



A Research Observatory for a Sustainable Future



## Newberry Geothermal Energy

Establishment of the Frontier Observatory for Research in Geothermal Energy (FORGE) at Newberry Volcano, Oregon



## Appendix L

## Research and Development Implementation Plan

April 27, 2016



# Contents

Acronyms and Abbreviations .....	L.ii
L.1 Summary.....	L.1
L.2 Introduction .....	L.1
L.3 NEWGEN Organization.....	L.2
L.4 NEWGEN Technical Vision and Alignment with GTO Objectives and Goals .....	L.2
L.5 Science and Technology Analysis Team.....	L.5
L.5.1 Composition and Meetings Schedule.....	L.5
L.5.2 Roles and Responsibilities .....	L.5
L.6 NEWGEN R&D Solicitation and Implementation.....	L.5
L.6.1 R&D Project Science and Technology Objectives .....	L.5
L.6.2 R&D Proposal Selection .....	L.7
L.6.3 R&D Project Implementation .....	L.9
L.7 Baseline Characterization, Monitoring, and Site Infrastructure to Support R&D Projects .....	L.10
L.7.1 Characterization and Monitoring by NEWGEN .....	L.10
L.7.2 Characterization and Monitoring Contributions by the R&D Teams .....	L.11
L.7.3 Site Infrastructure.....	L.11
L.8 Data Sharing and Reporting .....	L.11
L.8.1 Data Collection and Release .....	L.11
L.8.2 Reporting.....	L.12

# Figures

L.1 NEWGEN FORGE R&D Implementation Plan.....	L.7
---	-----

## Acronyms and Abbreviations

°C	degree(s) Celsius
COI	conflict of interest
DOE	U.S. Department of Energy
EGS	enhanced geothermal system(s)
ES&H	environmental, safety and health
FORGE	Frontier Observatory for Research in Geothermal Energy
GTO	(DOE's) Geothermal Technologies Office
HT	high temperature
in.	inch(es)
LOI	Letter of Intent
m	meter(s)
NEWGEN	Newberry Geothermal Energy
PNNL	Pacific Northwest National Laboratory
R&D	research and development
SMT	Site Management Team
STAT	Science and Technology Analysis Team
SubTER	Subsurface Technology and Engineering Research, Development, and Demonstration
TG	temperature gradient

## **L.1 Summary**

Newberry Geothermal Energy (NEWGEN) presents a robust Research and Development (R&D) Implementation Plan to support the establishment and management of the proposed Frontier Observatory for Research in Geothermal Energy (FORGE) on the western flank of the Newberry Volcano, near Bend, Oregon. The R&D Implementation Plan provides the technical vision for effectively planning and managing a process for solicitation, review, and selection of technologies that will be evaluated at the site. A Science and Technology Analysis Team (STAT) will establish formal procedures to ensure that selected technologies directly support the objectives of the U.S. Department of Energy's (DOE's) Geothermal Technologies Office (GTO), and that the process for selecting and evaluating proposals for research is fair, logical, competitive, and consistent with DOE and federal guidelines and regulations.

The NEWGEN Consortium includes public agencies, universities, and private companies to support execution of R&D activities to evaluate enhanced geothermal systems (EGS) technologies at the NEWGEN FORGE site. The site will be dedicated to the subsurface scientific and engineering community for developing, testing, and improving new technologies and techniques to gain a fundamental understanding of the key mechanisms controlling EGS success—in particular, how to initiate, control, image, and sustain fracture networks in basement rock formations using different stimulation technologies and techniques. This critical knowledge will be used to design and test a methodology for developing large-scale, economically sustainable heat-exchange systems, thereby paving the way for a rigorous and reproducible approach that will reduce industry development risk.

NEWGEN envisions NEWGEN FORGE becoming an international research center for EGS, where R&D teams, selected after a competitive and rigorous selection process, will find the infrastructure they need to succeed. NEWGEN will provide the facilities; test wells and materials; logistics; permitting; environmental, safety and health (ES&H) support; physical sample processing; cyber-infrastructure; outreach and engagement; and management structures necessary to execute research at the NEWGEN FORGE site. This includes the efficient operation and competitive distribution of FORGE resources, as well as the archiving, preservation, and dissemination of the data and knowledge gained.

Annual solicitations will be conducted to award 10 to 20 subcontracts for research and technology testing in characterization, drilling, stimulation and reservoir creation, and efficient and sustainable power production. This R&D Implementation Plan outlines a 5-year strategy that focuses initially on characterization and testing that takes advantage of the existing infrastructure, followed by testing of new stimulation and re-stimulation methods, and finally testing of methods to sustain reservoir integrity and produce power. Processes are defined to maintain the integrity of the proposal process, manage potential conflicts of interest, ensure that proposed work meets ES&H requirements, and provide triage support for the proposal process. Site infrastructure will provide the necessary site characterization and monitoring for implementing R&D projects.

The geothermal community will be engaged through annual workshops conducted in Bend to review NEWGEN FORGE progress and engage the community in the next annual solicitation. Information will be disseminated rapidly by providing data in near real time and issuing annual and topical reports on research progress.

## **L.2 Introduction**

NEWGEN FORGE will establish and manage a world-class research observatory dedicated to resolving the key scientific and technical challenges for commercially viable EGS. NEWGEN will engage and support the research community in competitive field laboratory R&D solicitations focused on the

development of subsurface technologies, auxiliary well activities, well characterization and multi-well stimulation technologies, inter-well connectivity, fluid path imaging and dynamic control of flow path physical and geochemical conditions, and long-term reservoir sustainability techniques.

The R&D Implementation Plan provides the technical vision for effectively managing and coordinating support for planning, solicitation, review, and selection of technologies that will be evaluated at the NEWGEN FORGE site. The NEWGEN Directorate in partnership with the STAT will establish formal procedures to ensure that selected technologies directly support the objectives of the DOE's GTO; and that the selection and evaluation process is fair, logical, competitive, and consistent with DOE and federal guidelines and regulations. Here we outline essential elements of this R&D Implementation Plan with the understanding that future engagement and input from the STAT is required prior to implementation.

### **L.3 NEWGEN Organization**

NEWGEN is a public-private consortium between public agencies, universities and private companies that brings world-class breadth and depth of scientific and technical knowledge, with industrial expertise to meet DOE goals for the FORGE project. The NEWGEN Core Consortium is composed of Pacific Northwest National Laboratory (PNNL), AltaRock Energy, Inc., GE Global Research, Oregon State University, and Statoil ASA. The NEWGEN Extended Consortium members include experts from the following institutions, offering a unique combination of assets for R&D of EGS, will also contribute fundamentally to the success of the NEWGEN FORGE: Blade Energy Inc., Cascade Volcano Observatory (U.S. Geological Survey), Cornell University, Lawrence Livermore National Laboratory, Paulsson, Inc., Stanford University, and the University of Oregon.

The NEWGEN FORGE Site Management Team (SMT) is composed of the NEWGEN Directorate, NEWGEN Governing Board, the STAT, and the Site Owner and Stakeholders Advisory Board. The NEWGEN Directorate will carry out technical, financial, and administrative activities, including the scheduling and contracting of subcontractors for standard field services for the safe and cost-effective execution of FORGE and associated testing and evaluation of EGS technologies. In addition, the NEWGEN Directorate will develop and implement formal procedures in accordance with DOE GTO goals and objectives for the FORGE, and review and award EGS technologies for testing and evaluation. Lastly, the NEWGEN Directorate will ensure all applicable state and federal permits have been acquired in support of FORGE activities and that all activities comply with the National Environmental Policy Act and other environmental, health and safety requirements, regulations or laws, including the current version of the Protocol for Induced Seismicity Associated with Enhanced Geothermal System (see Appendices C, J, and K).

The NEWGEN Directorate will be composed of consortium members needed to successfully execute all operations and provide the technical expertise to support all R&D activities executed as part of the project. Led by an Executive Director, the Directorate includes Research and Operations, Geosciences, Engineering, Commercialization, and Communication—all supported by a project management office and by the Extended Consortium with capabilities required to execute FORGE R&D activities.

### **L.4 NEWGEN Technical Vision and Alignment with GTO Objectives and Goals**

The overall objective of the NEWGEN FORGE is to demonstrate transformational science and technology in EGS through research at a world-class field laboratory. The NEWGEN FORGE will be dedicated to the subsurface scientific and engineering community to develop, test, and improve new technologies and techniques for EGS with total respect for the environment. This will allow the geothermal and other subsurface communities to gain a fundamental understanding of the key mechanisms controlling EGS success, and in particular, how to initiate, control, image, and sustain

fracture networks in basement rock formations using different stimulation technologies and techniques. This critical knowledge will be used to design and test a methodology for developing large-scale, economically sustainable heat-exchange systems, thereby paving the way for a rigorous and reproducible approach that will reduce industry development risk. Specific goals of FORGE are as follows:

- Establish a laboratory for EGS technological development that will be accessible to researchers and developers through a rigorous peer-review process;
- Reduce the cost of producing EGS power to economically sustainable levels, while building broad fact-based support for EGS among disparate stakeholder communities;
- Provide comprehensive instrumentation and data collection that will capture a higher-fidelity picture of EGS creation and evolution processes than any prior demonstration in the world;
- Allow highly integrated comparison of technologies and tools in a controlled and well-characterized environment;
- Rapidly disseminate technical data to the research community, developers, and other interested parties.

We envision NEWGEN FORGE becoming an international research center for EGS, where the research teams, selected after a competitive and rigorous selection process, will find the infrastructure they need to succeed. NEWGEN will provide the facilities, test wells and materials, logistics, permitting, ES&H support, physical sample processing, cyber-infrastructure, outreach and engagement, and management structures necessary to execute research at the NEWGEN FORGE site. This includes the efficient operation and competitive distribution of FORGE resources, as well as the archival, preservation, and dissemination of the data and knowledge gained.

Newberry Volcano has already been demonstrated to be extremely favorable for EGS technologies and the development of engineered fracture networks in very low permeability media (see Appendix A). The site is perfectly suited for FORGE based on its unique combination of natural attributes and existing infrastructure. An ideal temperature profile of 175°C and 225°C at a depth range of between 1750 and 2250 m has already been confirmed at the site via measurements in multiple deep wells. The existing boreholes cut across multiple rock types will enable NEWGEN to meet DOE's goal to develop EGS technologies that are generally applicable to many locations. NEWGEN's geological model builds on more than 40 years of intensive characterization work at the Newberry Volcano site (see Appendix A). Perhaps the greatest attribute of the site is the extensive infrastructure and site characterization history that is already in place, including three pads with sumps, two deep geothermal wells, two water wells with corresponding water rights, a microseismic network, 11 boreholes (6 in. diameter, ~250 m deep), stimulation pumps and several decades of geothermal exploration and site characterization activities. Field activities could commence immediately because a full set of permits are already in place.

Information gained at the NEWGEN FORGE site will be widely applicable across the Cascade Volcano chain, as well as other magmatically active areas across the western United States, and more broadly throughout the entire Pacific Rim, including Alaska and Hawaii. Specifically, direct transfer of knowledge and technologies demonstrated at the NEWGEN FORGE site are important elements of communications and outreach (see Appendix G) and commercialization efforts.

NEWGEN's R&D strategy will incorporate the best input from scientific and geothermal industry to define the most critical science and technology areas for targeted innovation under the FORGE project. The NEWGEN FORGE will be guided by two core tenets:

- FORGE-demonstrated technologies will not only enable development of greenfield EGS projects in the long term, but will also provide short-term benefits to existing geothermal operations. They will

both facilitate rehabilitation of underperforming existing geothermal wells and lower the risk of expanding existing geothermal fields into areas of low permeability that cannot currently be economically developed. These near-term applications must be considered during FORGE operations and research to promote adoption and tuning of EGS technologies by the geothermal industry.

- EGS has been around since the 1970s, but has not achieved its promise due to economic and technical barriers that will require creative, interdisciplinary thinking to overcome and to commercialize EGS. New technologies will need to come from outside the established geothermal community, and in particular, from the oil and gas industry. In this respect, a close relationship will be established and maintained with the DOE subsurface crosscut program, SubTER (Subsurface Technology and Engineering Research, Development, and Demonstration), which was launched in 2015.

In particular, following the 2013 GTO roadmap for strategic development of EGS the NEWGEN FORGE will promote and implement R&D in four main categories:

- **Better Characterization**

- *In situ* stress measurements
- Near-well fracture mapping
- Reflection seismology in crystalline rocks (fracture zone mapping and targeting)
- Tracers and active seismic sources (fracture zone mapping)
- Electromagnetic and ground deformation sensing (fluid infiltration monitoring)

- **Better Drilling**

- Technologies to assure wellbore integrity
- High-temperature (HT) steerable hard-rock drill bits
- Multilaterals/microholes

- **Better Stimulation**

- Technologies to fracture rock and maintain permeability that use less water and less toxic chemicals
- HT proppants, HT non-toxic gels to place proppants

- **More Efficient and Sustainable Power Production**

- HT pumps, flexible binary power plants
- Flexible binary power plants
- Controlling temperature break-through, short circuit repair
- Re-drills, re-stimulation.

These four research objectives all contribute to the ultimate goal of NEWGEN FORGE R&D efforts to design and test methodologies for large-scale economically sustainable heat-exchange systems, resulting in an approach for EGS development that reduces risk for industry. However, while progress in all categories is needed, there are complex interdependencies, multiple proposed solutions, and conflicting priorities within the research community. In order to systematically and efficiently address these research objectives and maintain alignment with DOE GTO research priorities and objectives, the NEWGEN FORGE will implement a science advisory panel of leaders in geothermal research. This panel is described in the following section.

## **L.5 Science and Technology Analysis Team**

NEWGEN will implement a STAT that provides scientific leadership and assures that the high-impact science and technology selected for implementation at the NEWGEN FORGE aligns with DOE GTO research objectives. The STAT also represents the geothermal research community—those that who respond to FORGE R&D solicitations.

### **L.5.1 Composition and Meetings Schedule**

The STAT comprises world leaders in geosciences, oil and gas, and geothermal energy technologies. The current plan is for a group of nine members appointed for two-year renewable terms, with three members appointed by DOE and six members appointed by the NEWGEN Governing Board. NEWGEN has already received letters of interest from world scientific leaders in relevant fields. The Chair of the STAT is elected by her/his peers and the NEWGEN Executive Director and Directors are Ex Officio members with non-voting seats. The current plans are for two plenary sessions per year and monthly tele-conferences with the NEWGEN Directorate. Additional meetings or ad-hoc sub committees could be formed based on STAT discussions to address STAT roles and responsibilities and NEWGEN FORGE needs.

### **L.5.2 Roles and Responsibilities**

The NEWGEN FORGE STAT will provide overall technical guidance and ensure GTO objectives are fully considered and incorporated into the execution of FORGE and associated R&D field projects. This will be accomplished through STAT engagement in several key activities:

- Assessment of R&D needs in accordance with GTO roadmaps and goals, leading to development of topics for recurring FORGE R&D solicitations.
- Review and select R&D projects, including establishing review criteria and proposing reviewers.
- Establish the technical baseline information and performance specifications, as needed, for the R&D field projects and guide ongoing site characterization and monitoring efforts.
- Assess the progress and results of all R&D technology and techniques implemented at the NEWGEN FORGE site to assure that the initial STAT objectives are being met by the selected R&D field projects.
- Identify potential opportunities for improvement in both topics for recurring FORGE R&D solicitations and alignment with DOE GTO objectives.
- Provide input to the NEWGEN FORGE Directorate for development of annual topical reports and partner with NEWGEN FORGE leadership to develop out-year R&D strategies.

## **L.6 NEWGEN R&D Solicitation and Implementation**

Of principal interest to the NEWGEN FORGE is the implementation of R&D field projects. These R&D projects need to be selected based on science and technology objectives that align with DOE GTO objectives and goals. The STAT will aid in this effort by providing input to the science objectives and R&D proposal selection, as described below.

### **L.6.1 R&D Project Science and Technology Objectives**

Science and technology objectives need to be established in partnership with the STAT prior to each solicitation of proposals for the NEWGEN FORGE. Members of the geothermal research community who

will respond to the solicitation also need to be engaged in establishing these objectives. The NEWGEN FORGE communication strategy addresses this in some detail (see Appendix D). This outreach is accomplished by leveraging the NEWGEN FORGE communication strategy. Briefly, NEWGEN will facilitate engagement regarding the solicitation objectives by conducting FORGE-specific workshops, making presentations at relevant conferences and meetings, and pursuing targeted engagement with research community leaders. The STAT is expected to provide additional input and guidance.

The overall aim of the annual NEWGEN FORGE solicitations are to award 10 to 20 subcontracts for research and technology testing in the EGS categories of 1) characterization, 2) drilling, 3) stimulation and reservoir creation, and 4) more efficient and sustainable power production described above. The current outline for the 5-year NEWGEN FORGE strategy to meet these science and technology objectives is as follows (Figure L.1):

- Year 1 – Fracture network imaging testing and demonstration projects on NWG 55-29, which was previously drilled and stimulated; well design development followed by drilling technology demonstration and testing NWG 46-16.
- Year 2 – Field demonstration of recent developments; well NWG 46-16 innovative stimulation projects, possibly at multiple depths; demonstration of innovative geophysical and geochemical monitoring and imaging techniques.
- Year 3 – Continued implementation of novel reservoir stimulation\re-stimulation technologies and methodologies (e.g., non-hydraulic, multi-zone, and simultaneous stimulation of multiple wells); design and drilling of auxiliary well(s) for R&D complementary to the primary EGS wells.
- Year 4 – Design and drilling of a production well; flow measurement experiments; initiation of reservoir sustainability testing; continue deployment of innovative geophysical and geochemical monitoring and imaging techniques.
- Year 5 – Characterization of reservoir and demonstration of long-term reservoir sustainability techniques; testing and evaluation of innovative power generation technologies tailored to EGS resources.

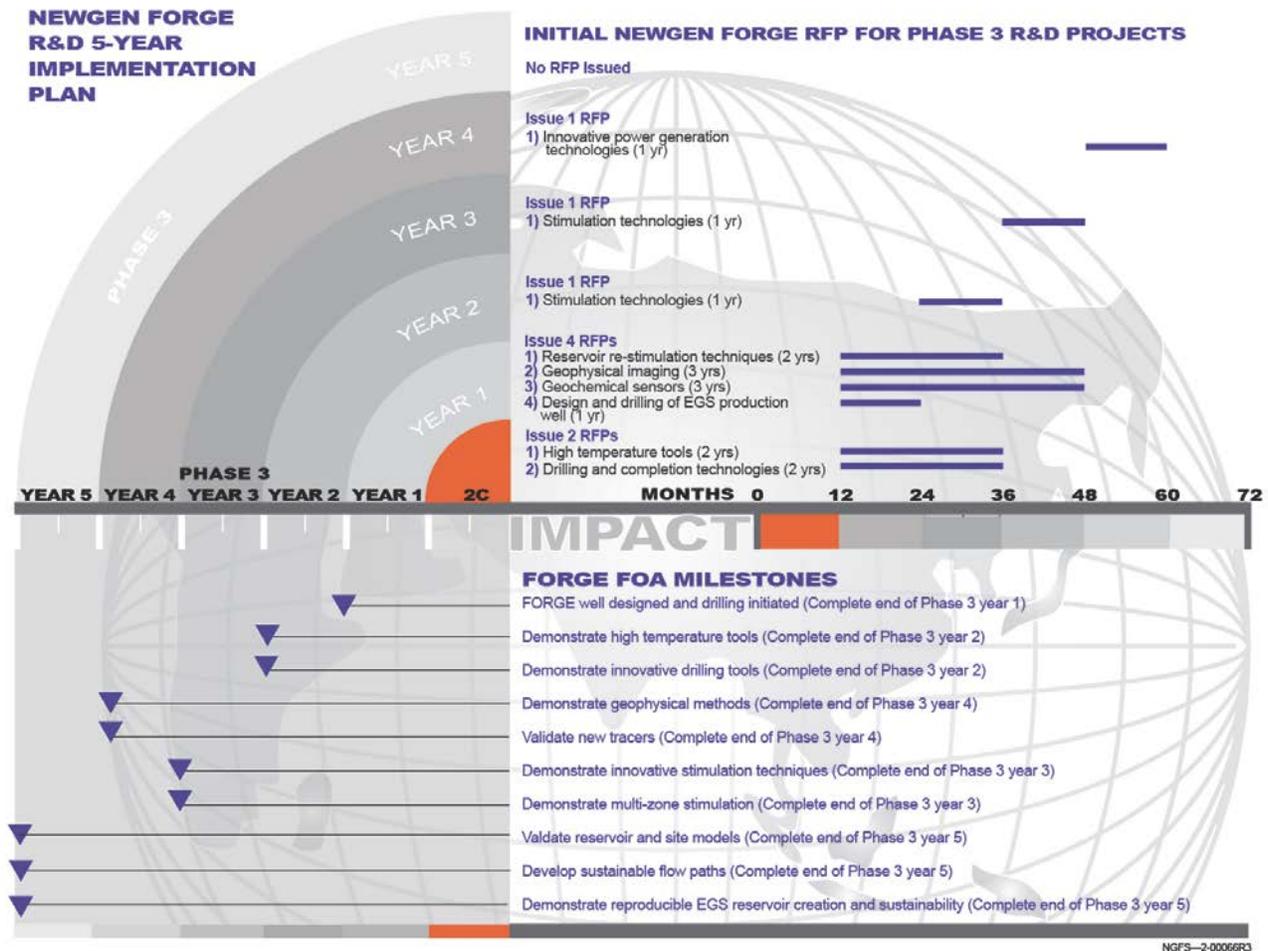


Figure L.1. NEWGEN FORGE R&D Implementation Plan.

## L.6.2 R&D Proposal Selection

NEWGEN Directorate implement the FORGE R&D solicitations based on the topics defined by the STAT. The first step of the solicitation process will consist of issuing a call for submission of Letters of Intent (LOIs). The LOIs will be reviewed by both the STAT and the NEWGEN Directorate to identify the ones that will be encouraged submit full proposals. This process is illustrated in Figure L.1 and described in greater detail below.

Prior to each call announcement, NEWGEN Directorate will determine the resources available for calls. Resources include FORGE capabilities supporting R&D projects such as those described below in Section L.6; carry-over R&D projects from prior years; and any staffing or other resource constraints. The 5-year FORGE science strategy for the annual solicitations is described above. This plan will be revised by the NEWGEN Directorate between solicitations. Combined, the available resources and science strategy provide the basis for the NEWGEN to develop the objectives for the annual solicitation.

These objectives and other annual solicitation requirements will be effectively communicated to the geothermal research science and technology community (see Appendix G). Potentially, during the last 3 months of Phase 2C, an initial scientific workshop will be held in Bend, Oregon, to present the NEWGEN FORGE site, facilities, and mode of operations. The solicitation schedule, requirements, and

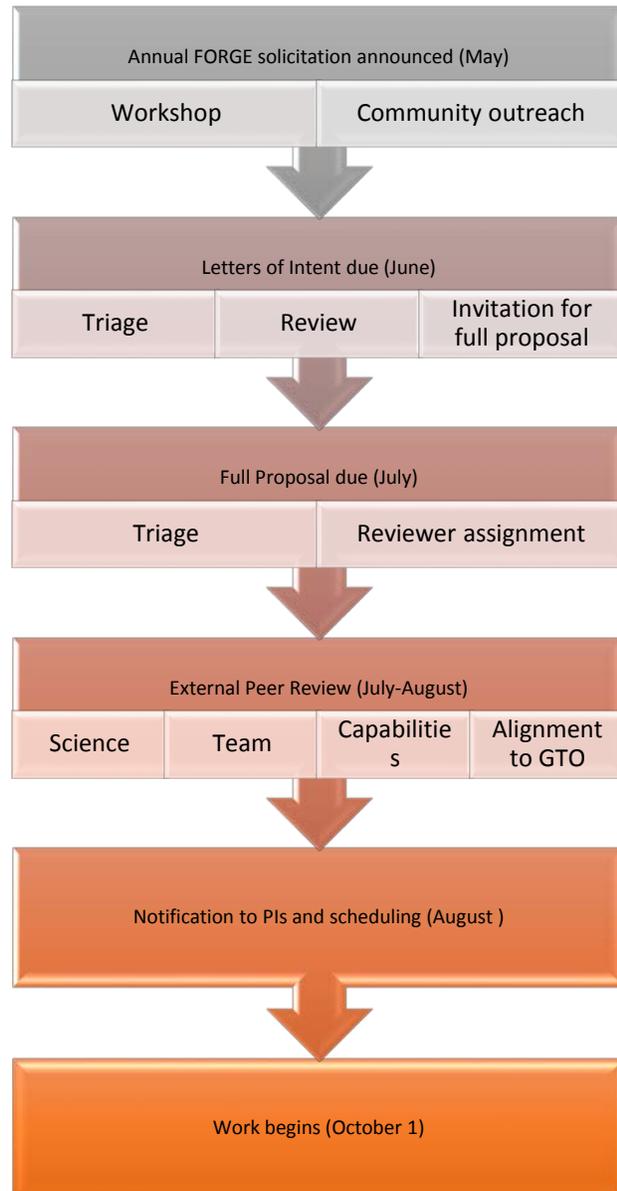
process will be presented at the workshop and described on the NEWGEN FORGE website. The Year 1 solicitation will be described at the workshop. This will enable R&D projects to be initiated at the start of Phase 3.

The NEWGEN FORGE proposals process will consist of an announcement and a call for submission of a LOI from potential R&D performers. One month between the announcement and submission of the LOIs will be provided for potential responders to develop research ideas and establish any needed partnerships. The LOI will require sufficient information to determine responsiveness to the call, but less information than will be required for evaluation of the full proposal. The LOI review for responsiveness has a great deal of flexibility. The minimum is typically if the LOI appears to meet the science objectives described in the solicitation. This review will be performed by the NEWGEN Directorate. Potential conflicts of interest will be identified at this stage, conflicted parties recused from the review process, and advice taken from STAT and GTO on appointing substitute reviewers or, where appropriate, substitute NEWGEN Directorate members to oversee the review process.

Additional requirements will include other factors such as permit compliance (see list below). The NEWGEN Directorate will offer proposal triage to assist with ones that have potential, but have issues that need to be addressed. The LOI review is intended to potentially reduce the total number of proposals needing full development and review.

Following the LOI review, selected teams will then submit full proposals. Evaluation of these proposals will proceed through several stages to better ensure that selected proposals can be successfully implemented with minimal unforeseen challenges. The full proposal triage evaluates proposals for any significant challenges for implementation based on a more complete description and in-depth review by the NEWGEN Directorate including the Deputy Director for R&D Operations and the Deputy Director for Site Operations to review the proposals for ES&H considerations. Evaluation criteria will be refined by the NEWGEN Directorate, but will include items such as

- permit compliance



**Figure L.1.** Annual NEWGEN FORGE solicitation process.

- constraints and impact to current or future activities
- safety concerns
- public/environmental acceptance
- technical feasibility.

Each proposal that passes the proposal triage, will then be reviewed for scientific and technical impact by STAT. Typical criteria include

- alignment with GTO objectives
- qualifications of the team
- responsiveness to the call.

Review criteria and weighting will be published as part of the solicitation process and will always be readily available to proposal teams prior to submission.

The NEWGEN Directorate will award proposals considering available resources, and resolve priority and access constraints, e.g., proposal A needs to be completed before proposal B. The STAT will review proposals selected to be awarded.

### **L.6.3 R&D Project Implementation**

Execution of the NEWGEN FORGE R&D projects will be a partnership between the R&D Performers and NEWGEN Directorate. The NEWGEN Directorate will provide logistical and technical support for implementation of R&D projects. Updates on R&D projects will be provided to the STAT and DOE including an annual R&D proposal progress evaluation. Underperforming R&D projects will be slowed or halted to make additional resources available to other R&D projects or future solicitation responders. The NEWGEN Directorate also will establish and describe the process for managing conflicts of interest between participating members, including between different R&D field projects. NEWGEN will deploy processes and software for advanced external peer-review proposal processes, developed for the Environmental Molecular Sciences Laboratory and adopted by the National Renewable Energy Laboratory for use at the Energy Systems Integration Facility.

The subsurface geothermal research community is highly collaborative and in an effort to have the world experts compose the STAT, NEWGEN FORGE Directors and Consortium participants, external reviewers, and R&D project proposers, there is significant potential overlap of individuals and organizations between these various interests. There are only so many world experts, particularly for some of the specific FORGE science and technology objectives. This suggests a significant potential for conflicts of interest during the R&D project selection and implementation. As is generally practiced, during the selection process reviewers and other participants will self-identify potential conflict of interest situations and mitigate the conflict as appropriate. For example, if one of the reviewers is a collaborator of one of the applicants and felt there was potential for conflict of interest, they would recuse themselves from the review of that particular proposal.

In addition, the impacts of conflict of interest will be minimized by a number of processes adopted by the NEWGEN FORGE project. For example, the scientific and technical review of the full proposals will be performed by a panel of external reviewers nominated by the STAT and selected by the FORGE directors. Selection will be based on availability, scientific expertise, but also based on a concerted effort to minimize conflicts of interest (COIs) with research teams that have submitted proposals. The NEWGEN FORGE COI guidelines will follow those of the DOE Ethics and Conflict of Interest Guidance adopted for DOE Advisory Committee Members, following the terms of 41CFR Parts 101-6 and 102-3, or amendments or successor regulations as they are adopted. Those submitting R&D proposals, as well as those reviewing the proposals or participating in NEWGEN will be required to submit COI disclosure

forms that are consistent with those distributed to DOE review team members. NEWGEN members will be required to take COI training prior to their involvement in proposal review processes.

As part of the COI disclosure requirements, R&D project proposers will include a list of individuals and organizations with whom they have significant collaborative efforts as part of the proposal submission package. This will identify potential COIs from an alternative perspective. Each proposal will be reviewed by a primary and two secondary reviewers not included on the collaborator list.

In situations where potential COIs come to light after the proposal process or cannot be mitigated through selection of alternative reviewers due to limited availability, the reviews submitted by a particular individual or panel will be evaluated for COI bias by a committee selected by the NEWGEN FORGE Executive Director. The COI situation will be reported to GTO, as will the COI mitigation strategy. Such panels typically consist of three individuals selected from project management office directors, chief science officers, and science and technology leaders that could be internal or external to NEWGEN FORGE or consortium members as appropriate. For example, if the bias to be evaluated is between two external parties, internal panel members would be appropriate. These panels will then evaluate whether evidence of bias is sufficient to warrant additional corrective action. For example, if there were concerns about a particular reviewer, reviews and scores from this reviewer relative to others and historical norms could be evaluated for evidence of significant deviations.

## **L.7 Baseline Characterization, Monitoring, and Site Infrastructure to Support R&D Projects**

The execution of the R&D projects and achievement of NEWGEN FORGE science objectives leverage an extensive collection of capabilities that compose the world-class NEWGEN FORGE field laboratory. This includes continued characterization and monitoring of the NEWGEN FORGE site, new capabilities to support R&D project impacts, and the extensive NEWGEN FORGE infrastructure. An overview of characterization and monitoring efforts by NEWGEN and contributions by R&D teams is provided below.

### **L.7.1 Characterization and Monitoring by NEWGEN**

Characterization and monitoring efforts will include the following:

- Continuously update the geological model.
- Conduct additional geophysical surveys (deformations, seismic reflection, gravity, magnetotelluric, electrical resistivity tomography).
- Develop fully coupled fluid flow and geomechanical models tailored to the NEWGEN FORGE site to test various well geometry and stimulation and completion scenarios before their field implementation.
- Further investigate the existing EGS reservoir (2014 EGS stimulation).
- Core out two or more of the temperature gradient (TG) holes (NN07, NN19, NN24) to a depth of 1500 m (~5000 ft); consider coring at least one TG hole to a depth of 3000 m (~9800 ft) to support borehole-to-surface and cross-borehole electrical resistivity tomography imaging.
- Perform seismic velocity calibration and in situ stress testing (mini-frac) in borehole(s).
- Permit more than 1000 instrument monitoring locations (variety to be determined) above the stimulation zone(s).

- Conduct continuous monitoring of seismicity and of long-term geofluid flow using both current and state-of-the art technologies (surface/downhole electrical resistivity and seismic tomography; magnetotellurics/controlled source electromagnetic methods, ground deformation monitoring, and reactive tracers).

## **L.7.2 Characterization and Monitoring Contributions by the R&D Teams**

R&D teams will

- Integrate the knowledge gained during each R&D project after authorization of the leading team or after the end of the embargo period.

## **L.7.3 Site Infrastructure**

Infrastructure at the NEWGEN FORGE site will include the following:

- three well-equipped pads and two full-sized geothermal wells
- well design that will be based on subsurface characterization efforts carried out during Phases 1 and 2, and will be optimized for in situ state of stress. The wells will be capable of testing a wide variety of reservoir creation and imaging technologies. New drilling can begin on any of the three pads in first year of Phase 3.
- seismic network of 15 borehole stations (7 new ones)
- auxiliary boreholes to test new monitoring tools
- deep monitoring horizontal wells for seismic monitoring and/or electric source
- innovative multi-lateral completions will be designed by drilling experts on consortium team
- oil and gas techniques should be melded with traditional EGS techniques
- horizontal drilling, multi-lateral completions
- advanced well completions and downhole control, advanced instrumentation
- fracture initiation and near wellbore permeability enhancement.

## **L.8 Data Sharing and Reporting**

Significant challenges and opportunities exist for the collection and sharing of the extensive and diverse measurements associated with NEWGEN FORGE site and R&D projects. An extensive data collection and dissemination plan has been developed and will be implemented. Below, R&D project data collection, released, and reporting are briefly discussed. The data collection and dissemination plan is described in greater detail in Appendix F.

### **L.8.1 Data Collection and Release**

NEWGEN FORGE supports the R&D projects by implementing a data collection and release strategy that can address the diverse data required to achieve FORGE science objectives. Many experiments benefit from real-time access to characterization and monitoring data from the NEWGEN FORGE site. This is achieved through the NEWGEN data system described in Appendix F. R&D projects will leverage different NEWGEN FORGE data assets, however, and the projects will broadly benefit from real-time sharing of characterization and monitoring data. In addition, the annual dissemination of data, physical samples, and results from drilling operations will provide significant benefits to the R&D projects. The



data will be made available by the NEWGEN team and R&D projects after authorization of the R&D team or after the end of the embargo period. In general, the embargo period is 1 year. Not only will the NEWGEN FORGE R&D projects benefit from this annual dissemination of data and results, but the geothermal research community generally will benefit.

## **L.8.2 Reporting**

In addition to the annual dissemination of data, physical samples, and results, a series of reports will be released as determined by the NEWGEN Directorate, which will include input from the STAT representing the research community and DOE GTO interests. The NEWGEN Directorate will identify annual topical reports and the process for reporting R&D project results. Such reports will include an update on site conditions and a summary of monitoring information. R&D project reports will include progress on objectives, risk mitigation strategies, remaining technical challenges, and the strategy for moving forward. Both NEWGEN FORGE and R&D reports will include information about lessons learned and best practices to share with the general community. These reports will be made available to the research community. In addition, these reports will be presented at an annual scientific workshop in Bend, Oregon. This presentation of prior results and reports will then be followed by the announcement of the next FORGE annual solicitation and presentation of the objectives and requirements for the solicitation.