CARBON CAPTURE, UTILIZATION & STORAGE CONFERENCE

JUNE 14-16, 2016 | SHERATON TYSONS CORNER | TYSONS, VA

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CO_2 as a Fracking Medium for Release of Production of Natural Gas/Oil

On-Site Generation of CO_2 from Waste and Low-Cost Feedstocks for Use in CO_2 Fracking

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Acknowledgements & Disclaimer

This is preliminary analysis that has not gone through peer-review yet.

The authors and Pioneer Energy acknowledge the support of DOE/*RPSEA (Research Partnership to Secure Energy for America)* on the predecessor system R&D.

The authors acknowledge Pioneer Energy for providing access to the pilot plant data and access to technology development. However, the information and opinions disclosed in this presentation represent the views of the authors and do not necessarily reflect the opinions of Pioneer Energy or its management.

The authors acknowledge David Dzombak, Greg Lowry, and Paulina Jaramillo at Carnegie Mellon University for assistance in modeling.

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Abstract

What is needed is a system that can provide CO_2 directly to fracking operators at a competitive cost, wherever they may be, without major capital expenditures, in a timely fashion after a decision has been made to undertake fracking. Accordingly, Pioneer has developed and patented in U.S. and Canada a portable system that can be transported by trailer to the site of an oil or gas field. The system can be used to generate high-purity CO_2 and electricity from raw field gas on-site of the oil field. The equipment is fully truck portable, and has many additional applications, such as CO_2-EOR. The system is self-powered, so no external utilities are required. Since the system also produces H_2, this can be used to power frack pumps, drilling rigs, or other on-site power needs. The system was originally developed for CO_2-EOR applications, but is being adapted for CO_2 fracking. The process works via a proprietary and patented apparatus, which integrates a portable steam reformer capable of reforming natural gas or biomass (two system designs) into CO_2 and H_2, with a portable separation unit capable of separation of the CO_2 from the H_2. The entire integrated system, capable of generating 200-1,000 mcf/day of CO_2, can fit on a semi-trailer, and a prototype unit in both natural gas and biomass feedstock has been built, in combination with private and DOE (RPSEA) funding. Over 12 patents have been granted, and applications to CO_2 fracking and industry sponsors are being sought for commercial demonstration. This technology also serves as a bridge for CO_2-EOR applications generating industry experience so that economies of scale can be achieved since the technology also allows for portable CO_2 generation on-site of an oil field needing CO_2-EOR. Since CO_2-EOR projects are hampered by high risk and large up-front capital outlays, this incremental portable CO_2-EOR technology opens the door to many small oil fields for CO_2-EOR application. This work analyzes the opportunities for CO_2 fracking using the portable CO_2 generation technology, while also examining it as a bridge to portable CO_2-EOR applications.

Pioneer Energy Background

Founder
- Astronautical engineer
  Dr. Robert Zubrin

Resources
- $30+ million private capital
- $550,000 DOE (RPSEA) grant
- $500,000 Canadian grant
- $2.7M NASA-funded research
- IP portfolio of 30+ issued U.S. patents, 3 in Canada

Product lines
- Field mobile flare gas processing plant
- Field mobile CO_2-EOR systems
- Synthetic fuel technology for butanol and C4+ chemicals/fuels

Team
- 15 engineers, chemists, technicians, and machinists

Partners

McMaster University

CLEMSON UNIVERSITY

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Wasted flare gas is both an economic & environmental problem

North Dakota from Space

Alberta from Space

***In 2014…** only 10% reduction in ND from oil price drop in 2016*

Alberta, Canada flared 1.1 **billion** cubic **meters** per year ……. 39 BCF/yr

North Dakota flared 120 **billion ft³** per year ……………………..120 BCF/yr *[107 BCF/yr in 2016]*

World flared 7 **trillion** ft³ (TCF) per year …………………….... 7,000 BCF/yr

Meanwhile, CO_2 isn't available for fracking!

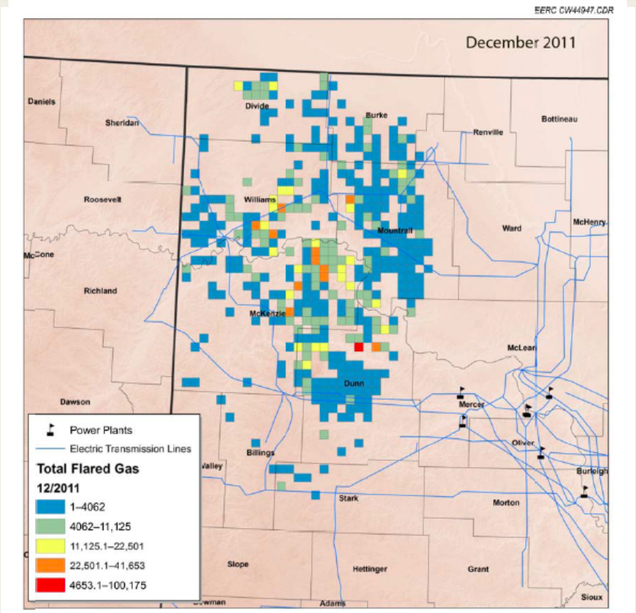
- CO_2 transported by truck is inherently expensive and logistically problematic
- Trucked CO_2 has an average cost of $12/MCF
- Pipeline CO_2 unavailable & impractical for CO_2 fracking
- Even in regions where pipelines exist, these are difficult to access for small volumes needed for fracking

Existing CO_2 pipelines

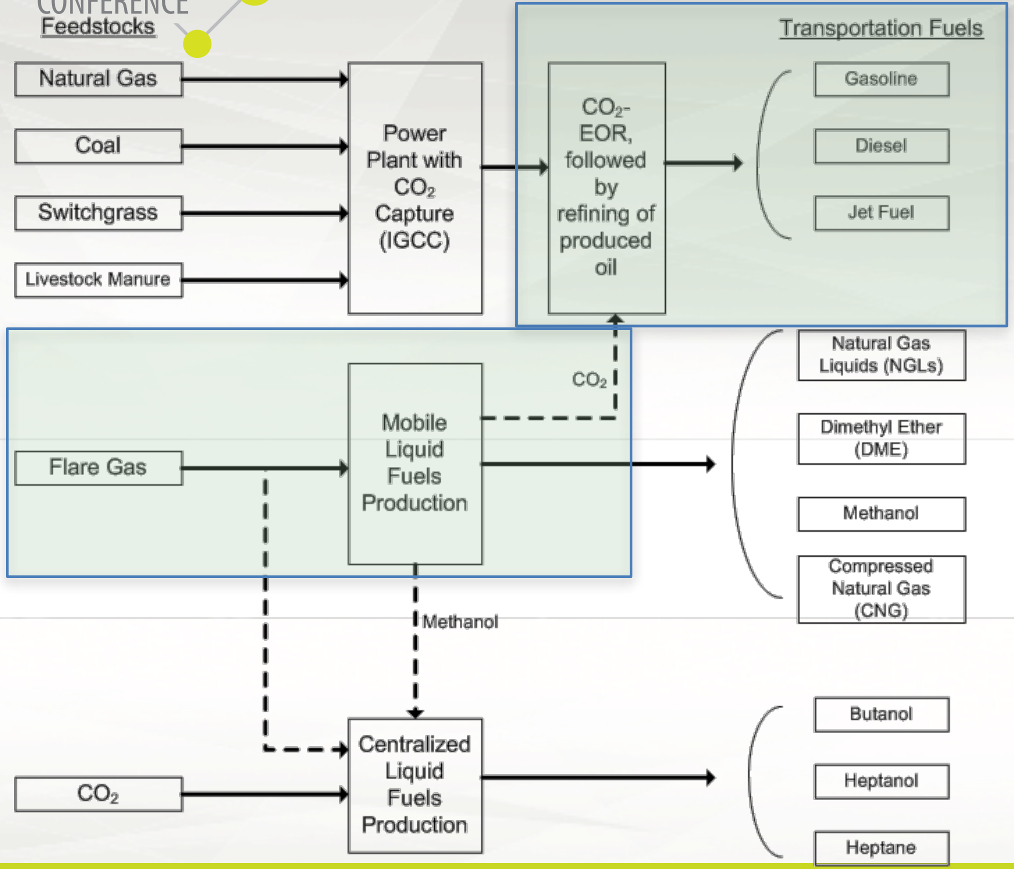
Note: It could take 5-10 years to build a new CO_2 pipeline

…but flare sites are inherently close to fracking operations!

Flare sites in ND



Flare gas as a source of CO_2 for fracking



Solution: Mobile CO_2 Soure for Fracking

Gas

Liquid

Flare gas

Mobile System

H_2 — Used to generate electricity

or

NH_3 — Used to manufacture fertilizer

Methanol — Used as a gasoline blender, additive, or commodity chemical

CO_2 — CO_2 Enhanced Oil Recovery (EOR)

or

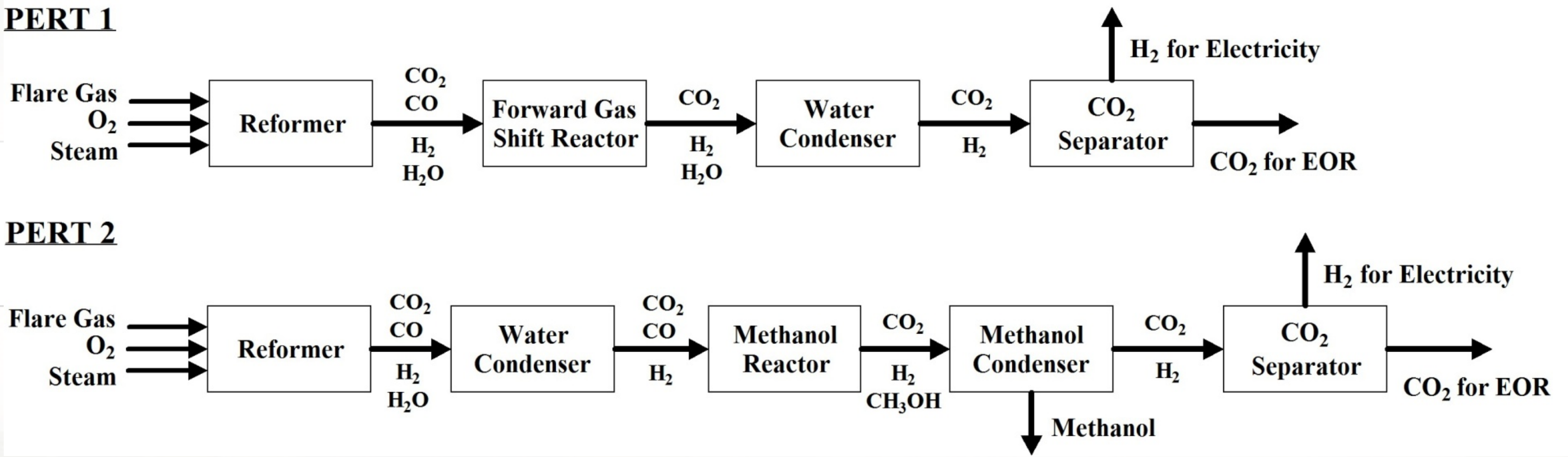
CO_2 Fracking

or

CO_2 Sequestration

Improving System Economics with Methanol Production

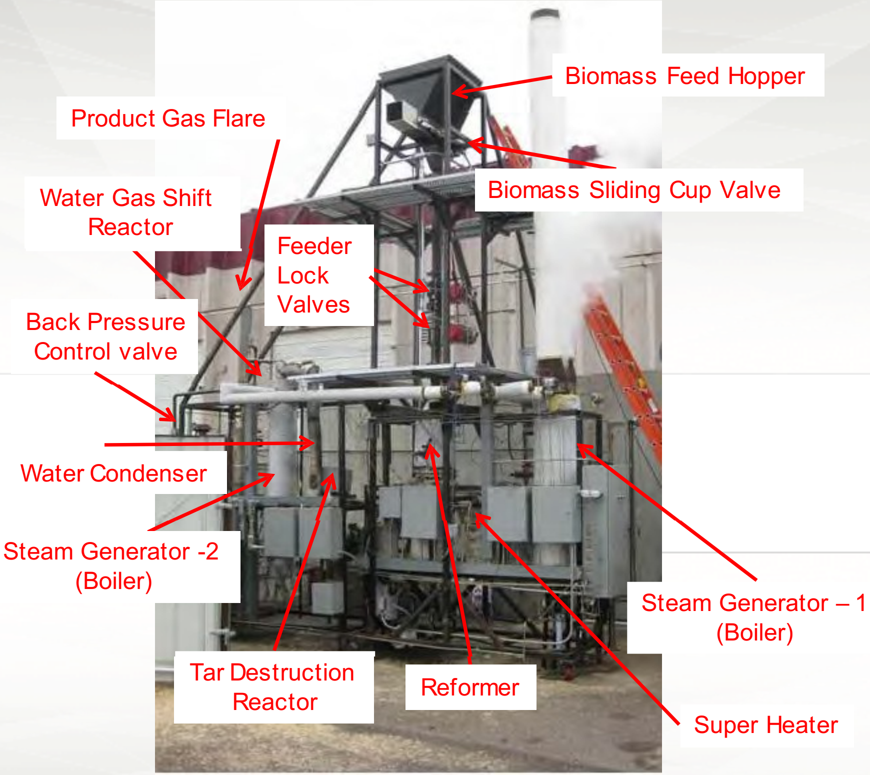
- PERT-2 improves economics by producing methanol from the reformer CO output, without the complexity of a complete methanol system



Experience with Flare Gas Capture/Processing

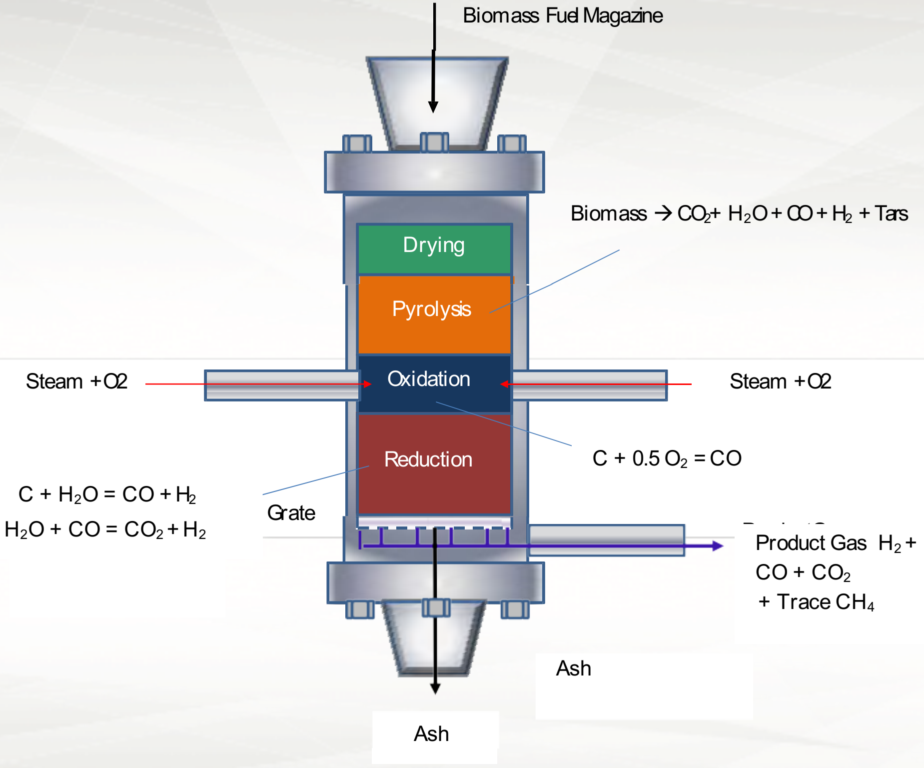
Pioneer Flare gas capture machines, 2 Flarecatchers™ deployed to Bakken flare site, North Dakota, 2015

Alternative Biomass-Fueled Reformer



- Modular assembly
  - Two skids, can be put on a mobile platform for transporting
- System fully instrumented with temperature, pressure, fluid level and flow control sensors, and automated valve control
- Slipstreams for gas analysis
- Built and tested for RPSEA

Alternative Biomass-Fueled Reformer



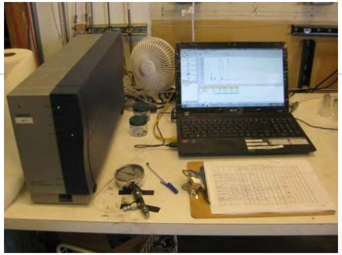
- **Portable Renewable Energy System for Enhanced Oil Recovery**
  - **Modular, truck portable biomass steam reformer**
    - **$C + 0.5\ O_2 = CO$**
    - **$C + H_2O = CO_2 + H_2$**
    - **$CO + H_2O = CO_2 + H_2$**
  - **Simultaneous generation of**
    - **CO_2 for on-site well flooding**
    - **H_2 for carbon-free electrical power for local use/grid**
- **Design for 1 MMCF/Day CO_2 (to recover ~100 bbl oil/day)**
- **Based on the legacy of downdraft biomass gasifiers**

Alternative Biomass-Fueled Reformer

Continuous Feed System

Pneumatic Conveyance System

Continuous On-line GC Station



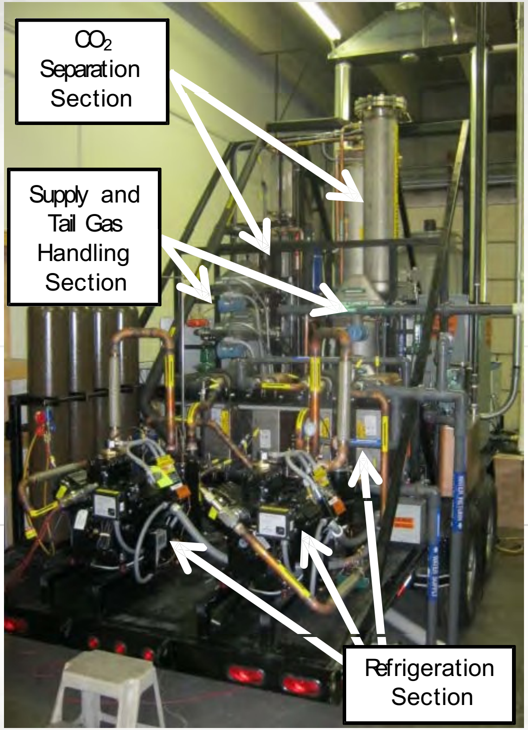
Fuels Tested: Charcoal & Pine Wood Pellets

Lump Charcoal Dimensions: Variable, < 4 cm L

Pine Wood Pellets Dimensions: ~0.6 cm dia. X 2 cm L

Proximate Analysis (As Received)	Charcoal	Pine Wood Pellets
Moisture Content, wt. %	3.54	6.20
Ash Content, wt. %	3.91	0.58
Volatile Matter, wt. %	30.38	76.94
Fixed Carbon, wt. %	62.17	16.28
Total	100.0	100.0
Ultimate Analysis (As Received)		
H		5.39
C		50.50
N		0.25
S		.07
O		37.01
Ash, wt%		0.58
Total		100.00
Heating Value (daf, Btu/lb)		8531

Portable CO_2 – H_2 Separator



- Methanol Temperature-Swing Separation System developed internally by Pioneer Energy
- 180 MCF/day scale for RPSEA
- Successfully operated to recover >92% of CO_2 from 25% CO_2 feed (output of the reformer)
- Became the basis for the Flarecatcher™ flare gas capture system deployed to the Bakken

Role of Mobile CO_2 Fracking in CCS Challenge

Mobile CO_2 fracking enables the CO_2-EOR "bridge"

- Pipeline construction costs >$100M and takes years to permit and construct
- Small scale demonstration projects and pilots solve "chicken-and-egg" problem
- CO_2 Fracking operations will develop CO_2 handling infrastructure
- Early experience with CO_2 handling will drive costs down through "learning by doing"

Small Scale CO2 Fracking & Injection Projects using Mobile CO_2 Machines

More Widespread Utilization of CO_2 for EOR & CCS

Source: Adapted from Robert Ferguson, et al., Advanced Resources International, 8th Annual CCS Conference, Pittsburgh, PA, 2009.

Mobile CO_2 solves key market barrier for EOR

Study conducted on CO_2-EOR in Alberta found that:

- Most oil fields cannot achieve financially viable CO_2-EOR production because "**currently, CO_2 supply cost (capture and transportation infrastructure) is too high in Alberta.**"

- "By far the bulk of the CO_2 waste streams are dilute CO_2 from combustion and cost in the range of $100/ton **($5.39/mcf)** for capture (including dehydration and compression)."

- "CO_2-EOR projects, on the other can nominally afford CO_2 in the range of $20 to $40/ton **(~$1 to $2/mcf)** depending on the reservoir."

- **Mobile CO_2 can achieved <$2/mcf CO_2**

Source: Gunter, B., Longworth, H., *Overcoming the barriers to commercial CO_2-EOR in Alberta, Canada*, AIEES, May **2013**.

Concluding Remarks

- **We put carbon that would otherwise be released as CO_2 from flare gas or wasted biomass to use as a waterless fracking fluid, and later for CO_2-EOR and/or sequestration**
- **In the process, we also produce:**
  - **Valuable liquid fuels (methanol)**
  - **On-site emission-free electricity, displacing diesel**

- **Mobile CO_2 enables:**
  - CO_2 fracking utilizing methane, biomass, or coal as feedstocks
  - Pilot EOR projects before building a CO_2 pipeline (subject of another CCUS talk)
  - EOR in small and medium-sized fields, and in fields that are far from CO_2 pipelines

Topics for Discussion

- Breakeven CO_2 cost for CO_2 fracking
- How to store produced CO_2 on-site between the time of production to the time of utilization for fracking? Surface tanks? Underground?
- What feedstock is most feasible? Raw natural gas? Biomass? Coal?
- Any questions on the mobile CO_2 machine?
- **Any potential partners for design/pilot discussions/investment?**