PNNL-24084

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Geothermal Power Generation and CO2 Capture Co-Production

Q1 FY15 Report

May 2016

DJ Heldebrant

U.S. DEPARTMENT OF ENERGY

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Geothermal Power Generation and CO_2 Capture Co-Production

AOP PROJECT 27342

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Q1 FY15

David J. Heldebrant

Key Accomplishments and Milestones

	Milestone	Progress	Met or Unmet	Explanation if Unmet
Q1 FY15	Provide detailed project management plan with refined scope per DOE discussions	Submitted	Met	
Q2 FY15	Complete detailed site-specific geothermal resource report	3/31/2015	Unmet	Work yet to begin
Q3 FY15	Revised site-specific process simulation complete with site conditions	6/30/2015	Unmet	Work has just started
Q4 FY15	Completion of final techno-economic analysis of candidate site	9/30/2015	Unmet	Work yet to begin

Key Accomplishments and Milestones Cont.

- Final report delivered covering FY14 study findings and key results
  - Site-specific cost parameters for production and injection well requirements at North Valmy plant
  - Net electric power and levelized cost of electricity (LCOE) estimates for each model case
  - Variable and fixed costs estimated for each case
  - Capital cost estimates for each model case
- Manuscript of report findings is currently being drafted

Expectations for Next Quarter

- Schedule on site visit to North Valmy (Nevada) for on site analysis and discussions with Geothermal site operator and coal plant operator

- Perform a site-specific lithography and resource analysis of a candidate site
  - Get site data from EIA database and prepare questions for contact site operator
  - Contact site operator to get specific information on steam cycle configuration, flows
  - Investigate regional lithography to get a more specific cost analysis of well drilling and stimulation

- Work with plant operator for alternative hybridization strategies of low-grade geothermal integration in conventional coal plant with and without CCS:
    - Reduce the main air compressor horsepower by cooling the inlet air or the booster air compressor by integration with the heat exchange network.
    - Reduction of cooling water temperature for increased vacuum in the condenser
    - Using geothermal steam in the coal-plant's low-pressure steam turbine

Spending as of Q1 FY15

		Total FY14 Budget Authority					Unsent Money at Lab	
	Project ID	FY14 New Budget Authority	FY13 Carryover NOT Including Forward Funding	Forward Funding Portion of FY13	Money Received by Lab in FY15 AOP	Total Money Spent in FY15	Unspent Uncommitted	Unspent Committed
DOE Data	1.1.0.10	$0	-	N/A	$0	-	-	-
Lab Data	1.1.0.10	$0	N/A	$0	$27,864	$115,448	$1,031	$0

- Carryover of $88,615 to begin FY15
- Describe any inconsistencies: received $27,864 for FY15 out of the $200,000 requested for FY15
- Project is on a stop-work until $172k of remaining funding arrives
- Cumulative project cost (FY14-15) as of this quarter: $326,833

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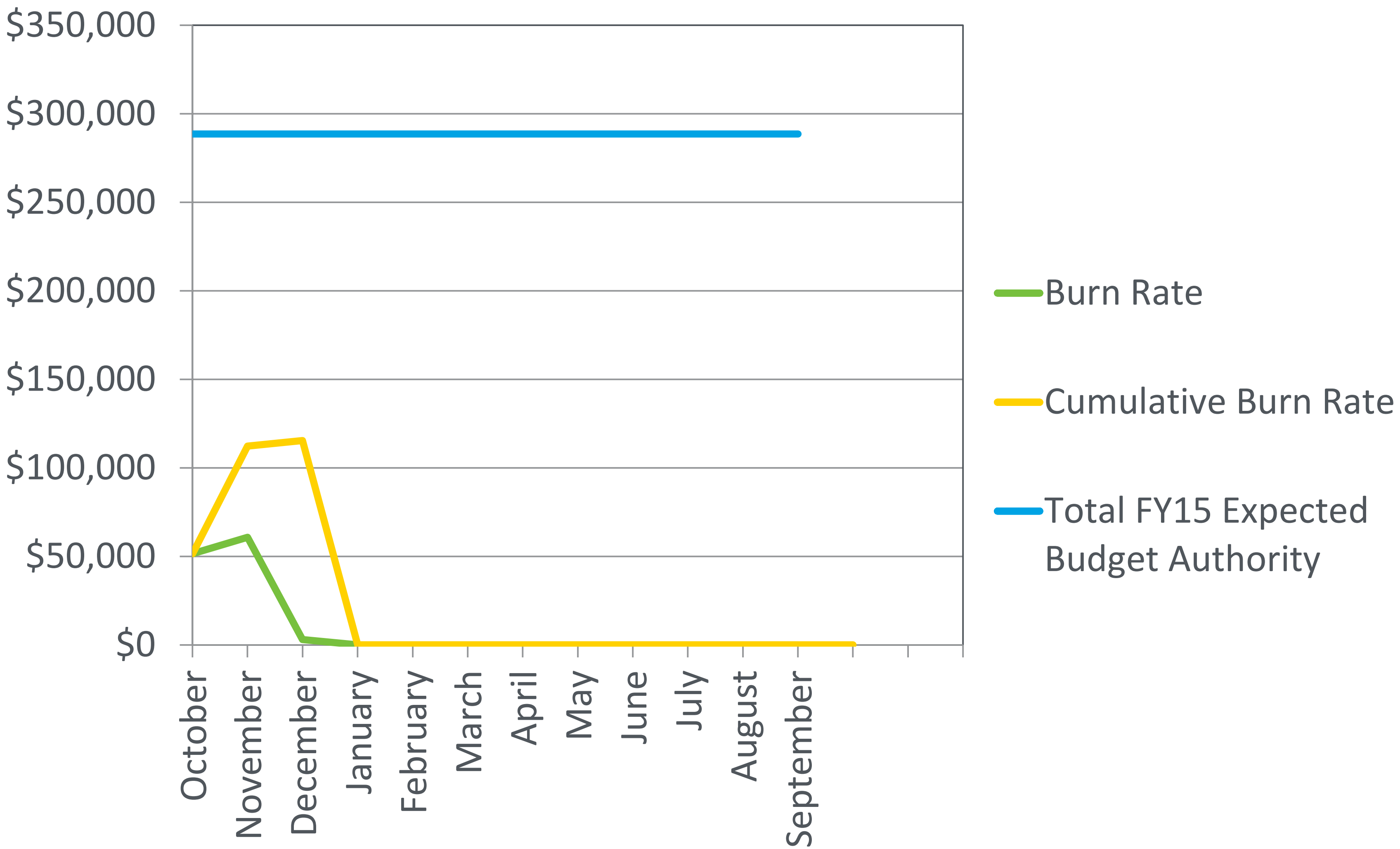
Burn Rate by Month



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Data Submissions

Data Element	Data Type	Date Collected (projected or actual)	Date Submitted (projected or actual)
Task 1: Site-specific geothermal resource and industrial site mapping	DOC file and independent Jpeg images	Projected for March 31, 2015	Projected March 31, 2015
Task 2: Coal Power plant with geothermal plant model	PPT file	Projected for June 30, 2015	Projected June 30, 2015
Task 3: Technoeconomic analysis	DOC and PPT files	Projected September 30, 2015	Projected September 30, 2015
Task 4: Project management	DOC and PPT files	Quarterly and Annual Reporting	Quarterly and Annual Reporting

Study Directions

CCS solvent system reboiler:

This is a CCS-only modeling case

The NETL Case 10 Econamine reboiler operating at about 116°C requires about half of the power plant steam for operation

- CCS solvent reboiler (MEA) with 121-150 ˚C water
- CCS solvent reboiler (MEA) with 121-150 ˚C water, followed by boiler water preheating
- Boiler water preheating only with 43-121 ˚C water.
- Energetics modeled as a function of Temp reboiler.
- CCS solvent reboiler (MEA, K_2CO_3, CO_2BOL) with XC water, followed by boiler water preheating

Aspen Economic Analyzer Estimate of Geothermal Heat Exchangers

Case 9 BFW Heating Only	
$	7,560,624
	304,333
BFW Heater	

Analysis suggests *ammonia has the lowest heat exchanger sizing*

But not used due to lowest power output of ORC candidates

	Ammonia Exchangers		
		Total Ammonia Exchangers	$ 2,149,692
Aspen EDR Cost (all shells)	$ 547,734	$ 1,102,536	$ 499,422
Area ft^2	32,230	63,984	24,393
	Condenser	Evaporator	BFW heater

Isobutane Exchangers			
		Total iC4 Exchangers	$ 10,304,992
$ 2,828,376	$ 4,734,672	$ 583,064	$ 2,158,880
175,825	325,335	19,103	103,575
Condenser	Evaporator	BFW heater	Recuperator

Propane Exchangers			
		Total Propane Exchangers	$ 33,919,988
$ 1,276,528	$ 30,872,820	$ 1,283,508	$ 487,132
69,377	2,197,479	40,488	32,560
Condenser	Evaporator	Recuperator	BFWHeater

Aspen Economic Analyzer Estimate of Case 9, and ORC Infrastructure

- Cost comparisons of the Case 9 boiler feed water heating capital
  - 1 mile 18” piping
  - Supply/return pumps
  - Cooling tower
  - Heat exchangers (tube and shell)
- Cost analysis of ORC system running *iso*-butane working fluid
  - 1 mile 18” piping
  - Supply/return pumps
  - Cooling tower
  - Heat exchangers (tube and shell)

Capital Increment Components		PNNL Case 9 Geothermal BFW Heating	PNNL Case 9 Geothermal ORC - Ammonia	PNNL Case 9 Geothermal ORC - Propane	PNNL Case 9 Geothermal ORC - i-Butane
Geothermal Pipeline	1 mile 18" Sply/Ret	7,200,000	7,200,000	7,200,000	7,200,000
Geothermal return pumps		1,821,233	1,821,233	1,821,233	1,821,233
Cooling Tower addition		3,601,622	3,601,622	3,601,622	3,601,622
Heat exchangers (including ORC)		7,560,624			10,304,992
ORC expander, generator, transformer		-		-	3,409,562
APE Total erected cost		20,183,479			26,337,409
Contingency (process and project)	0.12	2,422,017			3,160,489
Project indirect factor	0.6	12,110,087			17,698,739
Project Capital Increment		34,715,584			47,196,637

Aspen Economic Analyzer Estimate of Case 10 – CCS reboiler & BFW Heating

- Partial MEA Reboiler & BFW Heating with ~ 2.7 M lb/hr geothermal fluid
- Total MEA Reboiler & BFW Heating with 37 M lb/hr geothermal fluid
- Advanced CCS Reboiler (~80%) & BFW Heating with 10 M lb/hr geothermal fluid
- Cost comparisons of the Case 10 boiler feed water heating capital
  - 1 mile 18" piping
  - Supply/return pumps
  - Cooling tower (incremental)
  - Heat exchangers (tube and shell – stainless steel SS304 construction)

Capital Increment Components		PNNL Case 10 MEA Reboiler Duty & BFW Htg	PNNL Case 10 Max Reboiler Duty & BFW Htg	PNNL Case 10 10MMlb/hr GT Advanced CCS
Geothermal Pipeline	1 mile Sply/Ret	7,200,000	19,200,000	10,800,000
Geothermal return pumps		1,821,233	21,810,983	4,463,949
Cooling Tower addition		2,903,900	11,487,500	9,780,700
Heat exchangers		12,154,030	10,669,729	4,955,370
APE Total erected cost		24,079,163	63,168,212	30,000,019
Contingency (process and project)	0.12	2,889,500	7,580,185	3,600,002.28
Project indirect factor	0.6	14,447,498	37,900,927	18,000,011
Project Capital Increment		41,416,161	108,649,325	51,600,033

A note on Case 10 Results

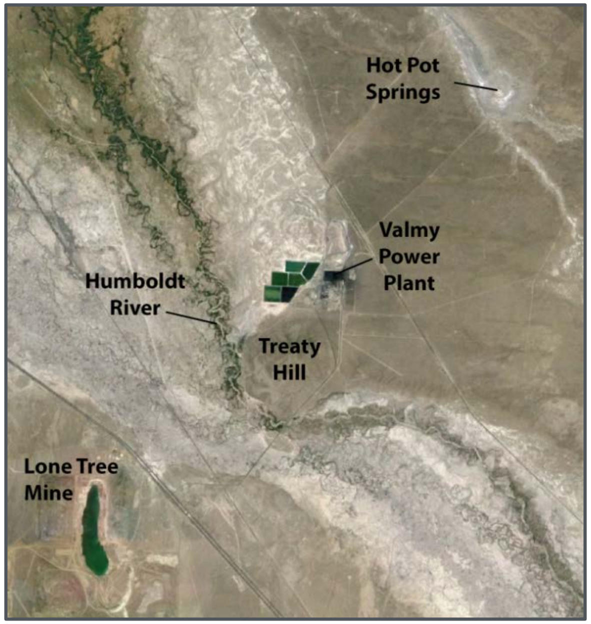
- Looking at the Case 10 studies…
  - The pipeline, return pumps, and incremental cooling tower addition cost are primarily a function of the geothermal water flow
  - The heat exchanger costs are primarily a function of the temperature difference in the specific heat exchanger and thus do not necessarily follow the trend of higher cost with higher flow.

Detailed Analysis of the North Valmy Site

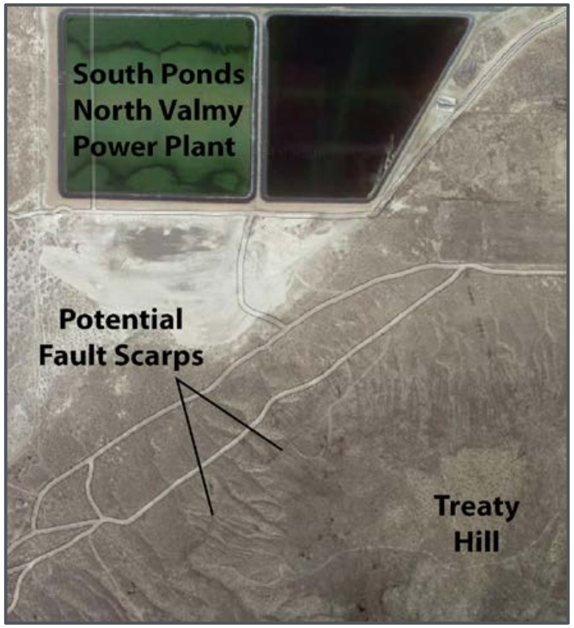
- North Valmy power plant is that it's located only 1.5 to 2 miles south-southwest of the "Hot Pot" thermal anomaly, which is an area currently leased for geothermal development by Oski Energy, LLC.
- If private development is already taking place just over the property line then there is likely a good resource.

Lane, M, R Schweickert, and T DeRocher. 2012. PROCEEDINGS, Thirty-Seventh Workshop on Geothermal Reservoir Engineering Stanford University, Stanford, California, January 30 - February 1, 2012 SGP-TR-194.

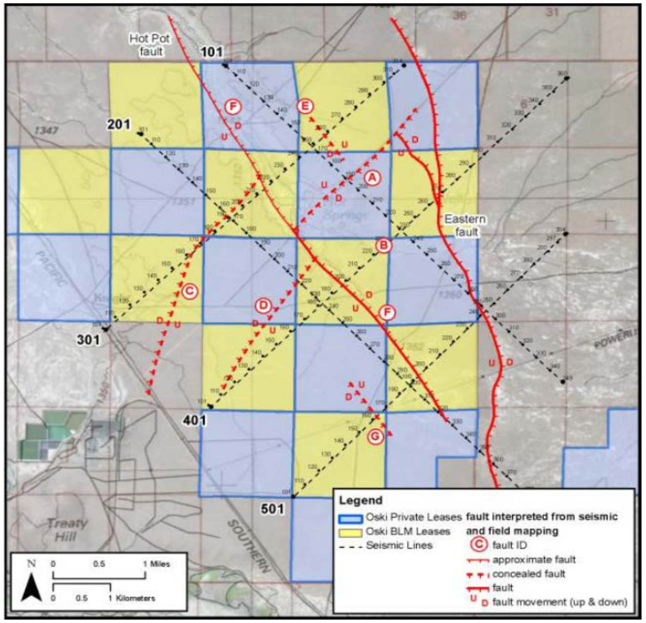
Location Map



Potential Quaternary fault scarp along the northwest flank of Treaty Hill.



Location of Oski Energy, LLC geothermal leases, the Hot Pot seismic program survey lines, and interpreted structures (Lane et a., 2012).



Site-specific cost parameters and resulting cost estimates for production and injection well requirements at North Valmy

- Drilling depths to reach a sufficient fluid temperature of 150°C with conservative gradient of 4°F/100' (70°C/km) to 5°F/100' (90°C/km)

- Drilling depths of approximately 5000 feet (Case 1) and 6600 feet (Case 2).

- Butler et al.[10] reported that at the similar Beowawe site, produces from the same heavily fractured reservoir of interest for this project,
  - 1.8 million lb/h, a per-well average of 600,000 lb/h.
- Assuming that this average rate could be replicated at the North Valmy site, process water needs
  - 2.5 MMlb/h could be met using 4 or 5 production wells

- Shevenell's,[11] review of efforts to estimate well drilling costs for geothermal projects in Nevada can be used to assume 5 required production wells,would require 3 injection wells.

- Site-specific, conservative approach is consistent with the 2:1 ratio at Beowawe.

- Cost estimates for projection and injection wells done based on work by Shevenell,[11] Klein et al,[12] Bradys[13] and Augustine et al.[14]

Site-specific cost parameters and resulting cost estimates for production and injection well requirements at North Valmy

- Average per-well costs for production wells is between \$1.2M and \$1.6M each,
  - cost variance resulting from increased depth to reach 150 ˚C water in Case 2 (70 °C/km) relative to Case 1 (90 °C/km)
- Injection wells appear to cost about 5% more than production wells at Beowawe
  - 5% adder was included in injection well cost estimates
- Total well costs for this project fall between \$10M and \$13M
  - Note that these estimates are based on averages and statistical relationships.
  - Estimates are a function of depth alone assuming average well diameters,
  - Assume typical drilling conditions and standard well completions

Site-specific cost parameters and resulting cost estimates for production and injection well requirements at North Valmy

Depth to recover 150 ˚C water

Case 1 = 5,000 ft

Case 2= 6,600 ft

	Case 1	Case 2
Avg Temp Gradient, °C/km	90	70
Desired Temp, °C	150	150
Projected Drill Depth, ft	4,922	6,562
Per-Well Flow Rate, lb/h	600,000	600,000
Required Flow Rate, lb/h	2,500,000	2,500,000
Required Wells, Production	5	5
Required Wells, Injection	3	3
Production Well Costs, each	$ 1,274,394	$ 1,618,930
Production Well Costs, total	**$ 6,371,969**	**$ 8,094,651**
Injection Well Costs, each	$ 1,338,114	$ 1,699,877
Injection Well Costs, total	**$ 4,014,341**	**$ 5,099,630**
TOTAL WELL COSTS	**$ 10,386,310**	**$ 13,194,281**

Energy and Cost Analysis of Hybrid Plant

- Energy and cost of electricity projection was performed for eight cases modeled in Aspen.
  - Case 9 and Case 10
  - Case 10 with CO_2BOLs advanced solvent used in place of MEA.
  - The five other cases give various hybrids of geothermal water integration.
    - Hybrid plants are operated in a system virtually identical to either Case 9 or 10 albeit with geothermal infrastructure auxiliary draws and capital costs and resource extraction costs.
- Advanced solvents such as CO_2BOLs are more amenable to lower grade geothermal resources.
  - 10,000,000 lbs/hr of geothermal water (at 150°C) could potentially offset 90% of the CO_2BOLs regeneration duty, producing an estimated 40 MWe more power than CO_2BOLs alone, and 121 MWe more power than Case 10.

Fuel Cost Estimates for Each Model Case

	No Carbon Capture (Case 9 reference: Subcritical PC)			With Carbon Capture (Case 10 reference: Subcritical PC with MEA capture solvent)					
Fuel Costs	Case 9 Only (recreated)	Case 9 with geothermal for BFW heating	Case 9 with geothermal for BFW, but through ORC [i-Butane] first	Case 10 Only (recreated)	Case 10 with geothermal for BFW, but for 7% of reboiler first	Case 10 with geothermal for BFW, but for 100% of reboiler first	Case 10 with low viscosity CO2BOLs solvent vs. MEA (no geothermal)	Case 10 w/ CO2BOLs, BFW via geothermal but for 90% of reboiler first	Assumptions (list below)
TOTAL (STEAM TURBINE) POWER, kWe	574,331	597,822	588,505	668,950	695,453	830,588	760,890	807,486	1
Portion of Total Power from ORC, kWe			15,767						
AUXILIARY LOAD SUMMARY, kWe									
Coal Feed, Boiler and Auxiliaries	21,360	21,360	21,360	30,470	30,470	30,470	30,470	30,470	5
CO2 Capture Plant Auxiliaries				19,231	19,268	19,584	27,660	19,584	1
CO2 Compression				48,790	48,790	48,790	48,790	48,790	9
Condensate Pumps	516	514	512	405	432	723	405	707	1
Circulating Water Pumps	4,963	5,844	5,896	10,199	10,984	14,221	10,199	13,486	5
Ground Water Pumps	540	636	641	930	1,001	1,296	930	1,229	1
Cooling Tower Fans	2,770	3,262	3,291	7,791	8,383	10,854	7,791	10,293	1
Transformer Loss	1,804	1,878	1,848	2,337	2,429	2,901	2,337	2,821	1
Geothermal Well Injection Pumps		3,039	3,039		3,039	50,879		7,954	1
TOTAL AUXILIARIES, kWe	31,953	36,532	36,587	120,152	124,796	179,718	128,581	135,333	2
NET POWER, kWe	542,379	561,289	551,918	548,799	570,657	650,870	632,309	672,153	2
Net Plant Efficiency (HHV)	36.3%	37.5%	36.9%	26.1%	27.1%	31.0%	30.1%	32.0%	2
Net Plant Heat Rate (Btu/kWh)	9,408	9,091	9,245	13,074	12,573	11,023	11,347	10,674	2
As-Received Coal Feed (kg/h)	198,391	198,391	198,391	278,956	278,956	278,956	278,956	278,956	5
Thermal Input, kWt	1,495,379	1,495,379	1,495,379	2,102,643	2,102,643	2,102,643	2,102,643	2,102,643	5
Total CO2 Production Rate (kg/h)	471,116	471,116	471,116	695,954	695,954	695,954	695,954	695,954	5
Percent CO2 Captured	0%	0%	0%	90%	90%	90%	90%	90%	5
Geothermal Water Flow (lb/hr)	0	2,695,600	2,695,600	0	2,695,600	37,000,000	0	10,000,000	1
Total Geothermal Duty (MMBtu/hr)	0	517	517	0	517	2,577	0	1,605	1
Annual Fuel Cost ($MM/year)	$62.2	$62.2	$62.2	$87.4	$87.4	$87.4	$87.4	$62.2	2
Utilization Factor	85%	85%	85%	85%	85%	85%	85%	85%	5
Fuel Cost (¢/kWe-hr)	1.54	1.49	1.51	2.14	2.06	1.80	1.86	1.24	2

Assumptions: 1) From Aspen Plus Simulation, 2) Calculated from Table Values, 3) From Aspen Economic Analyzer, 4) Average well cost estimates, 5) Same as Case 9 or Case 10, 6) Assumes 23% of TPC, 7) MEA from Case 10, CO_2BOLs from PNNL report, 8) Same as Case 9 or Case 10 normalized to new net power.

Capital Cost Estimates for Each Model Case

Total Capital Costs ($, Million)	No Carbon Capture (Case 9 reference: Subcritical PC)			With Carbon Capture (Case 10 reference: Subcritical PC with MEA capture solvent)					Assumptions (list below)
	Case 9 Only (recreated)	Case 9 with geothermal for BFW heating	Case 9 with geothermal for BFW, but through ORC [i-Butane] first	Case 10 Only (recreated)	Case 10 with geothermal for BFW, but for 7% of reboiler first	Case 10 with geothermal for BFW, but for 100% of reboiler first	Case 10 with low viscosity CO2BOLs solvent vs. MEA (no geothermal)	Case 10 w/ CO2BOLs, BFW via geothermal but for 90% of reboiler first	
Non-Carbon Capture Components:									
Coal & Sorbent Handling	$40	$40	$40	$50	$50	$50	$50	$50	8
Coal & Sorbent Prep & Feed	$19	$19	$19	$24	$24	$24	$24	$24	8
Feedwater & Misc. BoP Systems	$75	$75	$75	$99	$99	$99	$99	$99	8
PC Boiler	$267	$267	$267	$339	$339	$339	$339	$339	8
Flue Gas Cleanup	$135	$135	$135	$174	$174	$174	$174	$174	8
Combustion Turbine/Accessories	$0	$0	$0	$0	$0	$0	$0	$0	8
HRSG, Ducting & Stack	$39	$39	$39	$42	$42	$42	$42	$42	8
Steam Turbine Generator	$114	$114	$114	$129	$129	$129	$129	$129	8
Cooling Water System	$40	$40	$40	$65	$65	$65	$65	$65	8
Ash/ Spent Sorbent Handling Sys	$13	$13	$13	$16	$16	$16	$16	$16	8
Accessory Electric Plant	$52	$52	$52	$84	$84	$84	$84	$84	8
Instrumentation & Control	$21	$21	$21	$26	$26	$26	$26	$26	8
Improvements to Site	$14	$14	$14	$16	$16	$16	$16	$16	8
Buildings & Structures	$62	$62	$62	$63	$63	$63	$63	$63	8
Carbon Capture Components:									7
CO2 Removal System				$443	$443	$443	$445	$445	7
CO2 Compression & Drying				$50	$50	$50	$50	$50	5
Geothermal Components:									
Well Costs		$13	$13		$13	$181		$49	4
Geothermal Pipeline		$7	$7		$7	$19		$11	3
Geothermal Return Pumps		$2	$2		$2	$22		$4	3
Cooling Tower Addition		$4	$4		$3	$12		$10	3
Heat Exchangers (including ORC)		$8	$10		$12	$11		$5	3
ORC expander, generator, transformer			$3						3
Owner's Costs	$205	$213	$214	$372	$381	$428	$373	$391	6
Total Overnight Cost	$1,098	$1,139	$1,147	$1,991	$2,037	$2,291	$1,994	$2,091	2
Capital Charge Factor	0.117	0.117	0.117	0.124	0.124	0.124	0.124	0.124	5
Capital Cost (¢/kWe-hr)	3.17	3.18	3.25	6.06	5.96	5.88	5.26	5.19	2

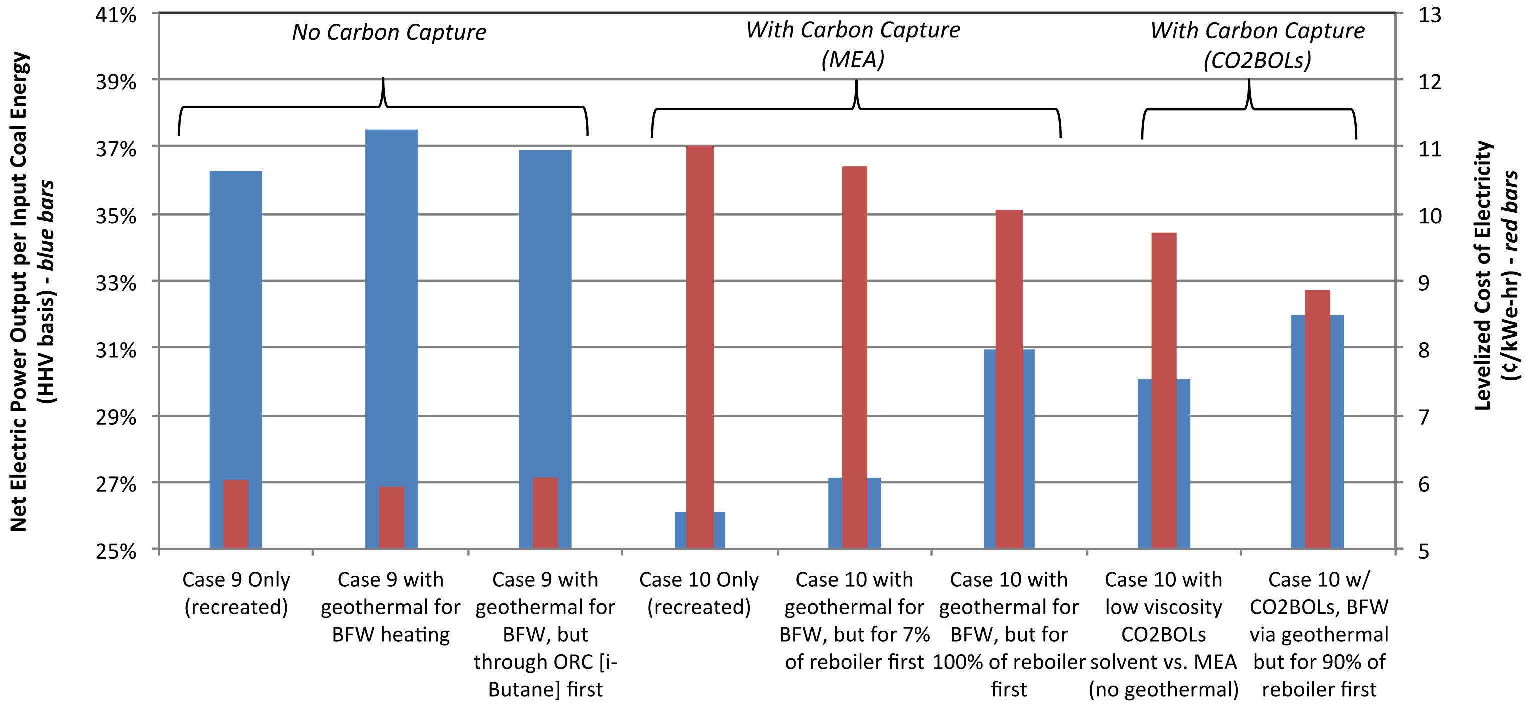
Assumptions: 1) From Aspen Plus Simulation, 2) Calculated from Table Values, 3) From Aspen Economic Analyzer, 4) Average well cost estimates, 5) Same as Case 9 or Case 10, 6) Assumes 23% of TPC, 7) MEA from Case 10, CO_2BOLs from PNNL report, 8) Same as Case 9 or Case 10 normalized to new net power.

Variable and Fixed Operating Costs Estimates for Each Case

	No Carbon Capture (Case 9 reference: Subcritical PC)			With Carbon Capture (Case 10 reference: Subcritical PC with MEA capture solvent)					
Variable Costs ($k/yr)	Case 9 Only (recreated)	Case 9 with geothermal for BFW heating	Case 9 with geothermal for BFW, but through ORC [i-Butane] first	Case 10 Only (recreated)	Case 10 with geothermal for BFW, but for 7% of reboiler first	Case 10 with geothermal for BFW, but for 100% of reboiler first	Case 10 with low viscosity CO2BOLs solvent vs. MEA (no geothermal)	Case 10 w/ CO2BOLs, BFW via geothermal but for 90% of reboiler first	Assumptions (list below)
Non-Capture System:									
Maintenance Material Cost	$8,763	$8,763	$8,763	$15,644	$15,644	$15,644	$15,644	$15,644	5
Water	$1,425	$1,425	$1,425	$2,712	$2,712	$2,712	$2,712	$2,712	5
MU & WT Chem	$1,103	$1,103	$1,103	$2,100	$2,100	$2,100	$2,100	$2,100	5
Limestone	$3,496	$3,496	$3,496	$5,043	$5,043	$5,043	$5,043	$5,043	5
Ammonia (28% NH3)	$3,136	$3,136	$3,136	$4,446	$4,446	$4,446	$4,446	$4,446	5
SCR Catalyst	$593	$593	$593	$832	$832	$832	$832	$832	5
Flyash Disposal	$2,050	$2,050	$2,050	$2,882	$2,882	$2,882	$2,882	$2,882	5
Bottom Ash Disposal	$512	$512	$512	$720	$720	$720	$720	$720	5
Capture System:									
Solvent	$0	$0	$0	$1,106	$1,106	$1,106	$4,826	$4,826	7
NaOH	$0	$0	$0	$1,062	$1,062	$1,062	$4,071	$4,071	7
H2SO4	$0	$0	$0	$324	$324	$324	$496	$496	7
Corrosion Inhibitor	$0	$0	$0	$7	$7	$7	$0	$7	5
Activated Carbon	$0	$0	$0	$616	$616	$616	$617	$617	5
Total ($k/yr)	$21,078	$21,078	$21,078	$37,496	$37,496	$37,496	$44,391	$44,399	2
Variable Operating Cost (¢/kWe-hr)	0.52	0.50	0.51	0.92	0.88	0.77	0.94	0.89	2
Fixed Operating Costs ($k/yr)									
Operating Labor	$5,524	$5,524	$5,524	$6,445	$6,445	$6,445	$6,445	$6,445	5
Maintenance Labor	$5,842	$5,842	$5,842	$10,430	$10,430	$10,430	$10,430	$10,430	5
Administrative & Support Labor	$2,842	$2,842	$2,842	$4,219	$4,219	$4,219	$4,219	$4,219	5
Property Taxes and Insurance	$17,849	$17,849	$17,849	$32,367	$32,367	$32,367	$32,367	$32,367	5
Total	$32,057	$32,057	$32,057	$53,460	$53,460	$53,460	$53,460	$53,460	2
Fixed Operating Cost (¢/kWe-hr)	0.79	0.77	0.78	1.31	1.26	1.10	1.14	1.07	2

Assumptions: 1) From Aspen Plus Simulation, 2) Calculated from Table Values, 3) From Aspen Economic Analyzer, 4) Average well cost estimates, 5) Same as Case 9 or Case 10, 6) Assumes 23% of TPC, 7) MEA from Case 10, CO_2BOLs from PNNL report, 8) Same as Case 9 or Case 10 normalized to new net power.

Levelized Cost of Electricity Estimates for Each Model Case And Summary of Costs



	No Carbon Capture (Case 9 reference: Subcritical PC)			With Carbon Capture (Case 10 reference: Subcritical PC with MEA capture solvent)					
Summary of Costs (¢/kWe-hr)	**Case 9 Only (recreated)**	**Case 9 with geothermal for BFW heating**	**Case 9 with geothermal for BFW, but through ORC [i-Butane] first**	**Case 10 Only (recreated)**	**Case 10 with geothermal for BFW, but for 7% of reboiler first**	**Case 10 with geothermal for BFW, but for 100% of reboiler first**	**Case 10 with low viscosity CO2BOLs solvent vs. MEA (no geothermal)**	**Case 10 w/ CO2BOLs, BFW via geothermal but for 90% of reboiler first**	**Assumptions (list below)**
Fuel Cost	1.54	1.49	1.51	2.14	2.06	1.80	1.86	1.24	2
Capital Cost	3.17	3.18	3.25	6.06	5.96	5.88	5.26	5.19	2
Variable Cost	0.52	0.50	0.51	0.92	0.88	0.77	0.94	0.89	2
Fixed Operating Cost	0.79	0.77	0.78	1.31	1.26	1.10	1.14	1.07	2
Transp, Seques & Monitoring (TSM)	----	----	----	0.59	0.57	0.50	0.51	0.48	8
Total	**6.02**	**5.93**	**6.06**	**11.01**	**10.72**	**10.06**	**9.71**	**8.87**	2
Increase versus Case 9 (No Capture)	----	***-1.5%***	***0.6%***	***83%***	***78%***	***67%***	***61%***	***47%***	2

Levelized Cost of Electricity Estimates for Each Model Case

- Levelized cost of electricity (LCOE) values for each of the modeled cases is based fuel, capital variable, fixed and TSM costs
- Using 150°C geothermal water for boiler feed water preheating appears to offer a higher net electric power, at a comparable LCOE, compared to a stand-alone Case 9 sub-critical power plant option
- Passing the resource through an ORC prior to using it for boiler feed water preheating is estimated to produce less overall net power than using it for boiler feed water preheating alone
- For CCS integration, massive amounts of geothermal water are required to fully offset the MEA (CO_2 capture solvent) regeneration energy need are not considered feasible amounts of geothermal resource for a single site
- A geothermal resource of (2,695,600 lb/hr) is estimated to offset ~7% of a MEA reboiler duty in NETL's Case 10, resulting in ~1% of recovered net electric power lost to the overall CCS parasitic load, but at a similar (high) LCOE to CCS alone.
- Advanced solvents (e.g. CO_2BOLs) more feasible, with ~0.75cents per kWe-hr projected LCOE savings and ~2 points of net electric power increase versus CO_2BOLs alone.
- Model case result could significantly change with higher (or lower) geothermal water temperatures.
- Economic sensitivities to geothermal temperature may be worth exploring in subsequent efforts.

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