IRON POWDER AS A CLEAN AVIATION FUEL SOURCE

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MEET THE TEAM

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Iron Powder

Solution:
IRON POWDER

1 COMBUSTIBLE

Combustion of iron powder can create energy through a heat cycle.

2 ACCESSIBLE

Iron is widely accessible globally and affordable in the current market.

3 RECYCLABLE

Electrolysis research can lead to proper recyclability of iron which can keep the source sustainable. .

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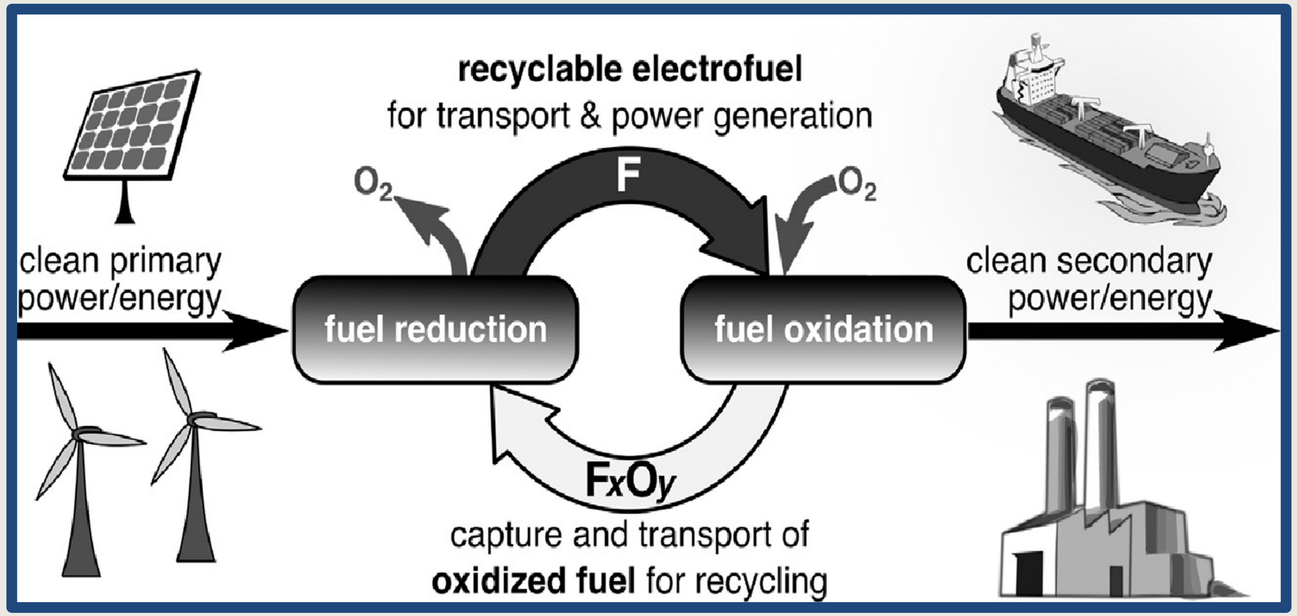
How it Works:

Energy Production & Recycling

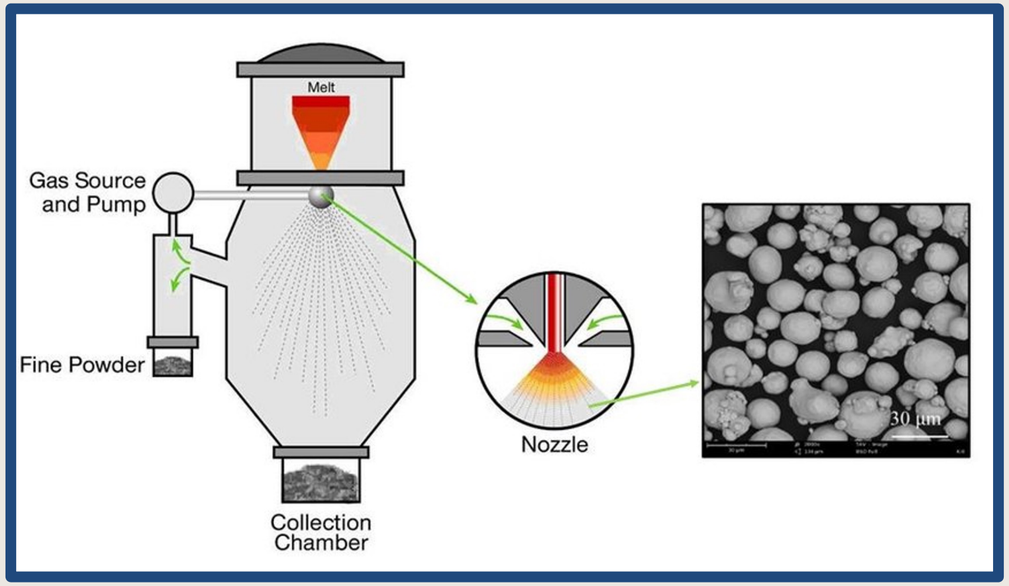
- Recycling powered by excess energy produced via renewable energy sources
- Electrolysis (Being researched at Boston University by Professor Uday Pal's Lab)
  - Electricity used to drive the non-spontaneous reaction
  - Returns iron and oxygen gas

$$4Fe\,(s) + 3O_2(g) \leftrightarrow 2Fe_2O_3\,(s)$$



Iron Powder: Implementation

- Atomization to manufacture iron powder
- Induction furnaces
  - Converts energy from electricity into heat
  - Does not produce CO_2 or any hazardous waste
- Electrolysis as a recycling method



Iron Powder: Supply Chain

- Dominant mining companies in Brazil and Australia are BHP Billiton, Vale, & Rio Tinto
- 405 and 906 million metric tons of iron ore produced in 2019, respectively
- China consuming 75% of global trade as of 2020
- Challenge: rising cost reliant on China's demand
- Cost increase after COVID-19 pandemic due to oversupply and a halted economy

Case Study

‘Brewery Swinkels’

Swinkels family brewers

- Brewery in the Netherlands which utilizes iron powder combustion for heat
- Equipped with a “megawatt” size iron fueled power plant
  - sustainable for the next 20 years
- Spoke with Max Winkel of Team SOLID at Eindhoven University
  - Discussed combustion techniques
  - Sources of iron
  - Collection and electrolysis research

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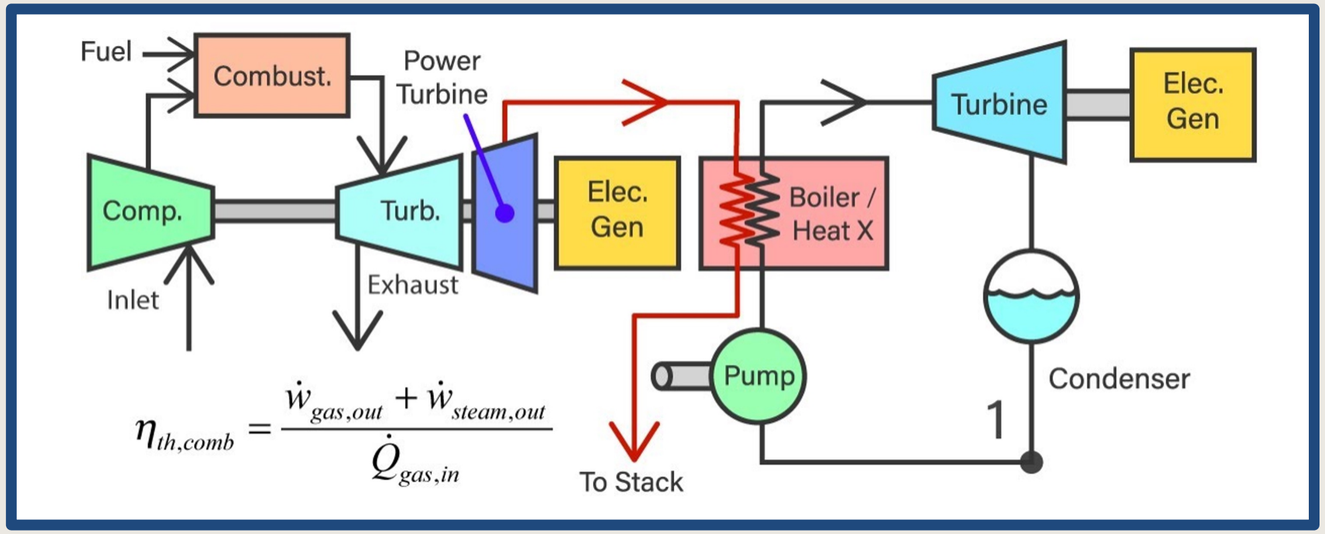
Heat Cycle

From Thermal Energy to Electricity:

Heat Cycle

- Combined Brayton-Rankine Cycle
- Chubu Electric Power Co., Inc. and Toshiba Energy System & Solutions Corporation
  - Thermal power plant
  - 63.08% efficiency (2017)



From Thermal Energy to Electricity:

Challenges

- Rust
  - Corrosion
  - Clogging → reduce heat transfer, slow flow rate
- Burns at temperatures up to 1976°C theoretically and over 1830°C experimentally
  - Material needs to withstand
  - Particle agglomeration (12-18% eff. loss at electrolysis)
- Full combustion

From Thermal Energy to Electricity:

Solutions

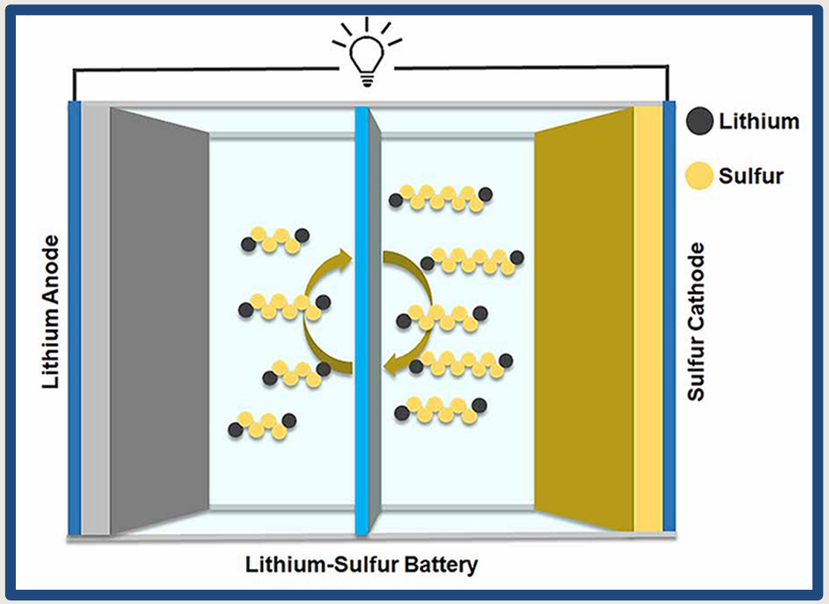
- Material selection: quartz tube burner
- Condensation & temperature management
- Fluidized mixture with 4-part apparatus: reservoir, pinch valve, ejector, scale

- Renewable Iron Fuel Technology (RIFT) from Team SOLID: iron fuel boiler for testing in Helmond, Netherlands near Eindhoven

Batteries

Batteries:

Energy Storage Source



- Lithium - sulfur batteries
  - Most promising alternative to a batteries on the market
- University of Michigan Lithium - sulfur batteries research
  - Elements used together are quadruple the energy capacity of a typical battery
  - Can withstand both extreme cold and hot temperatures
  - 10 year lifespan
- Projected to be in the market as soon as 2024

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Batteries:

Supply Chain

- Four main stages: raw material extraction, raw material processing, cell component production, and battery pack production
- China produces three quarters of all current lithium-ion batteries
  - 70% of cathode & 85% of anode global capacity
- Arising issues:
  - Human rights abuses
  - Changing trade alliances between individual countries
  - Supply impacted by geopolitics
  - Corporate consolidation

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Power Plants

Airport Implementation

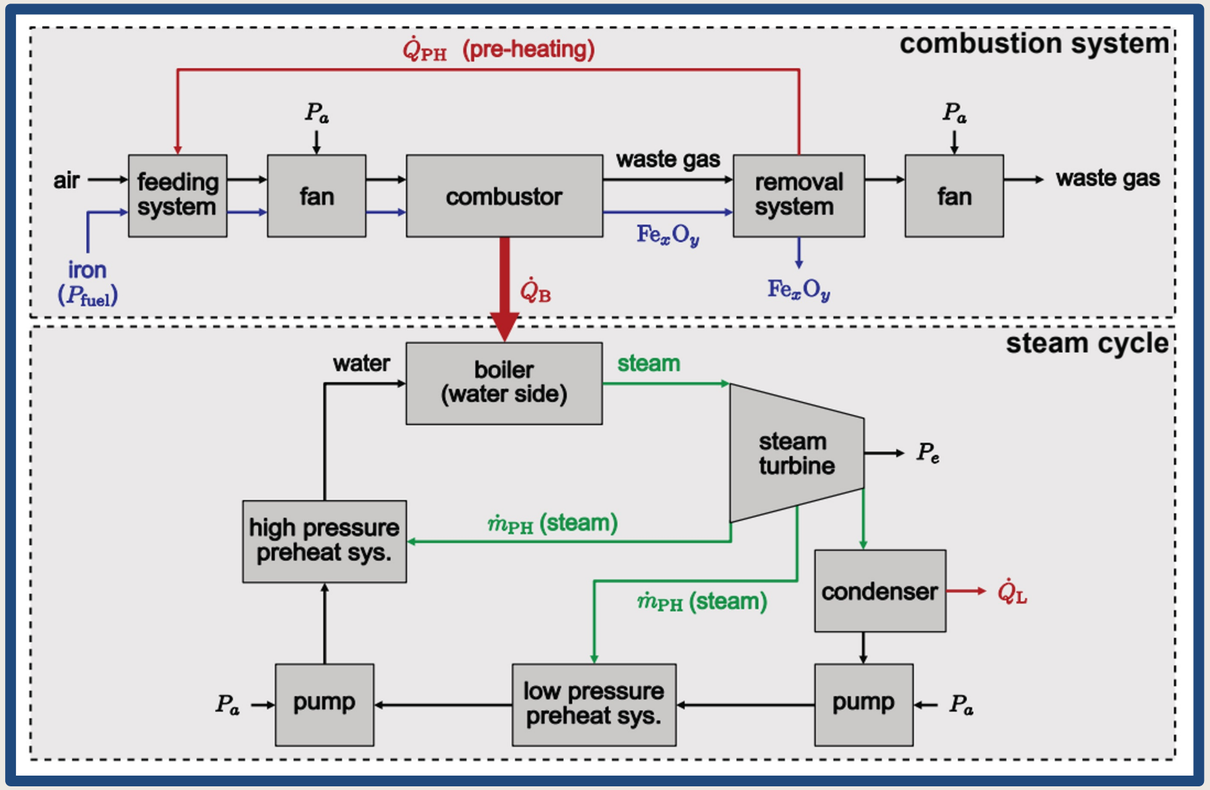
- Plan locations based on current land use in the US
  - 5,000 public airports and 14,400 private airports in the US
  - Largest international airports will be prioritized
- Ground transportation of batteries with electric trucks
  - eCascadia Freightliner, Tesla, General Motors, etc. are developing electric trucks
- Consistently have additional batteries at airports in order to supply flights

Retrofitting Coal-Fired Power Plants:

Challenges

➔ Simulation of 800 MW coal-fired power plant

- Clogging
- Iron powder more dense than bituminous coal but similar to lignite
- High temperature difference between high- and intermediate-pressure section



Retrofitting Coal-Fired Power Plants:

Solutions

- Cleaning and filtering system (cloth or magnetized filters)
- Particle size: 10-20 microns based on kinetics and velocity in hopper
- Biflux heat exchanger

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Retrofitting Coal-Fired Power Plants:

Benefits

- 2.3% higher efficiency due to high melting point of iron (less fouling)
- Existing denitrification system for possible NOx emissions
- Much smaller capital investment

Surrounding Factors

Surrounding Factors

SOCIAL FACTORS

- Education & public awareness
- Consumer demand
- Accessibility & convenience

POLITICAL FACTORS

- Timeline of fuel transition
- Commitment to transitioning
- Private companies
- Airlines
- Job generation (~14 million)
- Job loss (~5 million)

ECONOMIC FACTORS

- Fossil fuel convenience vs sustainability of iron powder
- Iron Powder:
  - Recyclable
  - Releases 7 MJ/kg
  - ~$0.06/lb ($0.12/kg)

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Environmental Impacts

Environmental Impacts

PROS	*CONS*

• Capturing of the solid oxide is easier to manage
• Closed loop reaction
  ○ little to no waste due to recyclability
• no CO_2 byproduct
	• Iron powder & iron oxide nanoparticles
	• Closed loop reaction
	  ○ Can disrupt the health &

- Releases of Jet A, JP-5, and JP-8 are not required to be reported under the Small Airplane Aviation Act (SARA)

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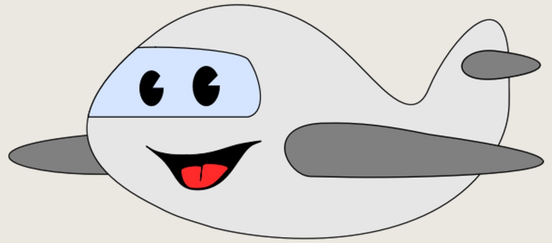
Conclusions

- Iron powder as a fuel is a cyclical process: return on investment
- Developing this technology by 2050 is realistic
- Changes to be made
  - Social → education & climate awareness
  - Political → support from political entities & job increases in renewable energy
  - Economical → increase demand for faster advancement
  - Technical → iron fuel boilers brought to the commercial market; iron fuel plants implemented with transportation between airports

THANK YOU!

Q&A



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