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Crossing the Barriers: An Analysis of Land Access Barriers to Geothermal Development and Potential Improvement Scenarios

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Land access, leasing, environmental, geothermal, GeoRePORT, geothermal resource potential, regulatory

ABSTRACT

Developers have identified many non-technical barriers to geothermal power development, including access to land. Activities required for accessing land, such as environmental review and private and public leasing can take a considerable amount of time and can delay or prevent project development. This paper discusses the impacts to available geothermal resources and deployment caused by land access challenges, including tribal and cultural resources, environmentally sensitive areas, biological resources, land ownership, federal and state lease queues, and proximity to military installations. In this analysis, we identified challenges that have the potential to prevent development of identified and undiscovered hydrothermal geothermal resources. We found that an estimated 400 MW of identified geothermal resource potential and 4,000 MW of undiscovered geothermal resource potential were either unallowed for development or contained one or more significant barriers that could prevent development at the site. Potential improvement scenarios that could be employed to overcome these barriers include (1) providing continuous funding to the U.S. Forest Service (USFS) for processing geothermal leases and permit applications and (2) the creation of advanced environmental mitigation measures. The model results forecast that continuous funding to the USFS could result in deployment of an additional 80 MW of geothermal capacity by 2030 and 124 MW of geothermal capacity by 2050 when compared to the business-as-usual scenario. The creation of advanced environmental mitigation measures coupled with continuous funding to the USFS could result in deployment of an additional 97 MW of geothermal capacity by 2030 and 152 MW of geothermal capacity by 2050 when compared to the business-as-usual scenario. The small impact on potential deployment in these improvement scenarios suggests that these 4,400 MW have other barriers to development in addition to land access. In other words, simply making more resources available for development does not increase deployment; however, impacts to deployment could increase when coupled with other improvements (e.g., permitting, market and/or technology improvements).

1. Introduction

Understanding the challenges to accessing land is important to increase geothermal deployment since environmental review 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 uses could cause projects to be delayed several years or more. In 2015, the Geothermal Technologies Office (GTO) at the U.S. Department of Energy (DOE) initiated a vision study (GeoVision) to conduct analysis of potential growth scenarios across multiple geothermal market sectors (e.g. electricity generation, commercial and residential thermal applications, heat pumps) for 2030 and 2050. As part of the GeoVision, the National Renewable Energy Laboratory (NREL) led an Institutional Barriers Task Force charged with analyzing non-technical barriers that create delay, increase risk, or increase the cost of project development. The non-technical barriers analyzed by the task force include land access, permitting, transmission, and market conditions. This paper focuses only on the impact to the available geothermal resource and its deployment due to barriers associated with the land access challenges, including tribal and cultural resources, environmentally sensitive areas, biological resources, land ownership, federal and state lease queues, and proximity to military installations. Separate papers describe the results for each of the non-technical barriers analyzed.

In this paper we discuss:

- The methodology used to analyze land access barriers, including analyzing land access as an “attribute” to geothermal development
- The sub-attributes that make up the land access attribute and a description of the barriers caused by each sub-attribute for geothermal development
- The influence that land access barriers have on the supply curve and potential deployment of identified and undiscovered geothermal resources
- Potential improvement scenarios to overcome land access barriers that may prevent geothermal development.

2. Methodology

2.1 The GeoRePORT System

The GeoRePORT System was developed to address the need of the GTO to track and measure the impact of research, development, and deployment funding for GTO-funded geothermal projects (Young et al., 2015). While other geothermal reporting systems exist, such as the Australian and Canadian Geothermal Reporting Codes (AGEA and AGEG 2010, CanGEA 2010) and the United Nations Framework Classification (UNFC) System (UNECE, 2013), the GeoRePORT System is unique in providing a detailed system for reporting both the resource grade and the project progress (a.k.a. project readiness level), and is particularly useful for describing early-stage exploration projects. The analysis presented in this paper discusses only resource grade, and not project readiness levels. GeoRePORT is comprised of three assessment tools: Geological, Technical, and Socio-Economic. Each of the assessment tool’s resource grades is divided into attributes and sub-attributes that describe the characteristics that contribute to feasibility of project development (Figure 1).

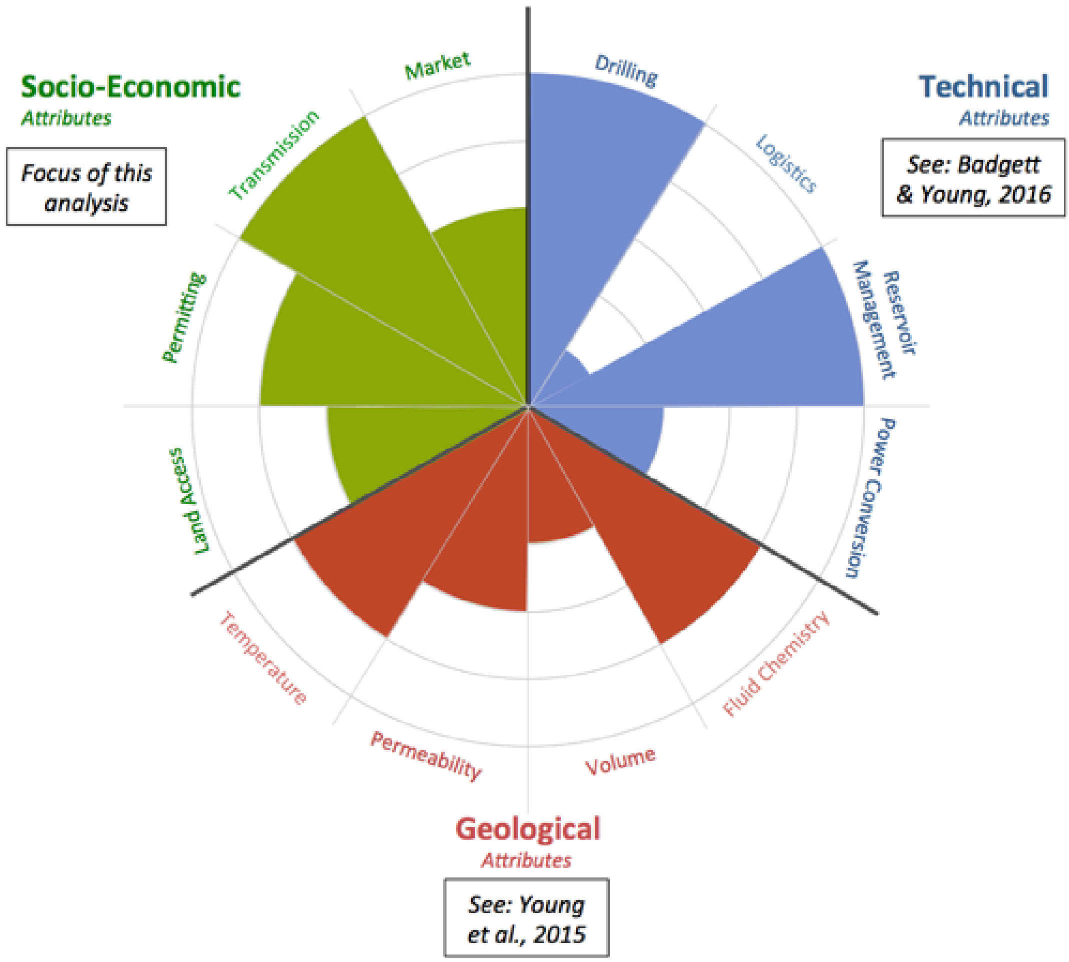


Figure 1. *Resource Grades*. The grade of a resource can be described as a combination of intrinsic features of the resource that contribute to economic viability. The GeoRePORT System allows developers to assign grades to each of twelve attributes, providing a clear picture of the development potential and challenges at each location. The highest grade, A, is represented as a full pie piece; the lowest grade, E, is represented as the smallest pie piece. Geological attributes include temperature, volume, permeability, and fluid chemistry. Technical attributes include drilling, logistics, reservoir management, and power conversion; socio-economic attributes include land access, permitting, transmission, and market. Sub-attribute grades, activity and execution indices are not reported in this graphic.

Previous work focused on the development of the Geological Assessment Tool (GAT, Young et al., 2015), the Technical Assessment Tool (TAT, Badgett and Young, 2016), and the Socio-Economic Assessment Tool (SEAT, Levine and Young, 2016). This paper focuses on use of the Socio-economic grade to analyze land access barriers. Related research and final draft protocol documents for all three tools can be found on the GeoRePORT website (http://en.openei.org/wiki/GeoRePORT).

In addition to the character grade (A–E) for each attribute, the GeoRePORT resource grading system includes an activity index and an execution index. The activity index describes the common activities used to understand the character attributes – both directly (measured values) and indirectly (proxy). The activity index is graded from A–E as well, with E representing the lowest level of certainty. For example, an activity grade of A (high certainty) for land access may be that an environmental assessment has been completed for the project.

For the purposes of the baseline analysis conducted for this GeoVision Study, the activity grade is E, reflecting that the data used are national-level spatial datasets and datasets we created based on our general knowledge of a state or region. Developers who begin exploration and research in a specific area will certainly research each attribute and sub-attribute in greater detail. This research may change (increase or decrease) the reported resource grade, and would increase the activity index, indicating a greater certainty in the reported land access character grade.

For the GAT and TAT, the grades also make use of an execution index, describing how well an activity (e.g., geothermometry) was implemented. The execution index is not used in the reporting of Socio-Economic resource grades.

2.2 Use of the GeoRePORT to Analyze Institutional Barriers

The SEAT of GeoRePORT includes four attributes: Land Access, Permitting, Transmission, and Market, each of which includes sub-attributes. The sub-attributes are assigned grades which, when combined, provide a single character grade for each attribute. As mentioned, the Land Access attribute has six sub-attributes: cultural and tribal resources, environmentally sensitive areas, biological resources, land ownership, federal or state lease queue, and proximity to military installations. Each sub-attribute is graded from A-E. An example for the biological resources sub-attribute is in Table 1.

Table 1. Example list of Sub-Attribute Grades for the Biological Resources Sub-Attribute of the Land Access Attribute.

Biological Resources Sub-Attribute Character Grade	Description	Estimated Time Frame
A	No biological resource issues present in the area	
B	Manageable biological resource issues (nearby species of concern)	Developers may expect a 3-6 month regulatory staff review
C	Biological concerns present, such as nearby migratory birds, bald/golden eagles, and or endangered or threatened species, or if the resource is located in a Sage Grouse General Habitat Management Area (GHMA)	Developers may expect a 6-12 month regulatory staff review and resolution
D	Difficult biological issues present, i.e. it is located in a Sage Grouse Priority Habitat Management Area (PHMA)	Not likely to resolve, 1-2 years or longer if resolution possible.
E	Project is located in a Sage Grouse PHMA Focal Area.	Development not allowed under current laws or regs.

Each sub-attribute (SA) is given a weight (wt), and the total sub-attribute-weighted sum is calculated as:

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

where Grades A=5 and E=1. The range of attribute-weighted sums corresponds to grades A-E for each attribute. For example, for the land access attribute, the maximum weighted sum (if all grades are A) is 60, while the minimum weighted sum (if all grades are E) is 12. The breakdown of grades based on weighted sum is in Table 2.

Table 2. Table of sub-attribute-weighted sum ranges for the Land Access attribute. The grades for all sub-attributes are multiplied by the corresponding sub-attribute weight, then added together to calculate the sub-attribute-weighted sum. This sum is then used to determine the attribute character grade using this table.

Land Access Character Grade	Sub-attribute-Weighted Sum
A	54-60
B	43-53
C	31-42
D	19-30 or any single *significant barrier* sub-attribute grade
E	12-18 or any single *unallowed* sub-attribute grade

For the Biological Resources sub-attribute example, the grade would be reported using one of the Land Access activity indices listed in Table 3.

Table 3. Land Access Activity Index. For each Land Access sub-attribute, an activity grade is assigned using the following index. It is often the case that all sub-attributes will have the same activity grade since all would likely be addressed in any study conducted.

	Land Access Activity Index	Description
Higher certainty	A	Secured all leasing and land access (geothermal lease, rights-of-way, surface access agreement)
	B	Land is posted for lease sale (including completion of any required environmental analysis)
	C	Land is available for leasing
	D	Land is included in a Resource Management Plan, other type of Land Use Plan, or zoned for geothermal development
Lower certainty	E	Developer is not aware if land has been evaluated or considered for geothermal development; publically available documents are used for assessment.

2.3 Institutional Barriers Expert Team

For the institutional barriers analysis we assembled a barriers expert team (BET) of geothermal experts from industry and federal agencies to provide regular, scheduled input and review of our methodology and results through monthly meetings and document review (see *Acknowledgments*).

We began by creating the socio-economic attributes and sub-attributes to reflect the non-technical barriers faced by the geothermal industry, as shown in Figure 2. We then created a grading system, providing each sub-attribute with a descriptive, objective qualifier for letters A-E, with E reflecting the most difficult barrier for the sub-attribute (e.g., Table 1). After grading each sub-attribute, we created a grade from A-E for each attribute that reflects the weighted sums of the sub-attributes to reflect the most difficult barrier for the attribute (e.g., Table 2).

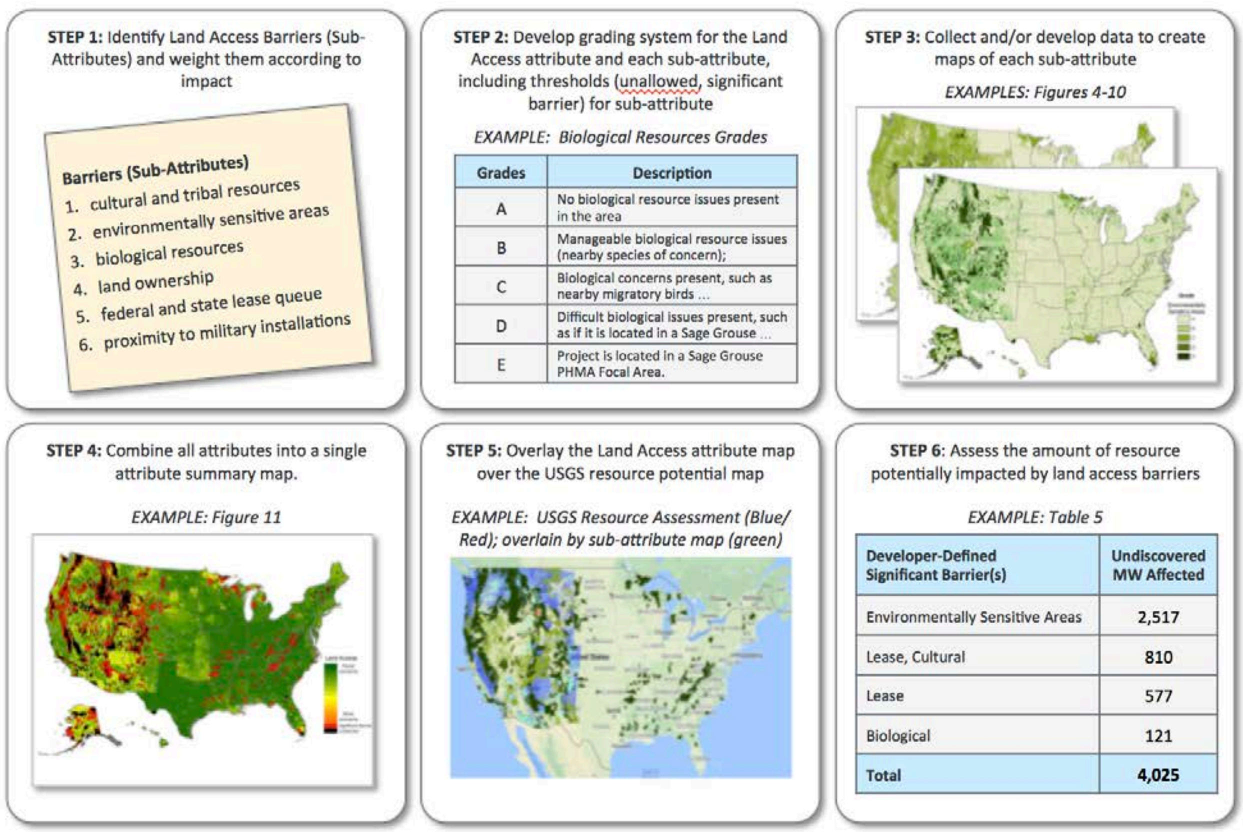


Figure 2: Barriers Analysis Process. Diagram shows the steps in the process of identifying barriers, developing a grading system, mapping the data, and analyzing the impact on geothermal development potential.

Next, we collected and/or created data to map each sub-attribute for the United States. We then identified specific thresholds for sub-attributes, if applicable, which would currently make a project *unallowed* and blacked them out on the map. For example, for the Biological Resources sub-attribute described in Table 1, any area mapped as a grade E was determined to be currently *unallowed* for project development and was blacked out on the Biological Resources grade map

(Figure 6). We also interviewed developers and members of the BET to understand their criteria for decision-making on geothermal projects, recording specific situations they would currently consider a *significant barrier* or might raise *flags* for project development. For example, all of the developers we interviewed said they would consider Sage Grouse PHMAs (grade D) to be a *significant barrier* situation.

The BET also assigned weights to each of the sub-attributes based on the sub-attributes' contribution to development barriers. Sub-attributes that had the potential to cause significant barriers (e.g., biological resources) were given higher weights than those that caused less significant barriers (e.g., land ownership).

The results of these analyses are presented in Section 3.

After completing this process, we combined the sub-attribute maps into a single land access attribute map (Figure 11) using the BET-defined sub-attribute weights. The land access attribute map reflects the attribute grade (i.e., weighed sum of the sub-attribute grades), including all of the areas where development was *unallowed*. All maps are available on Geothermal Prospector (https://maps.nrel.gov/geothermal-prospector) and the Geothermal Data Repository (https://gdr.openei.org).

We overlaid the attribute and sub-attribute maps over USGS maps of identified and undiscovered resource potential in the United States to assess the amount of resource potentially impacted by land access barriers. The Land Access summary map and impact to geothermal potential is presented in Section 4.

2.4 Market Penetration Modeling Methodology

The next step was to develop geothermal supply curves using the resource assessment methodology described above in conjunction with the Geothermal Electricity Technology Evaluation Model (GETEM). GETEM is an Excel-based tool used to estimate the levelized cost of energy (LCOE) for definable geothermal scenarios, as shown in Figure 3.

These supply curves were used as input (using several scenarios) into NREL's Regional Energy Deployment System (ReEDs) to understand how these barriers impact potential deployment of geothermal in the United States. The ReEDS model is a long-term capacity model for the deployment of electric power generation technologies and transmission infrastructure throughout the contiguous United States.[1]

The GeoVision utilized a combination of ReEDS and GETEM to forecast both baseline deployment scenarios and potential improvement scenarios for geothermal deployment in the contiguous United States.

The results of the market penetration modeling for Business-As-Usual (BAU) and Land Access Improvement scenarios are presented in Section 5.

[1] For more information see: http://www.nrel.gov/analysis/reeds/

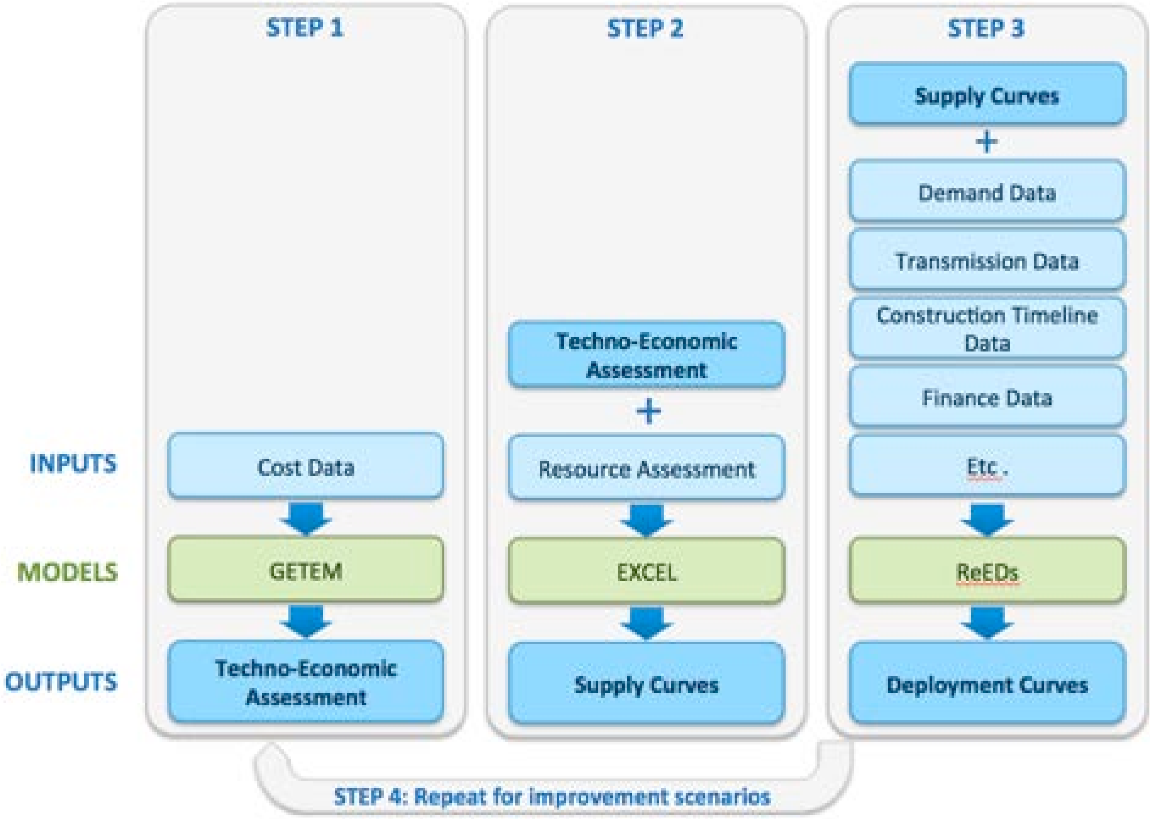


Figure 3. Market Penetration Modeling Process. Diagram shows the steps in the process of running various scenarios, including Business-As-Usual scenarios (including non-technical barriers) and Improvement Scenarios (including potential for reducing these non-technical barriers). The ReEDs model competes geothermal deployment with other renewable and non-renewable resources.

3. Analysis of Geothermal Land Access Barriers

We identified six sub-attributes that most significantly contributed to the ability to access land:

1. Cultural and Tribal Resources
2. Environmentally Sensitive Areas
3. Biological Resources
4. Land Ownership
5. Federal and State Lease Queue
6. Proximity to Military Installation.

This section discusses the definition of each land access sub-attribute grade and the results of mapping the grades for each land access sub-attribute.

3.1 Barrier 1: Cultural and Tribal Resources

The cultural and tribal resources sub-attribute grade and map (Figure 2) address whether a known cultural or tribal resource is present at the project location (including public, private, and tribal lands) and the anticipated complexity of addressing or mitigating those resource concerns.

Since cultural and tribal resources are difficult to map due to the lack of publicly available information, our map reflects grade estimates based upon known tribal areas. For the B grade, we mapped a 50-mile buffer around federally recognized tribal areas for the lower 48 states and all of Alaska and Hawaii. For the C grade, we mapped all federally recognized jurisdictional tribal boundaries. Many developers said a grade C would raise a *flag* in their assessments, and grade D would be a *significant barrier* potentially preventing them from pursuing development. In grade E areas, development is considered to be currently *unallowed*.

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 than projects without tribal concerns, while projects with significant tribal comments took 57 days longer to complete than projects without significant tribal comments (Young et al., 2014). However, because detailed maps of tribal resources are not publically 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 sub-attribute should be weighted as a three.

Note: Since data on culturally sensitive areas are not publically available, this map is only a proxy of the likelihood of encountering culturally sensitive areas, and developers should work with state historical preservation offices and/or tribal historic preservation offices to verify the presence or absence of cultural resources in project areas.

3.2 Barrier 2: Environmentally Sensitive Areas

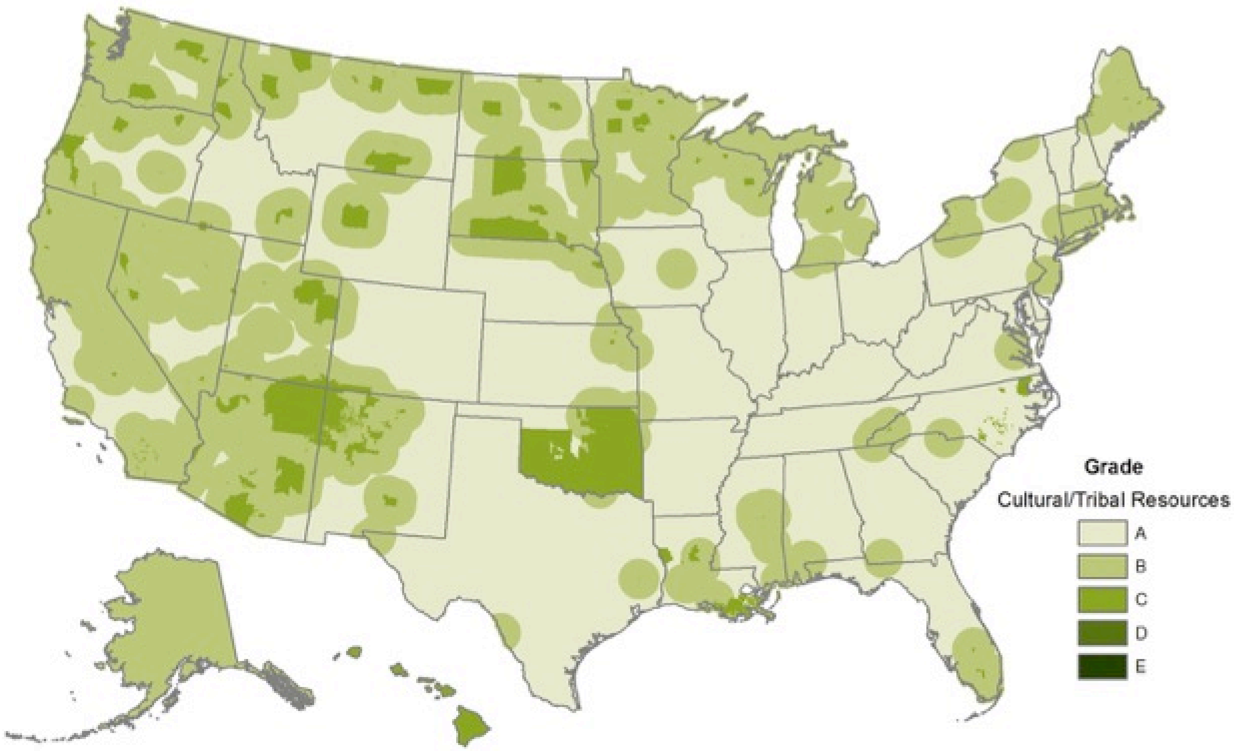
The environmentally sensitive areas (ESA) sub-attribute grades and map (Figure 3) address whether the project is located on or impacts an environmentally sensitive area such as Waters of the United States, national wildlife refuges, national parks or other areas that may complicate or prevent development.

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 (EGS) Demonstration Project, located next to the Newberry Volcano National Monument (NVNM), 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).

3.2.1 Environmentally Sensitive Areas Grading and Maps

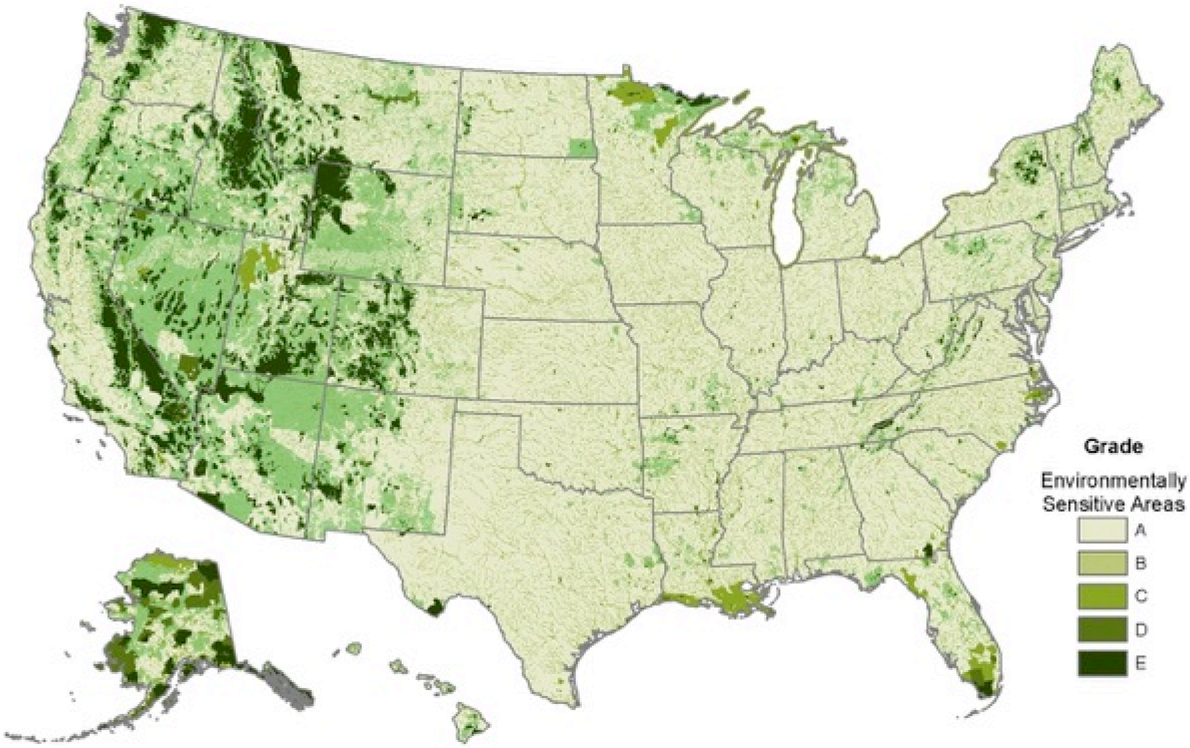
ESA grades A-E were defined as outlined in Figure 5. Many developers said a grade C would raise a *flag* in their assessments; they considered grade D, such as a National Wildlife Refuge, to be a *significant barrier* potentially preventing them from pursuing development. In grade E areas, such as national parks and wilderness Study areas, development is considered to be currently *unallowed*.

3.1.1 Cultural and Tribal Resources Grading and Map



A	No known cultural or tribal resources present. State Historic Preservation Office (SHPO) concurrence required, 60-90 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) and SHPO concurrence	
C	Cultural/tribal resource complications or federally recognized jurisdictional tribal boundaries. 6-9 months for BLM and SHPO concurrence	Flag
D	Difficult cultural/tribal resource complications. +/- 1 year for BLM and SHPO concurrence	Significant Barrier
E	Extreme cultural/tribal resource complications. 1-2 years for BLM and SHPO concurrence	Unallowed

Figure 4. ***Map of Land Access: Tribal and Cultural Resources Sub-attribute.*** **This map represents an activity level of E, with a weighting factor of 2 in the summary Land Access attribute map. As more is known about tribal and cultural resources in a project area, the activity level will increase, and the weighting factor will increase to 3 in the summary Land Access attribute map.**



A	Not located in an environmentally sensitive area. 2-3 month staff review.	
B	Manageable environmental sensitivities (recreational, geologic, wildlife or scenic value) 3-6 month staff review	
C	Environmentally sensitive area complications (Waters of the United States) 6 - 12 month staff resolution.	Flag
D	Difficult environmentally sensitive area complications (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 (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 (USFS 2001).

Figure 5. ***Map of Land Access: Environmentally Sensitive Areas Sub-attribute.*** **This map represents an activity level of E, with a weighting factor of 3 in the summary Land Access attribute map.**

3.3 Barrier 3: Biological Resources

The biological resources sub-attribute grades and map (Figure 6) address whether the project may impact species or their habitat, including species of concern, threatened and endangered species, protected avian species, and sage grouse habitat. We were able to map grades A-E for this sub-attribute.

The presence of federally endangered species and migratory birds were 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, recent changes in sage grouse rules have created challenges for geothermal developers. The BLM and USFS 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 eliminate most new surface disturbance in sage grouse PHMA focal areas, avoid or limit new surface disturbance in PHMAs, and minimize surface disturbance in GHMAs (BLM, 2015).

3.3.1 Biological Resources Grading and Map

Many developers said a grade C would raise a *flag* in their assessments; they considered grade D, such as a sage grouse PHMA, to be a *significant barrier* potentially preventing them from pursuing development. In grade E areas, such as sage grouse PHMA focal areas, development is considered to be currently *unallowed*.

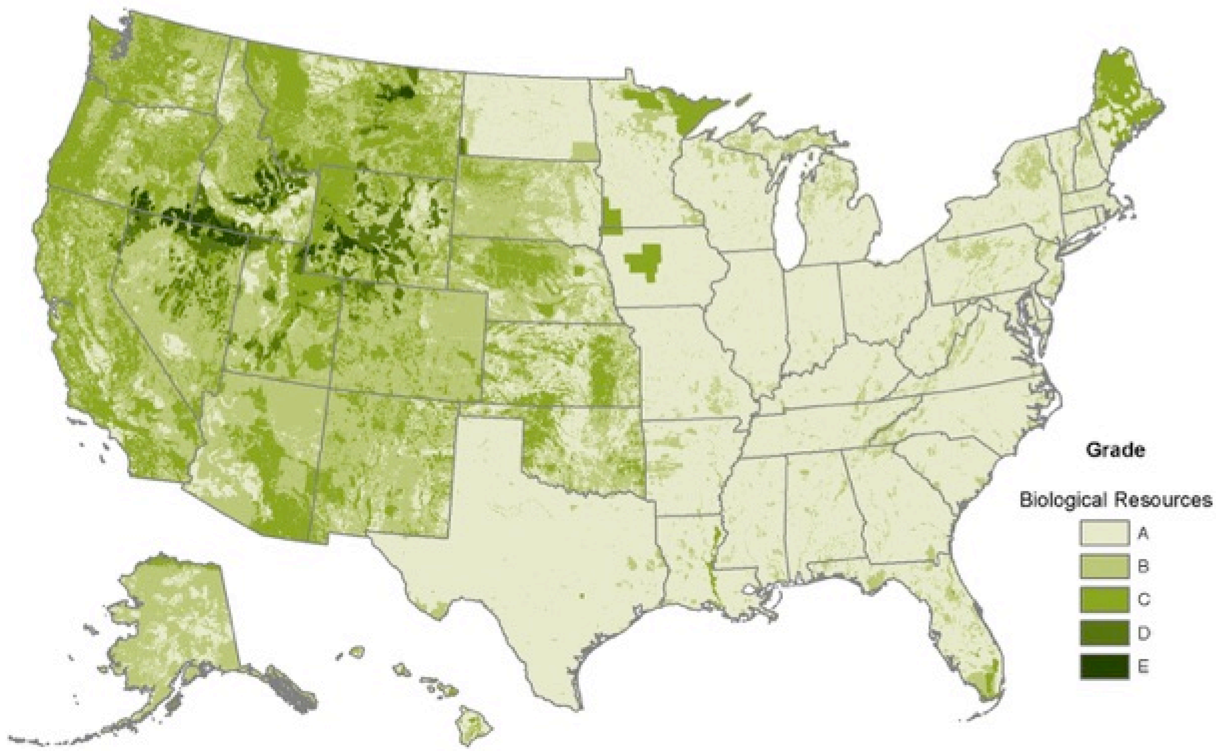
3.4a Barrier 4a: Federal Lease Queue

Federal lands nominated for geothermal leases must go through an environmental review process by the federal land management agency (potentially with participation of the BLM if not the federal land management agency). In the past, low levels of geothermal funding and available staff – particularly at the USFS – created backlogs of geothermal project leases awaiting processing, with some applications sitting in the queue for 34 years (BLM and USFS, 2008). The Energy Policy Act of 2005 (EPAct) temporarily increased funding for geothermal permit processing, helping to address the backlog, but with the end of this funding, the agencies returned to pre-EPAct funding levels (Witherbee et al., 2013). Funding from EPAct allowed for a Geothermal Programmatic Environmental Impact Statement, which helps to reduce time from geothermal nomination to lease sale (BLM and USFS, 2008).

The federal lease queue sub-attribute grades and map address the anticipated time a project proponent may have to wait on the BLM or the USFS to complete the applicable pre-leasing analysis and post the parcel for lease sale after nomination. This sub-attribute applies only to federal lands and complements the map in 3.4b State Lease Queue.

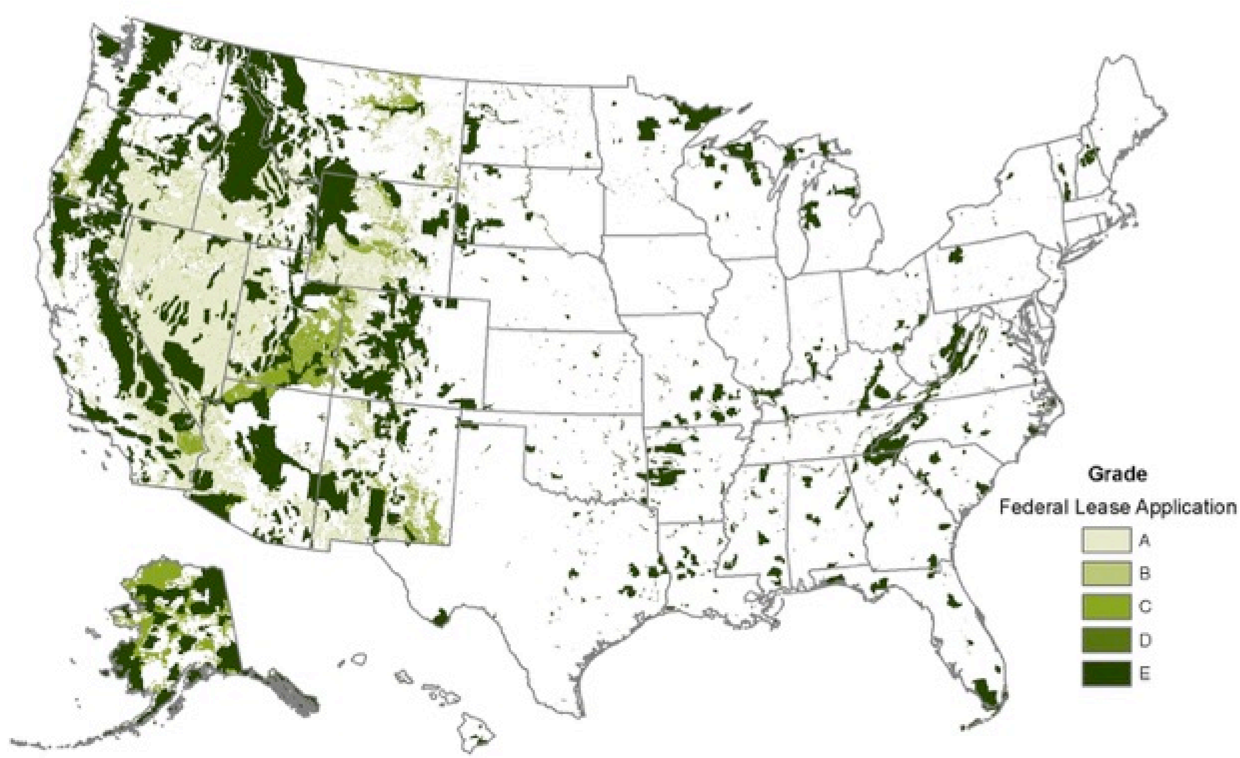
3.4a.1 Federal Lease Queue Grading and Map

For mapping purposes (Figure 7), we mapped the federal lease queue for BLM-managed federal lands included in the programmatic environmental impact statement (PEIS) to be an A (less than three years), BLM-managed federal lands not included in the PEIS to be a B (greater than three years), and USFS-managed federal lands to be an E (timeframe uncertain). Grade C was identified by industry to be a *flag*, and grade E was identified currently to be a *significant barrier*.



A	No biological resource issues, 60 - 90 day staff review.	
B	Manageable biological resource issues (nearby species of concern) 3-6 month staff review	
C	Biological resource complications (endangered or threatened species nearby, migratory birds, bald/golden eagles); Sage Grouse General Habitat Management Area (GHMA); 6 - 12 month staff resolution.	Flag
D	Difficult biological resource issues; 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

Figure 6. ***Map of Land Access: Biological Resources Sub-attribute.*** **This map represents an activity level of E, with a weighting factor of 3 in the summary Land Access attribute map.**



A	Queue for federal lease - BLM land with time delay less than 3 years	
B	N/A	
C	Queue for federal lease - BLM land with time delay > than 3 years	Flag
D	N/A	
E	Queue for federal lease application – U.S. Forest Service land	Significant Barrier

Figure 7. ***Map of Land Access: Federal Lease Queue Sub-attribute.*** **This map represents an activity level of E, with a weighting factor of 2 in the summary Land Access attribute map. White areas indicate non-federal lands where this grade was not applicable. See Figure 8 for State Lease Queue grades.**

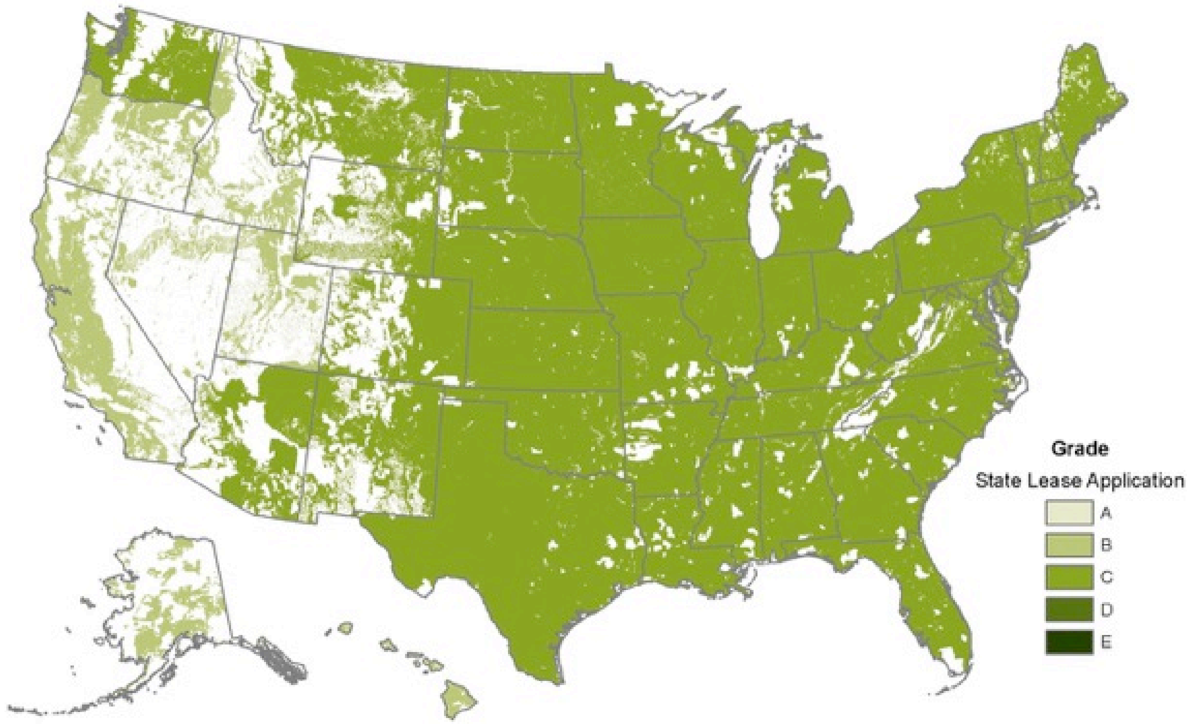
3.4b Barrier 4b: State Lease Queue

The state lease queue sub-attribute grades and map (Figure 8) 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 non-federal lands and complements the map in 3.4a Federal Lease Queue.

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.

3.4b.1 State Lease Queue Grading and Map

For mapping purposes we mapped states where geothermal projects currently exist as a B (between two and three years) and states where geothermal projects currently do not exist as a C (between three and five years) due to concerns over state staff knowledge and resources.



A	State Lease Queue: <1 year	
B	State Lease Queue: <2 years	
C	State Lease Queue: <3 years	Flag
D	State Lease Queue: <5 years	Flag
E	State Lease Queue: >5 years	Significant Barrier

Figure 8. ***Map of Land Access: State Lease Queue Sub-attribute.*** **This map represents an activity level of E, with a weighting factor of 2 in the summary Land Access attribute map. White areas indicate federal lands where this grade was not applicable. See Figure 5 for Lease Queue grades for these areas.**

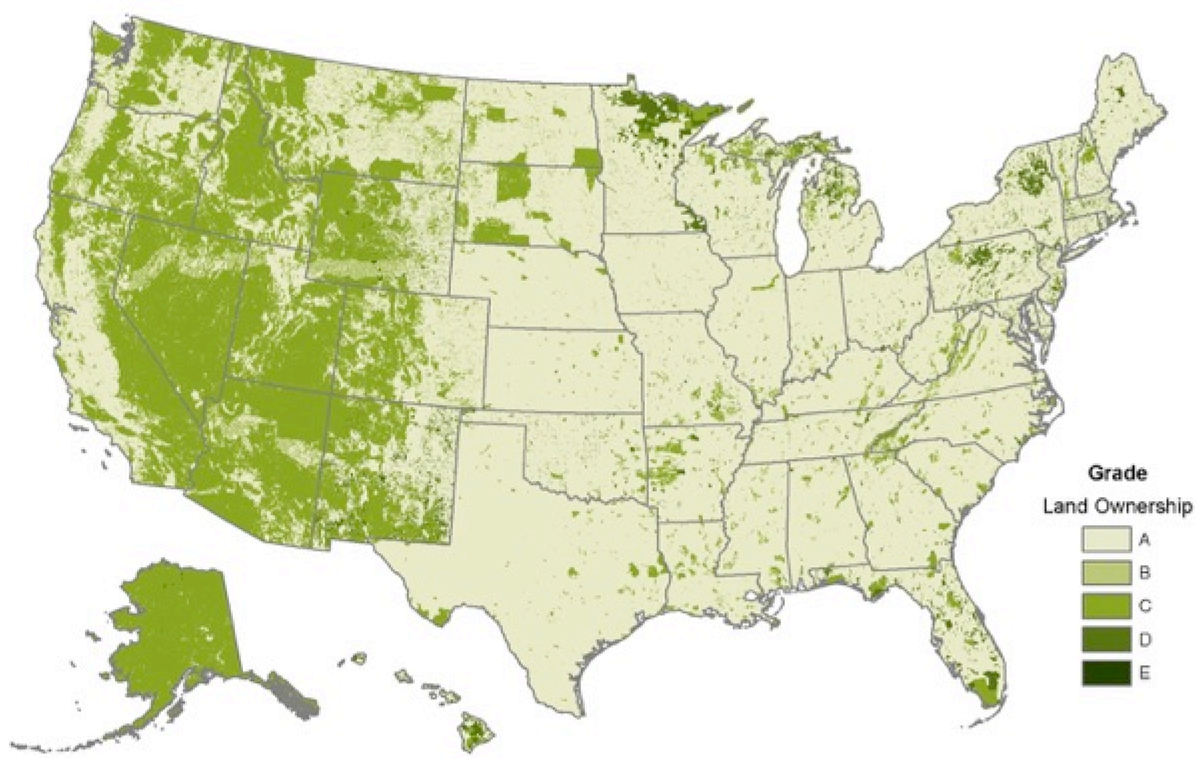
3.5 Barrier 5: Land Ownership

The land ownership sub-attribute grades and map (Figure 9) address 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, the Young et al. (2014) analysis looked at the timeframe for NEPA process for EAs, which showed that the average time for the 11 projects with USFS *and* BLM jurisdiction took 60 days longer to complete than the 28 projects completed solely by the BLM.

3.5.1 Land Ownership Grading and Map

For mapping purposes we mapped private land as an A, federal or state land with defined geothermal leasing regulations a C, and state land without defined geothermal leasing regulations a D. We were not able to identify split estates (distinct owners for surface and mineral estates) and other multiple owner grades (grades B and E).



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	Flag
E	Multiple landowners (federal, state or private combination with potential split estate issues)	Flag

Figure 9. ***Map of Land Access: Land Ownership Sub-attribute.*** **This map represents an activity level of E, with a weighting factor of 1 in the summary Land Access attribute map.**

3.6 Barrier 6: Proximity to Military Installations

All military installations have a demand for power as well as a desire to be energy independent. In 2012, President Obama pledged that the Department of Defense (DoD) was committed to deploying three gigawatts of renewable energy – including solar, wind, biomass, and geothermal – on Army, Navy, and Air Force installations by 2025 in addition to the broader goal of meeting 25% of DoD's energy needs with renewable energy by 2025 (White House, 2012). In the late 1970's, the Navy created what is now called the Geothermal Program Office (GPO) in order to complete exploration and development of the Coso geothermal field. Today the GPO oversees the 240 MW (installed capacity) Coso operations and conducts exploration for additional geothermal resources worldwide (Sabin et al., 2010). The GPO is the only federally funded organization that actively manages a geothermal field as well as conducts geothermal exploration.

Between proactive operations conducted by the Navy's GPO and the renewable energy initiatives outlined by President Obama, the DoD recognizes the strategic importance of renewable power to its mission. Development of clean, on-site, renewable energy sources enhances energy security to meet mission-essential requirements (NREL, 2013). Considerations must be made, however, to be sure that mission impacts associated with the development of renewable resources on a military installation are minimized.

A goal of the Navy's GPO is to explore DoD-managed ground with the objective of identifying potentially developable geothermal resources on military installations. Two barriers typically encountered on every DoD installation are (1) the potential impacts that the development of a geothermal resource, for instance, may have on the mission, and (2) understanding the authority for geothermal resource development on military land.

In the western United States, where a large portion of these 30 million acres of DoD-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 (ICOs) are meeting mission requirements and preventing encroachment[2]. 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. An example of encroachment mitigation is the operations at the Coso geothermal field, Naval Air Weapons Station (NAWS) China Lake, CA. Coso personnel are evacuated from the field up to 20-30 times per year in order to facilitate NAWS range tests. If

[2] 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)

Coso were not evacuated, these range tests might be limited and Coso might be seen as encroaching on mission activities. Proposed exploration and development activities on or near base boundaries may be perceived as encroaching on mission activities as well. The recent award of geothermal development leases to Ormat adjacent to an active Navy bombing range in southern California might result in curtailed Navy activities – or vice versa - if/when Ormat were to develop this land.

The second barrier is the lack of clarity in the authority to develop geothermal resources on military bases. Much of the land that constitutes military bases in the western United States was withdrawn from public use from the Department of Interior (DOI) by DoD for military purposes. All federal mineral rights – other than these DoD withdrawn lands – are managed by the BLM. The military manages all lands inside their installation fence lines. At the same time, the GPO invokes the authority to explore, develop, and sell geothermal resources on military installations as defined in 10 USC 2916 and 2917.

The apparent contradictory language embedded in 10 USC 2916 and 2917 versus specific withdrawal language, among other issues, was to be resolved by the Interagency Military Land Use Coordinating Committee (IMLUCC).[3] The IMLUCC was convened almost 6 years ago to address this issue; however, no resolution was generated. Despite the efforts by GPO and the IMLUCC, the impasse over who has the authority to develop potential geothermal resources inside DoD-managed land still exists and potentially developable resources described by the GPO in Dixie Valley and at Hawthorne Army Depot remain undeveloped (Alm et al., 2012; Meade el al., 2012).

<u>3.6.1 Proximity to Military Installation Grading and Map</u>

The *military installation* sub-attribute grades and map (Figure 10) address the distance to known military bases and other areas under military control. For mapping purposes we mapped the location of military bases as a grade of D, with grades A-C representing specified distances from these military bases up to ten miles. Grade E represents areas where a project negatively impacts a military installation. Because this is a site-specific determination made on a case-by-case basis, no E grade areas are mapped.

4. Land Access Summary: Influence on Geothermal Resource Potential

This section summarizes the weighting of each land access sub-attribute, the grading of the combined sub-attributes (i.e., attribute grade), and the impact on the 2008 USGS identified and undiscovered geothermal resources estimates.

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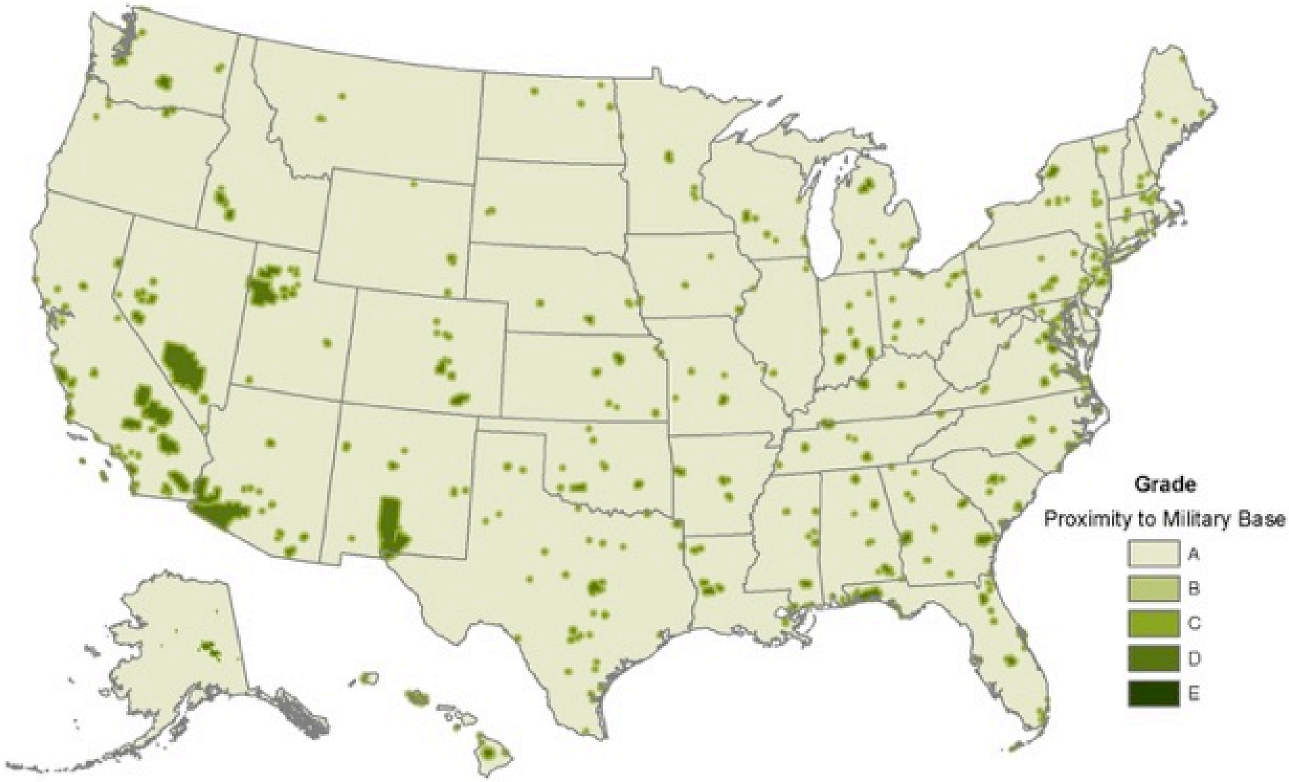
[3] The Interagency Military Land Use Coordination Committee (IMLUCC) is a policy organization at the Assistant Secretary/Deputy Under Secretary/Deputy Assistant Secretary level to resolve issues and provide guidance for the DOD, DOI, USDA, and DOT related to military use of Federal lands and airspace. (http://www.blm.gov/style/medialib/blm/co/field_offices/royal_gorge_field/planning0/hamet.Par.56482.File.dat/im2001-030attachment%202.pdf)



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

Figure 10. ***Map of Land Access: Military Installation Sub-attribute*. This map represents an activity level of E, with a weighting factor of 1 in the summary Land Access attribute map.**

4.1 Summary of Sub-Attribute Weights, Grades, and Cumulative Land Access Attribute Map

Scores for each of the land access sub-attributes were weighted as follows and summed to create a summary land access map:

1. Cultural and Tribal Resources (Weight = 2)[4]
2. Environmentally Sensitive Areas (Weight = 3)
3. Biological Resources (Weight = 3)
4. Federal and State Lease Queue (Weight = 2)
5. Land Ownership (Weight = 1)
6. Military Installation (Weight = 1).

Table 4 summarizes the currently *unallowed*, *significant barrier*, and *flagged* grades for each of the Land Access sub-attributes. The land access analysis identified three *unallowed* sub-attribute grades, six developer-identified *significant barrier grades* sub-attribute grades, and eleven *flagged* sub-attribute grades.

Table 4. Summary of Unallowed, Significant Barrier and Flagged Land Access Sub-attribute Grades. Bolded sub-attribute grades have been mapped for this analysis. Sub-attribute grades listed in italics were unable to be mapped using publically available data; they may impact additional areas not shown on these maps, and may prevent development of additional geothermal potential not indicated in this analysis.

Attribute	Sub-Attribute	Unallowed Grade(s)	Significant Barrier Grade(s)	Flagged Grade(s)
Land Access	Tribal and Cultural Resources	E	D	C
Land Access	Environmentally Sensitive areas	E	D	C
Land Access	Biological Resources	E	D	C
Land Access	Federal Lease Queue	--	E	C
Land Access	State Lease Queue	--	E	**C**, *D*
Land Access	Land Ownership	--	--	D, E
Land Access	Military Installation	--	E	C, D

[4] Although cultural and tribal resources can be a significant challenge to geothermal project development, maps of the locations of these resources are not publically available. The cultural map included in this analysis represents the locations of tribal lands and not the sacred resources themselves (which could occur on or off of tribal lands), and is therefore weighted less in this summary map than environmentally sensitive areas and biological resources. As projects develop and cultural studies are conducted in project areas, this sub-attribute will increase in weight to 3.

The colors in the summary map (Figure 9) reflect a range of scores from 12 (all six sub-attributes graded as A) to 60 (all six sub-attributes graded as E). *Unallowed* areas (grade E) are shown in black; *significant barrier* areas (grade D) are shown in red. The breakdown of grades based on weighed sum is shown in Table 2.

The map shows that many areas in the western United States where geothermal resources are most prevalent also show the greatest challenges to land access, as highlighted in the yellow and orange coloring.

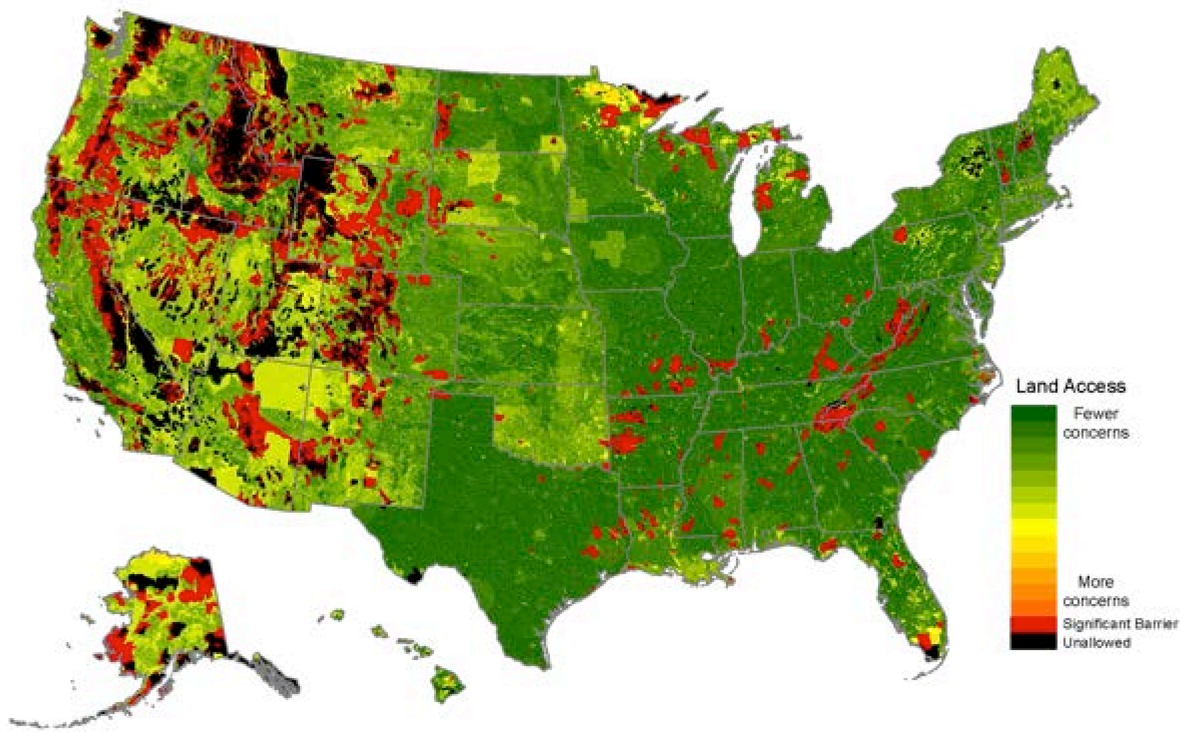


Figure 11. ***Land Access Attribute Summary Map.*** **This map represents the summary of all of the Land Access sub-attributes. The colors in the summary map reflect a range of scores from 12 (all six sub-attributes graded as A) to 60 (all six sub-attributes graded as E).** ***Unallowed*** **areas (grade E) are shown in black;** ***significant barrier*** **areas (grade D) are shown in red.**

4.2 Impact of Land Access Barriers on 2008 USGS Geothermal Resource Estimate

Table 5 lists the currently existing developer-defined *significant barriers* and the impacted capacity potential for the USGS Identified and Undiscovered potential. The only sub-attributes for which we were able to map *significant barrier* situations were Biological Resources, Environmentally Sensitive Areas and Lease Queue. For the Identified resource potential, Biological Resources were the largest cause of *significant barriers* potentially preventing the developer from pursuing development. For the Undiscovered resource potential, the Lease Queue was the largest causes of *significant barriers*. This suggests that much of this undiscovered potential is on National Forest Lands and due to the USFS lacking a line-item budget for geothermal lease and permit processing.

Table 5. Developer-Defined Significant Barriers and Affected MW

Developer-Defined Significant Barrier(s)	Identified MW Affected
Environmentally Sensitive Area (ESA)	49
Lease, Cultural	266
Lease	49
Biological	36
Total	400

Developer-Defined Significant Barrier(s)	Undiscovered MW Affected
Lease	2,517
Biological	810
Environmentally Sensitive Areas (ESA)	577
Combinations	121
Total	4,025

Note: For both the Identified and Undiscovered potential, it may be possible to access these resources from adjacent lands. Additionally, because the location of the Undiscovered potential isn't precisely known, it may be that they do not align with the barriers the way the maps suggest. These analyses were beyond the scope of this study, but would be areas for developers to investigate prior to developing in these resources.

In addition to a yes/no measure of land access impacts to deployment, land access barriers also have the potential to impact project timelines. Due to modeling limitations, project timeline impacts were not modeled for land access improvement scenarios.

5. Improvement Scenarios for Land Access Barriers

This section reviews the results of GETEM supply curve development and the ReEDS U.S. electricity generation forecasting to understand baseline deployment scenarios (i.e., business as usual) for geothermal resources as well as land access improvement scenarios that may increase deployment of geothermal resources in future forecasts for 2030 and 2050.[5]

5.2 Business as Usual Deployment

Before discussing potential improvement scenarios for geothermal deployment, this section provides an overview of the results of the ReEDS business-as-usual (BAU) scenario. The BAU scenario considers current and anticipated future conditions, assuming no drastic improvements in technical or non-technical barriers. The BAU scenario, therefore, does not consider any land access improvements and serves as a baseline to understanding the increased deployment in the potential improvement scenarios.

[5] For a summary of caveats associated with the ReEDS model see Regional Energy Deployment System (ReEDS) Model Documentation: Version 2016 p. 7. http://www.nrel.gov/docs/fy17osti/67067.pdf.

The ReEDs model assumes a current (2016) geothermal installed capacity of 2,685 MW. Under the BAU scenario, the model forecasts total deployed capacity for identified and undiscovered hydrothermal geothermal resources to be 4,109 MW by the year 2030 and 5,952 MW by the year 2050, as shown in Figure 12.

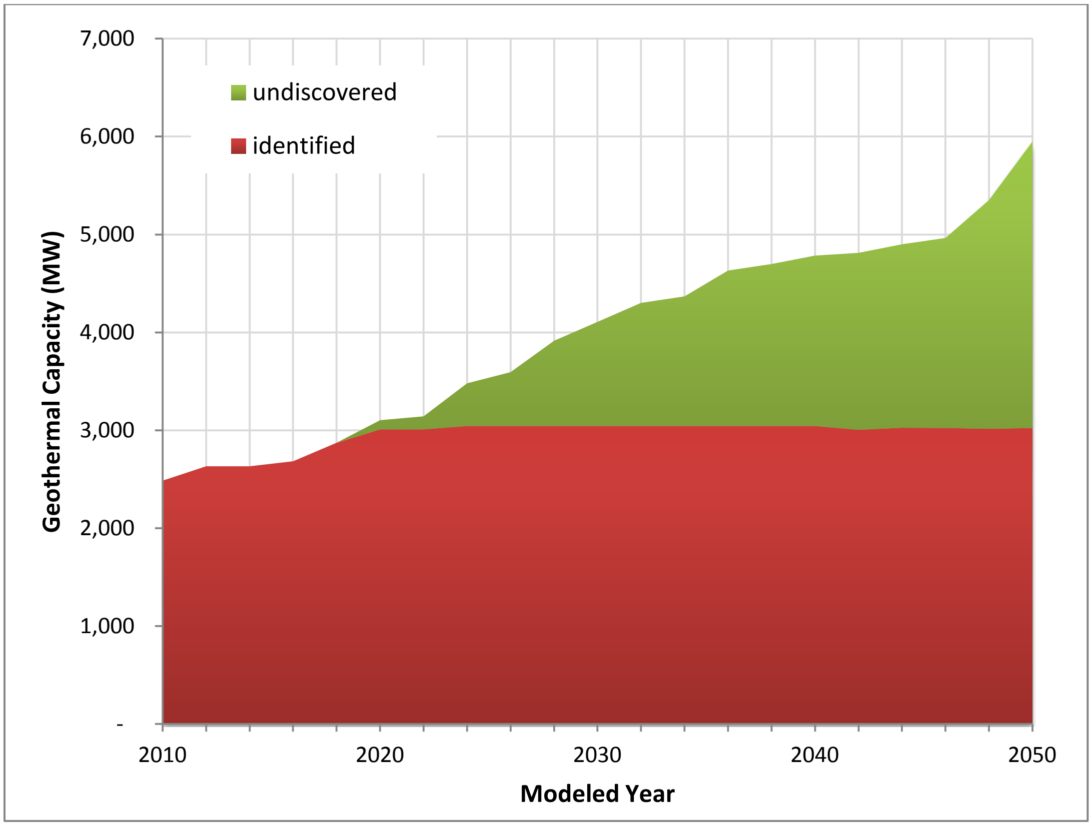


Figure 12. *Business As Usual Deployment Curve for Hydrothermal Geothermal Resources.* The graph reflects ReEDS model outputs for forecasted hydrothermal geothermal resource deployment through 2050 under business-as-usual assumptions.

In addition, the ReEDS model forecasts larger levels of geothermal deployment due to enhanced geothermal systems in scenarios analyzing improved technology impacts. These scenarios deploy cost-competitive enhanced geothermal systems beginning in 2024. For the impact of land access improvements under these scenarios, see Young et al., 2017.

5.3 Low Potential Improvement Scenario: USFS Obtains Continuous Funding to Process Geothermal Leases and Permits

While the BLM receives a specific line-item budget for processing geothermal lease applications and permits, the USFS does not have a geothermal specific line-item budget and instead geothermal activities requiring USFS approval are funded as part of the minerals and geology line-item, which accounts for less than 1% of the USFS annual budget (Witherbee et al, 2013). As discussed in section 3.4a, lack of funding for processing leases and permits, particularly at the

USFS, created backlogs of geothermal project leases (i.e., a federal lease queue) awaiting processing, with some applications sitting in the queue for 34 years (BLM and USFS, 2008). In response, as part of EPAct 2005, Congress established a program for leasing of lands in the National Forest System (i.e., lands managed by the USFS) and to reduce the backlog of geothermal lease applications pending on January 1, 2005, by 90% within 5 years of enacting the statute (EPAct § 225(b)(3)). With the end of the Congressionally authorized funding to clear the lease queue (cut short after only 3 of the 5 years planned), the USFS returned to its pre-EPAct funding levels, where it is expected that leases will again begin to become backlogged (Witherbee et al, 2013). As a result, we classified un-leased National Forest System lands as a developer-identified significant barrier.

This improvement scenario analyzes the impacts of a continuous geothermal line-item budget for the USFS to process lease applications and permits on National Forest System lands.

Under the low potential improvement scenario, the ReEDS model forecasts total deployed capacity for identified and undiscovered hydrothermal geothermal resources to be 4,189 MW by 2030 and 6,075 MW by 2050 – a 2% (124 MW by 2050) improvement over the BAU scenario. The low impact of this proposed improvement on deployment suggests that land access is not the only barrier to deployment for the 4,400 MW with significant land access barriers.[6]

5.4 Disruptive Potential Improvement Scenario: Environmental Mitigation Measures

As discussed in Section 3 generally, while much of the geothermal resource potential identified by the USGS is not legally “unallowed” for development (e.g. national parks, national monuments, Wilderness Areas, etc.), a large portion was identified by members of the BET as a significant barrier area potentially preventing development. Many of the sites were identified as significant barrier areas based on three of the land access sub-attributes: Cultural and Tribal Resources, Environmentally Sensitive Areas, and Biological Resources. These sites may include Wild and Scenic Rivers, National Wildlife Refuge, National Preserves, and Sage Grouse Priority Habitat Management Areas. The design of mitigation measures which allow development with minimal surface impact could move these areas out of the significant barrier classification. This disruptive improvement scenario combines the low improvement scenario of the USFS receiving continuous funding to process geothermal permits and leases with the design of mitigation measures that allow access to additional (but not all) significant barrier areas.

Under the disruptive potential improvement scenario, the ReEDS model forecasts total deployed capacity for identified and undiscovered hydrothermal geothermal resources to be 4,206 by 2030 and 6,103 by 2050 – a 3% (152 MW by 2050) improvement over the BAU scenario. The low

[6] Additional scenarios were run for the GeoVision study combining land access improvements with other improvements (e.g., permitting, market and/or technology improvements). These additional runs suggest that when other barriers are overcome, these land access improvements will have a greater impact on deployment. (Young et al., 2017)

impact of this proposed improvement on deployment suggests that land access is not the only barrier to deployment for the 4,400 MW with significant land access barriers.[7]

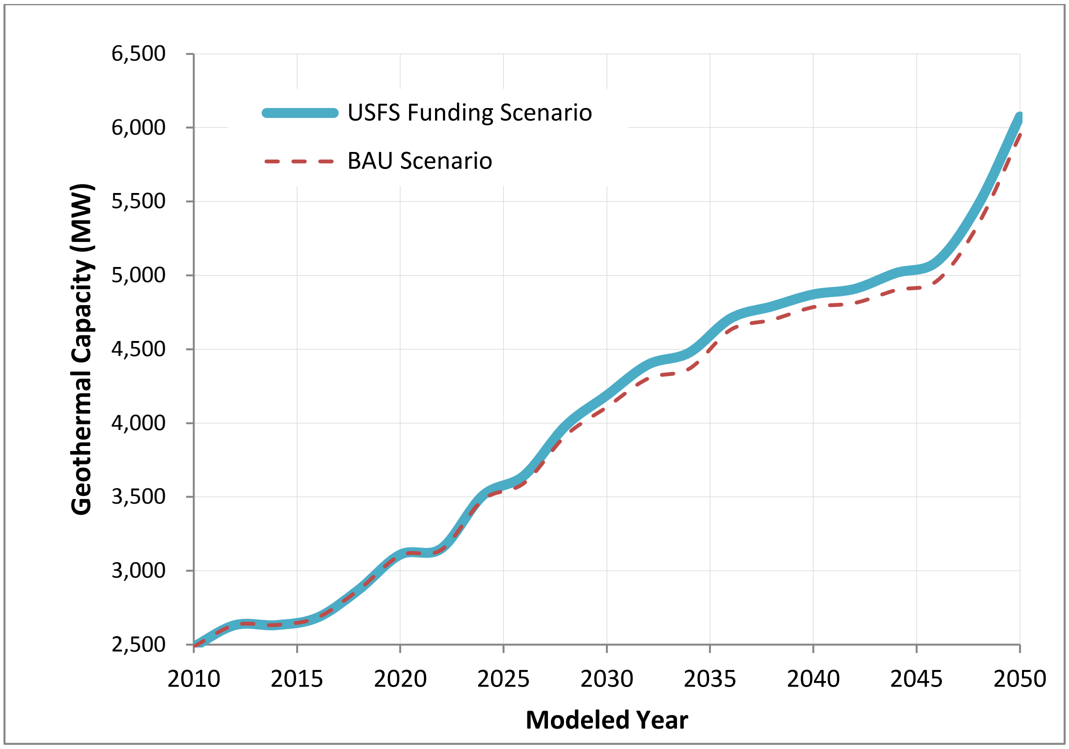


Figure 13. ***Low Potential Improvement Scenario Deployment Curve for Hydrothermal Geothermal Resources.*** **The graph reflects ReEDS model outputs for forecasted hydrothermal geothermal resource deployment through 2050 under a low potential improvement scenario that includes continuous funding to the USFS for lease and permit processing. The graph compares the results of the low potential improvement scenario to the business as usual scenario.**

6. Conclusion

This paper highlighted many of the identified geothermal barriers associated with accessing land for geothermal development. Of the identified land access barriers, leasing, biological resources, environmentally sensitive areas, and cultural and tribal resources were identified as posing significant barriers to potentially prevent a project developer from pursuing development. While these land access barriers decrease the available geothermal supply curve for identified and

[7] Additional scenarios were run for the GeoVision study combining land access improvements with other improvements (e.g., permitting, market and/or technology improvements). These additional runs suggest that when other barriers are overcome, these land access improvements will have a greater impact on deployment. (Young et al., 2017)

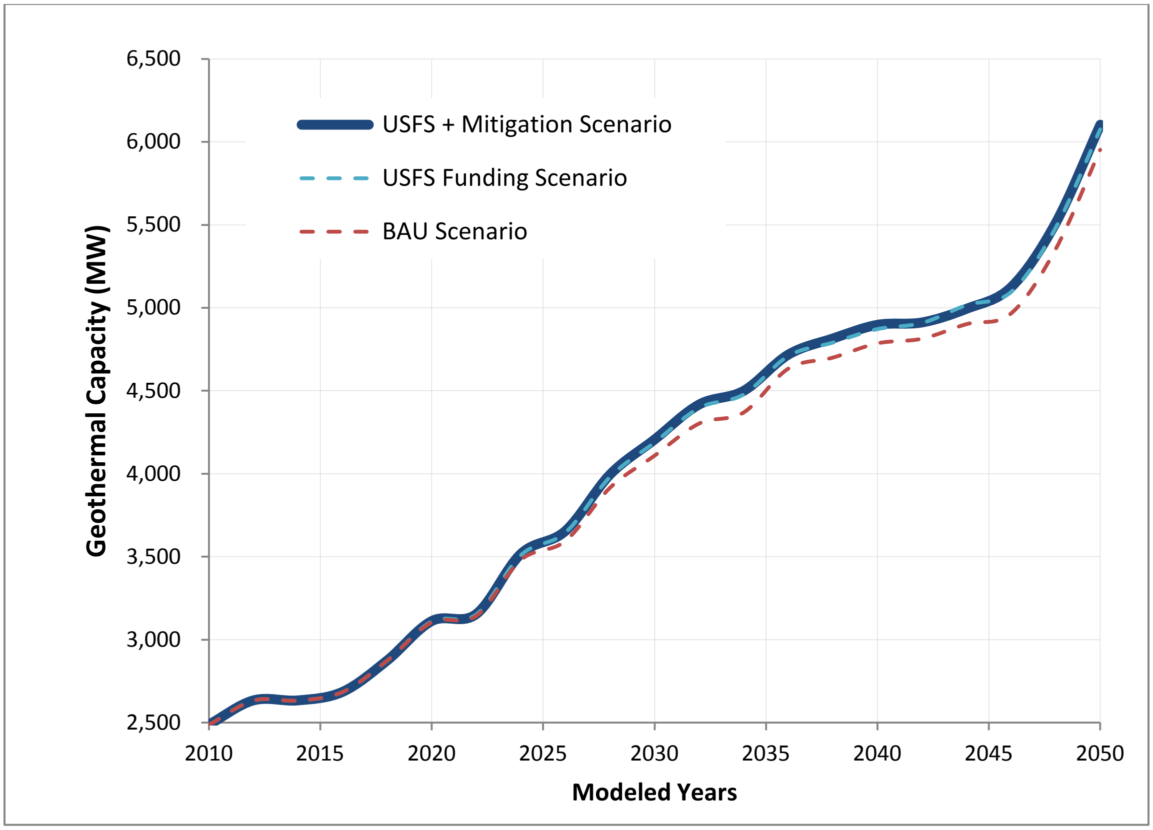


Figure 13. ***Disruptive Potential Improvement Scenario Deployment Curve for Hydrothermal Geothermal Resources.*** **The graph reflects ReEDS model outputs for forecasted hydrothermal geothermal resource deployment through 2050 under a disruptive potential improvement scenario that includes continuous funding to the USFS for lease and permit processing as well as advanced mitigation measures. The graph compares the results of the disruptive potential improvement scenario to the business as usual and low improvement scenarios.**

undiscovered geothermal resources by roughly 4,500 MWs, potential improvement scenarios have the potential to reduce the impact of the land access barriers on the geothermal supply curve.

The model results forecast that continuous funding to the USFS could result in deployment of an additional 80 MW of geothermal capacity by 2030 and 123 MW (2%) of geothermal capacity by 2050 when compared to the BAU scenario. The model results forecast that the creation of advanced environmental mitigation measures coupled with continuous funding to the USFS could result in deployment of an additional 97 MW of geothermal capacity by 2030 and 151 MW (3%) of geothermal capacity by 2050 when compared to the BAU scenario.

In addition to land access availability, land access barriers also have the potential to impact project timelines. Due to modeling limitations, project timeline impacts were not modeled for land access improvement scenarios. Timeline improvements were modeled in other scenarios, however, which suggest that timeline improvements (and therefore land access improvements) have the potential to have significant impact on geothermal deployment (see the to-be-published Levine and Young, 2017, for more details).

With technology improvements, we see land access improvements having a larger impact on deployment with large levels of enhanced geothermal systems occurring due to cost-competitive EGS costs beginning in 2024. For the comprehensive report, see Crossing the Barriers: An Analysis of Non-technical Barriers to Geothermal Development and Potential Improvement Scenario Analyses for the DOE GeoVision Study. (Young et al. 2017, NREL Report Forthcoming).

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