Methane Mitigation ThermoElectric Generator (MMTEG) Program

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Oil & Natural Gas

2020 Integrated Review Webinar

Program Overview

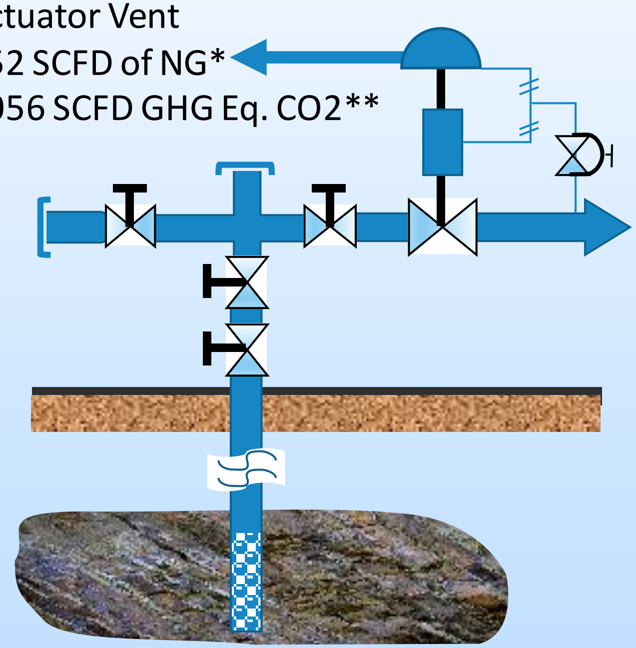
- $1.815M plus $500K cost share
- October 2016 to December 2020
- Project Participants
  - GTI, JPL, Morrison Applied Sciences (MAS)
- Overall Project Objectives - Development of Natural Gas (NG) leak mitigation technologies
  - Mitigate leaks from midstream equipment and/or facilities (including pneumatic valves, controllers, and field gathering lines)

Technology Background

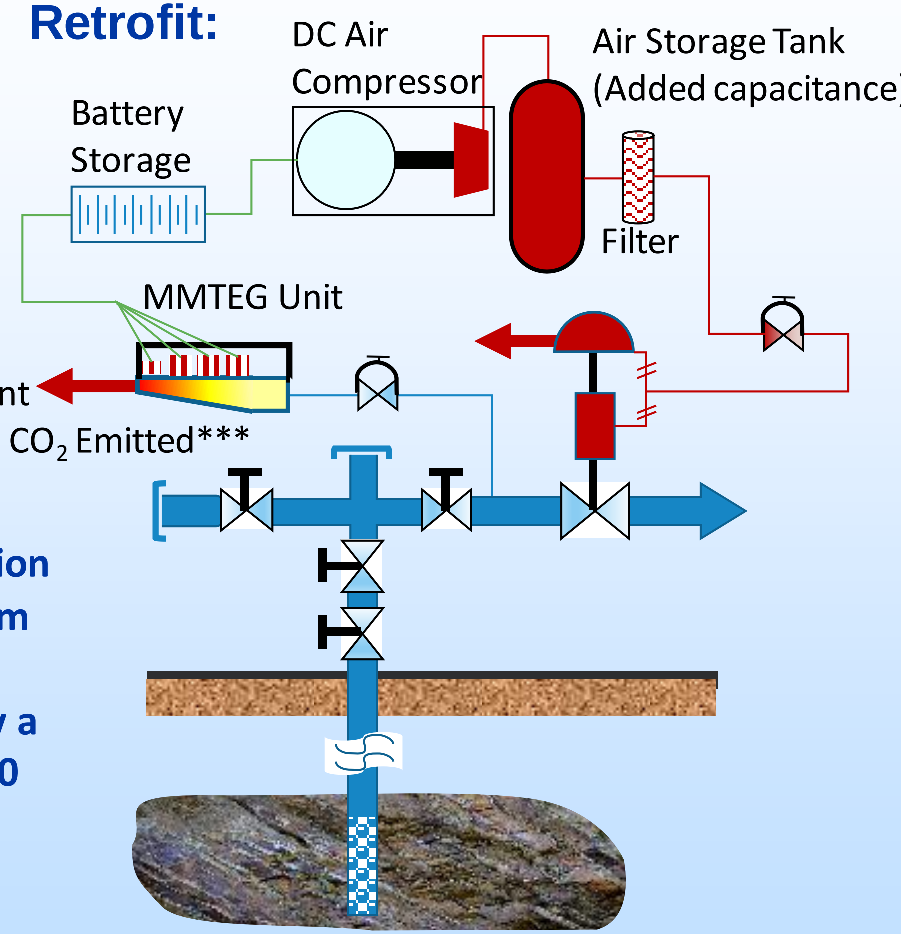
a. 571,000-911,000 tons of methane is emitted through use of pneumatically actuated valves using NG as the working fluid at well site
b. Combust a small fraction of the NG that would have normally been released into the environment to create heat for the thermoelectric generator (TEG) to produce electricity to drive a small air compressor, pressurized air is used as the working fluid to drive the actuator instead of releasing NG to the environment
c. Technology – combustion, thermodynamics, Seebeck effect
d. Previous activity - extensive industry thermoelectric generator development - now many commercially available
e. Advantages:
    a. Recovers 99.5% of NG typically released
    b. Reduces GHG emissions by >99.9%
    c. Less than 2-year payback
f. Key challenges
    a. Meeting cost targets and TEG development

Retrofit Concept to Existing Wellhead Arrangement

Current Systems:



Retrofit:



Implementation of this system reduces emissions by a factor >1000

- Based on Allen, et. al., Measurement of methane emissions at natural gas production sites in the United States, PNAS, Vol. 110, No. 44, pp 17768-17773

** Using GHG intensification factor of 28

*** Assumes 2.27 cycles per day per controller, per conversation with D. Sevier SWN

Technical Approach/Project Scope

a. Approach: Develop and test an integrated thermoelectric generator (TEG)/burner system
   - Design for a field pilot for oil and gas field operations
   - Test in a laboratory setting

b. Key milestones
   a. System Requirements Review – Complete August 2017
   b. System Design Review – Complete February 2020
   c. Integrated Commercial Configuration Burner/TEG testing- Complete June 2020
   d. Passive Burner Test - Complete September 2020
   e. Lab Test – Commercial Configuration Field Pilot System – planned for October 2020
   f. Lab Test – Passive Configuration Field Pilot System – planned for November 2020

Technical Approach/Project Scope

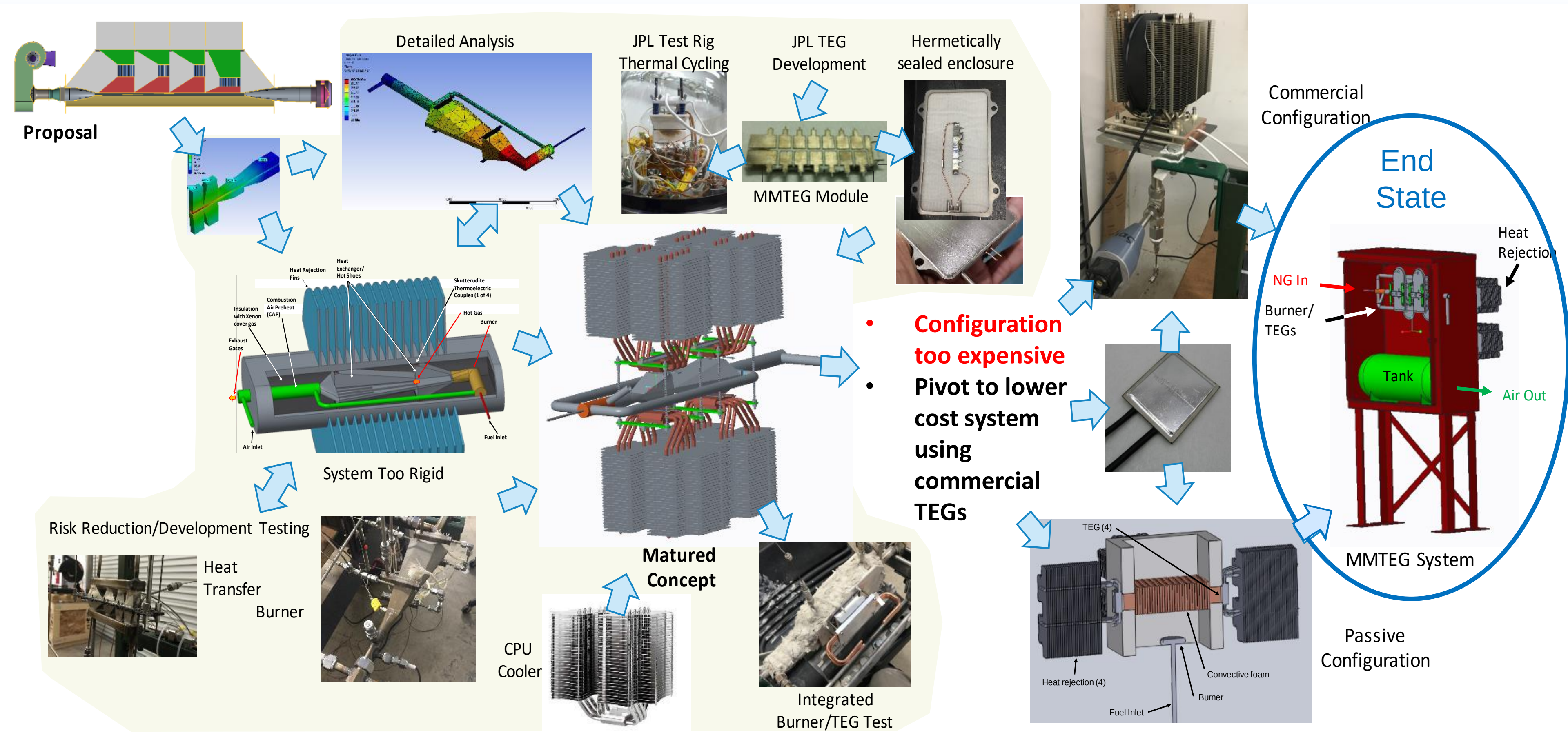
c. Key Objectives/Success Criteria

- Demonstrate the integrated TEG/burner - Complete
- Field system cost target of $1500 for 6 W_e system - Met
- Equivalent greenhouse gas (GHG) reduction of >1000:1 (assuming long term factor) - Met
- Demonstrate a Pilot Field System in laboratory testing – Next step

d. Project Risks and Mitigation Strategies

Risk #	Risk Title/Description	Likelihood	Consequence	Risk Discussion/Mitigation
T1	Forced Draft fan does not provide sufficient pressure head to achieve necessary gas velocities and overcome pressure losses	1	1	Fan provides sufficient pressure drop. Results in minor system performance loss. Passive system has no fan and delivers comparable power.
T2	Fouling or corrosion of the burner/heat exchanger impacts burner operation/performance	3	2	Material selection will reflect the environment/fuel. Define operational constraints (pressure drop, etc.) that require maintenance. No issues in development testing to date.
T3	Do not meet overall system efficiency due to heat rejection, parasitic losses, TEG output, thermal capacitance, etc.	4	1	Losses from TEG hot side temperature, thermal losses, electrical processing and losses will not meet efficiency goal but gas savings goals are met.
T5	Burner operational reliability does not meet requirement	2	2	Fuel-rich core and increased flameholding features demonstrated successfully in test.
C1	System cost target not met for Field Pilot	2	2	A lower cost commercial system has been defined which meets the financial goals.

Progress and Current Status of Project



a. Test equipment used/built in the project

Progress and Current Status of Project (Continued)

b. Significant accomplishments and how they tie to the technology challenges
  - Defined heat transfer coefficients for the heat exchanger
  - Demonstrated the high-performance Burner
  - Demonstrated low-cost heat rejection (CPU coolers)
  - Demonstrated high performance TEGs
  - Completed multiple sets of Integrated Burner /TEG tests with commercial TEGs

c. Performance levels achieved so far when compared to project goals and how the performance relates to the economic and technical advantages

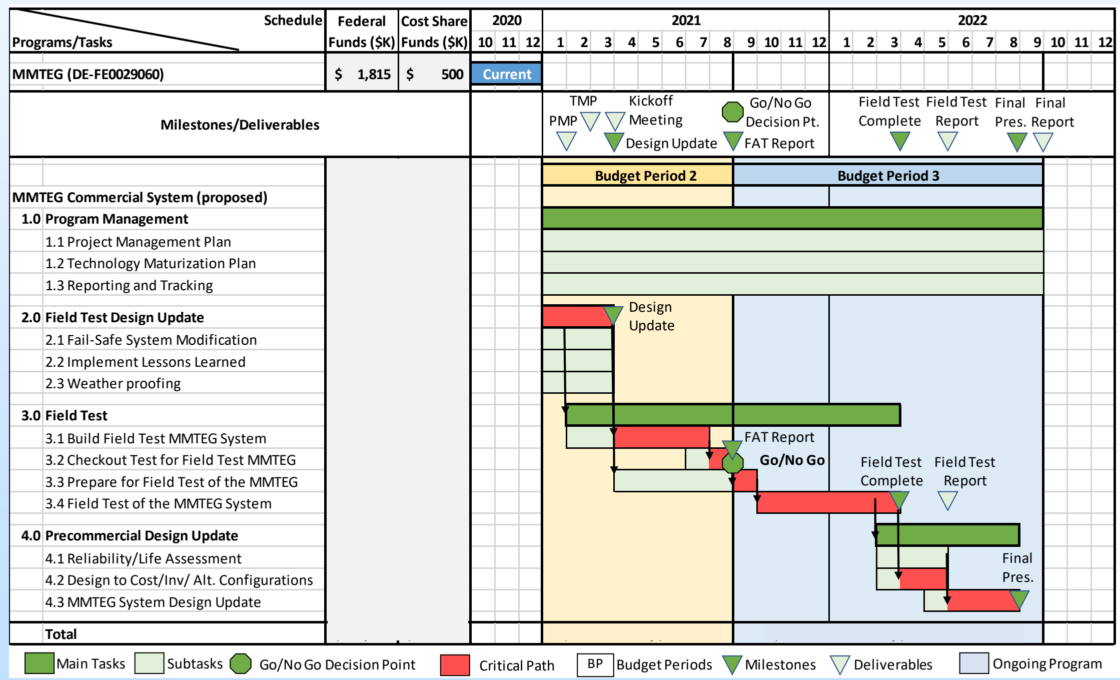
Configuration	TEGs	Stored Wattage (W)	System Efficiency (%)	Run Time to Charge (hrs)	Relative System Cost ($)	MMTEG NG Reduction %	MMTEG GHG Reduction
JPL Design	4 @ JPL TEGs	8.8	2.3%	52.8	4750-6250	99.52%	99.983%
Commercial Design I (HV)	4 @ Marlow 4 W	5.5	1.4%	84.4	1113.22	99.43%	99.980%
Passive	4 @ Marlow 4 W	8	2.1%	58.1	1313.95	99.49%	99.982%

Plans for future testing/development/ commercialization

a. In this project
- Simulate a field test
- Communicating with potential partners

b. After this project
- Follow-on field test
  - Site commitment from partner

c. Scale-up potential
- Modular concept
  - Likely to 100W
- Larger needs a configuration change to be cost effective



Summary

a. Project Summary
- Demonstrated all the key components in test
  - Burner, heat transfer, TEGs, heat rejection, integrated Burner/TEG
- Designed MMTEG System

b. Key findings and lessons learned
- System efficiency less important than unit cost
- Greatly simplified system required to meet cost goals
  - Low payback time

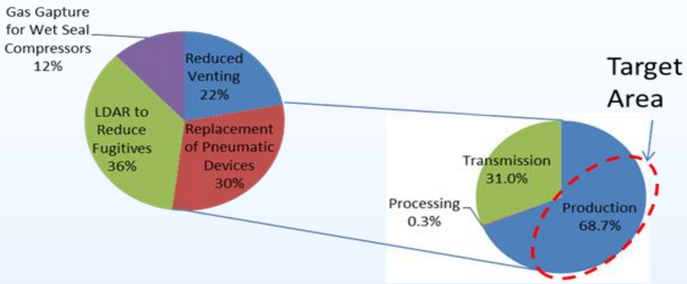
c. Future Plans
- Lab demonstration of the field system
- Propose field test follow-on

Appendix

Problem Statement

MMTEG Reduces Oil Field Emissions

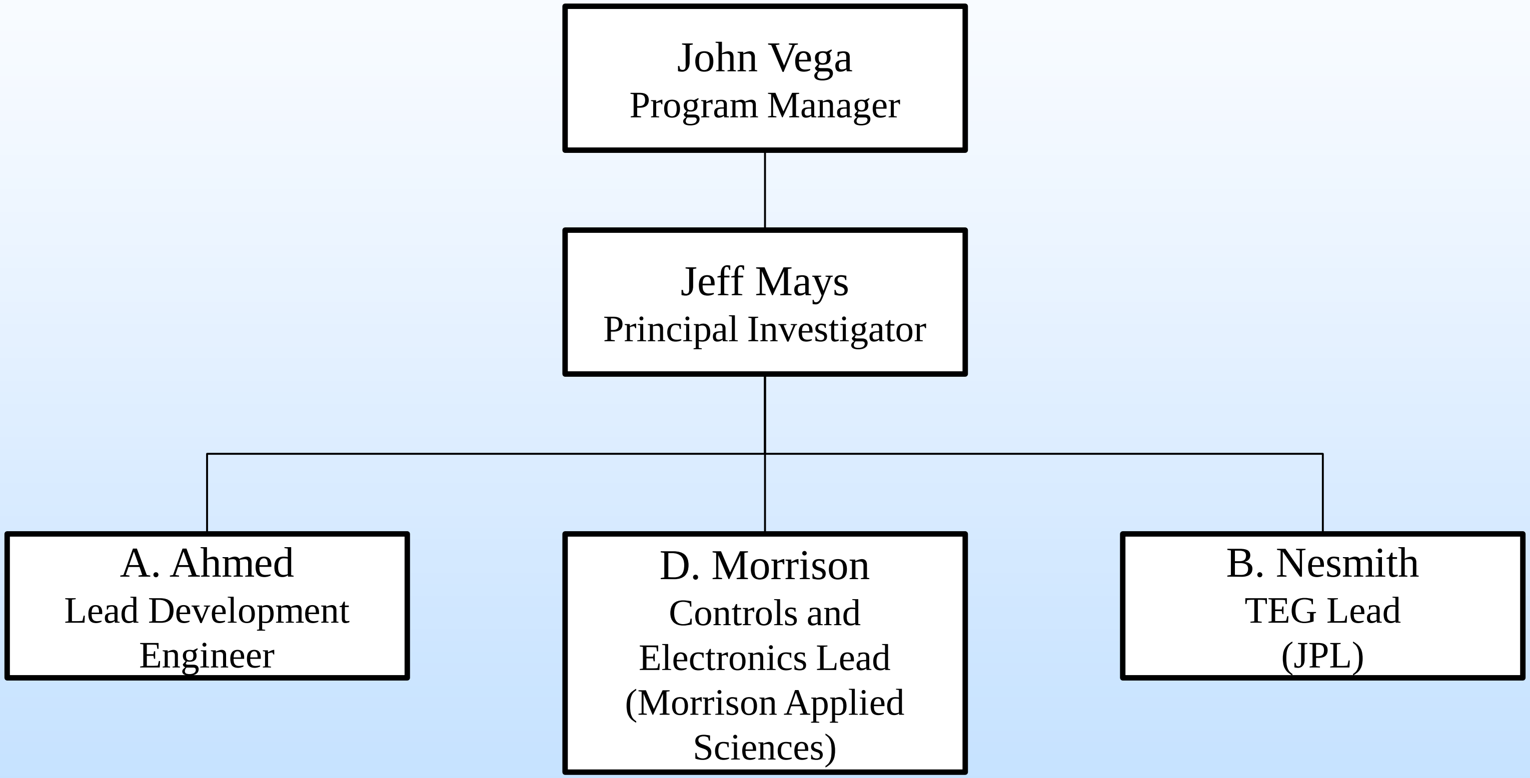
- Gas and oil field operation constitutes one of the more significant sources of greenhouse gas (GHG) emissions
  - Especially methane (CH4) leakage
  - A major gas leakage source is emissions from natural gas operated pneumatic devices



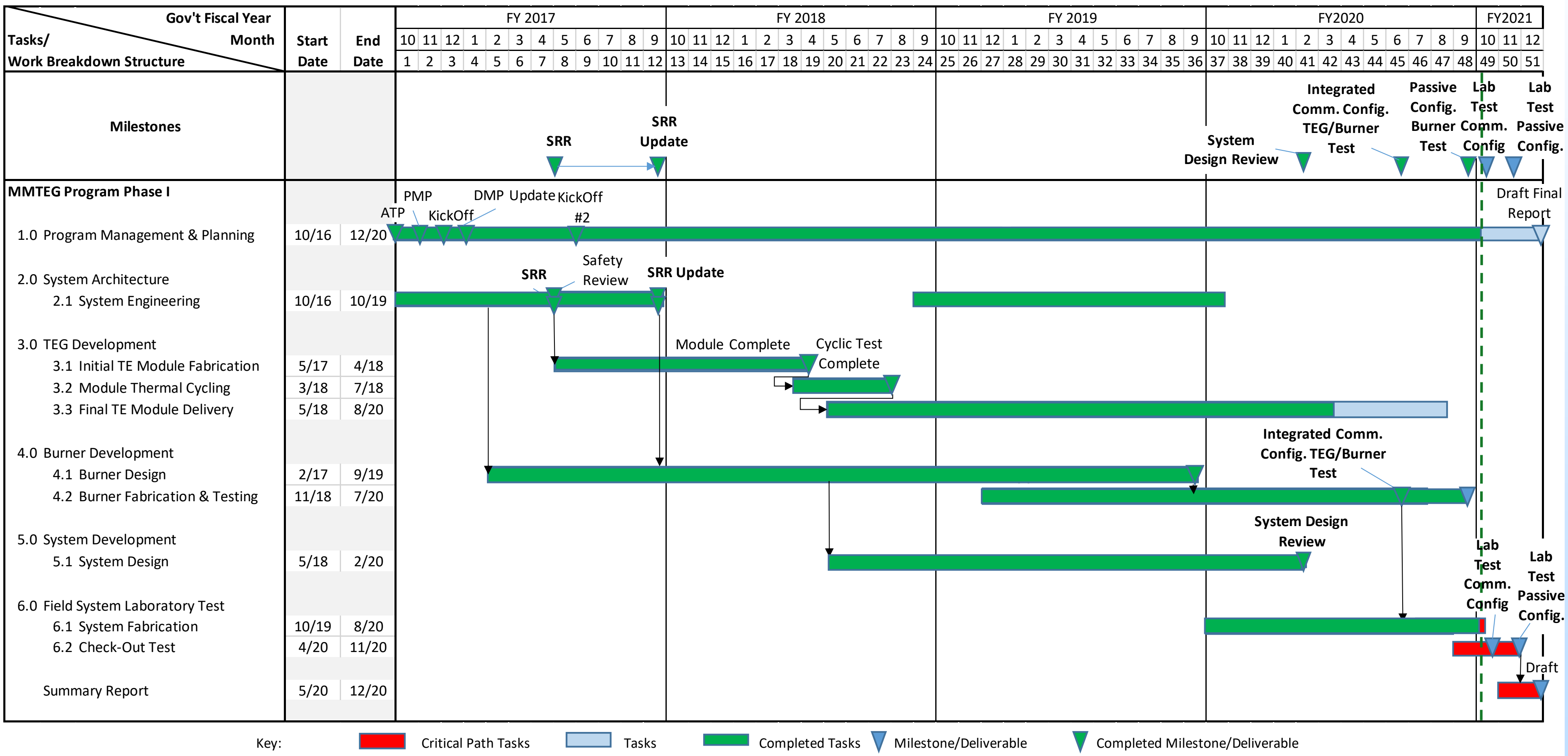
Distribution of Emission Reduction Potential (ICF, 2014)

- Our proposed simple, low-cost, reliable and efficient system is to initiate an economically attractive pathway for reducing the GHG emissions associated with these devices
  - Our effort will culminate in a full-scale integrated system test
- Our system will use a very small fraction of the methane gas that would have normally been released into the environment to power the system
  - The electricity drives a small air compressor that only takes in air and releases air instead of releasing methane gas directly to the environment like many existing actuators

Organization Chart



Gantt Chart


Gov't Fiscal Year
Month
Tasks/
Work Breakdown Structure
Start Date
End Date
FY 2017
FY 2018
FY 2019
FY2020
FY2021
Milestones
SRR
SRR Update
System Design Review
Integrated Comm. Config. TEG/Burner Test
Passive Config. Burner Test
Lab Test Comm. Config
Lab Test Passive Config.
MMTEG Program Phase I
ATP
PMP
KickOff
DMP Update
KickOff #2
Draft Final Report
1.0 Program Management & Planning 10/16 12/20
2.0 System Architecture
2.1 System Engineering 10/16 10/19
Safety Review
3.0 TEG Development
3.1 Initial TE Module Fabrication 5/17 4/18
3.2 Module Thermal Cycling 3/18 7/18
3.3 Final TE Module Delivery 5/18 8/20
Module Complete
Cyclic Test Complete
4.0 Burner Development
4.1 Burner Design 2/17 9/19
4.2 Burner Fabrication & Testing 11/18 7/20
5.0 System Development
5.1 System Design 5/18 2/20
6.0 Field System Laboratory Test
6.1 System Fabrication 10/19 8/20
6.2 Check-Out Test 4/20 11/20
Summary Report 5/20 12/20
Draft
Key:
Critical Path Tasks
Tasks
Completed Tasks
Milestone/Deliverable
Completed Milestone/Deliverable