RE+ EVENTS

Exploring the Promise of Hydrogen in California

A look at hydrogen-related activities

Keith Malone
Program Director, Hydrogen
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SEPTEMBER 9-12, 2024
ANAHEIM, CA

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A little about me

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To be clear…

- I am not an engineer, scientist or researcher
  - Be gentle with your questions
  - Expect a less-than-technical response
- Electric vehicles come in two flavors: battery and fuel cell
  - They complement each other – it's not OR, it's AND
  - I will not engage in electric vehicle death match conversations (EV Death Match)
- We need all the tools in decarbonization toolbox
  - Including batteries and fuel cells
  - All-of-the-above strategy

How is hydrogen made?

Sources of renewable and zero/low-carbon energy

- Solar
- Wind
- Geothermal
- Nuclear
- Hydropower
- Etc.

Inputs

- Water
  - Seawater
- Biomass (bio-gas)
  - Wood chips
  - Agricultural waste
  - Sewage
  - Landfills/trash
- Natural gas
  - with carbon capture

Production methods

- Steam methane reforming (aka SMR)
- Electrolysis
- Pyrolysis (
- Chlor-alkalai
- Tri-generation fuel cells
- And more…

Future methods (lab/startup)

- Artificial photosynthesis
- Variations/improvements on above technologies and more

These are partial lists!

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Hydrogen mobility

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Cars

Toyota Mirai 2021

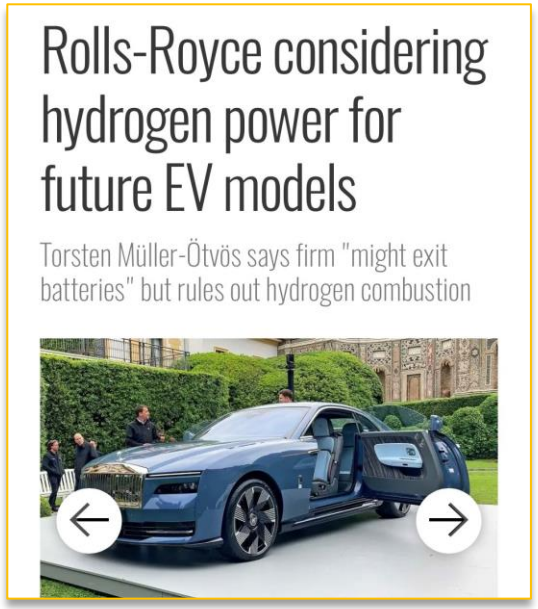
Toyota Mirai 2016

Hyundai
NEXO

BMW
iX5
Hydrogen

Clarity 2016

Honda
CR-V 2024



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Vroom H2!

Hyundai N Vision 74 Concept

Toyota Corolla Racing Car

Toyota GR Hydrogen Racing Concept

Hyperion XP-1

Gaussin Racing Truck

Hopium Machina

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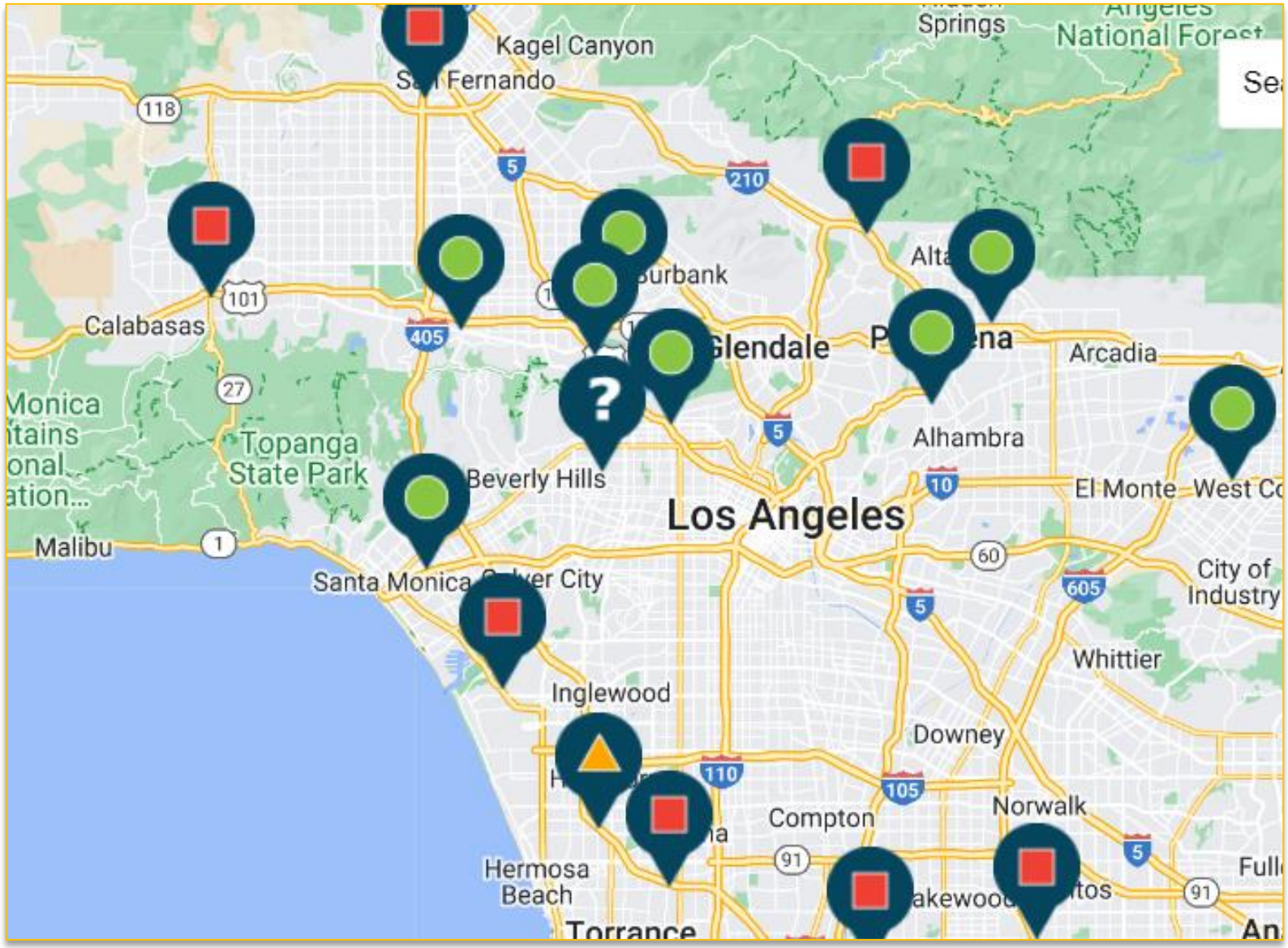
Hydrogen stations

H2 station = pumps and storage at gas stations

Stations near Beverly Hills



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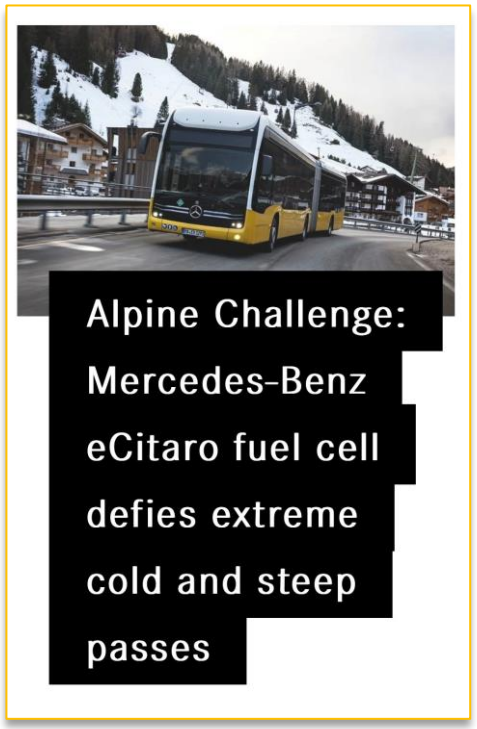
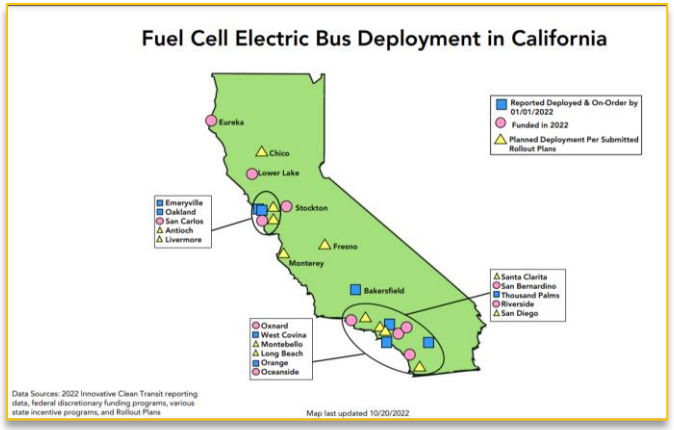
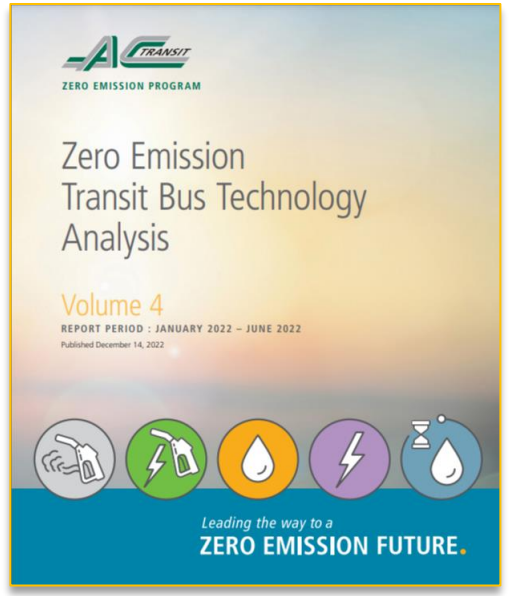
Transit buses

Canaries in the coal mine







ZETBTA (aka five-by-five study) compares drive trains

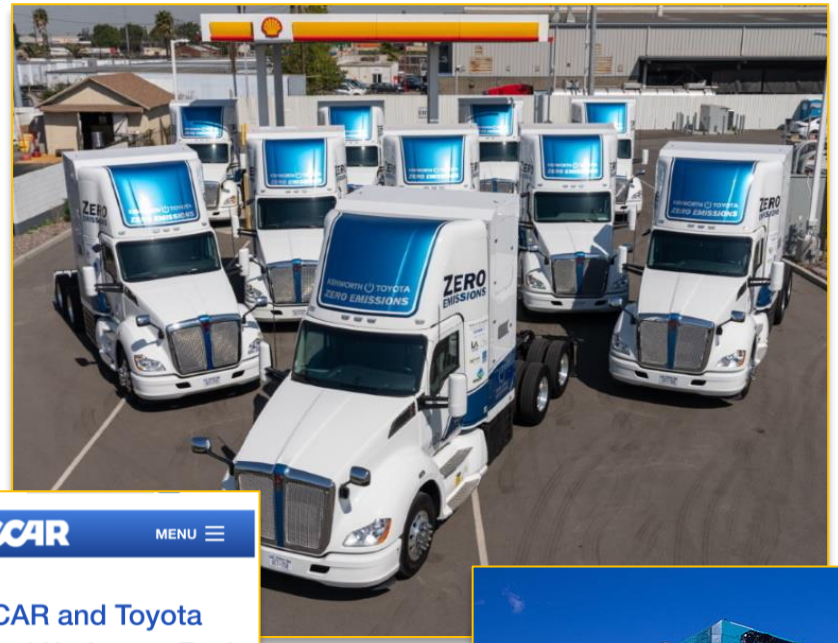
1. Fuel cell (recent buses)
2. Fuel cell (legacy buses)
3. Battery
4. Diesel
5. Diesel hybrid

Research conducted by **Stanford University**'s Precourt Institute

Trucks

Fuel cell electric truck manufacturers
(partial list)

- cellcentric
- Cummins
- Daimler Truck North America
- Hino/Toyota
- Hyundai
- Hyzon
- Nikola Motor
- Paccar/Kenworth
- Quantron



PACCAR MENU

PACCAR and Toyota Expand Hydrogen Fuel Cell Truck Collaboration to Include Commercialization

Dan Ronan | Senior Reporter
April 5, 2023 2:55 PM, EDT

NACFE Says Trucking's Future Is With Hydrogen

Group Notes It's Best Option to Reach Long-Term Goals

02/16/2023

BP to Acquire TravelCenters of America for $1.3B

TA's 281 highway locations will complement BP's off-highway convenience and mobility business.

bp

TA TravelCenters of America

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More mobility

CNBC WATCH LIVE

TECH

How Siemens and Alstom are preparing for a passenger rail boom in the U.S.

PUBLISHED TUE, JUL 11 2023 8:00 AM EDT
UPDATED 6 HOURS AGO

Magdalena Petrova
@MPETROVA92

WATCH LIVE

CISION PR Newswire

SIERRA NORTHERN RAILWAY AWARDED FUNDING BY THE CALIFORNIA STATE TRANSPORTATION AGENCY TO BUILD THREE ADDITIONAL ZERO EMISSION SWITCHING LOCOMOTIVES

Sierra Northern Railway Zero Emission Hydrogen Switching Locomotive

Sacramento, CA

Linde
Making our world more productive

Tri-Valley ▲ San Joaquin Valley
REGIONAL RAIL AUTHORITY

NEWS RELEASE *FOR IMMEDIATE RELEASE*

Linde Enters Strategic Collaboration with Valley Link
Move Advances Authority's Vision to be Nation's First Passenger Rail System to Operate on Self-Produced Green Hydrogen Fuel

Tracy, CA

Caltrans signs historic, $80 million contract with Stadler Rail

The contract includes a base order of $80 million for the first four trainsets with options for up to 25 additional trainsets that can be used throughout California.

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And some more mobility

OFFSHORE ENERGY

MENU

Prominent maritime ports, academia & innovation hubs unite to accelerate hydrogen innovation

First Mode to produce 36 nuGen™ systems annually from new Seattle facility

Posted by Paul Moore on 12th July 2023

A novel hydrogen fuel cell-powered ferry is scheduled to start carrying passengers in the San Francisco Bay in August

Bianca Giacobone Jun 30, 2023, 5:50 PM ET

Download the app

The Sea Change is a 70-foot catamaran ferry equipped with a hydrogen fuel cell system and the capacity to carry up to 75 passengers. Maurice

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AP ☰ WORLD U.S. POLITICS SPORTS ENTERTAINMENT BUSINESS SCIENCE FACT CHECK ODDITIES HEALTH

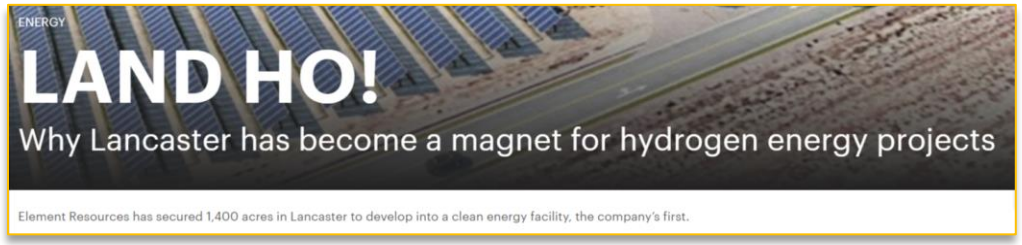
Election Day Israel-Hamas war Rashida Tlaib Carson Wentz Hunter Biden case

Lancaster, CA Becomes the First Hydrogen City in the United States

ENVIRONMENT

Green hydrogen plant in Lancaster will be one of California's largest

BY SUSAN CARPENTER | LANCASTER
PUBLISHED 11:38 AM PT JAN. 24, 2023



LANCASTER

City News & Updates

City of Lancaster Microgrid to Honor Consul General Akira Muto of Japan

Honda's Zero Emission Stationary Fuel Cell Provides Back Up Power to a Data Center

March 6, 2023 Corporate

- *Stationary fuel cell (FC) on American Honda campus in Torrance, Calif. is a first step toward future commercialization of zero-emission backup power generation*
- *In the coming years, Honda will begin applying stationary FC power station technologies to Honda manufacturing facilities and data centers around the world*
- *Honda is advancing hydrogen fuel cells to provide clean, safe and secure energy toward its global goal of carbon neutrality for all products and corporate activities by 2050*

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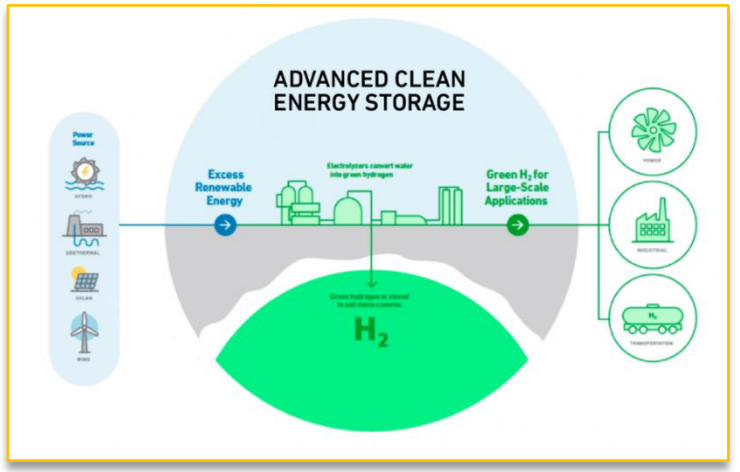
SoCalGas hydrogen home

Downey, CA

Utah > Los Angeles: Power generation, energy storage

July 2023

Los Angeles, CA

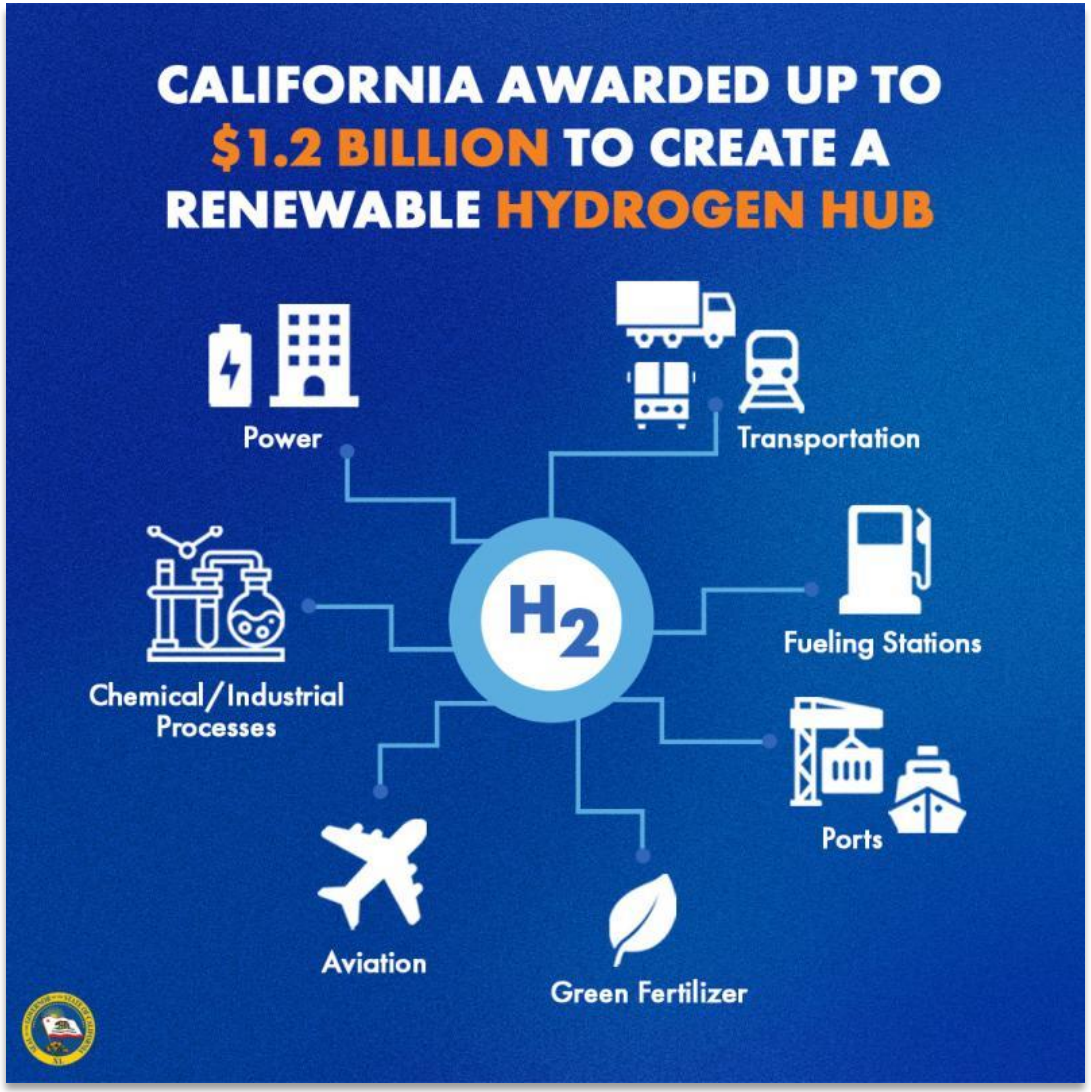


Just one of the salt caverns at the Advanced Clean Energy Storage site in Utah has the capacity to store the entire state of California's monthly curtailed energy.

November 2023

Mitsubishi Power Delivers First Shipment of Equipment to ACES Delta Hub for Clean Hydrogen Production at one of the largest systems in construction

2023-10-26



"This federal funding will help launch a hydrogen hub here in Southern California and will greatly help accelerate LA's conversion to clean, critical generation right here in the LA basin.

This is a win for the environment and for LADWP's power customers who want and need an affordable path to a clean energy future."

– Martin Adams, General Manager and Chief Engineer, Los Angeles Department of Water and Power

Resources: Learn more

- Fuel cells, DOE - https://www.energy.gov/eere/fuelcells/fuel-cells
- NASA - https://www.nasa.gov/content/space-applications-of-hydrogen-and-fuel-cells
- Hydrogen – https://www.eia.gov/energyexplained/hydrogen/
- Hydrogen Fuel Cell Partnership - https://h2fcp.org/
- H2 Tools, Center for Hydrogen Safety - https://h2tools.org/
- Hydrogen Safety Project - https://safehydrogenproject.org/

Questions? Follow up?

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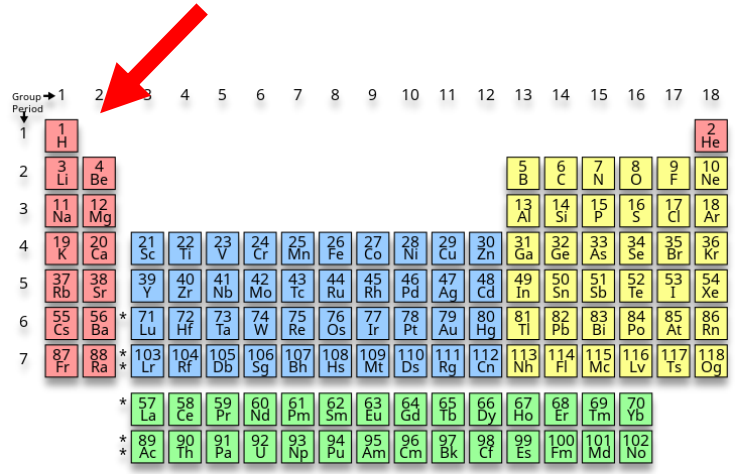
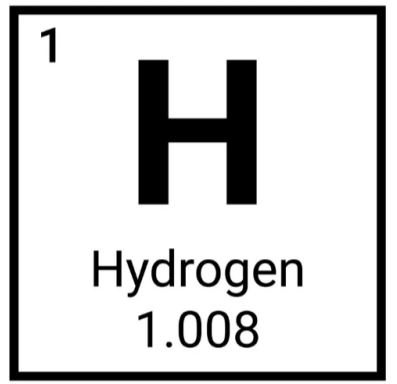
Threads: Keithman63

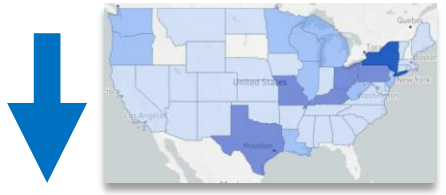
Hydrogen 101

- Hydrogen is the first element.
- It the most abundant element in the universe.
- It also the lightest element – 14 times lighter than air
  - It rises at almost 44 miles per hour and disperses rapidly.
- It is non-toxic and non-poisonous.





Drivers of renewable hydrogen production



- Infrastructure Investment and Jobs Act (2021)*
  - Clean hydrogen production – $9.5 billion:
    - **Hydrogen hubs** - $8 billion
    - Decrease cost of producing hydrogen with electrolyzers - $1 billion
    - Clean hydrogen manufacturing and recycling - $0.5 billion
- Inflation Reduction Act (2022)
  - Hydrogen Production Tax Credit
- $1 billion demand-side program announced (2023)

79 hub applicants
33 encouraged
April 7 submission

Fall 2023 negotiations
6-10 expected

WISHH
WESTERN INTER-STATE HYDROGEN HUB

SHINe

PNWH_2

HyVelocity Hub

Hawai'i Pacific
Hydrogen Hub

HALO hydrogen hub
LOUISIANA • OKLAHOMA • ARKANSAS

ARCH$_2$ES

ENERGY earthshots | Hydrogen
U.S. DEPARTMENT OF ENERGY

1 Dollar | 1 Kilogram | 1 Decade

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* IIJA is also know as the Bipartisan Infrastructure Law (BIL)

Example

Accelera by Cummins

- Since the signing of the Infrastructure Investment and Jobs Act and Inflation Reduction Act, **Accelera has received committed orders for nearly 300 megawatts of electrolyzer projects in North America**.
- In total, these projects will produce approximately **150 tons of hydrogen per day** once commissioned by the end of 2026.
- Context: 1 ton of hydrogen can power 60 transit buses for a day.

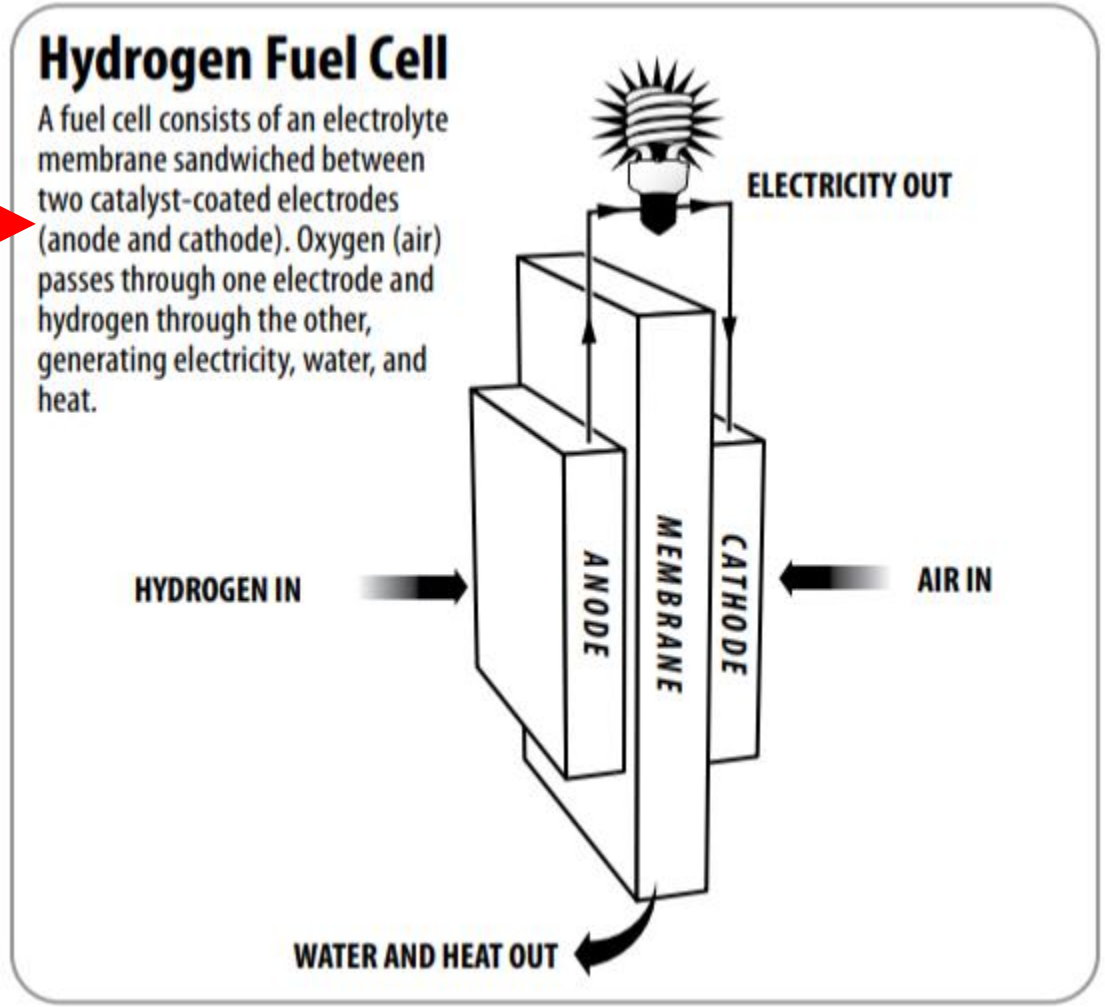
What's a fuel cell?

Different kinds of fuel cells

- Polymer Electrolyte Membrane Fuel Cells
- Direct Methanol Fuel Cells
- Alkaline Fuel Cells
- Phosporic Acid Fuel Cells
- Molten Carbonate Fuel Cells
- Solid Oxide Fuel Cells
- Reversible Fuel Cells

Different purposes

- Mobility
- Power generation



North American West Coast

California, Oregon, Washington and British Columbia

- Increasingly aligning and identical policies for zero-emission vehicles and hydrogen economy
  - Pacific Coast Collaborative
- Statement of Cooperation (October 6)
  - Accelerate charging and hydrogen fueling
  - Focus on I-5 corridor – San Diego to Vancouver
- Hydrogen hub efforts
  - CA – Alliance for Renewable Clean Hydrogen Energy Systems (ARCH2ES)
  - WA and OR – Pacific Northwest Hydrogen Association
  - BC - Hydrogen Changemakers Consortium – CICE

Pacific Coast COLLABORATIVE