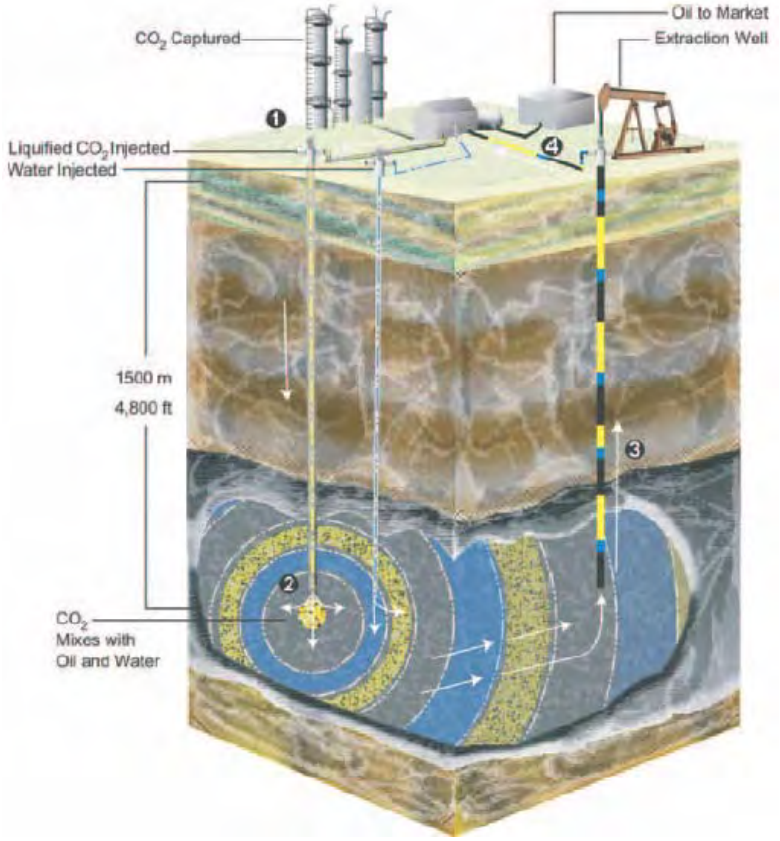
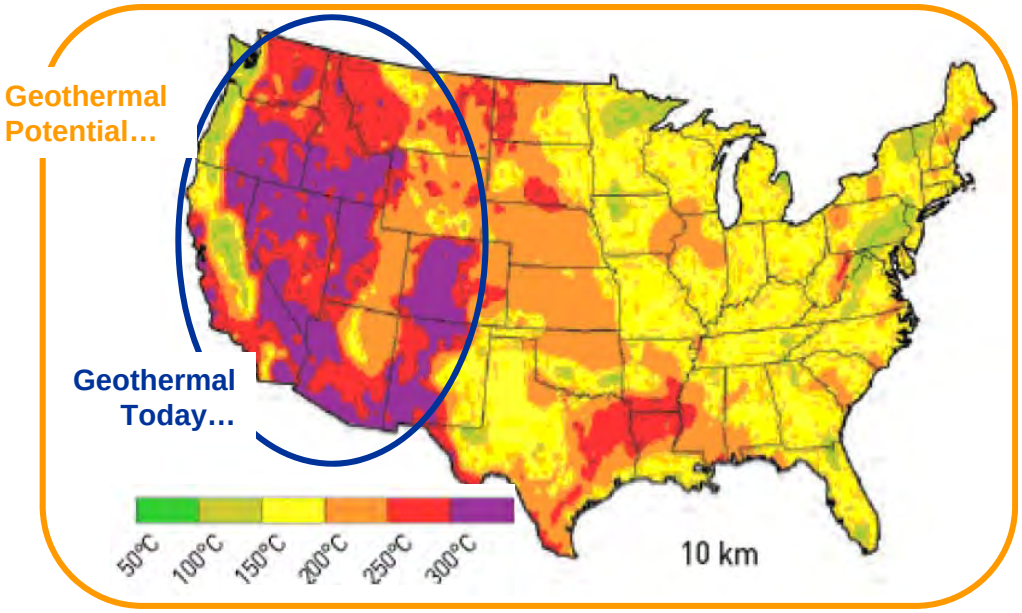
EEG

CO2 Generation for EOR and EGS



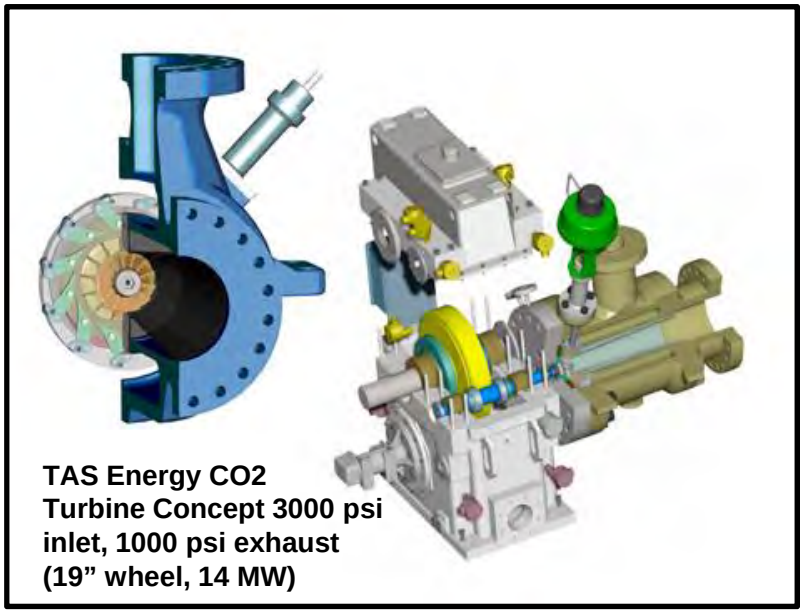


Paul Dunn, CTO
Rick Mobley, CEO
Enhanced Energy Group LLC

It's Good to Be Back…

- 50 MW DOE Geothermal Analysis effort final report now published, major findings:
  - 2-3X improvement in cycle efficiency of CO2 EGS over water EGS
  - 50% reduction in machinery cost using direct expansion of CO2 thermal siphon for power generation vs. Organic Rankine Cycle
  - Substantial reduction in number of wells, size of reservoir, and drilling cost

- Two main issues:
  - CO2 / water corrosion
  - CO2 cost



TAS Energy CO2 Turbine Concept 3000 psi inlet, 1000 psi exhaust (19" wheel, 14 MW)

Refresher… EGS Working Fluid: High Pressure Water or Carbon Dioxide?

High Pressure Water

- Well understood
- Reacts with bedrock
  - Direct use of steam problematic
- Mobility low and pressure drop high at depth
  - Viscosity / Density not favorable
- Very high pumping power
  - Could be ~40% of gross power
- High specific heat
- Temperature loss up-hole can be low (heat transfer driven)
- Cheap (working fluid price)
  - At least locally

Super Critical Carbon Dioxide

- Not as well understood
- Reacts with bedrock, but for the most part favorably
  - After development, direct use of working fluid in machinery may be possible
- Mobility higher and pressure drop lower than water at depth
  - Viscosity / Density favorable
- "Negative" pumping power
  - Strong thermal siphon
- Lower specific heat than water
  - But more than compensated by flow rate
- Temperature loss up-hole more complex
  - Think isentropic expansion
- "Lost" CO2 in the process is sequestered in deep rock (carbonates)
  - And that by itself is good
- Very high purchase price
  - And carbon credits are currently trading at low values

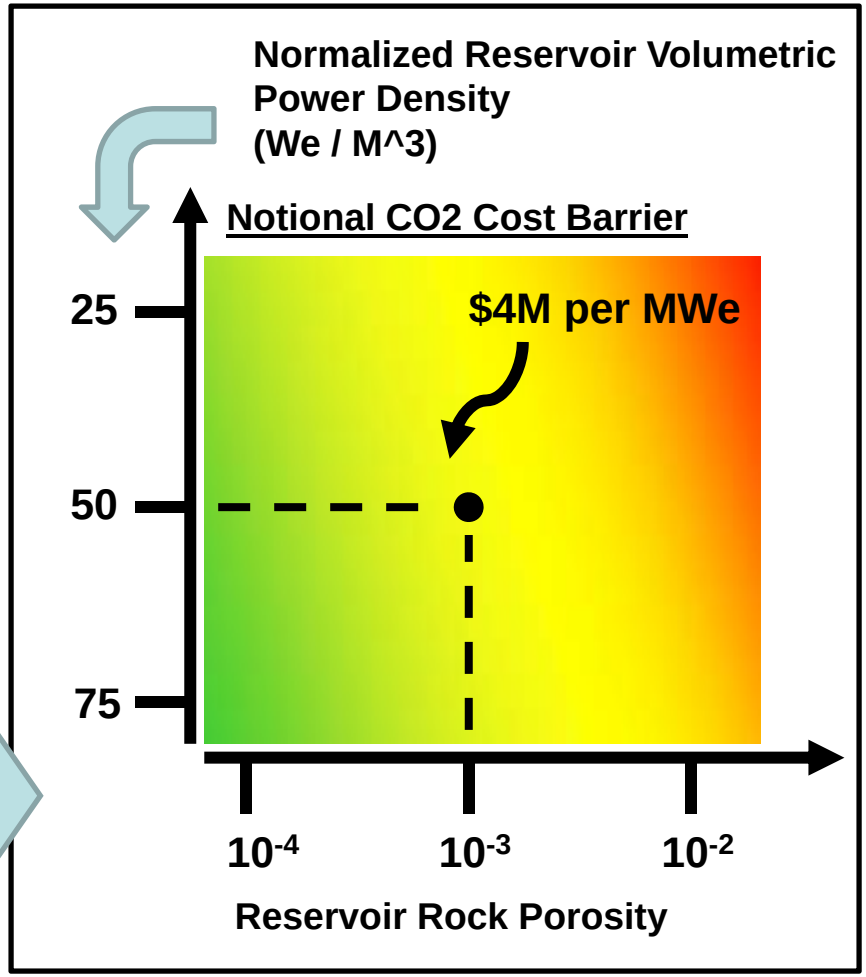
In CO2 vs. Water EGS, the yellows and greens are interesting, but the big issues are the huge cycle efficiency advantage for CO2 (confirmed by analysis), and the barrier, with a big "B", created by the purchase price of CO2

CO2 EGS Issues

The well cost is dominant, and 50-70+% of it is the casing and cement

- Complete dry out of a CO2 EGS would probably never occur, and the combination of water and CO2 makes carbonic acid
  - Stainless casing too costly
  - Fiberglass lined casing a potential solution

- CO2 in the quantities required is the bigger problem
  - Not just because the price to purchase it was high
  - The risk to the developer is a bigger deal, small errors in the understanding of reservoir properties could massively change the amount required



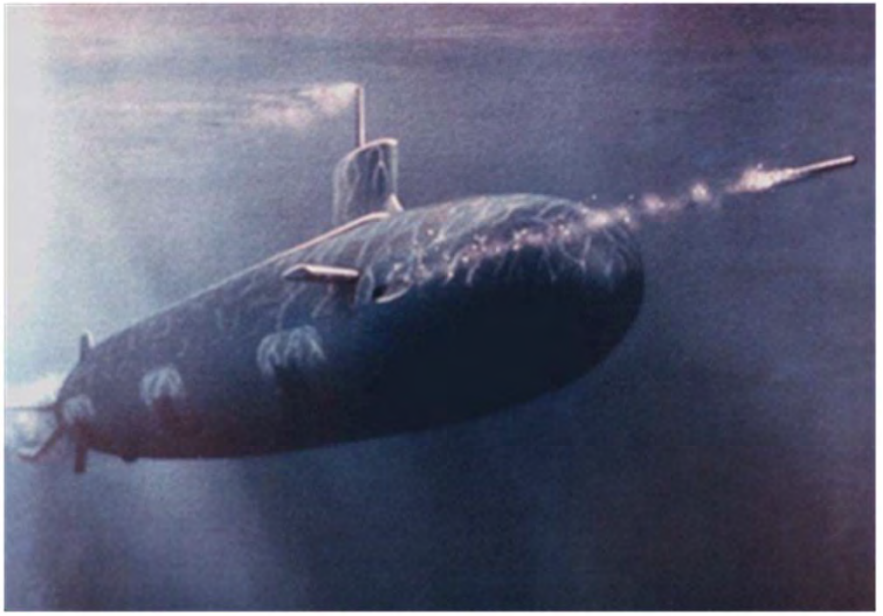
Enhanced Energy Group LLC
Established July 2011

- US / Canada representative for ALCO, Fairbanks Morse, and Colt Pielstick engines of EnPro Industries
  - 600 to 15000 kW

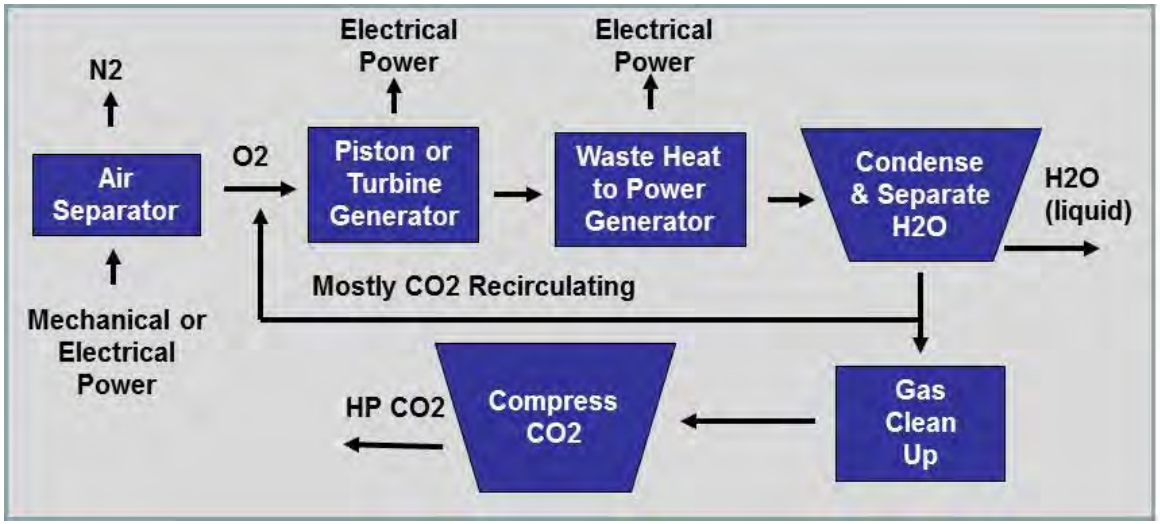
- EEG focus is on commercializing semi-closed cycle CO2 power systems (piston, then turbine) to enable CO2 EGS, and in the near term to support CO2 EOR
  - 5 patents were licensed from Gov't
  - 2 new patents (provisional) addressing the specifics of the gas clean up system were created

- The SCC Piston Engine provides a portable CO2 source for test floods or other EOR applications, and for EGS hybrid “top-off”

SCC Piston Engine



- Submarine heritage
  - High backpressure operation
- Semi-Closed Cycle oxygen fired combustion with CO_2 recirculation
- Compression or Spark Ignition
- Unique integration of: oxygen generation; waste heat to power (WHP); and gas separation, clean up, and compression



Current Effort

Objective: 1+ MW SCC Piston Engine Demo in Houston, TX

- EEG / FME Partnership / Joint Effort
  - Slater Seed capital for EEG
- Part 1: Assessment
  - Engineering / Costing
    - 3rd party simulation (AVL)
  - Market Assessment / Commitments
    - 3rd party review (Cap-Resources)
  - Patent / IP Work
- Part 2: Development / Demo
  - Beloit R&D testing
  - 1-2 MW Demo for customers in 2013

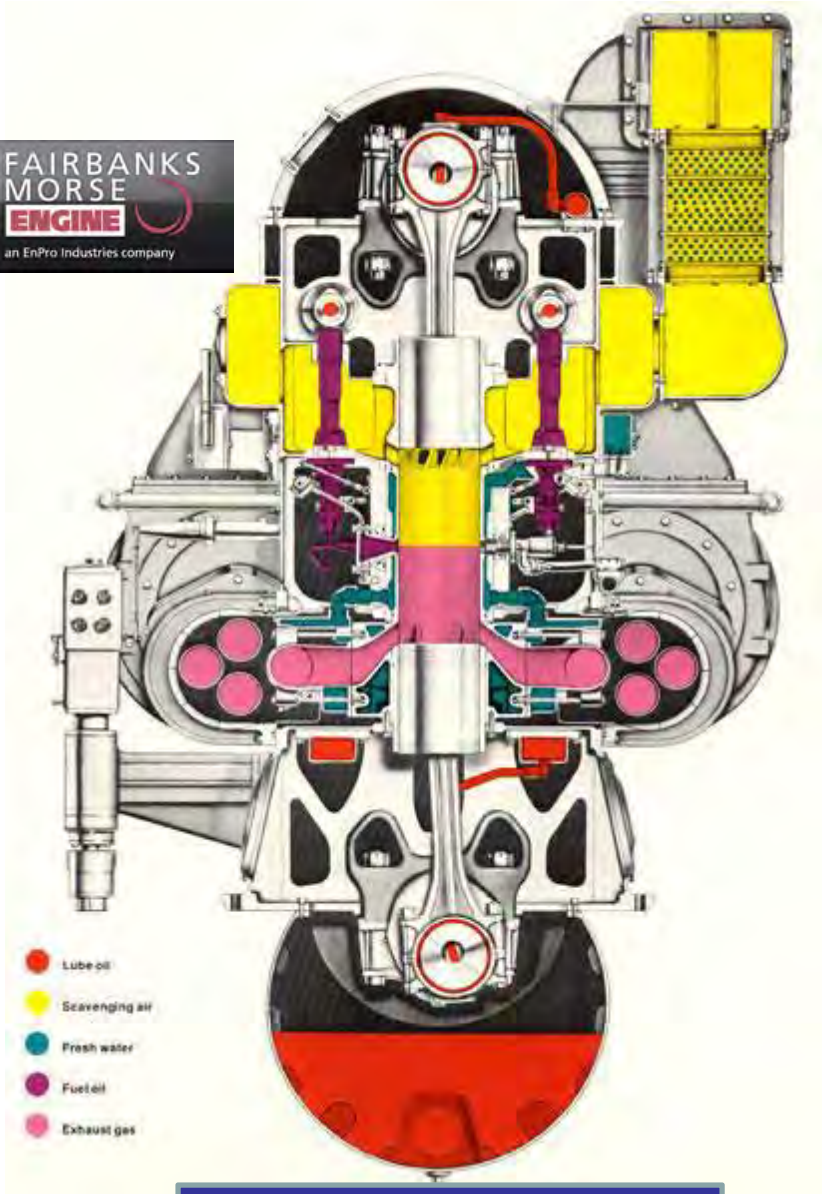
Supported / Followed by:

Praxair (Discount O2)

Quintana Minerals (LOI)

Phase 1 Engineering Effort Complete

- ✓ EEG: Initial model
- ✓ FME: Initial specific fuel consumption estimates
- ✓ FME: Engine configuration test data analysis
- ✓ EEG: Chemical Engineering Flow Sheet based system simulations:
  - ✓ Actual mixture properties, two phase, chemical equilibrium/combustion
- ✓ EEG: Component design / selection complete
- ✓ AVL – Engine modeling complete, will work on SI or Dual Fuel OP with minor modifications (CR)



FME 3 MW Opposed Piston Engine

Molecular Sieve Based (VPSA / PSA / TSA) Based Oxygen Generation and Gas Clean Up

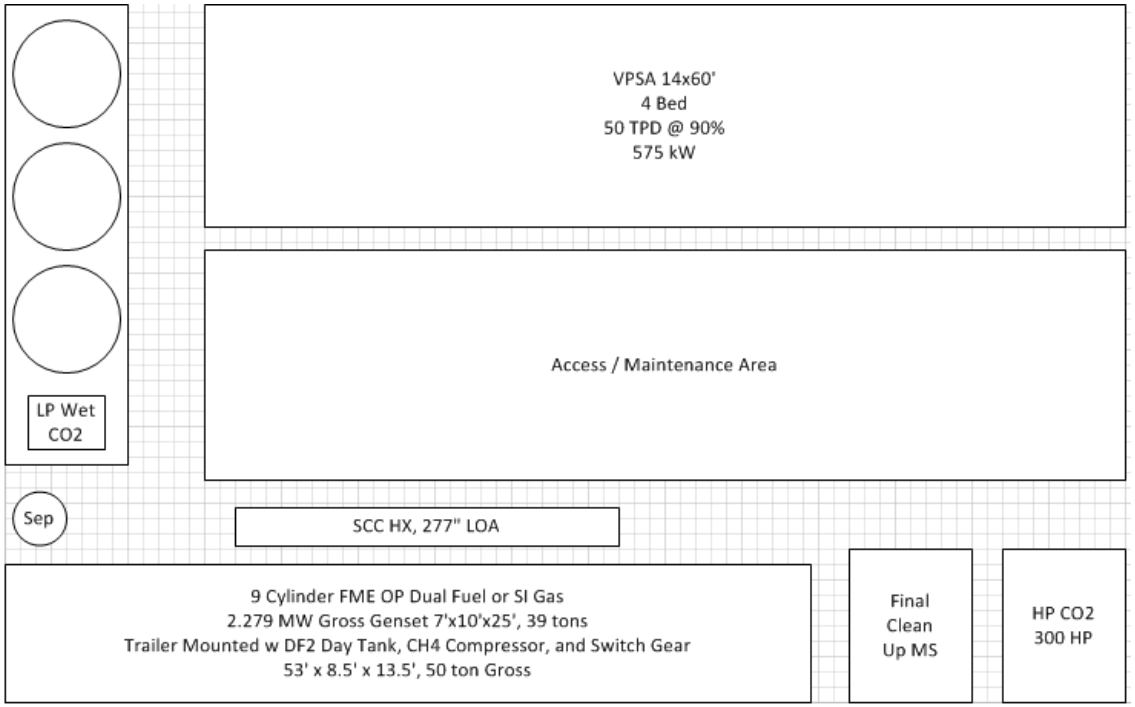
ModCGen™ Oxygen VPSA Product Range					
Nominal Capacity (STPD)	20	45	60	70	100+
Expected Power Use* (kW)	205	441	575	674	926
Site / Maintenance Area (ft)	27 x 46	29 x 52	31 x 60	32 x 70	32 x 70
Foundation Area (ft)	12 x 46	13 x 52	14 x 60	16 x 70	16 x 70
Electrical Supply 50/60Hz	380-575V, 3PH			3.3-6.6KV, 3PH	
Instrument Air Supply (SCFM)	40 @ 80psi	60 @ 80psi	60 @ 80psi	60 @ 80psi	80 @ 80psi
Cooling Water Supply	None required for 15 & 40 psig product pressure, at 150 psig estimate 1.4 GPM per STPD				

* Power at 15 psig, 90% purity product. To estimate power at 40 and 150 psig product add 1.0 and 2.9 kW/STPD respectively.

Mobile / Test Flood System (2 MW) Preliminary Characteristics

- Target Price: $6.5M
- FME 9 cylinder Dual Fuel or SI Opposed Piston Engine / Generator
- Adsorptech 50 TPD VPSA / PSA O2 Plant
- EEG Gas Clean Up System (Mole Sieve)
- HyperComp LP Wet CO2 compressor
- Ariel HP Dry CO2 compressor

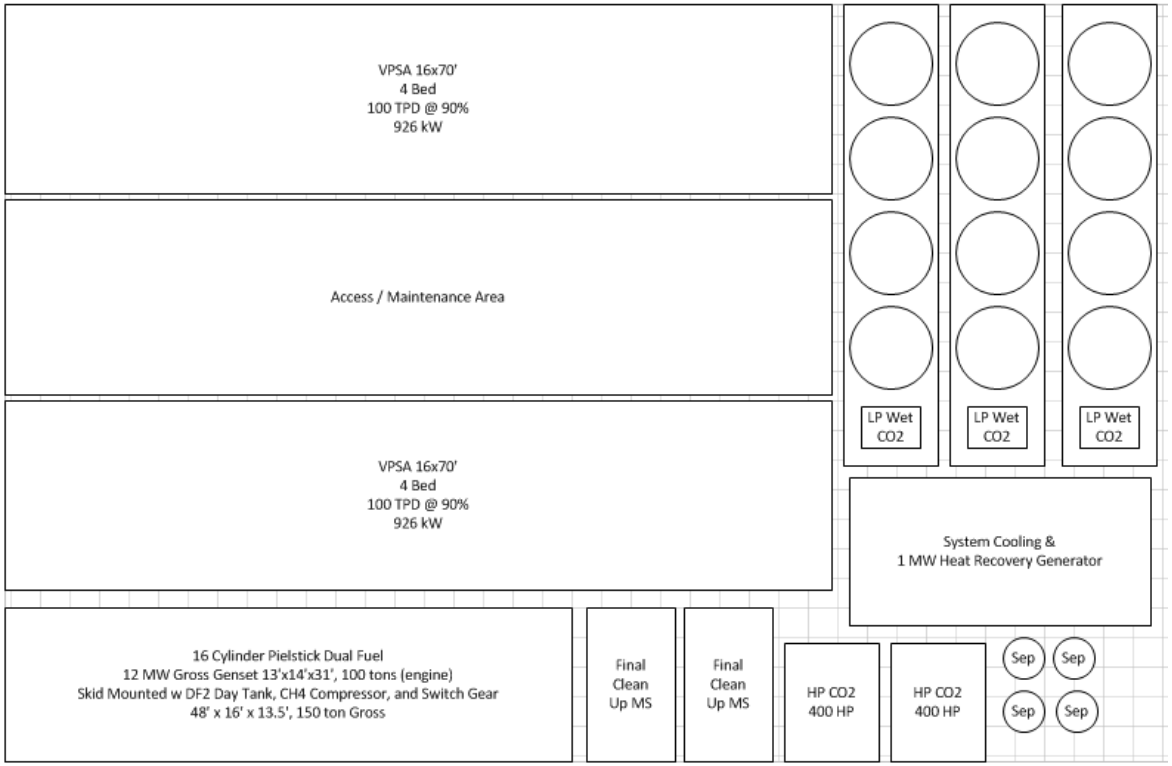
32 tons per day CO2
~37% Gross Cycle Efficiency
1400+ kW Net
50’ x 75’ Footprint



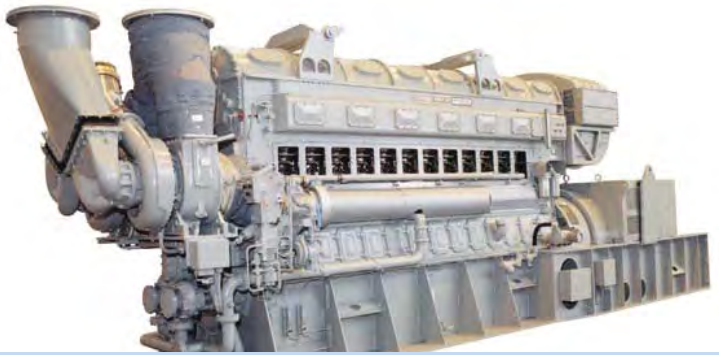
Small Field / Production Flood System (12 MW) Preliminary Characteristics

- Target Price: $28M
- Pielstick 16 cylinder 2.6B Dual Fuel Piston Engine / Generator
- SC CO2 / R134A WHP Generator
- Two Adsorptech 100 TPD VPSA / PSA O2
- EEG Gas Clean Up System (Mole Sieve)
- Two Ariel HP Dry CO2 compressors

135 tons per day CO2
10.3+ MW Net
70’ x 100’ Footprint



Cost / Value Comparison **



- 2 MW, 32 TPD System ($6.5M)

2.2 MW SCC OP @ 37%, $3 Gas, Dual Fuel, 10 yr SL AMT					
Net Revenue	Value of Power ($/kW-hr)				(Diesel)
or price of:	$0.03	$0.06	$0.09	$0.12	$0.25
CO2/ton	$95	$59	$22	-	-
CO2/MSCF	$5.43	$3.37	$1.26		
Net Revenue	-	-	-	$0.2M	$2M

2.2 MW SCC OP @ 37%, $3 Gas, Dual Fuel, No Amortization					
Operating Net	Value of Power ($/kW-hr)				(Diesel)
or price of:	$0.03	$0.06	$0.09	$0.12	$0.25
CO2/ton	$40	$4	-	-	-
CO2/MSCF	$2.29	$0.23	-	-	-
Operating Net	-	-	$0.4M	$0.8M	$2.7M

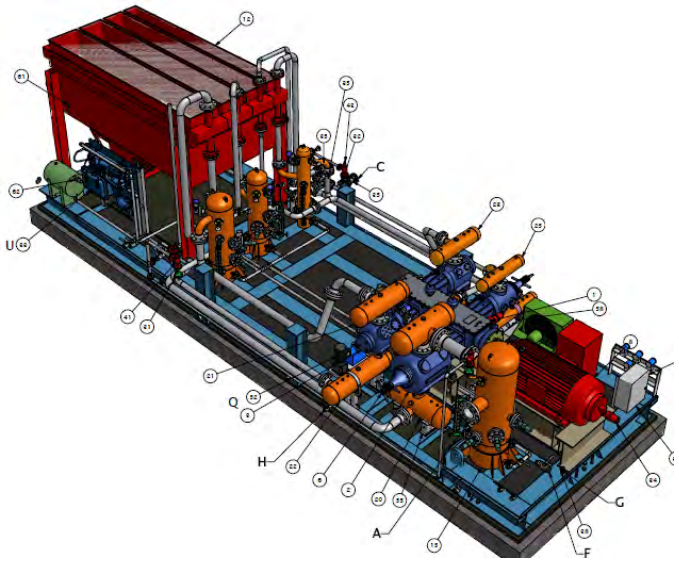
** Note: There are implementation specific tax and depreciation advantages not accounted for herein, and none of these numbers address the value of the oil

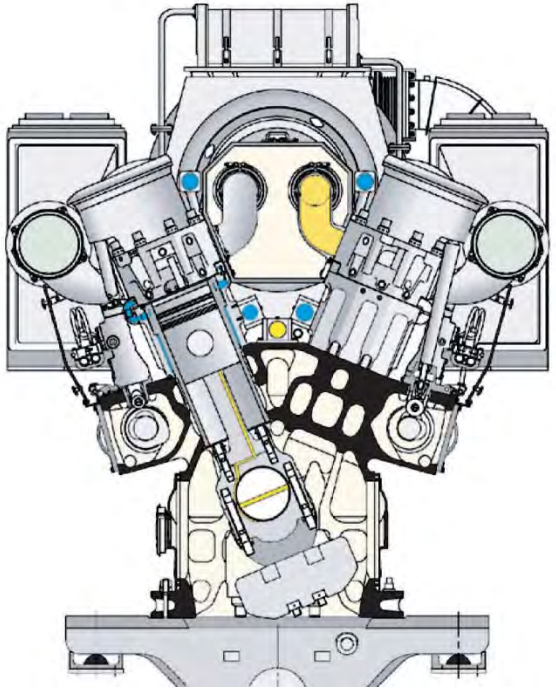
- 12 MW, 135 TPD System ($28M)

12 MW SCC 2.6B @ 52%, $3 Gas, Dual Fuel, 10 yr SL AMT					
Net Revenue	Value of Power ($/kW-hr)				(Diesel)
or price of:	$0.03	$0.06	$0.09	$0.12	$0.25
CO2/ton	$70	$13	-	-	-
CO2/MSCF	$4.00	$0.74			
Net Revenue	-	-	$2.1M	$4.9M	$16.7M

12 MW SCC 2.6B @ 52%, $3 Gas, Dual Fuel, No Amortization					
Operating Net	Value of Power ($/kW-hr)				(Diesel)
or price of:	$0.03	$0.06	$0.09	$0.12	$0.25
CO2/ton	$11	-	-	-	-
CO2/MSCF	$0.63	-	-	-	-
Operating Net	-	$2.2M	$5.0M	$7.7M	$19.6M

Invitation(s)





- Packager / Partner / Operator
- Customer / Expert inputs
  - Field requirements – field gas specifications
  - Desired CO2 specifications
  - Seems like there is some integration possible with CO2 recycle clean up
- Come see the demo(s)
  - Beloit in the summer!
  - Houston in the winter!

Wrap Up

- CO2 EGS has great advantage over Water EGS
  - In those fields compatible with CO2
- But CO2 EGS is not going to happen without cheap CO2, so that is what we are working on
  - And we think low cost / portable CO2 has a market now in EOR
- Cheap CO2 is also not happening without cheap fuel, that generates value (electricity, lift, recycle compression, etc)
  - Hence our dual fuel / field gas / flare gas / efficiency focus
- As always, we thank SMU for hosting this conference, and look forward to your input

LPD-21 USS New York
Steel from The World Trade Center
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