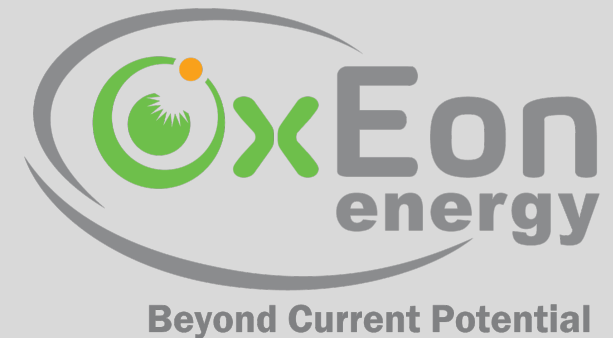


Energy & Geosciences Institute
2023 EGI Annual Technical Conference
September 20, 2023 | Salt Lake City Marriott University Park

Joseph Hartvigsen
CEO & Co-Founder
OxEon Energy



Utah, USA R&D/Manufacturing - 2017

- Office, laboratory, and manufacturing facility (24,000 ft²)
- NASA, DOE, DOD and commercial contracts
- Tape casting, cell and stack production, and testing
- End-to-end power to synfuels pilot plant
- 1 of 4 US manufacturers of Solid Oxide Stack Technologies

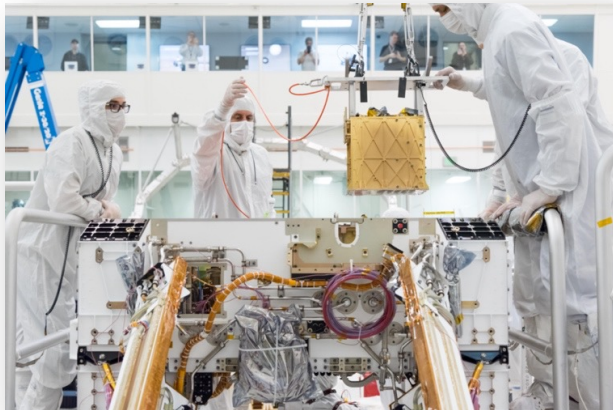


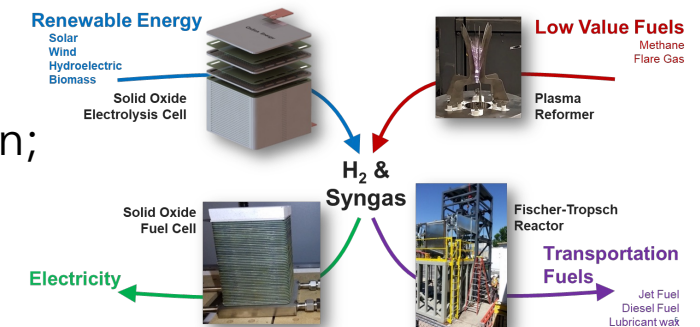
Image credit NASA/JPL-Caltec

Solid Oxide Fuel Cell and Electrolysis Stacks

- Longest running solid oxide fuel cell & electrolysis group in world
- Only flight qualified, TRL 9 SOEC unit with active NASA demonstration on Mars
- 30kW/10kW and 20kW/10kW reversible SOC system test programs
- Active members of the Mars2020 Science Team for NASA

Fuel Reformation and Generation

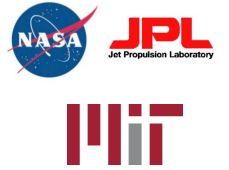
- Plasma Reformer - H₂ or syngas from flare gas; digester gas conversion; clean-up bio-gasification
- Fischer-Tropsch Reactors - Modular design for sustainable fuel production from H₂ and syngas
 - 2 bbl/day modular FT system delivered by team





NASA funded flight program

- Only flight qualified SOEC stack in history
- Only TRL9 SOEC device in history
- First production of oxygen from the Mars Atmosphere



MOXIE SOXE TEAM:

- **MIT:** Program Prime and Science Team Lead
- **JPL:** Systems integration
- **OxEon:** Stack development and production
 - **TRL3 to 6 in 18 months!!**
 - Hermetically sealed, ruggedized stack capable of withstanding launch, entry, descent and landing

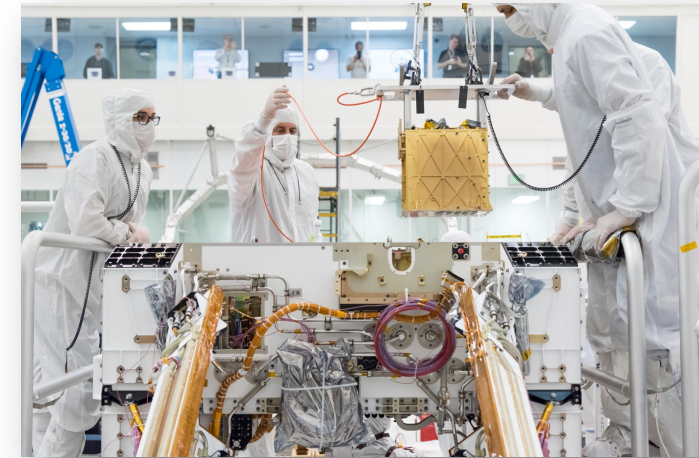
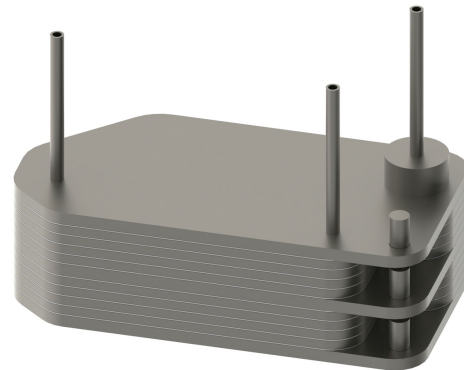


Image credit NASA/JPL-Caltech



Active OxEon Projects with NASA for Next Generation

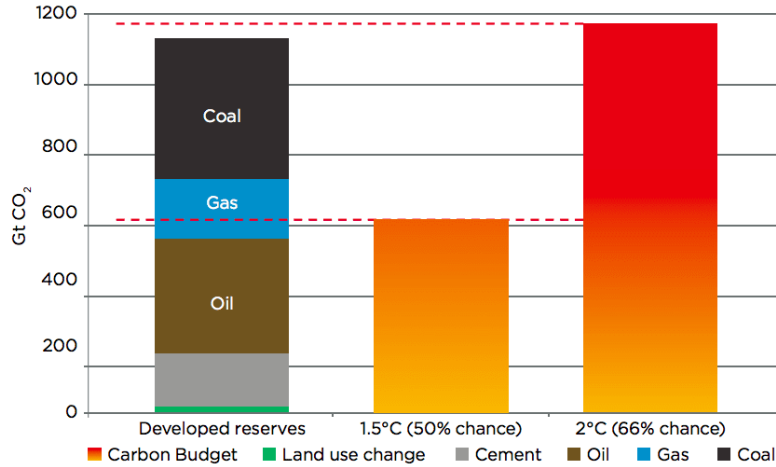
- **Mars:** Oxygen and Methane Production from co-electrolysis
- **Lunar:** Liquid Propellants for LH₂/LOx-Fueled Cislunar Transport
- **SBIR:** Cathode Development for Redox Tolerance

<https://oxeonenergy.com/>

- **Scroll down to find 3 minute video**

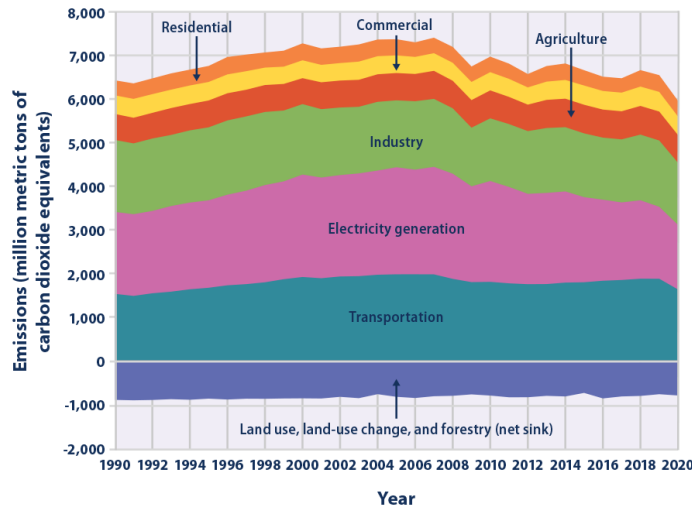
Why Decarbonize?

Figure ES-1: CO₂ Emissions from Developed Fossil Fuel Reserves, Compared to Carbon Budgets (as of Jan. 2018) within Range of the Paris Goals



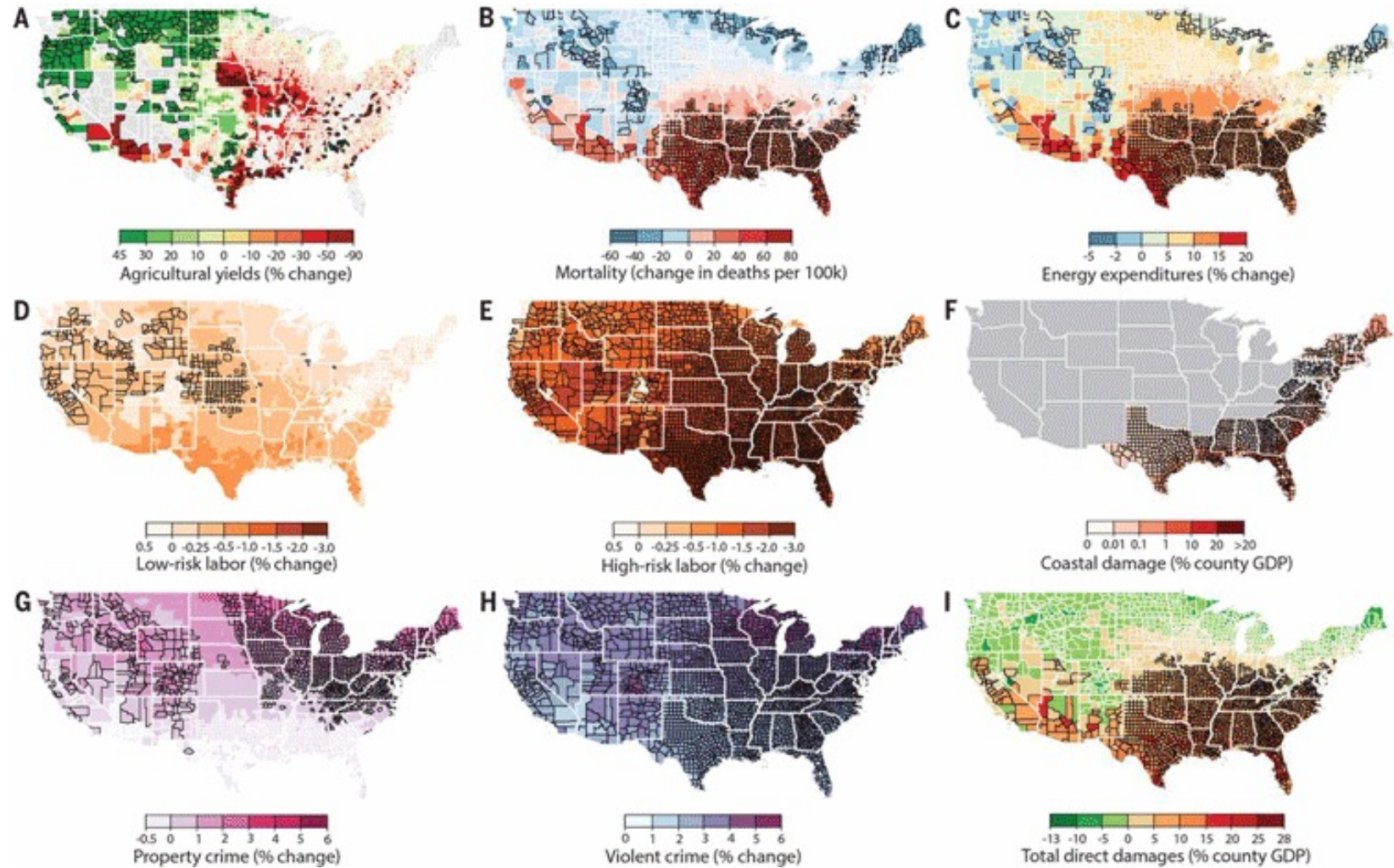
Sources: Oil Change International analysis²¹ based on data from Rystad Energy, International Energy Agency (IEA), World Energy Council, and IPCC

U.S. Greenhouse Gas Emissions and Sinks by Economic Sector, 1990–2020



Data source: U.S. EPA (U.S. Environmental Protection Agency), 2022. Inventory of U.S. greenhouse gas emissions and sinks: 1990–2020. EPA 430-R-22-003. www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.



Maps showing how climate change will adversely affect the United States in areas of agriculture, crime, life span, property damage, and labor. Source: Hsiang, et. al, 2017.

Mandate Driven Change

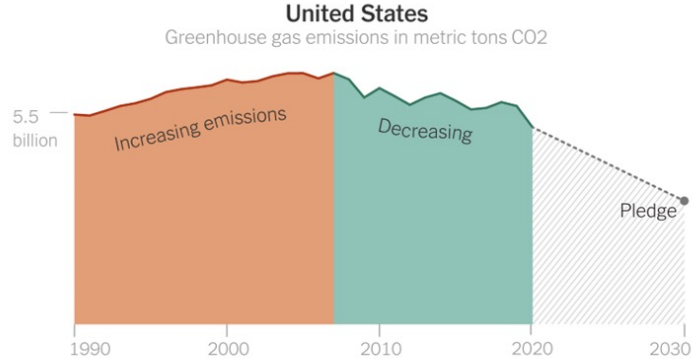
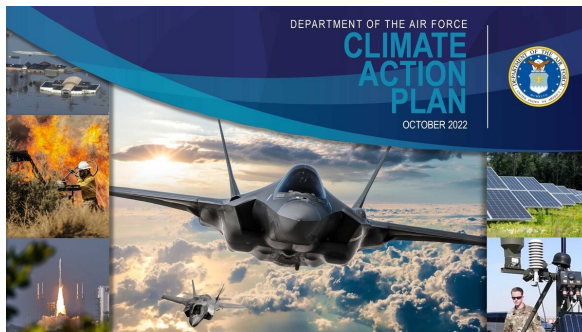
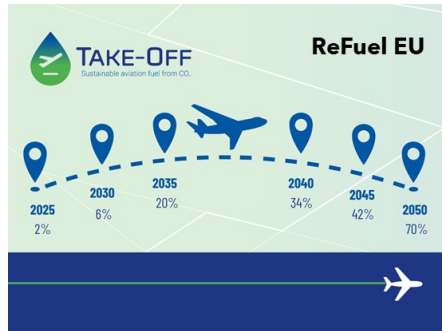
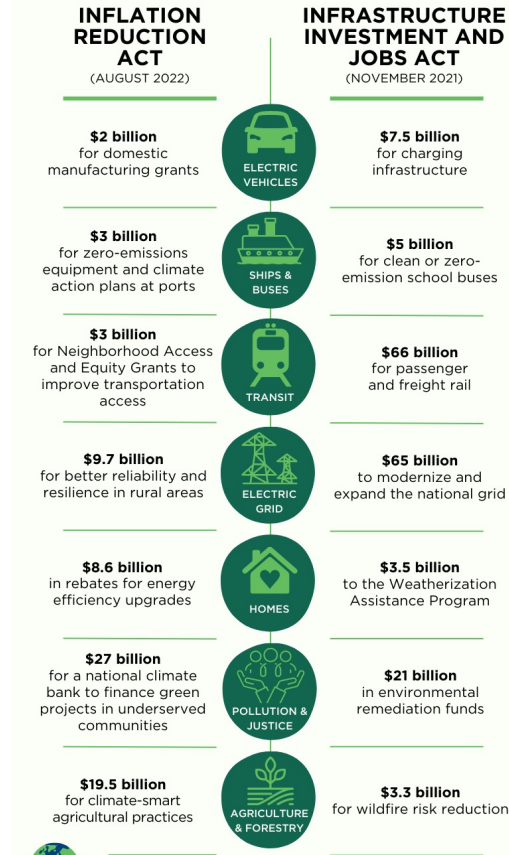


Image Courtesy The New York Times



Federal Legislation Backed Development

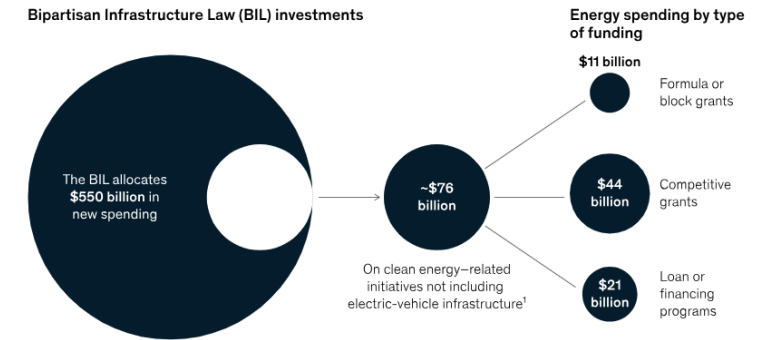
Complementary Climate Investments in Recent Legislation



Sources: Sen. Cantwell, the White House, BlueGreen Alliance, National Wildlife Federation, Evergreen Action, Bipartisan Policy Center

Graphic by: Alison Davis

The Bipartisan Infrastructure Law targets a sizable portion of spending to the energy sector.



¹An estimate of BIL clean-energy funding, which includes a combination of clean-energy, resilience, and environmental-remediation funding related to the utility and power sector. This does not include electric-vehicle-related funding. Source: Building a better America: A guidebook to the Bipartisan Infrastructure Law for state, local, tribal, and territorial governments, and other partners, The White House, May 2022

McKinsey & Company

Funding for New and Existing DOE Loan and Loan Guarantee Programs (As Discussed Below)

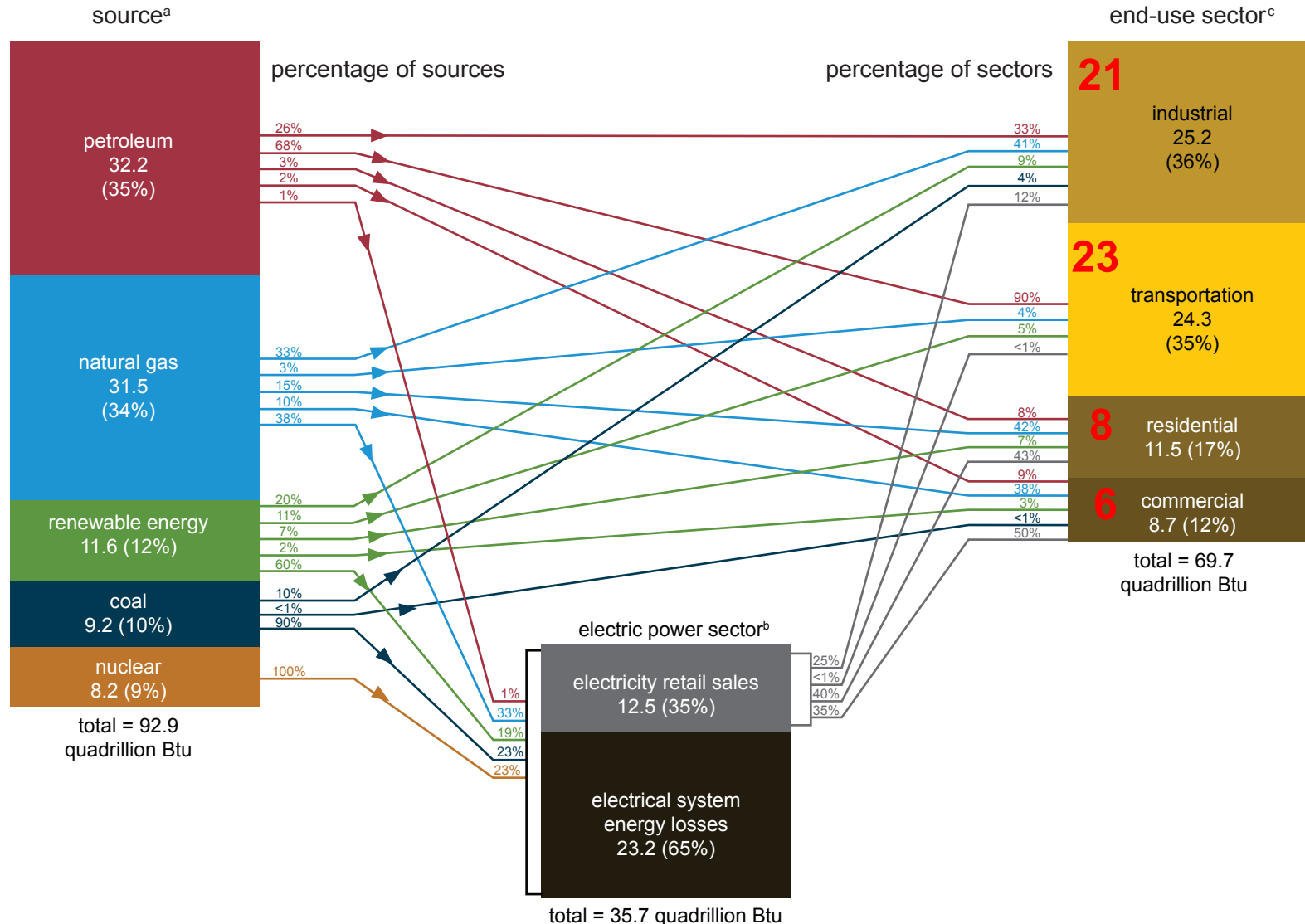


Sources: White House IJA guidebook, May 2022 edition; Infrastructure Investment and Jobs Act, which was signed into law on November 15, 2022; Inflation Reduction Act, which was signed into law on August 16, 2022.

How Big Is The Problem?

U.S. energy consumption by source and sector, 2020

quadrillion British thermal units (Btu)



- Fossil Quads By End-Use Sector

- 21 Industrial
- 23 Transportation
- 8 Residential
- 6 Commercial

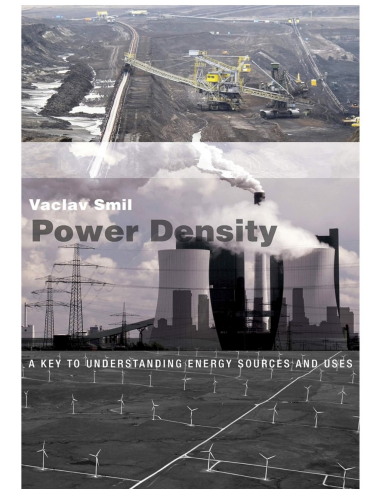
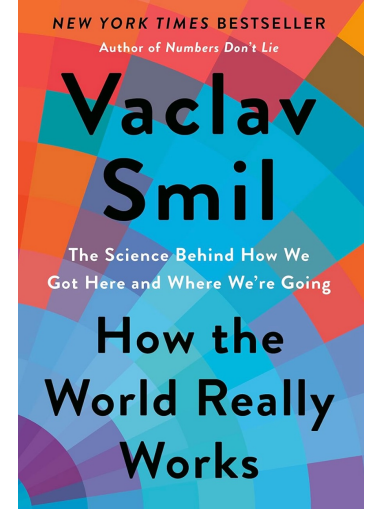
- Electric contribution

- 21 Electric in
- 6 Electric out

- Electrofuels & Chemicals

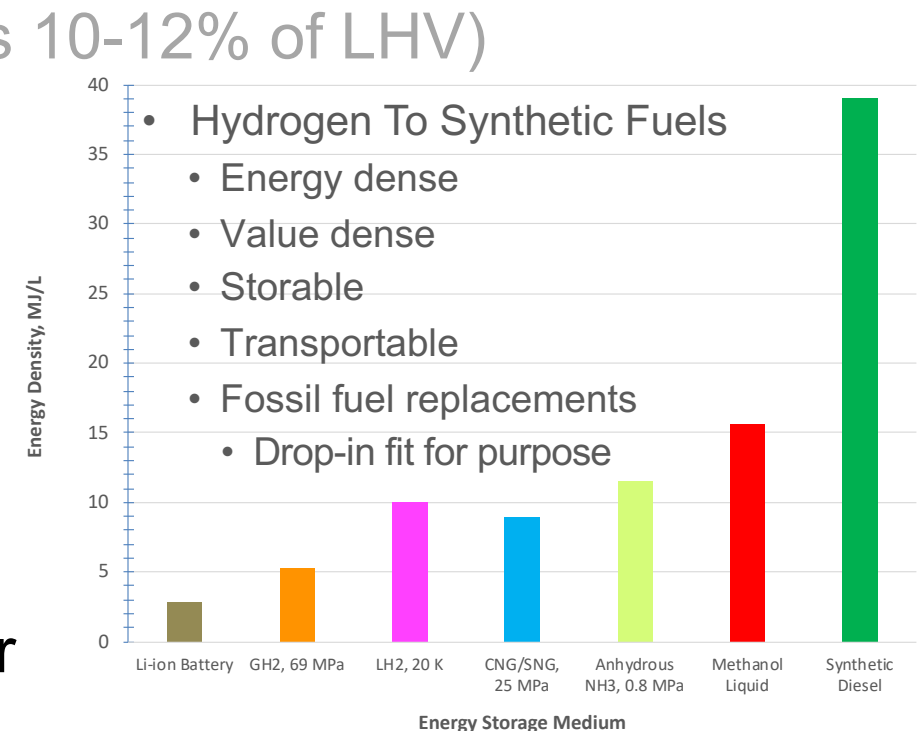
- (Too) Energy Intensive?
- Displacing 52 Fossil Quads is intense!
- 3.8x 458 GW annual average grid load
- 1,740 GW electrolysis at $\eta=100\%$
 - Mega-Tons/d of Hydrogen, 0.45GT/y
- How will we store, distribute, and use it?
- Fossil fuel replacements

- **How The World Really Works — Vaclav Smil**
- **The four pillars of modern civilization**
 - 4.5 billion tons of cement
 - 1.8 billion tons of steel
 - 400 million tons of plastics
 - 180 million tons of ammonia feeds half of the world's 8 B people
- **Energy is also material**
 - 8 billion tons of coal
 - 4.3 billion tons of oil
 - 3.1 billion tons of natural gas



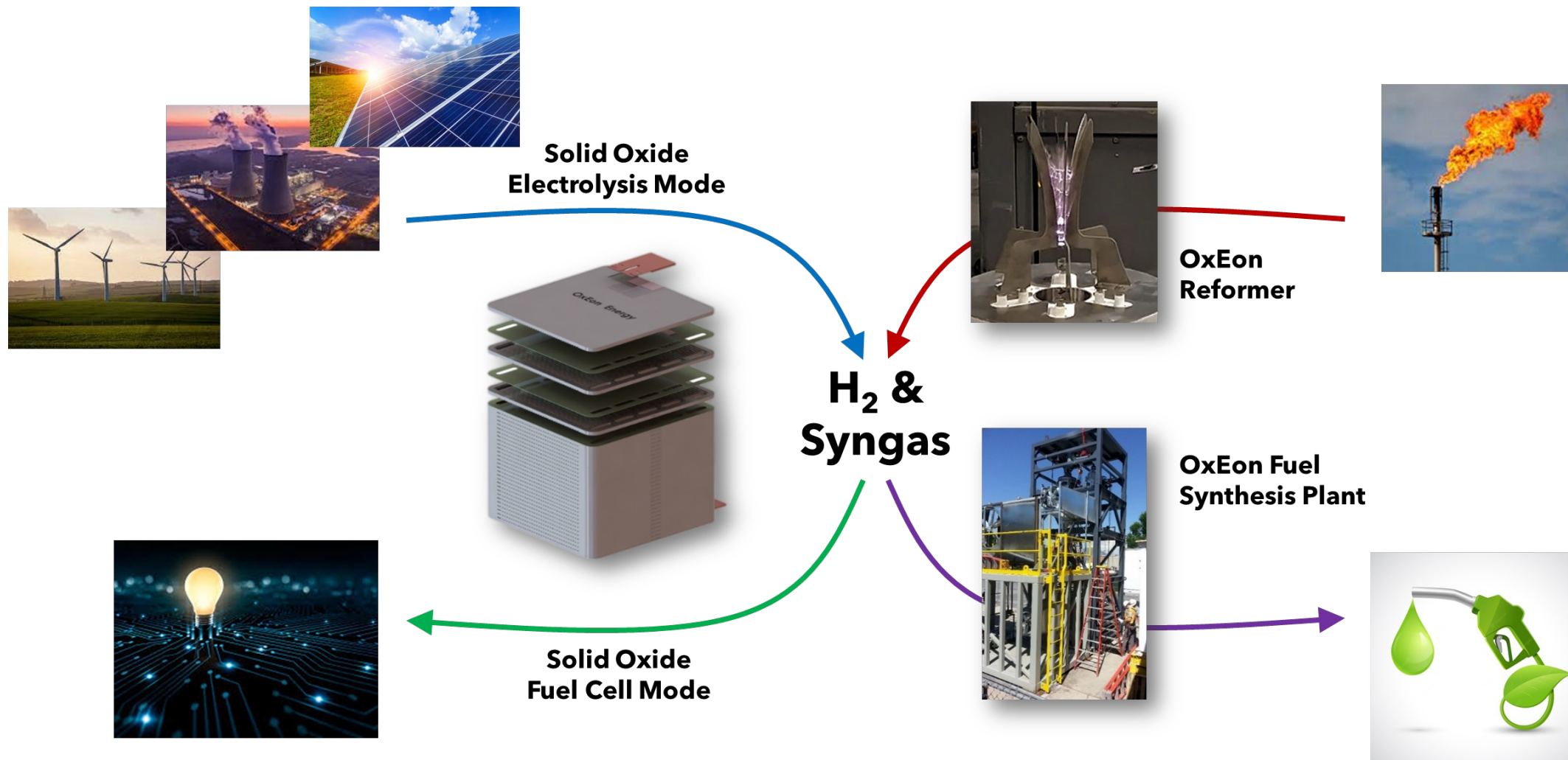
- Power Density!
- Comparative Energy Density
 - JP-8 33-36 MJ/liter (43 MJ/kg, 0.76 to 0.84 kg/liter)
 - Diesel 36 MJ/liter (46 MJ/kg, 0.86 kg/liter)
 - Hydrogen 4.4 MJ/liter (work of compression is 10-12% of LHV)
 - at 690 bar (10,000 psi) $Z=1.43$
- Storable, pumpable, for on-demand energy
- Established markets for liquid fuels
 - Highly developed infrastructure
 - Vehicle fleet will take decades to retire
 - US demand, 7.3 billion bbl/yr, > \$400 billion/yr

2 min "Recharge"
 at 0.5 kg/s & 46 MJ/kg
 = 23 MW recharge rate



The Solution: Enabling Cross-Sector Energy Conversion

DISPATCHABLE POWER SOLUTIONS | HYDROGEN PRODUCTION FOR INDUSTRIAL MANUFACTURING
FUEL LOGISTICS SOLUTIONS | SUSTAINABLE AVIATION FUEL PRODUCTION



Enabling Cross-Sector Energy Conversion

PTX | SUSTAINABLE AVIATION FUEL | ISRU PROPELLANTS | BIOGAS PROCESSING

PLASMA REFORMER



Low power requirement, soot free, sulfur insensitive
Compact conversion of any hydrocarbon to syngas

FISCHER-TROPSCH REACTOR



Produces "green" transportation fuels from syngas
Modular design for remote and small-scale application

SOLID OXIDE ELECTROLYSIS CELLS

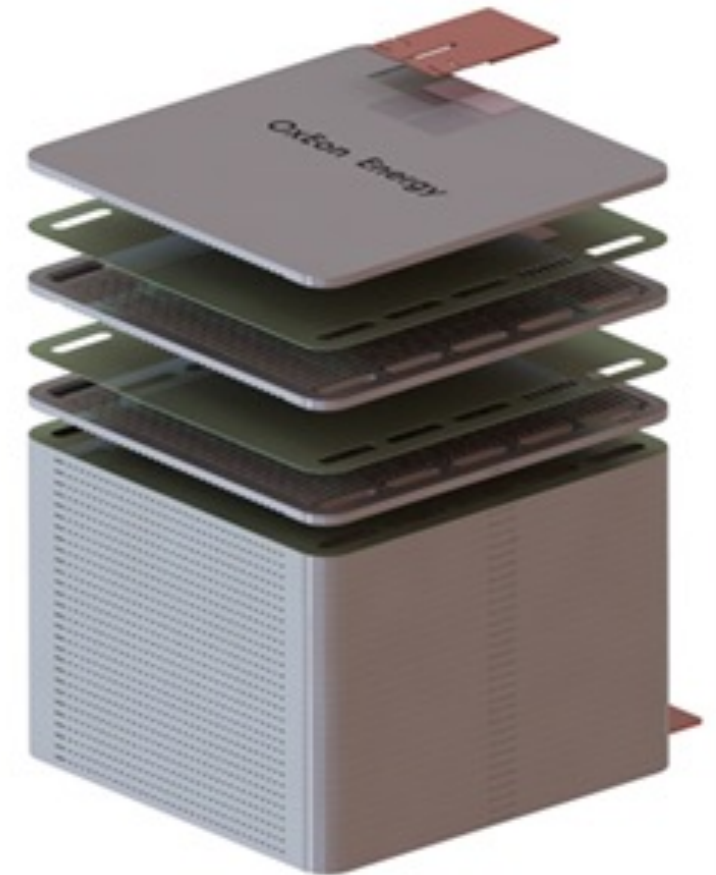


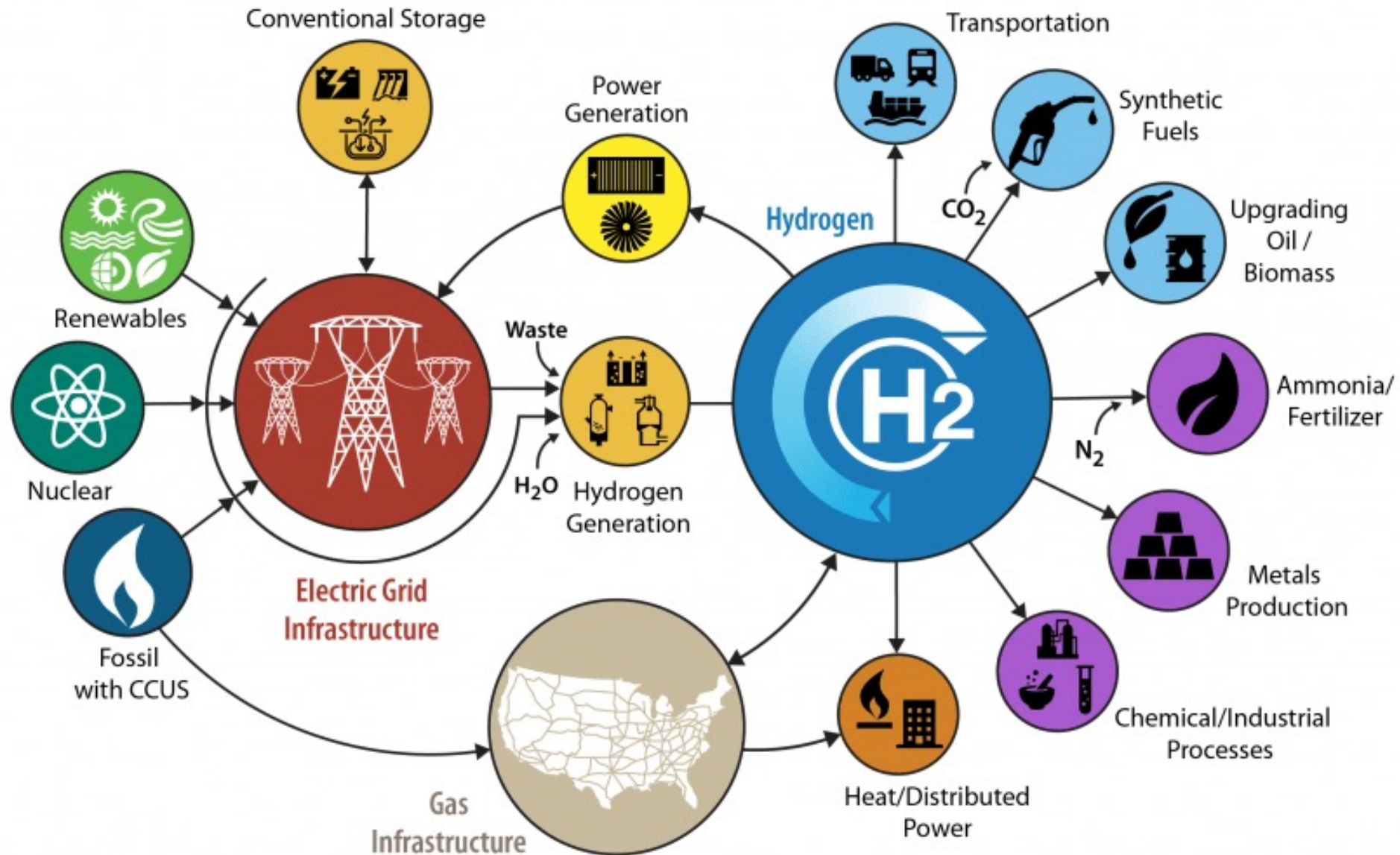
Stable, reliable electrolysis stack produces
hydrogen/syngas from steam/CO₂ electrolysis

SOLID OXIDE FUEL CELLS



One of the most environmentally friendly
methods for electricity and heat production





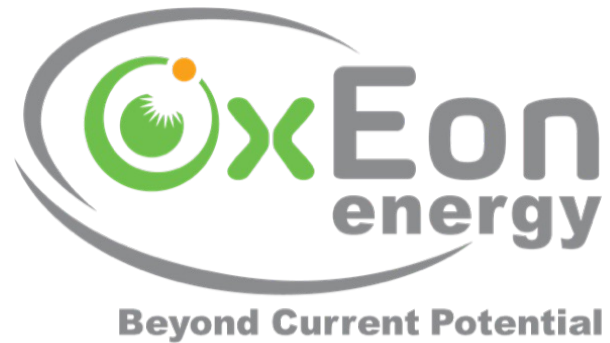
A Wave of Change Is Comming

- Waves come in sets
 - This one is so big we catch it or are crushed by it
 - Planning to catch the 2nd wave is risky
- IEA 2027 Projection
 - Main case 50 GW
 - Accelerated case 90 GW
 - <https://www.iea.org/reports/how-much-will-renewable-hydrogen-production-drive-demand-for-new-renewable-energy-capacity-by-2027>
- Brazilian surfer Rodrigo Koxa riding a 24.38 meter wave 08 Nov 2017 on Praia do Norte beach in the Portuguese fishing village of Nazaré.



Thank you

Joseph Hartvigsen
JJH@OxEonEnergy.com



OxEon Energy, LLC
257 Riverbend Way
North Salt Lake, UT 84054

info@oxeonenergy.com
+1-801-677-300
oxeonenergy.com

