



# Demonstration and Framework for H2@Scale in Texas and Beyond

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DOE Hydrogen Program

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# Project Goals

- Determine how hydrogen production costs can be minimized by using multiple generation sources with a baseload stationary power generation application co-located with hydrogen vehicle fueling. The goal is to achieve a pathway for \$4/kg-H<sub>2</sub> delivered to vehicles (production, delivery, compression, dispensing).
- Develop a 5-year plan (“framework”) for the Port of Houston/Gulf Coast region that expands existing hydrogen generation, distribution, and infrastructure assets to enable the deployment of hydrogen-based stationary power and transportation applications. The plan summarizes opportunities, challenges, and partners, and characterizes the economic and environmental benefits of at-scale hydrogen deployment for the region.

# Overview

## Timeline

- Project Start Date: 10/1/2019
- Project End Date: 7/31/2025\*

\* Pending DOE approval

## Budget

- Total Project Budget: \$11,882,947
  - Total Recipient Share: \$5,943,272
  - Total Federal Share: \$5,939,675
  - Total DOE Funds Spent:\*\* \$3,698,419
  - Total Cost Share Funds Spent:\*\* \$4,855,240

(\*\*As of 12/31/2023)

## Barriers

- Hydrogen and fuel cell technologies need to be demonstrated in complete, integrated systems operating under real-world conditions
- There is a high investment risk for developing H<sub>2</sub> delivery infrastructure, given the current absence of demand for hydrogen from the transportation sector

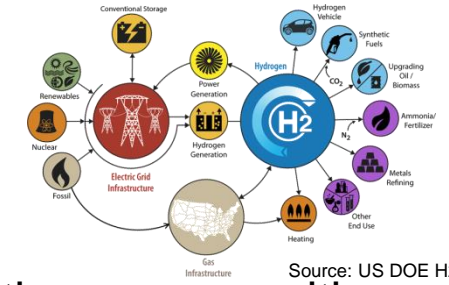
## Partners

- Air Liquide
- CenterPoint Energy
- Chart Industries
- Chevron
- ConocoPhillips
- Frontier Energy
- GTI Energy
- Hitachi Energy
- Low-Carbon Resources Initiative
- McDermott
- Mitsubishi Heavy Industries America
- OneH2
- ONE Gas
- ONEOK
- Shell
- SoCalGas
- TCEQ
- Toyota
- University of Texas at Austin
- WM

# Relevance/Potential Impact

## Objectives in support of US DOE H2@Scale vision

- Determine how hydrogen production costs can be minimized by using multiple generation sources with a baseload stationary power generation application co-located with hydrogen vehicle fueling
- Develop a 5-year plan for the Port Houston/Gulf Coast region that considers existing hydrogen generation, distribution, and infrastructure assets to enable the deployment of stationary fuel cell power and hydrogen-fueled vehicles



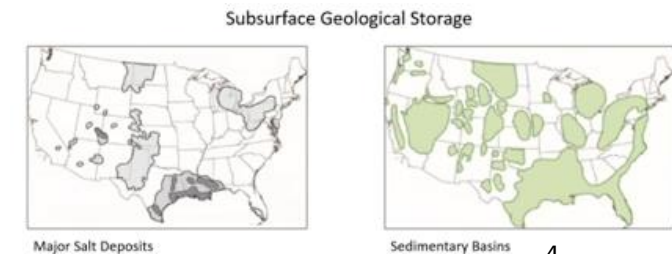
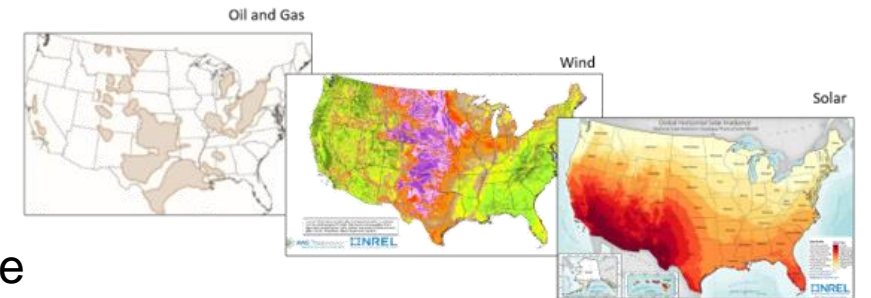
Source: US DOE H2@Scale

## Texas positioned to grow H<sub>2</sub> production for a sustainable energy system

- Regional development of H<sub>2</sub> infrastructure and end-use technologies could enable economies of scale, making hydrogen more affordable
- Existing and growing resources of RNG, solar- and wind-power with currently limited use for H<sub>2</sub> production
- Largest H<sub>2</sub> producer in the nation with existing supporting infrastructure and experienced workforce
- High emissions reduction potential using H<sub>2</sub> in current and emerging industries relying on conventional energy with direct benefits for adjacent communities



Data Source: IHS Chemical Economics Handbook Hydrogen Report, June 2015  
NREL



Source maps: NREL

# Approach

Two complementary RD&D tracks to understand the potential of integrating hydrogen with multiple co-located platforms and existing resources

1. Conduct integrated demonstration of four renewable H<sub>2</sub> generation units co-located with three end uses—stationary power (data center), light-duty FCEV, and an FC drone fueling trailer—for cost-effective H<sub>2</sub> energy solutions at a UT–Austin research campus
2. Develop framework for actionable infrastructure build-out in Texas, starting in Port Houston and Gulf Coast region, through stakeholder workshops and economic modeling

Anticipated month/quarter	Milestone/deliverable	Status (3/15/24)
M3 / Q1	Project Management Plan is complete and submitted	100%
M9 / Q3	Data center fuel cell power system models complete and validated with existing data	100%
M6 / Q2	Equipment engineering design plans complete and submitted	100%
M18 / Q6	Preliminary technoeconomic models completed with path identified for competitive hydrogen fuel, site plans approved, and initial construction commenced (Go/No-Go)	Completed
M27 / Q9	Draft H2@Scale opportunity feasibility study completed	Completed
M30 / Q10	Fuel cell power system is operational	Construction done; awaiting commissioning
M33 / Q11	Hydrogen generation and fueling systems operational	Construction finished; in commissioning
M36 / Q12	Initial demonstration activities have commenced with all systems operational and H2@Scale Port Houston/Gulf Coast framework report completed (Go/No-Go)	Framework report and demo construction done; site in commissioning
M39-53 / Q13-17	Data portal online for the demonstration	In development
M42-54 / Q14-18	Data center and fuel cell use with solar power	
M45-57 / Q15-19	Data center and fuel cell use with emulated wind power	
M48-60 / Q16-20	Cost-effective hydrogen with multiple sources for fueling vehicles co-located with baseload stationary fuel cell power user (End goal)	

# Approach - Integrated H<sub>2</sub> Demonstration

## Renewable H<sub>2</sub> generation

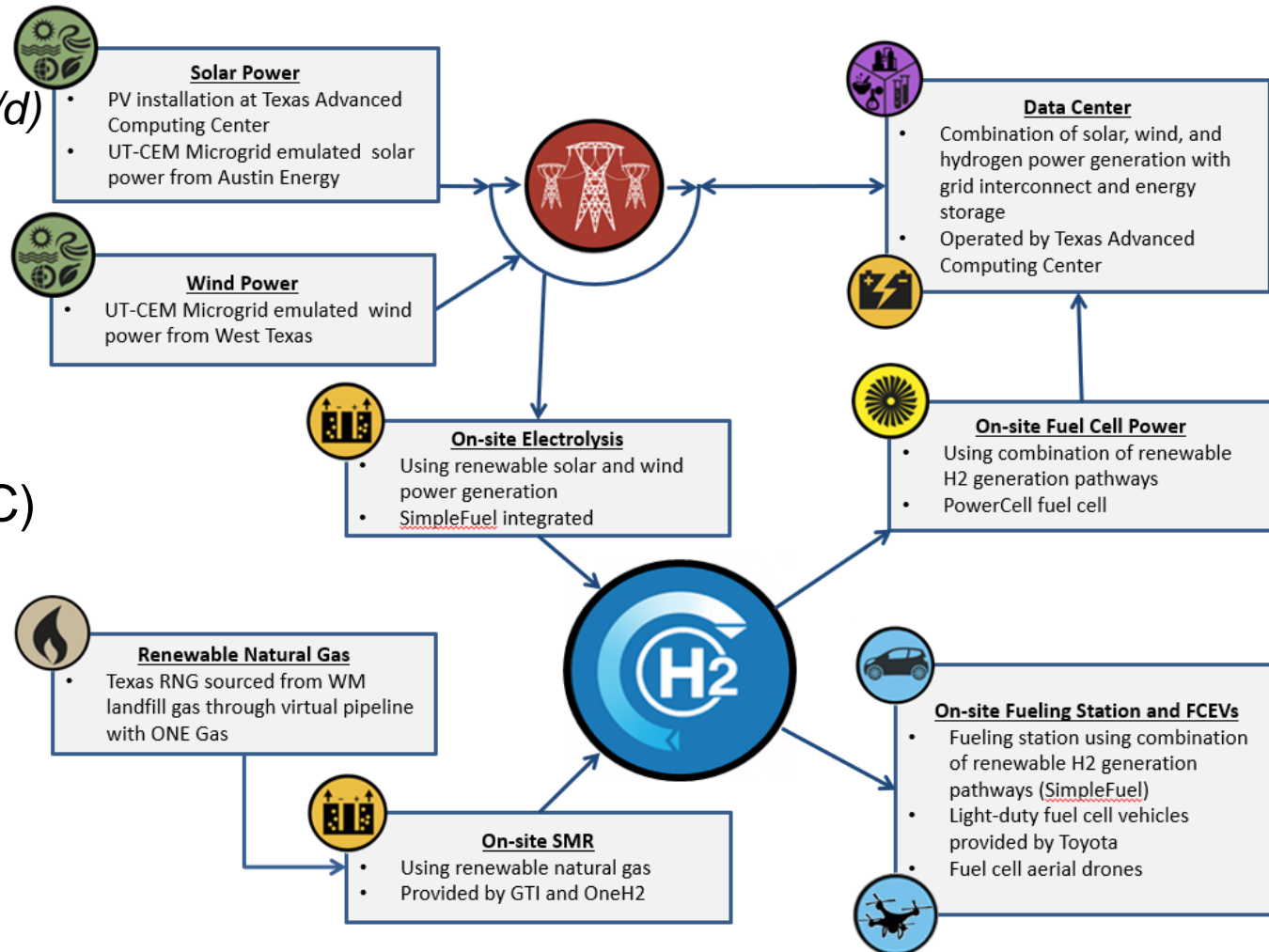
- Two SMR units using landfill RNG (~75 kg/d)
- Two electrolysis units using solar PV and wind power (2 x 20 kg/d)
  - Solar and emulated wind power from real assets

## Baseload stationary H<sub>2</sub> user

- 100 kW PEM fuel cell powering the Texas Advanced Computing Center (TACC)

## Mobility FC fueling

- Light-duty vehicles using WIP SAE J2601/4 fill
- Drone fueling trailer



# Approach - Planning and Safety Culture

## Hydrogen Safety Panel review

- HSP review (Rev 1) of project safety plan received August 2023; all elements “adequately addressed”
- Project team addressed HSP comments on draft plan, third-party risk consultant report, HAZOPs
- Submitted plan was project’s internal version 12, indicating an approach of continuous improvement; refinements expected to continue during operation

## Univ. of Texas Fire Marshal

- Project team met with UT Fire Marshal’s staff to review site safety and design for flame detectors/camera and panel tied to UT’s central fire response and Austin FD

## Work practices in Texas summer 2023 heat wave

- Interconnecting components pre-assembled in air-conditioned warehouse
- Outdoor work shifted to earlier in day, with ample water bottles supplies in work areas

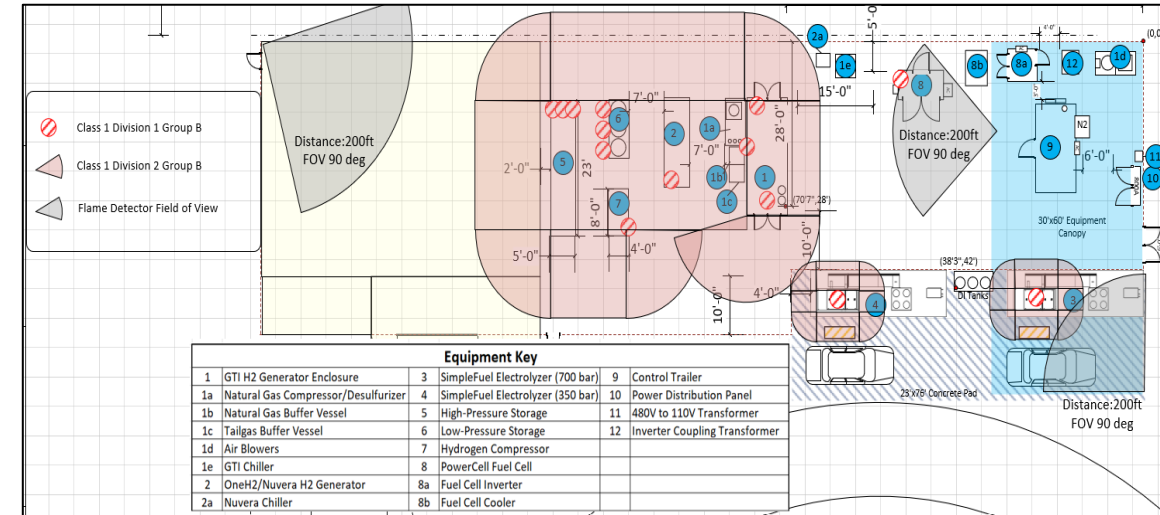


Image from Hydrogen Safety Plan, June 2023.  
Equipment placement modified to reduce fire risk.

# Accomplishments and Progress

## Demonstration Site – Construction Complete

- “Civil works” construction completed in May 2023
- Most major equipment placed on site by June 2023
- High-pressure H<sub>2</sub> tanks placed on site in August 2023
- Electrical construction commenced in August 2023 and completed with tie-in to data center in January 2024
- Process piping, electrical (power and instrumentation & control), other interconnections and supports installed by UT and GTI Energy teams (June 2023–March 2024)
- OneH2 SMR unit placed on site in January 2024
- No contractor change orders significantly affected cost
- Some issues caused modest schedule delays (e.g., buried obstacle found during trenching across roadway for conduit run required a boring specialist)

“Before” (March 2023)



Image courtesy of  
Mike Lewis, UT

# Accomplishments and Progress

Texas Advanced Computing Center, PV array, and 800 A conduit run (off photo to upper left)

800 A breaker (behind trailer)

PowerCell FC and Hitachi Inverter

DI water shed

Control Trailer

SimpleFuel H70 unit

OneH2 SMR

GTI Energy SMR and buffer tanks

SimpleFuel H35 unit

LP H2 Storage Tanks and Compressor

HP H2 Storage Tanks

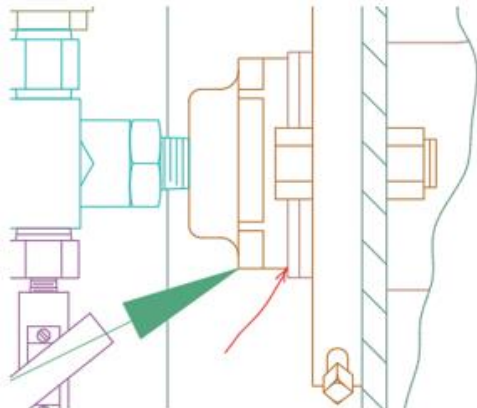
## Demo site aerial (March 2024)

Image courtesy of Roy Peña, UT

# Accomplishments and Progress

## Project team persistence and ingenuity #1: HP H<sub>2</sub> tank fittings seized and leaking

- H<sub>2</sub> tanks refurbished from prior project\*
- End fittings leaked during pressure test; vendor unable to supply new fittings in timely manner
- GTI Energy team carefully tried several means of “persuasion” before fittings loosened
- GTI Energy engineered and tested repair solution



“Before”



“After”



# Accomplishments and Progress

## Project team persistence and ingenuity #2: 800 A breaker panelboard unavailable through contractor until Spring 2024

- High-amperage cable run from data center to demo site was last step before commissioning
- Panelboard (internal) to main 800A circuit breaker at demo site was on backorder through electrical construction contractor
- Quoted delivery would cause a 6-month delay
- UT team pursued alternative options for procurement, ultimately finding an available refurbished breaker assembly
- Contractor credited back the breaker cost



# Accomplishments and Progress

## On-Site Partners Meeting (July 2023)

- 25 attendees representing more than a dozen organizations
- In-depth H2@Scale technical presentations, partner discussions, and demo site tour
- Hosted by UT-CEM
- Guest presentations
  - UT Bureau of Economic Geology
  - UT Energy Institute
  - Rock repository & rock garden tours



# Accomplishments and Progress

## Demonstration Site – Commissioning Under Way

- PDC Machines on site to commission SimpleFuel H70 (700 bar) and H35 (350 bar) in February– March 2024
- Toyota truck-mounted test rig on-site to validate fueling protocol in mid-March 2024
- Toyota Mirai fleet delivery to follow fueling protocol validation; vehicle demonstration will commence upon arrival of Mirais
- GTI SMR commissioning planned for April 2024; PowerCell fuel cell and Hitachi Energy inverter commissioning to follow
- OneH2 SMR commissioning planned for May–June 2024



# Accomplishments and Progress: Responses to Previous-Year Reviewers' Comments

- Several 2023 reviewer comments called for additional community outreach. Since mid-2023, project team activities in support of expanded outreach have included:
  - Demonstration site tours for the Texas National Guard, CapMetro (transit agency), Texas Hydrogen Alliance, a German delegation, and hydrogen infrastructure and clean fuel technology developers
  - Participation in the November 2023 Texas Energy Summit at the State Capitol in Austin
  - Participation in the October 2023 National Clean Hydrogen Day Celebration, including a Governor Abbott proclamation, technical presentations, and student posters
  - Co-teaching a continuing education course in hydrogen (November 2023)
  - Planning for an April 2024 demo site dedication (“ribbon cutting”) with numerous stakeholders and potentially a Toyota Mirai ride-and-drive

# Collaboration and Coordination

Partner	Role
Air Liquide	Support Gulf Coast framework report
Center for Houston's Future	Collaborate for Gulf Coast framework
CenterPoint	Support Gulf Coast framework report
Chart Industries	Support Gulf Coast framework report
Chevron	Support demo site and Gulf Coast framework
ConocoPhillips	Support demo site and Gulf Coast framework
Frontier Energy (PI)	Project management, coordination, data portal, and reporting
GTI Energy (Lead sub)	Coordinate and manage installation of H <sub>2</sub> equipment, supply and support SMR
Hitachi Energy	Demo site support
LCRI	Support demo site and Gulf Coast framework
McDermott	Support demo site and Gulf Coast framework

Partner	Role
MHIA	Support demo and Gulf Coast framework, wind power data
ONE Gas	RNG delivery, support Gulf Coast framework
OneH2	Supply and support SMR equipment
ONEOK	Support Gulf Coast framework
Rice University (Baker Institute)	Collaborate for Gulf Coast framework
Shell	Support Gulf Coast framework, advisory role for demo
SoCalGas	Supply fueling and electrolysis equipment
TCEQ	Electrolysis equipment
Toyota	Provide and support FCEVs
UT Austin (Co-PI & lead sub) (IdeaSmiths support)	Technical lead demo, site host, Gulf Coast and HOwDI model lead, user of fuel cell power, solar power data
WM	RNG supply

# Remaining Challenges and Barriers

- **Challenge (now overcome):** Potential 6-month delay for demo site construction due to unexpectedly long equipment leadtime quoted by contractors (possibly residual of COVID supply chain disruption); potential delay due to faulty fittings on refurbished H<sub>2</sub> storage tanks
  - Resolution: UT project staff found and procured an 800 A panelboard for the main site breaker; GTI Energy found approach to loosen “frozen” tank end fittings, without damage, enabling their repair
- **Challenge:** The time needed to build and commission the demo site encroached into the planned 12-month period for operation, data collection, and analysis and reporting
  - Resolution: Apply to DOE for a 12-month no-cost extension of Budget Period 3
- **Barrier:** Completion and adoption of WIP SAE J2601/4 *Ambient Temperature Fixed Orifice Fueling* as an SAE standard
  - Resolution in progress: Interactions with partners and contacts at SAE to track progress

# Proposed Future Work: Site Operation

- Control by GTI Energy using Hitachi Energy MicroSCADA-X for data collection/load-following
- Low-pressure H<sub>2</sub> storage tanks feed the PowerCell fuel cell powering the data center
- SMR units feed the LP H<sub>2</sub> tanks when fuel cell running or the HP H<sub>2</sub> storage tanks if not
- HP H<sub>2</sub> tanks supply H<sub>2</sub> to LP tanks if fuel cell demand exceeds SMR output
- SMR gas quality measured continuously to meet J2719 H<sub>2</sub> fuel quality; off-spec gas isolation procedures established
- SimpleFuel units (vehicle fuelers) export to HP H<sub>2</sub> tanks if their internal tanks are full
- Electrolyzer dispatch to be coordinated with UT solar power and emulated wind power
- Summary data to be posted to online portal

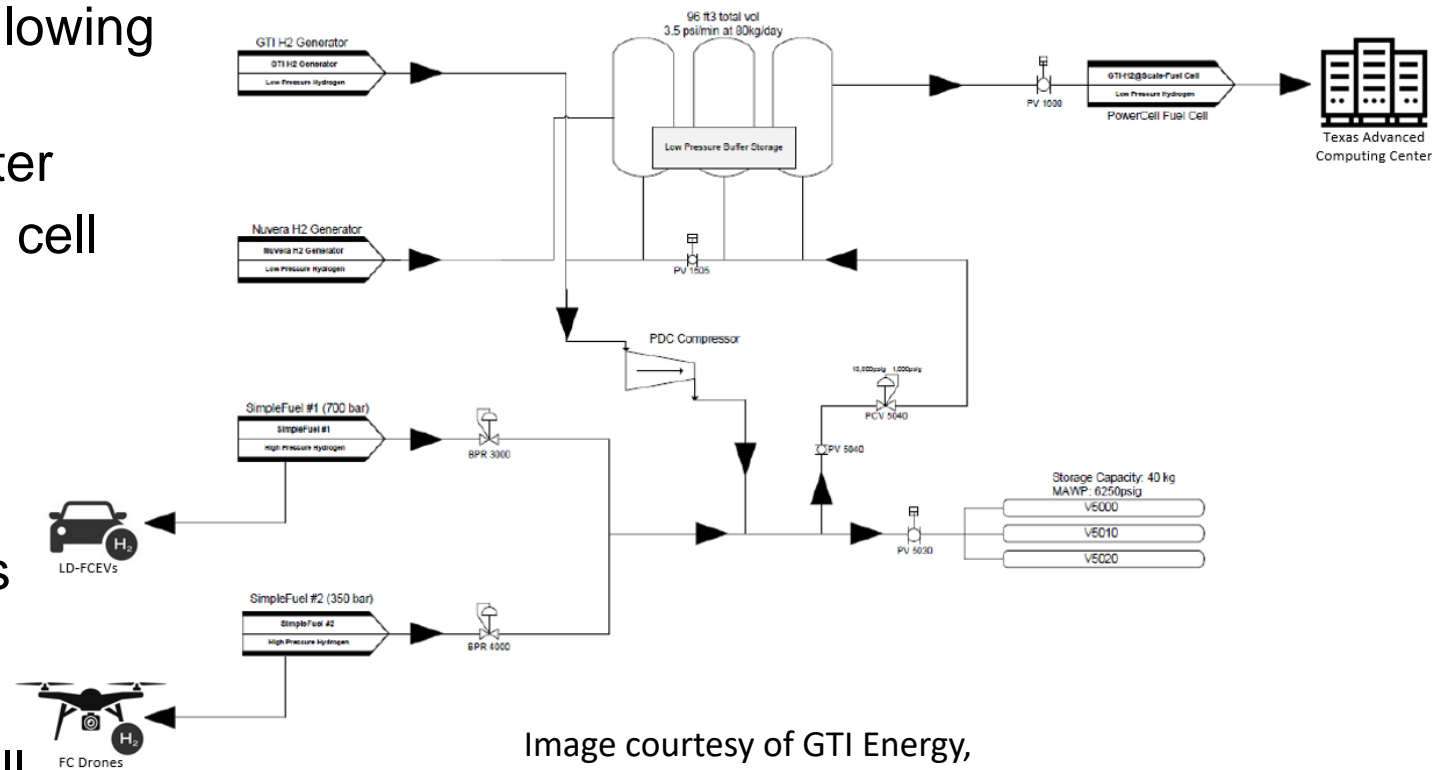
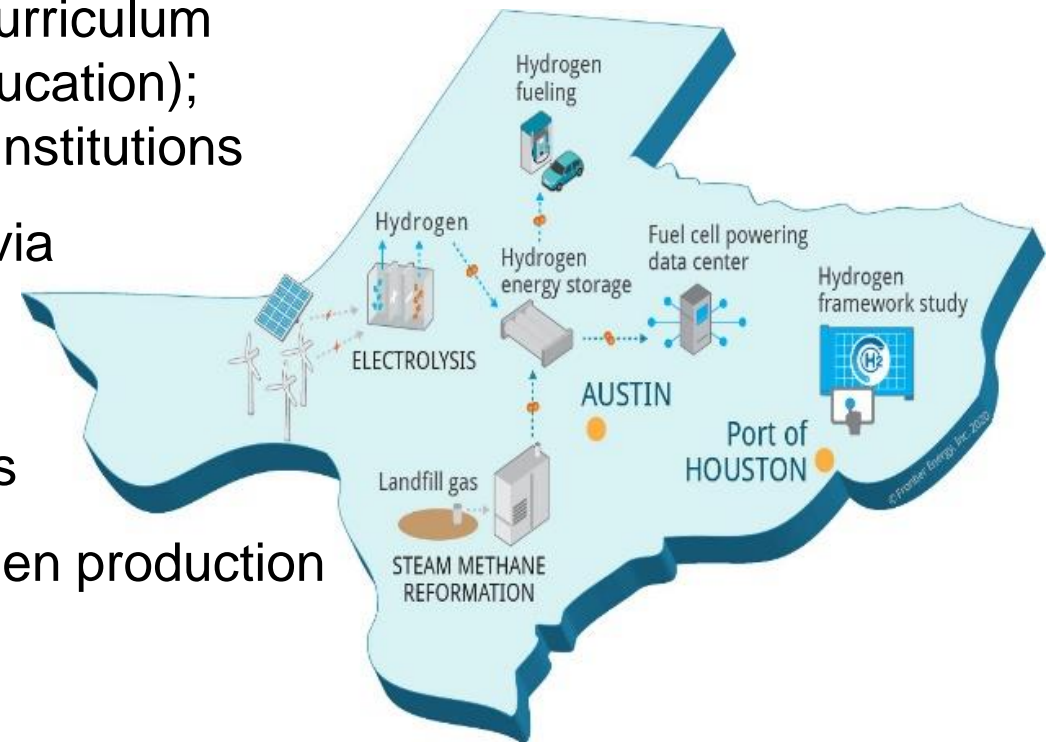


Image courtesy of GTI Energy, adapted by Mike Lewis, UT

# Proposed Future Work: Post-Project

- Potential fuel cell bus demonstration with Austin transit agency (would require H<sub>2</sub> storage and 350 bar fueler upgrades)
- Use of HOwDI model in Houston to Los Angeles (H2LA) I-10 hydrogen corridor project
- Further integration of demo site into UT hydrogen curriculum (undergraduate/graduate degree and continuing education); potential collaboration with community educational institutions
- Support coordinated community outreach in Texas via presentations, site tours, ride-and-drive events, etc.
- Results and HOwDI model sharing with Gulf Coast (HyVelocity) hub and potentially other clean H<sub>2</sub> hubs
- Demonstration of other hydrogen mobility or hydrogen production technologies; supply H<sub>2</sub> to visiting FCEVs



# Summary

## Two complementary RD&D tracks: one in its final phase, one completed

- Integrated hydrogen demonstration at UT–Austin—with construction completed and commissioning under way—includes four renewable H<sub>2</sub> production units, high- and low-pressure H<sub>2</sub> storage tanks, a PEM fuel cell powering a data center with dispatch coordinated with solar and wind assets, vehicle fueling for 3 Toyota “Generation 2” Mirais and a drone refueling trailer, and safety systems
- Economic build-out of H<sub>2</sub> supply infrastructure for demand centers throughout Texas modeled and published for 7 scenarios of carbon intensity and clean H<sub>2</sub> tax credits. Framework for actionable implementation projects, beginning in the Port Houston/Gulf Coast region, posted online.

	Key milestones & deliverables
BP 1 (8/1/20-1/31/22)	<ul style="list-style-type: none"><li>• Demonstration site planning and construction</li><li>• Technoeconomic H<sub>2</sub>@Scale models in Texas</li></ul>
BP 2 (2/1/22-7/31/23)	<ul style="list-style-type: none"><li>• Complete framework for H<sub>2</sub>@Scale in Texas</li><li>• Commence demonstration activities</li></ul>
BP 3 (8/1/23-7/31/25*) * Pending DOE approval	<ul style="list-style-type: none"><li>• Complete demonstration and assess ability to provide cost-effective hydrogen</li></ul>