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California Energy Commission

Title: Hydrogen Analysis for Electricity Generation in the 2023 IEPR

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Date: September 8, 2023

Presentation Overview

- Background
- Analysis Overview
- Challenges Overview
- Preliminary Takeaways

Background

- **Senate Bill 1075 (Skinner, Statutes of 2022)**
  - Study and model potential growth for "green" (clean renewable) hydrogen
  - Legislation required analysis of electric and transportation sectors
    - CARB Scoping Plan & Senate Bill 100 analysis, *2022 IEPR* envision other H_2 uses, particularly hard-to-electrify applications
  - Results of SB 1075 analysis in 2023 and 2025 IEPRs
- **Governor Office actions on hydrogen**

Analysis Overview

Power Generation

Scenarios to Evaluate
- SB 100 Scenario – 2045
- Scoping Plan Scenario – 2045

Results Evaluated
- Estimated potential of H_2 to replace gas burn by 2045

Factors Reviewed
- Production / electricity needs
- Ability to generate and store onsite
- H_2 delivery options
- Costs (monetary and social)

Preliminary Takeaways
- Challenges with each of the factors
- Identified further needs for analysis – SB 100 or other

Next Phase
- Ongoing analytical efforts
- 2025 IEPR

Transportation

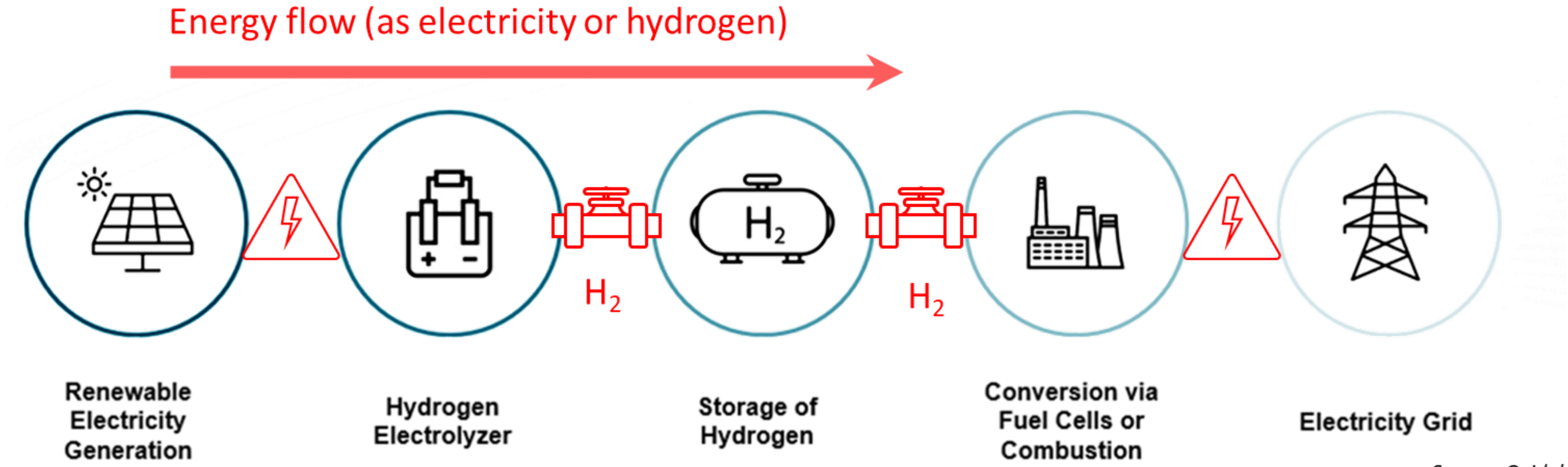
Setting up Scenarios
- 2022 IEPR Freight and Truck Choice Model as starting point
- Varying hydrogen fuel and FCEV price series

Prelim Results (2040)
- FCEV Stock Counts and Hydrogen Fuel Demand

Next Step
- Refine SB 1075 transportation scenarios

Challenge: Renewable Energy Needs/Electrolyzers

1 MW of renewable capacity produces enough H_2 to power only 0.142 MW of combined cycle gas turbine (CCGT) power: 7x



Source: Guidehouse

Best (but unrealistic) case: 100% of power is consumed by electrolyzer. Assume hybrid PV-wind capacity factor of 35%

Assume 50 MWh/tonne H_2

Assume compression energy is taken from the power grid

Assume: a Combined Cycle Gas Turbine (CCGT) plant, 44% efficiency, 85% capacity factor, fuel is 100% H_2

Challenge: Requires > 500 Large Electrolyzers

Electrolyzer specifications from Cummins show output and physical footprint

PEM Electrolyzers | HyLYZER® Series

Product	H2 Flow (Nm^3/h)	System efficiency (kWh/kg)	Equivalent power rating (MW)*	Output pressure (bar)	Outdoor / Indoor	Size Process module	Size Power module
HyLYZER® 200-30	200	≤ 55	1	30	Outdoor	40ft container	20ft container
HyLYZER® 250-30	250	≤ 55	1,25	30	Outdoor	40ft container	20ft container
HyLYZER® 400-30	400	≤ 54	2	30	Outdoor	40ft container	40ft container
HyLYZER® 500-30	500	≤ 54	2,5	30	Outdoor	40ft container	40ft container
HyLYZER® 1000-30	1000	≤ 51	5	30	Indoor	27.7ft x 7.5ft 8.5m x 2.3m	14.8ft x 8.2ft 4.5m x 2.5m
HyLYZER® 4000-30	4000	≤ 51	20	30	Indoor	50ft x 25ft 15.2m x 7.5m	23ft x 30ft 7m x 9m

Source: Cummins

Challenge:
Massive Delivery Volume

Options for hydrogen delivery to power plant

Trucks:

- Liquefying hydrogen adds cost and requires cooling infrastructure.
- Gaseous form demands compression.
- Unfeasible for power plants due to the immense volume needed.

Pipelines:

- Blending with natural gas (e.g., 5% blending) would not result in clean firm combustion.
- New dedicated hydrogen pipelines – would benefit from co-located facilities.

Challenge: Onsite Production

Onsite electrolysis at power plants resolves delivery problem but still has issues.

- GIS review of existing CA gas-fired generators
  - Only 33 to 40 have land space nearby to locate electrolyzers
  - Does not include renewable generation or water requirements
  - Does not include storage requirements to hold hydrogen
    - Need almost as many storage tanks as electrolyzers
    - Largest liquid H_2 storage tank (owned by NASA) holds 4700 cubic meters of H_2

Challenge:
Onsite Production Requires Storage

Source: NASA

Challenge:
Cost For Electrolyzers

Assume Total Capital Requirement (TCR) of $1500/kw (2023) for electrolyzers and size them to 80% of renewables capacity.

- Replacing Scoping Plan's 215 Bcf CH_4 with H_2 takes about 537 electrolyzers
- Average 2023-2045 Capital Outlay (electrolyzer costs fall over time)

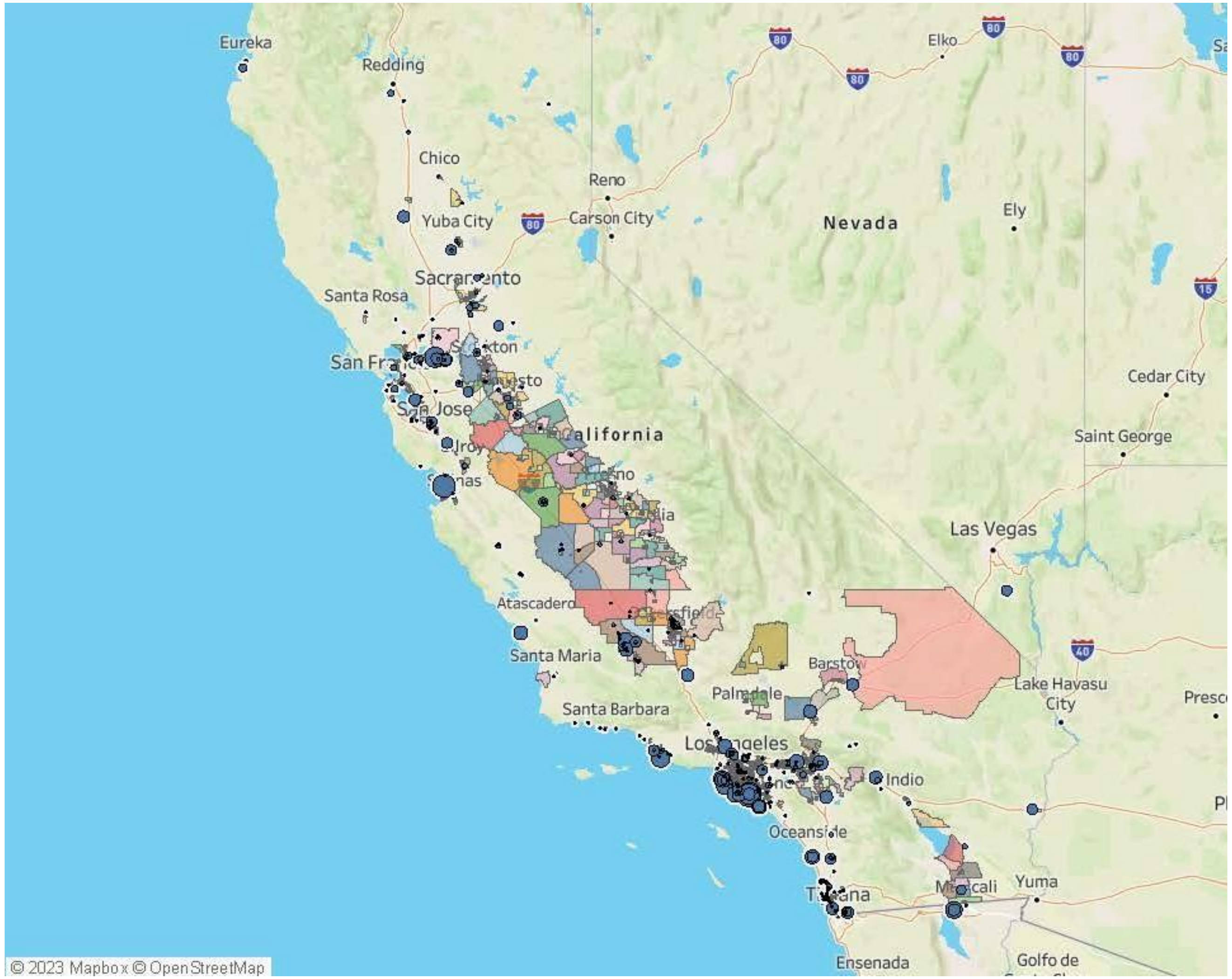
Electric output from Gas	33.3 GW
Electrolyzer capacity required	81.3 GW
Average electrolyzer TCR used	$879/kW
Total electrolyzer capital requirement	$71.5 B

- Excludes cost of the renewable electricity, compression or liquefaction, delivery, and storage and ignores capacity factor/operating pattern uncertainties
- Production tax credits help (only 10 years unless renewed)

Proximity to DACs

Switching to H_2 does not eliminate combustion.

- H_2 has greater NOx emissions control needs.
- Prioritize plants in DACs for conversion.
- Address in next phase/2025 IEPR.



Preliminary Takeaways

Explored current challenges and identified areas needing additional analysis

H_2 potential => substitute H_2 for CH_4 in 2045 resource mix

- Takes 662 Bcf of H_2 (~1.7 Billion kg) to replace the 215 Bcf gas burn shown in Scoping Plan 2045
- Requires about **537** large electrolyzers, ignoring hourly burn profile
- Operating the electrolyzers will require 7x more renewable capacity than will generate with the H_2
- Difficult to move that much hydrogen from production sites to power plants absent new pipelines
- 33 to 40 power plants may have space to co-locate electrolyzers and avoid delivery issue
- Need to store the H_2 from hour produced to hour combusted
- Estimated cost of electrolyzers is $71.5 Billion (assuming purchased over next twenty years and costs come down over time)

Thank you!