Clean Hydrogen in the Gulf Coast Region

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Arkansas Energy and Environment Innovation Plan, Industrial Decarbonization Workshop

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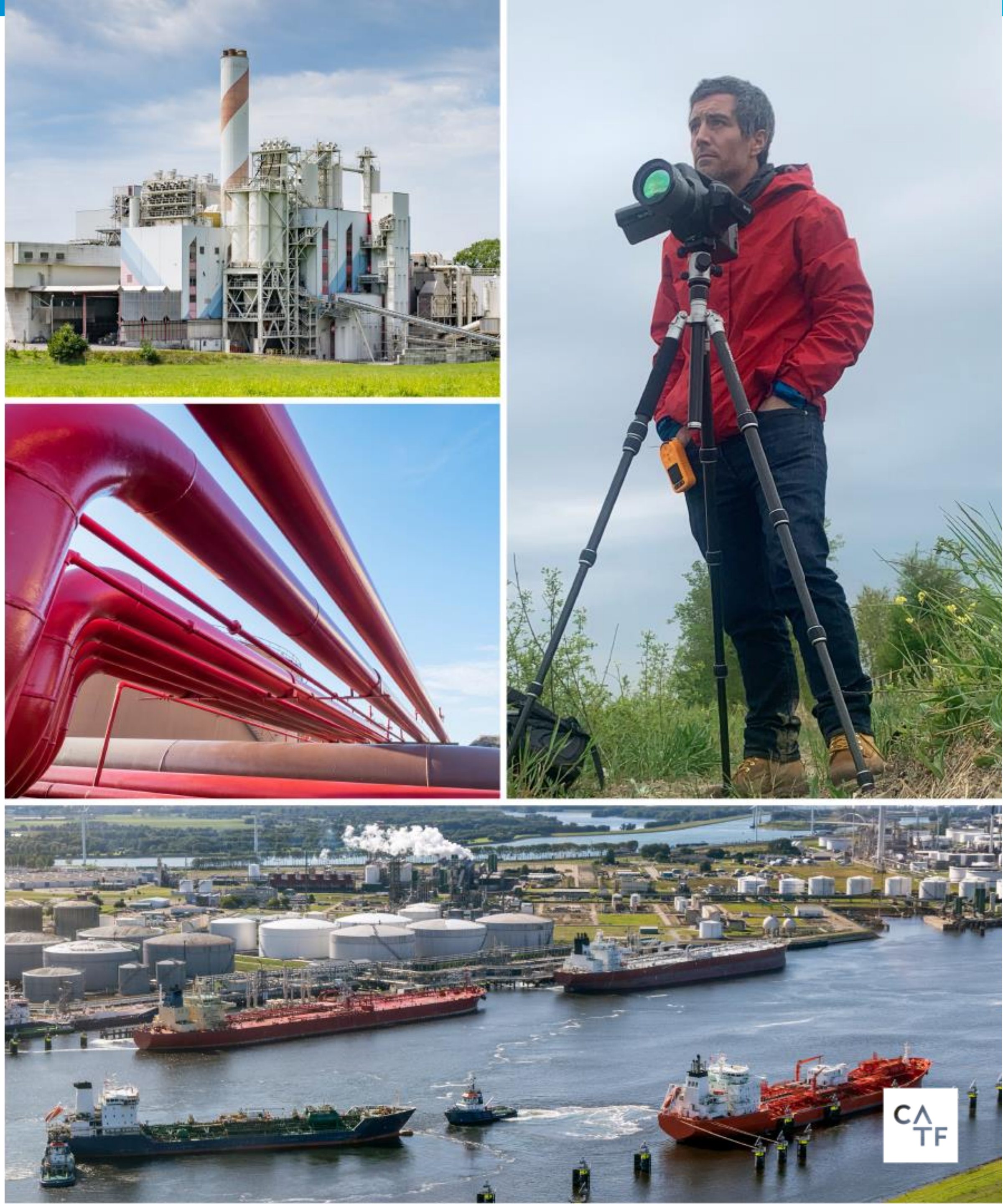
CLEAN AIR TASK FORCE

Clean Air Task Force: Who We Are

- Founded in 1996 in Boston.
- 175+ global staff: engineers, environmentalists, advocates, analysts, lawyers, and more.
- 100% funded by philanthropic donations, no government or industry funding. Awarded Founders Pledge top climate org.
- Our mission: Lead the way to an affordable, zero-carbon energy system by advocating for pragmatic policies, new business strategies, and advanced technologies.
- Find out more at www.catf.us



PROGRAMMATIC FOCUS

Mature

Methane Pollution Prevention

Leading the implementation of the Global Methane Pledge, working with countries to develop abatement strategies, working for strong standards in U.S. and EU

Mature

Carbon Capture

Leading innovation policy development and implementation in the U.S. and EU, exploring project and market development opportunities in MENA and SSA, though leadership on carbon take back obligations

Mature

U.S. Federal Climate Policy

Engaged on federal clean energy standards and federal procurement of 24/7 carbon free energy

Established

US Power Plants and Industrial Emissions

Engaged in a range of litigation and rule makings on emission limits for CO2, methane, and criteria pollutants (NOx, Sox, HAPs)

Established

Zero-Carbon Fuels

Focused on the U.S., EU, MENA, SSA, and SE Asia on developing standards and markets for hydrogen and ammonia fuels

Up and Running

Superhot Rock Energy

Focused on driving the technology from early development stage through commercial demonstration, as well as addressing needed regulatory and infrastructure issues

Up and Running

Innovative U.S. State Climate Polices

Engaged on U.S. state clean energy standards as well as deployment implementation, such as hydrogen hub development

Up and Running

Decarbonized Transport

Focus on both innovation policies and mandates (such as zero-carbon fuel standards) at the U.S. federal level, as well as engagement with international shipping companies and ports to facilitate ammonia bunker fuel adoption

Re-inventing

Land Use and Bioenergy

Leading the exploration of the limits of land use in abating global warming, including land availability, limits of biomass use, and complex forest-climate interactions

Re-inventing

Advanced Nuclear

Focused on hitting the “re-start” button for nuclear business models and confirming both innovation policy and regulatory strategies appropriately

Up and Running

Energy System Analysis

Developing new analysis tools and approaches to evaluating and planning for decarbonization strategies

Up and Running

Energy and Climate Innovation in Africa

Focused on the dual track of economic development and decarbonization by developing the central power grid to facilitate commercial growth, while engaging in domestic efforts to support technology innovations for zero-carbon power

Scoping

Industrial Decarbonization

Doing the needed work to understand and develop decarbonization strategies for each major type of industrial areas – such as steel, cement, chemicals, pulp and paper, etc. A specific focus on the three technology areas that can fully decarbonize the sector: carbon capture, hydrogen, and electrification

Scoping

Corporate/ Government Procurement

Developing the commercial sector strategies, government policies, and overall standards to facilitate the development of market pull for 24/7 carbon-free energy

Scoping

Fusion

Focused on driving the technology from early development stage through commercial demonstration, as well as addressing needed regulatory and infrastructure issues

Start-Up

Infrastructure Deployment

Developing the tools and strategies, initially in the U.S., that would facilitate full system decarbonization, with a particular focus on planning and community empowerment - particularly disadvantaged/environmental justice communities

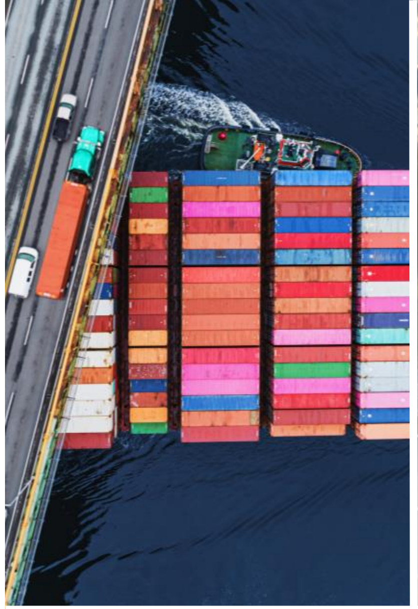
— Zero-Carbon Fuels Program

80% of end-use energy is currently provided by fuel molecules like coal, natural gas and refined petroleum.

In the future, many fuel end users will convert that consumption into electricity.

Despite critical efforts to expand electrification, there are many sectors of the economy where electrification is not a viable alternative to molecules.

Zero-carbon fuels—specifically hydrogen and ammonia—are fuels that do not emit carbon dioxide when consumed and can replace existing high-emitting fuels in hard-to-decarbonize sectors.



The Role of Clean Hydrogen

Clean Hydrogen is Required to Reach Net-Zero

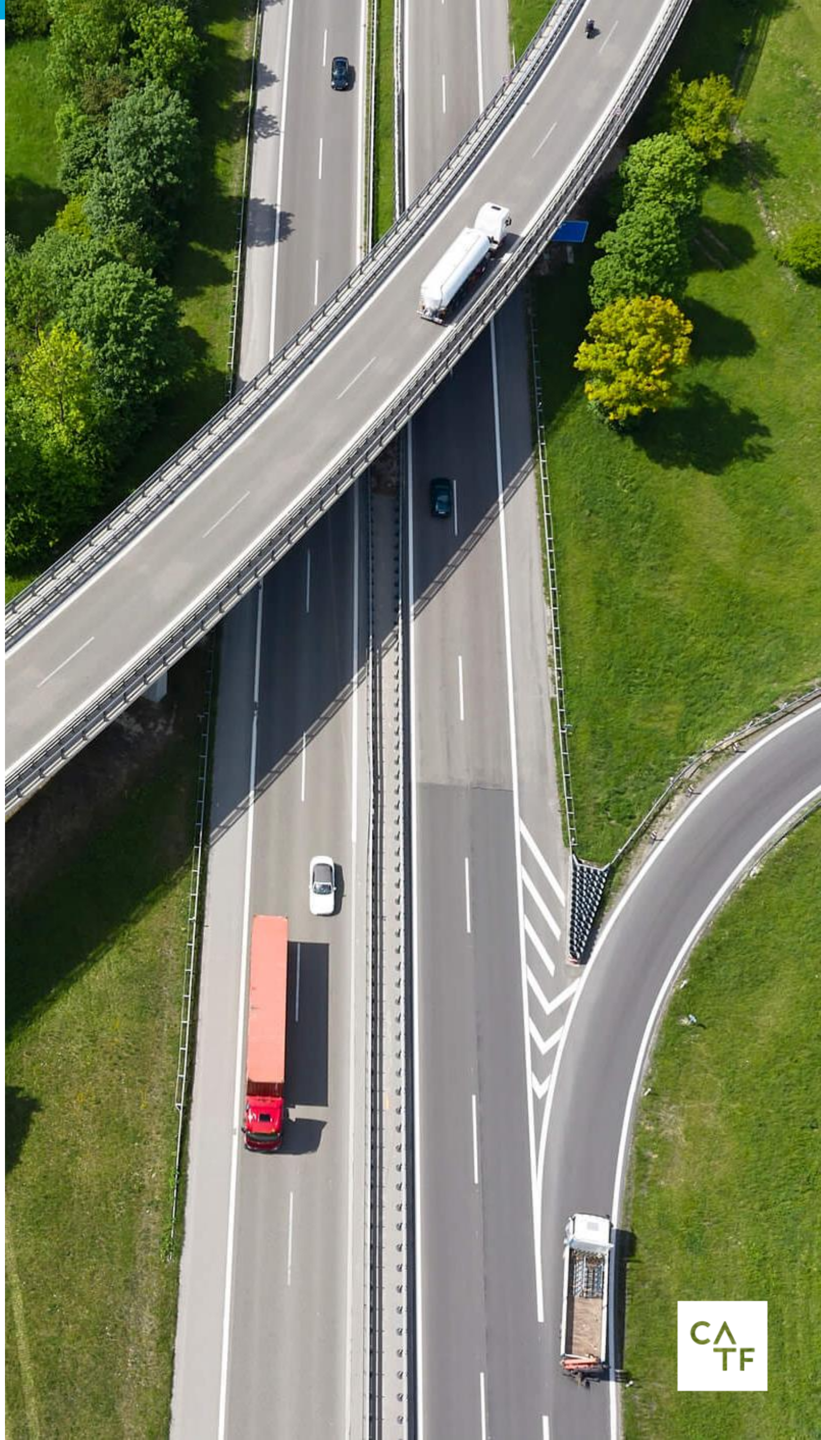
- Hydrogen is a potent energy carrier that contains no carbon and emits no CO_2 at its point of use.
- Hydrogen can play a key role in decarbonizing emissions sources and sectors where direct electrification or other low-carbon options might not be technically or economically feasible.
- Currently 95M Mt of annual global production. Net-zero scenario estimates from the IEA and others predict demand growth of 5-10x current production to meet 2050 goals. All of this will need to be clean, low-carbon hydrogen.
- Virtually all hydrogen produced today – more than 99% – is made from fossil fuels or uses fossil fuel energy inputs, with no carbon abatement. Direct CO_2 emissions from current modes of hydrogen production are estimated to account for approximately 2% of global CO_2 emissions.

Clean Hydrogen Production Pathways

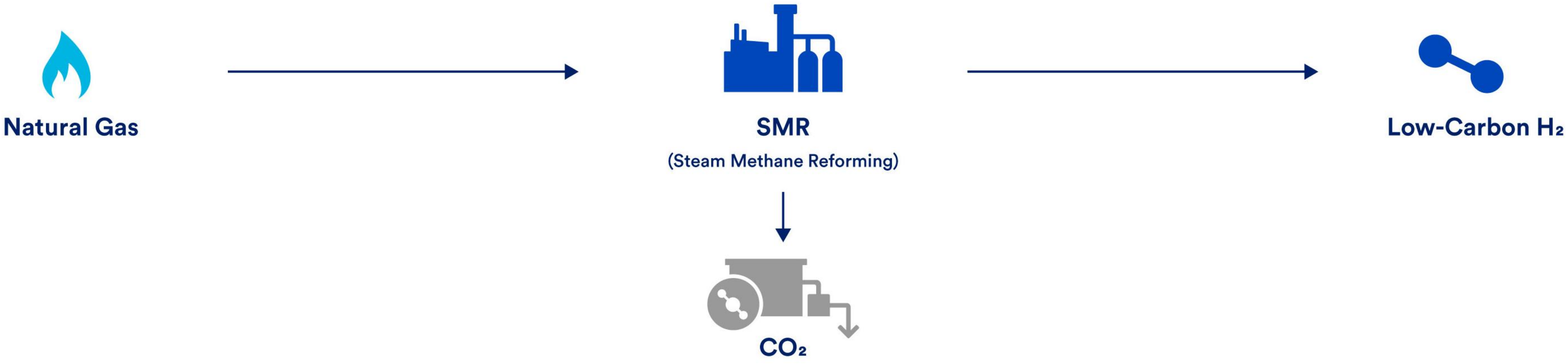
Clean hydrogen can be produced in multiple ways, primarily through electrolysis using zero-carbon electricity or through methane reforming using natural gas with carbon capture and upstream methane control.

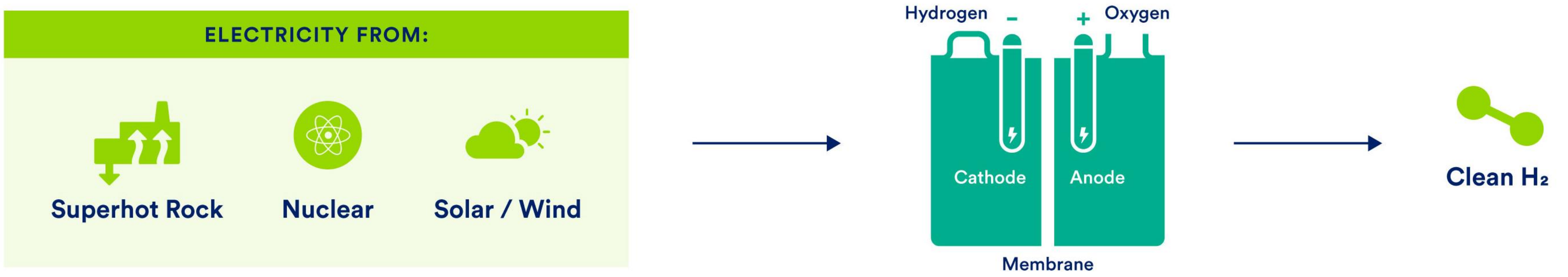
Clean hydrogen is the whole point. What constitutes "clean" depends on context and should evolve over time, but at a minimum:

- Natural gas-based production must feature very high levels of carbon capture for reformers, extremely low methane loss rates upstream, and a low CO_2 intensity of process electricity.
- Electrolytic production must utilize electricity that is renewable or clean.



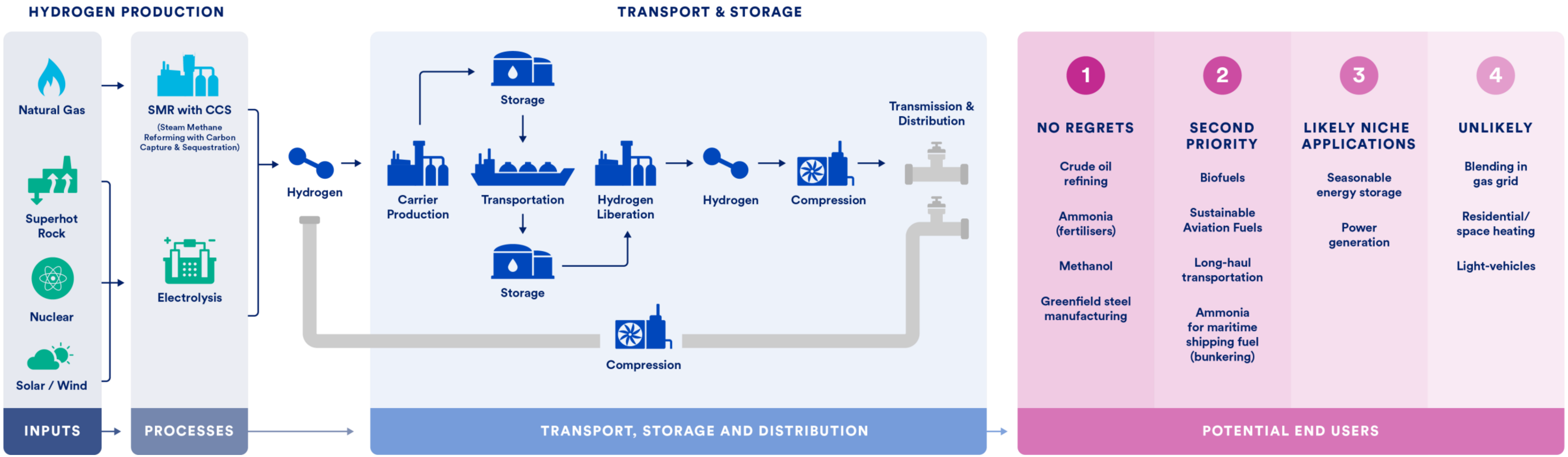
Clean Hydrogen Production Pathways





Why CATF Works on Hydrogen

Hydrogen is key for several hard-to-abate sectors & feedstocks



Hydrogen is an essential pillar for hard-to-abate sectors and will remain a critical feedstock for industrial purposes, but its use should be limited due to its energy-intensive nature and challenging physical properties. Production of hydrogen will likely be close to demand centers or transported via pipelines. Seaborne transportation of hydrogen is challenging, but could develop in the form of ammonia for fertilizers and maritime (bunkering) fuel.

No-Regrets and Priority End Uses

1 No-regrets applications of low-carbon hydrogen

- Crude oil refining
- Ammonia production (NH_3)
- Methanol production
- Steel manufacturing

2 Other potential applications of low-carbon hydrogen

- Aviation
- Marine shipping
- Heavy-duty trucking

3 Niche applications for low-carbon hydrogen

- Power generation
- Long-duration energy storage

4 Applications that lack justification

- Residential use
- Light-duty vehicles

Clean Hydrogen Challenges and Opportunities

- Clean hydrogen is necessary
  - Clean burning, CO_2-free fuel source
  - Useful as an energy carrier and fuel for high-heat processes in hard-to-abate industrial sectors (steel).
  - Key chemical feedstock in ammonia-based fertilizers and other chemical products

- Clean hydrogen is challenging
  - Costly and complex production pathways
  - Lack of transportation, distribution, and storage infrastructure
  - Physical and chemical properties create technical challenges for storage and transportation
  - Widespread end-user adoption will require technological retrofitting, price and supply certainty, and other incentives
  - Public perception: safety and necessity

Federal Support for Clean Hydrogen

CATF

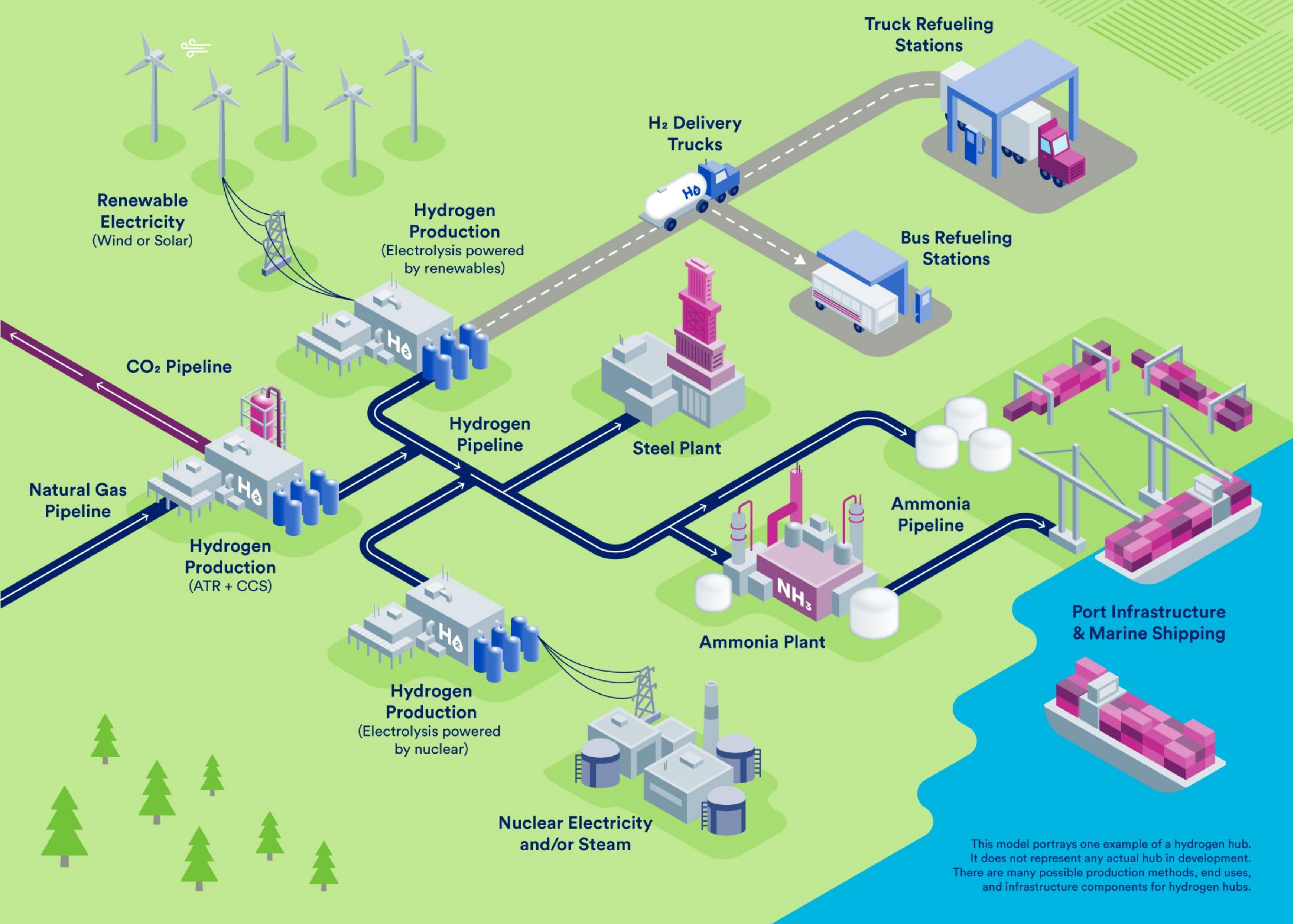
Federal Support for Clean Hydrogen

The Bipartisan Infrastructure Law (BIL) and the Inflation Reduction Act (IRA) created over $97 billion in direct funding for clean energy technology and infrastructure as well as establishing multiple tax credit and loan programs for clean energy development, many of which are focused on the development of clean hydrogen. These programs include:

- Regional Clean Hydrogen Hubs Program – $7 billion to support regional hubs and $1 billon for the development of a demand-side support mechanism.
- 45V Clean Hydrogen Production Tax Credit
- 45Q Carbon Capture and Sequestration Tax Credit – applicable to blue hydrogen
- 48C Advanced Energy Project Credit – extends the 30% investment tax credit to create funding for manufacturing projects producing fuel cell electric vehicles, hydrogen infrastructure, electrolyzers, and assorted other products.
- Clean Hydrogen Electrolysis Program – $1 billion in grant funding to reduce the cost of clean hydrogen production.
- Clean Hydrogen Manufacturing Recycling Program – $500 million n grant funding to advance clean hydrogen production, processing, delivery, storage, and use equipment manufacturing technologies and techniques.
- DOE's Loan Program Office (LPO) has approximately $300 billion in loan authority to finance projects that support clean energy deployment and energy infrastructure.

The Regional Clean Hydrogen Hubs Program

What is a hydrogen hub?



Program Goal:

Department of Energy (DOE) was allocated $8B to fund up to 10 hydrogen hubs across the United States.

The hubs will be localized centers for the production, transportation, storage, and end use of hydrogen closely connected and co-located in the same region.

This first-of-a-kind program intends to catalyze domestic clean hydrogen production in the United States and aims to bring the cost of production down by 80% to $1 per kilogram in one decade

Regional Clean Hydrogen Hubs Program Overview

- The Bipartisan Infrastructure Law allocated $8B to the Department of Energy's Office of Clean Energy Demonstrations to fund up to 10 Regional Clean Hydrogen Hubs
- $7B for hubs and $1B for a demand-side support mechanism
- The legislation directed that DOE fund Hubs that:
  - Demonstrate diverse production methods (nuclear, renewable, and fossil based)
  - Demonstrate diverse end uses (power, industrial, transportation, and residential/commercial heating)
  - Are geographically diverse (at least two in natural gas abundant regions)
- Seven regional hubs applications were selected for funding awards in October

Selected Regional Clean Hydrogen Hubs

- ~3 MMT of H2 Produced each year
- ~25 MMT GHG reductions each year

Regional Clean Hydrogen Hubs Program Timeline

Pre-application process:

Notice of Intent (NOI) – posted in June 2022

Funding Opportunity Announcement (FOA) – September 2022

Concept Papers due from interested applicants – November 2022 (79 papers submitted)

DOE Encouragement Notification for applicants to pursue a Full Application – December 2022 (33 applications encouraged)

Full Applications from Hubs due – April 7, 2023

DOE Selection of Awardees – October 13, 2023

Award Negotiations – Winter 2023-2024

Phase 1: 2024-2026
Detailed planning (12-18 months)

Phase 2: 2025-2029
Development, permitting, and financing (2-3 years)

Phase 3: 2028-2033
Install, integrate, construct (2-4 years)

Phase 4: 2030-2037
Ramp up & Operate (2-4 years)

CATF's H $_2$ Hubs Team Mission:

Ensure successful, equitable implementation of DOE's Regional Clean Hydrogen Hubs Program that maximizes climate and community benefits.

Getting clearer on our mission: What does it mean to **CATF to ‘maximize’ climate and community benefits?**

1. Low-carbon production

The hubs program will support hubs with a variety of production pathways ranging from renewables to natural gas, to nuclear. The upstream emissions from producing the natural gas and/or electricity used to make hydrogen must be absolutely minimized.

H2 Hubs should produce hydrogen that has a carbon intensity below 4 $kgCO_2e/kgH_2$ in alignment with the Clean Hydrogen Production Standard and accounting for full upstream emissions in the Life Cycle Assessment (LCA)

2. End-uses for maximum climate benefit

The hubs program is required to demo H2 in a variety of end uses, but not all end uses for hydrogen are equal in their climate impact. H2 Hubs should prioritize end users that require hydrogen to decarbonize.

Priority 1: crude oil refining, petrochemicals production, ammonia production, methanol production, steel & iron production

Priority 2: Renewable fuels production, sustainable aviation fuels, marine shipping fuel, heavy duty trucking fuel.

3. Maximizing community benefit

H2 Hubs should:

- Engage communities during the project design process prior to decision-making and give communities clear opportunities to influence key project decisions
- Empower and allow impacted communities to determine the local benefits that hubs are working to create as part of their Community Benefit Plans
- Ensure that hubs are developed safely and that all project risks are absolutely minimized.

Long term economic viability & proof point for other regions and countries

The 45V Clean Hydrogen Production Tax Credit and the Three Pillars

The 45V Clean Hydrogen Production Tax Credit

- The Clean Hydrogen Production Tax Credit (45V) was created to incentivize clean hydrogen production in the United States by providing a tax credit up to $3 per kilogram of H_2 based on the carbon intensity of the hydrogen produced.

Lifecycle Emissions (kg CO_2e per kg H_2)	PTC Value (per kg H_2)
4-2.5	$0.60
2.5-1.5	$0.75
1.5-0.45	$1.00
0.45-0	$3.00

The 45V Clean Hydrogen Production Tax Credit

- 45V will be critical to electrolytic hydrogen producers, many of whom are relying on the value of the credit to make projects economically feasible.
- The U.S. Treasury is currently working to set regulations which will clarify what steps grid-connected projects need to take to meet the statutory emissions standards for the credit.
- The nature of how 45V credits are awarded will determine the pace of clean hydrogen development and the ultimate emissions impact of future hydrogen production.
- Many project developers have indicated they are waiting on Treasury's 45V guidance before making final investment decisions on projects.

Why is 45V rulemaking so important?

- Electrolytic production of hydrogen requires a large amount of electricity. As a result, grid-based electrolytic H_2 has the potential to generate twice the GHG emissions of regular grey H_2 if the grid power used for production is not clean.
- In times when renewable power is not available from the grid, electrolytic producers may have to draw on more carbon-intensive sources of power generation like coal or natural gas.
- When solar or wind power is available, the energy-intensive requirements of electrolysis will increase demand on the grid, requiring additional power sources to come online which are likely to be more carbon intensive.

What are the three pillars?

Goal: to simulate new, behind the meter low-carbon electricity generation

Additionality

What: Projects must draw on new clean power

Why: Diverting low-carbon power away from existing uses could incentivize fossil-based generation to meet H2 demand

Hourly-Matching

What: H2 must be produced at the same time of day (hour) as new clean energy is flowing to the grid

Why: Ensure that power doesn’t come from dirtier sources when the project actually uses the electricity

Deliverability

What: Clean energy used for the hydrogen project must be “nearby”

Why: Local fossil plants may be required to meet a hydrogen producer’s electricity demand if the new clean generation is locked behind congestion

Iron and Steel Production with Clean Hydrogen

Clean Hydrogen in Iron and Steel Production

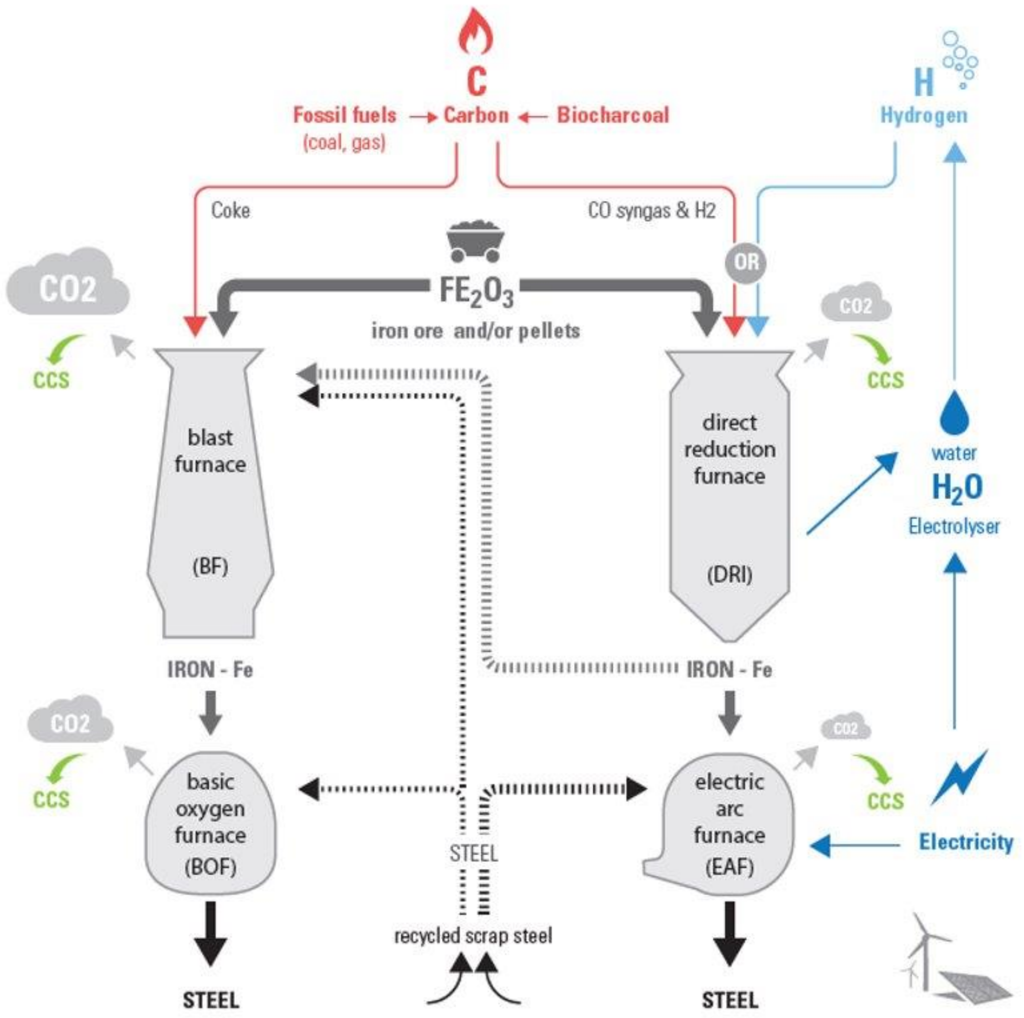
Steel production currently accounts for 7% of total global CO2 emissions. Clean hydrogen can be incredibly useful in efforts to decarbonize the steel industry.

- Hydrogen can act as a fuel source and replace some of the coking coal in iron ore blast furnaces where electrification is inefficient or incapable of reaching the high temperatures needed. However, it cannot entirely replace coal in a blast furnace process and CCS will be necessary to eliminate remaining emissions.
- Hydrogen can also act as a substitute for natural gas as a reducing agent in the direct reduction of iron (DRI) process, which is coupled with an electric arc furnace (EAF) for final steel production. H2-DRI has the lowest associated CO_2 emissions (with the potential for a 95% reduction in CO_2 emissions from conventional processes).[1]

1. GHD. "What's the deal with green steel? The Hydrogen Solution." 2023

Clean Hydrogen in Iron and Steel Production

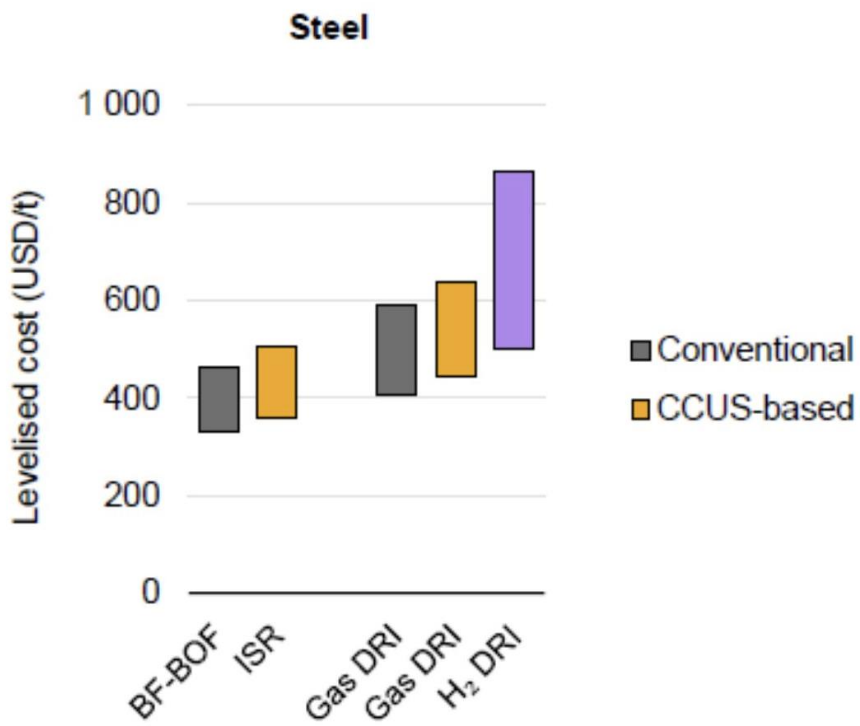
- ~25% of steel production is currently from scrap (electric arc furnace), and the remainder is primary steel from iron ore.
- Two basic configurations exist for primary steel manufacturing:
  1. Blast Furnace + Basic Oxygen Furnace (>90%)
  2. Direct Reduced Iron + Electric Arc Furnace
- Increasing the proportion of secondary steel or natural gas-fired DRI can reduce emissions intensity
- Deep decarbonization of primary steel production requires:
  - DRI using 100% low-carbon hydrogen
  - Carbon capture on blast furnaces or natural gas-DRI



Clean Hydrogen in Iron and Steel Production

The H2-DRI process has promise to eliminate emissions in the steel making sector, but there are numerous challenges to implementation.

- The technology is new, requires a higher level of capital investment to implement.
- The EAF process is power-intensive and will require a dependable source of renewable electricity to keep carbon impact low.
- Success of hydrogen-based processes for green steel production will require a steady, low prices for clean hydrogen and electricity, as well as reliable government support.
- As with most hydrogen end-uses, costs can be reduced by co-locating iron and steel facilities with H_2 production, which will lower the need for transportation infrastructure.



Hydrogen Pipelines

Considerations for Hydrogen Pipelines

- Hydrogen is difficult to transport and currently suitable only for industrial applications, so it is likely that early hydrogen transport will be limited to industrial clusters as seen in DOE's Regional Clean Hydrogen Hubs Program. However, regional networks of intra- and interstate pipelines will need to be built to connect new supplies of clean hydrogen to end-users.
- The existing network of hydrogen pipelines in the U.S. is minimal compared to that of oil and natural gas systems. There are currently around 1,600 miles of hydrogen pipelines in the U.S. (the largest network in the world), the majority of which are located in the Gulf Coast region. For reference, there are about 3 million miles of natural gas pipelines in the U.S.
- Hydrogen pipelines pose a technical challenge: the lightest element is prone to leakage through seams, cracks, and joints. It can also cause embrittlement in steel pipe and the material of welds, valves, and fittings.
- Retrofitting to convert existing natural gas pipelines to hydrogen is commonly proposed, but this approach poses additional technical challenges. Existing right-of-way could be taken advantage of, but new distribution lines will be required for differing locations of production and offtake sites.

Regulation of Hydrogen Pipelines

Entities

Regulation of H_2 pipeline siting, commercial service, security, and safety is currently divided among federal agencies and the states. Federal jurisdiction resides variously with the Surface Transportation Board (STB), the Federal Energy Regulatory Commission (FERC), the Transportation Security Administration (TSA), and the Pipeline and Hazardous Materials Safety Administration (PHMSA) within the Department of Transportation (DOT).

Siting

Unlike siting of interstate natural gas pipelines, which is overseen by FERC, there is no federal authority. Developers must seek approvals from each state through which a pipeline will pass.

Regulation of Hydrogen Pipelines

Commercial Service

The terms of commercial service for commodity pipelines may include provisions for access to pipeline capacity, rates for transportation service, requirements for commodity quality, and other commercial requirements.

- “Common carrier” and “open access” pipelines are open for use by multiple shippers or users.
- “Contract carriers” serve a specific group of users, typically under long-term capacity agreements.

Jurisdiction over commercial rates falls under the Surface Transportation Board (STB), who acts as a forum to resolve disputes related to pipelines.

Safety

The Pipeline and Hazardous Materials Safety Administration (PHMSA) currently oversees hydrogen pipeline safety regulation. PHMSA requires pipeline operators to comply with various requirements, including materials, design, construction, metering, corrosion control, operations, maintenance, and reporting.

Thank you!

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