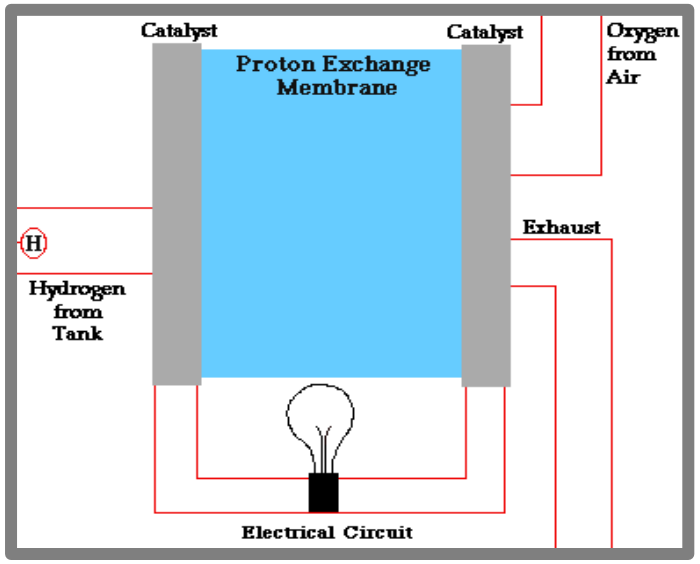
Ceramic Fuel Cells vs Polymer Fuel Cells

Yanhai Du, Kent State University

Hydrogen Fuel Cell (PEMFC)



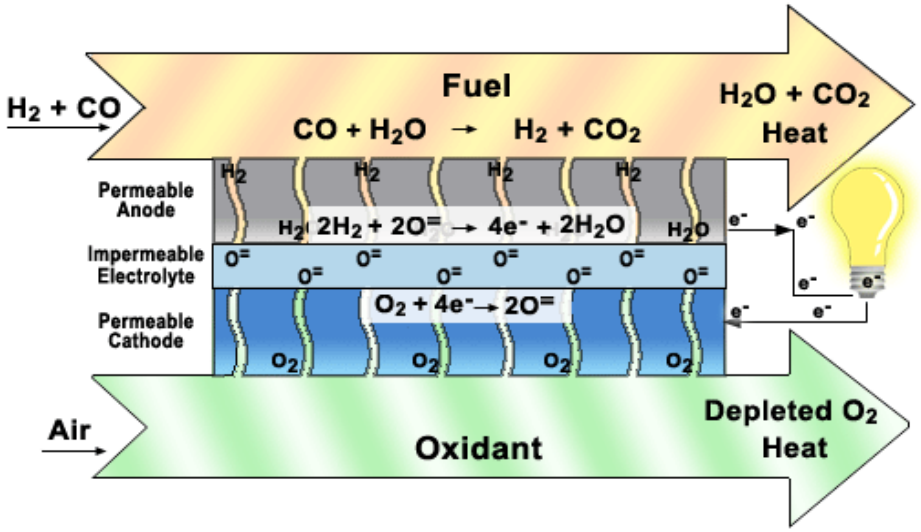
At Anode: $H_2 \rightarrow 2H^+ + 2e^-$

At Cathode: $O_2 + 2e^- \rightarrow 2O^=$

$2H_2 + O_2 \rightarrow 2H_2O + 2e^- + \text{Heat}$

$2H^+ + O^= \rightarrow H_2O$

Solid Oxide Fuel Cell (SOFC)



$2H_2 + O_2 \rightarrow 2H_2O + 2e^- + \text{Heat}$

$H_2 + CO + O_2 \rightarrow H_2O + 2e^- + CO_2 + \text{Heat}$

- H_2 is not a natural energy resource.
- H_2 +CO is called syngas from catalyst reforming of **hydrocarbon fuels**: natural gas, propane, gasoline, diesel or biofuel.

Applications

Hydrogen power

Germany launches world's first hydrogen-powered train

Two trains built by the French train maker Alstom are now operating on a 62 mile stretch of line in northern Germany

Agence France-Presse

Mon 17 Sep 2018 10.20 EDT

This article is over 5 months old

The world's first hydrogen fuel cell passenger train is now running in northern Germany. Photograph: David Hecker/EPA

Fuel Cell Technology Demonstrations at Kent State

Single Cell
- Materials
- Fabrication
- Performance

Stacking
- Design
- Assembly
- Evaluation

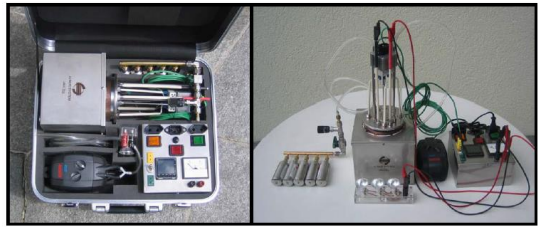
Power System
- Controls
- Self-Sustained
- User Interface

Applications
- Home Use (CHP)
- Mobile
- Stationary
- Compatible with Renewables

5kW
Methanol
Canada

50W
Hydrogen
Switzerland

UBOCELL SOFC Demonstration Kit



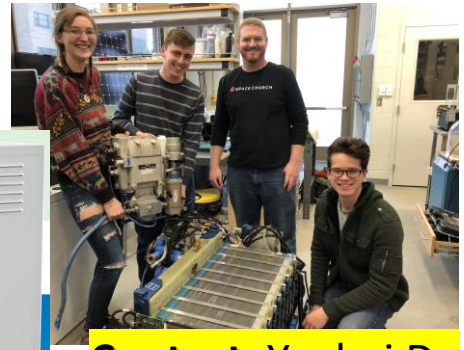
100W
Methanol
Singapore

650W for **UAVs**
Hydrogen
USA & UK

375W
Propane
United States

500W
Natural Gas
United States

150kW



Contact: Yanhai Du
ydu5@kent.edu

Research and Development Areas and Directions

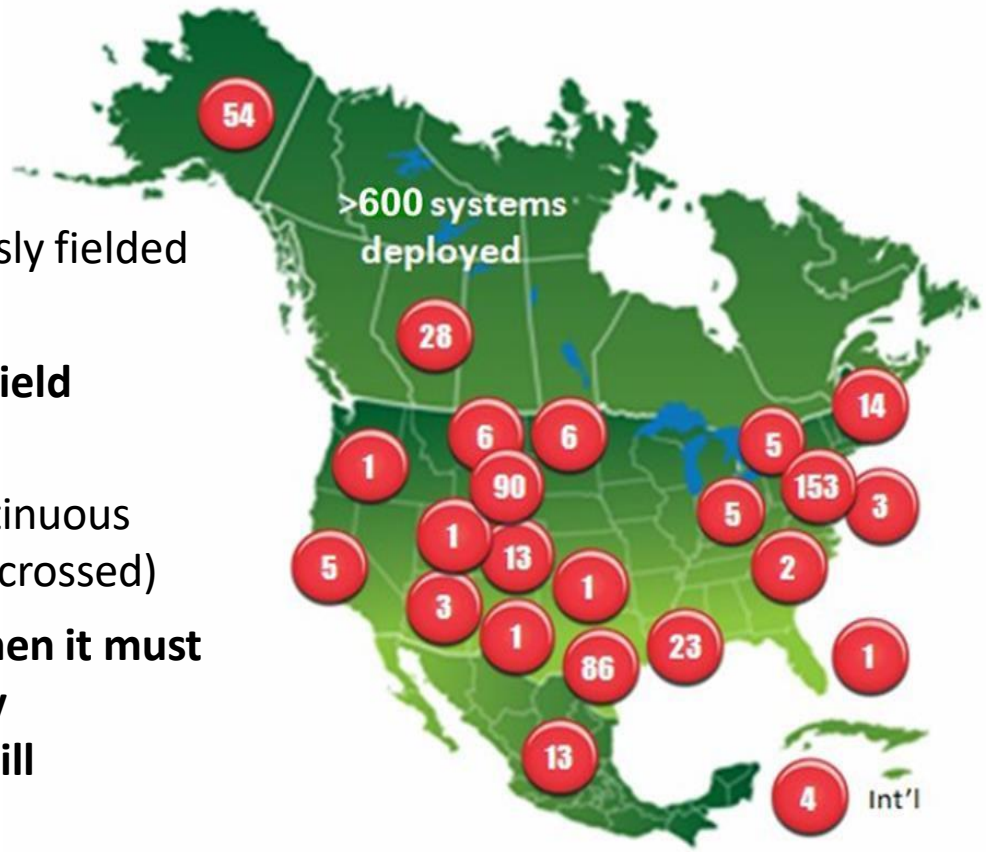
Contact: Dr. Yanhai Du, ydu5@kent.edu

- Tubular Ceramic Fuel Cell Development
- Advance the Freeze Casting Technology (NASA)
- 3D Additive Manufacturing (metals, ceramics)
- Liquid Fuel Desulfurization (AF)
- Universal Testing Kit – for Fostering SOFC R&D
- USA/UAV Power (Hybrid Fuel Cell-Battery-Capacitor)
- Electrolysis (SOEC) for H_2
- CO_2 Capture (or to Fuels)
- Develop H^+/$O^=$ Conducting Polymer-Ceramics at 300-500°C

August 30, 2022
Ted Ohrn

Radio Network Tower in Alaska

- 600+ systems previously fielded across North America
- **6,000,000+ hours of field operations**
- 35,000+ hours of continuous operations (25 units crossed)
- **99+% availability…when it must work in high-intensity cell applications…it will**



Instrumentation – Pennsylvania

Cathodic Protection Site in Wyoming

Chemical Injection Pumps at Multi-Wellhead Head Site in Colorado

SPS Power Generation System

SPS Special Power Sources
SUPPLYING YOUR REMOTE POWER NEEDS

Reliable Power

- Outputs from 100W up to 1500W
- 2VDC up to 60VDC
- Continuous duty, onsite power
- High availability
- Grid-independent

Clean, Quiet & Efficient

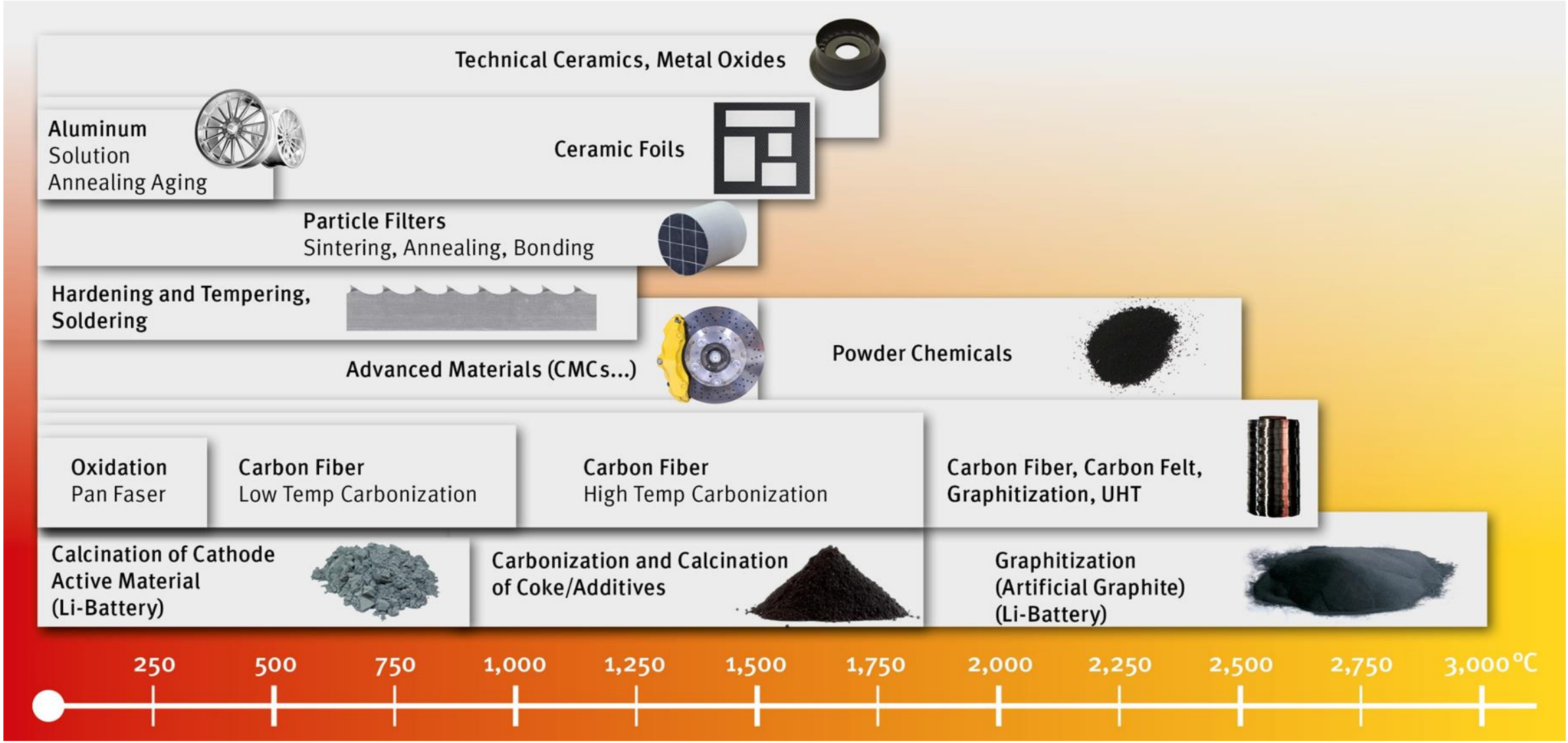
- 40-50% system efficiency
- Minimal emissions
- Small footprint
- Runs on natural gas or propane w/ no external reformer required
- Follows load, no need to set manually
- Remote monitoring and control

Cost-Effective

- Low-maintenance
- Scalable
- Hi fuel efficiency = low fuel consumption
- Competitive "Total Cost of Ownership"

SPS acquired Atrex Energy in October 2019, moving operations to Alliance, OH

Thermal Processes / Kilns & Furnaces
ONEJOON Expertise.



ONEJOON Kilns & Furnaces
for SOFC / SOEC thermal processes.

ONEJOON

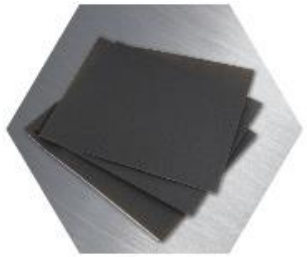
PRODUCT PORTFOLIO

SOFC / SOEC

- Continuous kilns & furnaces optimized for the mass production of SOFC / SOEC
- Turn-Key supply of kilns & furnaces, cell handling and material flow automation

ONEJOONs Lab2Production Program

- Bridges the gap between laboratory and large-scale production utilizing an End 2 End development process
- Process development and process optimization in OJ Testcenter in Korea and Germany
- Upscaling and industrialization



PEM Fuel Cells - GDL (Gas Diffusion Layer)

- Graphitization Furnaces
- Carbonization Furnaces

Test RHK @ ONEJOON Test Center

ceramics expo

Company Background

Utah, USA R&D/Manufacturing - 2017

- Office, laboratory, and manufacturing facility (24,000 ft^2)
- NASA, DOE, DOD and commercial contracts
- Tape casting, cell and stack production, and testing
- End-to-end power to synfuels pilot plant

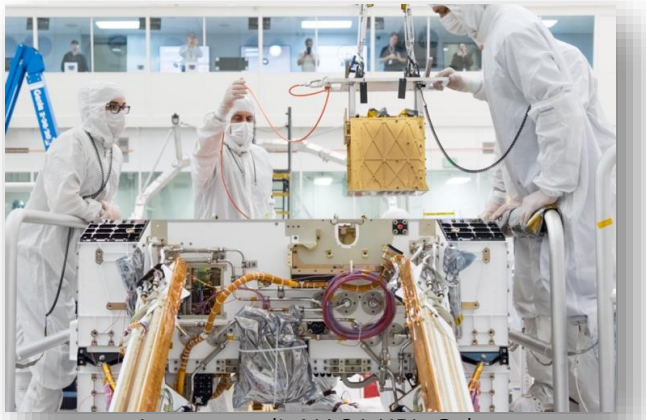


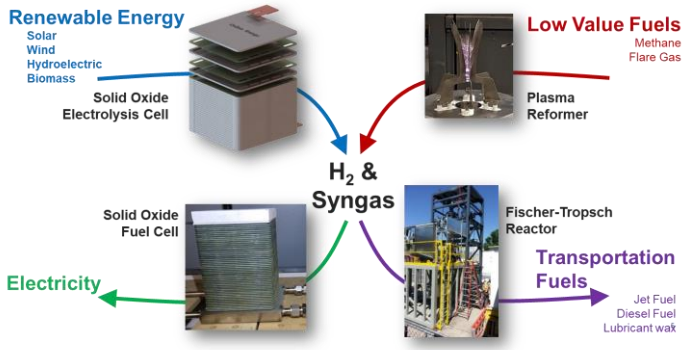
Image credit NASA/JPL-Caltec

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

Fuel Reformation and Generation

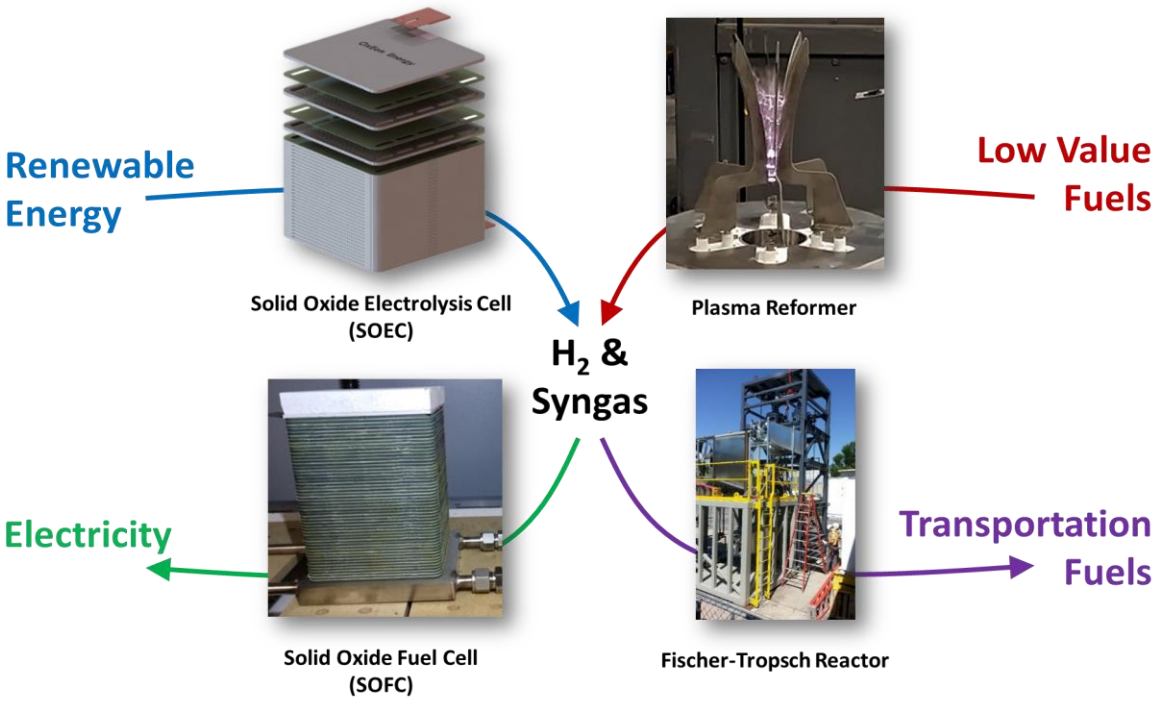
- Plasma Reformer – H_2 or syngas from flare gas; digester gas conversion; clean-up bio-gasification
- Fischer-Tropsch Reactors – Modular design for sustainable fuel production from H_2 and syngas



Enabling Cross-Sector Energy Conversion

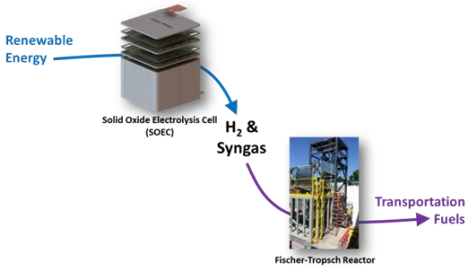
PTX | SUSTAINABLE AVIATION FUEL | ISRU PROPELLANTS | BIOGAS PROCESSING

OxEon's Technology Suite

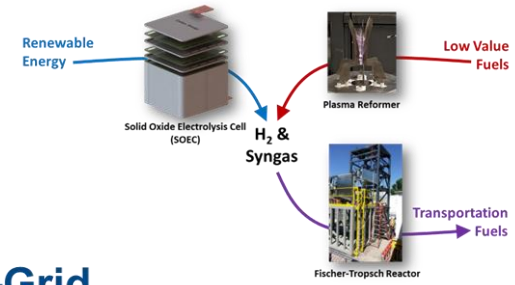


Syngas = CO + H_2

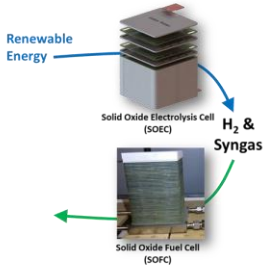
Nuclear Power and CO_2 To Fuels

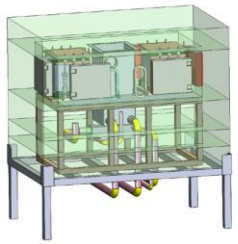


Food Waste to E-Fuels



Remote and Off-Grid





- Reversible fuel cell powered by Solar (or other renewable source)
  - Hydrogen production and storage during peak power production
  - Power from hydrogen during downtimes
- Future coupling with modular reactors for liquid fuel production