Breakout Session Instruction – what's happening?

1. <Discussion Lead> ask the audience "Are you in the right group? This is group xxx"
2. <Discussion Lead> announce/introduce yourself as the discussion lead; your role is to guide the topic discussion by filling out the template
3. <Shell Note Taker> announce/introduce yourself to do the recording. Share your screen to show the discussion template. Take notes in the template to share the discussion result.
4. Take a snip/screen shot of the attendees
5. Discussion guiding questions:
   - What did you learn? Main takeaways?
   - What surprised you?
   - Then guide the discussion towards filling out the table on opportunities/barriers/solutions/next step
6. Have the group decide who will present the discussion summary to the broader audience. Each group has 10min MAX

Day 1

Topic	Discussion Lead	Note Taker
Group1: CA Policies and attitude towards Hydrogen Technology	David Zilberman	Bert
Group2: The Role and Potential of hydrogen in California	Tim Olson	Arnab
Group3: Blue H2 value proposition for California	John Coates	Nikunj

Day 2

Topic	Discussion Lead	Note Taker
Group1: What is the near term opportunities for large scale H2 utilization?	David Zilberman	Nikunj
Goup2: How can policy help to realize this opportunity?	Jo Liao	
Group3: What are the major technical (scientific) challenges?	Bert Harvey	

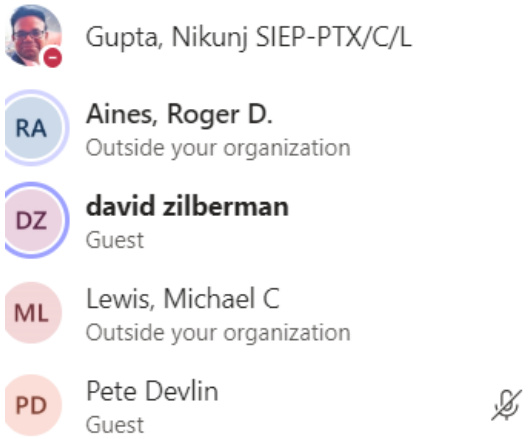
Breakout Session – Near Term Opportunities

Discussion Leader: David Zilberman

Note Taker: Nikunj Gupta

Who will represent the group: Mike lewis

Discussion Members



1. The intent of the break out session is to have a discussion on the topic of your choice. There are guiding questions to help organize the summary.
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Near Term Opportunities for large scale H2 utilization (Either Blue or Green)

What did you learn? Your main takeaways?

- There are several markets beyond transport for H2 but very little traction
- Importance of coordination/integration between sectors & within sectors
- Steel, Power, Cement & Gas grid are the applications which can take 500 ton/d in a single plant
- Texas & California is a unique & auspicious combination. **Key opportunity remains production & CCS in GC & supply to refinery in California**

What surprised you?

- Data Center related application
- Forklifts & several other applications are not driven by CI
- Cement Industry is always looking for deregulated environments
- Concrete allow you to green some of the black H2

Opportunities	Barriers	Potential Solutions	Next Steps? What's actionable?
Data center in the next 5 years & longer term	Bulk storage on the site & remote supply Low pressure Hydrogen removes a barrier	Huge opportunity to scale other markets Policy/subsidy Viewed as Investment into future US can be a great example	Coupling this as a energy storage solution starting with Data centers Joint development between Data Center & Energy company?
Steel Industry – single plant	Economics of H2 (<$1.5/kg) CAPEX : Conversion of your plant to run DRI process, entirely new plant (equivalent to replace BF)	Companies are demonstrating H2 DRI like technologies Policy for decarbonize H2 is not the only forward	
Decarbonizing the current H2 Industry (**Refinery** & Ammonia)	Economics Supporting regulation for Fertilizers	Renewable Hydrogen? Through CCS - Sequestration	
CCS is a huge opportunity to introduce Clean H2	Transport barrier CCS & use Permitting Land owners Change in LCFS policy	GC California pair is a key one to work one (45Q+EOR + LCFS) CCS & production in California	Engage with Refinery offtaker Techno-economic analysis of Shipping LH2 Check Pipeline feasibility & economic Explore California CCS option
Ports outside of California?	Non existent LCFS like regulations	Supportive policy/subsidy	
Replacement of DG			

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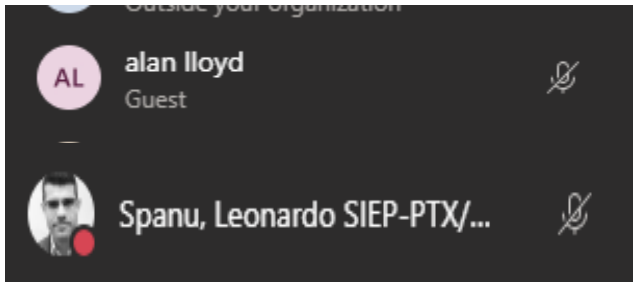
Group3: What are the major technical (scientific) challenges?	Bert Harvey	

Goup2: How can policy help to realize this opportunity?

Discussion Leader: Jo Liao

Who will represent the group:

Discussion Members



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Discussion Topic - How can policy help to realize this opportunity?

What did you learn? Your main takeaways?

- When you produce h2 from electrolyzer is automatically green? What if the electricity used was from the grid that could be from conventional source? Does this still count as "green H2"? What regulation do we have in place to clearly define "green" and "blue." There's a lot of desire for green H2 at this time. How do we **enforce "green H2"?**
- International enforceable standard for the various type of H2, like clean fuel. There's a lot of gaming of the system. **Needs clarity, definition and enforcement** would be where policy can help.
- Highlight the difference in approach from Texas to California. Plugpower did not rely on policy. That's **not driven by regulation**, but approach to forklift and expanding with the **commercial customers**.
- Commercial invest may push the policy
- But there's also some benefit where policy (Houston) can kickstart the commercial interest.
- **Policies from EU** can impact US policies even if current political climate doesn't support

What surprised you?

- In California, lack of equivalent of low carbon standard **beyond mobility**.
- **Policy outside of mobility** may be worthwhile to push decarbonization beyond transportation.

Opportunities	Barriers	Potential Solutions	Next Steps? What's actionable?
Texas policy to put a higher priority from VW settlement funds to support H2 development	TX – education of policy makers	Industry push for engagement with policy makers to demonstrate the benefit of H2 economy	Follow through with the identified opportunities/existing projects **Follow-up workshop with the policy makers**
What can we learn from H2 policy in California and how can it be applied to TX?			
What can we learn from Wind industry to apply to Texas for H2?	Cost and availability of blue/green H2 Wind was already matured technology with existing DS supply chain (power).	Cheap(er) electrolyzers from China to drive the cost down What other global market has demand for green H2 to help create $ for H2 to be produced in TX Leverage NG expertise and enable **H2 export from TX**	**Help the policy makers understand the value proposition** of H2 economy with market diversification and increase in employment (labor expertise)
CO2 capture in Permian probably not as appealing as before. How does H2 economy take advantage of the displaced work force? To apply to a more sustainable future. TX to look for tangible ways to enable transition.			
City of Houston understands the importance of diversifying the economy. This can be a great story for the city for Energy (ex/ with medical ind).			

What are the major technical (scientific) challenges (for H2)?

Discussion Leader: Bert Harvey

Note Taker: Bert

Who will represent the group: Bert

Discussion Members

Joe, Ajay, Ron Kent, John Coates, Chris Rao, Mukherjee Pulakesh, Max Wei and others – Jo to verify and update..

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5. **Wrap up at 40 past hour…**

What are the major technical (scientific) challenges (for H2)?

- Integrating production with existing industrial operations
- Pipeline retrofitting for transport (encouraging results from Ron Kent, SoCalGas)
  - Blending and mixing of H2 feeds in NG streams
- Standardization of H2 fueling systems (James Kast)
- Economical storage solutions
  - Subsurface geo storage solution – efficiency
  - Leasing tank volume for wider use (Mark Monroe)
- Electrolysis – materials – membranes, catalyst and electrodes (MEA development); scaling
- Control systems – leveraging curtailed power section of duck curve
  - Max Wei - Oversizing electrolyzer increases load flexibility rand can reduce overall system cost
- Production of steel using H2 – 3 levels of technology
- New (electrified) methane conversion technologies that also capture carbon (ron)
- FC durability – more worked need for HD applications – can learn from LD
- H2 safety – LH2, process safety (CHS AIChE)
- Carbon capture combined with industry

What are the major technical (scientific) challenges?

What did you learn? Your main takeaways?

- Gulf Coast corridor can be a good place to produce H2, store carbon and ship via LH2
- Green and value market sectors developing – w/challenges developing both – favour green but open to start out blue
- Mixing green and blue for capture LCFS
- Welds are major issue in integrated H2 in existing pipelines – oxide layer can protect – projects in UK (Leeds) – argue that switchover to 100% - should be examined
- Which approaches can be applied in distributed versus centralized – safety acceptance of LH2 trucks in populated areas
- LOHC and NH3 needs further development – LH2 more advanced?

What surprised you?

- **Power requirement forecast for data centers is staggering!**
- MS (data centers)– primary source is grid – emphasizing they need 100x the reliability
- Interesting successes reported – PP, how to leverage/progress? Does infrastructure exist?
- SoCalGas – distributed emerging techs- NG pipelines not needing much upgrading
- Much tech exist but not demonstrated at scale – long lead times for rollout
- Lack of concerted funding
- **Toyota and launch of LD Murai –pickup truck would be better choice? (biggest market segment)**
- Not much discussion on NH3
- Little focus on refining – integrating transportation with industry can be opp.

Opportunities	Barriers	Potential Solutions	Next Steps? What's actionable?
Hydrogen storage	Geologic other that salt domes;	Low pressure (MOFS, LOHCs); lower cost high pressure tanks	Carbon source needed in MOFS from blue H2 production
Standardizing truck design, fuelling protocols and safety	Tunnels and bridges, regulatory	More collaboration from manuf.	
Driving down Green hydrogen cost - electrolysis	Cost of materials and durability	Seawater electrolysis; control systems to take advantage of curtailed power	Manufacturing systems analysis – 3D printing, mass manufacturing; roll-to-roll processing of MEAs
Dedicated wind and solar for H2 production	Co-locating with electrolyzers; land use; interconnects;	Integrating electrolyzers with EC compression; direct connect; load follow and SU/SD as power available	
Burner design retrofit for H2	Integration with OEMs	Industrial burner options available; catalytic burners; precision combustion (PCI)	H2 torch in next Olympic games
Separation of H2 from pipelines	Purity;	EC compression as separator – requires ~20% H2	
FC durability to enable scaleup	HD sector needs work; reduce cost of materials	HD application – learning from LD; onboard storage solutions	
Marine and rail	Thin margins; competing with bunker fuel cost	Hybrid solutions – diesel electric to H2 electric	Regulatory assistance?
Advanced CH4 conversion w/carbon utilization	Carbon product quality; cost		