PROTOCOL VOLUME IV

SOCIOECONOMIC ASSESSMENT TOOL

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Prepared for:

The U.S. Department of Energy, Geothermal Technologies Office

GeoRePORT Protocol Volume IV: Socioeconomic Assessment Tool

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Suggested Citation
Levine, Aaron and Katherine R. Young. 2019. GeoRePORT *Protocol Volume IV: Socioeconomic Assessment Tool*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-72933. https://www.nrel.gov/docs/fy19osti/72933.pdf.

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Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-6A20-72933
September 2019

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Golden, CO 80401
303-275-3000 • www.nrel.gov

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This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Geothermal Technologies Office. The views expressed herein do not necessarily represent the views of the DOE or the U.S. Government.

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ACKNOWLEDGMENTS

This work was authored in part by the National Renewable Energy Laboratory (NREL), operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Geothermal Technologies Office. The views expressed herein do not necessarily represent the views of the DOE or the U.S. Government.

This work was also supported by the U.S. Department of Energy with Lawrence Berkeley National Laboratory (LBNL) under Contract No. DE-AC02-05CH11231.

The authors wish to thank Pierre Audinet (World Bank); Casey Strickland (DOE); Jeff Jones (U.S. Forest Service); Charlene Wardlow; David Batts (Environmental Management and Planning Solutions, Inc.); Laurie Hietter (Panorama); Paula Blaydes; Lorenzo Trimble (U.S. Bureau of Land Management); Colin Williams (U.S. Geological Survey); Karl Gawell (Geothermal Energy Association); Ben Matek (Geothermal Energy Association); Eric Hass (DOE); Brittany Segneri (Allegheny Science & Technology); Andy Sabin (Navy Geothermal Program); and numerous other participants for their insights and suggestions relating to this study.

The Geothermal Resource Portfolio Optimization and Reporting Technique (GeoRePORT) is a product of the considerable effort of many parties. Analysts at NREL, LBNL, and New West Technologies have spent several years deeply involved in research, meetings, outreach, reviews, and workshops, and analyzing and negotiating content to find solutions to divergent views.

The six documents of the GeoRePORT Protocol reflect the intellectual contributions of these many players. These end products have been enabled because of a shared vision that this work can make a significant contribution toward understanding and communicating available geothermal resources and advancing geothermal deployment.

LIST OF ACRONYMS

BLM	U.S. Bureau of Land Management
CAGR	cumulative annual growth rate
DOE	U.S. Department of Energy
EA	environmental assessment
EIA	U.S. Energy Information Administration
EPAct	Energy Policy Act of 2005
FERC	Federal Energy Regulatory Commission
FIT	feed-in tariff
GAT	Geological Assessment Tool
GeoRePORT	Geothermal Resource Portfolio Optimization and Reporting Technique
LBNL	Lawrence Berkeley National Laboratory
MOU	Memorandum of Understanding
NEPA	National Environmental Policy Act of 1969
NREL	National Renewable Energy Laboratory
NVNM	Newberry Volcano National Monument
PHMA	Priority Habitat Management Area
PPA	power purchase agreement
RPS	renewable portfolio standard
SEAT	Socioeconomic Assessment Tool
SHPO	State Historic Preservation Office
USFS	U.S. Forest Service

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I. PRINCIPLES OF THE METHODOLOGY

The Geothermal Resource Portfolio Optimization and Reporting Technique (GeoRePORT) system is based on the concept that a geothermal system can be described both in terms of the quality of the geothermal resource as it relates to the potential to extract heat (resource grade) and the progress of research and development over the lifetime of the project (project readiness level).

By assessing the major characteristics of a geothermal resource, categorizing the techniques used, and evaluating how well the research techniques were implemented, users can report a **resource grade** covering multiple geological, technological, and socioeconomic attributes that can be compared across play types and geothermal areas. The grade of each resource is intended to be refined, if needed, as new and better information is collected and interpreted.

By assessing the exploration and development activities of the project, users can report on past and planned incremental **project readiness levels**. Like the resource grade, the project readiness level will continually be updated throughout the project lifetime.

Resource grade and project readiness level are reported for three assessment categories: geologic, technical, and socioeconomic. Each category has specific criteria and guidelines for assessing both resource grade and project readiness level, as outlined in each of the following assessment tools (and associated colors):

- **Geological Assessment Tool** (representative color: red)
- **Technical Assessment Tool** (representative color: blue)
- **Socioeconomic Assessment Tool** (representative color: green).

These assessment tools are written for geothermal community professionals assigned to report the resource grade and project readiness level to the U.S. Department of Energy (DOE). Therefore, it is assumed that:

- The exploration activities described below will be planned, executed, and interpreted by skilled geoscientists.
- Preparers of reports using the GeoRePORT Protocol are knowledgeable of geothermal systems and the different exploration activities. The guidance in these documents does not replace intelligent expertise in preparing, selecting, and interpreting data.

For additional background on the GeoRePORT Protocol, see the Background Document.

II. PROJECT READINESS LEVEL

The GeoRePORT Protocol breaks the concept of project readiness level into ordered categories. As projects progress from one development phase to the next, they pass through "activity thresholds"—minimum activities required to qualify for the next category.

DEFINING SOCIOECONOMIC PROJECT READINESS LEVEL

Socioeconomic Project Readiness Level is an assessment of the development of a geothermal area as a power generation facility. Five separate progression levels ranging from "unknown/uneconomic" to "secured" are designated, with criteria specific to socioeconomic development that must be completed to move up the scale, as outlined in Table 1.

Table 1. Criteria to Move Between Levels of Technical Project Readiness Level

Socioeconomic Project Readiness Level		Qualifying Criteria
S1	**Unknown/ Uneconomic**	Resource undeveloped. For a resource to be considered "Unknown/Uneconomic," *one* of the following criteria must be met: 1. No site environmental (including a biological assessment and cultural resources study) or transmission interconnection analysis. 2. Site evaluated and determined not to have economic potential (e.g., development unallowed, or having significant barriers).
	Leasing and Transmission Analysis Complete	
S2	**Feasible**	For a resource to be considered "Feasible," *all* of the following criteria must be met: 1. Environmental analysis required for leasing complete and the land is available for leasing or a lease is secured. 2. Transmission interconnection analysis complete and determined to be economically feasible. 3. Site evaluated and determined to have economic potential.
	Exploration and Drilling Permits Approved	
S3	**Likely**	For a resource to be considered "Likely," the following criterion must be met: 1. Permits approved for exploration (e.g., Notice of Intent) and well field drilling (e.g., Geothermal Drilling Permit), which includes associated environmental analysis.
	Well field drilled and Power Purchase Agreement Secured	
S4	**Commercial**	For a resource to be considered "Commercial," the following criteria must be met: 1. Approval of a Utilization Plan for construction and operation and a Commercial-Use Permit (if on a federally managed mineral estate), AND 2. Approval of any state- or local-level permits/approvals for construction, operation, and sale of the resource. OR 3. Power purchase agreement secured with off-taker.

	Plant Development	
S5	**Secured**	For a resource to be considered "Secured," the resource must receive all necessary approvals from any federal and state authorities. The following criteria must be met: 1. Approval of a Utilization Plan for construction and operation and a Commercial-Use Permit (if on a federally managed mineral estate). 2. Approval of any state- or local-level permits/approvals for construction, operation, and sale of the resource. 3. Power purchase agreement secured with off-taker.

The **socioeconomic project readiness level** is meant to indicate whether the activities conducted in an area resulted in the identification of an economic geothermal reservoir that can obtain all of the necessary permits and approvals from federal, state, and local regulators. Choose the level of progress that best describes the successful socioeconomic progress that has occurred to date.

The GeoRePORT recognizes that a single axis cannot describe a viable geothermal resource. In this protocol, the project readiness level is determined by the combination of the geological, technical, and socioeconomic project readiness levels. Figure 1 below shows graphically the relationship between these combined project readiness levels. For more information on the Technical and Geological Progress Readiness Levels, please refer to the Background Document and the associated Assessment Tools.

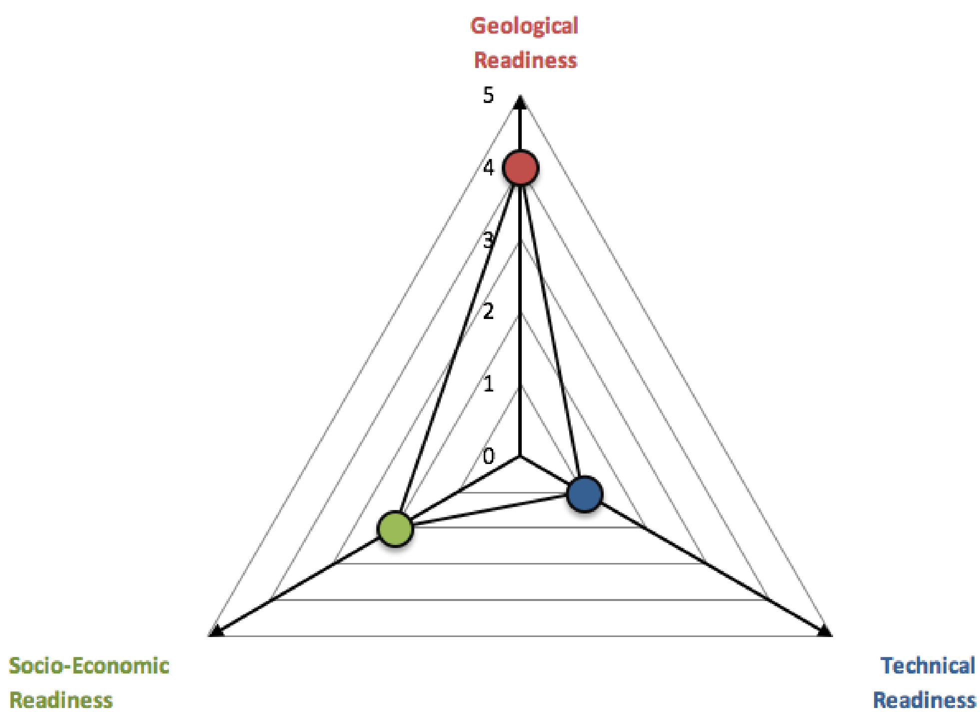

Figure 1. Depiction of socioeconomic progress in relationship to other forms of project readiness level

III. RESOURCE GRADE

The attributes used by this protocol to describe a geothermal resource include the constraints on the quality of the geothermal resource as well as the geological and socioeconomic characteristics that determine whether the heat can be produced.

Each attribute is ranked on a scale of A through E, with A indicating the highest of the range of values for that attribute. ***An attribute grade of A is not necessarily the "best" value for a specific project goal.*** Some business models or plant designs may target grades lower than A for some or all of the attributes. Each developer must evaluate which grades are appropriate for his or her target business model. Resources with all attribute grades equaling A rarely exist.

SOCIOECONOMIC ATTRIBUTES

The Socioeconomic Assessment Tool (SEAT) encompasses four attributes: Land Access, Permitting, Transmission, and Market. Each of these attributes includes sub-attributes that, when combined, provide a character grade for each attribute.

COMPONENTS OF SOCIOECONOMIC GRADE

In addition to the attributes listed above, the GeoRePORT also considers the activities conducted to understand each attribute, and what is known about the quality of the data collected. The methodology breaks each attribute into three separate indices describing distinct features of each attribute, outlined in Table 2. Note that the third column contains simple examples from the SEAT.

Table 2. Indices Used to Describe Resource Grades: Character Grade, Activity Index, and Execution Index

Index	Description	Example
Character Grade	Used to describe the character itself—i.e., what is the intrinsic measurement that best describes the geothermal socioeconomics?	Does the project impact no biological resources (Grade A), or is the project in a Sage Grouse Priority Habitat Management Area (PHMA) Focal Area (Grade E)?
Activity Index	Qualitative ranking of activities used to assign the character grade appropriate for each attribute—i.e., how well is the character grade known?	Has the project not started permitting process (Grade E), or have all permits for the power plant and ancillary facilities been approved (Grade A)?
Execution Index	Compares the diligence with which the activity was executed—i.e., how much do we know about the quality of execution of that activity?	Though this is used for the geological and technical assessments, the execution index is not used for socioeconomic grades.

For each attribute, the **character grade** uses quantitative and qualitative measurements that describe the current project within the range of possible outcomes found in geothermal resources and projects.

When evaluating a resource's attribute character grade, there are sometimes multiple aspects of the attribute that contribute to its grade. To assess these multiple aspects, **sub-attribute** indices have been developed for applicable components of the technical grade. For example, when considering the *land access* attribute, we look at several sub-attributes, such as cultural and tribal resources or environmentally sensitive areas.

To determine an attribute's character grade, first evaluate each sub-attribute. Each sub-attribute (SA in the formula below) is given a weight (wt) that was derived based on discussions with industry experts who determined the relative significance of the specific sub-attribute. The total attribute-weighted sum would be calculated as:

$$\text{Sub-attribute-weighted sum} = SA_1{*}wt_1 + SA_2{*}wt_2 + SA_3{*}wt_3 + \ldots + SA_n{*}wt_n \qquad \textit{(eq 1)}$$

The range of sub-attribute-weighted sums is then broken down into grades A–E for each attribute. For example, for *Land Access*, the minimum weighted sum (if all grades are A) is 7, while the maximum weighted sum (if all grades are E) is 38. The breakdown of grades based on weighed sum is as follows:

Land Access Grade	Sub-Attribute-Weighted Sum
Grade A	7–14
Grade B	15–21
Grade C	22–28
Grade D	29–35
Grade E	36–38

The **activity index** describes the common activities used to understand the character attributes—both directly (measured values) and indirectly (by proxy). Activity sub-indices are used to evaluate sub-attribute grades. The **execution index** describes how well the activity was implemented. During the exploration process, activities are performed (activity index), the quality of the data is determined (execution index), and the outcome is reported (character grade). Note, the socioeconomic attributes *do not* utilize the execution index.

These four attribute grades, and their associated activity and execution indices, can be displayed graphically in a polar-area chart (Figure 2). The dark wedges indicate resource grade (what is your resource like?); the light wedges indicate certainty (how much do you trust the data?). For more information, please see the Background Document.

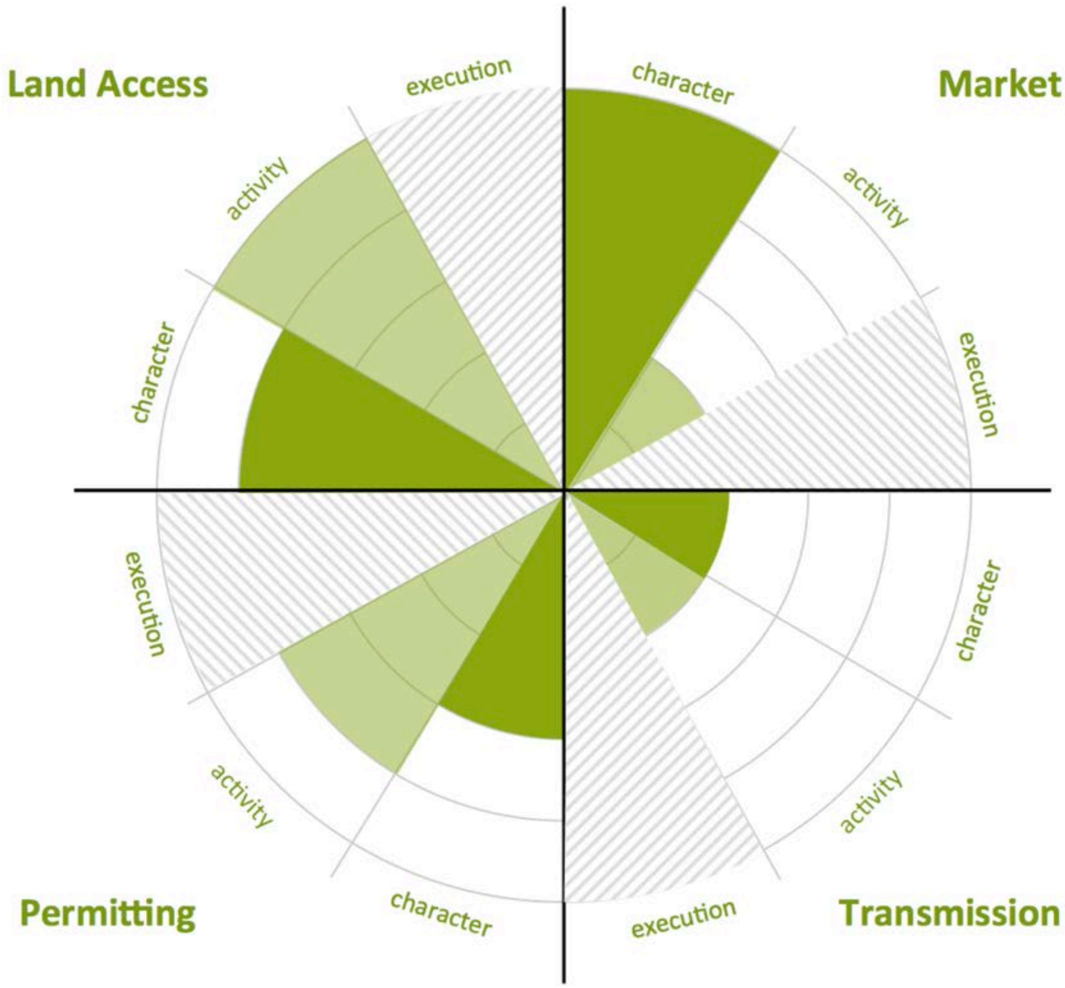

Figure 2. Combined socioeconomic grade diagram of a hypothetical project

As a reminder, this Protocol was developed to provide consistency among the user community in *reporting*; it is neither a prescription for conducting exploration and field development, nor a replacement for expertise and conceptual or reservoir models.

Refer to the Geological Assessment Tool and Technical Assessment Tool for details on the factors relevant to geological and technical grades.

ATTRIBUTE: LAND ACCESS

Understanding the challenges of accessing land for geothermal development is important, because environmental assessments and private and public leases can take a considerable amount of time and delay or prevent project development. Recent studies (Young et al. 2014) showed that the presence of certain resources and/or previous land uses could cause projects to be delayed several years or more.

Attribute Character Grade

The land access character grade is composed of six sub-attributes. These sub-attributes take into consideration multiple aspects of securing land to develop a project and allow users to assign a character grade based on those individual sub-attributes.

The sub-attributes and their associated weights are shown in Table 3 and are described in more detail below.

Table 3. Land Access Sub-Attribute Weights

Sub-Attribute	Weight
Cultural and Tribal Resources	2
Environmentally Sensitive Areas	3
Biological Resources	3
Federal and State Lease Queue	2
Land Ownership	1
Military Installations	1

The six sub-attribute grades are combined into a single resource grade using the sub-attribute-weighted sum ranges outlined in Table 4.

Table 4. Land Access Character Grade: Sub-Attribute Weighted Sum Ranges

Grade	Sub-Attribute-Weighted Sum	Description
A	12–18	Ideal land access conditions
B	19–30	Favorable land access conditions
C	31–42	Challenging land access conditions
D	43–53 or any significant barrier	Difficult land access conditions
E	54–60 or any unallowed	Very difficult land access conditions

Activity Index

The presented sub-attributes can be estimated at different times throughout the process of securing rights to use the land, with grade A representing the greatest level of certainty because the project has secured all leasing and land access.

For the Land Access attribute, the grade would be reported using one of the following activity indices:

Table 5. Sub-Attribute Activities: Land Access

Index	Description
A	Power plant environmental review(s) complete
B	Well field environmental review(s) complete
C	Land is posted for lease sale (including completion of any required environmental analysis)
D	Land is included in a Resource Management Plan, other type of Land Use Plan, or zoned for geothermal development
E	Developer is not aware if land has been evaluated or considered for geothermal development; publicly available documents are used for assessment.

Execution Index

Unlike the majority of Geological and Technical attributes considered within the GeoRePORT, the land access attribute does not typically vary in its execution of activities. As most sub-attributes can be evaluated accurately with publicly available data sets, an execution index was not developed. However, any reported values that are uncertain should be noted in a submitted report.

Sub-Attribute Character Grades

The following tables provide descriptions of each sub-attribute grade and associated weight, the sum of which is used to assign the land access grade in Table 4. For each sub-attribute, select the most appropriate grade to describe land access and the associated activity indices that describe how you arrived at the reported grade.

Land Access Sub-Attribute 1: Cultural and Tribal Resources

The cultural and tribal resources sub-attribute grades address whether a known cultural or tribal resource is present at the project location and the anticipated complexity of addressing or mitigating those resource concerns.

Tribal concerns, particularly tribal involvement through significant public comment, were recorded as some of the most significant variables in the length of the National Environmental Policy Act of 1969 (NEPA) process for geothermal development (Young et al. 2014). The median environmental assessment (EA) with tribal concerns took 81 days longer to complete on average, while projects with significant tribal comments took 57 days longer to complete (Young et al. 2014). However, because detailed maps of tribal resources are not publicly available, we applied a weight of two at activity level E for this sub-attribute because of the uncertainty in specific resource location. As the activity level increases to an activity level B, this factor should be weighted as a three.

Table 6. Land Access Sub-Attribute Grades: Cultural and Tribal Resources

Grade	Description	
A	No known cultural or tribal resources present. No State Historic Preservation Office (SHPO) concurrence required. 60- to 90-day review.	
B	Manageable cultural/tribal resources. State recognized jurisdictional tribal boundaries and 50-mile buffer for federally recognized jurisdictional tribal boundaries. ~4 months for U.S. Bureau of Land Management (BLM) (if applicable) and SHPO concurrence.	
C	Cultural/tribal resource complications or federally recognized jurisdictional tribal boundaries. 6–9 months for BLM (if applicable) and SHPO concurrence.	
D	Difficult cultural/tribal resource complications. +/- 1 year for BLM (if applicable) and SHPO concurrence.	Significant Barrier
E	Extreme cultural/tribal resource complications. 1–2 years for BLM (if applicable) and SHPO concurrence.	Unallowed

Land Access Sub-Attribute 2: Environmentally Sensitive Areas

The environmentally sensitive areas sub-attribute grades address whether the project is located on or impacts an environmentally sensitive area, such as Waters of the United States, national wildlife refuges, national parks, or other areas that may complicate or prevent development.

For example, the Crump Geyser Geothermal Project in Lake County, Oregon, included well sites determined to be in a wetland (i.e., Waters of the United States), which required extra permit approval from the state of Oregon and U.S. Army Corps of Engineers (Nevada Geothermal Power Inc. 2012). Another example is the Newberry Volcano Enhanced Geothermal System Demonstration Project, located next to the Newberry Volcano National Monument (NVNM) in Oregon. Development within the NVNM was strictly prohibited, and stipulations included a 500-meter buffer between the created reservoir and rocks under the NVNM, as well as a mitigation plan to protect the NVNM assets and visitors from the impacts of potential seismic events caused by the project (BLM, Record of Decision Newberry Volcano Enhanced Geothermal System Demonstration Project).

Table 7. Land Access Sub-Attribute Grades: Environmentally Sensitive Areas

Grade	Description	
A	Not located in an environmentally sensitive area. 2- to 3-month staff review.	
B	Manageable environmental sensitivities (e.g., recreational, geologic, wildlife, or scenic value). 3- to 6-month staff review.	
C	Environmentally sensitive area complications (e.g., Waters of the United States). 6- to 12-month staff resolution.	
D	Difficult environmentally sensitive area complications (e.g., Wild and Scenic Rivers, National Wildlife Refuge, National Preserves). Not likely to resolve. 1–2 years or longer if resolution possible.	Significant Barrier
E	Extreme environmentally sensitive area complications (e.g., National Park, National Monument, wilderness areas or wilderness study areas, U.S. Forest Service (USFS) inventoried roadless areas,* state and private conservation land). Not likely to be resolved. 2+ years.	Unallowed

**The 2001 USFS Roadless Rule prohibits road construction, road reconstruction, and timber harvesting on 58.5 million acres of inventoried roadless areas within the National Forest System.*

Land Access Sub-Attribute 3: Biological Resources

The biological resources sub-attribute grades whether the project may impact species or their habitat, including species of concern, threatened and endangered species, protected avian species, and sage grouse habitat.

The presence of federally endangered species and migratory birds was recorded as two of the most significant variables in the length of the NEPA process for geothermal development (Young et al. 2014). The median EA with federally endangered species present took 69 days longer to complete, while the median EA with migratory birds present took 177 days longer to complete (Young et al. 2014).

Additionally, current sage grouse rules have created challenges for geothermal developers. The BLM and U.S. Forest Service finalized new land use plans in 2015 to conserve habitat and identify threats to sage grouse and sagebrush. In part, the new land use plans seek to eliminate most new surface disturbance in sage grouse PHMA focal areas, avoid or limit new surface disturbance in PHMAs, and minimize surface disturbance in General Habitat Management Area (BLM 2015).

Table 8. Land Access Sub-Attribute Grades: Biological Resources

Grade	Description	
A	No biological resource issues. 60- to 90-day staff review.	
B	Manageable biological resource issues (e.g., nearby species of concern). 3- to 6-month staff review.	
C	Biological resource complications (e.g., endangered or threatened species nearby, migratory birds, bald/golden eagles); Sage Grouse General Habitat Management Area. 6- to 12-month staff resolution.	
D	Difficult biological resource issues (e.g., nearby or present endangered species); Sage Grouse Priority Habitat Management Areas (PHMA). Not likely to resolve. 1–2 years or longer if resolution possible.	Significant Barrier
E	Sage Grouse PHMA Focal Areas.	Unallowed

Land Access Sub-Attribute 4a: Federal Lease Queue

Federal lands nominated for geothermal leases must go through an environmental review process by the agency. In the past, low levels of geothermal funding and available staff—particularly at the U.S. Forest Service— created backlogs of geothermal project leases awaiting processing, with some applications sitting in the queue for 34 years (BLM and USFS 2008). Section 225 of the Energy Policy Act of 2005 (EPAct) required a program for reducing the backlog of geothermal lease applications on National Forest System lands by 90% within 5 years of enactment. In furtherance of this requirement, in October 2008, the U.S. Department of Interior (which oversees the BLM) and the U.S. Department of Agriculture (which oversees the Forest Service) finalized a Programmatic Environmental Impact Statement for Geothermal Leasing in the Western United States (BLM and Forest Service 2008). EPAct temporarily increased funding for geothermal lease processing, helping to address the backlog. However, with the end of this funding, the agencies returned to pre-EPAct levels. The federal lease queue sub-attribute grades address the anticipated time a project proponent may have to wait on the BLM or the U.S. Forest Service to complete the applicable pre-leasing analysis and post the parcel for lease sale after nomination.

Table 9. Land Access Sub-Attribute Grades: Federal Lease Queue

Grade	Description	
A	<1 year	
B	<2 years	
C	<3 years	
D	<5 years	
E	>5 years	Significant Barrier

Sub-Attribute 4b: State Lease Queue

The state lease queue sub-attribute grades address the anticipated time a project proponent may have to wait for a state land board to complete any applicable pre-leasing analysis and post the parcel for lease sale. This attribute applies only to nonfederal lands and complements the Federal Lease Queue sub-attribute.

State leasing may be an issue if the state does not have experience in leasing state land for geothermal development or does not have a specific regulation in place for leasing state land for geothermal development.

Table 10. Land Access Sub-Attribute Grades: State Lease Queue

Grade	Description	
A	<1 year	
B	<2 years	
C	<3 years	
D	<5 years	
E	>5 years	Significant Barrier

Land Access Sub-Attribute 5: Land Ownership

The land ownership sub-attribute grades whether the project is located on federal, state, or private land.

The ownership of land sought for geothermal development may increase project costs or development time. Projects with multiple landowners, particularly in the form of distinct surface owners and sub-surface owners (i.e., split estate) or multiple federal agencies may increase project complexity. For example, Young et al. (2014) analyzed the timeframe for NEPA process for EAs, which showed that the average time for the 11 projects with U.S. Forest Service *and* BLM jurisdiction took 60 days longer to complete than the 28 projects completed solely by the BLM.

Table 11. Land Access Sub-Attribute Grades: Land Ownership

Index	Description
A	Private land, single owner
B	Private land, multiple owners (with potential split estate issues)
C	Federal or state land with well-defined geothermal leasing regulations
D	State land without defined geothermal leasing regulations
E	Multiple landowners (federal, state, or private combination with potential split estate issues)

Land Access Sub-Attribute 6: Military Installations

In the western United States, where a large portion of the 30 million acres of U.S. Department of Defense-managed land exists, the potential for geothermal resources occurring near or on a military base can be high (e.g., Sabin et al. 2004; Sabin et al. 2010). Chief concerns among all installation commanding officers are meeting mission requirements and preventing encroachment.[1] By definition, the use of military land for anything other than mission-related activities (e.g., developing utility-grade or direct-use geothermal resources) is potentially in conflict with an installation's mission. Proposed exploration and development activities on or near base boundaries may also be perceived as encroaching on mission activities.

The *military installations* sub-attribute grades and map (Figure 3) address the distance to known military bases and other areas under military control.

[1] Encroachment is a term used by the U.S. Department of Defense to refer to incompatible uses of land, air, water, and other resources. Encroachment is "the cumulative impact of urban and rural development that can hamper the military's ability to carry out its testing and training mission." Certain types of land use near military installations can interfere with military operations by obstructing air routes and communications by cellular towers, power lines, and other similar structures; competing for or interfering with data and communications frequencies; depleting ground or surface water supplies, water treatment capacity, and other resources; using extra air emissions in areas that may have emission thresholds; and requesting changes in testing because of residents' noise concerns. New development can also drive threatened and endangered species onto a military installation, limiting its operations (http://www.ncsl.org/research/military-and-veterans-affairs/minimize-encroachment-on-military-installations.aspx).

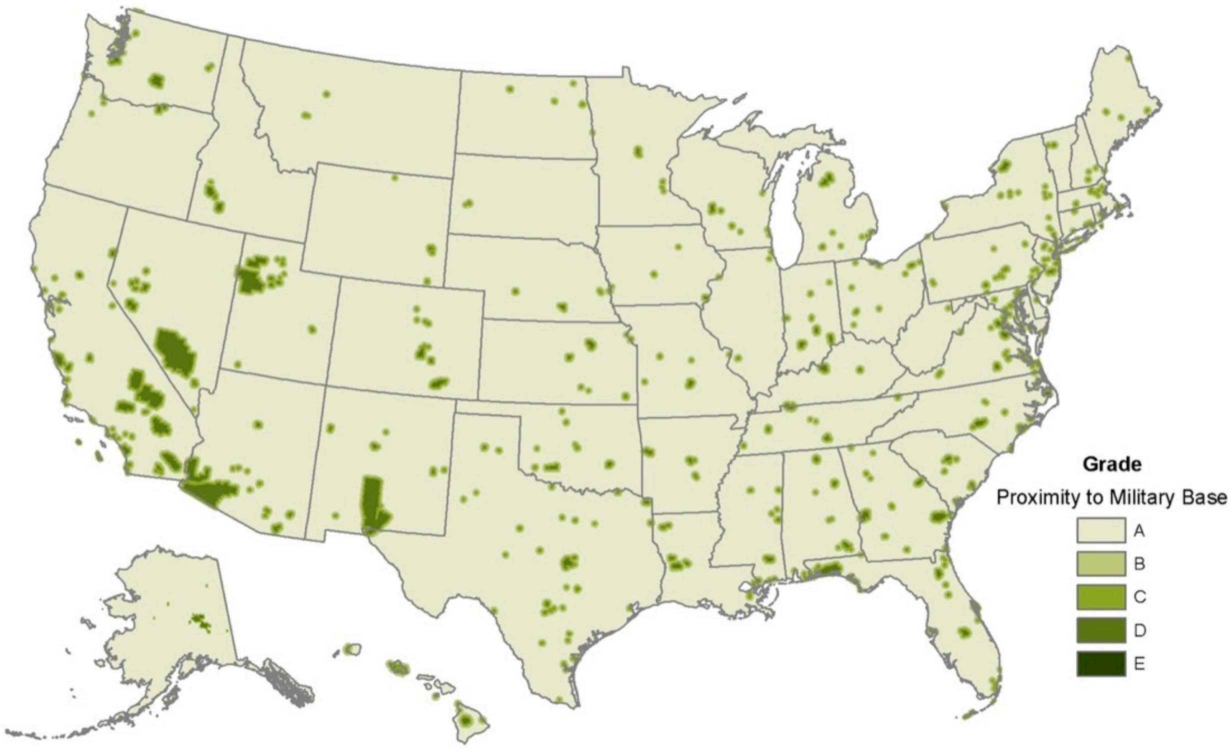

Figure 3. United States military installations sub-attribute grades and map, corresponding with Table 12

Table 12. Land Access Sub-Attribute Grades: Military Installations

Index	Description	
A	Not located near military installations	
B	Located within 10 miles of military installations	
C	Located within 5 miles of military installations	
D	Located on a military installation	
E	Negatively impacting a military installation	Significant Barrier

ATTRIBUTE: PERMITTING

Development of a geothermal project requires a variety of different permits, and these vary based on whether the project is on federally managed land and from state to state. The administrative procedures to obtain these permits involve several federal, state, and local authorities.[2] Delays can be caused by many factors, including a lack of knowledge of the details of geothermal development, under-staffed offices, vacation schedules, or the number of permits and/or parties involved. These complex and sometimes time-consuming procedures can impact the investment potential of the geothermal project (Levine et al. 2013).

Attribute Character Grade

The permitting character grade is composed of three sub-attributes (utilizing either the state *or* federal regulatory framework). These sub-attributes take into consideration multiple aspects of permitting and allow users to assign a character grade based on those individual sub-attributes.

The sub-attributes and their associated weights are shown in Table 13 and are described in more detail below.

Table 13. Permitting Sub-Attribute Weights

Sub-Attribute	Weight
State Regulatory Framework	2
Federal Regulatory Framework	2
Environmental Review Process	3
Ancillary Permits	1

Table 14. Permitting Character Grade Criteria

Grade	Sub-Attribute-Weighted Sum	Description
A	6–9	No permitting barriers present
B	10–15	Manageable permitting barriers
C	16–21	Permitting barriers present
D	22–27	Difficult permitting barriers
E	28–30 or any significant barrier	Extreme permitting barriers

Activity Index

The activity index for permitting is based on the project phase performed by developers, with activity index A representing approval of all permits required to develop a geothermal power plant and ancillary facilities.

[2] No exploration or drilling permits are required on military bases in California or Nevada, although a base's real estate or environmental office may want to seek concurrence of state authorities, for instance, before drilling.

Table 15. Sub-Attribute Activities: Permitting

Index	Description
A	Power plant and ancillary facilities permits approved.
B	Well field permits approved.
C	Exploration permits approved.
D	Lease issued. Activities permitted under lease authorization only.
E	Permitting process has not yet begun. Permitting grade is estimated using publicly available information and data.

Execution Index

Unlike the majority of Geological and Technical attributes considered within the GeoRePORT, the permitting attribute does not typically vary in its execution of activities. As most sub-attributes can be evaluated accurately with publicly available data sets, an execution index was not developed. However, any reported values that are uncertain should be noted in a submitted report.

Sub-Attribute Character Grades

Permitting Sub-Attribute 1a: State Regulatory Framework

The state regulatory framework sub-attribute grades address the relative sophistication of the permitting regulations and knowledge within the state specific to geothermal development. A state or county without geothermal regulations or experience successfully permitting a geothermal project may cause project delays.

Table 16. Permitting Sub-Attribute Grades: State Regulatory Framework

Grade	Description	
A	State/county has a permit coordinating office, geothermal regulations, and experience successfully permitting projects	
B	State/county has geothermal regulations and experience successfully permitting projects	
C	State/county has geothermal regulations, but has not successfully permitted a project or is in the process of changing the regulations	
D	State/county has a definition of geothermal resources, but does not have permitting regulations	
E	State/county does not have any geothermal regulations	Significant Barrier

Permitting Sub-Attribute 1b: Federal Regulatory Framework

A lack of experienced regulatory personnel and lack of interagency coordination were two situations cited by industry and agency personnel to delay geothermal project development (Young et al. 2014). The map shown in Figure 4 geographically identifies BLM field office areas with experience and facilitated coordination (MOUs) with the state regulatory agencies. These grades apply only to development on federal lands in these regions.

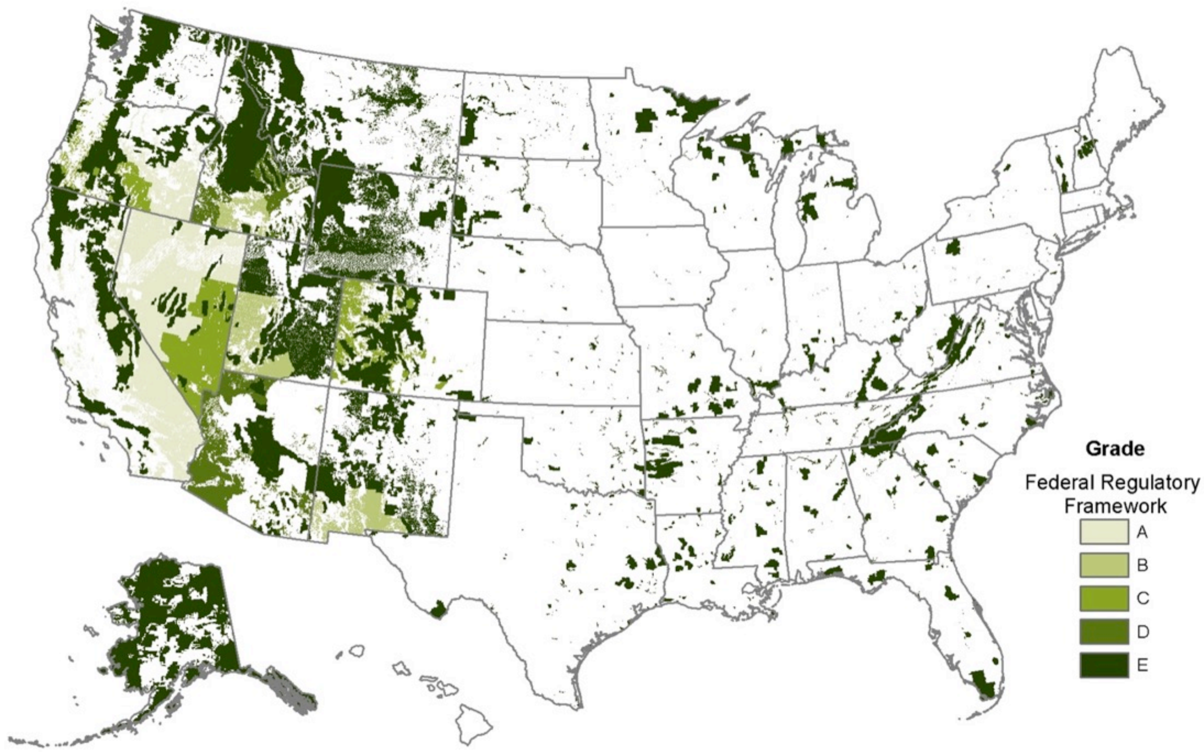

Figure 4. United States BLM field office areas with experience and facilitated coordination (MOUs) with state and regulatory agencies, corresponding with Table 17

The federal regulatory framework sub-attribute grades the relative sophistication of the permitting experts and knowledge within regional offices (BLM district level or individual national forest) specific to geothermal development as well as whether the regional office has a Memorandum of Understanding (MOU) with the applicable state.

Table 17. Permitting Sub-Attribute Grades: Federal Regulatory Framework

Grade	Description
A	BLM-administered mineral estate in an area with experience permitting geothermal exploration and development projects, and BLM has an MOU with the state.
B	BLM-administered mineral estate in an area with experience permitting geothermal exploration and development projects, and BLM **does not have an MOU** with the state.
C	BLM-administered mineral estate in an area **without experience** permitting geothermal exploration and development projects, and BLM has an MOU with the state.
D	BLM-administered mineral estate in an area **without experience** permitting geothermal exploration and development projects, and BLM **does not have an MOU** with the state.
E	No geothermal staff or funding.

Permitting Sub-Attribute 2: Environmental Review Process

Geothermal projects may have to go through the environmental review process as many as six times, and depending on the type of review (e.g., categorical exclusion, environmental assessment, environmental impact statement) and complexity of the proposed activity, each review may take anywhere from one month to three or more years (Young et al. 2014). If more than one jurisdiction (e.g., state, federal) requires review processes, the process may be slowed; however, coordination among these regulators can help facilitate permitting.

The environmental review process sub-attribute grades address the environmental review process specific to the land where the project is located. Our grading focused on which states had environmental review processes, whether the project was on federal land and would require NEPA review, and the level of environmental review required.

Table 18. Permitting Sub-Attribute Grades: Environmental Review Process

Grade	Description
A	Project is not subject to any federal or state environmental review process for any permits required for the project.
B	Project is subject to **one** federal or state environmental review process for any permits required for the project.
C	Project is subject to **two** or more federal or state environmental review processes for any permits required for the project.
D	Project is subject to **one** federal or state environmental review process for any permits required for the project and **has a significant impact on the environment**. Review will take >24 months.
E	Project is subject to **two** or more federal or state environmental review processes for any permits required for the project and **has a significant impact on the environment**.

Permitting Sub-Attribute 3: Ancillary Permits

Ancillary permits include air quality, water quality, waste disposal, highway and state land rights-of-way, and public utility commission approvals and siting processes. Ancillary permit approvals may require conducting studies, filing applications, public hearings, and other elements. The more time consuming the process is for receiving these permits, the greater the impact may be on project costs and timelines.

The ancillary permits sub-attribute grades address the number of permits the project may require not covered under geothermal specific regulations in the state (e.g., exploration and well field drilling regulations). For mapping purposes, we created a default power plant that was:

- Independent power producer-owned
- 20-MW, air-cooled, binary power plant
- 250°F (121°C) bottom-hole temperature
- Requires rights-of-way for ingress and egress, and
- All waste disposal by pit, surface water discharge, or injection well.

Table 19. Permitting Sub-Attribute Grades: Ancillary Permits

Grade	Description
A	Project requires ≤ 4 permits
B	Project requires 5–6 permits
C	Project requires 7–8 permits
D	Project requires 9–10 permits
E	Project requires > 10 permits

ATTRIBUTE: TRANSMISSION

Access to transmission is a critical component to a successful geothermal project (Hurlbut 2012). Even when a geothermal project is near a transmission line, the cost of interconnecting the project to the electric grid (if possible) and wheeling the power to the off-taker may create challenges.

Attribute Character Grade

The transmission character grade is composed of three sub-attributes. These sub-attributes take into consideration multiple aspects of transmission costs and allow users to assign a character grade based on those individual sub-attributes.

The sub-attributes and their associated weights are shown in Table 20 and are described in more detail below.

Table 20. Transmission Sub-Attribute Weights

Sub-Attribute	Weight
Distance to Nearest Transmission Line	1
Interconnection Costs (including upgrades)	1
Transmission Wheeling Costs	1

Table 21. Transmission Character Grade Criteria

Grade	Sub-Attribute-Weighted Sum	Description
A	3–5	Ideal transmission conditions
B	6–8	Favorable transmission conditions
C	9–11	Challenging transmission conditions
D	12–13 or any significant barrier	Difficult transmission conditions
E	14–15 or any unallowed	Very difficult transmission conditions

Activity Index

The activity indices for transmission are based on the project phase performed by developers, with activity index A representing constructed transmission requirements (electrons flowing to the grid).

Table 22. Sub-Attribute Activities: Transmission

Index	Description
A	Transmission fully constructed and electrons flowing to the grid.
B	Transmission NEPA analyses complete.
C	Transmission feasibility and grid connection analysis complete.
D	Transmission engineering studies completed and submitted for feasibility and grid connection study.
E	Transmission feasibility study not yet completed. Transmission grade is estimated using publicly available information and data.

Execution Index

Unlike the majority of Geological and Technical attributes considered within the GeoRePORT, the transmission attribute does not typically vary in its execution of activities. As most sub-attributes can be evaluated accurately with publicly available data sets, an execution index was not developed. However, any reported values that are uncertain should be noted in a submitted report.

Sub-Attribute Character Grades

Transmission Sub-Attribute 1: Distance to Nearest Transmission Line

Distance to the nearest transmission line is important because it reflects developers’ costs to permit and construct generation tie-lines to connect their projects to the grid.

Table 23. Transmission Sub-Attribute Grades: Distance to Transmission

Grade	Description	
A	Distance to nearest transmission line: <5 km	
B	Distance to nearest transmission line: 5–10 km	
C	Distance to nearest transmission line: 10–20 km	
D	Distance to nearest transmission line: 20–30 km	Significant Barrier
E	Distance to nearest transmission line: >30 km	Significant Barrier

Transmission Sub-Attribute 2: Interconnection Costs

Interconnection costs are upfront costs paid by the developer to connect to the grid. The interconnection process starts with a query to a utility/transmission line operator to access their lines, and the Federal Energy Regulatory Commission (FERC) models all requests. This process provides developers a path with available capacity and estimates the interconnection cost. Interconnection costs include:

- *Engineering costs*: for developer engineering drawings to submit with interconnection request to utility (approximately $10,000–$20,000).
- *Feasibility and grid connection study costs:* costs paid by developer to utility for utility to conduct feasibility and grid connection analysis (approximately $50,000–$150,000). These costs may vary, and as cluster participants and situations change over time prior to development, feasibility and grid connection analyses may need to be redone. Some developers reported paying more than $1,000,000 in study costs for a single plant due to the need for repeat analysis. Repeated cycles also take considerable time and delay project development.
- *Interconnection costs:* costs to connect to the grid including transmission system upgrade costs and distribution network upgrade costs. Costs are determined by feasibility and grid connection studies and vary from zero to millions of dollars per megawatt. Some costs (e.g., transmission network upgrade costs) are required by FERC to be paid back to the developer over time—either through reduction in transmission costs or through direct payback.

Engineering costs and feasibility and grid interconnection study costs are relatively inexpensive and predictable. Interconnection costs can vary significantly, however, and are node-specific.

For this sub-attribute, there are instances (grade E) where interconnection studies reveal that interconnection is not possible.

Table 24. Transmission Sub-Attribute Grades: Interconnection Costs

Grade	Description	
A	No interconnection system costs (plus engineering cost and feasibility costs)	
B	Minor transmission system costs (get paid back)—$2–3M (plus engineering and feasibility costs)	
C	Significant transmission system costs (get paid back) OR distribution network costs (do not get paid back)—up to $1M/MW (plus engineering and feasibility costs)	
D	Significant transmission system costs (get paid back) OR distribution network costs (do not get paid back)—greater than $1M/MW (plus engineering and feasibility costs)	Significant Barrier
E	Utility says interconnection is not possible	Unallowed

Transmission Sub-Attribute 3: Transmission Wheeling Costs

Transmission wheeling costs (or tariffs) are operational costs to transmit power from the point of interconnection to the power purchaser. If the point of interconnection is to the power purchaser's grid, there are no transmission, or "wheeling," costs. If the electricity must be transmitted over another utility's grid to the power purchaser, the operator must pay the utility for use of its grid (grade B). Transmission costs must be paid for each authority—or "wheel"—crossed (grades C–E). Because this cost is project-specific, calculating costs would require knowing where the project will tie in to the grid (point of interconnection), and who the purchaser is (delivery point).

Table 25. Power Conversion Sub-Attribute Grades: Water for Cooling

Grade	Description	
A	Customer is inside your utility power purchase agreement (PPA)—transmission cost = $0	
B	*Single wheel*—utility takes power into system and sells out of system (see prices above—$4–12/MWh—for examples given)	
C	*Two wheels ($4–12/MWh/wheel)* OR single wheel + system upgrade (path full), so one-time $50M transformer upgrade PLUS transmission costs ($4–12/MWh)	
D	*Three wheels ($4–12/MWh/wheel)* OR path does not exist, but transmission path proposed waiting for subscribers—developer can pay for subscription	
E	*Four wheels ($4–12/MWh/wheel)* OR no path to sell power, so need to build path (billions of $)	Significant Barrier

ATTRIBUTE: MARKET

The market attribute uses four sub-attributes: *Demand* drives development and *wholesale price of electricity* drives revenues; *policies* and *incentives* determine the type of development (e.g., geothermal, solar) deployed.

Attribute Character Grade

The market character grade is composed of four sub-attributes. These sub-attributes take into consideration multiple aspects of the geothermal power market and allow users to assign a character grade based on those individual sub-attributes.

The sub-attributes and their associated weights are shown in Table 26 and are described in more detail below.

Table 26. Market Sub-Attribute Weights

Sub-Attribute	Weight
Demand	1
Wholesale Price of Electricity	1
Policies	2
Incentives	2

Table 27. Market Character Grade Criteria

Grade	Sub-Attribute-Weighted Sum	Description
A	6–10	Favorable Market Conditions
B	11–15	Manageable Market Conditions
C	16–20	Acceptable Market Conditions
D	21–25	Difficult Market Conditions
E	26–30	Very Difficult Market Conditions

Activity Index

The activity indices for market are based on the project phase performed by developers, with activity index A representing electrons being delivered to customer.

Table 28. Sub-Attribute Activities: Market

Index	Description
A	Electrons being delivered to customer under a PPA (or other mechanism).
B	PPA is secured.
C	PPA is under negotiation.
D	PPA applied for (resource is demonstrated, transmission interconnection study completed), OR PPA was secured and was lost.
E	Market grade is estimated using publicly available information and data.

Execution Index

Unlike the majority of Geological and Technical attributes considered within the GeoRePORT, the market attribute does not typically vary in its execution of activities. As most sub-attributes can be evaluated accurately with publicly available data sets, an execution index was not developed. However, any reported values that are uncertain should be noted in a submitted report.

Sub-Attribute Character Grades

Market Sub-Attribute 1: Market Demand

Assessing future demand for additional electricity is important to identify markets that could have an appetite for geothermal-produced electricity. Future demand is a function of direct increases in demand, reductions due to increases in energy efficiency and demand response, and changes in a region's current electricity portfolio through planned retirements. These factors were evaluated by:

1. Calculating a 3-year cumulative annual growth rate (CAGR) for electricity demand by state, utilizing historical electricity consumption by state as reported by the U.S. Energy Information Administration (EIA) from 2011 to 2014.
2. Calculating a 10-year CAGR for projected electricity consumption by state using data from EIA's 2015 Annual Energy Outlook (EIA 2015) for 2015 to 2025.
3. Evaluating planned retirements of coal and natural gas power plants as reported in the ASEA Brown Boveri Energy Velocity Suite power plant database. Only currently operating power plants with planned retirement dates between 2016 and 2026 were utilized in this evaluation, and those plants were assumed to be operating as baseload generation until retirement. Additionally, it was assumed that a power plant's output is being consumed within the state in which it falls. In reality, the electricity may be exported to other markets.

The grade was assigned based on a combination of the expected increase in long-term electricity needs (the projected 10-year CAGR modified to account for potential retirements), and the historical 3-year CAGR. States with a greater than 5% increase in expected long-term electricity needs were graded either A or B; states with a 2%–5% increase were graded either C or D; and states with a <2% increase were graded E. The higher or lower grade within each category was determined by whether the 3-year historical CAGR was as significant (greater or lesser than 5% for grades A and B and greater or lesser than 2% for grades C and D).

Table 29. Market Sub-Attribute Grades: Demand

Grade	Description
A	Strong current and long-term electricity demand (either usage increase or from retirements)
B	Current demand and strong long-term demand (either usage increase or retirements)
C	Moderate current and long-term demand (either usage increase or retirements)
D	Current and long-term demand uncertain OR peak load only
E	Neither current nor long-term demand (e.g., energy market shrinking).

Market Sub-Attribute 2: Wholesale Price of Electricity

Using the wholesale price of electricity as a market sub-attribute, we can better understand the price point a geothermal plant may need to hit to be economically competitive. The wholesale electricity price generally reflects the marginal cost of generating electricity and delivering it through the transmission system. The prices for these different electricity prices fluctuate depending on the system conditions and fuel prices. The largest portion of the wholesale price is the cost of producing electricity, but this will also change based on consumer demand, transmission congestions, and line losses. As such, the average annual wholesale price is closely related to the PPA price a geothermal plant would currently receive, depending on the impacts of system congestion on the wholesale price.

We calculated the average PPA price for 16 available PPA contracts[3] placed between 1981 and 2015, with project sizes ranging from 2 to 50 MW. The PPA prices ranged from $0.0365/kWh to $0.1020/kWh, and the average price was $0.0781/kWh. This average PPA price was then compared to the regional 2015 wholesale price of electricity reported by EIA. Wholesale prices are reported for regional transmission operating market hubs (http://www.eia.gov/electricity/wholesale/) and were associated with each state based on proximity and regional transmission organizations. In the southeast, where no electricity pricing hubs were located, the national average price was assigned.

For each power project, a project-specific PPA could be estimated that would account for differences in regional fuel mixes (total system fuel costs being offset by geothermal energy), load patterns that affect transmission congestion, and other regulatory requirements.

Table 30. Market Sub-Attribute Grades: Wholesale Price of Electricity

Grade	Cost of Supplying Geothermal to the Market Relative to Weighted Average of Other Technologies on the Grid
A	**Slightly less:** Regional 2015 wholesale **price ≥ 1x** average geothermal levelized cost of electricity (LCOE)
B	**More:** Regional 2015 wholesale price between **1–0.6x** average geothermal LCOE
C	**More:** Regional 2015 wholesale price between **0.6x–0.5x** average geothermal LCOE
D	**More:** Regional 2015 wholesale price between **0.5x–0.4x** average geothermal LCOE
E	**More:** Regional 2015 wholesale price ≤ **0.4x** average geothermal LCOE

**Avg PPA price for 20-MW plant; $0.0781/kWh*

[3] PPA prices are a compilation of public press statements and reports. This work was expanded upon and used as a basis for Hernandez, Richard, and Nathwani (2016).

Market Sub-Attribute 3: Policies

Renewable energy policies such as feed-in tariffs (FITs), renewable portfolio standards (RPSs), and carbon emission limits (e.g., the former Clean Power Plan, *40 CFR Part 60 Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units; Final Rule*) can be large drivers of renewable deployment. FITs and RPSs are the most widely adopted renewable energy support policies around the world (Cox and Esterly 2016). As of 2013, 98 national and local governments had implemented FITs, a growth of nearly three times the number that had adopted them by 2004 (REN 21 2015). In the United States, RPSs are more common (see dsireusa.org); however, they are still large drivers of renewable deployment.

While RPSs tend to be driven by generation (MWh), some requests for proposals authorized by state legislatures or public utilities commissions are capacity-driven (MW) programs that favor solar and wind (e.g., Nevada SB 123 2013). For example, a capacity-driven program would treat a 20-MW wind farm (~35% capacity factor), a 20-MW solar plant (~25% capacity factor), and a 20-MW geothermal plant (~80% capacity factor) equally, despite the difference in MWh delivered. Even generation-driven (MWh) RPSs can favor specific renewables by having set-asides or multipliers for certain renewables. Set-asides require the purchase of a certain type of renewable, so even when geothermal can compete on price, the policy may require the purchase of a more expensive alternative. Multipliers allow utilities to effectively lower their compliance standards if they use the specified technologies. For example, the Oregon RPS had a 2.0x multiplier for utilities that use solar PV to meet the RPS requirements through the end of 2015 (ORS 757.375(2)).

Table 31. Market Sub-Attribute Grades: Policies

Index	Description
A	Feed-in tariff for geothermal (standard offer contracts)
B	Interconnection set-aside or RPS or state purchase requirement **specific for geothermal**
C	State renewable purchasing requirements or RPS—**not preferential to a particular renewable**
D	State purchasing requirements or RPS—**with preferential consideration or set-asides for nongeothermal renewables**
E	No policies beneficial to renewables (no RPS).

Market Sub-Attribute 4: Incentives

Much of the literature on geothermal incentives focuses on those programs that lower upfront exploration risk (e.g., Speer et al. 2014). Incentives, such as the grant-to-loan program in California (California PRC 3800 et seq.) favor smaller companies that do not have the risk tolerance of larger companies. Larger companies fund these exploration activities using their balance sheets. The wells funded by these grant-to-loan programs may have lower success rates than company-funded exploration, driving down overall industry success rates, making it harder for investors to trust geothermal investments. Others have suggested that programs, such as government-led exploration, would be more equitable for both large and small companies. Government could then recover the costs in public auctions. Additional incentives, such as the federal investment tax credit and the production tax credit can also be helpful.

Table 32. Market Sub-Attribute Grades: Incentives

Index	Description
A	Qualifies for federal or state incentives that offset exploration costs and reduce project risk (e.g., California's Geothermal Grant and Loan program, Alaska's Renewable Energy Grant program). Includes grant-to-loan programs and loan guarantees.
B	Qualifies for mix of both state and federal tax incentives AND financial incentives—includes grants, loans, and investment and productivity tax incentives.
C	Qualifies for mix of both state and federal tax incentives (includes state property tax incentives).
D	Qualifies for either federal or state financial and tax incentives (not mixed), may require renewal of incentive.
E	Does not qualify for state or federal incentives (no incentive available).

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