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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

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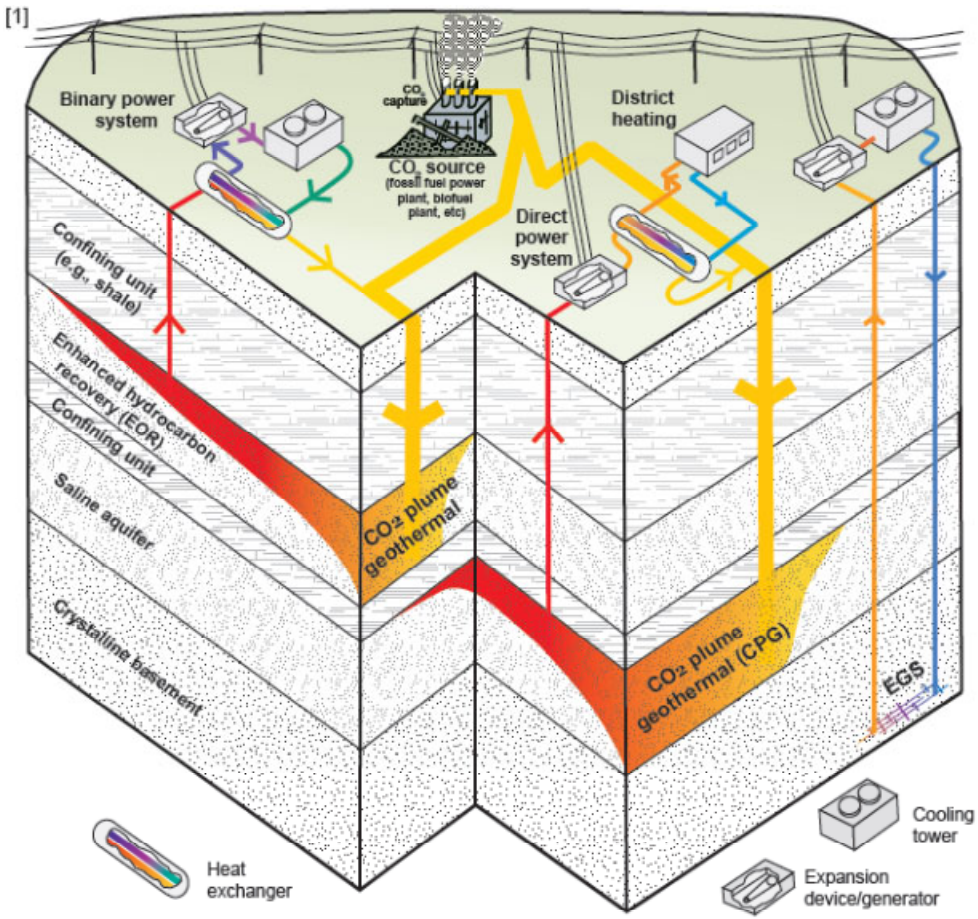
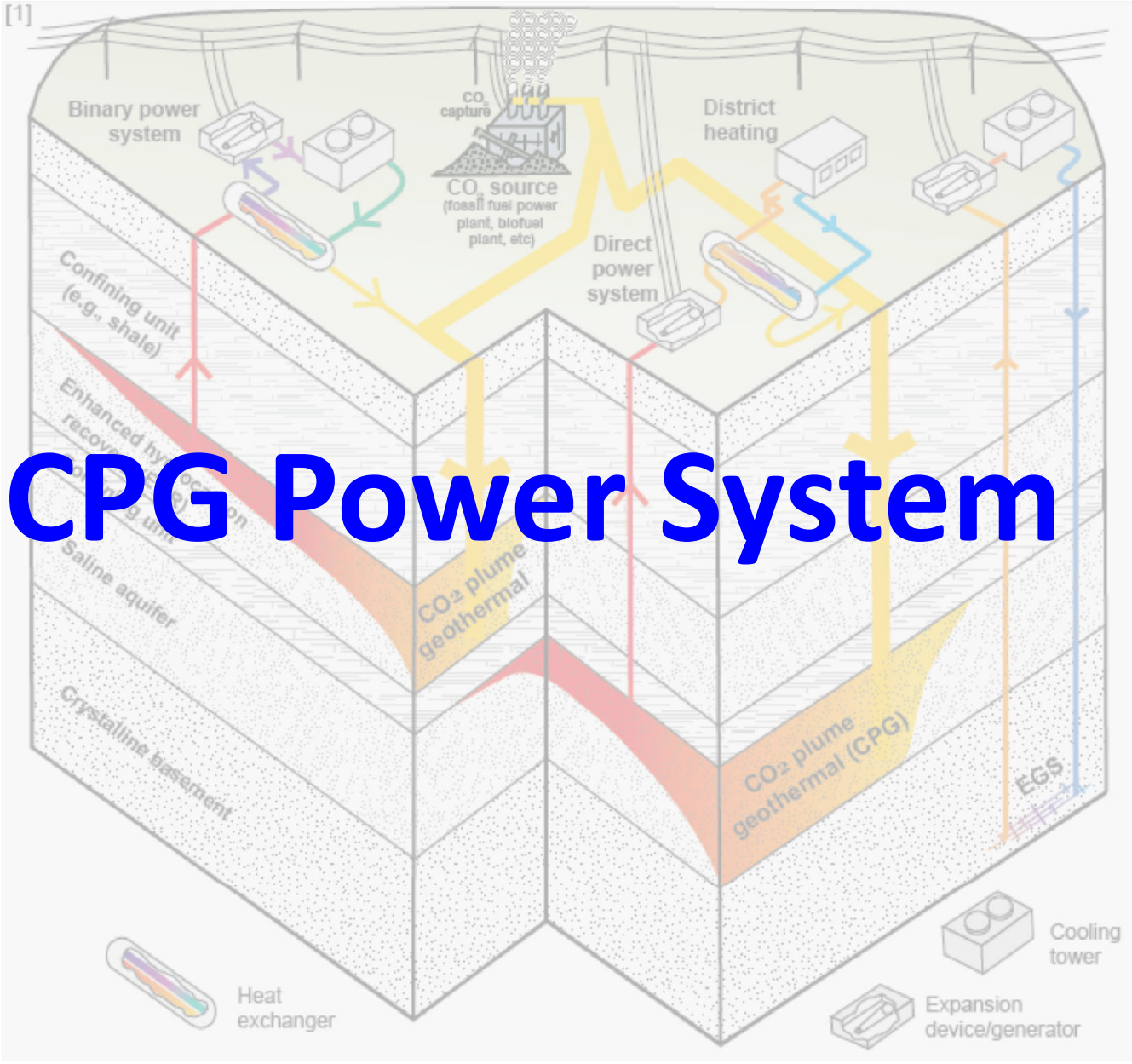
(UMN Startup) has been granted an exclusive, worldwide license to CPG



Randolph and Saar, 2011

CPG Power System



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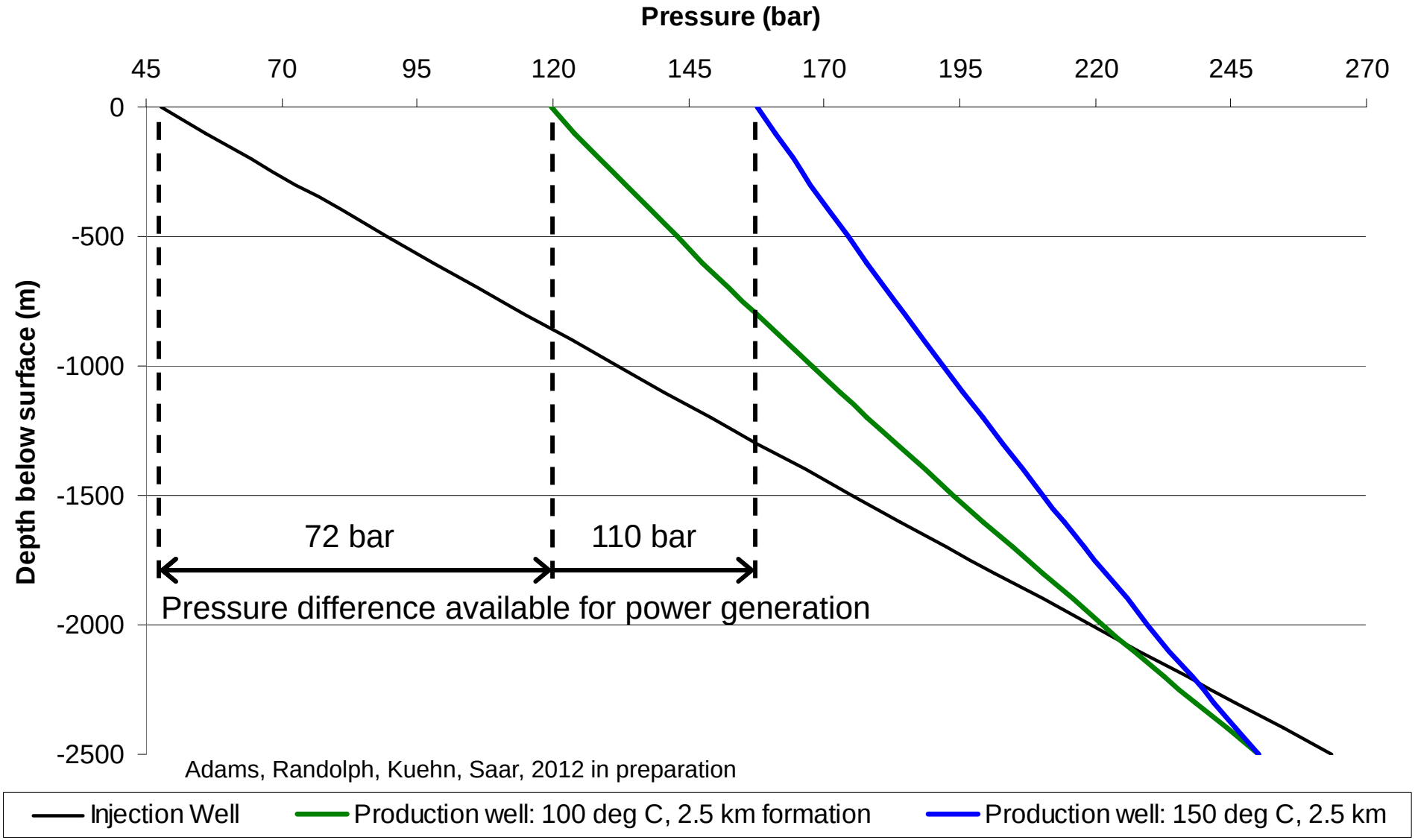
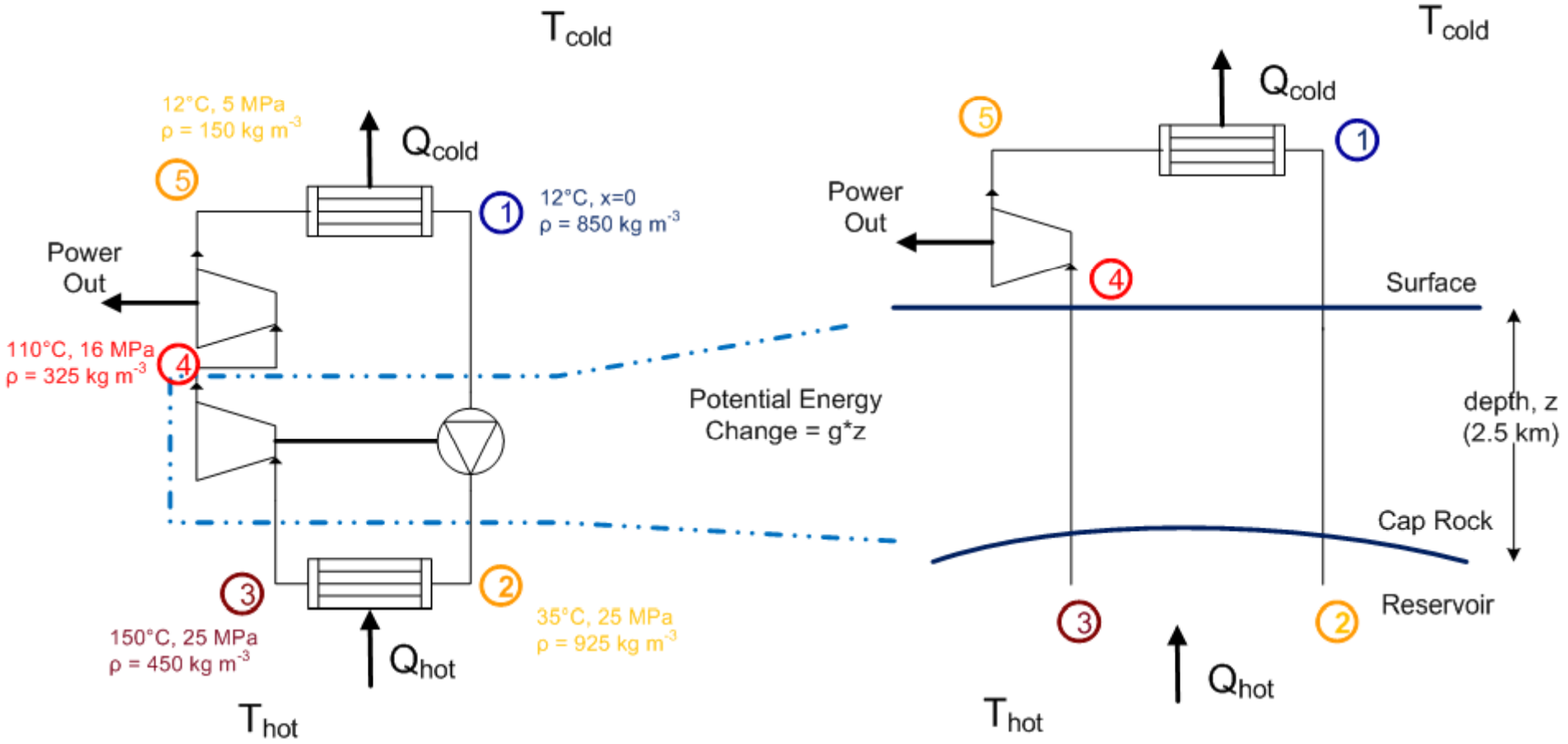
Wellbore effects – CO_2 pressure profiles



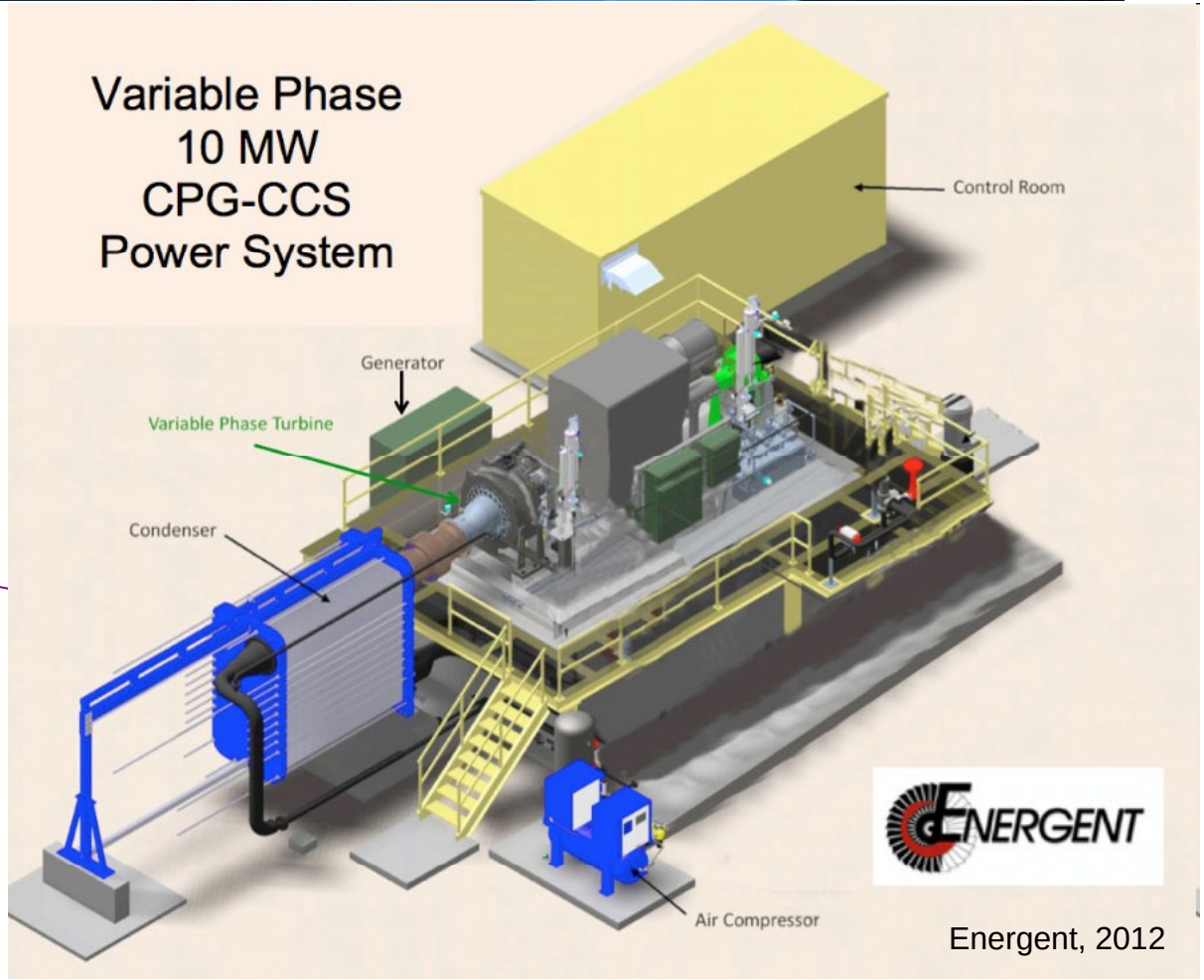
CO_2 power cycle



Typical fossil-fuel power cycle

CPG power cycle

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.

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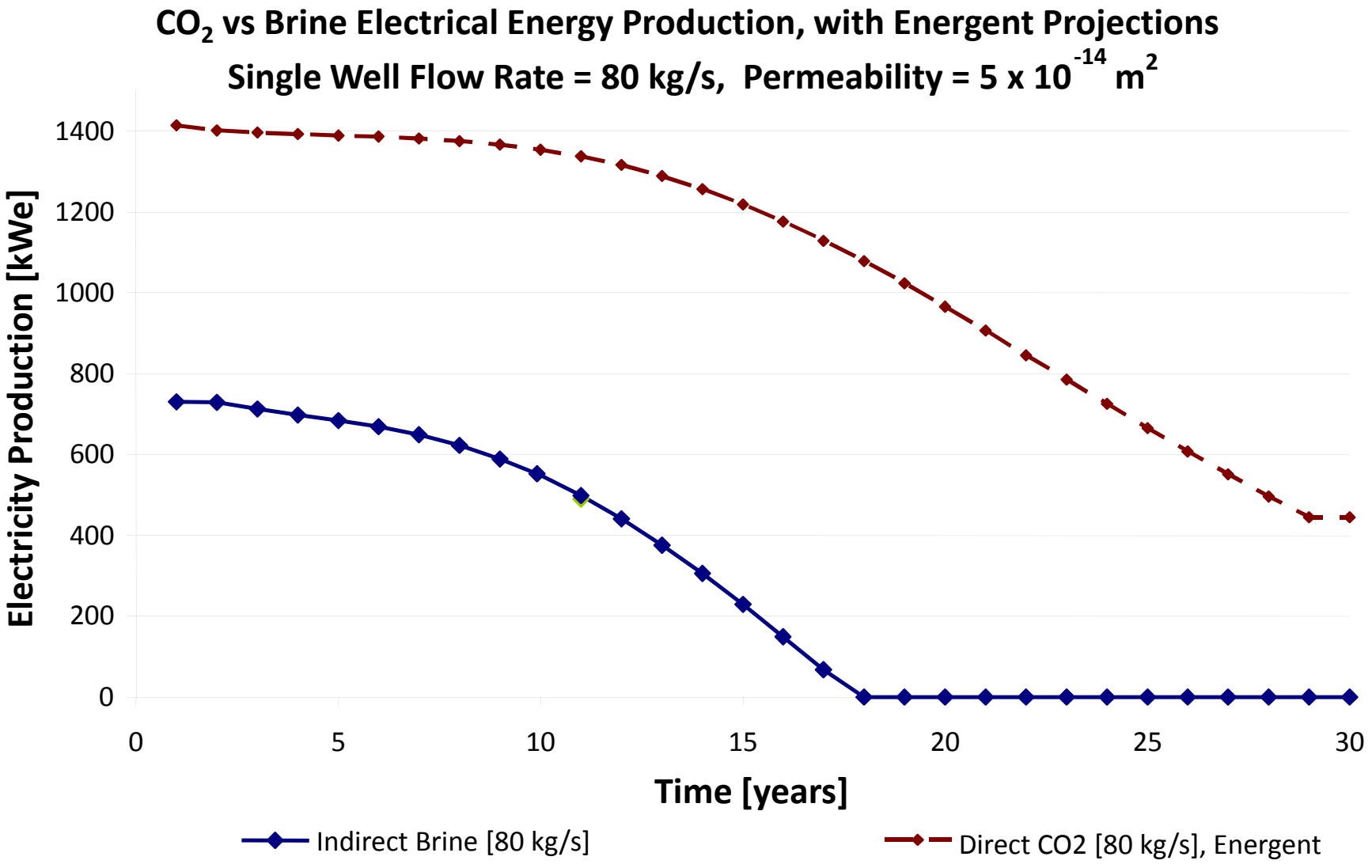
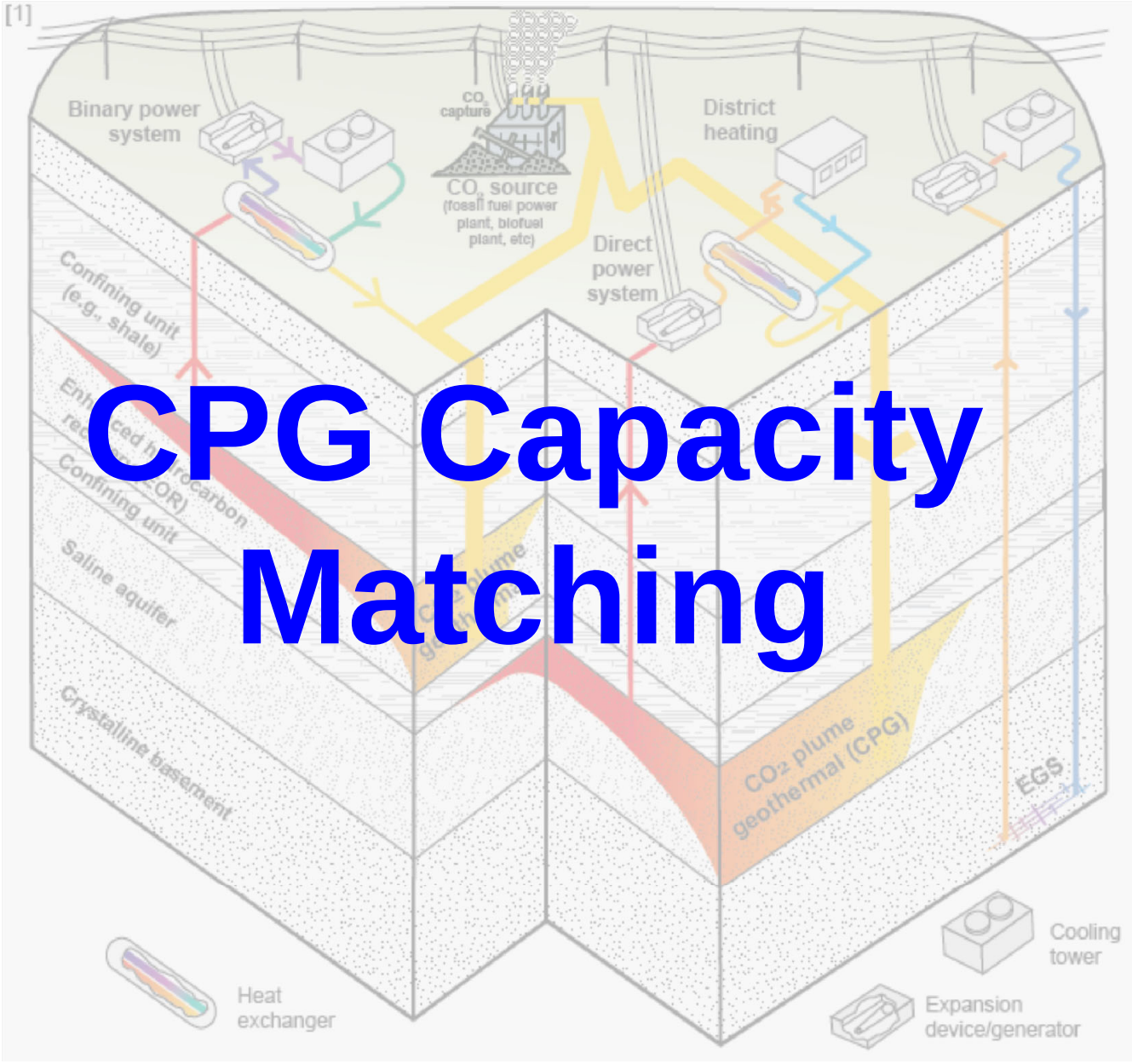
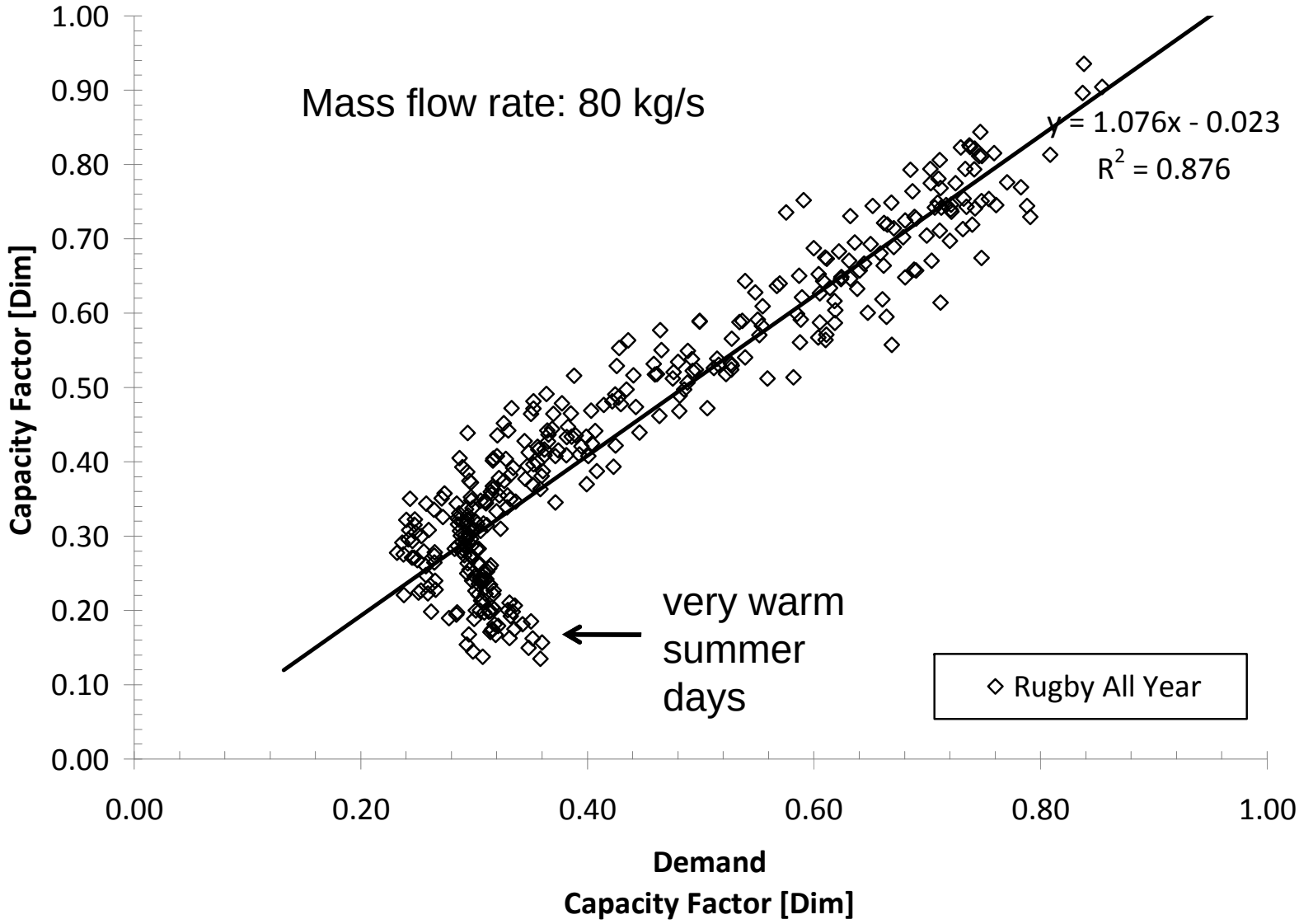
Power production with CO_2 Turbine



CPG Capacity Matching

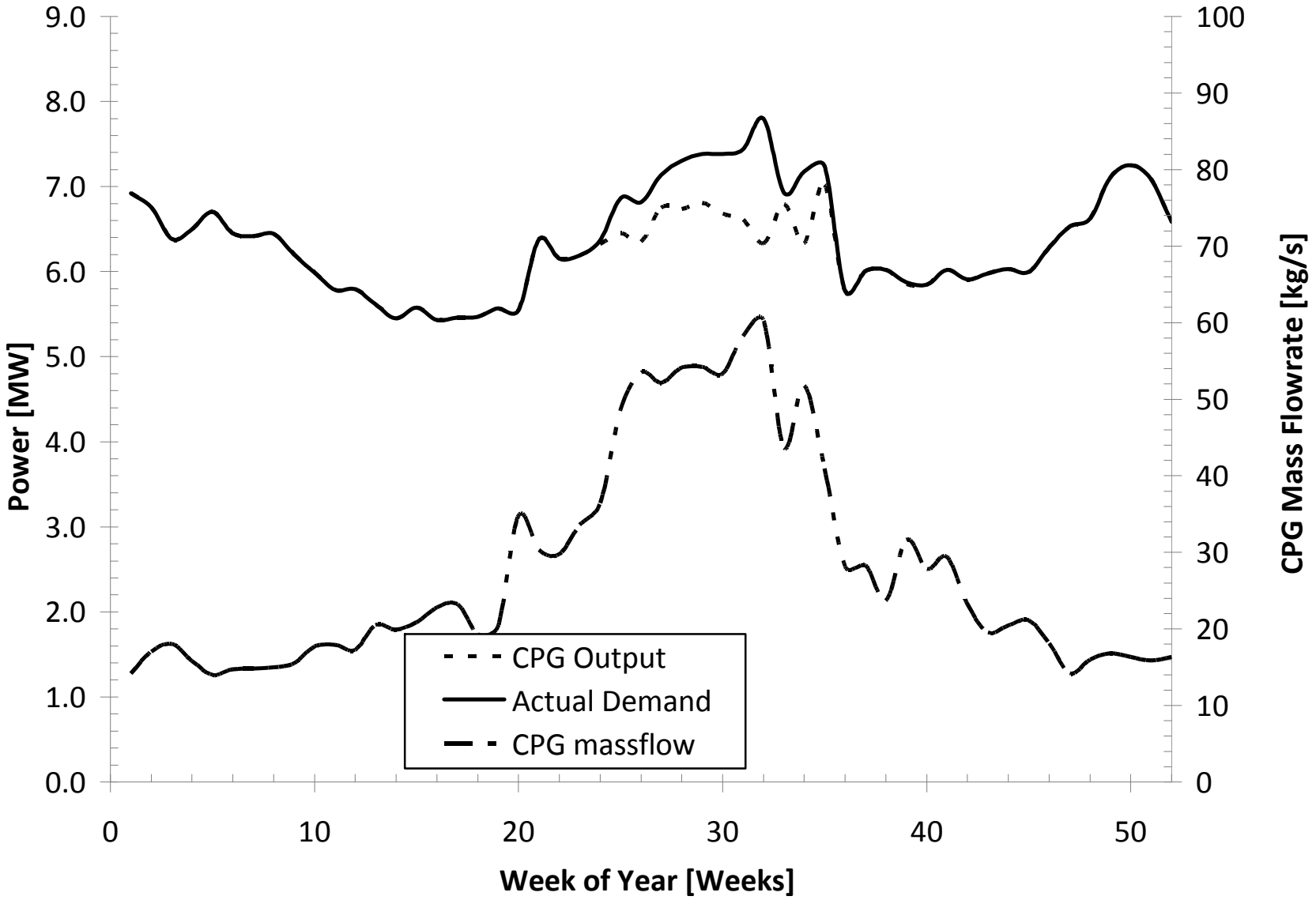


CPG capacity naturally matches demand



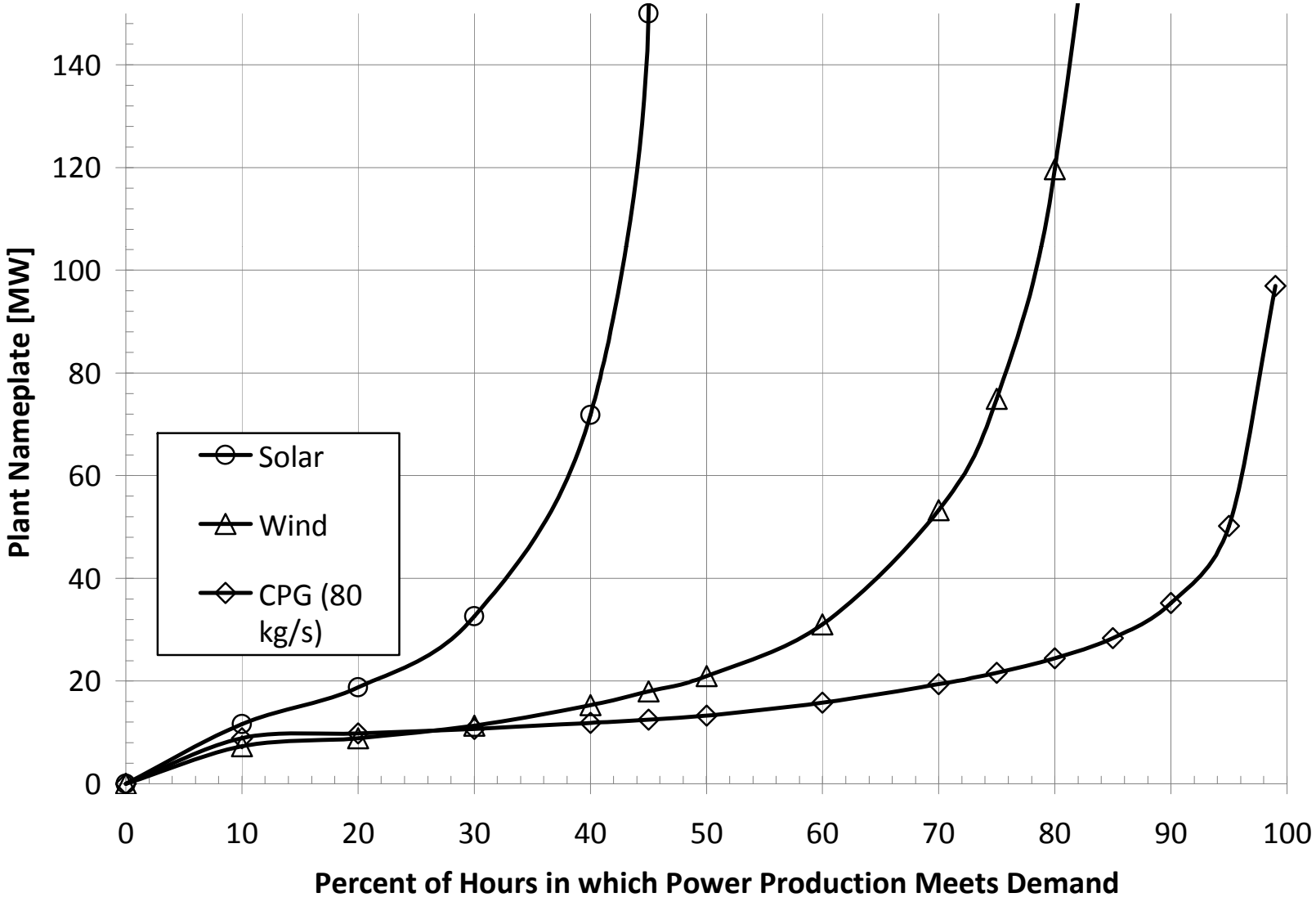
Adams, Randolph, Kuehn, Saar, 2012 in preparation

CPG scaled to meet demand



Adams, Randolph, Kuehn, Saar, 2012 in preparation

Renewable power plant nameplate requirements



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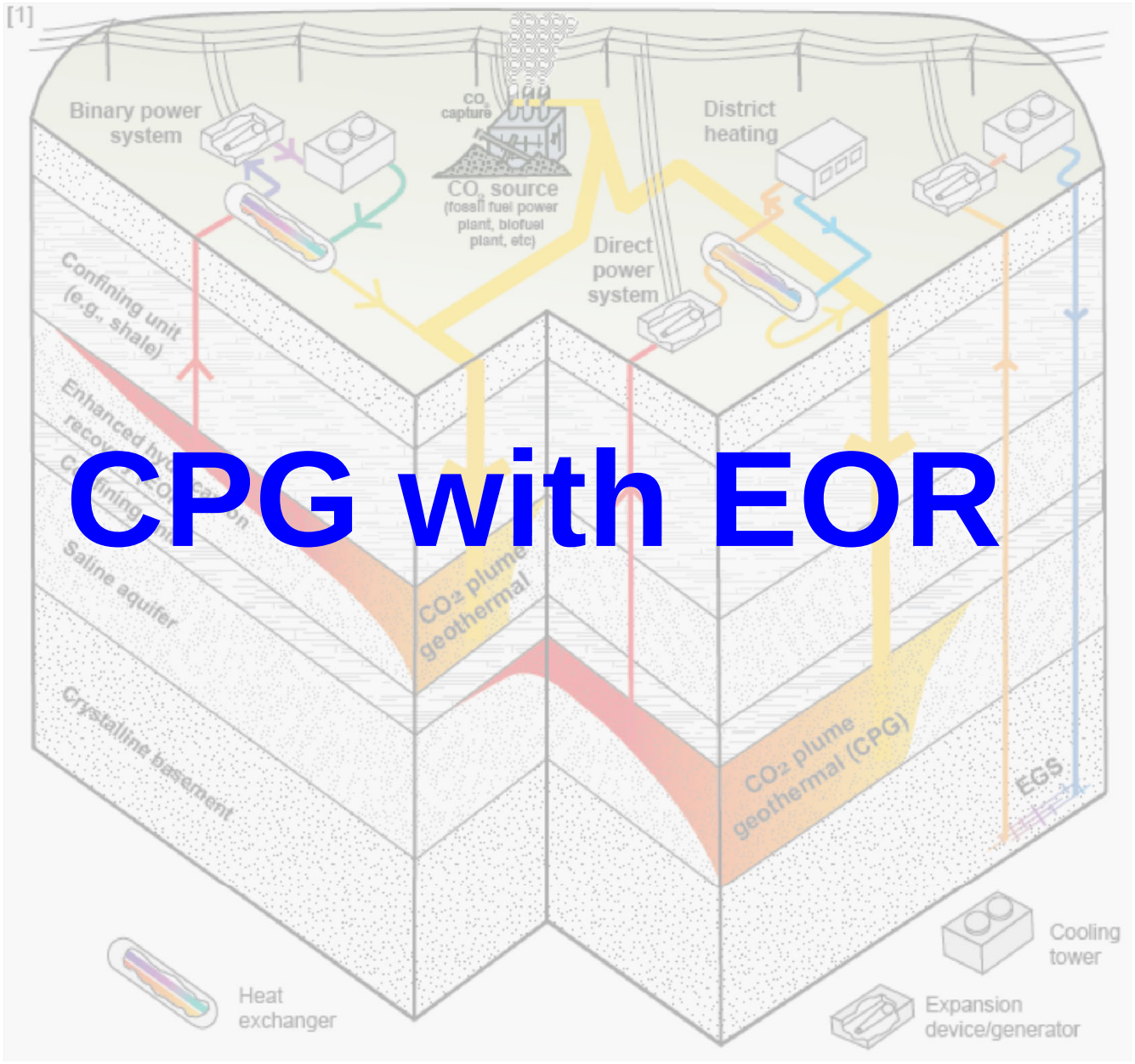
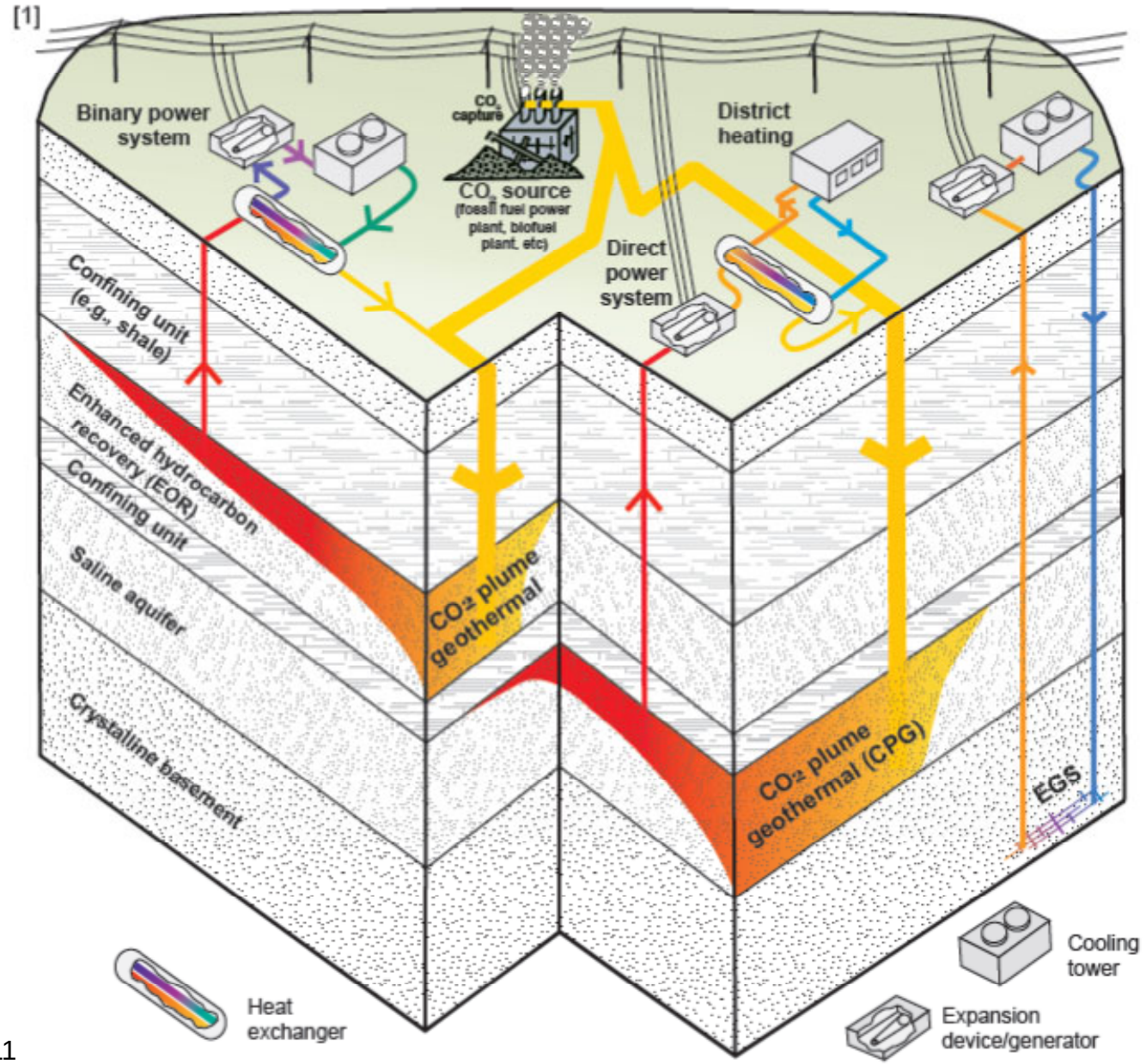

[1]
Binary power system
CO2 capture
CO2 source
(fossil fuel power plant, biofuel plant, etc)
District heating
Direct power system
Confining unit (e.g., shale)
Saline aquifer
Crystalline basement
CO2 plume geothermal
CO2 plume geothermal (CPG)
EGS
Heat exchanger
Cooling tower
Expansion device/generator

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.

Separator for separating produced fluids (oil, water, and gas)

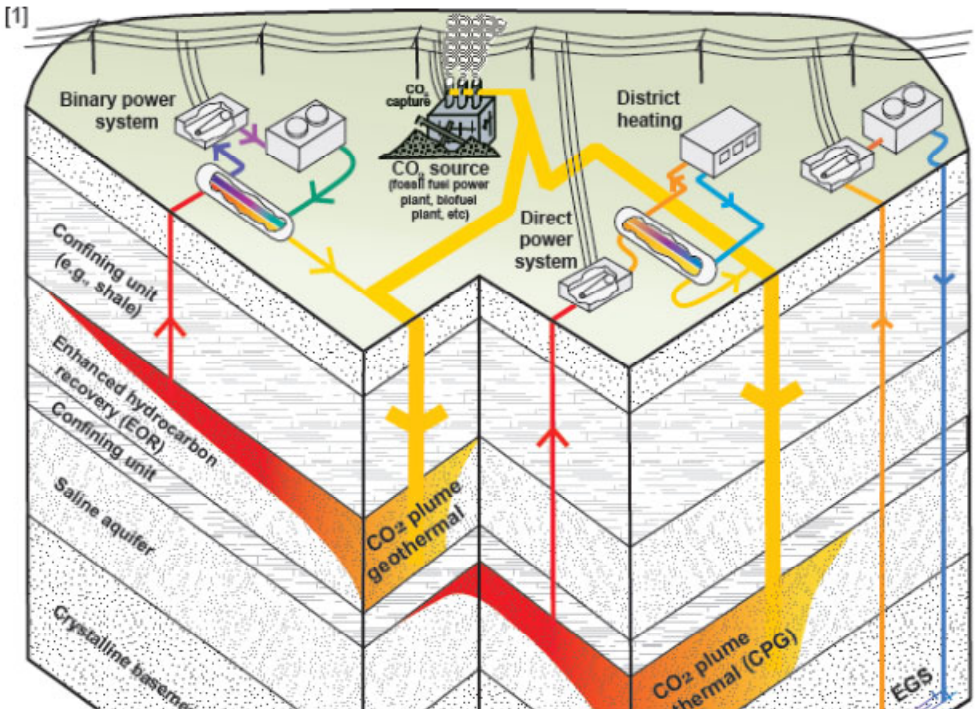
Well production manifold to allow individual testing of wells

What does this mean for EOR?

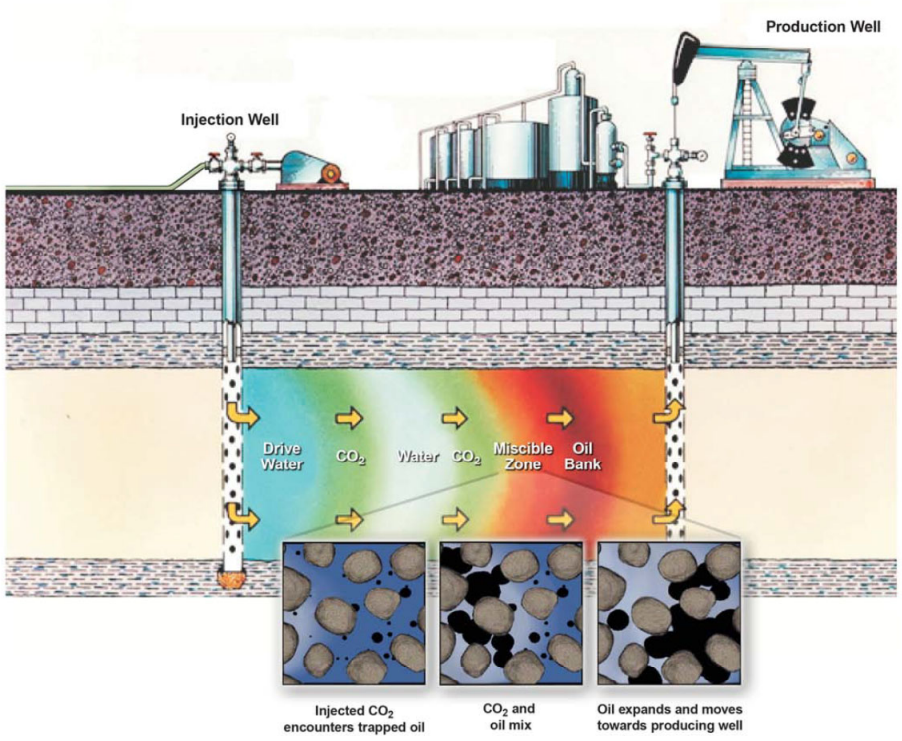
Two general applications:

-- Fields currently not producing – potentially similar to conventional CPG.

-- Low margin fields – multicomponent fluid production generally requires binary power systems.

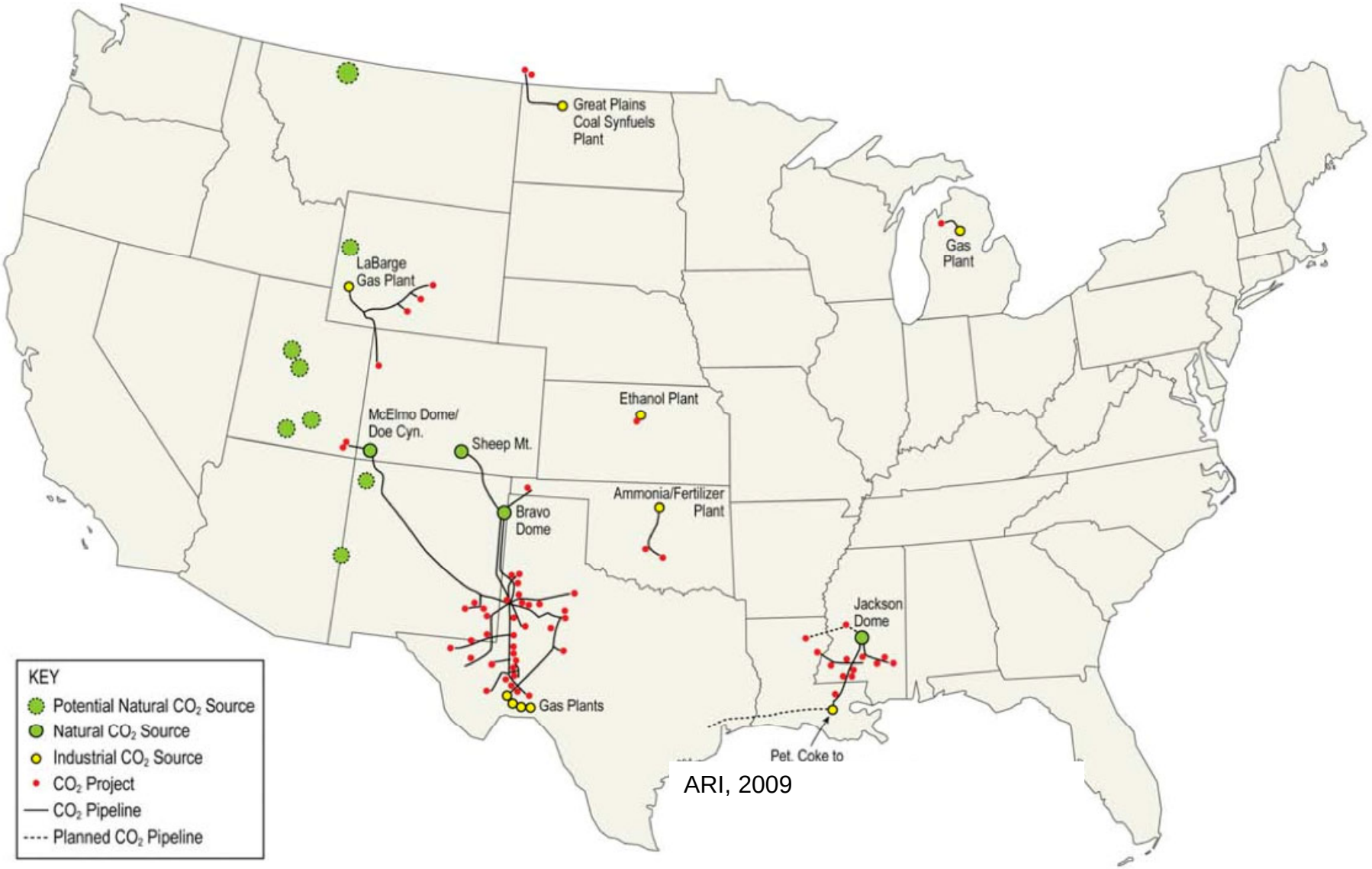


Randolph and Saar, 2011



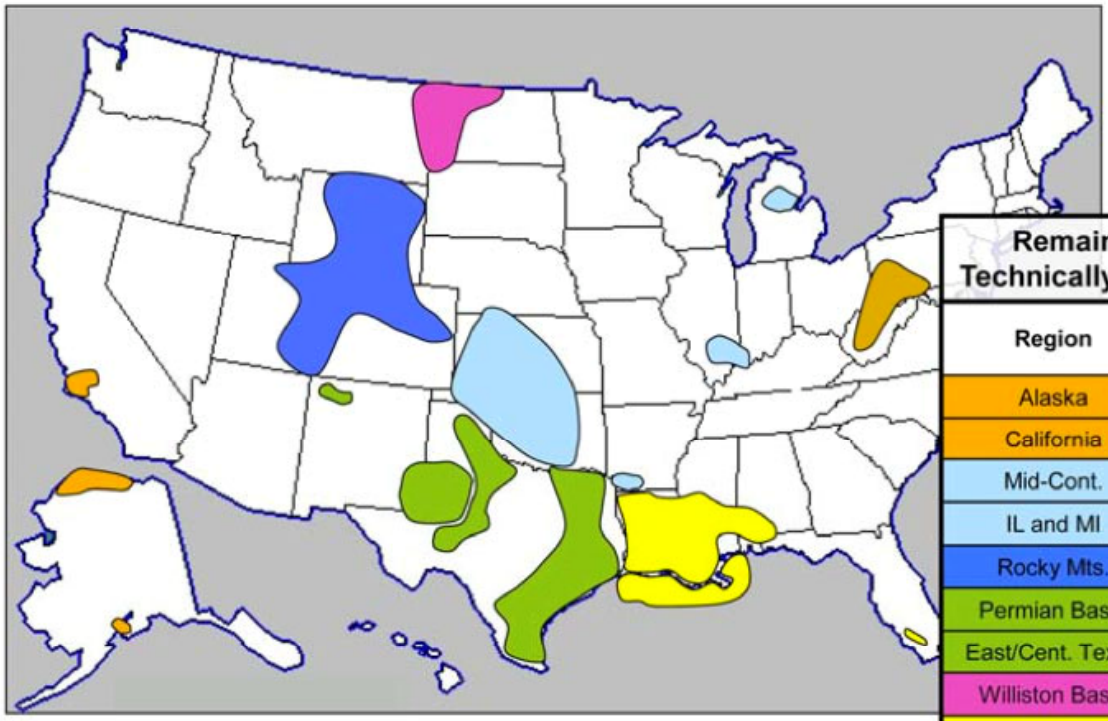
NETL 2010

Current CO_2 EOR projects and CO_2 pipelines.



ARI, 2009

Potential technically recoverable incremental oil with CO_2 EOR technology.



ARI, 2009

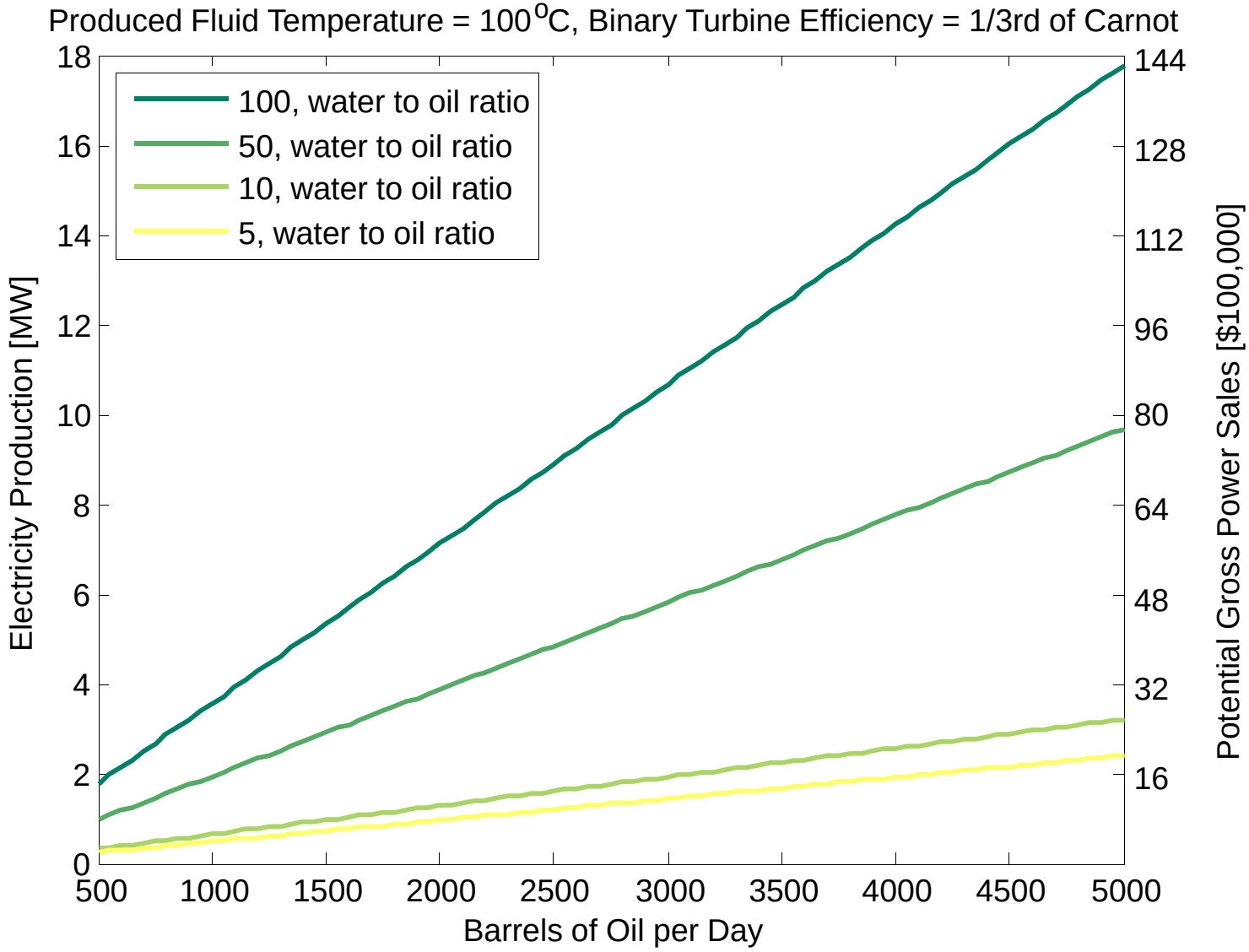
Remaining Oil in Place and Technically Recoverable Oil (BBIs)

Region	ROIP*	Technically Recoverable
Alaska	45.0	12.4
California	57.3	6.3
Mid-Cont.	65.6	10.6
IL and MI	11.5	1.2
Rocky Mts.	22.6	3.9
Permian Basin	61.7	15.9
East/Cent. Texas	73.6	17.6
Williston Basin	9.4	2.5
Gulf Coast	27.5	7.0
LA Offshore	15.7	5.8
Appalachia	10.1	1.6
Total	**400**	**84.8**

* Remaining Oil in Place

Producible if costs, oil price and risks justify investment

What does this mean for EOR?



Randolph, 2012 in preparation

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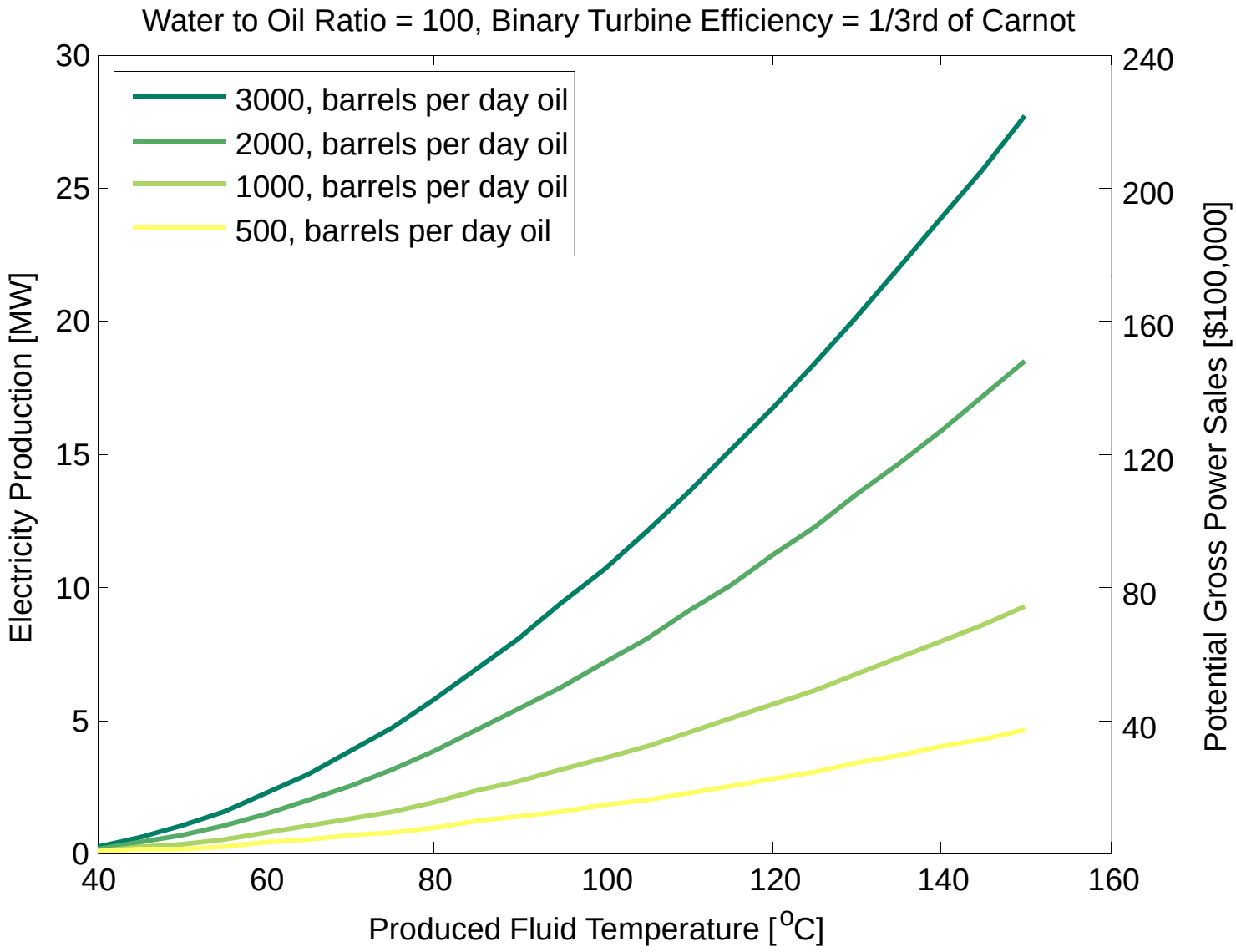
What does this mean for EOR?



Randolph, 2012 in preparation

Offsetting EOR field costs and enhancing economics.

Purchased electricity is used throughout EOR operations:

-- Water injection and CO_2 compression/injection

-- Hydrocarbon/water/CO_2 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 CO_2 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.

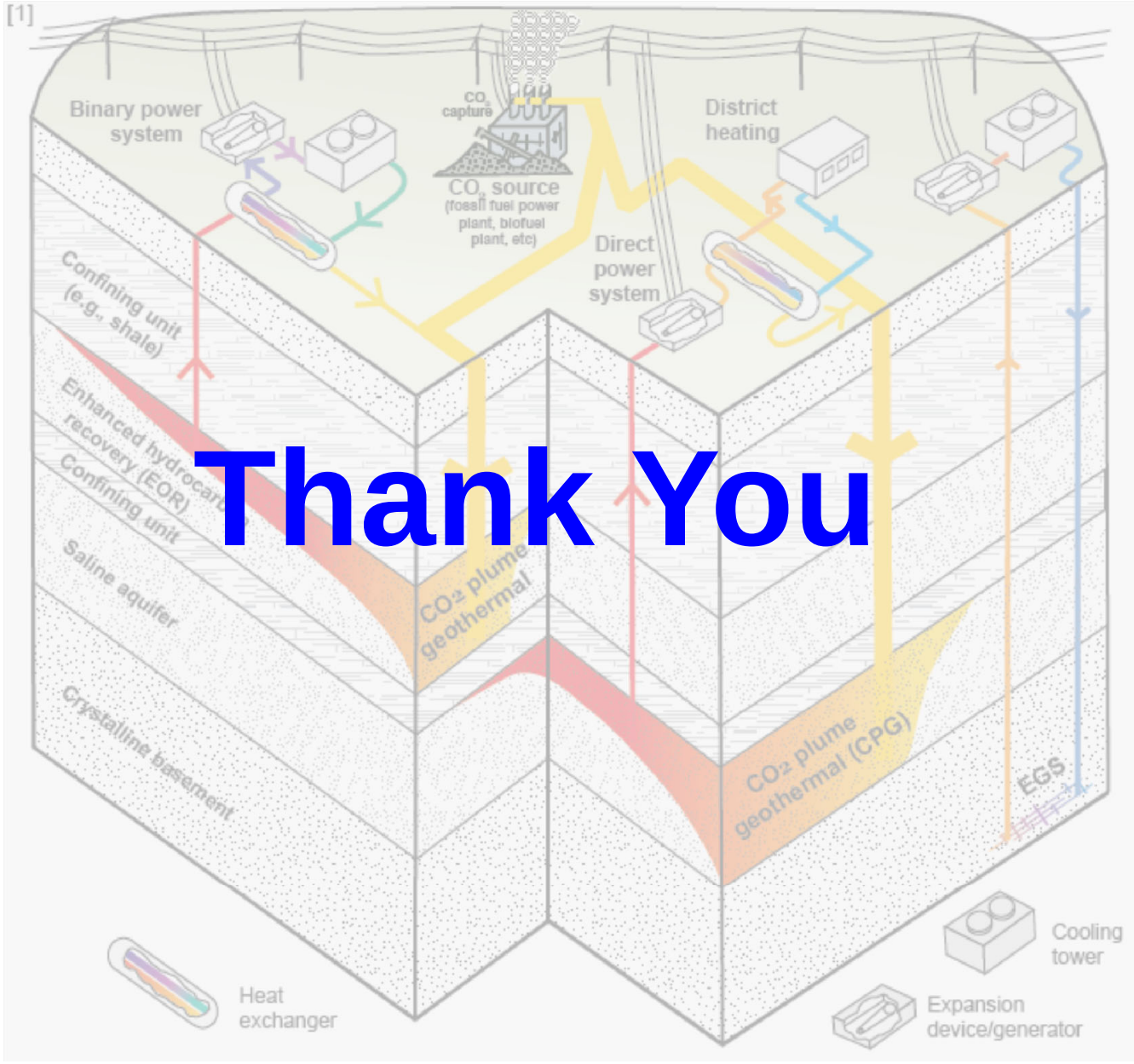
-- Offsetting field costs and extending field lifespan.

For more information: j.randolph@heatmining-sd.com

www.heatmining-sd.com

Or search online: Randolph + CO2 Geothermal

Thank you.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CO2 capture
CO2 source
(fossil fuel power plant, biofuel plant, etc)
District heating
Direct power system
Confining unit (e.g., shale)
Enhanced hydrocarb recovery (EOR)
Confining unit
Saline aquifer
Crystalline basement
CO2 plume geothermal
CO2 plume geothermal (CPG)
EGS
Heat exchanger
Cooling tower
Expansion device/generator

Thank You