Novel Plasma Catalysis Reformer of CO_2 for Power to Jet Fuel and Energy Storage

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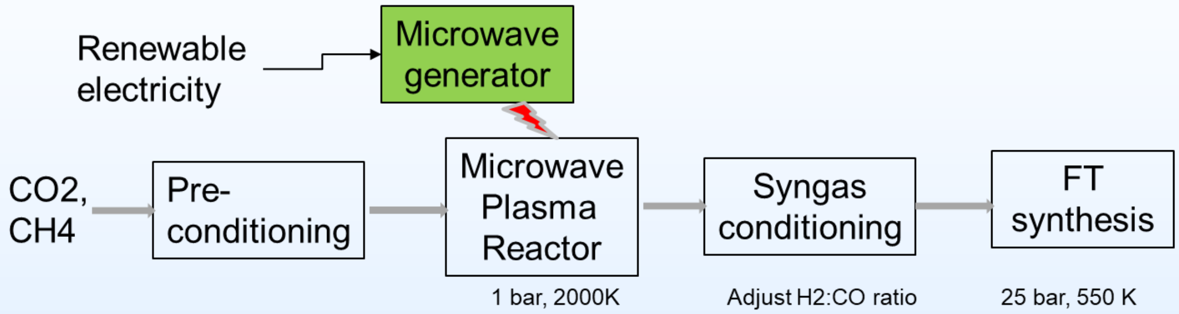
Project Overview

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

Technology Background - 1



a. Non-catalytic processing:
- Mostly a thermal process
- Appropriate temperatures (kinetics adequate at 2000 K)
- Atmospheric Microwave Plasmas (AMP) provide uniform heating

b. Technology spinoff from MIT:
- AMP technology developed at MIT for metal sensing
- Atmospheric plasma reforming also developed at MIT

Technology Background - 2

c. Advantages of technical approach
- Readily available, mass 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 AMP methane pyrolysis

d. Technical and economic challenges
- Present AMP 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
- Jet-fuel manufacturer

Technical Approach/Project Scope

a. Experimental design:
- Developed AMP without dielectric
- Temperature control in atmospheric microwave plasmas

b. Project schedule
- AMP testing with appropriate chemistry
- 1 kW successfully tested
- 6 kW in preparation, ultimately going to 100 kW (pilot scale)

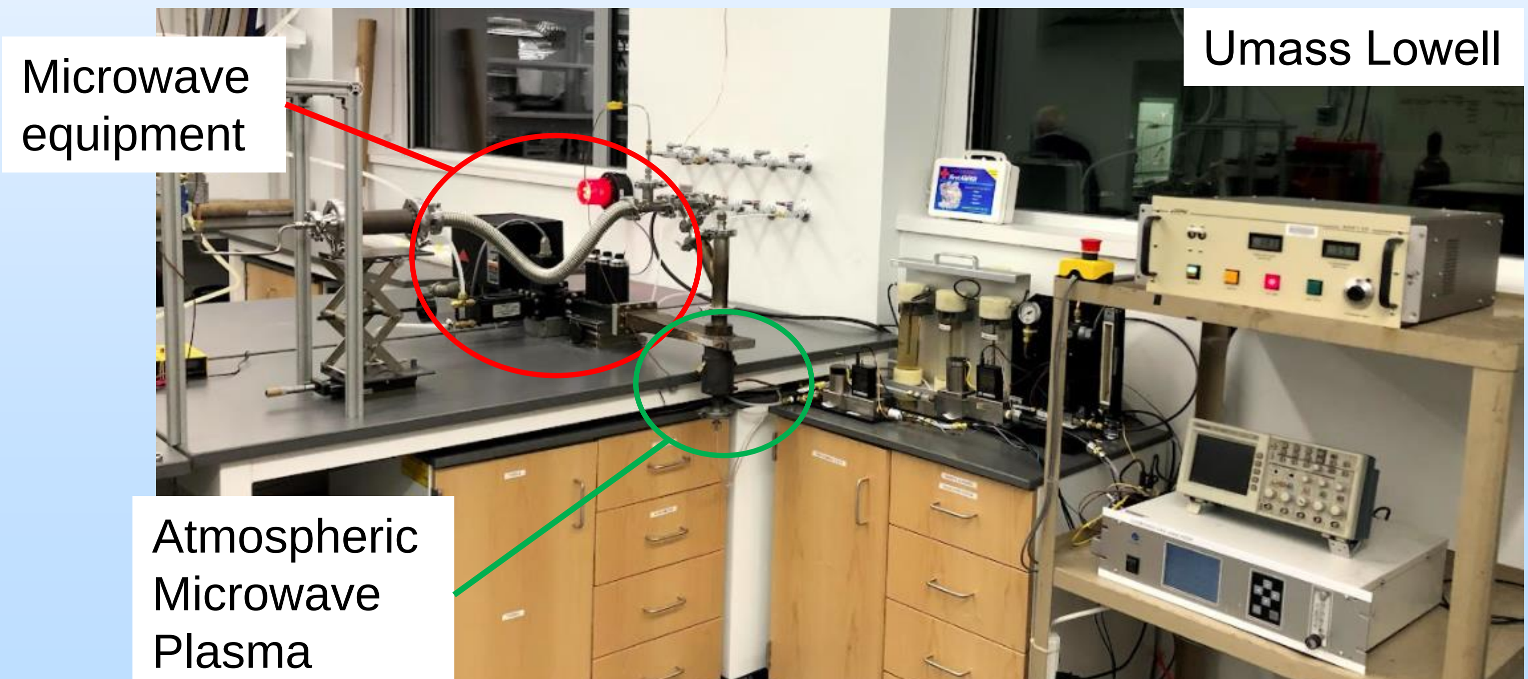
c. Project success criteria
- > 90% conversion of methane/CO_2 (super-dry reforming) with > 90% electricity efficiency

d. Project risks and mitigation strategies:
- Developed two designs for reactor without a dielectric

Progress and Current Project Status

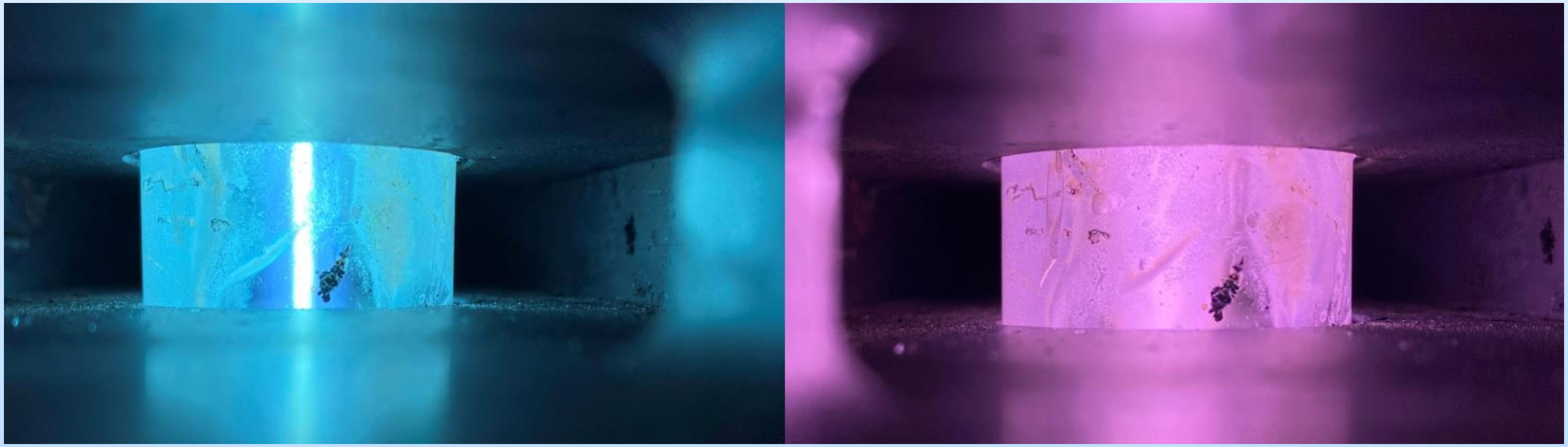
Built 1 and 2.5 kW system

- Most testing in 1 kW system
- Increased throughput by temperature control



Laboratory

- Moving to separate laboratory for higher power testing (Cambridge)
  - 6 kW (being installed)
  - 100 kW (being acquired)

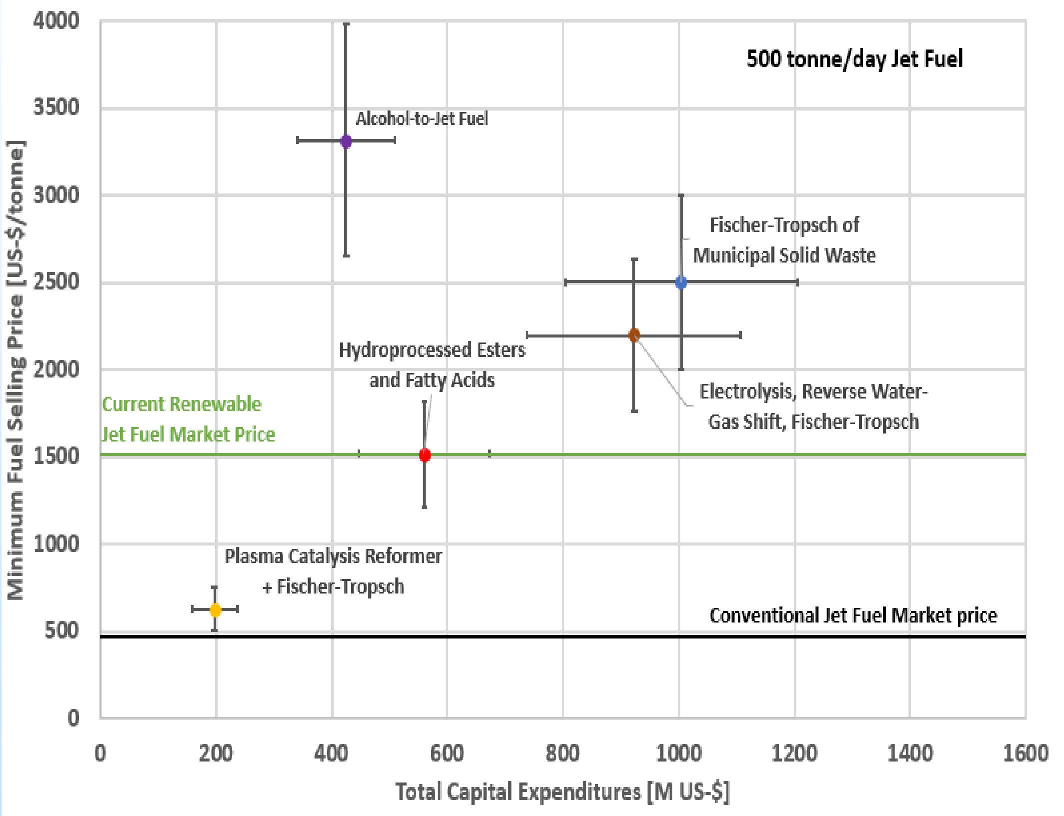


Achievements

- Demonstrated at 1 kW:
  - Electrical energy efficiency of > 60% demonstrated
  - 99% CH_4 conversion efficiency with super-dry reforming
- Demonstration of operation at lower temperatures
  - Temperatures difficult to measure; but:
  - Throughput increased by a factor of 2, enabled by lower plasma temperatures
- Developed two reactors without dielectric
- Testing automatic igniters for plasma initiation

TEA

- 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



Scale up

- 100 kW unit is PILOT scale
  – To be completed in Phase II
  – No need of further scaling!
- To achieve higher power, multiple 100 kW units will be multiplexed
- Pilot demonstration not performed in Phase II
  – Thermal/chemical integration, reliability, control work will be needed for a DEMO

Scaling up by multiplexing
8-10 units in one container
(1 MW)

Future testing/development/ commercialization

a. In this project
   - Demonstrating reforming technology to TRL 5-6 (PILOT scale)
   - Investigate total jet-fuel plant (with FT synthesis)

b. After this project
   a. Need source of hydrogen to provide appropriate H_2:CO ratio for FT
   b. Investigating (DOE and internally funded) methane pyrolysis by AMP
      - Same technology, different chemistry

c. Scale-up potential: Multiplexing 100 kW units!

AMP - Summary Slide

a. Atmospheric pressure plasmas are an attractive means of using electricity for converting CO_2 and methane into CO
   - Low carbon intensity (¼ lower than methane), making jet fuel with ¼ of the carbon intensity of conventional fuel
   - Efficient, high methane conversion
   - Easily scalable to practical commercial units (demonstrated in Phase II)

b. Need additional hydrogen for the process
   - Use same technology (AMP) for methane pyrolysis

c. Cost of jet-fuel around the same as present day jet fuel, much less expensive than low carbon alternative options

Appendix

Organization Chart

FT support and technology provider

<u>InfraTech</u>

Jack Haynie

LCA support

<u>Argonne National Laboratory</u>

Dr. Uisung Lee

Project lead, microwave plasma, business expertise , chemistry, TEA

<u>Maat Energy</u>

Dr. Leslie Bromberg – PI, Chief Technology Officer

CEO. KC Tran – Scientist

Dr. Jorj Owen – Physicist

Dr. Jonathan Whitlow – Chemical Engineer

Support for small scale experiments

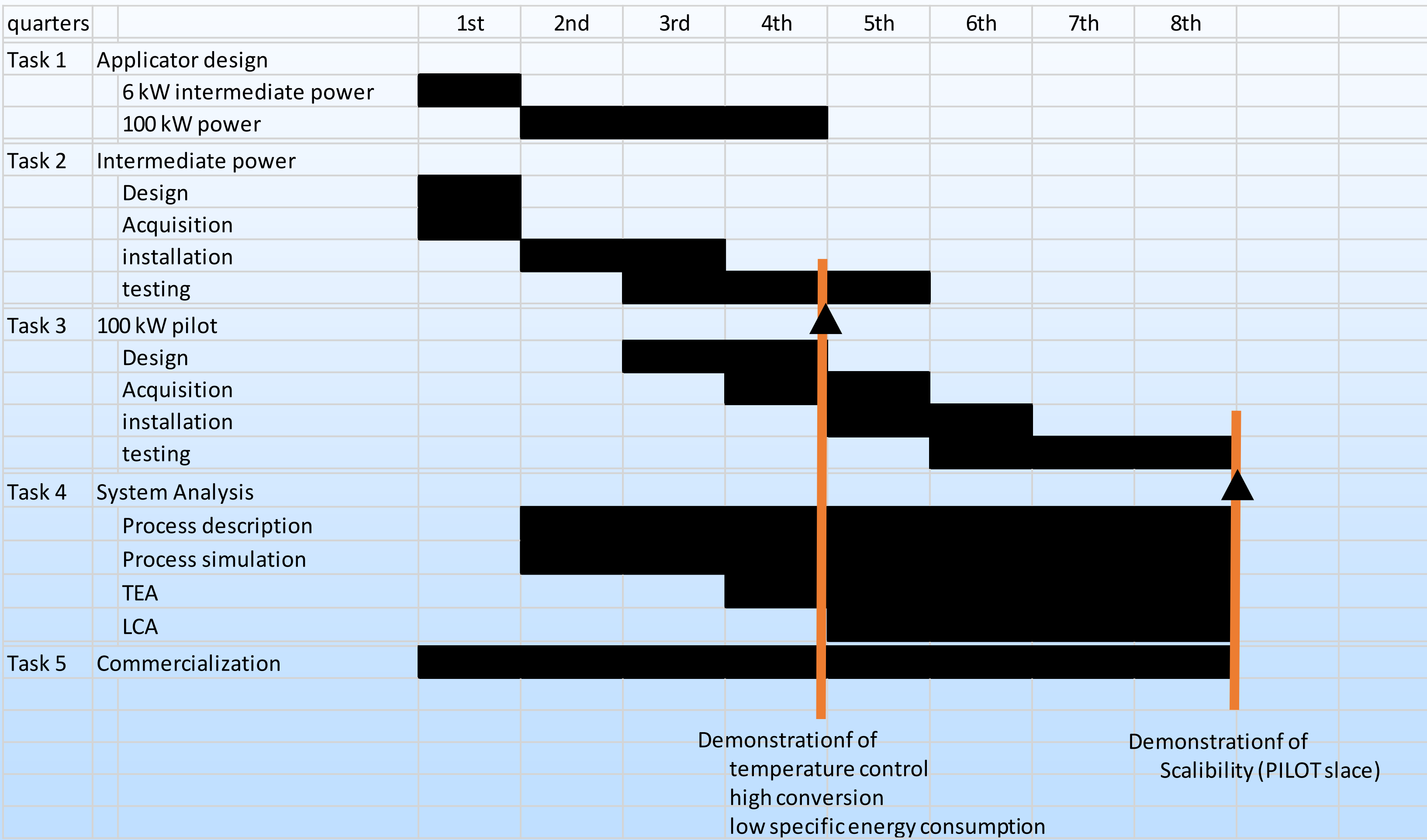
<u>Umass Lowell</u>
Dr. Hunter Mack
Dr. Juan Trelles

TEA support

<u>MIT</u>

Howard Herzog

Gantt Chart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1st
2nd
3rd
4th
5th
6th
7th
8th
Task 1
Applicator design
6 kW intermediate power
100 kW power
Task 2
Intermediate power
Design
Acquisition
installation
testing
Task 3
100 kW pilot
Design
Acquisition
installation
testing
Task 4
System Analysis
Process description
Process simulation
TEA
LCA
Task 5
Commercialization
Demonstrationf of
temperature control
high conversion
low specific energy consumption
Demonstrationf of
Scalibility (PILOT slace)