Exploring Green Hydrogen's Role in our Energy Future

Presented by the Environmental Law Institute

2.2.23
Slides from Sunita Satyapal
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

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

- Petroleum, 31%
- Natural Gas, 36%
- Renewable Energy, 13%
- Coal, 12%
- Nuclear Electric Power, 8%
- Solar, 12%
- Wind, 27%
- Hydroelectric, 19%
- Geothermal, 2%
- Biomass, 41%

**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
Carbon Dioxide Emissions by Sector

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

- **8%** Other
- **35%** Ammonia & Methanol
- **55%** Refining

**Examples of Hydrogen Production Locations**

- >620 MW of PEM* electrolysis in the U.S.
- >3X increase since 2021

**Examples of Deployments**

- **>500MW** Backup Power
- **>50,000** Forklifts
- **>620 MW** PEM* Electrolyzers
- **>80** Fuel Cell Buses
- **~50** H₂ Retail Stations
- **>14,000** Fuel Cell Cars

*Proton exchange membrane

**Examples of Deployments**

- Backup Power
- Forklifts
- PEM* Electrolyzers
- Fuel Cell Buses
- H₂ Retail Stations
- Fuel Cell Cars

*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

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

Enablers

- Workforce development
- Safety, codes and standards
- Policies and incentives
- Stimulating private sector investment
- Energy and environmental justice

Work with other agencies to accelerate market lift off
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

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

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
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**

- Core Team: National Labs
- University & Non-Profit
- Industry
- National Lab

**Basic science user facilities, theory, modeling**

**Enabling Activities**

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

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

**Regional Clean-Hydrogen Hubs**

- Clean-H₂ Producers
- Clean-H₂ Infrastructure
- Clean-H₂ Consumers

**U.S. DEPARTMENT OF ENERGY**
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.

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

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

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

www.energy.gov/fuelcells
www.hydrogen.energy.gov
Slides from Vanella Yadhati
Introduction to Ørsted’s Power-to-X business
Ørsted’s business areas

**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)
  - 2007: 424
  - H1 2022: 49
  - -88%

### Green transformation
- EBITDA, DKKbn, %
  - Share of renewables
  - 2007: 9.6
  - 2021: 24.3
  - 2007: 7%
  - 2021: 90%

### Renewable capacity
- Installed capacity, GW
  - 2007: 0.8
  - 2022: 13.7

### Profitability
- ROCE, %
  - 2007: 6.0
  - Q2 2022 (LTM): 14.8

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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

Renewable electricity is generated from wind or solar farms.

An electrolyzer separates water into oxygen and hydrogen. Powered by clean energy, this is green hydrogen.

Green hydrogen can be used directly for industry applications or combined with other feedstocks (e.g., CO2) to create other e-fuels such as e-methanol, e-ammonia, and e-kerosene.

Together, green hydrogen and e-fuels have a variety of applications in transportation and heavy industry as a replacement for fossil-based molecules and as an innovative fuel for new technologies.

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

Large-scale green electricity

Renewable hydrogen project development

OEM

EPC/ Turnkey

Dispatch

Further processing including e-fuels synthesis & purification

Renewable hydrogen & e-fuel distribution

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: 530MW
- 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

Ireland
- In operation: 327MW
- Under construction: 95MW
- Under development: 466/298MW

United Kingdom
- In operation: 6,233MW
- Under development: 4,000-5,000MW
- In operation: 62MW
- Under development: 195MW
- In operation: 2MW
- Renescience Northwich
- In operation: 20MW
- Sales of energy
- Under development: 101MW

Spain
- In operation: 20MW
- Bio plant
- Storage
- Sales of energy
- Under development: 101MW

Denmark
- In operation: 940MW
- In operation: our CHP plants, 2,865MW power and 3,560MW heat
- Sales of energy
- Under construction: 2MW
- Under development: 1,300MW

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

Poland
- Under development: 2,500MW

Germany
- In operation: 1,346MW
- Under construction: 1,106MW
- In operation: 22MW
- Under construction: 10MW
- Sales of energy
- Under development: 2700MW

Ireland
- In operation: 327MW
- Under construction: 95MW
- Under development: 466/298MW

France
- In operation: 34MW
- Under development: 1100MW

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

South Korea
- Under development: 1,600MW

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

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

Japan
- Under development: 1,600MW

833x521

Activities
- Offshore wind
- Onshore wind
- Solar
- Biomass-fired power plant
- Fossil-fired power plant
- Renewable fuels
- Bio plant
- Storage
- Sales of energy
- Under construction
- Under development

11/02/2022
P2X Pipeline in Europe

Gigastack
- FEED study, 100 MW
- element energy
- Ørsted

SeaH2Land
- 1000 MW
- ArcelorMittal
- Dow
- Ørsted

Yara Sluiskil
- 100 MW
- Ørsted

Lingen Green Hydrogen
- 50-530 MW
- Ørsted

FlagshipONE
- 70 MW
- Ørsted
- Liquid Wind

Green Fuels for Denmark
- 13 GW
- Ørsted
- MIGAS
- Haldor Topsoe
- COWI
- BCG

H2RES
- 2 MW
- Ørsted
- DSV
- ENERGINET
- Everfuel
- nel

Westküste 100 & HySCALE 100
- 30 MW with upscaling to 700 – 2100 MW
- Ørsted
- Holcim
- Hydrokraft
- H2 Norway
Our US renewable footprint

Activities
- Offshore wind
- Onshore wind
- Solar
- Storage
- Ørsted Offices

Status
- In operation
- Under construction
- Under development

Project Star: 675 MW Ørsted
- Location: Gulf Coast of United States
- Scale: 675 MW electrolyser
- Product: 300 kt eMethanol
- RES: ~1.2 GW ON wind & solar PV
- Exp. COD: 2025 H2
- Description: An integrated Ørsted project intended for supplying Maersk’s 12 methanol-powered vessels with green fuel.
#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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