

# Development of Metric for Measuring the Impact of RD&D Funding on GTO's Geothermal Exploration Goals



**Stanford Geothermal Workshop 2013**

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**Scott Jenne, NREL**

**Katherine R. Young, NREL**

**Hidda Thorsteinsson, formerly DOE GTO**

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## Objective

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Develop a cost- and time-based metric for measuring impact of Geothermal Technology Office (GTO) Exploration RD&D projects.

### Why Cost and Time?

- Need to be able to measure impact of GTO funding – helps to justify future funding
- For exploration funding, this means quantifying the impact that an innovative technique or set of techniques has on an exploration program
- One of many metrics that can be used to measure impact is cost and time
- Will help GTO measure impact of RD&D funds and help to justify future funding opportunities.

## Methodology

- **Create Data Set**
  - Collected cost and time estimates for exploration techniques
  - Developed baseline cost based on current industry input
  - Estimates encompass both data acquisition and data processing
- **Create Baseline Suite of Exploration Methods**
  - Based on previous literature
  - Validated by industry exploration experts
  - Incorporated cost and time data from data set
- **Create Open-Source Exploration Cost and Time Tool**
  - Allows user to adjust cost and time of exploration techniques to see overall impact on baseline
  - Allows user to save impacts for use in FOA proposals
  - Available on OpenEI.org  
[http://en.openei.org/wiki/Exploration\\_Cost\\_and\\_Time\\_Metric](http://en.openei.org/wiki/Exploration_Cost_and_Time_Metric)

Together, these items can be used and updated by industry to quantify how an innovative exploration method or set of methods can impact the cost and time of an exploration program.

# What is OpenEI?

- Wiki platform developed in 2009 as part of the Open Government Initiative
- Provides free and open access to energy-related data, models, tools, and information
- Gives Public access to a collaborative , knowledge sharing platform.

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## GEOHERMAL ENERGY

 Geothermal Home

### Resource Assessments

- USGS Maps (2008)
- Geothermal Resource Potential Map
- Geothermal Areas
- Geothermal Regions

### Installed & Planned Capacity

- Geothermal Generation
- Installed Capacity
- Planned Capacity

### Geothermal RD&D

- Enhanced Geothermal Systems
- Hydrothermal & Resource Confirmation
- Low-Temperature Resources
- GTP-Funded Projects
- Systems Analysis
- DOE Geothermal Data Repository

### Permitting & Policy

- Policymakers' Guidebook
- Developers' Permitting Checklist
- State Geothermal Incentives
- State Geothermal Electricity Incentives
- DSIRE - Database of State Incentives for Renewables & Efficiency

### Geothermal Information

- Geothermal Energy Overview
- Types of Geothermal Resources
- Energy Conversion Technologies
- Cooling Technologies
- Exploration Techniques
- Reference Materials

### Geothermal Models & Tools

- GETEM
- SAM
- PROSPECTOR

### Geothermal Financing

- Developers' Financing Handbook
- RE Project Finance
- CREST
- HOMER
- REFTI

Source: <http://en.openei.org/wiki/Gateway:Geothermal>

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## 8 Exploration Groups

- Data and Modeling
- Downhole Methods
- Drilling Methods
- Field Methods
- Geochemical Methods
- Geophysical Methods
- Lab Analysis Methods
- Remote Sensing Methods

	Exploration Group	Exploration Sub Group	Lithology Info Provided	Structure/Stratigraphic Info Provided	Hydrologic Info Provided	Thermal Info Provided
2-M Probe Survey	Drilling Methods	Exploration Drilling				Identify and delineate shallow thermal anomalies
Acoustic Logs	Downhole Methods	Well Log Methods		map discontinuities to determine their orientation.		
Aerial Photography	Remote Sensing Methods	Passive Sensors		map structures/faults	map surface water features	if photos taken in winter snow cover, can map thermal anomalies
Aeromagnetic Survey	Geophysical Methods	Magnetic Methods		map structure, basin fill thickness, and magnetic mineral concentrations in ore bodies		
Airborne Electromagnetic Survey	Geophysical Methods	Magnetic Methods	provide data on rock type and mineral content		can be used to detect changes in density of fluids and indicate if there is salt water intrusion	
Airborne Gravity Survey	Geophysical Methods	Gravity Methods				
Airborne Resistivity Survey	Geophysical Methods	Electrical Methods				

Source: [http://en.openei.org/wiki/Exploration\\_Techniques](http://en.openei.org/wiki/Exploration_Techniques)

## Data Set Collection Efforts

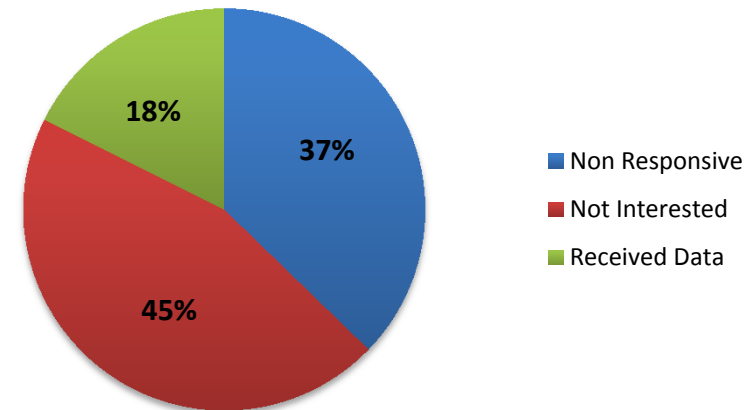
### Contacted 100+ Companies

- 18% shared information
- 45% were not interested
- 37% were non responsive.

### Data Collection Summary

- Collected cost data for 66 different methods
- 47% of cost data (31/66) includes more than one data point
- Collected time data for 51 different methods
- 31.6% of time data (18/51) includes more than one data point.

Companies Contacted



# Data Set Creation

## Creating the Data Set

1. Collect raw data from industry
2. Clean up data (e.g. make units consistent):

MT Example:

Data Inputs visible to NREL (Not Actual Data)				
MT survey	Low \$	Typical \$	High \$	Unit
Company A	\$550.00	\$1,400.00	\$2,500.00	Station
Company B	\$500.00	\$1,050.00	\$1,700.00	Station
Company C	\$1,000	\$2,000	\$2,000	Station
Company D	750	\$2,300	2500	Station

3. Aggregate Data:

MT Example:

Visible to Public on OpenELog (Not Actual Data)				
MT survey	Low \$	Typical \$	High \$	Unit
MT survey	\$500.00	\$1,737.50	\$2,500.00	Station

4. Post on OpenEI.

## MT data as shown on OpenEI (Actual Data)

Exploration Technique Information	
Exploration Group	Geophysical Methods
Exploration Sub Group	Magnetic Methods
Information Provided by Technique	
Lithology:	
Stratigraphic/Structural:	map subsurface clay structure
Hydrological:	
Thermal:	
Cost/Time Dependency:	Location, Size, Resolution, Terrain, Weather
Cost Information	
Low-End Estimate (USD):	522.22 / station
Median Estimate (USD):	1,738.83 / station
High-End Estimate (USD):	2,297.62 / station
Time Required	
Low-End Estimate:	1.67 days / 10 stn
Median Estimate:	3.77 days / 10 stn
High-End Estimate:	7.50 days / 10 stn

Source: <http://en.openei.org/wiki/Magnetotellurics>



## Baseline Methodology

### What is the Baseline?

- Generic suite of exploration techniques
  - Not any specific site
  - Not a checklist for future sites
- Based on previous literature
- Reviewed by industry.

### Assumptions

- 30 MWe hydrothermal
- Single site
- Western United States.



*Photo from Joel Renner, DOE, NREL 05425*

## Baseline Creation

### Walker et al. (2005)<sup>1</sup>

- **Regional Reconnaissance**
  - Literature Review (Geology)
  - Regional Seismicity
  - Regional Remote Sensing.
- **Prospect Identification**
  - Literature Review (Mineralogy)
  - Local Seismicity
  - Local Remote Sensing
  - Petrology
  - Initial Geochemistry (Surface).
- **Project Appraisal**
  - Geophysics (Seismic, MT, Gravity, Magnetics)
  - Local Field Mapping
  - TGHs
  - Initial Drilling
  - Down Hole Geochemistry
  - Cutting Analysis.

### NREL (2012)

- **Regional Reconnaissance**
  - Literature Review (All Available)
  - Initial Geochemistry (Surface)
  - Regional Remote Sensing.
- **Prospect Identification**
  - Local Remote Sensing
  - Detailed Geochemistry (Surface)
  - Regional Field Mapping.
- **Project Appraisal**
  - Geophysics (Seismic, MT, Gravity, Magnetics)
  - Local Field Mapping.
- **Initial Drilling**
  - TGHs
  - Initial Drilling
  - Cutting Analysis
  - Down Hole Geochemistry.

<sup>1</sup>Walker, J. D.; Sabin, A. E.; Unruh, J. R.; Combs, J.; Monastero, F. C. (2005). "Development of Genetic Occurrence Models for Geothermal Prospecting." *Transactions-Geothermal Resources Council*, p.312.

## Baseline Validation

- **Reviewed by 4 exploration experts**
  - Overall agreement as a reasonable starting point.
- **\$/phase driving factor for which methods are used in each phase**
  - \$/phase is a common approach.
- **Most significant differences between experts occur in Phase 4 (Initial Drilling)**
  - Range of \$1.5-10M; 3 of 4 experts felt \$6-7M was a safe estimate.
- **Note that first 3 phases account for less than 10% of total cost.**

### Phase costs assume one location and 30 MWe

Phase	Title	Permits Required	Typical Cost Range
1	Regional Reconnaissance	No	Up to \$50k
2	Prospect Evaluation	No	\$50-\$100k
3	Project Appraisal	Yes	\$250-\$500k
4	Project Appraisal, Initial Drilling	Yes	\$6-7M

# Final FY12 Baseline Suite

	Method	Unit Cost	Unit	Cost Source	# of Units
<b>Phase I (no site visit)</b>	<b>Regional Reconnaissance</b>				
	Geothermal Literature Review	\$ 200.00	hour	Database	80
	Geothermometry	\$ 30.00	sample	Database	20
	Multispectral Imaging	\$ 370.23	sq. mile	Database	40
	Data Acquisition-Manipulation	\$ 250.00	hour	Database	60
			<b>Phase 1 Total \$</b>	<b>\$46,409</b>	
<b>Phase II (no permit required)</b>	<b>Prospect Evaluation</b>				
	Hyperspectral Imaging	\$ 1,337.56	sq. mile	Database	40
	Compound and Elemental Analysis	\$ 30.00	compound	Database	50
	Geothermometry	\$ 30.00	sample	Database	50
	Field Mapping	\$ 600.00	hour	Database	40
	Modeling-Computer Simulations	\$ 195.00	hour	Database	40
			<b>Phase 2 Total \$</b>	<b>\$88,303</b>	
<b>Phase III (permit required)</b>	<b>Project Appraisal</b>				
	Ground Gravity Survey	\$ 68.31	station	Database	500
	Aeromagnetic Survey	\$ 167.34	mile	Database	200
	Magnetotellurics	\$ 1,738.83	station	Database	75
	Reflection Survey	\$ 44,946.67	sq. mile	Database	6
	Field Mapping	\$ 600.00	hour	Database	40
	Modeling-Computer Simulations	\$ 195.00	hour	Database	40
			<b>Phase 3 Total \$</b>	<b>\$499,515</b>	
<b>Phase IV (Initial Drilling)</b>	<b>Project Appraisal</b>				
	Thermal Gradient Holes	\$ 16.50	foot	Database	500
	Core Hole Drilling	\$ 200.00	foot	Interview	3500
	Cutting Analysis	\$ 4,000.00	100 feet cut	Database	15
	Core Analysis	\$ 10,000.00	30 foot core	Database	10
	Slim Holes	\$ 169.90	foot	Database	7000
	Compound and Elemental Analysis	\$ 30.00	compound	Database	50
	Modeling-Computer Simulations	\$ 195.00	hour	Database	80
			<b>Phase 4 Total \$</b>	<b>\$6,220,630</b>	
Phase costs assume one location and 30 MWe			<b>Phase 1-4 Cost</b>	<b>\$ 6,854,857</b>	

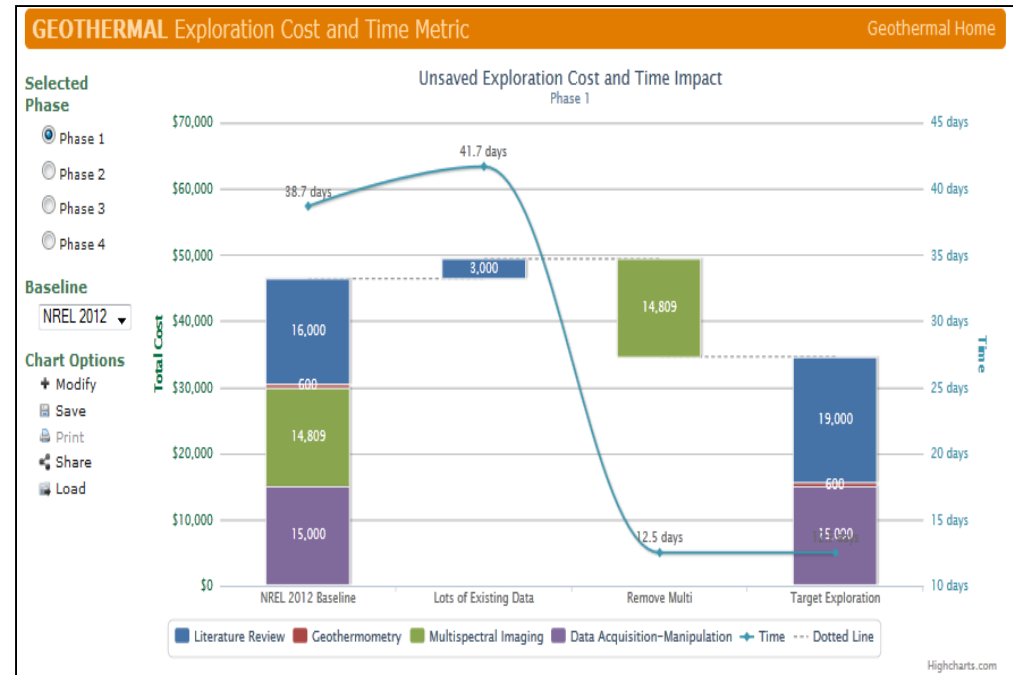
## OpenEI Tool Methodology

### Why a public tool?

- Quantitatively measure impact of RD&D projects
- Serve as a platform for future funding applicants to calculate impact to submit with proposals.

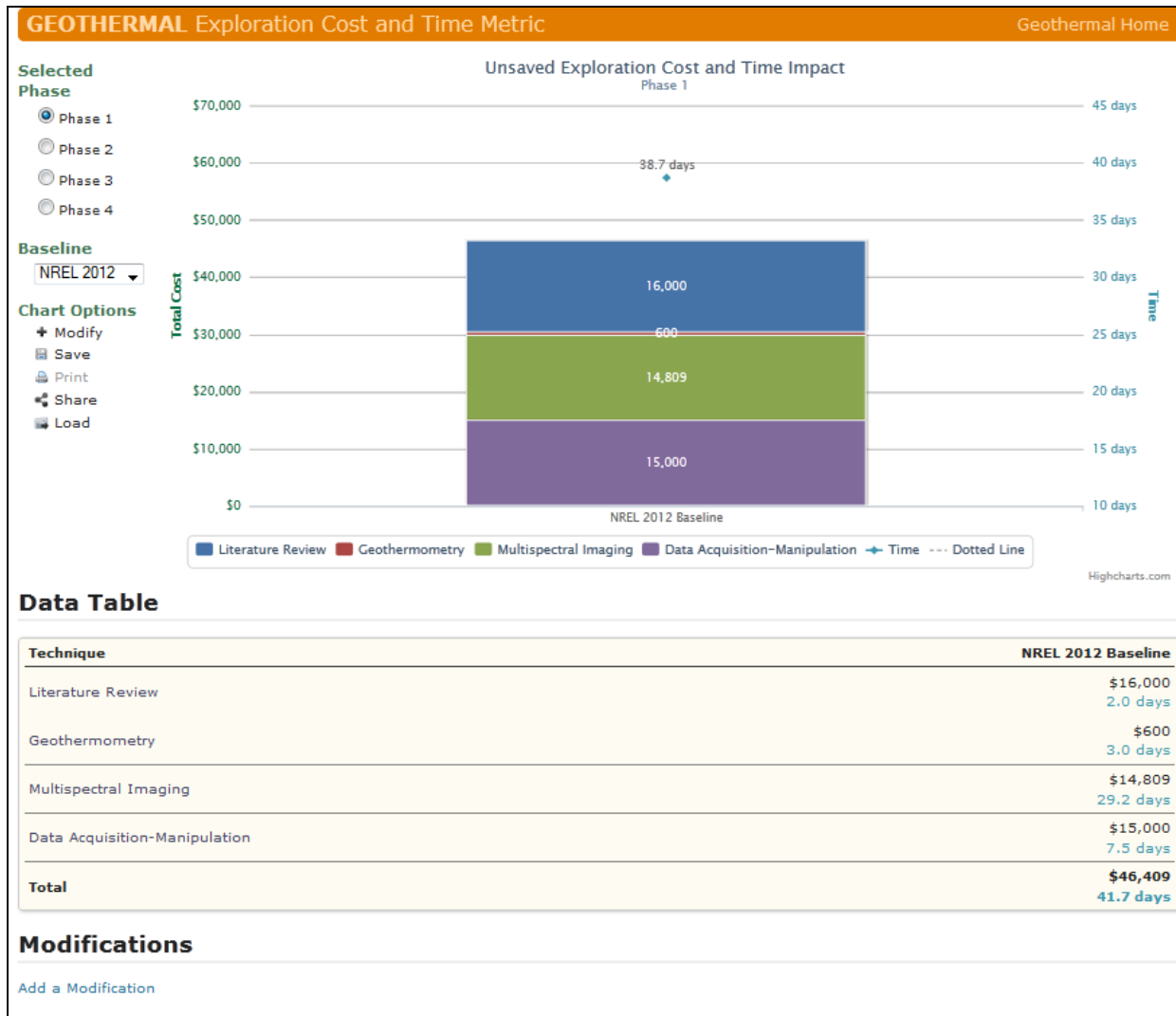
### Capabilities

- Visually represent a change in cost and/or time
- Show the impact of removing/replacing an exploration technique or set of techniques.
- Easy to read data tables
- Potential to add new baselines in the future.



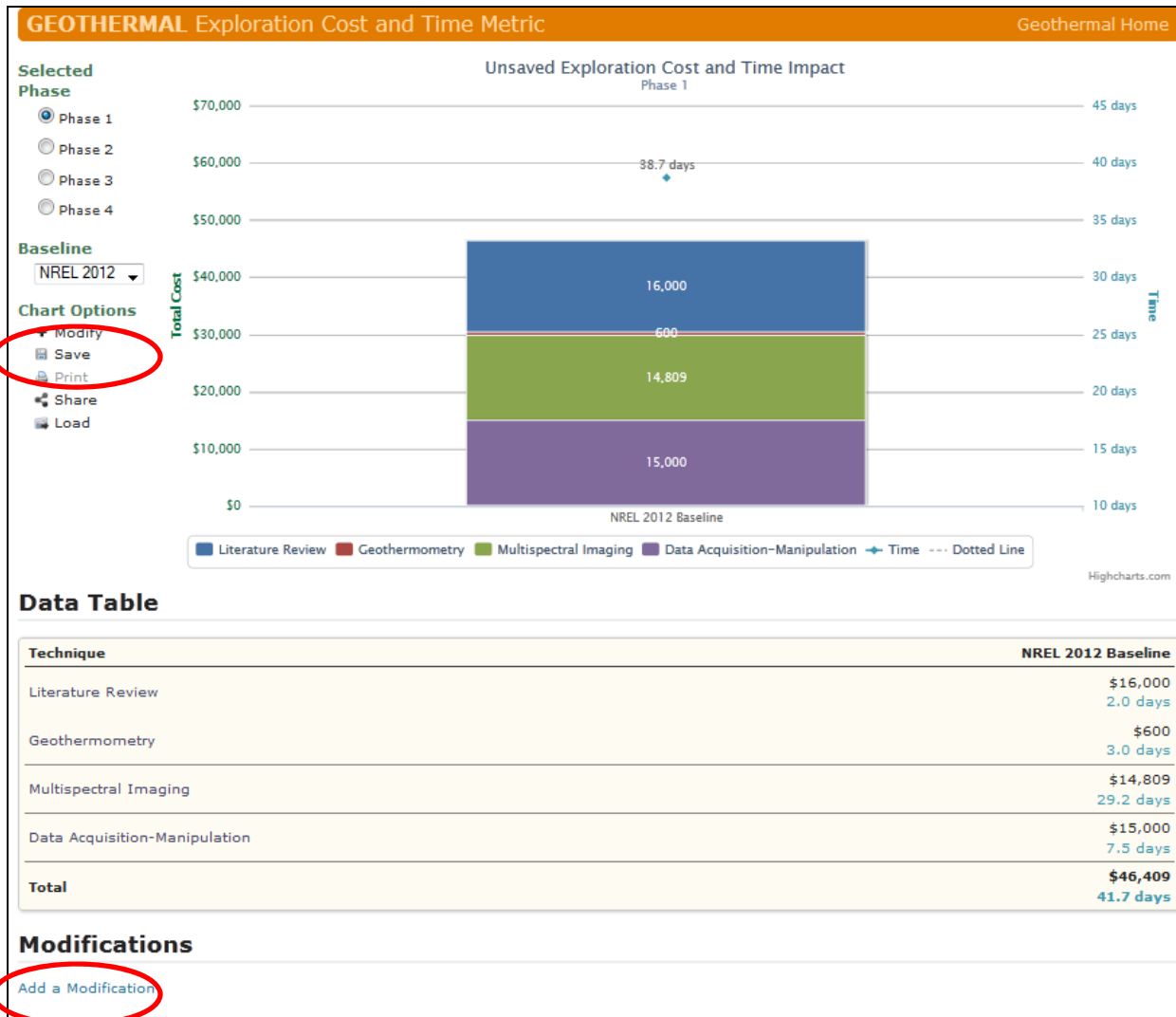
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# OpenEI Cost and Time Tool



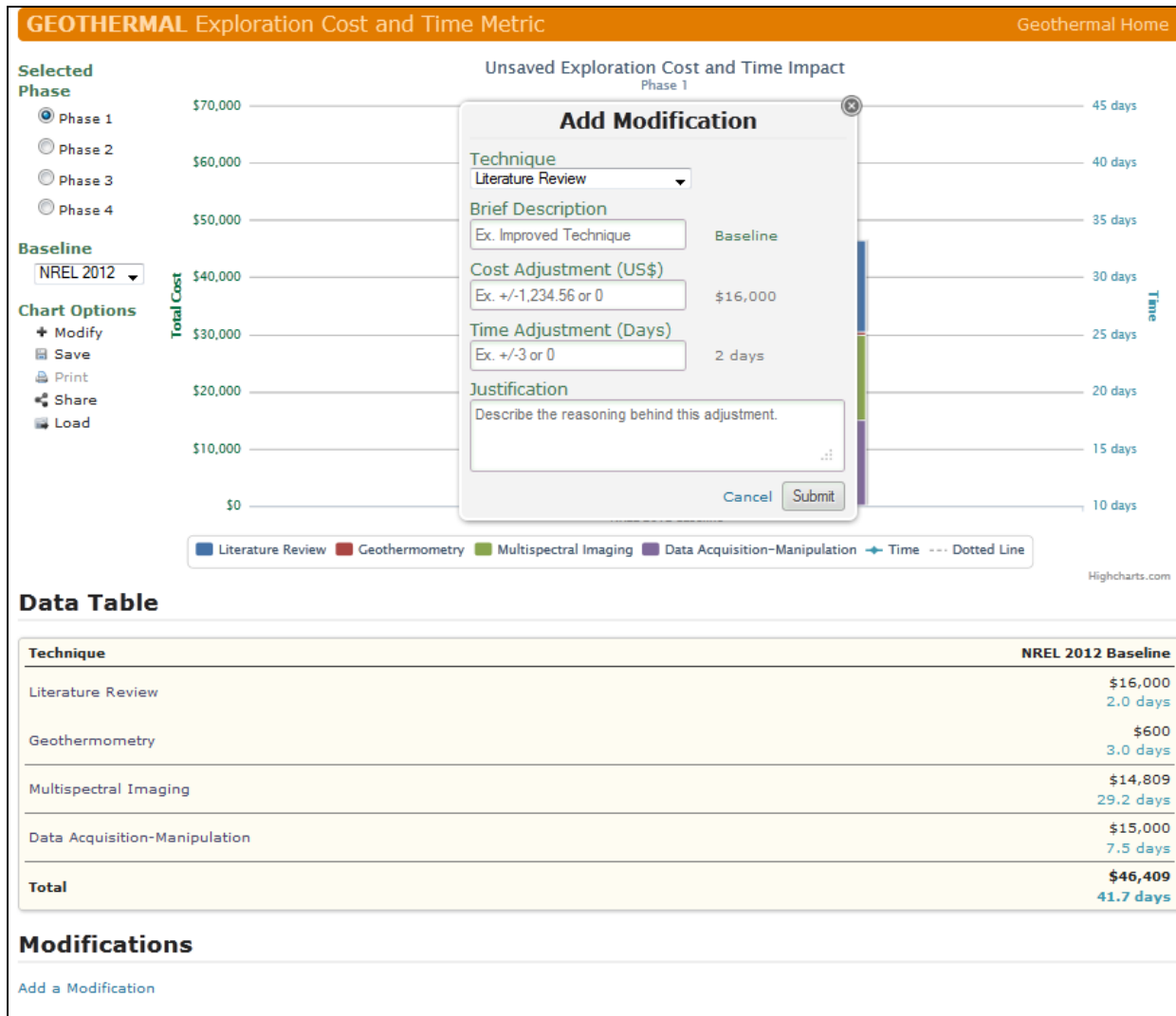
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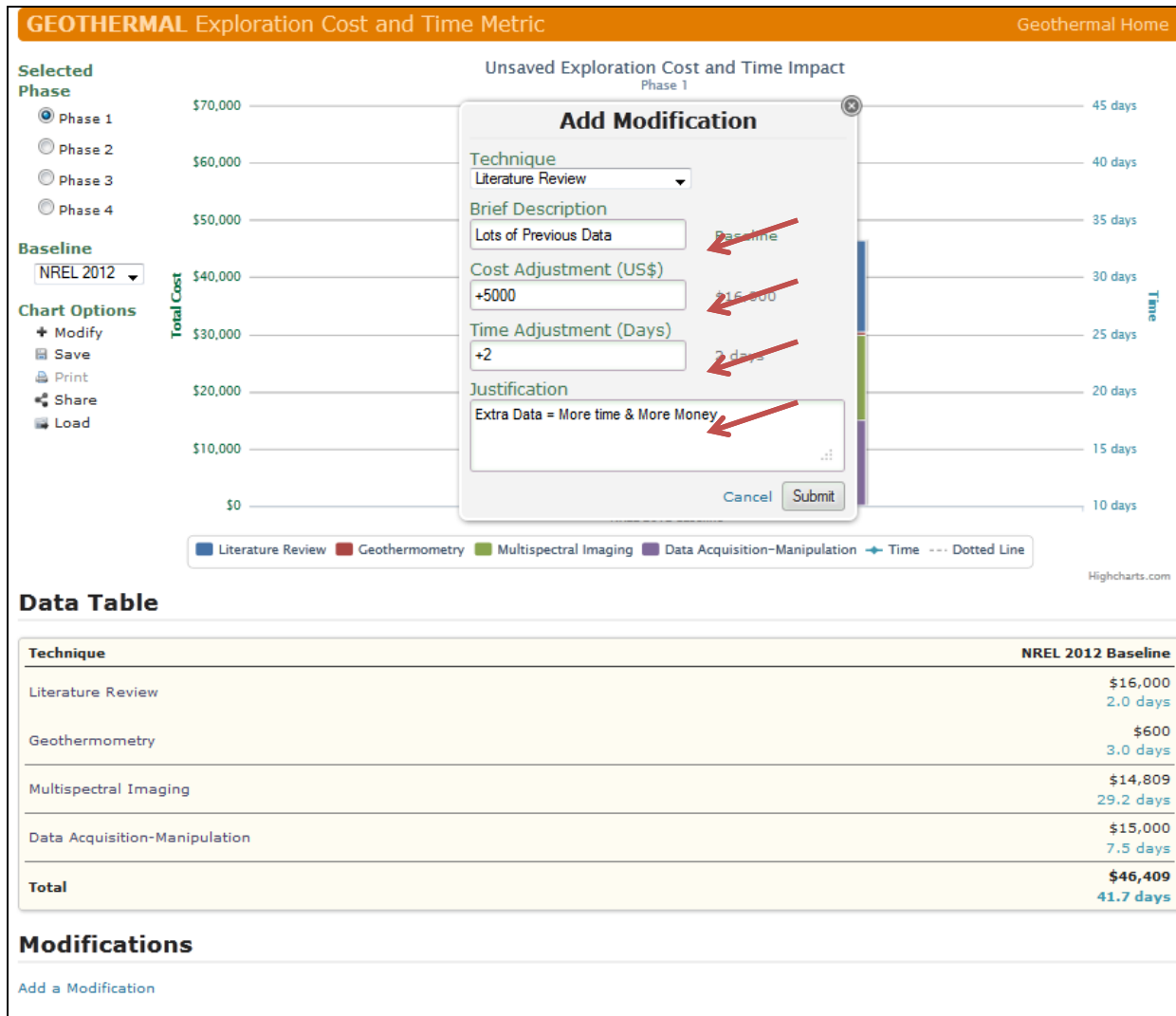
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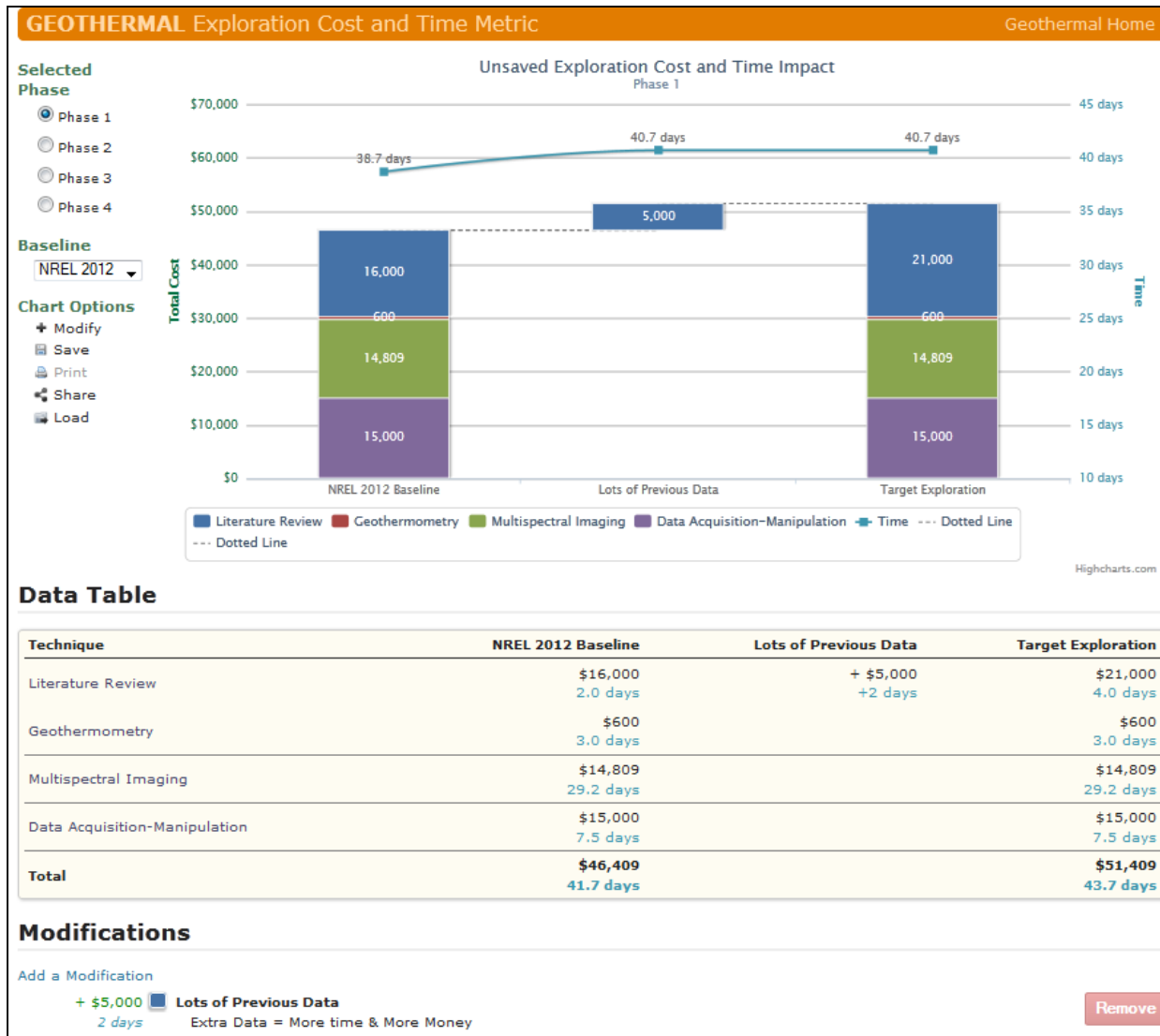


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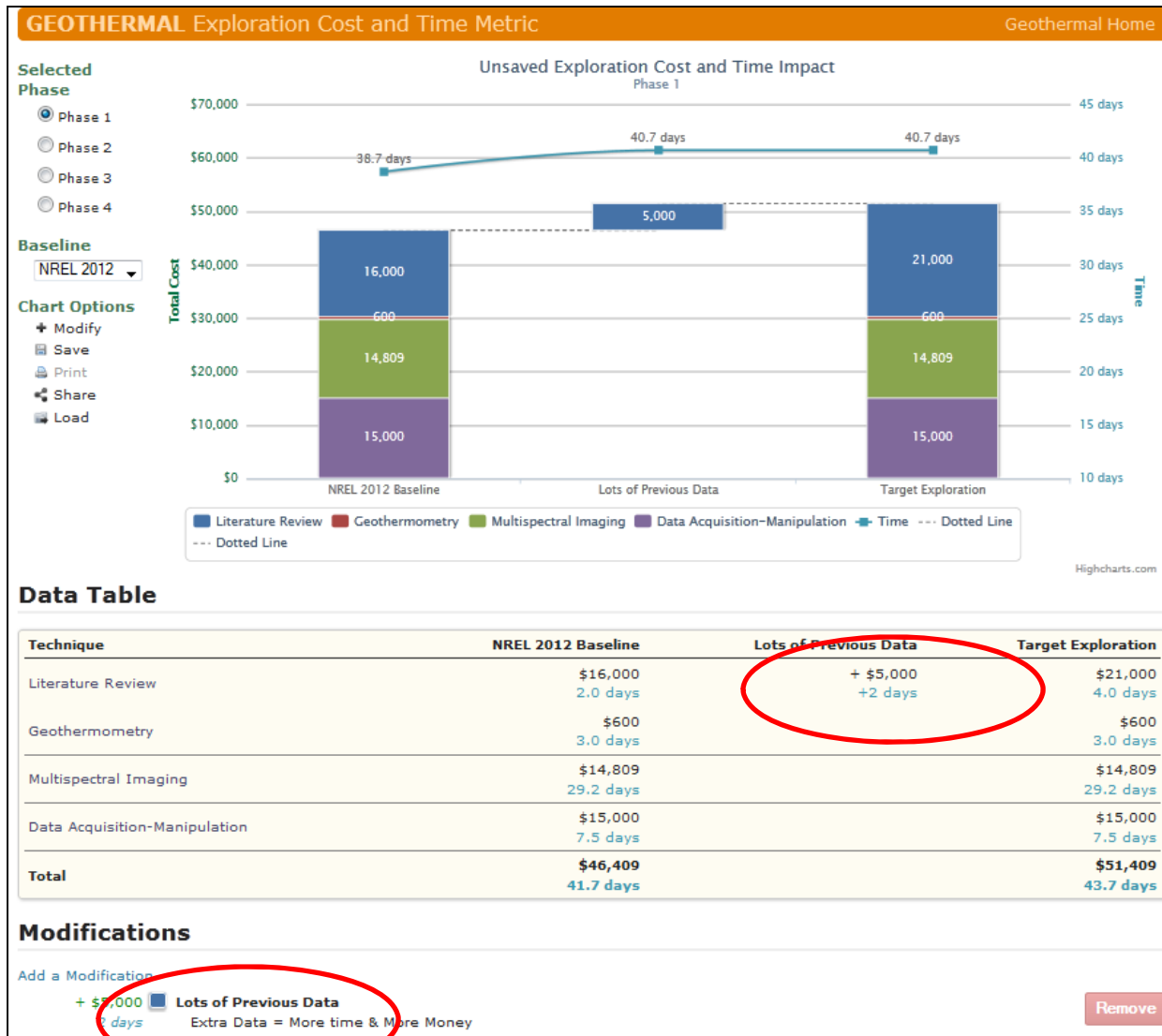
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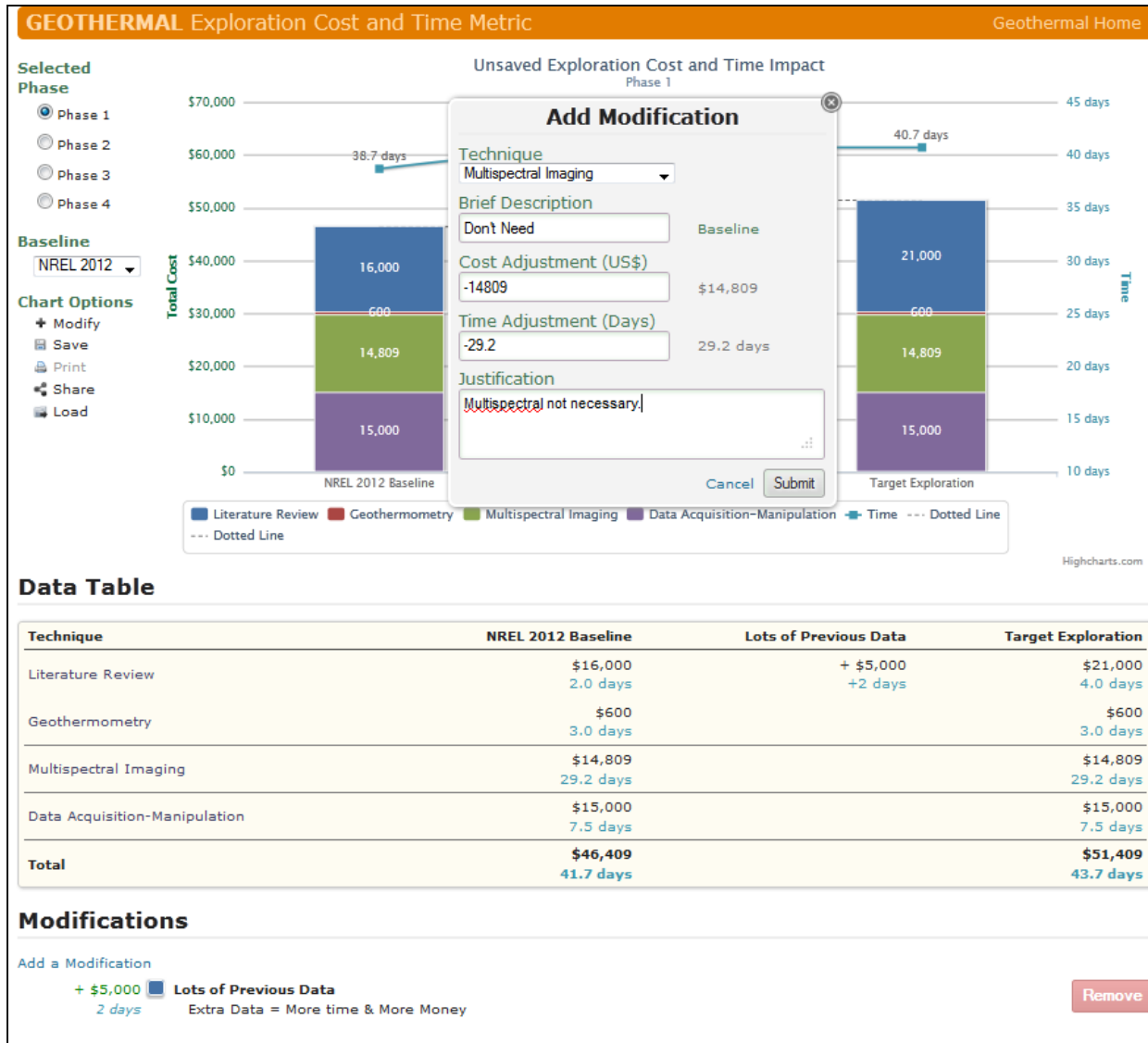
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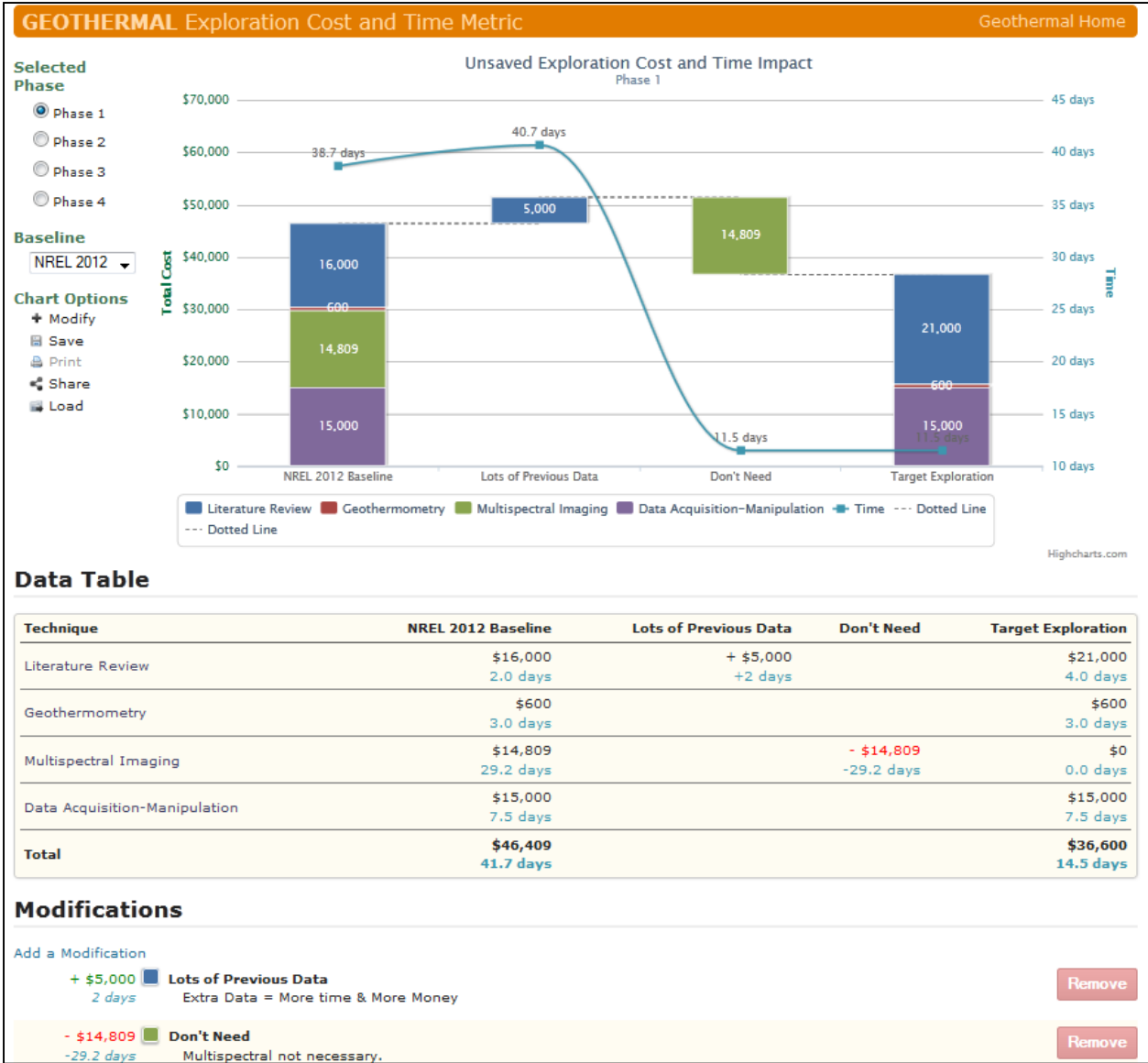
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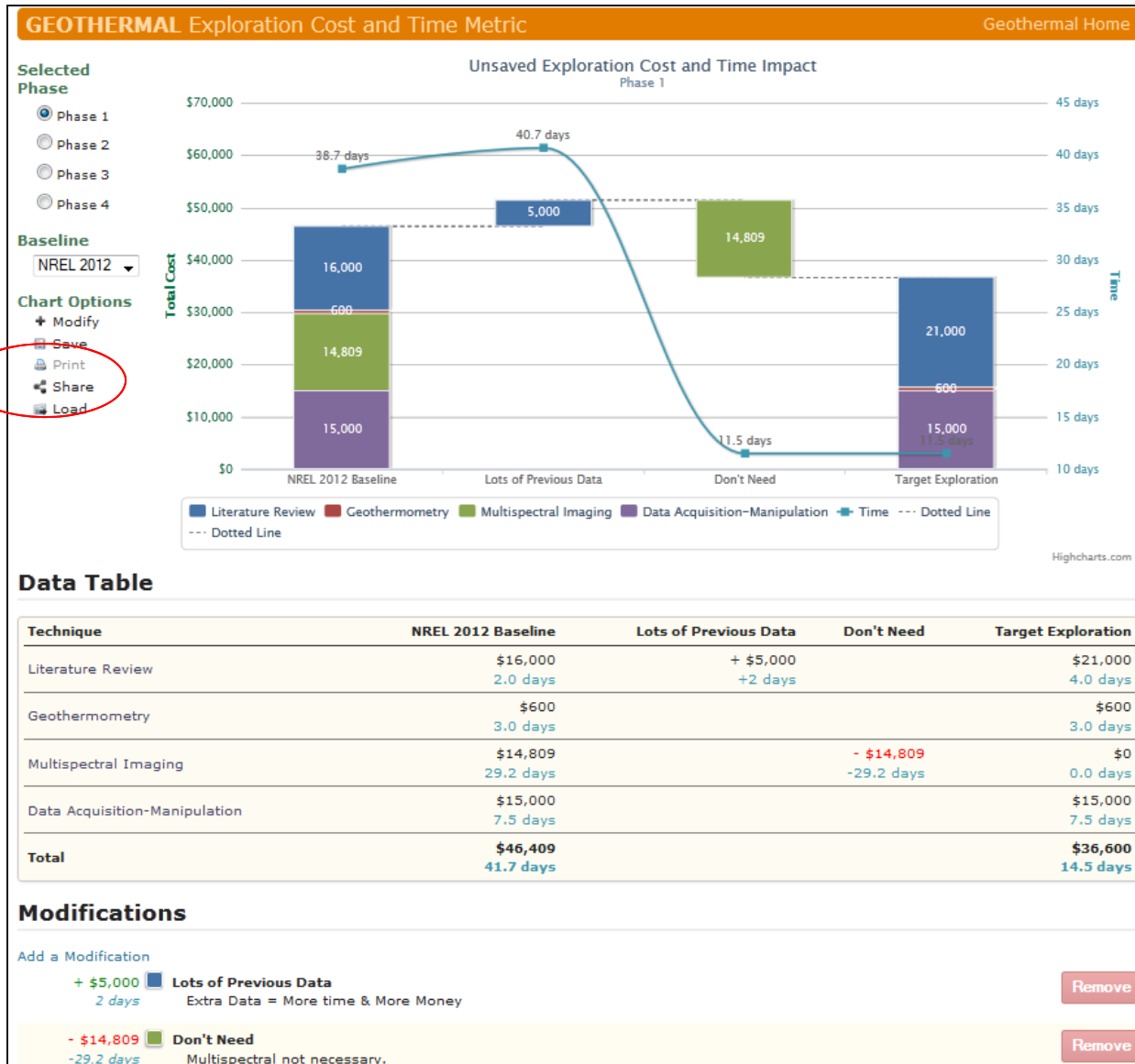
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# OpenEI Cost and Time Tool

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# THANK YOU



**Special thanks to those providing input for this project:** Eric Hass, Hidda Thorsteinsson and participating geothermal exploration contractors.

**Questions? Comments? Suggestions?  
We'd love to hear from you!**

Scott Jenne

[scott.jenne@nrel.gov](mailto:scott.jenne@nrel.gov)  
(303)-384-7248

Kate Young

[katherine.young@nrel.gov](mailto:katherine.young@nrel.gov)  
(303)-384-7402