FuelCell Energy

Hydrogen and the New Energy Landscape

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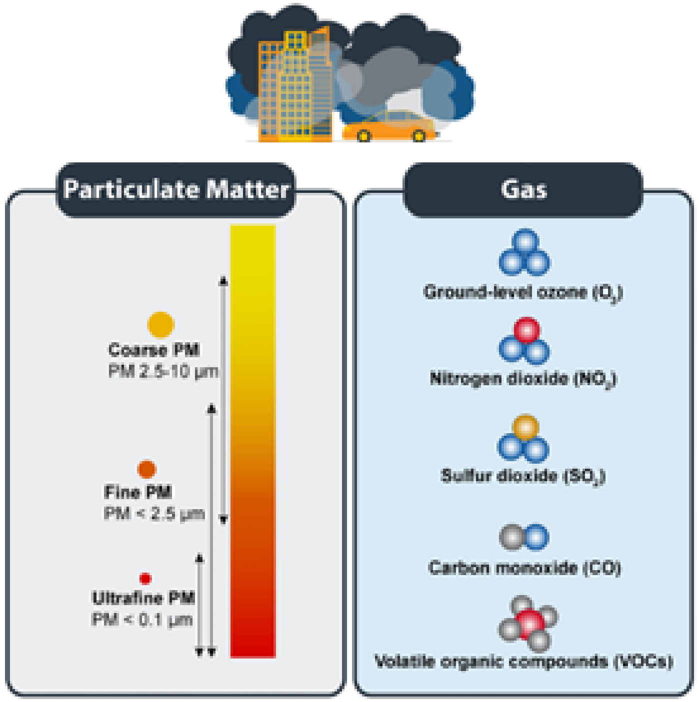
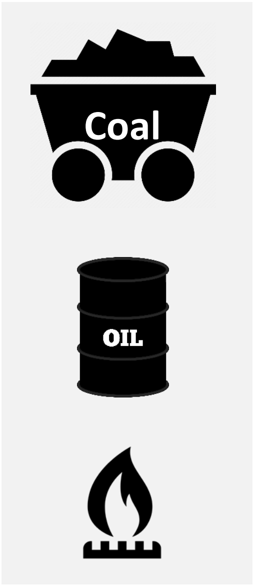
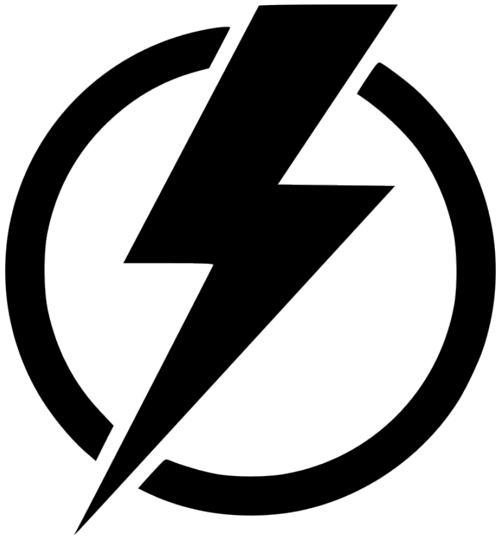
The New Energy Landscape





Fossil Fuels



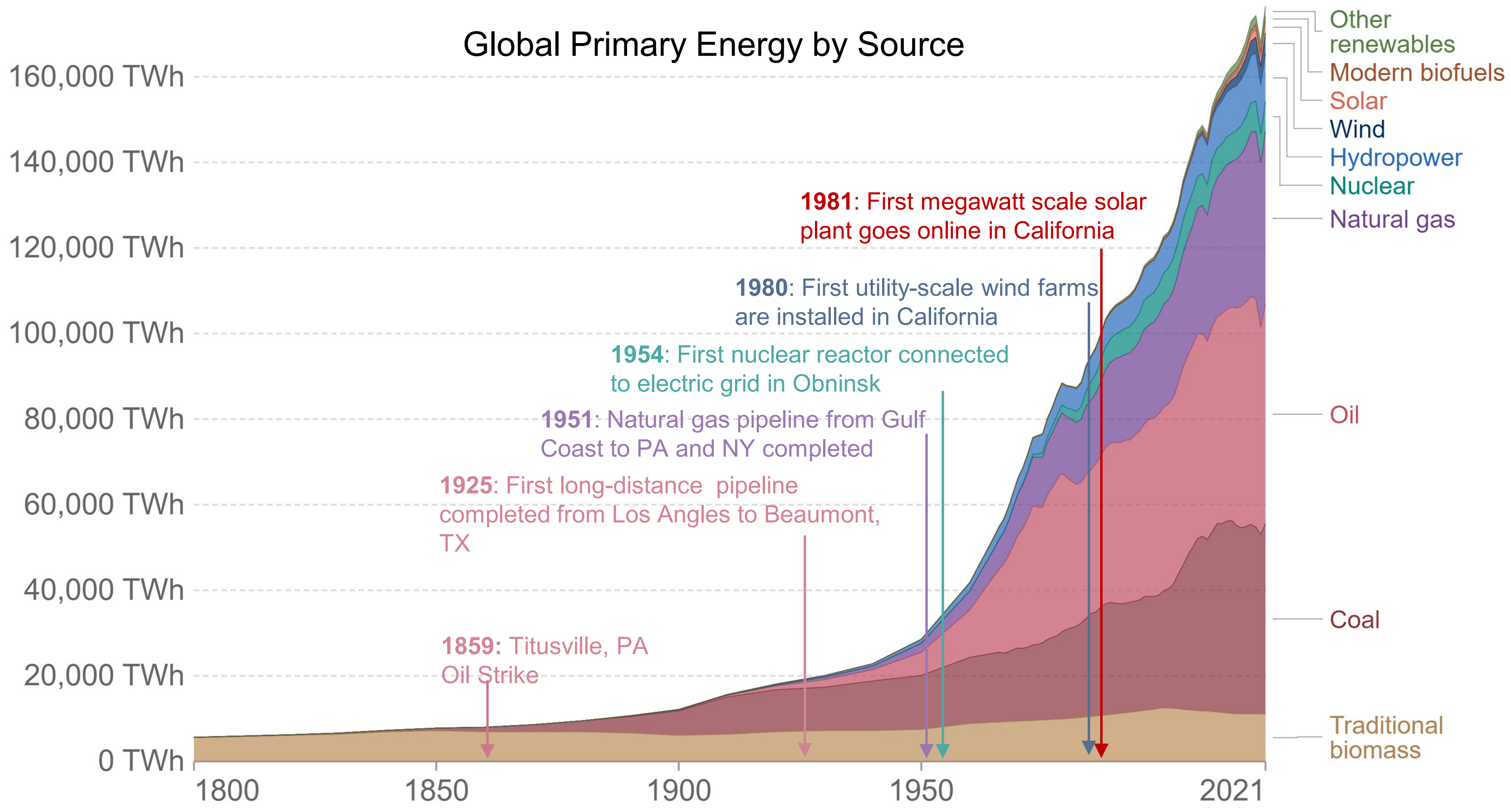
Electricity - The Catalyst

Non-Combustion
Zero Carbon
Replacement

CO_2 Capture Hydrogen Substitution Storage

Enablers

The History and Pace of Energy Transition



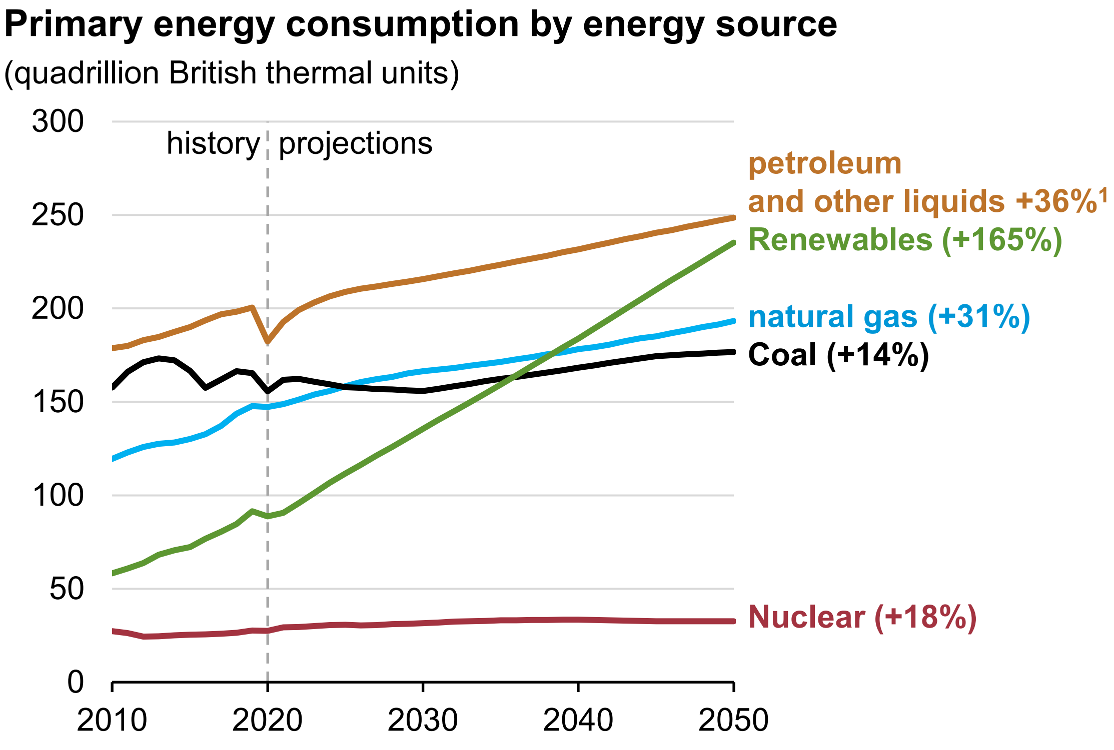
Source: Our World in Data based on Vaclav Smil (2017) and BP Statistical Review of World Energy

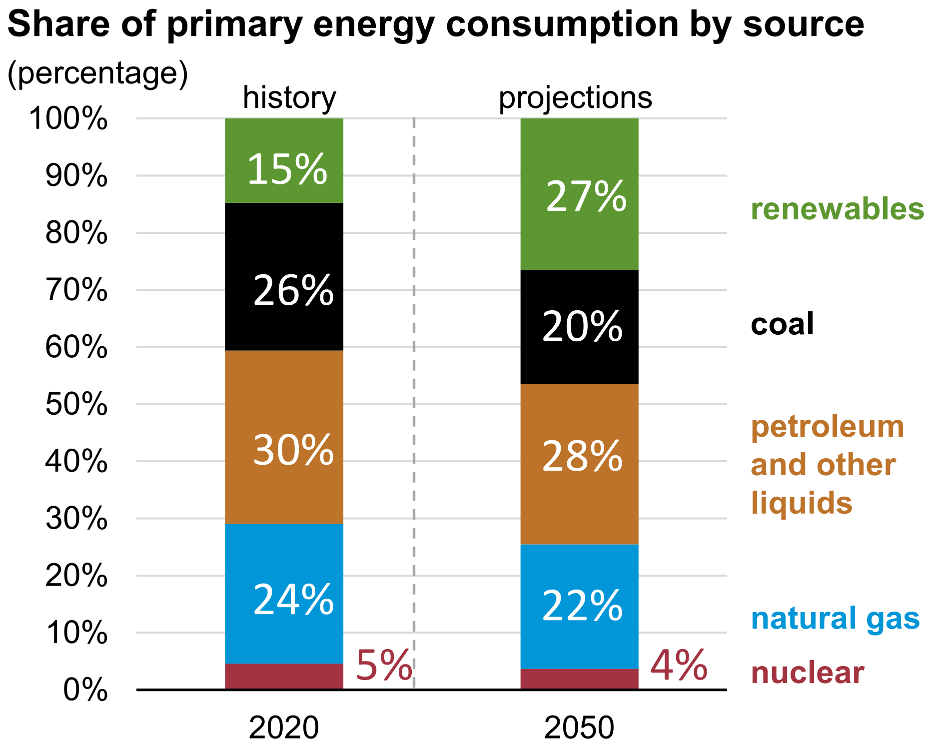
Primary Energy	Time from Viable Production to Impact on Energy
Oil	60 years
Gas	90 years
Wind	>40 years
Solar	>40 years

Key Drivers

- Cost
- Conveyance
- Substitutability
- Scalability
- Societal Attributes
- Policy

What Does 2050 Look Like?





Total Energy Consumption +64%

Source: U.S. Energy Information Administration, *International Energy Outlook 2021* (IEO2021) Reference case

[1] includes biofuels

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The Catalysts for Energy Transition

Technology

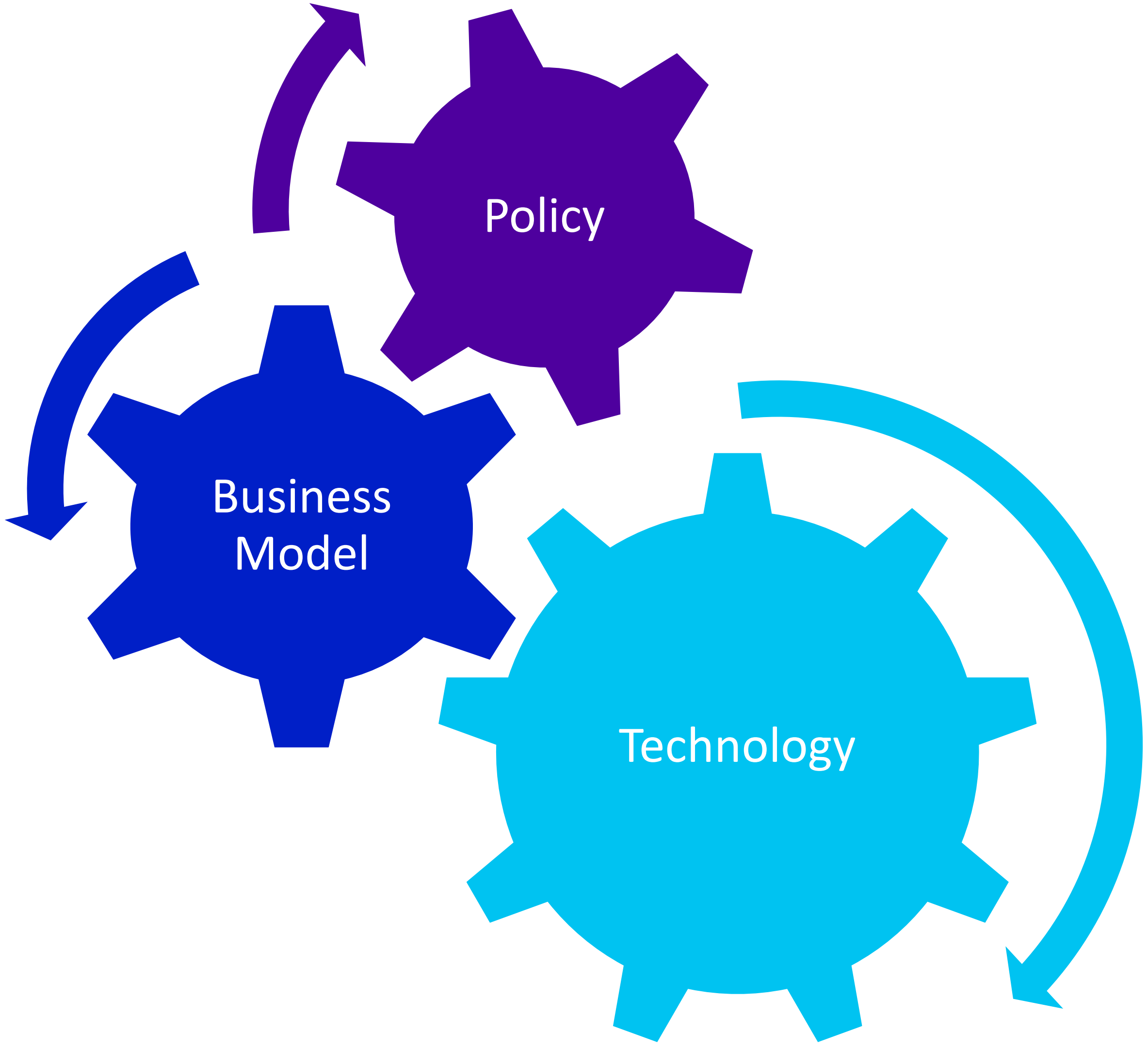
- Electrochemistry
- Digitalization

Business Model

- Deregulation
- Energy as a Service

Policy

- Clean Air Act
- Inflation Reduction Act
- Good Neighbor Policy



Inflation Reduction Act

Clean Hydrogen Production Credit creates a new ten-year incentive for clean hydrogen production tax credit (PTC) with up to $3.00 / kilogram or 30% investment tax credit (ITC). The level of the credit provided is based on carbon intensity.

Energy Credit extends the 30% fuel cell ITC through 2024 before a transition to the technology-neutral Clean Energy Investment Credit.

Energy Storage Credit adds a new provision to the energy ITC for energy storage, including hydrogen storage, available through 2025 before a transition to the Clean Energy Investment Credit.

Alternative Fuel Refueling Property Credit extends the credit through 2032, increases the 30% credit cap from $30,000 to $100,000.

Carbon Oxide Sequestration Credit provides an enhanced rate of carbon oxide captured for storage and utilization for qualified facilities through 2032.

Clean Vehicle Credit provides $7,500 for the purchase of fuel cell electric vehicles by creating a new clean vehicle credit built on the 30D credit for plug-in battery electric vehicles. Eliminates the per automaker cap of 200,000 vehicles. Adds a retail price cap of $55,000 for new cars and $80,000 for pickups, vans, and SUVs.

Qualified Commercial Clean Vehicles Credit creates a new 30% credit for commercial fuel cell electric vehicles through 2032 which is capped at $40,000.

Advanced Energy Project Credit revives the credit providing $10 billion to fund manufacturing projects producing fuel cell electric vehicles, hydrogen infrastructure, electrolyzers, and a range of other products.

Elective Payment for Energy Property adds an election for direct pay provisions to a range of tax credits

Good Neighbor

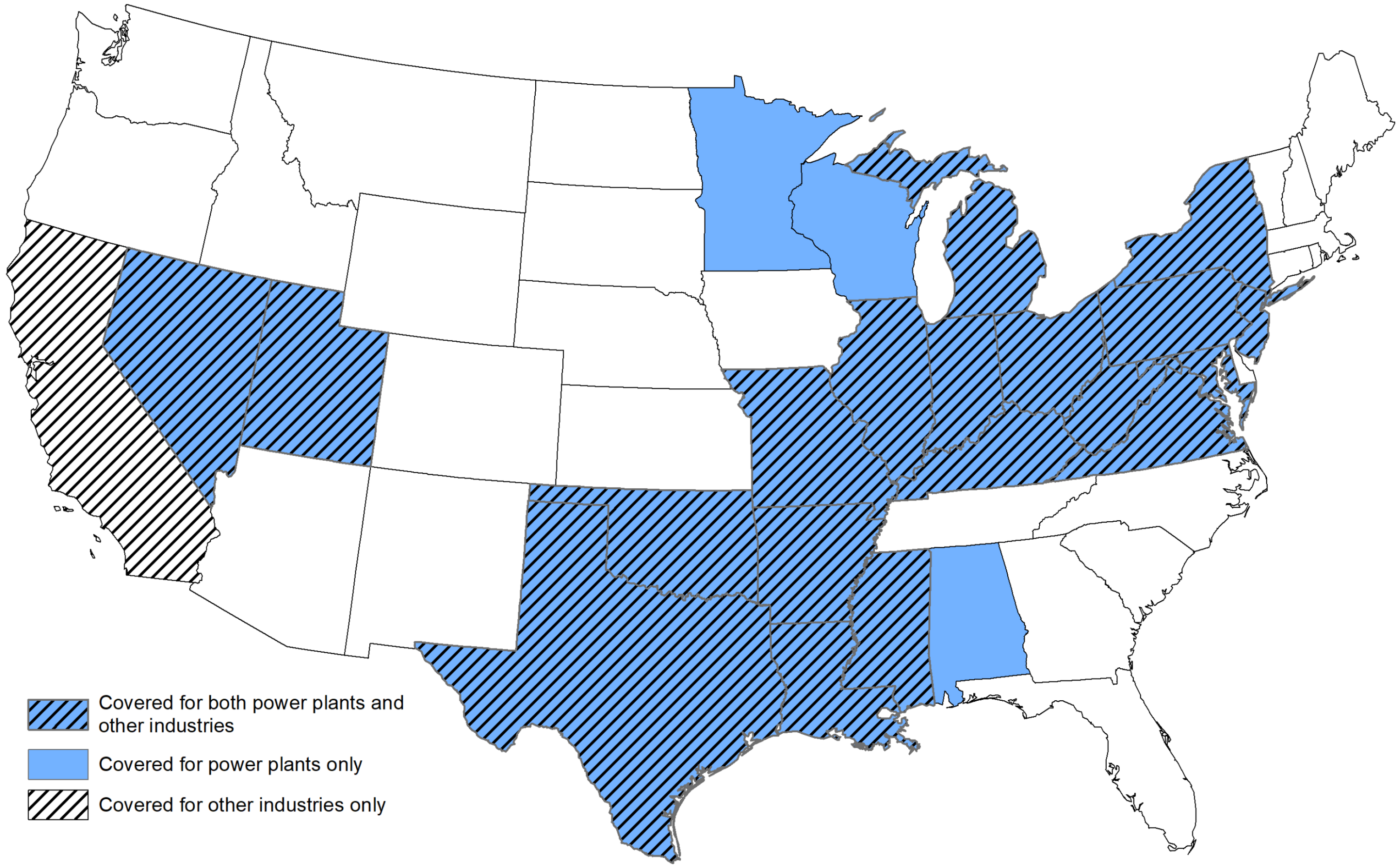
NO_X Emissions Standards for Nine Large Industries in 20 States Beginning in the 2026 ozone season

The EPA is setting enforceable NO_X emissions control requirements for existing and new emissions sources in industries that are estimated to have significant impacts on downwind air quality and the ability to install cost-effective pollution controls.

The reduction in NOx emissions comes from the following types of emissions sources:

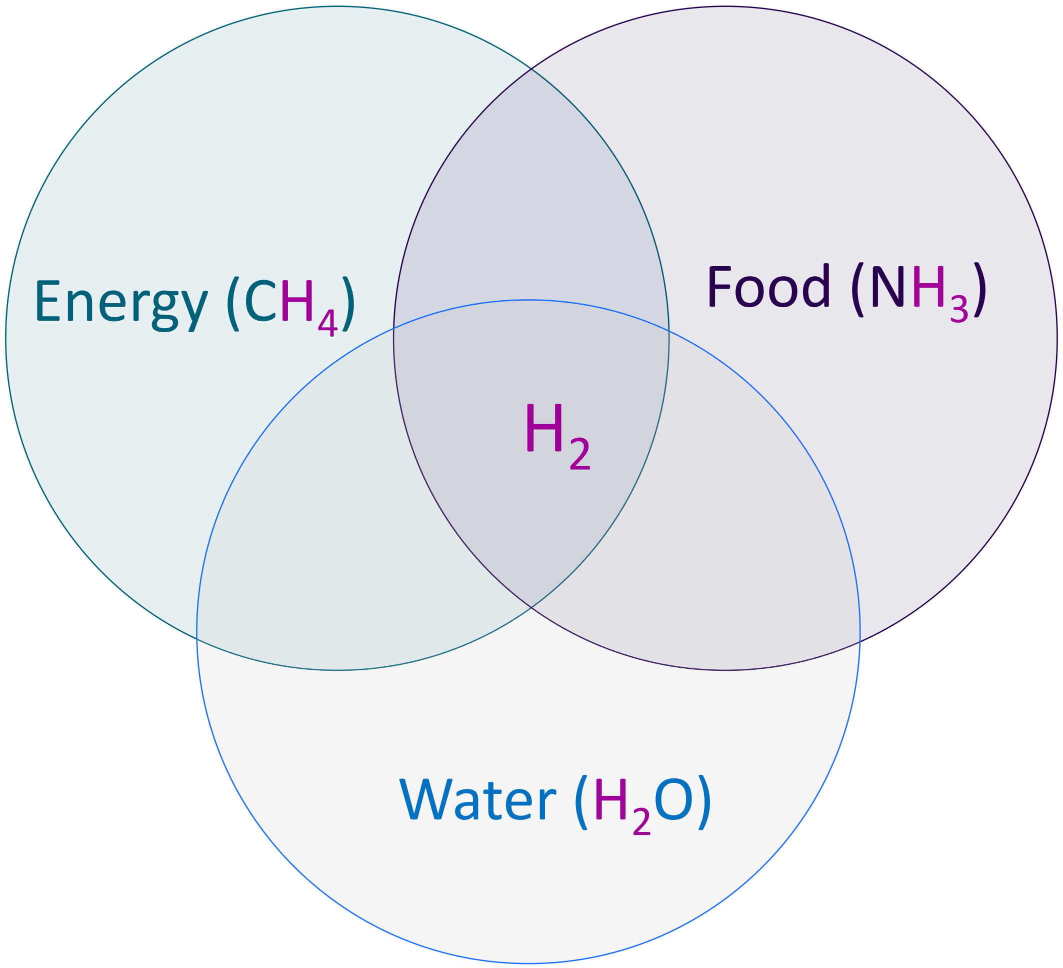
- reciprocating internal combustion engines in Pipeline Transportation of Natural Gas;
- kilns in Cement and Cement Product Manufacturing;
- reheat furnaces in Iron and Steel Mills and Ferroalloy Manufacturing;
- furnaces in Glass and Glass Product Manufacturing;
- boilers in Iron and Steel Mills and Ferroalloy Manufacturing, Metal Ore Mining, Basic Chemical Manufacturing, Petroleum and Coal Products Manufacturing, and Pulp, Paper, and Paperboard Mills; and
- combustors and incinerators in Solid Waste Combustors or Incinerators

States Covered Under the Power Plants and Other Industries Portions of the Final Good Neighbor Plan



Hydrogen

Why is Hydrogen Important?

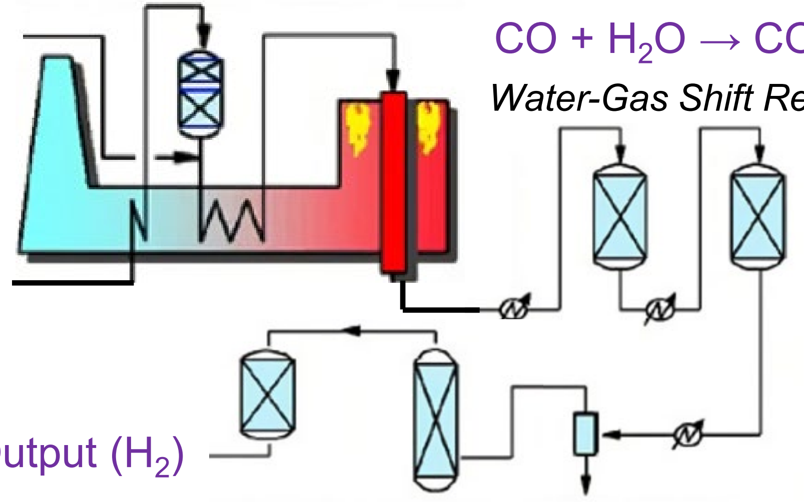


- Fossil fuels are made up of hydrocarbons
- Ammonia (NH_3) is a fertilizer that is a precursor to 45% of the world's food
- Water – the basis of the fluids of all living organisms
- H_2 is at the center of the Energy – Food – Water Nexus

Hydrogen From Direct Process

Method 1: Steam Methane Reformation (SMR)

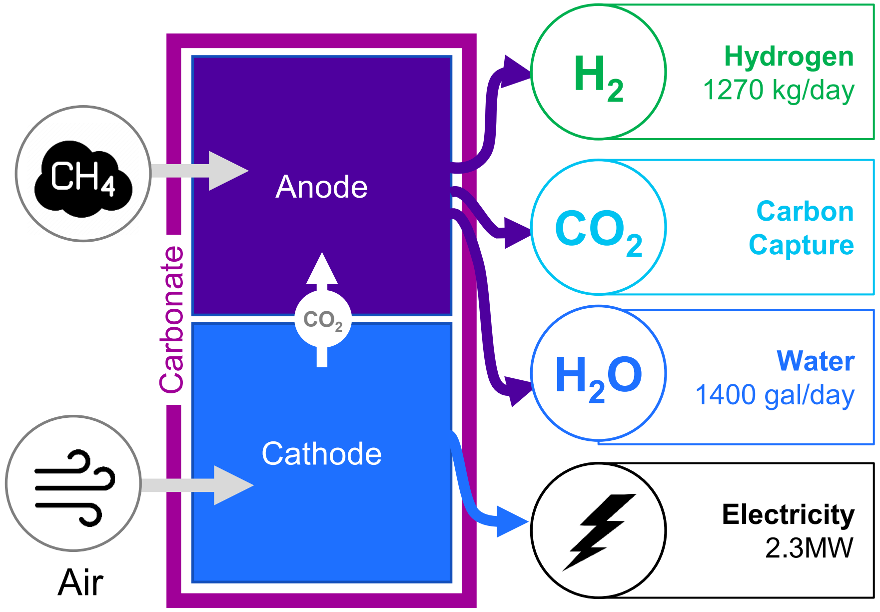
$CH_4 + H_2O \rightarrow CO + 3H_2$



Method 2: Electrochemical Trigen

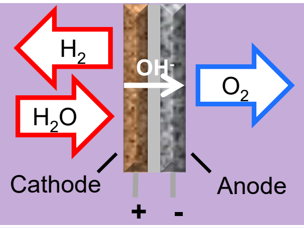
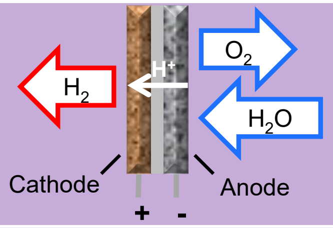
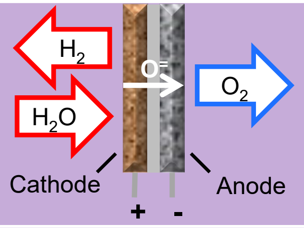
$CH_4 + 2H_2O \rightarrow 4H_2 + CO_2$

$4H_2O + 4CO_3 \rightarrow 4H_2O + 3CO_2 + 8e^-$



$2O_2 + 4CO_2 + 8e^- \rightarrow 4CO_3$

Hydrogen from Electrolysis

	Alkaline Electrolysis	PEM Electrolysis	Solid Oxide Electrolysis
			
Electrolyte	KOH	Polymer membrane	Ceramic membrane
Circulating medium	KOH	Water	Steam
Materials	Nickel, steel alloys	Uses platinum group metals for electrodes	Nickel, ceramics
Operating temperature	60 – 90°C	RT – 80°C	650 – 900°C
Ability to use waste heat	N	N	Y
Efficiency (%)	70	80	90-100
Technical maturity	Industrially mature	Emerging	Emerging
Reverse (fuel cell) mode	N	N	Y

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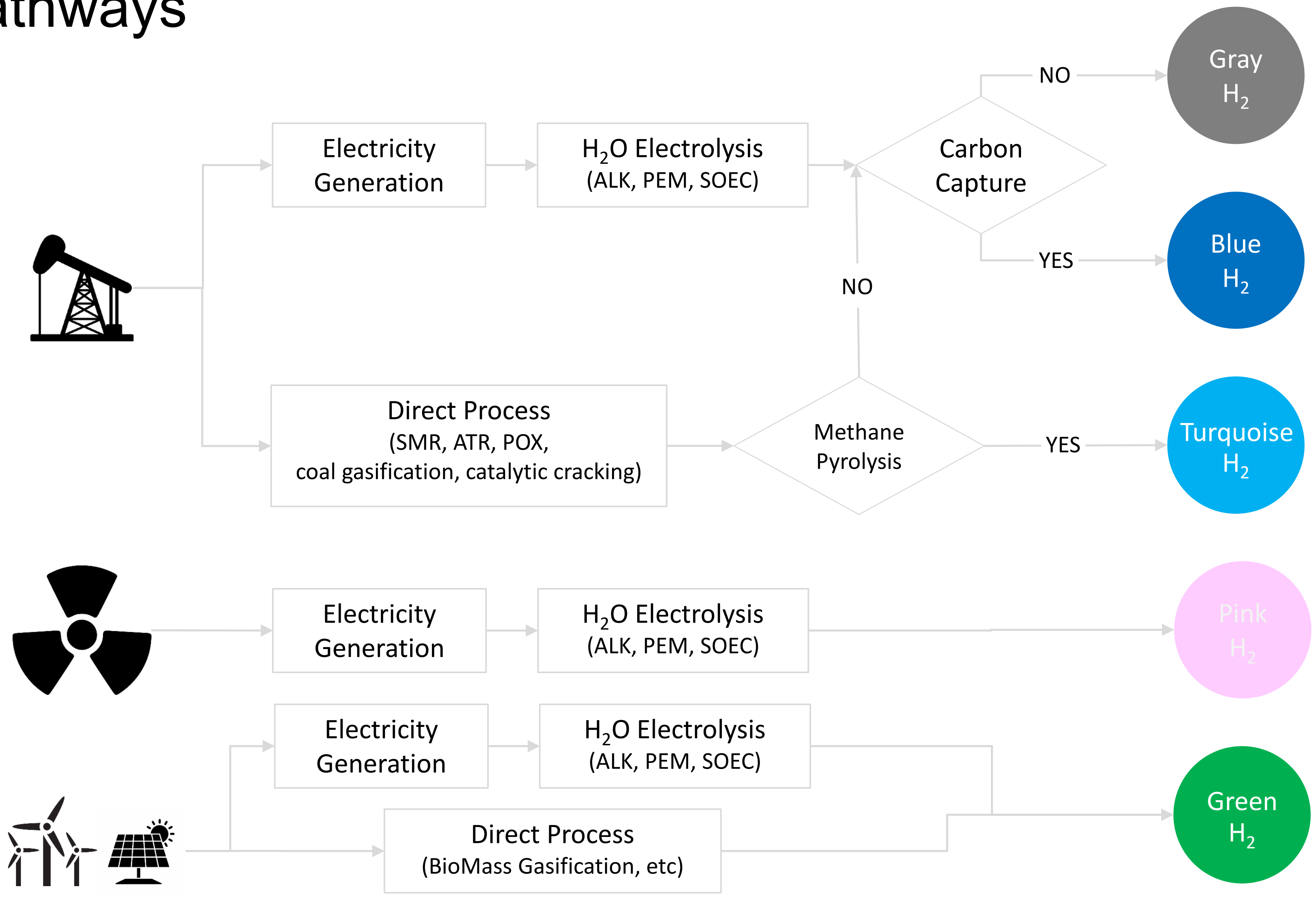
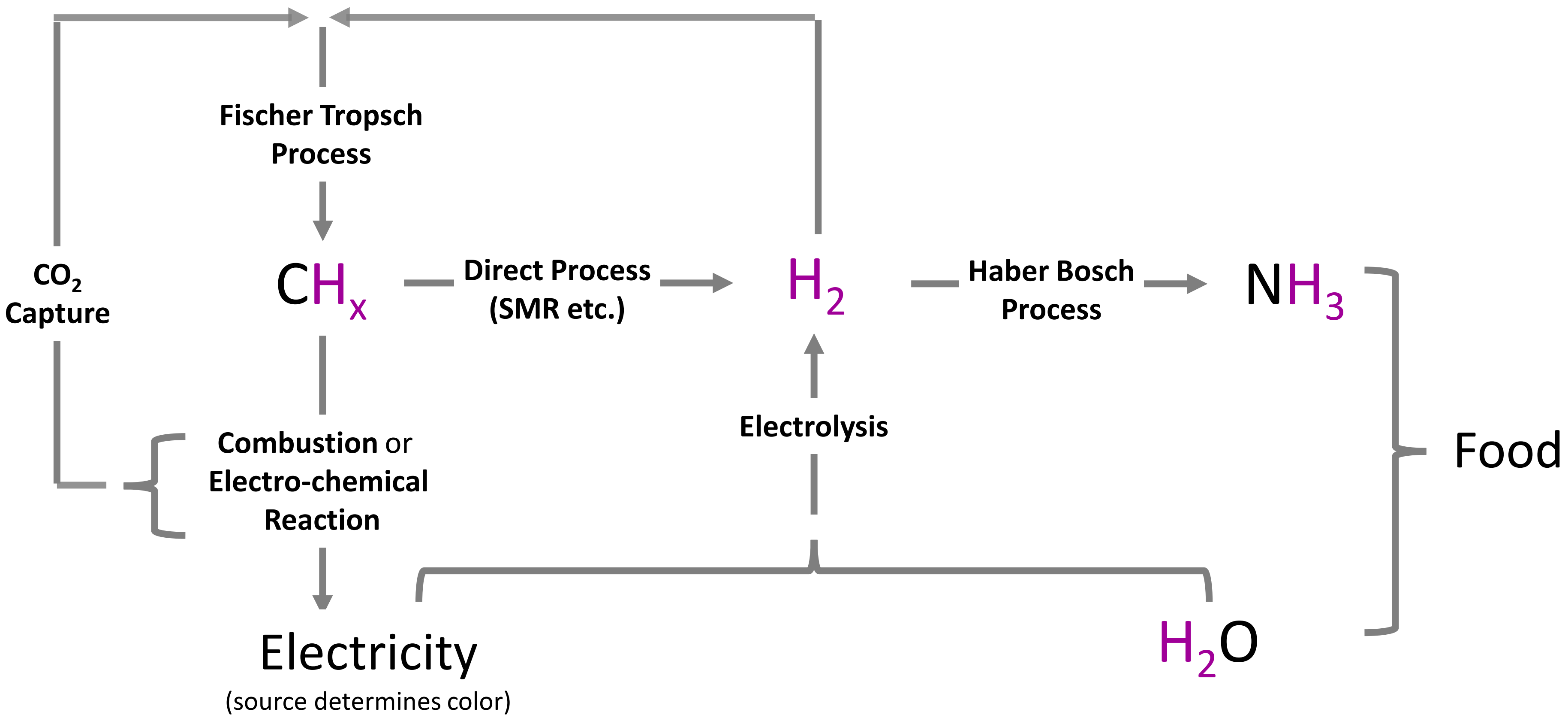
H_2 Pathways



Electricity Generation
H2O Electrolysis (ALK, PEM, SOEC)
Carbon Capture
NO
YES
Gray H2
Blue H2
NO
Direct Process (SMR, ATR, POX, coal gasification, catalytic cracking)
Methane Pyrolysis
YES
Turquoise H2
Electricity Generation
H2O Electrolysis (ALK, PEM, SOEC)
Pink H2
Electricity Generation
H2O Electrolysis (ALK, PEM, SOEC)
Direct Process (BioMass Gasification, etc)
Green H2

Hydrogen is a Vital Energy Carrier



FuelCell Energy

Our purpose ➡ Enable a world empowered by clean energy

Who We Are

A global leader in electrochemical technology

158 U.S. patents covering our fuel cell technology

338 patents in other jurisdictions covering our fuel cell technology

47 U.S. patents pending

128 patents pending in other jurisdictions

>500 Employees

1969 Founded

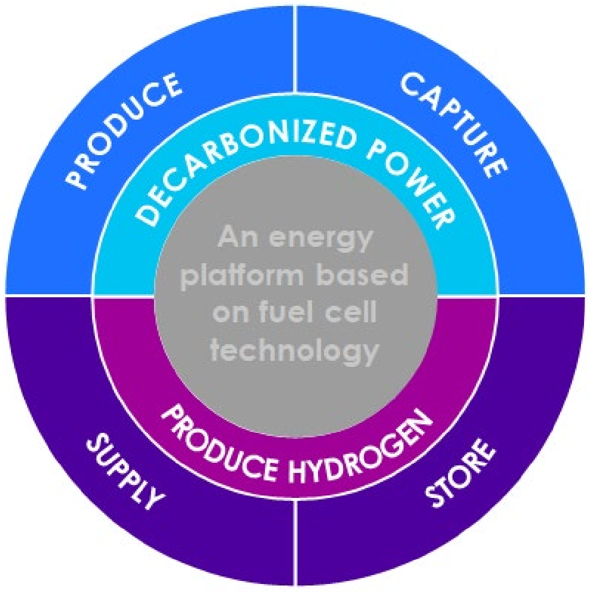
95 Platforms in Commercial Operation

3 Continents

FCEL Listing: NASDAQ

HQ Danbury, Connecticut

What We Do



Building Blocks for a World Empowered by Clean Energy

Delivering Better Energy Outcomes

Access to Energy → Reliability & Resilience → Optionality → Improved Sustainability → Affordability

Across a Wide Array of Energy Applications

Decarbonize Power							Produce Hydrogen
Combined Heat & Power	Microgrids	Carbon Recovery	Carbon Capture	Trigen Carbonate	Zero Carbon H_2 Power	Electrolysis	Energy Storage[1]
	Carbonate & Solid Oxide			Carbonate			Solid Oxide

[1] Under development

Good Neighbor Power Generation

SPECIFICATION	CARBONATE	SOLID OXIDE
Energy Output per Module	1.4 MW	250KW
Electrical Efficiency	47%	CH_4 - 62% / H_2 - 65%
Total CHP Efficiency	90%	90%
Hydrogen as feedstock	Up to 50%	100%
Capacity Factor	>90%	>90%
Capture of CO_2 from hydrogen rich fuel source	✓	✓
Output Temperature	700 ºF	600 ºF
Heat for Recovery to 120 ºF	3,730,000 BTU/Hr	382,195 BTU/Hr

Fuel Cells

- are **highly efficient** and create **more electricity** and emit **less CO_2** per BTU of gas than most comparably sized gas engines
- are good neighbors. They emit only trace amounts of SO_X, NO_X, particulate and therefore **can be sited in very strict air quality zones** and **operate very quietly.**
- have **high power density** – a 2.8 MW fuel cell energy sited on a 0.2 acre site will produce as much energy annually as 10MW solar array on 40 acres
- offer **fuel flexibility** to incorporate a wide array of feedstocks and pathways to lower carbon intensity as your operations and goals change over time

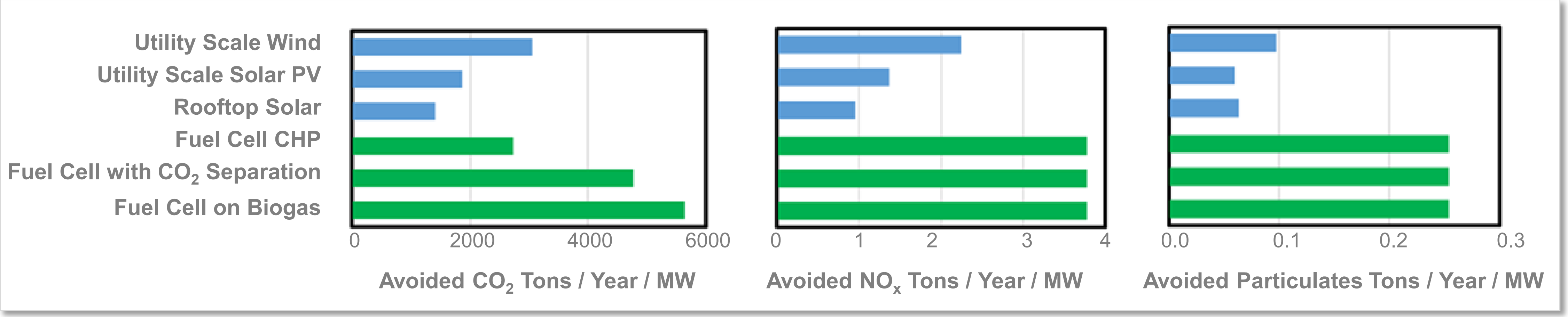
Effective Emissions Reductions in YOUR Community

The Data

	Capacity Factor, %	Emissions, lb./MWh			Avoided Emissions, Tons/y per MW		
		NOX	PM	CO2	NOX	PM10	CO2
Average US Grid		0.97[1]	0.06[2]	1432[1]			
SureSource Biogas fuel[5]	90%	0.01	0.00	0	3.8	0.25	5,646
SureSource w CO_2 Separation[5]	90%	0.01	0.00	221	3.8	0.25	4,773
SureSource 3000 w CHP[5]	90%	0.01	0.00	738	3.8	0.25	2,737
SureSource 4000	90%	0.01	0.00	778	3.8	0.25	2,577
Rooftop Solar	23%[3]				1.0	0.06	1,411
Utility Scale Solar PV[4]	29%[3]				1.4	0.06	1,874
Wind	47%[3]				2.2	0.10	3,057

The Takeaway

- Solar and wind provide clean energy when they are operating, however, most of the time they are not.
- When solar and wind are not operating, energy is drawn from the bulk power grid which, on average, is much dirtier than the power created by a fuel cell.
- Often times, solar and wind energy is created somewhere far from your community so local stakeholders do not experience the environmental benefit of your sustainability efforts.
- Fuel cells create clean energy 24/7 in your community



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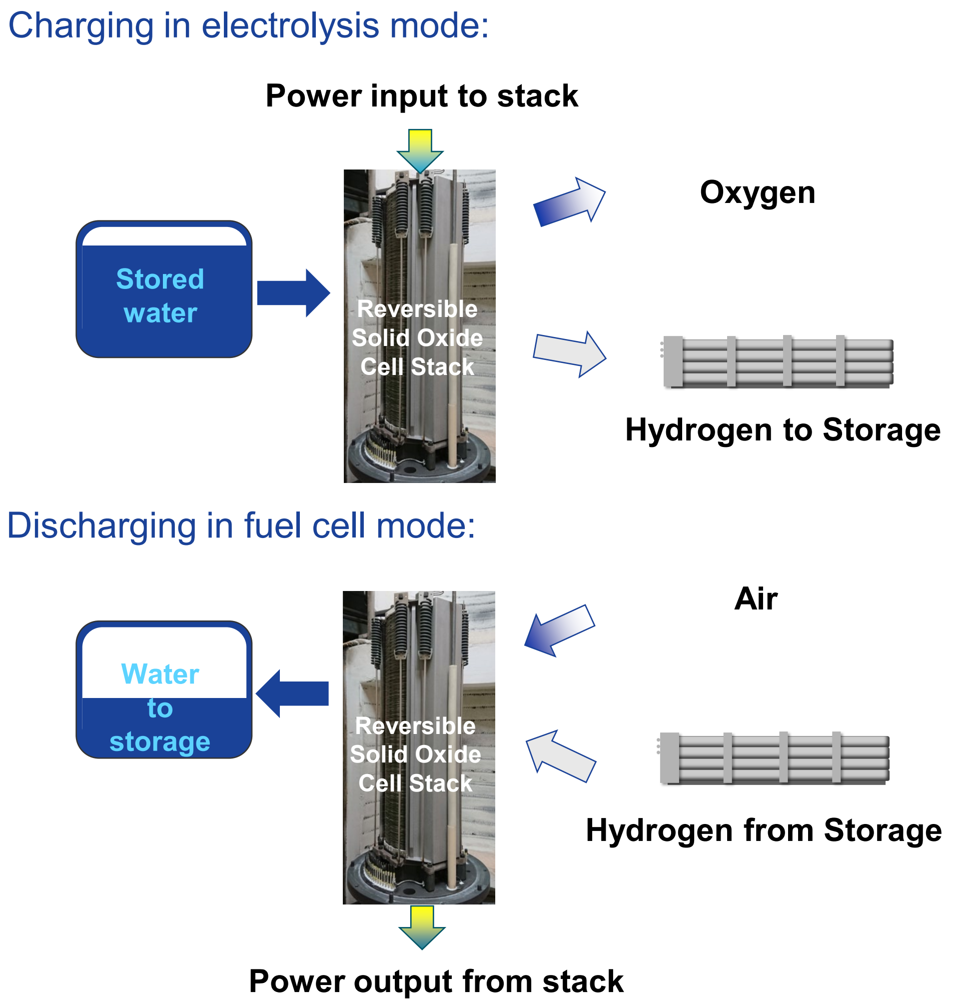
Sources:
1.Grid emissions rates for NOX and CO2 are from EPA eGrid 2018, US Average non-baseload rates.
2.Grid particulate emissions rate is from EPA eGrid PM 2.5 US average for 2018.
3.Solar and Wind capacity factors are average of range from Lazard LCOE Analysis version 13, November 2019.
4.Utility scale avoided emissions assumes 5% transmission and distribution losses.
5.SureSource estimates are based on Company specifications and estimates.

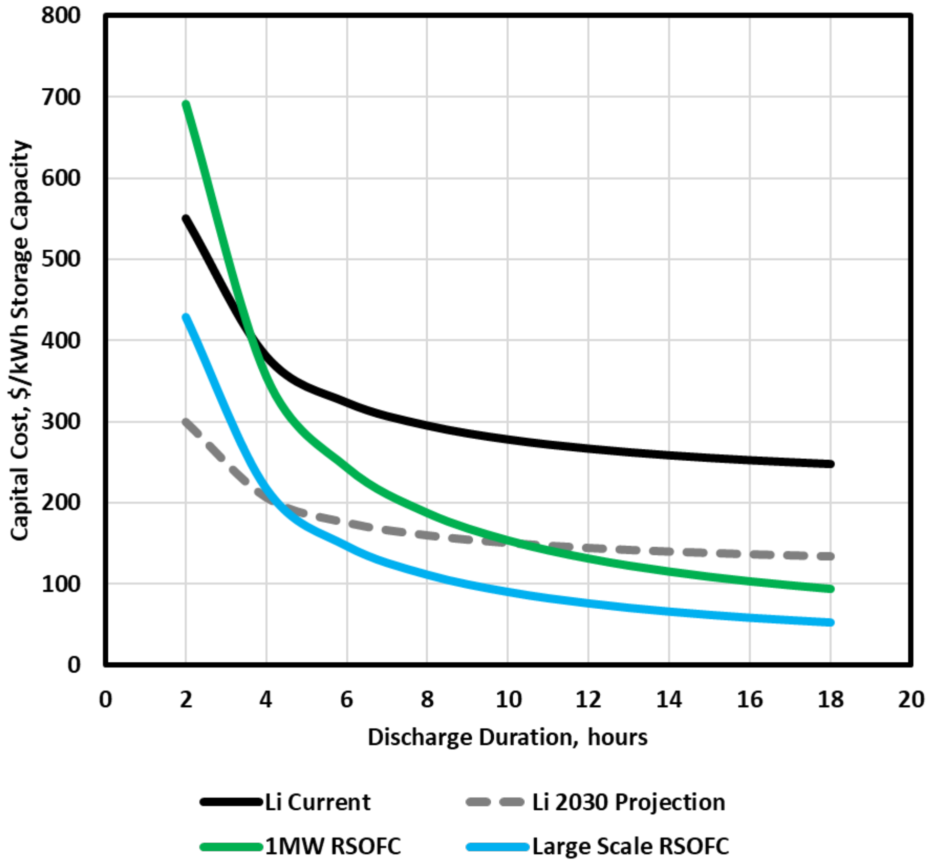
Solid Oxide Hydrogen Based Energy Storage

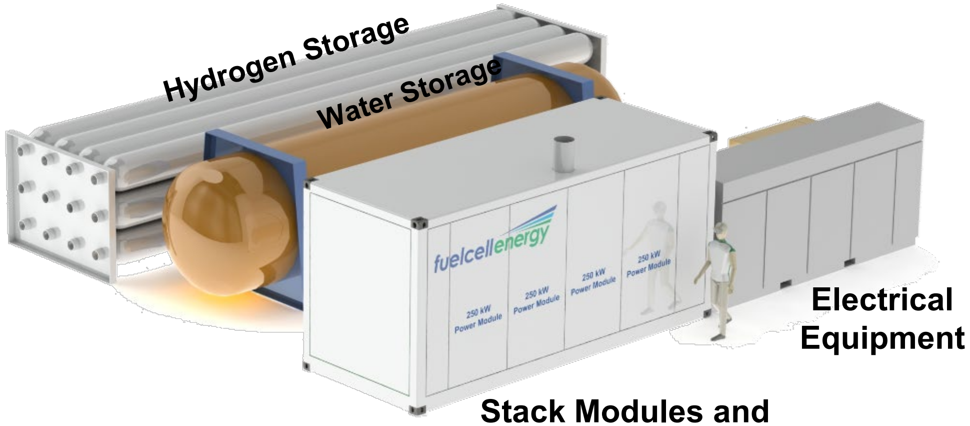
- In addition to operation in **electrolysis mode** Solid Oxide Fuel Cells (SOFC) can run in **fuel cell mode**, and can switch between modes, called Reversible Solid Oxide Fuel Cell **(RSOFC)**.
- High efficiency in electrolysis and fuel cell mode enable high round trip efficiency
- RSOFC stacks with hydrogen and water storage are an advanced energy storage approach:
  - High round trip efficiency
  - Long duration achieved by adding low-cost hydrogen and water storage capacity, without the need to add more stacks
  - Inexpensive water is the only reactant – added as an initial fill and regenerated with each discharge cycle



WITH WATER AS THE ONLY STORED REACTANT, HYDROGEN-BASED STORAGE HAS SIGNIFICANT ADVANTAGES FOR LONG DURATION STORAGE

Lithium and Reversible Solid Oxide Cost vs Discharge Duration





RSOFC Energy Storage System
Discharge duration is increased by adding Hydrogen and water storage – very low $/kWh cost components

Li projections based on NREL estimates from
Cole, Wesley, and A. Will Frazier. 2019. Cost Projections for Utility-Scale Battery Storage. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-73222. https://www.nrel.gov/docs/fy19osti/73222.pdf

RSOFC based on company estimates
1MW projected costs of $1345/kW plus $19/kWh
Large scale applies 80% scaling power factor to $/kW cost and assumes geologic H_2 storage, reducing energy cost factor to $5/kWh

LOW $/kWh COMPONENT OF HYDROGEN-BASED STORAGE REDUCES COST OF LONG DURATION SYSTEMS

Carbon Capture and NO_X Destruction

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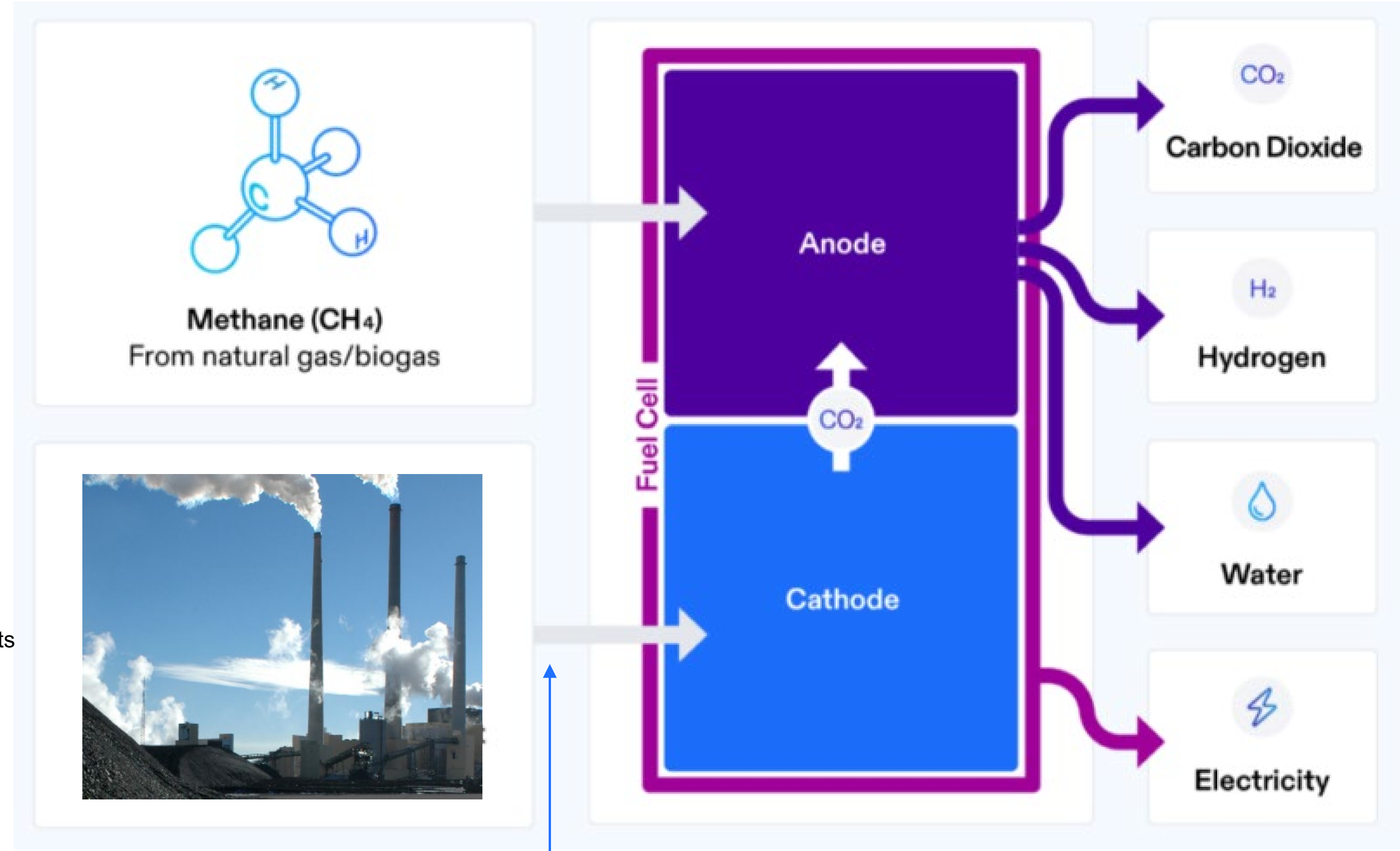
Clean Power + Carbon Capture

Fossil Emissions:
- Coal Power Plants
- Natural Gas Power Plants
- Industrial Boilers
- Steam Generators



90% Concentrated and Captured

Created

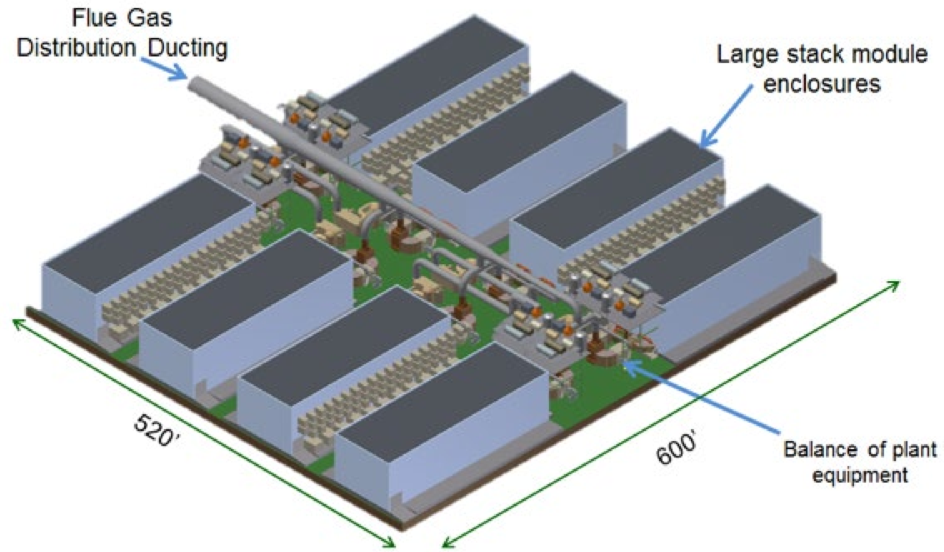
Created

Created

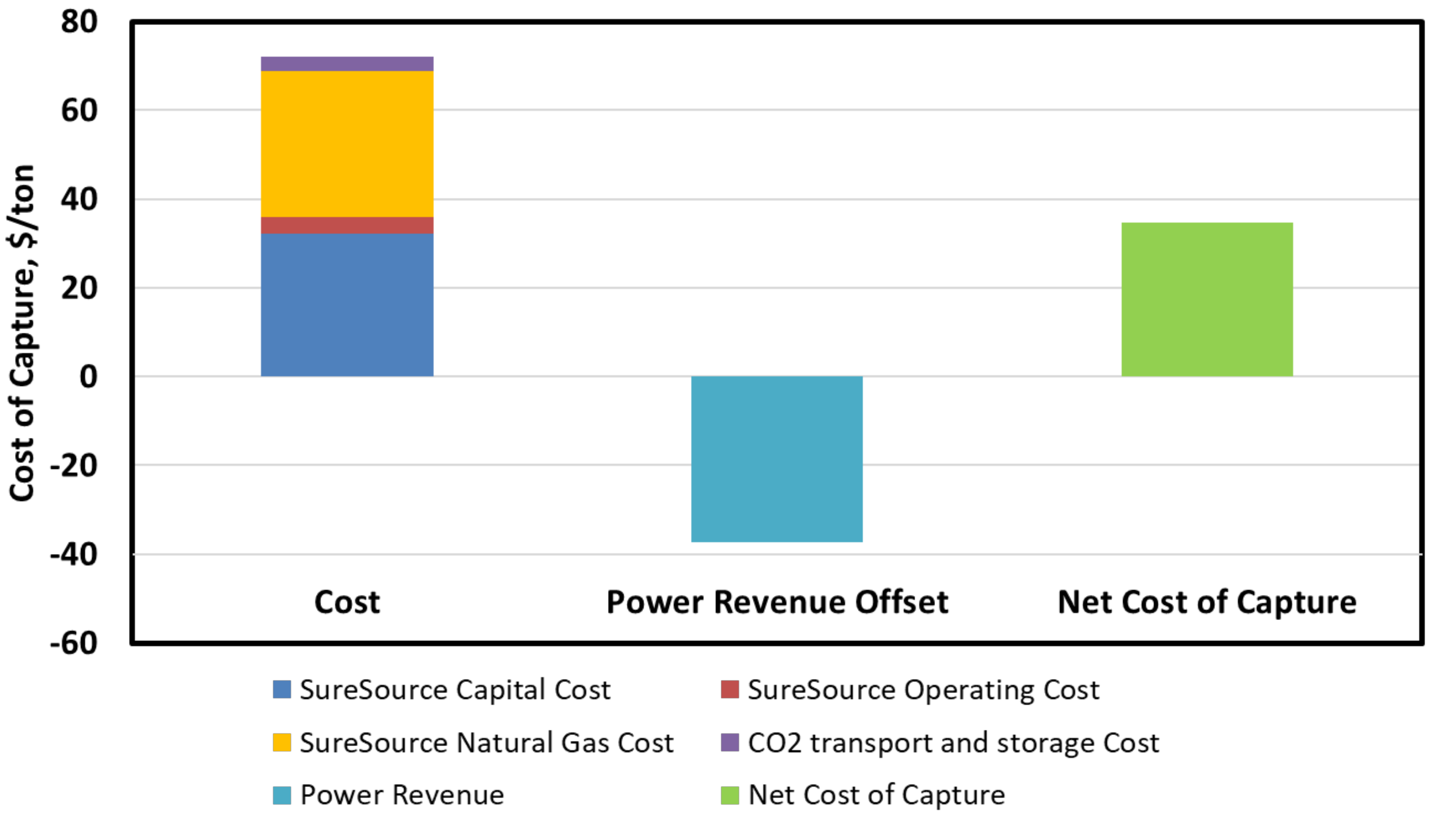
Up to 70% of NO_X in flue gas destroyed

FuelCell Energy's Carbon Separation & Unique Carbon Capture

Only Platform In The World That Can Capture Carbon From An External Source And Produce Power At The Same Time



319 MW SureSource plant for capture from coal systems – 90% capture from 550 MW coal plant



Cost analysis of fuel cell carbon capture applied to 550 MW Reference Supercritical PC Plant under DOE DE-FE0026580

Hydrogen co-production could reduce net cost of capture further

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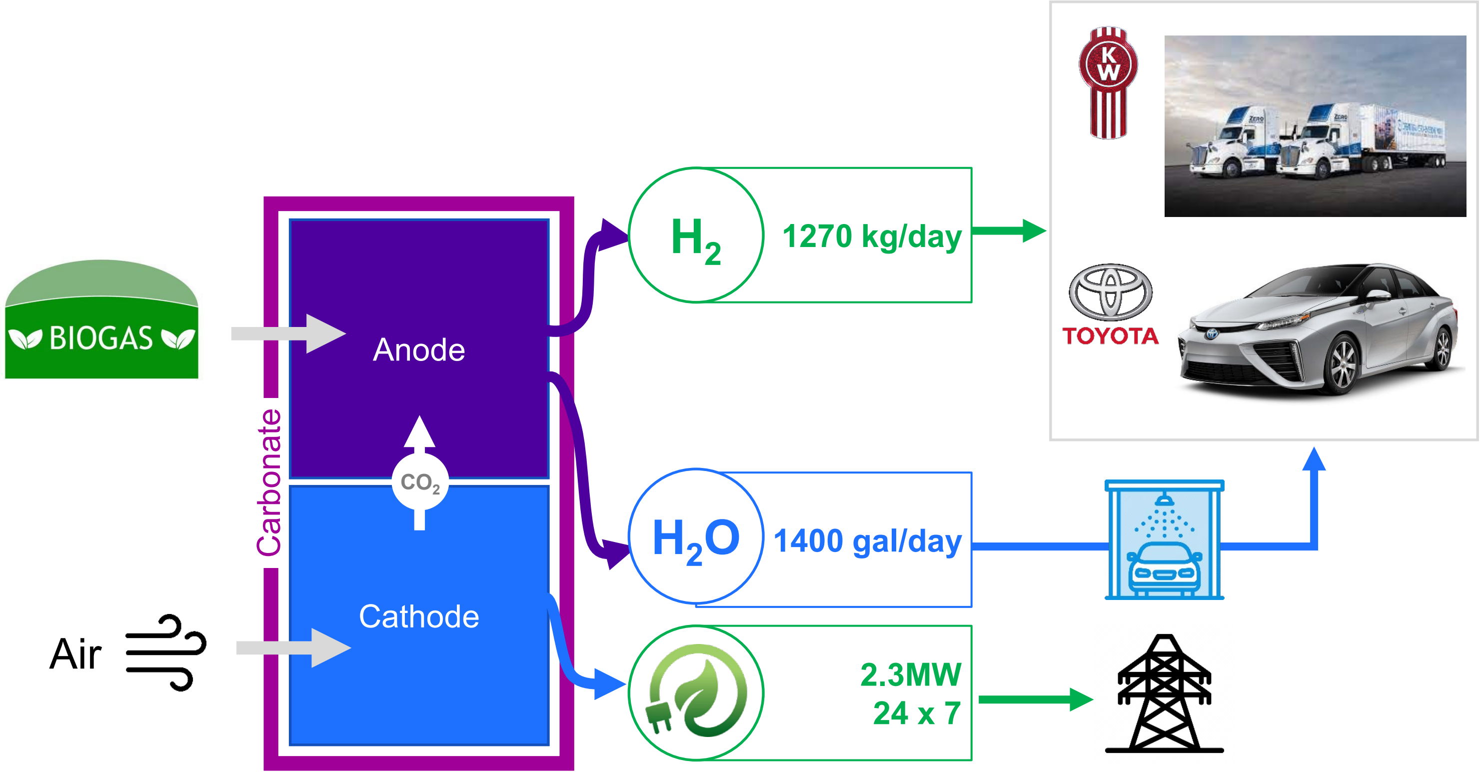
Source and for more information:
https://www.netl.doe.gov/projects/files/H-Ghezel-Ayagh-FCE-Electrochemical-Membrane-System.pdf
Pilot Test of Novel Electrochemical Membrane System for Carbon Dioxide Capture and Power Generation (DE-FE0026580)
2018 NETL CO2 Capture Technology Project Review Meeting, Pittsburgh, PA, August 13-16, 2018

Case Study – Port of Long Beach

A New Green Energy Hub in California

The Port of LONG BEACH



Trigeneration
Carbonate Platform

Take a
Virtual Tour

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Thank You! / Q&A

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