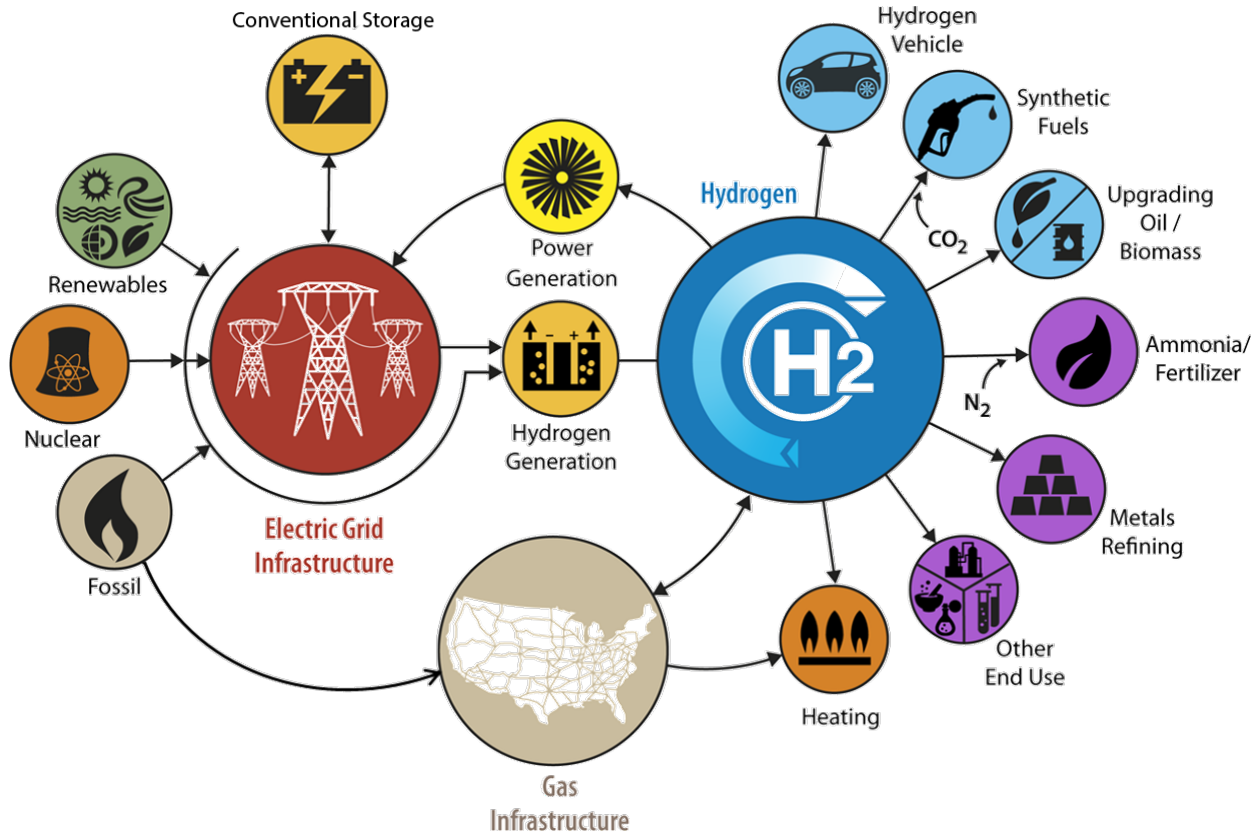


H2@Scale Value Proposition Considerations

Mark Ruth

H2@Scale R&D Consortium Kickoff Meeting
August 1, 2018

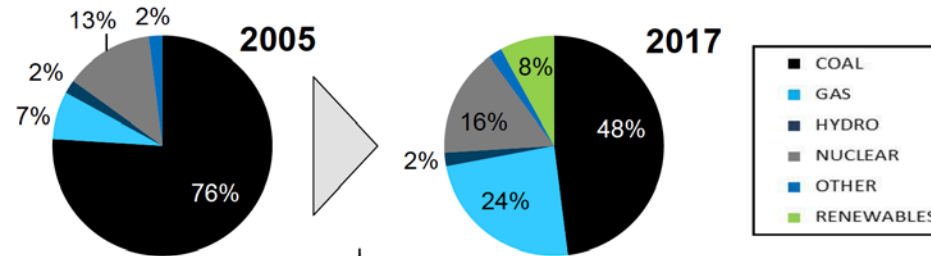
H2@Scale: An Interface Concept



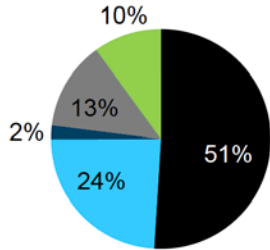
- Hydrogen could be a key energy interface
- Value propositions lie across the make, move, use, and store focus areas
- Key drivers:
 - Markets
 - Linkages
 - Partners

Renewable Electricity Generation is Growing

MISO expects significant growth in renewable and gas-fired generation

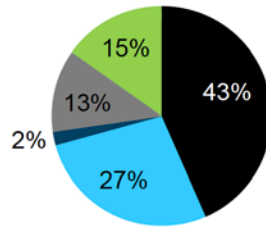


2032 MTEP18 Future Scenarios



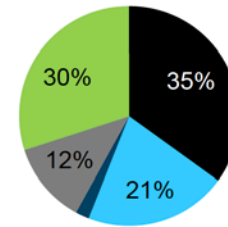
Limited Fleet Change

Stalled generation fleet changes. Limited renewables additions driven solely by existing RPS under limited demand growth.



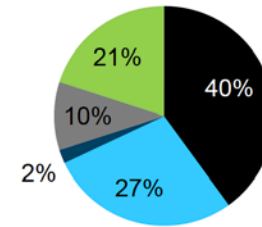
Continued Fleet Change

Continuation of the renewable addition and coal retirement trends of the past decade.



Accelerated Fleet Change

Renewables and demand side technologies added at a rate above historical trends. Fleet changes result in a 20% CO₂ emission reduction¹.

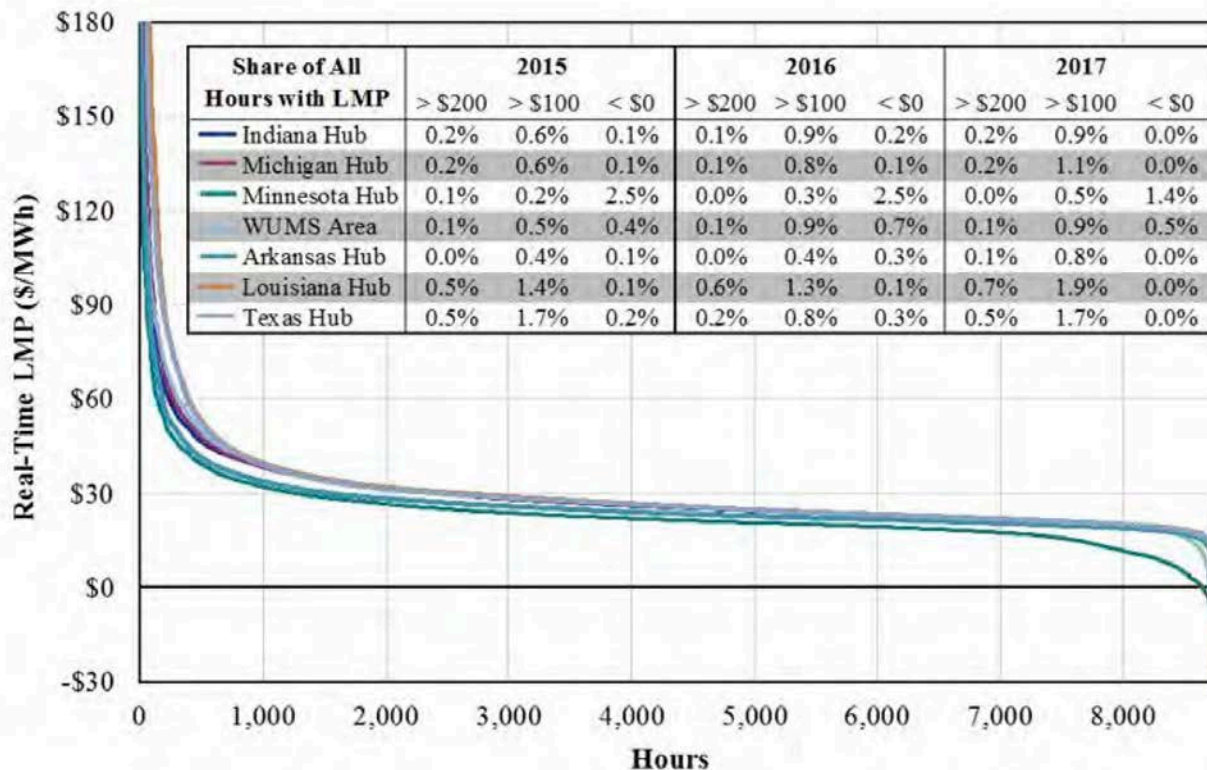


Distributed & Emerging Tech

New renewable additions largely distributed and storage resources co-located with largest sites.

Thus the Electricity Market is Changing

Figure A2: Real-Time Energy Price-Duration Curve
2017



- Hours with energy at very low and very high prices are increasing
- Other revenue streams (e.g., capacity, services) are becoming more critical
- Impacting generators' operations

And Leading to New Opportunities

Overall Summary and Pricing Received

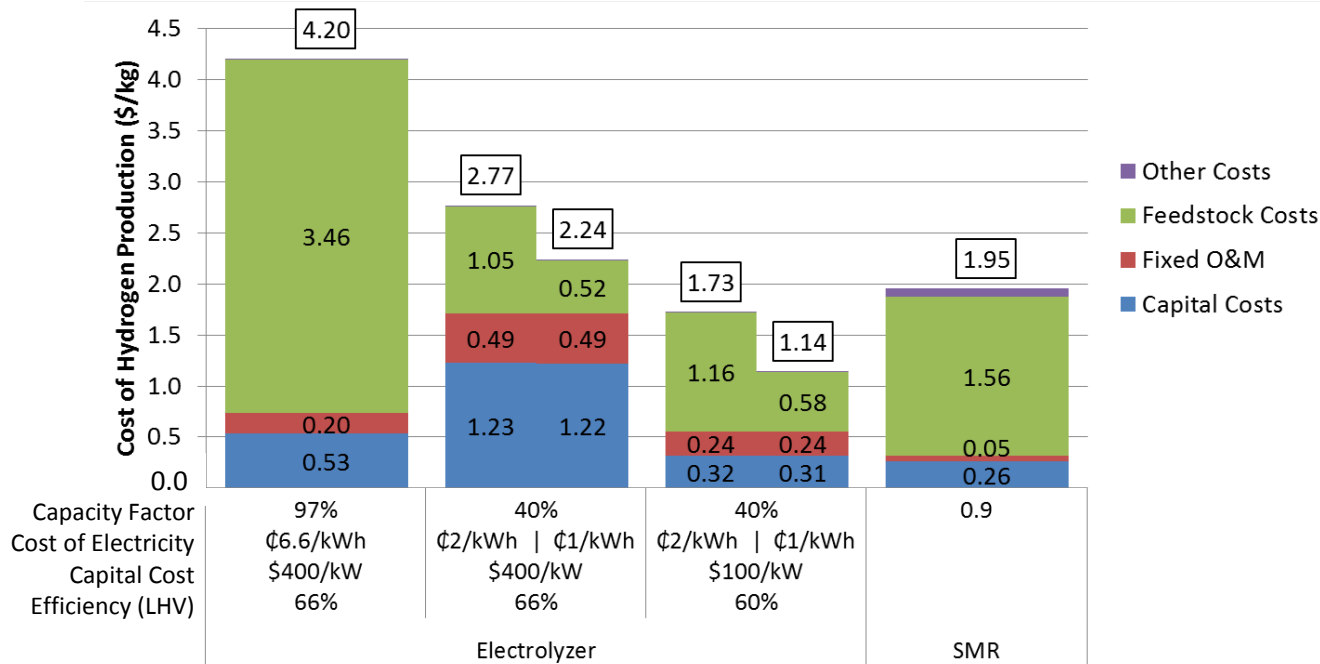
	Technology	# of Bids	Bid MW (ICAP)	# of Projects	Project MW	Average Bid Price	Pricing Units	Comments
Asset Sale or Option	Combine Cycle Gas (CCGT)	7	4,846	4	3,055	\$959.61	\$/kW	
	Combustion Turbine (CT)	1						
	Solar	9	1,374	5	669	\$1,151.01	\$/kW	
	Wind	8	1,807	7	1,607	\$1,457.07	\$/kW	
	Solar + Storage	4	705	3	465	\$1,182.79	\$/kW	
	Wind + Solar + Storage	1						
	Storage	1						
Purchase Power Agreement	Combine Cycle Gas (CCGT)	8	2,715	6	2,415	\$7.86	\$/kW-Mo	+ fuel and variable O&M
	Solar + Storage	7	1,055	5	755	\$5.90	\$/kW-Mo	+ \$35/MWh (Average)
	Storage	8	1,055	5	925	\$11.24	\$/kW-Mo	
	Solar	26	3,591	16	1,911	\$35.67	\$/MWh	
	Wind	6	788	4	603	\$26.97	\$/MWh	
	Fossil	3	1,494	2	772	N/A		Structure not amenable to price comparison
	Demand Response	1						
	Total	90	20,585	59	13,247			

Indiana NIPSCO IRP Pricing

- Wind and solar power purchase agreements (PPAs) are key opportunities.
- Indiana IRP Averages:
 - Wind <\$27/MWh
 - Solar <\$36/MWh
- Expiring PPSs may have lower prices

Opportunity: Electrolysis

Potential Levelized Costs of H₂ Production



- Electrolytic hydrogen has the potential to be cost competitive
- Need H₂ market access
- Business opportunities:
 - H₂ production
 - Electrolysis equipment and supply chain

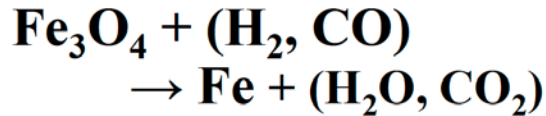
Example Market Opportunity: Transportation

- Nikola is planning up to 28 hydrogen stations to support trucks
- Toyota is developing trucks with a focus on the drayage market
 - Partnered with Fuel Cell Energy to use biogas
- Drivers
 - Emission reductions
 - Corporate green objectives



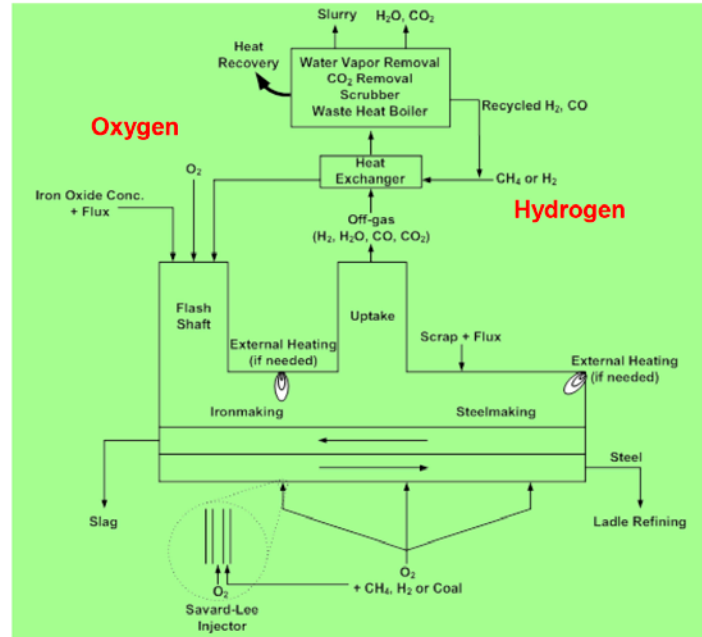
Example Utilization Opportunity: Novel Processing

Flash Ironmaking Technology



Gas-Solid Suspension Reduction
Hydrogen or Natural Gas

- ✓ Fine iron ore WITHOUT Coke/Pelletization/Sintering
- ✓ Significant Reduction in CO₂ & Energy Consumption
- ✓ Replace BF



- Today: primarily refining and ammonia production
- Future:
 - Metals
 - Organic products with CO₂ from ethanol and ammonia processing
 - Reductive processes

Credit: Hong Yong Sohn

Example Focused Partnership: Low Carbon Ammonia



- **BASF and Yara opened a low-carbon ammonia plant in April**
- **Freeport, TX**
- **Primary hydrogen supply:**
 - **By-product from Dow's ethylene cracking units**
- **Economic drivers:**
 - **Greener ammonia**
- **Linked to hydrogen pipeline and storage projects**
- **Reduction based on carbon credits**

Examples of Broad Partnerships

EnergiePark Mainz



Partners

- Hochschule RheinMain
- Linde AG
- Siemens AG
- Mainzer Stadtwerke AG

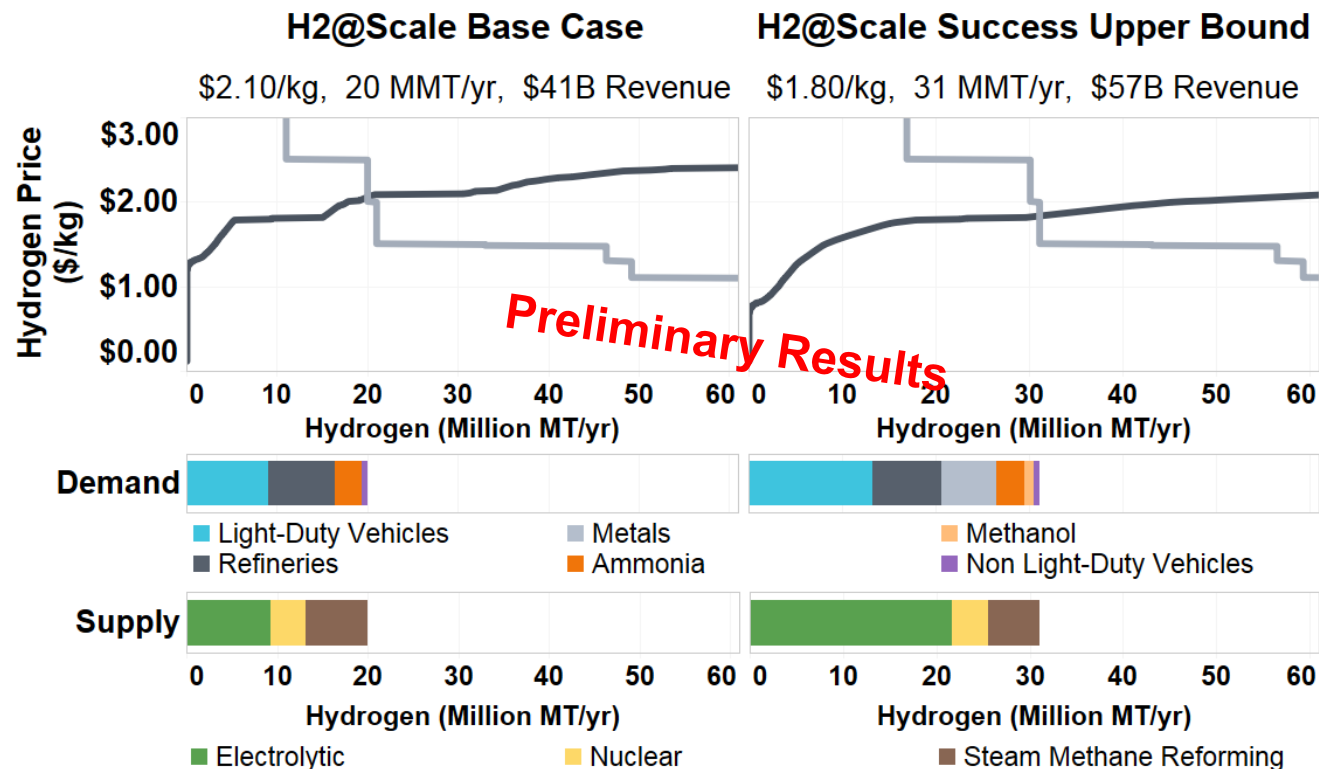
BIG HIT

Corporate Partners

- Calvera
- Community Energy Scotland
- Giacomini
- ITM Power
- Symbio FCell



National-Scale Value Proposition



- Preliminary analysis indicates that the U.S. hydrogen market can grow from 10 MMT/yr to >30 MMT/yr
- Requires realization of additional demands and lower cost production

Value Proposition Recommendations

- 1. Identify market opportunities**
- 2. Find linkages**
- 3. Partner**

**The H2@Scale R&D Consortium is a means to
identify and initiate opportunities**

Thank you

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Publication Number

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