CENTER FOR HOUSTON'S FUTURE

Energy Transition and the Houston Region: A New Vision

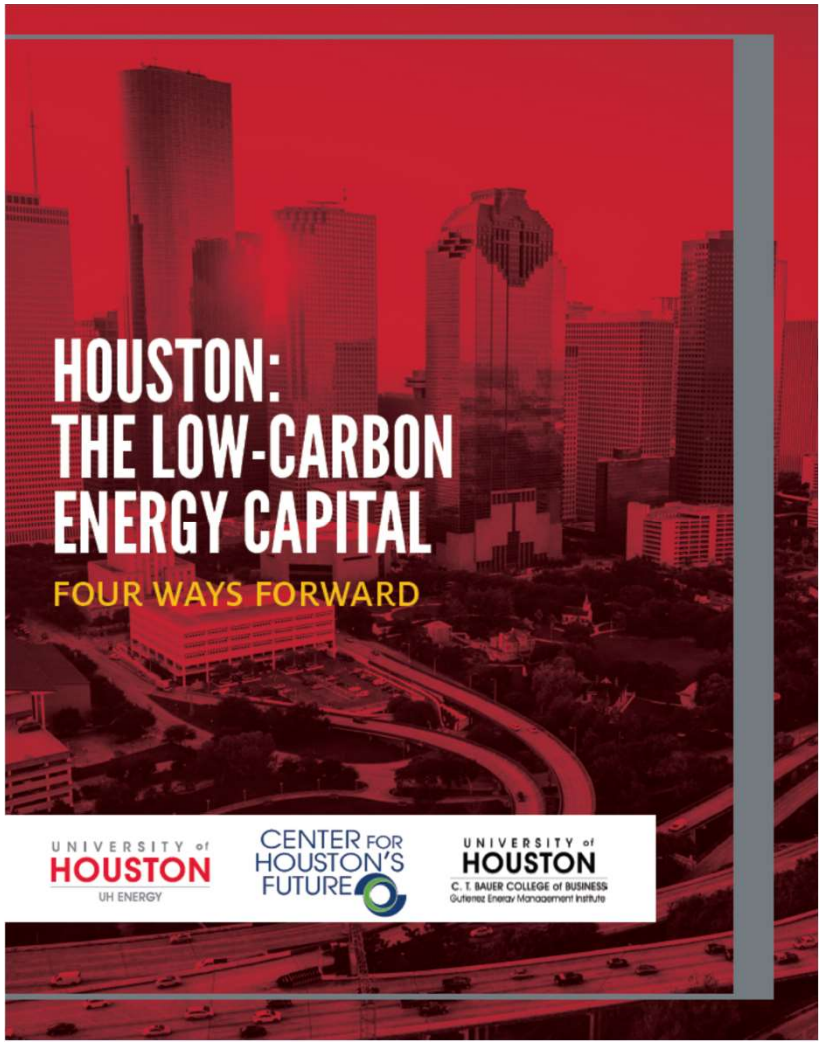
April 2021

About the Center for Houston's Future

We bring business, government, and community stakeholders together to engage in fact-based strategic planning and collaboration on issues of great importance to the Houston region.

Our areas of focus:

- **Strategic Initiatives**
- **Community Engagement**
- **Leadership**


HOUSTON:
THE LOW-CARBON
ENERGY CAPITAL
FOUR WAYS FORWARD
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CHF/UH Low Carbon Energy Market Assessment

- **Carbon Capture:** Carbon management technologies could remove more than 12 million tons of emissions per year from the Houston region by 2030, taking advantage of the region's globally unmatched geologic capacity. CCUS will be a key enabler of other emissions-reduction strategies, including hydrogen, petrochemicals and renewables integration.

- **Hydrogen: Houston,** already the world's largest producer of hydrogen, has the potential to create an entirely low-carbon hydrogen industry leveraging its existing assets, infrastructure and its leading position in renewables.

- **Low Carbon Grid:** Texas is already a leader in producing low-carbon energy from wind and solar and has the potential via its competitive electricity market to accelerate decarbonization of its grid by growing low-cost renewables, energy storage and green hydrogen.

- **Circular Economy/Plastics Recycling:** Houston is uniquely positioned to eliminate all plastic waste by taking advantage of plastics manufacturing facilities and low-cost renewable energy to innovate advanced recycling technologies.

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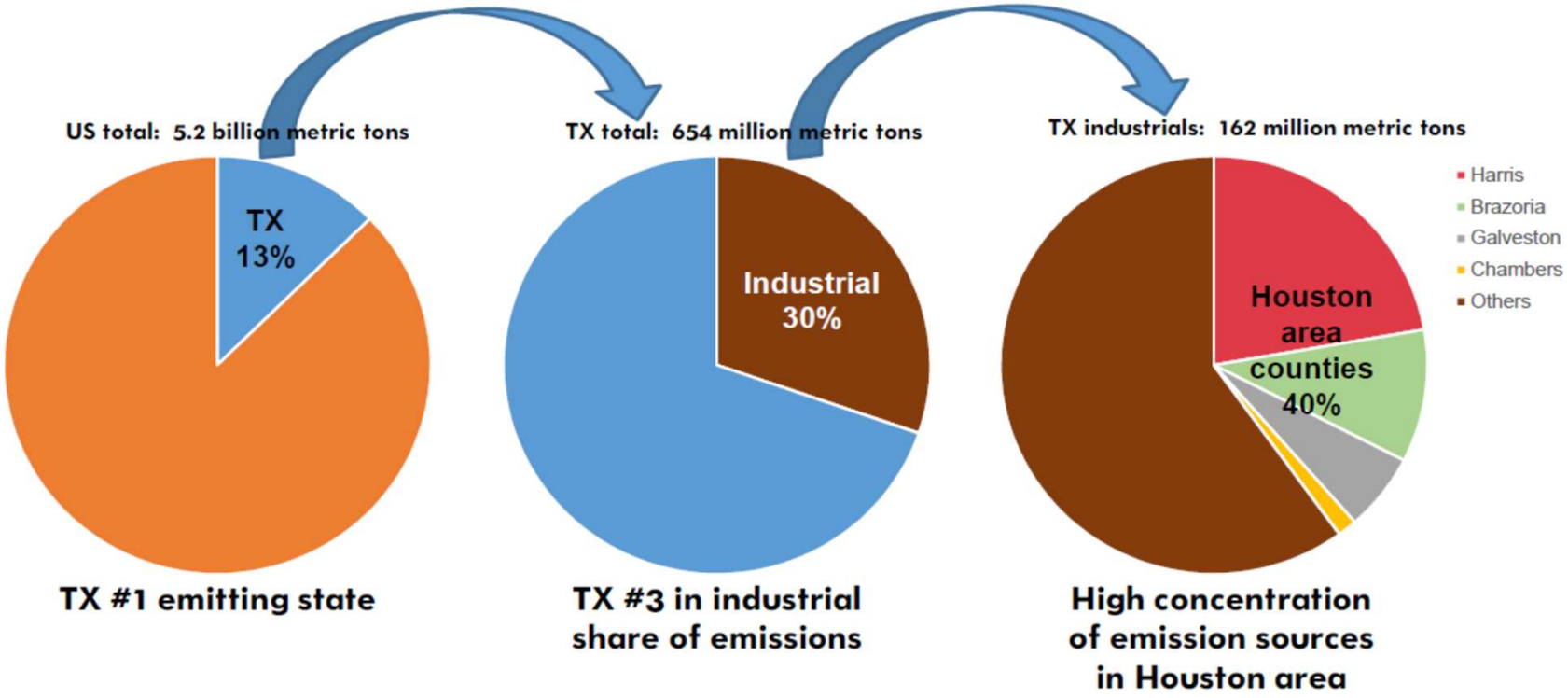
Houston Industrial Sector



Note: discrepancies in estimated emissions due to different data sources used

Key Challenges to Address in Project

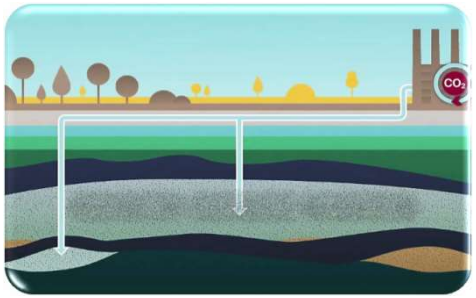
Carbon Capture

- Technology maturity
- Capture Cost of CO_2 (3/4 of total CCUS cost)
- Electricity cost for compression
- Separation cost to purify CO_2

Transportation

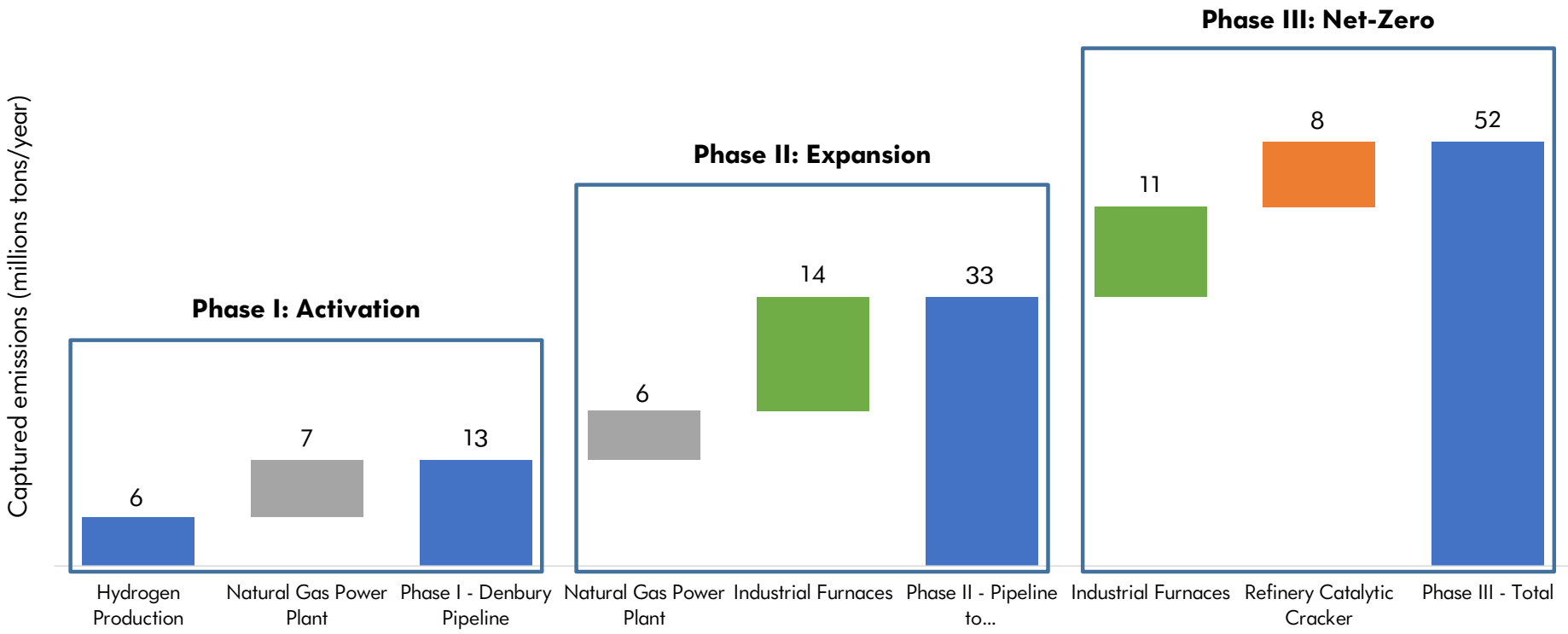
- Permits & Regulations
- Public acceptance
- Eminent Domain
- Cost of pipeline design and operating expense
- Infrastructure improvements

Storage



- Primacy
- Class 6 wells
- Low cost of oil
- Cost of surveillance (Liability for releases)
- Induced seismicity

Taking Houston to Net-Zero



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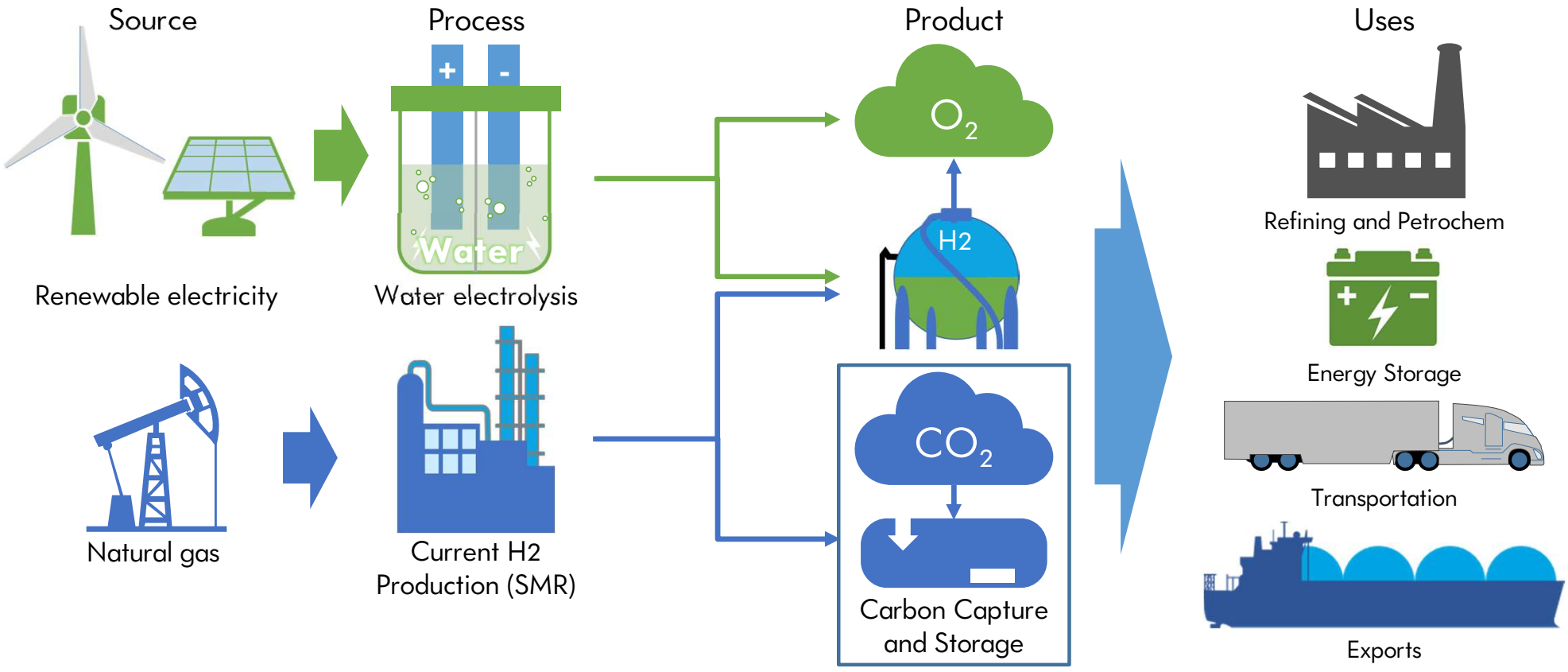
Hydrogen Pathways and End Uses



Hydrogen Market Assessment – Key Findings

- **Global decarbonization momentum is growing, catalyzing substantial global H2 gas market expansion of $800 billion by 2050, and a $2.5 Trillion total market including related H2 technologies**
- **The Houston area is poised to drive significant H2 growth in the energy system**
  - World leading existing H2 system positioned to bring H2 to market, at-scale, quickly
  - Opportunity to create a green H2 industry over time by leveraging significant low cost renewable power and storage synergies
- **There are four immediate initiatives to launch Houston area blue and green H2 market opportunities**:
  - Launch heavy trucking
  - Clean existing H2 system (via CCUS)
  - Exploit seasonal storage
  - Pilot long duration storage
- **Further, the Houston area has substantial regional, domestic, and global supply leadership potential by parlaying its scale and cost advantages across the hydrogen and carbon chains**
- **Unleashing Houston's near and long-term H2 market opportunities will require targeted public policy and funding support**

Notes: CCUS refers to carbon capture, usage, and storage

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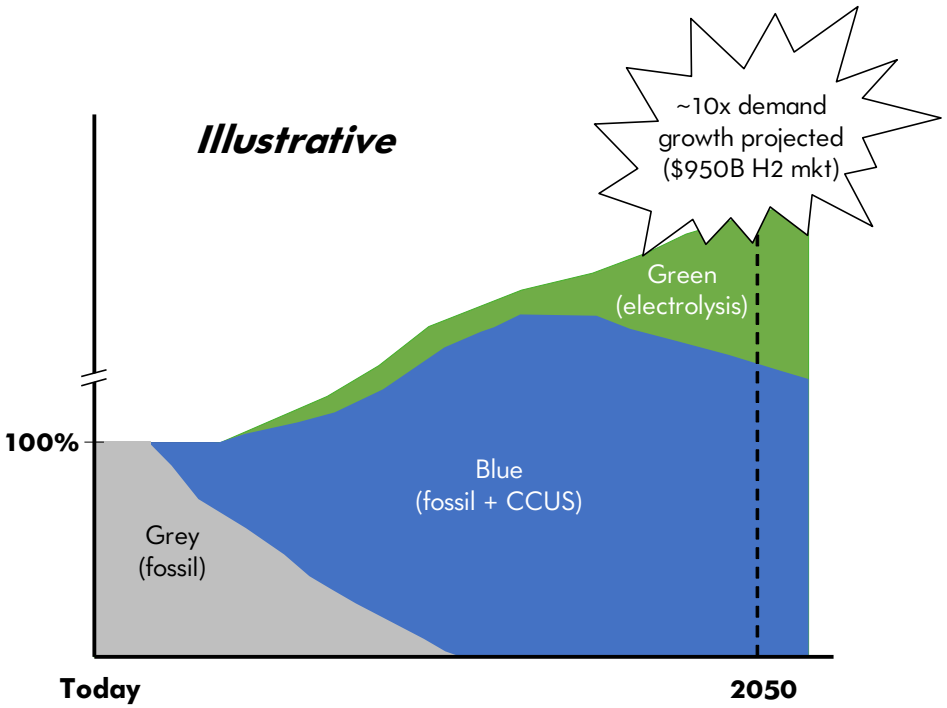
Decarbonization is catalyzing rapid H2 market expansion, and strategies are emerging to capture the opportunity

Hydrogen demand and mix over time



Source: Barclays, HSBC, Hydrogen Council

Localized Drivers

- Goals: 2050 net zero or similar
- Funding: Carbon fees or other
- Leverageable assets (blue)
  - H2 system
  - At-scale CCUS hub
- Leverageable assets (green)
  - Geologic storage
  - Low power prices

Cross cutting Enablers

- Cost and supply chain improvements
  - Electrolyzers
  - Renewables
- H2 and renewable synergies

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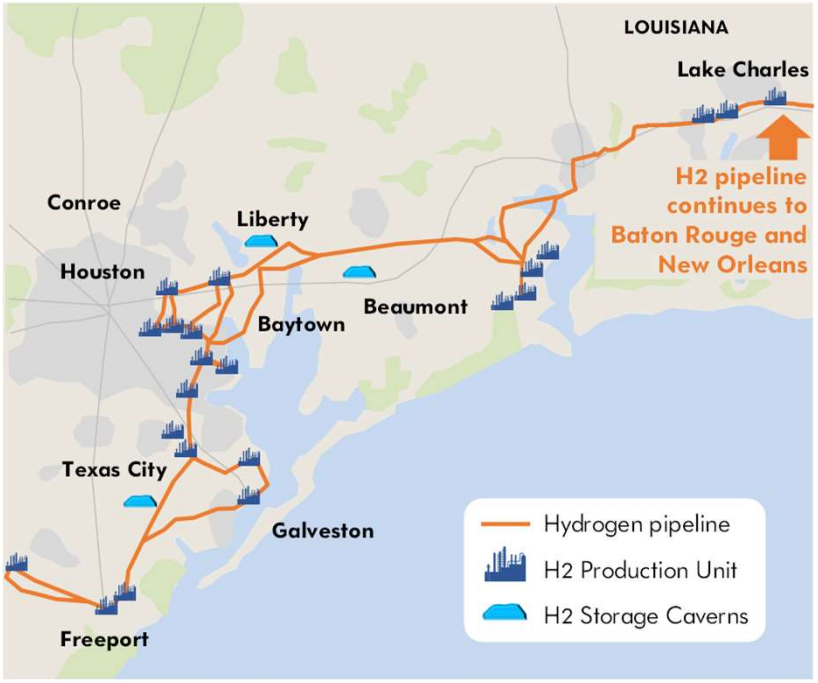
The Houston area holds an anchor position in a world class H2 system, enabling rapid, scale access to new markets

Existing hydrogen system in the Gulf Coast area



TX Gulf Coast H2 system advantages[1,2,3]

Over 900 miles H2 pipelines (56% of US; 32% of global)

~3.4MMt of H2 produced annually largely through steam methane reformation (34% of US; 8.5x Rotterdam)

48 H2 production plants

World's largest storage caverns for H2; adjacent to H2 network

** Existing H2 system could leverage in-place CCUS assets (e.g., Denbury pipeline) to readily add and scale CCUS to convert grey to blue H2

Notes: (1) Houston MSA defined Austin, Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery and Waller counties; (2) TX Gulf Coast includes a region from Corpus Christi, TX to Lake Charles, LA; (3) Number of global H2 plants estimated by dividing global H2 production by US avg. production per H2 plant (52k tons H2 / year)

Source: H2Tools; USDOT PHMSA - National Pipeline Mapping System; Seeking Alpha; Office of US Energy Efficiency & Renewable Energy; Hydrogen Europe

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Four immediate initiatives, with targeted policy/funding, will activate Houston's H2 growth potential

Activate

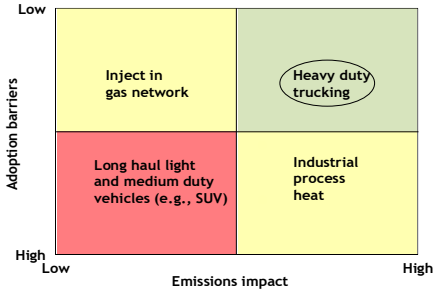
Launch heavy trucking

- Leveraging existing coalitions, assemble group(s) and select / optimize the most attractive market(s) to enter
- Develop roadmap from activate through rollout

Clean grey system

- Assemble coalition
- Develop a prioritized phased plan to couple the high-volume existing H2 system with existing and extended CCUS systems

Prioritization of blue markets



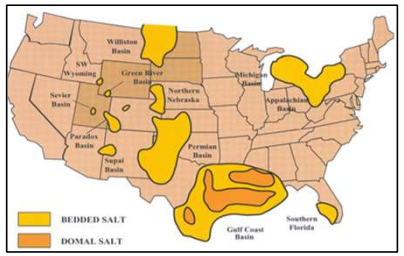
Existing TX H2 system

Activate

Exploit seasonal storage

- Conduct feasibility study (e.g., GTI DOE study) of most cost- effective options to leverage Houston's utility scale, low-cost salt caverns for H2 storage

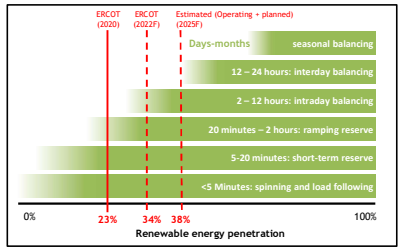
US salt cavern storage



Pilot long duration H2 storage

- PUC to assess H2 storage fit with substantial and growing renewables
- Evaluate funding/policy required to enable maximizing renewable value and ensuring reliability

Storage required by renewable penetration



Policy and funding

- Assemble group (e.g., state and federal attorneys, policy makers) to shape potential policy support for TX clean H2 economy
- Develop targeted policy / funding approach, which unleashes new attractive market opportunities, near and longer term

Critical to establish market opportunity for H2 and address looming impact of low carbon future on TX economy

Notes: (1) PUC refers to Public Utility Commission

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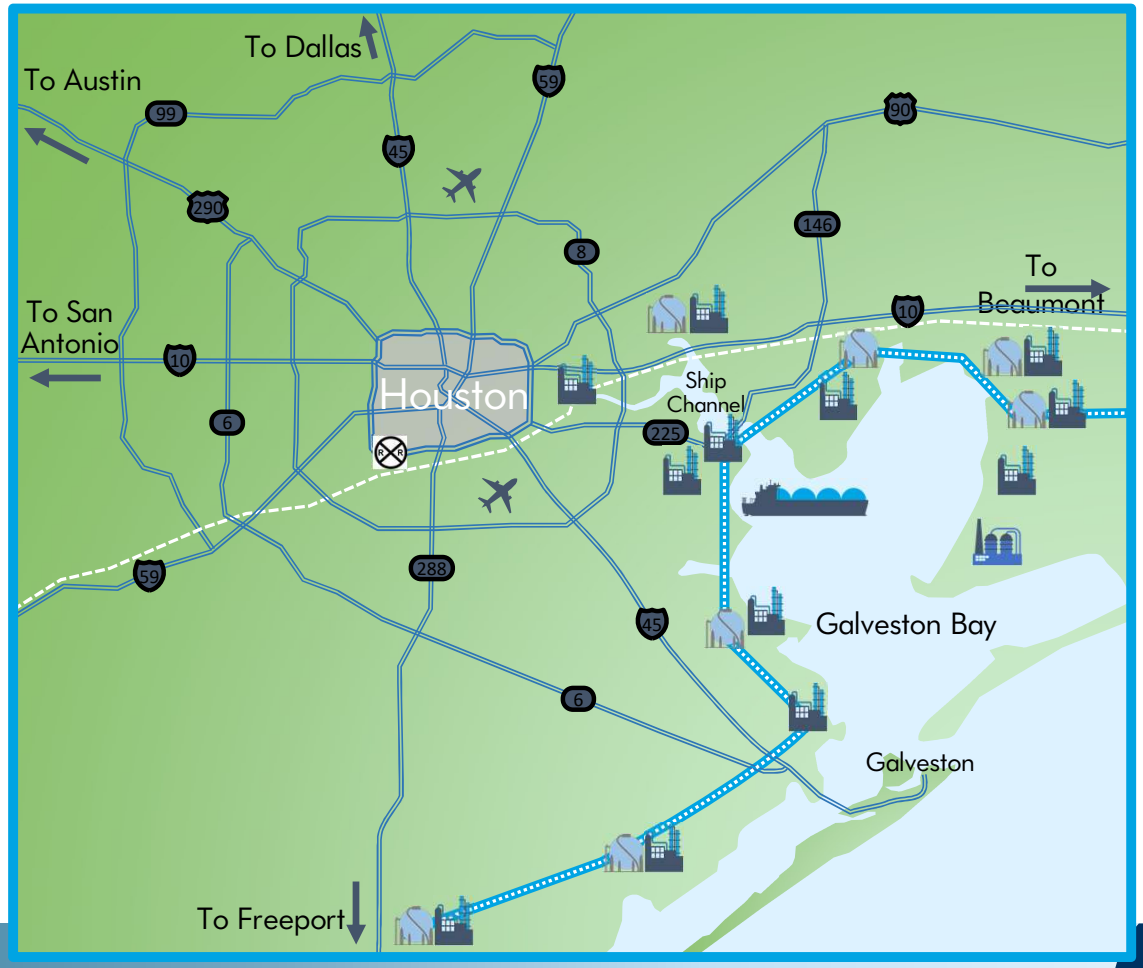
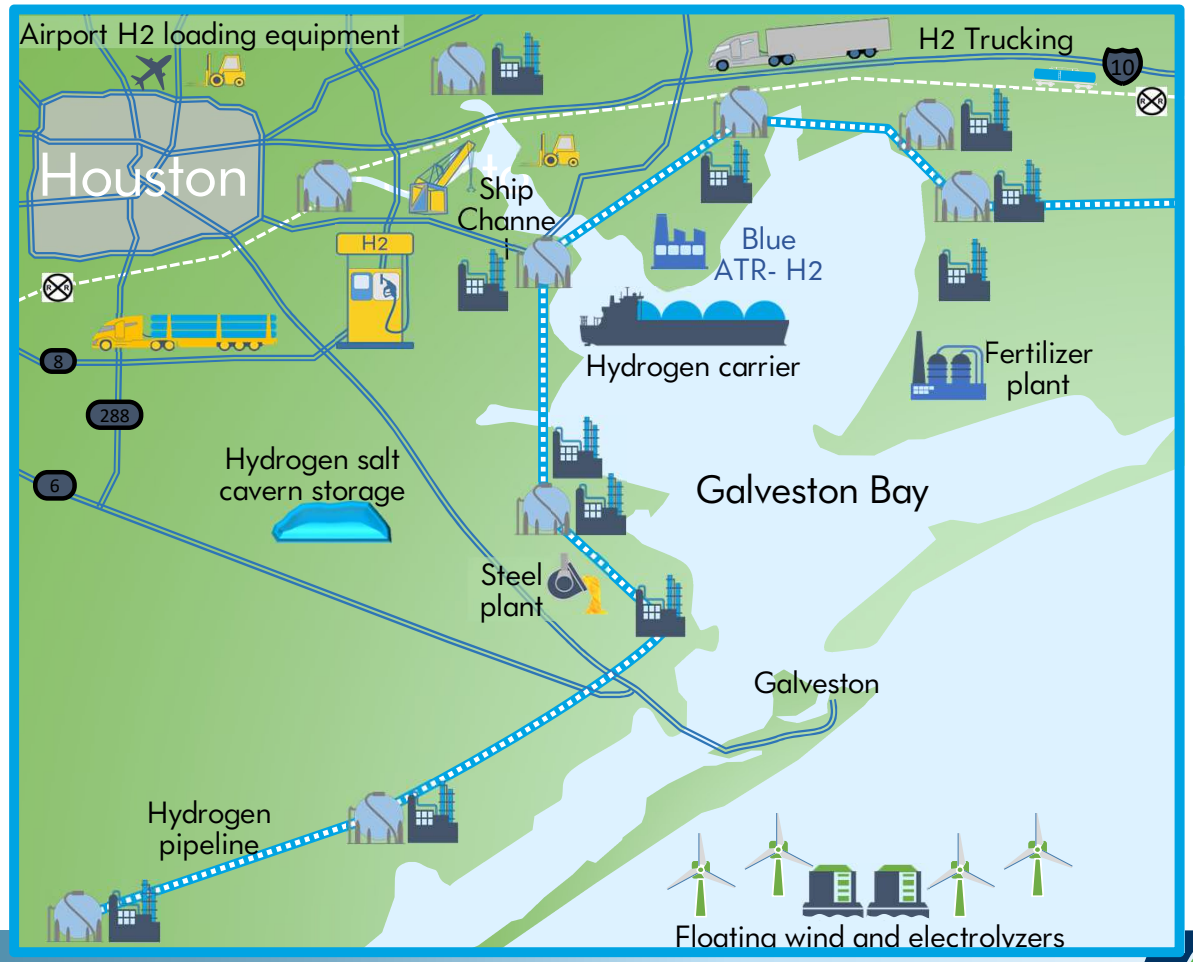
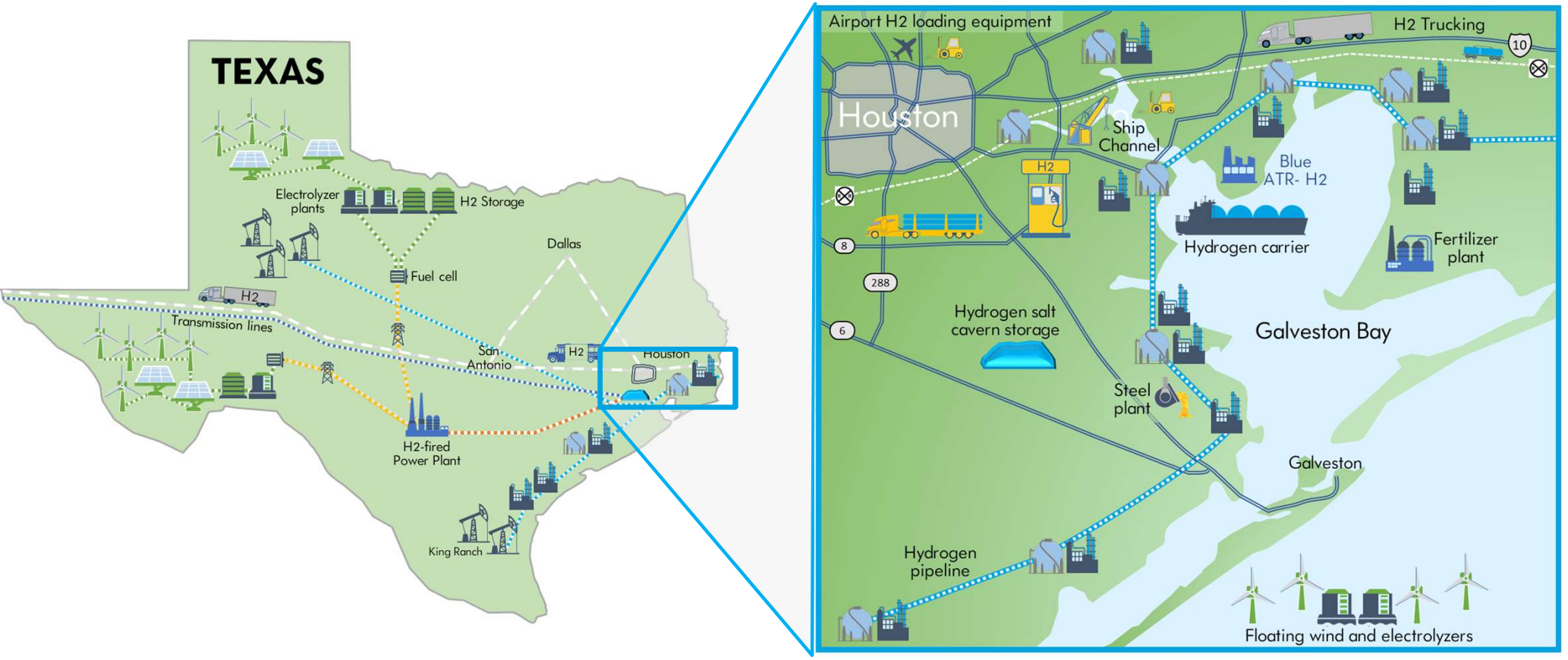
Houston's Hydrogen Cluster – Today



Houston's Hydrogen Cluster – Tomorrow



Texas Low Carbon Energy Vision



CHF's 2021 Low Carbon Energy Initiatives

Market Transformation: Catalyze creation of a Houston Low Carbon Energy Hub

- **Carbon capture:** Hold a CCUS "developers" conference to bring major players together and accelerate creation of a CCUS project pipeline
- **Hydrogen:** Create working groups to focus on near term opportunities in heavy duty transportation (such as a Port of Houston pilot) and energy storage; study opportunities for industrial applications and hydrogen export (potential project with Texas A&M Energy Institute).

Energy Innovation: Work Across Sectors to Create an integrated Clean Energy Innovation Eco-system

- **Acceleration:** Partner with Greentown Labs on a quarterly launch of four low carbon innovation cohorts (based on UH/CHF market assessment)
- **R&D:** Develop a coalition of universities, energy companies, accelerators and other stakeholders (e.g., EDF, Greentown, Welch Institute) interested in building a Texas-based low carbon energy R&D pipeline

Education and Awareness:

- **Webcast series:** Build interest in Houston-based low carbon opportunities
- **Low Carbon Energy Summit III:** Focus on local low carbon energy "wins"
- **Environmental Justice:** Raise awareness of impact of pollution and climate change on low income communities