



HEC Hydrogen Sessions

Decarbonizing the Gas Grid with Hydrogen

April 23, 2021

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Agenda

Hydrogen Energy Center

Velerity

Renewable Gas Consortium

Natural Gas – Industry Under Pressure

Hydrogen – Savior or Chimera?

Hydrogen Pathways

Hydrogen Energy Center

HEC is a nonprofit professional society focused on accelerating the hydrogen as an enabling solution for renewable energy

HEC provides public forums, conducts research and implements projects focused on accelerating the clean energy future

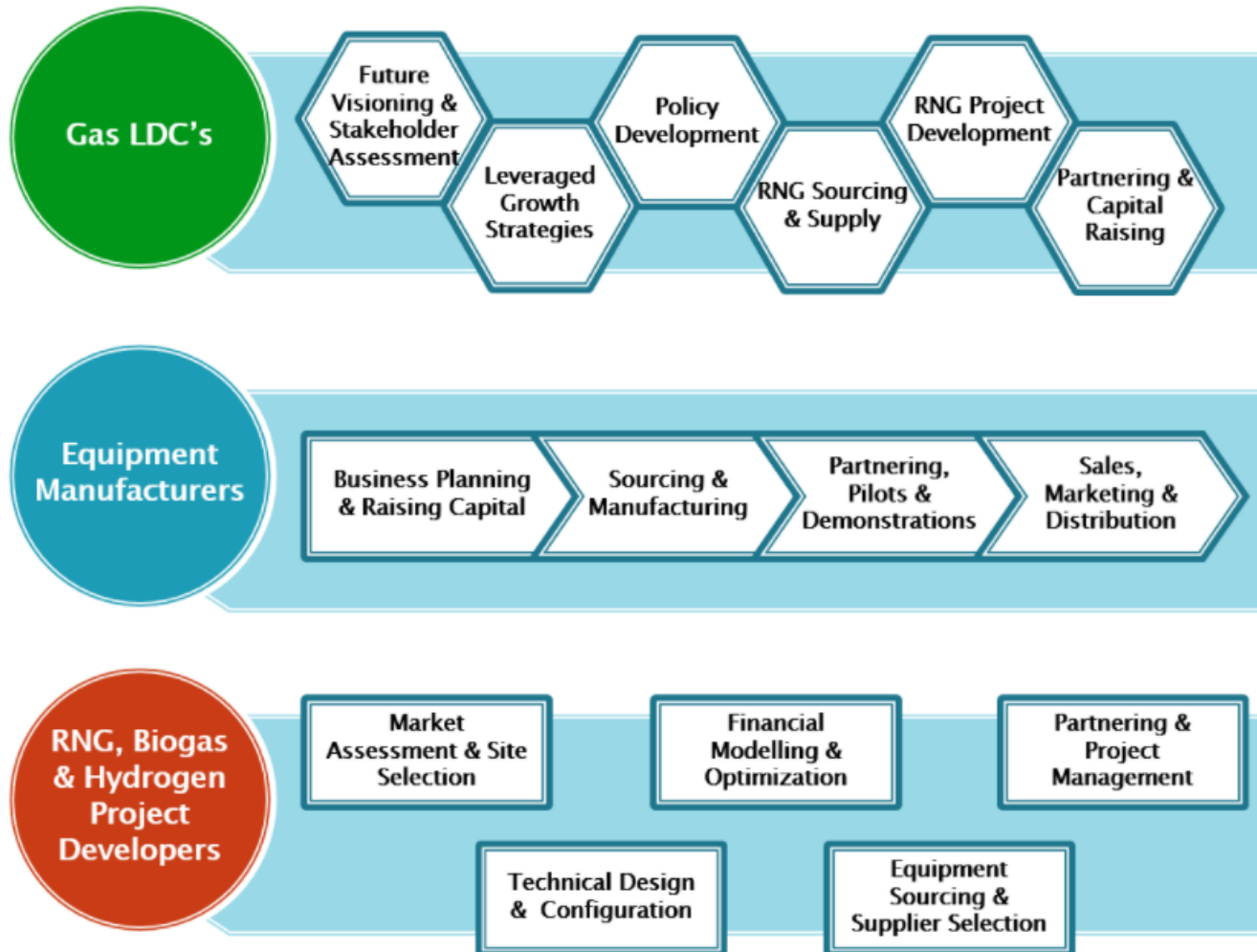
Consider supporting this important effort by becoming a member:

- Influence the course of renewable hydrogen energy technology and policy.
- Be a part of projects that really build hydrogen solutions.
- Have full access to white papers, technical reports, and meeting minutes from our projects and from other organizations.
- Immerse yourself in the hydrogen "goings-on" by connecting with developments & networking with people who are collectively driving the hydrogen "bus".

Upcoming Hydrogen Sessions

- ▶ April 23, 2021 Decarbonizing the Gas Grid with Hydrogen
- ▶ April 30, 2021 Bulk Long Duration Storage with Hydrogen
- ▶ May 7, 2021 Decarbonizing Long Haul Trucking with Hydrogen
- ▶ May 14, 2021 100% Hydrogen Pipelines
- ▶ May 21, 2021 Power Production with Hydrogen
- ▶ May 28, 2021 Building a Global Trade in Hydrogen
- ▶ June 4, 2021 Electrolysis and Water Splitting
- ▶ June 11, 2021 Hydrogen Production with Carbon Separation
- ▶ June 18, 2021 Wind to Hydrogen

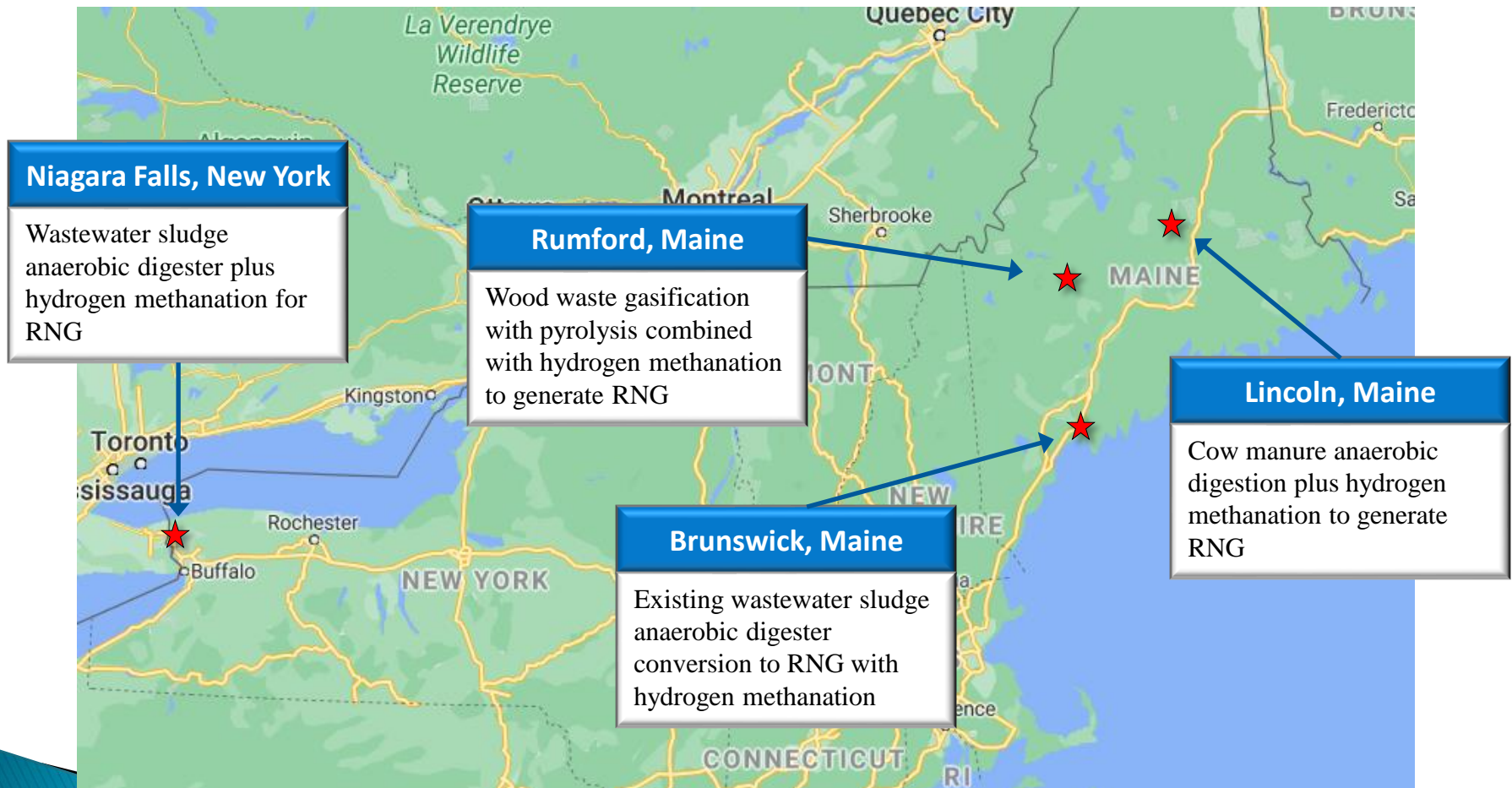
Velerity Services



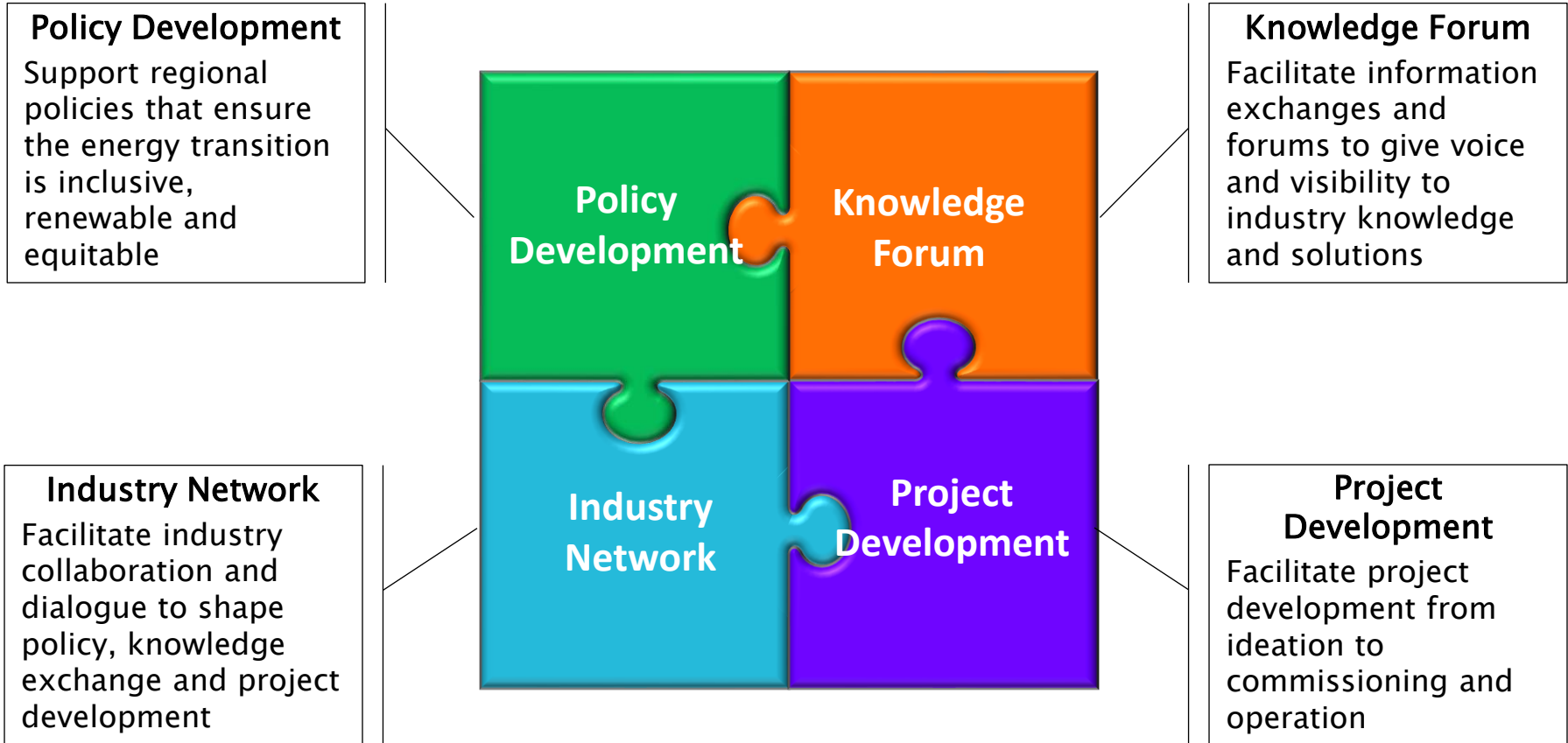
Velerity – Illustrative Clients



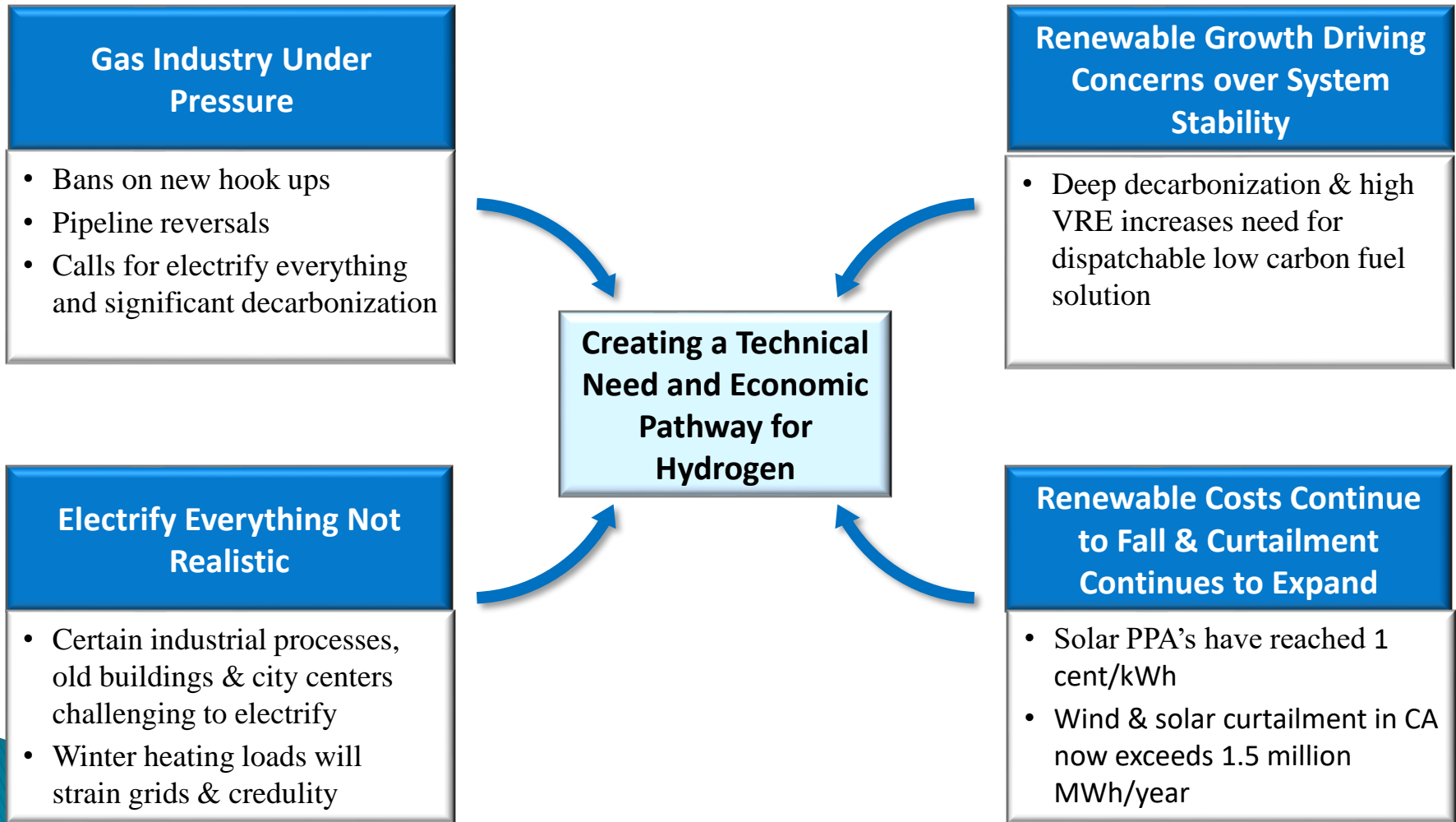
RNG project work undertaken by Velerity and the Hydrogen Energy Center initially supported by the Connecticut Center for Advanced Technology



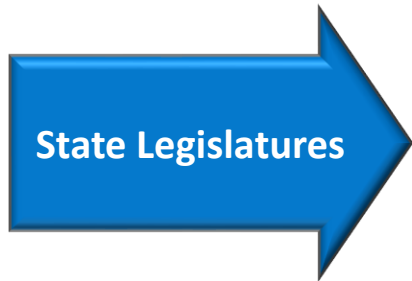
Renewable Gas Consortium – Driving \$10 billion investment in renewable gas, hydrogen and biomethane in the Northeastern United States



Hydrogen is emerging as a lynchpin in enabling the zero carbon economy



Gas companies are facing a changing business environment with substantive implications for future business performance



Enacting targets for economy wide greenhouse gas emission reductions

2050 CO2 Emission Reduction Targets

NY	-85%	MA	-85%	CT	-80%	ME	-80%
RI	-80%	NH	-80%	VT	-80 to -95%		



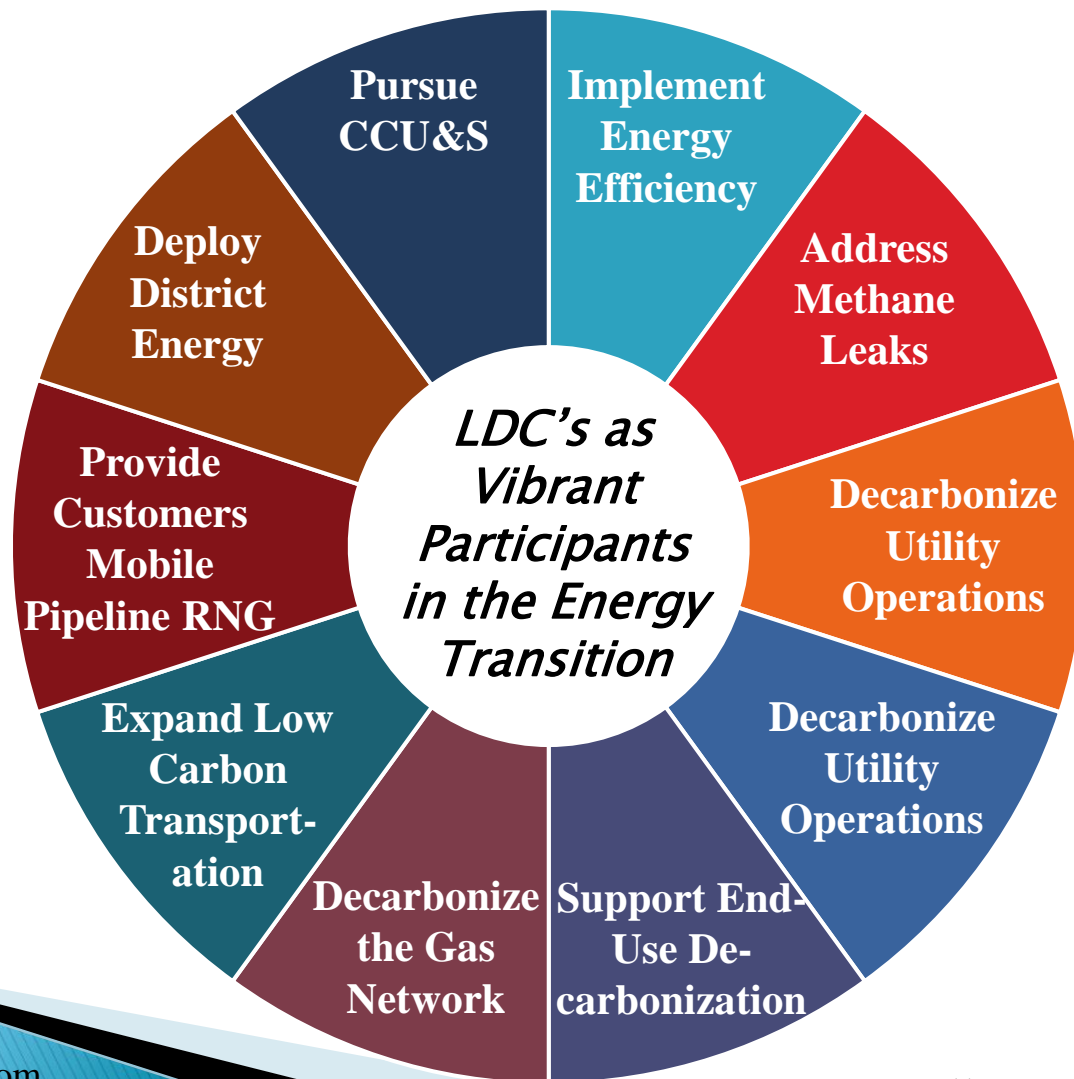
Thwarting plans for pipelines and new customer hookups

- Summit - Withdrew \$90 million pipeline extension
- Liberty – Withdrew \$340 million Granite Bridge pipeline project
- Cities that have banned new hookups: Berkeley, CA; San Jose, CA; Mountain View, CA; Santa Rosa, CA; Brisbane, CA; Brookline, MA; Denver, CO; and Seattle, WA

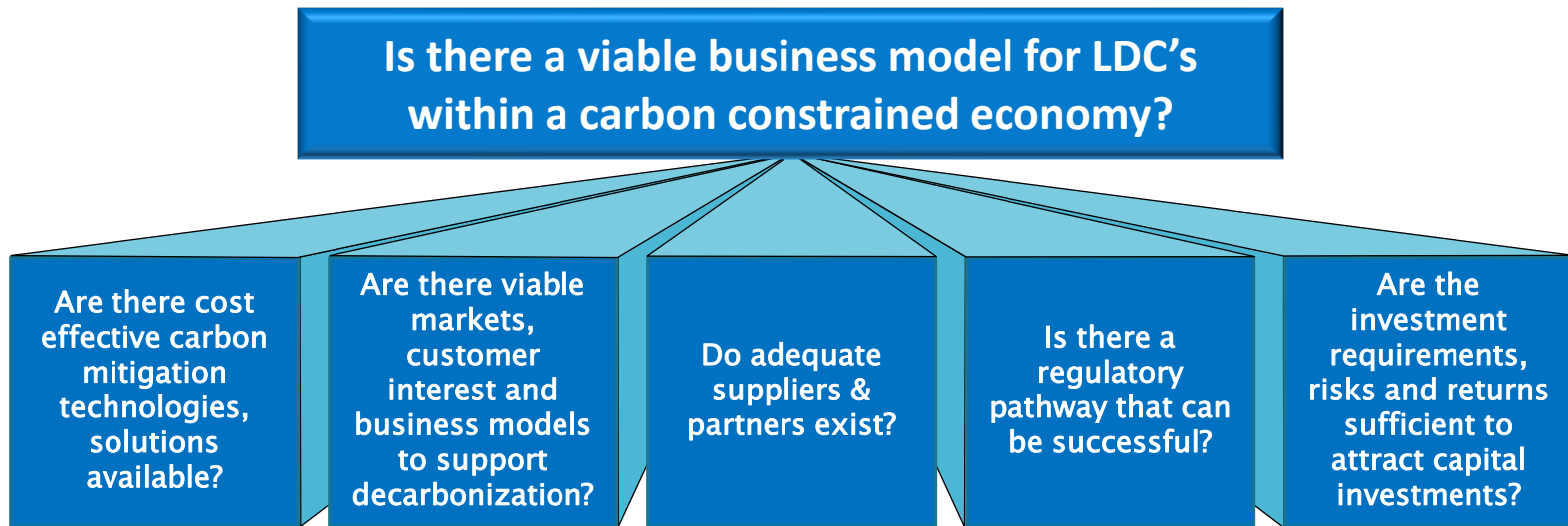


Electrification of building heat and transportation applications expanding

Gas companies have the opportunity to embrace the change, and become vibrant participants in the great energy transition



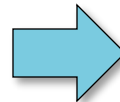
Key questions emerge, however, about how gas utilities can to survive in a decarbonized world



What about hydrogen?

Needs Emerging for Hydrogen Solutions

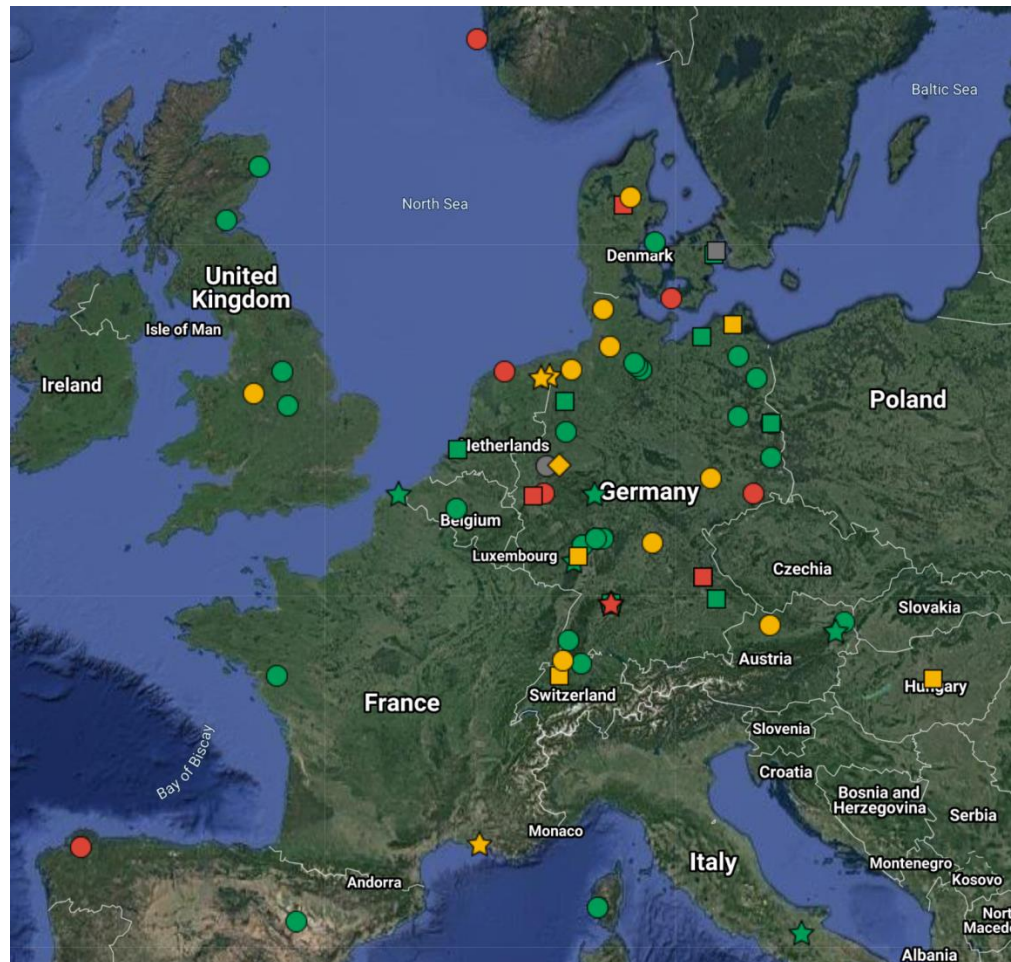
- Increasing penetration of variable renewable energy
- Challenges decarbonizing a range of heat energy and industrial applications such as steel and cement manufacture
- Interest in decarbonizing industrial uses of hydrogen, especially refining and ammonia production
- Solution for transportation including long-distance trucking, shipping and aviation



Power to gas provides the opportunity to solve several vexing energy challenges simultaneously

- Utilizes curtailed wind and solar electricity that would otherwise be wasted
- Creates a valuable product – either renewable hydrogen or renewable natural gas
- Reduces carbon emissions
- Addresses electric transmission constraints, expanding opportunities for expanding renewable energy
- Decarbonizes natural gas
- Provides a local “in region” source of natural gas, alleviating or at least mitigating natural gas transmission constraints

There are approximately 128 power-to-gas projects in Europe



Global electrolyzer market is accelerating for producing green hydrogen

Country & EU Electrolyzer Commitments

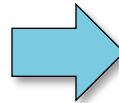
- 4 Countries plus the EU
- 100.5 GW in Electrolyzer Commitments by 2030

Wind to Hydrogen

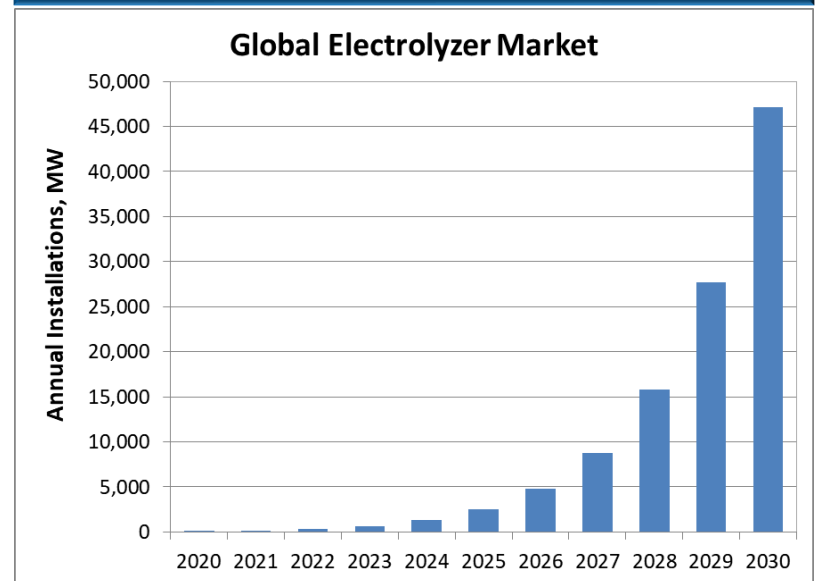
- 7 Projects
- 582 MW in Electrolyzer Capacity

Green Hydrogen to Ammonia

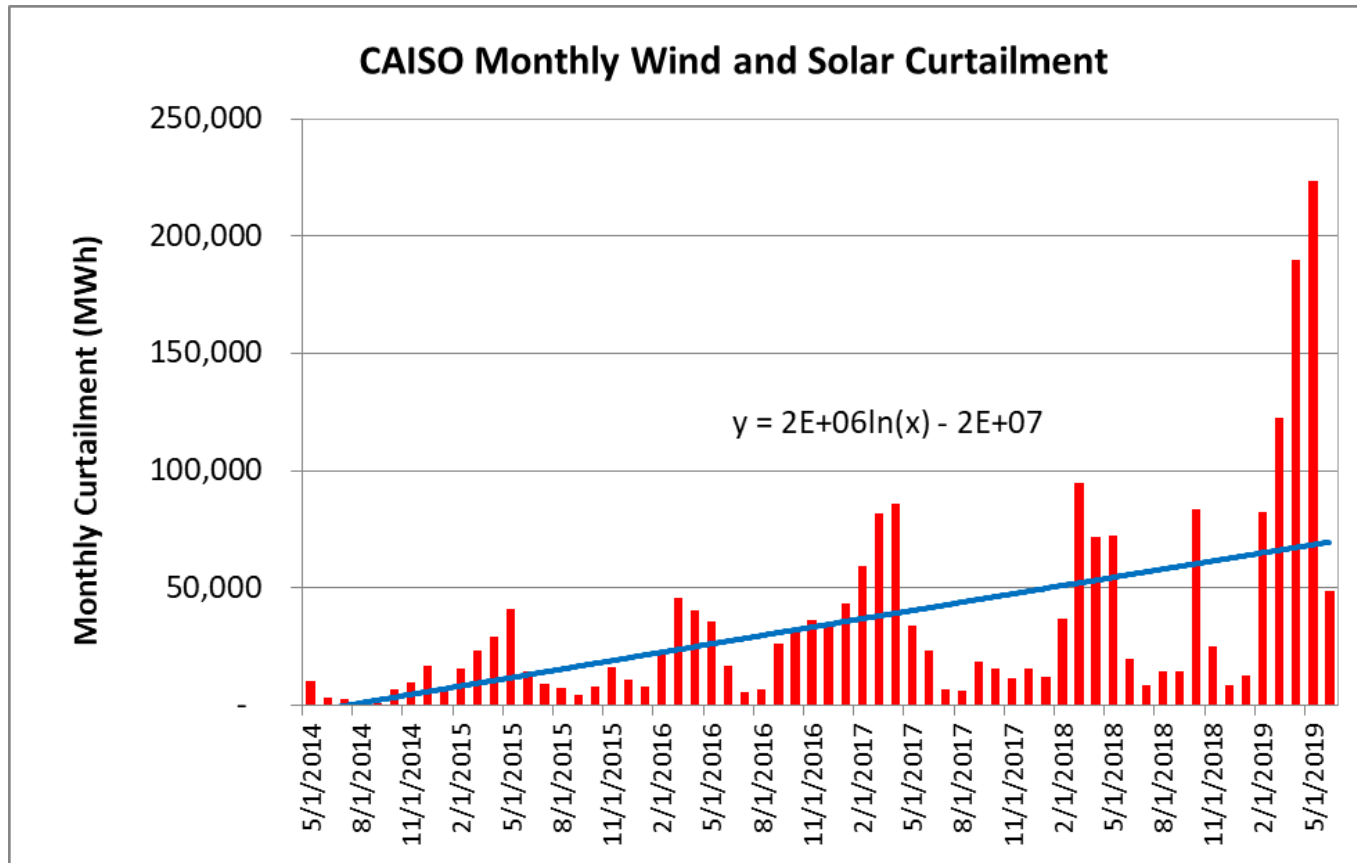
- 4 Projects
- 16.56 GW in Electrolyzer Capacity



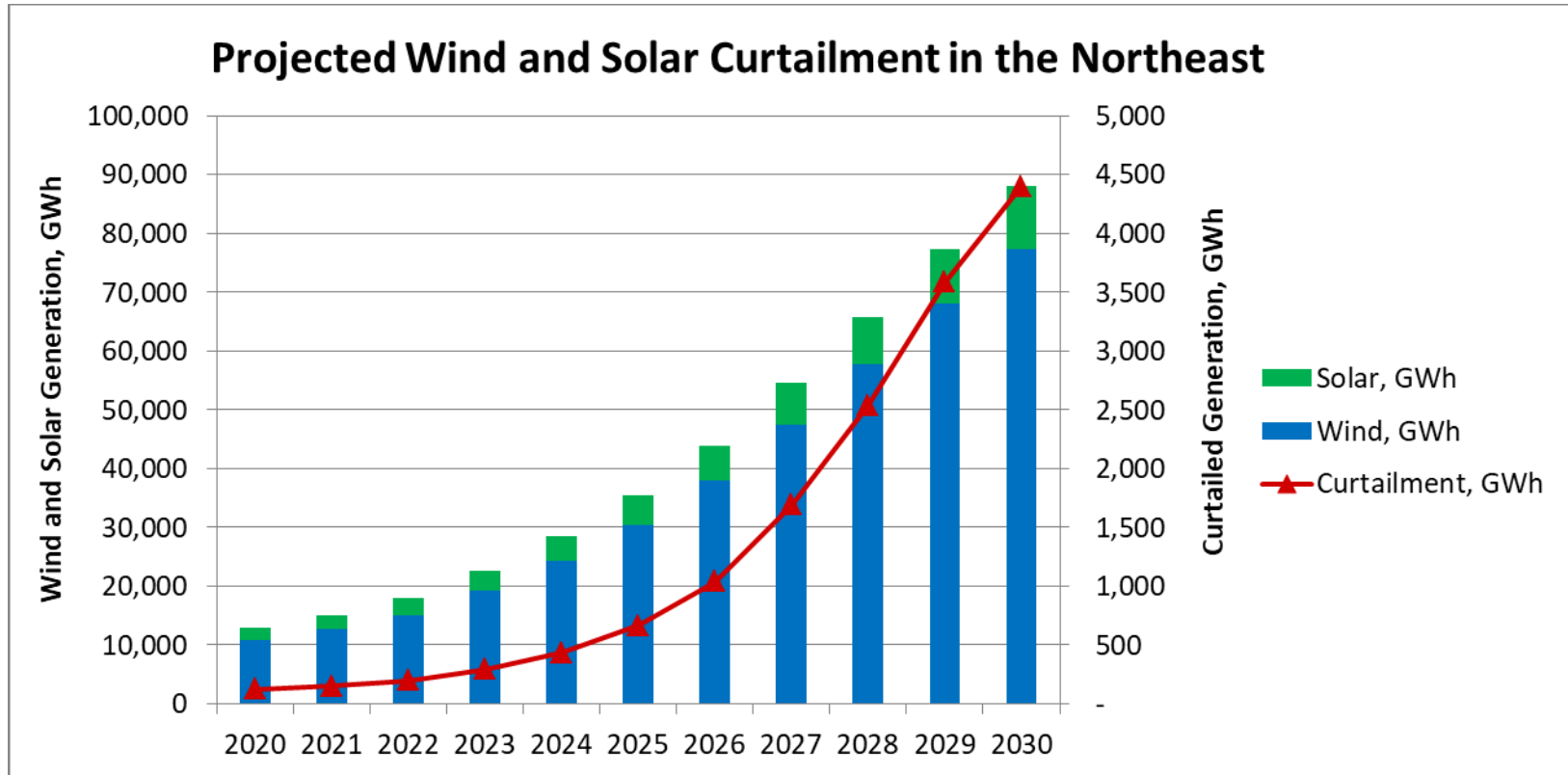
\$17 Billion Annual Market by 2030



Renewable energy curtailment growing significantly around the world – the challenge of stranded and low-cost electrons



Wind and solar curtailment in the Northeast could reach 4,500 GWh by 2030



What color is your hydrogen?

Green hydrogen

Technology: Electrolyser

Input: Renewable electricity

Process: Splitting water into hydrogen and air

GHG emissions: Depends on the GHG emissions from electricity supply

Blue hydrogen

Technology: (1) Steam Methane Reforming (SMR) plant with Carbon Capture and Storage (CCS); (2) Coal gasification plant with CCS

Input: (1) Natural gas; (2) Coal

Process: Converting (1) natural gas/(2) coal into hydrogen and CO₂

GHG emissions: Low, CO₂ stored and/or reused

Turquoise hydrogen

Technology: Methane pyrolysis plant with Carbon Capture and Utilisation (CCU)

Input: Mainly natural gas

Process: Splitting methane into hydrogen and solid carbon

GHG emissions: Depend on the input to generate the necessary heat

Grey hydrogen

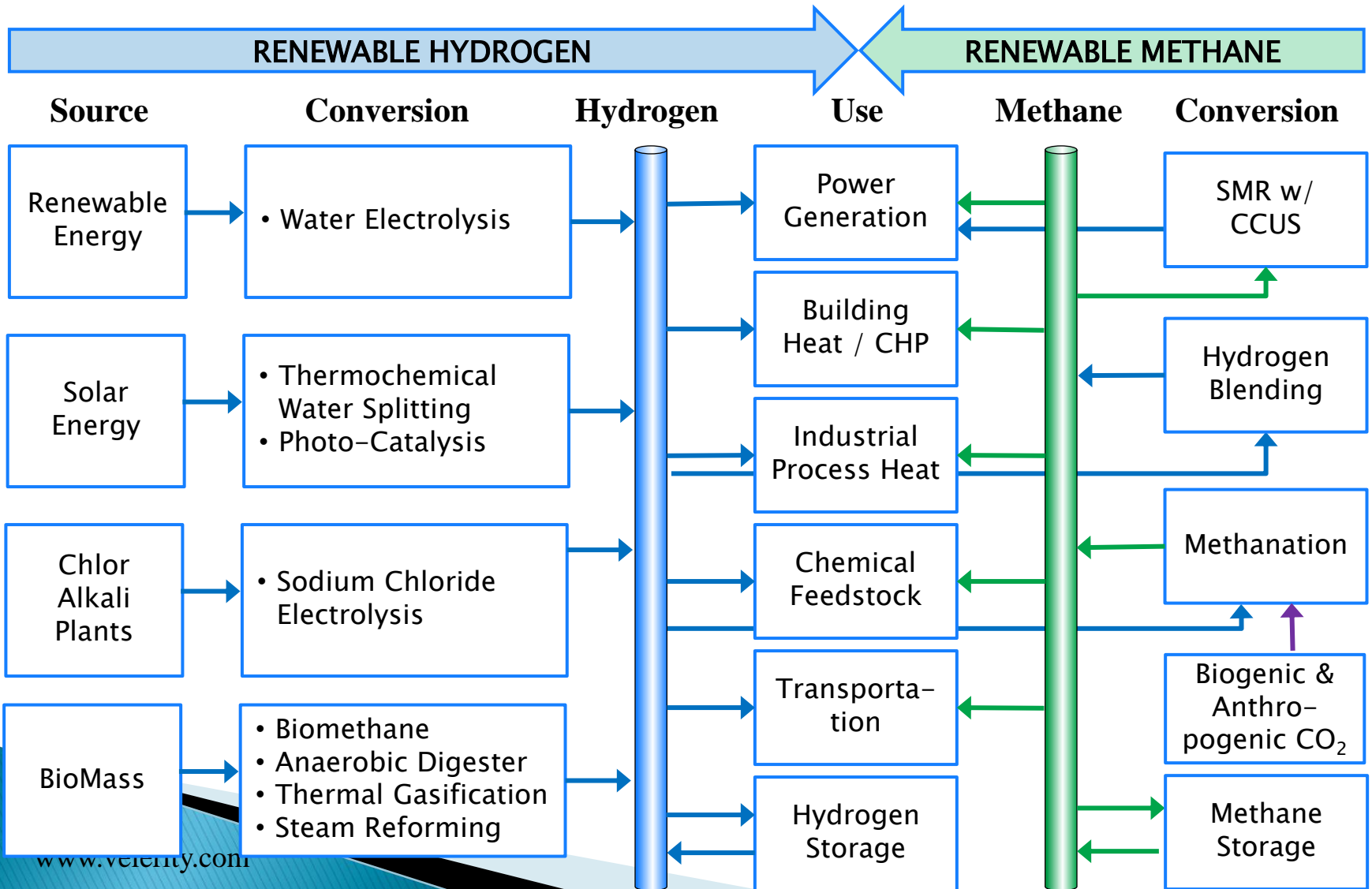
Technology: (1) Steam Methane Reforming (SMR) plant; (2) Coal gasification plant

Input: (1) Natural gas; (2) Coal

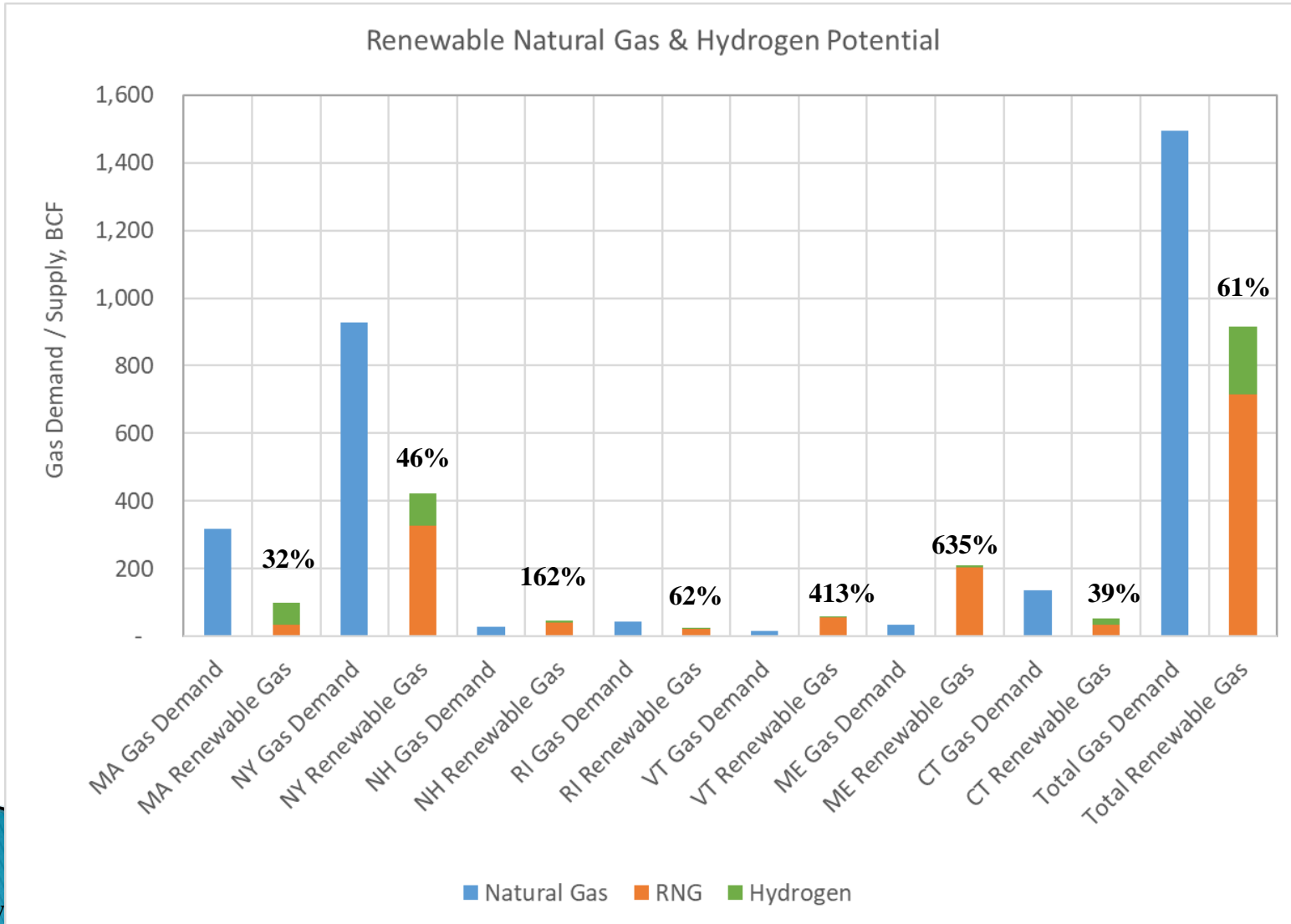
Process: Converting (1) natural gas/(2) coal into hydrogen and CO₂

GHG emissions: Yes

Green Hydrogen Pathways for Decarbonizing the Gas Grid



Non-Power Generation Natural Gas Demand and Renewable Gas Potential by State and for the Region



Hydrogen Pathways

- ▶ Hydrogen Blending
- ▶ 100% Hydrogen
- ▶ Methanation
- ▶ Hydrogen Power Production
- ▶ Methane Pyrolysis

Blending

- ▶ **Keele, England**
 - HyDeploy Project
 - Successfully tested 20% hydrogen by volume on campus setting with 130 buildings
- ▶ **ATCO - Alberta Canada**
 - 5% Blending, 5,000 customers
 - Hydrogen source likely blue hydrogen via pipeline
- ▶ **Enbridge - Markham, Ontario**
 - Building 6.8 km of pipeline
 - 3,600 customers
 - 2% by volume
 - Utilizing power-to-gas facility built with Cummins in 2018
- ▶ **E.On – Germany**
 - Piloting 20% blend to 400 homes

Blending

▶ SoCal Gas & SDG&E

- Announced blending project beginning with 1% hydrogen by volume, increasing up to 20%

▶ The ATCO Hydrogen Blending Project – An Overview

- ATCO, a local natural gas distribution system in Alberta, Canada, recently announced they will be investing \$5.7 million in a hydrogen blending project, to provide a mix of hydrogen and natural gas to 5,000 residential customers in Fort Saskatchewan, Alberta. ATCO will blend in up to 5% hydrogen by volume into their pipeline system.
- Based on national statistics for residential natural gas consumption in Canada, and based on blending in 5% hydrogen by volume, it is estimated that each residence will consume 4,512 cubic feet of hydrogen per year. With 5,000 residences as part of the program, total annual hydrogen demand will be approximately 52,190 kilograms per year.

▶ NREL – HyBlend Project

100% Hydrogen in the gas distribution network

▶ **H100 Fife in Levenmouth, Scotland**

- 300 homes - Phase 2 will be 1,000 homes
- Off-shore wind plus electrolysis
- Plans include Liquid Organic Carrier storage, oxygen separation and storage, and hydrogen for transportation

▶ **Gateshead, UK**

- Northern Gas Networks & Cadent - 2 homes

▶ **H21 Leeds City Gate - Leeds, UK**

- Northern Gas Networks - 264,000 customers

▶ **Rozenburg, Netherlands**

- Eight electrolyzers
- 25 apartments
- Gas fired boiler for backup

▶ **Stad aan 't Haringvliet, Netherlands**

- 550 homes

Leeds H21 Project



100% Hydrogen – dedicated industrial applications

▶ **HYBRIT, Lulea, Sweden**

- Swedish company HYBRIT is utilizing hydrogen and electricity for steel manufacturing instead of using coking coal and other fossil fuels. They are expected to have the first carbon free steel on the market by 2026.

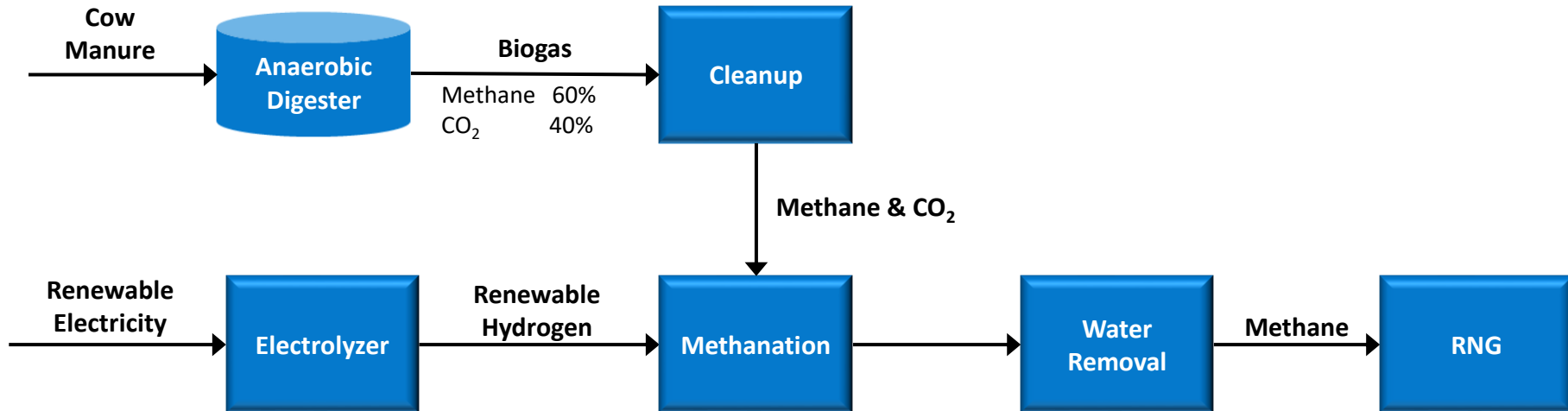
▶ **Shell, Eemshaven, Netherlands**

- Shell, along with Gasunie and the port of Groningen are the founding partners of the NorthH2 project evaluating a project to dedicate 3-4 GW of offshore wind power by 2030 and potentially 10 GW by 2040 dedicated to hydrogen production initially for use in Shell's petrochemical processing plant in Eemshaven.

▶ **Iberdrola & Fertiberia Green Hydrogen to Ammonia**

- In Spain, Iberdrola is investing \$174 million to build 100 MW solar facility with 6 GW of electrolyzers to produce hydrogen for ammonia and fertilizer manufacturing.

RNG Production with Methanation



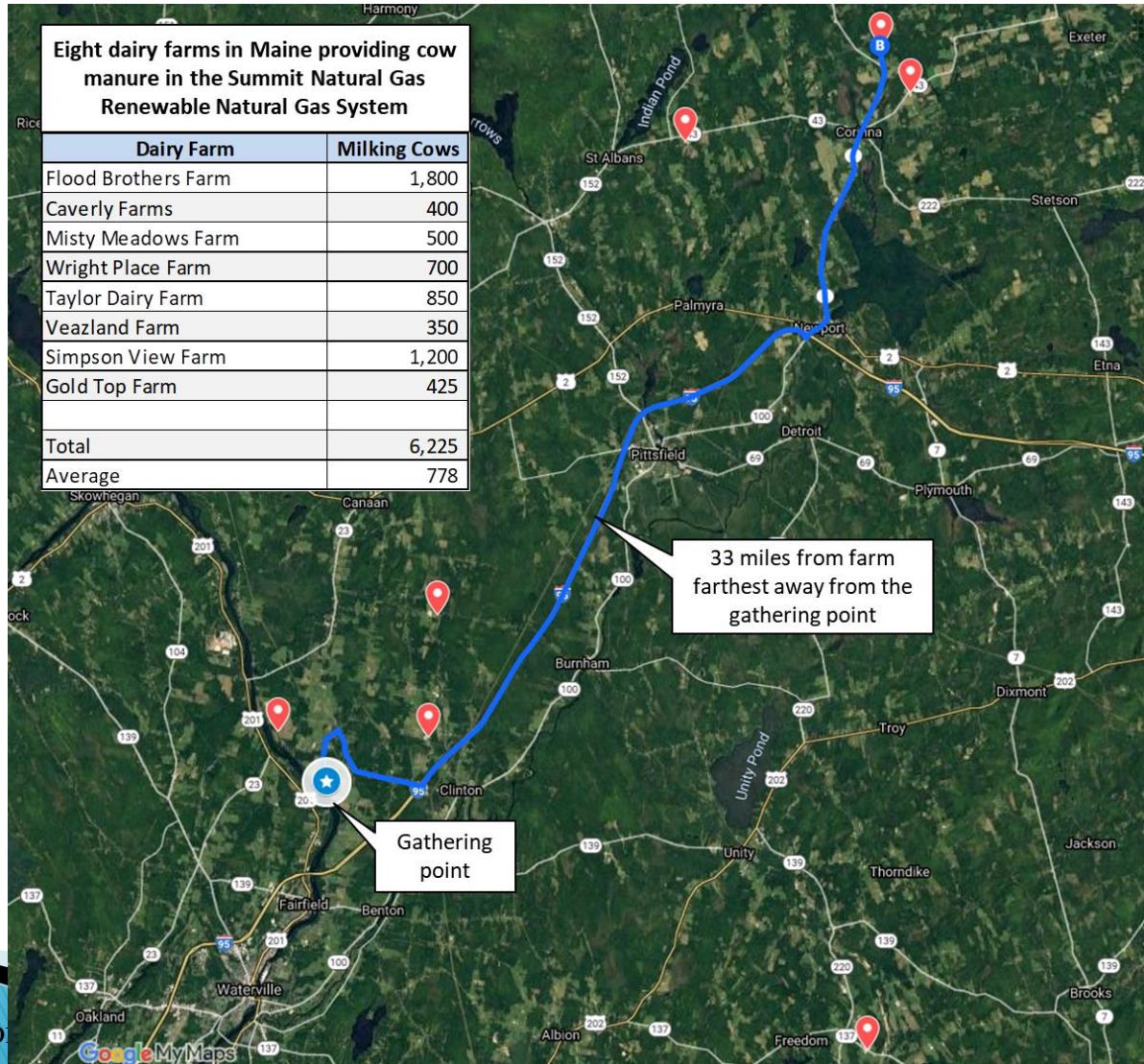
Methanation

- ▶ **Clinton, ME**
 - Summit Natural Gas, Manure to Methane w/Methanation
 - 6,225 cows
 - 8 farms
- ▶ **San Diego, CA**
 - SoCalGas, NREL Bioreactor
- ▶ **Eugene, OR**
 - NorthWest Natural, EWEB, 2-10 MW Electrolyzer + Methanation
- ▶ **Rotterdam, Netherlands**
 - Stedin
 - Methanation of CO₂ plus Hydrogen to produce methane for 25 apartments

Summit Gas Manure Gathering System

Eight dairy farms in Maine providing cow manure in the Summit Natural Gas Renewable Natural Gas System

Dairy Farm	Milking Cows
Flood Brothers Farm	1,800
Caverly Farms	400
Misty Meadows Farm	500
Wright Place Farm	700
Taylor Dairy Farm	850
Veazland Farm	350
Simpson View Farm	1,200
Gold Top Farm	425
Total	6,225
Average	778



33 miles from farm farthest away from the gathering point

Gathering point

Carbon separation utilizing methane pyrolysis

▶ Hallam, Nebraska - Monolith Materials

- Plant separates hydrogen and carbon through methane pyrolysis
- Produces 14,000 metric tons of carbon black per year
- Mitsubishi Heavy Industries invested an undisclosed amount in 2020
- Plans a second much larger plant to produce anhydrous ammonia using the hydrogen

▶ C-Zero

- Based in Santa Barbara - Developing carbon separation technology utilizing methane pyrolysis
- Recently received \$11.5 million investment from Mitsubishi Heavy Industries, Breakthrough Energy Ventures, AP Ventures, and Eni Next
- The company has also won \$3 million through two grants from the U.S. Department of Energy, and a \$350,000 project with California utilities Pacific Gas & Electric and Southern California Gas
- C-Zero, after experimenting with molten salts and metals, settled on a molten-nickel-based catalyst in a continuous flow process, he said.
- C-Zero expects its process to yield hydrogen at a cost of about \$1.50 per kilogram, about the same as gray hydrogen

Carbon separation utilizing methane pyrolysis

▶ **BASF - Germany**

- Chemicals giant BASF is building a turquoise hydrogen pilot plant in partnership with a consortium of German companies and research organizations

▶ **Hazer Group - Australia**

- Australian company Hazer Group has won government backing to build a pilot plant testing its own pyrolysis process.

▶ **TNO - Netherlands**

- TNO, in the Netherlands, has developed their EMBER methane pyrolysis process.

Carbon separation utilizing methane pyrolysis

Monolith Materials



C-Zero

