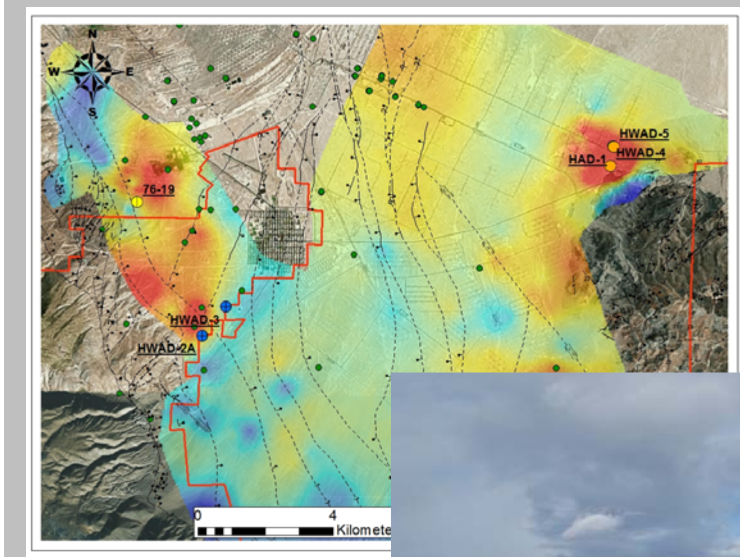

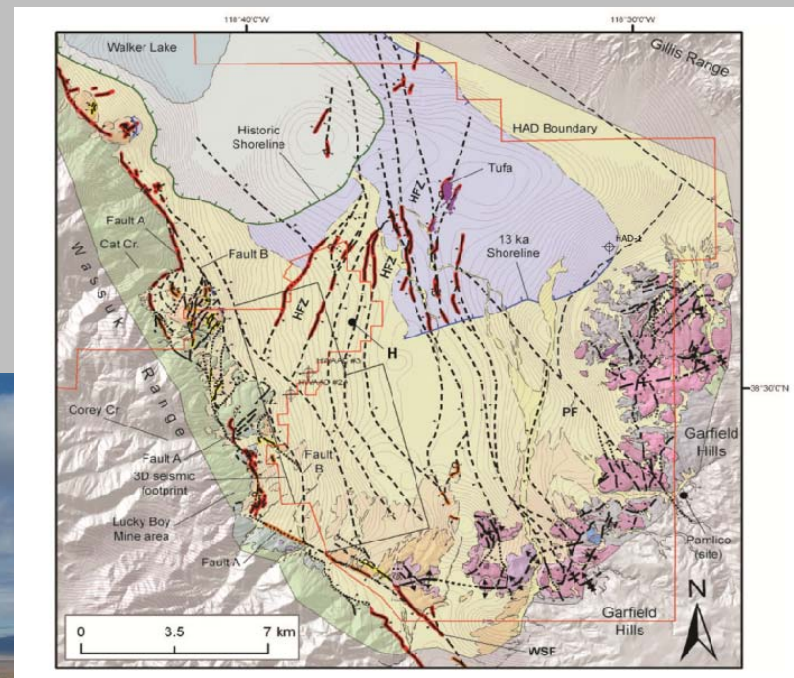

DDU Feasibility Study for the Hawthorne NV Army Depot and Surrounding Community

Project Officer: Arlene Anderson / Total Project Funding: $560k / November 13, 2017

Principal Investigator:
Thomas Lowry, Sandia National Labs

Deep Direct-Use Feasibility Studies Technical and Economic Working Group Kick-Off Meeting

Project Team

Energy Efficiency & Renewable Energy

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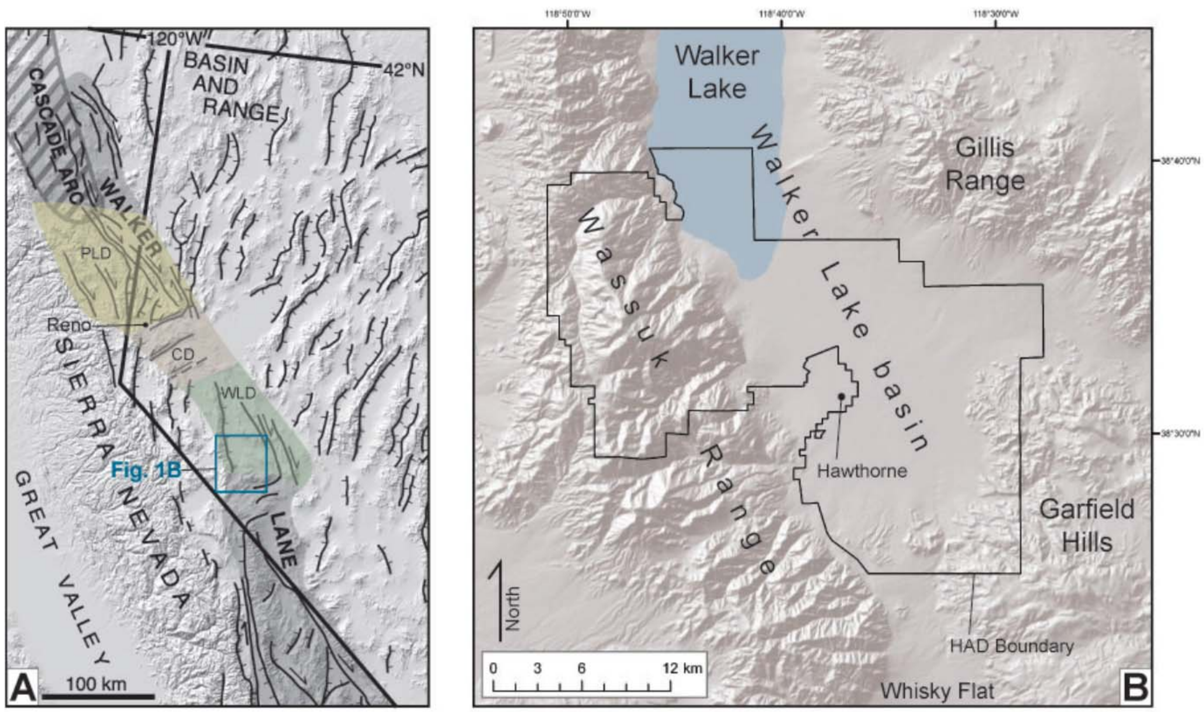
3. University of Nevada-Reno
4. Power Engineers, Inc.

Objective: to develop a multi-disciplinary, three-tiered analysis approach to assess the techno-economic feasibility of deep-direct use resources in Hawthorne, Nevada, including the Hawthorne Army Weapons Depot (HAD)



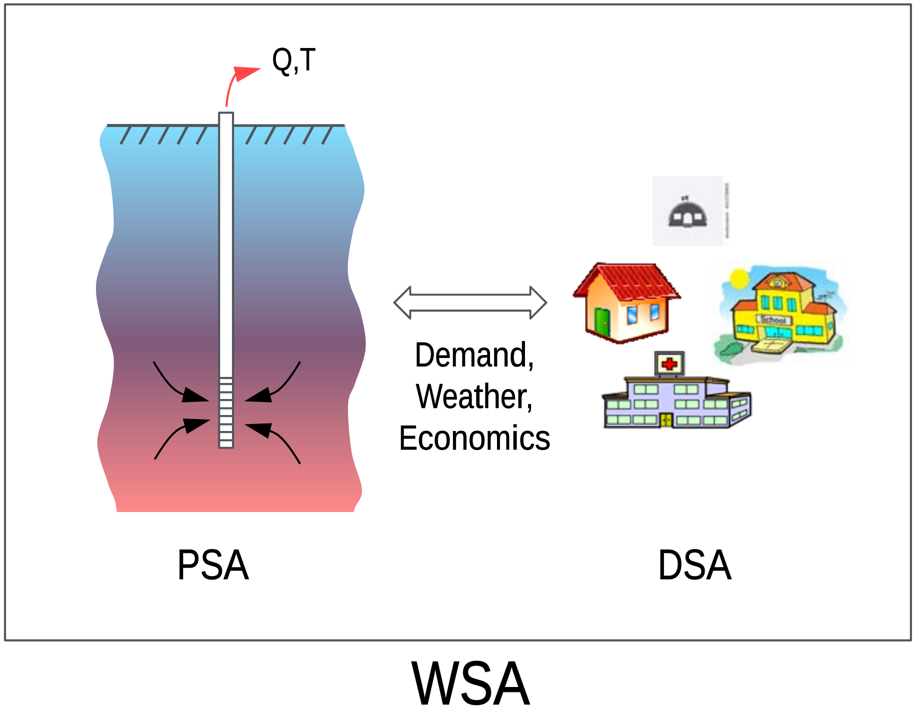
Innovation: Three-Tiered Approach

- Production Side, Demand Side, and Whole System Analyses

PSA: Predict the time dependent, long-term thermal performance as a function of flow rate

DSA: Determines the cumulative heating and cooling loads and the efficiencies and losses associated with their current systems

WSA: System dynamics modeling to simulate the integrated dynamic behavior between the PS and DS to identify and understand dynamic dependencies, uncertainty, and risk



The output is a comprehensive techno-economic feasibility assessment that presents Pareto-optimal results for different direct-use district heating and cooling configurations that show the respective tradeoffs amongst a set of decision metrics

Project Objectives

Supports the Geothermal Technologies Office's Goals:

- Promotes investment by better understanding the uncertainties and risks
- Improves the process of identifying, accessing and developing DDU resources
- Provides a means of optimizing system design around multiple decision criteria
- Extensible and versatile approach – can be applied to a wide range of problems of varying sizes and scope

Technical Scope Summary: Resource

Hawthorne Areas' History of Work: Promising Resource

Data Type	Collection Year
Aeromagnetic Survey	1960's
Lineament Study	1960's
Gravity Survey	1960's, 2000's
2m Probes	1960's, 2000's, 2009
Soil Mercury Survey	1960's
Flow Test El Cap Well	1982
3D Reflection Seismic	2005
Groundwater Analysis	2002
LiDAR	2005, 2010
Geologic Mapping	1900's, 2009
Injection Test HWAD-2A	2009
Pump Test HWAD-2A	2009
Thermochronology	2010
Fracture/Stress Analysis	2012

Well Number	Year Drilled
HHT-1	1967
HHT-2	1967
El Cap	1980
HWAD-3	2008
HWAD-2A	2009
HAD-1	2010
26 TGH's	2010-2011
HWAD-4	2011
HWAD-5	2011
76-19	2012

Technical Scope Summary: Resource

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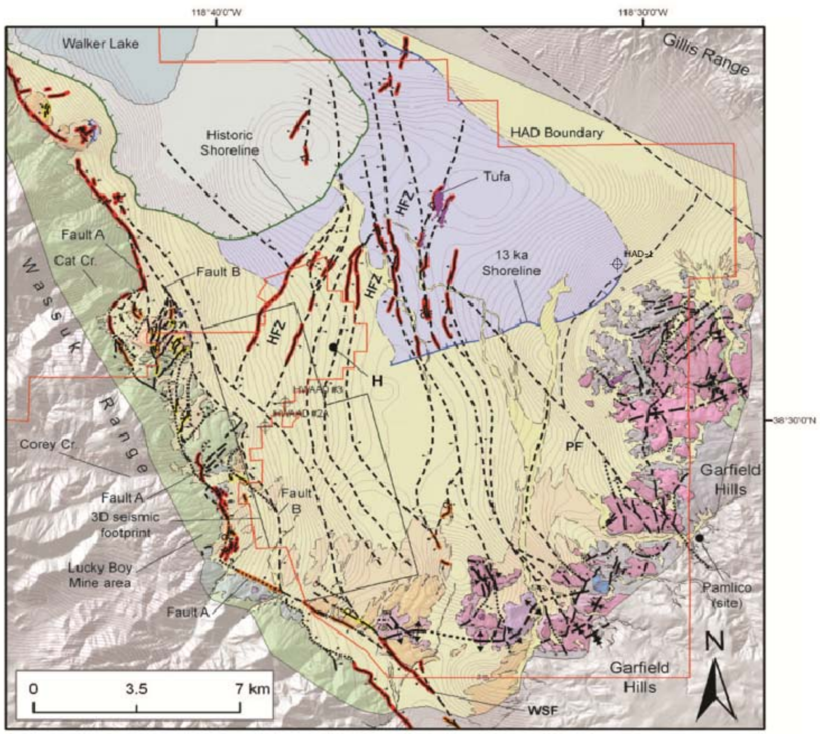
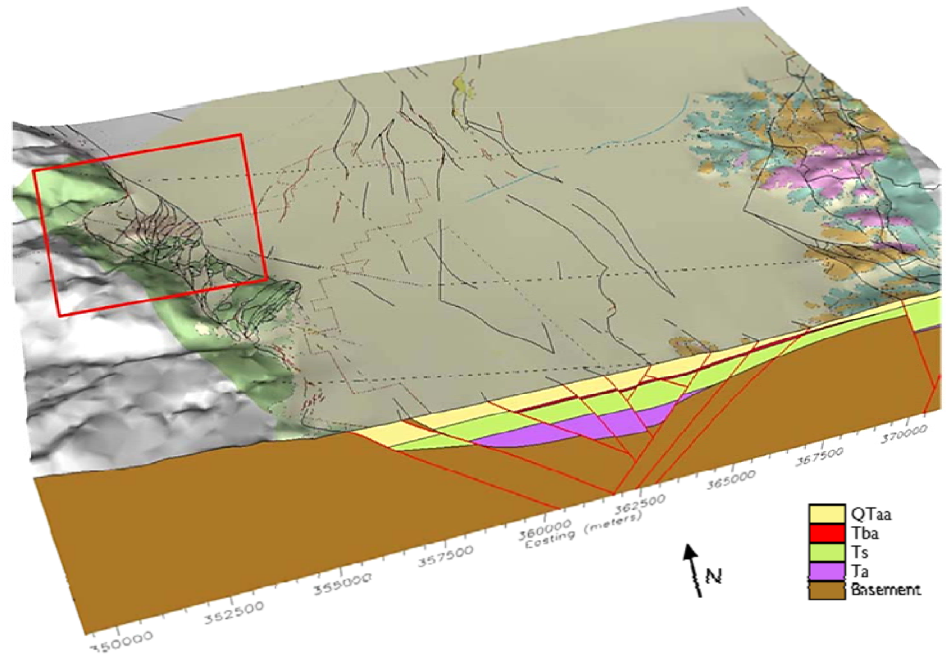
Hawthorne Areas' History of Work: Promising Resource



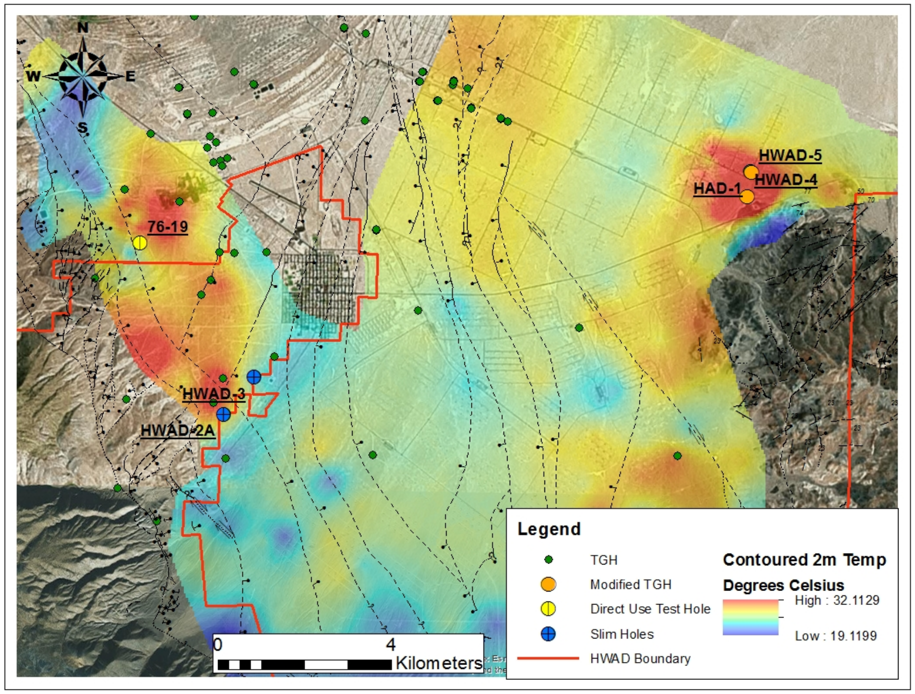
Hawthorne is located in the Walker Lane Tectonic Belt – contains known geothermal resources [1,2,3]

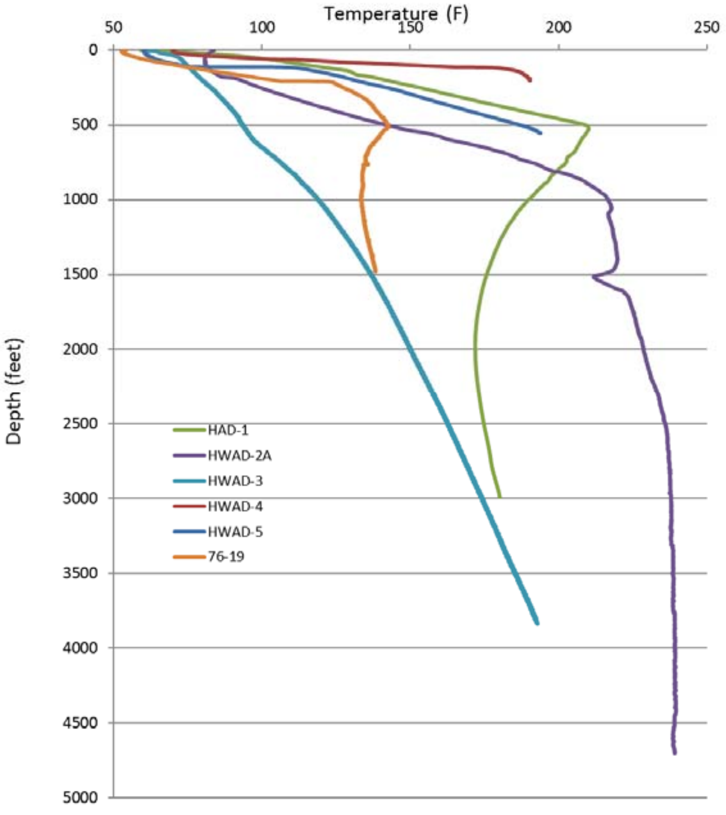


QTaa = Quaternary alluvial and lacustrine sediments, Tba = Late Tertiary basaltic andesitic lavas, Ts = Late Tertiary fluvial and lacustrine sediments, Ta = Late Tertiary andesite lavas, Basement = Mesozoic volcanics, sediments, and granite

3D Geologic model of the Walker Lake Valley Region, from [4]. The City of Hawthorne is in the lower right hand portion of the red square, which highlights the complex releasing bend along the Wassuk Range front that is thought to be favorable to geothermal fluid flow.

Hawthorne Areas' History of Work: Promising Resource





Multiple wells with temperatures > 190 °F (88 °C) with two having confirmed flow rates of 196 and 500 gpm[5,6,7,8]

Technical Scope Summary: End Use

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- Hawthorne: Population ~3200, Mineral County Seat
  - Hospital, K-12, county courthouse, library, and sheriffs office
  - 1981 study [9] estimated annual heat demand at 10.8×10^9 BTU/yr with a peak of 8.8×10^6 BTU/hr
- Power Engineers 2012 [10] Study of the HAD
  - 35.4×10^9 BTU/yr Total Annual Demand
  - Three Scenarios:
    - Full system retrofit
    - Preheating makeup water
    - Preheating makeup and condensate return water

Parameter	Units	Scenario A	Scenario B	Scenario C
Resource temperature	^oF	180	140	180
Annual fuel savings	Gallons	256,200	12,310	21,724
Equivalent fuel savings	$/year	$986,370	$47,394	$83,637
Equivalent power expenditure	$/year	$33,514	$5,405	$2,162
Net annual savings	$/year	$952,856	$41,989	$81,475
Total project cost	M$	$7.5M	$3.9M	$4.4M
Payback	years	8	93	54

Technical Scope Summary

Feasibility Determined by Answering the Following:

- What is the sustainable, heating and cooling potential of the geothermal resource?
- What are the heating and cooling demand loads of the service area?
- What is the optimal direct-use configuration to exploit the resource?
- What are the economics of that configuration?

Scientific Questions That Must Be Considered:

- What are the hydrogeologic characteristics of the resource?
- What is the sustainable pumping capacity and the thermal drawdown as a function of pumping rate?
- How does seasonality and/or future trends affect:
  - Plant and system efficiencies?
  - Heating and cooling demands?
- How do system uncertainties influence the feasibility estimates and risk of development?

Technical Scope Summary

Project Start-up

- Site visit, data acquisition, data inventory, gaps analysis

Thermal Resource and Site Suitability (PSA)

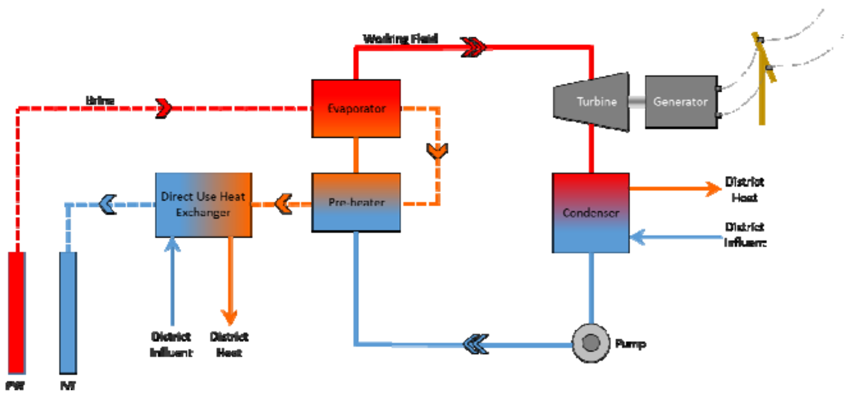
- Geologic interpretation, mapping, and conceptualization
- Lumped parameter flow and heat-transport modeling

Energy End Use Potential (DSA)

- Building inventory, meteorological environment
- Heating and cooling load modeling using Energy Plus
- Scenario development and costing

Whole System Analysis

- System dynamics modeling
- Uncertainty quantification
- Scenario analysis



Schematic of possible combined heat and power scenario.

Technical Scope Summary

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Economic assessment will follow the approach used in the Power Engineers 2012 [10] study

- American Association of Cost Engineers [11]
- ‘Class 3’ estimates that provide preliminary equipment sizing and material specifications but is still considered a “scope or budget authorization” estimate
- Advantage of casting a project in its suitable estimate class

PSA economics (e.g. drilling costs) will rely on the appropriate literature

Gannt chart of project schedule and table of project milestones

Quarter	Milestone	Responsible Task
1	M1.1: Complete stakeholder meeting and site visit	T1.0 – SNL
2	M2.1: Upload raw data to the DOE-GDR	T2.0 – UNR
3	M3.1: Upload maps and processed data to the DOE-GDR M4.1: Complete estimates of building loads and document in a white paper	T3.0 – UNR T4.0 – PE
4	M5.1: Complete flow and heat transport model M5.2: Submit to a suitable conference or journal the project results to date M6.1: Create schematic of WSA conceptual model	T5.0 – SNL T5.0 – SNL T6.0 – SNL
5	M7.1: Document scenarios in white paper	T7.0 – PE
6	M8.1: Complete the calibrated WSA model	T8.0 – SNL
7	M9.1: Submit results of WSA to a suitable conference or journal for publication	T9.0 – SNL
8	M10.1: Complete and submit final report. Upload balance of data to the DOE-GDR	T10.0 – SNL

	Quarter	Q1			Q2			Q3			Q4			Q5			Q6			Q7			Q8		
	Project Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	MO-Yr	O-17	N-17	D-17	J-18	F-18	M-18	A-18	M-18	J-18	J-18	A-18	S-18	O-18	N-18	D-18	J-19	F-19	M-19	A-19	M-19	J-19	J-19	A-19	S-19
Task #	Task Description																								
1.0	Site Visit & Data Acquisition			1.1																					
2.0	Data Inventory and Gaps Analysis						2.1																		
3.0	Mapping and Data Processing									3.1															
4.0	Modeling Cumulative Building Loads									4.1															
5.0	Lumped Parameter Model Development												5.1 5.2												
6.0	WSA Conceptualization												6.1												
7.0	Scenario Development															7.1									
8.0	WSA Model Development																		8.1						
9.0	Scenario Analysis																					9.1			
10.0	Documentation																								10.1

Proposed Metrics

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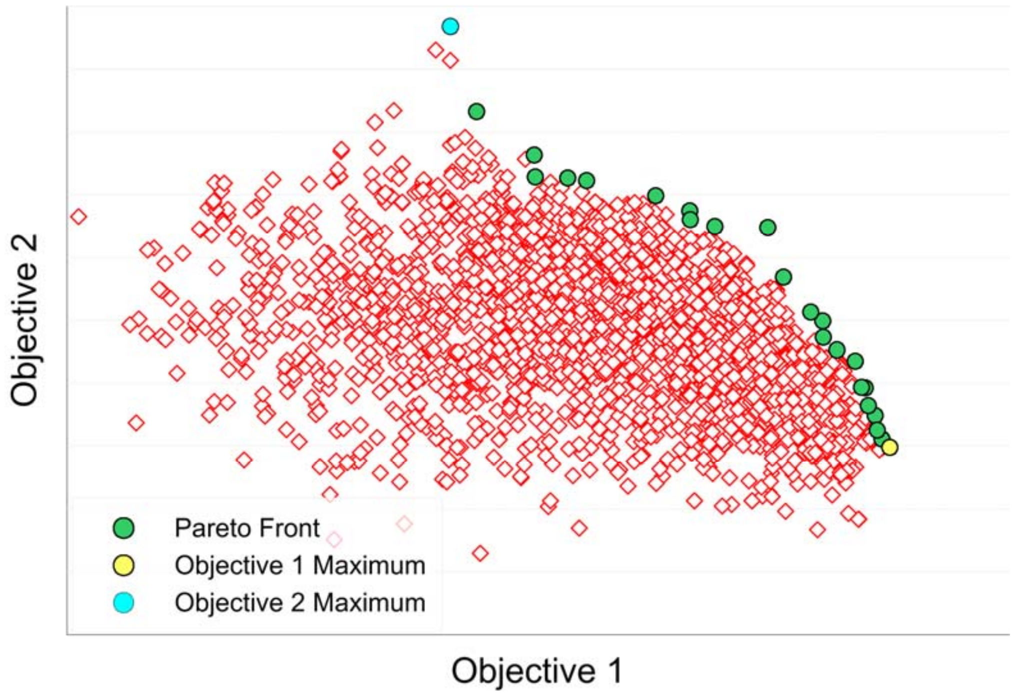
- The choice to adopt and implement a direct-use geothermal project is a multi-objective decision making process involving multiple alternatives
- The output from this project supports that process by providing insight into how decisions about system design (e.g., target facilities, surface infrastructure, CHP versus no CHP, etc.) and system operations (e.g., pumping rates) can impact the techno-economic performance of the system.
- Decision metrics may include thermal drawdown over time, LCOE, LCOH, energy savings, cost savings, GHG emissions, capital investment requirements, and return on investment
- Results will be presented as Pareto-optimal curves

Proposed Metrics

- Pareto-optimal curves describe the conditions where improvements in one metric cannot be obtained without a decrease in one or more other metrics
- It illustrates the tradeoffs amongst the evaluation metrics, allowing for town, county, and HAD personnel to select configurations that best meet their priorities and financial capabilities
- Can be presented as probabilistic estimates of techno-economic performance



Research Collaboration, Data Sharing & Technology Transfer

- Collaboration
  - We are open to sharing results, data, algorithms, etc. with the other projects as needed
  - We do not anticipate any limitations on this although there may be exceptions with proprietary data from the HAD, the City of Hawthorne, and Mineral County
- A priority for this project is to make the data that are collected and generated available to the public in as close to real time as possible
- In support of this priority, specific milestones have been created for uploading data and other project output to the DOE Geothermal Data Repository

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