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IGU

Utilizing Advanced Thermoelectrics to Mitigate Methane Emissions at Remote Locations

Abdelallah Ahmed, Engineer

Gas Technology Institute

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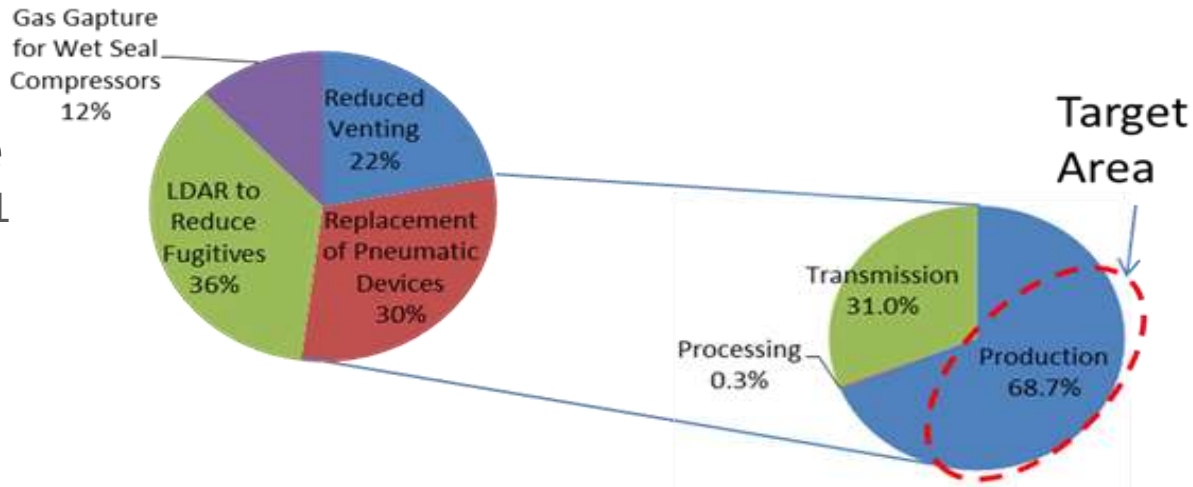
Problem Statement – Reduce Natural Gas

- Natural gas is working fluid for pneumatic actuators
- Results to 518-826 Gg of methane emissions just in the United States[1]
  - $110-175M in lost revenue[2]
  - 14500-23100 Gg of equivalent CO2 emissions
- Natural gas production is expected to increase by 40% within the next 10 years



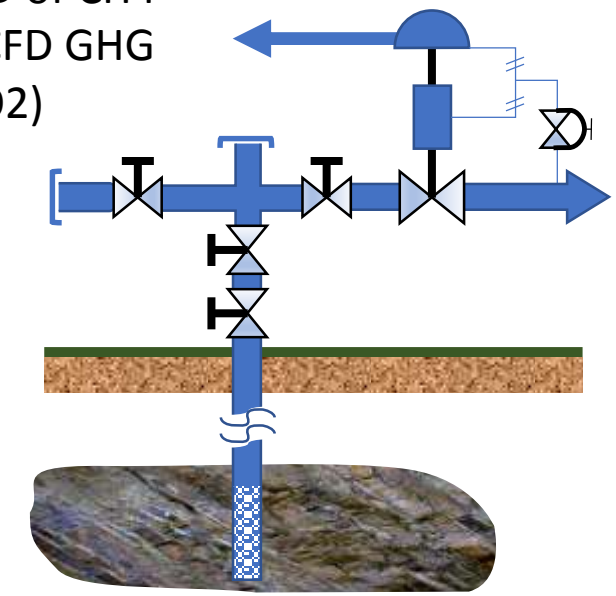
Distribution of Emission Reduction Potential (ICF, 2014)

[1]Allen, D. T. *et al.* Methane emissions from process equipment at natural gas production sites in the United States: Pneumatic controllers. *Environ. Sci. Technol.* **49,** 633–640 (2015).
[2]For natural gas price of $4/MMBtu

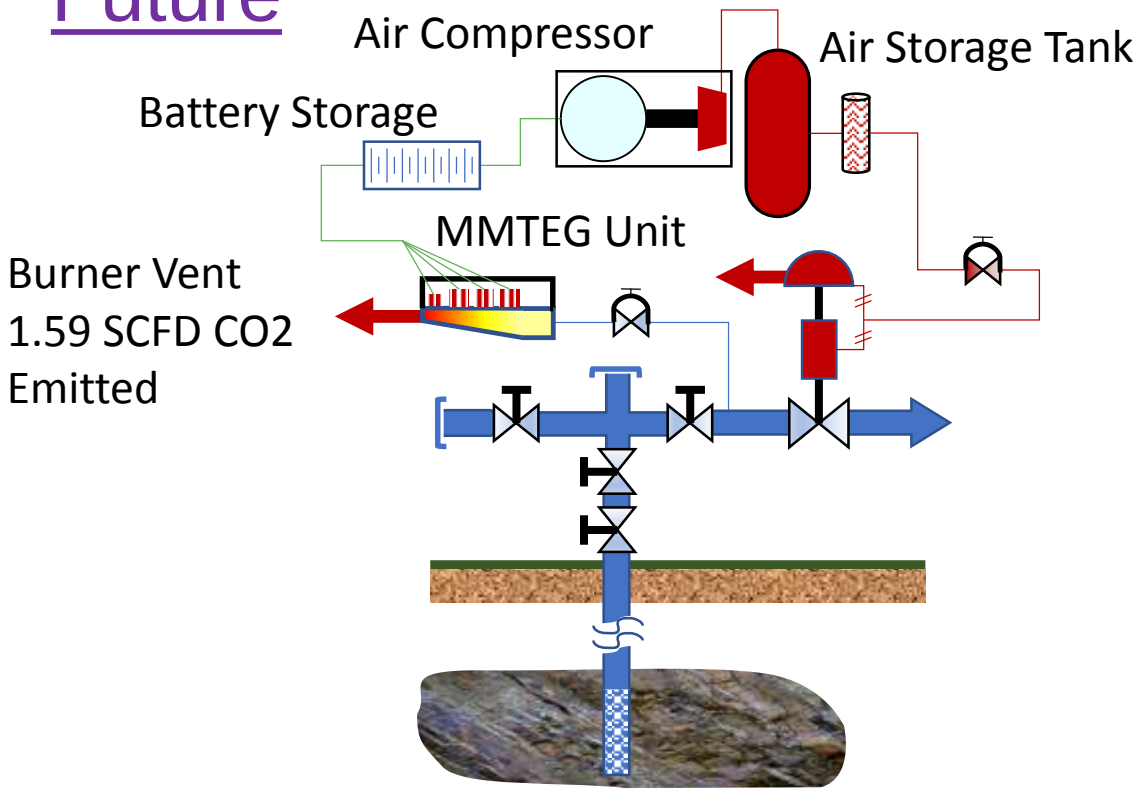
Simple Retrofit to Existing Wellhead Arrangement

Current

Actuator Vent
252 SCFD of CH4
(7056 SCFD GHG
Equiv CO2)

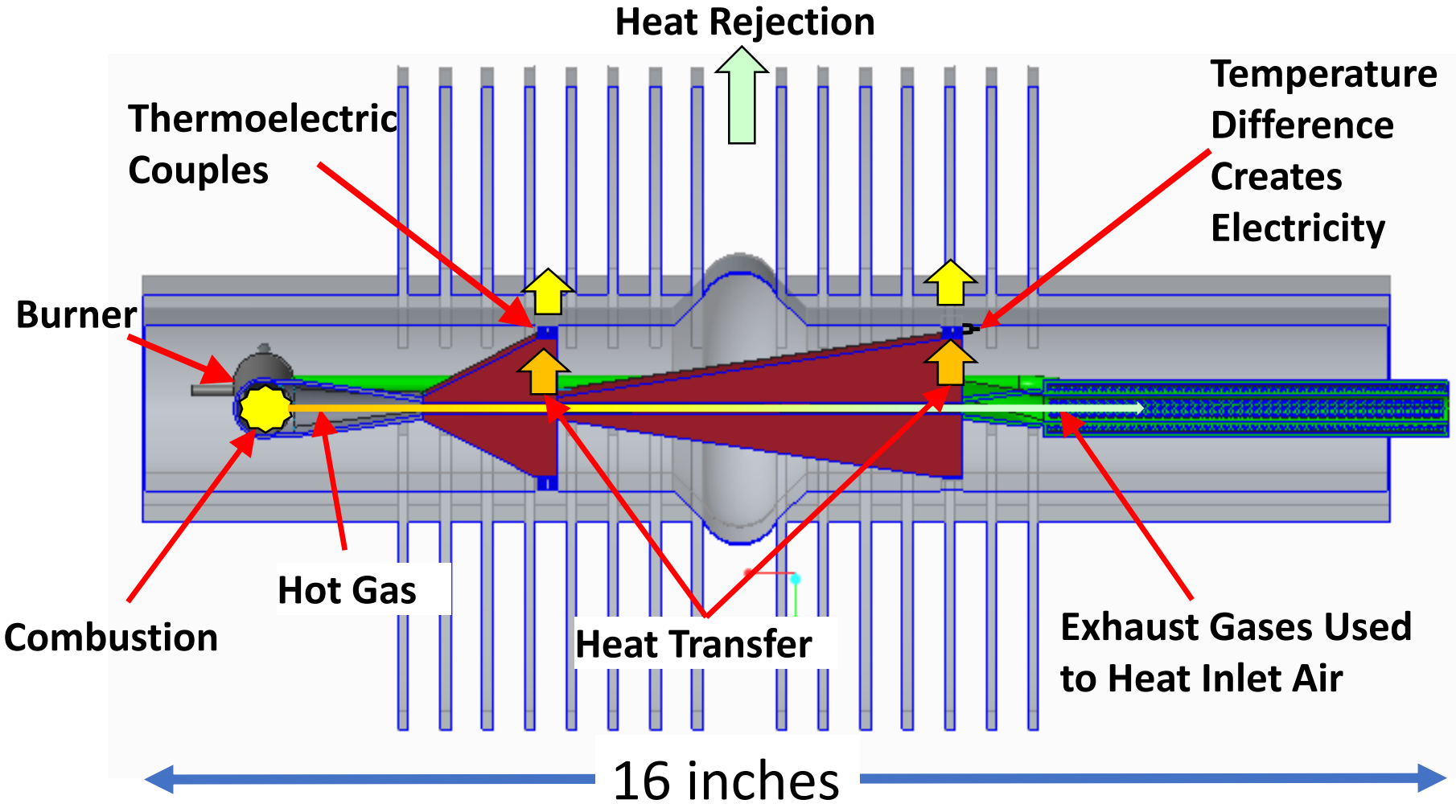


Future



Reduces emissions by 1000X & Increases Revenue

Integrated MMTEG System Utilizes Heat to Create Electricity



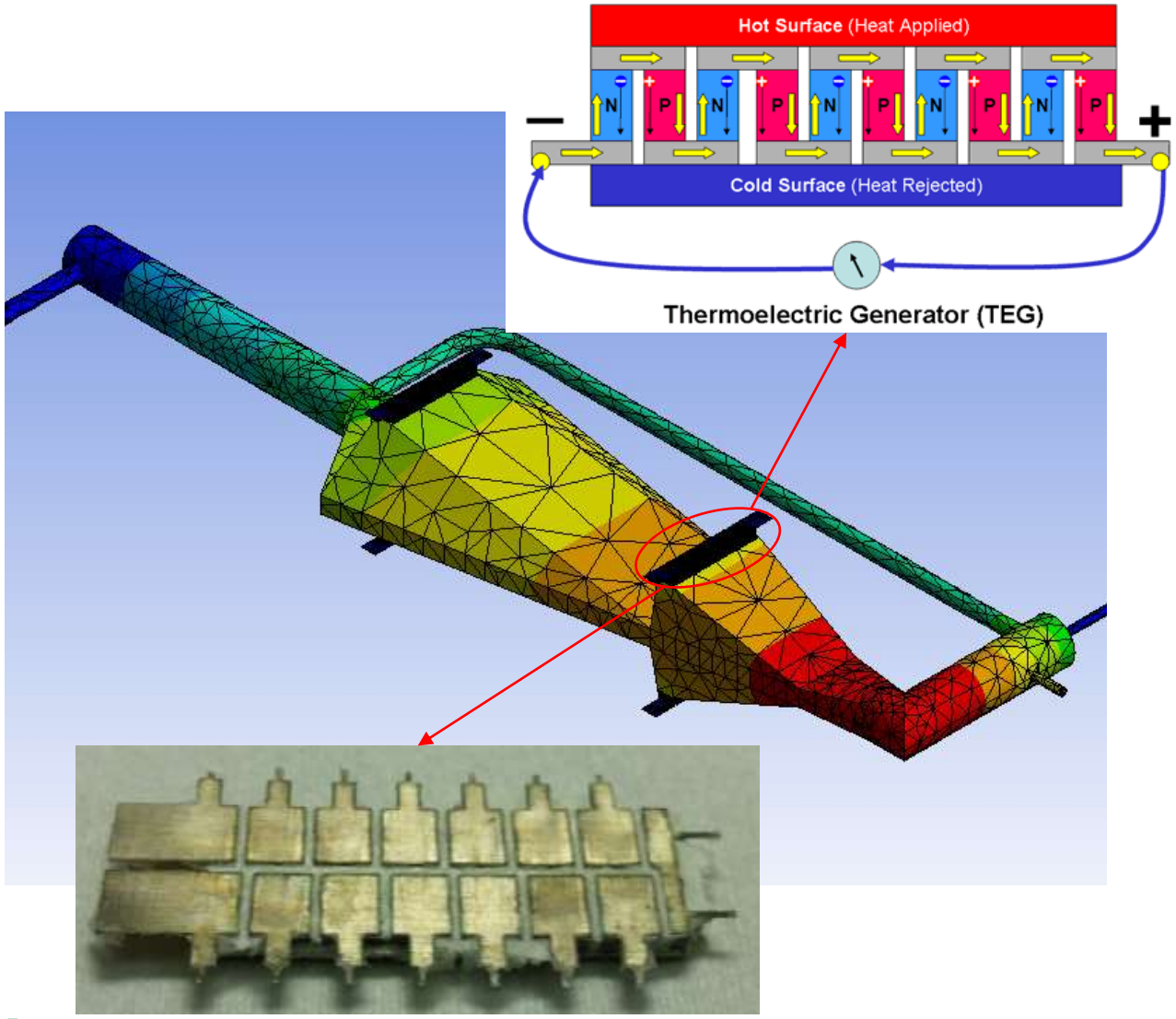
Full System Model

Finite element analysis:

- Performance of the TEG assembly
- Heat flux and temperature
- Heat loss
- Structural integrity

Results Indicate:

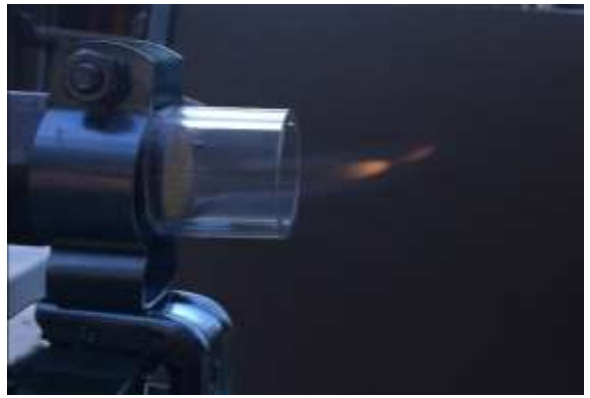
- 24 We produced for 0.025 Kg/hr of NG
- ~4x TEG efficiency vs. SOA
- Exhaust gas heats inlet air – recovers energy



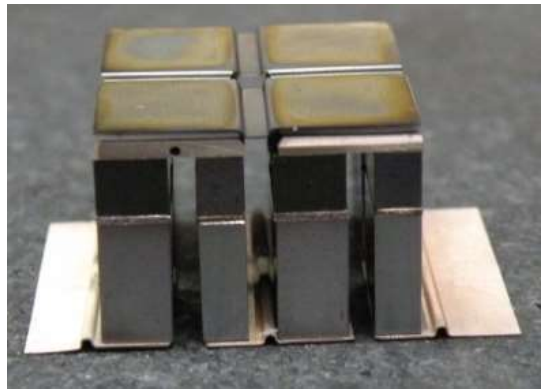
Test Verifications

- Stable burner demonstrated
- Finite element analysis substantiated through testing
- Data confirms heat flux and heat transfer coefficients agree with analytical values
- Temperatures at hot TEG surface allows maximum efficiency

Burner Testing



Heat Transfer Testing



Segmented, High Efficiency TEG Module

Proposed MMTEG Wellhead Field Demo Site

Performance/Economic Targets

	Technology	System Complexity	Reliability/ Maintainability	GHG % Reduced	Recoverable Revenue %	Capital Cost	TRL	Applicability
	Pneumatic Actuator. Methane Working Fluid		Failure & Wear of Intermittent devices	0%	0%	N/A	9	**Current**
	Replace working fluid with Instrument Air (IA) via MMTEG system	Uses existing controls	Air Compressor	99.2%	82.7% (15 month Payoff)	Target <$1.5K	5	**Proposed** **BEST** Lowest Capital Cost and Highest Recoverable Revenue for mature technology
Other Candidate Technologies Evaluated								
A	Replace working fluid with IA via Advanced TEG system	Uses existing controls	Air Compressor	99.8%	83.5% 14 month payback	Target <$1.5K	3	**Not Applicable** – Does not meet TRL requirement and advanced TEG development cost is greater than available Doe Funding
B	Replace Working Fluid with IA via PV Panel	Added controls are solid state	Intermittency, site security issue-theft	100%	13.3%	$3K	9	**Abandoned** by operator due to high incidence of theft
C	Replace working fluid with IA via Bi2Te3 TEG System	<250°C Temp adds complexity	Air Compressor	97.6%	12.8%	3.6K	7	**Not Cost Effective**. Higher capital cost and lower efficiency reduce recoverable revenue.

KEY - Exceeds Requirement - Effort Required to Meet Requirement - Cannot Meet Requirement

MMTEG Most Attractive Option

Summary

- Simple, low-cost and reliable system to eliminate natural gas (NG) emissions from pneumatic control devices
- Efficient, low NOx combustor utilizes minor amount of wellhead NG to produce heat
- High efficiency, segmented thermoelectric modules (600˚C) convert heat to electricity
- Compressor pressurizes air to operate pneumatics vs methane
- Reduces GHG emissions by 99.8% and unlocks recoverable revenue by reducing methane leakage