CPG: Geologically sequestered carbon dioxide as a geothermal heat mining fluid -- applications and opportunities

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Carbon Dioxide Plume
Geothermal (CPG) technology:
Developed at the University of Minnesota (UMN) by Drs. Martin Saar, Jimmy Randolph, and Thomas Kuehn

UMN filed for CPG patents in March, 2009 (U.S. and International), U.S. patent allowed July 2012; Additional patents for CPG EOR applications filed in 2012

Heat Mining Company LLC (UMN Startup) has been granted an exclusive, worldwide license to CPG
CPG Power System
Wellbore effects – CO$_2$ pressure profiles

Pressure difference available for power generation

72 bar

110 bar

Adams, Randolph, Kuehn, Saar, 2012 in preparation
**CO₂ power cycle**

**Typical fossil-fuel power cycle**

- **12°C, 3 MPa**
  - \( \rho = 150 \text{ kg m}^{-3} \)

- **110°C, 16 MPa**
  - \( \rho = 325 \text{ kg m}^{-3} \)

- **150°C, 25 MPa**
  - \( \rho = 450 \text{ kg m}^{-3} \)

**CPG power cycle**

- **12°C, x=0**
  - \( \rho = 850 \text{ kg m}^{-3} \)

Potential Energy Change = \( g^\Delta z \)

Adams, Randolph, Kuehn, Saar, 2012 in preparation
Higher efficiency power system than water, 76 to 85% depending on T,P.
Smaller equipment footprint than water-based facilities.
Capable of operating at below water freezing temperatures.
Power production with CO₂ Turbine

CO₂ vs Brine Electrical Energy Production, with Energent Projections
Single Well Flow Rate = 80 kg/s, Permeability = 5 x 10⁻¹⁴ m²

Electricity Production [kWe]

Time [years]

Indirect Brine [80 kg/s]  Direct CO₂ [80 kg/s], Energent
CPG Capacity Matching
CPG capacity naturally matches demand

Mass flow rate: 80 kg/s

\[ y = 1.076x - 0.023 \]

\[ R^2 = 0.876 \]

Adams, Randolph, Kuehn, Saar, 2012 in preparation
CPG scaled to meet demand

- CPG Output
- Actual Demand
- CPG massflow

Adams, Randolph, Kuehn, Saar, 2012 in preparation
Renewable power plant nameplate requirements

- **Solar**
- **Wind**
- **CPG (80 kg/s)**

<table>
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<tr>
<th>Plant Nameplate [MW]</th>
<th>Percent of Hours in which Power Production Meets Demand</th>
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Adams, Randolph, Kuehn, Saar, 2012 in preparation
CPG with EOR
Why CPG with EOR?

Not a new method for extracting hydrocarbons.

Is a new approach for harnessing the available resource (hydrocarbons + geothermal energy) more effectively, thus improving EOR economics.

Randolph and Saar, 2011
CPG with EOR – Minimal impact on EOR operations

Produced fluid is simply directed through a heat recovery system then returns to the production line.

Bolt-on system with minimal to no impact on EOR operations. Can be installed while EOR operations cease for maintenance. Heat recovery apparatus can be bypassed if maintenance is needed.
What does this mean for EOR?

Two general applications:

-- Fields currently not producing – potentially similar to conventional CPG.
-- Low margin fields – multicomponent fluid production generally requires binary power systems.

Randolph and Saar, 2011
Current CO$_2$ EOR projects and CO$_2$ pipelines.
Potential technically recoverable incremental oil with CO₂ EOR technology.

ARI, 2009

Producible if costs, oil price and risks justify investment
What does this mean for EOR?

Produced Fluid Temperature = 100°C, Binary Turbine Efficiency = 1/3rd of Carnot

100 water to oil ratio
50, water to oil ratio
10, water to oil ratio
5, water to oil ratio
What does this mean for EOR?

Water to Oil Ratio = 100, Binary Turbine Efficiency = 1/3rd of Carnot

- 3000, barrels per day oil
- 2000, barrels per day oil
- 1000, barrels per day oil
- 500, barrels per day oil

Produced Fluid Temperature [°C]

Electricity Production [MW]

Potential Gross Power Sales [$100,000]

Randolph, 2012 in preparation
Offsetting EOR field costs and enhancing economics.

Purchased electricity is used throughout EOR operations:
-- Water injection and CO₂ compression/injection
-- Hydrocarbon/water/CO₂ production pumps
-- Fluid separation equipment

The estimated annual cost of electricity for U.S. EOR operations: $400 million.
-- Estimated total number of EOR wells in Texas -- 16,000
-- E.g., estimated potential EOR/CPG sites in Texas -- 800

Significant opportunity for economically-favorable renewable electricity generation.
Summary – Why CPG?

CPG in general:
-- Negative atmospheric CO₂ emissions.
-- Power system efficiency far greater than standard geothermal.
-- High fluid mobility = efficient geothermal heat mining.
-- Thermosyphon = minimal parasitic power losses.

EOR in particular:
-- Significant utilization of otherwise lost energy.
-- Offsetting field costs and extending field lifespan.

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Or search online: Randolph + CO₂ Geothermal

Thank you.
Thank You