Vinson&Elkins

Energy Series

Developing & Financing Low Carbon Hydrogen Projects

March 29, 2022

Introduction

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Agenda

Discussion Topics

Hydrogen Applications and Usage

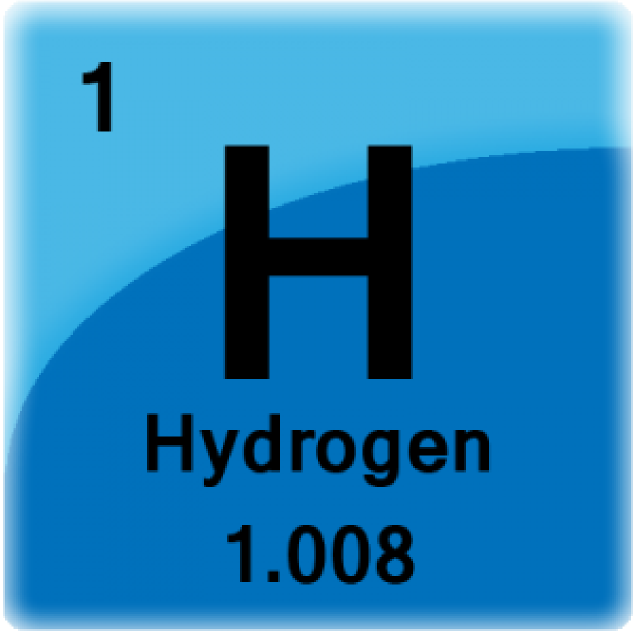
Hydrogen could meet nearly 25% of the world's energy needs by 2050 if governments support policies that advance hydrogen technologies

(as predicted by BloombergNEF)

Overview

Hydrogen

- Symbol on the Period Table: H
- Atomic Number: 1
- Discovered by Henry Cavendish in 1766 (thought it was “Phlogiston”)
- Made up of one proton and one electron
- At room temperature, it is a colorless, odorless and flammable gas
- The lowest density gas
- Liquified at -253° Celsius
- When compressed, it behaves like a metal
- When burned, water is produced
- Most abundant element in the universe (3 times more so than helium)
- By weight, it is 75% of visible light
- The sun consumes 600mm tons/second converting the hydrogen to 596mm tons of helium
- When combined with oxygen, hydrogen forms water
- With nitrogen, carbon and oxygen, it bonds together blood and body of all human things



Hydrogen Applications and Usage

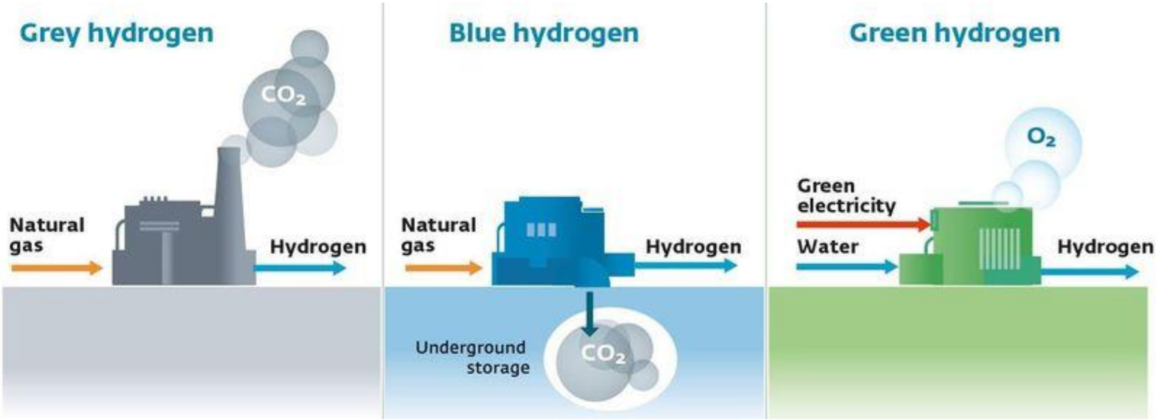
Hydrogen is a highly versatile substance that can be combusted, compressed, liquefied, or used to store or produce energy for electricity

- ***Traditional Industrial Uses:***
  - Petroleum refining, ammonia and fertilizer manufacturing, and as a high-grade heat source
- ***As a Fuel Source:***
  - Used by fuel cells in an electrochemical reaction to release and capture ions to produce electricity, which can be used by certain fuel cell electric vehicles
  - Used for power generation
    - Gas turbines powered by synthetic gas (a mixture of hydrogen, carbon monoxide, and carbon dioxide), which contains up to 95% hydrogen by volume, are commercially produced at scale
  - Used to power heavy transportation and in industrial sectors, such as steel making and iron smelting
- ***As a Means of Storing Energy:***
  - Acting as a chemical energy store
    - An option for dealing with the intermittency and reliability of electricity generated through traditional renewable sources
    - Accomplished through electrolyzers, where the electricity produced from the renewable source is converted into hydrogen (*i.e.*, “power-to-gas-to-power”)

Types of Hydrogen

- "**Grey hydrogen**" - Normally produced at scale by reforming natural gas in a steam methane reformer or through coal gasification
  - Emits significant amounts of carbon dioxide
  - Currently ~95% of hydrogen production in the United States
  - Low Cost: ranging from less than $1 to $2 per kilogram of hydrogen

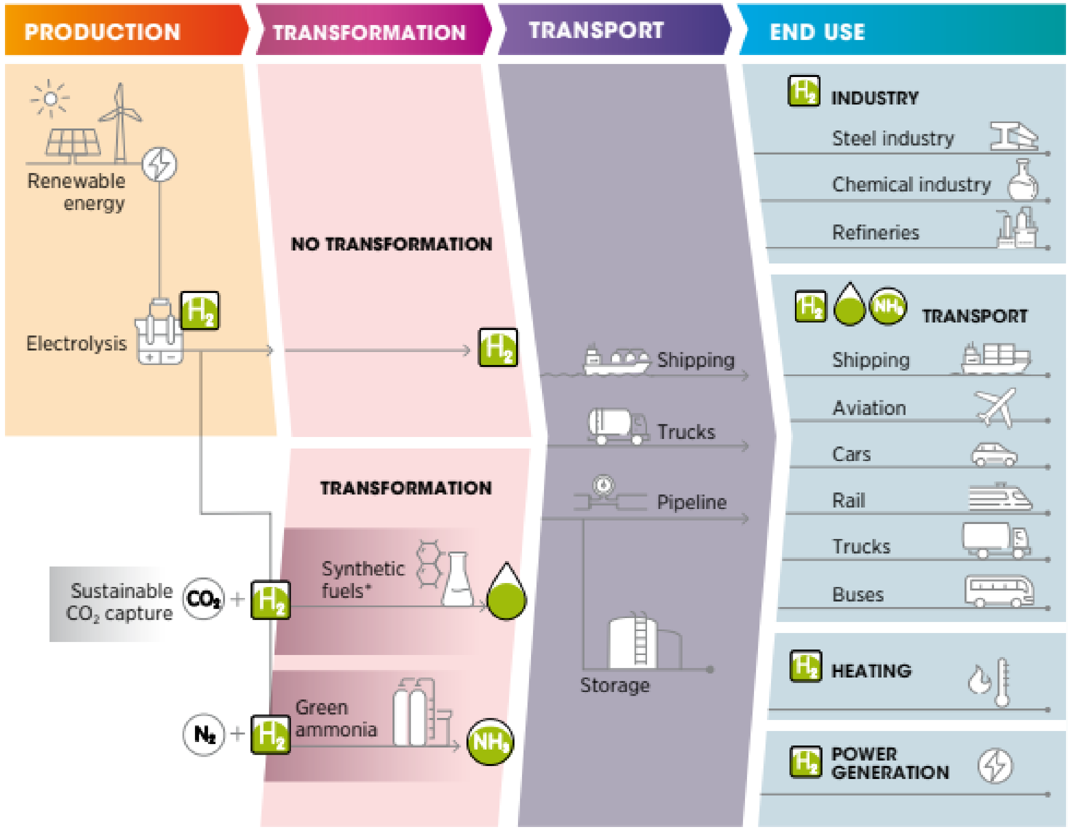
- "**Blue hydrogen**" - Same processes used to produce grey hydrogen, however carbon emissions are captured and sequestered
  - Carbon capture and sequestration adds about half a dollar per kilogram of hydrogen



Source: *What is Hydrogen and How is it Made?*, The World of Hydrogen, https://www.theworldofhydrogen.com/gasunie/what-is-hydrogen/.

Types of Hydrogen (*cont'd*)

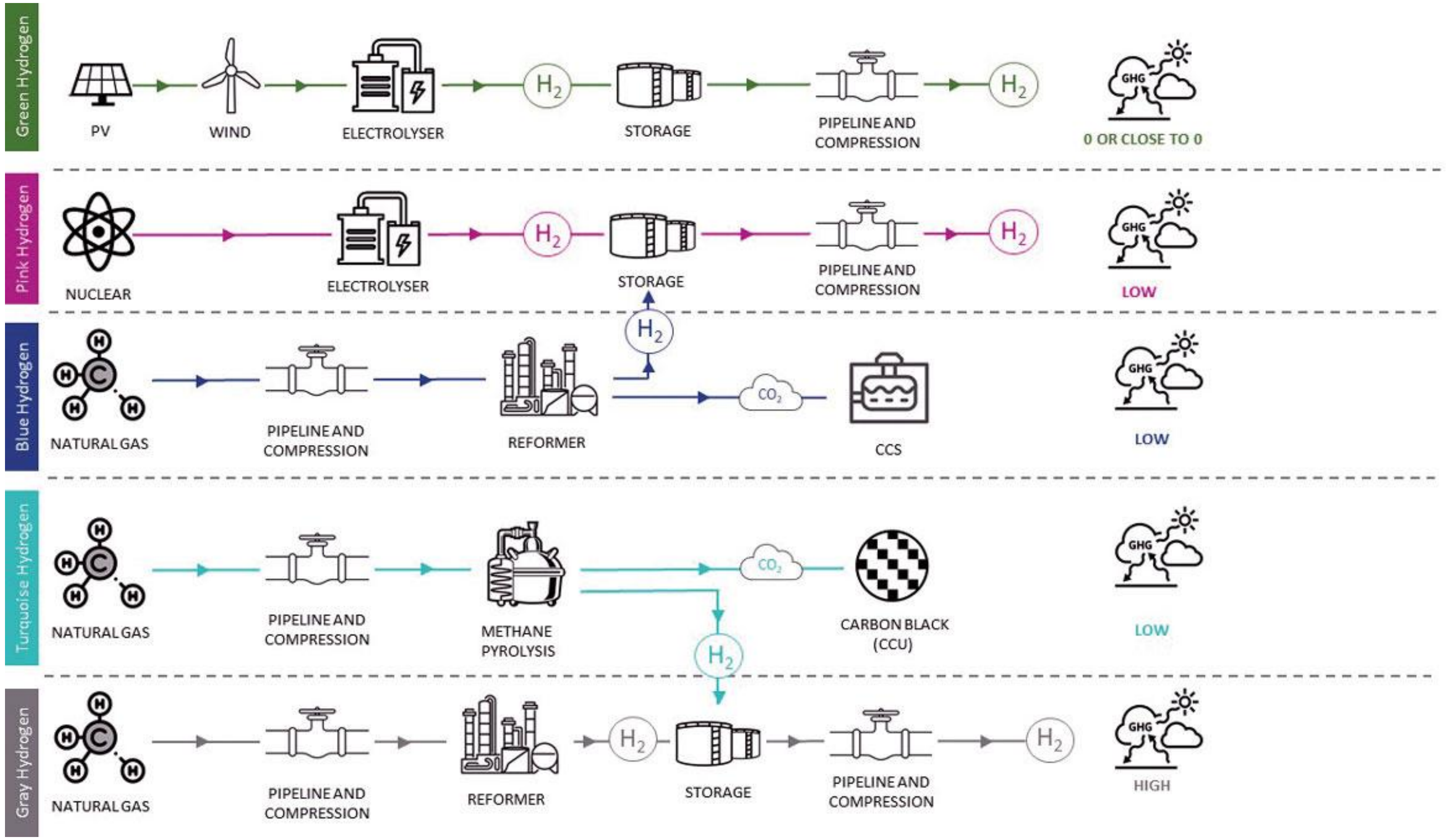
- "**Green hydrogen**" - Uses renewable energy to electrolyze water, separating the hydrogen from the oxygen
  - Currently no green hydrogen plants operating at commercial scale in the United States
    - Several pilot and demonstration projects in the pipeline
  - Cost is a function of:
    - (1) plant utilization rates,
    - (2) power prices of renewable sources (the levelized cost of energy, "LCOE"),
    - (3) electrolyzer efficiency, and
    - (4) electrolyzer manufacturing costs
  - The cost of one kilogram of green hydrogen can range from $3 to $8, depending on the LCOE



Source: *IRENA (2020), Green Hydrogen: A guide to policy making, International Renewable Energy Agency, Abu Dhabi*
*The term synthetic fuels refers here to a range of hydrogen-based fuels produced through chemical processes with a carbon source (CO and CO_2 captured from emission streams, biogenic sources or directly from the air). They include methanol, jet fuels, methane and other hydrocarbons. The main advantage of these fuels is that they can be used to replace their fossil fuel based counterparts and in many cases used as direct replacements – that is, as drop-in fuels. Synthetic fuels produce carbon emissions when combusted, but if their production process consumes the same amount of CO_2 In principle it allows them to have net-zero carbon emissions.

Types of Hydrogen *(cont'd)*

- "Turquoise hydrogen" - Uses the thermal splitting of methane (by methane pyrolysis) to extract carbon in a solid form instead of a gas
- "Pink hydrogen" - Generated by electrolysis using nuclear energy
- "Purple hydrogen" - Made using nuclear power and heat through combined chemo thermal electrolysis splitting of water
- "Red hydrogen" - Produced through high-temperature catalytic splitting of water using nuclear power thermal as an energy source
- "White hydrogen" - Naturally occurring hydrogen
  - There are no strategies to exploit this hydrogen currently



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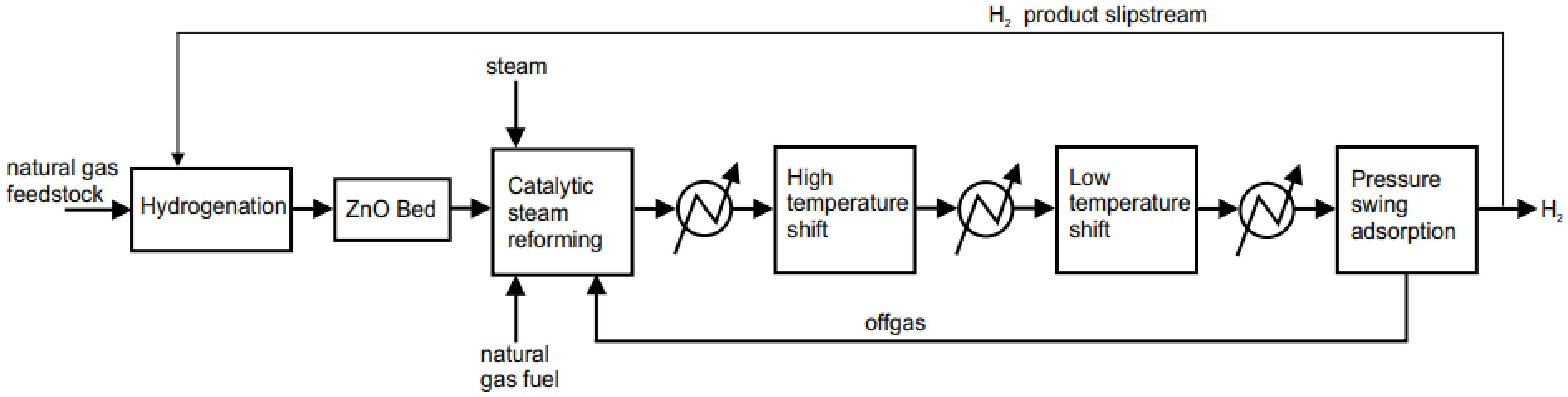
Steam Methane Reforming

- Hydrogen is traditionally made via steam-methane reforming, a mature production process in which high-temperature steam is used to produced hydrogen from a methane source, such as natural gas
  - Methane reacts with steam under 3-25 bar pressure in the presence of a catalyst to produce hydrogen, carbon monoxide and carbon dioxide
  - The carbon monoxide and steam are reacted using a catalyst to produce carbon dioxide and more hydrogen (the “water-gas shift reaction”)
  - Carbon dioxide and other impurities are removed from the gas stream, leaving essentially pure hydrogen (the “pressure swing absorption”)

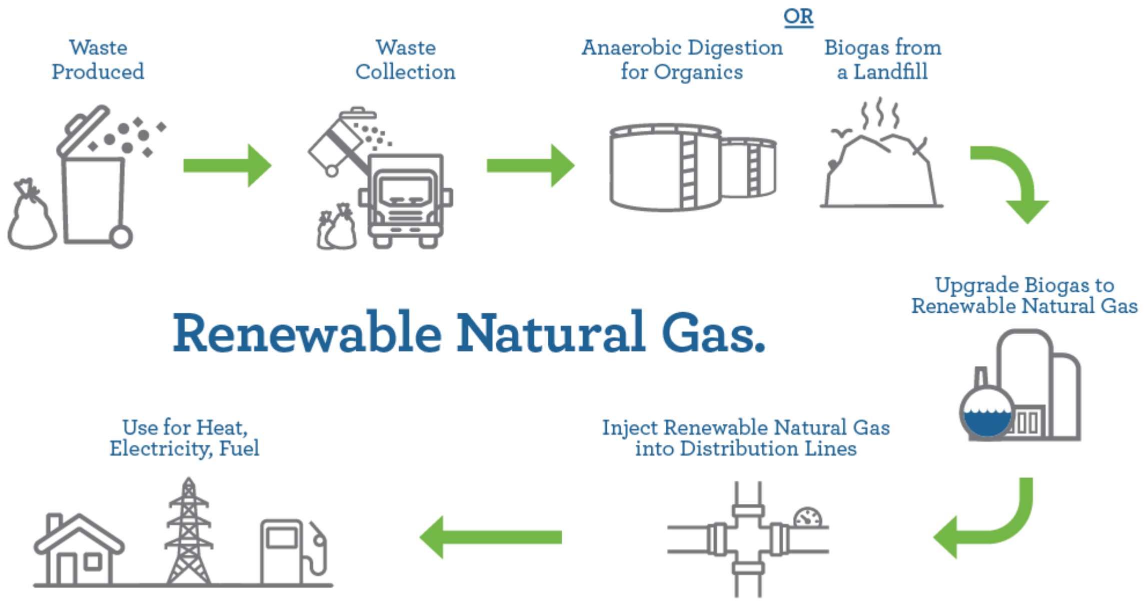


Source: *Hydrogen Source*, Washington State University, https://hub.wsu.edu/ise/design/hydrogen-source/

Production of Renewable Natural Gas

- Renewable natural gas (RNG) is a high-BTU, pipeline quality biomethane generated from renewable resources
- RNG is typically produced from the anaerobic digestion of organic materials. Common feedstock materials include:
  - Livestock manures (e.g., from dairy farms);
  - Municipal solid waste (i.e., landfills)
- Predominate uses include: (i) thermal applications (e.g., use in boilers, greenhouses and kilns), (ii) generation of electricity, (iii) vehicle fuel, (iv) as feedstock for bio-products (e.g., biodegradable plastic), and (v) hydrogen production

Leveraging RNG in the hydrogen production process can dramatically impact hydrogen's carbon intensity score



Source: *Turning our Waste into Renewable Energy*, Heritage Gas, https://www.heritagegas.com/renewable/

Ammonia as a Power Generation Tool

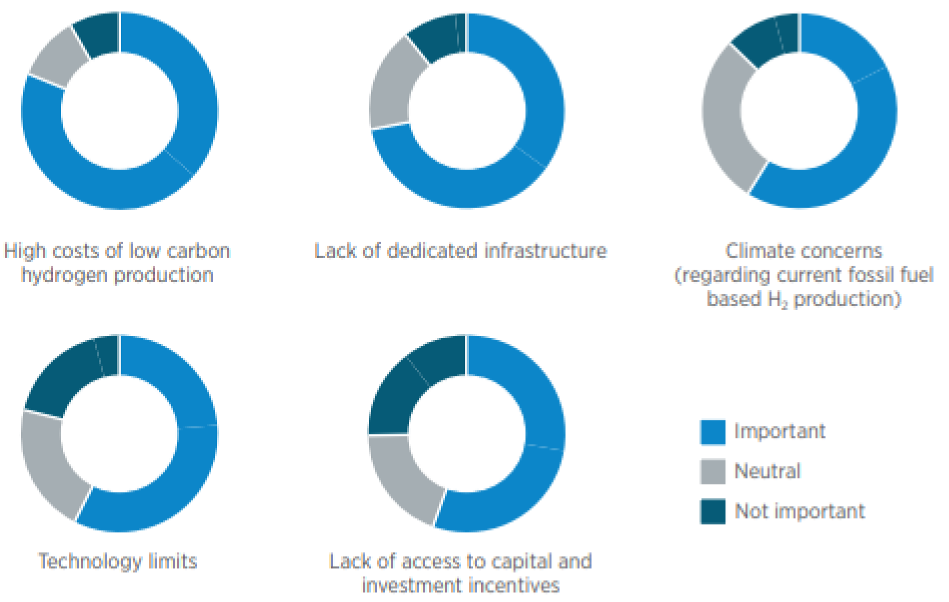
- Ammonia is a compound consisting of three parts hydrogen, one part nitrogen
- Recently emerged as a power generation fuel
  - Can be used as fuel in thermal power generation
  - Does not emit carbon dioxide when burned
  - Utilizing technology that enables direct combustion of ammonia will contribute to the ammonia fuel supply chain
  - Commercialization will support decarbonization systems for small and medium scale power plants in industrial applications
  - There are still challenges to address in the production of nitrogen oxide from the combustion of the nitrogen component of the fuel
- Japan and Korea are aggressively pursuing ammonia for power generation
  - Mitsubishi Power is developing the world's first ammonia-fired 40MW Class Gas Turbine System
    - Mitsubishi is targeting commercialization in or around 2025

Clean Hydrogen Project Finance

Practical Challenges

- ***Economics as compared to non-green hydrogen***: Clean hydrogen ($3 to $8 per kilogram) is currently uneconomic relative to grey hydrogen ($1 to $2 per kilogram)
- ***Storage***: Despite a high gravimetric energy density, hydrogen has a low physical density – requiring extensive means of storage
  - Must be stored in either larger spaces, carrier chemicals (*e.g.*, methanol or ammonia), or under very high pressure/low temperature
  - Highly reactive, so it requires careful handling

Figure 2.5 **Main perceived barriers to develop hydrogen policies and strategies**



Source: IRENA Member survey, 2021

Practical Challenges *(cont'd)*

- ***Shipping***: long-distance transportation and local distribution of hydrogen present significant challenges
  - There are approximately 1,600 miles of hydrogen pipelines in use today, compared with approximately 3 million miles for natural gas pipelines
  - Because hydrogen has a very low energy density it needs to be compressed for economical transportation and storage for use in final applications. The gas compression process uses considerable energy resulting in leakage
  - Most of the current natural gas pipeline infrastructure is unsuitable to transport hydrogen in high amounts (*i.e.*, above 20%) without significant upgrades, as hydrogen causes embrittlement of pipeline steel and welds
  - However, hydrogen can be shipped in bulk by using methodologies including converting the gas into ammonia, liquid hydrogen or other forms and project sponsors are rapidly developing technology to address these issues
  - Hydrogen shipped through pipelines is not likely to be subject to interstate transportation regulations under the Federal Energy Regulatory Commission ("FERC") because it is not "oil" under the Interstate Commerce Act
    - But an interstate pipeline transporting a commodity other than water, gas, or oil will be subject to the Surface Transportation Board's jurisdiction

Financing Challenges and Opportunities

- Project finance lenders and investors must manage certain issues and risks inherent in the hydrogen market, including:
  - Demonstration of commercial viability / technical due diligence
    - Mitigated by turn-key contracts, involvement of experienced consultants and advisors, risk allocation between lenders/investors and project sponsor
  - Availability (or lack thereof) of long-term offtake arrangements
    - ESG concerns may work to emolliate this issue as large companies (such as Amazon and Walmart) are pressured to “green” their fleet
    - Municipalities are also making public sector investments in hydrogen fueled buses, trains, and other heavy vehicles
    - Similar opportunities could be made available for airplanes and ships (*e.g.*, the “Poseidon Principles” – a framework for the International Maritime Organization’s goal of reducing GHG emissions by 50%)
  - Experience and balance sheet of project sponsors

Financing Challenges and Opportunities *(cont'd)*

- Relatively high capital and operating expenses
  - Similar to renewables, U.S. federal tax benefits may help to close the gap (*e.g.*, Blue Hydrogen production may be eligible for current 45Q credits and, if the Build Back Better Act is passed, production of clean hydrogen would be eligible for an ITC or PTC)
  - Price of electricity for green hydrogen may reduce as renewable installation increases
- Economies of scale (there exist only a very limited number of closed transactions and these are for small-scale demonstration projects)
  - However, lenders and investor who enter the market early will be well poised to capitalize on its expected expansion
- Management of regulatory risk
  - See below discussion

Environmental and Regulatory Issues

Environmental and Regulatory Issues

- No comprehensive, direct regulatory regime for hydrogen production (*i.e.*, no specific permitting program)
- However, various existing regulations that touch on hydrogen production and transportation:
  - **Pipeline and Hazardous Materials Safety Administration** (“PHMSA”)
    - 49 C.F.R. Part 192 – regulation of approximately 700 miles of hydrogen pipelines (hydrogen falls under “flammable gas” provision)
    - 49 C.F.R. Part 173 – regulate transportation of compressed hydrogen and the design, filling, and marking of hydrogen fuel cells
  - **Environmental Protection Agency** (“EPA”)
    - Greenhouse Gas (“GHG”) Reporting and Effluent Standards
      - 40 C.F.R. § 98.160 – reporting of GHG data from (i) process units that produce hydrogen by transforming feedstocks, (ii) from hydrogen production sources that emit 25,000 metric tons of CO_2
      - Effluent standards apply to discharge of materials to water from production of hydrogen as a refinery by-product
    - Chemical Action Prevention Scheme (Clean Air Act)
      - 40 C.F.R. Part 68 – requires a Risk Management Program (“RMP”) for facilities storing hydrogen over 10,000 pounds (threshold amount)

Environmental and Regulatory Issues *(cont'd)*

Occupational Safety and Health Administration ("OSHA")

- 29 C.F.R. § 1910.103 - Installation of hydrogen systems (location, containers and piping characteristics, safety relief devices, equipment assembly, marking, testing, etc.)
- Other sections that could regulate hydrogen (*e.g.*, safety standards applicable to compressed gases and flammable liquids)

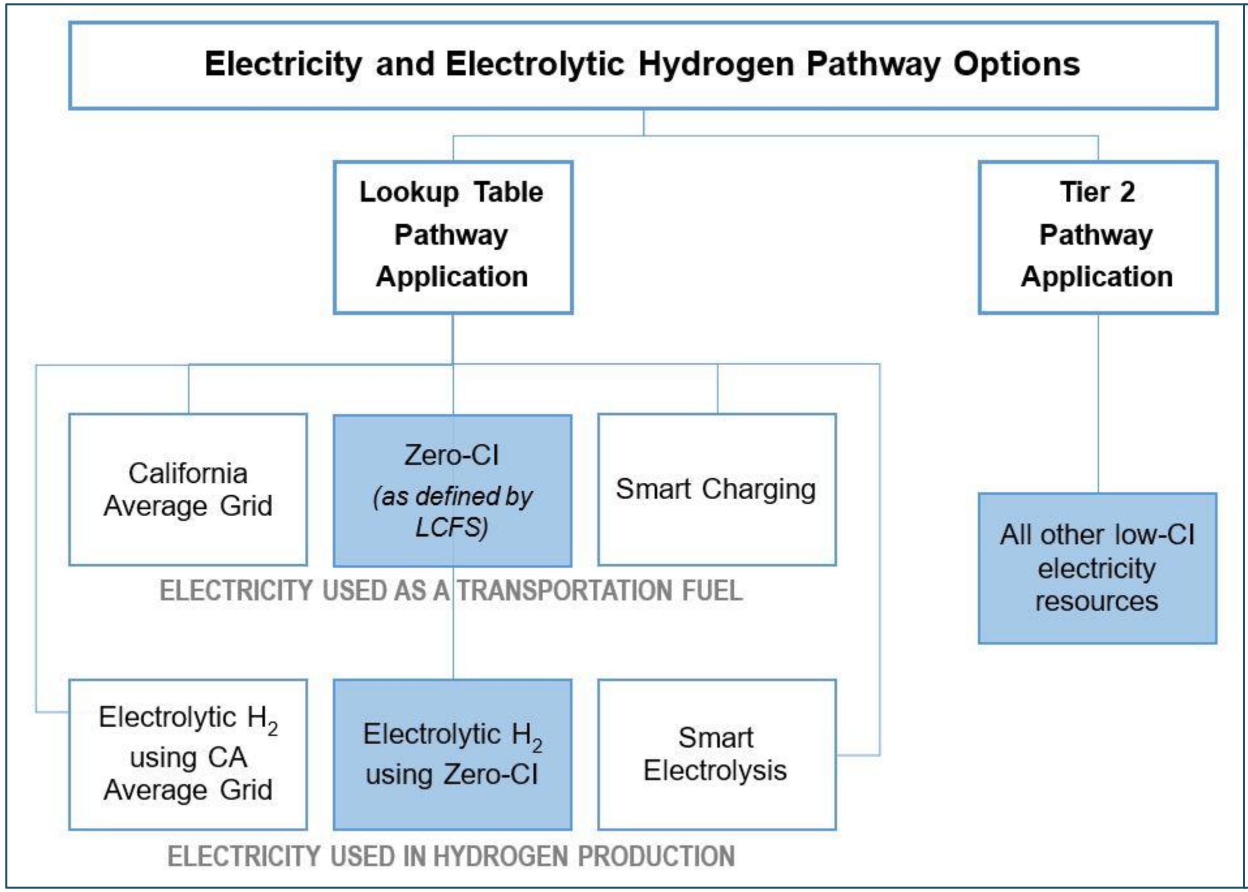
Potential future regulation may include:

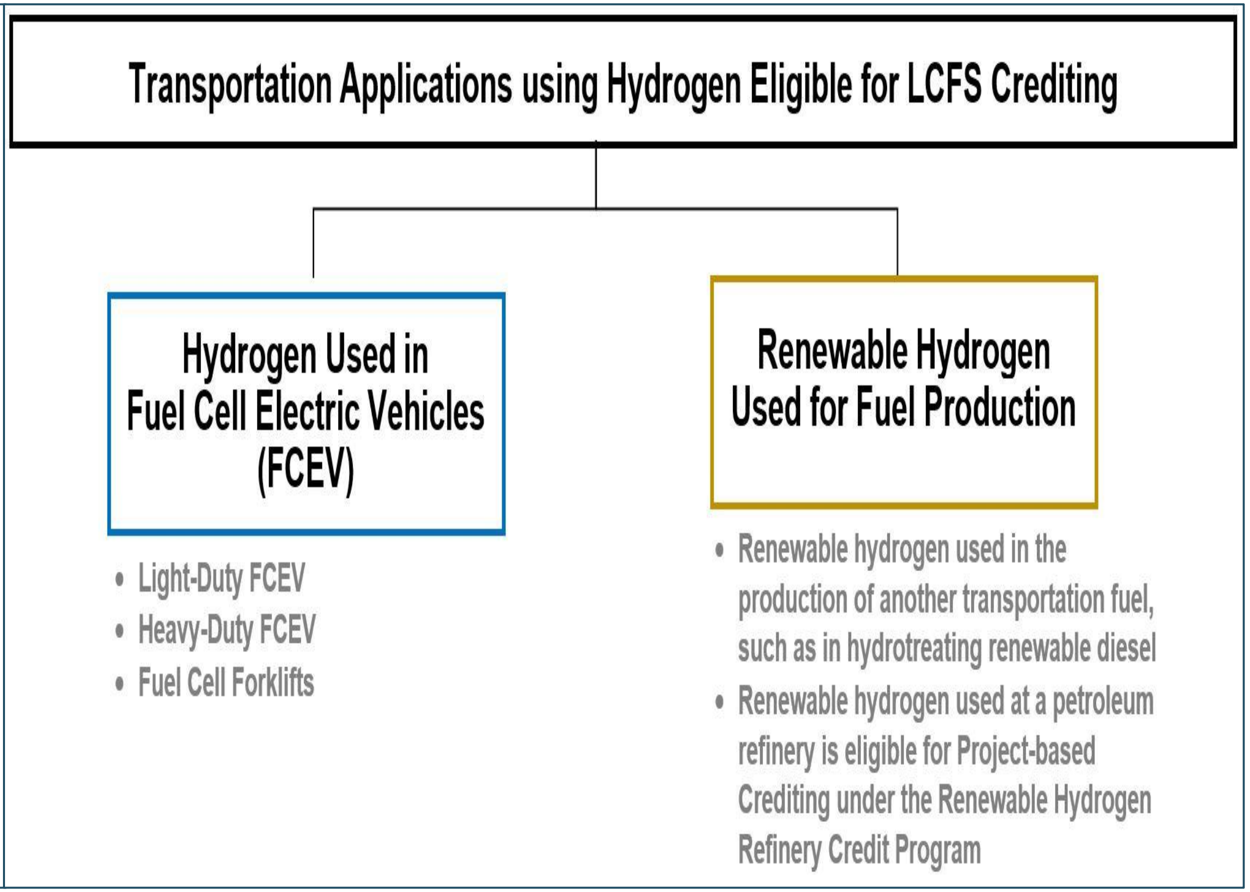
- **FERC**
  - Pursuant to the Natural Gas Act, could regulate the transportation of hydrogen if it is transported in a blended stream with natural gas
  - *Could* classify specific hydrogen-based technology—a solid oxide fuel cell system—as "useful thermal energy output" to encourage hydrogen production. Cogeneration facilities entitled to beneficial regulatory treatment
- **EPA**
  - May develop new regulatory standards for hydrogen production distinct from fossil fuel processing
- **PHMSA**
  - May introduce hydrogen-specific storage and transportation requirements

Environmental and Regulatory Issues – Renewable Fuels

- Hydrogen and LCFS Credit Generation
  - Fuel Pathway
  - Project Crediting (renewable hydrogen)
  - Capacity Crediting (ZEV “fueling” infrastructure)
- Hydrogen and RIN Generation
  - Renewable Biogas → Hydrogen →Gasoline/Diesel
  - Creation of Cellulosic biofuel (D3)
  - Delays at EPA approving pathways
  - E-RIN Questions

Environmental and Regulatory Issues - LCFS





Source: California Air Resources Board

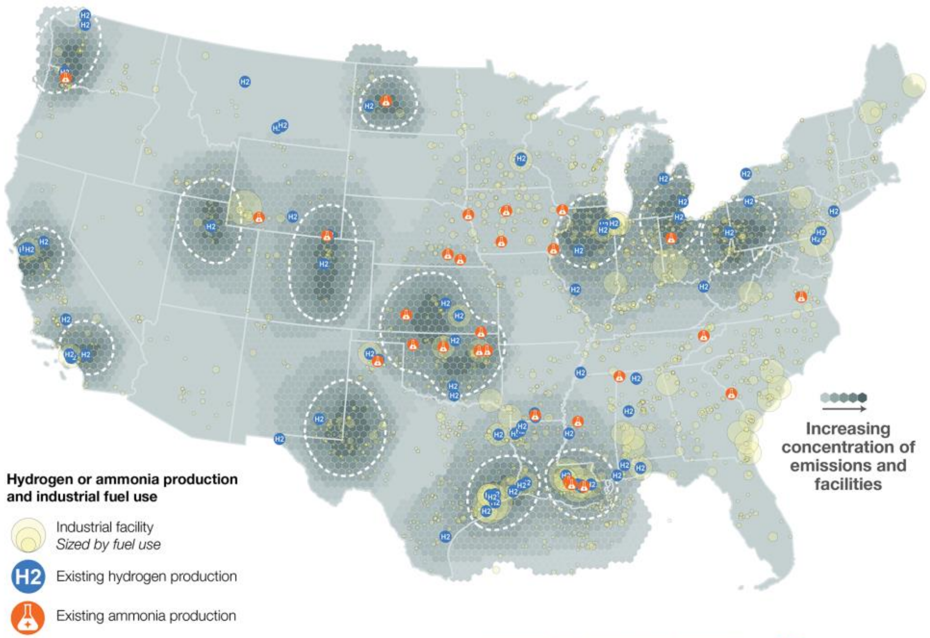
Environmental and Regulatory Issues – Greenwashing and ESG Risks

- Relevancy to Net-Zero and ESG goals
  - Type of hydrogen matters with respect to energy transition thesis
    - Investment targets
    - Allocation of capital
    - Fuel Switching
- Greenwashing
  - FTC Green Guides
  - Material Misrepresentation to Investors
  - Reputational Risks

Governmental Incentives

The U.S. Department of Energy: Clean Hydrogen Hub Program

- The Bipartisan Infrastructure Law includes $8 billion for Regional Clean Hydrogen Hubs, $1 billion for a Clean Hydrogen Electrolysis Program and $500 million for Clean Hydrogen Manufacturing and Recycling Initiatives
- The U.S. Department of Energy ("DOE") has until May 2023 to select at least four Regional Clean Hydrogen Hubs from proposals submitted in 2022
- On February 15th, the DOE announced two Requests for Information (RFI) to collect feedback from stakeholders to inform the implementation and design of the programs



Source: An Atlas of Carbon and Hydrogen Hubs, GPI, 2022. Full citation and data sources are detailed in the atlas.

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Legislative Acts

- **Infrastructure Investment and Jobs Act of 2022:** Programs and funding to accelerate clean hydrogen production
  - Section 40314. Additional Clean Hydrogen Programs
    - Section 815 – Clean Hydrogen Manufacturing and Recycling – research, development, and demonstration projects to support a clean hydrogen domestic supply chain (production, processing, delivery, storage, and use equipment manufacturing technologies and techniques)
      - $500 million for FY 2022 through 2026
    - Section 816 – Clean Hydrogen Electrolysis Program – "establish a research, development, demonstration, commercialization, and deployment program for purposes of commercialization to improve the efficiency, increase the durability, and reduce the cost of producing clean hydrogen using electrolyzers"
      - $1 billion for FY 2022 through 2026
    - Section 814 – Clean Hydrogen Strategy and Roadmap – develop a "technologically and economically feasible" strategy and roadmap for the United States to facilitate widescale production, processing, delivery, and use of clean hydrogen
  - Section 40315. Clean Hydrogen Production Qualifications
    - Instructs DOE Secretary, in consultation with the Administrator of EPA, to develop an initial standard for the carbon intensity of clean hydrogen production from renewable, fossil fuel with carbon capture, utilization, and sequestration technologies, nuclear, and other fuel sources

Legislative Acts *(cont'd)*

- **Consolidated Appropriations Act of 2022**
  - Support for renewable energy and carbon capture and storage ("CCS")
    - § 4002 – includes "developing technologies for the capture of carbon dioxide produced during the production of hydrogen from natural gas"
    - § 4007 – Study on Blue Hydrogen Technology
      - "Study to examine opportunities for research and development in integrating blue hydrogen technology in the industrial trial power sector and how that could enhance the deployment and adoption of CCS"
- **Build Back Better Act** (***not enacted***)
  - Creates a rebate program administered by the DOE Secretary for electric vehicle supply equipment, including for hydrogen fuel cell refueling equipment.
  - Zero Emissions Vehicle Infrastructure Grants (Section 30431)
    - $200 million for hydrogen fueling equipment through State Energy Programs
  - Domestic Manufacturing Conversion Grants (Section 30443)
    - Appropriates $3.5 billion to the DOE Secretary for domestic manufacturing of conversion grants for hydrogen fuel cell electric, plug-in electric hybrid, and plug-in electric drive vehicles.

New Section 45X Clean Hydrogen Tax Credit

- While the fate of the Act still very much remains in flux (and is subject to change), we remain optimistic that some version of tax credit extension/expansion or portion thereof will be enacted this year (potentially retroactive to the beginning of the year).
- **New Clean Hydrogen PTC** – 10-year production tax credit under new section 45X for the production of “qualified clean hydrogen”
  - “**Qualified clean hydrogen**” is defined as hydrogen which is produced through a process that results in a lifecycle greenhouse gas emission rate of not greater than 6 kilograms of carbon dioxide equivalent per kilogram of hydrogen
- **ITC-in-lieu-of-PTC Election** – Taxpayers have the option to elect the ITC in lieu of the PTC with respect to a clean hydrogen production facility
- **Direct Pay:** Taxpayers otherwise eligible for the Hydrogen Tax Credit are entitled to elect for “**direct payment**” of the credit amount.

New Section 45X Clean Hydrogen Tax Credit *(cont'd)*

- Green Hydrogen Projects: Any renewable energy used to produce qualified hydrogen may be eligible for production or investment tax credits with respect to such renewable energy.
  - Blue Hydrogen Projects: if the facility includes property for which a Section 45Q credit is allowed, the Hydrogen Tax Credit is not allowed
- **Amount** – The Hydrogen Tax Credit amount depends on the greenhouse gas emissions rate and whether the project satisfies the prevailing wage and apprenticeship requirements

New Section 45X Clean Hydrogen Tax Credit *(cont'd)*

- **Production Hydrogen Tax Credit Rates**:

Carbon Dioxide equivalent (“CO2e”) per kilogram of Hydrogen (“X”)	Prevailing Wage and Apprenticeship Requirements Not Satisfied	Prevailing Wage and Apprenticeship Requirements Satisfied
$6 \geq X \geq 4$	$0.09 per kg of qualified clean hydrogen	$0.45 per kg of qualified clean hydrogen
$4 > X \geq 2.5$	$0.12 per kg of qualified clean hydrogen	$0.60 per kg of qualified clean hydrogen
$2.5 > X \geq 1.5$	$0.15 per kg of qualified clean hydrogen	$0.75 per kg of qualified clean hydrogen
$1.5 > X \geq .45$	$0.20 per kg of qualified clean hydrogen	$1.00 per kg of qualified clean hydrogen
$.45 > X$	$0.60 per kg of qualified clean hydrogen	$3.00 per kg of qualified clean hydrogen

New Section 45X Clean Hydrogen Tax Credit *(cont'd)*

- **Investment Hydrogen Tax Credit Rates**:

Carbon Dioxide equivalent ("CO2e") per kilogram of Hydrogen ("X")	Prevailing Wage and Apprenticeship Requirements Not Satisfied	Prevailing Wage and Apprenticeship Requirements Satisfied
$6 \geq X \geq 4$	0.9% of eligible basis	4.5% of eligible basis
$4 > X \geq 2.5$	1.2% of eligible basis	6.0% of eligible basis
$2.5 > X \geq 1.5$	1.5% of eligible basis	7.5% of eligible basis
$1.5 > X \geq .45$	2.0% of eligible basis	1.0% of eligible basis
$.45 > X$	6.0% of eligible basis	30.0% of eligible basis

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