Edison Electric INSTITUTE

Zero-Carbon Fuels

Critical Consumer Issues Forum – Summit 1 Virtual Education Series
The Customer-Centered Clean Energy Transition: Balancing Technology, People & the Planet

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March 2, 2022

The Edison Electric Institute (EEI) is the association that represents the U.S. investor-owned electric industry. Our members provide electricity for 220 million Americans, operate in all 50 states and the District of Columbia, and directly employ more than 500,000 workers. Reliable, affordable, and sustainable electricity powers the economy and enhances the lives of all Americans.

The EEI membership also includes dozens of international electric company Affiliates, and hundreds of Associate organizations.

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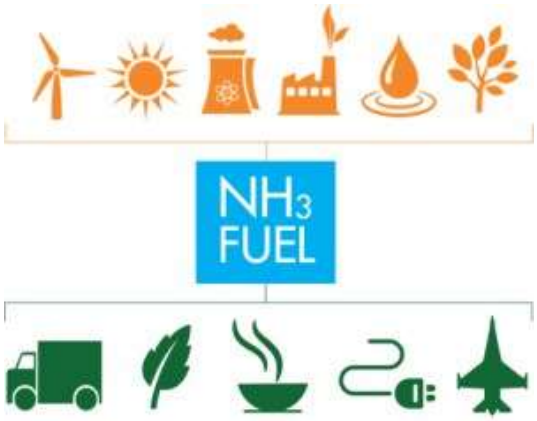
Zero-Carbon Fuels

- Includes a number of energy-dense fuels
- Portable, storable, affordable
- Help power portions of the economy not served by electrification





Hydrogen

- Most abundant element in the universe
- Second lowest boiling point (-423 ºF) and melting point (-434 ºF) of all substances
- Colorless, odorless, and tasteless
- Smallest molecule and lightest element
- Highest energy-to-weight ratio of any fuel – 1/3 mass of hydrogen required as compared to hydrocarbons
  - But low energy density (measured by volume)

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Hydrogen

- Estimated current global annual consumption is appx. 70-80 million metric tons/year
  - Current U.S. production is appx. 10 million metric tons/year
  - Forecasted to rise significantly in the next several decades
- Main applications at present:
  - Oil refining
  - Agricultural fertilizer
  - Industrial applications
- Most hydrogen currently is produced on-site

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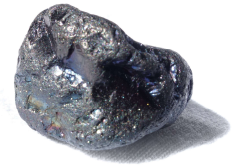
Producing Hydrogen

Multiple production pathways – four most common:







Coal with steam reformation

Methane with steam reformation and no CCS

Methane with steam reformation and CCS

Renewable electricity + water and use of electrolysis

Over 90% of hydrogen today

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Producing Hydrogen

Multiple other pathways



- Pink – nuclear power



- Turquoise – methane pyrolysis (splits methane into hydrogen gas and solid carbon)



- White – naturally occurring hydrogen (rare)



- Yellow – solar power or electricity from the grid?
- And more…

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Hydrogen Uses (Current and Potential Future)

- Transportation
  - Forklifts
  - Medium and heavy-duty vehicles
  - Maritime
  - Aviation
  - Aerospace
  - Rail
- Data centers
- Renewable energy storage
- Home heating
- Replacement for natural gas in power generatior
- Replacement for coke in steel manufacturing
- And more…



Electric Companies and Hydrogen

- Multiple potential opportunities for electric companies in the hydrogen economy, including:
  - Using otherwise curtailed/excess power from variable renewable generation
  - Producing and storing hydrogen to assist in firming variable generation
  - Using purpose-built renewables to generate hydrogen for sale
  - Using hydrogen in gas turbines

Electric Companies and Hydrogen

- EEI members are exploring hydrogen projects across the value chain including:
  - Renewable hydrogen blending
  - Dual fuel combined cycle power plants
  - Nuclear-to-hydrogen projects
  - Renewable power-to-gas projects
  - Hydrogen as a long-duration energy storage
  - Hydrogen as a microgrid component

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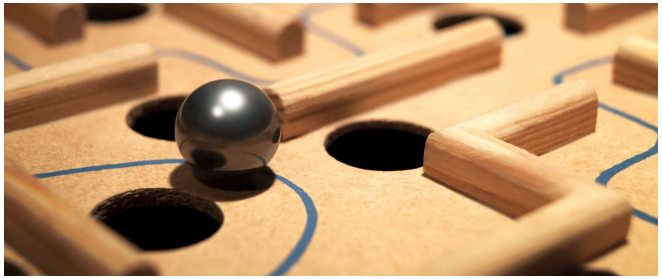
Challenges for Hydrogen at Scale

- Classic chicken or the egg
- Transportation from production to end-use
- Energy required to prepare hydrogen for transport
- First-mover disadvantages
- Carbon markets, storage, and transportation
- Product fungibility
- Stakeholder engagement



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Federal Regulation: Production and Storage

- Environmental Protection Agency
  - 40 CFR Part 98, Subpart P
    - Applies to emissions from hydrogen production
- Occupational Health and Safety Administration
  - 29 CFR Part 1910, Subpart H
    - Safety requirements for gaseous and liquefied hydrogen systems
    - Regulations applicable to flammable liquids and compressed gases

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Federal Regulation: Interstate Pipelines

- Safety - PHMSA
  - 49 CFR Part 192 regulations apply to hydrogen pipelines
  - Regulations may need to be modified as the hydrogen economy develops
    - PHMSA hosted a 3-day workshop in late 2021



Federal Regulation: Interstate Pipelines

- Siting and Rates/Terms of Service – Unclear
  - FERC
    - Natural Gas Act (15 USC 717, *et seq*) may apply, particularly to hydrogen mixed with natural gas
      - Would require FERC interpretation of "natural gas" or congressional action
    - If NGA applies, eminent domain authority likely would apply
  - Surface Transportation Board
    - Congressional Research Service March 2021 paper concluded that STB could have jurisdiction over hydrogen pipelines
    - Untested in the industry
    - STB does not require rates or tariffs to be filed and only acts in response to disputes

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Federal Regulation: Vessel Transport

- Jones Act
  - Administered by Customs and Border Control/Dep't of Homeland Security
  - Requires vessels that carry goods between US ports to be US built and flagged, among other requirements (46 USC Chapter 551)
- USCG/PHMSA
  - US Coast Guard and PHMSA regulations include liquefied and compressed flammable gases (e.g., 49 CFR Parts 172, 173, 176, 178, and 180; 33 CFR Parts 154 and 156; and 46 CFR Subch. O)

Federal Regulation: Truck Transport

- Federal Motor Carrier Safety Administration
  - Primary jurisdiction over hydrogen transportation in commercial trucking
  - 49 CFR Part 397 includes guidance on transportation of hazardous materials (including hydrogen)
  - 49 CFR § 390.19 includes guidance on hazardous materials safety permits and intermodal equipment provider identification reports
- PHMSA
  - Jurisdiction over transportation hazardous materials (includes flammable gases and liquids) on public highways
  - Regulations in 49 CFR Parts 173 and 177 include inspection procedures, loading and lading pressures, and compliance with federal motor carrier safety regulations

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Federal Regulation: Rail Transport

- PHMSA
  - Transportation of hazardous materials by rail (40 USC §§ 5101-5127)
  - Federal Railroad Administration enforces hazardous materials regulations for rail transportation
  - Inspection and safety precautions included in 49 CFR Part 174


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Zero Carbon Fuels

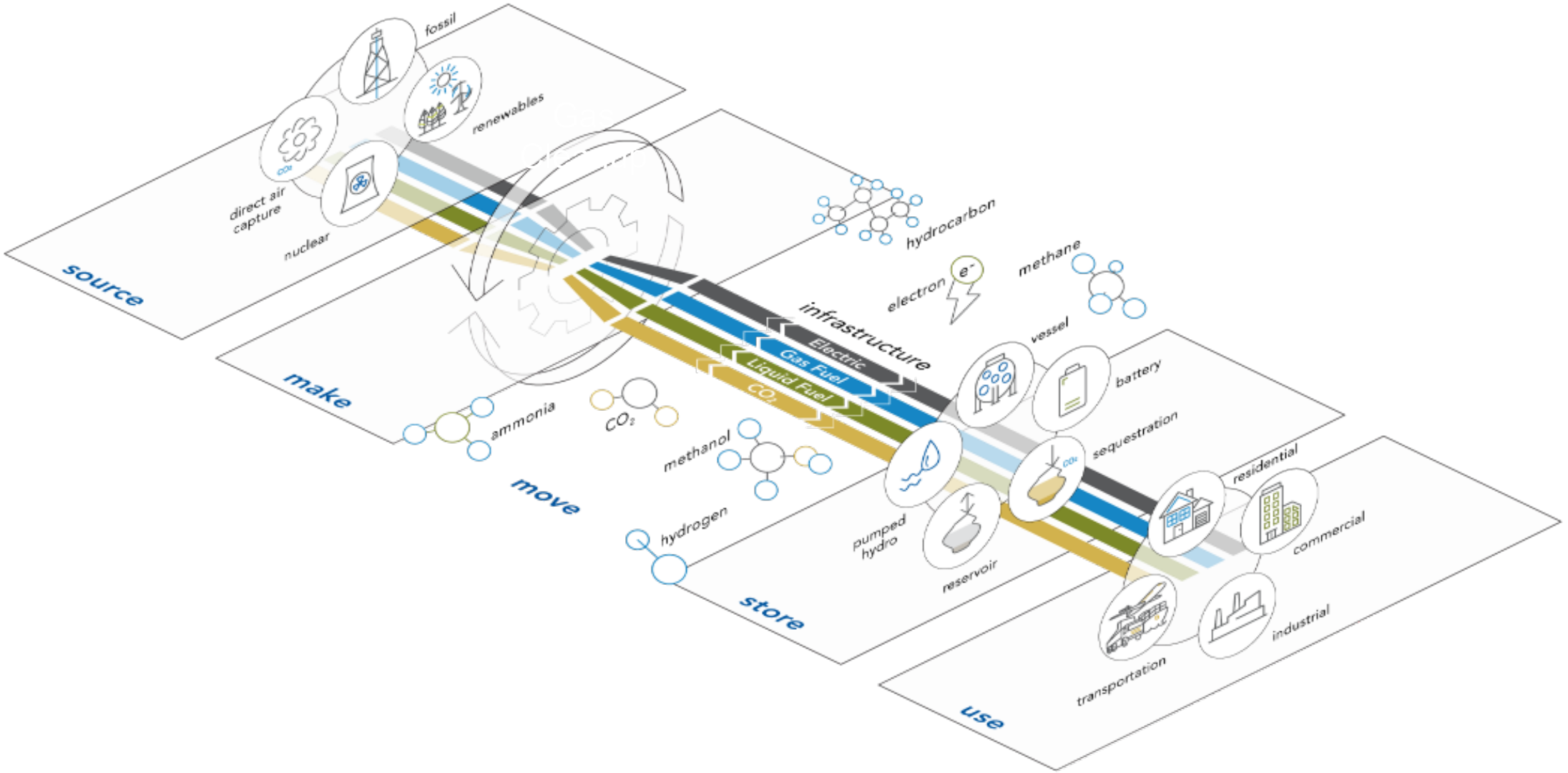
The Role of Hydrogen

HYDROGEN TECHNOLOGY CENTER

Kristine Wiley
VP, Hydrogen Technology Center, GTI
March 2 , 2022

gti

INTEGRATED ENERGY SYSTEMS



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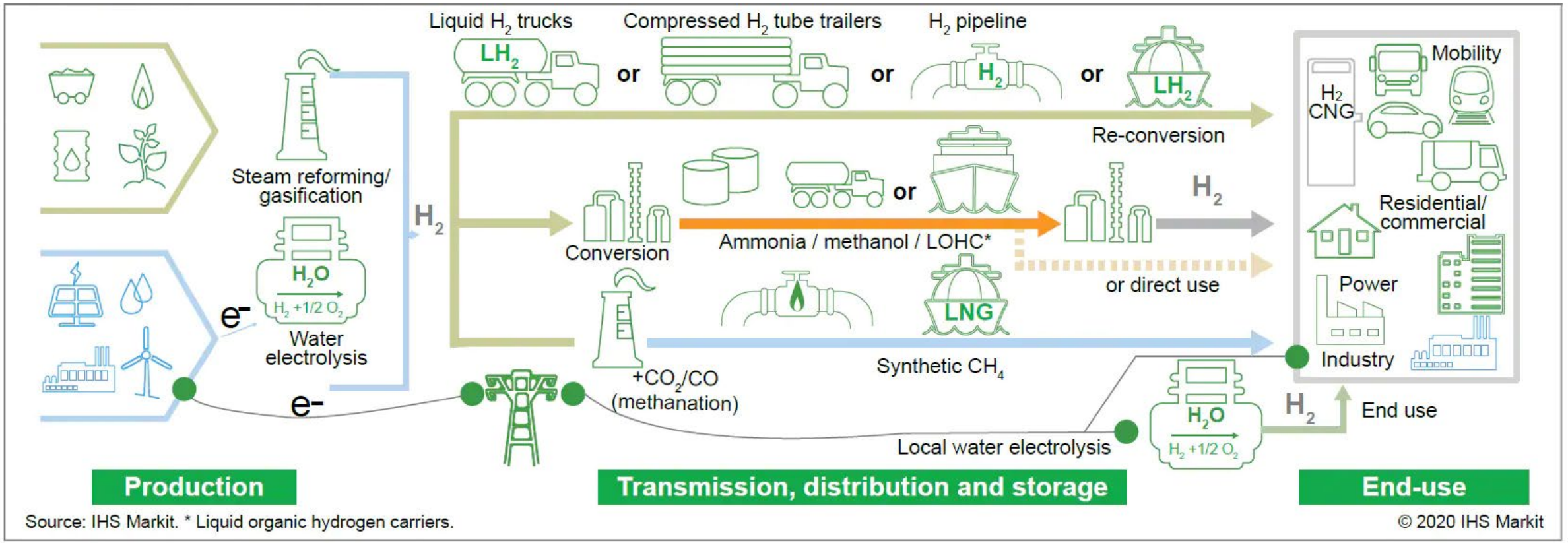
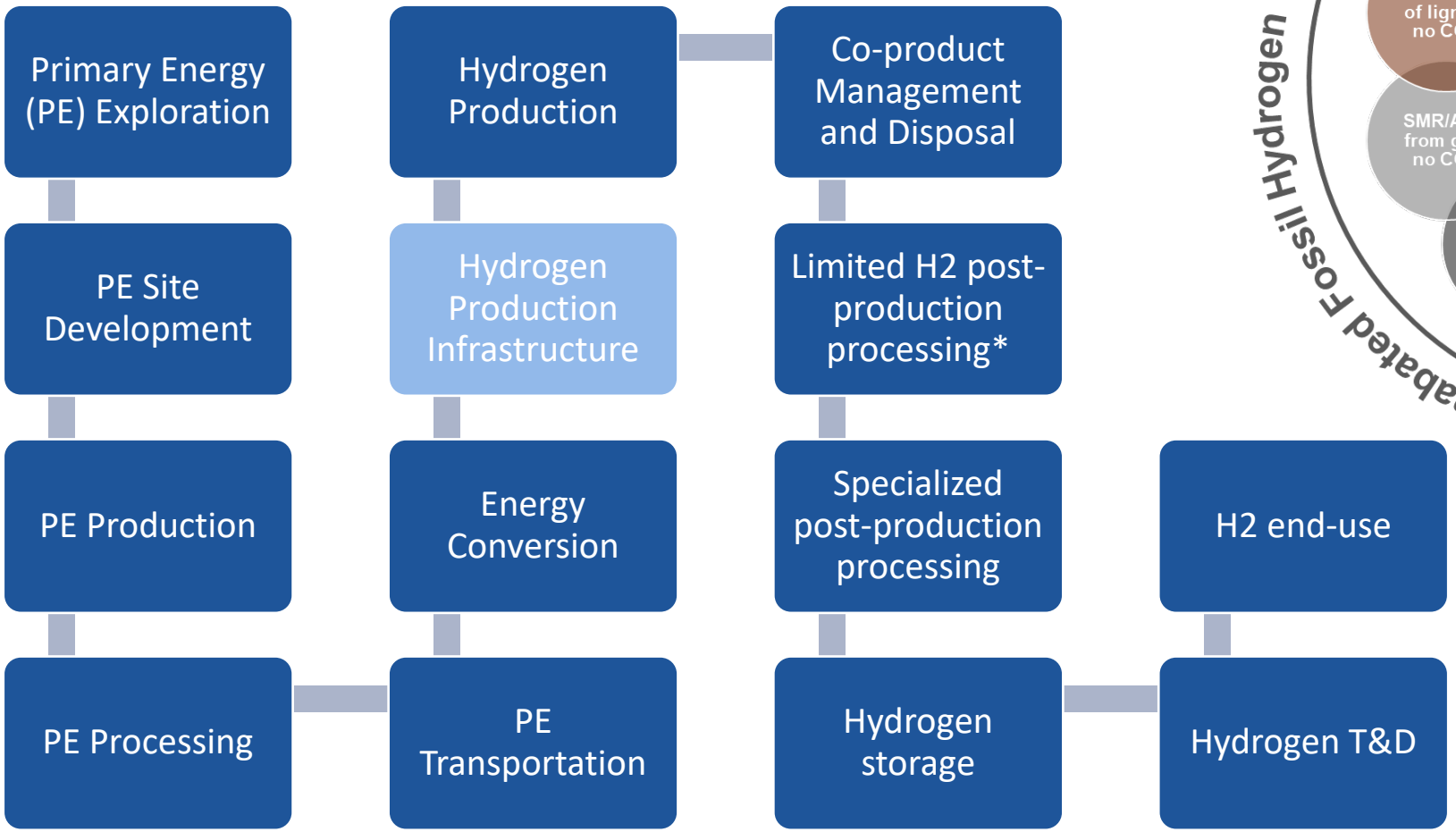
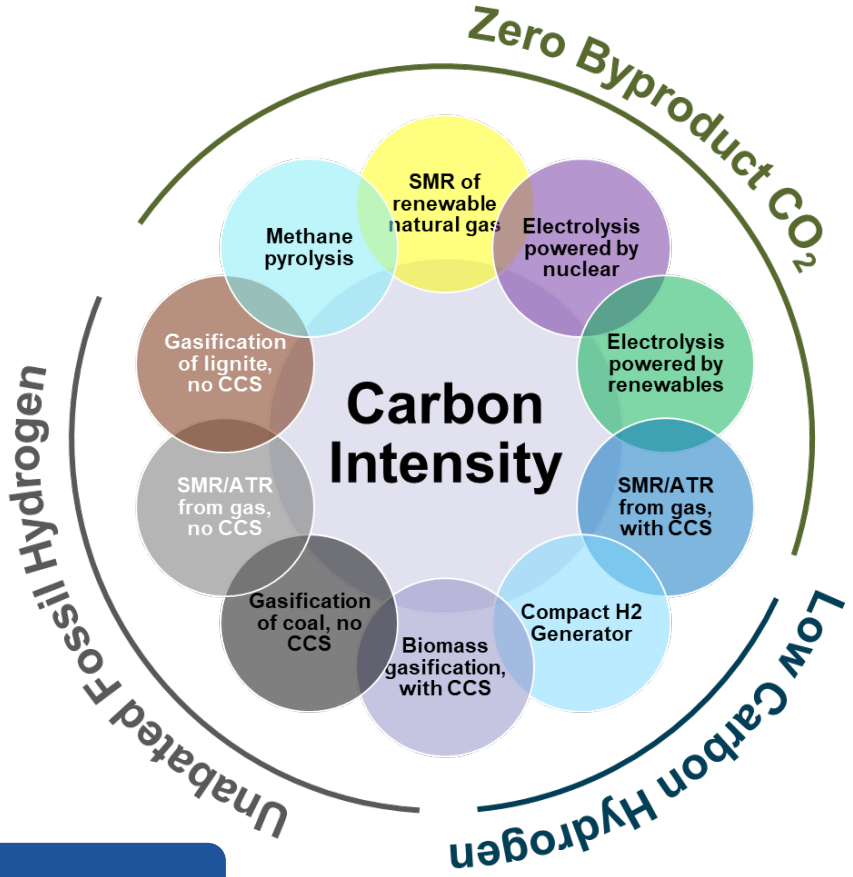
HYDROGEN SUPPLY CHAIN



DEFINING HYDROGEN PATHWAYS

Assessing Emissions Intensity

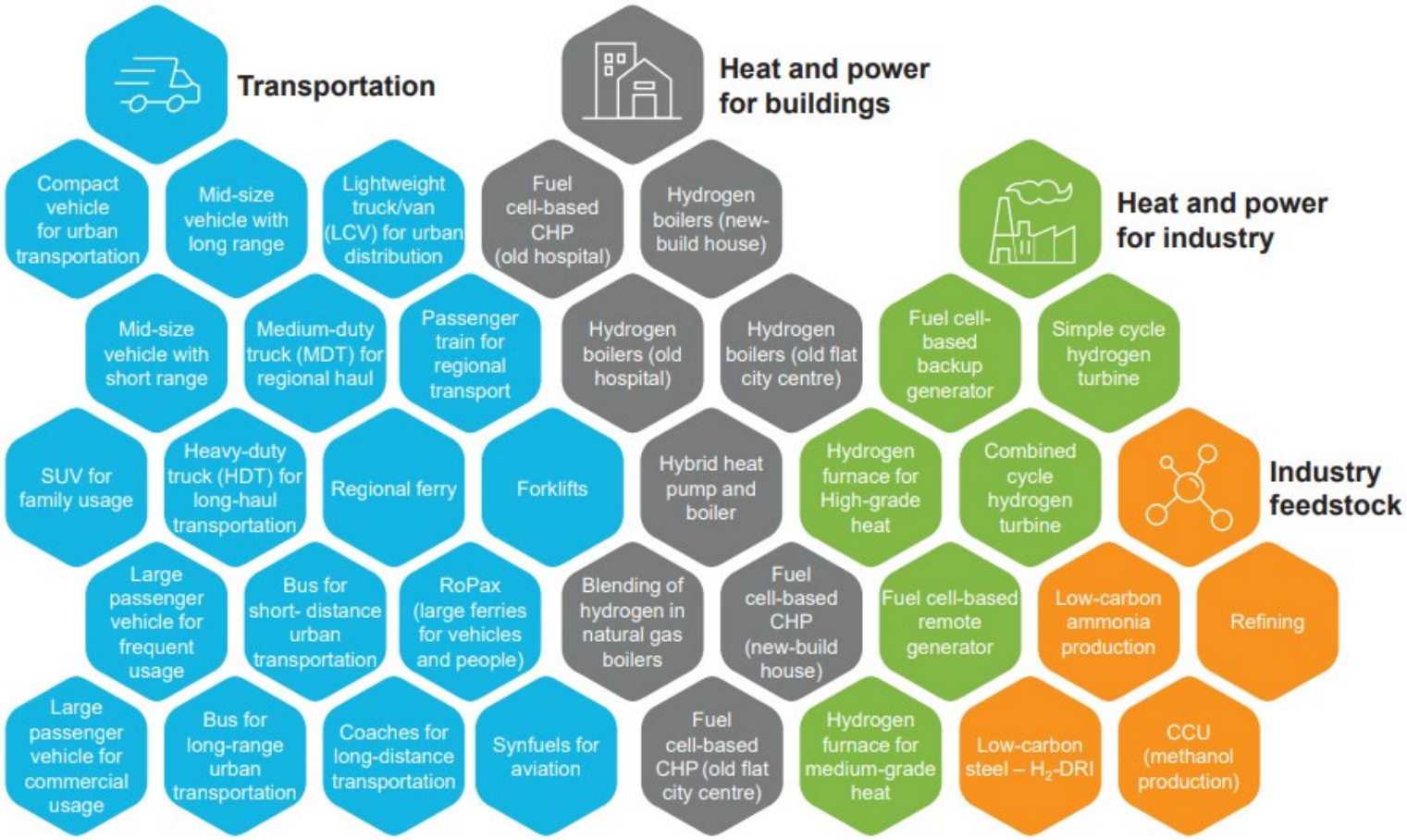




EXPANDING USES OF HYDROGEN

Technical Challenges

- Lower cost of low carbon hydrogen production (feedstock cost, utilization rates, technology components, supply chain)
- Overcome technical barriers to using gas infrastructure for hydrogen transport and deliver (energy delivery, equipment operability, materials impact)
- Modify equipment, appliances, processes for the use of hydrogen as an energy source for power generation, buildings, industry, transportation (hydrogen purity, flame characteristics, safety, by products)



Source: Hydrogen Council

Assessing Compatibility with Natural Gas Infrastructure

Scope of Current GTI research

- Evaluating effects of various % hydrogen-natural gas blend on metallic & non-metallic **material properties**
- Determining **safety factors** for hydrogen gas blended systems based on materials tests
- Developing **engineering tools** to allow an integrity assessment and a safety margin determination of hydrogen blended gas use
- Determining **operational impacts** of a hydrogen blend in pipelines, such as leak detection, surveys, metering accuracy, pressure control, emergency response
- Supporting **pilot projects** for operators to gain experience safely & controlled





Factors on Hydrogen Embrittlement Susceptibility
Environmental Factors
Role of Microstructure
Hydrogen Traps
Inclusions and Precipitates
Texture and Grain Boundary
Effects of Alloying Elements

Material Properties most affected by H2
Toughness
Reduction in Area
Crack Growth Resistance

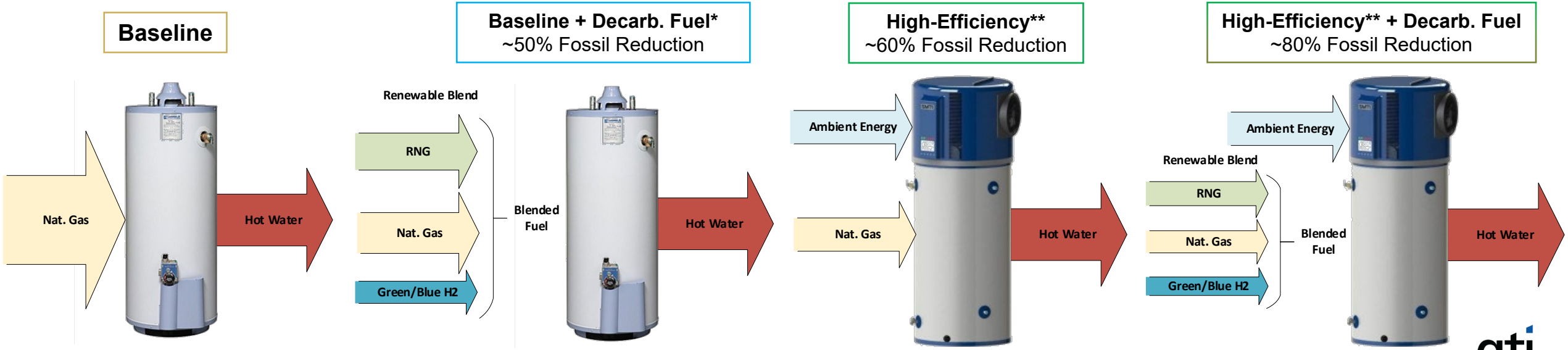
Energy Efficiency + Decarbonized Fuels

Energy efficiency coupled with **decarbonized fuels** can drive GHG reductions

- As a fuel, Hydrogen (H_2) emits no CO_2 and can be blended with natural gas or **biomethane** for standard products, or utilized directly (100% H_2) by **specially-designed equipment**
  - Used for **long duration**, mega-scale storage of renewable energy

Typical Furnace Burner



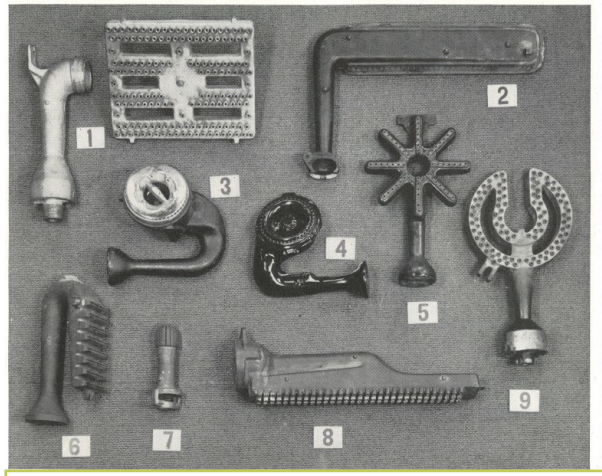


*Assumes near-term achievable targets of H2 & RNG blending / ** Fuel-fired GHPWH performance assumptions from *Glanville, P., Fridlyand, A., Mensinger, M., Sweeney, M., Keinath, C. (2020) Integrated Gas-fired Heat Pump Water Heaters for Homes: Results of Field Demonstrations and System Modeling, ASHRAE Transactions; Vol. 126 325-332,* image source: SMTI.

Hydrogen Blending Basics – Historical Context

- Public gas distribution begins in US in 1816 (Baltimore)
  - ~1000 US plants at peak (1890s), various feedstocks
  - Syngas (H_2/CO), “water gas” and “coal gas”, byproducts sold too
  - First lighting, then appliances (leasing), then industrial
- Between WWI / WWII, pipeline advances & leak abatement bring “Natural Gas” to major urban centers
  - Majority “enriched” mfd. gases by blending (NG ~2X HHV) – NOLA (1928), Chicago (1931), Minneapolis (1935)
  - Others did straight conversion – DC (1946), NYC (1949-51)
  - Conversion took **30-40 years in US,** “single largest task” was converting equipment (utility-led or contractor)
- Legacy of transition remains in appliance design/codes
  - Many equipment certifications use **variety of test gases**


Gas Works Park – Seattle (Decomm. 1956)



$$P = \left(\frac{2.5 \times 10^{6} \sqrt[4]{pd\,A_m\,A_p}}{\sqrt{RH}}\right)\left(\sqrt{\frac{540}{T}}\right) \quad (1)$$

Where:

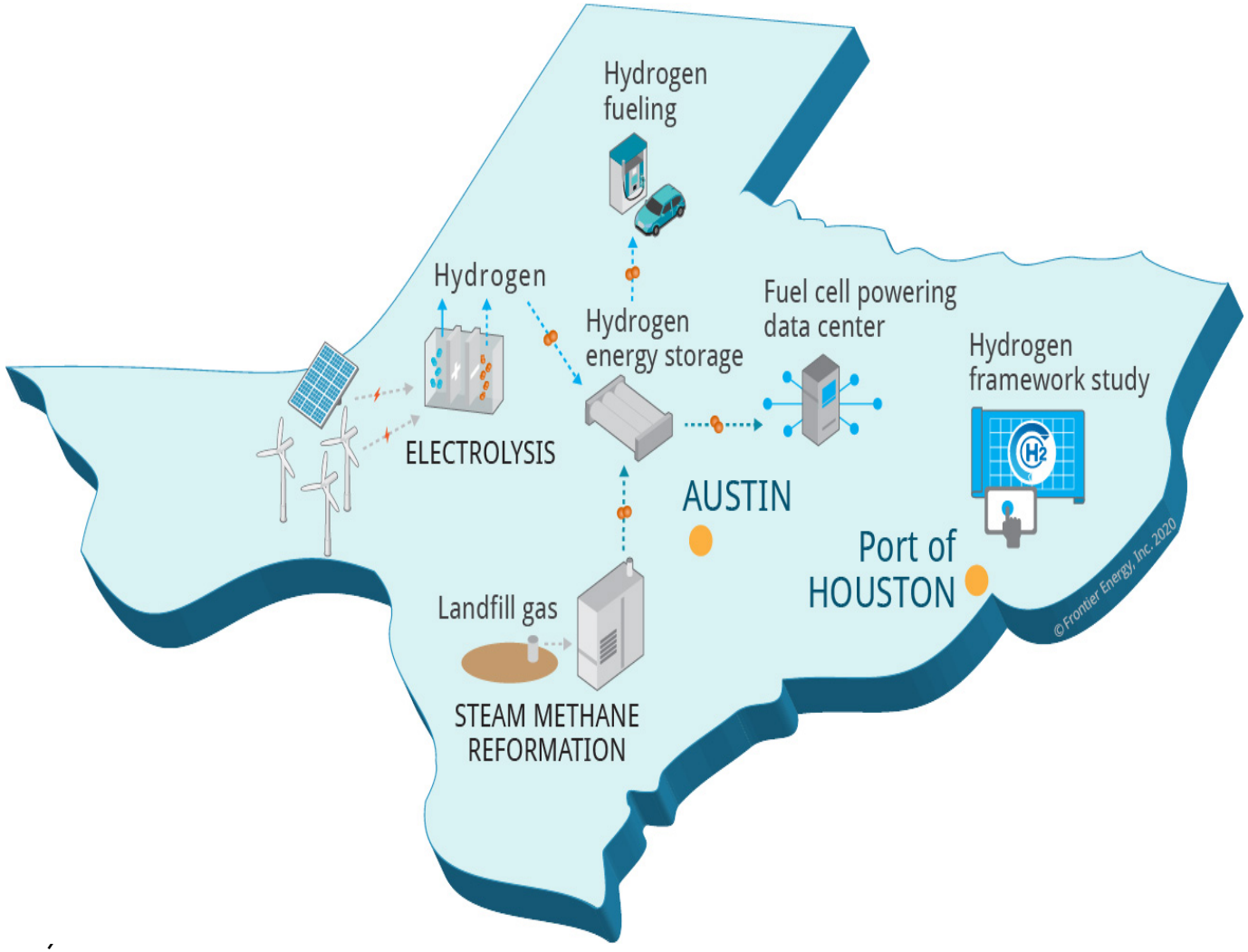
P = primary air, per cent theoretically required for complete combustion
p = pressure of gas back of orifice, in. of water
d = specific gravity of gas, (air = 1.0)
A_m = average area of throat and mixer tube outlet, sq in.
A_p = total area of ports, sq in.
R = input rate, Btu per hr
H = heating value of gas, Btu per cu ft, and
T = average absolute temperature of air-gas mixture in burner head, F.

Appliance Design Guide (1944) – Still Used by Industry!!**

* Source: Tarr, J. “Transforming An Energy System: The Evolution of the Manufactured Gas Industry and the Transition to Natural Gas in the United States (1807-1954),” in Olivier Coutard (ed.), *The Governance of Large Technical Systems* (London: Routledge, 1999), 19-37. // ** AGA Testing Laboratories, Primary Air Injection Characteristics of Atmospheric Gas Burners – Research Bulletin No. 26, 1944.

H2@SCALE – INTEGRATED HYDROGEN NETWORK

Laying a Foundation for Hubs



~100% renewable H_2 generation

- 75 kg/day SMR: GTI, OneH2, ONE Gas, Waste Management
- 20 kg/day PEM electrolyzer in H70 SimpleFuel: MHI, SoCalGas, TACC
  - Emulated wind and solar power through UT CEM microgrid

Large scale, industry H_2 user

- 100kW fuel cell powering Texas Advanced Computing Center

Vehicle refueling

- Published SAE J2601-4 fueling of 7-10 Toyota Mirai's
- Drones included

Advancing a Clean Energy Future

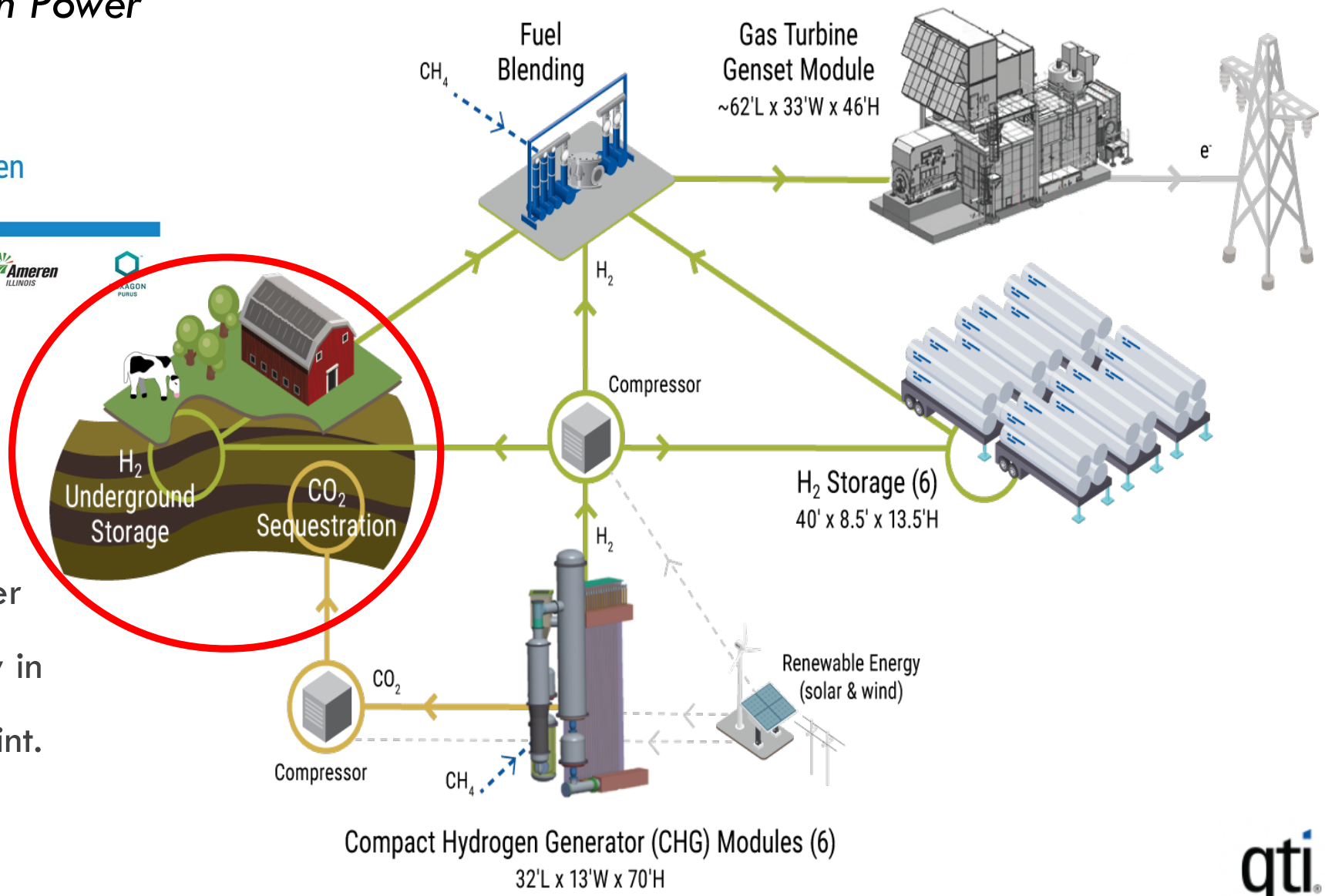
Hydrogen for Zero Carbon Power

Zero-Carbon Power & Hydrogen for Illinois' Energy Future

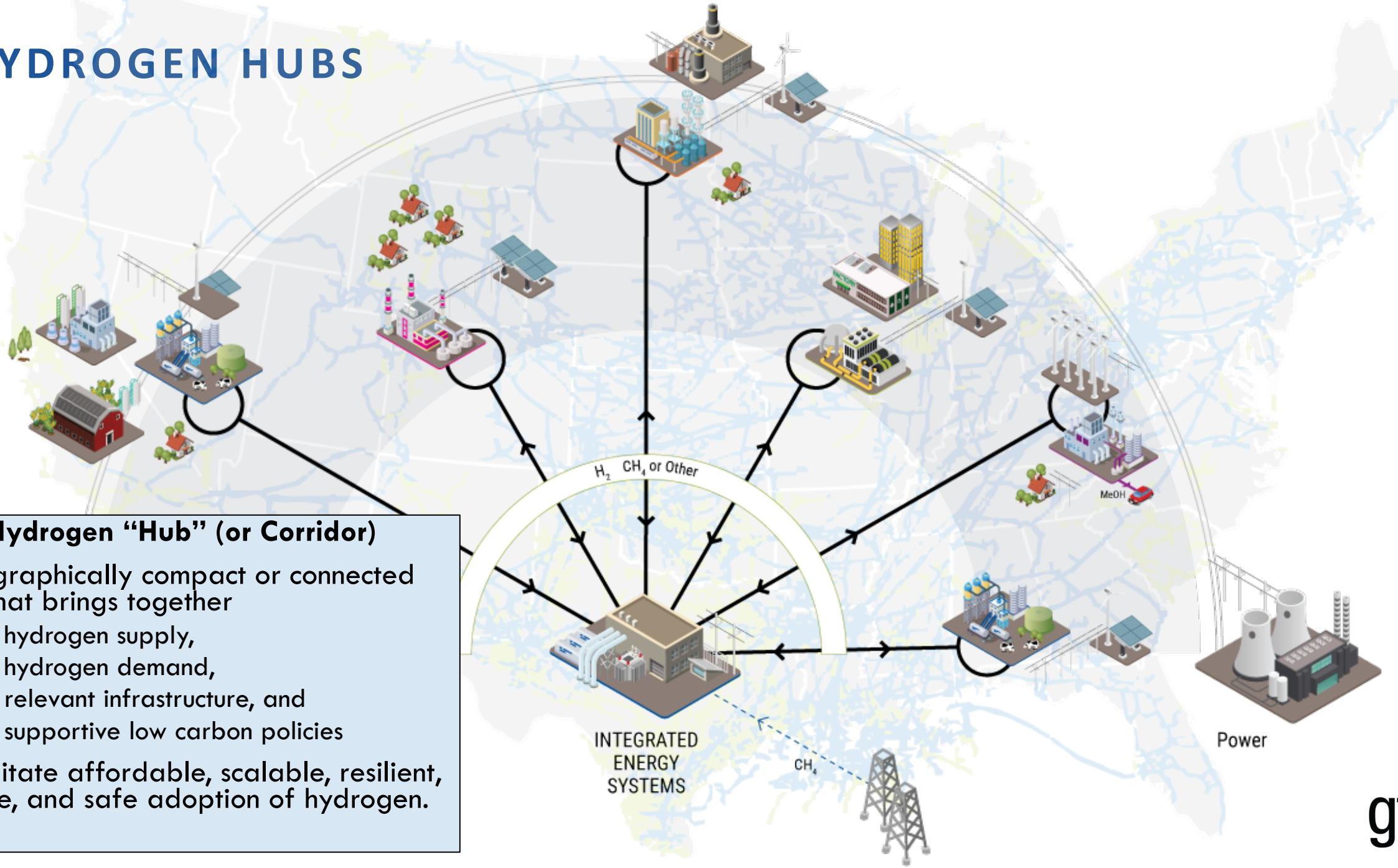
ZERO CARBON POWER • CLEAN HYDROGEN PRODUCTION • UTILIZING LOCAL GEOLOGY

gti · ILLINOIS Illinois State Geological Survey · MITSUBISHI HEAVY INDUSTRIES · Ameren ILLINOIS

This **pilot and test facility** will support development of commercial zero-carbon power and hydrogen to help industry in Illinois lower its carbon footprint.



HYDROGEN HUBS



Hydrogen "Hub" (or Corridor)

A geographically compact or connected area that brings together

- ✓ hydrogen supply,
- ✓ hydrogen demand,
- ✓ relevant infrastructure, and
- ✓ supportive low carbon policies

to facilitate affordable, scalable, resilient, reliable, and safe adoption of hydrogen.

GTI envisions low-carbon, low-cost integrated energy systems which leverage gases, liquids and infrastructure.

Ambition. Innovation. Scale. Collaboration.

All Required.