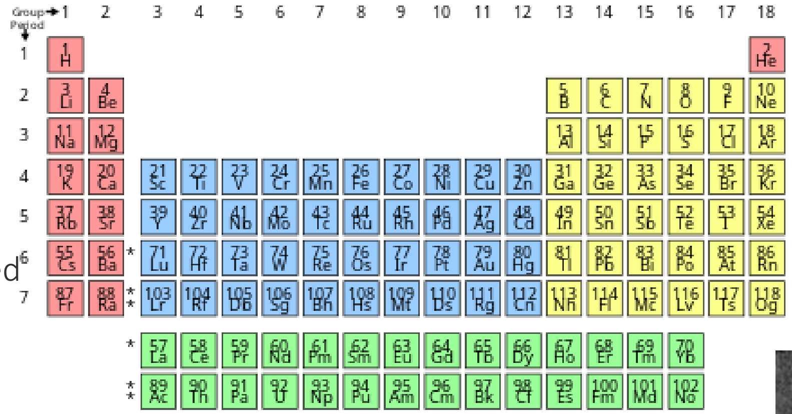
Natural gas → Biofuel/ hydrogen

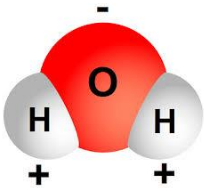
Today:
Daily

Future:
Infrequently

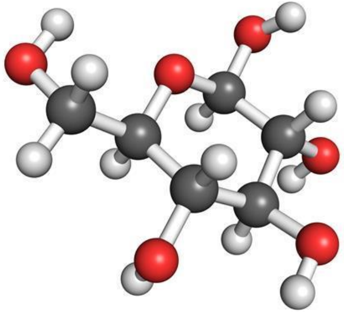
Hydrogen Basics

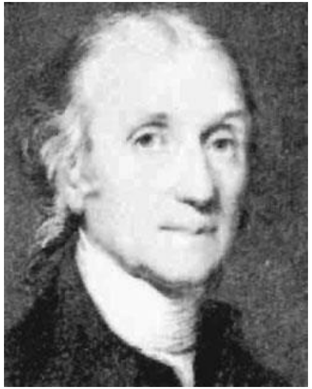
- Hydrogen is the smallest and simplest element (atomic number 1 and atomic weight 1.00794)
- Hydrogen is the most abundant element in the universe (≈75% of normal matter)
- Hydrogen fusion is the dominant process that generates energy in stars
- On earth, hydrogen atoms are almost all contained in more complex molecules
- Robert Boyle produced hydrogen gas in 1671 (experimenting with iron and acids) but no one realized that it was a distinct element before 1766 (Henry Cavendish)
- Like electricity, hydrogen is an energy carrier
- Michael Faraday discovered electrolysis in 1800 and Sir William Robert Grove is credited with creating the first hydrogen fuel cell a few years later
- Jules Verne imagined a hydrogen future in *The Mysterious Island*





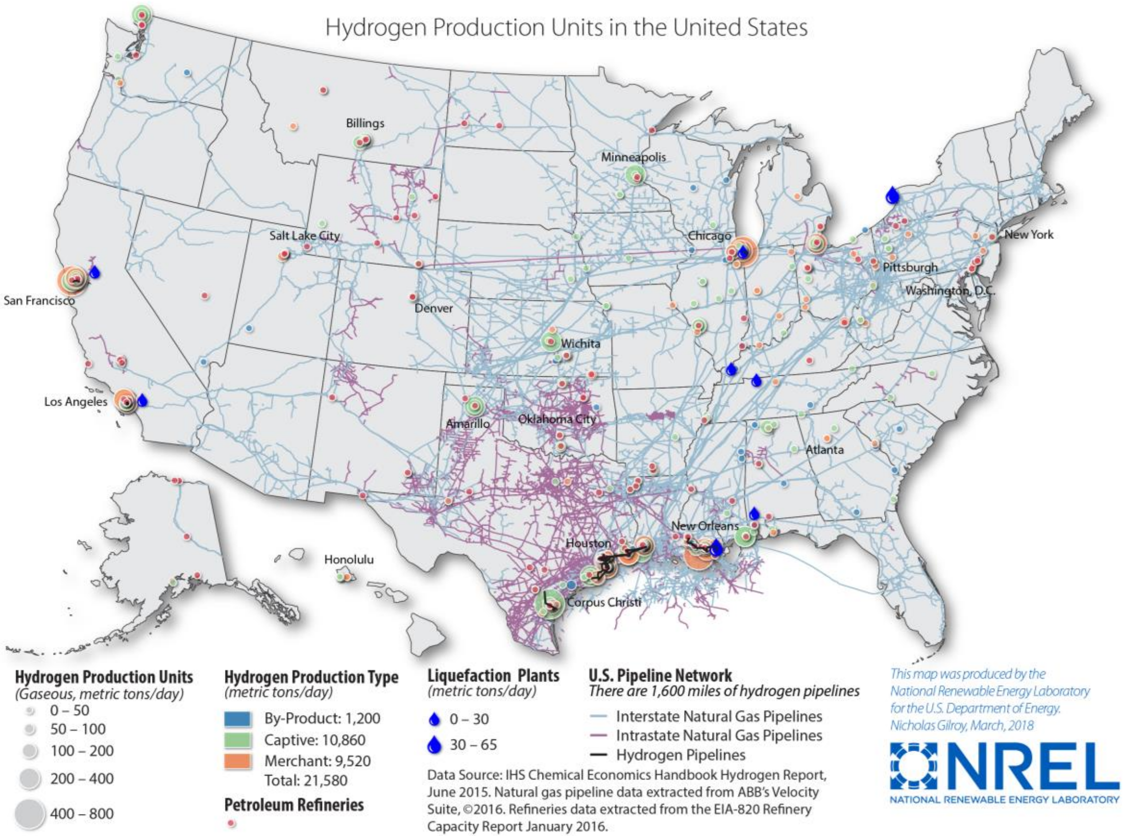
Water molecule


Glucose molecule


Henry Cavendish

Current Hydrogen Energy in the U.S.

- ≈10 MMT H_2/yr primarily for oil refining and ammonia production
- Almost all the hydrogen is produced by reforming natural gas which requires about 2 quad natural gas annually: ≈2% of total energy use
- The U.S. has ≈1600 miles of hydrogen pipelines including ≈40 miles in the L.A. Basin



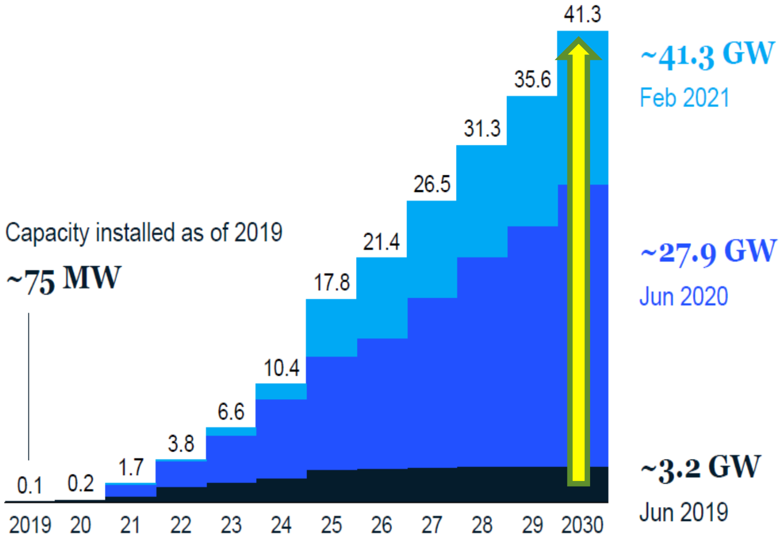
Recent Increased Interest in Hydrogen: Global Drivers

✓ **Low-cost renewables** are now available

✓ **Countries see clean H_2 can help meet climate goals**

- Hard to decarbonize sectors
- Energy storage
- Import/export opportunities

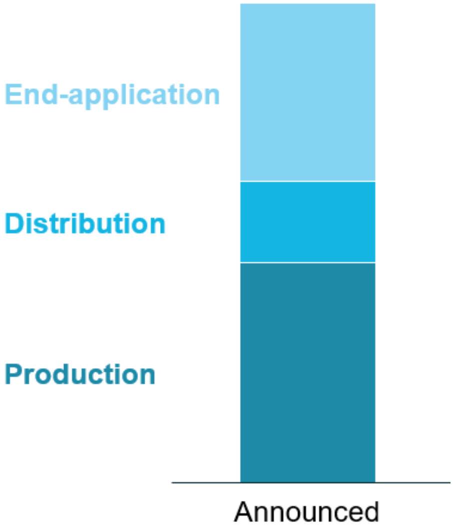
200-fold electrolyzer growth by 2030
Over 40 GW planned



1. For projects without known deployment timeline capacity additions were interpolated between known milestones

Source: McKinsey Hydrogen Project database

$80B Global Government Funding. 6X More with Private Sector through 2025



Source: McKinsey, H2 Council, Spring 2021

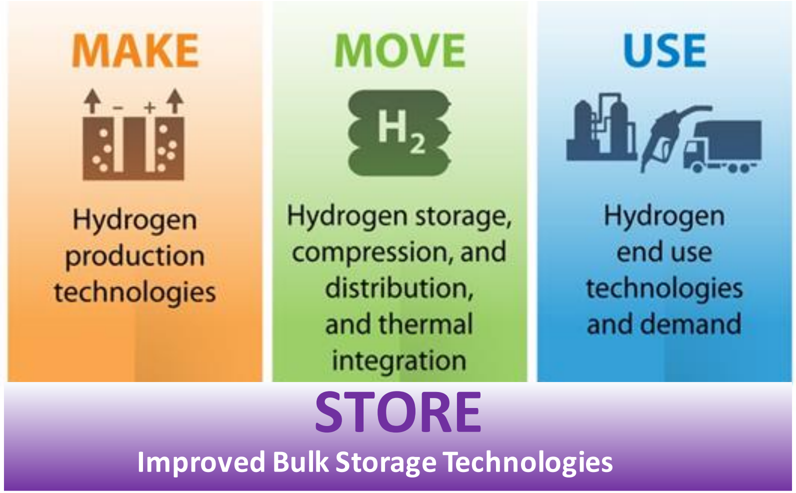
(From Sunita Satyapal, HFTO)

Studies show potential for 10 to 25% global GHG reduction using clean hydrogen. $2.5T Revenue. 30M Jobs.

DOE is Also Investing in RD&D Across the Hydrogen Supply Chain

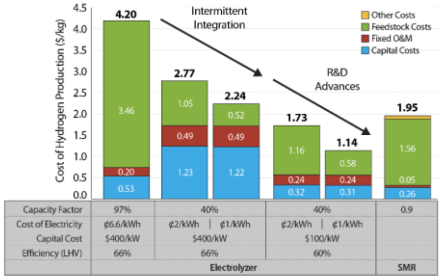
DOE is focused on developing technologies to make, move, use, and store hydrogen and cost-sharing deployment of systems that integrate the four areas.

Early-stage research is required to evolve and de-risk the technologies

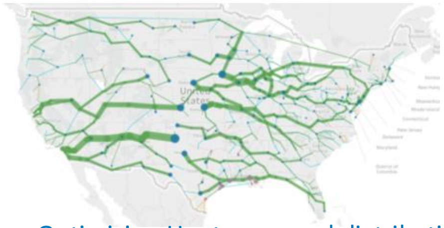


Preliminary

Use	Potential MMT/yr
Refineries & CPI	8
Metals	6
Ammonia	5
Methanol	1
Biofuels	1
Natural Gas	7
Light Duty Vehicles	28
Other Transport	3
Electricity Storage	28
Total	**87**



Decreasing cost of H_2 production

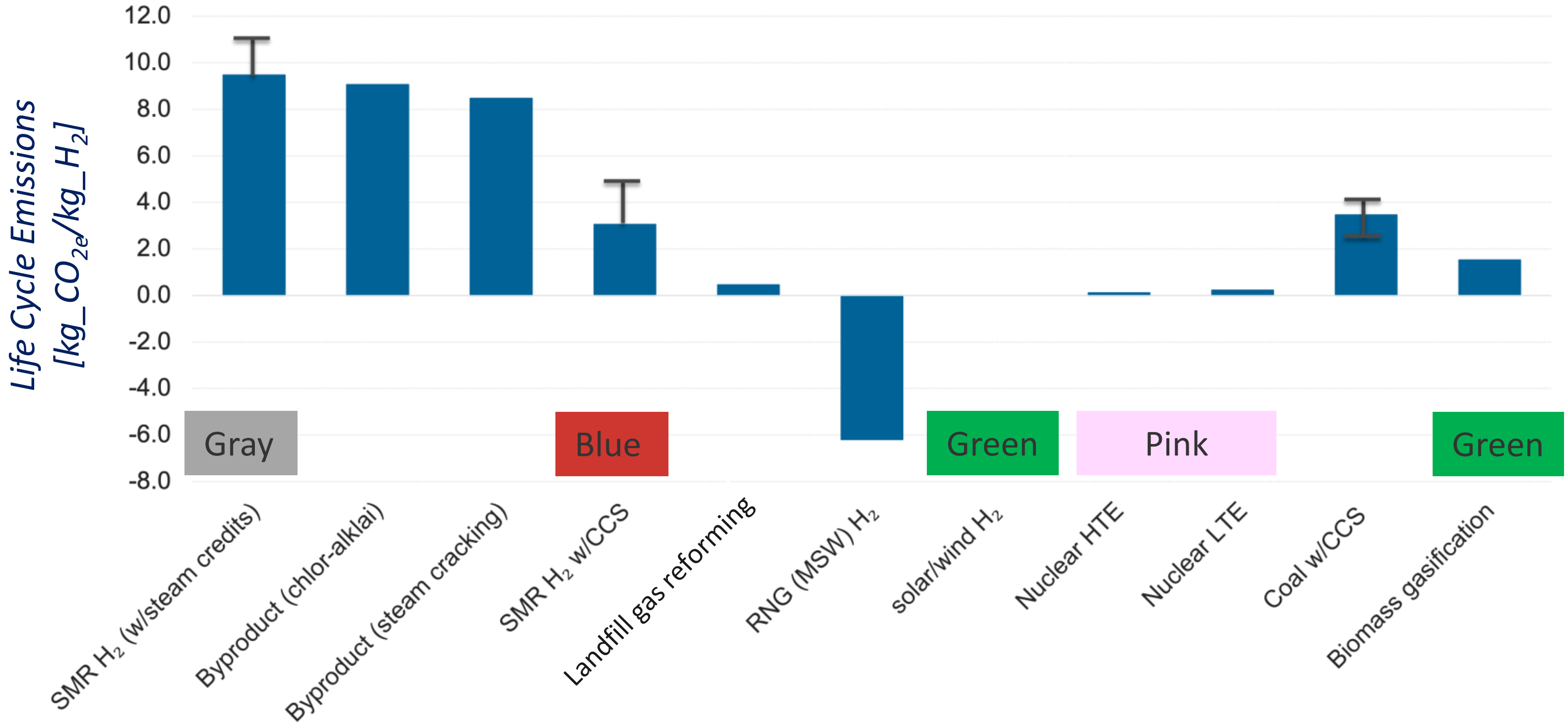


Optimizing H_2 storage and distribution

Leveraging of national laboratories' early-stage R&D capabilities needed to develop affordable technologies for production, delivery, and end use applications.

https://www.hydrogen.energy.gov/pdfs/review18/tv045_ruth_2018_o.pdf

DOE Uses Carbon Intensity Instead of Colors to Discuss Environmental Impacts



Ranges shown reflect potential variability in upstream methane leak rates, plant energy efficiency, and CO_2 capture rates. Baseline assumes 90% capture rate

Source: Elgowainy. H2IQ October 28, 2021

Questions?

The Los Angeles 100% Renewable Energy Study

Combustion Turbine vs Fuel Cell

	Combustion Turbine	Fuel Cell
Cost	Much Lower	Much Higher. Cost reduction potential is significant but highly uncertain
Fuel Flexibility	High – and can transition (hydrogen blends at IPP for example)	Much lower
Footprint and siting Flexibility	Large - Probably only at existing OTC site	Smaller, more flexible (*but probably more total area per unit of capacity*)
Operation flexibility	Some limits, but utilities very comfortable with rotating machines	More operational flexibility. Uses power electronics which can provide additional services
Emissions	A little NOx, but much less than current OTC units	None
Life	Long, well understood	Less certain

Fuel Cells

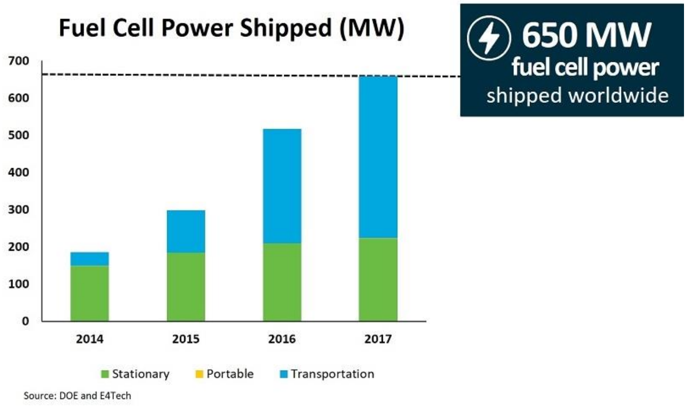
Two main types:

1. Proton exchange membrane
   - This is the type used in cars.
   - Requires super clean pure H2
2. Solid oxide fuel cell
   - **This is the type being deployed in limited numbers at banks, data centers and other locations for backup power**
   - Typically used with natural gas (can be any color)

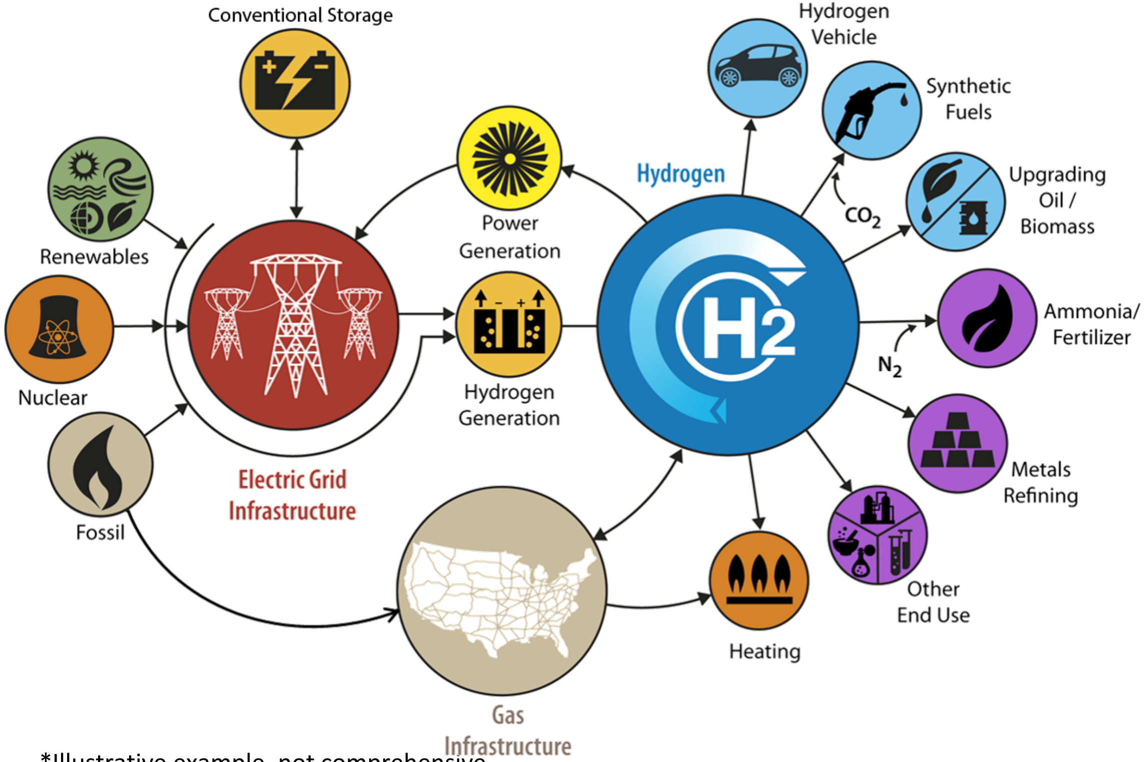
Fuel Cells – Technology Status

- As of the end of October 2020, there were about 161 operating fuel cells at 108 facilities in the United States with a total of about 250 megawatts (MW) of electric generation capacity
- That’s equal to a single, small natural gas power plant
- Is this like wind in 2000? Or PV in 2010?
- Or is it like solar water heating in 1976?

Compare to 30,000 MW of gas turbines in 2018 just for power generation



H2@Scale and Hydrogen's Potential



*Illustrative example, not comprehensive

Current DOE focus is moving to hydrogen as an energy carrier and in additional chemical operations

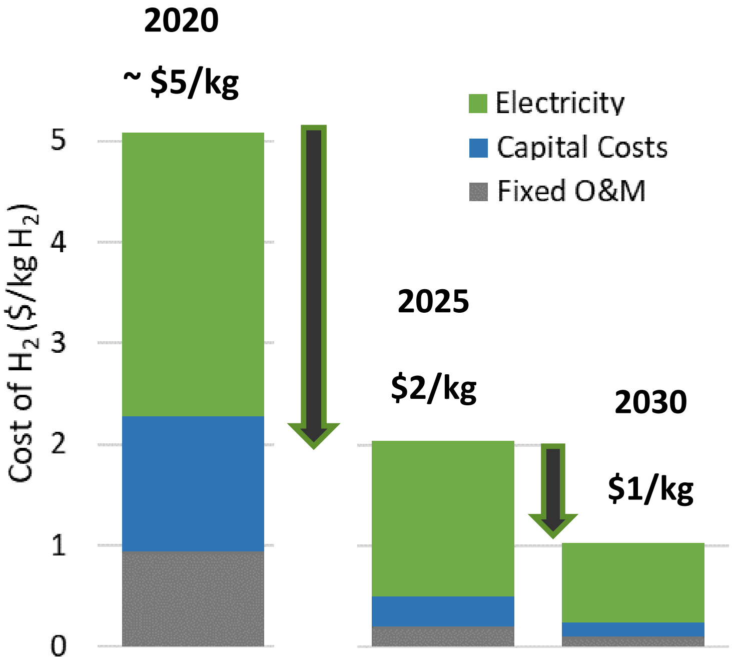
Hydrogen Shot: "1 1 1"

$1 for 1 kg in 1 decade for clean hydrogen

ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Hydrogen

Launched June 7, 2021
Summit Aug 31-Sept 1, 2021

Example: Cost of Clean H_2 from Electrolysis



Electrolysis: One of several pathways to reach goals

- Reduce electricity cost from >$50/MWh to
  - $30/MWh (2025)
  - $20/MWh (2030)
- Reduce capital cost >80%
- Reduce operating & maintenance cost >90%

All pathways for clean hydrogen included: Thermal conversion w/ CCS, advanced water splitting, biological approaches, etc.

Bipartisan Infrastructure Law – $9.5B H2 Highlights

- $8B for at least 4 regional clean H2 Hubs
- $1B for electrolysis (and related H2) RD&D
- $0.5B for clean H2 technology mfg. & recycling R&D
- Aligns with H2 Shot priorities by directing work to reduce cost of clean H2 to $2/kg by 2026
- Requires developing a National H2 Strategy & Roadmap

2020 Baseline: PEM low volume capital cost ~$1,500/kW, electricity at $50/MWh. Need less than $300/kW by 2025, less than $150/kW by 2030 (at scale)

(Adapted from multiple briefing slides from Sunita Satyapal, DOE's HFTO)