HEC Hydrogen Sessions

#11

United States Hydrogen Hubs

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Today's Agenda

- Hydrogen Energy Center
- Velerity
- DOE Hydrogen Hubs Initiative
- Inflation Reduction act of 2022
- Global Hydrogen Hubs
- United States Hydrogen Hubs
- Hydrogen Hub Consortia
- Summary and Perspectives

Background of Today's Presenter
Brad Bradshaw

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Boston, Massachusetts

Areas of Expertise

Functional

- Strategy
- Marketing & Product development
- Raising Capital
- **Partnering & Implementation**

Sectors

- Energy
- **Telecommunications**

Biography

Current Positions

- **President of Velerity, providing marketing, technology and business strategy consulting services**
- **President of the Hydrogen Energy Center, a non-profit organization that conducts research and provides forums on hydrogen**

Previous Positions:

- **CEO of Hy9, a hydrogen purification and generation company**
- **Senior Consultant in the Global Energy Practice at Arthur D. Little**
- **Director of the Utility Practice at Yankee Group**
- **Senior Consultant at DMC Services, a national utility energy services company**

Academic Credentials

- **Bachelor of Arts, Engineering Major, Dartmouth College**
- **Masters in Business Administration, Specialized in Finance, Olin School of Management, Babson College**

Accomplishments and Impact

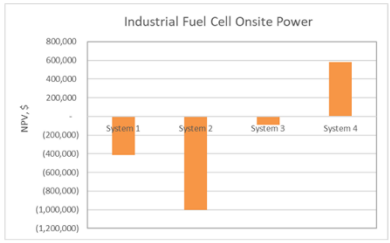
- **Led the development and implementation of a comprehensive business strategy and implementation plan for a billion-dollar electricity and natural gas company,**
- **Developed the business and market strategy for a nationwide wholesale communications service provider.**
- **Developed the business plan, raised $5 million in capital and led development of an industry leading hydrogen generation company**
- **Turned around the financial performance of the largest district energy system in the United States.**

Hydrogen Energy Center: 30 years of being a resource to the hydrogen industry through forums, publications and projects

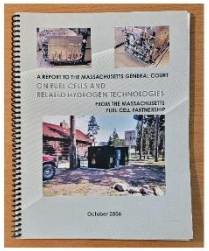
- HEC is a nonprofit professional society focused on accelerating the hydrogen as an enabling solution for renewable energy
- HEC provides public forums, conducts research and implements projects focused on accelerating the clean energy future
- Consider supporting this important effort by becoming a 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".

Velerity:
Illustrative Hydrogen and Related Projects

Market Assessment for Industrial Fuel Cell CHP Systems

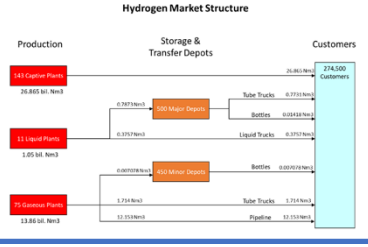


Development of Hydrogen Roadmap for the State of Massachusetts

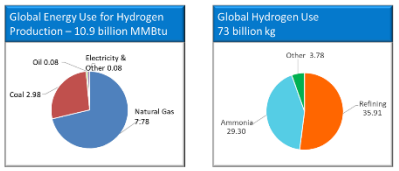


Business Strategy for a Zero Carbon Hydrogen Generation Company

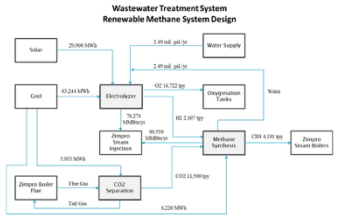
Hydrogen Market Strategy for High Pressure Electrolyzer Manufacturer



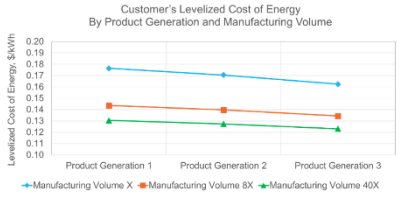
Hydrogen Entry Strategy for $7 Billion Global Materials Manufacturer



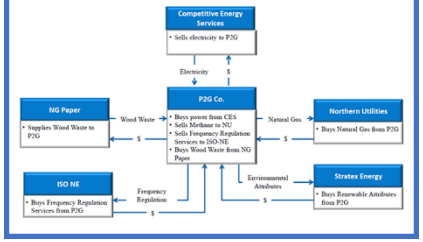
Producing Renewable Methane & Methanol at a Wastewater Treatment Facility



Solid Oxide Fuel Cell Company Acquisition – Due Diligence

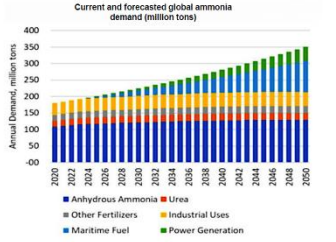


Producing Renewable Natural Gas from Wood Waste

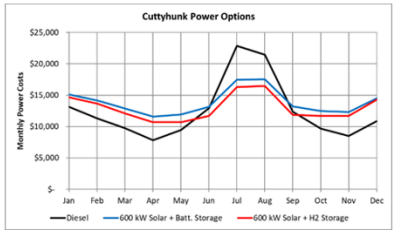


Velerity:
Illustrative Hydrogen and Related Projects

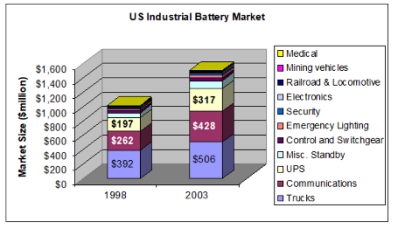
Green Ammonia Market Assessment & Business Strategy



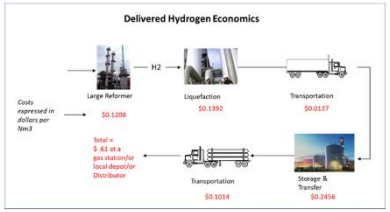
Designing a Hybrid Diesel, Solar, Storage and Hydrogen Microgrid



Redirected Energy Storage Company's Strategy, Resulting in Over $100 million in Sales



Market Strategy for Hydrogen Storage Company

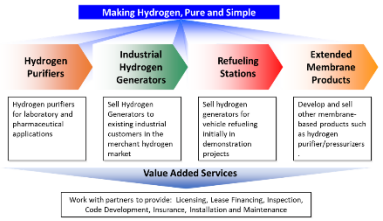


Business Plan & Financials for High Temperature Membrane Company

Membrane Processes: Major Applications & Markets
Sales in million US$ per year

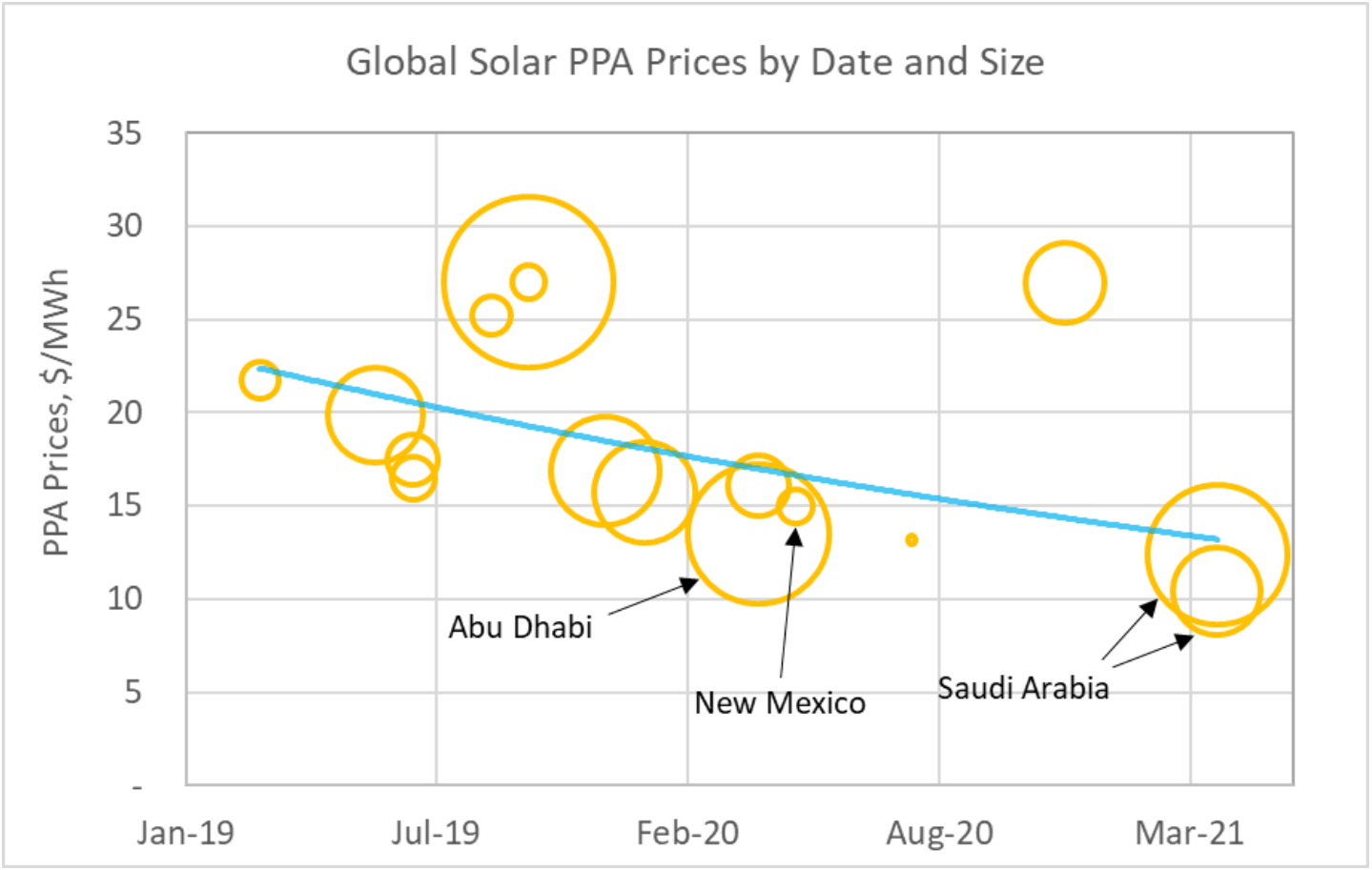
	Water Treatment	Food Industry	Medical Devices	Chemical & Pharma	Total
Microfiltration	310	95	20	35	460
Ultrafiltration	60	44	130	15	249
Reverse Osmosis	120	15	-	10	145
Electrodialysis	60	15	-	20	95
Dialysis	-	-	900	-	900
Gas Separation	-	-	-	45	455
Pervaporation	-	-	-	5	5
Total	550	169	1050	130	1899

Growth Strategy for Hydrogen Generation Company

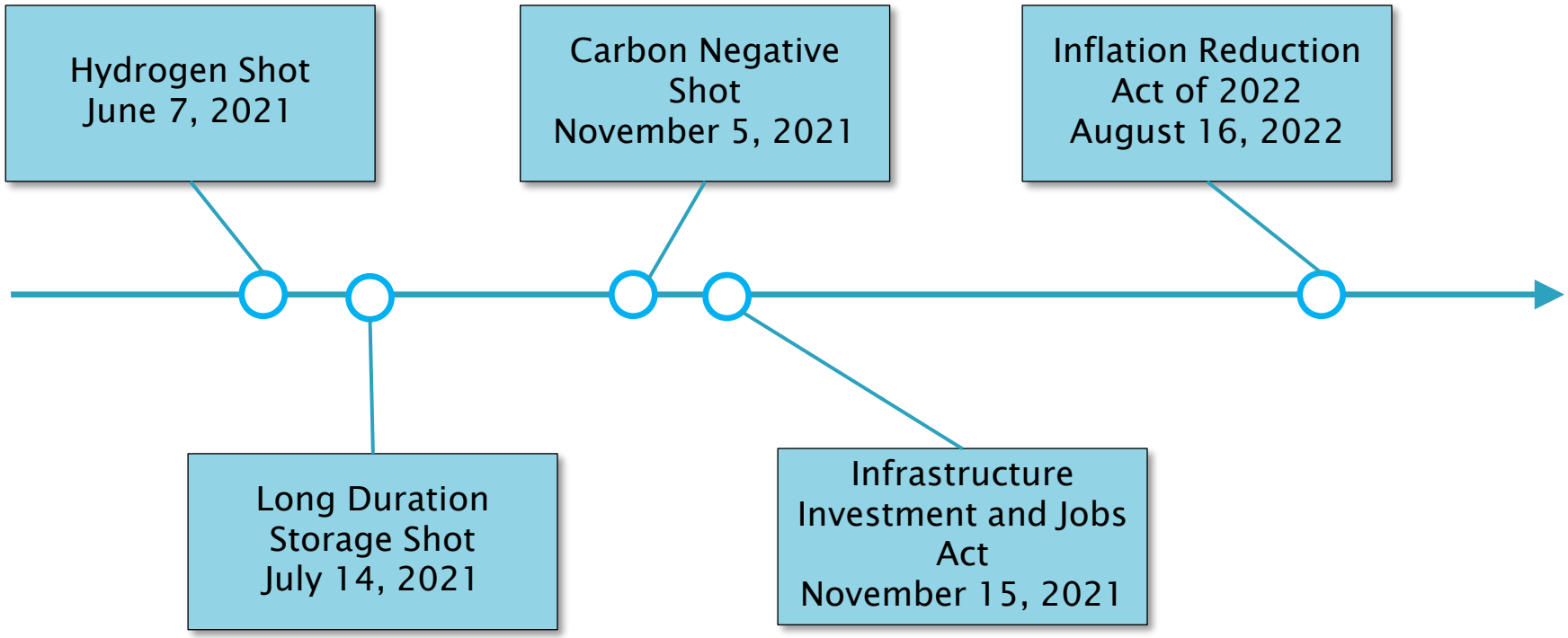


District Energy System – Turnaround Strategy

Globally, PPA prices for solar are nearing 1 cent per kWh, implying marginal cost of hydrogen production at 50 cents per kilogram



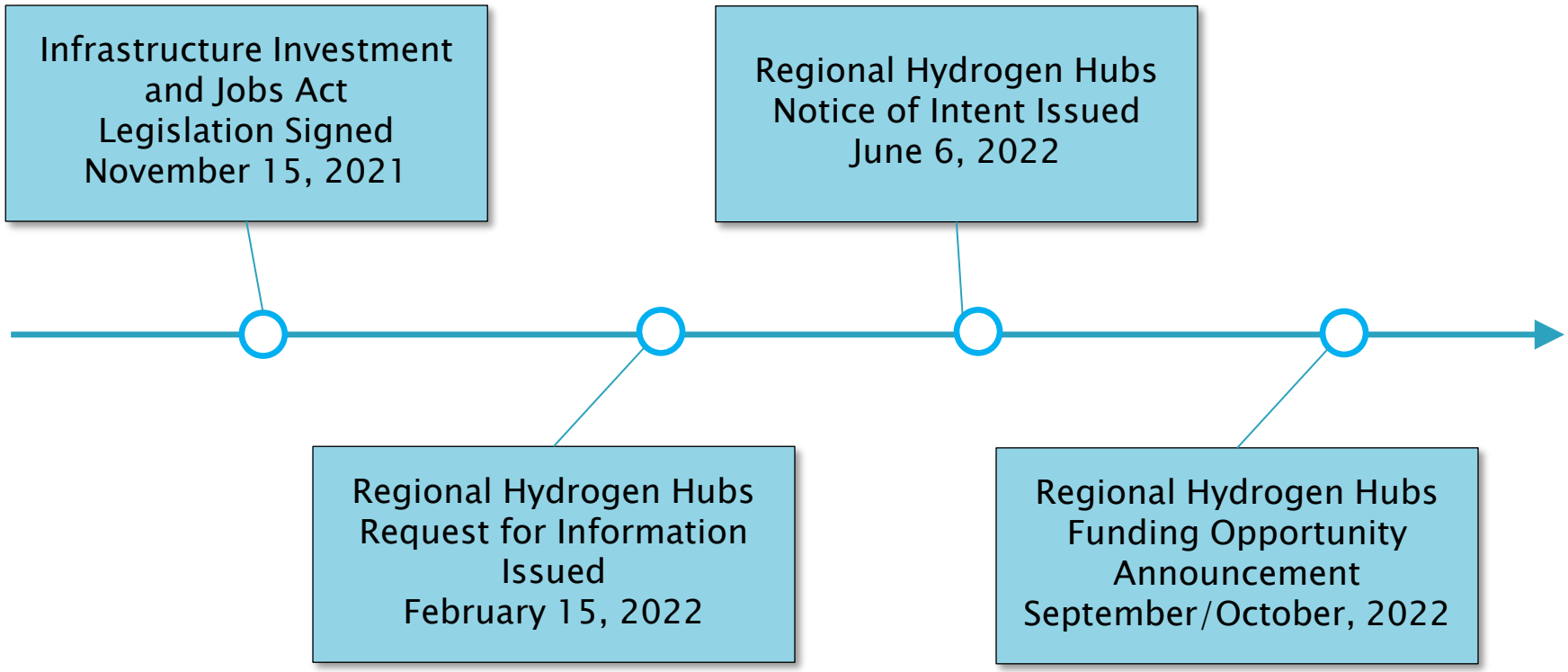
DOE Energy Earthshots & Legislative Timeline



Hydrogen Shot: $1/kg in 10 years

- The U.S. Department of Energy's (DOE's) Energy Earthshots Initiative aims to accelerate breakthroughs of more abundant, affordable, and reliable clean energy solutions within the decade.
- Achieving the Energy Earthshots will help America tackle the toughest remaining barriers to addressing the climate crisis, and more quickly reach the Biden-Harris Administration's goal of net-zero carbon emissions by 2050 while creating good-paying union jobs and growing the economy.
- The first Energy Earthshot, launched June 7, 2021—Hydrogen Shot—seeks to reduce the cost of clean hydrogen by 80% to $1 per 1 kilogram in 1 decade ("1 1 1").
- The Hydrogen Shot establishes a framework and foundation for clean hydrogen deployment in the American Jobs Plan, which includes support for demonstration projects. Industries are beginning to implement clean hydrogen to reduce emissions, yet many hurdles remain to deploying it at scale. Currently, hydrogen from renewable energy costs about $5 per kilogram. Achieving the Hydrogen Shot's 80% cost reduction goal can unlock new markets for hydrogen, including steel manufacturing, clean ammonia, energy storage, and heavy-duty trucks. This would create more clean energy jobs, reduce greenhouse gas emissions, and position America to compete in the clean energy market on a global scale. These efforts would ensure that environmental protection and benefits for local communities are a priority.

Regional Hydrogen Hubs FOA Timeline



Infrastructure Investment and Jobs Act

- Signed into law, November 15, 2021
- The law appropriates $62 billion to the DOE to “deliver a more equitable clean energy future for the American people
- Authorizes appropriations of $8 billion for the five-year period encompassing fiscal years 2022 through 2026 for the development of regional clean hydrogen hubs that demonstrate the production, processing, delivery, storage and end-use of clean hydrogen
- Goal of the legislation with respect to hydrogen hubs: Accelerate research, development, demonstration and deployment of hydrogen from clean energy sources

Regional Hydrogen Hubs Request For Information

- Issued February 15, 2022
- RFI sought input to help the DOE in their planning purposes to develop the Regional Clean Energy Hydrogen Hubs FOA, specifically:
  - Regional Clean Hydrogen Hub Provisions and Requirements
  - Solicitation Process, FOA Structure, and Implementation Strategy
  - Equity, Environmental and Energy Justice Priorities
  - Market Adoption and Sustainability of the Hubs

Regional Hydrogen Hubs
Notice of Intent

- On June 6, 2022, the Department of Energy (DOE) announced its Notice of Intent (NOI) to fund at least four clean hydrogen hubs across the United States.
- The NOI announced that DOE anticipates issuing a Funding Opportunity Announcement ("FOA") in September or October of 2022 with requests that concept papers or project summaries be submitted within six to eight weeks of the FOA.
- DOE expects that it will provide feedback to potential H2Hub funding recipients encouraging or discouraging full applications approximately four weeks later.
- Full applications will be requested four months after DOE provides feedback on concept papers or project summaries.

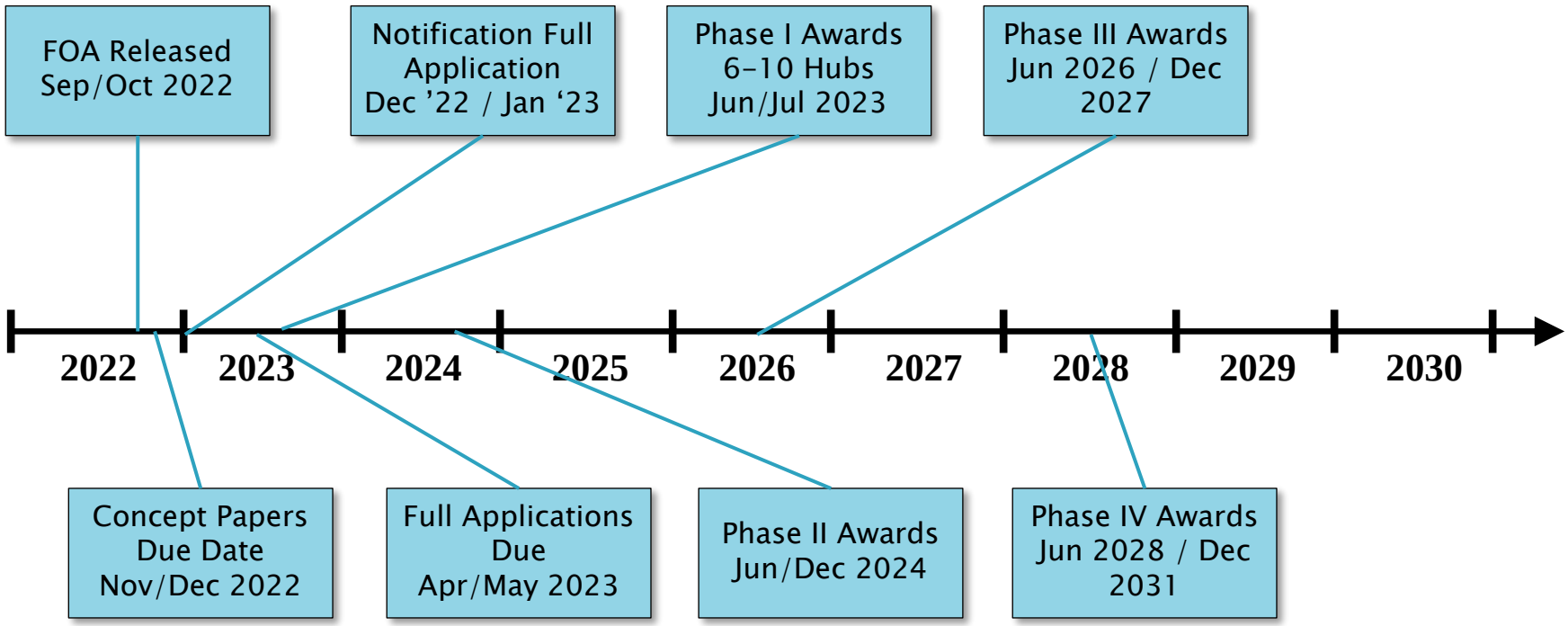
Hydrogen Hub selection criteria, which the DOE shall use to the maximum extent practicable:

- **Feedstock diversity** – at least one hub shall demonstrate the production of clean hydrogen from fossil fuels, one hub from renewable energy, and one hub from nuclear energy.
- **End-use diversity** – at least one hub shall demonstrate the end-use of clean hydrogen in the electric power generation sector, one in the industrial sector, one in the residential and commercial heating sector, and one in the transportation sector.
- **Geographic diversity** – each regional clean hydrogen hub shall be located in a different region of the United States and shall use energy resources that are abundant in that region.
- **Hubs in natural gas-producing regions** – at least two regional clean hydrogen hubs shall be located in the regions of the United States with the greatest natural gas resources.
- **Employment** – DOE shall give priority to regional clean hydrogen hubs that are likely to create opportunities for skilled training and long-term employment to the greatest number of residents in the region.
- **Additional Criteria** – DOE may take into consideration other criteria that are necessary or appropriate to carry out the regional clean hydrogen hubs program.

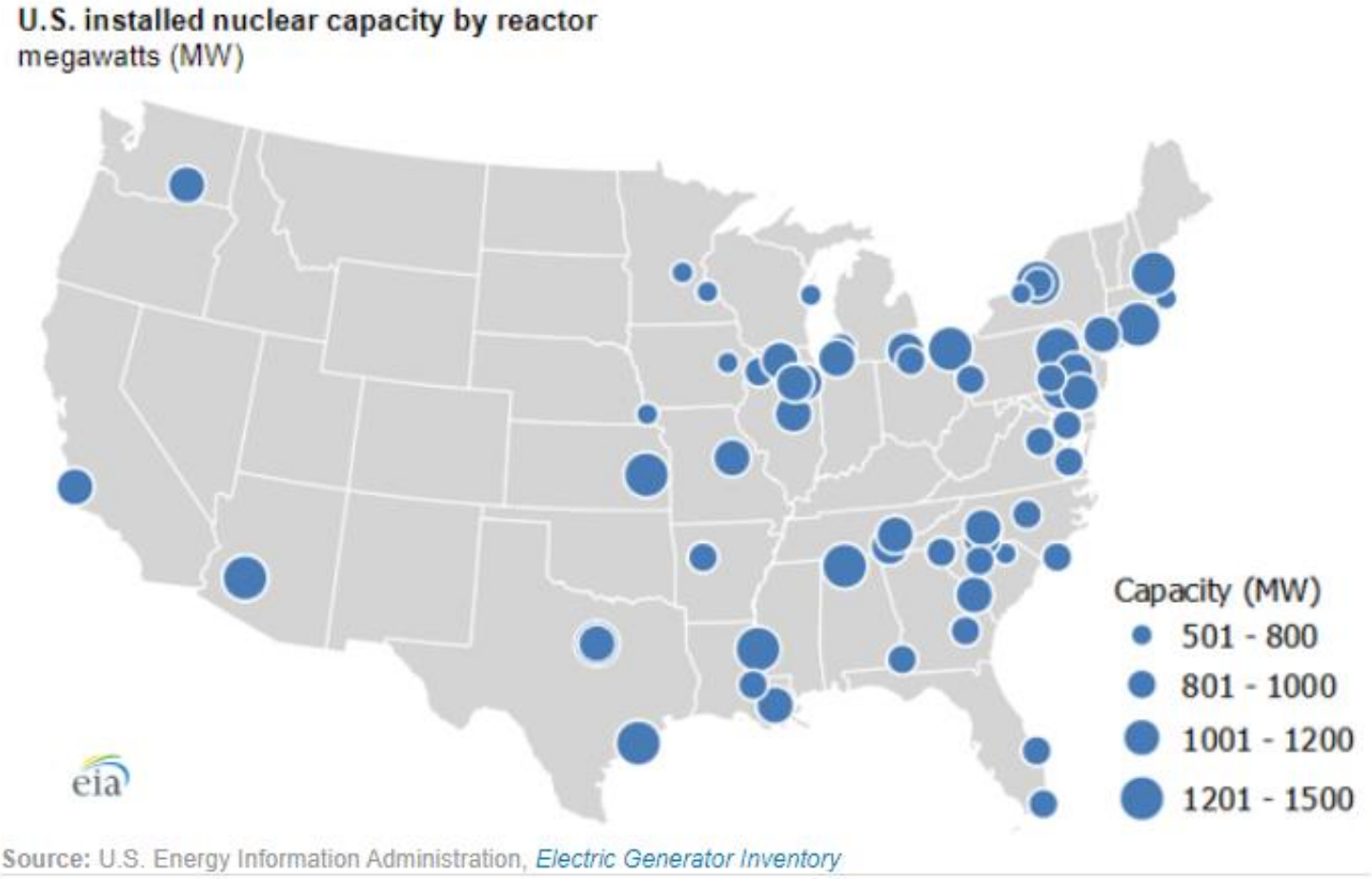
Additional metrics

- Preference given to applications that reduce GHG emissions across the full project lifecycle
- Preference will be given to hydrogen hubs that produce larger quantities of clean hydrogen
- Preferences associated with equity considerations:
  - Energy and environmental justice
  - Labor and community engagement
  - Consent-based siting
  - Quality jobs
  - Inclusive workforce development

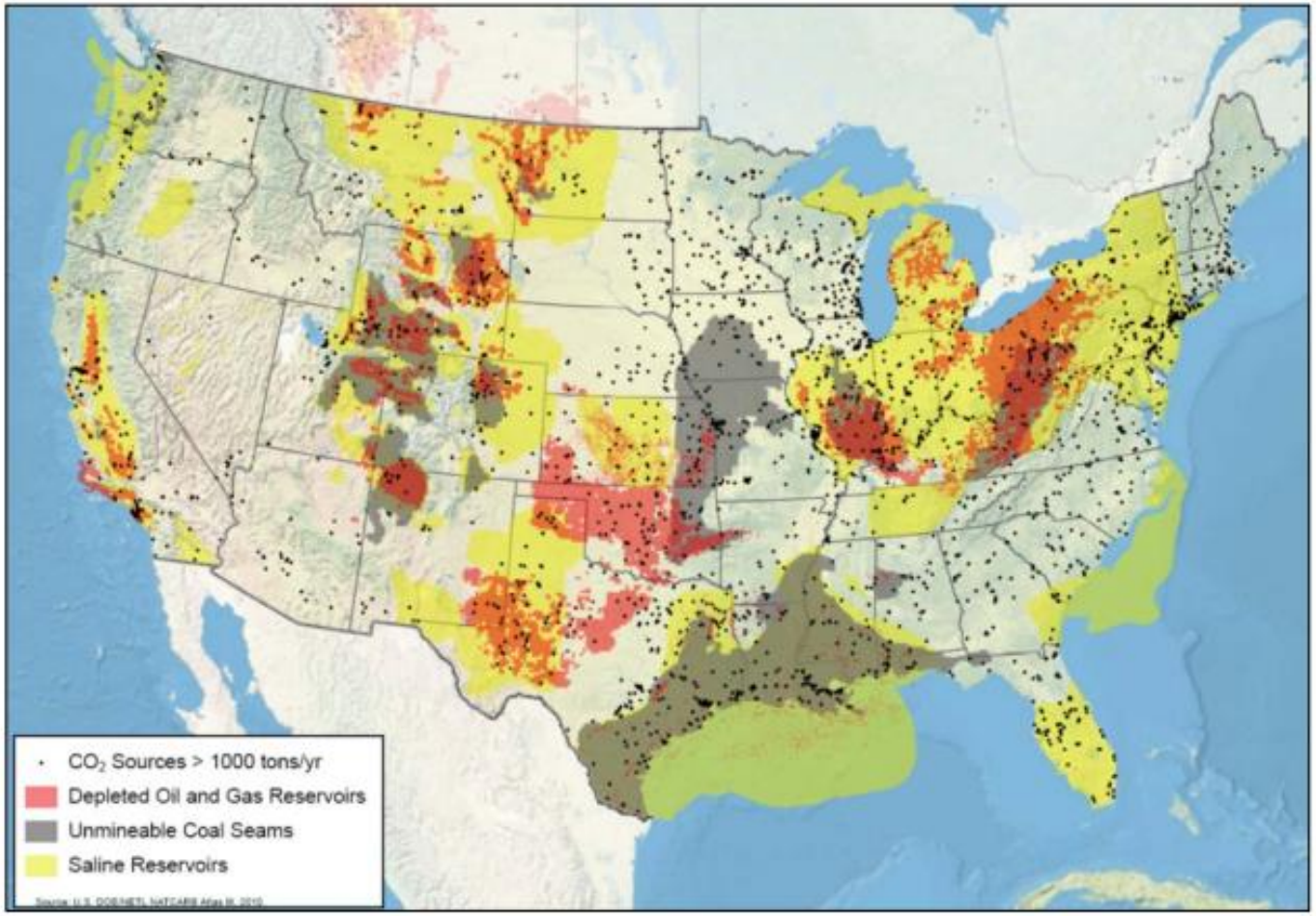
Regional Hydrogen Hubs Timeline



Location and size of nuclear power plants

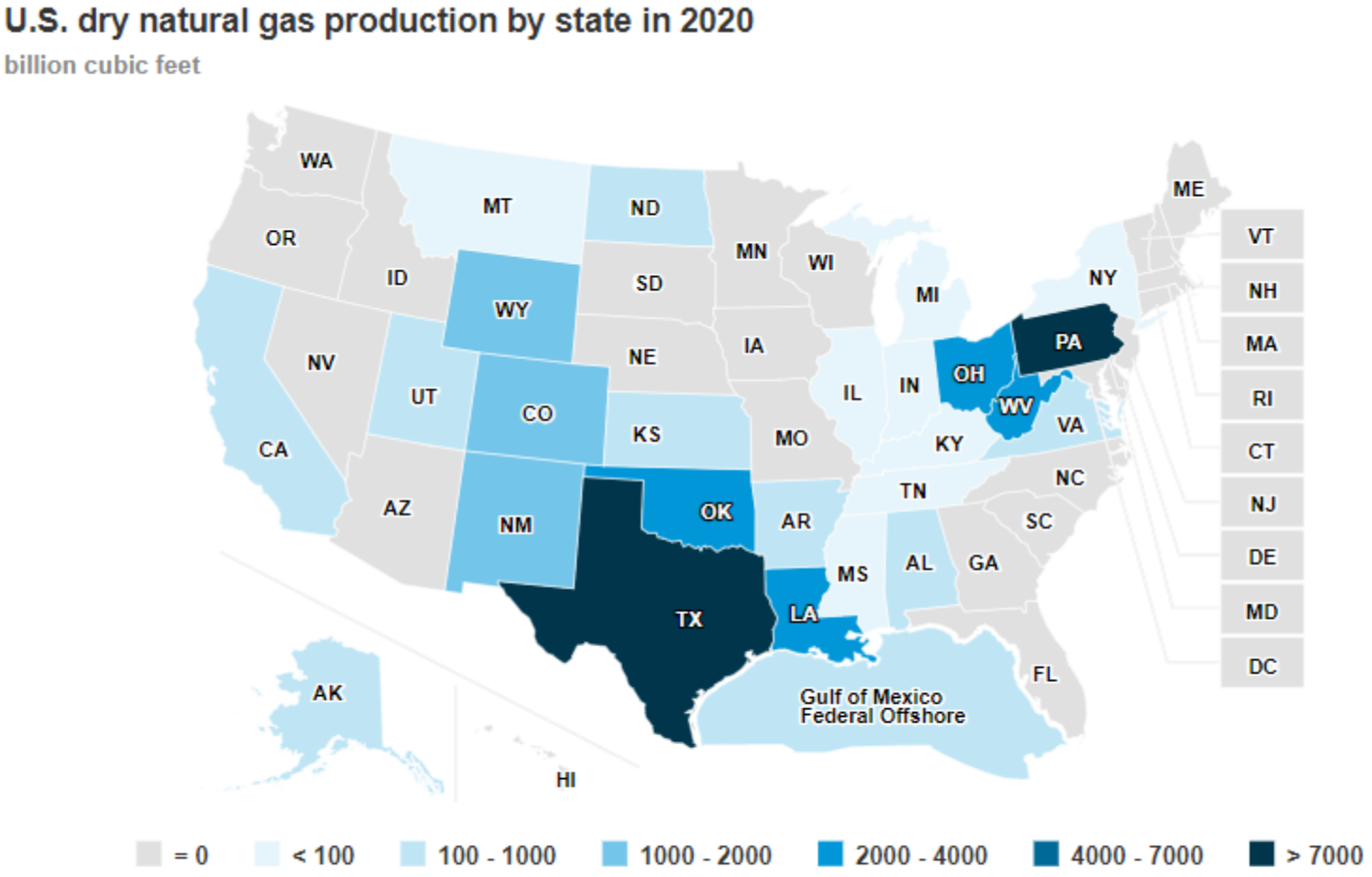


Potential North American CO2 Geological Storage Areas and Major CO2 Sources



Source: Department of Energy NATCARB GIS database[3]

Regions with Natural Gas Resources



eia Data source: U.S. Energy Information Administration, *Natural Gas Annual*, September 2021

Inflation Reduction Act of 2022

- Overview
  - Significant investments in energy product and manufacturing
  - Reduce carbon emissions approximately 40% by 2030
  - Expands tax credit provisions for renewable energy and carbon capture use and sequestration
  - Includes incentives for hydrogen production, storage and utilization
- Hydrogen Summary
  - Hydrogen Production Tax Credit
    - 10 years for clean hydrogen production
    - Opportunity to claim the investment tax credit in lieu of the PTC
  - Making energy storage technologies eligible for the ITC with a definition specifically including hydrogen
  - Revises the clean vehicle credit for passenger vehicles and introducing substantial credit for clean commercial vehicles (key use case for hydrogen)
  - Revising and expanding the alternative fuel station credit which will foster more hydrogen fueling stations

Hydrogen Production Tax Credit

- Section 45V
- Commence construction before 2032
- Value of the PTC ranges from $0.60/kg to $3.00/kg hydrogen produced

Kg of CO2 per kg of H2	Credit Value ($)
2.5 - 4 kg CO2/kg H2	$0.60/kg H2
1.5 - 2.5 kg CO2/kg H2	$0.75/kg H2
0.45 – 1.5 kg CO2/kg H2	$1.00/kg H2
0 - 0.45 kg CO2/kg H2	$3.00/kg H2

Additional Qualifications

- No credit shall be allowed for clean hydrogen produced at a facility which includes property that claims the 45Q tax credit for CCUS
- Taxpayer may elect to take section 48C ITC for a qualifying clean hydrogen facility in lieu of the PTC. The ITC will be adjusted for same factors used in the PTC calculation
- Eligible for direct payment (full refundability) for non-taxable entities, state, local, or tribal governments, the TVA, or Alaskan Native Corporation, as per section 13801
- For all other entities, taxpayer elect for direct pay for five consecutive years of the total tax credit period, with the period no later than the end of 2032
- Eligible for transferability
- $13 billion in value over the next ten years

Thirty largest Hydrogen Hub projects around the world

Feedstock source and hydrogen production levels of the 30 largest hydrogen hubs around the world

Source	Hydrogen Production (million TPY)	Percentage of Hydrogen Produced	Number of Projects	Average Hydrogen Production (million TPY)
Natural Gas	4.91	9.3%	5	0.98
Petroleum	1.00	1.9%	1	1.00
Renewable Energy	46.79	88.8%	24	1.95
Total	52.69	100.0%	30	1.76

Project Example:
Asia Renewable Energy Hub
A $36 billion investment in Northwestern Australia

- Project will be developed in multiple phases up to 26 GW of combined solar and wind power generating capacity – the equivalent of producing over 90 terawatt hours per year, which is around a third of all electricity generated in Australia in 2020.
- Will produce around 1.6 million tons of hydrogen or 9 million tons of green ammonia, per year.
- Will abate around 17 million ton of carbon in domestic and export markets annually, which would equate to roughly 0.5 gigatons (Gt) of carbon savings over the lifetime of the project.

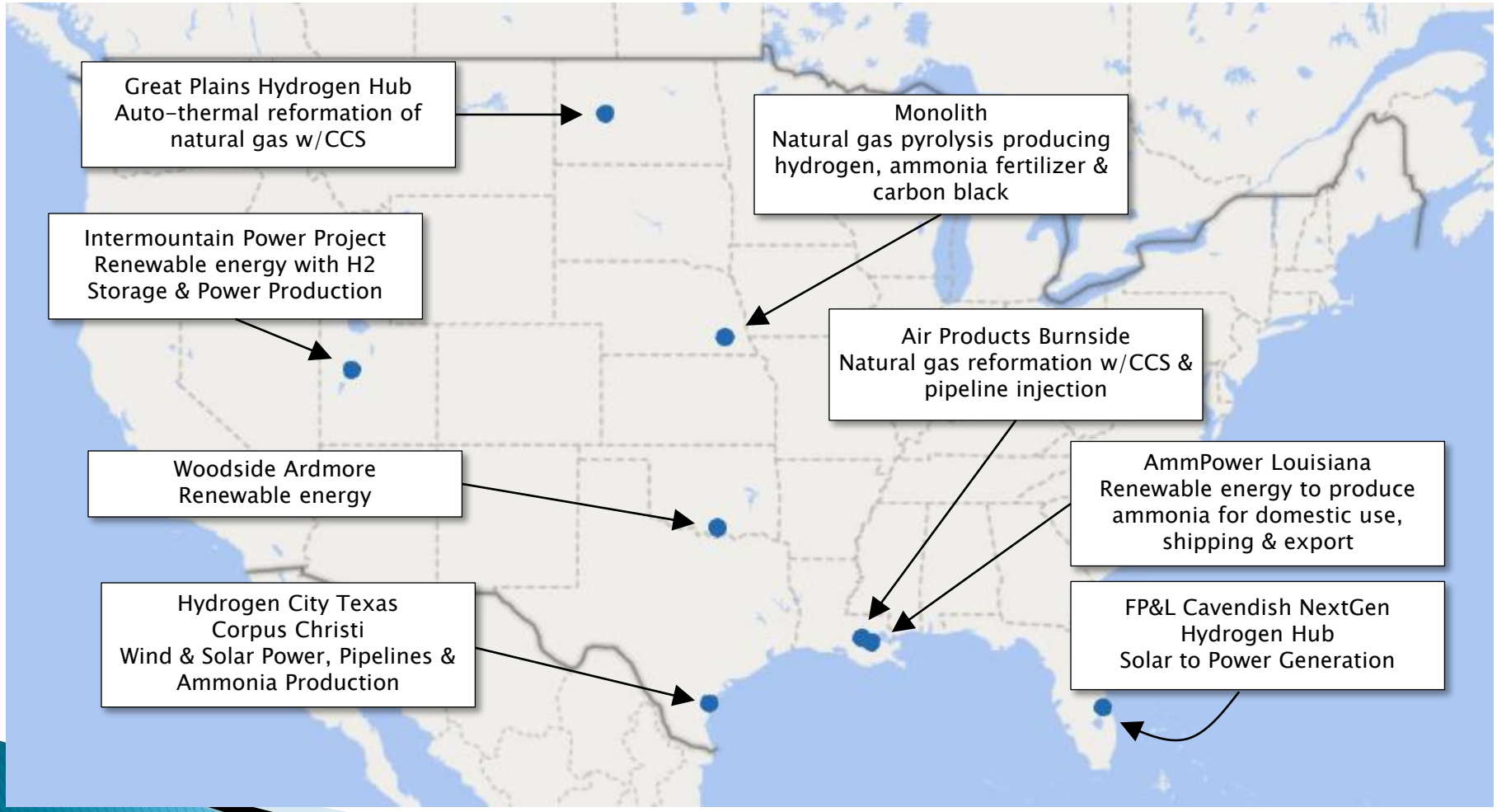
Asia Renewable Energy Hub		
Investors		
BP	40.50%	
Intercontinental Energy	26.40%	
CWP Global	17.80%	
Macquarie Capital	15.30%	
Footprint	6,500	square miles
Wind & Solar	26	MW
Electrolyzer	14	MW
Hydrogen	2.4	million TPY
Ammonia	9	million TPY
Capital Requirements	$36	billion

Project Example: AcquaVentus Converting offshore wind power to hydrogen

- Electricity from offshore wind farms is converted to hydrogen.
- Hydrogen is also produced at high sea, directly at the wind turbines or in the immediate vicinity of the wind farms.
- The green hydrogen is transported to Heligoland via pipelines.

- AquaVentus cooperation partners alongside RWE are the Island of Heligoland, Reuther, Vattenfall, Shell, Gasunie, Siemens, Parkwind and MHI Vestas.
- By 2035:
  - Electrolyzer – 10 GW
  - Hydrogen – 1 million TPY
  - Undersea Hydrogen Pipelines

United States Hydrogen Hubs Announced and In Development



Global Hydrogen Hub Business Models

- Dominant Hydrogen Hub Business Models
  - Global Hydrogen Trade with Ammonia
  - Industrial Process Decarbonization
  - Value Added Products
- Key Drivers
  - Supply – Low cost of photovoltaics and other renewable energy
  - Supply – Increasing Variable Renewable Energy supply creating longer duration low price regimes
  - Demand – Sector-wide decarbonization
  - Demand – Hard to abate sectors

Global Hydrogen Hub Business Models
Key Success Factors

- **Sourcing**
  - Low-cost renewable energy sourcing
  - In-the-fence / Behind-the-meter renewable energy
- **Demand**
  - Productizing hydrogen on-site to ammonia, fertilizer, methanol, e-fuels and sustainable aviation fuels
  - Securing off-take agreements for resultant products
  - Integrating hydrogen storage with power generation to maximize energy arbitrage opportunity
- **Integrated Strategy** – Complete solution from supply to demand, optimize across the entire value chain
- **Scale** – large scale to achieve strong economics
- **Siting** – Siting solar and wind to maximize production
- **Capacity Factor** – Integrating wind, solar and storage to maximize capacity factor
- **Minimize hydrogen transportation costs**
  - Consume hydrogen in-place by producing value added products such as ammonia, methanol, fertilizer or sustainable aviation fuels
  - Convert to ammonia or LOHC to facilitate transport or integrate hydrogen production with pipeline interconnects

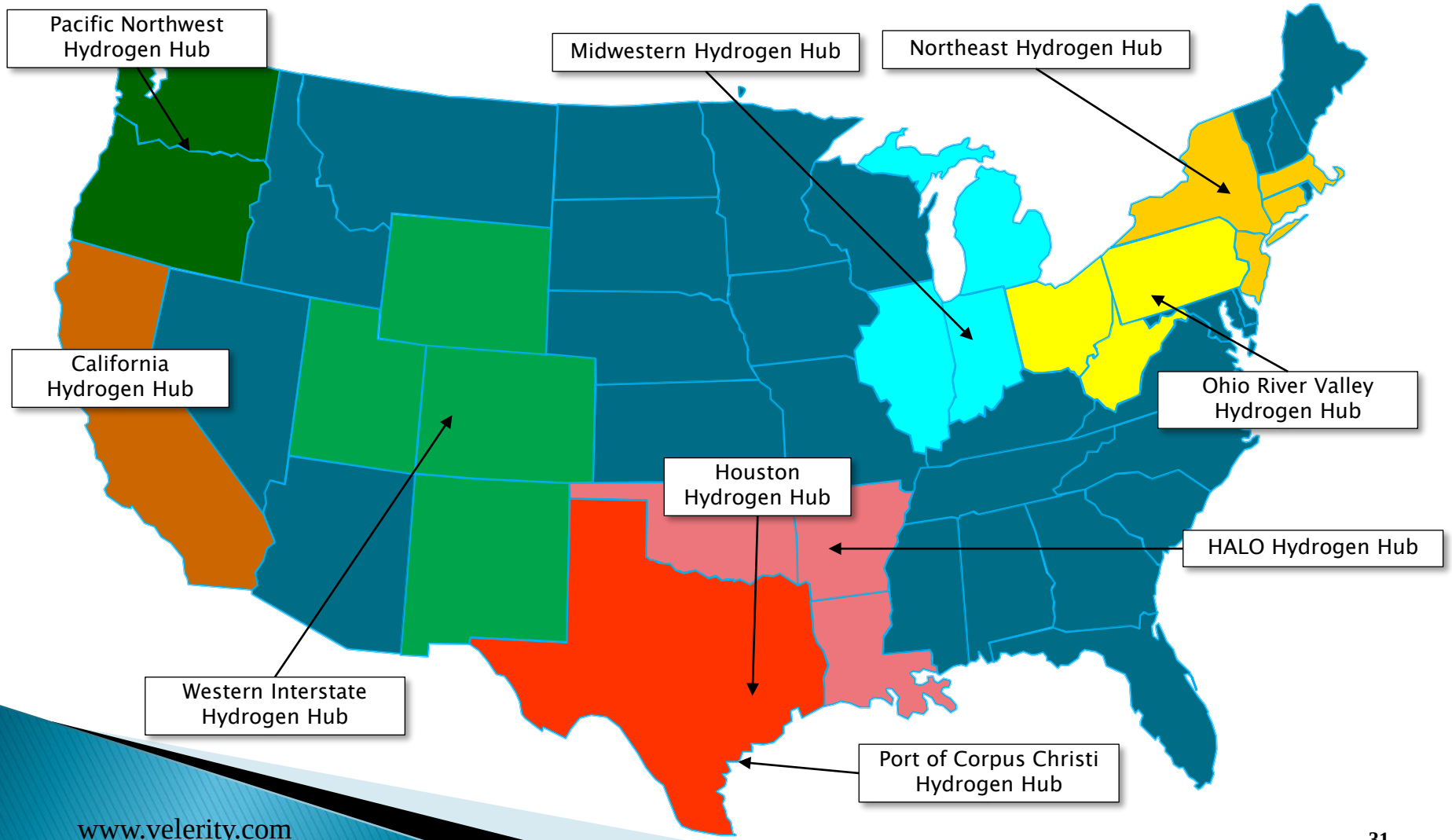
A total of twenty-four hub consortia have been identified

Consolidation and new entrants likely

Hydrogen Hub Consortium	States
ACES Delta	UT
Arizona Hydrogen Hub	AR
California Hydrogen Hub	CA
Cavendish Next Gen Hydrogen Hub	FL
Georgia Hydrogen Hub	GA
Great Plains Hydrogen Hub	ND
HALO Hydrogen Hub	LA, OK, AR
Houston Hydrogen Hub	TX
Hydeal Los Angeles	CA
Hydrogen City	TX
Kentucky Hydrogen Hub Workgroup	KY
Midwest Nuclear Hydrogen Hub	OH

Hydrogen Hub Consortium	States
Midwestern Hydrogen Hub	IL, IN, MI
Mississippi Clean Hydrogen Hub	MS
Nebraska Hydrogen Hub	NE
Northeast Hydrogen Hub	CT, MA, NJ, NY
Ohio Clean Hydrogen Hub	OH
Ohio River Valley Hydrogen Hub	OH, PA, WV
Pacific Northwest Hydrogen Hub	WA, OR
Pennsylvania Clean Hydrogen Hub	PA
Port of Corpus Christi Hydrogen Hub	TX
Upper Midwest Hydrogen Hub	
West Virginia Hydrogen Hub	WV
Western Interstates Hydrogen Hub	CO, NM, UT, WY

Major Hydrogen Hub Consortia



The Role and Opportunity of Hydrogen in a Transitioning Global Energy System

- Hydrogen has a central role in a clean energy future
  - Heavy Transportation: Ships, trucks, trains
  - Energy Storage: Energy price arbitrage with gas turbine power generation coupled with large scale storage and large scale RE production
  - Feedstock Decarbonization: Ammonia, Methanol
  - Hard to Abate: Industrial processes such as steel manufacturing
  - Synthetic Fuels – Sustainable Aviation Fuel
- A Massive Shift in the Geopolitics of Energy is Underway
  - Countries with large tracts of high insolation land and strong wind resources will lead the emerging renewable energy revolution
- With over $300 billion already committed, hydrogen hubs represent an opportunity that goes well beyond the DOE H2Hubs initiative

Perspectives on the H2Hub opportunity

- At least two hubs in natural gas-producing regions
  - This criteria has the largest potential impact, likely placing an advantage on a likely Texas consortium and the PA/WV/OH consortium
  - Of the minimum four hub slots, this means only two slots may be available for all remaining bidders
- Preference given to applications that reduce GHG emissions across the full project lifecycle
  - This criteria may hurt applicants proposing natural gas solutions with carbon sequestration, as many factors, including the measuring approach, and upstream emissions, will negatively impact GHG emissions rates
- Preference will be given to hydrogen hubs that produce larger quantities of clean hydrogen
  - This criteria will favor large production facilities, requiring access to very large behind the fence wind and solar facilities for renewable energy production, for example.
  - This criteria will also likely favor multi-state consortia