Fossil and Geothermal Energy Resource Assessments and Energy Solution Options at Camp Dawson

Randall Gemmen

Ken Means, Timothy Murin, Neal W. Sams, Danylo B. Oryshchyn, Ray Boswell, Dale Keairns, Roy H. Miller, III, Devin M. Justman, Randall S. Gemmen, Mark L. McKoy, Tracy Thewlis, Edward J. Boyle, George Richards

Sponsors: DOE Office of Energy Efficiency and Renewable Energy & DOE Office of Fossil Energy

2016 West Virginia Governor's Energy Summit: Tackling America's Energy Challenges, October 6-7, 2016

NATIONAL ENERGY TECHNOLOGY LABORATORY

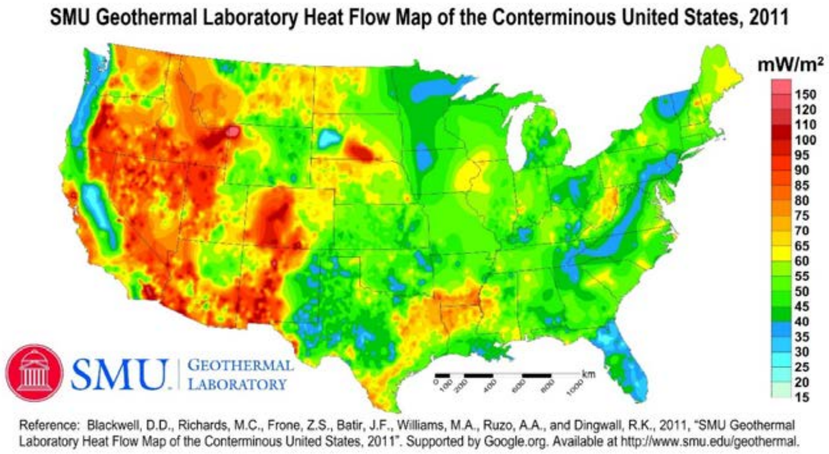
U.S. DEPARTMENT OF ENERGY

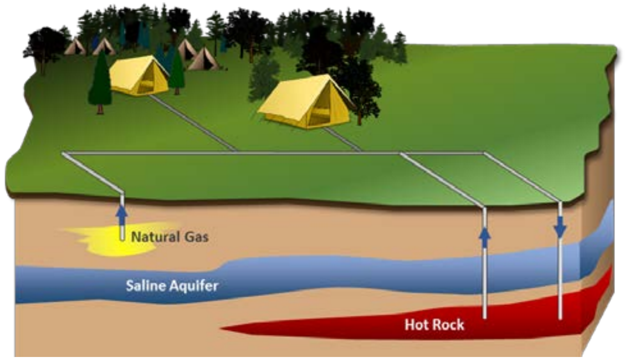
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Some Background…

- In eastern U.S., technically accessible (but deep) geothermal resources are 'low temperature'—these are suitable for direct use applications such as heating and industrial processes. (25% of U.S. energy < 120 deg. C.)
- DOE's Geothermal Technologies Office has interest in achieving cost effective use of these geothermal resources—aka Deep Direct Use.
- In 2010, Google sponsored study conducted by Southern Methodist University showed West Virginia had a geothermal energy 'hot spot'*
  - Results suggested 14-18 GW of electricity capacity was possible. (Recent work lowered this.)
- Most subsequent work in geothermal energy has remained at shallow depths (e.g., geothermal heat pump applications.) No doubt in recognition of the high cost of accessing deeper hotter resources.
- Camp Dawson has interest in utilization of its energy resources, both geothermal and fossil energy.
- 2016 NETL and WVNG developed an MOU whereby NETL will support WVNG in an assessment of available resources for Camp Dawson.

Tester, 2015

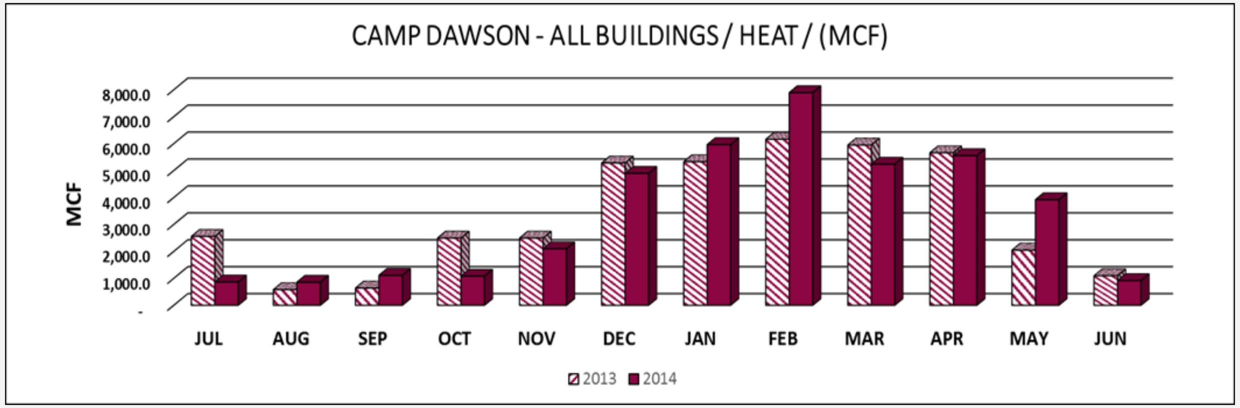


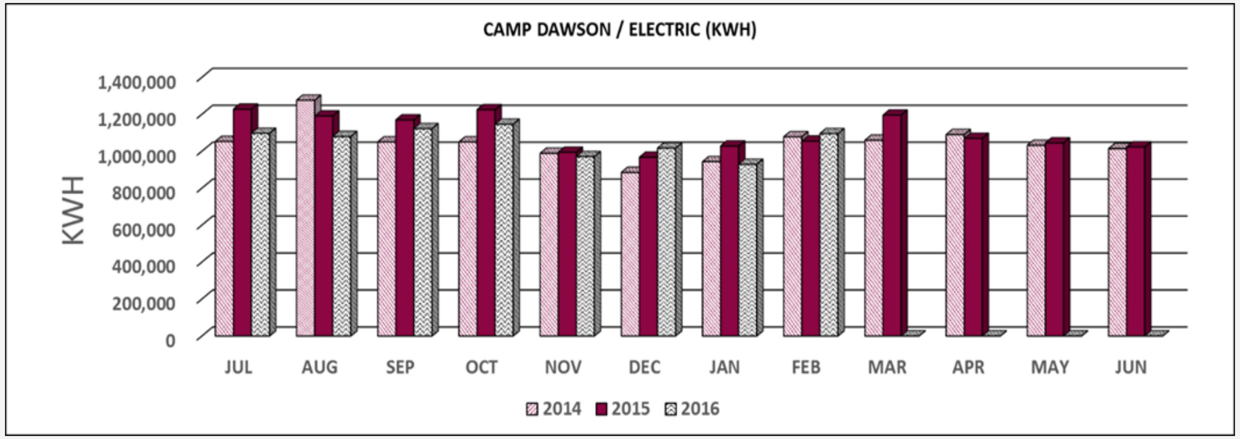


*Renewable Energy World, Oct. 6, 2010.

Camp Dawson Energy Loads

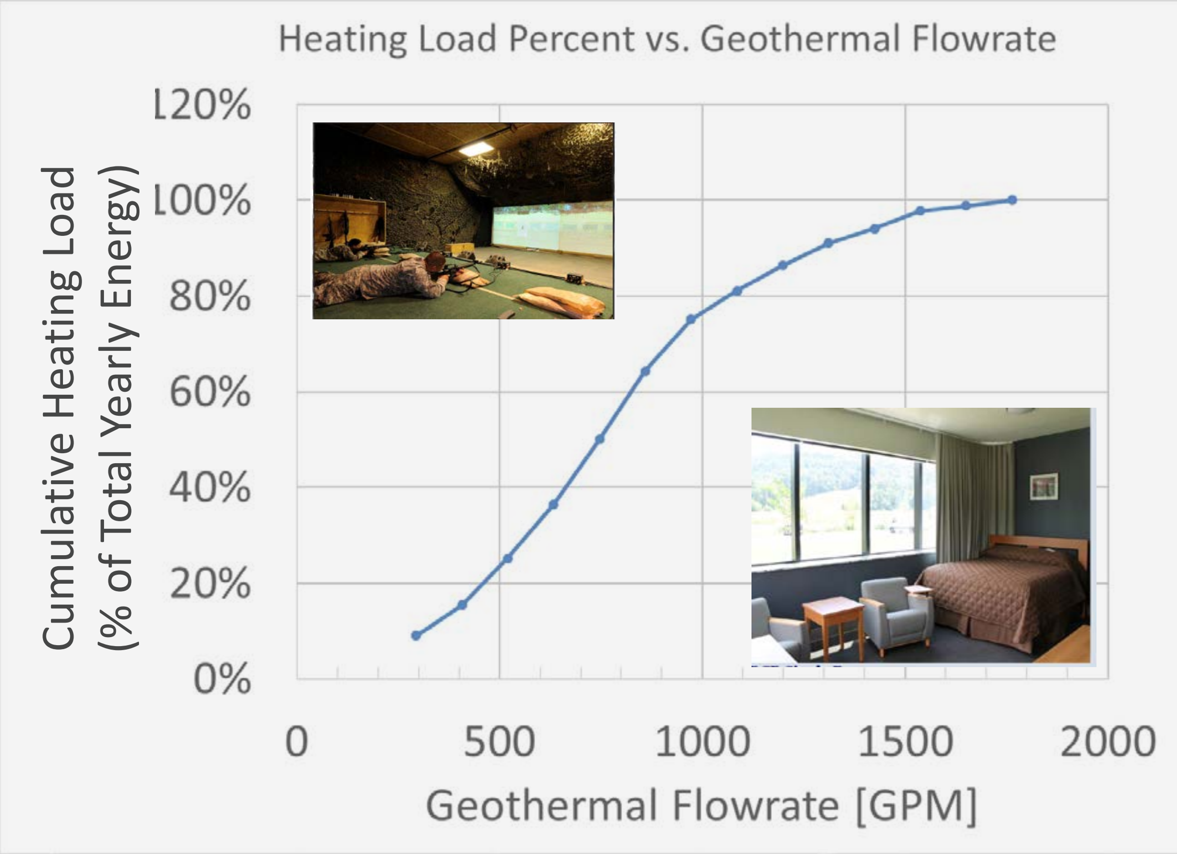
- 9 Buildings (534k ft²)
  - WWI to few years old
  - Hydronic heating; NG fired boilers
  - 135 deg F to 180 deg F supply.
- Heat Demand
  - 40,350 MCF/yr NG (13 GWh/yr)
  - $302k/yr
- Electric Demand
  - 12.8 GWh/yr
  - $827k/yr ($64/MWh)





Camp Dawson Energy Loads

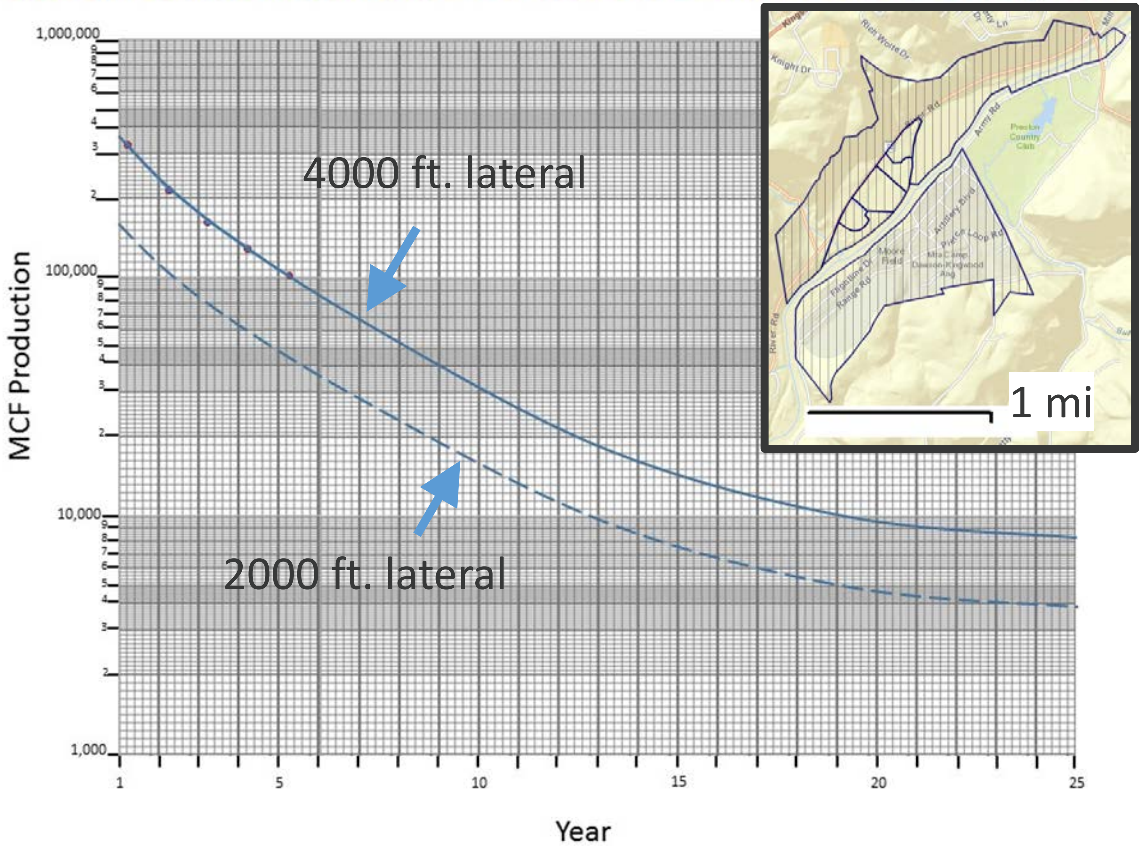
- Heat Load Analysis
  - Average January load ~ 1100 GPM
  - About 80% of the heat load is achieved via 1100 GPM capacity, which is 60% of peak.
  - Possible Heating Design
    - Geothermal heat supplied up to 1100 GPM.
    - Balance NG boiler.
- Electrical Load Analysis
  - Relatively small annual load change
  - Peak Power = 2.4 MW; Baseload = 1 MW
  - Possible Electrical Design
    - Cover baseload with on-site NG, balance with grid support
    - Cover full on-site load; cover heat load with excess heat from generator (CHP)



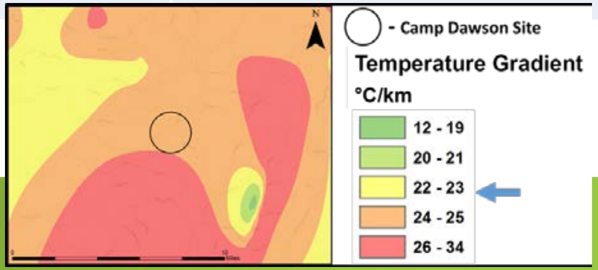
Geology…

Name	Depth ft.	Description
Upper Devonian	2,500-4,000	Sandstone; significant NG westward, but little at Camp Dawson; T=125°F
Marcellus Shale	7,400-7,500	Dry NG resource; Total resource ~ 1,400 MMCF on a 4000 ft. lateral.
Huntersville Chert & Oriskany Sandstone	7,500-7,700	Some NG; Faults trend northeast to southwest. Open natural factures likely similar oriented. Potential for heat storage use; T=160°F
Tuscarora Sandstone	10,300-10,800	Some production of NG. Risk of low porosity and permeability; T=193°F
Utica Shale	13,300-13,500	Uncertain NG resource.
Trenton-Black River Limestone	13,500-14,700	Reservoir temp. Little information available; T=250°F

Generalized Marcellus Shale Decline Curve for Preston County, WV



Total 30 yr. resource for 4000 ft. lateral = 1,400 MMCF



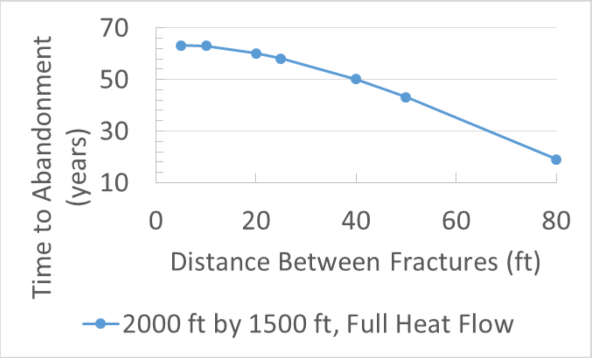
*Temperature gradients may be only slightly greater than average regional values.

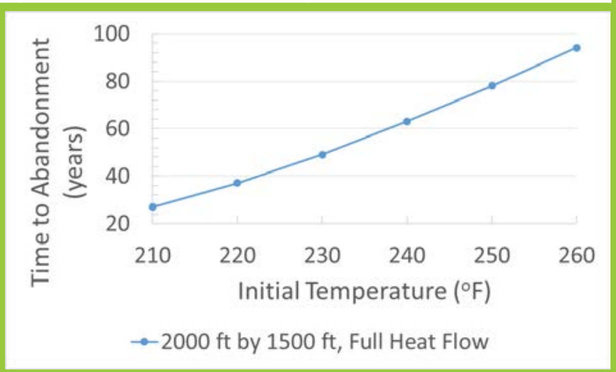
SIMPLE

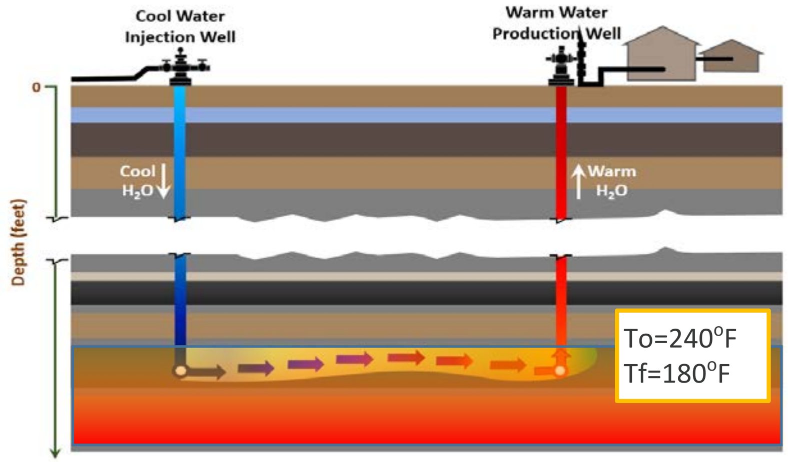
Model for Assessing Lifetime of Geothermal Energy Mining

Effects of Reservoir Area and Energy Requirement on Time to Abandonment

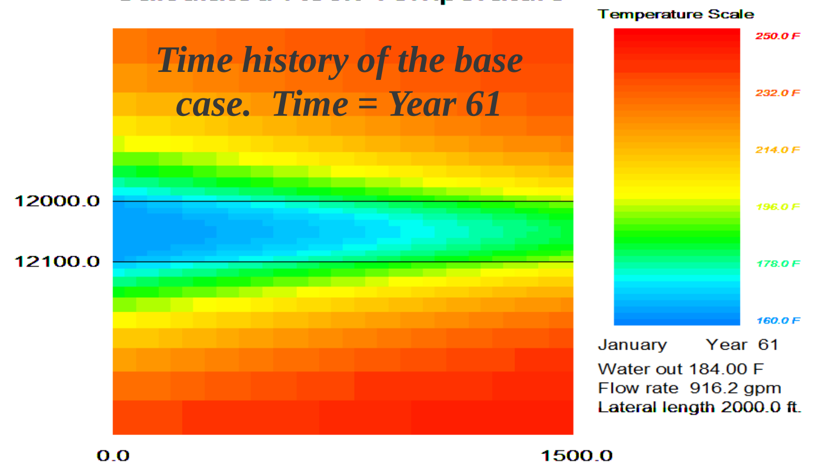
Lateral Length (ft)	Lateral Separation Distance (ft)	Pattern Area (ft²)		Fraction of Base Heat Flow	Time to Abandonment (years)
1000	1000	1000000		1.00	12.00
1000	1000	1000000		0.50	33.00
1000	1000	1000000		0.25	101.08
2000	1500	3000000		1.00	63.08
2000	1500	3000000		0.75	101.25
2500	1500	3750000		1.00	91.08
2500	2000	5000000		1.00	149.17







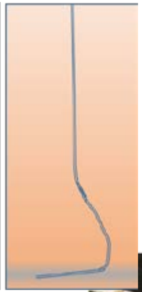
Calculated Rock Temperature

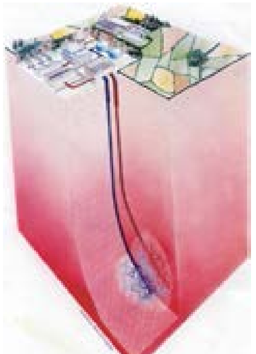


Preliminary July 23, 2016

Energy Options for Camp Dawson

- **On-Site NG for Existing Boiler System**
  - Preliminary study + seismic survey + well development + surface hardware for NG distribution through site
- **Direct Use Geothermal Heat**
  - Well options (horizontal and vertical)
- **On-Site NG for Baseload Electric – NG Turbine**
- **On-Site NG for Full Electric + Heating – NG Turbine + CHP Hxgr.**
- **Geothermal Energy for Electric Power (ORC)**
- **Advanced Systems—Solid Oxide Fuel Cell**





Tester, 2015

Energy Options for Camp Dawson

Draft

NATIONAL ENERGY TECHNOLOGY LABORATORY

Option	Well Specs	Lifetime yr	Cost Details $	Annual Costs $ (Percent of Current Costs)
NG for Heating	4,000 ft. lateral well	30	$4,750,000 = well	$158k (52%)
	2,000 ft. lateral	15	$3,750,000 - $4,500,000 = well	$300k (100%)
Direct Use of Geothermal Energy (Heating)	2 horizontal wells; 2000 ft. x 1500 ft.	63	$19,950k - $28,150k = study+well+above ground hardware	$375k to $506k (125% to 168%)
	4 vertical wells (same footprint)	50	$18,650k – $24,650k = (same)	$432k to $522k (143% to 183%)
NG for Baseload Electric Power (non-CHP)	4000 ft. lateral	12	$6,950k = turbine system+well	$1,510 (182%) (incl. O&M)
NG for 100% Electric Power and Heating (CHP)	4000 ft. lateral well	7	$8,984k = turbine system with CHP hxgr+well	$2,700k (239%) (incl. O&M)
Geothermal for Electric Power (ORC)	4 vertical wells	4.8	$23,000k = ORC system+well system	$8,614 (1040%)
NG + SOFC (1MW Baseload)	4000 ft. lateral well	24	$1,224k = SOFC plant	$810k (98%)

Conclusions & Recommendations for Future Work

- **Heating**
  - NG gives lowest cost.
  - DDU geothermal for space heating offers long lifetime (2x vs. NG)--has greater risk and cost.
  - Depths of useful geothermal heat ca. 8,000 ft. (temperature gradients may be only slightly greater than average regional values.)
  - Rock strata should have as great an initial temperature as possible to meet the full needs of the existing hydronic heating systems at Camp Dawson with long lifetime. Lower initial reservoir temperatures may be acceptable if either a reduced life-span for the geothermal system is acceptable or if natural gas is used to help meet peek demands.
- **Electricity**
  - NG offers lowest cost approach (but is still more than today's cost).
  - In future, using high efficiency SOFCs offer up to 24 year lifetime and at close to today's cost.
- **Consideration should be given toward accessing additional resources from outside Camp Dawson. This lowers costs by achieving a longer lifetime from a greater resource at little additional cost.**
- **If any resource (geothermal or natural gas) is pursued, a seismic survey + exploratory well will be required in order to reduce the uncertainty in project costs and resource assessment. Needed are:**
  - Geothermal heat flux data.
  - Porosity and permeability data for both NG and geothermal assessments.
  - Uniformity of strata flow properties -- any short-circuiting of water flow will reduce the expected lifetime.

Acknowledgments

This work was completed as part of National Energy Technology Laboratory (NETL) research for the U.S. Department of Energy's (DOE) Geothermal Technologies Office and the DOE-NETL's Natural Gas Program (Office of Fossil Energy). The authors wish to acknowledge Cpt. Kyle McGaha (WVNG), Arlene Anderson (GTO), Jared P. Ciferno (NETL), Shailesh D.Vora (NETL), West Virginia Governor's Office, and Brian Anderson (WVU).

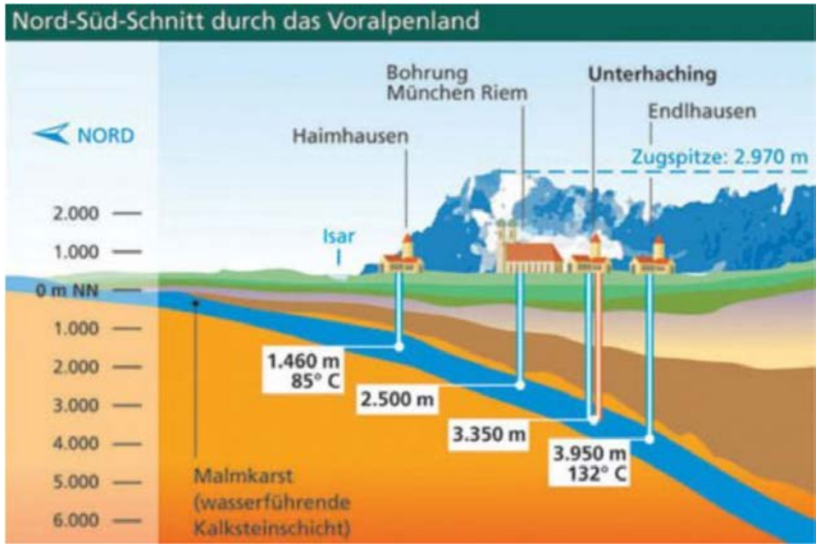
Project Personnel

Ken Means, Timothy Murin, Neal W. Sams, Danylo B. Oryshchyn, Ray Boswell, Dale Keairns, Roy H. Miller, III, Devin M. Justman, Randall S. Gemmen, Mark L. McKoy, Tracy Thewlis, Edward J. Boyle, George Richards

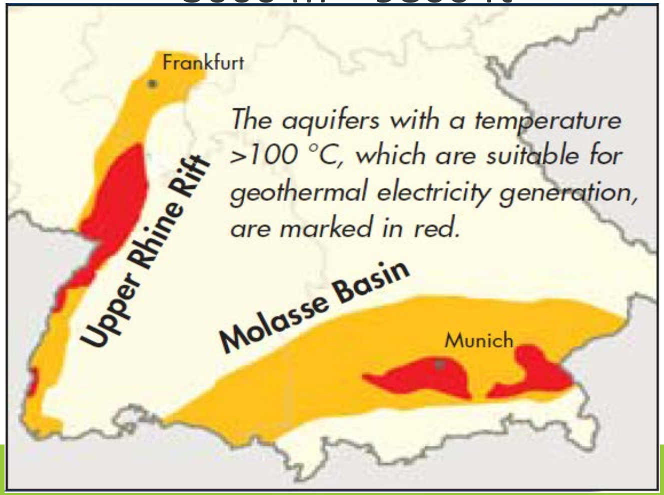
Deep Direct Use Geothermal Energy

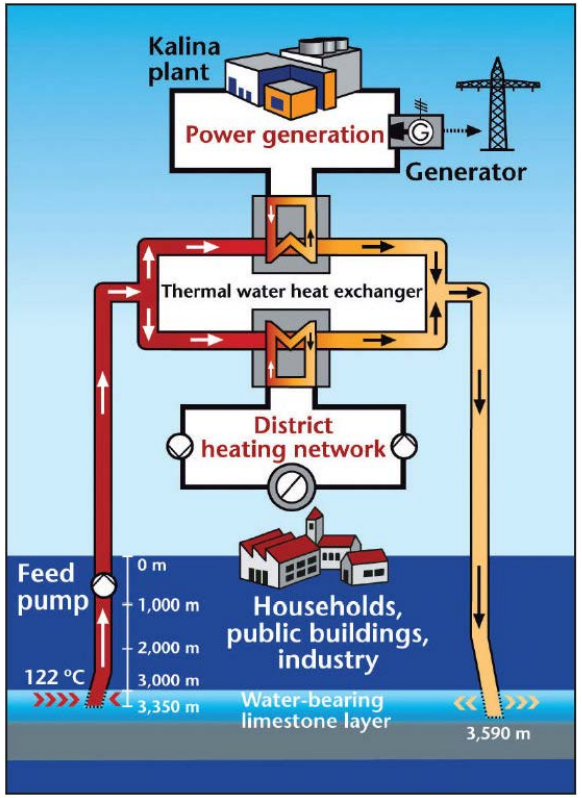
Example from Germany--2007

- Deep Geothermal Output: 38 MW
- Power Plant: 11,500 ft, 122deg. C., 150 l/s, 3.4 MWe Power Plant
- District Heat: 25% of City Heat Requirement
- Development-Risk managed with private insurance companies.



~3000 m = 9800 ft

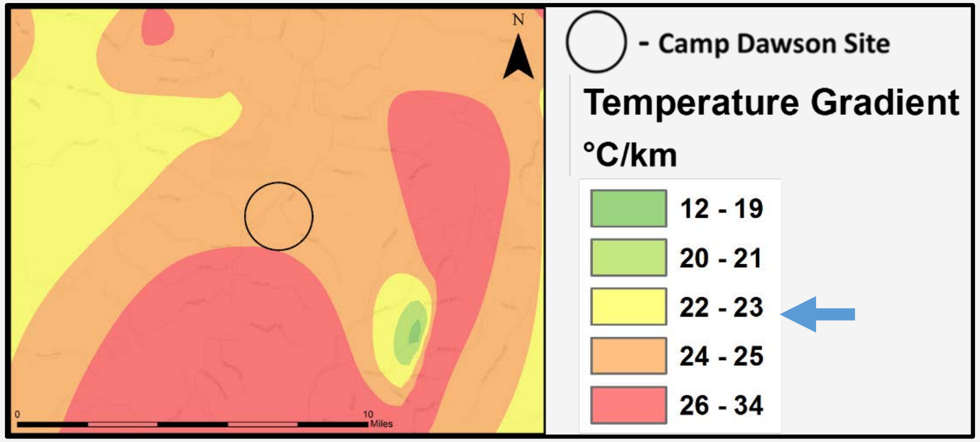


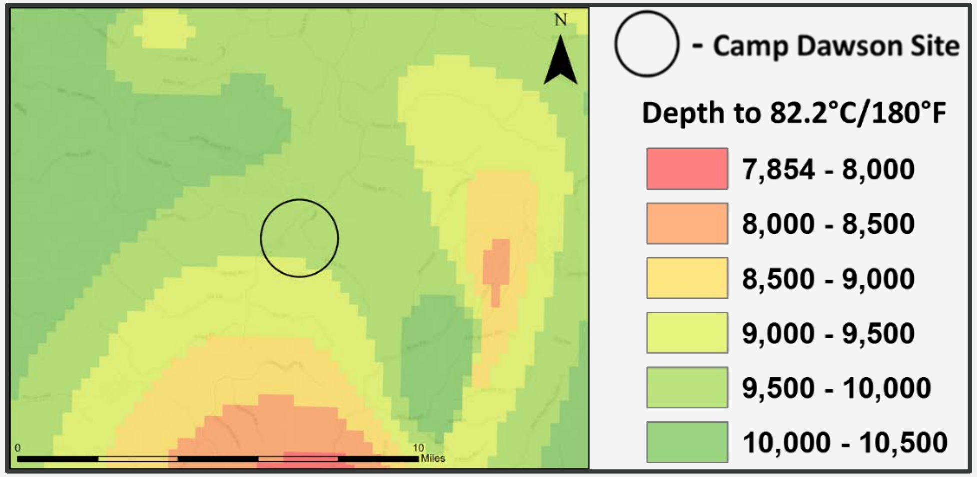


Geothermal Map Data

Interpolation of SMU Well Data

- **Geothermal Gradient**
  - Likely 24 to 25 °C/km
- **Depth to 180 deg. F/80 deg. C**
  - 9,000 to 10,000 ft. (notable uncertainty)
- **Available data shows a range of potential geothermal quality at Camp Dawson, with some not showing a 'geothermal anomaly' as reported by SMU (2010), and remains relatively normal.**





Overview of DDU Plant Design