Assessment of Geothermal Data Resources and Requirements

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Background

Purpose

The U.S. Department of Energy's (DOE's) Geothermal Technologies Program (GTP) has recently reordered its priorities and made major changes to its research and development strategy. As one element of this reorganization, the GTP requires a review of its activities and archives related to data collection and analysis.

In planning for data management, it is generally recognized that which data[1] should be collected and preserved depends on the purpose the data is intended for. The purposes that may be served in the case of the GTP include:

1) Support for industry activities, including:
    a. Identification of prospects for commercial development
    b. Leasing, permitting, and communications and outreach to critical stakeholders
2) Support for GTP R&D, including:
    a. Selection of sites for program experiments
    b. Support for and validation of modeling of economics, performance, and other critical metrics
    c. Tracking trends in systems performance and commercial development, both to assess the success of research activities and to enable identification of industry needs
    d. Planning and prioritization of research and development
3) Support for decisionmakers outside the geothermal community, including regulators and policy makers, such as:
    a. Information on geothermal resources and costs
    b. Information on policy options and incentives for development

As a starting point to prioritizing these activities and achieving the related objectives, the GTP requires an assessment of the current state of geothermal data, future program and stakeholder data needs, existence of and access to critical data, and high-level direction and prioritization of next steps to meet the Program's data needs. This paper is intended to provide the required assessment, and recommendations on GTP strategy for data collection and management.

There are several motivations for this assessment. One driver is the Program's new focus on Enhanced Geothermal Systems (EGS), which was a major GTP research subject before the mid-1990s. In order to maximize the benefit of this earlier investment in EGS technology, the data and analyses generated by that research must be reevaluated.

Another motivation is the ongoing evolution of the geothermal industry, which is in a phase of rapid development of hydrothermal resources. This accelerated market growth will set benchmarks for cost of energy and other metrics that can be used to track geothermal technology and market progress.

[1] In this report, the term "data" is used in the singular, with the definition "a body of facts; information", as opposed to the plural "data", meaning "items of information or individual facts."

A third driver is a legislative requirement imposed on DOE by Congress. As a part of Public Law 110–140, the Energy Independence And Security Act Of 2007, passed on Dec. 19, 2007, DOE is required to create a Center for Geothermal Technology Transfer. The relevant text is Sec. 618:

Public Law 110–140: Energy Independence And Security Act Of 2007
Sec. 618. Center For Geothermal Technology Transfer.

(a) IN GENERAL.—The Secretary shall award to an institution of higher education (or consortium thereof) a grant to establish a Center for Geothermal Technology Transfer (referred to in this section as the ‘‘Center’’).

(b) DUTIES.—The Center shall—
- (1) serve as an information clearinghouse for the geothermal industry by collecting and disseminating information on best practices in all areas relating to developing and utilizing geothermal resources;
- (2) make data collected by the Center available to the public; and
- (3) seek opportunities to coordinate efforts and share information with domestic and international partners engaged in research and development of geothermal systems and related technology.

(c) SELECTION CRITERIA.—In awarding the grant under subsection (a) the Secretary shall select an institution of higher education (or consortium thereof) best suited to provide national leadership on geothermal related issues and perform the duties enumerated under subsection (b).

(d) DURATION OF GRANT.—A grant made under subsection (a)—
- (1) shall be for an initial period of 5 years; and
- (2) may be renewed for additional 5-year periods on the basis of—
  - (A) satisfactory performance in meeting the duties outlined in subsection (b); and
  - (B) any other requirements specified by the Secretary.

Previous Work

This is not the first data assessment effort. Several related reports developed between 1998 and 2002 describe the status of GTP-generated data and reports at that time, and make recommendations for the disposition of that data. The most useful reports include “Data Review of the Hot Dry Rock Project at Fenton Hill, New Mexico”, Geothermex, Inc., December 1998; “Prioritization of Data from the Fenton Hill Hot Dry Rock Project for Archiving”, GeothermEx, Inc., November 1999; “Indexing and Archiving U.S. Hot Dry Rock Quantitative Data and Other Technical Information”, Princeton Energy Resources International, November 30, 1999; and “Geothermal Studies and Analyses, Report 6A. Status of DOE Geothermal Technical Report Collections”, Princeton Energy Resources International, March 21, 2002. While these reports were more limited in scope and subject, they do a good job of describing the rationale for maintaining the data and making it available, and of cataloging what data was available at the time the reports were written.

Some of the recommendations in these reports have since been acted on, most notably through the archiving of many of the GTP’s technical reports at the Office of Science and Technical Information (OSTI) website (currently at http://www.osti.gov/energycitations/index.jsp). Other actions recommended by these reports have not yet been carried out, in part due to changes in the GTP itself, although the rationale for the recommendations has not changed.

Along with the data collected by the GTP during 30 years of R&D, there are other U.S. databases with varying degrees of relationship to geothermal energy development. These databases include bottomhole temperatures from oil and gas wells; lists of springs, some including data on temperature and chemical composition; characterizations of geology of varying degrees of sophistication; transmission line information; land cover data; zoning information; and numerous other types of information which would be of potential interest to geothermal developers, researchers, or the general public seeking to learn about the resource and the technology. Much of this data is available for download from the Internet, either for free or for a fee. In some cases, proprietary information is known to be held by private firms that either use or intend to use it for competitive advantage. While such proprietary data may be made available in some circumstances for research purposes, it is unlikely that the firms will ever find it acceptable to release it to the public.

In addition to information applying specifically to the United States, there is also a body of information on foreign projects that are relevant to U.S. geothermal development. The most notable of these are the project at Soultz, in Europe, and Rosmanowes, in England. There may also be data available from the Hijiori project in Japan, but translating the documentation would require a significant level of effort in itself.

This report surveys these data types, covering both data generated within the GTP and data from other entities, and domestic and foreign data sources. The intent is first, to summarize the available Program data, identify the data with sufficient utility to justify including it in the Center for Geothermal Technology Transfer, and make recommendations regarding the actions to be taken in making the data available to the public; second, to identify other available data that could or should be collected by the program, as well as any gaps in information that could be collected; and finally, to make recommendations on next steps.

I. Geothermal-Specific Information Sources

Information that may be of use to the GTP and to developers can be divided into two major categories: Information specifically about geothermal resources, markets, and development; and ancillary data that is not specifically related to geothermal energy, but may be useful in evaluating the economics and potential of geothermal resources. Within these categories, additional subdivisions have been made based on the type of entity holding the data.

A. Geothermal Program Archives

From the perspective of industry and the GTP itself, the most important data is likely to be that developed by the GTP, both for its own use and for use by industry. This report focuses first on the status of the GTP's archives, which are the result of over 30 years of research, in order to identify information that could be used in future development, and to identify gaps that could be filled by other databases or by program R&D.

A significant portion of the raw data from early program experiments conducted at the National Laboratories has been destroyed because it has reached the end of its lifetime under data retention policies. However, there are some key exceptions to this that may be able to provide benefits to the GTP as it now exists. In some cases this data is literally being kept in the garages of former researchers.

The majority of existing data currently resides at a number of specific repositories. In some cases, the information is in a readily-accessible electronic format; in others, it is either not in electronic format, or the format it is in may not be easily accessible. The major sites with GTP-related data are listed below.

1. OSTI Reports

One of the recommendations of earlier reports on GTP data was to archive the majority of technical reports in a system where they could be easily searched and retrieved. This was accomplished through the development of a Geothermal Legacy Reports Collection, which is housed at the Office of Scientific and Technical Information (OSTI). This collection, currently containing about 7,350 documents, is located at http://www.osti.gov/geothermal/. These documents in searchable PDF format, many of which date from the 1980s or earlier, were included in the archive on the basis of recommendations from the Sandia, Idaho, and Los Alamos National Laboratories, and from selected geothermal experts. These reports serve as an account of work sponsored by the GTP.

The reports came primarily from the National Laboratories, but also from the collections of about 30 specialists in geothermal topics and from several universities, particularly the University of Utah Research Institute. About 60% of the content consists of technical reports; about 30% of conference papers; and 10% other sources such as conference proceedings, journal articles, theses and dissertations, etc.

In addition to the Legacy Reports, there are over 10,000 other document references included in the OSTI database, many of which are also technical reports. However, only a fraction of these non-legacy documents are available on line; these records consist of metadata referring to the documents. These documents can be ordered from OSTI in

hardcopy, with the exception of citations from journals and other publications, by email at reports@osti.gov or by phone - (865) 576-8401, or fax - (865) 576-5728. This collection is currently being managed by Lynn Davis.

2. Los Alamos National Laboratory (LANL) – Fenton Hill Experiments Data

The creation of a geothermal reservoir at Fenton Hill is the past GTP activity most closely related to today's focus on EGS. The data generated in the course of these experiments could potentially be used as a basis for calibrating models and comparing results. Analysis techniques developed since the experiments were completed may yield new information about the results that could assist with R&D planning.

In 1998, the GTP sponsored the development of a report on the disposition of the Fenton Hill data[2] that identified what data was available, broken out into separate sections on hydraulic fracturing and well pressurization data; seismic data; flow test data; tracer data; and log data. The report also made recommendations on next steps to be taken in processing the available data. For various reasons, not all of the data is likely to be useful: Some of the data was context-dependent, and the context has been lost; other data may be site-specific; in some cases the necessary analysis may already have been completed and documented.

In the ten years since the report was completed, there have been significant changes at LANL. In particular, due to the events of September 11, 2001, security clearances are required to access records stored at Los Alamos, even for items not related to national security. Also, many of the personnel who were maintaining the records listed in the report have retired or moved to other positions, leaving the status of any data stored there uncertain. This data apparently never entered a formal records retention system, so while it could still be present at the laboratory it could also have been disposed of at some point in the past decade.

According to Mike Fehler at MIT, who had some responsibility for the geothermal work at LANL, some paper records probably still exist. Digital records might be unreadable due to the deterioration of the storage media (often 5 ¼ inch floppies) or to the use of formats from obsolete software programs. Some data was transferred to other media, such as compact discs, by Jim Albright in the late 1990s. Mr. Fehler has some data, and there was a basement space with filing cabinets full of data maintained by Don Brown, although there was pressure to use the space for other purposes.

Don Brown is writing a book on the Fenton Hill Hot Dry Rock work. The book has been accepted for publication by Springer-Verlag, but it is still in draft form and a publication date has not been set. According to Mr. Brown, much of the raw data (probably the same data referred to by Mike Fehler) has been disposed of due to space requirements, but he still has a large quantity of relatively low-level reports.

Bob Potter, who also worked on the Fenton Hill project, has some data and analyses in his garage, but some of this is his own work that he now considers proprietary, since he is working for a company that may become involved in EGS projects. He has said that he will look through the materials and determine what is public domain. (Although the data

[2] "Data Review of the Hot Dry Rock Project at Fenton Hill, New Mexico", Geothermex, Inc., December 1998

was produced by Los Alamos, if it was disposed of or given to Mr. Potter it may no longer be considered government property.)

Dan Swensen at Kansas State University has a CD of compressed data from the Fenton Hill project on Phase II flow testing that includes all data from the last major test at the site. He has agreed to make a copy of the CD. He also has some modeling data for the Hijiori project in Japan that may or may not be proprietary. This data mostly consists of or is included in reports that have already been published.

Leigh House at LANL has a large quantity of Fenton Hill seismic data and analyses fully converted from analog magnetic tape and stored on external hard drives. Some, but not all, of the paper documentation describing the context of these data is also available. It is possible that the data set maintained by Don Brown includes information relevant to these data. Archiving these data was a recommendation of earlier reports. It appears that nobody aside from Mr. House is aware that this archive has been transferred to modern media (he was never tasked with this activity, which he undertook of his own accord).

3. Lawrence Berkeley National Laboratory (LBNL)

The Earth Sciences division of LBNL maintains a site on Enhanced Geothermal Systems Induced Seismicity (http://esd.lbl.gov/EGS/) with links to papers and seismic data, particularly that related to The Geysers geothermal system.

4. Idaho National Laboratory (INL)

In addition to its technical library (http://www.inl.gov/library/) which houses a number of geothermal reports, INL has a significant amount of data from earlier phases of the GTP, mostly at least ten years old. Most of this material is being held by Greg Mines. According to him, there is a lot of data on the Mammoth geothermal facilities, including sizes of equipment, specifications sheets, and operating data over some period for one facility including flow rates, temperatures, and power output. There is also limited data from other facilities, including Steamboat, Heber, Brady, the Salton Sea, and possibly East Mesa (some of the facilities tracked are no longer in existence). All Raft River data is probably gone because it has passed its records retention date. Some of the existing data is proprietary in nature. Data from these datasets that was published omitted some key information (such as ambient temperature) to prevent reverse engineering of the plant capabilities. The data may be difficult to interpret because while printouts are available, the keys to the data channels changed from one experiment to another. Some of the data was put in electronic format for processing (usually on 5 ¼ or 3 ½ inch disks); many of these disks went bad and the data was not retrievable. Some of the data has been transferred to CDs.

The most valuable remaining data may be that from the Heat Cycle Research Facility, which was a 75 kW power facility designed to test different power cycles. Greg Mines has the notebooks from the experiments on those facilities, which are the most recent DOE data on use of hydrocarbon mixtures for cycles. This is work which has not been taken up by industry that provides greater efficiency at low temperatures that existing commercial plants. Industry has not commercialized this technology, and the information does not exist elsewhere. Some of this data was published, but much of it was not. Most of this data is not in digital form (it may be laboratory notes), but some has been converted.

Data on noncondensible gases collected by Chuck Mohr was digitized, but the computer it was on has been disposed of and it is not known whether backup copies were made. A search would have to be done to try to locate backups. Similarly, Judy Partin's data on plant process monitoring and Pete Pryfogle's data on biofilms is probably in their notebooks, but it is unclear which notebooks contain the data; they would have to be searched. Manohar Sohal has some hardcopy data on condenser performance, but the quantity is small.

5. Southern Methodist University (SMU)

Dr. David Blackwell, at SMU, maintains a heat flow database covering the United States at a regional level of resolution, and a database of heat flow and temperature for the Western states at a higher level of resolution. The data can be downloaded at http://www.smu.edu/geothermal/georesou/alldata.htm. This data is fundamental to understanding of the U.S. geothermal resource, and Dr. Blackwell has received significant funding from the GTP over several years. Dr. Blackwell has stated that there are additional private-sector databases available for purchase that could be added to the heat flow databases. On August 19, 2008, Google announced that SMU will receive a $489,521 grant "to improve understanding of the size and distribution of geothermal energy resources and to update geothermal mapping of North America."

6. The Energy and Geoscience Institute at the University of Utah (EGI)

A listing of core data and reports from the Industry Coupled Case Study Program in the EGI library can be found at the end of a document produced as a closeout report for the GTP, "A History of Geothermal Exploration Research in the Geothermal Technologies Program", Renner, Moore, and Ross, US Department of Energy, January 3, 2008.

In FY08, EGI received funding from the GTP to scan and catalog all public-domain geothermal data in its library, which is currently stored in filing cabinets, and make it available over the Internet. The data includes reports, well logs, maps, and other information that could be valuable for EGS development. The most significant electronic files will undergo optical character recognition (OCR) to make them searchable. EGI is also scanning some or all of its core library into high-quality digital photos. While the funds provided to date may be inadequate to complete the task, a large amount of data has already been entered into the system. According to the most recent quarterly report on the task, over 3,000 documents comprising approximately 200,000 pages have been scanned, OCRed, and entered into the database as of the end of June. The electronic catalog will be populated and tested during August and September, and is expected to be completed by September 30, 2008.

EGI also provides geospatial data from the UHOC Project (an oil and gas project in Utah and Colorado); Dixie Valley, Nevada; Fish Lake Valley, Nevada; Cove Fort, Utah; The Geysers, California; and Roosevelt Hot Springs, Utah, at http://www5.egi.utah.edu/Geospatial_Data/body_geospatial_data.html

Of the identified data repositories, the EGI and University of Nevada-Reno sites are the ones most similar to that implied by the language of EISA 2007.

7. University of Nevada – Reno (UNR)

UNR's Great Basin Center, devoted to geothermal energy in the Great Basin geologic province, has the most extensive collection of geothermal-related databases available on the Internet, including geochemical data, groundwater data, geodesic data, location data, geologic data, land status data, geophysical data, geothermal favorability maps, geothermal data, and Google Earth geothermal data. An index of the data can be found at http://www.unr.edu/geothermal/ExplAssessData.html. Much of the data is GIS-based for importation into mapping software, with metadata describing the exact information included in the file. These files are being updated as new information becomes available, but the updates may end at the end of the calendar year when DOE funding runs out.

The contents of data-related UNR webpages are described briefly in the following table.

Description	Web Page
Index of regional-scale GIS data	http://www.unr.edu/geothermal/datalist.html
Project-level data for two projects (to date)	http://www.unr.edu/geothermal/GIS_download3.htm
Topographic, digital elevation, digital orthophoto, and national land cover data	http://www.unr.edu/geothermal/basemaplayers3.html
"Favorability" data for both the Great Basin and Nevada, in several formats (PDF, ArcIMS, ArcView 3x, and Arc Map 9), combine various GIS layers into a predictive map of geothermal favorability for the Great Basin.	http://www.unr.edu/geothermal/geothermal_gis2.htm
Great Basin Center geophysical data layers including gravity and magnetic data.	http://www.unr.edu/geothermal/abmain.htm
Data from temperature gradient surveys for a limited number of sites	http://www.unr.edu/geothermal/tgrad.html
Gravity data for the Desert Peak/Brady site	http://able1.mines.unr.edu/Geophysics_website/Desert_PK_gravity/download.htm
BLM data for the Great Basin	http://www.unr.edu/geothermal/httpBLMdownload.htm
Excel databases of geothermometers and groundwater geochemicals	http://www.nbmg.unr.edu/geothermal/databases.htm
The GeoHeat Center's Geochemical Database for the Great Basin Geothermal GIS	http://able1.mines.unr.edu/Geophysics_website/Geothermal_GIS_build/GeoT_1st_Run/GeoHeat_intro_v2.htm

8. Stanford University Geothermal Program

The Stanford University Geothermal Program maintains a web page with downloadable technical reports dating back to 1974 at http://pangea.stanford.edu/ERE/research/geoth/publications/index.html. These reports were researched at Stanford under contract with the GTP.

9. Geothermal-Biz.com

The Geothermal-Biz site (http://www.geothermal-biz.com/home.htm) was a resource for geothermal developers that was funded through the GeoPowering the West initiative. This site includes useful information on leasing and financing requirements and best practices.

B. Other DOE and Federal Government Geothermal Data Sources

1. Bureau of Land Management (BLM)

BLM has a relatively limited set of information directly related to geothermal development, and a much larger amount of information that is of relevance, but not directly connected to geothermal energy. The directly relevant information includes:

1) A USGS Heat Flow Database for California, at http://earthquake.usgs.gov/heatflow/.
2) USGS Open-File Report 99-425 online version 1.0, "Geothermal Industry Temperature Profiles from the Great Basin", at http://pubs.usgs.gov/of/1999/of99-425/webmaps/home.html, which includes data from an evaluation of over 100 geothermal prospects by Chevron Geothermal, Phillips Petroleum, Geothermal Resources International (GEO), Aminoil USA, AMAX, and other companies in the 1970s. Subsurface temperature data from several hundred of those holes were purchased by the GTP for curation by Idaho National Laboratory (INEEL). As part of that transaction, the USGS agreed to digitize the data and make them available on the World Wide Web.
3) Status information on BLM Nevada geothermal wells, at http://www.blm.gov/nv/st/en/prog/minerals/leasable_minerals/geothermal0/geothermal_operations/geothermal_wells.html, indicating whether the wells are in service and for what purpose.
4) The exact latitude and longitude of BLM Nevada geothermal power plants, at http://www.blm.gov/nv/st/en/prog/minerals/leasable_minerals/geothermal0/geothermal_operations/power_plants.html.
5) BLM Nevada geothermal leasing information, at http://www.blm.gov/nv/st/en/prog/minerals/leasable_minerals/geothermal0/ggeothermal_leasing.html, showing regulations and procedures, parcels for lease, and results of past leasing activities.
6) BLM's Legacy Rehost 2000 system athttp://www.blm.gov/lr2000/ provides reports on BLM land and mineral use authorizations for oil, gas, and geothermal leasing, rights-of-ways, coal and other mineral development, land and mineral title, mining claims, withdrawals, classifications, and more on federal lands or on federal mineral estate. The data here is also mapped at Geocommunicator, http://www.geocommunicator.gov/NILS-PARCEL2/map.jsp?MAP=ENERGY.
7) The Geothermal Programmatic Environmental Impact Statement assessing the direct, indirect, and cumulative effects of leasing, exploration and development of geothermal resources, at http://www.blm.gov/wo/st/en/prog/energy/geothermal/geothermal_nationwide.html.

2. National Oceanic and Atmospheric Administration (NOAA)

NOAA has a National Geophysical Database on the internet that includes data on 1661 springs across the country: http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?dataset=100006&search_look=1&display_look=1

However, this data has not been updated since 1980. The data includes maximum temperature and location.

3. Energy Information Administration (EIA) of the U.S. Department of Energy

EIA collects geothermal energy generation data for the purpose of tracking generation and market penetration. A page listing EIA electricity-related databases is at http://www.eia.doe.gov/cneaf/electricity/page/data.html. Among these, historical data on power production is available from the Forms 906 and 920 web page at http://www.eia.doe.gov/cneaf/electricity/page/eia906_920.html. Capacity data is available from the Form 860 database at http://www.eia.doe.gov/cneaf/electricity/page/eia860.html. EIA also has a page devoted to geothermal heat pumps at http://www.eia.doe.gov/cneaf/solar.renewables/page/heatpumps/heatpumps.html.

4. Federal Energy Regulatory Commission (FERC)

FERC collects data on geothermal power purchase agreements, utility ownership, certifications for power facilities, and (in some cases) power sales. A database of scanned forms dating back to the 1990s can be found at http://www.ferc.gov/docs-filing/elibrary.asp. Most information that is considered competitively sensitive (such as power sales prices) has been redacted from the on-line document database, and data that has been redacted is not accessible by non-FERC personnel (including DOE employees, although FERC reports to the Secretary of Energy).

5. Oregon Institute of Technology (OIT) GeoHeat Center

The GeoHeat Center (http://geoheat.oit.edu/) specializes in direct-use applications of geothermal energy. For $27.50, the Center supplies a set of databases related to Western states (Alaska, Arizona, California, Colorado, Idaho, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming) on CD. These databases were compiled from other sources, and are supplied in xls, csv, and wb3 format. The databases include:

1) Wells and Springs with a temperature typically greater than 20°C.
2) Fluid chemistry for the wells and springs listed in the Wells and Springs database. Chemistry information is not available for Texas and Nebraska.
3) Other Information - this database contains additional information found in the original databases, but did not fit in the above two databases.
4) Direct-Use Sites known locations of existing direct-use sites for each state. The states of Arkansas, Georgia, Hawaii, New York and Virginia were included since they all have direct-use applications.
5) Collocated Sites - population centers located within 8 km of a known resource with a temperature of 50°C or greater.

1) QuattroPro 8 extension *.wb3
2) Microsoft Excel 97 extension *.xls
3) Comma Delimited Text extension *.csv

The Center also provides a set of case studies developed at the request of the National Renewable Energy Laboratory (NREL) to describe a variety of U.S. geothermal direct-use projects (http://geoheat.oit.edu/pdf/tp115.pdf) and reports on various aspects of development (http://geoheat.oit.edu/task.htm). Other resources include quarterly bulletins in PDF, software for technical and economic calculations, and a library maintained at the Geothermal Resources Council (GRC) (see below).

6. U.S. Geologic Survey (USGS)

The USGS has several web pages on geothermal topics, most of which are linked from http://www.usgs.gov/science/science.php?term=477. USGS Circulars and Open-File Reports contain additional geothermal-specific information; of particular interest is USGS Circular 790, which contains resource estimates (http://pubs.er.usgs.gov/usgspubs/cir/cir790). Other documents cover hot springs (http://pubs.usgs.gov/of/1995/of95-689/; the springs database is downloadable in GIS format from http://wrgis.wr.usgs.gov/docs/northwest_region/ofr95-689.html) and descriptions of geothermal sites.

7. Northern California Earthquake Data Center (NCEDC)

The Northern California Earthquake Data Center is a joint project of the University of California Berkeley Seismological Laboratory (BSL) and the USGS. The NCEDC, which serves as an archive for digital data relating to earthquakes in central and northern California, has a web page devoted to seismic events at The Geysers ((http://www.ncedc.org/geysers/). This page covers over 10 years of digital microearthquake seismograms. The NCEDC provides a stable and permanent archival and distribution center of digital geophysical data for northern and central California such as seismic waveforms, electromagnetic data, GPS data, and earthquake parametric data. The NCEDC houses a wide collection of geophysical data, including earthquake catalogs, seismograms, GPS observations, strain, creep, and tilt data, and InSAR data. Most of these data are focused on northern and central California, but some collections span all of California or the western United States. All of the documentation about the NCEDC, including the research users' guide, is available via the Web. Access to all datasets is available via research accounts at the NCEDC.

C. State-Based Geothermal Data Sources

At least three states (California, Nevada, and Utah) have either taken steps to define their geothermal energy potential, or collected data on geothermal activity in the state, or both. While Nevada collects geothermal information from plant operators, it is not available in electronic format because the state has not provided funds for data entry.

1. State of California

Of the states, California has the most comprehensive collection of information, and it is available for download from the Internet.

1) The Public Interest Energy Research (PIER) Report, published in 2004, is available at http://www.energy.ca.gov/pier/project_reports/500-04-051.html. This report was intended "to provide a portfolio of well-characterized geothermal resources within California and western Nevada", and "to quantify each geothermal resource in terms of its minimum and most-likely generation capacity, estimated costs of exploration and confirmation, and estimated total development costs and unit development costs ($/kW installed), including transmission-line costs … [The database] has relied on information in the public domain and such other information as private developers have agreed to contribute. A principal outcome of the work has been the creation of a database … in MS Access … The

PIER Geothermal Database includes information about the resource characteristics of 155 separate geothermal projects at 83 resource areas. It also includes embedded documents describing the methodology of the study and tables summarizing results." The database described here can be downloaded from http://www.energy.ca.gov/pier/project_reports/500-04-051_PIER_GEOTHERMAL_DATABASE.ZIP

2) The California Department of Conservation's Division of Oil, Gas, and Geothermal Resources maintains a database on the locations of approximately 3,500 geothermal wells in California, in a compressed DBF or Access format, that can be downloaded at http://www.conservation.ca.gov/dog/maps/Pages/goto_wellloc_geotherm.aspx. The information contained in the file includes API number; operator; well name and number; section, township, and range; the date the well was started; the latitude and longitude, and the source of the location data; and an extensive set of well status codes. Additional information on some wells can be found through the GeoSteam and Well Record Programs: http://geosteam.conservation.ca.gov/WellSearch/GeoWellSearch.aspx. Instructions for using this database can be found at http://www.consrv.ca.gov/DOG/geothermal/geosteam/Pages/geothermal_owr_help.aspx. These well records include the history and logs that compose the hard-copy well files. There are nearly 4,000 well records in the districts, and all of them have been scanned. Information on confidential wells is not available. Wells can be screened against various criteria (location, operator name, etc.), and records for individual wells include the purpose of the well (commercial, exploratory, injection, water, etc.), status (active, abandoned, plugged, etc.), mineral rights (Federal, state, or private), and the availability of data logs and forms. If the well is not confidential, logs and forms, including monthly production and injection values, can be downloaded in PDF, TIFF, or Excel format, depending on the type of data represented. Unless drilled with public funds, wells on active federal leases are confidential and remain confidential until the lease is no longer active, or the operator voluntarily releases these records. Some low-temperature wells are exempt from submitting production and injection data.

3) Some additional information is available in reports at http://www.energy.ca.gov/geothermal/documents/index.html. Most of this is California-specific overview reports from various sources.

2. State of Nevada

The Nevada Commission on Mineral Resources' Division of Minerals Oil, Gas, & Geothermal Forms and Publications, http://minerals.state.nv.us/formspubs_ogg.htm, shows the types of data collected by the state of Nevada (fluid injected, temperature, well completion data, etc.) The actual data is not available on line due to a lack of resources to digitize the completed forms.

3. State of Utah

The Utah Geological Survey has geothermal-specific reports, maps, and data at http://geology.utah.gov/emp/geothermal/geothermal_resources_in_utah.htm, including a database of temperature gradient data (http://geology.utah.gov/emp/geothermal/geothermal%20access%20db/ut_tg_data.xls)

taken from a 2004 Utah Geological Survey report on geothermal gradient data[3] that cites the Department of Energy and the National Renewable Energy Laboratory (NREL); and data on 2981 wells and springs (http://geology.utah.gov/emp/geothermal/wells_springs_database.htm) listing properties such as temperature, depth, flow, status, date, references, pH, conductivity, and chemical content, in addition to location, from a 2002 Utah Geological Survey report[4].

D. Other Data Sources

A few universities have state or regional geothermal data available on line, and the two industry associations (the Geothermal Resource Council [GRC] and the Geothermal Energy Association [GEA]) also provide information resources. Geothermal firms obviously could be another source of information, although much is likely to be considered proprietary; less obviously, some oil and gas industry members have previously undertaken geothermal exploration. Finally, there are some resources available internationally.

1. University of Idaho

The University of Idaho has Idaho Geologic Survey geological data available on line for a subset of regions in Idaho at http://inside.uidaho.edu/geodata/geologic/Geologic.htm , and additional browsable and downloadable GIS data (most of it not geothermal-specific) at http://inside.uidaho.edu/asp/geodata.asp. The non-geothermal-specific data includes small-scale digital elevation models, census data, Congressional districts, etc.

2. The University of Wyoming

The University of Wyoming's Wyoming Geographic Information Science Center at http://www.wygisc.uwyo.edu/24k/bedgeol.html provides a clearinghouse for GIS data on Wyoming, including elevation, hydrography, and surficial geology (surface geographic features) at http://www.wygisc.uwyo.edu/24k/surfgeol.html.

3. Virginia Polytechnic Institute and State University (Virginia Tech)

Virginia Tech maintains a Geothermal Data WWW Home Page (http://rglsun1.geol.vt.edu/) that focuses on the eastern United States. The site has information on heat flow and practical applications of low-temperature geothermal energy, and a temperature versus depth database. The site also includes temperature data from hundreds of temperature and other geophysical logs, rock thermal conductivity, and heat flow values from New Jersey, Maryland, Delaware, Virginia, North Carolina, South Carolina, and Georgia.

4. Geothermal Resources Council (GRC)

According to its web page (http://www.geothermal.org/databases.html), the GRC provides "the most comprehensive bibliographic geothermal library in the world." Over 30.000

[3] Blackett, Robert E., February 2004, Geothermal Gradient Data For Utah, Utah Geological Survey
[4] Blackett, R.E., and Wakefield, S.I., 2002, Geothermal resources of Utah, a digital atlas of Utah's geothermal resources: Utah Geological Survey, OFR-397, CD-ROM

citations for individual articles from GRC and other geothermal publications are searchable via keywords. The GRC lumps these articles into five categories:

1) Bibliographic information on technical articles on all aspects of geothermal energy research, exploration, and development worldwide;
2) Bibliographic information about news, commentary, technical articles and announcements included in the bi-monthly GRC Bulletin;
3) U.S. geothermal power generation, hosted by the Geothermal Energy Association (see below);
4) The GeoHeat Center Library, owned and maintained by the Oregon Institute of Technology, provides information on geothermal direct use of geothermal resources and geothermal heat pumps.
5) The GeoHeat Center Bulletin (copies also at the Geo-Heat Center site, referenced above) contains technical reports and articles about direct use of geothermal resources and geothermal heat pumps.

The GRC also provides PDF copies of Geotermia, a Mexican professional journal with articles about geothermal energy research, development and use; copies of articles from the Geothermal Bulletin, a GRC publication, some of which contain data on geothermal use worldwide; and recent copies (since 2005) of the International Geothermal Association's IGA News.

A previous study of geothermal data[5] indicated that the GRC is holding several industrial and public sector library collections that have not been indexed or put in electronic format due to a lack of funds. These include:

a. The B.C. McCabe library, probably documenting early geothermal exploration and development efforts.
b. The Pat Muffler library, probably documenting geothermal resource assessments by the USGS.
c. The Tsvi Meidav library, probably documenting domestic exploration and development.
d. Materials from the California Energy Commission, consisting of geothermal project management and technical files, mostly for direct use.
e. The Giancarlo Facca library, mostly documenting geothermal work in Italy.

5. Geothermal Energy Association (GEA)

The GEA website contains a database of operating geothermal power plants in the United States (http://www.geo-energy.org/information/plants.asp) with information on capacity and plant type, and additional pages with short descriptions of planned generating facilities. A publications page (http://www.geo-energy.org/publications/reports.asp) links to PDF reports on various aspects of geothermal markets and development.

6. Geothermal and Oil and Gas Industry Members

The data held by industry is generally considered to be proprietary due to its potential for providing competitive advantage. Firms must have data on sites where plants are actually

[5] Geothermal Studies and Analyses, Report 6A. Status of DOE Geothermal Technical Report Collections, D.J. Entingh, March 21, 2002

operating, as well as data on sites under consideration for development, and in specific instances it may be possible to collect this data for use in analyses under a non-disclosure agreement. In some cases (for example, USGS Open-File Report 99-425, which includes 1970s site exploration data from Chevron Geothermal, Phillips Petroleum, and other companies) the data has already been made available. Negotiating with firms for data on every geothermal site and plant would not be a useful exercise, but if a R&D benefit can be identified that would serve the interests of the GTP and the industry, it should be possible to access data from specific sites for limited purposes. (For example, the services firm Geothermex [http://www.geothermex.com/]) is known to maintain an archive of proprietary geothermal data internally due to its past work with geothermal companies.)

7. The International Geothermal Association (IGA)

The IGA website includes an on-line geothermal conference database with proceedings from the World Geothermal Congress; Stanford Geothermal Workshop; New Zealand Geothermal Workshop; European Geothermal Conference; Iceland Geothermal Conference; Indonesian Geothermal Association Conference; Beijing International Geothermal Symposium; International Geothermal Workshop – Russia; and Geothermal Energy in Underground Mines -Ustron – Poland, for a current total of 5,204 papers. The database is actually hosted at Stanford University: http://pangea.stanford.edu/ERE/db/IGAstandard/default.htm

The IGA also provides miscellaneous geothermal-related documents (http://www.geothermal-energy.org/iga_about.php?sub=doc) and copies of the IGA newsletter dating back to 1999 (http://www.geothermal-energy.org/iga_pub.php?sub=newsletter).

8. Enhanced Geothermal Innovative Network for Europe (ENGINE)

The ENGINE webpage includes an on-line bibliography of journal articles (http://engine.brgm.fr/bibliography.asp) and another bibliography of materials from ENGINE partner organizations (http://engine.brgm.fr/partners.asp). These bibliographies consist of metadata only; the articles are not provided.

9. Soultz HDR Project

The reservoir enhancement project at Soultz, in France, under the auspices of the European Commission, (http://www.soultz.net/version-en.htm), has extensive experimental data available for researchers, but it is not available for download from the Internet. Microseismic data is in the possession of Ernie Majer at LBNL, while other test data are at the University of Neuchâtel (http://www2.unine.ch/). Some of these data are only available in paper format. The MIT experts group that developed the recent Enhanced Geothermal Systems report planned to have the data scanned for evaluation if sufficient funds were available, but the funds were used for other purposes.

10. International Energy Agency Geothermal Implementing Agreement (IEA-GIA)

The IEA-GIA (http://www.iea-gia.org/default.asp) has a number of potentially valuable resources. One is a collection of metadata on geothermal research documents available through the Energy Technology Data Exchange (ETDE) World Energy Base (ETDEWEB) (http://www.etde.org/etdeweb). This database links to other Internet bibliographies, and

provides a few documents within the database itself, but also includes citations for documents not available on the Internet. The database is searchable, but has no keyword index. Searching for "geothermal" brings up a list of nearly 34,000 individual items from numerous countries, with subjects including geothermal heat pumps and direct use. The majority of the documents appears to be technical reports.

Other useful data-related documentation includes reports and protocols for project decisionmaking for EGS; information on induced seismicity; a handbook on geothermal drilling best practices; and other reports and presentations (http://www.iea-gia.org/publications.asp). The protocols are potentially valuable because they define what data should be collected, and provide formats for reporting.

11. The Geothermal Heat Pump Consortium (GHPC)

The GHPC maintains a publications web page (http://www.geoexchange.org/geoexchange-explained/publications.html) that includes case studies and other informational materials.

II. Non-Geothermal-Specific Data Sources

A significant amount of general information is available that potentially can be used by the GTP and industry for site selection and evaluation. This includes information on transmission lines, roads, terrain, population and load centers, general geological information, availability of water, etc. Much of this material has been developed by Federal or state agencies for other purposes, and is now available on the Internet. In many cases, the data is made available in a format suitable for use in Geographic Information Systems (GIS) software, which enables overlaying information of different types on a map to help assess the suitability of a given location for an intended purpose. Unlike some of the geothermal-specific information, the majority of this is actual technical data (i.e. items of information), as opposed to reports.

Some of the sites here could also be considered as examples of "best practices", in that the data they present, or the mode of presentation, could be used as a template for other organizations and/or stakeholders.

A. Federal Databases

1. Federal Geographic Data Committee (FGDC)

The Federal Geographic Data Committee (http://www.fgdc.gov/index.html) is an interagency committee that promotes the coordinated development, use, sharing, and dissemination of geospatial data on a national basis. This nationwide data publishing effort is known as the National Spatial Data Infrastructure (NSDI). The NSDI is a physical, organizational, and virtual network designed to enable the development and sharing of this nation's digital geographic information resources. FGDC activities are administered through the FGDC Secretariat, hosted by the National Geospatial Programs Office (NGPO) of the U.S. Geological Survey.

2. Geospatial One-Stop

Geospatial One-Stop (http://gos2.geodata.gov/wps/portal/gos) is a clearinghouse for data of many kinds, including a geological and geophysical category page listing the metadata records of information pertaining to the sciences dealing with the composition, structure, and origin of the Earth's rocks and soils.

3. National Atlas

The National Atlas at http://nationalatlas.gov/atlasftp.html#geology has GIS data of multiple types, including magnetic field-related maps, quaternary faults, seismic hazard, surficial deposits and materials, and volcanoes.

4. Bureau of Land Management (BLM)

The BLM has numerous web pages with information on land use and geology. Among those most likely to be relevant to the GTP and the geothermal industry are:

1. The BLM Oregon/Washington GIS web page: http://www.blm.gov/or/gis/data.php

2. BLM Arizona GIS files on numerous land management-related issues: http://www.blm.gov/az/st/en/prog/maps/gis_files.html#statewide

3. BLM GIS datasets for California: http://www.blm.gov/ca/gis/

5. U.S. Geological Survey (USGS)

In addition to its geothermal web pages, the USGS maintains abundant data on other relevant geological and land-use features. Among these, digital line graphs are available at http://edc.usgs.gov/products/map/dlg.html that include township, range, and section lines; boundaries for state, county, city, and other national and State lands such as forests and parks; roads and trails, railroads, pipelines and transmission lines; hydrography; contours and supplementary spot elevations; non-vegetative features such as glacial moraine, lava, sand, and gravel; and vegetative surface cover. Digital elevation models can be found at http://edc.usgs.gov/products/elevation/dem.html, and digital orthophoto quadrangles are at http://edcwww.cr.usgs.gov/products/aerial/doq.html

The USGS National Water Information System's water quality webpage at http://waterdata.usgs.gov/nwis/qw provides chemical and physical data on streams, lakes, springs, and wells.

6. U.S. Fish and Wildlife Service

GIS data sets by state are available at http://www.fws.gov/data/statdata/index.html.

B. State-Based Data Sources

1. State Geological Surveys

State Geological Surveys for 45 states are linked at http://www.lib.berkeley.edu/EART/surveys.html. Many of these Surveys include energy-related or geothermal-related data on their home pages. The Idaho Geological Survey at http://www.idahogeology.org/data/idgml.asp has geological databases for Idaho, Montana, and Washington.

2. California State Government

Various GIS data sets for California (not geothermal-specific) are available at http://gis.ca.gov/index.epl.

3. Idaho Department of Lands

The Idaho Department of Lands has an extensive collection of links to GIS data at http://gis1.idl.idaho.gov/GIS_Links.htm

4. Idaho Department of Water Resources (DWR)

The Idaho DWR supplies GIS data at http://www.idwr.idaho.gov/gisdata/gis_data.htm, including Administrative Boundaries (IDWR, State, and Federal), aquifers, census, municipal boundaries, Digital Raster Graphics (1:24,000-scale, 1:100,000-scale, and 1:250,000-scale quads), geology (generalized geology and aquifer lithology), GNIS

geographic names from USGS, geothermal springs and generalized resource areas, ground water, hydrography, lakes and rivers, and areas administered by IDWR under regulatory rules, Landsat satellite data and aerial photography, soil surveys for 10 counties, state and local streets, water rights, watersheds, wells, and wetlands.

5. Oregon Geospatial Enterprise Office (GEO)

GEO, at http://www.oregon.gov/DAS/EISPD/GEO/sdlibrary.shtml, has spatial data at http://www.oregon.gov/DAS/EISPD/GEO/alphalist.shtml , Digital Orthophoto Quads at http://www.oregon.gov/DAS/EISPD/GEO/data/doq.shtml , and Digital Elevation Models at http://www.oregon.gov/DAS/EISPD/GEO/data/dems.shtml .

6. Oregon Water Resources Department (WRD)

Oregon's WRD (http://www.wrd.state.or.us/) includes data on well logs and a mapping tool for water rights.

7. Utah GIS Portal

The government of Utah has a Utah GIS Portal at http://agrc.utah.gov/agrc_sgid/sgidlib/statewide_gdb.htm with download links at http://gis.utah.gov/download (registration required to enter). Links include water rights, LIDAR, contour, soils, and other non-geothermal-specific data.

8. Montana Department of Environmental Quality (DEQ)

Montana's DEQ has basic data on 50 springs at http://www.deq.state.mt.us/Energy/geothermal/sites.asp. Site information includes some or all of name, location (lat/longitude), nearest town, county, depth, temperature, flow, total dissolved solids, Site ID, pH, and several chemical species.

9. Arizona Land Resource Information System (ALRIS)

ALRIS (http://www.land.state.az.us/alris/index.html) includes GIS layers for geographic data such as faults and geology.

10. North Carolina OneMap

North Carolina's OneMap site (http://www.nconemap.com/default.aspx?tabid=286) provides free geology data, including data on known faults, as well as numerous other attributes.

C. Other Sources

1. UNR Great Basin Geoscience Database

An entire geoscience database on the Great Basin geologic province can be downloaded from the University of Nevada-Reno at http://keck.library.unr.edu/data/gbgeosci/gbgdb.htm. This material overlaps with that cited above in section I.A.6 on UNR's geothermal work.

2. University of Arizona Southern Arizona Data Services (SADS) Program

The SADS Program provides numerous GIS shapefiles, including power transmission lines, geologic faults and formations, hydrographic features, springs, lakes, soils, roads, and urbanized areas (http://sdrsnet.srnr.arizona.edu/index.php?page=datamenu&lib=1&sublib=15).

3. Database of State Incentives for Renewable Energy (DSIRE)

DSIRE (http://www.dsireusa.org/) provides information on market incentives for renewable energy sources, including geothermal.

III. Recommendations on Next Steps

As an overall recommendation, the GTP should develop a proactive strategy for data collection and management that anticipates the Program's needs, responds to the EISA 2007 data center requirements, and provides industry with the support it requires. In order to achieve this, there are several interrelated activities that should be undertaken by the GTP to take advantage of the data already available, and to enable the best use of the data that will be generated by the program in the future.

One aspect of data categorization and collection that applies to both raw data and analyses, and to both pre-existing data and data yet to be developed, is creation of protocols (i.e. templates and procedures to ensure that formats, search terms, database structures, etc. are consistent across databases), in order to make it easier for people to use and combine data from multiple sources. The IEA-GIA appears to have some protocol development efforts underway, and it would simplify exchange of data with foreign researchers if these templates were either used by U.S. researchers, or improved on by U.S. researchers and adopted by the IEA. It is recommended that the IEA efforts should be assessed, and a U.S. working group should be created to work on standards and protocols for data collection and reporting, to assist with harmonization of international standards.

A. Preservation and Use of Existing Data

The first category of activities relates to preservation and use of existing data. This information can be divided into two types: Raw experimental data, and analyses of the data as documented in reports.

1. Raw Data

The most relevant raw data of potential significance for the GTP in its current manifestation, which is prioritizing EGS, is that from the Fenton Hill, Soultz, Hijiori, and Rosmanowes experiments. This data is potentially useful for a variety of purposes, including testing models against real-world results and identifying similarities to and differences from oil and gas field fracturing experience. Much of this data appears to be at risk, and some has already been lost. Collection and preservation of this data should be given the highest priority.

It is difficult to evaluate the importance of the Fenton Hill data, but based on consultations with experts the best previous evaluations[6] suggested that some subsets of the data would be particularly useful, including seismic data, flow test data, tracer data, and a subset of well log data. Some of these data are still archived, while others have apparently been lost. As a first step, with the older evaluations as a starting point, the remaining data should be catalogued (again) and assessed, and any data of value should be converted to electronic format, archived, and disseminated to the relevant experts working on the current EGS effort. The seismic data maintained by Leigh House is an example of this.

[6] Particularly "Indexing and Archiving U.S. Hot Dry Rock Quantitative Data and Other Technical Information", Princeton Energy Resources International, November 30, 1999.

The data from other projects (Soultz and Rosmanowes) appears to be available, but the Rosmanowes project data may be at risk because it is stored on obsolete media (laserdisc), and the Soultz data may require a significant effort to make it available in electronic format. The data from both these projects should be assessed, and any data of value should be converted to a contemporary electronic format, archived, and disseminated to the appropriate experts working on EGS.

An additional potentially valuable dataset is the information from the Heat Cycle Research Facility. This data is unique, and to recreate the results of this work would require a time-consuming and expensive effort. The data should be assessed by experts in the field, and the data that is considered to be of value should be archived. While the data may not be of immediate use to the program, it should be stored for future use on energy conversion research. Other raw data at INL should be archived for future GTP use; although the current focus of the GTP is not on energy conversion, it is highly likely that research in this area will be necessary in the future.

The raw data stored at EGI, which is now being electronically archived and catalogued, should also be assessed for its potential usefulness in EGS research.

A wealth of GIS-based data is becoming available as this technology matures. Relevant data from other sources (USGS, State Geological Surveys, and other sources) should be collected and used in GTP economic modeling.

2. Reports, Analyses, and Other Documentation

While a wealth of reports and information is available, it is not organized in a fashion that allows easy location of information for a researcher new to the field. Most of the data can be located only through keyword searches in a variety of databases, or by contacting one of a rapidly shrinking number of technical experts in the field (many experts have retired over the past five years, and many of the remaining experts may retire within the next five years). While the information will remain available, it will be of far more value to researchers if it is systematically organized.

The documentation available at the major archives of GTP data should be assessed and catalogued to make it easier to identify key information across different categories, and to enable newcomers to the field to identify documentation relevant to their interests. It would be useful to be able to search at the major sites (particularly OSTI) using defined keywords to rapidly narrow the field of documents of interest.

B. Development and Dissemination of New Data

1. Information for GTP Use

Due to its experiment-driven focus, the GTP can be expected to generate large quantities of new data. As noted above, the formats and structures of the databases should be decided on before large-scale data collection begins, to enable the GTP to specify what data should be collected and how. Data requirements should account for the need to use the data for program defense, as well as for validation of models and theories. It would be valuable to track program metrics over time to evaluate research progress. It is recommended that an assessment of data required for evaluation of research progress be

completed at an early stage, and collection of the required data should be an element of all research projects.

Other projects, both in the United States and abroad, can also be expected to result in information of interest to the GTP. To the extent possible, the GTP should use its funding to leverage these efforts in support of EGS research and in support of the U.S. geothermal industry.

In addition to collecting data from new GTP projects, there are a number of opportunities for supplementary data collection and analyses. These activities could potentially be an element of the Center for Technology Transfer (see below), depending on the GTP's interpretation of the FISA law. These include:

1. Case studies of hydrothermal and EGS projects (both past and current), building on existing materials. Case studies enable identification of both best practices and common mistakes.

2. Support for ongoing data collection efforts (such as those at UNR, EGI, and SMU) and maintenance and expansion of archives as new data is generated by industry.

3. Creating databases of critical metrics and project information for industry and foreign projects. In some cases, this will overlap with the case studies.

4. Collecting information on new geothermal plants to support cost analyses and market projections.

2. Information for Geothermal Industry Use

a. Center for Technology Transfer

The core rationale for the creation of the Center is in collection and dissemination of information that will support the development of the geothermal industry. The scope of this effort potentially covers a wide variety of types of data, from information on best practices in project development to data on site geology, cost of power for specific sites and systems, plant emissions, royalty payments, capital and operational costs for equipment, and other data relevant to geothermal research, exploration, and development.

The language of EISA is not precise, and is subject to multiple interpretations: Although the title is "Center for Technology Transfer", the Center's duties will clearly go beyond technology transfer in including dissemination of information on best practices in "all areas relating to developing and utilizing geothermal resources", and making data (of an unspecified nature) available. This could potentially be interpreted to cover generating technologies only; generation and direct use; or generation, direct use, and geothermal heat pumps. Thus DOE has some latitude, though limited, to interpret the language to meet its own needs based on strategic programmatic considerations and budget constraints. If funding is constrained, DOE may choose to limit the scope of the Center through a narrow interpretation of the legislation. Long-standing relationships with organizations that have previously filled similar roles should also be taken into consideration. Any interpretation must fulfill the intent of Congress, which appears to be the collection and dissemination of data that will support the development of the

geothermal industry and promote coordination and cooperation among developers of geothermal technologies.

The terms and phrases “best practices,” “all areas relating to developing and utilizing geothermal resources,” and “partners” are especially open to interpretation. Generally, the term “best practice” means a standard (consistent) or superior way of doing things that can be used widely across organizations. In the legislation, the term could be interpreted narrowly as the most efficient and effective way to accomplish something. Under such a narrow interpretation, raw data, such as geophysical data, would not fit within the interpretation even though the data might be beneficial to the geothermal industry. However, the term could be broadly interpreted to mean both raw data and other information. Also, it is not always clear as to what works “best” in different circumstances or when more than one alternative is available. In such cases, it is valuable to know what does and does not work and the circumstances inherent in those cases. There is as much to be learned from failures as from successes. Case studies could be an element of the Center’s activities.

Depending on the reading of the language, the Center’s data requirements could be very broad, or relatively limited. Along with the technical areas that are subjects of research by the GTP (exploration, wellfield construction, reservoir enhancement, and generation), there are other activities that are normally taken in the course of project development (such as land leasing, permitting, outreach and communication, etc.) that are common to the development of power plants in general, and the policy environment is also critical for “developing and utilizing” geothermal energy. This information is not data in the technical sense, but it could be interpreted as being covered by the language of the law (“all areas relating to developing and utilizing geothermal resources”).

Some information of value to the GTP will also be useful to the geothermal industry, but while industry’s data requirements overlap with those of the Program, there are areas of interest to industry that may not be of immediate value to the GTP (some kinds of exploration data, for example, are not of use for EGS research, but are valuable for firms seeking hydrothermal resources to exploit). As a first step in meeting the industry’s needs, as required by EISA 2007, it is recommended that the GTP meet with or otherwise poll industry representatives to determine what data and analyses would be most valuable to them (including existing data sets).

The GTP should also inventory past activities and relevant organizations (e.g. Geo-Heat Center, Geothermal Education Office, GRC, etc.) and determine which of these, if any, should be incorporated in the Center.

Even if the interpretation selected is the broadest possible, the data collected by the Center is unlikely to serve all of the requirements of the GTP, which needs data for a wide variety of purposes not directly related to geothermal resource development or technology transfer. For example, the GTP needs data to assess the success of its research activities, to track trends in industry development, and to plan and set priorities for future R&D. Because of this, the Technology Transfer Center should be only one element of a comprehensive strategy for collection and management of data.

b. Other Industry Support

In the past, the GTP has supported the industry by developing State Working Groups and other outreach and communications fora to involve regulators, utilities, and other stakeholders. Working with state and other entities to develop and disseminate information provides both benefits and limitations that the Center for Technology Transfer cannot. In particular, it may be possible to leverage state funds for industry support, particularly in evaluation of geothermal resources and coordination of state regulatory requirements (including environmental assessments and reporting requirements). In these cases, the GTP would be able to use the information developed by states to support analyses of geothermal potential.

Summary

- Some results of past GTP research are relevant for industry and for the current R&D program, but the raw data is at risk of being discarded. The remaining data should be assessed for its importance, and digitized and preserved where necessary.

- While the most meaningful analyses and results from previous research have been collected, they are not organized in a manner that allows ready identification of relevant documents for people unfamiliar with the GTP's past history. Summary documents, indices, or other methods of categorization should be developed to enable researchers to quickly identify relevant materials.

- A significant amount of information is available from sources not directly associated with the GTP. This information is partly identified here, and includes data on geothermal projects (such as that from the Soultz project) and other material relevant to metrics such as cost of power (e.g. data on geology, transmission, population density, etc.) This information should be collected and made accessible for use by geothermal researchers.

- GTP data collection and dissemination should be coordinated with other such efforts (such as that being undertaken by the IEA) to simplify comparisons and cross-cutting analyses through development of common protocols and data reporting standards. Data collection, analysis, and dissemination activities should be planned and structured in advance of field work to ensure that data collection is integrated with field work, that the right data is collected, and that the usage of the data is optimized.

- The Center for Technology Transfer should be one element of an integrated strategy for managing program and industry data. The GTP should inventory past activities and relevant organizations (e.g. Geo-Heat Center, Geothermal Education Office, GRC, etc.) and determine which of these, if any, should be incorporated in the Center.

- The geothermal industry should be consulted, both to enable and harmonize the collection of market-related data and to identify information that the industry would want to have provided by the Program.