5.0 Program Analysis

Figure 5.1. Geothermal Technologies Program policy and planning documents

The Geothermal Technologies Program intends to conduct a broad spectrum of analyses–resource and infrastructure assessment, technical and economic feasibility analysis, deployment analysis, environmental analysis, risk assessment, and benefits analysis–to support decision-making, demonstrate progress toward goals, and direct research activities. Programmatic analysis, or strategic analysis, helps frame the overall program goals and priorities and covers issues that impact all aspects of the program. Maintaining these capabilities at the cutting edge is essential to ensuring that the analysis provides the most efficient and complete answers to technology developers and the Program Management. The analytical methodologies and tools planned for use by GTP are outlined below.

5.1 Program Analysis Technical Goal

Goal: The Program Analysis technical goal is to provide program-level analysis products to support geothermal technology development and technology readiness by evaluating technologies and pathways, guiding the selection of RD&D projects, and estimating the potential value of RD&D efforts. Analysis activities provide GTP with information and context for decision-making at all levels. These activities include benefits' analysis, based on modeling projections from the Office of Energy Efficiency and Renewable Energy (EERE) versions of the National Energy Modeling System (NEMS) and the Market Allocation Model (MARKAL), that estimate the program's contribution to the achievement of DOE and EERE economic, environmental, and energy security goals, and technical analysis (techno-economic and engineering systems analysis) that informs R&D activities on a daily basis. Overall, analysis quantifies goals, targets, and potential impacts of program activities, and informs the development of alternative pathways for program R&D.

Analysis plays three main roles in the GTP decision-making process:

- Defines and validates performance targets for geothermal technologies and systems;
- Guides program planning functions, R&D project selection, and assessment of progress;
- Provides engineering knowledge for enhanced geothermal systems development.

5.2 Program Analysis Barriers to Commercialization

The following discussion details the technical and programmatic barriers that must be overcome in order to attain the Program analysis goal and objectives set forth by GTP.

Barrier S: **Stove-Piped/Siloed Analytical Capability** – Lack of coordination and integration of program elements.

Analytical capabilities and resources have been largely segmented functionally by the Program element (drilling, energy conversion, etc.), as well as by performers/analysts (laboratories, specialized teams, industry/academia, etc.). Successful Program analysis requires the coordination and integration of those capabilities and resources across all facets of the analytical domain.

Barrier T: **Market Behavior** – Lack of understanding of how geothermal electricity generation interacts with the behavior and drivers of the electricity markets to determine the long-term applications of EGS.

Understanding the behavior and drivers of the electricity markets is necessary to predict long-term EGS applications. Developing new or refining existing market penetration models will allow analyses of various geothermal deployment scenarios, and enable the GTP to understand emerging issues.

Barrier U: **Policy** – Lack of understanding of applicable current policies and impacts. Geothermal technologies are not on a level playing field with respect to competing technologies at all jurisdictional levels.

A firm understanding of the Federal, state and local policy interaction and impact on geothermal electricity development is necessary to provide input to Program planning. Additionally, results of the analyses will inform policy-makers on the incentives that create greatest value added, leading to development of geothermal electricity and market transformation.

Barrier V: **Infrastructure** – Infrastructure barriers are not clearly understood for EGS development.

Many infrastructure questions arise in addressing commercialization, including water supply, water rights, transmission, permitting, waste water issues/regulations. These and other infrastructure issues must be fully understood for market transformation, policy analyses, and creation of models and tools.

Barrier W: **Benefits** – The environmental, economic, and security benefits of the Enhanced Hydrothermal Systems and EGS are not fully understood or articulated.

Often, the drivers for state and local decision-making are the environmental, economic and energy security benefits of energy technologies. The Benefits section of this plan discusses our understanding of the benefits of geothermal technologies, but as Enhanced Hydrothermal Systems and EGS technologies are developed, created and monitored, these analyses will have to be updated to guide decision-making.

Barrier X: **Data, Assumptions and Guidelines** – Inconsistent and largely uncontrolled datasets are used by individual analysts and organizations, which make their own value decisions in performing analyses.

Analysis results are strongly influenced by the data sets employed, as well as the assumptions and guidelines established to frame the analytical tasks. These elements have been largely uncontrolled in the past, with individual analysts and organizations making independent value decisions. Although this does not necessarily render the results incorrect, it does make it more difficult to place the results and ensuing recommendations in context with other analyses and the overall objectives of the GTP. Establishing a Program-endorsed consistent set of data, assumptions, and guidelines is necessary for program success.

Barrier Y: **Suite of Models and Tools** – Existing models have limitations and cannot sufficiently address all of the GTP analytical needs and requirements.

The limited number of models and tools available to the Program for analysis cannot sufficiently address all of the GTP analytical needs and requirements; current models and tools must be refined and new ones developed.

5.3 Program Analysis Technical Objectives

Achievement of the objectives for Program analyses help to overcome each of the above-listed barriers. These objectives were developed based on an understanding of the gaps in geothermal technology analyses relative to other renewable energy technologies, as well as perceived future analysis needs that will be required as renewable energies applications become more widespread.

Table 5.1. Program Analysis Technical Objectives

Number	Description	Barrier
1	On an ongoing basis, coordinate and integrate geothermal capabilities and resources across the analytical domain.	S
2	On an annual basis, develop new or refine existing market penetration models to allow analyses of various geothermal deployment scenarios, and enable the GTP to understand emerging issues.	T

Table 5.1. Program Analysis Technical Objectives (Continued)		
Number	Description	Barrier
3	By 2009, analyze the current Federal, state and local policies that could affect the commercialization of geothermal throughout the policy development.	U
4	By 2009, design model policies that maximize impact on geothermal benefits (e.g. economic, environmental and energy diversity) and inform policy makers through the models.	U
5	By 2011, develop decision tree tool for geothermal policy implementation.	U
6	By 2015, develop a road map for best practice policy development throughout the market transformation (R&D for technology development, market preparation, and commercialization).	U
7	On an ongoing basis, understand policy impact on geothermal development at multiple jurisdictional levels as policies evolve and develop and the market for geothermal changes.	U
8	By 2010, identify Federal, state and local laws and regulations that have the potential to apply to EGS development.	V
9	By 2011, set objectives for addressing and overcoming the infrastructure hurdles.	V
10	By 2012, complete life-cycle environmental studies that are necessary to better understand and mitigate the environmental consequences and impacts of geothermal technologies..	V
11	On an ongoing basis, estimate GHG-emission impacts of various types of EGS technologies.	W
12	On an ongoing basis, incorporate GHG-emission analysis results into cross-cutting carbon models for benefits analyses (MiniCAM, MERGE, GREET, and MIT's climate model).	W
13	On an ongoing basis, understand how geothermal energy generation will benefit national energy security in the changing energy market.	W
14	On an ongoing basis, understand the economic benefits of geothermal energy generation as the technology progresses, as construction and knowledge resources evolve with the technology, and as demonstration projects move into commercialization.	W
15	By 2010, establish a Program-endorsed consistent set of data, assumptions, and guidelines necessary for program success.	X

Table 5.1. Program Analysis Technical Objectives (Continued)		
Number	Description	Barrier
16	On an ongoing basis, update the data set with program and industry data as it is obtained and/or gathered.	X
17	By 2010, refine current models to meet the analytical needs and requirements of the GTP.	Y
18	On an ongoing basis, update the model assumptions and calculations with program and industry data as it is obtained and/or gathered.	Y
19	By 2010, develop a technology characterization report, outlining the current state of the technology for each of the program elements (drilling, energy conversion, etc.), both implemented and unimplemented.	S,V,W,X
20	By 2015, develop a technology readiness report, outlining the latest technologies, improvements and demonstrations of Enhanced Hydrothermal Systems and EGS technology.	S,V,W,X
21	By 2015, analyze the ultimate potential for EGS. The analysis will address necessary resources, transmission, reservoir sustainability, water needs, and interactions between an EGS economic sector and other sectors.	A,V
22	By 2015, conduct deployment analyses exploring how rapidly EGS might be deployed to make a significant contribution to the country's electrical energy need.	T,U,V,X,Y
23	By 2011, incorporate risk analyses into refined geothermal technology models.	Y,S

5.4 Program Analysis Technical Approach

The overall approach to implementing a robust Program analysis capability is based on the need to support Program decision-making processes and milestones, provide independent analysis when required to validate decisions and/or ensure objective inputs, and to respond to external review recommendations. Program Analysis will generate outputs necessary to support programmatic needs, which include recommendations, reports, input to plans, validated results, and supporting data. As depicted in Figure 5.2, the outputs are supported by analysis of EGS development scenarios, environmental analyses, and technical analyses. The analyses are dependent upon tools that the program is developing and/or modifying. Both the analyses and tools are dependent upon the framework that has been developed and will be continuously updated. To ensure that the analysis effort is focused, objective and effective, internal and external peer reviews will be conducted. The peer review process is further described in Section 8.2.4 Program Evaluation.

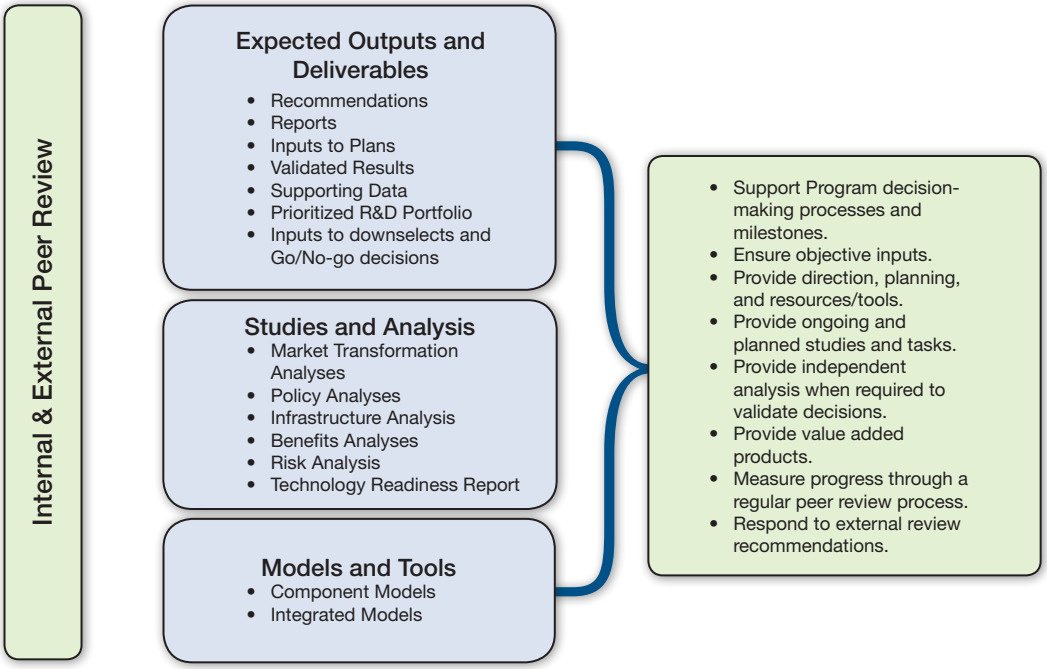

Figure 5.2. Systems analysis approach overview

5.4.1 Studies and Analysis

The analysis work planned for the next five to 10 years builds on past efforts to understand the economic factors and key uncertainties related to geothermal technologies and systems. Continued public-private partnerships with the geothermal scientific community and multi-lab coordination efforts will help ensure that the analysis results from the program are transparent, transferable, and comparable. Studies will include:

Market Analysis: *(Barrier T)* Market Analysis helps the program to understand the behavior and drivers of the electricity markets that determines the commercialization potential for geothermal applications. Analysis of the market drivers as renewable energy technologies and policies become more widespread will be. Developing new and refining existing market penetration models will allow analyses of various geothermal deployment scenarios, and enable the GTP to understand emerging issues.

Policy Analysis: *(Barrier U)* Policies are one way that markets can be altered to promote renewable energy implementation. A firm understanding of the Federal, state and local policy interaction and impact on geothermal electricity development is necessary to provide input to program planning. Results of the analyses will inform policy-makers of the incentives that add the greatest value and lead to development of geothermal electricity and market transformation.

Infrastructure/Environmental Analyses: *(Barrier V)* The Program will use analysis to quantify the many infrastructure questions that arise, including water supply, water rights, transmission, permitting and wastewater. These and other infrastructure issues must be fully understood for market transformation, policy analyses, and creating models and tools. The environmental impacts of geothermal production technologies will also be assessed. Specifically, life-cycle

assessment (LCA) will be used to identify and evaluate the emissions, resource consumption, and energy use in all steps of the process of interest. Also known as cradle-to-grave or well-to-wheels analysis, this methodology helps users understand the full impacts of existing and developing technologies, so that efforts can be focused on mitigating negative effects. Analyses related to EISA reporting requirements will also be conducted.

Benefits Analysis: *(Barrier W)* Benefits analysis helps the Program quantify and communicate the overarching outcomes from within the Program, such as greenhouse gas mitigation and displacement of conventional fossil fuel generation, using integrating models such as NEMS and MARKAL. The scenarios that are developed and the costs and benefits that are quantified are used to develop a broad understanding of the most viable routes for achieving geothermal utilization. Results are useful in crosscutting benefits analysis and are one of the key inputs to decision-making across all renewable technologies in the EERE portfolio. Using the program-provided outputs and assumptions, the Office of Planning, Budget, and Analysis (PBA) works with the Program to prepare the technical assumptions needed to run the NEMS and MARKAL models. These models estimate the economic, energy, and environmental outcomes that would occur over the next 20 to 50 years if the Program is successful and the future unfolds according to the business-as-usual scenario. PBA also coordinates the assessment of Government Performance and Results Act (GPRA) benefits, which estimate some of the economic, environmental and security benefits or outcomes from achieving Program goals.

Supplemental analysis tasks that will be conducted to support the above analyses include:

National Geothermal Database: *(Barrier X)* A technical data management system will be developed to provide a consistent database and a list of assumptions, information standards, and tools for analytical activities supporting GTP. This geothermal data center will provide data for standardized input to systems analysis, for the establishment of the base case geothermal system, and for development of the subsequent trade-off analyses. This technical data management system will ensure consistency in analyses conducted by the Program. The database will be updated annually and made available to the community through the Web. For additional information, program data needs are described in Section 4.2.

Models and Tools: *(Barrier Y)* Modeling tools provide the basis for analyzing alternatives at the system, technology or component level in terms of their cost, performance, deployment potential, and impacts. While specific tools are used to analyze system components (e.g., elements of the energy conversion system) and discipline-specific concerns (e.g., drilling, geochemistry), there are two types of models currently in use to provide an integrated framework for analysis:

- A techno-economic systems analysis modeling tool for evaluating and comparing the cost of geothermal project cases, addressing all elements of a project, from exploration to power generation. The Geothermal Electric Technology Evaluation Model (GETEM) is the tool currently used.
- Integrated energy/economic models that project the deployment and associated impacts of electricity generation technologies, including geothermal, based on cost and performance characterizations of specific technologies and economic, market, and policy assumptions (e.g., GDP growth, future fuel prices). There are several models in use, each of which provides a unique perspective, including: NEMS, MARKAL, the Regional Energy Deployment Systems Model (ReEDS), and the Stochastic Energy Deployment System (SEDS).

In addition to the analyses relating to a particular barrier listed above, further cross-cutting analyses will address multiple barriers. Planned cross-cutting studies and analysis are separated into the following categories:

Resource and Infrastructure Assessment: *(Barriers A, V)* Resource assessment determines the quantity and location of geothermal resources at regional, state and county levels. A variety of integrated modeling tools and databases will be used for estimating geothermal resources. Geographic Information Systems (GIS) modeling tools can be used to portray and analyze resource data.

Technical and Economic Feasibility Analysis: *(Barriers S,V,W,X)* Feasibility analysis determines the potential viability of a process or technology and helps to identify the most significant opportunities for cost reduction. Results from the feasibility analysis provide input to decisions regarding portfolio development and technology validation plans. The economic competitiveness of a technology is assessed by evaluating its implementation costs for a given process compared with the costs of either current technology or other future options. These analyses are useful in determining which projects have the highest potential for near-, mid- and long-term success. Parameters studied include production volume benefits, economies of scale, process configuration, materials, and resource requirements. Tools used for technology feasibility analysis include unit operation design flow and information models, process design and modeling, capital costs and operating cost determination, discounted cash flow analysis, and Monte Carlo sensitivity analysis/risk assessment (e.g., Crystal Ball software).

Deployment Analysis: *(Barriers T,U,V,X,Y)* Analyses exploring how rapidly enhanced geothermal systems might be deployed to make a significant contribution to the country's electrical energy must be initiated.

Modeling EGS development will accomplish the following:

- Identify and evaluate paths by which geothermal energy can make a large contribution to meeting future demand for electricity. This will help answer questions such as:
  - Which technologies are most likely to be a part of an enhanced geothermal system?
  - What are the interactions between these technologies and other established technologies?
  - What market penetration pathways are likely?
- Determine what can be done to accelerate geothermal energy use and once deployed, when associated benefits can be realized, by understanding:
  - What external economic factors are most important?
  - What are the most likely bottlenecks or limiting factors?
  - What are the effects of government policy?

Risk Assessment: *(Barriers Y, S)* The identification, quantification, and evaluation of risk and uncertainty are used to focus RD&D activities and resources where they are most critical. Clearly identifying critical-path technologies and addressing and mitigating issues that could derail technological progress are all crucial to ensuring the success of program activities and to encouraging greater private sector investment by increasing confidence in the likelihood

of technical and commercial success. Risk analysis will be conducted across the program activities along with benefits analysis. The major objective of risk assessment is to evaluate planned and ongoing technology development activities in the context of industry deployment requirements to maintain focus toward meeting the Program goals. This assessment will include all R&D efforts that DOE has sponsored. Activities making good progress toward the goals will be identified, as well as those that are making little progress or are not contributing. The gaps remaining in technology development will be identified. Finally, commercialization pathways will be identified by estimate of effort (financial and time). The risk analysis will also focus on understanding how program activities could impact specific technology performance measures in terms of the range of potential improvement, and how these impacts compare to ultimate cost and performance targets. The risk assessment tools must be credible for industry, researchers, and managers to realize these opportunities.

The GTP follows the risk analysis principles released by the Office of Management and Budget (OMB), which aids the Program in risk assessment and priority setting. The DOE EERE has issued further guidance through documents such as Risk Analysis for Energy R&D Programs, A Practice Best-Practice Guide for R&D Managers and Staff.[26]

5.4.2 Unplanned Studies and Analysis

Many analysis questions require rapid responses, particularly when they are driven by external requests or needs from DOE senior management, Congress, OMB, etc. A flexible capability to perform additional, quick-response analyses and provide those results is necessary.

5.4.3 Systems Analysis Plan

A detailed Systems Analysis Plan (SAP) may be developed if the extent and complexity of analysis efforts warrant the effort to create the plan. The goal of the SAP would be to lay out the overall approach, tasks and processes for the systems analysis efforts of the Program. It would define how specific analysis activities relate to the objectives of the overall program. The SAP would contain a catalog of resources, systems analysis processes, and analysis results.

26 Risk Analysis for Energy R&D Programs, A Practice Best-Practice Guide for R&D Managers and Staff

5.5 Program Analysis Programmatic Status

Current activities in Program Analysis are listed in Table 5.2.

Table 5.2. Program Analysis Activities

Analysis Type	Description	Organization
National Resource Assessment	Physical Geothermal Resources Evaluation-data collection and evaluation (depth, cost of energy over various regions)	National Renewable Energy Laboratory
Technology + Characterization	Survey of current state of systems and components. Perform technology assessments in each of the major technological areas of drilling, reservoir creation and characterization, and energy conversion. Update of 1997 Renewable Energy Technology Characterizations (EPRI)	National Renewable Energy Laboratory
Technical and Economic Feasibility Analysis	Energy conversion Technology Evaluation GETEM Updates and Revisions	National Renewable Energy Laboratory
Deployment Analysis	Geothermal Modeling in Energy Markets (NEMS, MARKAL, SEDS, ReEDS) Geothermal Market, Policy, and Technology Analysis Integrated Energy Modeling for Budget Support (NEMS and MARKAL)	National Renewable Energy Laboratory
Risk Assessment	Program Risk Analysis (@Risk-GETEM model)	National Renewable Energy Laboratory
Environmental Analysis	Geothermal air emissions (CO2, NOx, SO2) Impact Analysis (NEMS, MARKAL and ReEDS) Water use, Water quality, Land use	National Renewable Energy Laboratory
Benefits Analysis	Greenhouse gas mitigation and displacement of conventional fossil fuel generation, Mitigation of foreign oil dependency, and other activities TBD	National Renewable Energy Laboratory
Provide Support Functions and Conduct Reviews	Maintain and Update the Geothermal Data Center	TBD, per solicitation award

5.6 Program Analysis Tasks

The following program analysis tasks were identified to support the above-named objectives.

Table 5.3 Program Analysis Tasks		
Number	Description	Barrier
1	Set first meeting of all analysts to discuss this document and future plans.	S
2	Identify joint projects that leverage different groups' capabilities.	S
3	Incorporate algorithms that distinguish between hydrothermal systems (Hydrothermal Systems), enhanced hydrothermal systems (Enhanced Hydrothermal Systems), and enhanced geothermal systems (EGS) in the market into new and existing models .	T
4	Identify and evaluate early market transformation scenarios consistent with infrastructure needs and EGS resources.	T
5	Identify the range of policy options that could affect the commercialization potential of geothermal technologies.	U
6	Evaluate the targets (e.g., consumer, geothermal industry, utilities, and state governments) of such policies and determine possible impacts on market transformation.	U
7	Understand how different policies (mandates and incentives) drive all parts of the market in various stages of EGS development.	U
8	Identify innovative policies that can lead to the technology and market development of EGS.	U
9	Develop Programmatic Environmental Impact Statement (PEIS) in support of commercial development.	V
10	Quantify exploration, construction, and operation land-use needs and impacts.	V
11	Quantify initial and ongoing water requirements.	V
12	Develop detailed understanding of fluid chemistry impacts on environment - both for flash systems and closed-loop systems.	V
13	Analyze GHG emissions.	W
14	Analyze environmental impacts of inclusion of carbon sequestration into EGS.	W
15	Develop guidelines and standards for data quality and validation.	X

Table 5.3 Program Analysis Tasks		
Number	Description	Barrier
16	Develop consistent and transparent economic assumptions for cost analyses.	X
17	Develop data input guidelines (i.e. units, resolution, completeness, etc.).	X
18	Design a database framework for ease of incorporation and display of all data types.	X
19	Manage and oversee development of database by lab or contractor.	X
20	Establish a robust, consistent, and transparent techno-economic EGS model (expand on GETEM).	Y
21	Identify needed modeling frameworks based on questions that current models are not addressing.	Y
22	Initiate EGS model validation with systems demonstration project data and benchmark to international EGS demonstration projects.	Y
23	Integrate analyses on externalities (e.g., water use, land use, CO2) into EGS modeling and evaluation tools.	Y
24	Continue ongoing EGS model validation with systems demonstration project data.	Y