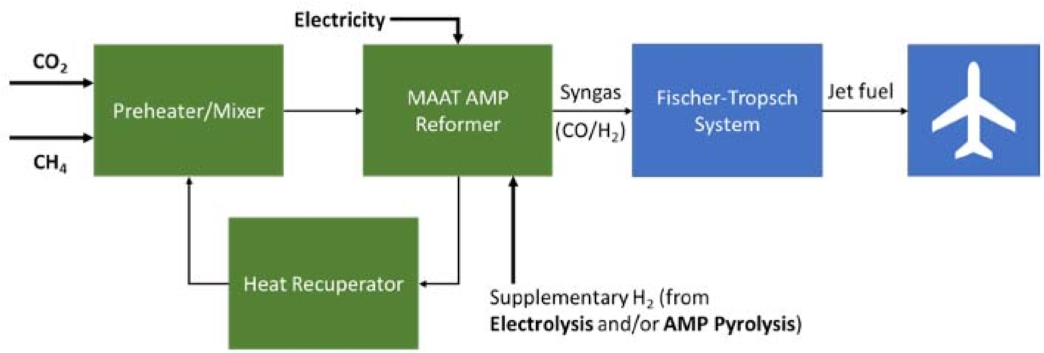
Atmospheric Microwave Plasmas for CO_2 Reuse for Jet-fuel Synthesis (SC0019791)

Leslie Bromberg | CTO, Principal Investigator |
MAAT Energy Company

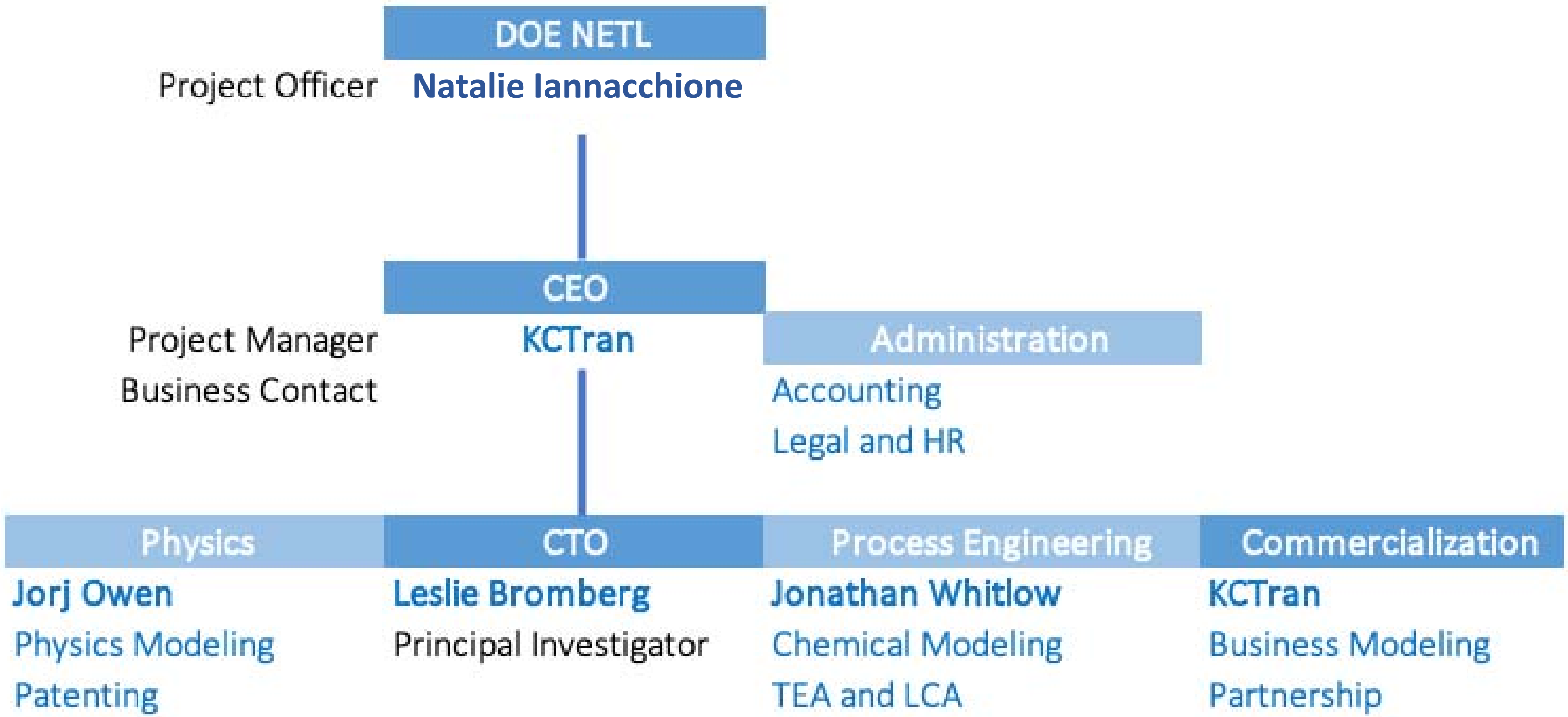
U.S. Department of Energy
National Energy Technology Laboratory
Carbon Management Project Review
August 16, 2022

Project Overview

- Overall Project Objectives:
  - Low carbon intensity jet fuel by re-using CO_2
  - Maximize CO_2 re-use
- Project Participants:
  - Maat Energy Co, MA
  - University of Massachusetts Lowell, MA
  - FT partner
  - Massachusetts Institute of Technology, MA
  - Argonne National Laboratory, IL
- Funding : $1,150,000 (for SBIR Phase II)
- Project Performance Dates
  - August 24, 2020 – August 23, 2022



Project Organization



Founders

KC Tran – CEO, MAAT Energy, Developing world class innovation teams and partnerships. Scaled large scale production of hydrogen, carbon capture, and built the world's first industrial power to methanol plant as CEO of Carbon Recycling International ehf. Visiting Scientist, MIT Plasma Science and Fusion Center.

Dr. Leslie Bromberg – CTO, MAAT Energy. Leading innovator in plasma reforming technologies, receiving more than 20 plasma reformer patents and publishing more than 100 papers. Senior Scientist, MIT Plasma Science and Fusion Center.

Dr. Jorj Owen – Principal Physicist, MAAT Energy. Developing plasma reaction system and analyzing prior arts in plasma chemistry. US Patent and Trademark Office patent examiner.

Dr. Jonathan Whitlow – Principal Chemical Engineer, MAAT Energy. Developing chemical conversion and carbon separation systems and modeling techno-economics and carbon emission life cycle. Professor of Chemical Engineering, FIT.

Technology Background - 1

@ MIT:

- Microwave plasma technology developed for metal sensing
- Atmospheric plasma reforming (POX)

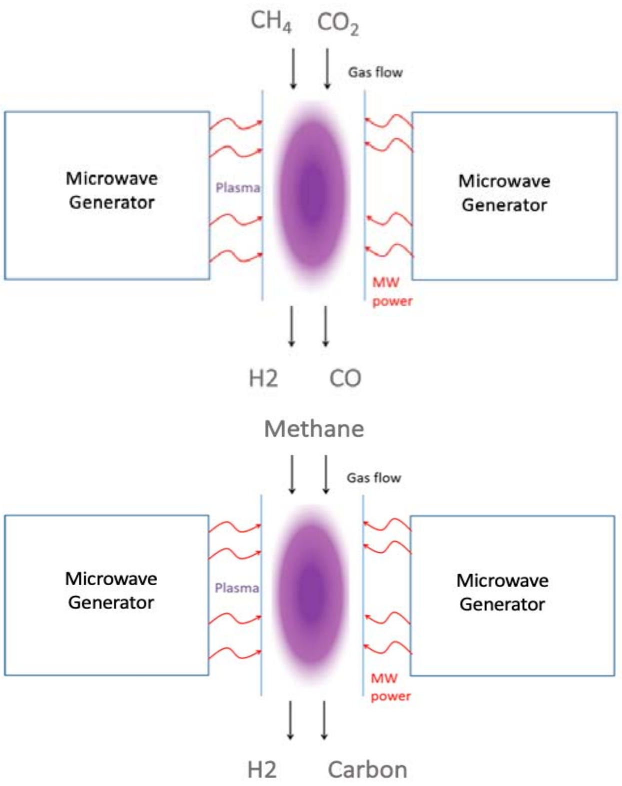
@ MAAT:

- A warm non catalytic plasma process
- Appropriate temperatures (kinetics adequate at 2000 K)
- Plasma chemistries for synthesis gas and hydrogen

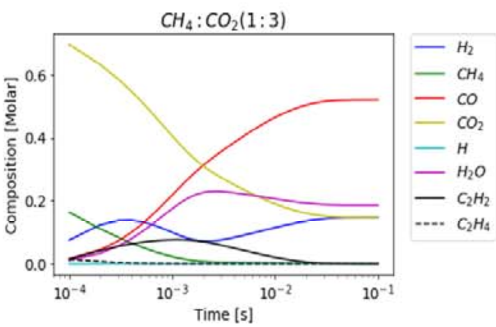
Technology Background - 2

- Advantages of technical approach
  - Readily available, high volume produced microwave components
    - Efficient, inexpensive, good coupling, highly uniform
  - High reuse of CO_2
    - $3CO_2 + CH_4 \rightarrow 4\ CO + 2H_2O$
    - Make-up H_2 produced through methane pyrolysis

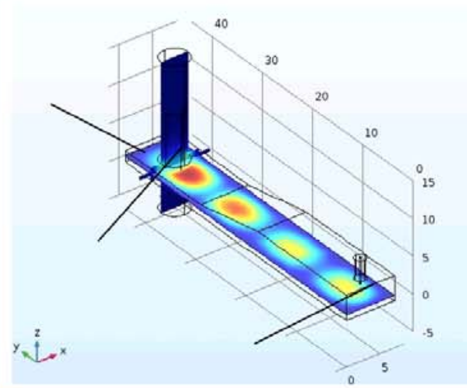
- Technical and economic challenges
  - Present microwave plasma require the use of a dielectric, which requires frequent replacement
  - Atmospheric pressure plasmas operate at high temperature,
    - requiring high energy consumption
    - Renewable electricity consumption to re-use CO_2
  - Decentralized Jet-fuel production



Advancing State of the Art of Microwave Plasmas



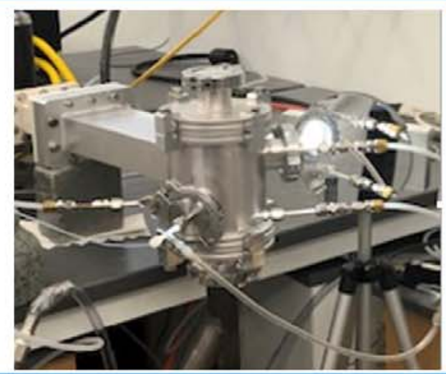
Underlying Mechanisms



Experimentation-Simulation

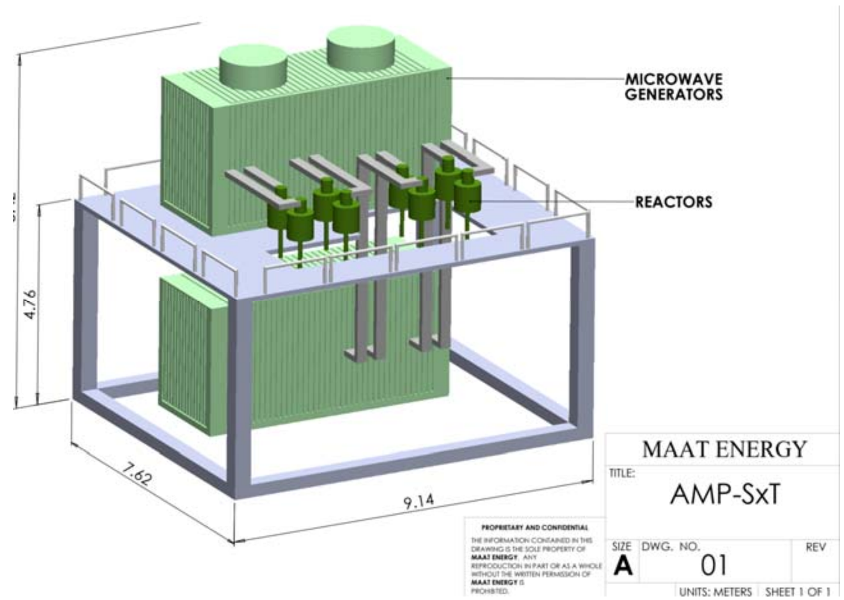
In-situ Probing

Innovative
Reactor Design



Technical Approach/Project Status

- Experimental design:
  - Reactor developed without dielectric
  - Temperature control in atmospheric microwave plasmas
- Achievements
  - 6kW reactor installed and tested with appropriate chemistry
  - Demonstrated igniter for plasma initiation
  - Developed third generation designs for reactor without a dielectric
  - > 90% conversion of methane/CO_2 (super-dry reforming) with > 90% electricity efficiency
- Project schedule
  - Commissioning 100 kW reactor (pilot scale)



Scale up

100 kW unit is pilot scale

To be completed in Phase IIA

No need of further scaling!

To achieve higher power, multiple 100 kW units will be multiplexed

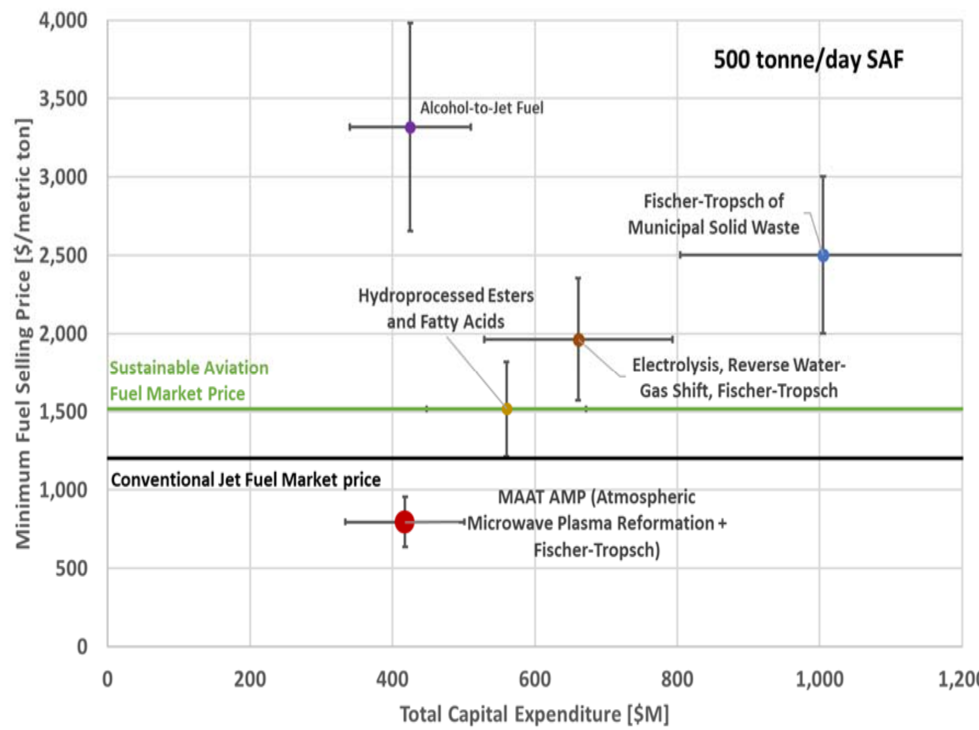
Pilot demonstration performed in Phase IIA

Thermal/chemical integration, reliability, control work will be carried out

Techno-economic Analysis

- Goal: low-carbon jet fuel at a minimum selling price of $625/tonne
  - Teaming with Infra Technology Group, an FT technology developer
  - Cost competitive with present jet-fuel

- Subsidies will make jet fuel more competitive
  - Carbon tax or CO_2 avoidance credit



Next Steps

- In SBIR IIA (carbon monoxide)
  - Demonstrating reforming technology to TRL 6-7 (PILOT scale)
  - Testing total jet-fuel plant (with FT synthesis)
- In SBIR II (Hydrogen)
  - Developing methane pyrolysis for source of hydrogen to provide appropriate H_2:CO ratio for FT
  - Same technology, different chemistry
- Scale-up potential: Multiplexing 100 kW units!

Commercialization Roadmap

2022

Technical demonstrator

- Pilot size at 30kW
- Reproducible performance

2023

Business demonstrator

- Near Commercial Unit 100 kW
- High conversion and efficiency
- Reliable operation

2024

First commercial projects

- 1-2 MWe
- Industrial plant

2025

Multiple commercial projects at industrial scale

- Successful construction and start-up
- Operation at commercial scale

MAAT Energy Company

- Decarbonizing energy with Atmospheric Microwave Plasma

Dr. Leslie Bromberg| CTO, Principal Investigator | MAAT Energy