Operational Results for Geothermal Co-production of Electricity from Oilfield Operations*

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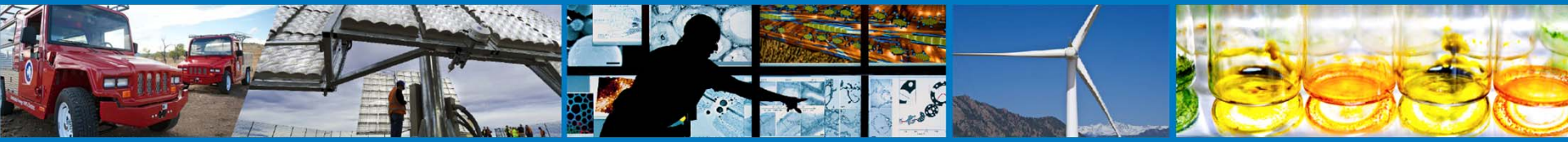
Abstract

Wastewater is a common byproduct of oil and gas production, and as geothermal conversion technologies have improved it has become possible to efficiently generate electricity from this waste-stream in certain situations. This co-production of hydrocarbons and electricity provides the opportunity to reduce operating costs and can extend the economic lifetime of producing fields. The limited field data from operating coproduction systems makes it difficult to evaluate opportunities, and thereby presents a market barrier to effective utilization of the technology.

This article reports on the results of a multi-year field demonstration of co-production conducted by DOE at the Rocky Mountain Oilfield Testing Center (RMOTC). The results are from two separate co-production geothermal power plants operating at RMOTC. The results provide the most comprehensive and detailed information on plant operating efficiency, power offset to grid, reliability, and maintenance that have ever been published. The data establish the baseline reliability and performance of geothermal co-production, and establish the impact of weather on the performance and energy generation of the plant. Conditions most conducive to co-production are also discussed.

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Operational Results for Co-Production of Electricity from Oilfield Operations



AAPG 2012 Convention

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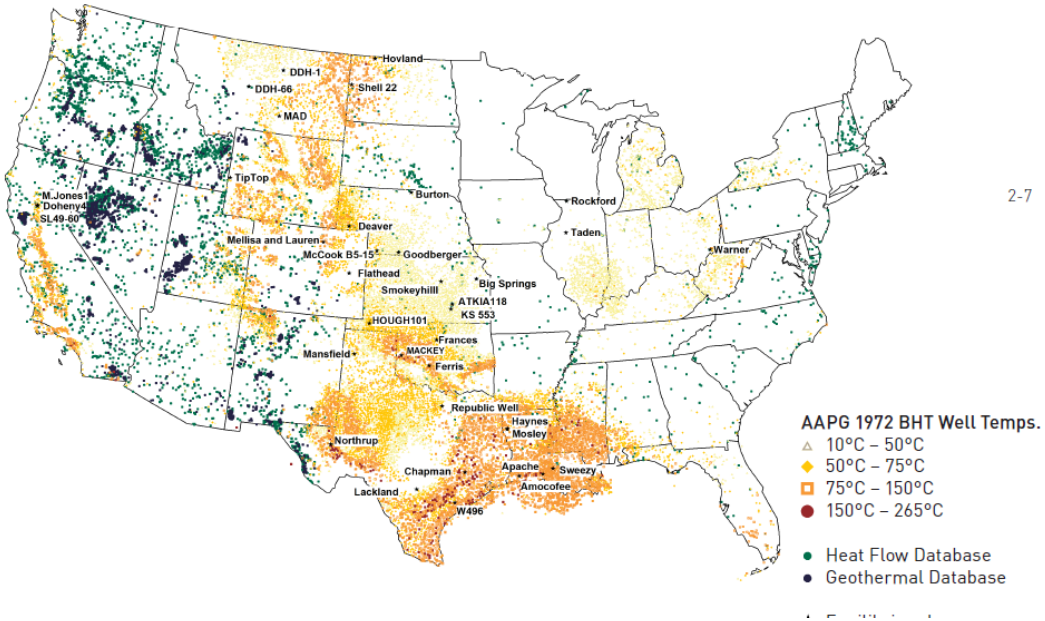
Coproduction of Geothermal Energy

Water produced as a byproduct of oil and gas operations can have significant thermal energy

Geothermal technologies have advanced to allow production of electricity at resource temperatures below 100 °C

Resources are abundant



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Potential benefits include

- Electricity for field operations
- Green power and renewable energy credits for sale
- Extension of the economic life of field

U.S. Water Production from Oil & Gas

Processed Water from U.S. Hydrocarbon Production

State	State	Total Processed Water, 2004, (bbl)	Water Production Rate, kGPM	Water Production Rate kg/s	Power, MW @ 100°C	Power, MW @ 140°C	Power, MW @ 150°C	Power, MW @ 180°C
AL	Alabama	203,223,404	18	1,026	18	47	64	88
AK	Alaska	1,688,215,358	153	8,522	153	389	528	733
AZ	Arizona	293,478	0.0265	1.4814	0.0267	0.0676	0.0918	0.1274
AR	Arkansas	258,095,372	23	1,303	23	59	81	112
CA	California	5,080,065,058	459	25,643	462	1,169	1,590	2,205
CO	Colorado	487,330,554	44	2,460	44	112	153	212
FL	Florida	160,412,148	15	810	15	37	50	70
IL	Illinois	2,197,080,000	199	11,090	200	506	688	954
IN	Indiana	72,335,588	7	365	7	17	23	31
KS	Kansas	6,326,174,700	572	31,933	575	1,456	1,980	2,746
KY	Kentucky	447,231,960	40	2,257	41	103	140	194
LA	Louisiana	2,136,572,640	193	10,785	194	492	669	927
MI	Michigan	188,540,866	17	952	17	43	59	82
MS	Mississippi	592,517,602	54	2,991	54	136	185	257
MO	Missouri	17,082,000	2	86	2	4	5	7
MT	Montana	180,898,616	16	913	16	42	57	79
NE	Nebraska	102,005,344	9	515	9	23	32	44
NV	Nevada	13,650,274	1	69	1	3	4	6
NM	New Mexico	1,214,796,712	110	6,132	110	280	380	527
NY	New York	1,226,924	0.1110	6.1931	0.1115	0.2824	0.3840	0.5326
ND	North Dakota	182,441,238	16	921	17	42	57	79
OH	Ohio	12,772,916	1	64	1	3	4	6
OK	Oklahoma	12,423,264,300	1,124	62,709	1,129	2,860	3,888	5,393
PA	Pennsylvania	18,571,428	2	94	2	4	6	8
SD	South Dakota	6,724,894	1	34	1	2	2	3
TN	Tennessee	62,339,760	6	315	6	14	20	27
TX	Texas	12,097,990,120	1,094	61,067	1,099	2,785	3,786	5,252
UT	Utah	290,427,704	26	1,466	26	67	91	126
WV	Virginia	2,235,240	0.2022	11.2828	0.2031	0.5145	0.6995	0.9703
VA	West Virginia	252,180,000	23	1,273	23	58	79	109
WY	Wyoming	3,809,086,632	344	19,227	346	877	1,192	1,654

Data Source: Curtice and Dalrymple, 2004.

Geothermal Coproduction Strategy

Opportunities:

- An estimated 10 barrels of water are produced per barrel of oil in North America
- Facilities have lower cost, shorter lead time, broader geographic distribution than conventional geothermal

Strengths:

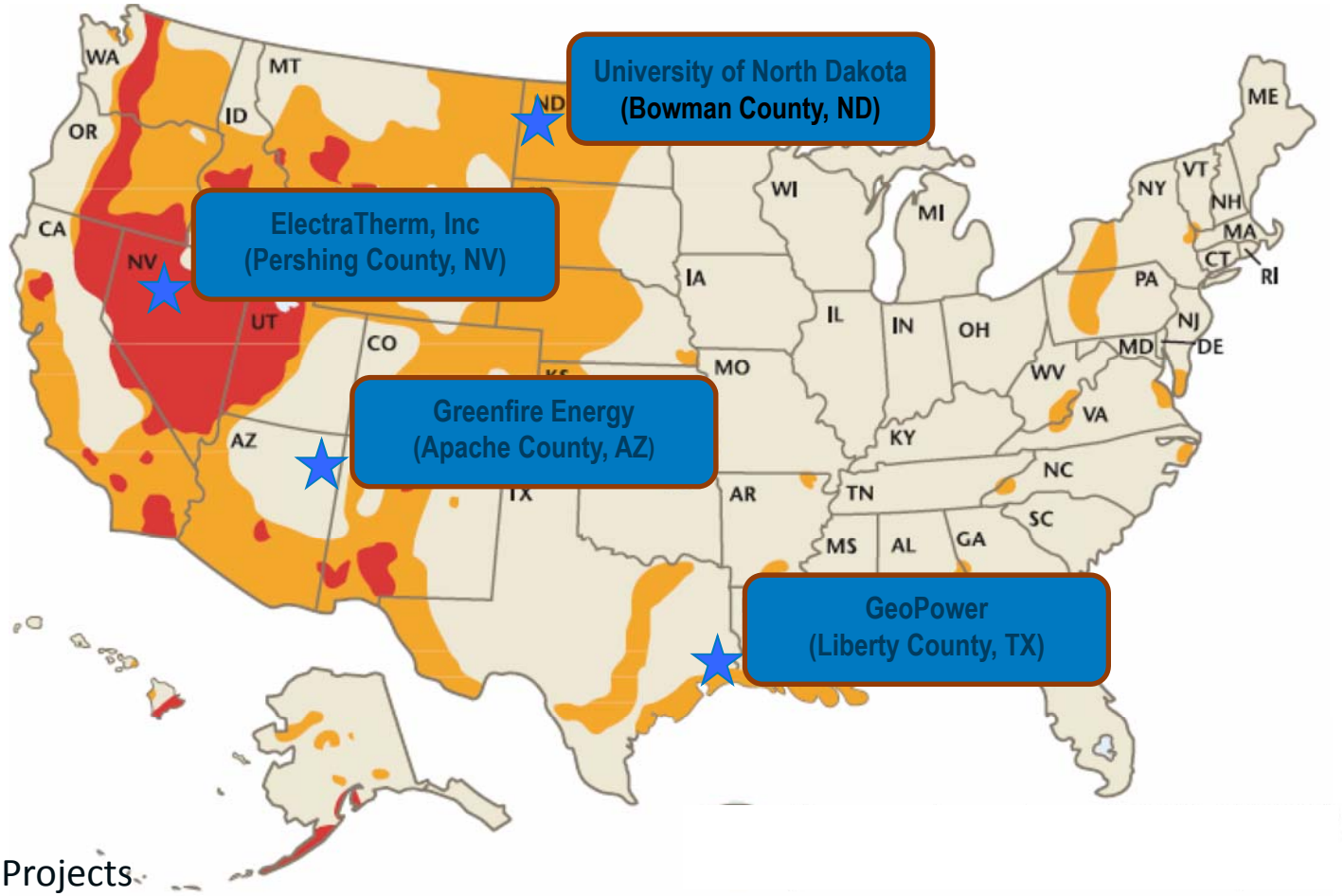
- Geothermal technology demonstrated and established in other applications
- Potential for producing power

Weaknesses/Barriers: Validation with Objective Data

- Electricity production
- O&M issues and expenses
- Economic Feasibility

DOE Coproduced Projects

Coproduced awards under GTP from ARRA and an FY10 FOA are located in four states and have a wide variety of applications from oil/gas wells and mining operations to plans to utilize geothermal energy to compress naturally occurring CO2.



★ Coproduced Projects

Test Site – Rocky Mountain Oilfield Test Center

Photo: Timothy Reinhardt, U.S. Department of Energy

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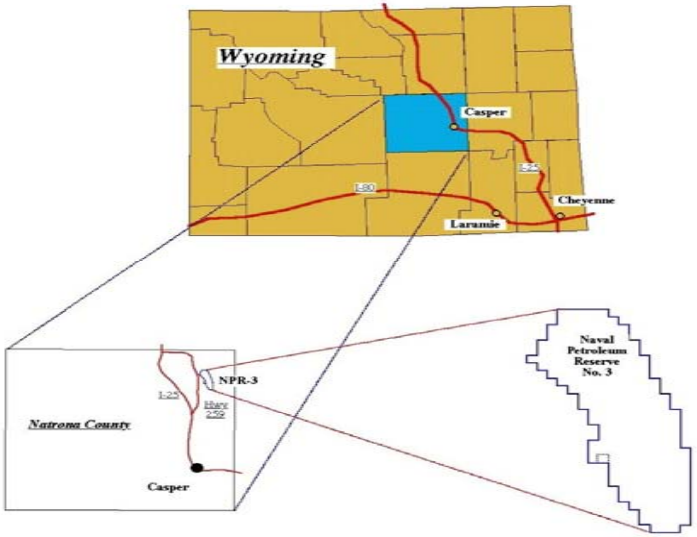


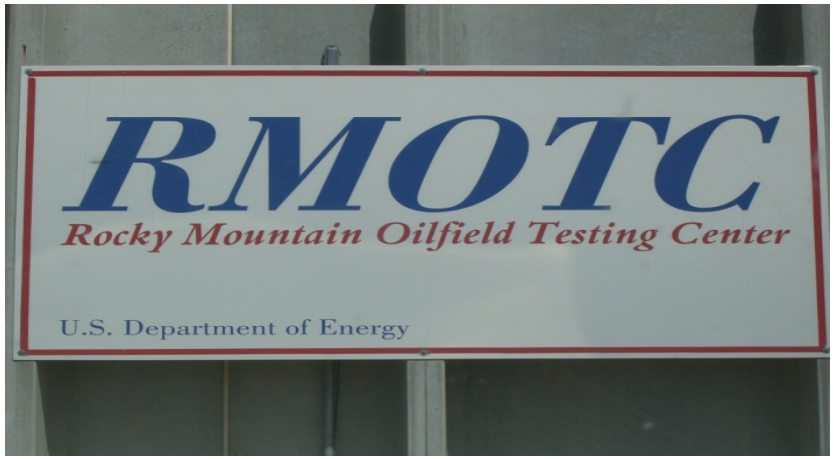


Photo: Timothy Reinhardt, U.S. Department of Energy

Benefits of testing at RMOTC

Facility Capabilities

- 9,481 acre stripper oil field
- 150 producing wells, 250 – 5,500 feet depth
- Water produced at 195 °F

Capacity for multiple geothermal tests

- Space
- Cooling water
- Infrastructure

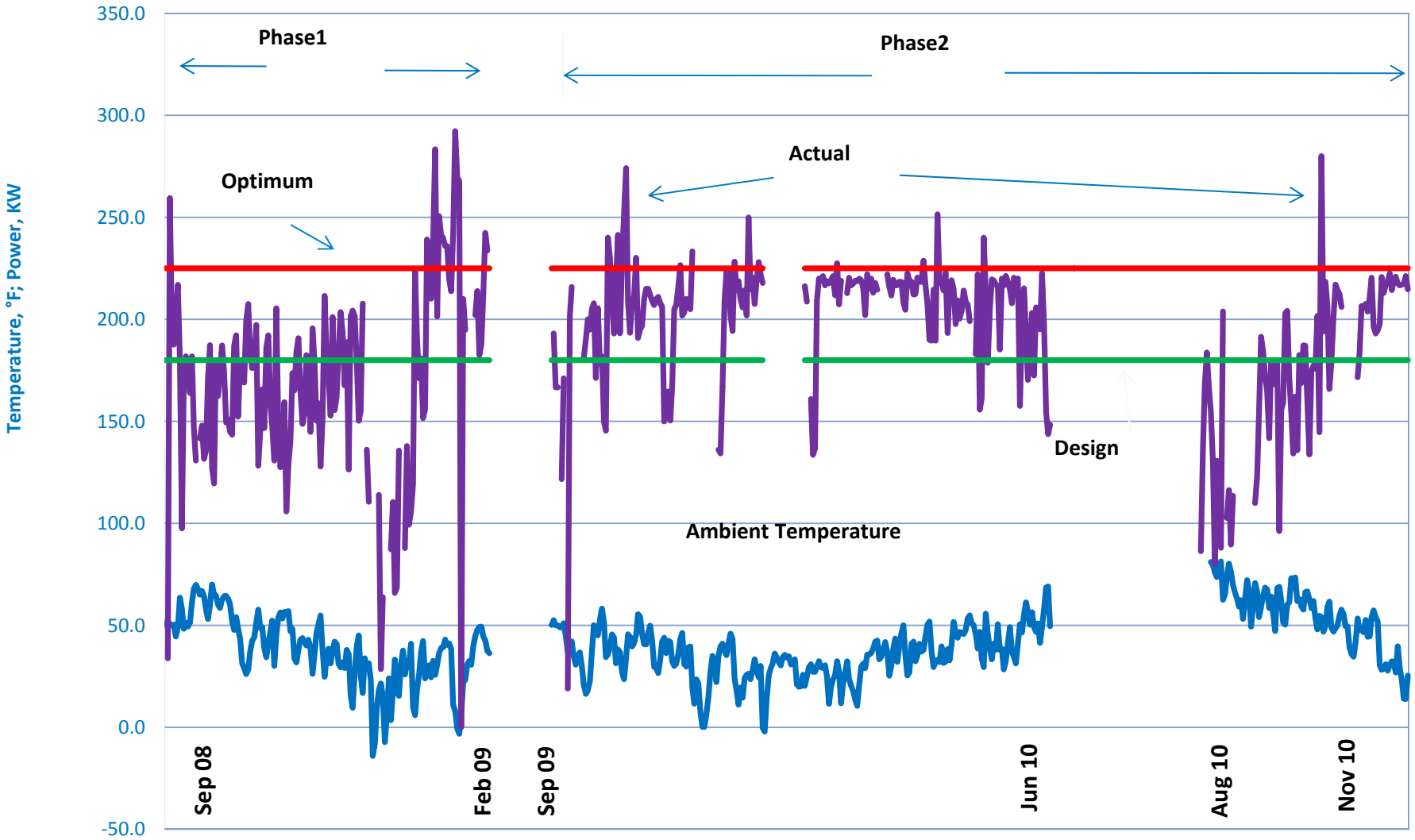
RMOTC maintains operability of units, RMOTC and NREL collaborate on collecting performance data

RMOTC Operational Results

	Design	Operational Results	
		Phase 1	Phase 2
Flow rate, bpd	40,000	12,000 to 40,000	11,000 to 50,000
Total hot water used, bbl		3,047,192	7,860,737
Inlet water temperature, °F	170	195 to 198	196 to 198
Outlet water temperature, °F	152	80 to 170	47 to 150
Average ambient temp., °F	50	-7 to 85	-2 to 81
Generator gross power, kW	180	105 to 305	105 to300
Daily avg. net power output, kW	132	80 to 280	80 to 275
Overall avg. net power, kW		171	185
Total power produced, MH		586	1,332

- Phase 2 has produced over 1,332 megawatt hours of power from 7.8 million barrels of coproduced hot water
- Total produced power from the unit is 1,918 megawatt hours of power from 10.9 million barrels of coproduced hot water
- Online percentage for the unit, eliminating downtime caused by field activities, has been a 97%

RMOTC Power Production and Temperature Effects



Expanding RMOTC data collection to understand transient operations

Data Collection

Instrumentation to monitor working fluid temperatures and pressures, brine temp and pressure, brine and working fluid flow rate, parasitic loads, and weather

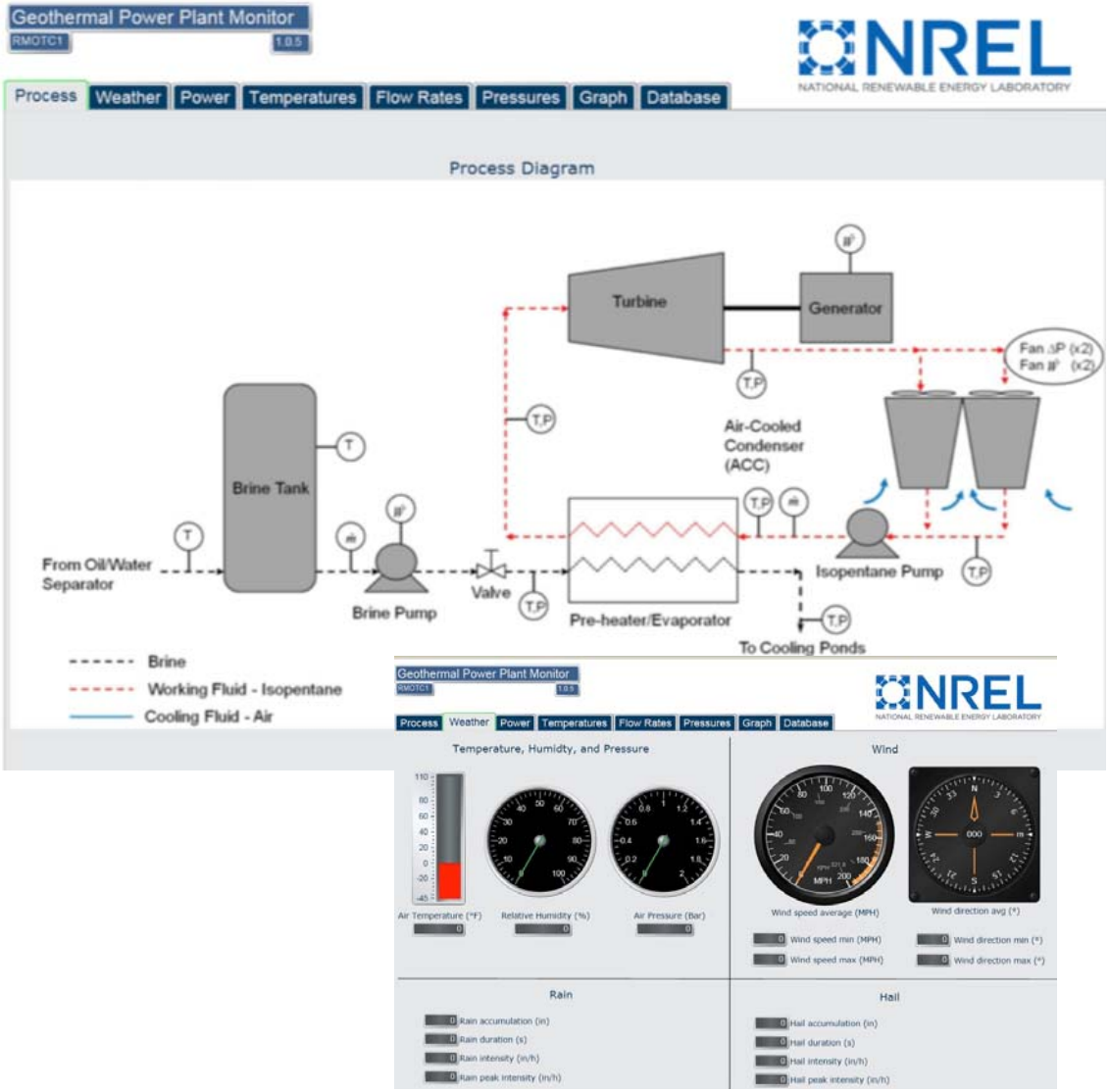
- 15 minute logging interval

Database design completed, ability to access via NGDS and OpenEI, long-term storage on Geothermal Data Repository

Status

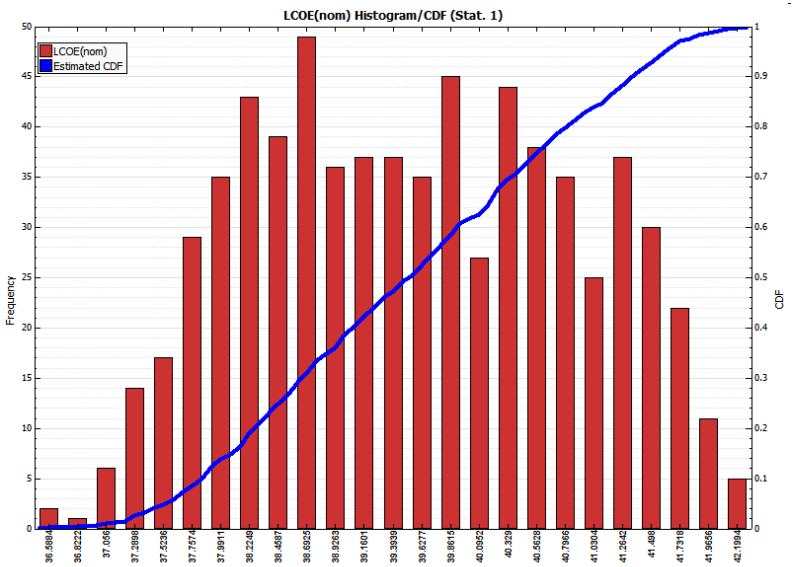
Design and Installation –complete

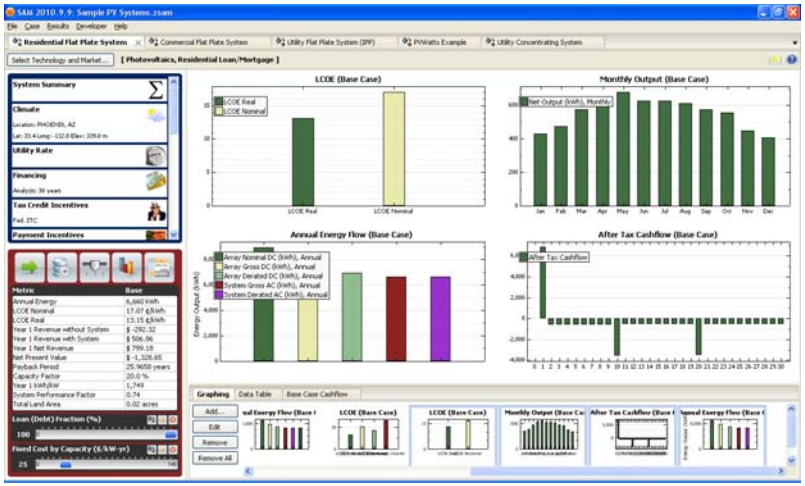
Data Collection will commence May 2012



Using the data in the System Advisor Model (SAM)

Complete System Modeling





Description

SAM combines detailed performance modeling with detailed finance modeling, cost data, detailed incentive abilities and weather files. This tool brings lab and academia developed models to the industry.

Users Initial Status

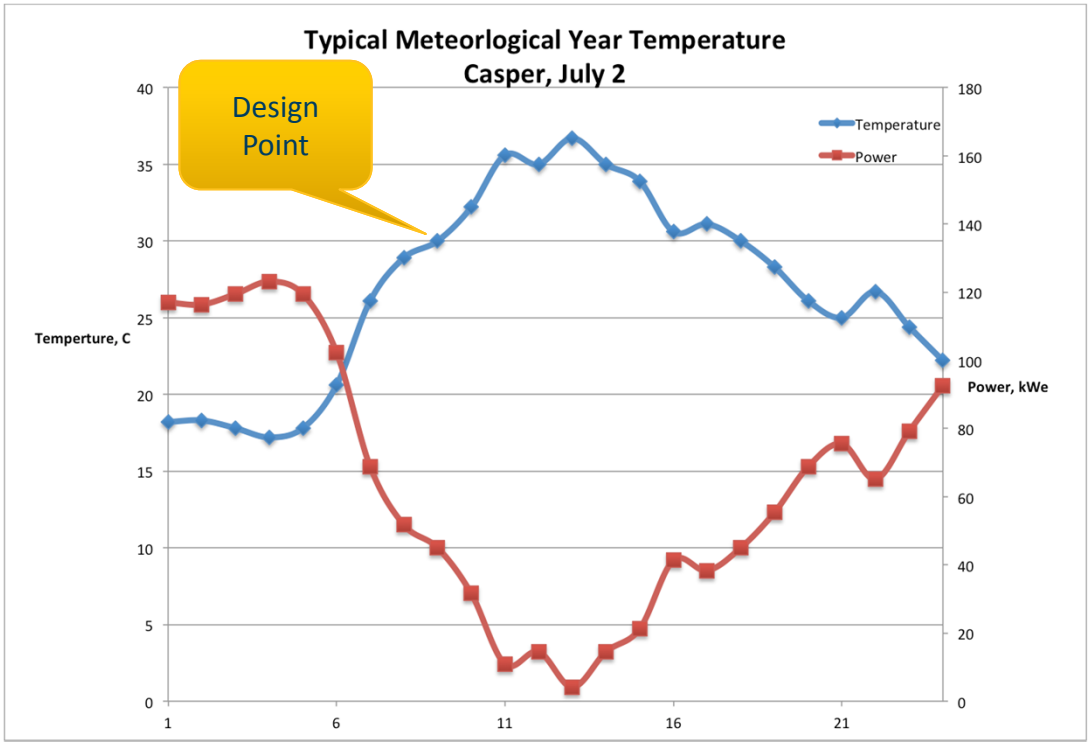
- Widely used by solar industry
- Over 18,000 individual users
- Only basic geothermal power plant treatment (no ability to model coproduction)

http://www.nrel.gov/analysis/sam

Adding Coproduction Simulation Capabilities to SAM

SAM Model Development

- Developed capabilities to simulate performance on hourly basis using TMY weather data
- Core of computational engine taken from GETEM code
- Provides a consistent basis for comparison to other renewable technologies (SAM platform already used for solar and wind)
- Hourly prediction of plant power output

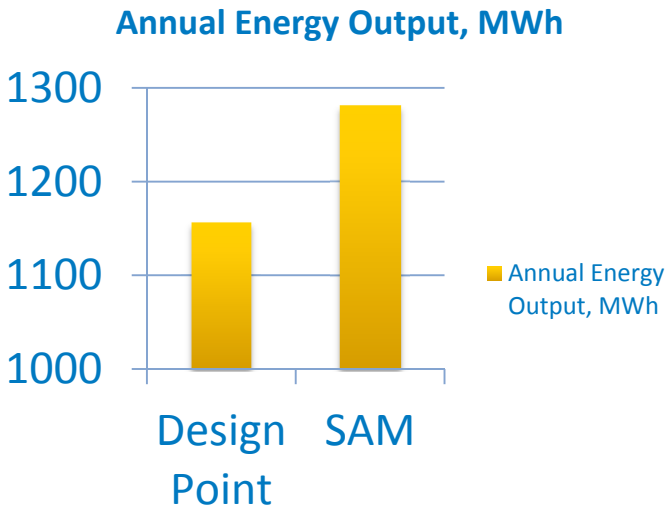


Results show significant deviations from design point depending on ambient conditions

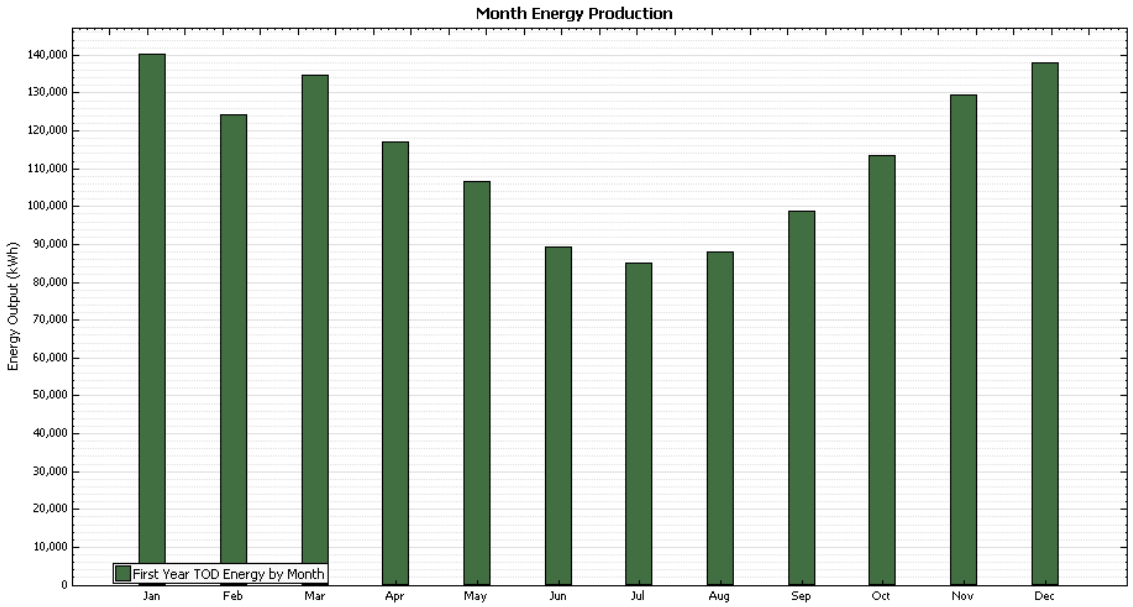
Design point calculations match design point measured output within 3%

Simulation Results for RMOTC

SAM – Annual Results

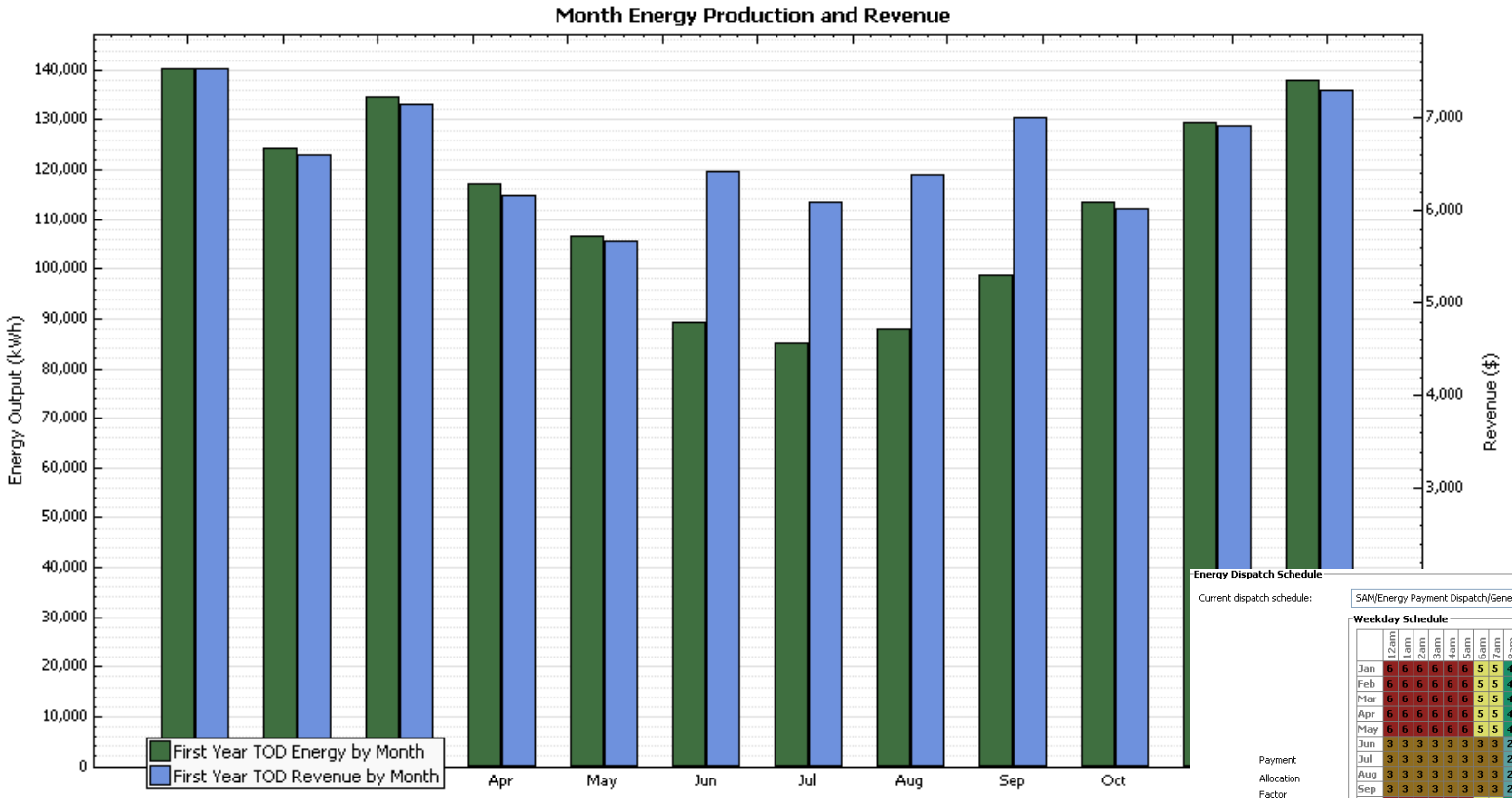


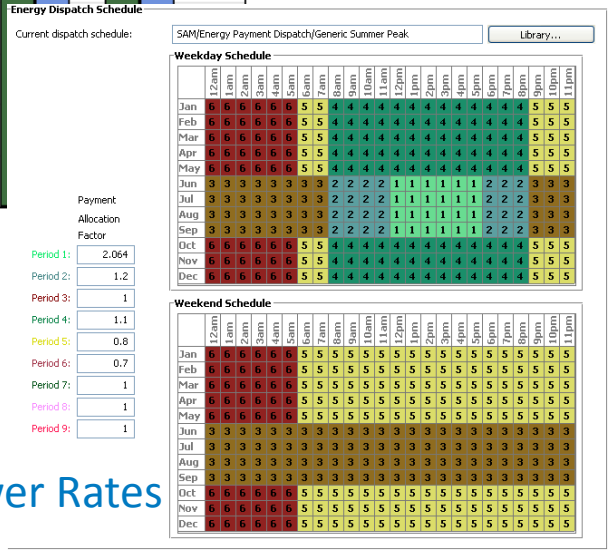
On annual basis, the generally cool weather in Casper results in generation of 10% more energy than predicted by design point analysis



Monthly energy production varies significantly due to changes in ambient temperature

Economics of a ‘peak pricing’ contract





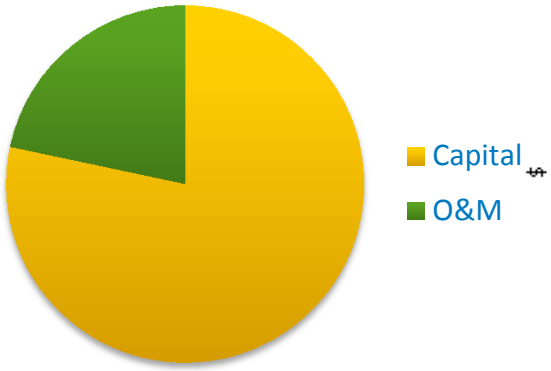
A typical summer peaking payment schedule can result in higher revenues even when total production is decreased

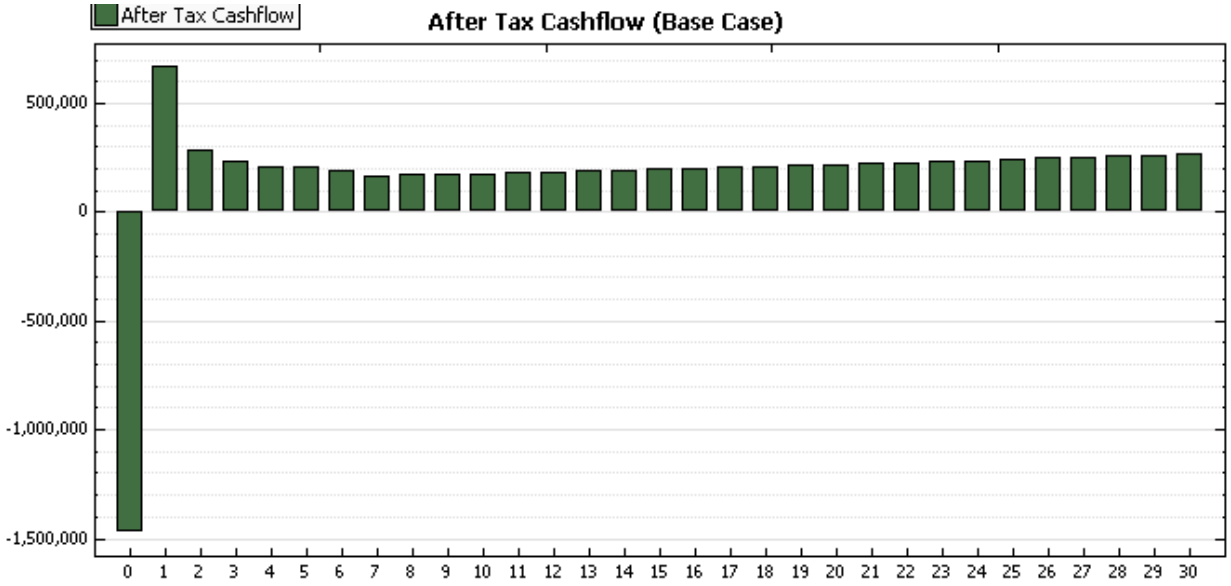
Peak Power Rates

Levelized Cost of Energy (LCOE)

LCOE Results

LCOE Breakdown





For a good site an LCOE of $0.06/kWh or better appears possible in coproduction

Basis

Water at 210 °F or higher
300 kW net
$4900/kWe Capital Cost
$50K/yr O&M

100% equity financing
14% discount rate
2% inflation
20 year life
5 year MACRS depreciation

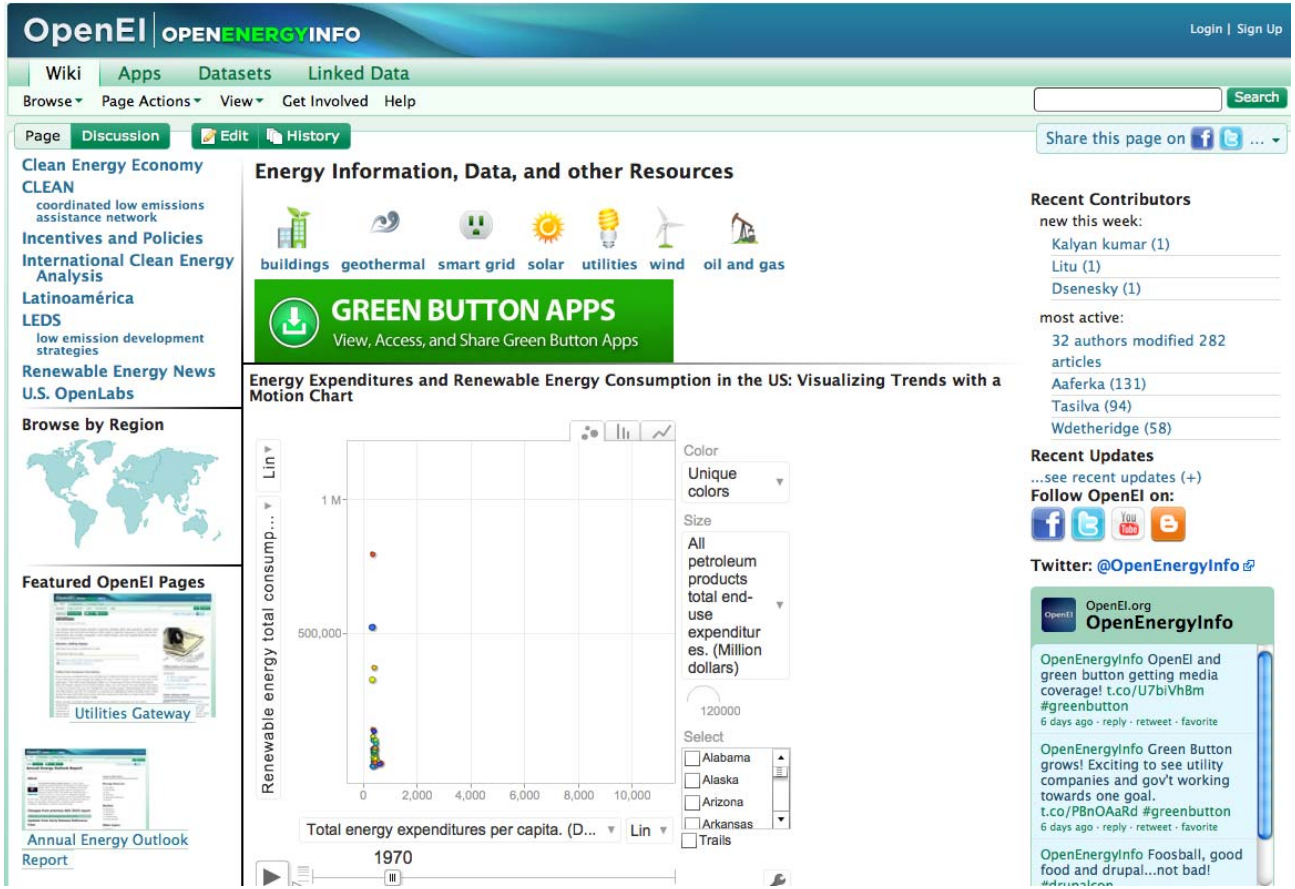
Future Plans

- Commission RMOTC data acquisition system May 2012
- Use data set to calibrate SAM model to match performance at off-design conditions
- Provide operational data and SAM tool to public
- Develop two-year demonstration projects in working oil and gas fields

Online Data Sharing

- **Data will consist of numerical data sets including working fluid temperatures and pressures, brine temp and pressure, brine and working fluid flow rate, parasitic loads, and ambient weather conditions**

- **Data will be stored on OpenEI**
  - Data available on OpenEI is searchable and queryable, and as such will be part of the DOE GDR on OpenEI, when the GDR is available.



Geothermal Power/ Oil & Gas Coproduction

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

The Department of Energy's (DOE) Geothermal Technologies Program (GTP), is exploring opportunities to partner with Industry to deploy binary systems in operating commercial oil and gas (O&G) fields. These GTP units could be available for two year demonstration periods.

100% proceeds/electricity goes to industry partner.

GTP Provides:

- Units at low/nominal cost (subject to final contract)
- Funds for minimally invasive and fast installation
- Necessary O&M of the unit

Industry Partner Provides:

- Site Access for installation and contingency operations
- Shared information on coproduced water volumes, temperature, flow rate, fluid chemistry, and power production and operability
- Design and engineering of the field (for cost estimate)
- Clearly defined site ownership/control

Coproduced geothermal resources can deliver near-term energy savings, diminish greenhouse gas emissions, extend the economic life of oil and gas fields, and profitably utilize oil and gas field infrastructure.