DOCKETED	
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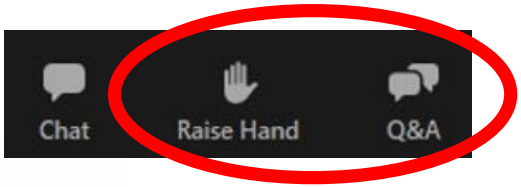
Staff Workshop on the Implementation of the Clean Hydrogen Program

Energy Research and Development Division
California Energy Commission
December 1, 2022

Housekeeping

- Zoom recording
- Muting on Zoom
- Questions



- Today's presentation slides and recording will be posted on the CEC webpage for this event: https://www.energy.ca.gov/event/workshop/2022-12/staff-workshop-implementation-clean-hydrogen-program

Agenda

- Overview of the Hydrogen Program (Chapter 7.6, AB 209)
- Hydrogen Development and Future Opportunities
- Proposed Technical Scope and Funding Areas for Clean Hydrogen Program
- Overarching Requirements and Considerations
- Public Comments and Questions
- Next Steps and Ways to Engage

Hydrogen Program

- Clean Energy Programs: adopted in Chapter 7.6, AB 209 (2022) [1]
  - Hydrogen Program: in-state demonstration of the production, processing, delivery, storage, or end use of hydrogen
- **Eligible Hydrogen**
  - Hydrogen derived from water using eligible renewable energy resources
    - Splitting of water using an electrolyzer powered by renewable electricity
  - Hydrogen produced from eligible renewable energy resources
  - Eligible projects produce, process, deliver, store, or use hydrogen

[1] Assembly Bill 209

Hydrogen Program Scope

- Financial incentives for eligible in-state hydrogen projects.
- Demonstration or scale-up of hydrogen production, processing, delivery, storage, or end use of eligible hydrogen.
- Financial incentives may be used as matching funds for federal grants.

Hydrogen Program Incentive Requirements

- Not supplant or result in duplicative offset credits, renewable energy credits, or other forms of compliance credits.
- Reduce sector-wide emissions.
- Benefit geographically diverse areas of the state.

Brief Technical Background

Technical Background Topics

- Overview of Hydrogen Supply Chain
- Hydrogen Production and Use
- State and Federal Funding for Advancing Hydrogen
- Future Opportunities for Hydrogen in California

Overview of the Hydrogen Supply Chain

Feedstock	Production	Conversion	Transmission and Distribution	Storage	Applications
Fossil (Gas, Coal, Oil) **Bio-feedstocks** **Electricity**	**Reforming** (SMR, ATR) **Gasification/ Thermal Cracking** **Electrolysis** (ALK, PEM SOEC)	**Compression** **Liquefaction** **Liquid organic hydrogen carriers (LOHC)**	**Pipelines** **Trucks** **Shipping** **Rail** **LOHC transport**	**Geological storage** **Pressurized containers** **Liquid hydrogen terminals** **LOHC storage**	**Electric Power** **Syngas-based Synthesis** **Mechanical power** **H2 as Feedstock**

Hydrogen Production and Use

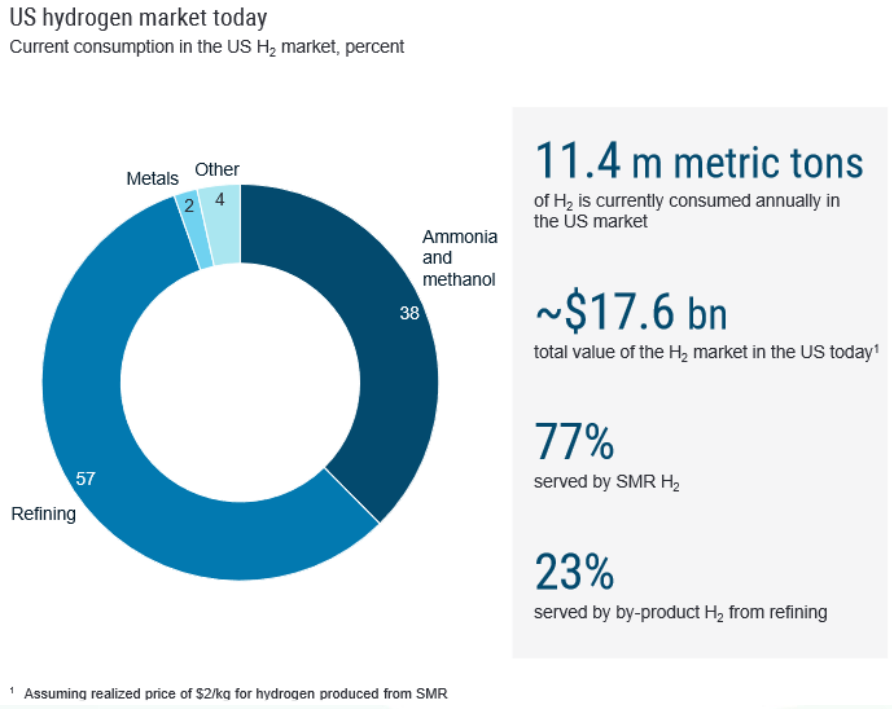
Production (2016*)

- 2,101 mt/day of merchant hydrogen (14% of U.S. capacity)
- 97% hydrogen capacity was reserved for oil refining industry

End-use

- Mostly in petroleum refining
- Other uses in fertilizer production, food processing, and treating metals

*Source: Hydrogen Tools. January 2016. North America Merchant Hydrogen Plants.



Source: Fuel Cell and Hydrogen Energy Association. 2020. Road Map to a US Hydrogen Economy.

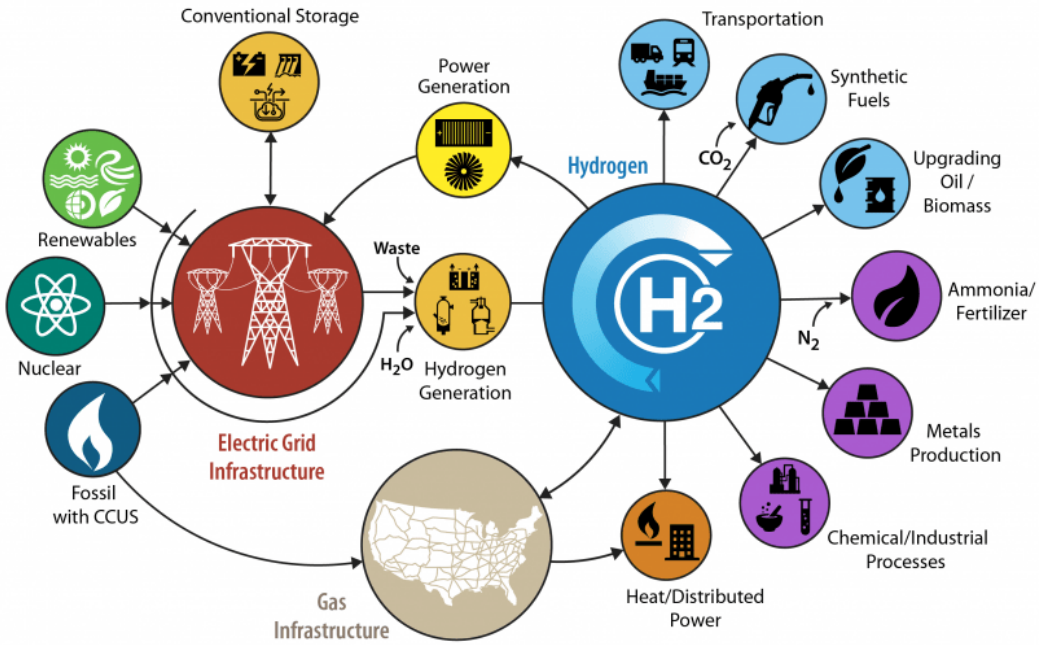
Synergistic R&D and State and Federal Funds for Advancing Hydrogen

- Over $934M current and planned in state funding and $9.5B in federal funding for hydrogen
- Over $45M investments made under the EPIC and Gas R&D Programs
  - Hydrogen production, conveyance, and storage
  - Applications in transportation, industry, and power generation

Credit: https://carbonherald.com (top); https://fuelcellsworks.com (bottom)

Future Opportunities for Hydrogen in California

- Twofold increase in hydrogen production needed by 2045 (*CARB's Draft 2022 Scoping Plan Update*)
  - Increasing emerging end uses:
    - Trucks, rail, ocean going vessel, and aviation
    - Petroleum refining, industrial process heat
    - Power generation, seasonal storage
    - Synthetic fuels, green ammonia, and methanol



Source: U.S. DOE. 2022. H2@Scale

Proposed Technical Scope of Clean Hydrogen Program

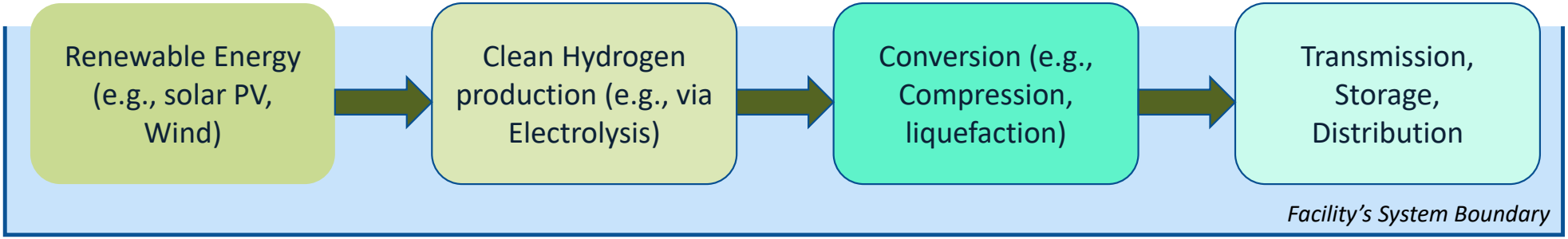
Proposed Technical Scope

- Stimulate increased production and use of clean hydrogen in California through strategic demonstration and deployment:
  - Large-scale centralized clean hydrogen production
  - Onsite/distributed clean hydrogen production and use
  - Emerging technologies, studies, and federal cost-share
  - Studies, database, and assessments through technical support

Proposed Funding Allocation and Timeline

Program Component	Tentative Budget	Tentative Schedule
Large Scale Centralized Hydrogen Production	$40M	Q2 2023
Onsite Hydrogen Production and Use	$30M	Q4 2023
Federal Cost Share	$20M	Q1 2023
Technical Assistance and Administrative Support	$10M	Ongoing
Total	$100M	

Large-scale Centralized Clean Hydrogen Production



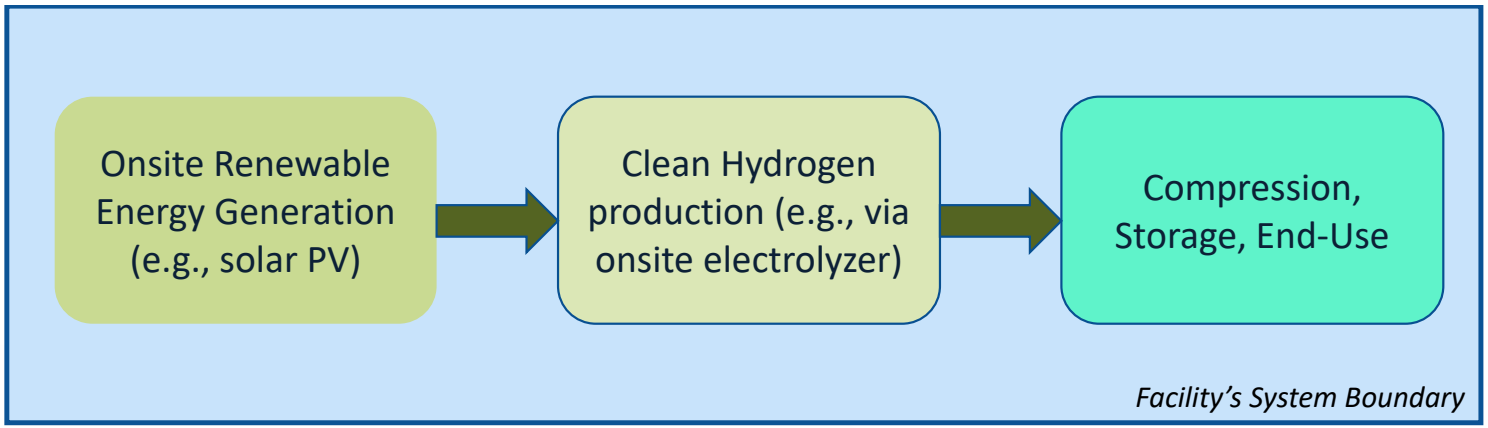
- Integration of renewable energy resources and hydrogen technologies to produce large quantities of merchant clean hydrogen.
- Example 1: Planned 30 mt/day liquid hydrogen plant with 120 MW PEM electrolyzers and 300 MW solar generation by Plug Power.
- Example 2: 10 mt/day liquid hydrogen facility using renewable power and alkaline electrolyzers, being built in AZ to serve CA market, by Air Products.

Large-scale Centralized Clean Hydrogen Production (cont.)

- **Proposed Funding (project range):** $40 Million ($10 - 20 Million)
- **Estimated timeline:** Q2 2023
- **Goals:**
  - Leverage existing technologies for nearer-term large-scale production
  - Demonstrate cost effectiveness of centralized clean hydrogen production, delivery, and storage
- **Scope:** Production, central storage, and transport
- **Scale:** Greater than 5 metric tons per day
- **End-Use:** Specified end-uses not required; ***end-uses cannot include petroleum refining***
- **Technology Readiness Level:** 8 or higher (pre-commercial)
- **Production Technology:** limited to electrolysis

Credit: cngdelivery.com (top); bloomberg.com (bottom)

Onsite/Distributed Clean Hydrogen Production and Use



- Renewable-powered distributed clean hydrogen production and use onsite.
- Includes clean hydrogen recovered as a by-product from process streams.
- Examples include clean hydrogen produced onsite for refueling.

Onsite/Distributed Clean Hydrogen Production and Use (cont.)

- **Proposed Funding (project range):** $30 Million ($4 - 7.5 Million)
- **Estimated timeline:** Q4 2023
- **Goals:**
  - Advance earlier stage technologies to support longer term, sustainable, cost-effective deployments
  - Demonstrate technological and market advancement of onsite clean hydrogen production and use
- **Scope:** Production and storage at a point-of-use
- **Scale:** 1 to 5 metric tons per day
- **End-Use:** Must be in alignment with state carbon neutrality goals; ***end-uses cannot include petroleum refining***
- **Technology Readiness Level:** 6 or higher (pilot scale)
- **Production Technology:** neutral

Credit: new.siemens.com (top); hydrogen.energy.gov (bottom)

Federal Cost Share

- **Proposed Funding:** $20 Million
- **Goals:**
  - Leverage federal funding opportunities to lower the cost and accelerate commercial readiness of emerging clean hydrogen technologies
  - Support California entities applying for federal funding such as from following IIJA funding areas:
    - Improving efficiency, durability, and costs of producing electrolytic hydrogen
    - Advancing new clean hydrogen equipment manufacturing technologies
    - Innovative and practical approaches to increase the reuse and recycling of clean hydrogen technologies

Questions for Stakeholders Regarding Scope

1. Are the proposed topics a feasible and impactful approach for promoting clean hydrogen's role in helping California achieve deep decarbonization? If not, what are your recommendations?
2. Are the proposed scales and funding allocation feasible and effective? Are there other scales, technological parameters, and funding levels that we should consider?
3. What types of technologies are sufficiently mature to support widescale production and use of clean hydrogen? Would a stronger focus on pilot-scale technologies support cost-effective clean hydrogen production?

Overarching Requirements and Considerations

- Technical performance
  - Water use
  - Energy efficiency
  - Emissions
- Costs and technology readiness considerations
- Geographic distribution, community impacts, and other considerations

Technical Performance Considerations

- **Water Use**
  - Water requirement varies by production technologies and pathways.
  - Preferred pathway should be highly efficient and able to process and use wastewater.
  - Example of water usage for different methods:

Technology	Average Water Use
Steam Methane Reforming (SMR)	22 kg water/kg H2
Biomass Gasification	305 kg water/kg H2
Biomass Reformation	31 kg water/kg H2
PEM Water Electrolysis	18 kg water/kg H2
Dark Fermentation with Microbial Electrolysis	104 kg water/kg H2

* Water use in H2 production technologies (Mehmeti et al. 2018)

Technical Performance

- **Energy Efficiency**
  - Parity or improvement over current pathways in energy efficiency.
  - For electrolysis, 1 kg of H2 (about 40 kWh/kg) requires a reported 50-55 kWh electricity (72-80% efficiency), but actual efficiency for entire process is typically lower than 72%.
  - Consider efficiency based on Lifecycle Analysis (LCA).

Technical Performance (cont.)

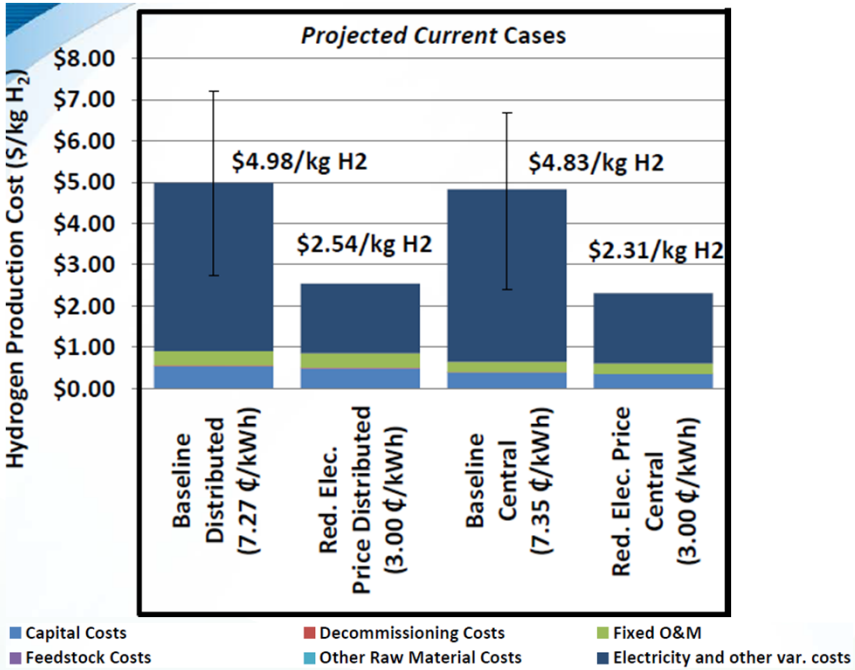
- **Emissions**
  - Hydrogen combustion could produce more NOx than methane combustion does for untreated exhaust streams.
  - Consider best possible reductions in NOx and other criteria air pollutant emissions.
  - Consider pathways with lowest Global Warming Potential (GWP).

Example Hydrogen Production Method	Production Capacity (kg/day)	GWP (g/kg H2)
Steam reforming of fossil gas	111,200	11,893
Coal gasification	284,000	11,299
Water electrolysis via wind energy	14	970
Water electrolysis via solar energy	160	2412
Thermochemical water splitting via Cu-Cl cycle	124,800	12,300

Source: Cetinkaya et al 2012. International Journal of Hydrogen Energy. 37:3(2071-2080).

Costs and Technology Readiness Considerations

- **Costs**
  - Cost improvements over steam reforming of fossil gas to help achieve DOE EarthShot Goals
  - Clean hydrogen currently not competitive with fossil-based hydrogen (e.g., >3x the cost) and sensitive to price of electricity
- **Technology readiness**
  - Large Scale Centralized Hydrogen Production: near-commercial or commercial technology
  - Onsite Hydrogen Production and Use: pilot-scale



Source: US DOE. 2020. Analysis of Advanced Hydrogen Production and Delivery Pathways

Benefits, Geographic and Other Considerations

- **Decarbonization and air quality and health benefits**
  - Direct GHG emissions reductions and reductions in criteria air pollutants
  - Estimate of other environmental and health benefits
- **Geographic distribution, community impacts, and workforce**
  - Diverse geographic benefits, especially for under-resourced communities
  - Direct and indirect job benefits
  - California-located projects

Questions for Stakeholders

Proposed Scope

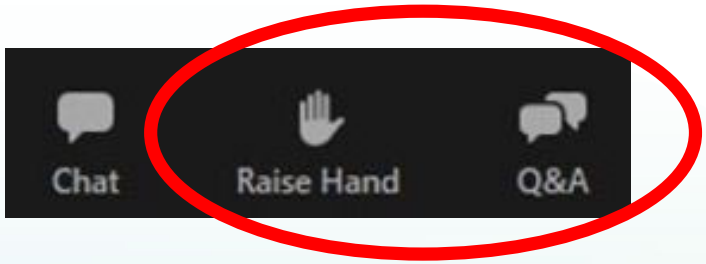
1. Are the proposed topics a feasible and impactful approach? If not, what are your recommendations?
2. Are the proposed scales and funding allocations feasible and effective?
3. Are clean hydrogen technologies sufficiently mature or should we focus more on early stage and emerging technologies?

Proposed Requirements and Considerations

4. How should we weigh different benefits, and which should we be prioritizing the most?
5. How do water concerns impact the success of the prospective projects?
6. What criteria should CEC consider for equity benefits?
7. Should CEC set requirements regarding end use (offtake agreements, commitment letters)?
8. What safety considerations should CEC include as requirements?
9. Are there permitting concerns, and if so, how should they be addressed in future solicitations?

Comments and Questions

- Raise your hand and you will be called on to unmute yourself, or type your question in the Question and Answer window.
- Introduce yourself by stating your name and affiliation.
- Keep comments/questions under 2 minutes to allow time for others.



Next Steps

- **Please submit written comments & questions:**
  - Via e-mail to docket@energy.ca.gov by no later than 5:00 p.m. on ***December 16, 2022***, PDT.
    - Include docket number 22-ERDD-03 and “Clean Hydrogen Program” in subject line.
  - Directly to the docket:
    - https://efiling.energy.ca.gov/EComment/EComment.aspx?docketnumber=22-ERDD-03
    - Include “Clean Hydrogen Program” in subject line.
  - By paper copy to California Energy Commission II Docket Unit, MS-4 II Docket No. 22-ERDD-03 II 715 P Street II Sacramento, California 95814
- CEC staff to compile and consider feedback in developing solicitations.

Future Engagement Opportunities

Program Component	Tentative Schedule
Federal Cost Share	Q1 2023
Large Scale Centralized Hydrogen Production	Q2 2023
Onsite Hydrogen Production and Use	Q4 2023

- Provide comments to draft solicitations once released.
- Participate in pre-application workshops.
- **Visit website to view workshop notice, presentation, and recording** (forthcoming): https://www.energy.ca.gov/event/workshop/2022-12/staff-workshop-implementation-clean-hydrogen-program

Other Ways to Engage

✓**Sign up to receive the Clean Hydrogen Program Announcements:**

- https://public.govdelivery.com/accounts/CNRA/signup/31897

✓**Application Process:**

- Solicitation documents, once released, will be available at the CEC funding opportunity website: https://www.energy.ca.gov/funding-opportunities/solicitations

✓**Join the Team:**

- The Energy Research and Development Division is hiring! For hiring opportunities at CEC visit: https://www.energy.ca.gov/careers

Thank You!