Low-Temperature, Coproduced, and Geopressured Geothermal Technologies

Strategic Action Plan

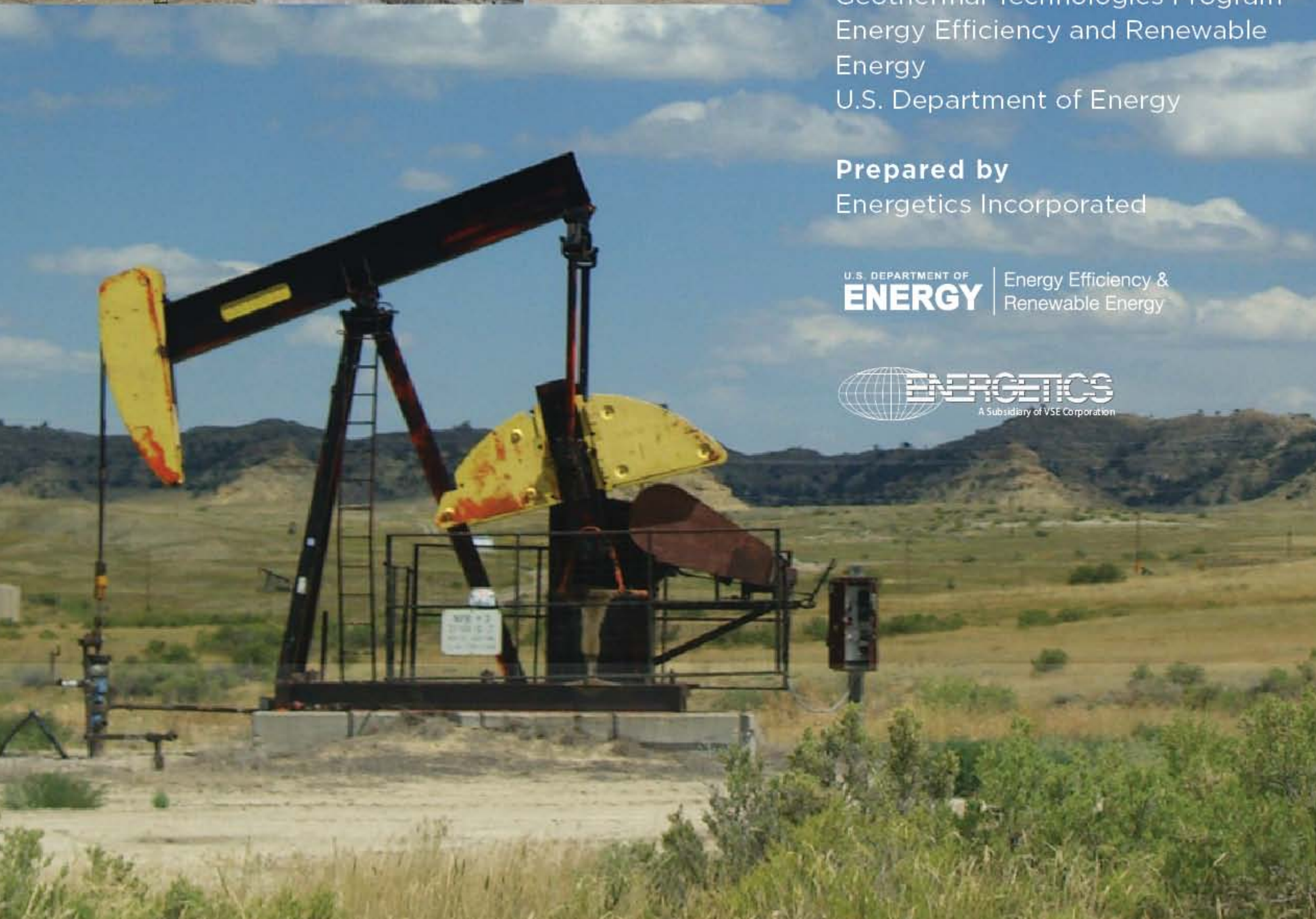


September 2010

DOE/EE-0392

Sponsored by
Geothermal Technologies Program
Energy Efficiency and Renewable Energy
U.S. Department of Energy

Prepared by
Energetics Incorporated



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ACKNOWLEDGMENTS

This report was sponsored by the Department of Energy Geothermal Technologies Program and prepared by Energetics Incorporated.

Executive Summary

The *Low Temperature, Coproduced, and Geopressured Geothermal Technology Strategic Action Plan* presents an agenda for the Low Temperature and Coproduced Subprogram to efficiently and effectively leverage its resources in support of the geothermal community's goals and priorities. This action plan is based upon the input of experts in the geothermal industry. Specifically, implementing the action plan will help provide the geothermal community with the means to develop and widely deploy economically viable, innovative, and scalable technologies. By 2020, the United States could ultimately achieve the vision of 3 gigawatts equivalent (GW_{eq}) of installed low temperature, coproduced, and geopressured geothermal capacity.

Vision and Goal

The geothermal community envisions widespread deployment of economically viable, innovative, and scalable technologies—including those involving coproducts where geothermal brine is produced in conjunction with hydrocarbons—that will capture a significant portion of the low temperature geothermal resource base over the next two decades. The Subprogram has translated this vision of the future into a concrete and measurable goal of 3 GW_{eq} of installed low-temperature geothermal capacity by 2020, including direct use applications.

Key Characteristics of the 3 Gigawatt Equivalent Future

To translate the vision into more concrete terms, the action plan identifies key characteristics of the envisioned future to direct Geothermal Technologies Program activities. In particular, the document identifies the following general characteristics of strategic targets.

- ***Risk Mitigation*** through improved characterization of potential geothermal resources and increased availability of risk mitigation strategies, such as cost-sharing mechanisms
- ***Industry Engagement and Partnerships*** to include the oil and gas industry, renewable industries, and other industrial, residential, and commercial communities that can take advantage of widespread point-of-use generation
- ***Informing Policy and Improving Permitting Processes*** to include streamlined permitting processes, clear legal frameworks for property rights, greater financial incentives, and more supportive and efficient government operations that ease the financial burdens of deploying new, higher-risk Low Temperature, Coproduced, Geopressured (LTCG) technologies
- ***Demonstration and Validation of Critical Advanced Technologies*** that meet the advanced criteria needed to reduce costs and risk
- ***An Educated and Engaged Public*** to include citizens, investors, and lawmakers who are equipped with accurate data and knowledge to understand and support LTCG production and use
- ***Fully Integrated Systems*** that enable LTCG technologies to be deployed on a large scale and integrated into the existing energy infrastructure, for example, through connections to the grid and other industry processes

HIGH-PRIORITY ACTIONS

The strategic action plan describes specific activities that have been identified as high-priority actions that would best enable the geothermal community to achieve characteristics of the 3 GW_{eq} future. To help the Low Temperature and Coproduced Subprogram allocate resources effectively, this document organizes the activities into their corresponding Subprogram activity areas: Advancing Technologies, Fostering Deployment, and Informing Policy. These activity areas were the result of stakeholder input to the roadmapping process.

ACTIVITY MAPS

For the 18 high-priority action items identified by stakeholders, this document provides activity maps, or implementation plans, that outline key tasks, barriers, partnerships, milestones, and outcomes. These maps are intended to guide the Subprogram efforts to achieve each of the high priorities. Seven activities were identified for Advancing Technology, seven for Fostering Deployment, and four for Informing Policy.

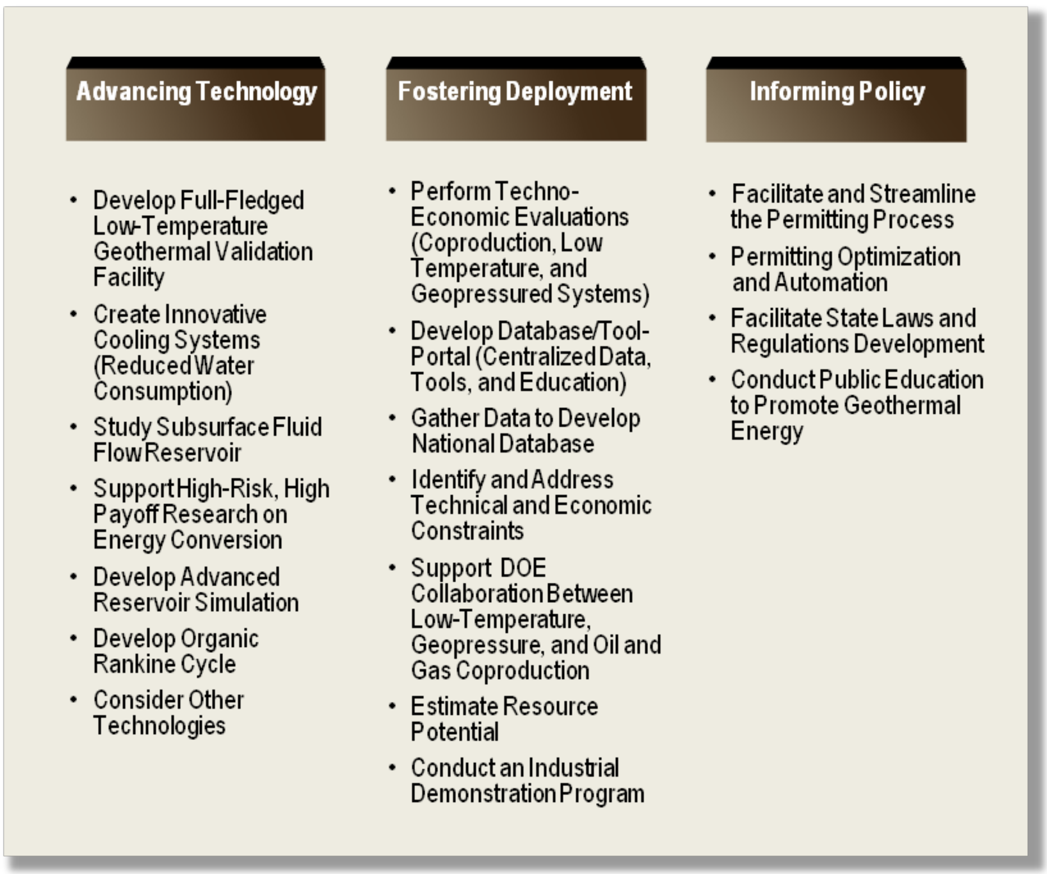


Figure I: List of High-Priority Activities by Low Temperature and Coproduced Subprogram Area

RESOURCE ALLOCATION FOR LTCG SUBPROGRAM ACTIVITY AREAS

The action plan also documents the expected relative impact of effective action in the three areas and assigns the percentage of time and resources that should be devoted to each area. Informing Policy was given the smallest allocation (23%), while Advancing Technology and Fostering Deployment each received a nearly equal allocation of the remaining 77%. This allocation is consistent with the breakdown of high-priority action items; both indicate the workshop participants' general consensus that Advancing Technology and Fostering Deployment have greater potential to facilitate the realization of the 3 GW_{eq} future than Informing Policy.

The same analysis was done for each activity area broken down by technology area (low temperature, coproduction, and geopressured). The results for Informing Policy remained the same across the three technologies, with the smallest, yet still significant, allocation. More variation can be seen in the comparison of Advancing Technology and Fostering Deployment.

For coproduction, significantly more emphasis was placed by workshop participants on Fostering Deployment. This likely reflects the fact that coproduction technology is more developed, so relatively greater focus should be placed on deploying existing technology. Conversely, for low temperature, which is less economically viable than coproduced, the workshop determined more focus should be placed on advancing newer technology.

PATH FORWARD

As the Subprogram completes the high-priority actions, it will need to evaluate and measure its own effectiveness in implementing the activities as well as their impact on industry, i.e., whether and how much the activities are contributing toward achievement of the 3 GW_{eq} vision and associated key characteristics. Four distinct metric areas were identified as the best means to measure the Subprogram's performance (and related industry performance) and allow for objective comparison between low-temperature geothermal energy and other technologies: levelized cost of energy (LCOE); number of projects started or completed; installed capacity; and capacity factor.

It is important to note that as performance is measured and evaluated, action items may be revised and resources reallocated. Evolving industry trends may cause Subprogram priorities to shift, resulting in new priorities and activities. Information from performance evaluations and changes in the industry landscape are likely to feed back into specific activity plans and the overall strategic action plan.

CONTENTS

I. INTRODUCTION

The United States faces serious challenges regarding how energy resources are to be protected and managed. Energy is the vital force powering business, manufacturing, and the transportation of goods and services to serve the domestic and international economies. Beyond an economic concern, energy is an issue with multiple dimensions; for instance, dependence on foreign energy resources poses a challenge to national security, and greenhouse gas (GHG) emissions resulting from the use of fossil fuels threaten the natural environment. As population growth and industrial expansion drive increasing demand, these combined economic, security, and environmental challenges will further intensify.

Ensuring the future of the U.S. energy supply will require the rapid development and deployment of more energy efficient and renewable energy technologies, particularly technologies that enable us to harness clean, sustainable, and abundant domestic resources. Low temperature geothermal power is an important energy resource that meets these requirements, but one that requires multidisciplinary scientific and technical expertise as well as long-term investments.

The U.S. Department of Energy (DOE) Geothermal Program's Low Temperature and Coproduced Subprogram aims to provide the geothermal community with the means to achieve development and widespread deployment of economically viable, innovative, and scalable technologies. These technologies will capture a significant portion of the low temperature geothermal resource base—all geothermal resources less than 150°C, as well as those that are coproduced with hydrocarbons to include geopressured systems over the next two decades.

PURPOSE AND CONTENT

This document presents a strategic action plan for the Subprogram to implement in its efforts to spur industry growth in Low Temperature, Coproduced, Geopressured (LTCG) technology development and deployment. The plan is meant to help the Subprogram prioritize and allocate its resources and guide the implementation of the high-priority action items in its three activity areas: Advancing Technology, Fostering Deployment, and Informing Policy.

STRUCTURE

The document is organized as follows:

- **Chapter II** presents background on the Subprogram.
- **Chapter III** presents the strategic framework from which the action agenda has evolved.
- **Chapter IV** discusses the key characteristics (enablers) of the future that are essential for achieving the vision: 3 GW_{eq} by 2020.
- **Chapter V** presents the high-priority action items in Advancing Technology.
- **Chapter VI** presents the high-priority action items in Technology Deployment.
- **Chapter VII** presents the high-priority action items in Influencing Policy.
- **Chapter VIII** discusses approaches to measuring progress towards goals and next steps.

II. Low-Temperature Geothermal Subprogram

Geothermal Technologies Program

DOE's Energy Efficiency and Renewable Energy (EERE) Geothermal Technologies Program (GTP) leads in supporting development of innovative technologies to find, access, and harness the nation's geothermal resources as usable energy. Through its research, development, and demonstration efforts, GTP is working to provide the United States with an abundant, clean, and renewable baseload energy source. Widespread but underutilized low-temperature geothermal resources, such as heated water produced by oil and gas (O&G) operations, present a near-term opportunity to rapidly scale up geothermal power generation. For example, heated water produced as a result of O&G operations (averaging ten barrels of water per barrel of oil) is currently treated as waste. However, low-temperature coproduction from O&G wells in just a few states is estimated to have a potential generation capacity of 12 GW_{eq} (Tester, et. al., 2006).

Low-Temperature and Coproduced Subprogram

To explore the potential of low temperature geothermal, GTP established the Subprogram in April 2009. Previously GTP had very limited funds and staffing dedicated to pursuing low temperature geothermal potential and was prohibited from conducting research outside of enhanced geothermal system (EGS) technologies. In less than one year, with authorizations from the American Recovery and Reinvestment Act (ARRA) and Energy Independence and Security Act (EISA) providing the blueprint, GTP dedicated itself to a much broader portfolio, with low-temperature resources and technologies among the new areas of focus.

The Subprogram benefits from program-wide component research and development to drive down capital and operating costs through improved efficiencies in working fluids, cooling systems, heat exchangers, and other system components. Additional capital, operations and maintenance (O&M), and waste disposal costs will be driven down by knowledge gained and technical advances made in both the demonstration projects and applied research and development (R&D) science.

III. Strategic Framework

An enhanced vision of low temperature geothermal's role in the U.S. energy portfolio in 2020 provides the framework for the development of this action plan. Six characteristics (or strategic targets) were identified as critical components of the vision, as well as 18 high-priority activities for the Low Temperature and Coproduced Subprogram to pursue.

Vision and Goal

The geothermal community envisions widespread deployment of economically viable, innovative, and scalable technologies—including those involving coproducts—that will capture a significant portion of the low-temperature geothermal resource base over the next two decades. The Subprogram has translated this vision of the future into a concrete and measurable goal of 3 GW_{eq} of installed low-temperature geothermal capacity by 2020, including direct use applications.

Key Characteristics of the 3-Gigwatts-Equivalent Future

Geothermal energy has a bright future as a renewable, low-emission energy source to provide stable, cost-competitive, baseload-capable power that is valued by the public and well-integrated with other resources and infrastructure. Large-scale deployment of LTCG technologies uses a mix of existing and new infrastructure ranging from distributed geothermal to power plants producing megawatts (MW) of electricity. The wide range of uses includes direct use activities such as district heating, internal use at oil and gas fields for onsite power production, and ultimately grid power. The following describes the key characteristics of a future with a 3 GW_{eq} geothermal installed capacity.

- ***Risk Mitigation* —**In a 3 GW_{eq} future, potential geothermal resources are better characterized; and risk mitigation strategies, including cost-sharing mechanisms, are widely available.
- ***Industry Engagement and Partnership***—In addition to fully integrated systems, a 3 GW_{eq} future for LTCG technology requires engagement of and partnerships with the O&G industry and other renewable industries as well as a broad range of industrial, commercial, and residential communities that can take advantage of widespread point-of-use generation.
- ***Inform Policy and Improve Permitting Processes*—**Streamlined permitting processes, financial incentives, and more supportive and efficient government operations will be in place to ease the financial burdens of deploying new, higher-risk LTCG technologies.
- ***Demonstration and Validation of Critical Advanced Technologies*—**Industry and government will test, demonstrate, and validate innovative technologies that meet the advanced criteria (e.g., improved efficiency for reducing O&M costs), reducing costs, and risk.
- ***An Educated and Engaged Public*—**Citizens, investors, and lawmakers will be equipped with accurate data and knowledge to understand and support low temperature resource production and use.
- ***Fully Integrated Systems*—**When advanced LTCG is deployed on a large scale, it will be integrated into the existing energy infrastructure, for example, through connections to the grid and other industry processes (e.g., carbon dioxide (CO_2) sequestration, combined heat and power (CHP) and, O&G wells).

Three gigawatts, including equivalent energy from direct use, of installed capacity is an ambitious goal that will require integrated action on several fronts. These key characteristics identify conditions and specific changes needed to achieve that goal and as such represent specific strategic targets. Additional detail is given on these future characteristics in the following chapter.

High-Priority Actions

The scope of the LTCG Subprogram's efforts is delimited by three areas of activity: Advancing Technologies, Fostering Deployment, and Informing Policy. This strategic plan identifies high-priority actions in each of these areas, through which the Subprogram will help the community reach the 3 GW_{eq} goal. Chapters V–VII present the high-priority action items, along with implementation plans, that are associated with each area of activity.

Figure 3.1, on the next page, presents the overall structure of the strategic action plan presented in this document. The figure depicts the logic by which the 3 GW_{eq} goal gives rise to the key characteristics, which in turn provide strategic targets for the high-priority actions. The figure also shows how the 3 GW_{eq} goal, the key characteristics, and the high-priority actions integrate to provide a plan for the Subprogram's ongoing and future efforts.

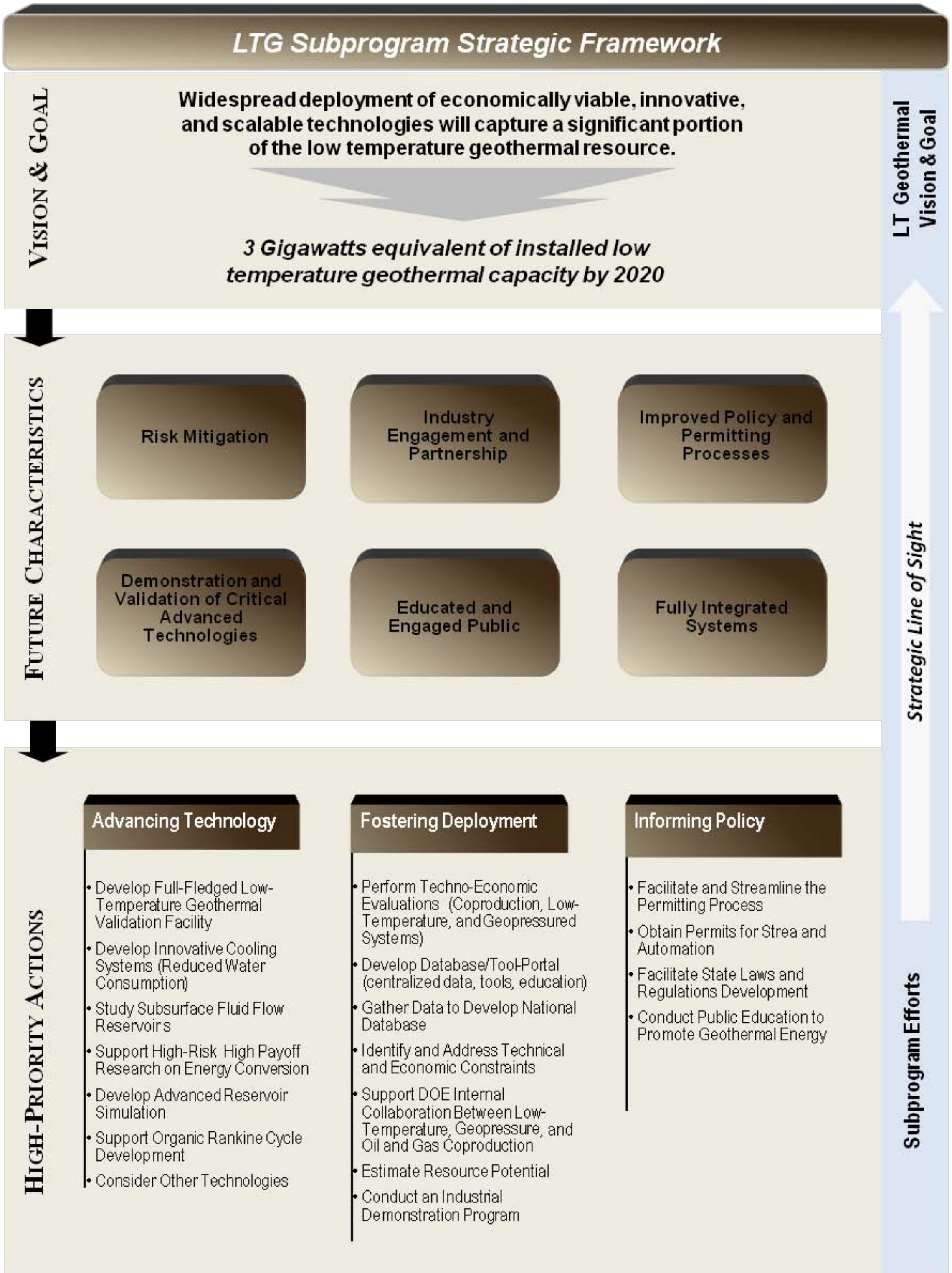


Figure 3.1 Proposed Structure for the Strategic Action Plan

IV. Key Characteristics of the Future

Although low-temperature, geopressured, and coproduced geothermal energy has not attracted significant investment or attention in the United States until recently, it has a bright future as a renewable, zero-emission energy source to provide stable, cost-competitive, reliable baseload-capable power that is valued by the public and well-integrated with other resources and infrastructure. In this future, the U.S. low-temperature geothermal community will have reached its vision of 3 GW_{eq} installed geothermal capacity and will overcome current barriers preventing geothermal energy's advancement. The following sections describe the characteristics of a successful future for geothermal energy in the United States.

Risk Mitigation

Today, investment in geothermal energy is inhibited by a lack of reliable resource information and risk mitigation strategies for early stages of development. In a 3 GW_{eq} future, the potential resources for diverse geothermal sources are clearly characterized. Advanced exploration technologies support identification of low-temperature hydrothermal resources. Additionally, risk mitigation strategies, including cost-sharing mechanisms, are widely available to support the diverse types of geothermal energy in accordance with their varying risk profiles.

A 3 GW_{eq} future relies on advanced geologic, thermal, and hydraulic modeling and other tools to support cost-effective exploration in search of low-temperature resources and reduce resource risk in the identification of diverse sources. Technology enables cost-effective resource assessment and utilization, and multiple suppliers make above-ground equipment available for resource development. In particular, well construction and the production and disposal of fluids are available at lower costs. Also in the 3 GW_{eq} future, research has defined the unique risks associated with low temperature geothermal development.

To support field projects, appropriate funding or low-interest loans are available. Where project risk is high, DOE takes on or shares the risks associated with exploration in unproven areas. Reasonable financing costs and terms are available, as are reasonable power sales terms and rates after the plant begins production.

Industry Engagement and Partnership

In a 3 GW_{eq} future for geothermal energy, strong partnerships connect geothermal projects to the O&G industry and with renewable energy industries, while a broad range of industrial, residential, and commercial communities take advantage of widespread distributed generation and direct use applications.

Active partnerships between geothermal projects and O&G companies allow fossil fuel partner companies or utilities to reduce their total emissions and derive additional value streams from O&G fields. The geothermal partners, in turn, receive valuable expertise and strengthened local infrastructure and workforce from O&G participation. In addition, other renewable energy industries stand to benefit from hybridization with geothermal energy. Geothermal technologies can be hybridized with CHP, combined heat, cooling and power (CHCP), storage and fuel cells to derive greater benefits from the resource base through combined land use, energy storage, transmission infrastructure, etc. Geothermal electricity sources also power a low-emissions method for creating hydrogen, which then serves remote off-the-grid locations.

In a 3 GW_{eq} future, industrial parks, residential districts, and planned communities make widespread use of distributed geothermal generation, district heating, and other benefits. By means of expanded distributed generation capacity, they avoid high and fluctuating energy costs, transmission losses and inefficiencies, and damage to air and environmental quality. Especially for residential areas, installation of district heating and cooling projects has grown substantially in a 3 GW_{eq} future, especially near population centers and in newly planned and constructed communities. Industries as diverse as food dehydration, laundries, gold mining, milk pasteurization, greenhouses, fish farms, and spas continue their traditional use of geothermal energy by siting facilities to leverage available geothermal resources. Beyond heat, cooling, and power uses, geothermal energy also fulfills its potential for supporting desalination projects in the American West.

Improved Policy and Permitting Processes

Established "best practices" for working with policy and permitting will guide many dimensions of the future's effective geothermal project management. Facilitated permitting processes; financial incentives, credits, and agreements; and more supportive and efficient government operations ease the burdens of meeting requirements and assist geothermal energy in attaining its potential.

In a 3 GW_{eq} future for geothermal power, permitting and development processes are streamlined—particularly the National Environmental Policy Act (NEPA) processes, by which government agencies formally consider the environmental impact of propose projects. Permitting is inexpensive and fast, taking less than 18 months for large operations and less than three months for smaller distributed generation operations. Coordination among various regulatory agencies increases the efficiency of permitting and development. Federal involvement is time- and resource-efficient. For small producers, regulatory or permitting issues are not a barrier to entry, and preliminary site permitting is more easily available.

Financial incentives also form an important foundation of geothermal energy's successful future. In a 3 GW_{eq} future, state and federal incentives exist to support technology development and deployment, providing dependable, crucial support for green power's ability to find stable markets at a premium price. In particular, state and federal governments have considered policies involving power purchase agreement (PPA) rate guarantees; feed-in tariffs; emission reduction; and renewable portfolio standards, including geothermal megawatts electric (MWe) and megawatts thermal (MWt) and energy saved through energy efficiency.

Along with permitting and incentive policies, U.S. government agencies recognize opportunities to effectively support geothermal energy via R&D policy and improved internal processes. In a 3 GW_{eq} future, a strong business case has been established for energy production, district heating, and other geothermal benefits. DOE takes advantage of opportunities to develop standard property and model locations to enable the rapid evaluation of technologies, such as for electricity production.

A 3 GW_{eq} future requires clarification on legal issues surrounding property rights (surface water rights, mineral rights, and capture of fluids) and consensus on definitions of geothermal resource terms, including water and minerals. The implications of O&G field unitization laws with respect to hot water ownership rights are reconciled and under a clear legal framework. O&G field unitization becomes an advantage, rather than a barrier, that enables unit owners to amass and exploit a larger geothermal resource base.

DEMONSTRATION AND VALIDATION OF CRITICAL ADVANCED TECHNOLOGIES

To expand geothermal power production to 3 GW_{eq}, advanced technologies must be developed and deployed at all stages of establishing a plant: from exploration, to drilling, to production and generation, to systems analysis.

In this future, an enhanced exploration toolbox provides increased certainty for locating low-temperature hydrothermal resources and improves the success rates of exploration wells and the siting process overall. Technologies also radically advance the effectiveness of drilling, pumping, and extracting operations for these new wells. A new engineering toolbox enables low-temperature geothermal production from a range of resource conditions, and enhances rates of penetration while extending the lifetimes of tools and materials. Inexpensive, reliable, and flexible well pumps become available, which enables efficient and high-flow processing. At the same time, unique research projects explore the potential of unconventional non-hydrothermal and non-coproduced low-temperature sources.

The advanced technologies and processes of a 3 GW_{eq} future also capture improved efficiencies in power generation, energy conversion, and energy recovery. Power production units become economically viable operating at lower temperatures and include higher-efficiency power conversion cycles and advanced thermodynamics cycles with mixed working fluids. Power production methods expand beyond binary organic Rankine cycle generation to include hybrid power systems and future disruptive technologies. In the plant itself, cooling systems and waste heat recovery have improved efficiencies and reduced water consumption, lowering costs. Where today's heat exchangers and coolers have limited resistance to extreme conditions, the systems of a 3 GW_{eq} future are robust and reliable. Waste heat is recovered via advanced low-temperature engine options, such as a very low temperature binary cycle that can be deployed on a large scale to create several GW_{eq} of power that would have been wasted.

On a systems level, improvements in modeling that allow for the analysis and performance optimization of entire systems become available, as do technologies that enable LTCG plants to be modularized and reproduced at scale and dispatched using turnkey operating systems. These technologies and others will be developed, validated, and demonstrated by government and commercial entities as geothermal energy takes its expanded role as a domestic renewable energy source.

EDUCATED AND ENGAGED PUBLIC

Greater public knowledge, awareness, and acceptance are essential to realizing geothermal energy's potential as a clean, renewable, affordable, and reliable power source. Today, public attention paid to renewable energies typically focuses on the promising but intermittent wind and solar sources, and the "true cost of power" (e.g., emissions, transmission, and energy security) is neither available nor widely understood. In a future where low-temperature geothermal energy attains its full potential, the geothermal community will have conducted outreach efforts, perhaps through a nationally recognized society, and worked effectively to inform and gain acceptance from communities, end users, and knowledgeable political figures. The O&G industry, the general public, and lawmakers will be educated about geothermal energy's benefits, supporting effective LTCG technology branding and marketing, and managing negative perceptions of side effects for low-risk Subprogram projects. Broad awareness of the "true cost of power" will facilitate comparison across sources for developers to choose the most cost-effective renewable resource(s).

Data that provides reliable, accurate, and available knowledge of geothermal resources serve to decrease uncertainty in the development process and encourage greater investment. Where current data are disorganized or scattered among different libraries and collections, a centralized database would make existing research and analysis easier to access. Of particular interest are data on well locations, temperature, field permeability and porosity, water-producing potential, and geopressured zones. If accessible via the Internet, a database would serve both investors and developers and could also assist in inventorying high-potential areas for low-temperature geothermal and coproduction.

FULLY INTEGRATED SYSTEMS

In a 3 GW_{eq} future for geothermal energy, different systems are combined with geothermal energy to provide heating, cooling, and power while preserving the environment and reducing waste of resources. Improved integration of systems takes place on both an economic and a technical level, as more technologies become affordable and available to developers while also benefiting from improved system integration.

Integrated distributed generation is another component of the future. As a distributed generation source, geothermal energy helps to decongest the transmission grid by providing power to areas closer to the production source. To fully optimize the use of geothermal energy, it will be integrated with the transmission grid; one of the key advantages of geothermal energy is its dispatchability, and as a reliable baseload power source, it complements other renewable energy sources and supports grid stability.

Improved, integrated use of geothermal heat is also included in the 3 GW_{eq} future. Via numerous wells and modular interchangeable systems, geothermal heat energy is transported for applications such as district heating. A market or exchange for waste heat may be established, which would serve to match the supply capacity of industrial, municipal, and other sources with demands for heat.

In a 3 GW_{eq} future, the geothermal heating and power cycle is better integrated with the needs of developers, operators, and end users. Standardized modular designs and complete “turnkey” installation options enable mass production and transportation of geothermal plants across the country, driving down the costs and uncertainties associated with deploying new geothermal plants. Leaders of projects involving different technologies and energy systems (such as solar and wind) communicate to better understand each other’s current plans and priorities.

V. ADVANCING TECHNOLOGY—HIGH-PRIORITY ACTIVITIES

The Low Temperature and Coproduced Subprogram carries out actions, projects, and initiatives that are directly focused on advancing technology. Such activities range from applied science research projects that produce technology innovations to the testing, validation, and deployment of new technology.

The majority of the high-priority action items in this area are aimed at producing technological innovations that will mitigate risks associated with resource uncertainties and improve LTCG technology's efficiency and performance. Such improvements help to reduce O&M costs and make LTCG technology energy competitive with other generation sources. Examples of specific R&D focus areas include water consumption advancements; fluid flow reservoir studies; high-risk research on energy conversion; reservoir simulations; organic Rankine cycle development; exploration, drilling, and production tools; and pumping technologies.

In addition, one high priority targeted in later stages of the technology development process, namely the development of a full-scale LTCG technology validation facility. Such a facility would enable industry-wide standardized testing, established baselines, and comparisons across technologies to established benchmarks and targets.

Advancing Technology – High Priority Activities

- Develop Full-Fledged Low-Temperature Geothermal Validation Facility
- Create Innovative Cooling Systems (reduced water consumption)
- Study Subsurface Fluid Flow Reservoir Studies
- Support High-Risk Research on Energy Conversion
- Develop Advanced Reservoir Simulation
- Develop Organic Rankine Cycle
- Consider Other Technologies

The figures on the following pages are activity maps, outlining key tasks, milestones, partnerships, and outcomes for seven high-priority action items for the Subprogram's Advancing Technology action area.

Develop Full-Fledged Low-Temperature Geothermal Validation Facility

Key Components/Tasks

- Technical support
  - Mechanical and electrical
  - Instrument and controls
- Physical testing
  - Calibrated load system
  - Calibrated measurement system (flow, temperature, pressure, and geochemical)
- Evaluation and prediction
  - Technical and economic
  - Simulation and modeling

Partners/Stakeholders

- Industry equipment manufacturers and providers
- Federal facilities such as the Rocky Mountain Oilfield Testing Center and National Renewable Energy Laboratory (NREL).
- Utilities

Results/Desired Outcome

- A facility for industry-wide standardized testing

Challenges/Obstacles

- The need for varying temperatures and flow rates

Milestones

- 6 months: Facility technical requirements developed
- 9 months: Specific facilities identified based on requirements
- 12 months: 90% facility design achieved
- 18 months: Design and ground-breaking completed
- 24 months: Facilities on-line

Duration:
Two years

Develop Innovative Cooling Systems (reduced water consumption)

Key Components/Tasks

- Air cooling
- Chillers
- Hybrid—dry and wet towers and combination systems
- Alternative or new configurations

Partners/Stakeholders

- Power system manufacturers
- Engineering design firms
- Equipment manufacturers
- State agencies for surface water permitting

Results/Desired Outcome

- Improved air cooling systems—at present large air cooling systems are limited in the hotter areas of the Western geothermal area
- Tested and validated higher-efficiency system
- Reduction of risk-associated costs

Challenges/Obstacles

- Too expensive on a large enough scale to validate
- Obtaining sources of water (e.g., water, surface well)

Milestones

- Year 1: Funding opportunity announcement focused on cooling systems issued
- Year 2: Systems and initiation of testing project identified
- Year 3: Validated testing started
- Year 5: Long-term testing completed

Subsurface Fluid Flow Reservoir Studies
(understanding flow, permeability, size, lifetime/longevity of reservoir)

Key Components/Tasks

- Model thermal properties of horizontal wells
- Develop new exploration tools and new subsurface working fluids (e.g., CO_2)
- Update knowledge on geopressured reservoirs and related technologies
- Develop methods to evaluate geothermal resources associated with O&G reservoirs during coproduction of geothermal energy
- Investigate effects of coproducing geothermal energy from O&G reservoirs on O&G production

Partners/Stakeholders

- Universities, national laboratories, and O&G industry
- Medical imaging community (for MRI) and seismic O&G industry with national laboratories and universities
- CO_2 regeneration partnerships (e.g., Plains CO_2 Reduction Partnership) and O&G and coal industries (e.g., power plants or ethanol plants, national laboratories, and universities)

Results/Desired Outcome

- Improved (~double) heat mining efficiencies compared to water (reduce or eliminate water usage)
- Improved heat extraction rates that are scalable
- Characterize reservoirs that minimize investment risks
- Addition of geopressured reservoir database to U.S. Geological Survey
- Reservoirs sized for longevity and production rates

Challenges/Obstacles

- Lack of numerical simulators or input data
- Cultural noise, e.g., electromagnetic, seismic, and vibrations
- Obstacles associated with CO_2 sequestration and enhanced oil recovery, e.g., CO_2 leakage, establishment of carbon cap-and-trade market (not necessary), and CO_2 hydrocarbon mixing
- Difficulties identifying over-pressured formations

Milestones

- Coproduction base engaged (partnership development with O&G industry)
- Reservoir research on fluid and heat extraction (low-temperature/geopressured/EGS sedimentary basin)
- Other fluids/CO_2 and creative exploration

Duration:
Three years

High-Risk, High-Payoff Research on Energy Conversion

Key Components/Tasks

- Improve working fluids (binary, well, and chemical heat pumps)
- Improve system components to decrease cost and improve efficiency (turbine machinery, new materials, modular and standardized units, and cost reduction)
- Develop thermal-to-electric conversion methods and equipment
- Explore advanced heat and mass transfer (heat exchange and heat rejection)
- Investigate hybridization with alternate heat sources (solar, CHP, and methane production)

Partners/Stakeholders

- Laboratories
- Universities—include university competition
- Industrial partner(s)
- High schools and technology schools

Results/Desired Outcome

- 20% reduction in electricity costs
- 85% of maximum theoretical efficiency
- Small scalable systems as efficient as large

Challenges/Obstacles

- Limited current data (baseline required)
- Existing infrastructure and negative public perception
- Complex system with many
- Limitations with existing materials and systems

Milestones

- Milestone 1: Baseline on efficiency and cost (status quo) established
- Milestone 2: Selected conceptual designs and practical concepts developed
- Milestone 3: Final design completed
- Milestone 4: Prototype and validation completed
- Milestone 5: Field test and performance data collected and evaluated

Duration:
Five years

Advanced Reservoir Simulation

Key Components/Tasks

- Develop coupled geomechanics and multiphase flow simulator
- Develop higher-resolution subsurface characterization methods
- Characterize fracture network and represent in continuum mechanics models

Partners/Stakeholders

- National laboratories
- O&G industry
- Universities

Results/Desired Outcome

- Increased reliability of predictions
- Benefits provided to wider geothermal industry
- Reduced project cost and faster development

Challenges/Obstacles

- Sparse number of capable simulators
- Lack of validation opportunities

Milestones

- Milestone 1: Completion of 3–4 validation exercises (2 years)
- Milestone 2: New simulators released (2–3 years)
- Milestone 3: Completion of field testing of 1–2 new reservoir characterization tools (4–5 years)

|-------------Simulators------------|-------------Validation------------|

Start Date
Year 0

|------------------Field Testing-----------------|

Year 10

Organic Rankine Cycle Development/Improvement

Key Components/Tasks

- Identify organic Rankine cycle technology suppliers—
  ≥ 1 MW, ≤ 1 MW
- Develop advanced design and organic fluids development
- Improve heat transfer, advanced technology and second-stage air coolers (condensers)

Partners/Stakeholders

- Industrial partners
- ORC system suppliers
- Universities (e.g., Southern Methodist University, Syracuse University)

Results/Desired Outcome

- Establish a path for better system development
- Cheap energy (e.g., waste heat) widely utilized via energy efficiency improvements
- Establish a standard for utilizing heat, processing, or system efficiency improvements

Challenges/Obstacles

- Lack of policy incentive for utilizing waste energy, pressure, heat, and system efficiency
- Lack of reward for energy efficiency that recognizes reductions in the carbon intensity of industrial applications

Milestones

- Milestone 1: Heat transfer research conducted (now)
- Milestone 2: Suppliers identified
- Milestone 3: Fluid applications sites developed for deployment (3 months)
- Milestone 4: Waste avoidance to heat transfer technology (6 months)

Other Critical Technologies

Key Components/Tasks

- Systems-level analysis and modeling
- Advanced drilling, exploration techniques, and tools
- Pumping technologies—high-flow and efficient
- Heat rejection advancements

Partners/Stakeholders

- Industry
  - Manufacturers
  - Service providers
  - Developers
- Research facilities for up front theoretical and experimental work
  - Universities
  - National laboratories

Results/Desired Outcome

- Improve performance and efficiency
- Lower costs
- Improve R&D gaps in these areas filled (currently limited)

Challenges/Obstacles

- Modeling—lack of defensible opportunities
- Current market too small to justify R&D
- Lack of "unbiased" bi-partisan focus by DOE, universities and national labs as to which equipment to promote

Milestones

- Milestone 1: First model, tools, and prototypes released in 4–5 years
- Milestone 2: Validation and testing completed in 2–3 years

Duration:
Seven years

VI. Fostering Deployment—High-Priority Activities

The Low Temperature and Coproduced Subprogram also focuses efforts on initiatives to commercialize technology that has been tested and validated. Such efforts focus on changing industry's and communities' behaviors in terms of geothermal energy's use and deployment by, for example, reducing risks for suppliers of new technology and increasing adoption of new technology solutions and products on the demand/consumer side.

At the top of the list of high-priority actions is development of a centralized information database for dissemination to industry and communities. Such a database will enable industry to make informed decisions about deployment. Additional high priorities involve performing important studies that generate information for the database. For example, it is imperative that the resource potential be mapped and techno-economic evaluations performed for each LTCG system (low temperature, coproduction, and geopressured) to provide industry with the necessary resource, technical, and economic risk information to make decisions. Easily accessible and shared information will also increase dialogue and facilitate partnerships between different stakeholders (e.g., the geothermal community and O&G industry).

Fostering Deployment – High Priority Activities

- Perform Techno-Economic Evaluations (coproduction, low-temperature and geopressured systems)
- Develop Database/Tool Portal (centralized data, tools, education)
- Gather Data to Develop National Database
- Identify and Address Technical and Economic Constraints
- Support Collaboration Initiative Between Low-Temperature, Geopressure, and Oil and Gas Coproduction
- Estimate Resource Potential
- Conduct an Industry Demonstration Program

The figures on the following pages outline key tasks, milestones, partnerships, and outcomes for the seven high-priority action items for the Subprogram's Fostering Deployment action area.

Perform Technoeconomic Evaluations
(coproduction, low-temperature, and geopressured systems)

Key Components/Tasks

- Gather existing cost data for capital and drilling, and surface and subsurface
- Collect relevant reservoir data and develop design scenarios and reservoir simulations for subsurface scenarios
- Conduct sensitivity analysis on reservoir production; design scenarios, policy, or incentives to characterize uncertainty
- Calculate financial systems based on the sensitivity analysis of cash flow, net present value, and payback
- Apply learning curves to cost curves

Partners/Stakeholders

Coproduced and geopressured

- O&G—need their data and buy-in
- Local communities—have a demand for distributed electric or direct-use needs

Low temperature

- Geothermal producers—have potential for bottoming cycles and wells of opportunity
- Manufacturers of plants
- Local communities

Results/Desired Outcome

- Provision of a rated list of options, in financial terms, of the benefits of deploying low-temperature, coproduced, or geopressured geothermal energy systems
- Private industry better able to make informed decisions for deployment; use of improved inputs to supply curves

Challenges/Obstacles

- Lack of availability or accuracy of data
- Uncertainty of the lifetime of reservoirs, analysis, and predictive methods
- Uncertainty in PPAs, requirement-type contracts

Milestones

- Database of relevant existing cost data, reservoir, and available technology options completed
- Ranked list of technology scenarios based on economic evaluation completed
- Costs of a wide range of inputs (design scenarios) documented

Develop Database/Tool-Portal (centralized data, tools, education) – "NGDB"

Key Components/Tasks

- Resource data acquisition
- Power plant information—Google earth location
- Information on taxes, incentives, renewable energy portfolio standards, and permits
- Built-in ability and functionality to interactively post data
- Information on news, big events, who is doing what, and who is who
- GPS display and maps

Partners/Stakeholders

- National Geothermal Database groups
- Google
- National laboratories
- State energy office and other agencies
- Bureau of Land Management and state permitting organizations
- Industry, including the O&G industry
- Forest services
- Geothermal Resources Council (GRC) and Geothermal Energy Association (GEA)

Results/Desired Outcome

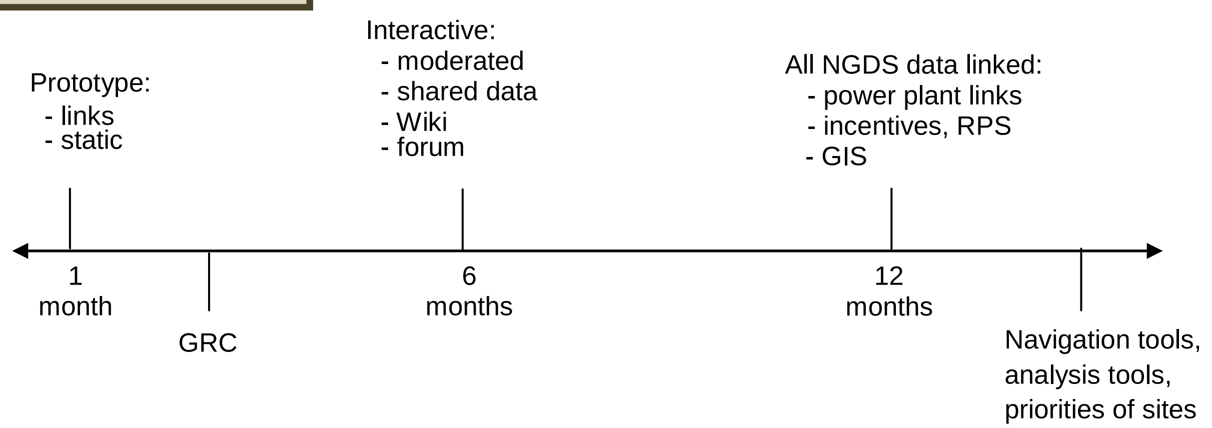
- Availability of information and tools that people need to do conceptual analysis
- Improved education by teaching through use
- Completion of a preliminary economic analysis
- Technical solutions

Challenges/Obstacles

- Security issues (DOE sites)
- Budget to build and (lower) budget to maintain

Note: This is low risk with few obstacles

Milestones



Gather Data to Develop a National Database (supports NGDB priority)

Key Components/Tasks

- Clarify data needs of the low-termperature community and secure access to data sources early on
- Digitize legacy data such as geothermal, water, O&G, and mining
- Bring in O&G borehole data
- Identify gaps and other resources
- Put land use in digital form
- Include sustainability
- Ensure flexibility of database platform

Partners/Stakeholders

- Federal government
- State governments
- Universities
- Developers

Results/Desired Outcome

- Increased development of geothermal resources
- Improved understanding and decision making regarding land use
- Useful research obtained
- Reduced project time and risk
- Development of accurate assumptions
- Improved public relations

Challenges/Obstacles

- Time and budget
- Proprietary data issues
- Prioritization of tasks and data
- Data driven as user driven

Milestones

- Milestone 1: Gaps studied and understood
- Milestone 2: Work prioritized
- Milestone 3: Data (best practices, standardization, and metrics) developed and documented
- Milestone 4: Long-term funding secured
- Milestone 5: Data acquired

|------------Milestone 1----------------------------|

|------------Milestone 2 and 3-----------------|

|---------------------------------------Milestone 4--------------------------------------|---------Maintenance---------→

|--Milestone 5---→

Identify and Address Technical and Economic Constraints

Key Components/Tasks

- Collect industry input and feedback
- Assess technology and economic benefits and incorporate system performance and development costs into an overall system model to identify and prioritize constraints
- Validate findings with industry
- Feed results into program planning process
- Improve relationships with utilities and transmission line operators

Partners/Stakeholders

- O&G industry
- Geothermal industry
- Equipment suppliers
- National laboratories

Results/Desired Outcome

- Identify key barriers
- Increase industry buy in and an eagerness to collaborate on barriers

Challenges/Obstacles

- Misrepresentative and conflicting data
- Balancing level of technical detail with generally applicable results and actionable items
- Transparency and traceability of results—is the outcome credible?

Milestones

- Milestone 1: Feedback obtained and documented
- Milestone 2: System model developed
- Milestone 3: Constraints identified and prioritized (end of Year 1)
- Milestone 4: Power purchase agreements with utilities/transmission companies streamlined
- Milestone 5: Validation completed (Year 1.5)
- Milestone 6: Activity/priority completed (Year 2)

DOE Internal Collaboration Initiative Between Low-Temperature Geothermal and Oil & Gas Production

Key Components/Tasks

- Facilitate information exchange between groups
- Identify common areas of focus and potential overlap
- Facilitate external relationships between aggressive or early adopters within the industry and professional organizations and state governments (e.g., California and Texas)
- Hold cross-functional workshop on opportunities, barriers, and action plans
- Complete successful demonstration within the O&G industry in more than one state

Partners/Stakeholders

- DOE senior management must support collaboration
- DOE Geothermal Technologies Program and DOE O&G (producers, service, and professional organizations)
- Leading state governments (e.g., Texas and California)
- Industry experts (service organizations, balance of plant, and organic Rankine cycle conversion companies)

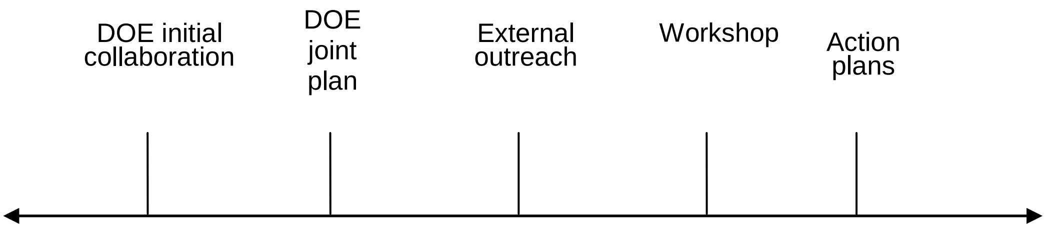
Results/Desired Outcome

- Focus of limited resources
- Foster cross-sharing information
- Identify early adopters with common interests
- Clear breakdown of deployment barriers
- Accelerate progress and obtain results

Challenges/Obstacles

- Limited staff within DOE, with different goals and philosophies
- Support at high levels required to foster cooperation
- Industry resistant to change
- Education and knowledge of opportunities is limited
- Superseded by other priorities

Milestones



Duration:
17 months

Estimate Resource Potential

Key Components/Tasks

- Gather raw data
- Develop methodology for processing data and filling in missing information

Partners/Stakeholders

- DOE
- National laboratories
- O&G industry to help with data collection and feasibility studies of technology scenarios
- Universities (data)

(see National Database worksheet)

Results/Desired Outcome

- Establish realistic geothermal potential for national renewable energy deployment goals
- Identify and gather information on areas of opportunity in Subprogram

Challenges/Obstacles

- Gaps in data
- Results depend on projected advances in technology

Milestones

None identified by the workshop participants.

Conduct an Industry Demonstration Program
(with mobile demonstration program as a subset)

Key Components/Tasks

- Identify O&G partners
- Identify applications (coproduced fluids, thermal systems, and pressure systems)
- Identify available technologies and vendors
- Define DOE and industrial partnering and funding structure
- Execute projects

Partners/Stakeholders

- O&G industry
- DOE
- National laboratories
- Geothermal practitioners
- Entities that produce waste heat or pressure

Results/Desired Outcome

- Improved energy efficiency
- Additional new electricity source
- Reduced O&G industry's environmental impact

Challenges/Obstacles

- Payback period too long for typical O&G industry company's current economic model
- Lack of "middle man" companies being developed for O&G industry
- Legal issues regarding ownership of rights to geo fluids and entrained gas

Milestones

- Milestone 1: Priorities identified
- Milestone 2: Design parameters established
- Milestone 3: Project completed

VII. Informing Policy—High-Priority Activities

The third activity area of the Low Temperature and Coproduced Subprogram involves actions, projects, or initiatives directed at informing policymakers about the benefits and challenges of adopting and utilizing low temperature geothermal energy. These activities involve getting the buy-in and support necessary to overcome policy and regulatory issues that inhibit technology adoption. This area could include education programs that alert policy makers to specific permitting and regulatory issues that inhibit adoption.

Streamlining the permitting and citing process for commercial operation is essential for LTCG technology deployment. The lengthy and complex permitting process currently increases project risk and capital for developers, inhibiting private investment and ultimately the technology's deployment/adoption. Efforts need to be made to understand the current permitting requirements (and associated agencies) and to educate/alert policymakers about the major inefficiencies involved. Ideally, the process should be streamlined by reducing agency overlap, redundancies, inconsistencies in definitions, and required approval turnaround times.

The other set of activities involves raising public awareness of geothermal energy's benefits, especially its potential contribution to overall national energy targets with respect to the environment, climate change, and reduced dependence on fossil fuels. Education programs should be targeted both towards policymakers and the general public.

Informing Policy – High Priority Activities

- Facilitate and Streamline Permitting Process
- Permit Optimization and Automation
- Facilitate State Laws and Regulations Development
- Conduct Public Education to Promote Geothermal Energy

The figures on the following pages outline key tasks, milestones, partnerships, and outcomes for the four high-priority action items in the Subprogram's Informing Policy activity area.

Facilitate and Streamline Permitting Process

Key Components/Tasks

- Conduct background and literature studies based on wind and solar development challenges
- Identify relevant agencies and their respective requirements
- Map out current processes and highlight problem areas
- Streamline process by eliminating agency overlap (i.e., federal, state, and county)
  - Memoranda of Understanding (MOUs) with Bureau of Land Management and state entities
- Unify definitions of geothermal, mineral, etc., for permitting process

Partners/Stakeholders

- Developers—finance and approval
- Federal Agencies
  - Bureau of Land Management
  - Forest Services
  - Department of Energy
- State and local governments
- Regulatory bodies

Results/Desired Outcome

- Thorough understanding of the permitting process for site locations and transmission
- Easier identification of favorable opportunities (locations) for owners and operators
- Reduce permitting risk
- Increase efficiency of permitting processes, including increased likelihood of approval

Challenges and Obstacles

- Conflicts among and within existing bureaucracies over jurisdiction, authority and requirements
- Variations and inconsistencies across states and agencies
- Lack of resources (e.g., time and budget) to improve permitting process
- Constantly changing regulations

Milestones

- Milestone 1: Completion of background study on permitting process
- Milestone 2: Map of current permitting processes and problem areas
- Milestone 3: States convinced to develop MOUs to align permitting processes
- Milestone 4: Complete final deliverables including issuance of FOA
- Milestone 5: Streamlined permitting process

Facilitate State Laws and Regulations Development

Key Components/Tasks

- Develop legal definition of geothermal resources including water and minerals; clarify and develop consensus on property rights issues (surface water, minerals, etc.); clarify and address the implications of O&G field unitization law
- Develop a set of regulations concerning leasing on private and state land
- Create an agency or subset of an existing agency to implement regulations and arrange for funding of the entity

Partners/ Stakeholders

- State and federal agencies
- Legal forum
- Producers
- Landowners and leaseholders
- Users

Results/Desired Outcome

- Establish processes for leasing and regulations for drilling (necessary to advance geothermal development)

Challenges and Obstacles

- Possible difficulty navigating state legislatures
- Resistance from competing industries and environmental groups

Milestones

- Successfully navigate state legislative processes in 2–3 years

Conduct Public Education to Promote Geothermal Energy

Key Components/Tasks

- Target audiences:
  - Identify targets and demographics
  - Conduct market research to identify current knowledge base
  - Focus on "elites" as specific target (e.g., policymakers, business leaders, early adopters, "thought leaders," Microsoft, Google, Apple, and relevant non-government organization leaders)
  - Define target state (end point)
- Design campaign targeted by demographics:
  - TV, print, radio, Internet (e.g., YouTube [viral videos], Twitter, Facebook, webcasts), T-shirts, bumper stickers, and road shows
- Implement campaign
- Measure results
- Publish and widely publicize results

Partners/Stakeholders

Innovative and creative marketing firm working in conjunction with:

- Geothermal Energy Association
- Geothermal Resources Council
- Google
- DOE
- Universities

Results/Desired Outcome

- Increased public awareness such that, by the end of the project, the majority of the public is aware of and supports geothermal energy
- Increased demand for geothermal energy and industry growth through energy security, reduced dependence on fossil fuels, more jobs, and policies that foster industry growth

Challenges and Obstacles

- Perception of federal promotion of an industry
- Insufficient funding
- Responding to critics

Milestones

- Year 1: Complete planning and market research
- Year 2: Complete the design of 2–3 campaigns and roll out "elite" campaign
- Year 3: Roll out mass public campaign and second campaign targeting younger audience
- Year 4: Monitor and adjust campaigns
- Year 5: Assess success (measure and publicize)

VIII. ACTION PLAN IMPLEMENTATION

AN INTEGRATED ACTION PLAN FOR MAXIMUM IMPACT

The Low Temperature and Coproduced Subprogram must take steps to integrate the implementation plans for the high-priority actions identified and outlined in the three previous chapters. To maximize the collective impact of the activities, an effective allocation of resources is necessary across the three activity areas: Advancing Technologies, Fostering Deployment, and Informing Policy.

The determination on how to integrate these implementation plans to the Subprogram's efforts was formed by participants in the roadmapping process. The participants were asked to consider the relative impact of effective action in the three activity areas and assign the percentage of time and resources that should be devoted to each area. The participants identified Advancing Technologies and Fostering Deployment as primary and nearly equally important focus areas. Informing Policy was identified as secondary to these two areas, though still a significant area worthy of attention. More detailed results can be found in Appendices C and D.

MEASURING SUCCESS

Methodical, concerted, and organized efforts to complete the high-priority activities are anticipated to yield significant benefits to the geothermal community. As the Subprogram completes the high-priority actions, it will need to evaluate and measure its own effectiveness in implementing the activities as well as the impacts of the activities on industry, i.e., whether and how much the activities are contributing toward the achievement of the 3 GW_{eq} vision and associated key characteristics.

Four distinct metric areas have been identified as the best means to measure the Subprogram's performance (and related industry performance): levelized cost of energy (LCOE), number of projects started or completed, installed capacity, and capacity factor. These metrics can be used as a means to provide annual comparison and to allow for objective comparison between low-temperature geothermal energy relative to other energy technologies.

LEVELIZED COST OF ELECTRICITY

While upfront capital investment in geothermal systems is relatively high, once a geothermal site is producing power, its yields versus O&M costs are quite favorable compared to other baseload alternatives such as coal. The first metric, LCOE,[1] accounts for the costs of geothermal energy production over the system's lifetime (assumed to be 30 years). Lifetime costs include initial capital investment, operations costs (which normally include fuel but do not in the case of geothermal), and initial capital cost. LCOE is calculated as net present value, showing a result in today's dollars.

[1] The formula for LCOE is as follows, where I_t = investment expenditures in the year t; M_t = O&M expenditures in the year t; F_t = fuel expenditures in the year t; E_t = electricity generation in the year t; r = discount rate; and n = life of the system.

$$\mathrm{LCOE} = \frac{\sum_{t=1}^{n} \frac{I_t+M_t+F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

NUMBER OF PROJECTS STARTED

The number of low-temperature, coproduced, and geopressured geothermal projects initiated is an important indicator of the LTCG Subprogram's progress in supporting the geothermal community and accelerating advanced technology deployment.

INSTALLED CAPACITY

Installed capacity refers to the rate of power generation expected from, or measured from, a power generation plant. It is a direct measurement of the magnitude of power a particular energy source can generate at any given moment (measured in units of gigawatts). It is therefore a direct measurement of progress made towards achieving the 3 GW_{eq} geothermal energy vision.

CAPACITY FACTOR

The fourth metric, capacity factor, refers to the ratio of a plant's actual output over a certain period of time to its hypothetical total output if it had operated at full capacity during that entire time period. In the case of other alternative energies, actual power production rates depend on sunlight availability, wind conditions, and weather. In contrast, geothermal energy generation continues during nighttime hours, in all types of weather, and during all seasons.

Based on the geothermal community's understanding of the current baseline measures, the 2010 current status and targets for the four metrics for 2012 and 2015 are being developed for coproduced, geopressured, and other types of low-temperature geothermal production sites. A preliminary table of the current status and targets is in Appendix E.

GOING FORWARD

It is important to note that as performance is measured and evaluated, action items may be revised and resources reallocated. Evolving industry trends may cause LTCG Subprogram priorities to shift, subsequently resulting in new priorities and activities. Figure 8- 1 depicts the overall pathway from the strategic action plan's development through activity implementation, increased deployment of LTCG technologies, and achievement of the vision. The same figure also shows that information from performance evaluation and changes in the industry landscape are likely to provide feedback into specific activity plans and the overall strategic action plan.

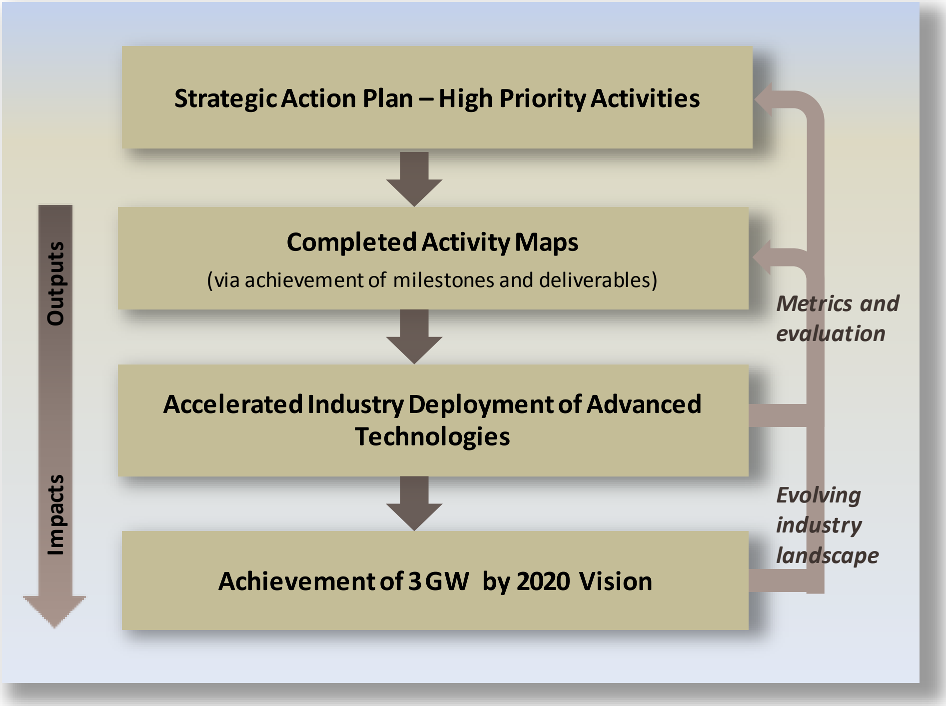


Figure 8- 1: Strategic Action Plan Implementation and Evaluation

Appendix A: Workshop Overview

The strategic action agenda is based on the outcomes of a two-day technology planning workshop that took place on July 13–14, 2010, in Golden, Colorado. The workshop brought together a diverse cross-section of the geothermal community. Experts from industry, academia, and government discussed how LTCG can best leverage its efforts and resources to enable technology breakthroughs and promote deployment of new technology. In order to maintain a clear focus and maximize participation, facilitated small group sessions were used to tap participants' diverse knowledge, expertise, and perspectives; distill themes and organizing concepts; and foster consensus on the most promising action pathways for LTCG to pursue over the next two to three years.

Low-Temperature, Coproduced, and Geopressured Geothermal Subprogram Vision Workshop

Prior to the strategic planning workshop, many participants also attended a visioning workshop held on February 5, 2010, at Lawrence Berkeley National Laboratory to discuss the future of low-temperature geothermal technologies and markets and to craft a forward-looking vision for the Subprogram. At the workshop, participants established a common understanding of the high-level assumptions about the definition of low-temperature geothermal, the boundaries of that definition, and a realistic view into the future opportunities available in low-temperature geothermal markets. Participants also identified and developed consensus around the more specific issues related to the Subprogram's strategy.

APPENDIX B: WORKSHOP PARTICIPANTS

BREAKOUT GROUP 1

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Appendix C: Action Plan Charts

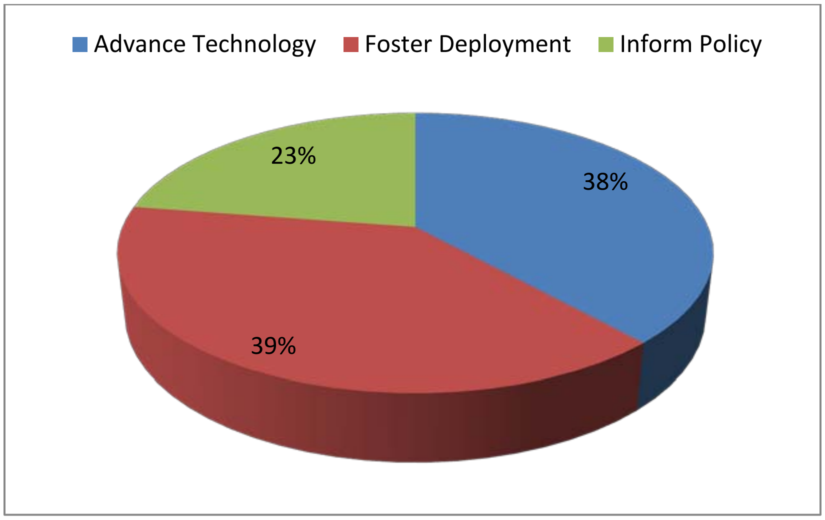


Figure C- 1: Relative Impact Rating

To maximize overall impact, the Subprogram must allocate effort and resources to all three areas. Informing Policy was given the smallest allocation; however, with a result of 23%, it still represents a significant area of activity. Advancing Technology and Fostering Deployment received nearly equal allocations of the remaining percentage of time and resources.

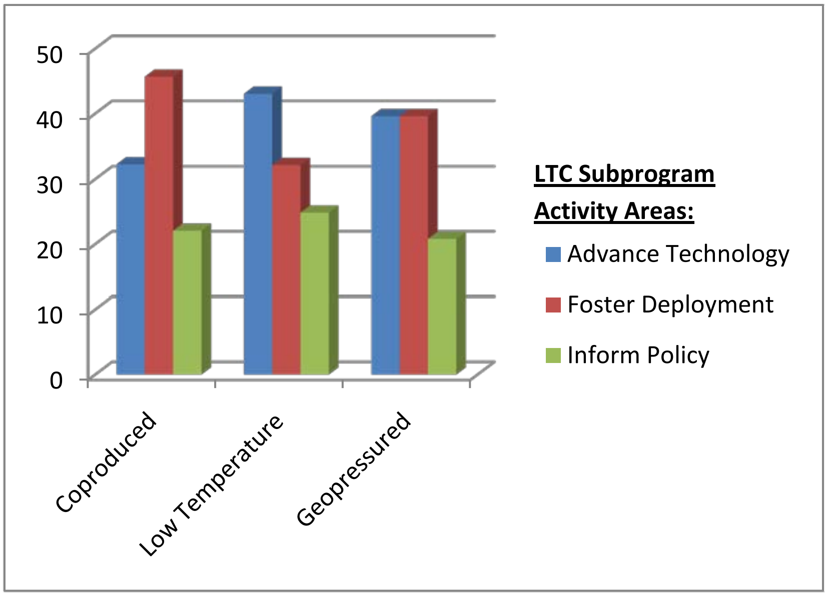


Figure C- 2: Relative Impact Area (by activity area)

The results from the expert elicitation provide useful guidance to the Subprogram about how to move forward with an integrated action plan that maximizes its potential impact overall.

Appendix D: Workshop Results

Key Enablers and Characteristics of a 3 GW_{EQ} Future

Breakout Group 1

Technical Advancement (Specific to Low Temp)	Integrate with Existing Systems Infrastructure	Resource Assessment/Risk Mitigation
• Power production units that operate efficiently below 200°F ●●● • Sub step: GW low temperature waste heat recovery ●●● • Technologies for Welec generation beyond binary organic Rankine – cogeneration, hybrid ●●● • “Out-of-box” research projects ●● • Cooling systems that are more efficient and lower cost ●● • Unconventional sources— non-hydrothermal, non-co-produced will be included ● • Robust, reliable building blocks (Hx, turbo-expanding water treatment), small footprint • Heat exchangers/coolers that deal with extreme conditions of temperature, pressure, and chemistry • Technology/design development for communal (district) heating/cooling with low-temp geothermal sources. 100 kW range with thousands of applications in home heating • Technology demonstrations sedimentary rock EGS at shallow depth for industrial applications, e.g., for mining or for oil and gas energy recovery (100 kW range with thousand of applications) • Technology development—get industry to develop very low-temperature binary cycle that can operate in the waste heat regime. A module of a few kW x 10^6 = a few GW	• Costs driven down by standard designs/mass production ●● • Different systems are combined, e.g., cogeneration, CO_2 sequestration and geothermal while reducing/eliminating water resources ● • Turnkey(s) systems • 3 GW power—30+ GW thermal (10% efficiency), numerous wells, modular interchangeable systems • Utilities should have incentives to purchase distributed geothermal power • Dispatchable—complements other renewables, grid stability	• DOE to take or share risk in unproven areas (e.g., loan guarantees) ●●●●● • Geologic/thermal/hydraulic modeling ●● • Resource assessment/ enablement ●● • Direct use of low-temperature resources that offset fossil-based energy—not just heating, energy integration ● • Many immediate test projects to examine varying conditions • Hot spring community and geothermal small systems

Policy Support	Education/Public Perception
• Incentives such as production tax credits and Renewable Portfolio Standard need to be in place—increase and extend ●●●● • State and federal incentives exist supporting technology development and deployment ● • Financial incentives ● • Streamline NEPA processes ● • Large power companies accept and pay for “small” amounts of distributed electric power—feed-in tariffs ● • Federal involvement (permitting) should be streamlined • Strong business case established—e-production, district heating, other benefits\established “best practices” in the field that address analysis, engineering, leasing, permitting, NEPA, PPA, etc.	• Active O&G partnerships ●●●● • Conditions—acceptance from communities, knowledgeable politicians • National Research Council-specific initiatives ● • Education of oil/gas industry, public, lawmakers ● • A marketing campaign should be developed to educate both investors and society on low-temperature technology and its benefits ● • Better marketing • Public acceptance achieved through exposure to geothermal exploration, drilling, (stimulation, fluid distribution) • Assigned owner(s) for geothermal education • Public acceptance is achieved

● = Idea voted by group member as important component of the 3 GW_{eq} future

Breakout Group 2

Advancement in Technology

- Exploration toolbox enhanced to enable improved ability to locate LTCG technology resources ●●●●●
- Drilling technologies radically advanced to increased rate of penetration and lifetime of tools/materials ●●●
- Advanced thermodynamics cycles—using mixed working fluids ●●●
- Technology developed to bring the geothermal heat to the surface with minimal loss of “availability” or energy when used for power generation (e.g., using multiple fluids loses energy) ●
- Engineering toolbox that enables LTCG production from a range of resource conditions ●
- Modular LTCG plants that can be transported cross-country, with switch “on,” turnkey operation ●
- Inexpensive, reliable, and flexible well pumps
- Efficiencies improved (e.g., by 20%) in energy conversion/recovery
- Hot air for heat rejection by natural convection
- Geo-powered cars equipped with GPS devices and are essentially self operating
- LTCG toolbox for exploration, drilling, and production

Industry (especially O&G) Engagement and Adoption of New Practices

- Engaged oil and gas industry with increased number of companies and professionals producing geothermal energy, such as he American Association of Petroleum Geologists ●●●●●●●
- Widespread point-of-use generation—industrial parks, district heat, planned communities ●●●
- Hybridization of geothermal with other renewable energy resources (storage/fuel cells/CHP)—geothermal seen as another tool ●
- Industries choose to site facilities to utilize geothermal resource ●
- Hydrogen projection for remote off-grid locations ●
- Adoption of Iceland practices in United States greenhouses, recreation ●●
- Thermal desalination of Colorado River and Salton Sea ●
- District heating/cooling—using geothermal to develop communities
- Lots of installations close to population centers
- Well electric production for distributed power(thermal-electric)
- Geothermal heating and cooling in new construction

Public Education, Awareness, and Acceptance

- Greater public knowledge, awareness, and acceptance of low-temperature geothermal ●●●●●
- True cost of power (including emissions, transmission, energy security, etc.) is calculated to allow true comparison of relative merits across sources ●●●
- Effectively manage side effects, and perceptions of side effects, of LTCG that are low risk but controversial ●
- LTCG is effectively marketed/ branded with general public
- Expansion of skilled workforce in LTCG (i.e., entire process from exploration to production) ●
- Based on true cost/benefit comparisons and accurate, complete knowledge

Cross-over Fertilization and Systems Integration

- Cross-technology fertilization caused by better communication (different areas and technologies, e.g., solar, wind); all know who’s doing what ●●
- Transmission grid decongestion through distributed generation ●
- Transport geothermal energy for cogeneration applications; integrate geothermal/power cycle/end user
- Establish an exchange or market of waste heat supply and demand for matching capacities (industrial, municipal, etc.)

Breakdown of barriers and differences across sources, technologies, infrastructure, etc.

Improvement of General Policy Orientation and Approach

- State and federal Renewable Portfolio Standards include geothermal MWe and MWt and energy saved (energy efficiency) ●●●
- There are GHPs in the White House, Capital
- Long-term consistent, DOE research, development, and demonstration program ●
- Energy policy is not an ideological position of political parties—energy policy is bipartisan and depoliticized

RPS, incentives, funding, policy maker awareness

Improvement of Permitting and Regulatory Processes

- Fast and inexpensive permitting; <18 months for large operations, < 3 months for smaller distributed generation operations below 50 MW ●●●●●●
- Develop standard property and model bases for rapid evaluation of technologies (e.g., for electric energy production)

Streamlined—faster, easier, smoother

Reduced Resource Risk and Cost

- Geo energy production cost at 20% less than competition ●●●
- Effectively manage side effects, and perceptions of side effects, of LTCG that are low-risk but controversial ●
- Multiple suppliers of above-ground equipment
- Reasonable power sales terms and rates
- Reasonable financing cost and terms
- Elevated cost of petroleum and natural gas
- Lower cost well construction and reduced costs for production and disposal of fluids

● = Idea voted by group member as important component of the 3 GW_{eq} future

Breakout Group 3

Risk Reduction	Information Resources (Public Outreach++)	Permitting Optimization

• Support cost-effective exploration ●●
• Develop research program to clearly define the risks associated with low-temperature geo development vs. "business as usual." The risks associated with geothermal already make financing difficult—so additional risk is an issue ●
  o Difficult to obtain funding for technology with unknown risks
• Development of field projects with appropriate funding/low-interest loans ●
• Better understanding of geo-hydrodynamics
	• Centralized database ●●●●●●●
	• Informed public, end user, local governments on technical efficiencies ●●
	• Public education about benefits of geothermal ●●
	  o Stay ahead of negative perception
	  o Aggressive approach to public outreach
	  o Need a national organization to undertake outreach efforts
	  o Public relations campaign similar to the wind industry
	• Data ● (e.g., location of wells; temperature; field permeability/ porosity; water-producing potential; geopressured zones)
	• Digital legacy—ease access to info for permitting, exploration, etc., in digital database
	• Information reporting requirements—engage O&G and their existing knowledge and data
	• Identification of potential O&G sources
	• Inventory high-potential low-temperature areas—"low-hanging fruit"—coproduction
		• Streamlined permitting process; streamlined development process (in areas that can be) ●●●●●●●●
		• Low/no barriers to small producer entry
		  o Regulatory
		  o Permitting
		• Preliminary site permitting
		• Permitting/development streamlining—coordination among various regulatory agencies

Resource Potential and Classifications	Advanced Technology Capabilities	Industry Partnerships

• Technology characterization and potential: ●●●●●
  o What are the technologies?
  o How big is the resource?
• Needed to achieve 3 GW:
  o 12,000 Rocky Mountain Oilfield Testing Center
  o 3,000 Pleasant Bay
100 30 MWe sedimentary Low Temperature EGS
	• Improved pumping technologies ●●●
	  o Efficient and high-flow pumping
	• Improved whole system analysis and modeling ●●●
	• Efficient exploration technology ●●●
	  o Reduce dry hole risk
	• Low water consumption cooling systems ●
	• Higher efficiency power conversion cycles ●
	• Advanced low-temperature engine options ●
	• New power production paradigm—group a set of smaller engines, adapt to resource over time
		• O&G must see produced water as desirable; O&G acceptance and interest ●●
		• Paradigm shift in economics (i.e., payback period)
		  o Income from cogeneration

Market Demand (Policy Support)
• Price on carbon or emissions policy ● • Stable markets for green power at premium price • Green power demand development • Some sort of PPA rate guarantee or feed in tariff enforced by government to eliminate risk of getting a PPA • National RPS • Strong desire to offset carbon/negative environmental impacts

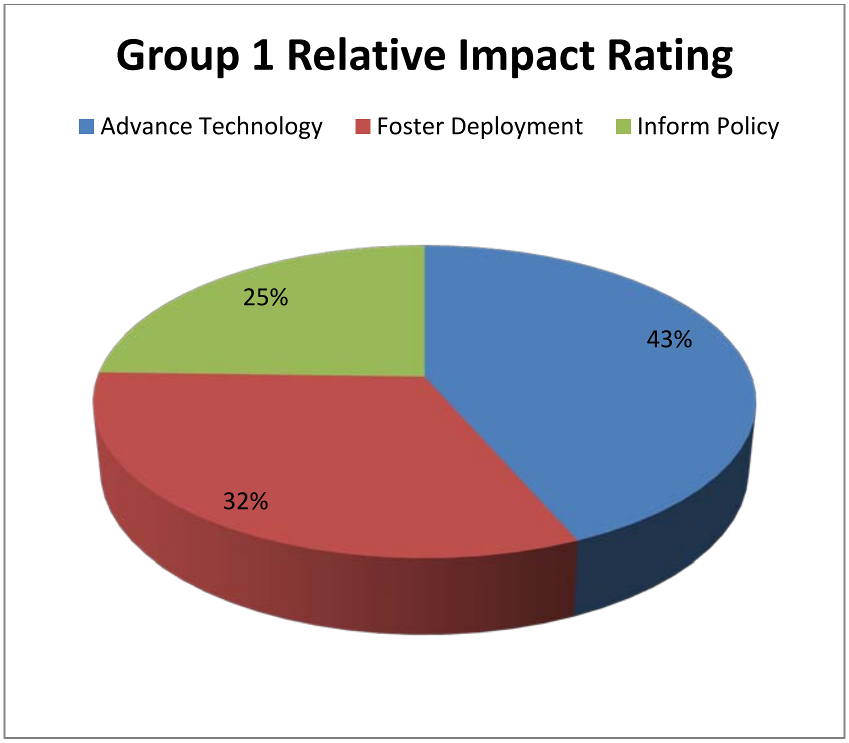
● = Idea voted by group member as important component of the 3 GW_{eq} future

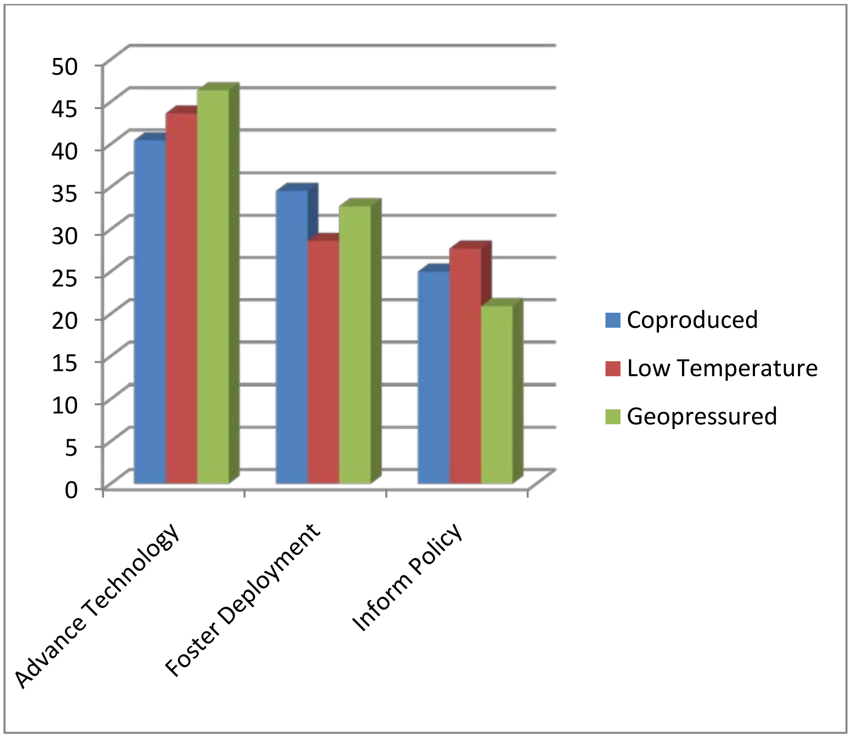
ACTIONS, PROJECTS, AND INITIATIVES TO ACHIEVE 3 GW_{EQ} FUTURE

BREAKOUT GROUP 1

ADVANCING TECHNOLOGY	FOSTERING DEPLOYMENT	INFORMING POLICY
• Develop full-fledged low temperature geothermal validation facility or facilities C, G, L ●●●● • Improve cooling systems/reduced water consumption. Water efficient and R&D project include field test demo C, L, G ●●●● • Reservoir studies including modeling and field studies ●●●● • Support ultra-low, binary or chemical energy cycle to convert heat (140°F) to electricity—research, DOE L. Stand-alone, modular (<200°F) energy recovery unit (~100kW) Research, DOE L ●● • Conduct fundamental and applied research on using CO_2 as a subsurface working fluid in both EGS and reservoir geothermal systems to double efficiency compared to water. Also test and validate method L, C ●● • Conduct research in hybrid systems—solar thermal and adsorption chillers ●● • Site survey—thermal, accessibility, infrastructure, etc. design bases ●● • Fund R&D focused on lowering usable temperatures for electricity generation C, L ● • Identify cost of energy drivers entitlement vs. laggards ● • DOE projects (funding opportunity announcement) targeting low-temp challenges: resource assessment, high flow rates, efficient electric production • Focused research on efficient low-temperature power production units—C, L, G	• Support demo projects, L, G, C. Support multiple CHP projects to prove and improve low temperature generation units—modular and scalable ●●●● • Perform detailed technoeconomic evaluations of C, L, G technologies and publish ●●● • Identify local/state/federal incentives and publish in one location ●● • Create new markets by getting utilities to readily connect to and accept power from new projects no matter how small (i.e., <1MW) C, L, G ● • Hold/host conference or workshop with oil/gas industry, mining industry and geothermal ● • Combine CO_2 sequestration and/or EOR with geothermal energy recovery, using CO_2 as the subsurface working fluid L, C ● • Work on tax incentives for installation of low temperature geothermal systems in new and old oil and gas operations C, G • Cascading usage study/deployment • Develop numerical simulation models for recovery prediction and cost analysis G, L • Work with utility grid owners to ensure access of geothermal power	• Cut permitting time and cost, Geothermal Energy Association, industry government partner C, L, G ●●● • Increase marketing—elevator pitch and slogan, impacts politicians and society C, L ●● • Calculate LTCG supply curves for three C, L, G technologies for range of scenarios in policy and technical deployment ● • Develop the trade or professional group that can effectively lobby for what you need C,L,G ● • Identify basic science research National Research Council L ● • Facilitate state laws and regulations development

● = Activity identified by group member as important to achieving a 3 GW_{eq} Future
Breakout groups: C=coproduced; L=low temperature; and G=geopressed


Group 1 Relative Impact Rating
Advance Technology
Foster Deployment
Inform Policy
25%
43%
32%


50
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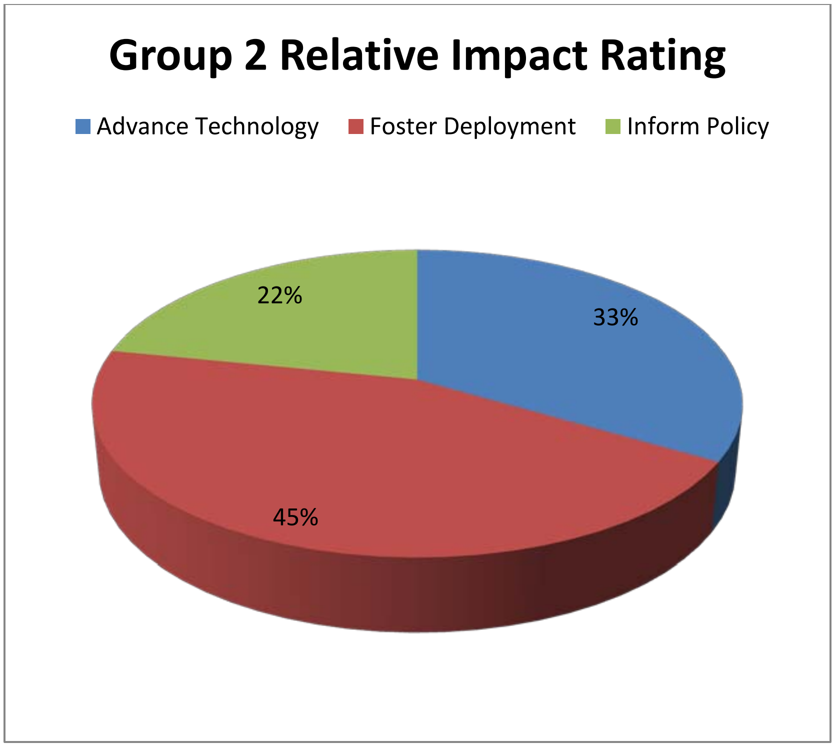
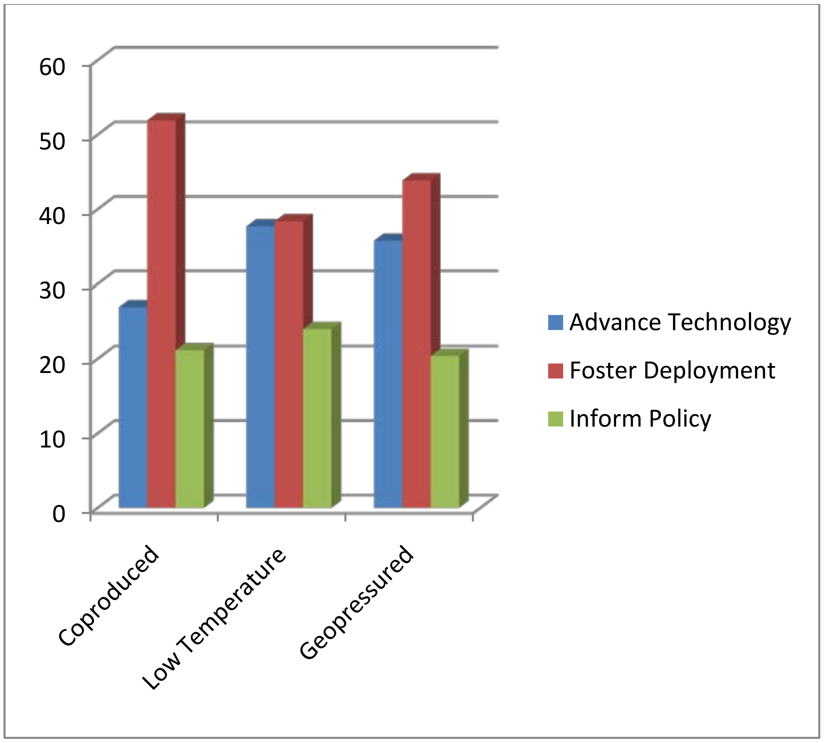
5
0
Advance Technology
Foster Deployment
Inform Policy
Coproduced
Low Temperature
Geopressured

Breakout Group 2

Advancing Technology	Fostering Deployment	Informing Policy
• Create R&D Funding Opportunity Announcement targeted to specific needs—e.g., drilling, efficiency, exploration, field validation of promising technology • Establish a competition between states for the next "new plant" demo—e.g., an LTCG technology prize • Fund/implement R&D initiative on a submersible well pump • Fund/initiate basic research of thermal energy storage technology (chemical, physical) • Fund/implement R&D initiative on ground cooling of binary cycle plant • Fund/initiate research to increase geothermal electric during hot summer days (utility peak) • Fund/initiate low-temp RD focused projects—fluids for geothermal (down hole and binary), reduced cost drilling technology—enhanced casings/cements (different than enhanced geothermal systems) • Actively seek/identify transferable technology from other industries • Develop student, university team competition for making the most power from a defined resource	• Enhance and centralize comprehensive geological data on BLM land to reduce risk • Create a program to provide technical support to new opportunities (Department of Defense, government, community) • Establish petroleum GT working group to develop strategic roadmap US/industry/laboratories • Cosponsor new conferences and workshops with O&G • Bring together the DOE low-temperature group and DOE O&G group to exchange information and establish joint plan • Make paperwork for geothermal development by O&G companies less of a burden (tax savings and green credits)—need to reduce O&G's entrenched resistance to working with federal government • Identify low-temperature resources adjacent to existing communities. Publish information—make locals/government aware • Engage utilities and break down interconnection issues, e.g., in California Rule 21 for distributed generation • Initiate program to couple industry to resource (servers, greenhouses) • Develop education program and market platform for geothermal industry—directed at users (industry, communities, municipalities) • Support geothermal curricula at community colleges—would include LTCG technology uses (power generation, heat, CHP, direct use) • Engage professional O&G organizations to connect with independent producers for co-produced and distributed power generation • Establish panels/subpanels (industry/government/academic) from other DOE/Department of Defense programs for cross-pollination • Conduct analysis of obstacles to moving from validation to commercialization and address them • DOE O&G group + LTCG technology group work together to find independent O&G early adopters to build successes—include existing industry groups • Establish Internet-accessible database that includes a resource assessment of oil and gas well fields as well as data storage and collection with GIS layers for geothermal, wind, solar, ocean, and tidal with industrial and large commercial • Create a comprehensive digital tool kit (data, analysis, information) cross-cutting • Work with O&G industry on demonstration projects and develop reliable technology and economic database; establish dedicated funding opportunity for petroleum LTCG technology demonstration projects $100 million	• Create a viral Internet, Google, YouTube, Facebook, Twitter campaign designed to create excitement and intrigue around geothermal—"the other renewable energy" • Raise awareness of geothermal/successes by state—within government and public • Develop a "Geothermal" Spa, Museum. Attract visitors (high-visibility areas) • Definitive, objective studies on resource, technology options, benefits to inform policymakers • Public education campaign to generate interest in and excitement for geothermal; fund public relations/ awareness program—spokesperson and staff—a LTCG technology community outreach (this would be non-political deployment of objective data) • Develop a rating system that quantifies such values as "independence from foreign sources," and local advantages—best use policy/multiple use ability


Group 2 Relative Impact Rating
Advance Technology
Foster Deployment
Inform Policy
22%
33%
45%

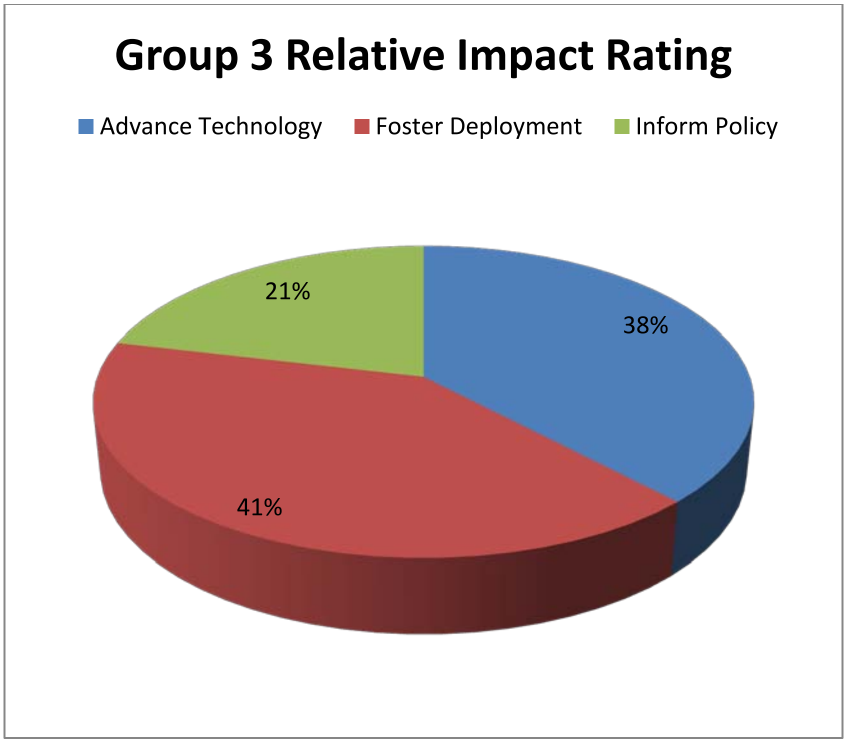

60
50
40
30
20
10
0
Coproduced
Low Temperature
Geopressured
Advance Technology
Foster Deployment
Inform Policy

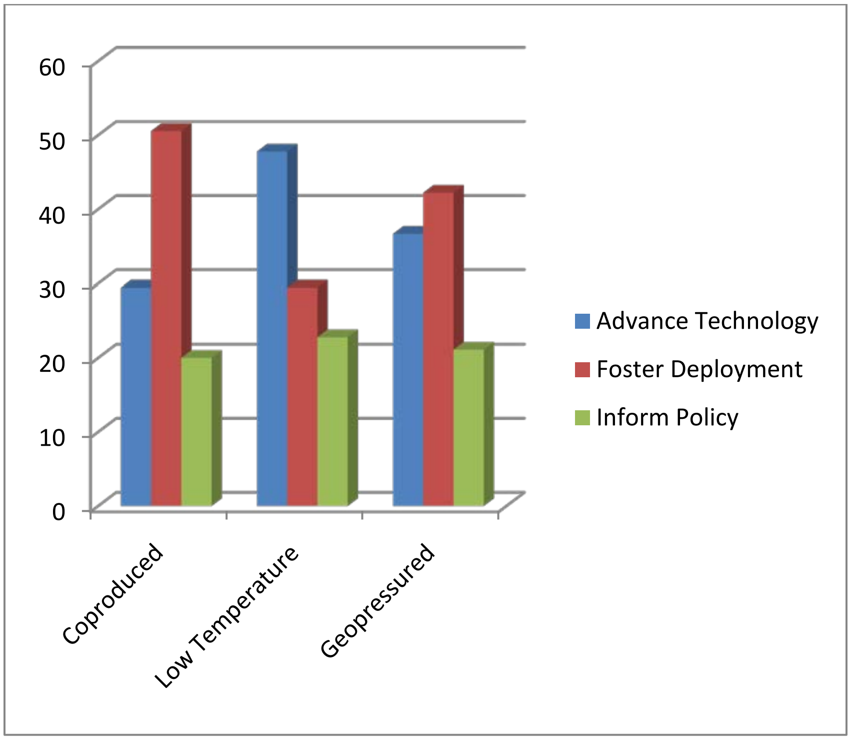
Breakout Group 3

Advancing Technology ●●●●	Fostering Deployment ●●●●●●●●	Informing Policy ●●●●●●●●

• Identify technological or economic constraints to further deployment ●●●●●
• Advanced reservoir simulation development ●●●●
• Organic Rankine cycle for low-temperature; advanced working fluid initiative ●●●●
• Define opportunities to create [promote and install] energy efficiency—recognize and require—for existing technologies ●●●
  o Industrial process efficiency = low-hanging fruit
• Develop transparent and defensible system analysis tools to prioritize R&D ●
  o Oil and gas company needed
  o Modeling—coupled geomechanics
  o Government research into sedimentary basins
• Prioritize technical capabilities, then focus on priority tech
  o Most industry benefit
  o Quickest R&D → deployment
  o Involvement with industry to prove confidence
  o Increased funding and industry support
  o Faster execution
• Advanced drilling technology initiative
• Perform tech characterization
  o Models for each type of tech to identify what works
• Coproduction
  o Demo projects
  o Bring in O&G operations
  o Economic modeling
• Resource assessment
  o Coproduced
  o Geopressure
  o Mineral ownership
    - Federal
    - Non-federal
    - State
• Look for different types/users and/or new resources with innovative technology
	• National database/data gathering ●●●●●●●
	  o Partner with Fossil Energy to obtain oil & gas industry research data
	  o Partner with Google for search functionality (don't reinvent the wheel)
	  o Structure database to configure groups of wells—coproduction
	• Industrial partnering demonstration program ●●●●●●●
	  o Oil and gas exploration leveraging
	• Mobile demonstration project to foster deployment in promising locations ●●●●●●
	  o Overcome oil and gas industry hesitancy due to costs, etc.
	  o Partner with industry to deploy where opportunities exist
	  o Will require large amount of funding to get under way
	• Optimize and automate permitting ●●●●
	  o National best practices for permitting
	  o Automate permitting
	  o Clarify well classification
	  o Develop a way to compare proposed projects to existing projects
	  o Flow chart
	  o Work with Department of the Interior (BLM) and states to standardize process
	• Estimate resource potential for each technology; identify and inform on areas of opportunity ●●
	• Supercritical carbon dioxide demonstration program, joint DOE Office of Energy Efficiency and Renewable Energy/Fossil Energy ●
	• More emphasis and funding for projects that have clear success [potential]
	  o More funding for fewer projects
	  o Identify projects that can happen without DOE
	• Sponsor/participate in seminars to educate prospective investors and lenders
	• Funding sources for development
	• Low/no interest loans for projects
		• White Papers:
		  o Committee briefing Congress
		  o Western Governors Association
		  o National Association of Counties
		  o State geothermal working groups
		• Develop prototype designs for low temperature systems to support education and research

● = Activity area identified by group member as having <u>greatest</u> potential for impact
● = Activity area identified by group member as having <u>least</u> potential for impact
● = Activity voted by group member as important to achieving the 3 GW_{eq} future


Group 3 Relative Impact Rating
Advance Technology
Foster Deployment
Inform Policy
21%
38%
41%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Coproduced
Low Temperature
Geopressured
Advance Technology
Foster Deployment
Inform Policy

APPENDIX E: PROGRAM PERFORMANCE METRICS

PRELIMINARY TARGETS FOR PROGAM PERFORMANCE METRICS

METRIC	UNIT OF MEASUREMENT	2010 STATUS	2020 TARGET	2030 TARGET
Levelized Cost of Electricity (LCOE)	Dollars ($)	TBD	TBD	TBD
Number of Projects	Integer Number (#)	27	TBD (GEA data)	TBD (GEA data)
Installed Capacity	GW_{eq} (or MW_{eq})	TBD	TBD	TBD
Capacity Factor	Percent (%)	95	95	95

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