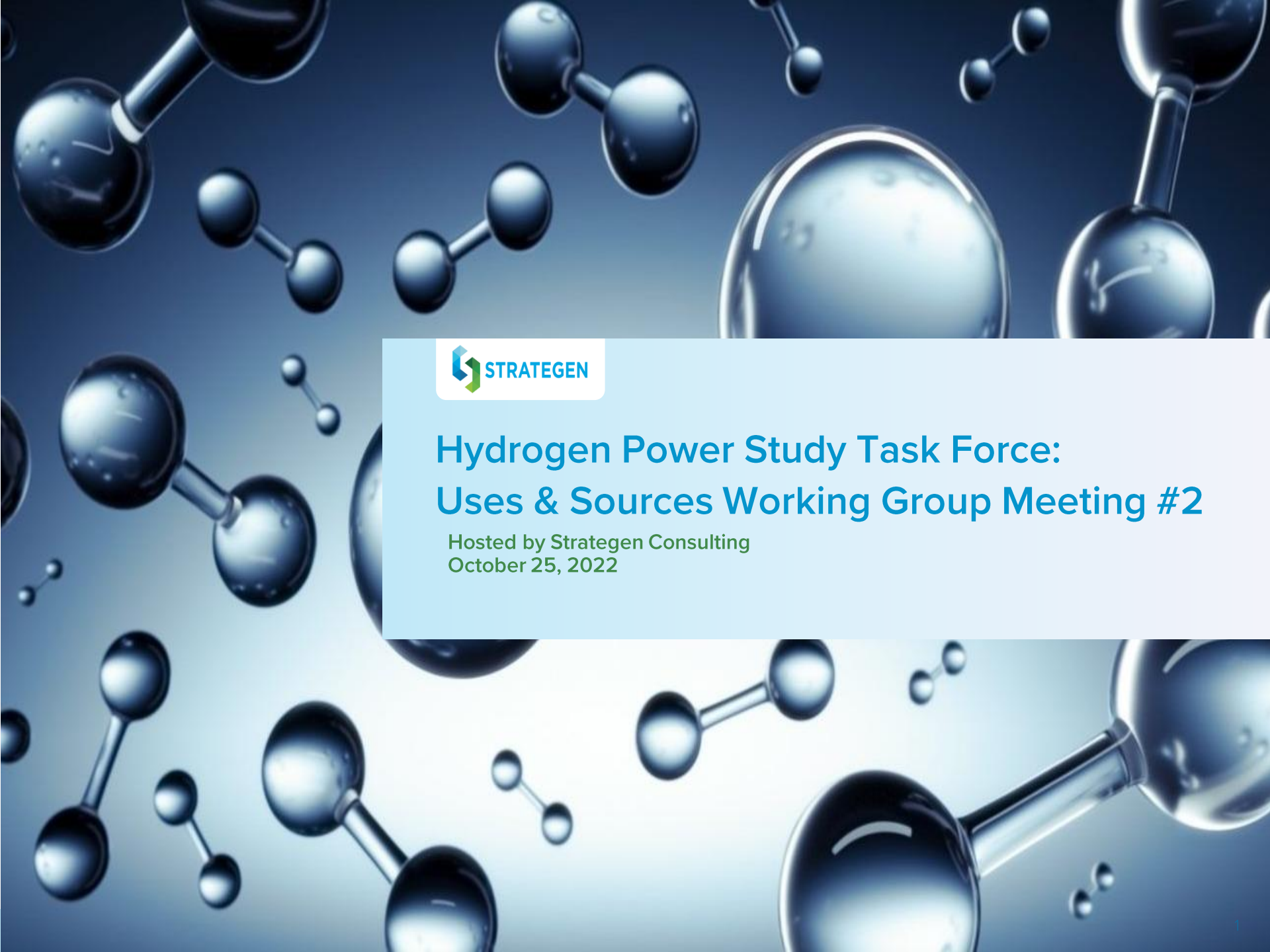

Hydrogen Power Study Task Force: Uses & Sources Working Group Meeting #2

Hosted by Strategen Consulting
October 25, 2022

Meeting Logistics

- Mute Microphone – in order to prevent background noise that disturbs the meeting, if you aren't talking, please mute your microphone or phone.

- Chat Box – if you aren't being heard, please use the chat box or raise your hand to ask a question. Please try to limit comments in the chat as these may not be officially captured in the record.

- Recording Meeting – we will record and post the meetings at www.ctgreenbank.com/hydrogentaskforce and you can also access meeting dates and dial-in information through Secretary of State.

- State Your Name – for those talking, please state your name for the record.

Agenda

- Welcome and Introductions (15 min)
- Review of Working Group Schedules (5 min)
- Review Updated Hydrogen End Use Evaluation (20 min)
- Discussion of End Use Evaluation (20 min)
- Presentation of Hydrogen Price Curve Analysis (10 min)
- Q&A and Next Steps (20 min)

Reminder: Strategen's Role

- The Strategen team will handle meeting logistics including scheduling and recording meeting minutes.
- The Strategen team will coordinate with Working Group Co-Chairs to develop meeting agendas which will be provided to participants in advance of Working Group meetings.
- The Strategen team will provide technical assistance (including research), where appropriate, for the Working Group.
- It is expected that this working group will meet on a monthly cadence. Meeting recordings and meeting minutes will be publicly available.

Introductions

Please share your name, title, and organization

Working Group Meeting Schedule

	September	October	November	December
Funding	9/27 4-5pm	10/26 10:30am-12 pm	11/18 10:30am-12 pm	12/15 10:30am-12:00 pm
Infrastructure	9/28 2-3pm	10/24 2-3pm	11/17 3-4pm	12/19 3-4pm
Policy & Workforce Development	9/26 3-4pm	10/20 12-1pm	11/29 12-1pm	12/15 12-1pm
Sources	9/27 1-2pm	10/25 2-3:30pm	11/17 11am-12pm	12/20 1-2:30pm
Uses	9/27 12-1pm		11/22 12-1pm	

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Hydrogen End Use Evaluation

Context, Description, and Updated Results

Description and Application to Analysis

- **Framework provides a simplified way of comparing end uses for hydrogen.**
  - Can provide an organized approach to assessing and comparing H2 use in different applications.
  - Cannot capture all nuance involved in decision-making within the energy system.

- **Framework will directly inform demand analysis via a tiered approach to create high/medium/low demand scenarios (more details on next slide).**

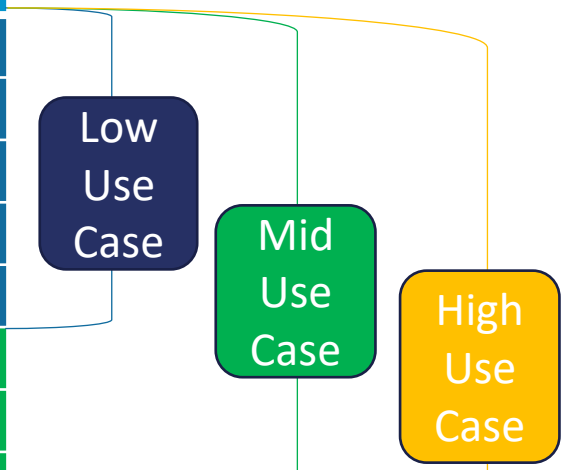
- **Framework will indirectly inform recommendations in final report. Other factors that will be considered include:**
  - Demand for H2 or fuel cells form a particular end use.
  - Complementarities between end uses (e.g. H2 truck fueling stations supporting H2 forklifts or industrial H2 use).
  - Ability for state policy levers to impact end use's development (e.g. regional vs. in-state applications).

Scenario Development from Evaluation Framework

- H2 demand from all cost-competitive end uses will be evaluated
- Low/Medium/High demand scenarios will be developed based on evaluation framework
- Potential demand will be compared against assessment of local H2 production potential (from Sources WG)
- Other scenario development approaches are possible (e.g. based on specific criteria)

Sample Scenario Development

End Use Type	Rank
Tier 1 End Use	1
Tier 1 End Use	2
Tier 1 End Use	3
Tier 1 End Use	4
Tier 1 End Use	5
Tier 2 End Use	6
Tier 2 End Use	7
Tier 2 End Use	8
Tier 3 End Use	9
Tier 3 End Use	10
Not Cost-Competitive	N/A
Not Cost-Competitive	N/A



Note: Some end uses have been added since initial evaluation

Criteria Ranking Description

Criteria	1 / Lowest Rank	2 / Median Rank	3 / Highest Rank
Cost-Competitiveness Compared to Alternatives	Alternative is cost-effective / preferred	Uncertain / ongoing competition with alternative	No alternative / alternative not economically feasible
GHG Reduction Potential	Lowest third of CT's GHG emission sources	Middle third of relevant CT's GHG emission sources	Highest third of CT's GHG emission sources
Technological Maturity / Commercial Readiness	Deployment Timeline: 2040-2050	Deployment Timeline: 2030-2040	Deployment Timeline: Now-2030
Infrastructure Requirements	Statewide infrastructure development required	Infrastructure needed at a limited number of sites	No new infrastructure needed
Environmental Justice	Increases pollution impact to frontline communities	Does not change level of localized pollution	Reduces pollution impact to frontline communities
Workforce Development	Reduces workforce need	Keeps workforce need the same	Increases workforce need
Resilience Benefits	Resilience is not a major consideration	Resilience is valuable but not critical	Resilience is a critical need
Safety Regulation	More safety regulations are needed than for the most likely alternative	New safety regulations needed, but same as would be required for the most likely alternative	No new safety regulations needed

Most criteria rankings indicate *direction* of an impact but not the *magnitude* of the impact

Overview of Evaluation Approach

Criteria	Evaluation Questions
Cost-Competitiveness	• Are H2-based technologies likely to be cost-competitive on a total cost of ownership basis? • Do forecasts indicate H2 technologies take a significant percentage of market share? • In these forecasts, is market share for H2 technologies growing faster than alternatives? • Do systems-level decarbonization studies allocate H2 to this application?
GHG Emission Reductions	• Out of the use cases for which H2 is cost-competitive, what percentage of CT's GHG emissions does this end use contribute over the long term (i.e. in 2040)?
Commercial Readiness	• Are there commercial or pilot deployments of this technology in CT or elsewhere? • Does this technology require CT-specific tests with local infrastructure? • When do industry players expect this technology to be commercially ready?
Infrastructure Requirements	• Does this technology require supporting networked infrastructure (e.g. pipelines, fueling stations)? Does this network need to cover the entire state? • Can this application for H2 re-use existing infrastructure or equipment?
Environmental Justice	• Does H2 use increase or decrease levels of local pollutants compared to current option? • Does pollution from this end use substantially impact disadvantaged or frontline communities? • Is it reasonable to assume pollution control technologies can be deployed?
Workforce Development	• Does using H2 in this application require additional processes or industries that would increase local workforce needs?
Resilience	• Does this end use serve a purely commercial function? • From a societal standpoint, how important is it that this remain available through inclement events?
Safety Regulation	• Does this H2 use require storage of flammable material in tanks? • Would H2 combustion need similar safety procedures to what currently exist?

Next Steps in End Use Evaluation

- **Rankings are NOT finalized.**
  - Participants will have opportunities in this meeting to ask questions and provide feedback on updated rankings.
  - Participants who have already provided feedback are also welcome to provide more details on their reasoning here.
  - Areas where past stakeholder feedback suggested a ranking be higher or lower are indicated in subsequent slides.

- **Participants are also welcome to provide additional feedback over the course of this week, as well as studies or other resources to support their suggested revisions.**

- **Finalized evaluations will be sent out next week so that focus can shift to demand analysis.**

Tier 1 Applications

Key:
"+" = Stakeholder suggested rank should be higher
"-" = Stakeholder suggested rank should be lower

	Critical Facilities (24-hr backup)	Heavy-Duty Trucks*	Aviation	Power Sector	
				Fuel Cell	Turbine
Cost	3	2	3	2	2
GHGs	1	3	2	3-	3-
Maturity	3	3-	2	2	2
Infrastructure	3	2-	3	1**	2
EJ	3	3	2	3	2-
Workforce	2	2	3	2	2
Resilience	3	2	2	3	3
Safety	2	2	2	3	2
Total	**20**	**19**	**19**	**19**	**18**

*Higher H2 use assumed for long-haul trucking (e.g. >400 miles/day)
**Lowered due to inability to reuse existing gas turbine equipment

Tier 2 Applications

Key:
"+" = Stakeholder suggested rank should be higher
"-" = Stakeholder suggested rank should be lower

	Material Handling Equipment	*Specialty Vehicle Fleets**	Trans-Oceanic Shipping	Harbor Craft**	Buses***
Cost	3	*2*	3	2	2
GHGs	1	*1*	1	1	1^{+}
Maturity	3	*2*	2	3	3
Infrastructure	3	*3*	3	2	2
EJ	3	*3*	3	3	3
Workforce	2^{+}	*2*	3	2	2
Resilience	1^{+}	*3*	2	2	2
Safety	2^{+}	*2*	1	2	2
Total	**18**	***18***	**18**	**17**	**17**

*Special-purpose vehicles with long uptimes and localized refueling (e.g. ambulances, police cruisers). *These values are representative as additional research is needed to finalize evaluation.*
**Localized port vessels and water transport (e.g. ferries)
***Higher H2 use assumed for long-distance bus travel (e.g. intercity routes)

Tier 3 Applications

Key:
"+" = Stakeholder suggested rank should be higher
"-" = Stakeholder suggested rank should be lower

	Rail	Industrial Heat (high heat processes)	H2 Blending (non-core customers)
Cost	2	2	2-,+
GHGs	1	2	1+
Maturity	3	2	2+
Infrastructure	2	2	3
EJ	2	2-	1*
Workforce	2	2	2
Resilience	2	1	2
Safety	2	2	2**
Total	**16**	**15**	**15**

The following end uses were excluded as not cost-competitive with alternatives:

- Passenger cars
- 100% hydrogen residential / commercial heat
- Hydrogen blending for non-core customers (e.g. residential, commercial)
- Low heat industrial processes

*Score could increase if blending is isolated to pipeline networks feeding only non-core customers employing technological and operational measures to reduce NOx emissions
**When kept within minimum blend percentage that's deemed safe for any equipment exposed to the blended gas stream

Discussion Questions

+ Are there any rankings that looked like they should be revisited? Are there any that you'd like explained in more detail?

+ Are there any questions on the approach to evaluating specific criteria?

+ Do you have any suggestions on using this evaluation to develop demand scenarios?

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Hydrogen Price Curves

Context and Initial Analysis

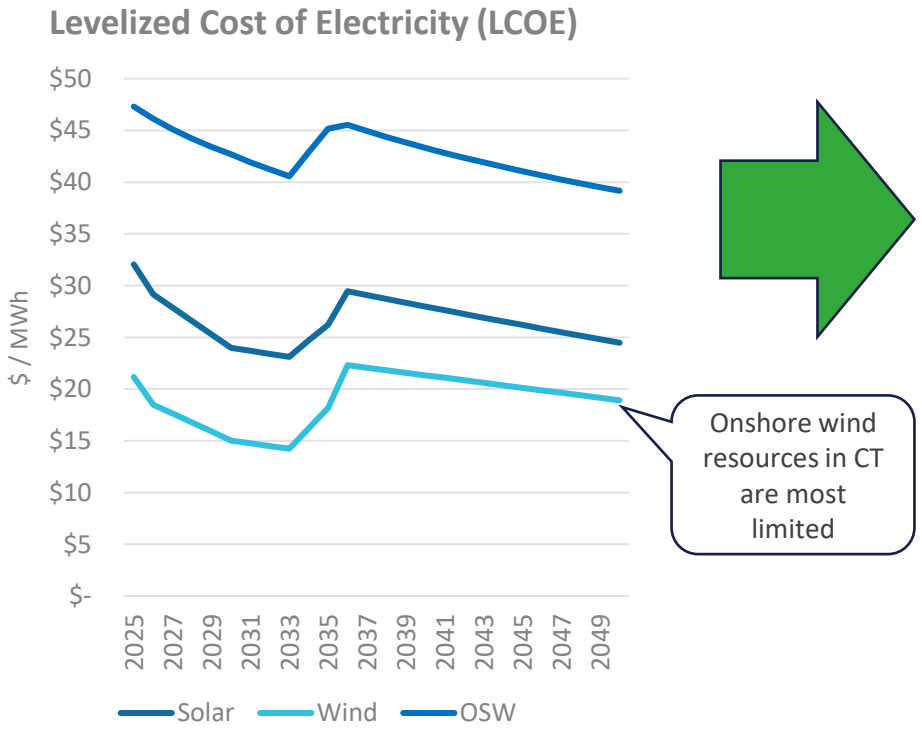
Hydrogen prices impact consumption and can inform state policy

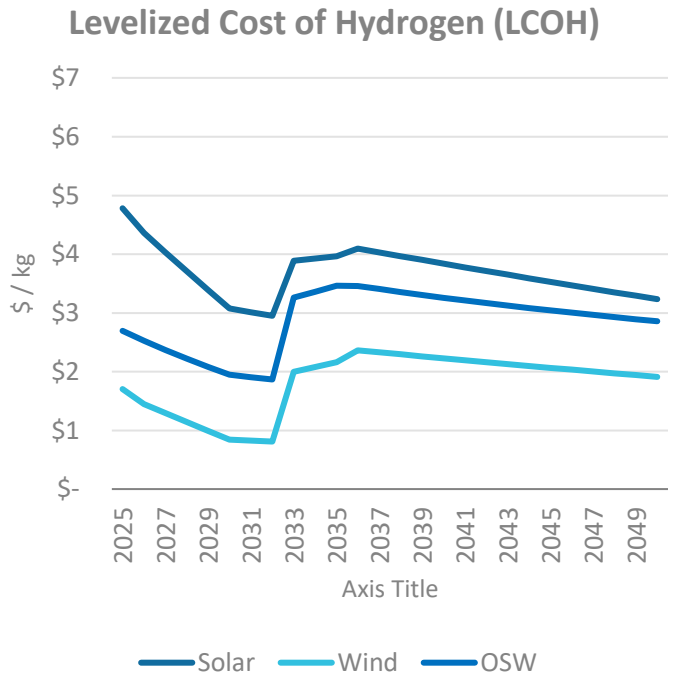
- **Primary components of electrolytic hydrogen prices are:**
  - Cost of electricity
  - Cost of electrolyzer
  - Electrolyzer utilization rate

- **Current federal policy creates incentives for both clean electricity and hydrogen production**
  - Clean electricity can benefit from a 30% investment tax credit or a $1.5 cents/kWh production tax credit.
  - Clean hydrogen can receive up to $3 per kg produced.

Tax credits can significantly reduce cost of H2 in short term

Note: Electrolyzer cost curves to be refined through stakeholder interviews



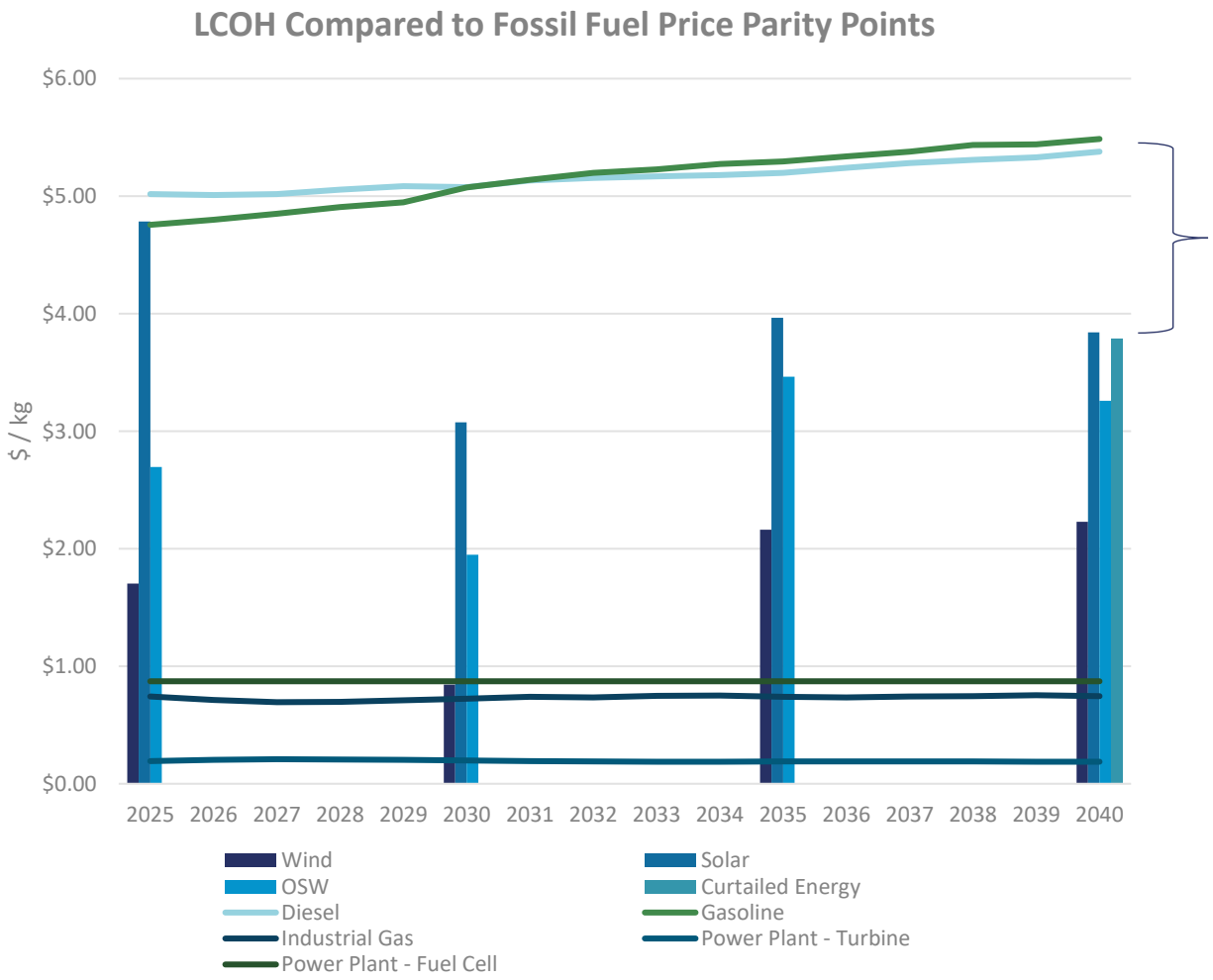


LCOH is price at point of production and does not include additional infrastructure costs (e.g. pipeline, storage)

Preliminary

Hydrogen Price Curves

Hydrogen economics are strongest in transportation sector, but will depend on cost of connecting infrastructure



Additional costs for connecting infrastructure (e.g. liquefaction, fueling stations) not included

Graph Key

Bars represent the price of H2 produced form different feedstocks. Lines represent the price H2 would need to be to reach price parity with different fossil fuels, based on relative energy content and conversion efficiencies

Next Steps

- **Refine LCOH forecasts through conversations with project developers and other industry stakeholders, focusing on:**
  - Expected changes to electrolyzer prices.
  - Impact of ancillary costs for hydrogen production (e.g. Balance of Plant, water supply).
  - Type of electrolyzers to be used (current analysis assumes alkaline electrolyzers as default).
  - Preferred project structures.
- **Incorporate infrastructure costs (e.g. pipelines, storage) into LCOH estimates.**
- **Include analysis on hydrogen supply and potential from different feedstocks and end uses.**