TEXAS HYDROGEN ROUNDTABLE, 12 JANUARY 2021

The University of Texas at Austin
Energy Institute

9:30 – 9:40 **Welcome and Objectives**

Christine Dixon Thiesing, Associate Vice President for Research (Innovation & Economic Impact), UT Austin

Bob Hebner, Center for Electromechanics, UT Austin

Varun Rai, Energy Institute, UT Austin

TEXAS HYDROGEN ROUNDTABLE, 12 JANUARY 2021

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9:40 – 10:00 Energy in Texas: Policymakers' View

Remarks by **The Honorable Michael McCaul**, U.S. House of Representatives
Co-Chair, Congressional High Tech Caucus

Remarks by **The Honorable Drew Darby**, Texas House of Representatives
Vice Chair of the House Business & Industry Committee and Member, House Energy Resources Committee

10:00 – 10:45 Underlying Context for Hydrogen: Global and U.S. Perspective

***Bob Hebner*,** Center for Electromechanics, UT Austin

***Daryl Wilson*,** Hydrogen Council

***Sunita Satyapal*,** U.S. Department of Energy

The University of Texas at Austin
Center for Electromechanics
Cockrell School of Engineering

HYDROGEN – *Opportunity for Texas and the U.S.*

Bob Hebner, Ph.D.
Center for Electromechanics
The University of Texas at Austin

Global Enthusiasm

- Billions of dollars of industry and government investment globally
  - Europe
  - Middle East
  - North Africa
  - South America
  - Asia
- Benefits
  - Helps meet global emission standards
  - Increases efficiency
- Risk
  - Needs cost reduction

Efficiency Impacts Can Be Impressive

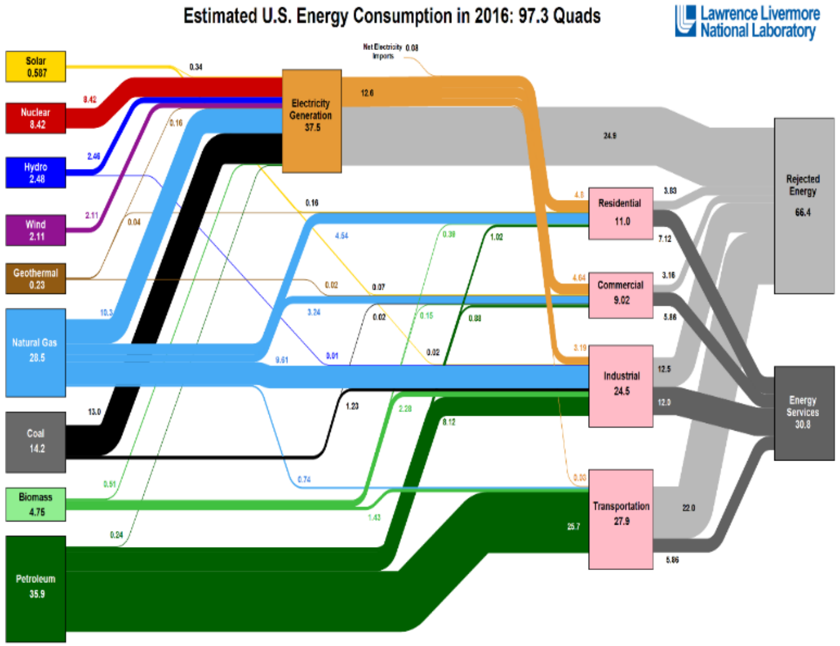
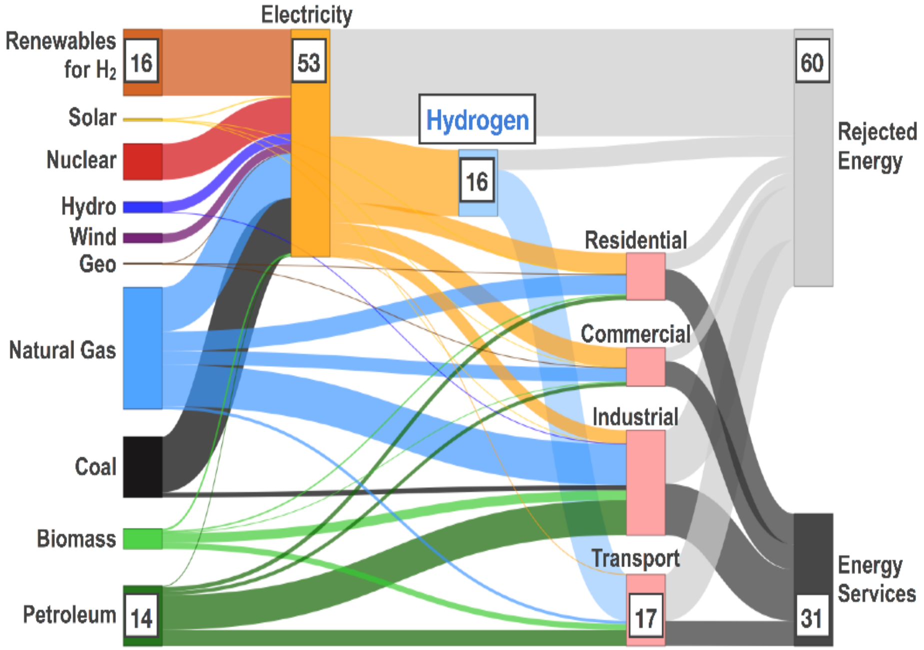
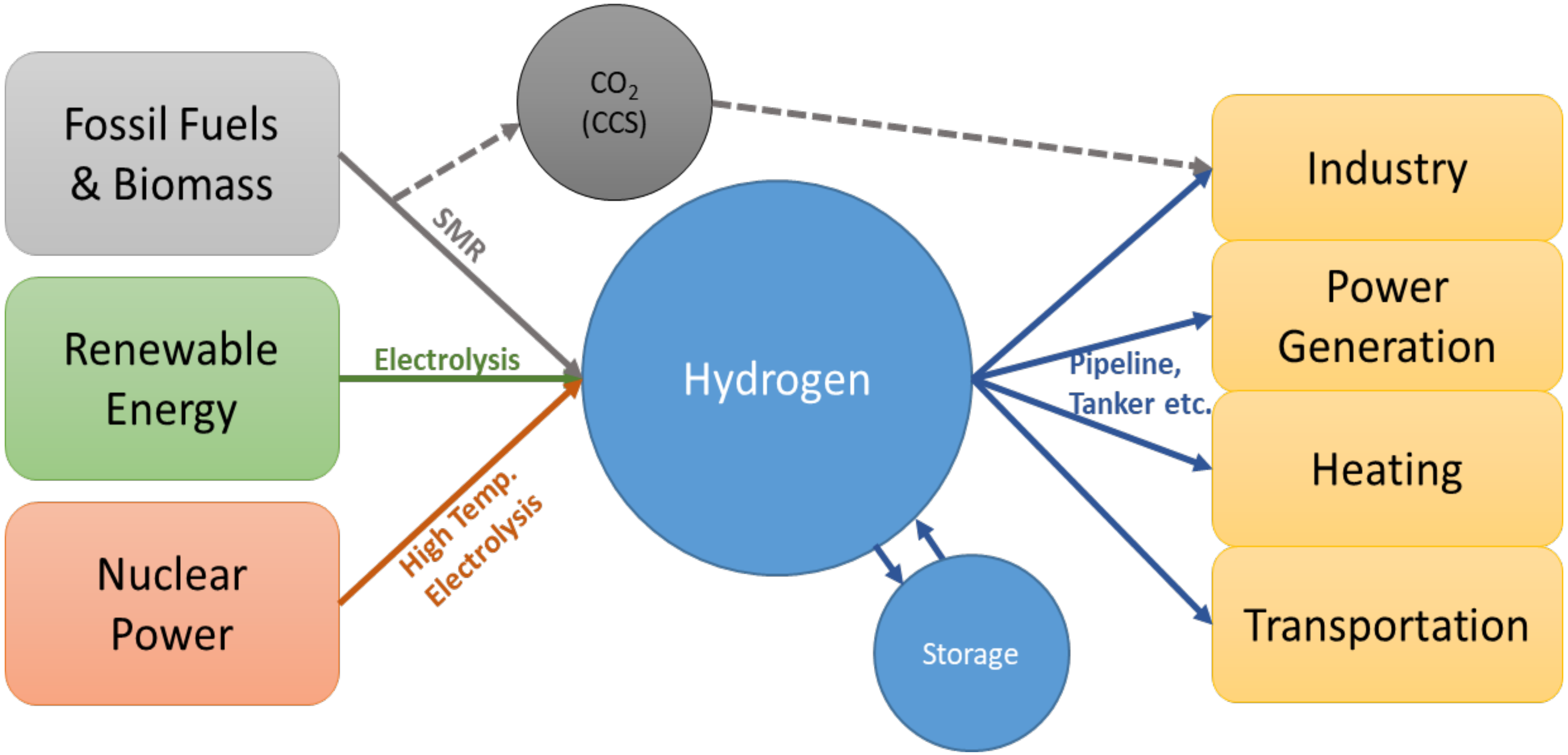


Figure 4. Energy Flows within the United States' economy in 2016 from sources (on the left-hand side) to end-uses (on the right-hand side), with values listed in Quads (quadrillion Btu).
(Source: Lawrence Livermore National Laboratory, U.S. Department of Energy)



Using hydrogen for transportation reduces “Rejected Energy” from 66.4% to 60%.

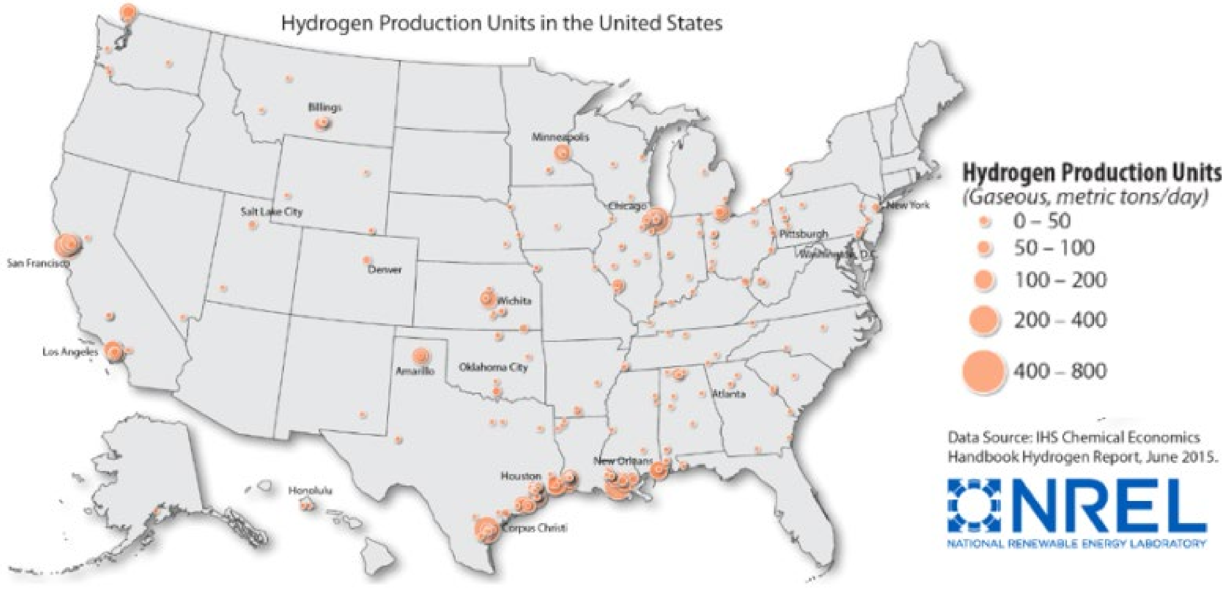
Hydrogen Serves as Storage/Carrier



The role of hydrogen highlights the Texas potential.

Texas is Positioned to Lead - I

- Existing hydrogen pipeline infrastructure
- Leading domestic producer of hydrogen
  - Experienced workforce
- Large presence of leading companies
  - Toyota, Shell, Air Liquide, for example
  - Corporate leadership
- Abundant renewables, natural gas and nuclear power
- Potential large-scale storage



Texas is Positioned to Lead - II

- Academic institutions with relevant programs:
  - University of Texas at Austin
  - Rice University
  - University of Houston
  - Texas A&M University
  - Texas Tech University
- Universities are important to
  - Provide R&D needed to drive down the cost of the technology
  - Educate the next generation of leaders in the hydrogen economy.

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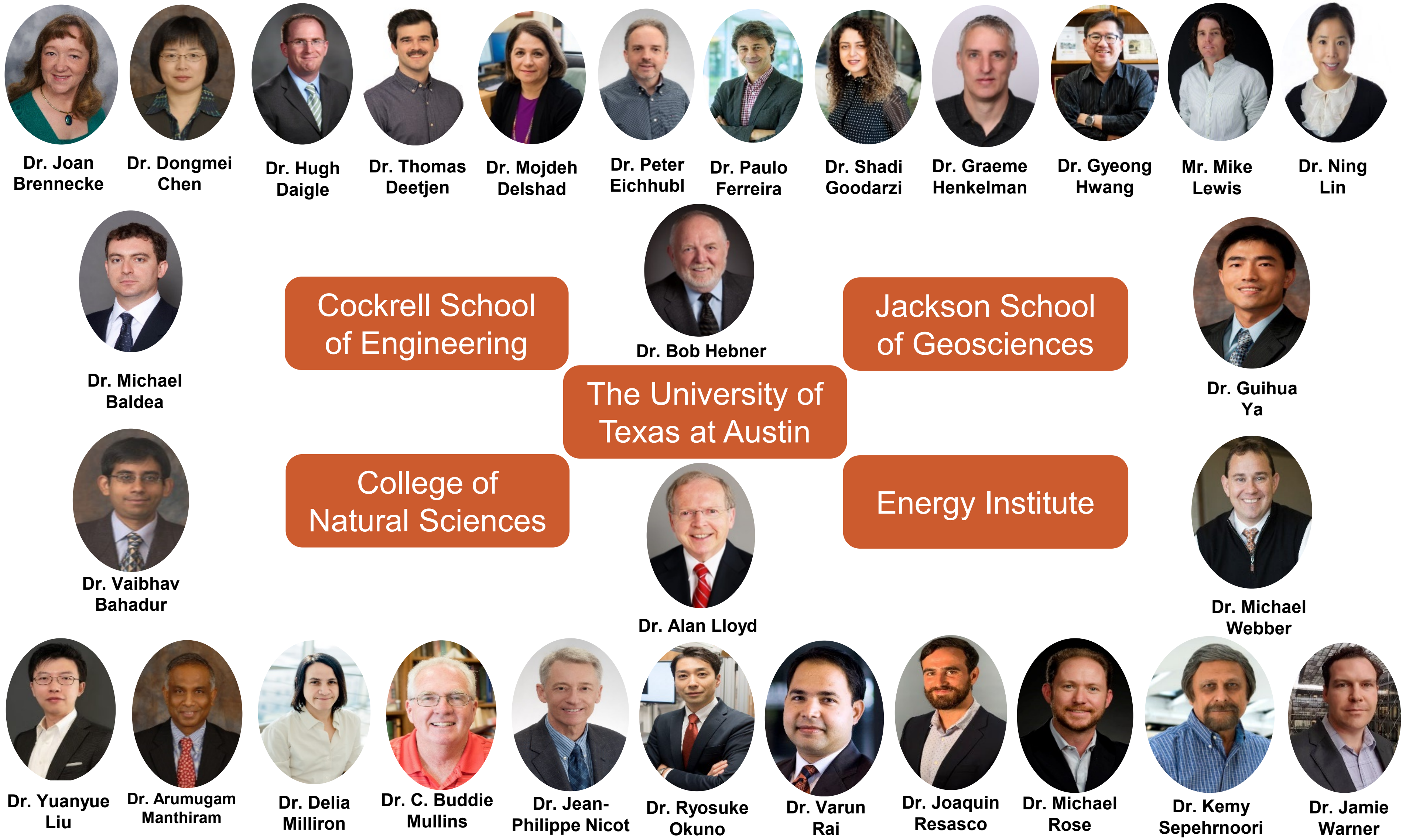
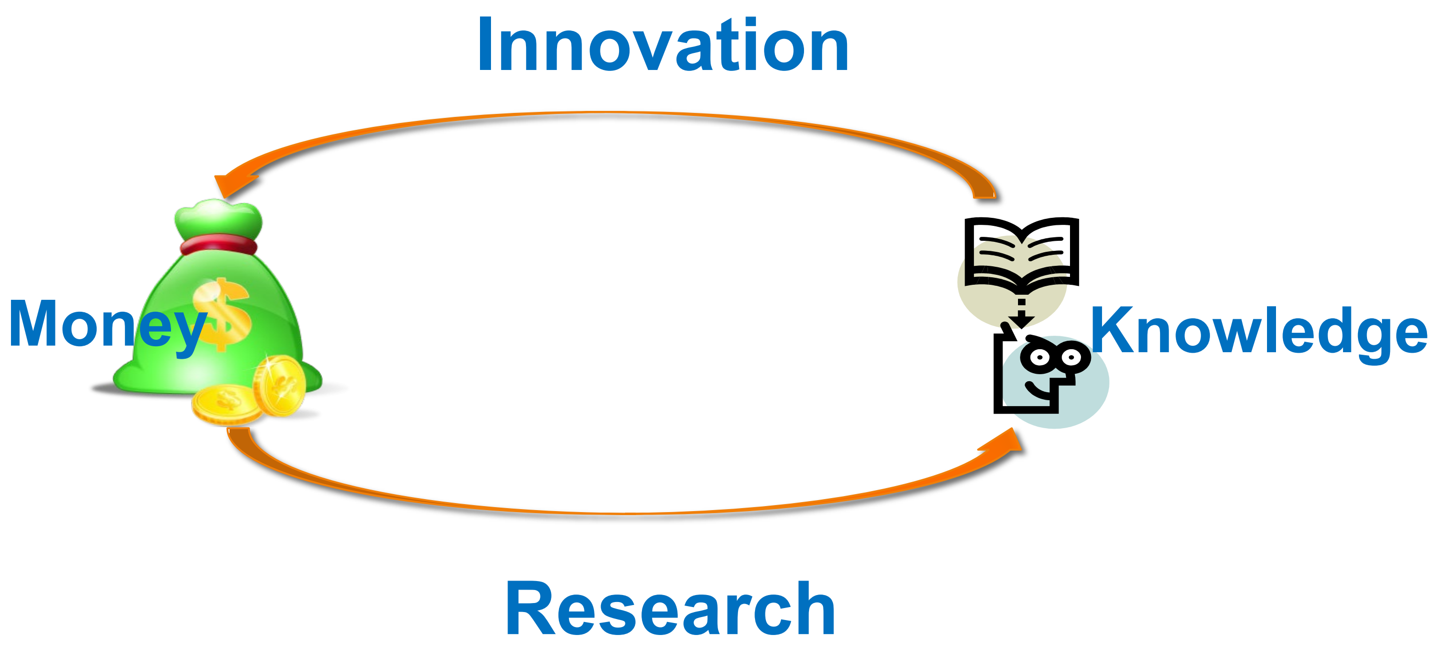
H2 Experts at UT



Need the High-Tech Economy of Scale

- Most famous example is Moore's Law in the semiconductor industry



Most Promising Killer App - Trucks

- Commitments have been made:
  - China is investing more than $7B in hydrogen truck development
  - Toyota announced a new hydrogen truck development
  - Cummins is developing hydrogen drive trains
  - UPS and FedEx have hydrogen delivery vans on the road.
- Key advantages
  - Fuel cell and battery drive train are smaller and lighter than battery alone
  - Greater range than battery alone
  - Short refueling times.
- A truck is a relatively low cost investment, so large quantities can be sold.
- Drives down supporting technology cost.

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Takeaways

- Cost limits hydrogen growth today.
- Huge upside potential to improve efficiency and reduce greenhouse emissions.
  - Governments and industry globally are investing in reducing cost.
    - Economy of scale
    - Research and development
      - Materials
      - Controls
      - Storage
      - Techno-economic optimizations
- Texas has the economic and academic base on which to be a world leader in hydrogen.
- With effective leadership, hydrogen economy can be a huge economic benefit for Texas.

Hydrogen Council

AN INTRODUCTION TO THE HYDROGEN COUNCIL

By Daryl Wilson, Executive Director

12 January 2021

TEXAS
The University of Texas at Austin

HYDROGEN COUNCIL

A global CEO-led initiative

Founded at

WORLD ECONOMIC FORUM

Davos 2017

Grown from 13 to

103

Companies

18

Countries

4

Continents

Representing

6.5

MILLION jobs

€18.9

TRILLION

in revenues

ONE SHARED VISION

OUR OBJECTIVES

Unlock scale markets for hydrogen
by positioning the technologies among key solutions for energy transition and advocating for their uptake

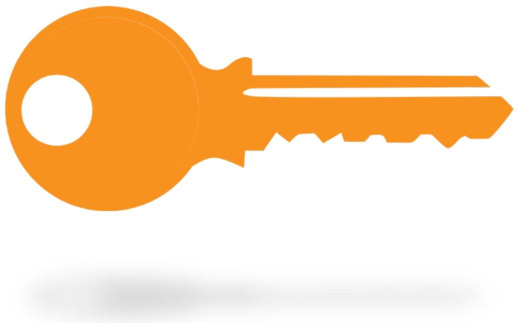
Create significant business opportunities
along the value chain to ensure proper industrial developments of key components and comprehensive deployments

Accelerate massive investment
in the development and commercialization of the hydrogen and fuel cell sectors

Encourage key stakeholders to back hydrogen
as part of the future energy mix with appropriate policies and supporting schemes

OUR VISION

Hydrogen has a key role to play in the energy transition



Based on **real industry data**, the Council sees hydrogen as an enabler of the future energy system, growing its role over time and delivering tangible benefits:

By 2030

H_2 scales up to achieve competitiveness

✓ Cost falls sharply, making hydrogen a competitive low-carbon option across 22 applications – equivalent to 15% of annual global energy demand

By 2050

H_2 reaches full potential

✓ 6 GT of CO_2 abatement annually
✓ 30 million jobs
✓ $2.5 trillion market

Sources:
“Hydrogen, Scaling Up” report, 2017
“Path to Hydrogen Competitiveness” report, 2020

OUR PRIORITIES

1. Bring together key stakeholders to enable investment & large scale projects
-Build a business marketplace
-Stimulate investment

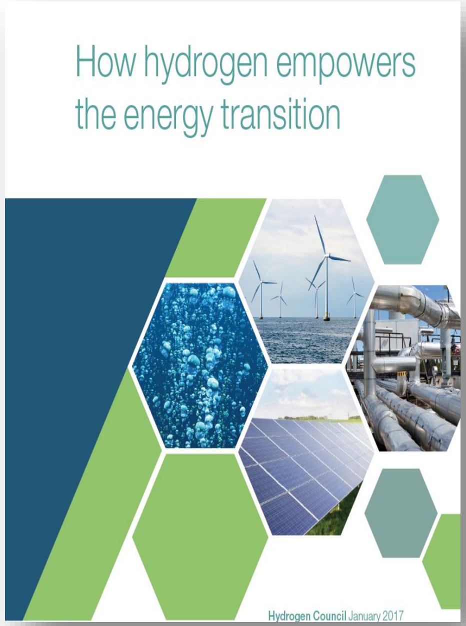
2. Amplify the voice of hydrogen worldwide
-Understand hydrogen perception & challenges
-Address issues & leverage new/broader opportunities

3. Guide policymakers toward appropriate regulations
-Identify key policies & technical recommendations
-Influence through key organizations

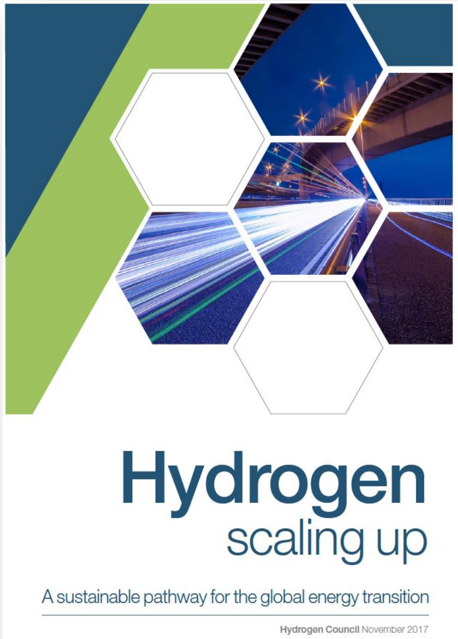
4. Ensure transversal coverage of safety topics globally
-Close safety/standards gaps
-Reputation management and crisis preparedness

MAKING THE CASE FOR HYDROGEN

The Council creates studies on the use, development and deployment of hydrogen across sectors and industries. These studies further our understanding of **how to make the hydrogen economy a reality through concrete data provided by Council members** and informed conversations with key stakeholders around the globe. All studies are available **here**.

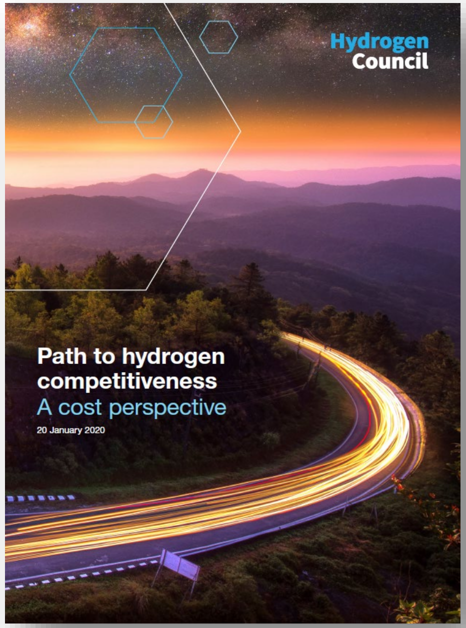


Explores the role of hydrogen in the energy transition and offers recommendations to help accelerate deployment | LINK



Discusses the feasibility of our 2050 hydrogen vision and proposes tangible steps to get there | LINK

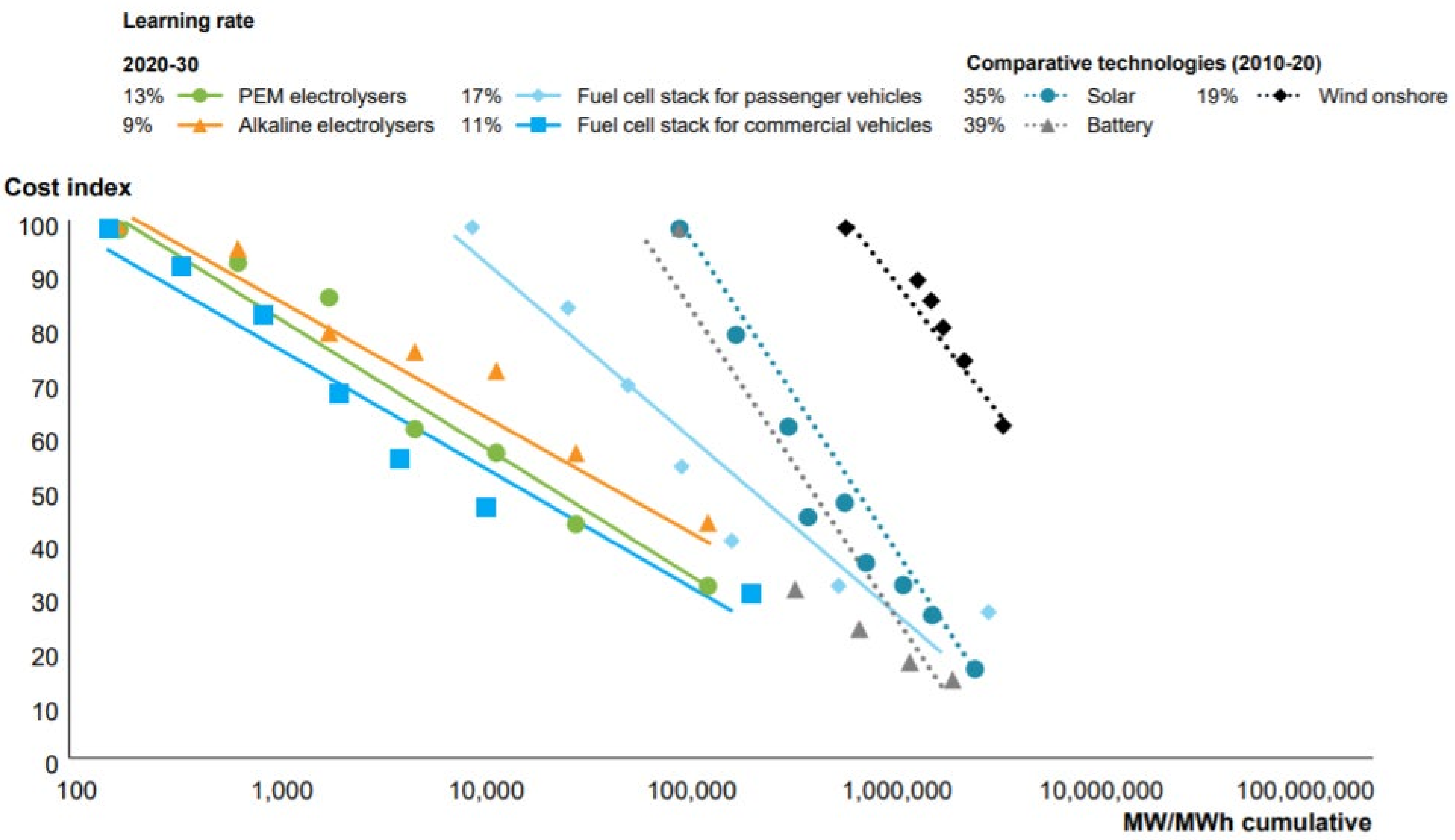
Considers how digitization and hydrogen could complement each other in the energy transition | LINK



Presents a cost trajectory for hydrogen to become cost competitive to other low carbon and conventional alternatives by 2030 | LINK

COMPETITIVNESS OF HYDROGEN APPLICATIONS

LEARNING RATES OF HYDROGEN APPLICATIONS



Hydrogen Council

Thank you for your time!

www.hydrogencouncil.com

@HydrogenCouncil
#HydrogenNow

U.S. DEPARTMENT OF
ENERGY

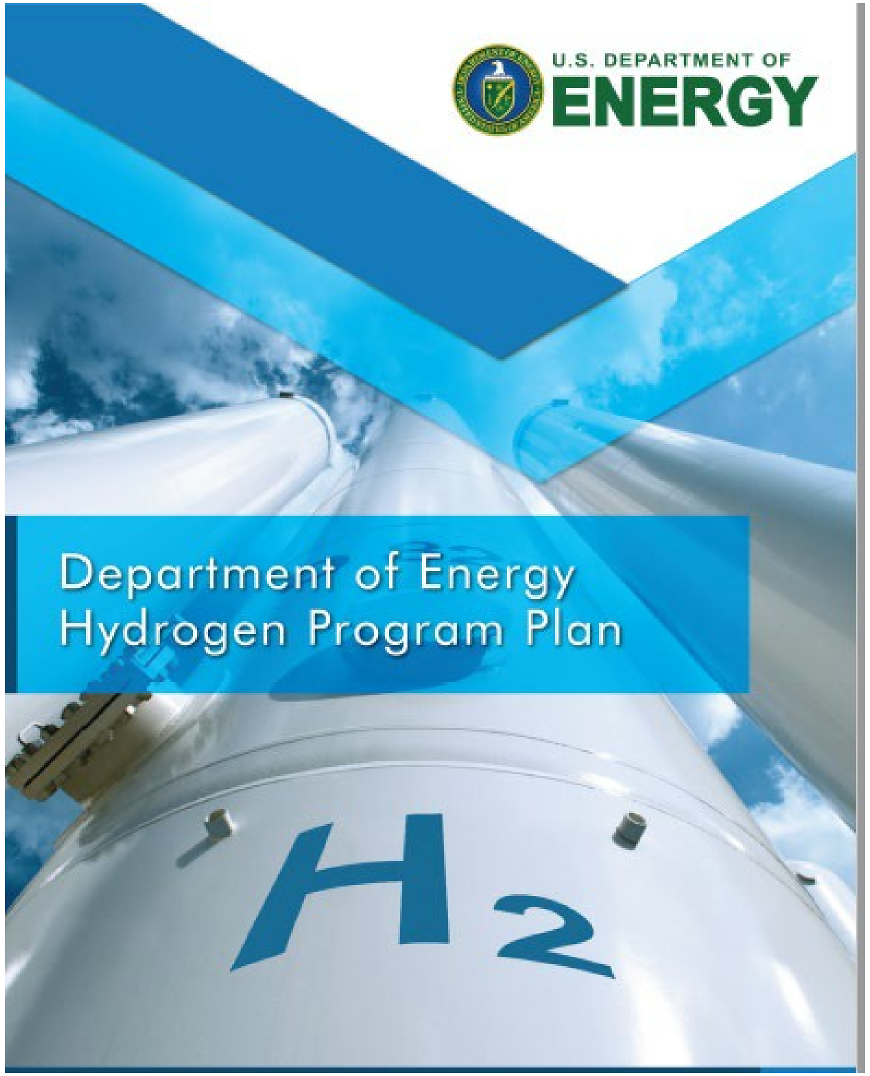
Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

U.S. Department of Energy Hydrogen and Fuel Cell Technologies Office Perspectives

Dr. Sunita Satyapal
Director, Hydrogen and Fuel Cell Technologies Office

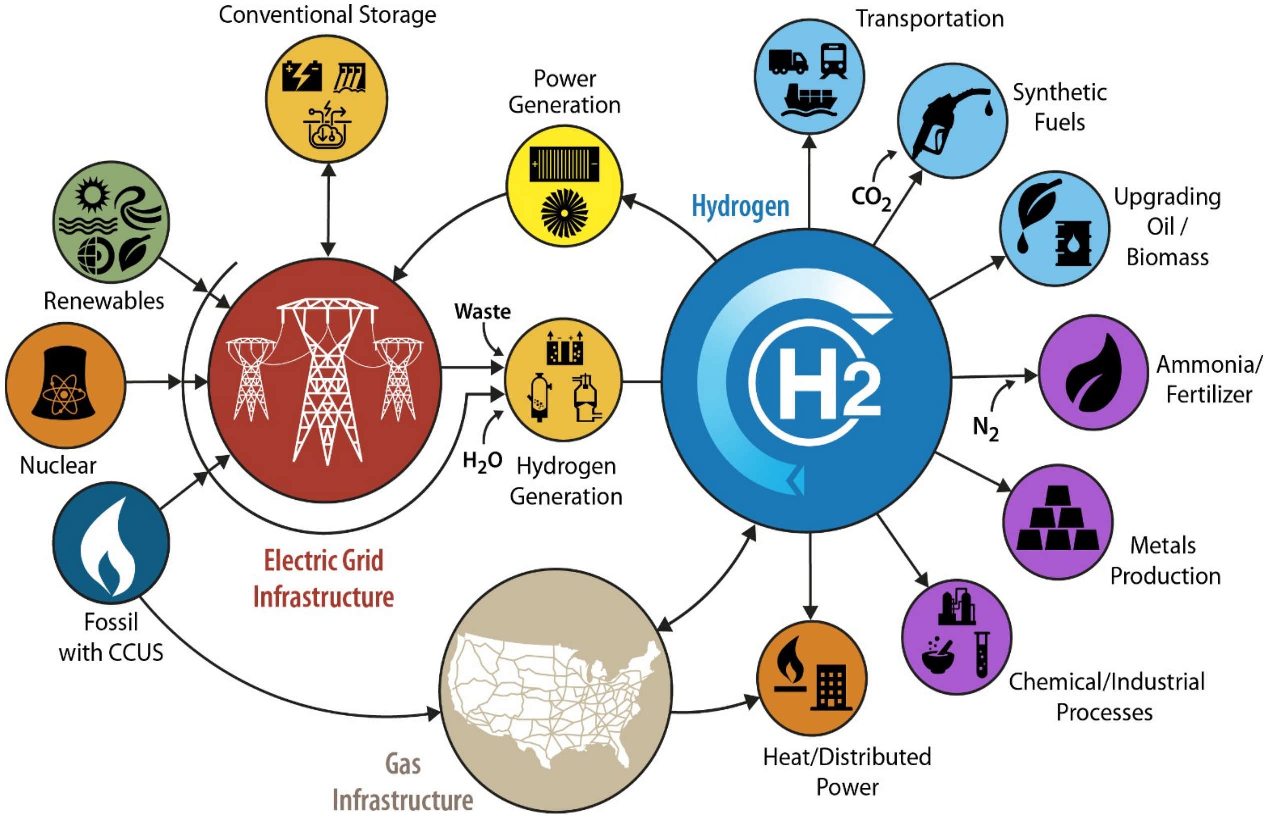
Texas Hydrogen Roundtable – January 12, 2021

US DOE Integrated Hydrogen Program



Released November 2020 - www.hydrogen.energy.gov

H2@Scale to enable affordable, reliable, clean and secure energy across sectors
Strategies include: R&D to reduce cost and improve performance, enable scale and end uses across sectors



Examples of DOE-Funded Innovation and Impact

U.S. DEPARTMENT OF ENERGY

Impact due to HFTO Funding

Innovation

1,110 H_2 and fuel cell patents enabled by HFTO funds

Approx. **35%** of H_2 and fuel cell patents come from National Labs

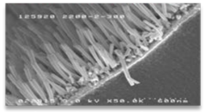
Market Impact

More Than **30** Technologies Commercialized by private industry

And Over **65** with potential to be commercial in the next 3 – 5 years

Can be traced back to HFTO R&D

Fuel Cell Catalysts



Catalyst and Supports for PEM Fuel Cells
3M

Hydrogen Tube Trailers

Hydrogen Tube Trailers
Hexagon Lincoln

Forklifts

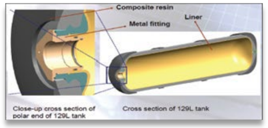
Class-1, -2, and -3 Forklifts
Plug Power (GenDrive FCs)

Electrolyzers

Electrolyzer System
Proton Series

PEM Electrolyzer System
Giner

Hydrogen Tanks



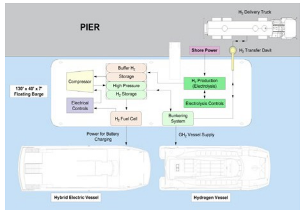
Optimized 129L Tank
Quantum Technologies

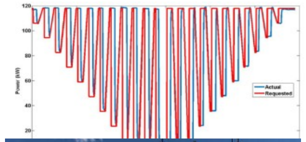
- Small scale H_2 fueler now available
- 5 to 20 kg unit, 700 bar fueling

$1M H-Prize H2Refuel Winner: SimpleFuel

First-of-a-Kind Demonstrations

- Marine application- ½ton H_2 fueling for vessel
- Data center- 1.5 MW
- First ground support equipment
- Parcel delivery vans (2x range vs BEVs)
- Mobile H_2 fueler
- First nuclear to H_2 demos
- First tri-gen system
- Dynamic response of electrolyzers and systems integration
- First H_2+CO_2 to renewable methane demo
- H_2/NG blending





Example: American Recovery Act co-funded few hundred fuel cell forklifts and backup power units for cell phone towers

Today ~40,000 systems commercially deployed at major companies, millions of H_2 fuelings to date

Snapshot of Hydrogen and Fuel Cell Applications in the U.S.

Examples of Applications

>500MW
Backup Power

>35,000
Forklifts

>14 MW
PEM* Electrolyzers

>60
Fuel Cell Buses

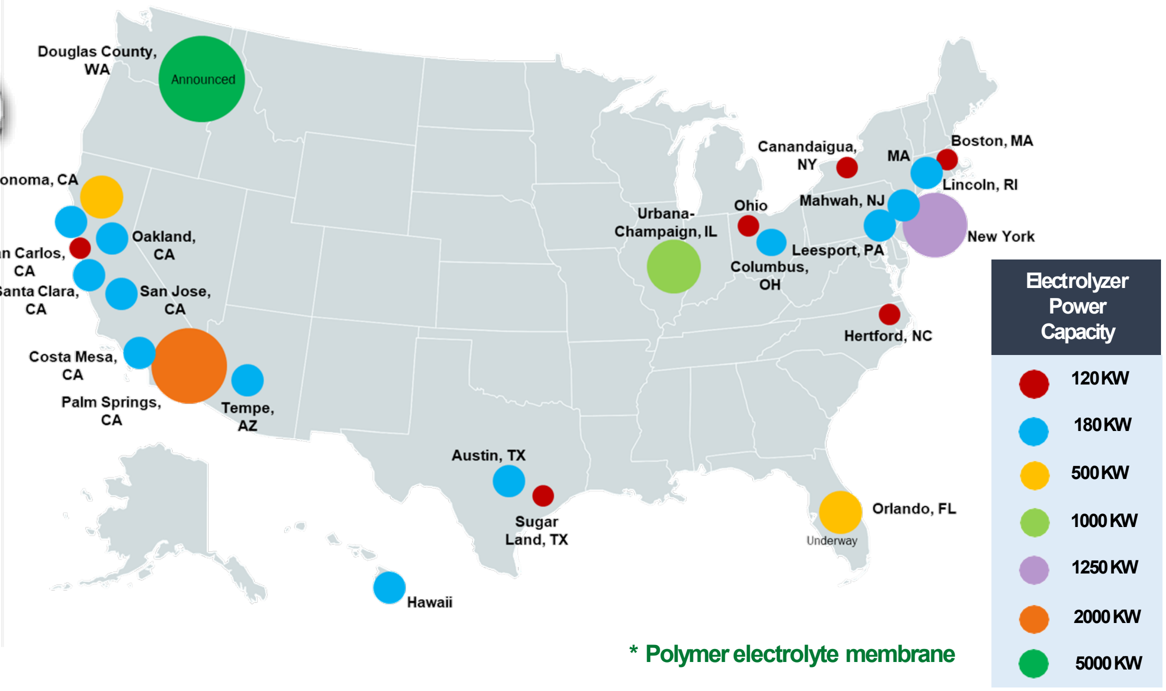
>45
H_2 Retail Stations

>9,000
Fuel Cell Cars

Hydrogen Production Across the U.S.

- 10 million metric tons produced annually
- More than 1,600 miles of H_2 pipeline
- World's largest H_2 storage cavern

PEM Electrolyzer Deployment Across the U.S.



Hydrogen Stations Plans Across States

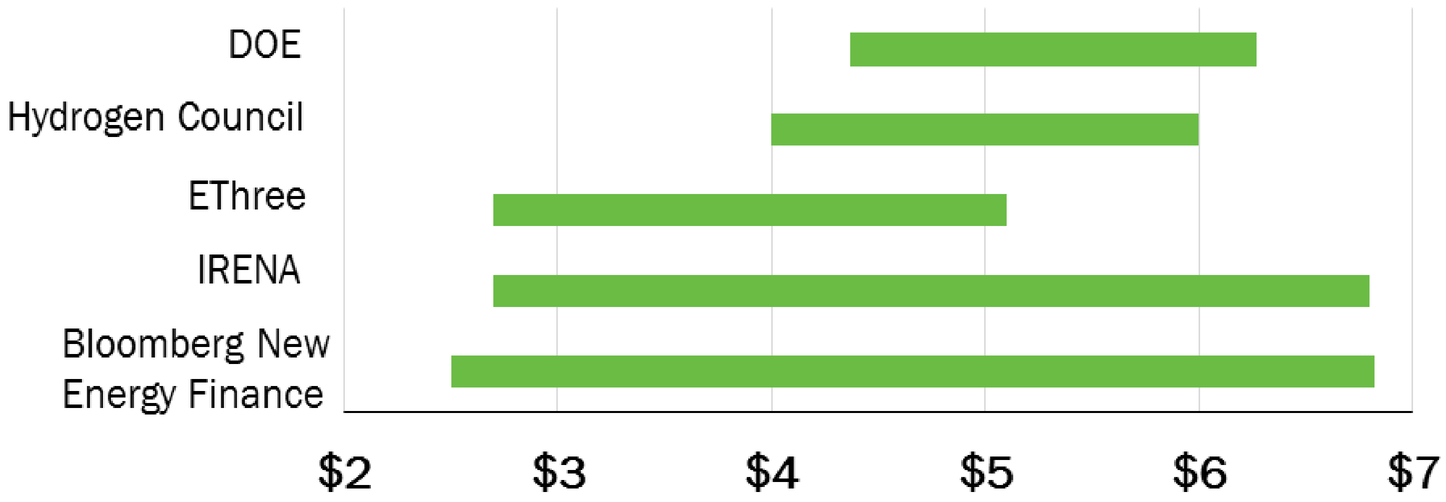
California	Northeast	HI, OH, SC, NY, CT, MA, CO, UT, TX, MI
200 Stations Planned CAFCP Goal	12 – 20 Stations Planned	And Others

* Polymer electrolyte membrane

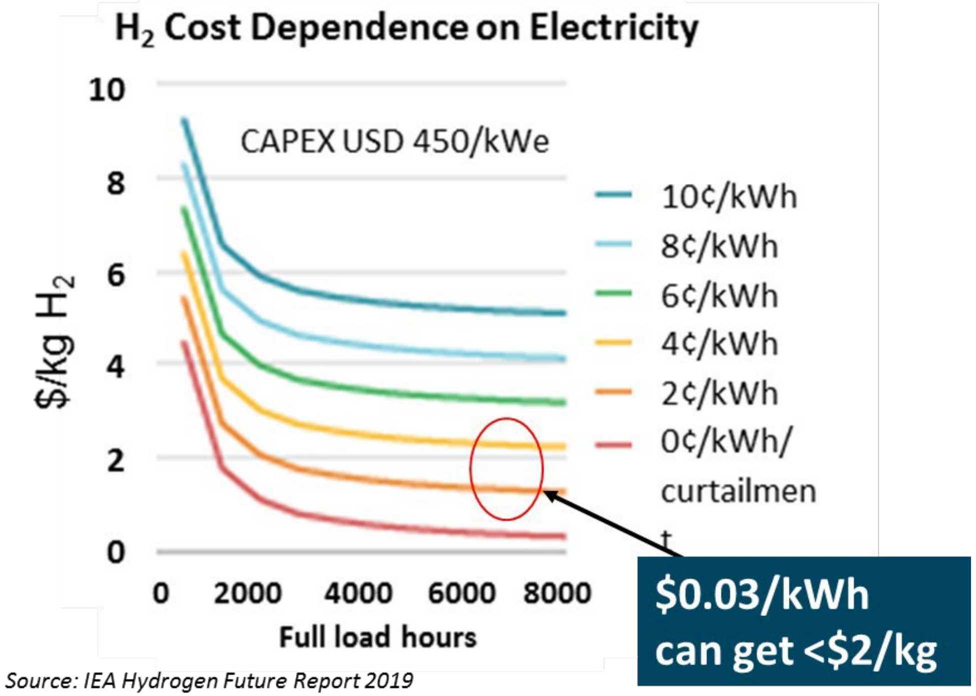
Cost of Hydrogen from PEM Electrolysis - Example

Multiple studies show H_2 from PEM electrolysis can be much less than $7/kg.
Example - $5 to $6/kg at $0.05 to $.07/kWh

Current PEM Electrolyzer Hydrogen Production Cost Estimates ($/kg)



Source: DOE Record 20004



Source: IEA Hydrogen Future Report 2019

Example to achieve <$2/kg

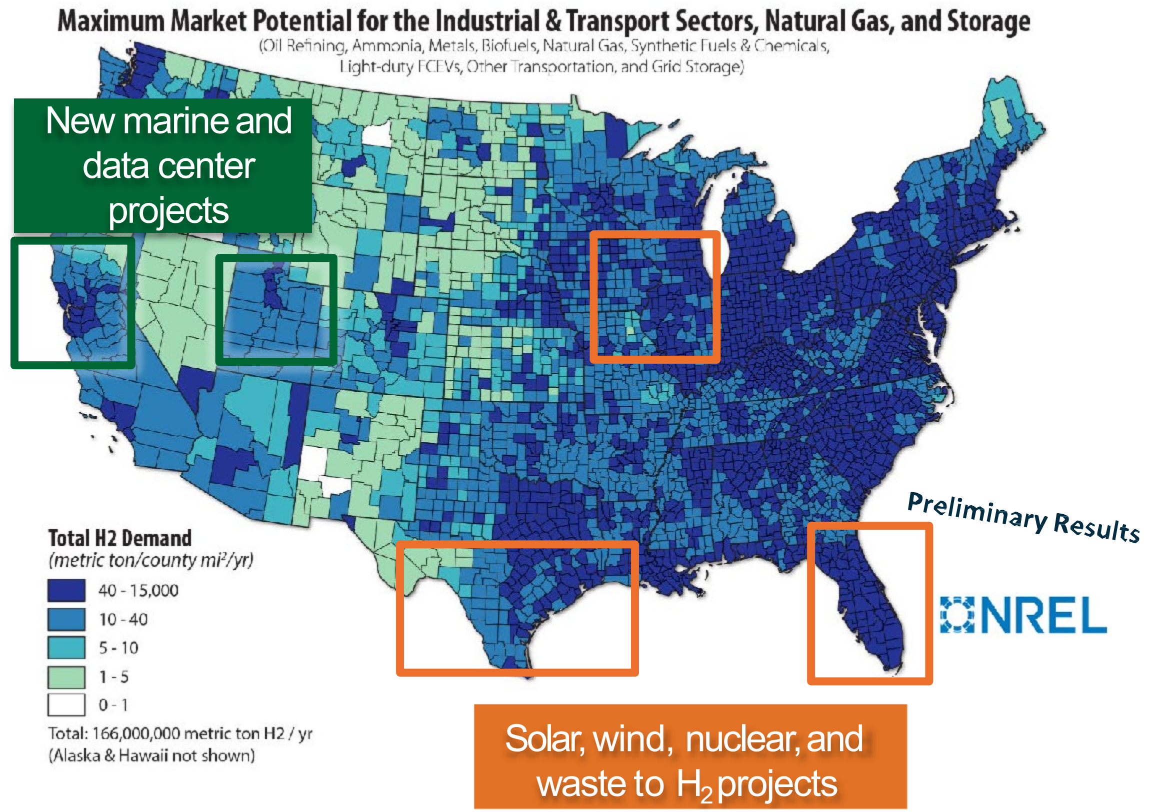
Strategy

- Launch H2NEW consortium on electrolysis to achieve <$2/kg ($100/kW stack target)
- De-risk deployment through systems integration (e.g. labs, ARIES)
- Ramp up scale through demonstrations – co-locate production and end use

Examples of DOE H2@Scale Demonstration Projects

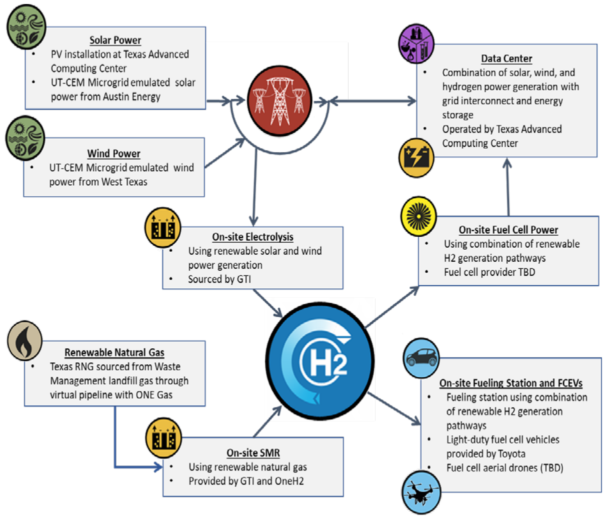
New H2@Scale demonstration projects cover range of applications and regions

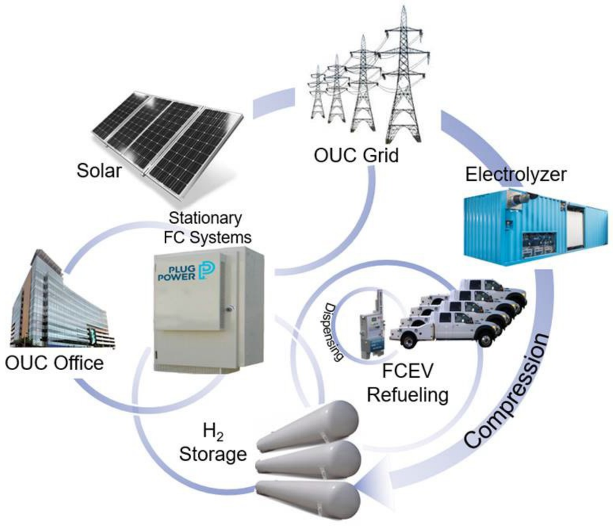
Hydrogen Demand Potential



H2@Scale clean H_2 production, end uses and integration demonstrations (~$ 70M)

- Sites include: TX, FL, CA, UT, OH*, MN*
- H_2 from: Wind, solar, renewable NG/waste, and nuclear
- Stationary and transportation uses include: Data centers, vehicles, maritime applications, and enabling H_2 for steel manufacturing





*** Nuclear project in collaboration with Office of Nuclear Energy**

Examples of DOE HFTO Activities in Texas

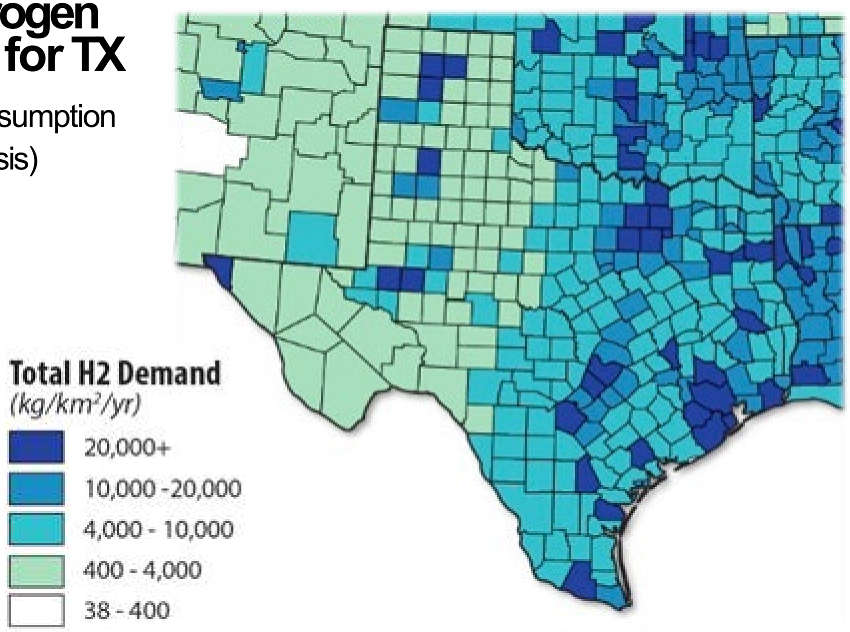
DOE-funded projects include a wide range of technologies

- Solar water-splitting for hydrogen production
- Composite ionomers for high current densities
- Linear motor reciprocating compressors
- Durable high-power membrane electrode assemblies
- H2@Scale demonstration and framework projects

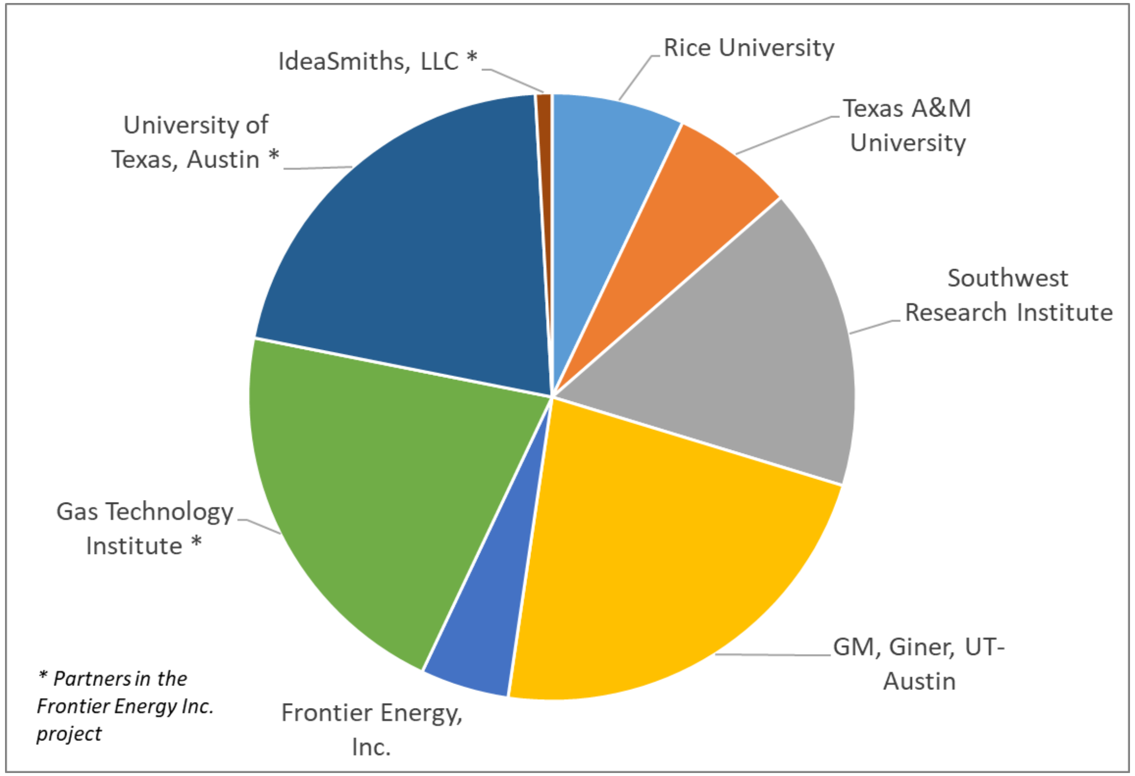
Scenario for hydrogen demand potential for TX

(H2@Scale Serviceable Consumption Potential, NREL analysis)

- Ammonia
- Metals
- Biofuels
- Natura Gas
- Synthetic Hydrocarbons
- Refineries
- Fuel cell vehicles
- Grid storage



DOE HFTO has provided $11.3 million in funding for hydrogen projects in Texas (2014-2020)



Opportunities exist for large-scale hydrogen infrastructure projects

Summary of ways to engage with DOE HFTO

Lab-Based Consortia

HydroGEN Advanced Water Splitting Materials

HyMARC Hydrogen Materials Advanced Research Consortium

ElectroCat Electrocatalysis Consortium

New Consortia

Being launched now:

- H2NEW: Electrolyzer Consortium
- Million Mile Fuel Cell Truck Consortium

Lab - Industry Bridge

- H2@Scale Consortium
- CRADAs
- Strategic Partnerships
- L'Innovator
- Technology Commercialization Fund
- Center for H_2 Safety

Private Sector

- FOA Projects
- SBIRs
- Prizes
- State Funding
- Demos & Deployments
- Partnerships
- Loan Guarantees

H-Mat™ Hydrogen Materials Compatibility Consortium

H_2 materials R&D, enable codes & standards, reduce regulatory barriers

Safety – Lessons learned, best practices, enable safe infrastructure across sectors






Thank You

Dr. Sunita Satyapal
Director, DOE Hydrogen and Fuel Cells Program
Sunita.Satyapal@ee.doe.gov

Looking for more info?

#H2IQ

hydrogen.energy.gov

11:00 – 11:30 **H2@Scale Project and Other Hydrogen Research at UT Austin**

Varun Rai**,** Energy Institute, UT Austin

Nico Bouwkamp, Frontier Energy

JANUARY 2021

TEXAS
The University of Texas at Austin
Energy Institute

H2@UT

Hydrogen Research at UT

VARUN RAI
Director, Energy Institute at The University of Texas at Austin
rai@energy.utexas.edu

Texas Hydrogen Roundtable, 12 Jan 2021

Energy@UT: Changing the World

- ***Unparalleled diversity and depth of research across the energy spectrum***
  - 350+ faculty and researchers working on various energy research areas
  - Building blocks for truly interdisciplinary research and education
  - Global coverage of issues
- ***Over 30 active and established topical energy centers/consortia***
  - Keen awareness of key applied problems from the beginning
  - Enables a built-in applied focus in research activities
- ***Pioneering energy education and training***
  - Arguably the largest and most impactful footprint reg. energy professionals
  - Focus on an integrated, systems-oriented, holistic understanding of energy systems
- ***Complementary assets of outsized excellence and impact***
  - Bureau of Economic Geology (BEG), Texas Advanced Computing Center (TACC), Oden Institute for Computational Eng. & Sc., Texas Materials Institute (TMI), Center for Electromechanics (CEM), Institute for Machine Learning (IML), and more
- ***Connected across industry, foundations, government, and policy: High Impact***

Energy@UT: Changing the World

The depth and breadth of the research and innovation of our faculty and researchers enables UT to take a **balanced view of the global energy system.**

The **Energy Institute serves as a gateway to UT's world-class researchers** dedicated to solving the grand energy challenges facing society.

- The Institute leverages UT's breadth and depth of expertise to catalyze rigorous interdisciplinary research and foster innovation.
- Focuses on integrated solutions that have the best chance of penetrating at scale in Fueling a Sustainable Energy Transition. (FSET)

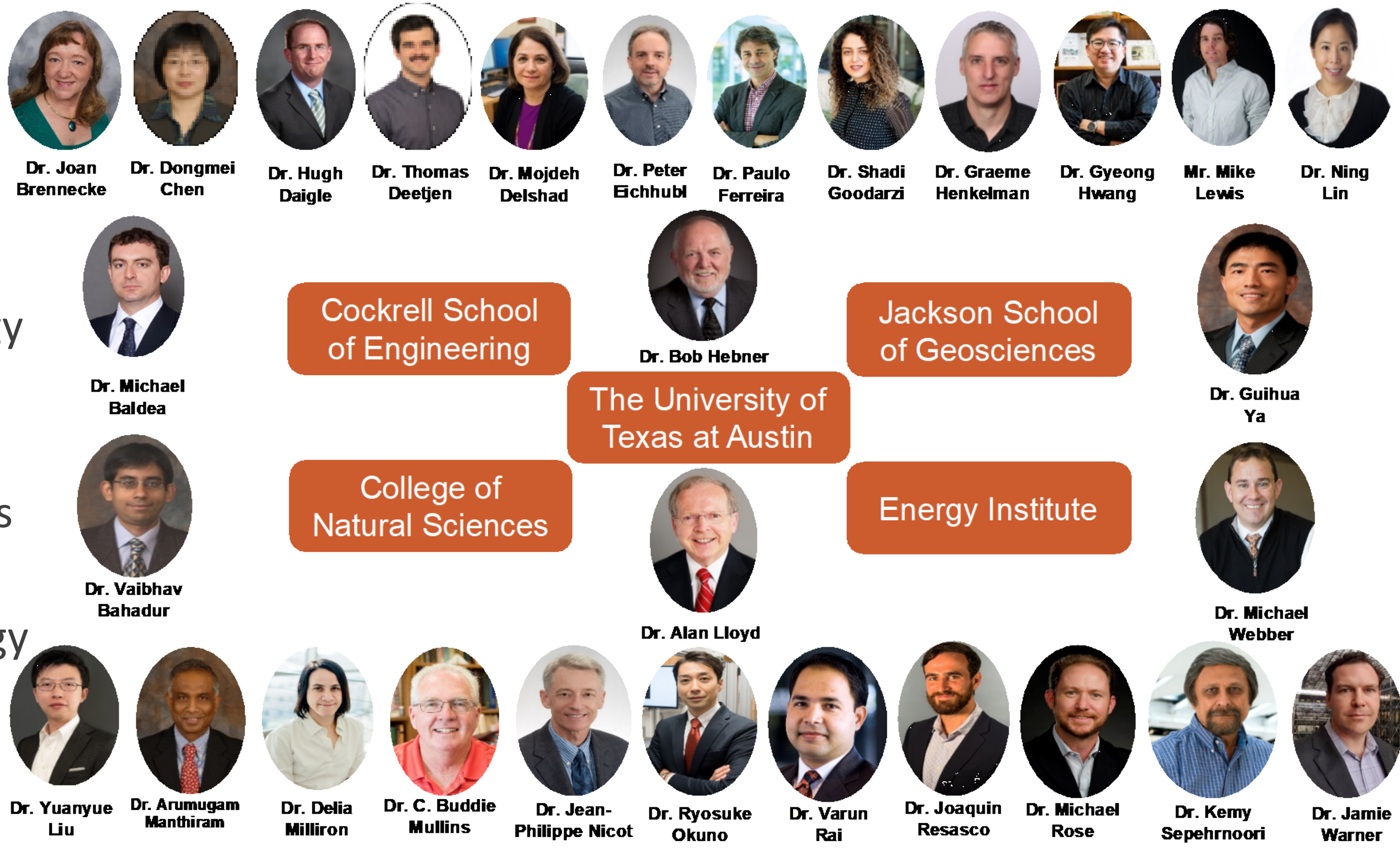
H2@UT: A research cluster at The University of Texas at Austin with the mission to help enable a hydrogen economy.

- ***The Hydrogen (H_2) Ecosystem of The University of Texas at Austin***
- UT Austin has a history of leadership in advancing the Hydrogen (H_2) Economy, from deploying Texas' first H_2-powered bus on the road to developing new materials to produce H_2 from sunlight and water.
- As one of the world's leading research institutions, H_2@UT brings together faculty and researchers from the Cockrell School of Engineering, the Jackson School of Geosciences, the College of Natural Sciences, and coordination from the Energy Institute.

http://sites.utexas.edu/h2/

H2 Experts at UT

- 25+ researchers
  - Catalysts
  - Membranes
  - Controls
  - Power electronics
  - Vehicle design
- Associated Centers
  - Bureau of Economic Geology
  - Texas Materials Institute
  - Oden Institute for Comp.
  - Center for Electromechanics
  - Center for Electrochemistry
  - Center for Subsurface Energy and the Environment



http://sites.utexas.edu/h2/

H2@UT: Thrust Areas

Materials and Devices | Storage and Distribution | System Integration | Implementation

Materials and Devices

Focus – Improving materials to lower the cost and raise the performance of fuel cells and electrolyzers.

Storage and Distribution

Focus – Developing subsurface H_2 storage reservoirs, novel vessels, and the distribution systems to fuel next-generation transportation.

System Integration – from Vehicles to Trains

Focus – Leading the development of future transportation systems by providing key engineering data today – from H_2 powered-trains, to vans, to buses.

Implementation – Supply Chain, Techno-economic Analysis, Infrastructure, and Policy

Focus – Driving technology adoption to create a sustainable supply chain and curb greenhouse gas emissions through techno-economic analysis, infrastructure development, and policy advancement.

H2@Scale Project Launched in Texas

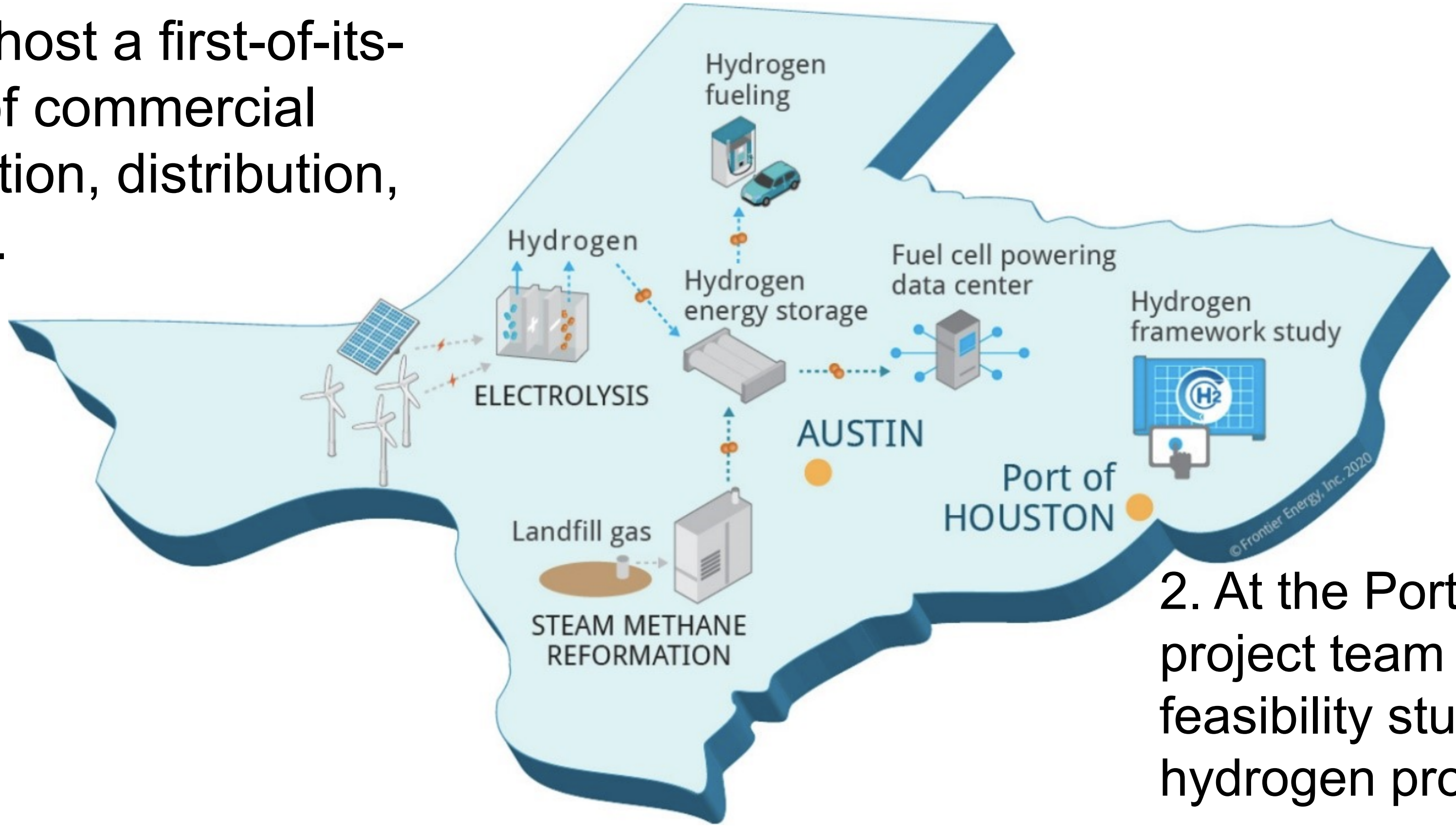
Sponsoring partner
U.S. DOE EERE HFTO

FOR IMMEDIATE RELEASE

September 15, 2020

Frontier Energy, Inc., in close collaboration with GTI and The University of Texas at Austin, announces the launch of a U.S. Department of Energy project, *Demonstration and Framework for H2@Scale in Texas and Beyond*. The project is supported by DOE's Hydrogen and Fuel Cell Technologies Office within the Office of Energy Efficiency and Renewable Energy. *H2@Scale in Texas and Beyond* intends to show that renewable hydrogen can be a cost-effective fuel for multiple end-use applications, including fuel cell electric vehicles, when coupled with large, baseload consumers that use hydrogen for clean, reliable stationary power.

1. UT-Austin will host a first-of-its-kind integration of commercial hydrogen production, distribution, storage, and use.



2. At the Port of Houston, the project team will conduct a feasibility study for scaling up hydrogen production and use.

H2@UT: Part of an Integrated and Comprehensive Energy Research Platform

TEXAS
The University of Texas at Austin
Energy Institute

WHAT STARTS HERE CHANGES THE WORLD

Energy Institute's <u>Fueling a Sustainable Energy Transition</u> (FSET) Initiative: 12 Project Teams with ~ 60 Faculty

Funding Priorities

Sustainable
Economic, Environmental, Social

Energy
Technologies, Systems, Policy

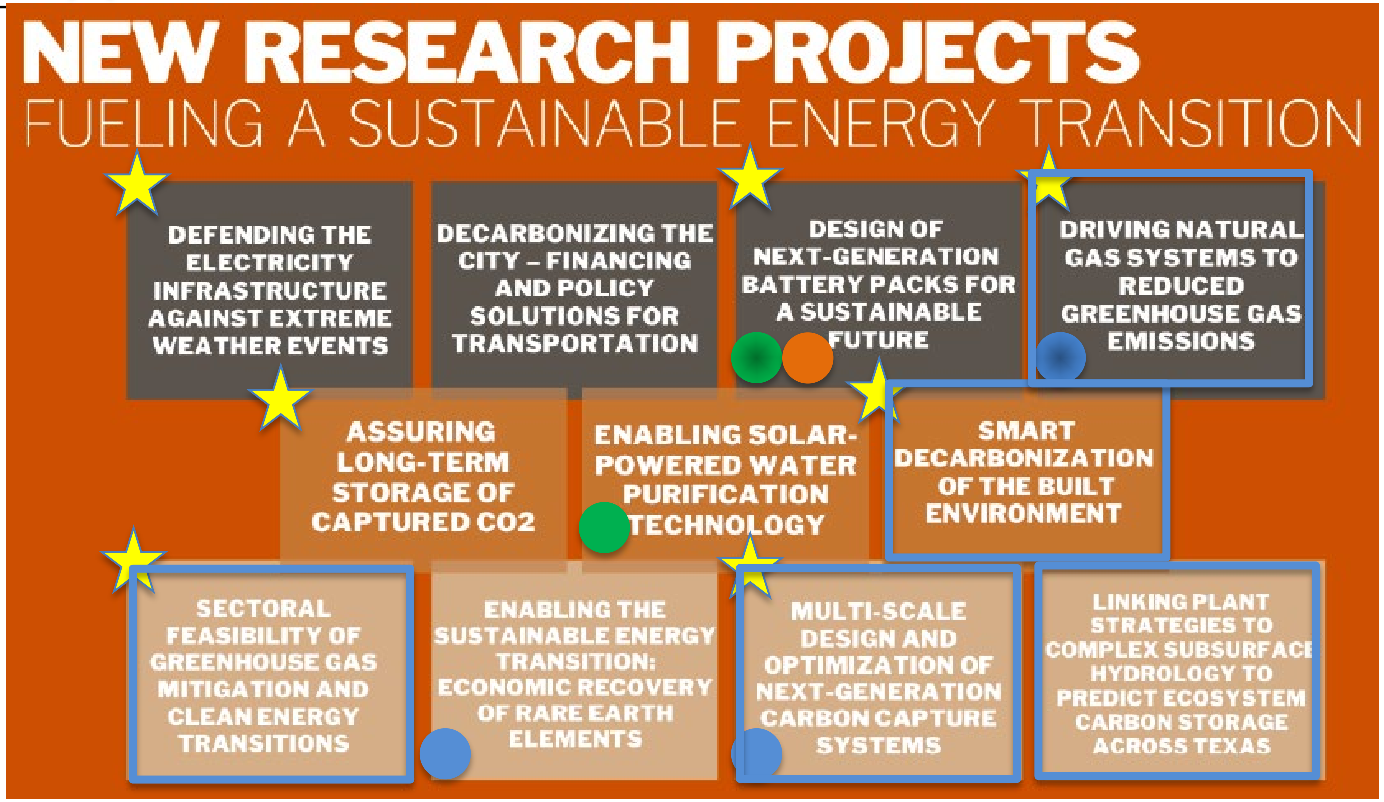
Transition
Shift in paradigm

Year One Overview (since Jan 2020)

The FSET program's about 60 supported researchers (across nine Schools) had a productive year in pursuit of critical, interdisciplinary energy research.

- The program's intentional team composition strategy yielded network and learning benefits program wide.
- Clear research objectives and timeline expectations brought to bear strong research productivity during the program's first year.
- **From grants to patents to startup companies, inventive and commercialization activities are an integral part of the FSET fixture.**

★ Major software/algorithm/data platform development



Partner funded

Invention disclosure filed/expected
Patent granted/filed
Startup (DOE STTR)

Details about the teams and project webpages are at:
https://energy.utexas.edu/news/Energy-Institute-CFP-FSET-announcement-new-UT-collaborations

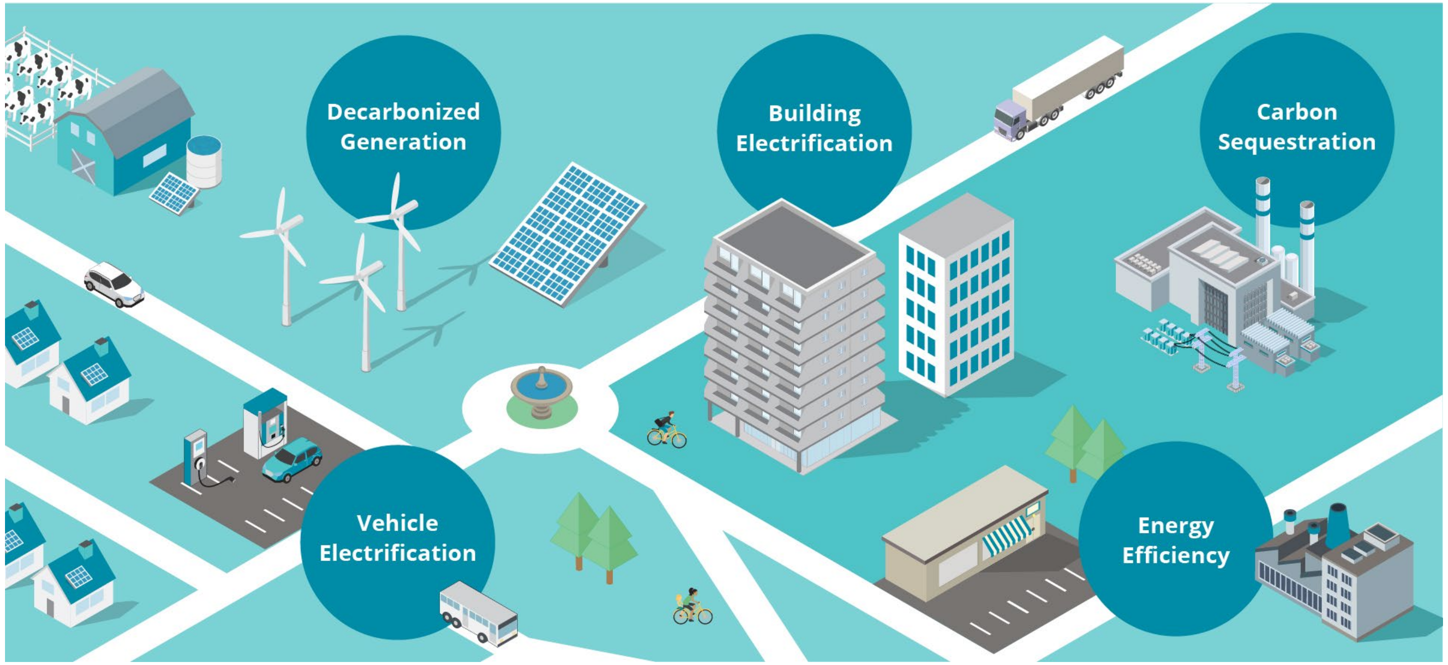
Sponsoring partner

- U.S. DOE EERE HFTO

Industry partners

- Air Liquide
- Chart Industries
- Frontier Energy*
- Gas Technology Institute*
- Mitsubishi Heavy Industries
- OneH2
- ONE Gas
- ONEOK
- Shell
- SoCalGas
- Toyota
- University of Texas at Austin*
- Waste Management

* Project team leads



Demonstration and Framework for H2@Scale in Texas and Beyond

UT Austin and Port of Houston region

Nico Bouwkamp

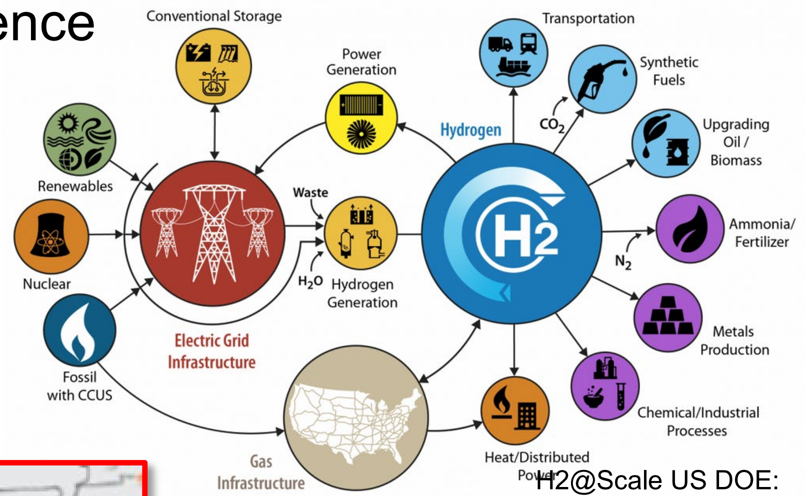
Texas Hydrogen Roundtable: Benefiting from an Emerging Technology

January 12, 2021

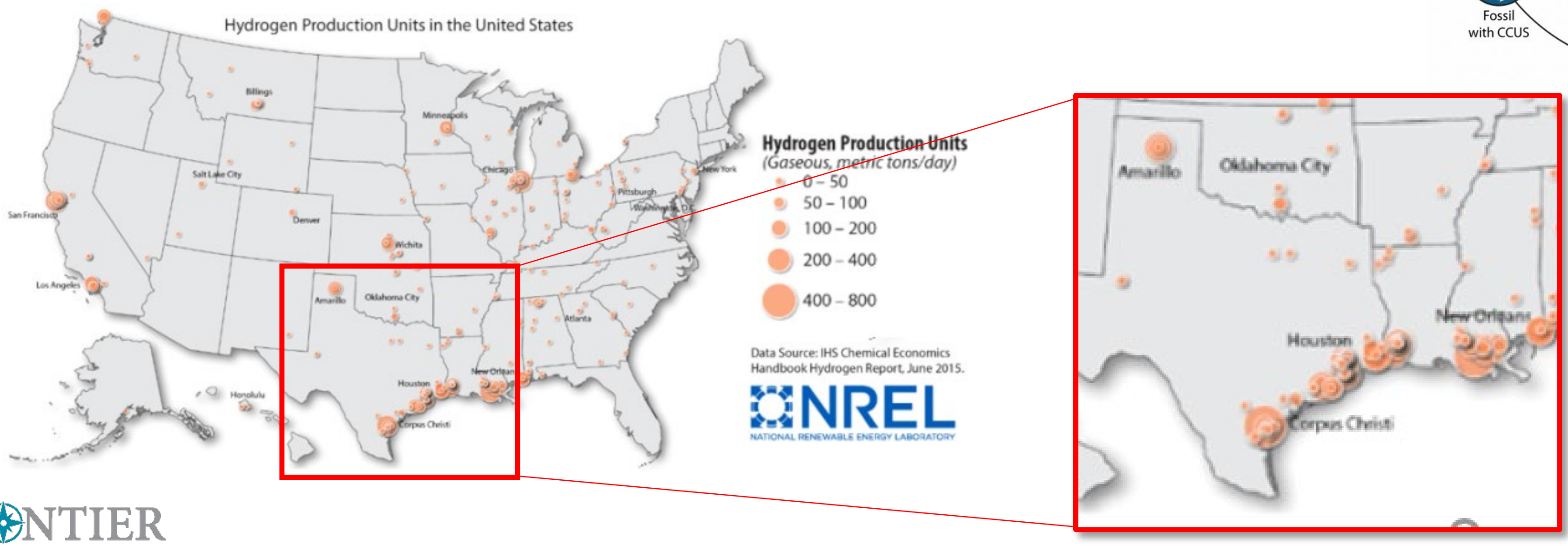
Growing H2@Scale in Texas

Texas ideal to lead H_2 production for a sustainable energy system

- Major industry leaders on Hydrogen Council have significant presence
- Excellent resources of NG, RNG, solar and wind for RH_2
- Largest established H_2 producer in the nation



H2@Scale US DOE:
https://www.energy.gov/eere/fuelcells/h2scale

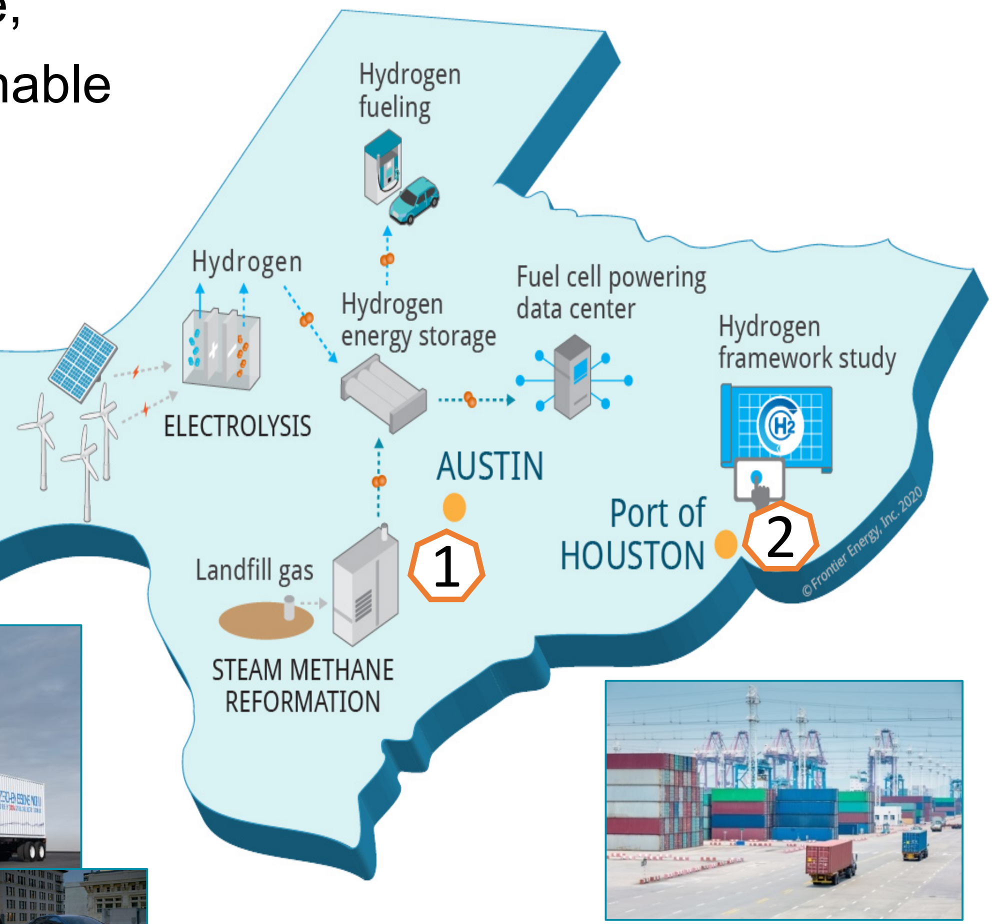


H2@Scale TX Project

Two unique tracks to grow understanding of H_2 integration potential

1. Demonstrate multiple RH_2 generation options w/ storage, vehicle fueling and base load user (UT Austin TACC) to enable cost-effective H_2 energy solutions

2. Develop framework for actionable H2@Scale plans in Texas, incl. energy decarbonization, energy storage & FCEV rollout
   - Identify policy and regulatory barriers
   - Leverage existing industry resources



(Source: Toyota)

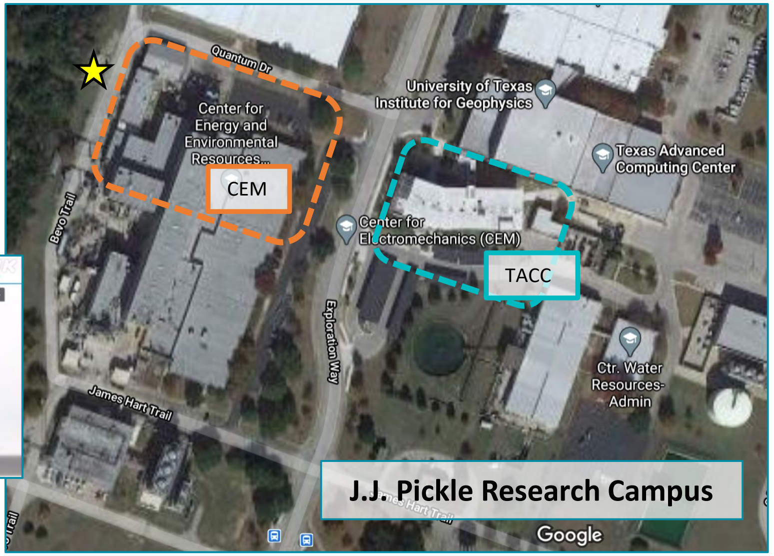
FRONTIER energy

Progress to Date

Project management

- Press release 9/15/20 (shorturl.at/kmxyD)
    - Industry and media interest from Texas, US and globally
- Stakeholder engagement and planning

(Credit: Ricky Sakai, MHI)



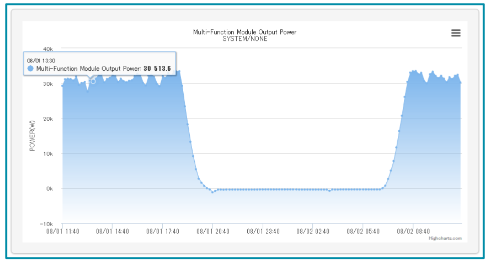
1 Demonstration activities

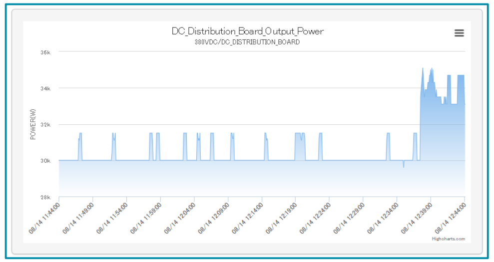
- Working with UT Facilities to cost and select equipment site
- Shipped existing H2 equipment to GTI for upgrades
- Initiated procurement of long-lead equipment
- Analysis of TACC & solar power data

2 Port of Houston Framework

- Compiling data existing infrastructures and energy systems
- Developing list of stakeholders for workshops (50+ identified)
- Initial stakeholder engagements

(Source: GTI)





Example power data from Texas Advanced Computing Center. Solar array power on top, DC distribution power on bottom.

FRONTIER energy

Expansion and Integration Opportunities

- Domestically sourced decarbonized H_2 for multiple sectors and/or export
- H_2 enables zero emissions in all transportation modes, and for stationary, remote, and portable power
- H_2 used as a grid "responsive load" for grid stability and GWh scale energy storage, and to increase power generators utilization
- H_2 critical feedstock for process and chemicals industries
- Combinations of any of the above
  - Economic growth

Questions or follow up

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Michael Lewis
Sr. Engineering Scientist
University of Texas at Austin, CEM
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11:30 – 12:00 **Hydrogen Production: Pathways and Critical Needs**

Joe Powell, Shell

Brian Weeks, Gas Technology Institute

Al Burgunder, Linde

Hydrogen Opportunities for Texas

Texas Hydrogen Roundtable
The University of Texas at Austin
12 January 2021

Joseph B. Powell, PhD
retired Shell Chief Scientist - Chemical Engineering

Disclaimers

Definitions & cautionary note

The companies in which Royal Dutch Shell plc directly and indirectly owns investments are separate legal entities. In this [REPORT/BOOKLET/VIDEO/PRESENTATION, etc.] "Shell", "Shell Group" and "Royal Dutch Shell" are sometimes used for convenience where references are made to Royal Dutch Shell plc and its subsidiaries in general. Likewise, the words "we", "us" and "our" are also used to refer to Royal Dutch Shell plc and its subsidiaries in general or to those who work for them. These terms are also used where no useful purpose is served by identifying the particular entity or entities. ''Subsidiaries'', "Shell subsidiaries" and "Shell companies" as used in this [REPORT/BOOKLET/VIDEO/PRESENTATION, etc.] refer to entities over which Royal Dutch Shell plc either directly or indirectly has control. Entities and unincorporated arrangements over which Shell has joint control are generally referred to as "joint ventures" and "joint operations", respectively. Entities over which Shell has significant influence but neither control nor joint control are referred to as "associates". The term "Shell interest" is used for convenience to indicate the direct and/or indirect ownership interest held by Shell in an entity or unincorporated joint arrangement, after exclusion of all third-party interest.

This [REPORT/BOOKLET/VIDEO/PRESENTATION, etc.] contains forward-looking statements (within the meaning of the U.S. Private Securities Litigation Reform Act of 1995) concerning the financial condition, results of operations and businesses of Royal Dutch Shell. All statements other than statements of historical fact are, or may be deemed to be, forward-looking statements. Forward-looking statements are statements of future expectations that are based on management's current expectations and assumptions and involve known and unknown risks and uncertainties that could cause actual results, performance or events to differ materially from those expressed or implied in these statements. Forward-looking statements include, among other things, statements concerning the potential exposure of Royal Dutch Shell to market risks and statements expressing management's expectations, beliefs, estimates, forecasts, projections and assumptions. These forward-looking statements are identified by their use of terms and phrases such as "aim", "ambition", ''anticipate'', ''believe'', ''could'', ''estimate'', ''expect'', ''goals'', ''intend'', ''may'', ''objectives'', ''outlook'', ''plan'', ''probably'', ''project'', ''risks'', "schedule", ''seek'', ''should'', ''target'', ''will'' and similar terms and phrases. There are a number of factors that could affect the future operations of Royal Dutch Shell and could cause those results to differ materially from those expressed in the forward-looking statements included in this [REPORT/BOOKLET/VIDEO/PRESENTATION, etc.], including (without limitation): (a) price fluctuations in crude oil and natural gas; (b) changes in demand for Shell's products; (c) currency fluctuations; (d) drilling and production results; (e) reserves estimates; (f) loss of market share and industry competition; (g) environmental and physical risks; (h) risks associated with the identification of suitable potential acquisition properties and targets, and successful negotiation and completion of such transactions; (i) the risk of doing business in developing countries and countries subject to international sanctions; (j) legislative, fiscal and regulatory developments including regulatory measures addressing climate change; (k) economic and financial market conditions in various countries and regions; (l) political risks, including the risks of expropriation and renegotiation of the terms of contracts with governmental entities, delays or advancements in the approval of projects and delays in the reimbursement for shared costs; (m) risks associated with the impact of pandemics, such as the COVID-19 (coronavirus) outbreak; and (n) changes in trading conditions. No assurance is provided that future dividend payments will match or exceed previous dividend payments. All forward-looking statements contained in this [REPORT/BOOKLET/VIDEO/PRESENTATION, etc.] are expressly qualified in their entirety by the cautionary statements contained or referred to in this section. Readers should not place undue reliance on forward-looking statements. Additional risk factors that may affect future results are contained in Royal Dutch Shell's Form 20-F for the year ended December 31, 2019 (available at www.shell.com/investor and www.sec.gov). These risk factors also expressly qualify all forward-looking statements contained in this [REPORT/BOOKLET/VIDEO/PRESENTATION, etc.] and should be considered by the reader. Each forward-looking statement speaks only as of the date of this [REPORT/BOOKLET/VIDEO/PRESENTATION, etc.], October, 2020. Neither Royal Dutch Shell plc nor any of its subsidiaries undertake any obligation to publicly update or revise any forward-looking statement as a result of new information, future events or other information. In light of these risks, results could differ materially from those stated, implied or inferred from the forward-looking statements contained in this [REPORT/BOOKLET/VIDEO/PRESENTATION, etc.].

We may have used certain terms, such as resources, in this [REPORT/BOOKLET/VIDEO/PRESENTATION, etc.] that the United States Securities and Exchange Commission (SEC) strictly prohibits us from including in our filings with the SEC. Investors are urged to consider closely the disclosure in our Form 20-F, File No 1-32575, available on the SEC website www.sec.gov.

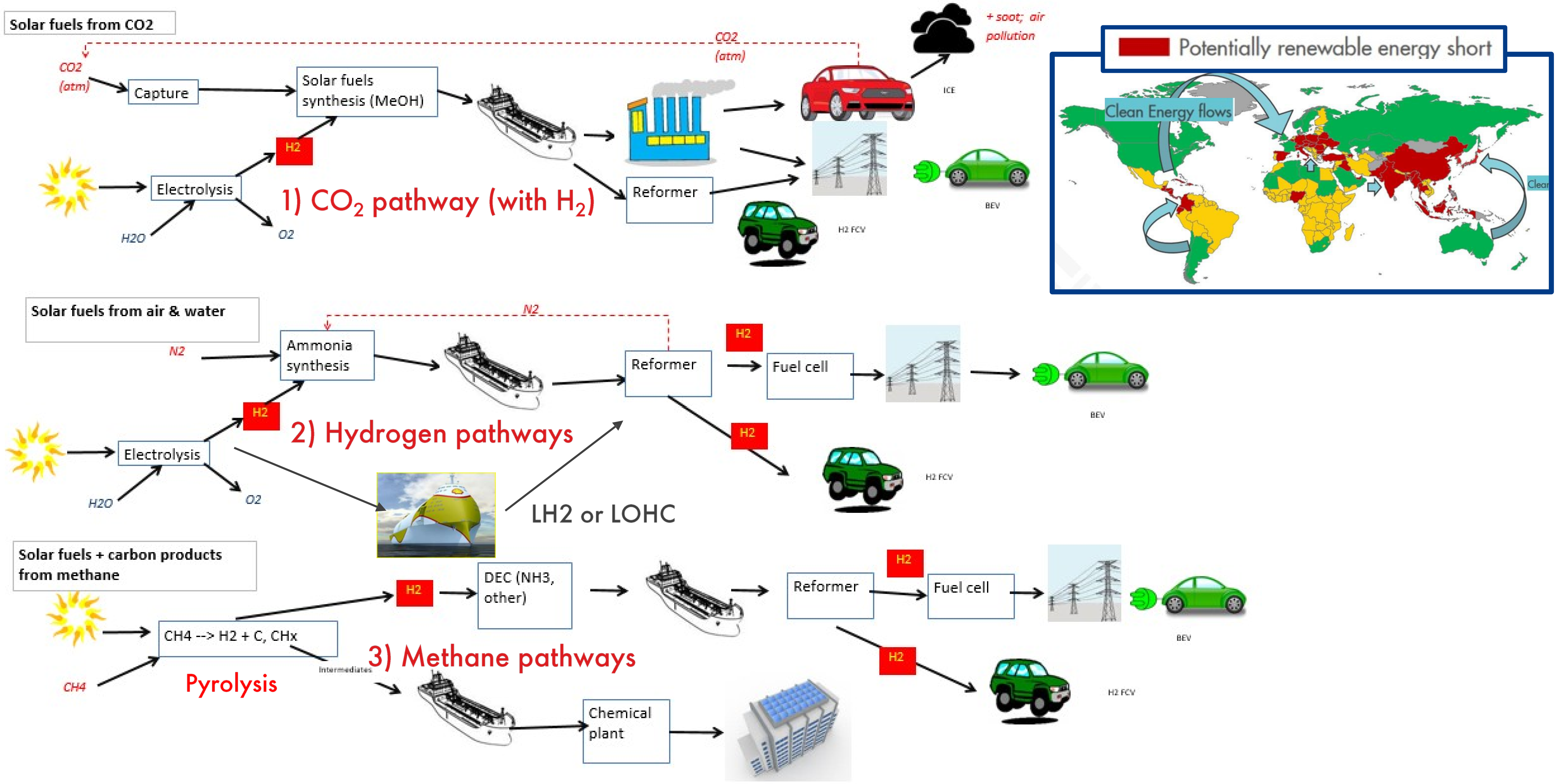
Definitions & cautionary note

This [REPORT/BOOKLET/VIDEO/PRESENTATION, etc.] contains data and analysis from Shell's Sky scenario. Unlike Shell's previously published Mountains and Oceans exploratory scenarios, the Sky scenario is based on the assumption that society reaches the Paris Agreement's goal of holding the rise in global average temperatures this century to well below two degrees Celsius (2°C) above pre-industrial levels. Unlike Shell's Mountains and Oceans scenarios, which unfolded in an open-ended way based upon plausible assumptions and quantifications, the Sky scenario was specifically designed to reach the Paris Agreement's goal in a technically possible manner. These scenarios are a part of an ongoing process used in Shell for over 40 years to challenge executives' perspectives on the future business environment. They are designed to stretch management to consider even events that may only be remotely possible. Scenarios, therefore, are not intended to be predictions of likely future events or outcomes.

Additionally, it is important to note that as of August 2020, Shell's operating plans and budgets do not reflect Shell's Net-Zero Emissions ambition. Shell's aim is that, in the future, its operating plans and budgets will change to reflect this movement towards its new Net-Zero Emissions ambition. However, these plans and budgets need to be in step with the movement towards a Net-Zero Emissions economy within society and among Shell's customers.

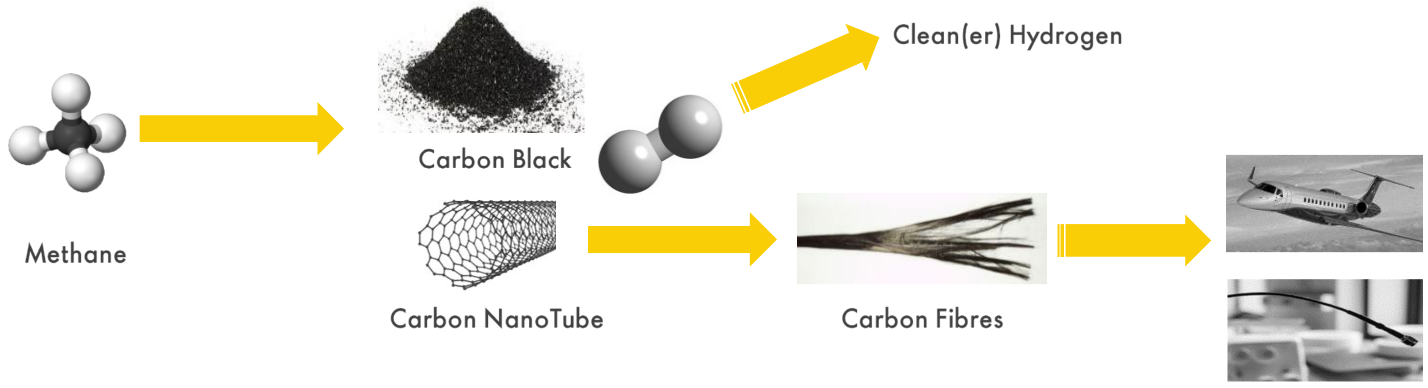
Also, in this [REPORT/BOOKLET/VIDEO/PRESENTATION, etc.] we may refer to Shell's "Net Carbon Footprint", which includes Shell's carbon emissions from the production of our energy products, our suppliers' carbon emissions in supplying energy for that production and our customers' carbon emissions associated with their use of the energy products we sell. Shell only controls its own emissions. The use of the term Shell's "Net Carbon Footprint" is for convenience only and not intended to suggest these emissions are those of Shell or its subsidiaries.

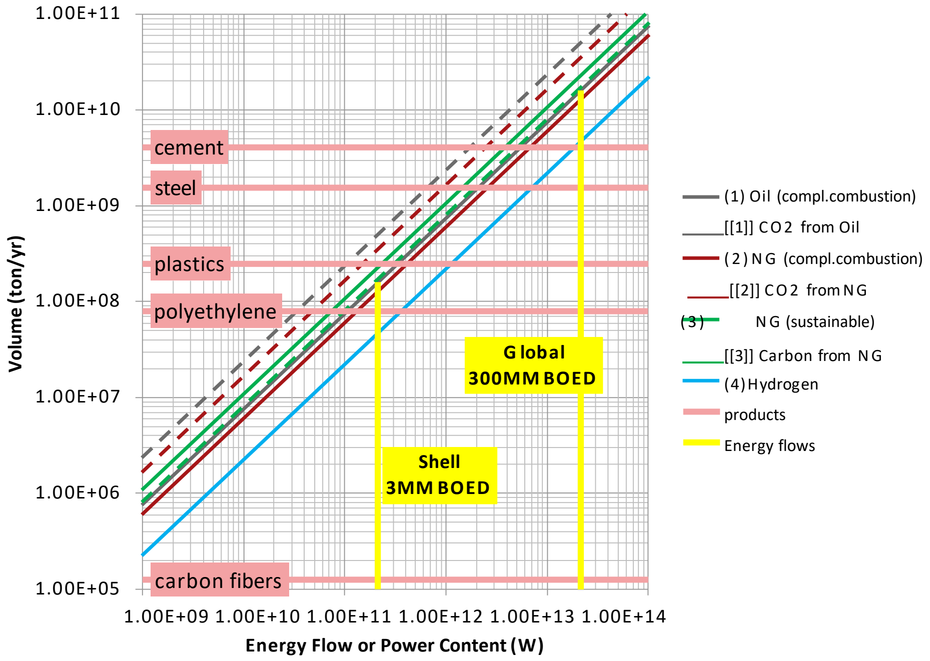
Systems Modeling: Renewable Energy Transport & Storage



4) Alternative: local Solar & Wind with electrical energy or pumped hydro storage

Methane pyrolysis

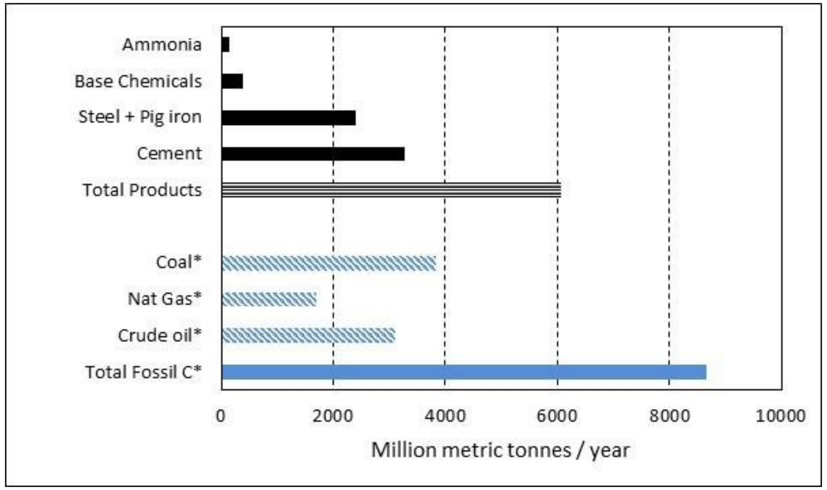




- **Impact:**
  - Large carbon sink via carbon utilization to build industry products.
  - H2 is freed for clean energy systems use (fuel cell)

3D printed advanced composite Shelby Cobra (ORNL)

Low cost advanced manufacturing composite building (Mark Goulthorpe MIT)



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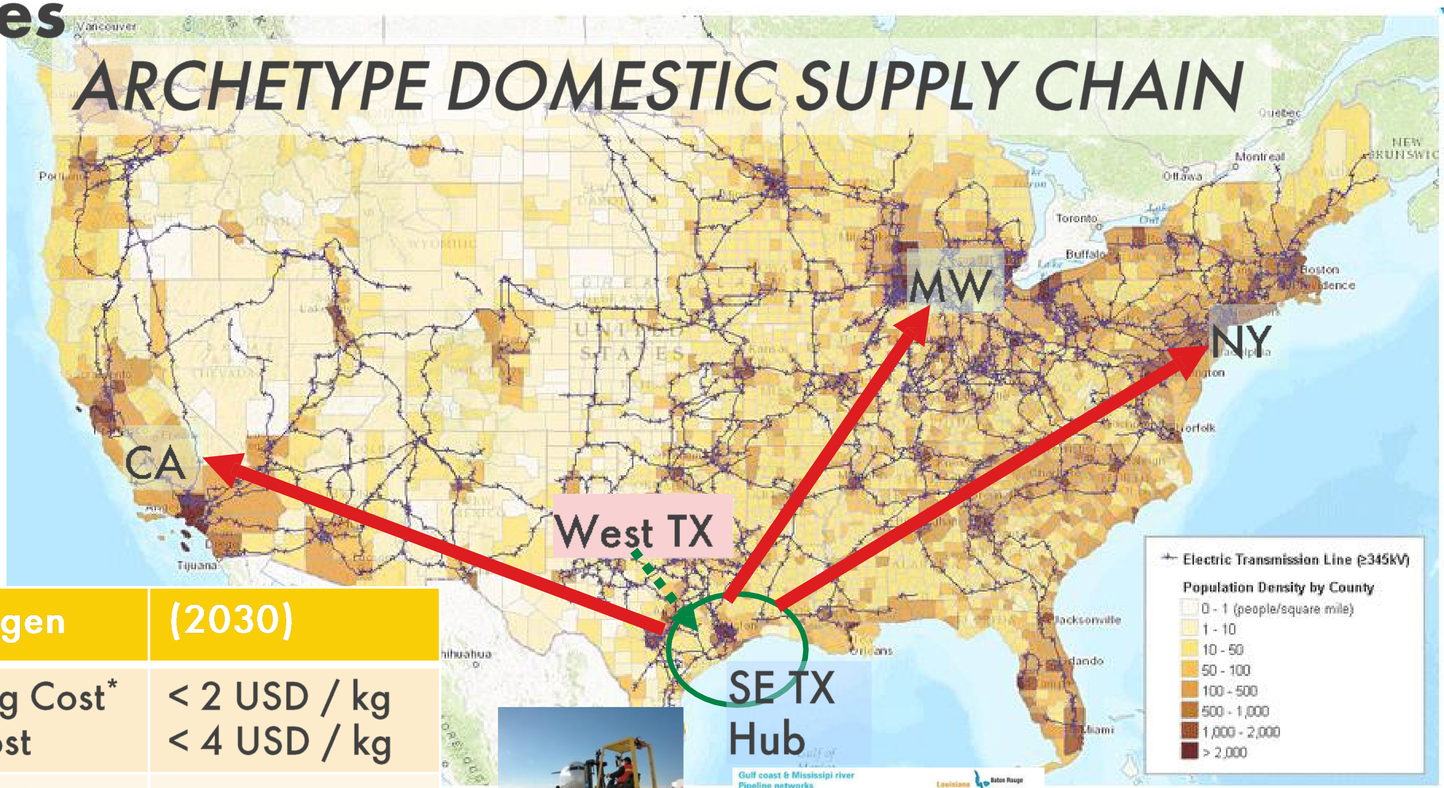
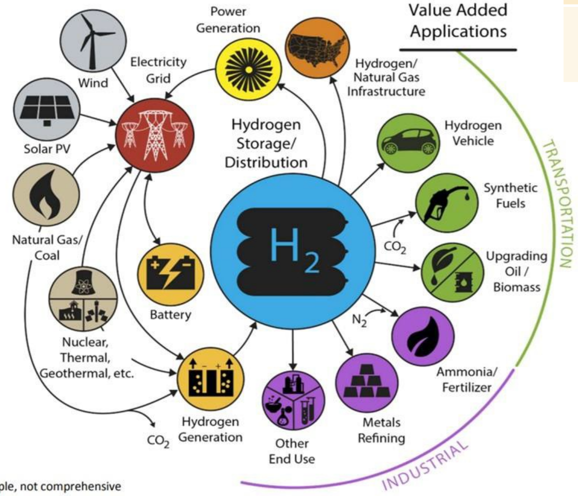
Hydrogen: US Opportunities

- ✓ Green / clean H_2 from West TX renewable + SE TX (Houston GC) waste heat
  - ✓ SMR/ Methane pyrolysis / water electrolysis
- ✓ H_2 heavy duty trucking, industry
- ✓ Commercial ride-share (Uber fleet)?
- ✓ City lift trucks / buses?
- ✓ H_2 Rail transit to US States with clean energy incentives; H_2 + NH_3 pipelines
  - ✓ LH_2 or NH_3
- ✓ Leveraged demo hub



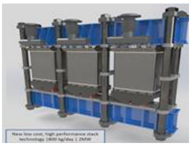
Clean Hydrogen	(2030)
Manufacturing Cost* Dispensed Cost	< 2 USD / kg < 4 USD / kg
Scale (per Site)	> 1500 kg / d

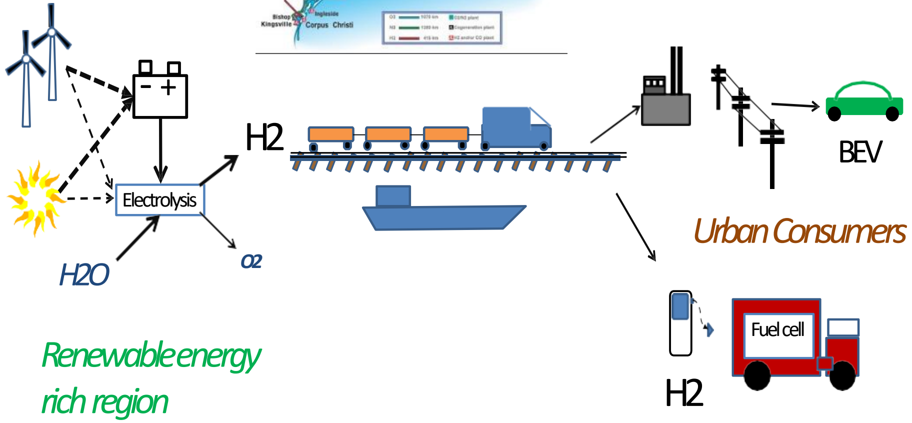
H_2 at Scale Energy System



*Illustrative example, not comprehensive
Source: NREL

Fuel Cell Electric Vehicle Prototype 2





* Distributed small/medium scale

Questions and Answers

JBP@ChemePD.com

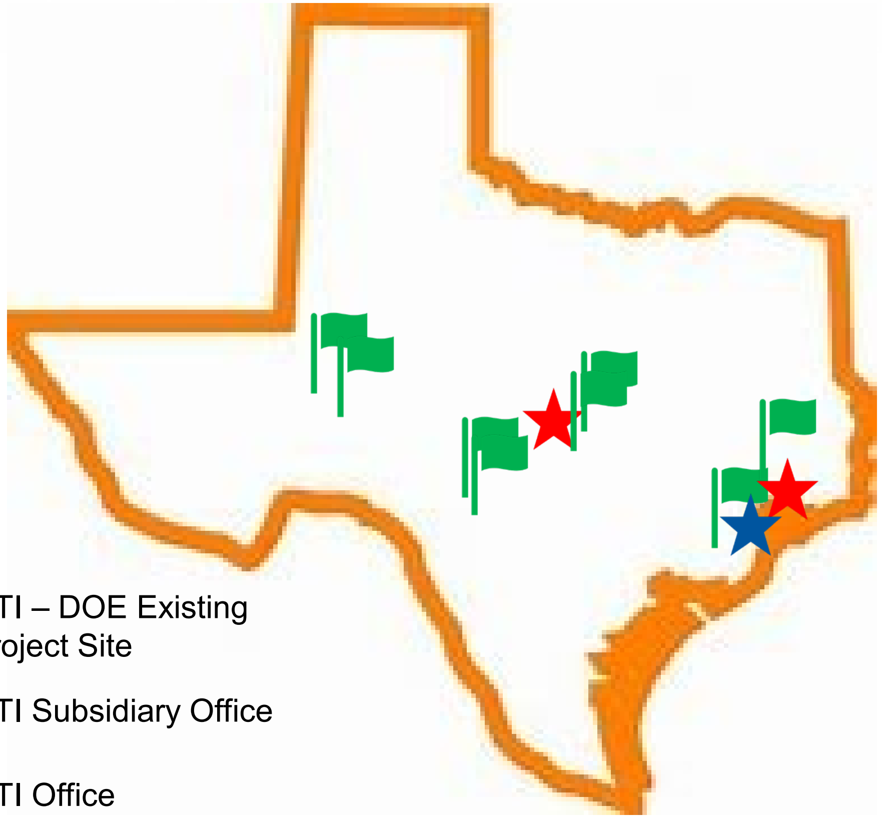
Q&A

Texas Hydrogen Roundtable

Texas Energy Institute
January 12, 2021

GTI
Brian Weeks, P.E.
bweeks@gti.energy
281.235.7993

80-year History of Turning Raw Technology into Practical Energy Solutions
Long and Active Role in Texas Energy R&D



GTI – DOE Existing Project Site

GTI Subsidiary Office

GTI Office

FOR A BETTER ECONOMY AND A BETTER ENVIRONMENT

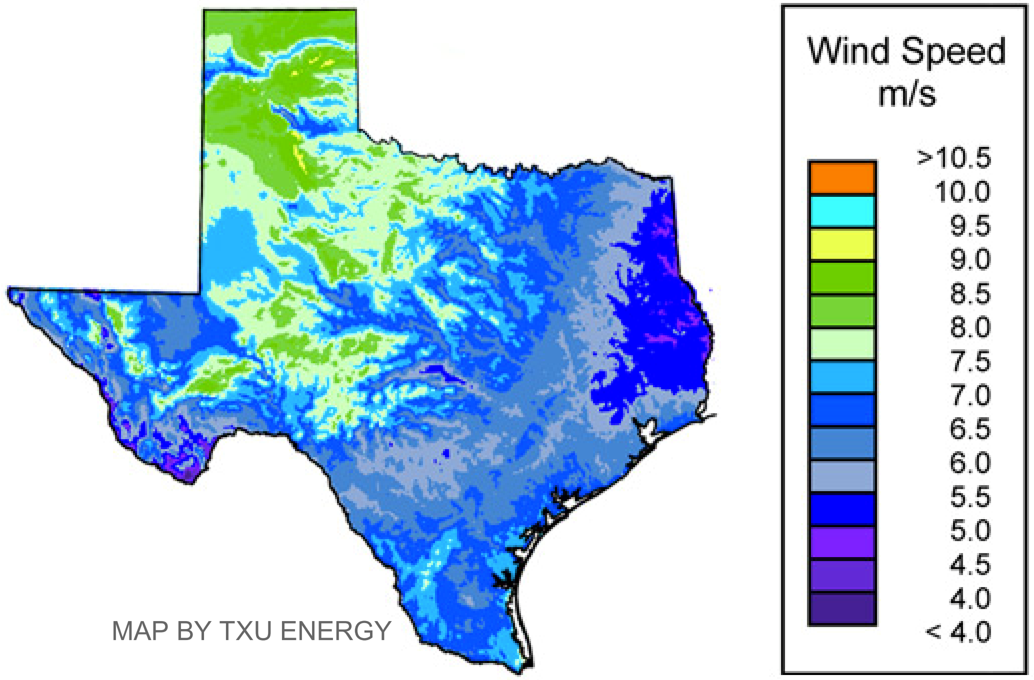
SUPPLY ▶ CONVERSION ▶ DELIVERY ▶ UTILIZATION

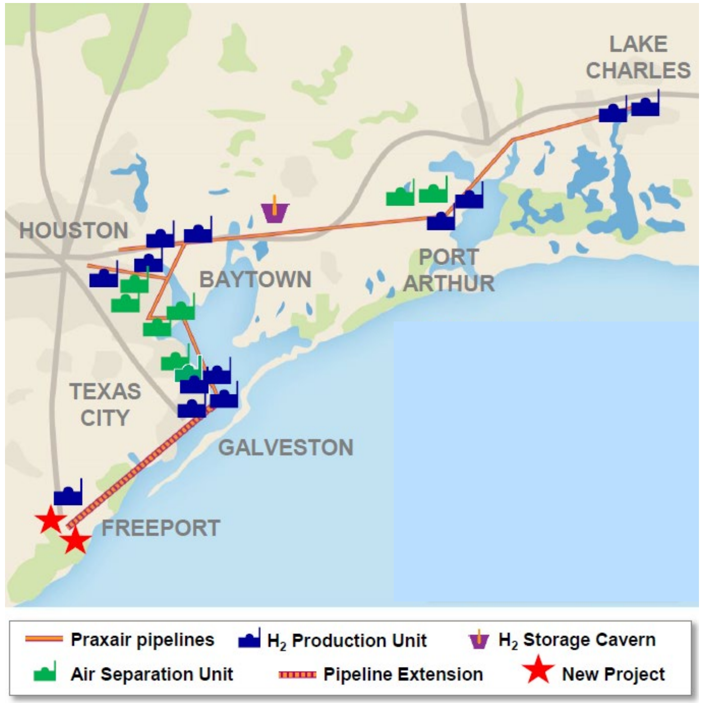
RESEARCH & DEVELOPMENT | PROGRAM MANAGEMENT | TECHNICAL/ ANALYTICAL | CONSULTING | TRAINING | COMMERCIALIZATION

400+ EMPLOYEES

"Green / Blue" Locations for Hydrogen Production in Texas

Texas Annual Average Wind Speed





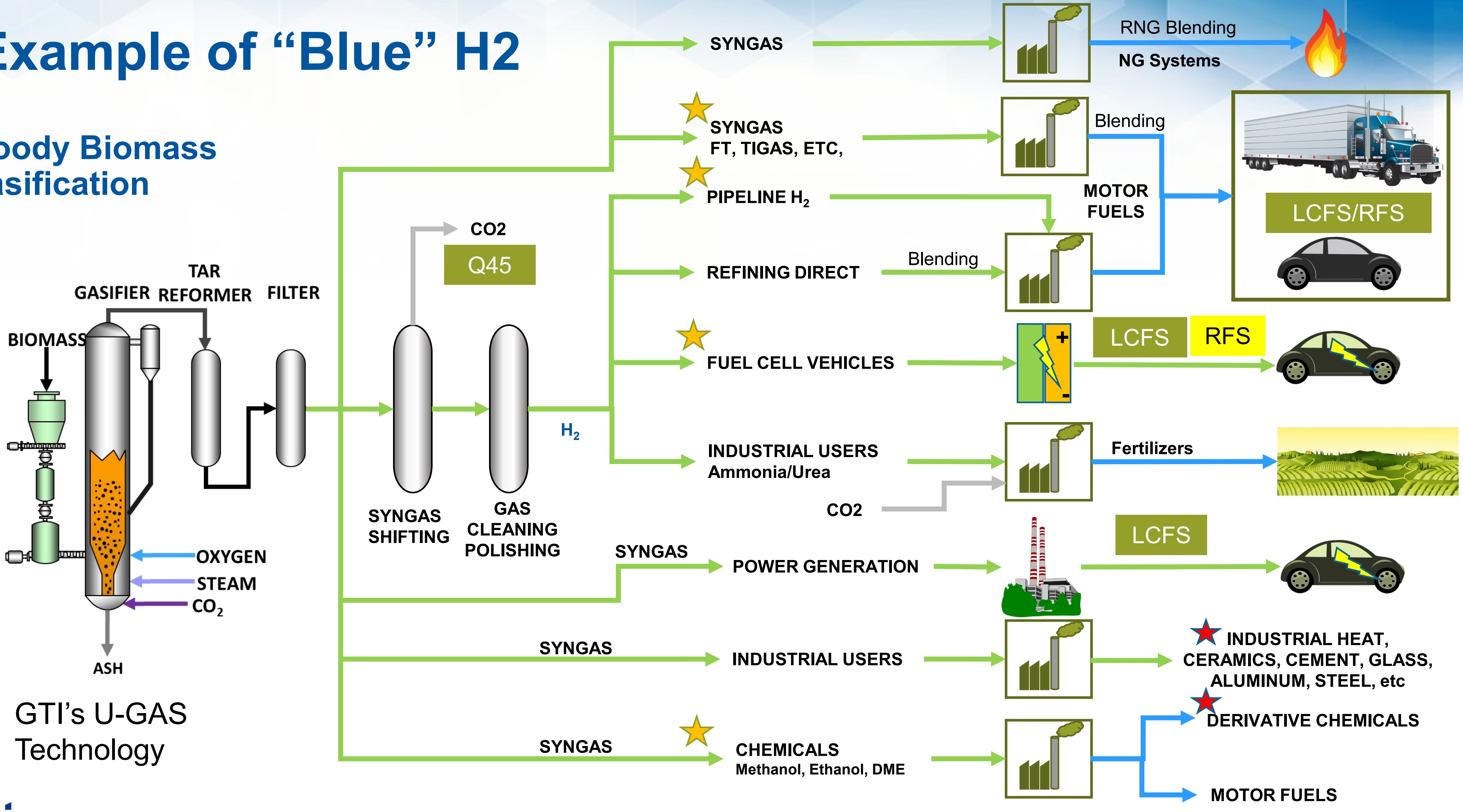
Hydrogen from wind/electrolysis will be in the western half of Texas (possibly some offshore) while most existing hydrogen infrastructure is in eastern half of the state.

Is “Green Hydrogen” our goal or is Decarbonization our Goal?

Let’s look at some ways to make Low/Zero/Negative Carbon Energy

Example of "Blue" H2

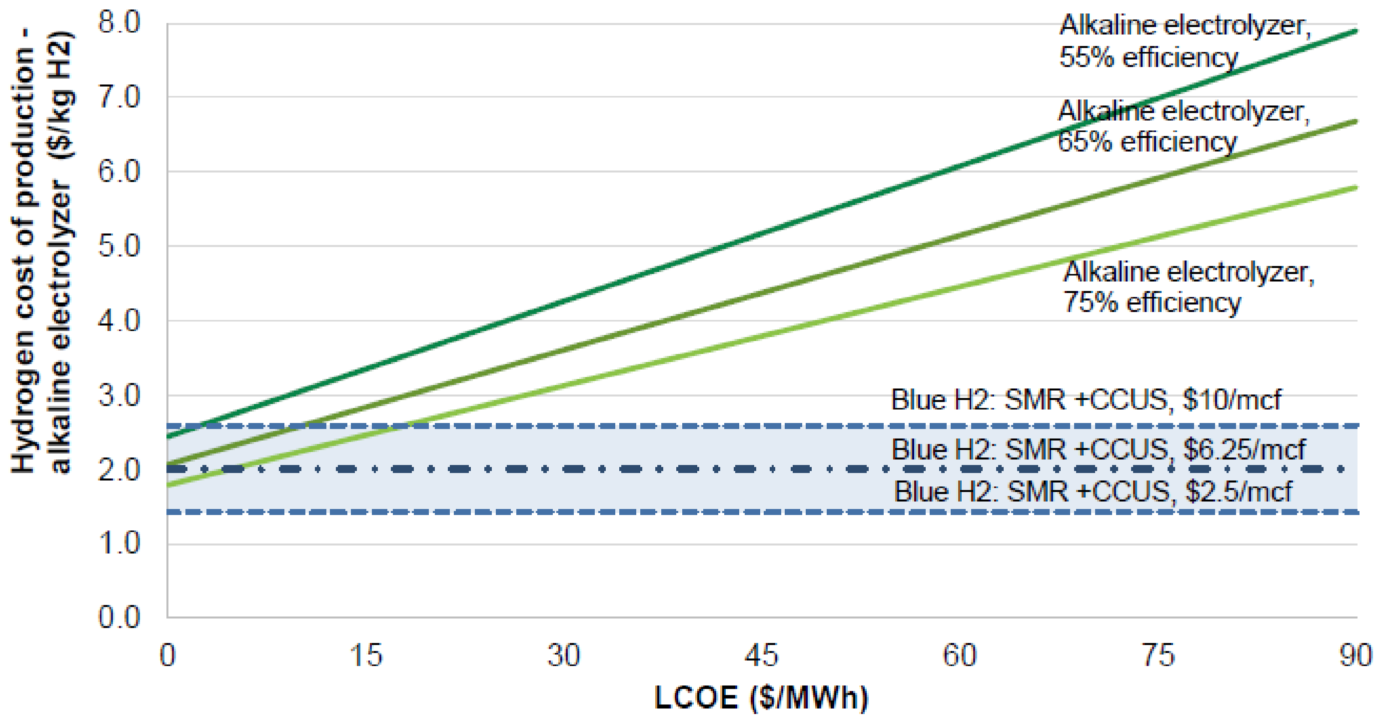
Woody Biomass Gasification



GTI's U-GAS Technology

Blue Hydrogen has a strong cost advantage in the near and medium term

Hydrogen cost of production ($/kg H2) vs LCOE ($/MWh)

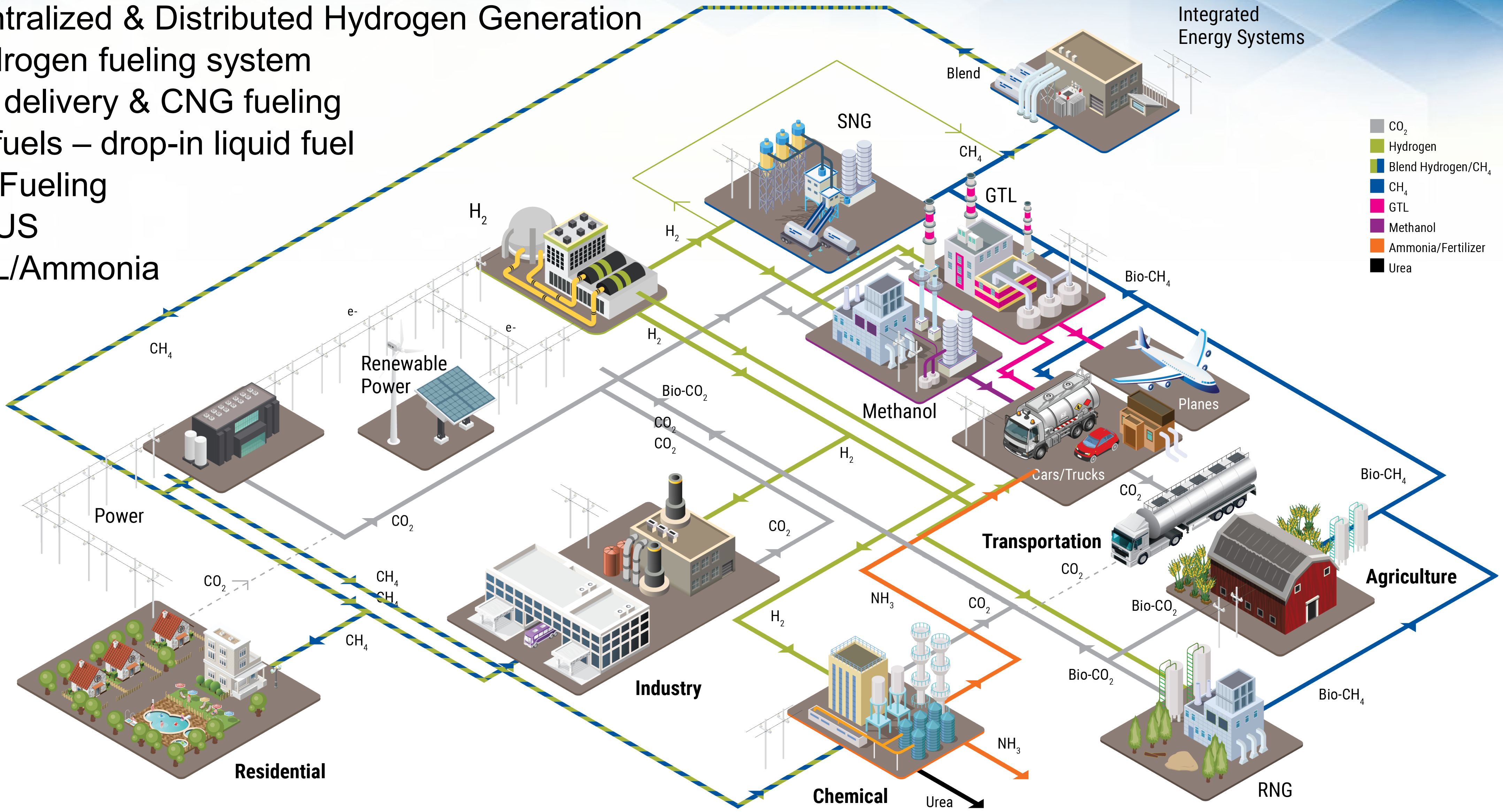


Source: Goldman Sachs Global Investment Research

Hydrogen can move energy across space and time – but we need new transport infrastructure.

- Liquid Organic Hydrogen Carriers (LOHC) in combination with rail car or update of nearby liquid products pipeline to transport to industrial markets
- Ammonia. Conversion of hydrogen to ammonia and transport to both conventional and non-conventional ammonia end use markets,
- Natural Gas Pipeline blending. Injection of hydrogen in nearby natural gas transmission pipeline.
- Liquid hydrogen – on-site cryogenic plant.
- Compressed gaseous hydrogen for nearby vehicle fuel markets or other markets that can utilize hydrogen via tube trailers.
- Other chemical carrier options, including DME or H2O2.

- **Hydrogen – Part of an Integrated Energy System**
  - Centralized & Distributed Hydrogen Generation
  - Hydrogen fueling system
  - NG delivery & CNG fueling
  - Biofuels – drop-in liquid fuel
  - EV Fueling
  - CCUS
  - GTL/Ammonia



12:30 – 1:00 **Hydrogen Storage and Distribution: Infrastructure Development and Coordination**

Gordon Salahor, Wolf Midstream

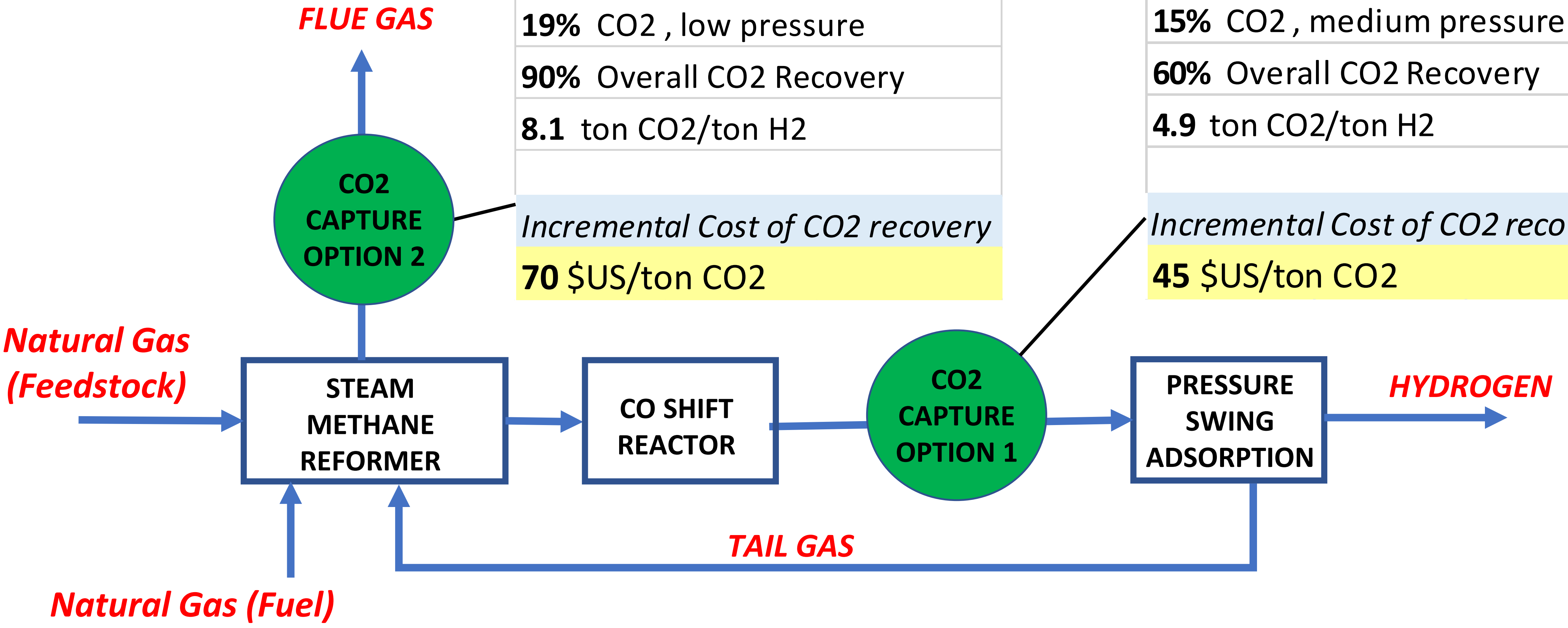
Mark Shuster, Bureau of Economic Geology, UT Austin

Bob Oesterreich, Chart Industries

CO2 CAPTURE OPTIONS IN SMR HYDROGEN PLANT (“BLUE H2”)

CO2 Volume
19% CO2 , low pressure
90% Overall CO2 Recovery
8.1 ton CO2/ton H2
Incremental Cost of CO2 recovery
70 $US/ton CO2

CO2 Volume
15% CO2 , medium pressure
60% Overall CO2 Recovery
4.9 ton CO2/ton H2
Incremental Cost of CO2 recovery
45 $US/ton CO2



Note: CO2 Capture Options 1 and 2 above are separate and mutually exclusive.
Both options include cost of compression of CO2 to 2175 psig
Volume and cost estimates derived from Collodi, Chemical Engineering Transactions, vol 19

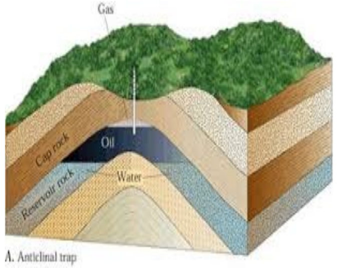
WOLF MIDSTREAM

FIVE REGIONAL ATTRIBUTES TO SUPPORT CO2 CAPTURE /STRG

1. Critical Mass of CO_2 Supply

Clusters of large emitters (industrial, refining/chemicals, power generation)

2. Proximate Geology



Depleted oil reservoirs and/or deep aquifers, suitable for long term secure CO_2 disposition

3. CO2 Transportation Infrastructure

4. Regulatory Framework

i. Defined price on carbon emissions, offsets, or tax credits
ii. Established process for government permitting and oversight of gas injection into geological reservoirs

5. Workforce/Services

Skilled workforce and service equipment (e.g. regional oil and gas industry)

WOLF MIDSTREAM

CO2 PIPELINES – FREQUENTLY *UNASKED* QUESTIONS ANSWERED

- CO2 most efficiently transported in high pressure, **dense phase** (supercritical) “liquid”
- This pressure requires a special (non-standard) design pipe thickness. Generally <u>not</u> efficient or feasible to repurpose typical oil or gas pipelines for CO2.
- Pipelines have a dramatic economy of scale wrt to ***diameter and capacity*** (cost$\propto$radius, hydraulic capacity$\propto$radius^2). This creates a strong economic rationale to aggregate volume (supply and demand clusters, common locations)
- For a given pipe diameter (capacity), the pipeline capital cost and/or resulting transport toll is directly proportional to the length. (minimal economy of scale for *distance*)
- Most existing industrial-scale CO2 pipelines are 50-300 miles in length. Approximate rule of thumb for transport cost in this range would be $10-$20 / ton.
- By comparison, H2 plant CO2 <u>*capture*</u> costs ($45-$70 from previous slide) are multiples higher than transport. (transport cost is usually **not** the main hurdle to CCS from H2)

WOLF MIDSTREAM

Why Geological Storage ?

- *H_2 ~ 1/3 energy of natural gas by volume*
- *Current H_2 storage in US is ~6 Bcf (14,000 tonnes H_2)*
- *Potential H_2 Growth*

H_2 Future Share of Natural Gas Market	Equivalent H_2 Storage Needed*
1 %	94 Bcf
10 %	940 Bcf

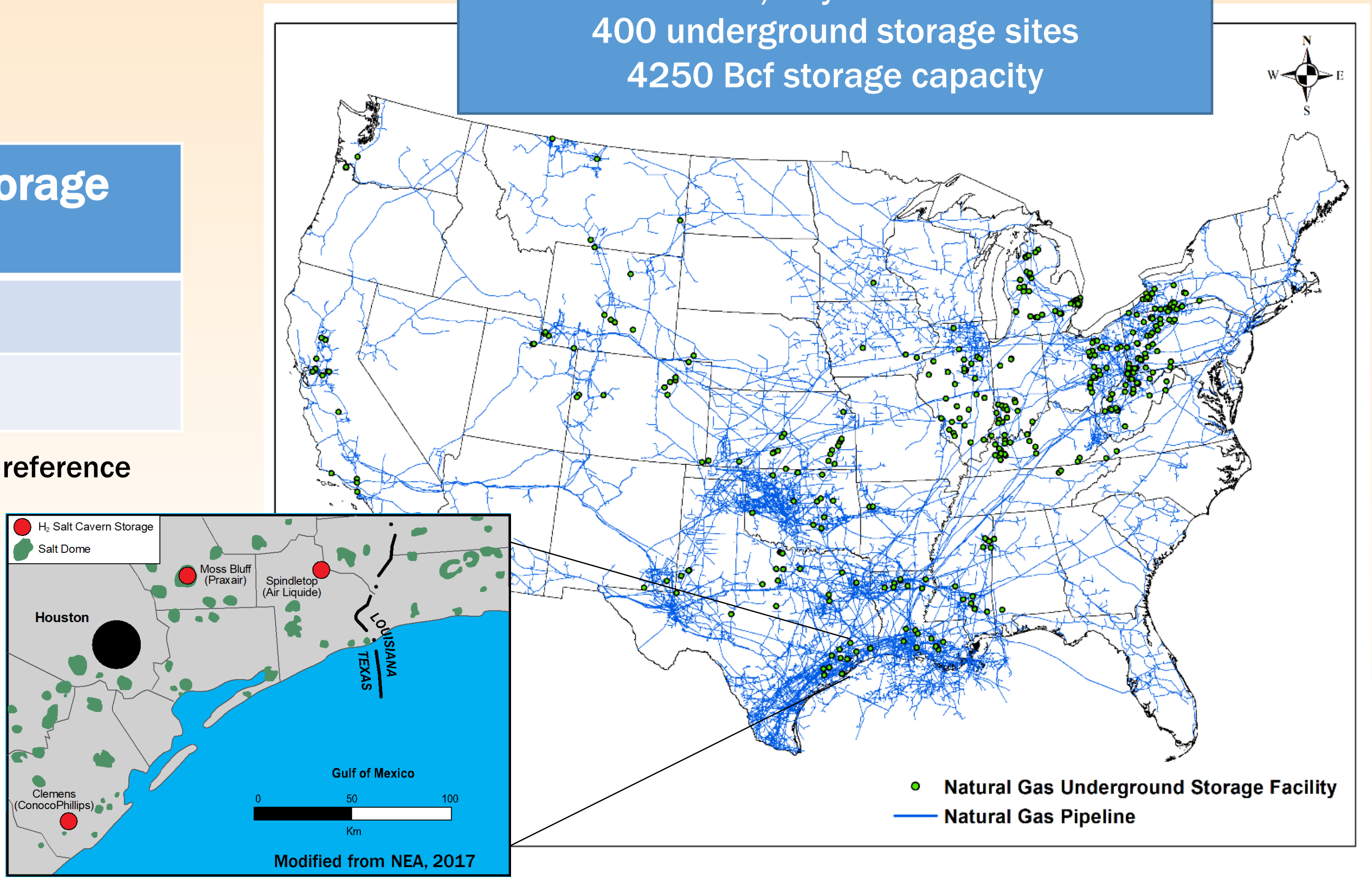
* Assumes 10 % storage/consumption requirement; 2019 NG market reference

Main envisioned application categories of H_2

Industrial	Power backup and balancing	Heavy transportation

United States Natural Gas Storage & Pipeline Infrastructure

US Natural Gas
85 Bcf/day consumed
400 underground storage sites
4250 Bcf storage capacity



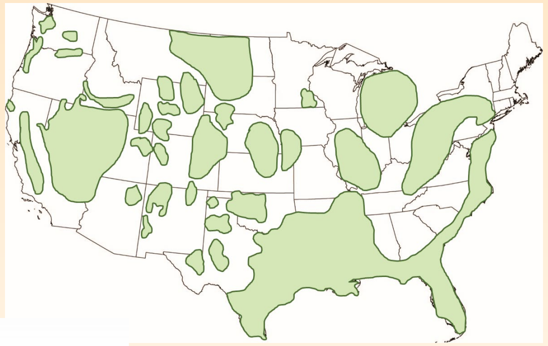
Modified from NEA, 2017

Bureau of Economic Geology

Geological Storage

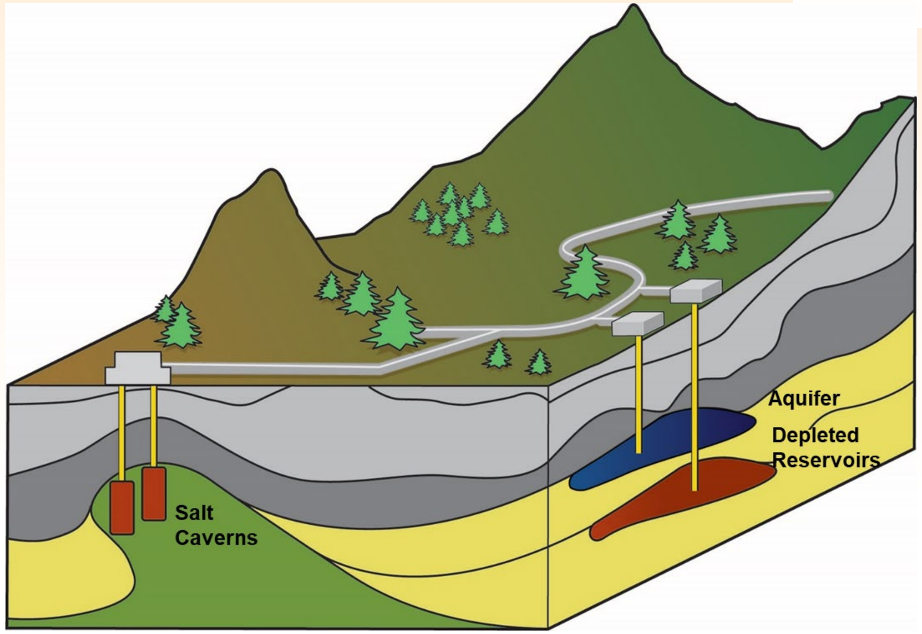
- Geological storage provides options for large (> 1000 tonne H_2) storage sites
- Viable geological storage options include:
  - Dissolution caverns in salt domes
  - Depleted oil & gas fields
  - Saline aquifers
- Geographic coverage important
  - Generation sites
  - End use sites
  - Infrastructure

Sedimentary Basins

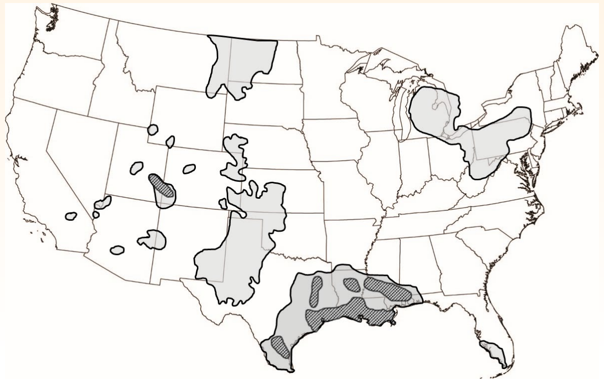


Oil & Gas Producing Areas

Geological Storage



Major Salt Deposits



Diagrams modified from EIA; Lord et al, 2014

Bureau of Economic Geology

Large-scale Geological Storage of H_2 in US

Type	Status	Comments	Research
Salt (dissolution) caverns	3 active H_2 storage sites in Texas for industrial use	• Limited geographic distribution of suitable salt deposits	• Cost/life-cycle analysis • Catalog areas for expanded storage
Depleted oil & gas fields	Untested for H_2 storage (proven for NG)	• Wide geographic distribution • H_2-reservoir interaction is not well understood	• Cost/life-cycle analysis • storage in reservoirs • Chemical reactions • Geomechanics • Pilot field tests of H_2 • Catalog suitable sites
Saline aquifers	Untested for H_2 storage (proven for NG)	• Wide geographic distribution • H_2-reservoir interaction is not well understood • Suitability of sealing caprocks	• Cost/life-cycle analysis • storage in reservoirs • Chemical reactions • Geomechanics • Pilot field tests of H_2 • Catalog suitable sites

Bureau of Economic Geology Hydrogen Working Group:

- Peter Eichhubl, Seyyed Hosseini, JP Nicot, Ian Duncan, Ning Lin, Jay Kipper, Farzam Javadpour, Mark Shuster
- *Large-scale geological storage, H_2 generation, and economics*

BUREAU OF ECONOMIC GEOLOGY

HYDROGEN

WHERE GREEN IS THE NEW BLUE

TX Hydrogen Roundtable January 12, 2021

Bob Oesterreich- VP Global Hydrogen Sales

Cooler By Design.™

Broad Offering of Highly Engineered Cryogenic Equipment

CHART
Cooler By Design.

Brazed Aluminum Heat Exchangers

Cold Boxes

Gas Pre-Treatment and Nitrogen Rejection Units

Specialty Pressure & Heat Transfer Equipment

Air Cooled Heat Exchangers

Axial Flow Fans

Integrated Energy Systems

Lifecycle Services

Cryogenic Bulk Storage Tanks

Vaporizers

Cryogenic Storage & Regasification Systems

Packaged Gas Systems

Cryogenic Launch Umbilicals & Storage

Nitrogen Dosing & Food Preservation

Fueling Stations

HLNG Vehicle Tanks

Cryogenic Transport Trailers

LNG Virtual Pipeline Solutions

LNG by Rail

FEMA Valve Portfolio

Servicing & Repairs

Chart Locations

Sites shown are Chart's operations including those of our recent acquisitions. Global satellite sales officesare not shown.

Europe

D&S East
- Ferox – Decin, CR
- GOFA –Germany
- Flow – Germany
- VCT Vogel – Germany
- VRV – Italy
- VRV/Cryo Diffusion –France

E&C
- VRV – Italy
- IMB – Italy
- Hudson/Cofimco – Italy

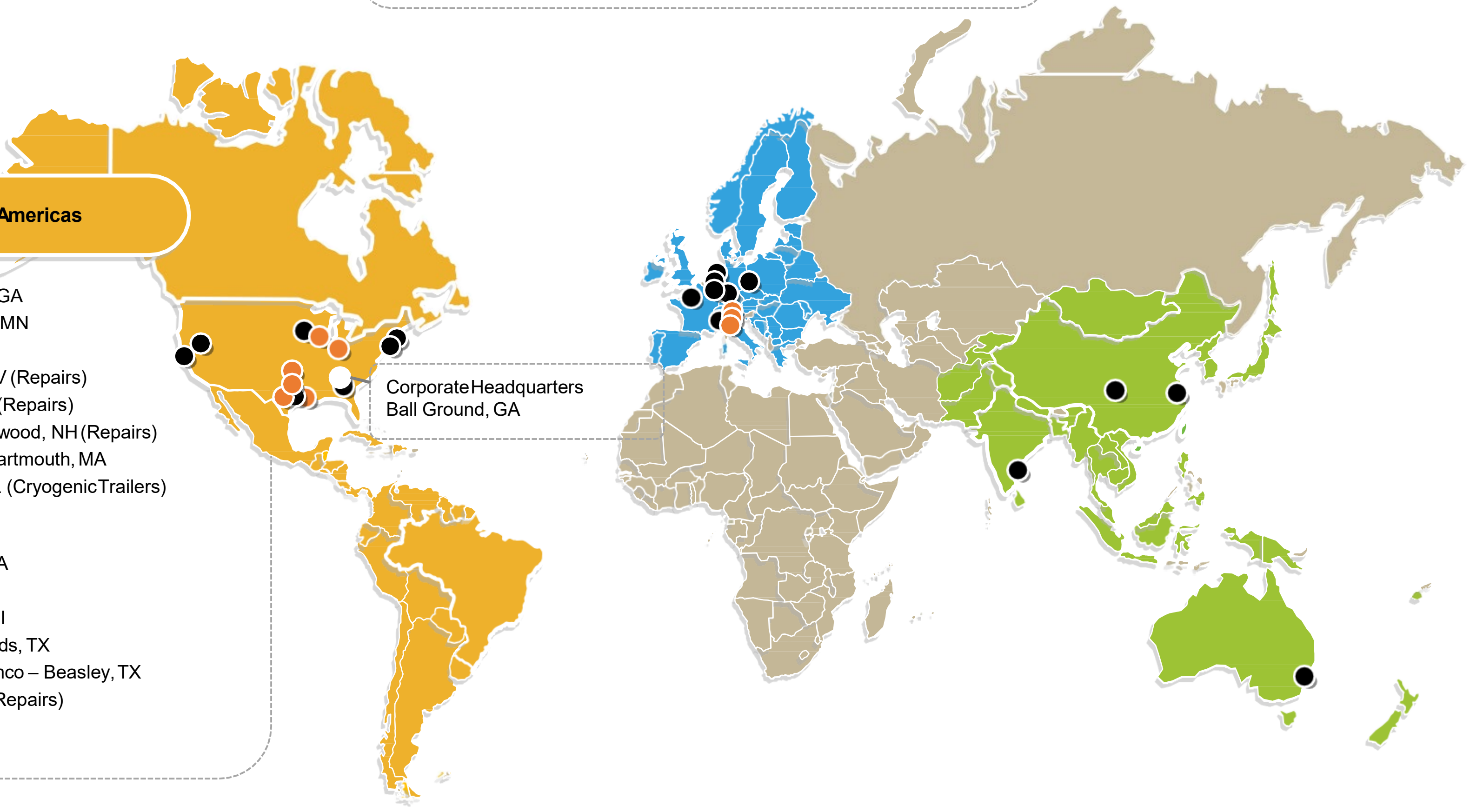
Asia-Pacific

D&S East
- Changzhou, China
- VRV – India
- Australia

Americas

D&S West
- Ball Ground, GA
- New Prague, MN
- Fremont, CA
- McCarran, NV (Repairs)
- Houston, TX (Repairs)
- Skaff – Brentwood, NH (Repairs)
- Thermax – Dartmouth, MA
- Theodore, AL (Cryogenic Trailers)

E&C
- New Iberia, LA
- Tulsa, OK
- La Crosse, WI
- The Woodlands, TX
- Hudson/Cofimco – Beasley, TX
- Franklin, IN (Repairs)



Where We Play In the Hydrogen Supply Chain

CHART
Cooler By Design.

Indicates recently completed or announced investments, commercial partnership and acquisitions

CHART

McPhy

Electrolysis

PRODUCTION

Gasification/ Reformation

Liquefaction

Including Large Cryogenic Storage, BAHX, Load-Out Systems

Distribution

WORTHINGTON INDUSTRIES

Liquid Transport Trailers, ISO Containers, Rail Cars, Marine Transport

Storage

Cryogenic Liquid Tanks

Equipment used by end customers

Electricity Generation

Vehicle Fuel Stations

Ammonia production (fertilizers)

Fueling Systems for Aerospace

Refining

Electronics Manufacturing

Marine Fuel

Key Components Integrated within Systems

Pumps and Compressors	Regulators
Flowmeters	Sensors
Vacuum Insulated Piping	High Pressure Storage
Valves and Sealing Connections	

HTEC
Hydrogen Technology & Energy Corporation

PLUG POWER

FIRSTELEMENT FUEL

Users of Hydrogen (Examples)

ULA
America's Ride to Space

BLUE ORIGIN

Thank you!

1:00 – 1:30 **Hydrogen Applications in Transportation and Power Generation**

***Nakul Prasad*,** Siemens

***Ricky Sakai*,** Mitsubishi Heavy Industries

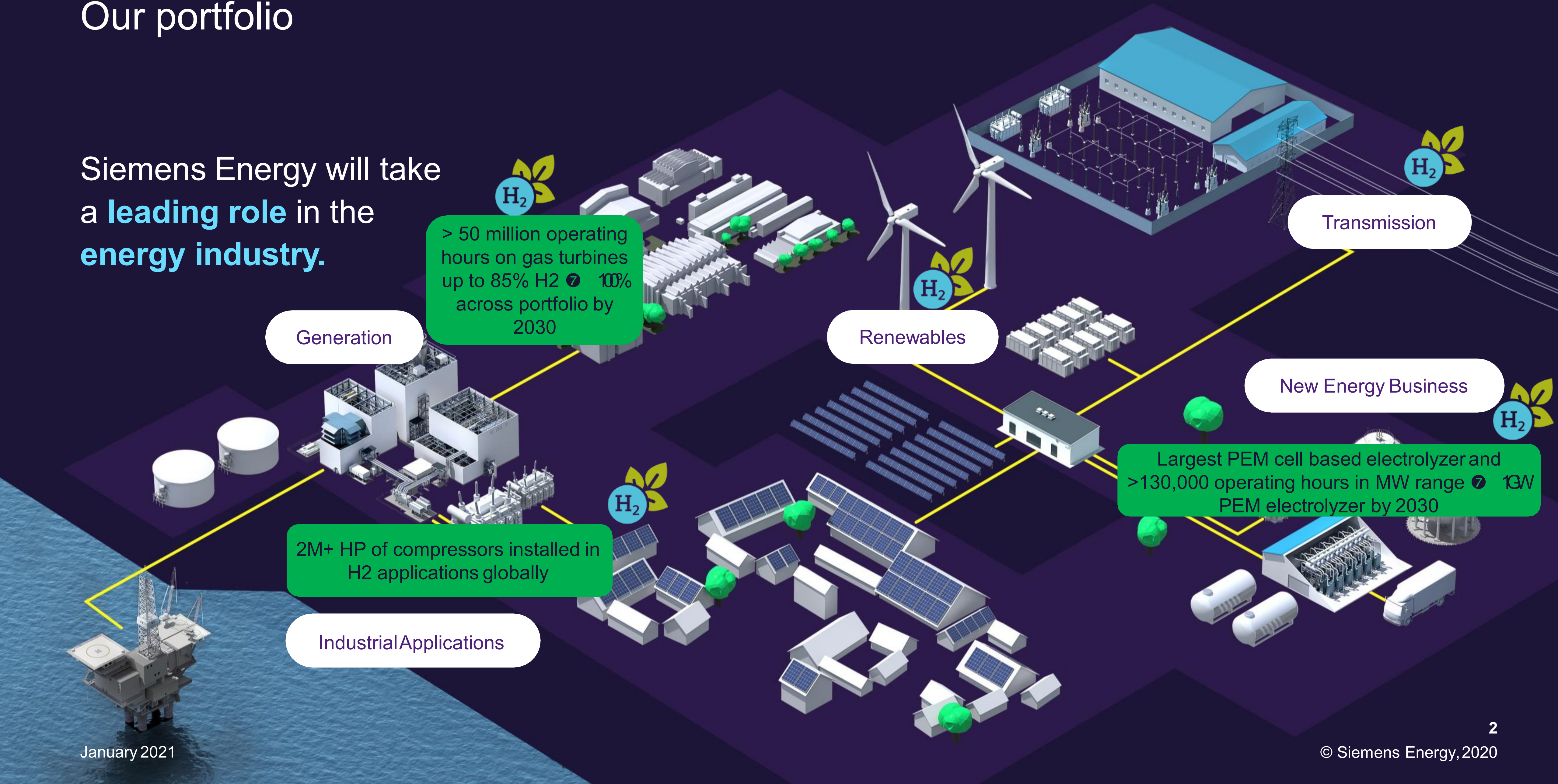
***Ed Young*,** Toyota

Hydrogen in the energy industry

Dr. Vinayaka Nakul Prasad
Corporate Strategy Manager

The entire energy value chain
Our portfolio

Siemens Energy will take a **leading role** in the **energy industry.**



Silyzer portfolio scales up by factor 10 every 4-5 years driven by market demand and co-developed with our customers

SIEMENS energy

Silyzer portfolio roadmap

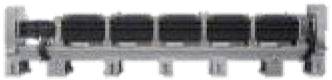
0.1 MW | 1 MW | 10 MW | 100 MW | 1000 MW

2011

Silyzer 100
Lab-scale demo
~4.500 OH[1]
~150k Nm³ of H_2

2015

Silyzer 200
~86.500 OH [1)]
~7.3 mil. Nm³ of H_2



World's largest Power-to-Gas plants with PEM electrolyzers in 2015 and 2017 built by Siemens!

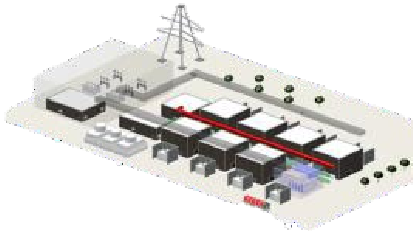
2018

Silyzer 300

Biggest PEM cell in the world built by Siemens!

2023+

Next generation
Under development



2030+

First investigations in cooperation with chemical industry

1) Operating Hours; Data OH & Nm³ as of Dec 2019

What can Siemens Energy offer to the P2X customers?
Siemens Energy competence along the value chain

Siemens Energy covers important parts of the value chain to deliver Power-to-X projects on turnkey basis

Planning & Consulting | Financing | Components and Equipment: Renewable Power | Grid Connection | Electrolysis | PtL-/PtG-Equipment | CO_2 / N_2 Supply | Synthesis

Solution provider for Power-to-liquids (i.e. Methanol)

- One face to the customer
- Overall system design
- Integration of Siemens products and technology & products from external partners

Wind Park

- Onshore wind
- Offshore wind

Siem.-Gamesa

Photovoltaics

- Solar Fields/ Storage Systems

External Sourcing

Power Grid

- Transmission
- Distribution
- Substations
- Transformers
- Power cable systems

Electrolysis

PEM technology

Silyzer 300

Machinery

- Compressors
- Storage systems
- Water treatment
- Elec. equipment
- Mech. equipment
- Turbines/engines (back up power)

CO_2 Capture

- Capture from flue gas (PostCap)
- DAC: external

N_2 Supply

- Air separation: external

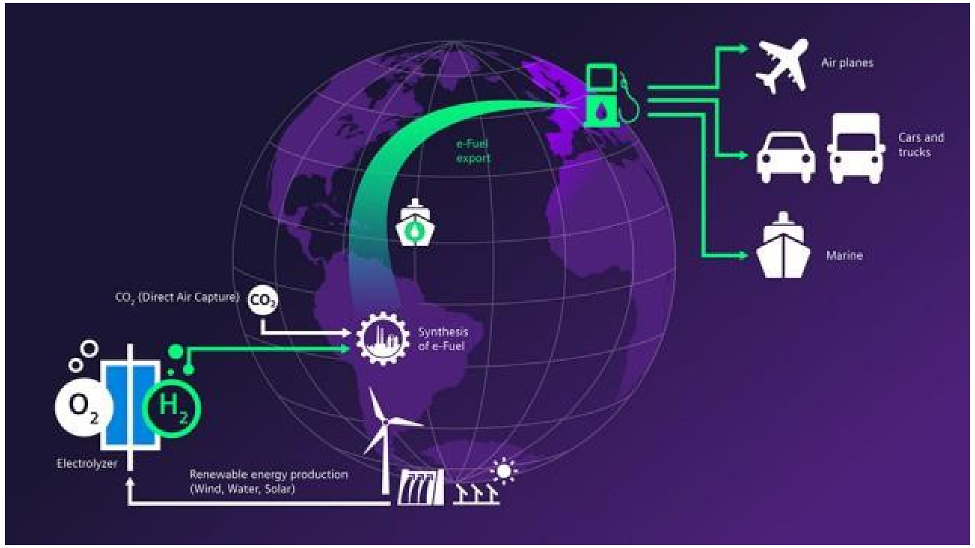
Synthesis

- Partnering
  - CH3OH
  - CH4
  - NH3
- Own concepts
- Novel, flexible methanol reactor concept in R&D stage

BoP

DAC: Direct air capture: Under development; no Siemens Energy activities | **CCU:** Carbon Capture and Utilization | typical share in value addition

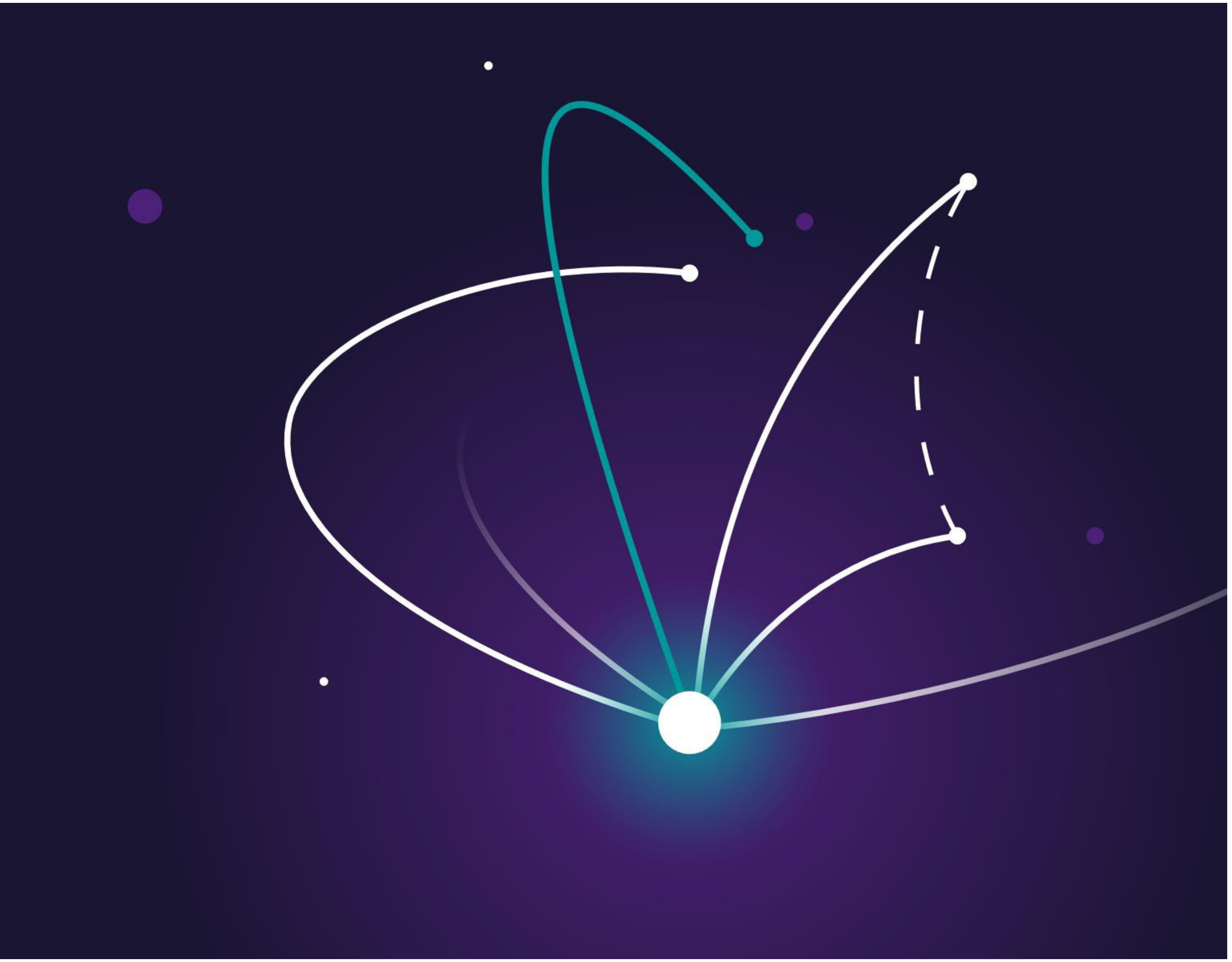
Haru Oni – Hydrogen based supply chain of renewable energy from Chile to Europe



https://www.siemens-energy.com/global/en/offerings/renewable-energy/hydrogen-solutions/haru-oni.html

https://newsroom.porsche.com/en/2020/company/porsche-siemens-energy-pilot-project-chile-research-development-synthetic-fuels-efuels-23021.html

Contact page



Published by Siemens Energy

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MHI Group Capabilities around Hydrogen

MITSUBISHI HEAVY INDUSTRIES

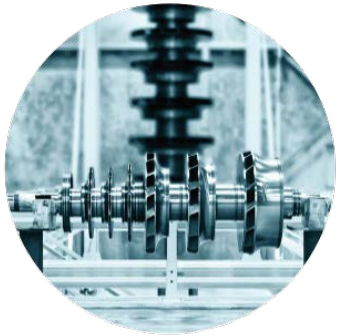
The MHI Group has a vast range of technologies and end-to-end solutions for hydrogen value chain

Production → **Transportation** → **Demand**

Gasification Plants

CO_2 Capture Plants

Offshore Wind Turbines



Compressors/Pump

Ammonia & Methanol Co-production Plants

Gas Carriers

Hydrogen Gas Turbines

Hybrid Fuel Cell

Hydrogen Gas Engine

Steel Making (DRI Process)

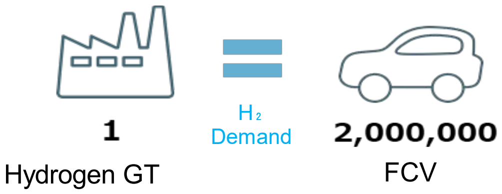
Rocket

Expanding this value chain by R&D activities and partnership initiative

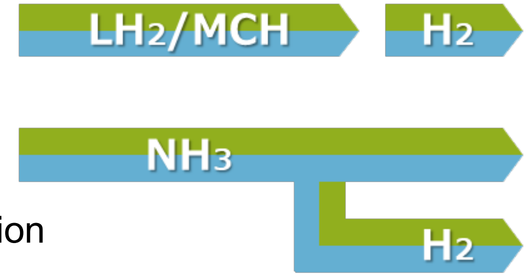
World's most advanced Hydrogen combustion technology

Hydrogen GT

- **Saving Investment Costs**
  Can be applied to existing power plant facilities with minimum modifications
- **Stimulate Large-scale Hydrogen Demand**
  Expansion of hydrogen supply chain and reduction of costs



- **Carrier Flexibility**
  Low purity hydrogen is usable and can be transported with any carrier
- **Power Output range**
  40 – 430 MW (60 Hz)
- **Timeline**
  2018 Achieve 30% H_2 Co-combustion
  2025 Achieve 100% H_2 Combustion



Fuel Cell (SOFC)

- Multi-fuel capability (hydrogen, natural gas biogas, etc.)
- Rated Output：200kW～1MW
- Power Generation Efficiency: 53%
- Overall Efficiency: 73%（when supplying hot water）
- Can be applied to SOEC (hydrogen production)

MHI group has been actively developing Green and Blue Hydrogen/Ammonia projects in US, Europe and Asia Pacific

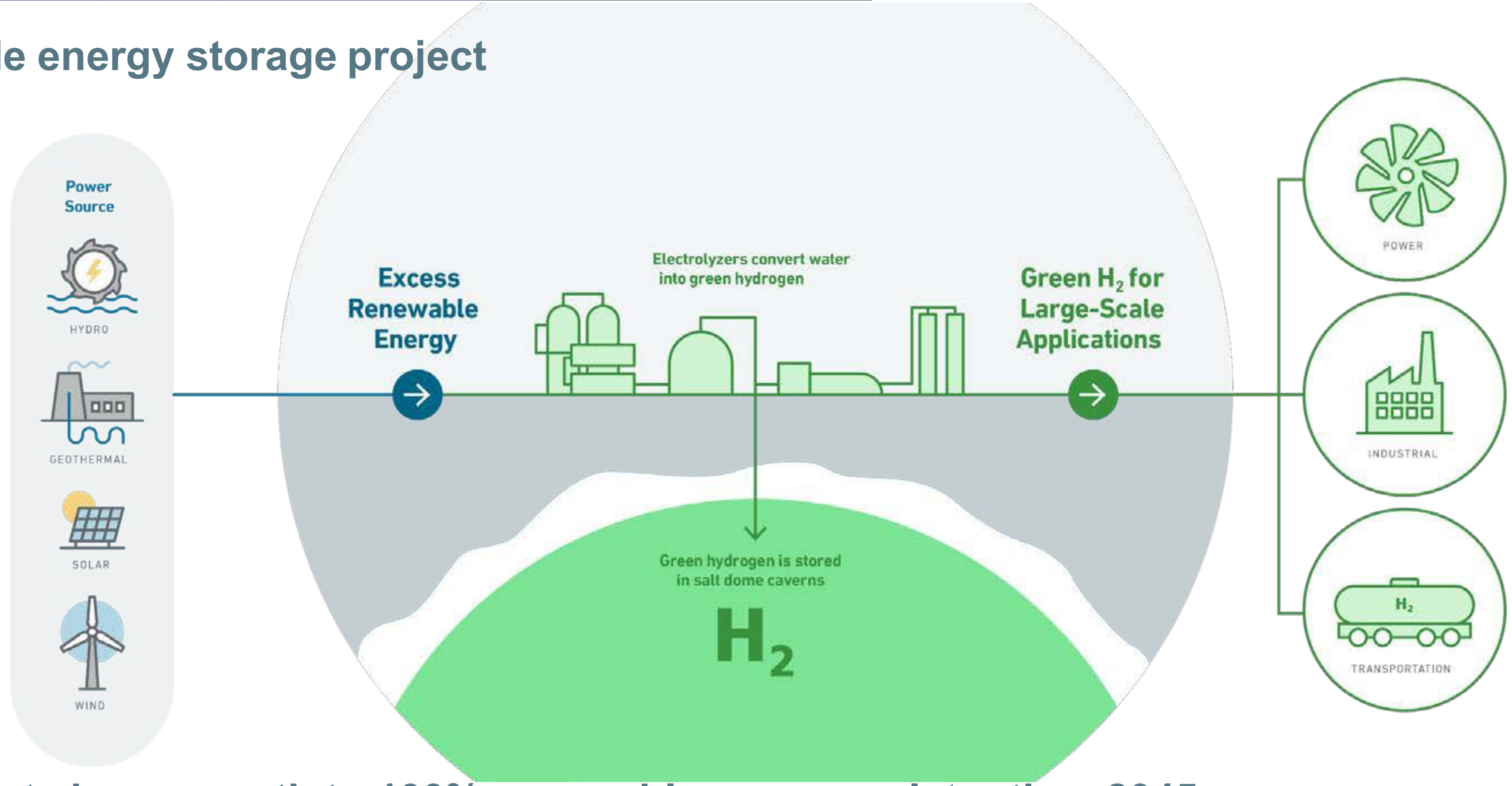
US: Advanced Clean Energy Storage Project & Intermountain Power Plant

The world's largest renewable energy storage project

Storage Capacity	150 GWh
Location	Utah, USA

Technology for Renewable-Hydrogen Energy Hub

Gas Turbine Model	M501JAC
Power Output	840 MW (by 2 CCGT)



This utility-scale project shows a path to 100% renewable power no later than 2045.

1:45 – 2:15 **Industrial Applications and Opportunities for Hydrogen**

Brett Perlman, Center for Houston's Future

Jack Broodo, Dow

Tristan Aspray, ExxonMobil

Industrial Applications for Hydrogen

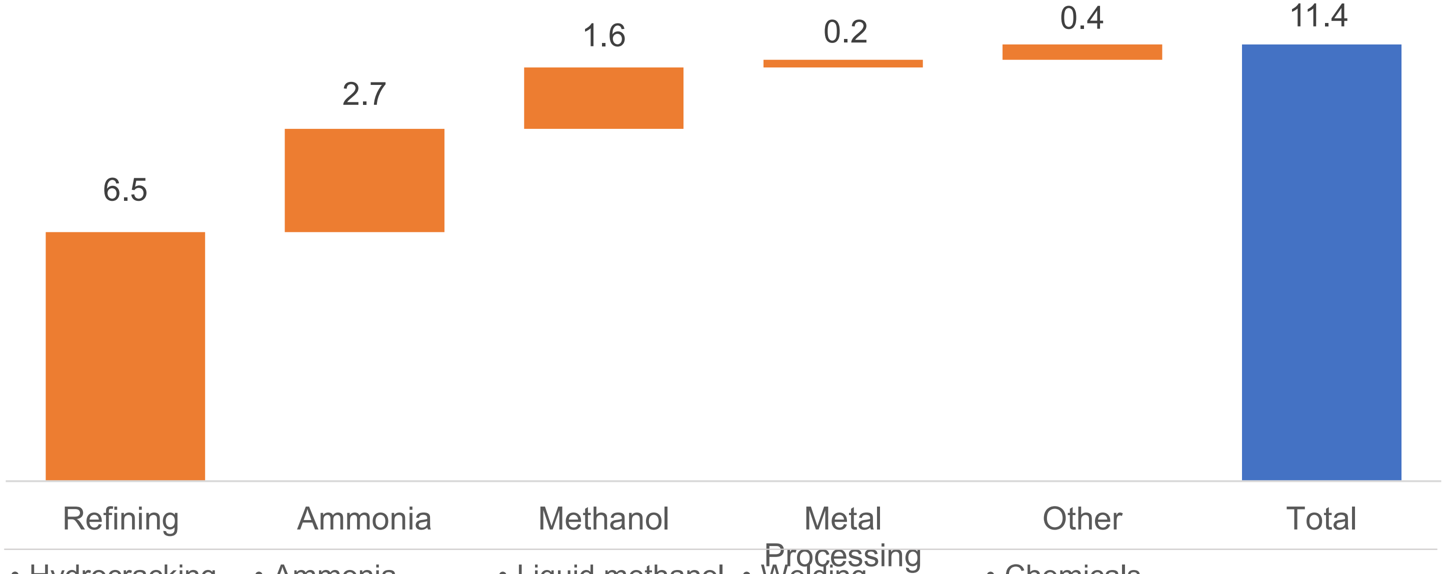
CENTER FOR HOUSTON'S FUTURE

Industrial Applications for Hydrogen – Key Conclusions

- **Substantial Industrial Applications Market Opportunity for Hydrogen**: Potential available industrial market for hydrogen is over 4x the current industrial market and will likely exceed the potential available market for energy storage, renewable natural gas and transportation
- **From Feedstocks to Fuels and New Integrated Processes:** While hydrogen is used primarily today as a feedstock in oil refining and chemicals manufacturing, it is likely to have applications in the future as a zero or low carbon industrial fuel or as an input into integrated manufacturing processes (such as steel manufacturing).
- **New Applications Considered "Hard to Abate":** While hydrogen can be a drop-in fuel replacement for coal or natural gas in some applications (like aluminum or glass), larger opportunities in cement and steel will require an entire manufacturing process re-design.
- **Gulf Coast Well Positioned as an Industrial "Hydrogen Hub":** Given the presence of industrial manufacturing facilities and hydrogen production, the Gulf Coast is well positioned to become a hydrogen hub. It could even attract new industries, such as a decarbonized steel industry.

Current Industrial Applications for Hydrogen

Total hydrogen use in U.S.
Million metric tons per year



Refining
- Hydrocracking
- Hydrotreating (such as desulfurization of petroleum)
- Refining of biomass/biogas

Ammonia
- Ammonia production
- Ammonia derivatives (such as urea/ fertilizer)

Methanol
- Liquid methanol fuel
- Chemical derivative production from methanol

Metal Processing
- Welding
- Heat treatment of steel
- Glass production
- Forming and blanketing of gas

Other
- Chemicals (polymers, other petrochemicals)
- Float glass
- Rocket fuel
- Electronics (semiconductors)
- Hydrogeneration of liquid fuels

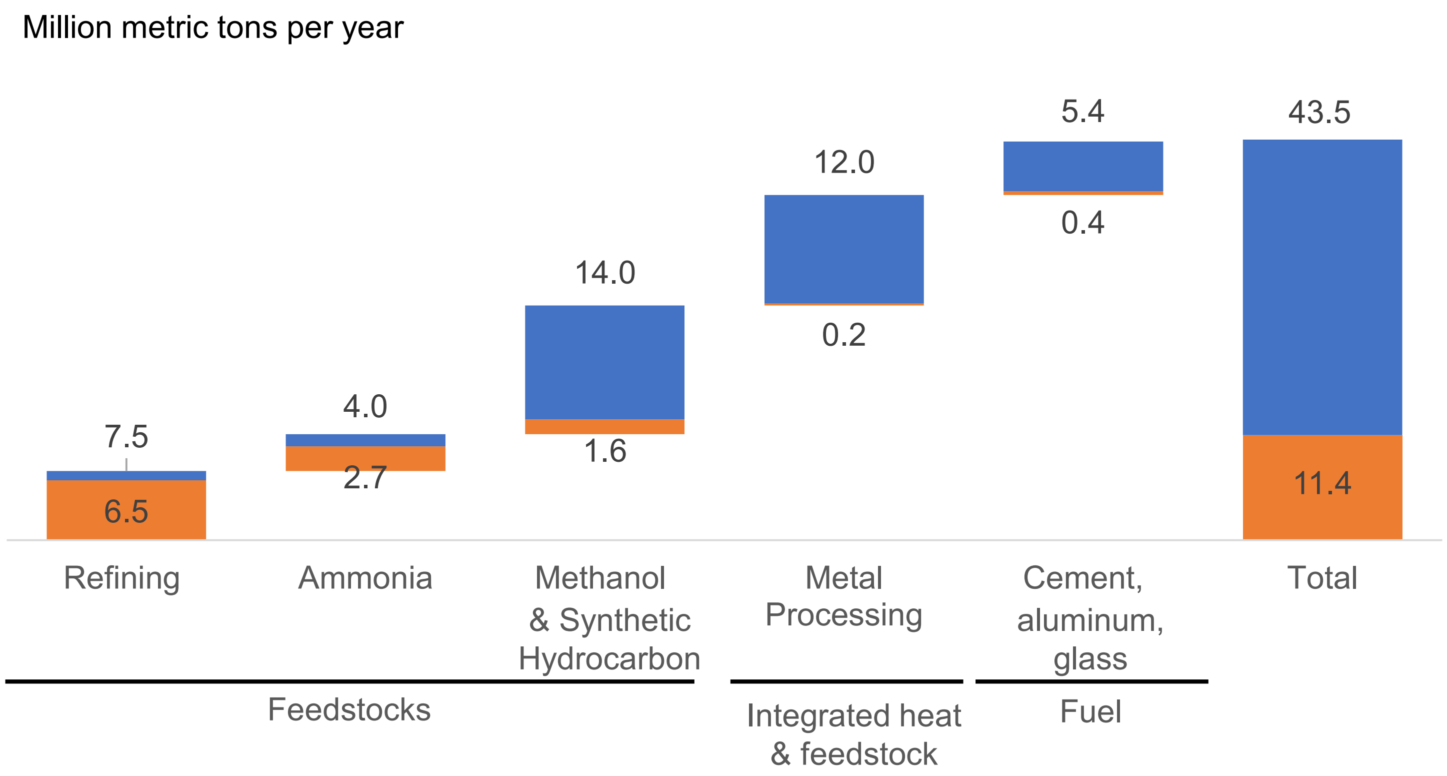
Source: Roadmap to a U.S. Hydrogen Economy, Fuel Cell and Hydrogen Energy Association

Hydrogen’s Role in Industrial Decarbonization Strategies

Target	Type	Decarbonation Strategies	Rationale
Fuel (e.g. industrial high temperature heat application)	Cement	Hydrogen or CCUS	• Hydrogen could substitute for fossil fuels to reduce heat emissions • CCUS could capture post combustion emissions
	Aluminum	Use hydrogen for aluminum recycling	• Substitute hydrogen for natural gas on recycling operations
	Glass	Use hydrogen as a fuel for glassmaking	• Substitute hydrogen for natural gas on recycling operations
Integrated Heat and Feedstocks (e.g. Steel and Iron Production)	Blast Furnace – Basic Oxygen Furnace	Hydrogen inappropriate given the role of coal in the process	• N/A
	Direct Reduction/Arc Furnace	Green or Blue Hydrogen	• Decarbonized hydrogen can reduce emissions from natural gas or coal
Feedstocks: Oil and Chemical Production	Oil Refining	Blue (SMR + CCUS) or Green	• Decarbonize existing oil refining processes
	Ammonia Production	Blue (SMR + CCUS) or Green	• Substitute low carbon hydrogen for gray hydrogen
	Methanol Production	Low benefit	• Emissions are retained during the production process
	Synthetic Hydrogen	Hydrocarbon methanol to gasoline	• React hydrogen & CO_2

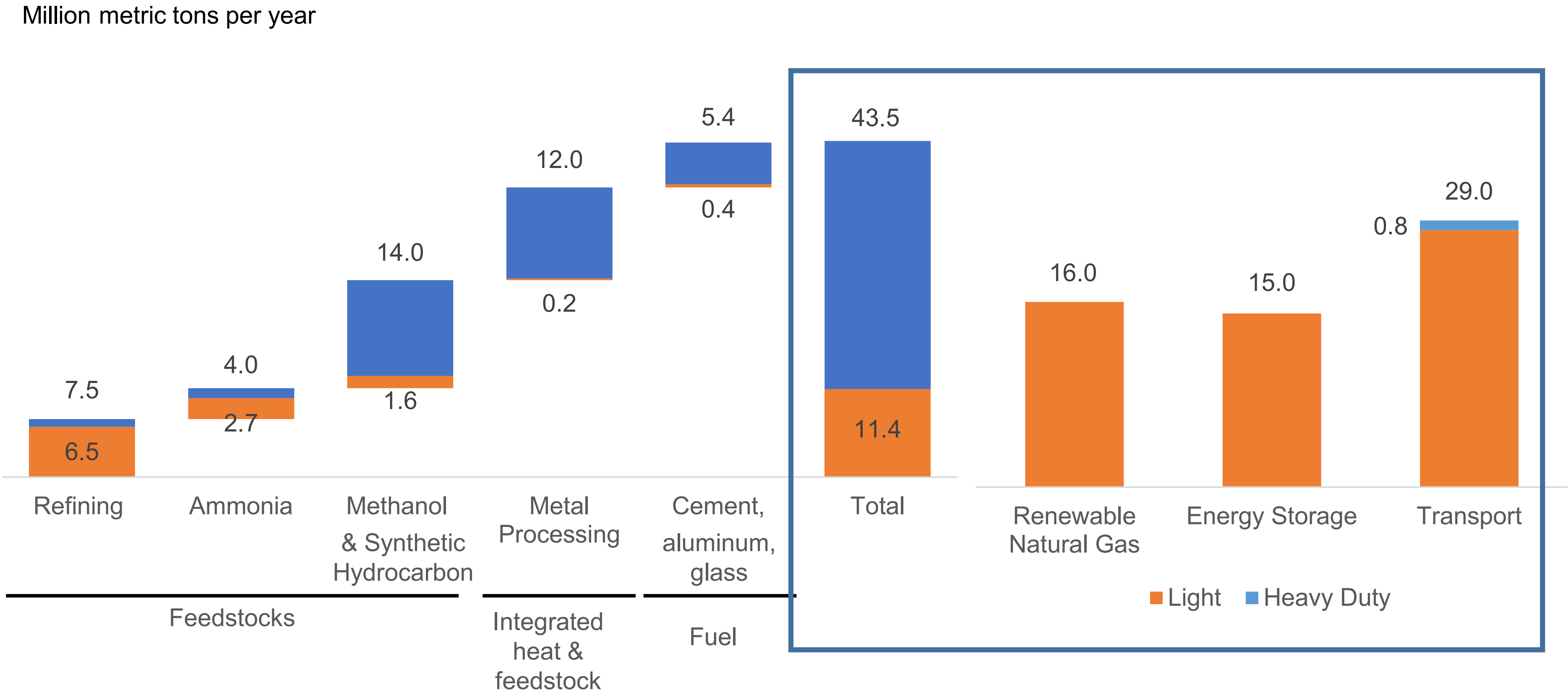
Source: Roadmap to a U.S. Hydrogen Economy, Fuel Cell and Hydrogen Energy Association , NREC, Technical & Economic Potential, H2@Scale; RFF Decarbonized Hydrogen in the US Power & Industrial Sectors

Serviceable Consumption Potential for Industrial Applications for Hydrogen



Source: Roadmap to a U.S. Hydrogen Economy, Fuel Cell and Hydrogen Energy Association , NREC, Technical & Economic Potential, H2@Scale; RFF Decarbonized Hydrogen in the US Power & Industrial Sectors

Industrial Markets vs. Other Markets for Hydrogen



Source: Roadmap to a U.S. Hydrogen Economy, Fuel Cell and Hydrogen Energy Association , NREC, Technical & Economic Potential, H2@Scale; RFF Decarbonized Hydrogen in the US Power & Industrial Sectors

Locations for Serviceable Consumption for Industrial Hydrogen Applications

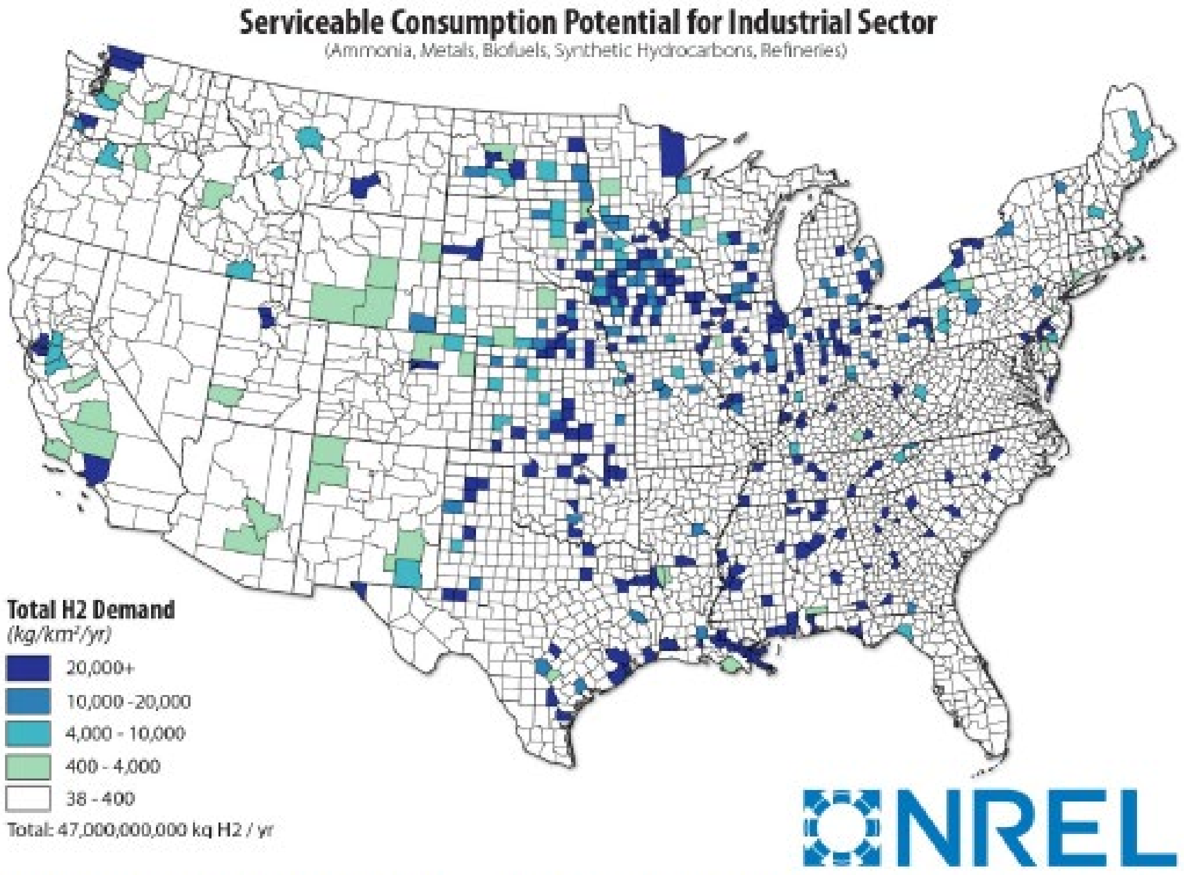


Figure 18. Locations of aggregated serviceable consumption potentials for industrial hydrogen applications

Industrial applications include oil refining, metals refining, ammonia, biofuels, and synthetic HC.

The University of Texas at Austin
Energy Institute

2:15 – 2:30 **Preparing Texas for a Hydrogen Future: Concluding Remarks and Next Steps**

Varun Rai, Energy Institute, UT Austin

Bob Hebner, Center for Electromechanics, UT Austin