

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

### Hydrogen and Fuel Cell Technologies Office (HFTO) Involvement in Industrial Decarbonization

**Tomas Green** Technology Manager, HFTO

3/21/2024



### **Systems Development & Integration: Industrial & Chemical Processes**



### **Potential Clean Hydrogen Demand for Chemical & Industrial Sectors**



\* Delivered H<sub>2</sub> cost to end user

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## **Iron & Steel: Current Projects**

### Missouri U. of S&T - Grid Interactive Steelmaking with H<sub>2</sub> (GISH)

#### Goals:

- Demonstrate H<sub>2</sub>-based direct reduction of iron & steelmaking
- 1 tonne/week iron production using variable H<sub>2</sub>/NG content; scalable to 5,000 tonnes/day



#### Key Accomplishments:

- Developed technoeconomic analysis of GISH process
- Kinetic model for DRI operation and melting
- GISH pilot reactor constructed and campaigns completed exceeding 1 ton/week

### U. of California Irvine - H<sub>2</sub> SOEC integrated with Direct Reduced Iron (DRI) plants

#### Goals:

• Demonstrate a thermally and chemically integrated high-temperature electrolyzer system with a DRI plant



#### Key Accomplishments:

- System models show potential energy intensity of <8 GJ/ton (crude steel) compared to 19-20 GJ/ton for traditional blast furnace + basic oxygen furnace
- Electrolyzer tested to show electric-to-H<sub>2</sub> efficiency <35 kWh/kg

## **Iron & Steel: New Projects**

#### Molten – Scaled Solid Oxide Co-Electrolysis for Low-Cost Syngas Synthesis from Nuclear Energy

#### Goals:

Design, build, and test the first thermally integrated methane pyrolysis and Direct Reduction of Iron (DRI) pilot scale system at TRL 6.

- Demonstrate use of solid carbon produced by pyrolysis for carburization
- >75% reduction in electrical energy intensity over H<sub>2</sub>-DRI production using water electrolysis.
- 400 kg/day DRI production demonstration
- 85% reduction in carbon intensity from existing BF-BOF crude steel

#### PROPOSED PROCESS (DRI + EAF, MOLTEN INDUSTRIES)



# **Potential Impact:** Demonstrate low-carbon steel production with methane pyrolysis

### Hertha Metals, Inc. – Hydrogen-Electric Smelting Reduction for Green Iron & Steel Production

#### Goals:

Develop a pilot-scale technology that converts any grade of direct shipping iron ore into ultra-low carbon iron and steel through a hydrogenelectric smelting reduction approach.

- 300 kg/day scale with a carbon intensity demonstration
- >90% reduction in carbon intensity from existing BF-BOF crude steel (0.1 tons of CO<sub>2</sub>e/ton of crude steel).



**Potential impact:** Demonstrate low-carbon steel production with novel reactor

### **Iron & Steel: New Projects**

### **Expansion of HySteel Project, FOA 0002997**

# University of Wisconsin-Madison – Demonstration of a SOEC Hydrogen Direct Reduction (HDR) at the Toledo, OH steel plant

#### Goals:

Thermally and chemically integrate a high temperature electrolyzer (250 kW SOEC system) able to operate in steam and co-electrolysis to demonstrate the potential (at scale) to reduce the  $CO_2$  emissions of an existing commercial DRI furnace in Toledo, OH

- Production capacity of 1.6 MT/year
- 90% reduction in CO2 emissions
- TRL 4 to TRL 6
- Demonstrate operation for 3600 hr of a 250 kW
- Demonstrate LCA and TEA in comparison to incumbent NG DRI



### **Iron & Steel: Modeling Projects**



## "Green Steel" Project Overview

Funded by HFTO/WETO NREL (lead) + ANL, LBNL, ORNL, & SNL

#### Vision:

Develop a national roadmap and reference designs for purpose-built, <u>off-grid</u>, **GW-scale** hybrid energy system, tightly-coupled w/ green H<sub>2</sub> production, co-located with industry end uses, that can accelerate the path to decarbonization.

### **Novelty and Advantages:**

- Optimized LCOH delivered for the specific end use,
- Holistic approach, increased efficiency, & reduced capital costs,
- Independence from natural gas price volatility, grid connection permits and new large-scale transmission build outs.

Off-grid hybrid energy system H2 production is important as it will take full advantage of IRA 45V \$3/kg Clean Hydrogen Production Tax Credit.

### **Iron & Steel: Modeling Projects**



#### Off-grid costs less than on-grid:

- Reduced electricity costs (retail vs. dedicated PPA results in decrease)
- Dynamic operation of H2 allowed (and accounted for in increased replacement costs)
- Low-cost hydrogen storage (salt caverns)
  \*Made conservative assumptions.

\*Distributed includes electrical efficiency gains ~4%

\*Potential conversion efficiencies are not included

Key Insight: With max policy, all locations compete with SMR

#### Notes:

- Technology year (TY) 2030 corresponds to operational year 2035
- CCS credit considered for over 12 years
- H2/wind PTC applied over 10 years
- Model does not account for RECs

#### LCOE for TX 2030

- Off-grid: 1.3 cents/kWh with PTC
- On-grid: 8.6 cents/kWh (retail rates), 4.1 cents/kWh (wholesale rates)

### **Systems Development & Integration: Transportation**



### **Potential Clean Hydrogen Demand for Chemical & Industrial Sectors**



<sup>\*</sup> Delivered H<sub>2</sub> cost to end user

# **Applications of Hydrogen and Fuel Cells – HDVs**

### SuperTruck 3 Demonstrations include H<sub>2</sub> Fuel Cells (>75% GHG Reduction)

# DAIMLER



#### Goals:

- Demonstrate 2 total (Class 8) HD longhaul fuel cell electric trucks (B-sample & final truck demo)
- 6.0 mi/kg H2 fuel economy
- 600-mile range (onboard LH<sub>2</sub> storage)
- 65,000 pounds GVW

#### Fleet Operators: Schneider National, Walmart

## general motors



Argonne 合

CINREL

OAK RIDGE

AUBURN

Oregon Scate University



#### **Goals:**

- Demonstrate 8 total (Class 4-6) MD trucks 4 fuel cell & 4 battery electric trucks
- Fuel Cell System Goals:
  - 65% peak efficiency
  - o <\$80/kW system cost (100K units/yr)</pre>
  - 20K-30K hour lifetime
- Demonstrate microgrid w/ electrolyzer & fuel cell (H<sub>2</sub> fueling & fast charging)

#### Fleet Operators: Southern Co, Metro Delivery

The above image is not final product/visual and is subject to change



### Ford Motor Company

#### % FERGUSON



FEV

**SoCalGas** 

Consumers Energy

#### Goals

- Demonstrate 5 total (Class 4-6) MD vocational trucks
- 300+kW net vehicle power, H<sub>2</sub> PEM FC + Li-Ion battery
- 300-mile range (700 bar H<sub>2</sub> storage)
- 10K/20K pounds payload/tow capacity

Fleet Operators: Consumers Energy, Ferguson, SoCalGas

### **Seven Regional Clean Hydrogen Hubs Selected**

**Bipartisan** Infrastructure Law Clean H<sub>2</sub> Hubs Leveraging:

- Natural gas resources with carbon management;
- Renewable and nuclear power generation coupled with electrolysis
- Other regional resources supporting H<sub>2</sub> production, distribution, and end use



## **Thank You**

**Tomas Green** 

tomas.green@ee.doe.gov