

Exploring Green Hydrogen's Role in our Energy Future

Presented by the Environmental Law
Institute

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Slides from Sunita Satyapal

DOE Hydrogen and Fuel Cell Remarks

**Dr. Sunita Satyapal, Director, Hydrogen and Fuel Cell Technologies Office
and DOE Hydrogen Program Coordinator
U.S. Department of Energy**

February 2, 2023

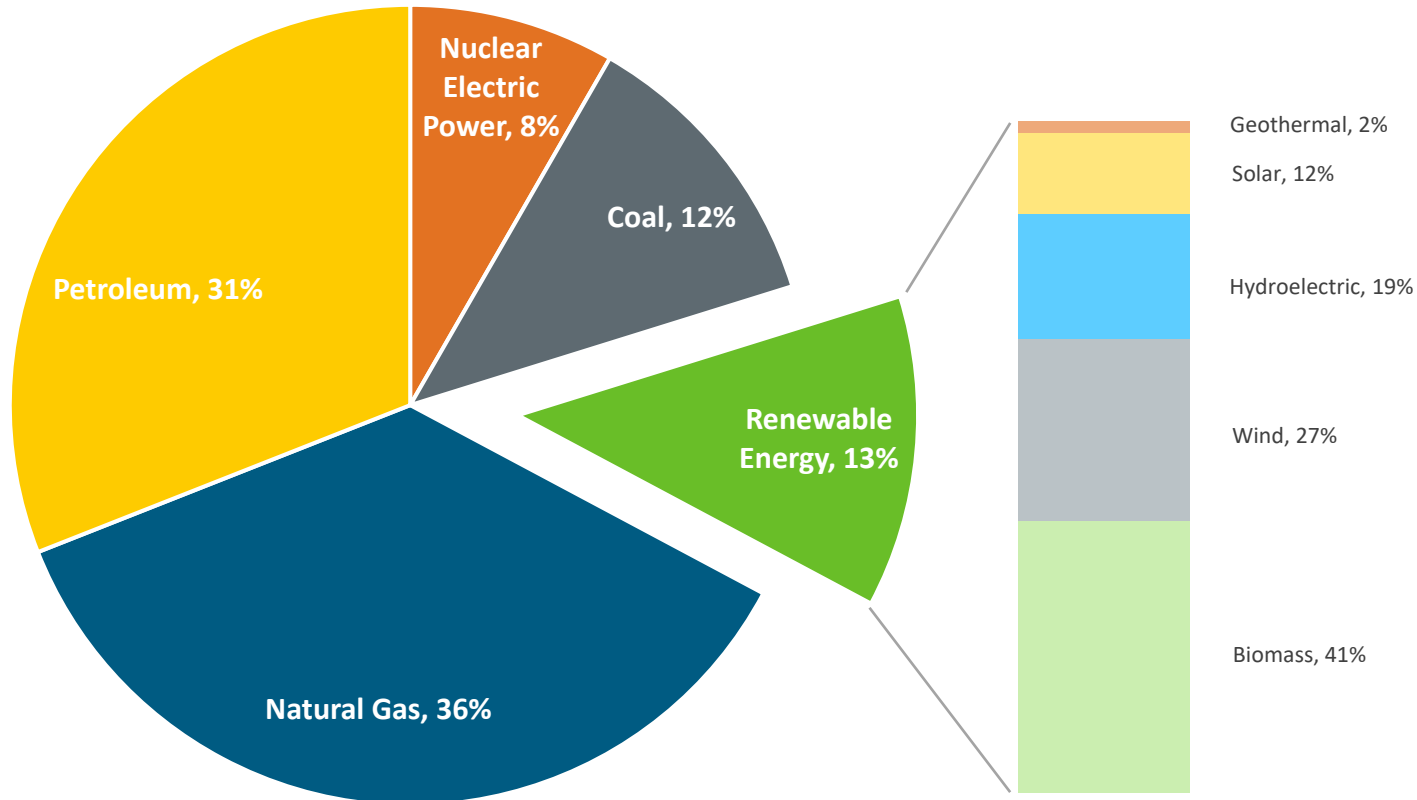


U.S. Energy Landscape and Key Goals

U.S. primary energy consumption by energy source, 2021

Total = 97.8 quadrillion
British thermal units (Btu)

Total = 12.3 quadrillion Btu



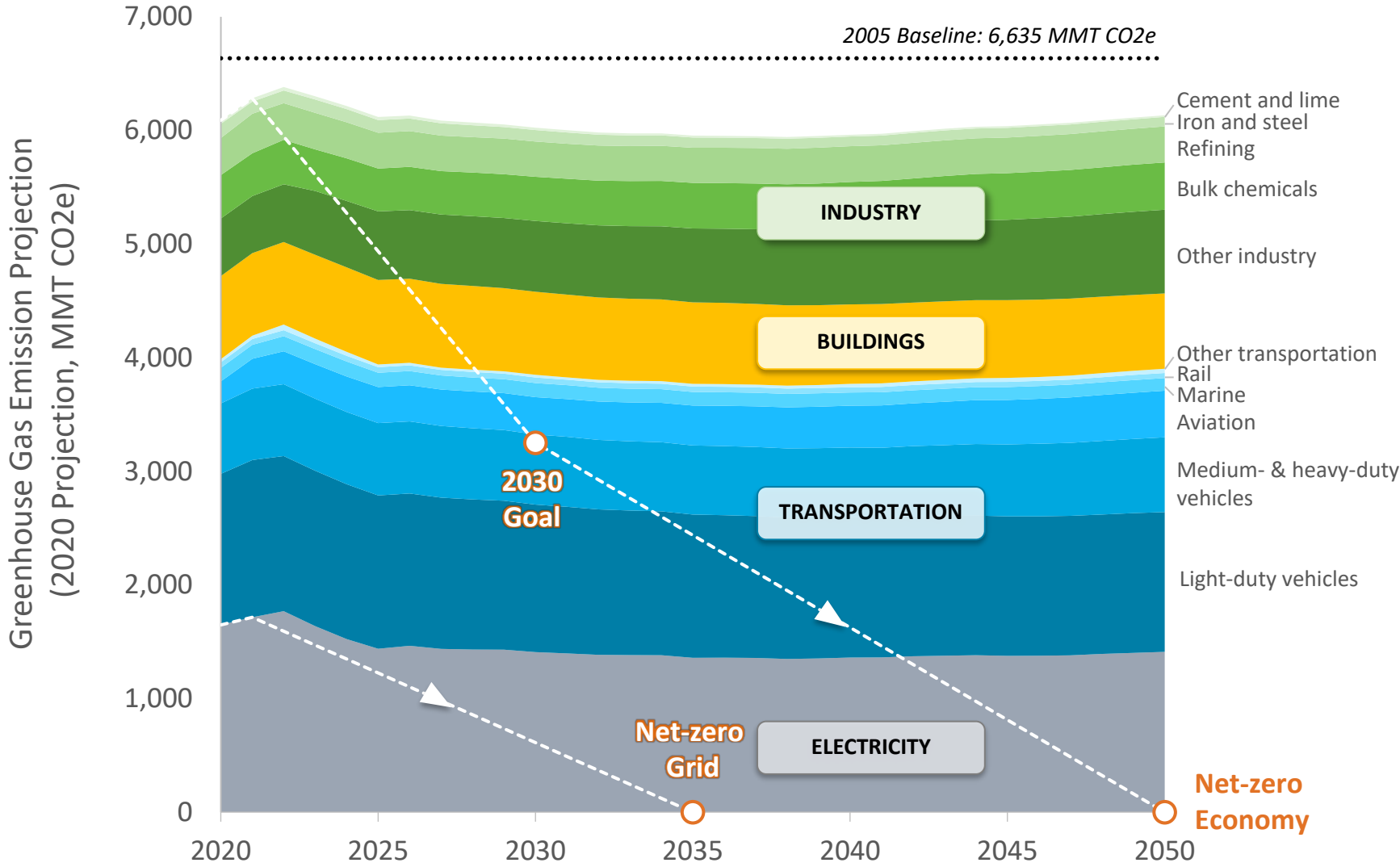
Note: Sum of components may not equal 100% because of independent rounding
Source: Data collected from U.S. Energy Information Administration, April 2022, *Monthly Energy Review*, preliminary data

Administration Goals include:

- **Net-zero emissions economy by 2050 and 50–52% reduction by 2030**
- **100% carbon-pollution-free electric sector by 2035**

Priorities: Ensure benefits to all Americans, focus on jobs, Justice40: 40% of benefits in disadvantaged communities

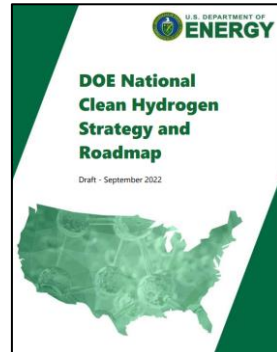
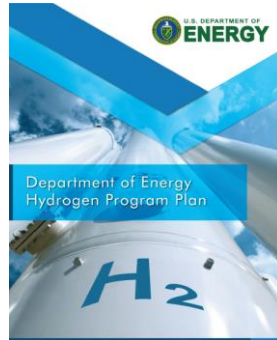
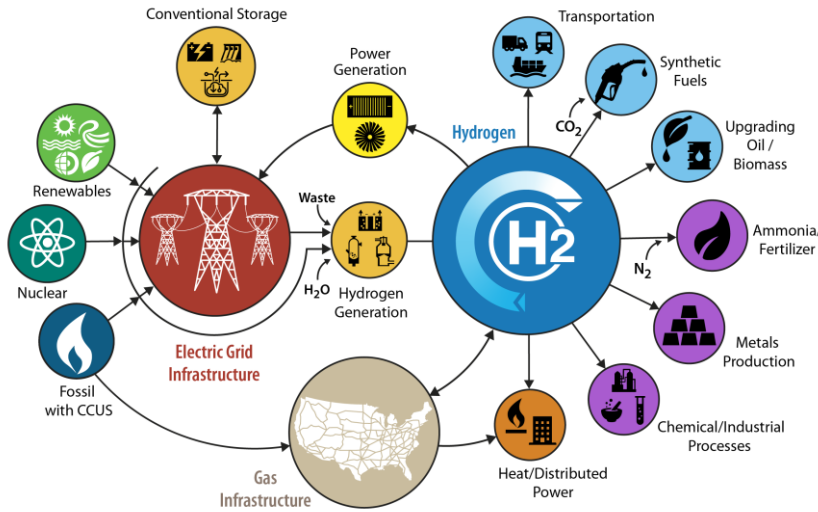
Carbon Dioxide Emissions by Sector



Source: Annual Energy Outlook 2021, DOE National Clean Hydrogen Strategy and Roadmap

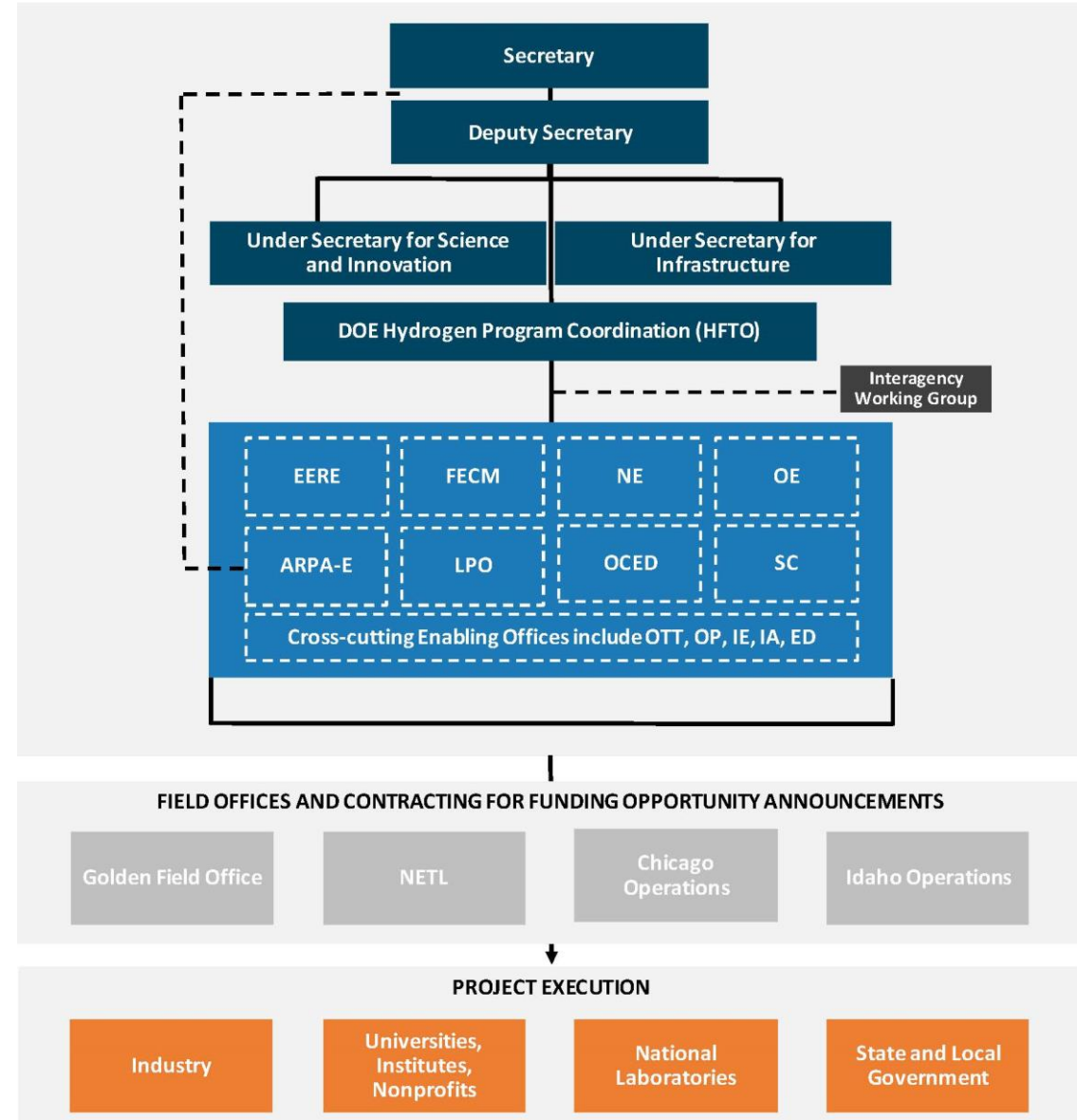
U.S. DOE Hydrogen Program

Hydrogen is one part of a broad portfolio of activities
Includes multiple offices and the entire RDD&D value chain from production through end use



www.hydrogen.energy.gov

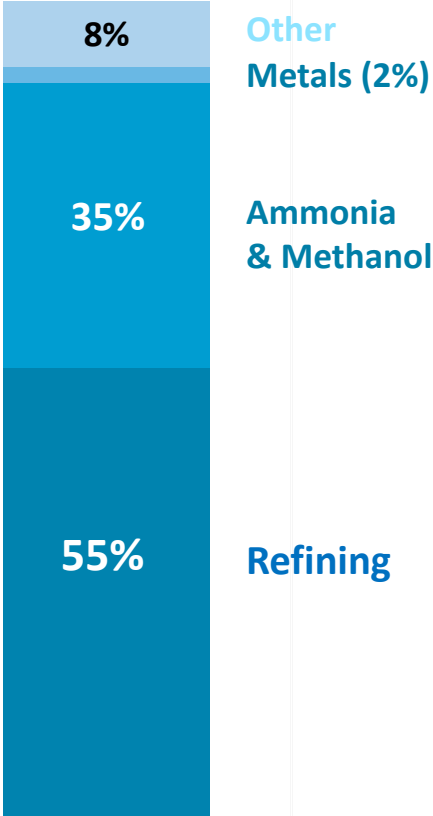
Coordinated across Offices by DOE Hydrogen and Fuel Cell Technologies Office (HFTO)



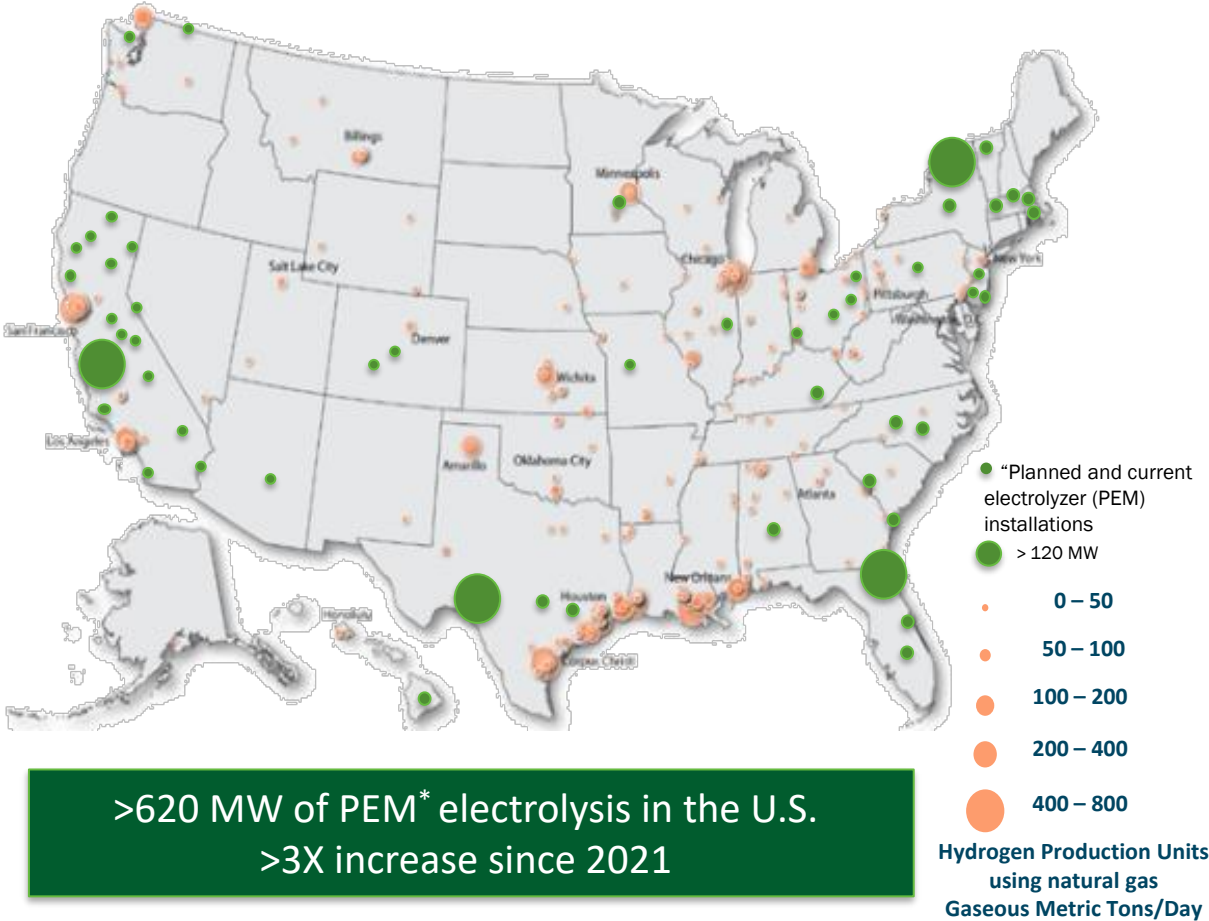
Snapshot of Hydrogen and Fuel Cells in the U.S.

- 10 million metric tons produced annually
- More than 1,600 miles of H₂ pipeline
- World's largest H₂ storage cavern

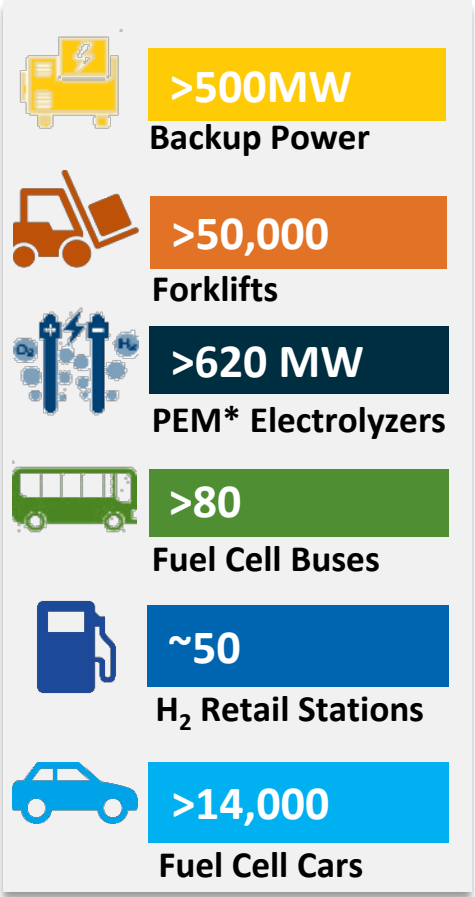
Use of Hydrogen in the U.S. Today



Examples of Hydrogen Production Locations



Examples of Deployments



*Proton exchange membrane

Recent Legislation Highlights

Bipartisan Infrastructure Law

- Includes \$9.5B for clean hydrogen:
 - \$1B for electrolysis
 - \$0.5B for manufacturing and recycling
 - \$8B for at least four regional clean hydrogen hubs
- Requires developing a **National Clean Hydrogen Strategy and Roadmap**



President Biden Signs the Bipartisan Infrastructure Bill into law on November 15, 2021. Photo Credit: Kenny Holston/Getty Images

Inflation Reduction Act

- Includes significant tax credits (e.g., up to \$3/kg for production of clean hydrogen)

National Clean Hydrogen Strategy and Roadmap for Public Comment

Strategy



1

Target strategic, high-impact end uses

Achieve 10 MMT/year of clean hydrogen by 2030



2

Reduce the cost of clean hydrogen

Enable \$2/kg by electrolysis by 2026 and \$1/kg H₂ by 2031



3

Focus on regional networks

Deploy 4 or more clean hydrogen hubs and ramp up scale

Vision:

Affordable clean hydrogen for a net-zero carbon future and a sustainable, resilient, and equitable economy

Benefits:

Emissions reduction; job growth; energy security and resilience

Work with other agencies to accelerate market lift off

Enablers



Workforce development



Safety, codes and standards



Policies and incentives



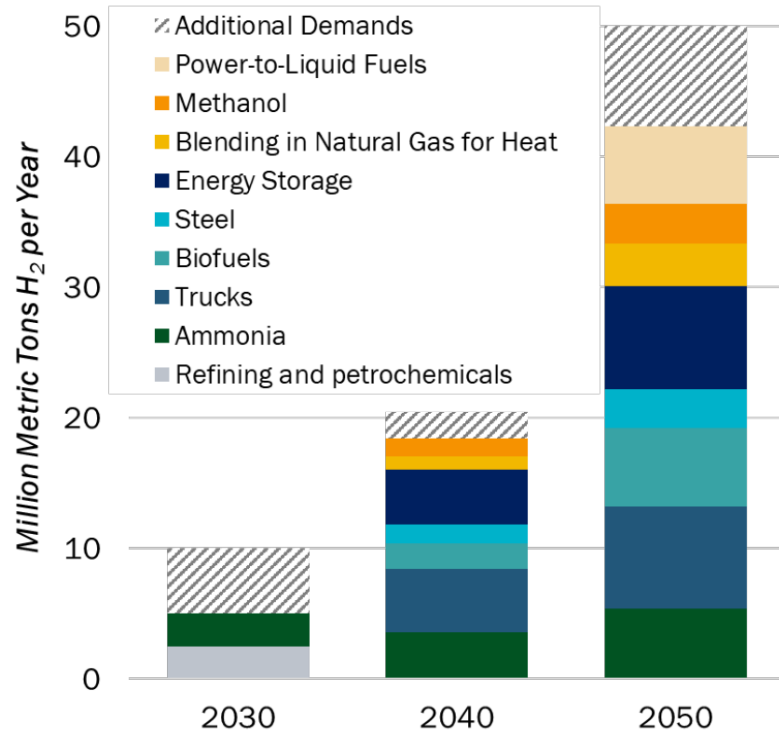
Stimulating private sector investment



Energy and environmental justice

National Clean Hydrogen Strategy - The Opportunity for Clean Hydrogen

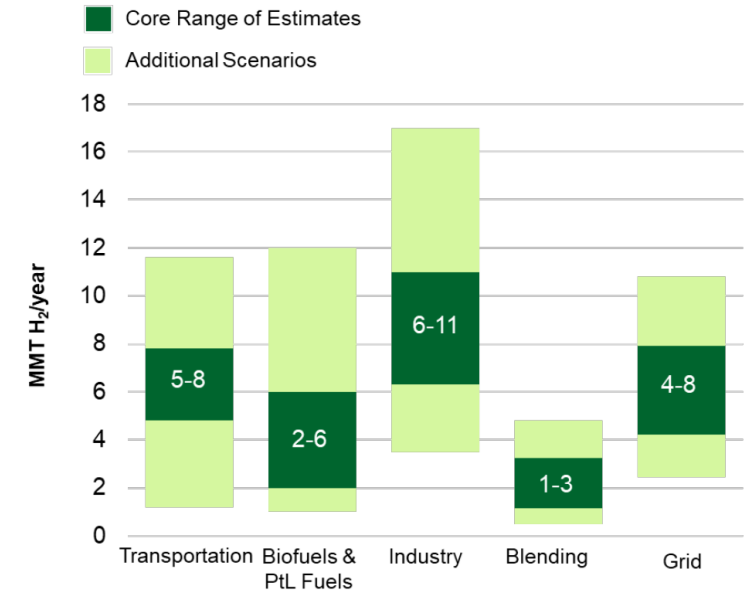
The Opportunity for Clean Hydrogen



Clean Hydrogen Use Scenarios

- Catalyze clean H₂ use in existing industries (ammonia, refineries), initiate new use (e.g., sustainable aviation fuels (SAFs), steel, potential exports)
- Scale up for heavy-duty transport, industry, and energy storage
- Market expansion across sectors for strategic, high-impact uses

Range of Potential Demand for Clean Hydrogen in U.S. by 2050



- **Core range:** ~ 18–36 MMT H₂
- **Higher range:** ~ 36–56 MMT H₂

Refs: 1. NREL MDHD analysis using TEMPO model; 2. Analysis of biofuel pathways from NREL; 3. Synfuels analysis based off H2@Scale ; 4. Steel and ammonia demand estimates based off DOE Industrial Decarbonization Roadmap and H2@Scale. Methanol demands based off IRENA and IEA estimates; 5. Preliminary Analysis, NREL 100% Clean Grid Study; 6. DOE Solar Futures Study; 7. Princeton Net Zero America Study

U.S. Opportunity: 10MMT/yr by 2030, 20 MMT/yr by 2040, 50 MMT/yr by 2050



Hydrogen

Hydrogen Energy Earthshot

“Hydrogen Shot”

“1 1 1”

\$1 for 1 kg clean hydrogen in 1 decade

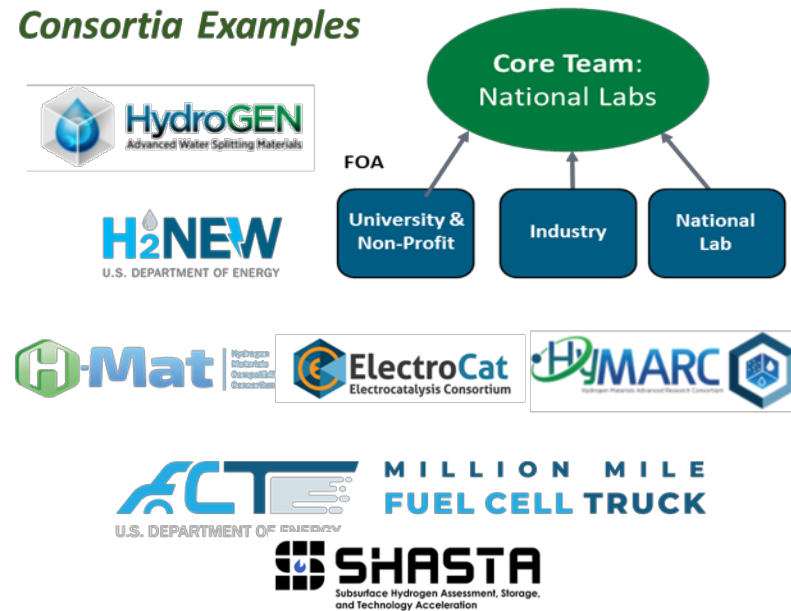
Launched June 7, 2021
Summit Aug 31-Sept 1, 2021

DOE Hydrogen Activities across RDD&D – Examples

Research and Development

Basic and applied research through individual projects and consortia

Consortia Examples

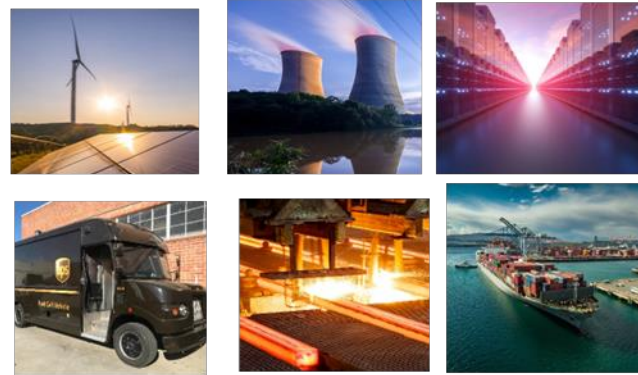


Basic science user facilities, theory, modeling

Technology Integration, Validation, Demos

1st of a kind demonstrations and systems integration to de-risk deployments

Examples:



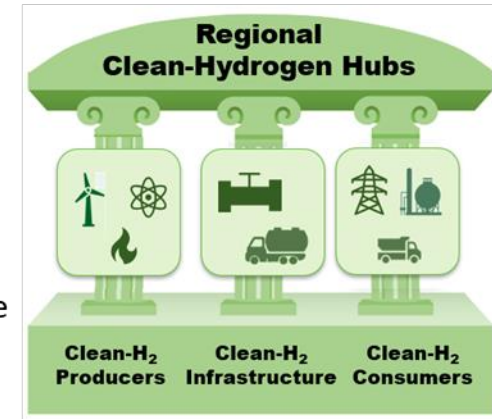
Renewables and nuclear to H₂, 15 delivery trucks in disadvantaged area, 3 Super Truck projects, data center, fueling for passenger ferry, energy storage, H₂ for steel

Deployment and Financing

H2 Hubs, loan guarantee program, workforce development

Example:

\$8 billion for at least 4 hubs:
Renewables, fossil w/CCS, nuclear; multiple end-uses



2 new loan guarantee projects (\$1.5B total) on pyrolysis and large-scale electrolysis, H₂ energy storage and power generation

Enabling Activities

- Analysis and tools
- Safety, codes & standards
- Manufacturing
- Workforce development



H2 Matchmaker

Examples of Global Collaboration

Collaborating through multiple global and bilateral partnerships—key priority is creating coordinated framework to leverage activities, identify gaps, and avoid duplication to accelerate progress



CEM Global Ports Coalition with EC
Numerous Bilaterals on Hydrogen
Hydrogen Council, IRENA, and more



The International Partnership for Hydrogen and Fuel Cells in the Economy
Enabling the global adoption of hydrogen and fuel cells in the economy

H₂ Production Analysis (H2PA)
To facilitate international trade
Common analytical framework for
GHG emissions footprint

**Regulations, Codes, Standards,
Safety and Education &
Outreach Working Groups**

www.iphe.net

Early Career Network: 38 Countries

www.iphe.net/early-career-chapter



Breakthrough Agenda in collaboration with other partnerships is mapping activities across global H₂ initiatives to identify gaps, focus areas, and prioritized workstreams

LEADER COUNTRIES	Hydrogen Production	Hydrogen Distribution	Hydrogen Storage	Hydrogen Utilization	Hydrogen Infrastructure	Hydrogen Safety	Hydrogen Policy	Hydrogen Education & Outreach
USA, Canada, UK, France	USA, Canada, UK, France	USA, Canada, UK, France	USA, Canada, UK, France	USA, Canada, UK, France	USA, Canada, UK, France	USA, Canada, UK, France	USA, Canada, UK, France	USA, Canada, UK, France
Germany, Japan, South Korea	Germany, Japan, South Korea	Germany, Japan, South Korea	Germany, Japan, South Korea	Germany, Japan, South Korea	Germany, Japan, South Korea	Germany, Japan, South Korea	Germany, Japan, South Korea	Germany, Japan, South Korea
China, India, Australia	China, India, Australia	China, India, Australia	China, India, Australia	China, India, Australia	China, India, Australia	China, India, Australia	China, India, Australia	China, India, Australia
EU, Middle East, Africa	EU, Middle East, Africa	EU, Middle East, Africa	EU, Middle East, Africa	EU, Middle East, Africa	EU, Middle East, Africa	EU, Middle East, Africa	EU, Middle East, Africa	EU, Middle East, Africa
South America, Southeast Asia	South America, Southeast Asia	South America, Southeast Asia	South America, Southeast Asia	South America, Southeast Asia	South America, Southeast Asia	South America, Southeast Asia	South America, Southeast Asia	South America, Southeast Asia
Other regions	Other regions	Other regions	Other regions	Other regions	Other regions	Other regions	Other regions	Other regions

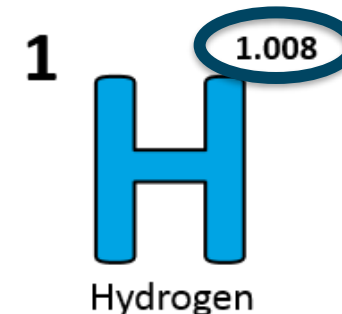
Resources and Opportunities for Engagement



Save the date!
2023 DOE Annual Merit Review and Peer Evaluation Meeting
June 5-8, 2023

Hydrogen and Fuel Cells Day
October 8

- Held on hydrogen's very own atomic weight-day



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www.energy.gov/eere/fuelcells/fuel-cell-technologies-office-newsletter

Learn more at: energy.gov/eere/fuelcells AND www.hydrogen.energy.gov

Thank you

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www.energy.gov/fuelcells
www.hydrogen.energy.gov





Slides from Vanella Yadhati

Introduction to Ørsted's Power-to-X business



02 February 2023

Ørsted's business areas

An illustration showing various renewable energy sources: an offshore wind turbine in the water, an onshore wind turbine, solar panels, a bioenergy plant with a leaf icon, and a hydrogen truck. Dotted lines connect these icons to their respective business area descriptions on the right.

Offshore wind

- Global leader in offshore wind
- Develop, construct, own and operate offshore wind farms

Onshore wind, solar PV & storage

- Building a leadership position in onshore renewables
- Energy storage solutions and solar

Bioenergy & other

- Presence in Europe, including bioenergy plants, legacy gas activities and patented waste-to-energy technology

Renewable hydrogen and green fuels

- Emerging platform with 10+ pipeline projects (6+ GW)
- Ambition to become a global leader in renewable hydrogen and green fuels by 2030



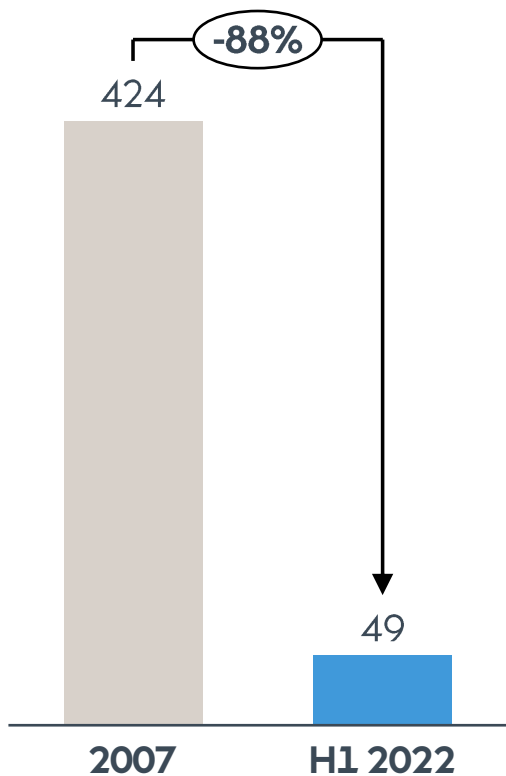
6,400+ employees
worldwide



Ranked most sustainable
energy company in the world

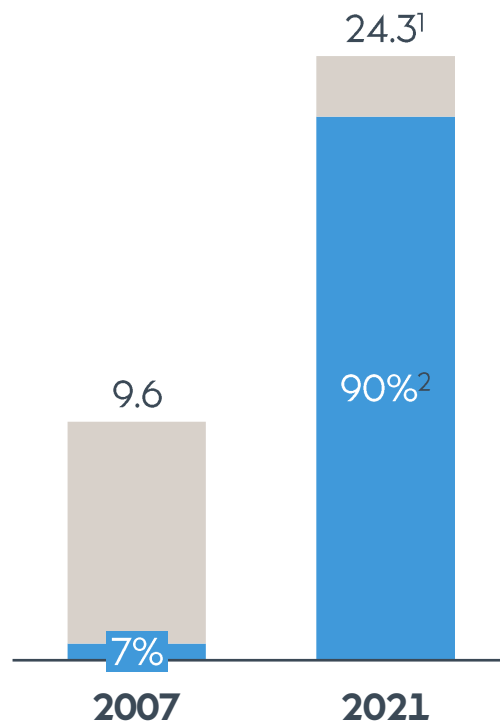
Ørsted has undergone a profound transformation

CO₂ reduction
g CO₂e/kWh (scope 1 & 2)

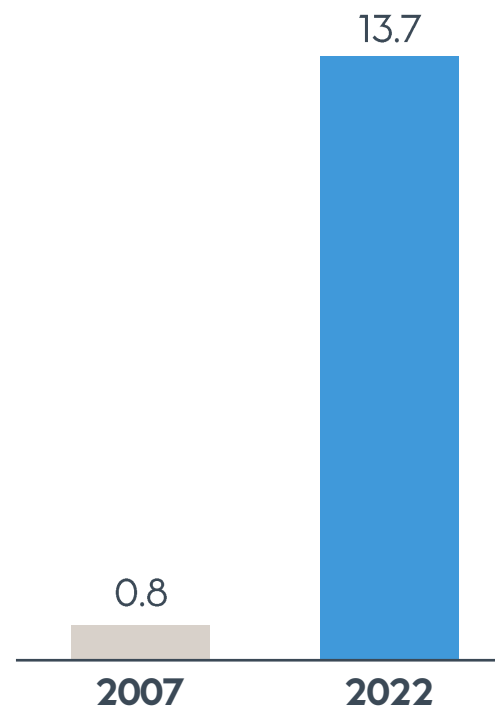


Green transformation
EBITDA, DKKbn, %

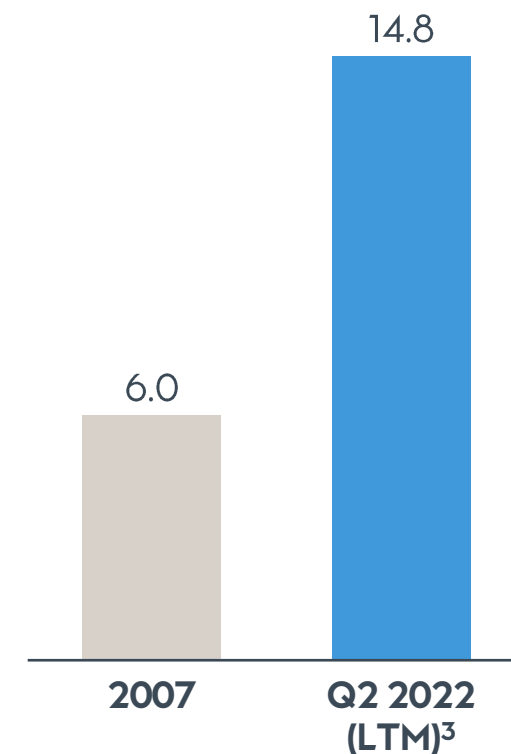
■ Share of renewables



Renewable capacity
Installed capacity, GW



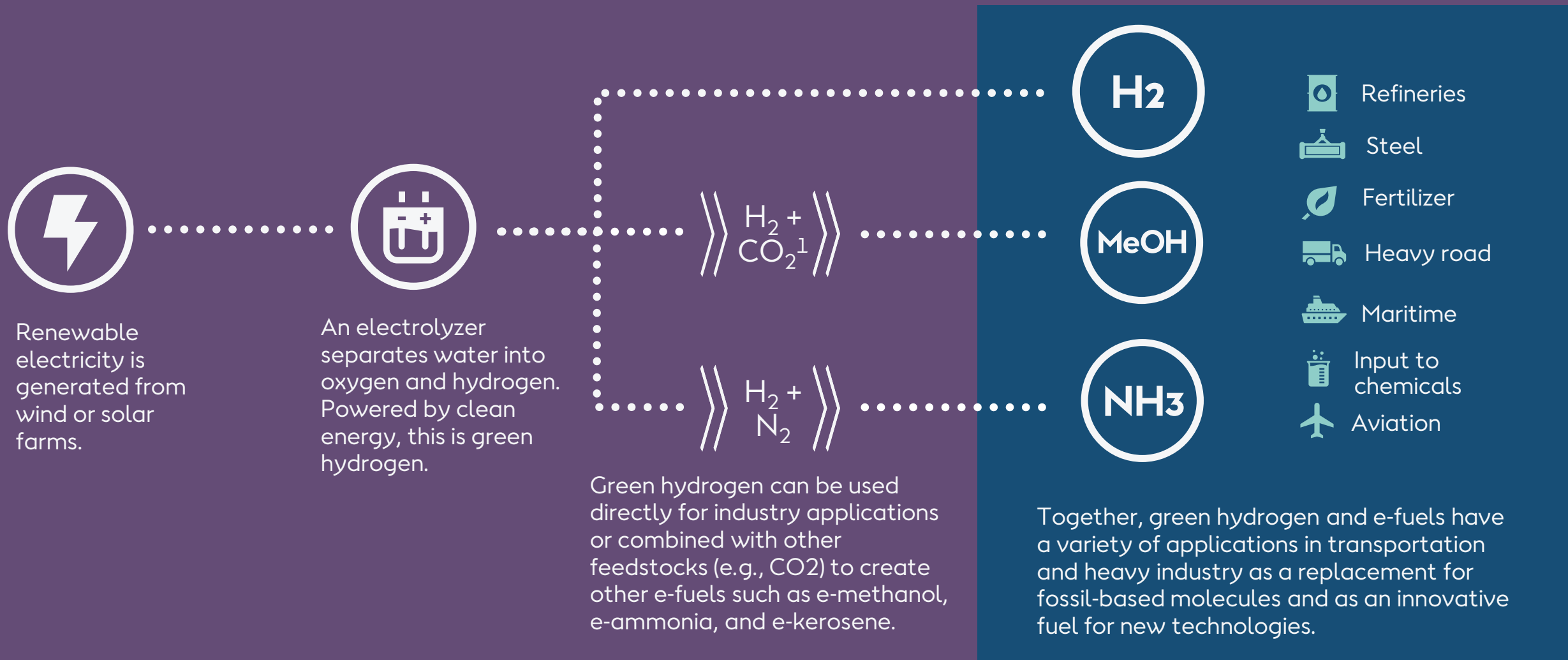
Profitability
ROCE, %



1. Including EBITDA from new partnerships 2. Taxonomy-aligned 3. LTM: Last twelve months

Source: Ørsted Interim Financial and ESG Report Q1 2022

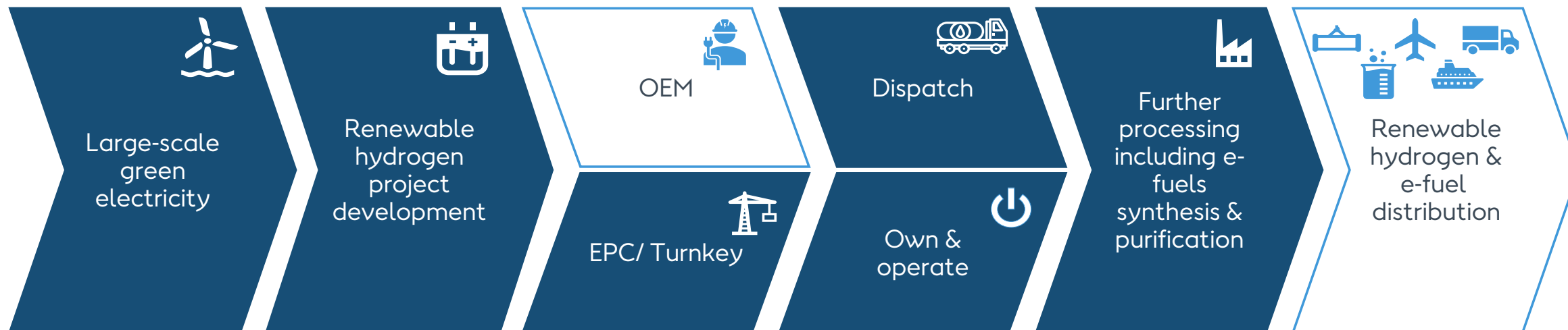
Our Power-to-X business makes molecules from renewable energy to decarbonize industry



1. Any CO₂ Ørsted uses is captured from biogenic carbon sources as part of the natural CO₂ cycle, creating a carbon negative e-fuel

We are leaning forward into the renewable molecules value chain as a natural extension of our core business

Ørsted role



Ørsted well-positioned to deliver P2X solutions



Access to green electrons



Proximity to offtake



Shaping market conditions



Portfolio synergies








Technology scale-up







Trusted Partner

Our global footprint

United States of America





-  In operation: 30MW
Under construction: 130MW
Under development: 4,842MW
-  In operation: 3,013MW
Under construction: 200MW
Under development: 252MW
-  In operation: 647MW
Under construction: 680MW
Under development: 1,156MW
-  In operation: 40MW
Under development: 520MW
-  Under development: 675MW

- ## Denmark
-  In operation: 940MW
 -  In operation: our CHP plants, 2,865MW power and 3,560MW heat
 -  Sales of energy
 -  Under construction: 2MW
Under development: 1300MW

- ## Ireland
-  In operation: 327MW
Under construction: 45MW
Under development: 466/298MW

- ## United Kingdom
-  In operation: 6,233MW
Under development: 4,000-5,000MW


-  In operation: 62MW
Under development: 195MW





-  In operation: Renescience Northwich
-  In operation: 20MW
-  Sales of energy
-  Under development: 101MW



Spain


- ## Sweden
-  Sales of energy
 -  Under development: 3,000MW
 -  Under development: 70MW


- ## Poland
-  Under development: 2,500MW


- ## Germany
-  In operation: 1,346MW
Under construction: 1,166MW


-  In operation: 22MW
-  Under construction: 10MW
-  Sales of energy
-  Under development: 2700MW

- ## France
-  In operation: 34MW
 -  In operation: 4MW

- ## Japan
-  Under development: 1,600MW










- ## South Korea
-  Under development: 1,600MW

- ## Taiwan
-  In operation: 128MW
Under construction: 900MW
Under development: 6,590MW




- ## Vietnam
-  Under development: 1,600MW

- ## The Netherlands
-  In operation: 752MW
 -  Under development: 1100MW

Activities

-  Offshore wind
-  Onshore wind
-  Solar
-  Biomass-fired power plant
-  Fossil-fueled power plant
-  Renewable fuels
-  Bio plant
-  Storage
-  Sales of energy

Status

-  In operation
-  Under construction
-  Under development

P2X Pipeline in Europe

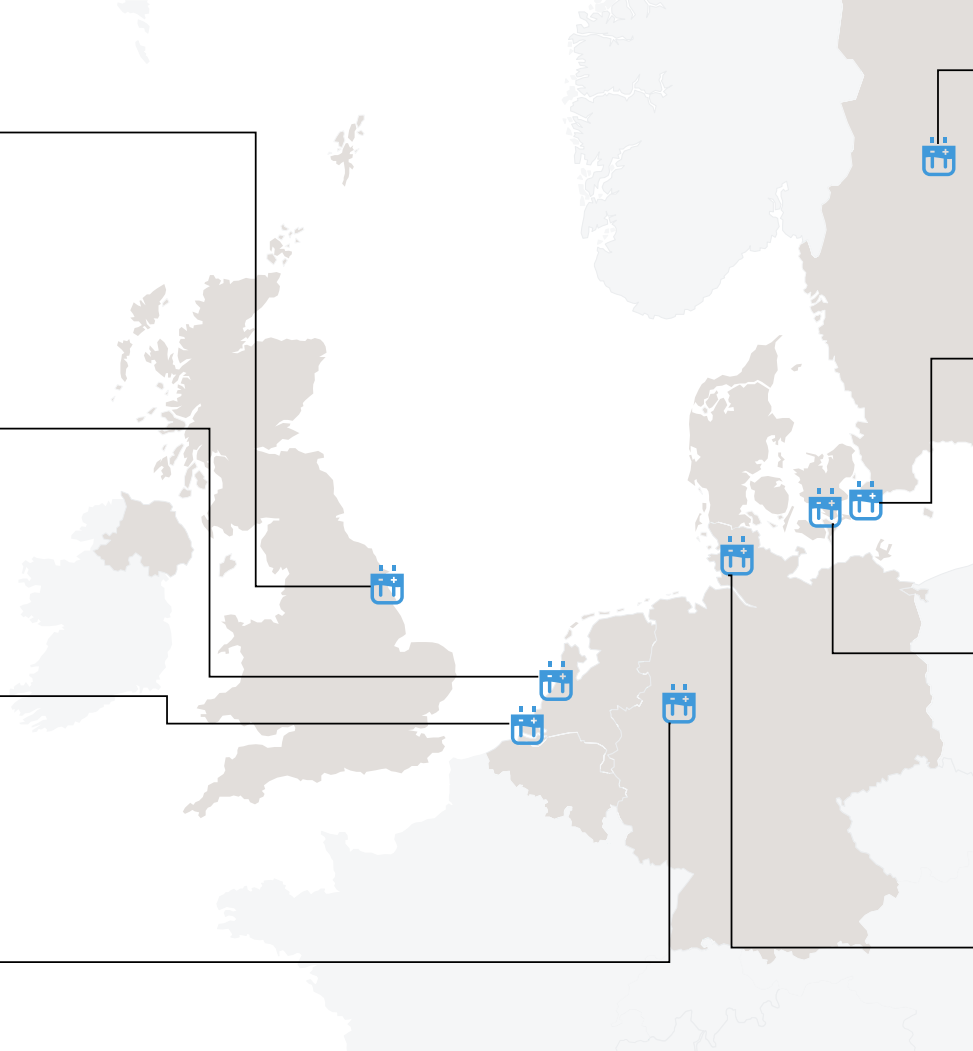
Chemical/Industrial Heavy Transport

Gigastack
• FEED study, 100 MW

SeaH2Land
• 1000 MW

Yara Sluiskil
• 100 MW

Lingen Green Hydrogen
• 50 - 530 MW



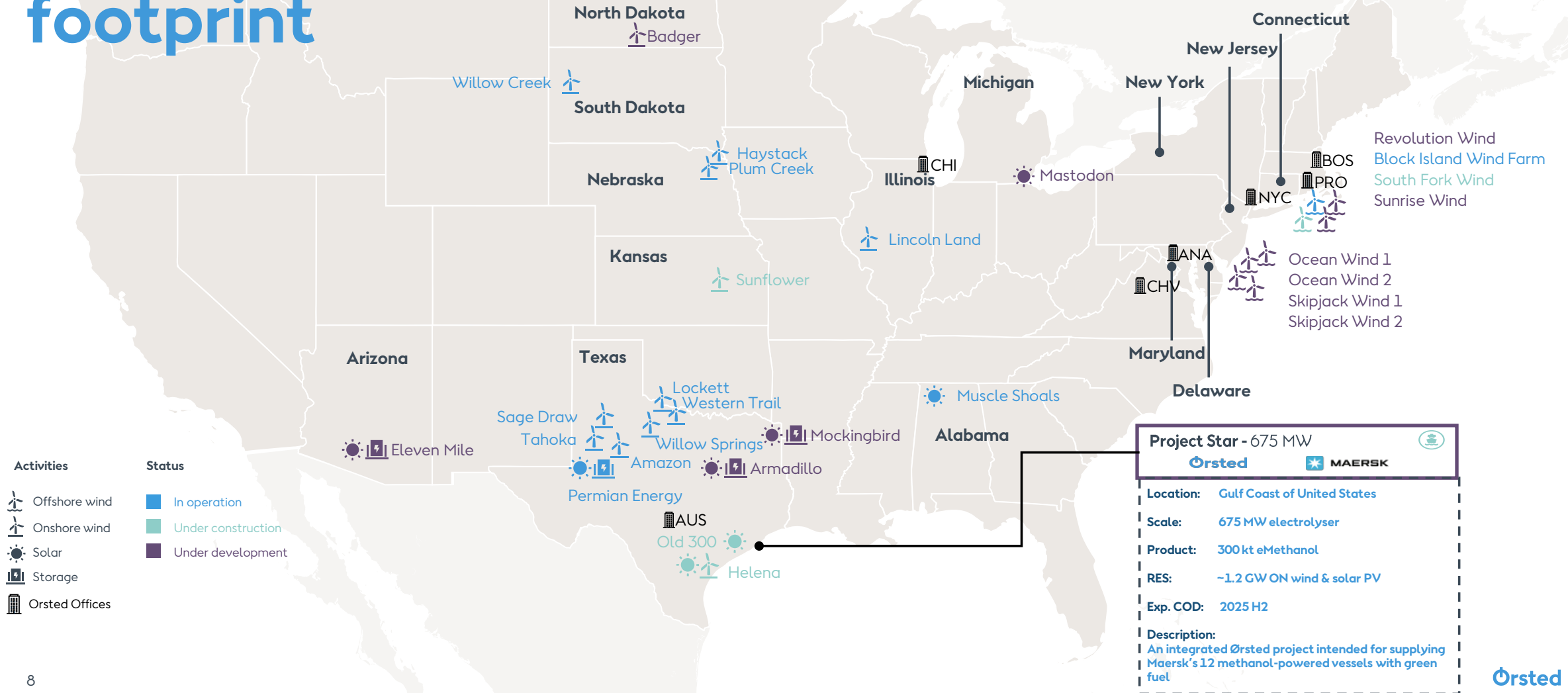
FlagshipONE
• 70 MW

Green Fuels for Denmark
• 1.3 GW

H2RES
• 2 MW

Westküste 100 & HySCALE100
• 30 MW with upscaling to 700 – 2.100 MW

Our US renewable footprint



#1

World's most sustainable energy company – four years in a row

By 2025, we will be carbon neutral.

By 2040, we will reach net
zero emissions across our
entire carbon footprint

Let's create a world that runs entirely on
green energy





Thank you for your interest in
GreenTech's '*Exploring Green
Hydrogen's Role in our Energy
Future*' Webinar

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