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Technical Report
NREL/TP-7A40-70526
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Foreword

Under H.R. 7324, passed in the 110th Congressional Session, the National Academy of Sciences (NAS) was tasked with generating a report detailing the energy development potential on all lands currently managed by the U.S. Department of Energy (DOE). In 2013, DOE tasked the National Renewable Energy Laboratory (NREL) with conducting an analysis of large-scale power production potential on DOE lands and tasked NAS with providing oversight to the NREL analysis. NREL had previously conducted similar analyses for DOE that examined renewable energy (RE) potential on DOE lands. While the focus of those earlier analyses was the power production potential for on-site energy use, the focus of the new analysis was the potential for off-site export of power.

NREL's scope for this assessment included conducting a preliminary analysis of RE techno-economic potential at 55 individual DOE sites. This scope included estimating the technical potential at each site along with an electricity production cost for several RE generation technologies that were commercially available at utility scale in 2015, including photovoltaics (PV), concentrating solar power (CSP), wind, biomass, landfill gas (LFG), waste to energy (WTE), and geothermal. DOE directed that this analysis of power potential would utilize NREL's REopt model, which was used in the DOE site analyses that NREL had previously conducted for DOE. NREL was also tasked with conducting a more detailed analysis of energy development potential at specific sites that showed high techno-economic potential in the initial screening. The scope also included an assessment of the potential to develop fossil fuel and nuclear material resources at the 55 DOE sites, which was conducted by the Colorado School of Mines (CSM).

DOE determined the 55 sites for the analysis of resource potential and provided NREL and CSM with basic data on these sites in spreadsheet form, including the site name, DOE program office, latitude and longitude, city, county and state, and site acreage. DOE directed that only these data should be used for the preliminary analysis; individual DOE sites were not to be contacted by NREL or CSM during the preliminary screening stage. The analysis was conducted in 2015 and thus the reference year was established as 2015. The analysis did not attempt to project technology costs in future years, but it should be taken into consideration that these costs would likely vary from those in 2015 due to the dynamic nature of renewable technology costs. For example, utility-scale PV costs dropped 39% from 2015 to 2017, and wind costs dropped 4% over a similar period according to the NREL Annual Technology Baseline. As the assessment results were intended for DOE's internal use, they did not undergo a separate external technical peer review prior to being submitted for NAS review.

This report documents the methodologies, assumptions, preliminary findings, and limitations of the analysis and is divided into three areas—RE resources and associated power generation technologies, fossil fuel resources, and uranium and thorium resources. The RE section is the main focus of the report and it includes a high-level screening analysis of the techno-economic potential of PV, CSP, wind, biomass, LFG, and WTE, and the resource potential of geothermal for all 55 sites. The RE section also includes a market barriers and opportunities analysis for 14 of the sites that showed high techno-economic potential in the initial screening. While RE resources were examined for commercial power production potential, fossil fuel and nuclear material resources were examined only for extraction potential. The fossil fuel section describes a high-level screening for the potential presence of oil, gas, and coal resources at the same 55 sites, but does not include consideration of economics or market factors. The uranium and thorium section describes a high-level screening for the potential presence of these resources at the same 55 sites, and also includes a market barriers and opportunities analysis for the five highest-ranked sites that emerged from the initial screening.

The methodology applied in the RE resource assessments for the 55 sites relies on levelized cost of energy (LCOE) as the primary high-level screening metric, following the practice applied in previous assessments for DOE. This LCOE analysis relies on the minimal site-specific information provided by DOE along with many assumptions necessary to complete the analysis. While the LCOE metric is an estimate of the cost to generate power at a site, it does not consider the market value of the generated power (e.g., what the power could be sold for), which can be a major driver for RE projects. The LCOE does not capture the difference between a dispatchable and a non-dispatchable technology, nor does it incorporate land-use or utility interconnection constraints that affect project viability.

It should also be noted that each resource or technology screening was conducted independently; the use of lands for the development of one resource or technology would necessarily reduce the availability of those lands for other energy project development, and this consideration was not taken into account in this analysis. Further, given differences in the screening methodologies applied for renewable energy, fossil fuel, and nuclear material resources, it is not possible to compare opportunities between these types of resources.

Acknowledgments

This work was sponsored by the U.S. Department of Energy's (DOE's) Asset Revitalization Initiative and Office of Legacy Management (LM). Tony Carter and Tania Smith directed this work. They provided DOE land area and location information and helped guide the analysis. The following National Renewable Energy Laboratory (NREL) subject matter experts provided consultative guidance at various stages of the analysis: Craig Turchi, Gregg Tomberlin, Jeff Bedard, Billy Roberts, Dan Olis, Kate Anderson, Ran Fu, Jenny Melius, Gian Porro, Doug Arent, Robin Newmark, and Gary Schmitz. David Shafer and Deb Steckley from DOE LM also provided invaluable support.

In addition to the reviewers noted above, the following DOE offices reviewed this work: General Counsel, Science, Energy Efficiency and Renewable Energy, Bonneville Power, Environmental Management, Nevada Field Office, Sandia Field Office, Congressional and Intergovernmental Affairs, National Environmental Policy Act (NEPA) Policy and Compliance, Asset Management, and National Nuclear Security Administration (NNSA).

List of Acronyms

ANL	Argonne National Laboratory
AU	Assessment Unit
BCFG	billion cubic feet of gas
BLM	Bureau of Land Management
BNL	Brookhaven National Laboratory
BPA	Bonneville Power Administration
CNTA	Central Nevada Test Area
CSM	Colorado School of Mines
CSP	concentrating solar power
DC	direct current
DOE	U.S. Department of Energy
EA	environmental assessment
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ESPC	energy savings performance contract
EUR	estimated ultimate recovery
FNAL	Fermi National Accelerator Laboratory
GIS	geographic information system
INL	Idaho National Laboratory
ITC	investment tax credit
LCOE	levelized cost of energy
LFG	landfill gas
LM	Office of Legacy Management
LMOP	Landfill Methane Outreach Program
LADPU	Los Alamos Department of Public Utilities
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
MACRS	modified accelerated cost recovery system
MMBNGL	million barrels of natural gas liquids
MMBO	million barrels of oil
MRDS	Mineral Resources Data System

MSW	municipal solid waste
NAS	National Academy of Sciences
NEPA	National Environmental Policy Act
NETL	National Energy Technology Laboratory
NNSA	National Nuclear Security Administration
NNSS	Nevada National Security Site
NRC	Nuclear Regulatory Commission
NREL	National Renewable Energy Laboratory
O&M	operations and maintenance
ORNL	Oak Ridge National Laboratory
PPA	power purchase agreement
PTC	production tax credit
PV	photovoltaics
RE	renewable energy
REC	Renewable Energy Certificate
RFI	request for information
RFP	request for proposals
RPS	Renewable Portfolio Standard
SAM	System Advisory Model
SIL	surge impedance loading
SNL	Sandia National Laboratories
SPO	Sustainability Performance Office
SPRU	Separations Process Research Unit
SREC	Solar Renewable Energy Credit
TEAM	Transformational Energy Action Management
TPS	Total Petroleum System
UMTRCA	Uranium Mill Tailings Radiation Control Act
USGS	U.S. Geological Survey
WIPP	Waste Isolation Pilot Plant
WTE	waste to energy

Executive Summary

This report summarizes a screening assessment of the potential for independent power producers to generate large-scale power on 55 U.S. Department of Energy (DOE) lands (sites) for export to power markets, rather than serving on-site DOE loads. The analysis considered renewable energy (RE) technologies that are currently commercially viable at utility scale, including photovoltaics (PV), concentrating solar power (CSP), wind, biomass, landfill gas (LFG), waste to energy (WTE), and geothermal technologies. The methodology applied relies on levelized cost of energy (LCOE) as the primary high-level screening metric, following the practice applied in previous related assessments conducted for DOE. The report also summarizes an assessment of the presence of fossil fuel, uranium, or thorium resources for potential extraction, but not for commercial power production potential, at these same 55 DOE sites.

The report addresses the three energy resources—RE resources and the associated power generation technologies, fossil fuel resources, and uranium and thorium resources. The report presents the methodology and assumptions applied in each of the assessments, and describes the preliminary findings, limitations, and potential next steps for each. The RE section, the main focus of the report, estimates the techno-economic potential at all sites (the technical potential[1] of a project combined with an associated electricity production cost) of the above commercially available renewable technologies at the 55 sites. The report also includes a more comprehensive analysis of market barriers and opportunities at 14 of the sites that showed high techno-economic potential in the initial screening. The fossil fuel section describes a high-level screening for the potential presence of oil, gas, and coal resources at the same 55 sites, but does not include consideration of economics or market factors. The uranium and thorium section describes a high-level screening for the potential presence of these resources at the 55 sites, and also includes a market barriers and opportunities analysis for the five highest-ranked sites that emerged from the initial screening.

DOE determined the 55 sites for the analysis of resource potential and provided some basic data on these sites for use in the screening analysis. DOE directed that only these data should be used for the preliminary analysis; individual DOE sites were not to be contacted by the National Renewable Energy Laboratory (NREL) or Colorado School of Mines (CSM) during the preliminary screening stage. DOE lands withdrawn from the Bureau of Land Management (BLM) for specific purposes that do not include resource extraction or the generation of electricity for external distribution were not included in the 55 sites.

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[1] Technical potential for a site can be understood in relation to other types of RE potential. The largest potential, resource potential, is the amount of energy physically available. Technical potential takes into account real-world geographic constraints and energy generation system performance, but not economics. Economic potential is the subset of the technical potential that is available where the cost required to generate the energy (which determines the minimum revenue requirements for development of the resource) is below the revenues associated with the generation. Lastly, market potential is the amount of energy we expect to be generated through market deployment of renewable technologies after considering the impact of current or future market factors, such as incentives and other policies, regulations, investor response, and the economic competition with other generation sources. Definition from Brown, Austin, et al. 2016. *Estimating Renewable Energy Economic Potential in the United States: Methodology and Initial Results*. TP-6A20-64503. National Renewable Energy Laboratory, Golden, CO. https://www.nrel.gov/docs/fy15osti/64503.pdf.

Each resource or technology screening was conducted independently; the use of lands for the development of one resource or technology would necessarily reduce the availability of those lands for other energy project development, and this consideration was not taken into account in this analysis. Further, given differences in the screening methodologies applied for renewable energy, fossil fuel, and nuclear material resources, it is not possible to compare opportunities between these types of resources. While some of the 55 sites show techno-economic potential for hosting RE technologies, or show potential for the presence of fossil fuel, uranium, or thorium resources, many DOE sites are subject to restrictions (e.g., security considerations, mission-related uses, and environmental contamination) that may significantly impact the development of energy resources on site.

Renewable Energy Resources

The high-level RE screening analysis estimated the techno-economic potential of commercially available PV, CSP, wind, biomass, LFG, and WTE at the 55 sites determined by DOE. The analysis considered a variety of factors, based on data available in 2015, the year the analysis was conducted and thus the analysis reference year. For example, the potential of solar energy technologies (PV and CSP) at each site was estimated by considering solar resource, available land area (site acreage), and the cost and performance of the technologies in 2015. While the results of the screening analysis are, in most cases, not sufficient to inform a definitive go/no-go decision regarding RE development at these sites, they may help DOE identify those sites with relatively high techno-economic potential that warrant further analysis. Further, technology costs and other factors are not static.[2] As such, this type of screening analysis should be updated if these factors change significantly going forward. For example, if costs, especially for PV and wind, continue to fall, some sites may show increased techno-economic potential in the future.

The techno-economic potential for all RE technologies, except geothermal, included an estimate of the levelized cost of energy (LCOE). The LCOE has the same units ($/kWh), as utility-purchased energy and can be thought of as the average cost of energy produced by an energy-generating system. While every one of the 55 DOE sites shows technical potential for at least one of these RE technologies, the estimated LCOEs vary widely between sites and between technologies (Figure 1). For the lowest-cost wind and WTE sites, estimated LCOEs are $0.05/kWh or less.[3] For the lowest-cost PV, LFG, and biomass sites, estimated LCOEs are near $0.10/kWh. CSP LCOEs start at $0.20/kWh.

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[2] For example, utility-scale PV costs dropped 39% from 2015 to 2017, and wind costs dropped 4% over a similar period according to the NREL Annual Technology Baseline. “Annual Technology Baseline and Standard Scenarios.” NREL, http://www.nrel.gov/analysis/data_tech_baseline.html.

[3] The WTE LCOE is highly dependent on the cost of feedstock, which is assumed in this analysis to be a revenue equal to the average tipping fee in the state. The WTE plant would rely on a revenue stream for providing a disposal option rather than paying for a more traditional fuel, which is the reason for negative LCOEs in some cases.

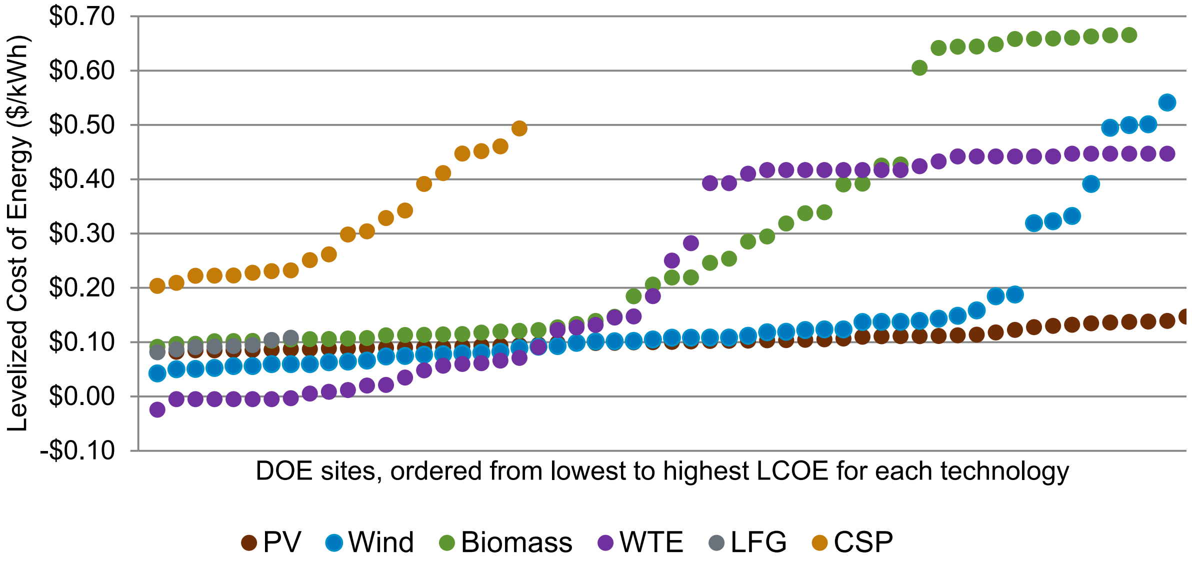

Figure 1. Estimated LCOE by RE technology and site, ordered from lowest to highest cost for each technology

At DOE's direction, LCOEs in this analysis were calculated using an NREL model called REopt. REopt and its predecessor, REO, were used in previous site screening studies for DOE. The model was developed at NREL to efficiently screen a large number of sites by leveraging geospatial renewable resource data, technology cost curves, and technology performance equations. While the REopt model is often used for system integration and optimization across multiple technologies, those capabilities were not used in this analysis. Rather, system sizes for this analysis were determined based on a set of constraints and each technology was screened individually. While not all REopt capabilities were utilized, its application across multiple technologies ensured use of a standardized set of assumptions to enable consistent individual technology screenings.

While LCOE can be a useful metric for comparing the cost of different technologies at a given location, it does not indicate whether a technology has the potential to be cost-effective or result in a profitable project. To determine economic viability, or economic potential, LCOE must be compared to the market value of the generated electricity. For example, LCOE could be compared to a utility's avoided cost in order to understand the profitability of exporting energy to the power market. However, at the time of this analysis, values for utility avoided costs were not uniformly available. Existing datasets were not sufficiently granular to apply to specific sites and had gaps where wholesale electricity price data was not reported for some regions of the country. Therefore, the screening analysis relies only on the LCOE metric. A more detailed assessment to inform a project development decision would need to include estimation of the market value of the energy production potential at the site.

The RE analysis also considered the technical potential of geothermal resources. Based on hydrothermal resource viability, literature review, and expert judgment, four sites show potential for hosting hydrothermal reservoirs.

In addition to the screening analysis of DOE's portfolio of 55 sites, an analysis framework for identifying market barriers and opportunities was developed and applied to 14 sites as illustrative examples of project development considerations and processes. This framework included a review of common project development considerations for site availability: offtake (a purchase agreement for the energy produced by a power generation project), permitting processes, and economic constraints. For each site, each of these categories was assigned a qualitative color-coded rating based on the level of project risk. This rating system is coded into four separate bins: Green (acceptable project risk); Yellow (significant uncertainty/moderate risk); Red (unacceptably high risk); and Gray (not evaluated).

Based on this market barriers and opportunities analysis framework, even the sites with the highest techno-economic potential for large-scale power production (lowest LCOEs) face significant challenges. For example, sites in the Southwest (Nevada National Security Site [NNSS] and Los Alamos National Laboratory [LANL]) have high quality solar resources and show good techno-economic potential for both PV and CSP. However, while LANL has 400 acres that could be available within existing security restrictions, the site is adjacent to Bandelier National Monument and is home to four endangered species, the land value is high, and the project would be limited to 58.6 MW by existing (2015) transmission line capacity, three-quarters of the site's technical potential. NNSS would need to install 10 miles of transmission lines to connect its generation to the transmission network, obtain approval from BLM for use of the land for other than weapons testing, mitigate the impacts to desert tortoise species, and address cultural resources.

Several DOE sites have successfully implemented both small- and large-scale RE projects, including PV at Brookhaven National Laboratory (BNL) and NREL, wind at Pantex, and biomass at the Savannah River Site. With the exception of PV at BNL (which exports all power off site), the purpose of these projects is to meet on-site energy loads or serve research purposes, neither of which was considered in this report. In order to more fully assess the potential for large-scale RE project development for power export on DOE lands, the market barriers and opportunities analysis framework could be applied to more of the DOE sites, starting with those sites that show the highest techno-economic potential. While not considered in the scope of this report, DOE could also continue to pursue RE projects dedicated to serve on-site energy loads or to meet research purposes.

Fossil Fuel Resources

Researchers from CSM screened the same 55 DOE sites considered in the RE screening analysis for their potential to produce oil, gas, or coal in commercial quantities. Given limitations in the resources and time available for analysis, the screening analysis did not attempt to estimate either the magnitude of the potential resource that might be accessible from the site or the exploration and production costs associated with developing that resource. An initial screening of the sites was conducted; a further market barriers and opportunities analysis for specific sites was not performed.

A single assessment was done to identify either oil or gas potential. Once this initial site assessment was performed, sites were screened out of consideration for more detailed analysis if any of the criteria were not met. The following criteria were applied in the screening: site area larger than 160 acres; site unlikely to be released for alternative use, or no past or present activities that would most likely preclude its transfer; site located in a sedimentary basin; active drilling or production in the basin; and active drilling or production near the site. Seventeen sites were screened out on the basis of inadequate acreage. Two sites were screened out because DOE was unlikely to permit oil and gas drilling on these sites. Twenty-two sites were identified as low or very low priority because they were outside a sedimentary basin, on the edge of a sedimentary basin, or showed no evident oil and gas activity in the basin. Another seven sites were screened out due to lack of active drilling or production nearby in the basin. The remaining six sites were considered to have distinct potential for oil and gas production, although on varying development time scales.

The high-level evaluation of coal potential at these DOE sites relied extensively on information provided to the NAS Panel by coal resource experts from the U.S. Geological Survey (USGS).[4] The following criteria were applied in the screening: site located in a sedimentary coal-producing basin; site area larger than 160 acres; and depth to the coal formation likely to be less than 3,000 feet (commonly considered a cutoff for the economic production of coal). Thirty-six sites were identified as falling outside coal-producing sedimentary basins and were screened out on that basis. Another seven sites were screened out on the basis of inadequate acreage. Of the remaining ten sites, two sites are known to be in areas where the coal formation appears at depths much greater than 3,000 feet. The eight sites that emerged from the screening for further consideration have coal resources that may be present but of unknown potential and cost to develop. Further analysis of these sites could include assessing the depth to the coal-producing formation and other potential development factors, including whether coal mining operations would be permitted on the sites.

Uranium and Thorium Resources

This report provides a high-level assessment of the potential for uranium or thorium commercial resource development on the same 55 DOE sites assessed for both RE and fossil fuel potential. Researchers from CSM conducted an initial portfolio screening analysis in two stages. The first eliminated 36 of the 55 potential sites from consideration for nuclear resource development based on their distance from known resources (mines, mining claims, mining prospects, and sampling sites). The second stage of the screening process ranked the remaining 19 potential sites by assessing nearby mine production status and type of material production to identify the sites for a market barriers and opportunities analysis.

The market barriers and opportunities analysis performed on the top five potential nuclear resource sites considered the production history of the sites and adjacent mining operations. The analysis also considered ongoing mining projects that were being evaluated by mining companies in adjacent or inclusive areas relative to the DOE sites. This evaluation provides an overview of the public and commercial interest in these areas and indicates which sites could be worthy of further investment.

While these top five ranked sites are known to be in proximity to uranium deposits, they may be too small to produce meaningful quantities of uranium ore. As such, economically viable mineral

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[4] Warwick, Peter D. and Steven M. Cahan, “Review of Coal and Geologic Carbon Dioxide Storage Resources Underlying DOE Lands,” (presented May 21, 2015).

extraction would likely require the return of these sites to a local mining company to be incorporated into a larger existing operation on land adjacent to the DOE sites. Commercial development at any site would require a mineral survey to determine if nuclear resources are indeed present. Additionally, for those sites that are disposal cell sites, an inquiry with respect to 10 CFR 40 could be made to determine if mining operations can be performed at the sites. Finally, the support of the local public is a high priority for all nuclear operations; without significant support from the local populace, most projects are unlikely to proceed.

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1 Introduction

In the 110th Congressional Session, under H.R. 7324, the National Academy of Sciences (NAS) was tasked with creating a report that details the energy development potential on all lands currently managed by the U.S. Department of Energy (DOE). The full text follows:[5]

> H.R.7324 - Energy and Water Development and Related Agencies Appropriations Act, 2009, Section 313: Energy Production. The Secretary of Energy shall provide funding to the National Academy of Sciences to conduct an inventory of the energy development potential on all lands currently managed by the Department of Energy together with a report, to be submitted not later than July 1, 2009, which includes (1) a detailed analysis of all such resources including oil, gas, coal, solar, wind, geothermal, and other renewable resources on such lands, (2) a delineation of the resources presently available for development as well as those potentially available in the future, and (3) an analysis of the environmental impacts associated with any future development including actions necessary to mitigate negative impacts.

In 2013, DOE tasked the National Renewable Energy Laboratory (NREL) with conducting an analysis of energy production potential on specific DOE-managed lands and tasked NAS with providing oversight to the NREL analysis. The NREL scope included conducting a high-level analysis of techno-economic potential (the technical potential of a project combined with the associated economic aspects of developing that project) for large-scale energy production at all specified DOE sites, and a detailed analysis of potential at the most promising (approximately ten) sites. Technologies or resources that DOE directed NREL to include in the analysis are electricity-producing technologies including photovoltaics (PV), concentrating solar power (CSP), wind, biomass, landfill gas (LFG), waste to energy (WTE), geothermal, fossil fuels, and uranium or thorium resources for nuclear power production. NREL contracted with the Colorado School of Mines (CSM) to conduct the fossil fuel and nuclear analyses.

The NAS formed a committee[6] to oversee this project, which the NAS calls "Energy Resource Potential for DOE Lands." NREL and CSM provided three briefings to the committee on analysis methodology, assumptions, and findings to date. One final briefing occurred in early fall 2015. Proceedings from the briefings are available.[7] NREL and CSM have provided answers to committee questions and continued dialog with the committee as requested. The committee reviewed an initial draft of this report and issued its own related report in late 2017 entitled *Utilizing the Energy Resource Potential of DOE Lands*.[8]

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[5] Energy and Water Development and Related Agencies Appropriations Act, 2009, H.R.7324, 110th Cong. (2007-2008); accessed July 17, 2015; https://www.congress.gov/bill/110th-congress/house-bill/7324/text.

[6] "Committee Membership Information: Energy Resource Potential for DOE Lands." National Academies of Sciences. 2014. http://www8.nationalacademies.org/cp/CommitteeView.aspx?key=49647.

[7] "Project Information: Energy Resource Potential for DOE Lands." National Academies of Sciences. 2014. http://www8.nationalacademies.org/cp/projectview.aspx?key=49647.

[8] National Academies of Sciences, Engineering, and Medicine. 2017. *Utilizing the Energy Resource Potential of DOE Lands*. Washington, DC: The National Academies Press. https://doi.org/10.17226/24825.

1.1 Previous Studies Related to Energy Systems That Serve On-Site Consumption

NREL and others have previously conducted numerous studies that have considered on-site generation to serve on-site building and process energy requirements at DOE sites. A synopsis of each of these studies follows (this may not be an exhaustive list). These studies were delivered to DOE headquarters staff and site staff, but with few exceptions are not generally published or publicly available; they were meant for DOE internal use.[9] Initially, studies were funded by the DOE Federal Energy Management Program (FEMP), and subsequently the responsibility was transferred to the DOE Sustainability Performance Office (SPO). Many of the studies were completed by NREL; others were produced by other contractors supporting FEMP or SPO activities:

1. *Renewable Energy Screening for the Sustainability Performance Office at Twenty Select DOE Facilities*, September 31, 2014; (Internal); NREL, Emma Elgqvist, Kate Anderson, and Travis Simpkins; NREL/TP-7A40-62604. This report, requested by SPO, identifies an opportunity to save $66–$95 million in energy costs over 25 years by implementing four to six potentially cost-effective renewable energy (RE) projects. The study evaluates PV, solar water heating, solar ventilation air preheating, wind energy, biomass, and WTE. This may be considered a high-level screening study with only limited information about details such as available land area at each site.
2. *Solar Thermal and PV Applications for Site Long-Term Surveillance and Maintenance, Tuba City, Arizona*, January 30, 2011; NREL. This report considers the potential for both solar thermal and PV technologies for long-term research purposes at Tuba City, Arizona.
3. *Renewable Energy Analysis for Department of Energy Savannah River Site*, September 31, 2009; DOE Federal Energy Management Program; NREL, Andy Walker. The RE technologies considered include PV, wind, solar thermal and solar thermal electricity, solar ventilation air preheating, solar water heating, biomass thermal and biomass electricity (combustion, gasification, and anaerobic digestion), daylighting, LFG, and ground-source heat pumps.
4. *Renewable Energy Optimization (REO) for 31 Department of Energy Facilities*, October 14, 2008; NREL, Andy Walker; DOE, Anne Crawley. This high-level screening study is based on geospatial databases of RE resources and utility rates and policies. Technologies considered include PV, wind energy, solar ventilation preheating, solar water heating, solar parabolic trough collectors for heat and electricity, biomass gasification for heat and electricity; anaerobic digestion for heat and electricity, and daylighting by adding skylights to buildings.
5. *DOE Fermi National Accelerator Laboratory (FNAL) Renewable Energy Feasibility Assessment*, October 14, 2008; NREL, Alicen Kandt, Scott Haase, and Robi Robichaud. This study considers roof-top and ground-mounted PV, solar hater heating, solar ventilation preheating, wind energy, biomass for heat and power, and biodiesel.

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[9] The studies may be available from the authors by request, with the permission of the site's staff and the study sponsor.

6. *Nevada Test Site Solar Energy Feasibility Assessment*, September 9, 2008; DOE; NREL, Alicen Kandt. This study considers PV on small communications loads and carport structures (building rooftop applications were not considered due to security issues); solar hot water, and solar ventilation preheating.
7. *Renewable Energy Feasibility Assessment Argonne National Laboratory (ANL)*, August 25, 2008; Transformational Energy Action Management Team (TEAM) Renewable Energy Feasibility Assessment ANL; NREL, Alicen Kandt, Scott Haase, and Robi Robichaud. This study evaluates PV, solar water heating, solar ventilation preheating, biomass, and wind energy.
8. *PV, CSP, and Biomass Feasibility Assessment*, July 29, 2008; TEAM Renewable Energy Feasibility Assessment DOE Hanford; NREL, Jesse Dean and Scott Haase. This study considers CSP, ground-mounted PV, and biomass for cogeneration of heat and electricity.
9. *Idaho National Laboratory (INL) Solar Thermal Assessment*, July 14, 2008; Federal Energy Management Program DOE TEAM Initiative; NREL, Andy Walker. This study considers solar water heating, solar ventilation air preheating, CSP for heat and power, and biomass energy.
10. *Stanford Linear Accelerator Center Renewable Energy Site Assessment*, July 9, 2008; ANTARES Group Inc.; Contract Reference: 20.007.01. This study evaluates PV, daylighting, solar hot water, wind, and biomass.
11. *Lawrence Berkeley National Laboratory (LBNL) Renewable Energy Site Assessment Final Report*, July 3, 2008; Prepared by ANTARES Group Inc.; Contract Reference: 20.007.01; Anneliese Schmidt. This study considers rooftop and ground-mounted PV, solar hot water, and wind energy.
12. *Renewable Energy Feasibility Assessment, Pantex Plant, Amarillo, Texas*, May 23, 2008; DOE/National Nuclear Security Administration (NNSA); NREL, Otto VanGeet. This study considers PV, solar hot water, and small-scale wind energy. Large-scale wind energy was covered by a separate report. Only nonproduction areas of the facility were included due to security issues.
13. *Brookhaven National Laboratory (BNL) Renewable Energy Site Assessment Final Report*, May 15, 2008; ANTARES Group Inc.; Contract Reference: 20.007.01; Anneliese Schmidt. This study considers roof-top and ground-mounted PV; stand-alone PV area lighting, solar water heating, solar ventilation preheating, wind energy, and biomass heat and power.
14. *DOE Pacific Northwest National Laboratory—PV, Solar Hot Water and Biomass Feasibility Assessment*, April 3, 2008; NREL, Jesse Dean and Scott Haase. This study considers rooftop and ground-mounted PV, solar water heating, biomass heat and power, and participation in a regional bio-oil plant as a source of renewable fuel.
15. *Assessing the Potential for Renewable Energy Development on DOE Legacy Management Lands*, February 2008; NREL, Doug Dahle, Dennis Elliott, Donna Heimiller, Mark Mehos, Robi Robichaud, Marc Schwartz, Byron Stafford, and Andy

Walker; DOE/GO-102008-2435.[10] This study uses geographic information system (GIS) data to analyze and assess the potential for CSP, PV, and wind power generation, on Office of Legacy Management (LM) lands.

16. *Sandia National Laboratories Solar Feasibility Assessment*, February 26, 2008; Sandia National Laboratories (SNL), Jack Mizner, Greg Kolb, Matthew Brito, and Roger Hill. This study includes roof-mounted building-integrated PV systems, ground-mounted PV systems, parking lot PV shade structures, solar parabolic trough systems, Dish Sterling engine, and a discussion of other renewable energy opportunities.
17. *DOE Los Alamos National Laboratory (LANL)—PV Feasibility Assessment NREL Final Report*, January 30, 2008; NREL, Otto VanGeet. Updated August 12, 2015; NREL, Jesse Dean. This study considers ground-mounted PV, rooftop PV, and wind energy.
18. *Waste Isolation Pilot Plant Renewable Screening Results*, December 5, 2007; NREL. This report describes PV, wind energy, and biomass and identifies the proximity of an LFG and wastewater treatment plant in the vicinity for methane production and use.
19. *DOE Germantown Facilities—PV Feasibility Assessment*, October 19, 2007; NREL, Alicen Kandt, Andy Walker, and Kevin Lynn. This study considers rooftop, ground-mounted, and carport PV systems.
20. *DOE TEAM Initiative Initial Screening: PV, Wind, and Biomass at DOE Sites*, October 10, 2007; NREL, Alicen Kandt. This study considers PV, wind, and biomass systems at 58 DOE sites across the United States; high-level screening study based on RE resources and utility rates.

This assessment differs in that this analysis contemplates energy production on DOE lands for export into a larger power market rather than serving the smaller energy requirements of the buildings on each site. Many of these previous screening studies were conducted using NREL's REO method. REO is an early planning tool, and its primary value is to identify and prioritize sites for subsequent detailed economic and feasibility studies. The REO analysis method has been improved in recent years, and is now named REopt.[11] Here we conduct an updated REopt analysis of pre-selected DOE sites, with modifications to prioritize power exports.

1.2 Scope of the National Renewable Energy Laboratory and Colorado School of Mines Analysis

In 2013, DOE tasked NREL with conducting an analysis of large-scale power production potential on DOE lands and tasked NAS with providing oversight to the NREL analysis. NREL had previously conducted similar analyses for DOE that examined renewable energy (RE) potential on DOE lands. While the focus of those earlier analyses was the power production potential for on-site energy use, the focus of the new analysis was the potential for off-site export of power.

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[10] Dahle, Doug, et al. 2008. *Assessing the Potential for Renewable Energy Development on DOE Legacy Management Lands*. DOE/GO-102008-2435. National Renewable Energy Laboratory, Golden, CO. http://www.nrel.gov/docs/fy08osti/41673.pdf.

[11] Cutler, Dylan, et al. 2017. *REopt: A Platform for Energy System Integration and Optimization*. TP-7A40-70022. National Renewable Energy Laboratory, Golden, CO. https://www.nrel.gov/docs/fy17osti/70022.pdf.

NREL's scope for this assessment included conducting a preliminary analysis of RE techno-economic potential at 55 individual DOE sites. This scope included estimating the technical potential at each site—based on minimal data provided by DOE and not in consultation with the 55 DOE sites—along with an electricity production cost for several RE generation technologies that were commercially available at utility scale in 2015, including PV, CSP, wind, biomass, LFG, WTE, and geothermal. Per the scope, DOE directed that this analysis of power potential would utilize NREL's REopt model, which was used in the DOE site analyses that NREL had previously conducted for DOE. NREL was also tasked with conducting a more detailed analysis of energy development potential at specific sites (approximately ten) that showed high techno-economic potential in the initial screening. Unlike the preliminary analysis, the detailed analysis was to include consult with the smaller subset of sites. The scope also included an assessment (conducted by CSM) of the potential to develop fossil fuel and nuclear resources at the 55 DOE sites, and it stipulated that NREL would compile the CSM and NREL findings into one report.

1.3 Site Data Used in the Analysis

DOE provided NREL and CSM with basic data on 55 DOE sites that formed the basis of this analysis. The data were provided in spreadsheet form in 2013 and included the following data relevant to this analysis: site name, DOE program office, latitude and longitude, city, county and state, and site acreage. Appendix A lists the sites that were included and the site-specific information provided by DOE. Excepting the sites included in the Market Barriers and Opportunities Analysis Framework in Section 2.2 and at the direction of DOE, site data was not validated with site managers.

Sites included in the analysis are DOE-owned lands for which DOE has outright title, or a land withdrawal of federal public lands that was established for purposes of a DOE mission. For the latter category, the withdrawal is usually from land that is managed by the Bureau of Land Management (BLM), although some DOE withdrawals have been made for land managed by the U.S. Forest Service. However, for land-withdrawal DOE sites, the jurisdictions granted to DOE may or may not allow development of energy resources.[12]

A number of DOE sites that are managed by the Office of Legacy Management (LM) were excluded from this analysis because DOE does not have ownership of the lands. Although LM may conduct long-term surveillance and maintenance at the site, DOE either never had title to the land or has ceded title to the land. Examples of these include most of the sites being cleaned up or that have been cleaned up under the Formerly Utilized Sites Remedial Action Program; these sites were the locations of private companies that made components or performed specialized testing with materials for DOE. In other cases (e.g., the Durango, Colorado, processing site), DOE transferred the title to a local government even though some contamination (usually subsurface) may remain on the site. These situations are usually a result of LM making former DOE sites available for beneficial use by other government entities, although deed restrictions typically accompany the land that prevent some types of use.

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[12] David Shafer, email response to NAS Committee question, June 29, 2015.

2 Renewable Energy Analysis

NREL was tasked by DOE to assess DOE sites for RE potential. The analysis consisted of two steps: a portfolio analysis at all 55 sites, and an analysis of market barriers and opportunities for a smaller subset of sites. The focus of this analysis is commercially available, electricity-producing technologies for power production at a large scale by an independent power producer, not DOE, with the intent of selling the power off site.

NREL performed a portfolio screening analysis with limited data input from DOE, which resulted in a levelized cost of energy (LCOE) estimate for PV, wind, biomass, LFG, WTE, and CSP technologies at each of the 55 sites. Sites were analyzed for geothermal potential purely on the presence of resource. The LCOEs were used to prioritize the sites for further analysis.

NREL leveraged previous project development experience to develop a framework for market barriers and opportunities analysis to further explore project potential. For demonstrative purposes, the framework was applied to the top sites (usually top two sites) per technology having the lowest LCOE. This framework can be used by DOE, developers, and other interested parties to further explore the potential for RE generation on federal lands.[13]

Throughout the analysis, the assumptions and input data were refined based on feedback from DOE and technology experts. The process applied in this analysis is outlined in Figure 2.

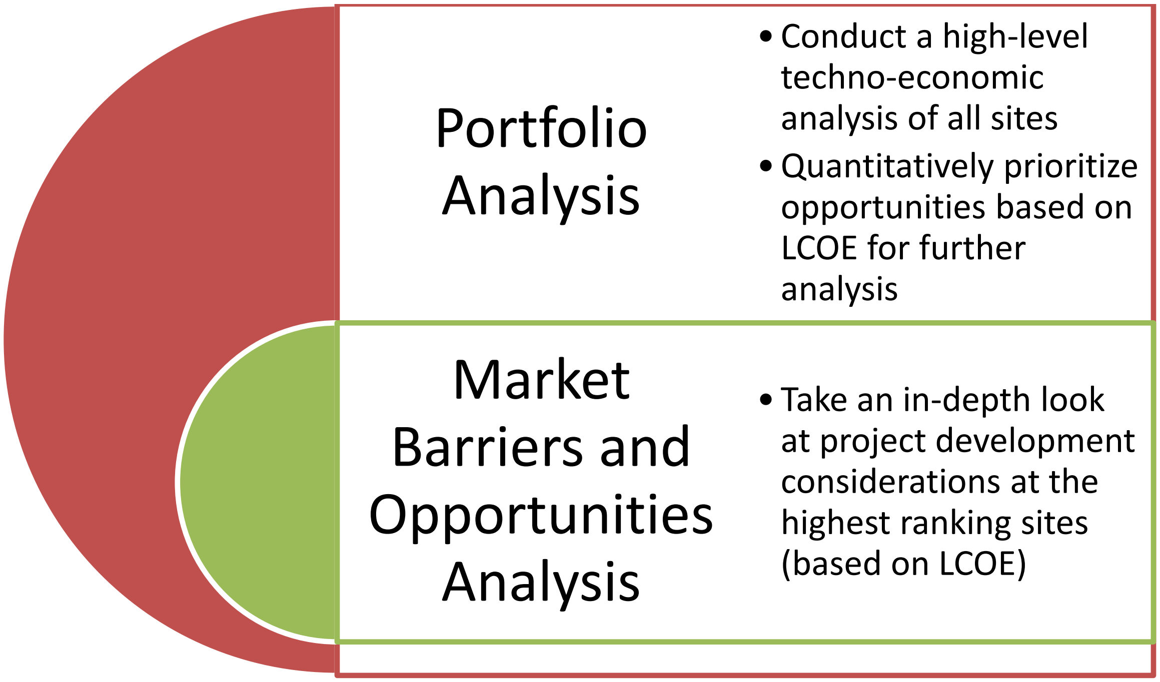

Figure 2. Project analysis process

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[13] Springer, R. 2013. *A Framework for Project Development in the Renewable Energy Sector*. TP-7A40-57963. National Renewable Energy Laboratory, Golden, CO. http://www.nrel.gov/docs/fy13osti/57963.pdf.

2.1 Portfolio Analysis

The portfolio analysis was used as a screening method to rank potential energy projects from lowest to highest LCOE. The results of this analysis are unlikely to produce results sufficient to base a decision on to design, procure, and build an energy production facility; however, the level of detail is sufficient as a first cut to help prioritize sites for further analysis.

Figure 3 shows various ways in which RE generation development potential can be defined. Previous NREL studies have estimated the technical potential for RE technologies in the United States. Lopez et al (2012)[14] describes a methodology and assumptions for estimating the technical potential of six different RE technologies; these estimates do not consider economic or market constraints, and therefore do not represent a level of renewable generation that might actually be deployed. Brown et al (2015)[15] describes a methodology for estimating RE economic potential, defined as the subset of the available resource technical potential where the cost required to generate the electricity is below the revenue available in terms of displaced energy and displaced capacity. Economic potential does not consider market dynamics, customer demand, or most policy drivers that may incent RE generation.

This portfolio analysis took into consideration resource, technical, and economic potential. The market barriers and opportunities analysis (Section 2.2) also briefly explores the market potential of the sites, but was limited to a high-level comparison of the modeled LCOEs against local retail prices (i.e., identifying where energy projects' LCOEs were below the retail rate).

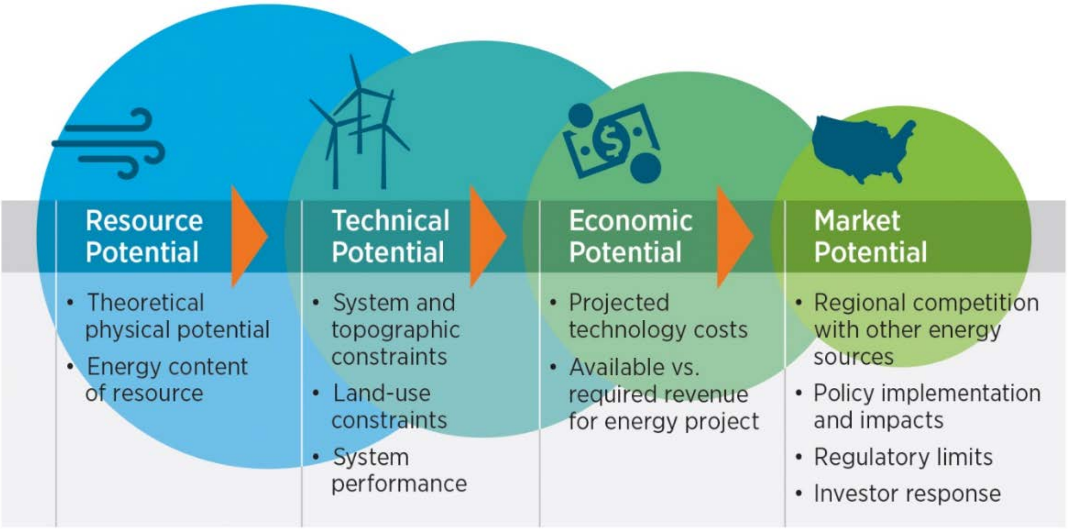

Figure 3. Defining types of renewable generation potential

Source: NREL[16]

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[14] Lopez, A., et al. 2012. *U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis*. TP-6A20-51946. National Renewable Energy Laboratory, Golden, CO. https://www.nrel.gov/docs/fy12osti/51946.pdf.

[15] Brown, A., et al. 2015. *Estimating Renewable Energy Economic Potential in the United States: Methodology and Initial Results*. TP-6A20-64503. National Renewable Energy Laboratory, Golden, CO. https://www.nrel.gov/docs/fy15osti/64503.pdf.

[16] "Renewable Energy Economic Potential." NREL, http://www.nrel.gov/gis/re_econ_potential.html.

2.1.1 Methodology

The analysis uses LCOE as a primary metric for project screening. While many factors influence energy decision-making and project viability, LCOE can be a helpful overarching metric because it incorporates resources, system performance, and fixed and variable costs. LCOE is calculated as the present value of all costs (initial costs and operations and maintenance [O&M] costs, minus any incentives) divided by the energy produced over the life of the system. It is presented as a dollar per kilowatt hour ($/kWh) value and can be used to compare alternative investments in energy-producing equipment or utility-purchased power. Appendix B provides more information about the LCOE calculation.

The LCOE calculation used in the portfolio analysis provides an initial estimate of the techno-economic potential, which includes portions of the resource, technical, and economic potential shown in Figure 3. However, the LCOE analysis was a high-level portfolio screening analysis based on minimal site inputs from DOE; it required many assumptions to be made. For example, we assumed that all land at each site would be available for development and factors such as land use, slope, and environmentally sensitive areas were not considered. Resource data was based on national data sets that may not fully capture the specific resource at a site. Furthermore, for technologies that rely on a feedstock, we assumed all feedstock in a given area would be available for energy generation; these may in reality be tied up in contracts for other purposes. We did not include the cost of interconnection to the bulk power system, or account for the declining value of variable renewables to the grid at higher levels of penetration.

Although the LCOE can be a useful metric for comparing different technologies at a given location, it does not consider market conditions, which can be a major driver for RE projects. LCOE does not indicate whether a technology has the potential to be cost-effective or turn into a profitable project. It must be compared to the market value. For energy projects that offset on-site energy loads, the LCOE can be compared with the site's current or projected utility rates. However, as previously noted, numerous other studies have considered on-site generation to serve on-site building and process energy requirements at DOE sites. In this analysis, DOE directed NREL to focus on the value of energy generation for export.

For projects that export energy to an off-taker, the LCOE can be compared to current power purchase agreement (PPA) prices or a utility's avoided cost, known as the levelized avoided cost of electricity (LACE). Projects that have an LCOE less than LACE would have a positive net value. However, at the time of this analysis, values for PPA prices and utility avoided costs were not uniformly available, and we were not able to determine estimates within this scope of work. Existing datasets were not sufficiently granular to apply to specific sites and had gaps where price data was not reported for some regions of the country. Therefore, we were not able to determine the relationship of LCOE to wholesale power prices.

Furthermore, LCOE does not capture the difference between a dispatchable and a non-dispatchable technology. A dispatchable technology such as CSP or biomass may be of more value to an energy system because it provides electricity generation and capacity. LCOE also does not capture the value of generation to the system at any given time of day due to resource variability. Projects in states with high cost of electricity, or with aggressive Renewable Portfolio Standard (RPS) requirements may also be valued higher than those in states with low cost of electricity or no RPS requirements. Ultimately, the developer of such projects would be well advised to assess their economic potential based on this more comprehensive set of factors.

While LCOE is an imperfect metric for assessing economic potential, it is useful nonetheless as an initial screening metric given the data available and the limitations of the scope of this work. and therefore we calculated LCOEs for each technology. The subsequent market-oriented analysis was then used to better understand the economic and market considerations for a subset of the sites. The LCOEs for PV, wind, biomass, LFG, and WTE were calculated using a model called REopt.[17] REopt is a techno-economic decision support model that identifies the cost-optimal set of energy technologies and dispatch strategy to meet site energy requirements at minimum life-cycle cost, based on physical characteristics of the site and assumptions about energy technology costs and electricity and fuel prices.[18] REopt analysis is a starting point for additional research and consideration of investment options, but it does not consider all factors that can inform decision-making, and is not intended to be the sole basis of investment decisions.

REopt and its predecessor REO were used in previous screening studies for DOE, and DOE specified that REopt should be used again in this analysis for consistency. However, in this case, REopt was not used to size cost-optimal systems to meet site energy requirements. Instead, the tool was used to efficiently calculate LCOEs for various individual technologies across a large number of sites by leveraging GIS resource data, technology cost curves, and technology performance equations. Using one tool across multiple technologies enables a standardized set of assumptions to be used for consistent individual technology screening.

REopt focuses on distributed generation technologies and does not include a CSP module at this time. Accordingly, the LCOEs for CSP were calculated in the System Advisory Model (SAM), also developed at NREL and available for download.[19] NREL analysts worked to ensure the consistency of assumptions used in REopt and SAM. Although SAM is capable of calculating LCOEs for geothermal potential projects, SAM requires fairly detailed site-specific information, which was not available for this analysis. NREL instead relied on resource maps and its own technology experts to evaluate the potential for geothermal development on DOE lands and did not calculate an LCOE for this technology.

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[17] Cutler, Dylan, et al. 2017. *REopt: A Platform for Energy System Integration and Optimization*. TP-7A40-70022. National Renewable Energy Laboratory, Golden, CO. https://www.nrel.gov/docs/fy17osti/70022.pdf.

[18] For example, see: Anderson, Kate, et al. 2017. "Portfolio Analysis of Renewable Energy Opportunities." Accepted for publication in *Proceedings of Society of Telecommunication Engineers Cable-Tec Expo 2016*, Philadelphia, PA, 2016. http://www.nrel.gov/docs/fy17osti/67281.pdf.

[19] Blair, Nate, et al. 2014. *System Advisor Model, SAM 2014.1.14: General Description*. TP-6A20-61019, National Renewable Energy Laboratory, Golden, CO. https://www.nrel.gov/docs/fy14osti/61019.pdf.

The purpose of the LCOE calculation is not to optimize system size, but rather to provide an initial indication of the techno-economic feasibility of an RE project at a specific site. To select a size at which to calculate the LCOE of each technology at each site, NREL applied a set of constraints to determine a maximum technically feasible size. The technology size used in the LCOE calculation was determined by the minimum of the following constraints:

- **Total land available at the site (for PV, CSP, and wind):** The total site acreage provided by DOE was used to determine an upper bound on the system size for PV, CSP, and wind. PV requires 6 acres/MW for fixed-axis systems and 7 acres/MW for tracking systems,[20] CSP requires 15 acres/MW,[21] and wind requires 30 acres/MW.[22] Although the remaining technologies (biomass, LFG, and WTE) would require a nominal amount of land (fewer than 10 acres), all sites had at least 10 acres available, so land availability was not used to constrain the size of a project for these technologies.
- **Total resource available (for LFG, biomass, and WTE):** Because LFG, biomass, and WTE draw on resources from the surrounding area, the sizes of these systems were limited by the resource available in a given radius. LFG candidate landfills and their potential capacity are determined by the U.S. Environmental Protection Agency's (EPA's) Landfill Methane Outreach Program (LMOP); LFG projects were considered only at sites with a candidate landfill within a 15-mile radius from the latitude and longitude provided by DOE. Biomass feedstock used in the analysis includes annual primary mill, secondary mill, forest, and crop resources available within a 50-mile radius. WTE projects rely on municipal solid waste (MSW) that is available in a 25-mile radius and is estimated based on the population in that area. In this preliminary portfolio analysis, NREL assumed that the entire waste stream is available.
- **Carrying capacity of the nearest transmission line:** Export of RE power may be limited by the physical capacity of the transmission line to the site or by operational reservations on the capacity of the line for other purposes. Both require detailed information to determine the actual limit on the line. For this early screening, the physical capacity of the line to carry power was approximated and the sizes of the potential energy projects constrained so as to not exceed the line capacity.
- **Maximum size:** A 100-MW maximum system size was applied for all technologies. This allows potential projects to capture economies of scale associated with larger systems and puts an upper bound on the project size for LCOE calculations. While there may be additional economies of scale available for systems greater than 100 MW, there is limited cost and production data available for systems above this scale, and therefore larger system sizes were not considered in this analysis.

Appendix B lists the system size at which each LCOE was calculated and the constraint that limited that size.

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[20] Ong, Sean, et al. 2013. *Land-Use Requirements for Solar Power Plants in the United States*. TP-6A20-56290. National Renewable Energy Laboratory, Golden, CO. http://www.nrel.gov/docs/fy13osti/56290.pdf.

[21] Land-use requirements for CSP are based on input from an NREL subject matter expert.

[22] Denholm, Paul, et al. 2009. *Land-Use Requirements of Modern Wind Power Plants in the United States*. TP-6A2-45834. National Renewable Energy Laboratory, Golden, CO. http://www.nrel.gov/docs/fy09osti/45834.pdf.

Table 1 shows how these constraints were used to determine the system size for three example technologies based on the minimum of the four constraints. In this example, the size of the PV project was determined by the transmission line capacity, the size of the wind project was determined by the amount of land available, and the size of the biomass system was determined by the amount of feedstock available in the 50-mile radius. "Unlimited" means that a constraint did not limit the system size.

Table 1. Hypothetical Example Showing How the System Size of Technologies Was Determined

Site 1	Max Size Based on Land	Max Size Based on Resource	Transmission Line Capacity	Max Project Size	Size for LCOE Calculation
PV	125 MW	Unlimited	**85 MW**	100 MW	**85 MW**
Wind	**25 MW**	Unlimited	85 MW	100 MW	**25 MW**
Biomass	Unlimited	**45 MW**	85 MW	100 MW	**45 MW**

Economies of scale for CSP are not well established; however, the minimum developable size is estimated to be 50 MW,[23] which would require about 750 acres of land. The LCOE of a CSP power tower was calculated at a fixed 50-MW size for DOE sites of at least 750 acres. The land area would have to be flat and contiguous—these criteria would need to be investigated as a next step.

The LCOEs were ordered from lowest to highest for each technology type—a lower LCOE would typically be more financially attractive than a higher one—to help prioritize the in-depth analysis. For each technology, a market barriers and opportunities analysis was conducted for the two sites with the lowest LCOEs. Section 2.2 includes the results of that analysis.

Many inputs to the LCOE calculation have inherent uncertainty and others may vary from site to site. To explore some of that variability, we performed a simple sensitivity analysis on four of the input parameters (Table 2). The first three inputs were varied by ±20% from the central scenario and were consistent among all technologies. The fourth scenario attempted to capture uncertainties that were more specific to the technology, for instance, the value of ITC for solar and feedstock costs for biomass. Uncertainties remain beyond those presented here; the ±20% high and low scenarios may not capture the full range of values for these inputs.

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[23] "Concentrating Solar Power Projects." NREL, https://www.nrel.gov/csp/solarpaces/index.cfm.

Table 2. Parameters Varied in Sensitivity Analysis

Input Varied	Lower LCOE	Central Scenario	Higher LCOE
1. Discount Rate	8%	10%	12%
2. Technology Costs	–20%	Varies, see Appendix C	+20%
3. Energy Output	+20%	Varies, see Appendix C	–20%
4. Other			
PV: ITC, SRECs[a]	30% ITC	10% ITC	No ITC
Wind: Production Tax Credit (PTC)[b]	2014 PTC	No PTC	No PTC
Biomass: Feedstock Cost	–20%	Varies, see Appendix C	+20%
WTE: Tipping Fee	–20%	Varies, see Appendix C	+20%
LFG: Fuel Cost	–20%	Varies, see Appendix C	+20%

[a] At the time this analysis was conducted, the ITC had not been extended.

[b] At the time this analysis was conducted, the PTC had not been extended.

The sensitivity analysis captures neither the full range of variability of these parameters nor any underlying probabilistic distribution. The purpose is simply to capture the range of effects an increase or decrease in these inputs would have on the LCOE. A 20% increase or decrease in technology costs may be likely depending on the location of the project; however, the energy production would most likely not increase by 20%, and the discount rate for the project would be likely to vary beyond the 20% increase or decrease modeled here. However, varying these inputs by the same amount shows the relative impacts.

- **Discount rate:** For the central scenario, the discount rate was 10% for all technologies. Developers may be able to attain a different discount rate based on technology type and project location. For example, a PV project in California, where more than 5 GW of PV was installed in 2013,[24] would most likely be able to attain a lower discount rate than a WTE plant, which has not been built in the United States in more than 25 years.
- **Technology costs:** The technology costs in the LCOE calculation are based on 2015 installed costs and use a cost curve (see Appendix C.3) to capture economies of scale associated with larger projects. Many factors can influence today's total system cost, including the cost of the hardware, installation labor, land acquisition, and developer overhead. These ranges aim to capture uncertainty about future technology cost. The analysis did not attempt to project technology costs in future years, but it should be taken into consideration that these costs would likely vary from those in 2015 due to the dynamic nature of renewable technology costs. For example, utility-scale PV costs dropped 39% from 2015 to 2017, and wind costs dropped 4% over a similar period according to the NREL Annual Technology Baseline.[25] On the other hand, only one new

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[24] U.S. Department of Energy. 2014. "2013 Renewable Energy Data Book," DOE/GO-102014-4491. National Renewable Energy Laboratory. Golden, CO. http://www.nrel.gov/docs/fy15osti/62580.pdf.

[25] "Annual Technology Baseline and Standard Scenarios." NREL, http://www.nrel.gov/analysis/data_tech_baseline.html.

WTE facility has been constructed in the United States in more than 25 years, and comprehensive historical data for project costs are not readily available.

- **Energy output:** The energy outputs represent a best estimate of those systems installed today, but with project lengths of 25 years, production in future years remains uncertain. Wind and solar resources used in the LCOE calculation are for a typical meteorological year, but in reality the quality of the resource varies from year to year and impacts the energy output of the wind or solar system. For a biomass, LFG, or WTE system, resource variability may come in the form of resource availability. Changes in planned or unplanned downtime for maintenance can impact annual energy production for any energy system.
- **Other (technology-specific):** Although scenarios 1–3 in Table 2 vary the same input by the same percentage across all technologies, scenario 4 examines significant inputs that vary from one technology to another.
    - For PV and CSP, this includes the value of the ITC, which at the time this analysis was conducted (2015) was set to drop from 30% to 10% for projects that are not implemented by 2016.
    - For wind, this includes the PTC, which at the time this analysis was conducted (2015) had not been renewed.
    - For biomass LFG and WTE, this includes the cost of feedstock, which may vary by location or type beyond what was captured in the model.

2.1.2 Assumptions

Appendix C details the assumptions used for the portfolio analysis. A brief summary of these assumptions follows.

The energy production for each technology depends on the system size and capacity factor. The capacity factor, in turn, depends on resource magnitude, system availability, system efficiency, losses, downtime, and other modeling parameters. Appendix C documents the technology assumptions.

The cost data set used for this analysis is based on 2015 research and market data, and on RE projects that were recently constructed in 2015. Costs are very dynamic and likely to change in the future, but we did not project future costs. These costs reflect 2015 U.S. national averages and include assumed contracting costs for design, supervision, and contingency. Grid improvement costs such as the cost of interconnection to the bulk power system are not included. REopt uses a segmented system cost curve to account for the economies of scale that can be realized when constructing larger systems. Appendix C includes the cost curves for each technology.

Geospatially disaggregated RE resource information used in this analysis from various national data sets is used in the RE technology equations to represent the quality of a RE resource in the area. Appendix C includes the RE resources for each site.

This analysis assumes that the projects would be owned by a taxable entity, which would be able to capture the value of current incentives, including the sale of solar renewable energy credits

(SRECs) where available. Federal incentive data were obtained from the Database of State Incentives for Renewables and Efficiency;[26] estimated SREC prices were provided by a solar financing firm, SolSystems.[27] Federal tax incentives include the investment tax credit (ITC) and modified accelerated cost recovery system (MACRS). Currently, the ITC for solar energy is 30%. However, at the time the analysis was conducted, this incentive was set to be reduced to 10% for projects implemented after 2016. Therefore 10% ITC was used. Except for SRECs, state and local incentives were not included in the LCOE analysis because those incentives are typically offered for systems much smaller than those evaluated for this analysis. Appendix C shows the incentive values assumed for each site.

2.1.3 Findings

The estimated LCOEs for the central scenario, displayed from lowest to highest for each technology type, are shown in Figure 4 for the 55 DOE sites. Across these sites, there are 55 PV projects, 20 CSP projects, 54 wind projects, 8 LFG projects, 54 WTE projects, and 52 biomass projects. Due to lack of available resource, we were unable to estimate an LCOE for some technologies at some sites. Figure 4 illustrates how LCOE values vary between technologies. LCOE is affected by a variety of factors including project size, technology cost, and energy output, which leads to the differences seen in the figure. The LOCEs indicate that there may be opportunities for some wind and WTE projects at LCOEs of $0.05/kWh or less; at $0.10/kWh, there are many PV, LFG, and biomass opportunities as well. CSP LCOEs start at $0.20/kWh. As noted previously, LCOE is just one of many factors affecting project viability, albeit a foundational one.

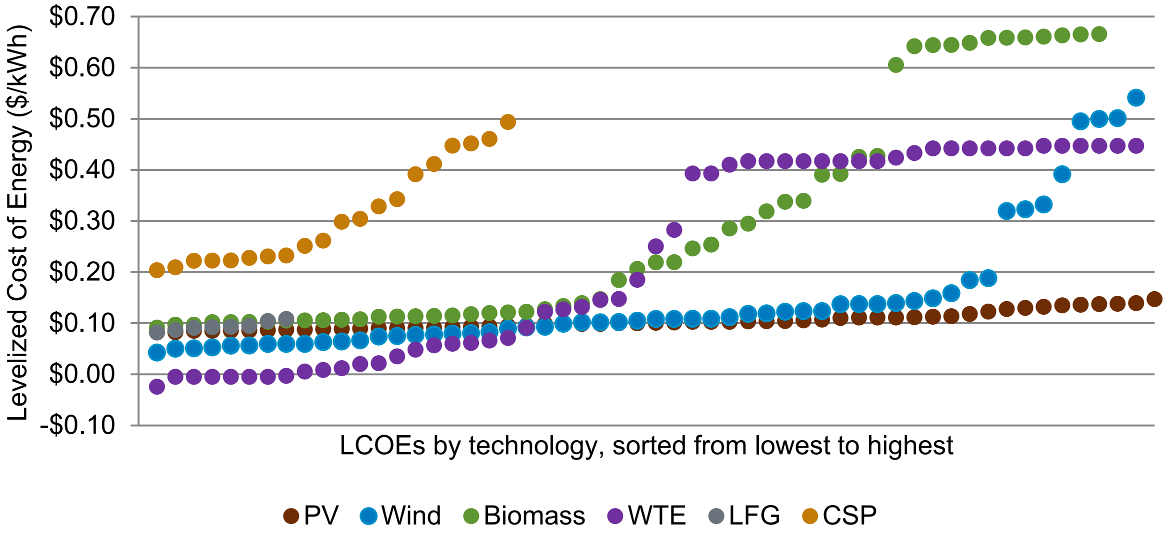

Figure 4. Summary results of LCOE calculation

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[26] "Database of State Incentives for Renewables & Efficiency." N.C. Clean Energy Technology Center and DOE, www.dsireusa.org.

[27] "SREC Customers: State Markets." SolSystems, http://www.solsystems.com/sell-your-srecs/the-srec-landscape/state-markets.

It can also be seen in Figure 4 how LCOEs vary within a technology type. PV, for example, has only a $0.05/kWh spread between the highest and lowest LCOE; the spread between the highest and lowest biomass LCOE is more than $0.50—ten times as much. In general, the differences in spreads between technologies are driven by variability of resource and impacts of economies of scale. For example, the solar resource varies by only a factor of 2 across the country;[28] the biomass resource varies by a factor of 10.[29] Furthermore, solar is a scalable technology generally with relatively small cost reductions at larger scale. Biomass, on the other hand, experiences significant cost reductions at larger sizes. Therefore, smaller biomass systems will likely have significantly higher LCOEs than larger biomass systems.

Given these ranges, LCOE may be useful for identifying potential biomass projects but is less helpful for prioritizing among potential PV projects. Although the LCOE value may not be enough to choose one PV project over another, it can be used to identify projects with little to no potential.

2.1.3.1 Photovoltaic

The LCOEs for a single axis tracking PV system were calculated for all 55 sites. The LCOEs are $0.08–$0.15/kWh. Figure 5 shows the locations of the projects, the system sizes at which they were evaluated, and the relative LCOE values. Appendix B, Table 41 includes detailed information about the inputs and results for each site.

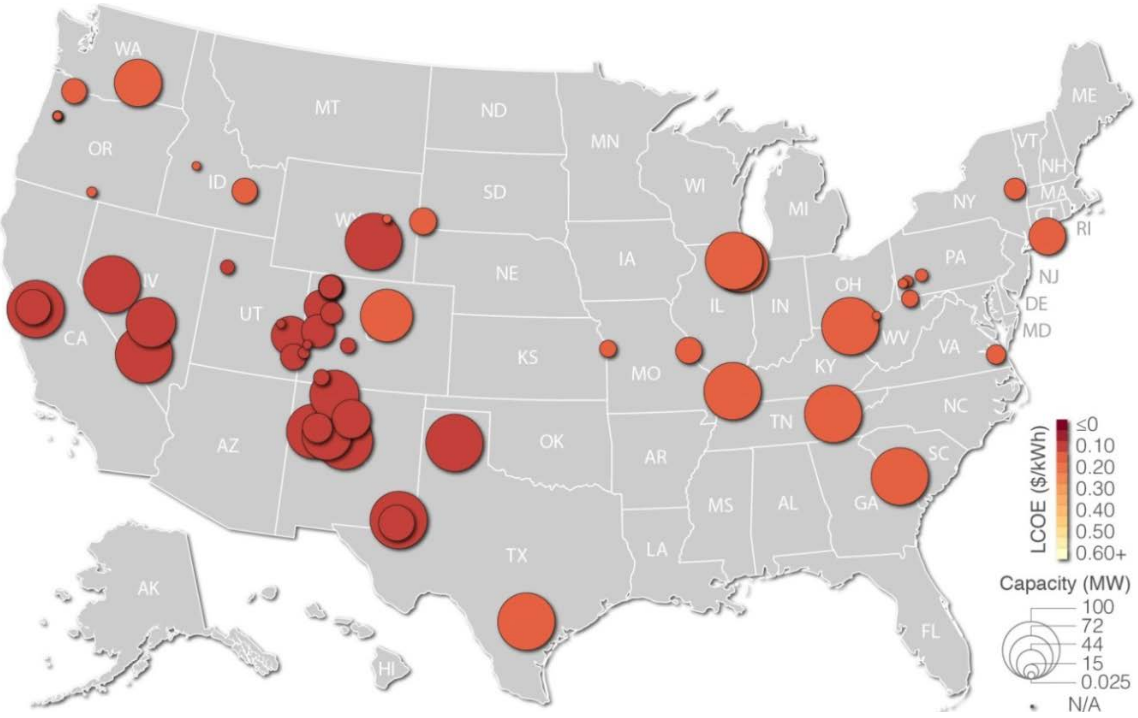

Figure 5. Potential PV project locations, sizes, and relative LCOE values

Illustration by Billy J. Roberts, NREL

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[28] "Photovoltaic Solar Resource of the United States." NREL, http://www.nrel.gov/gis/images/eere_pv/national_photovoltaic_2012-01.jpg.

[29] "Solid Biomass Resources by County." NREL, http://www.nrel.gov/gis/images/biomass_2014/national_biomass_solid_total_2014-01.jpg.

Solar projects of varying sizes are being implemented in all 50 states. In 2014, 318 MW of utility-scale PV was installed in Nevada (which has some of the best solar resource at more than 6.5 kWh/m^2/day); 390 MW were installed in North Carolina (where the solar resource is not nearly as favorable at 4.5–5.5 kWh/m^2/day). Although utility-scale PV systems represent the largest share of 2014 installations by capacity (more than 3 GW direct current [DC]), more than 1 GW DC in small-scale residential projects were installed in the same year.[30]

2.1.3.2 Wind

The LCOEs for wind projects were calculated at 54 of the 55 sites. The exempted site was located in an Idaho valley where the wind resource was not strong enough for a wind project to be feasible. The LCOEs are $0.04–$0.54/kWh with an average of $0.15/kWh. Figure 6 shows the locations of these projects, the sizes at which they were evaluated, and the relative LCOE values. Appendix B, Table 42 includes detailed information about the inputs and results for each project.

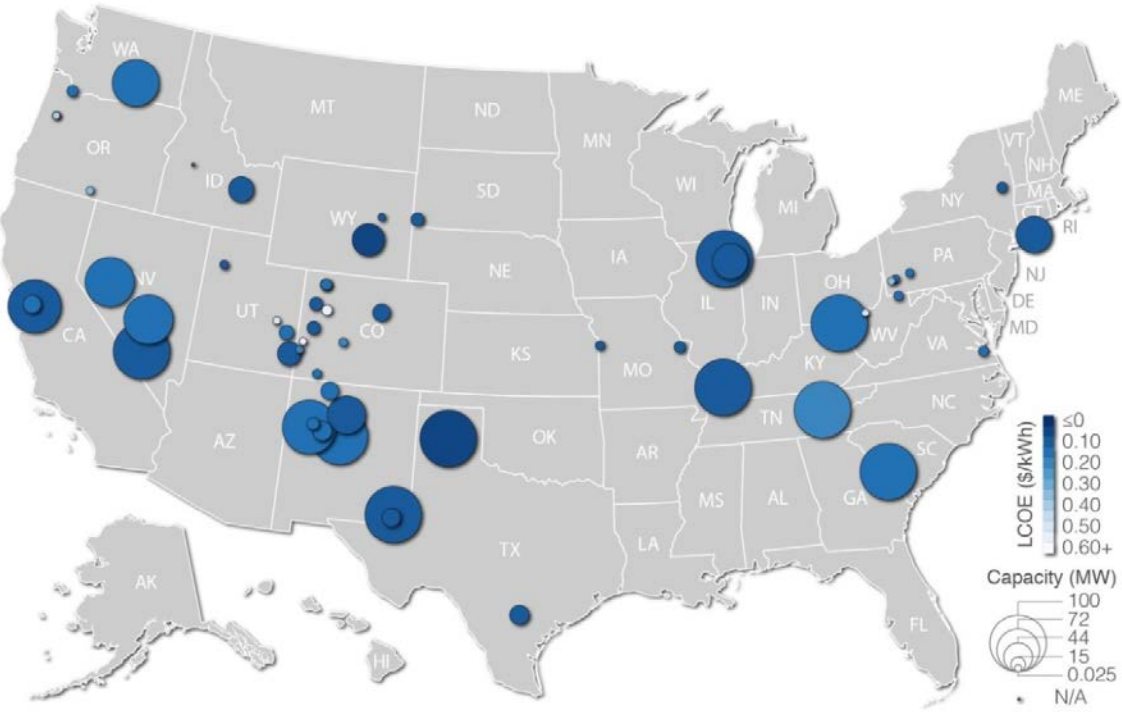

Figure 6. Potential wind project locations, sizes, and relative LCOE values

Illustration by Billy J. Roberts, NREL

Potential projects with the lowest LCOEs have both a good wind resource and enough land to host large wind farms. The economies of scale are more significant for wind than for PV and are reflected in the LCOE, but small wind projects still have the potential to be cost-effective. For example, some small potential wind projects in Wyoming have excellent wind resource and a

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[30] Fu, Ran, et al. 2015. "Economic Competitiveness of U.S. Utility-Scale Photovoltaics Systems in 2015: Regional Cost Modeling of Installed Cost ($/W) and LCOE ($/kWh)." *IEEE PVSC*. https://doi.org/10.1109/PVSC.2015.7356261.

lower LCOE than 100-MW potential wind projects in an area of Tennessee with a very poor wind resource. Wind can be one of the lowest-cost RE technologies in certain locations but requires a more complex and lengthy development process than PV.

2.1.3.3 Biomass

Potential biomass projects[31] were evaluated at 52 of the 55 sites. The exempted sites were located in parts of Nevada and Utah where no resource (feedstock) was available. The LCOEs are \$0.09–\$0.67/kWh with an average of \$0.29/kWh. Figure 7 shows the locations of these potential projects, the sizes at which they were evaluated, and the relative LCOE values. Appendix B, Table 43 provides detailed information about the inputs and results for each potential project.

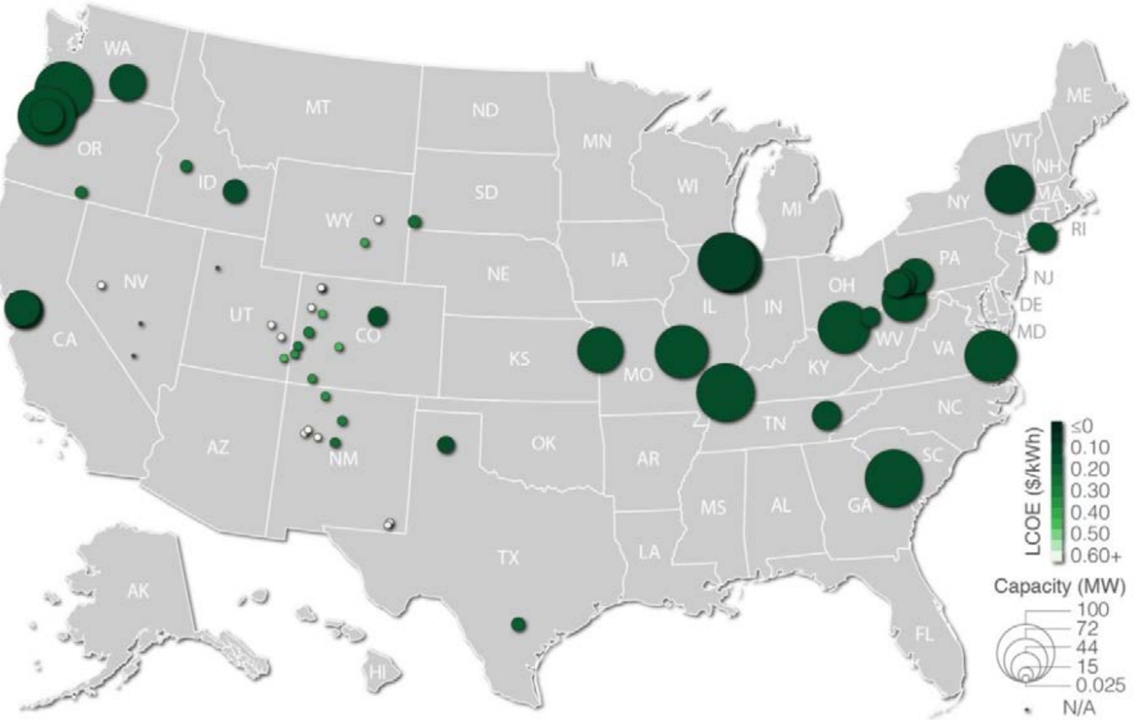

Figure 7. Potential biomass project locations, sizes, and relative LCOE values

Illustration by Billy J. Roberts, NREL

The economies of scale of biomass projects are significant, and small electricity-generating projects are typically not cost-effective. Potential biomass projects smaller than 5 MW have an average LCOE of \$0.55/kWh; projects larger than 20 MW have an average LCOE of \$0.11/kWh. The LCOE depends largely on the size of biomass system evaluated. The potential biomass projects are limited in some cases by the amount of feedstock available in a 50-mile radius. We assume that all biomass is available for electricity generation, and there is no competition from other uses. The availability of this feedstock has not been confirmed, and changes in feedstock availability could alter the potential project size and resulting LCOE. For the LCOE calculation,

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[31] Dedicated biomass projects were modeled for this analysis. These are not co-fired with coal.

a national average feedstock cost was used. In actuality, this cost is likely to vary from one region to another, between different types of feedstock, and by transportation distance. An increase or decrease in feedstock cost will impact the LCOE.

2.1.3.4 Landfill Gas

The LCOEs for potential LFG projects were calculated at 8 sites; the remaining 47 sites were not located within a 15-mile radius of a candidate landfill as identified by EPA's LMOP. The LCOEs are \$0.08–\$0.11/kWh with an average of \$0.09/kWh. Figure 8 shows the locations of these potential projects, the sizes at which they were evaluated, and the relative LCOE values. Appendix B, Table 44 provides detailed information about the inputs and results of each potential project.

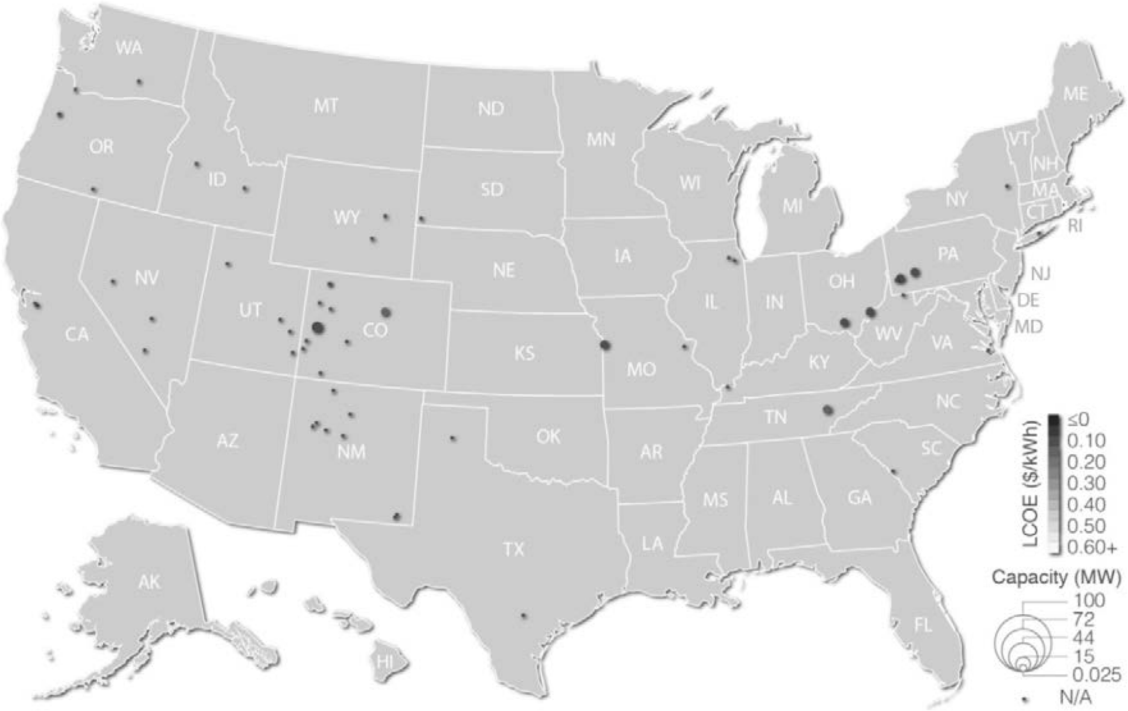

Figure 8. Potential LFG project locations, sizes, and relative LCOE values

Illustration by Billy J. Roberts, NREL

The potential LFG projects are 1.3–6.8 MW and were all constrained by the maximum size based on resource. Economies of scale associated with larger systems and added cost of pipeline for sites that are further from the landfill drive the differences in LCOE. Still, the range of these LCOEs is relatively narrow and project success will likely be driven by the feasibility of piping and building these systems rather than the LCOE value. For example, highways, rivers, and development between the DOE site and the landfill may prohibit the construction of a gas pipeline required to connect the two. Although the focus of this report is on energy generation on DOE lands for export, LFG's relatively small electricity generation potential may make it more suitable for on-site use. Only electricity generation was evaluated for this report, but these projects could also be configured for CHP applications, which typically improve project economics.

2.1.3.5 Waste to Energy

Potential WTE projects were evaluated at 54 of 55 sites. The exempted site is located in a remote part of Nevada where no resource (waste stream) was available. The LCOEs are -\$0.03–\$0.45/kWh with an average of \$0.31/kWh. Figure 9 shows the locations of these potential projects, the sizes at which they were evaluated, and the relative LCOE values. Appendix B, Table 45 includes detailed information about the inputs and results for each potential project.

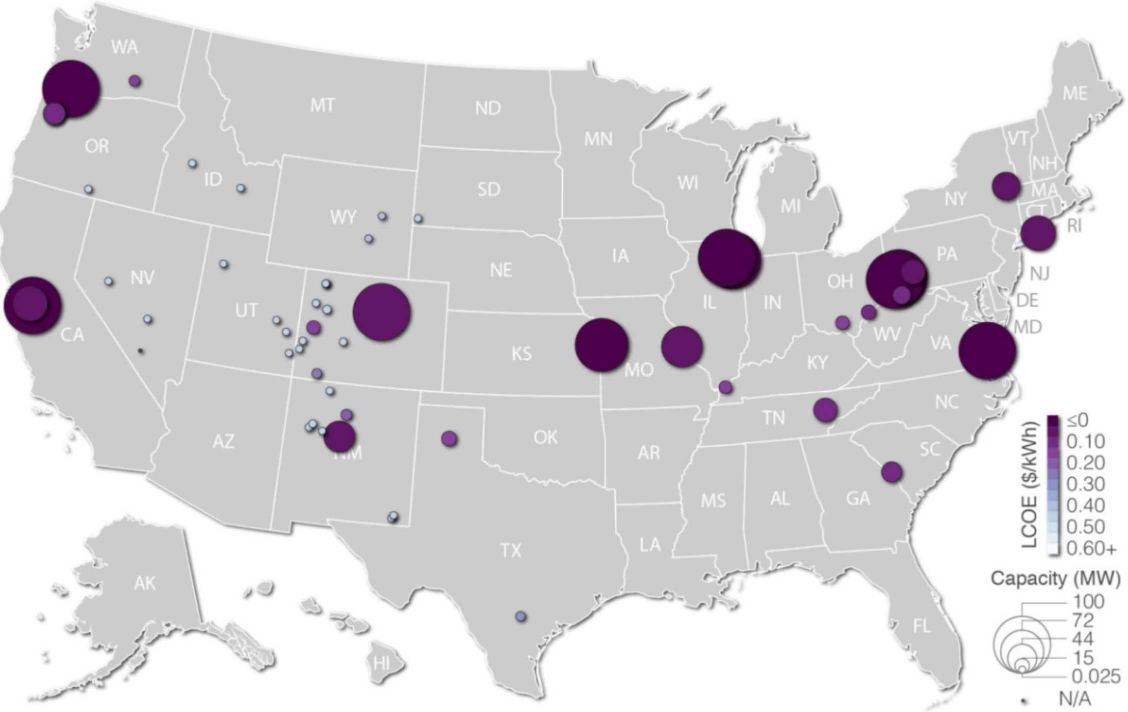

Figure 9. Potential WTE project locations, sizes, and relative LCOE values

Illustration by Billy J. Roberts, NREL

The differences in LCOEs are driven by economies of scale, availability of resource, and state average tipping fees. The economies of scale for WTE typically favor projects that are larger than 20 MW in capacity. For this analysis, all potential project sizes except one, which is limited by the transmission capacity, are limited by resource availability or the 100-MW maximum project size. Although the LCOEs for potential WTE plants may at a first glance appear economically attractive (some systems have a negative LCOE), the deployment of this technology is faced with many barriers. The resource availability is based on population in a 25-mile radius and waste generation per capita.[32] It was assumed that all waste generated would be available for energy generation; in reality much of this waste stream may be tied up in long-term waste management contracts and may not be available for energy generation.

Unlike biomass and LFG, which also rely on an annual feedstock resource, the feedstock for WTE would not be purchased but rather would be received at a price equal to the average tipping

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[32] van Haaren, Rob, Nickolas J. Themelis, and Nora Goldstein. 2010. "The State of Garbage in America," *BioCycle*, October 2010. http://www.biocycle.net/images/art/1010/bc101016_s.pdf.

fee in the state; that is, the WTE plant would rely on a revenue stream for providing a disposal option rather than paying for a more traditional fuel, which is the reason for negative LCOEs in some cases. Whether or not a WTE plant would be able to achieve the same tipping fee as local garbage disposal facilities remains to be seen. Even if a potential project is able to secure available waste stream under a long-term contract and receive payment equal to the average state tipping fee, community acceptance of WTE facilities has proven difficult. Still, should the barriers be overcome, the techno-economic potential for this technology remains strong.

2.1.3.6 Concentrating Solar Power

The LCOEs for CSP were calculated at 20 sites; the remaining 35 sites did not have sufficient land to host a 50-MW CSP plant, currently the minimum developable size. The LCOEs are \$0.20–\$0.49/kWh with an average of \$0.31/kWh. Figure 10 shows the locations of these potential projects, the sizes at which they were evaluated, and the relative LCOE values. Appendix B, Table 46 provides detailed information about the inputs and results for each potential project.

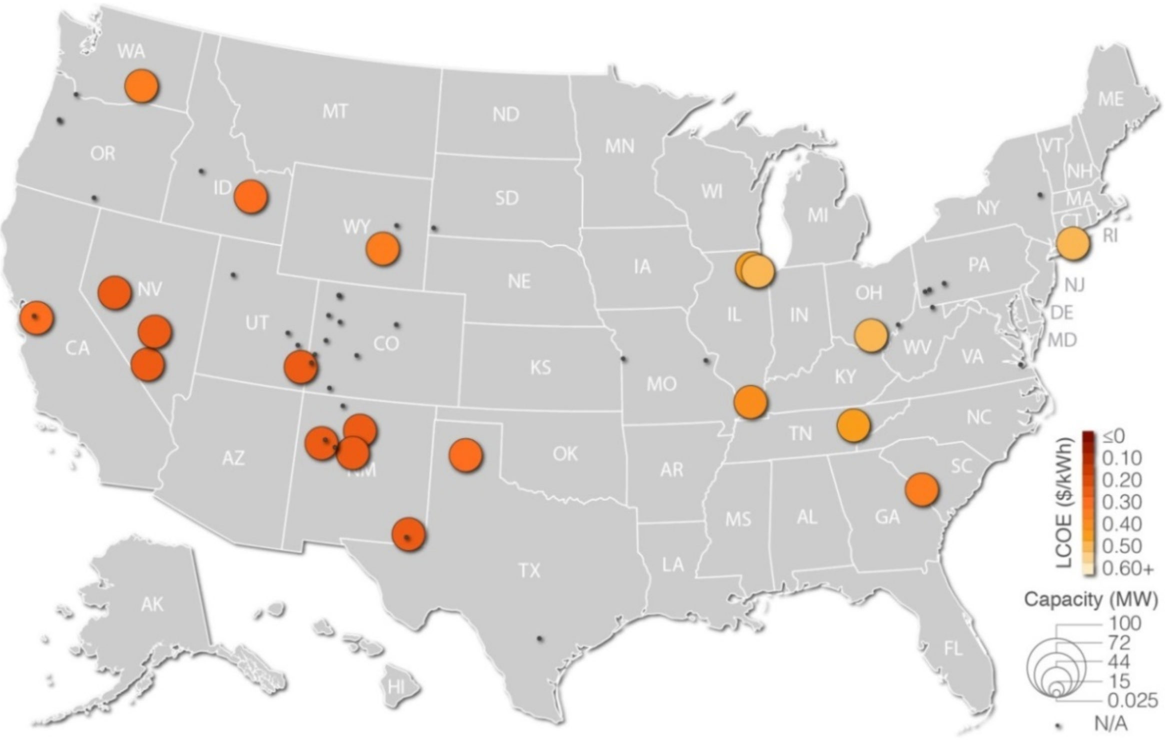

Figure 10. Potential CSP project locations, sizes, and relative value of LCOE

Illustration by Billy J. Roberts, NREL

Because these LCOEs were all calculated at the same size, the only input driving the differences is the solar resource. Unlike PV, which uses both diffused and direct-normal solar resource, CSP uses only direct-normal, which is much more prevalent in the Southwest.[33] California, Arizona,

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[33] "Concentrating Solar Resource of the United States." NREL, http://www.nrel.gov/gis/images/eere_csp/national_concentrating_solar_2012-01.jpg.

and Nevada together host more than 90% of the 918 MW of CSP that was operational in the United States in 2013.[34] In this analysis, the potential CSP projects evaluated in Nevada, New Mexico, and Utah had an average LCOE $0.15/kWh lower than potential projects in the rest of the United States. CSP LCOEs, compared to PV LCOEs for similar project sizes and location, tend to be about twice as high. In this analysis, the lowest CSP LCOE ($0.20/kWh) is higher than the highest PV LCOE ($0.15/kWh). However, the CSP system will be dispatchable and therefore have value to the electrical power system beyond the annual useful energy it will produce. This value is not captured in the LCOE.

2.1.3.7 Geothermal

The three basic types of geothermal reservoir systems are hydrothermal, sedimentary (which includes geopressured and coproduction), and enhanced/engineered geothermal. Exploiting any of these reservoir types for any thermal utilization (i.e., electricity generation and/or thermal direct-use applications) depends on three factors: 1) resource temperature, 2) reservoir rock permeability and porosity, and 3) fluid presence. Finding all three in one place is uncommon, which leads to a much smaller geothermal resource base than would be expected given the large amount of heat stored in Earth's crust.

Hydrothermal systems are currently the only geothermal reservoir type that has proven to date to be commercially viable at utility scale. Therefore, it is the only type of geothermal reservoir system evaluated for this analysis. DOE sites were evaluated for their hydrothermal viability by overlaying their locations on a hydrothermal resource probability map developed by the U.S. Geological Survey (USGS) and identifying sites that have high "relative favorability" for finding a hydrothermal system (Figure 11).[35] This methodology resulted in seven sites with potential for hosting a hydrothermal system (Table 3).

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[34] DOE. 2014. "2013 Renewable Energy Data Book," DOE/GO-102014-4491. National Renewable Energy Laboratory. Golden, CO. http://www.nrel.gov/docs/fy15osti/62580.pdf.

[35] Williams, C.F., et al. 2008. *Assessment of Moderate- and High-Temperature Geothermal Resources of the United States.* U.S. Geological Survey Fact Sheet 2008-3082. https://pubs.usgs.gov/fs/2008/3082/.

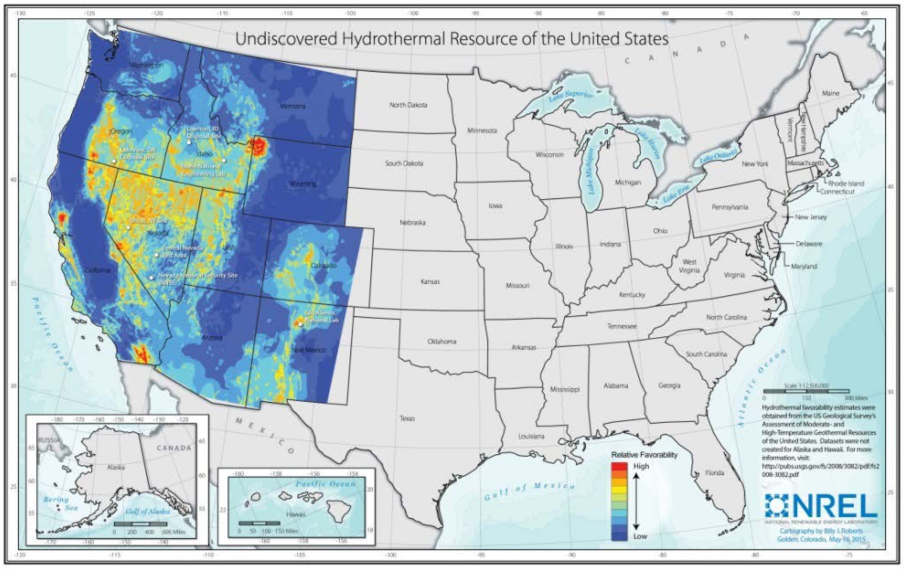

Figure 11. Hydrothermal system probability map showing locations of DOE sites

Illustration by Billy J. Roberts, NREL

Table 3. List of DOE Sites That Showed Potential for Hosting Hydrothermal Systems

Site Name	State	Limiting Factor
Shoal, NV, Site	NV	–
Lakeview, OR, Disposal Site	OR	–
Central Nevada Test Area (CNTA) Site	NV	–
Nevada National Security Site (NNSS)	NV	–
Lowman, ID, Disposal Site	ID	Low temperature
LANL	NM	Low temperature, low flow
INL	ID	Low temperature, low flow

The site list was further evaluated based on a literature review and expert judgment. Previous DOE studies have shown that neither LANL nor INL has large-scale, viable hydrothermal systems; however, both sites have the potential to support enhanced/engineered geothermal. The site at Lowman, Idaho, is small and based on work completed by NREL at the request of the EPA Repowering America Initiative, this site is known to have a low-temperature system (kilowatt-scale). However, little evidence supports the presence of a larger, higher-temperature reservoir.[36] The remaining four sites (Shoal, Lakeview, CNTA, and NNSS) showed good indication of hosting hydrothermal reservoirs and are worth further consideration (see Section 2.2.3.7).

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[36] Visser, personal communication with Mike Hillesheim, June 2015.

2.1.3.8 Levelized Cost of Energy Sensitivity Analysis

Many of the inputs to the LCOE calculation are uncertain. To explore potential variability in these estimates, we performed a simple sensitivity analysis as described in the methodology section above.

Appendix B includes the 48 scenarios captured in the sensitivity analysis (six technologies, four inputs, two scenarios per input); shown below are two illustrative examples. Table 4 shows the relative impact of each of the four scenarios for PV at NNSS. The central scenario LCOE is $0.082/kWh. Varying one parameter at a time resulted in an LCOE of $0.065–$0.103/kWh. Varying the technology cost has the largest impact on LCOE.

Table 4. Sensitivity Analysis Example for PV at Nevada National Security Site

Scenario	Percentage Change	Lower LCOE	Central LCOE	Higher LCOE	Percentage Change
1. Discount Rate	–20%	$0.065	$0.082	$0.090	10%
2. Technology Cost	–17%	$0.068	$0.082	$0.103	25%
3. Energy Output	–17%	$0.068	$0.082	$0.096	17%
4. Technology Specific	–14%	$0.070	$0.082	$0.095	16%

Figure 12 and Figure 13 show the impacts of varying technology costs at all sites for PV and wind. The sites are ordered from lowest to highest LCOE for each technology. The differences in PV LCOE are relatively small, and the error bars for most of the sites overlap. LCOE may thus not be sufficient to choose one PV project over another. The differences in wind LCOE are relatively small for the majority of sites but are significantly higher at a few sites. LCOE may not be sufficient to choose one wind project over another, but could be used to exclude wind projects at sites with significantly higher LCOE.

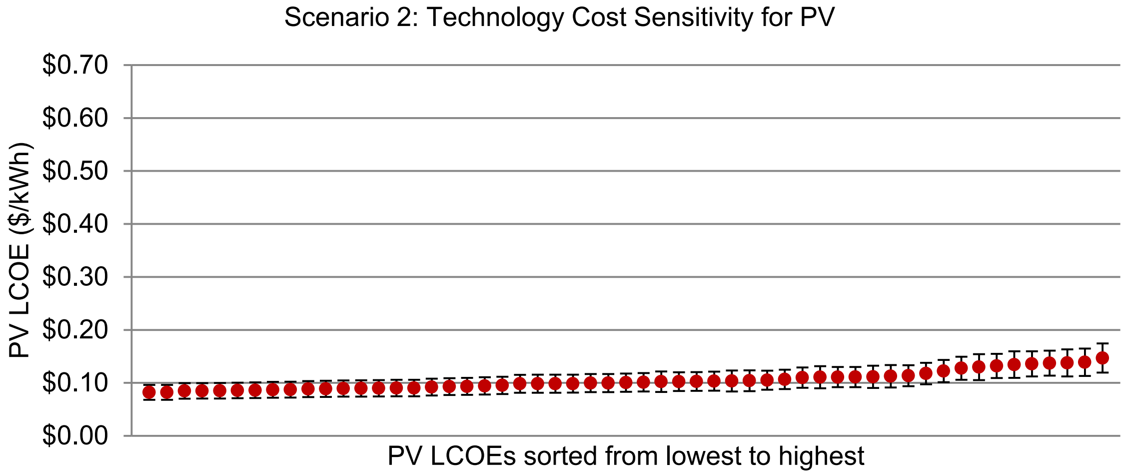

Figure 12. Sensitivity analysis showing impact of technology cost on PV projects

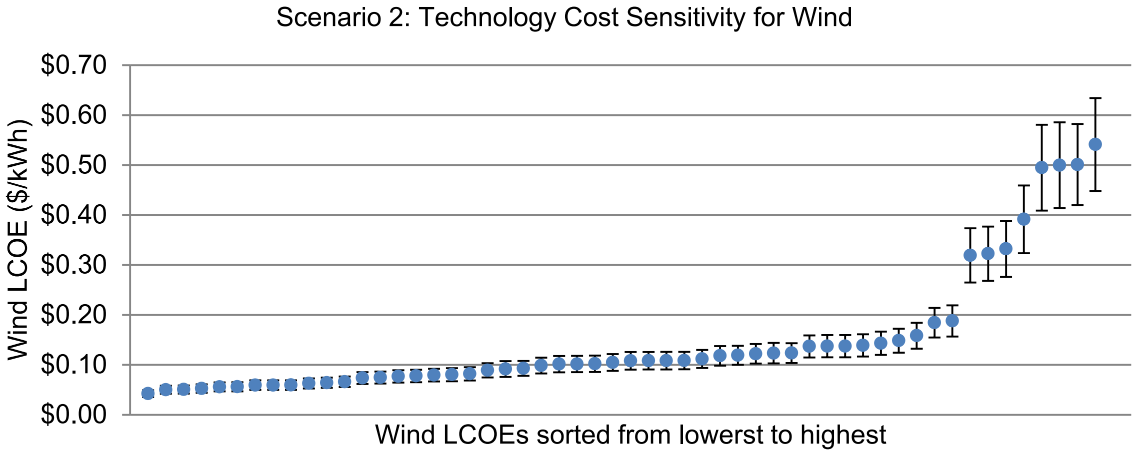

Figure 13. Sensitivity analysis showing impact of technology cost on estimated wind LCOEs at 54 DOE sites

2.1.4 Potential Next Steps

The LCOE analysis was a high level, portfolio screening analysis based on minimal site inputs from DOE; it required many assumptions to be made. While the LCOE would typically be compared to wholesale power prices to understand whether a project may be cost-competitive in the market, in this case the data required (values for PPA prices or utility avoided costs) were not available, and limitations to the scope of work and funding did not allow us to determine estimates. Thus, the results are high level and further, more detailed assessments (including validation of data with the specific sites) would be needed for project development. Therefore, the results should be used as an initial screening, but further work must be done to quantify potential. The next section describes an example of how project development considerations could be evaluated in more detail going forward.

2.2 Market Barriers and Opportunities Analysis Framework

This section provides a subsequent analysis of the development potential for the lowest LCOE DOE energy projects—usually two per technology—based on the lowest projected LCOE modeled within the portfolio analysis. Those sites are listed in Table 5. The LCOE of the selected sites was not subsequently updated to account for the potential development challenges identified within this analysis. This analysis serves as an illustrative example of evaluating project development considerations and processes. Although only a subset of DOE sites were analyzed here, most DOE sites show potential for development of one or more technologies; projects not included in this market barriers and opportunities analysis may be equally viable for development.

The development criteria for the PV, CSP, and wind resources were developed in an NREL report[37] and are summarized in Appendix E. Only PV, CSP, and wind resources were evaluated using a geospatial analysis approach due to their relatively large acreage requirements, in comparison to the other technologies (biomass, geothermal, LFG, and WTE plants typically require much less land per megawatt of capacity).

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[37] Lopez, A., et al. 2012. *U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis*. TP-6A20-51946. National Renewable Energy Laboratory, Golden, CO. https://www.nrel.gov/docs/fy12osti/51946.pdf.

Table 5. Sites Analyzed in Market Barriers and Opportunities Analysis Framework

Technology	Site Name	Area (acres)	Resource Available (MW)	System Capacity (MW)	Electric LCOE ($/MWh)
PV	NNSS	775,680	Unlimited	100.0	$82
	LANL	28,000	Unlimited	62.8	$82
Wind	Pantex Plant	3,170	Unlimited	100.0	$42
	Shirley Basin South, WY, Disposal Site	1,527	Unlimited	50.9	$46
Biomass	Separations Process Research Unit (SPRU)	200	82.1	82.1	$91
	FNAL	6,811	187.1	100.0	$97
LFG	Grand Junction	360	6.8	6.8	$81
	National Energy Technology Laboratory (NETL), PA	63	2.5	2.5	$86
	Kansas City Plant (Bannister Rd.)	120	2.5	2.5	$91
WTE	Bonneville Power Administration (BPA) Ross Complex	250	138.3	100.0	-$25
	ANL	1,700	487.9	100.0	-$5
CSP	NNSS	775,680	Unlimited	50.0	$200
	LANL	28,000	Unlimited	50.0	$210
Geothermal	Shoal, NV, Site	2,560	N/A	N/A	N/A
	Lakeview, OR, Disposal Site	40	N/A	N/A	N/A
	NNSS	775,680	N/A	N/A	N/A
	CNTA, NV, Site	2,560	N/A	N/A	N/A

This second phase of the screening process includes a review of market barriers and a further assessment of opportunity based on a guide for developing large RE projects on federal lands.[38] For each site evaluated, discussions were held with site contacts and additional analysis was conducted. These included a review of common project development considerations, such as site ownership and control, offtaker (an agreement for the purchase of the energy produced by a

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[38] DOE. 2013. *Developing Renewable Energy Projects Larger Than 10 MWs at Federal Facilities.* Federal Energy Management Program, DOE/GO-102013-3915. March 2013. https://energy.gov/sites/prod/files/2013/10/f3/large-scaleguide.pdf.

power generation project) and infrastructure constraints, regulatory processes, and economic constraints. For each site, each of these categories is given a qualitative color-coded rating based on the level of project risk (explained in detail in Section 2.2.3).

2.2.1 Methodology

This analysis is intended to provide additional information on the evaluated sites and to highlight a systematic approach to project development that could be applied in a future evaluation of all potential sites identified in the portfolio analysis. Project development is an iterative process. To successfully develop projects, additional sustained effort will be required from a project team that includes members from diverse organizations with expertise in environmental, real estate, legal, and technical areas.

Although the development approaches utilized by organizations will vary, there are common steps taken to explore a project's feasibility. The first steps are to conduct an initial examination of a site's comparative advantage in terms of its ease of development, as well as whether there is a potential market for the power produced by the site. Due to the project scope, limited resources and time available for this analysis, only these first steps were examined, using the market barriers and opportunities framework discussed in greater detail below. If a site initially appears to be developable based on this initial analysis, it could be further vetted by seeking input from developers through an RFI (request for information). Then, assuming that a site receives sufficient interest, a site can gather more detailed site information in order to issue an RFP (request for proposals) for developers to build a project. This entire development approach is discussed in greater detail in Section 2.2.5.

The framework in Figure 14 is not fully inclusive, but it summarizes some of the major criteria that were evaluated during this analysis as preliminary steps to determine if a project might be commercially developable. Project development is an iterative process; investments of time and money are made incrementally to reduce losses on ultimately infeasible projects.

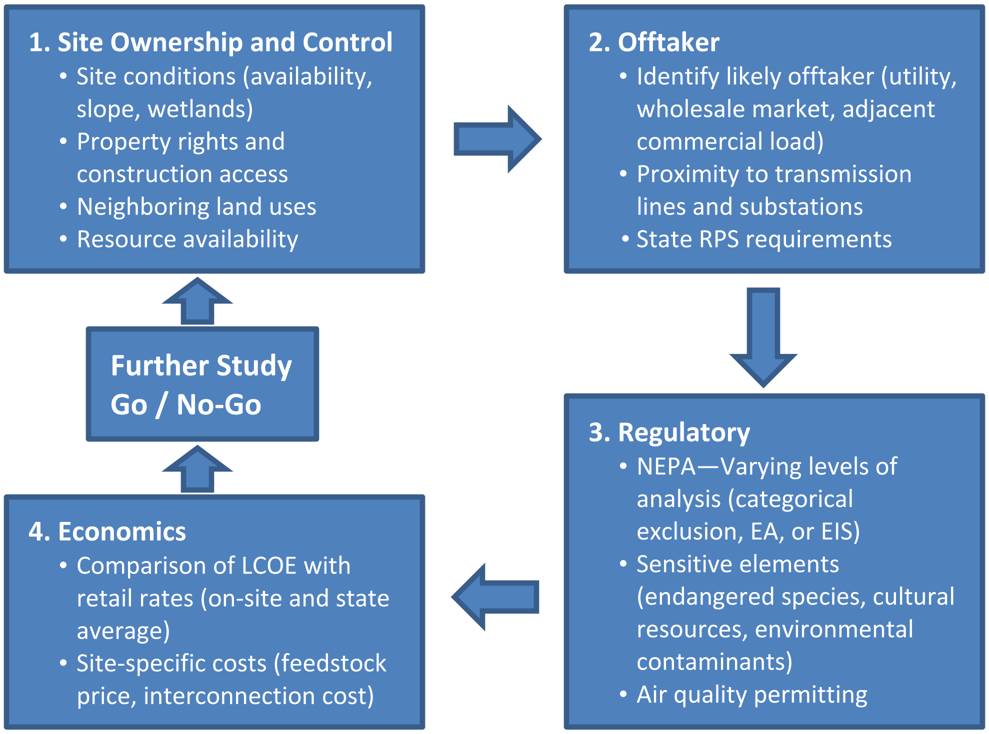

Figure 14. Market barriers and opportunities analysis framework overview

For this analysis, the major development considerations (site ownership and control, offtaker, regulatory, and economics) were evaluated in order.

1. **Site ownership and control.** The site ownership and control criteria (site availability, construction access, site conditions, site ownership, and adjacent land uses, among others) were primarily evaluated through outreach to each site's points of contact, but additional GIS-based analysis of the site conditions was also performed. This analysis focused primarily on slope gradient as a potential disqualifying factor (see exclusion factors listed in Section 2.2.2), as well as the proximity of transmission substations.

2. **Offtaker.** The primary criteria examined included likely offtakers, drivers of RE demand, and the capacity and proximity of transmission infrastructure at the site. In addition to site responses and GIS-based analysis, a high-level analysis of the potential for on-site and off-site offtake was also performed.

3. **Regulatory.** Regulatory considerations were primarily evaluated through questions to the site contacts about National Environmental Policy Act (NEPA) issues, right-of-way, air/water quality, emissions, and other regulatory concerns (identified more fully in Appendix D). Early consultation with additional agencies, such as the Department of the Interior, on a project-specific basis should also be conducted early in the regulatory process to identify potential fatal flaws, although this consultation was not performed in this analysis.

4. **Economics.** The economic potential was evaluated at a high level by researching on-site and regional retail power prices and then comparing these findings with each project's

modeled LCOE. A comparison with wholesale rates would have been performed, but wholesale rate data was unavailable, so retail rates were used as the closest available approximation. Economic criteria are perhaps the most important factor in the project validation process, but an accurate assessment of a project's economic viability requires more detailed information than was available for this early-stage evaluation. The characteristics of development entities show some variability, including access to capital, risk appetite, development objectives, development experience, portfolio objectives, and other distinguishing factors. However, some approximation of the economic attractiveness was attempted by comparing LCOE and retail power purchase rates, because the varying developer elements listed above will still center on a total unlevered project return of 8%–12%.

Each major subject area includes numerous considerations. However, given that development time and money are costly, these criteria can be evaluated iteratively and the simplest questions addressed upfront. Then, only if the project still appears to be viable would additional resources be spent on addressing more specific concerns or answering more complex questions. This process should be performed iteratively until the desired stage of development is reached. This stage will typically vary based on the objectives of the developing party. For a project developer with design-build expertise, the project may be developed all the way through to system interconnection. For an early-stage developer, this process may be pursued to the execution of a PPA. A federal site that seeks to develop an RE project on its land can pursue several development pathways, including:

- RE development as part of an energy savings performance contract (ESPC) for on-site consumption
- Execution of a PPA with RE production for on-site consumption
- Execution of a land lease agreement with an RE developer to develop the property for power sales to an off-site offtaker.

For the third option, less investment in development is required for a federal site that seeks an additional beneficial use of its land because the desired goal would be a site access agreement, or other similar agreement.[39] Although there is potential for the first two options, given the nature of the sites under investigation (generally low site load and large available land areas) and the focus of this report, the potential for a site access agreement is the primary option investigated. Information on additional development pathways is also available on the FEMP website.[40]

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[39] DOE. 2014. *Best Practices and Lessons Learned for Federal Agency ESPC Projects.* Federal Energy Management Program, September 22, 2014, accessed May 2015. http://energy.gov/sites/prod/files/2014/09/f18/espc_best_practices_0.pdf.

[40] "Federal On-Site Renewable Energy Project Financing Options." DOE, http://energy.gov/eere/femp/financing-mechanisms-federal-renewable-energy-projects.

2.2.1.1 Examination of On-Site Offtaker Potential

Although the focus of this report is on the third option listed above (site access agreement with a developer pursuing off-site power sales), the potential for on-site offtake of the proposed projects was evaluated at a high level whenever feasible. The availability of an on-site offtaker could be an additional incentive for a developer to select a DOE site. However, there are many additional development criteria to consider when developing an on-site offtake agreement (either a PPA or ESPC), such as the site's load profile, the relevant contracting authority, etc.

A helpful summary of the development process from the previously cited report[41] is included in Figure 15. This second phase of the screening process will address the project validation stage of the process and iteratively examine the main thematic development concerns (site ownership and control, offtaker, regulatory, and economics), with an additional general examination of the basic project economics (Figure 15). The relevant development criteria used in this analysis are listed in Appendix D. Although an attempt was made to address as many of the listed criteria as possible, this analysis was conducted primarily for illustrative purposes. Further analysis of the promising sites, particularly concerning transmission availability and environmental legal requirements, would need to be conducted before any formal project solicitation (RFI or RFP) is issued.

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[41] DOE. 2013. *Developing Renewable Energy Projects Larger Than 10 MWs at Federal Facilities.* Federal Energy Management Program, DOE/GO-102013-3915. March 2013. https://energy.gov/sites/prod/files/2013/10/f3/large-scalereguide.pdf.

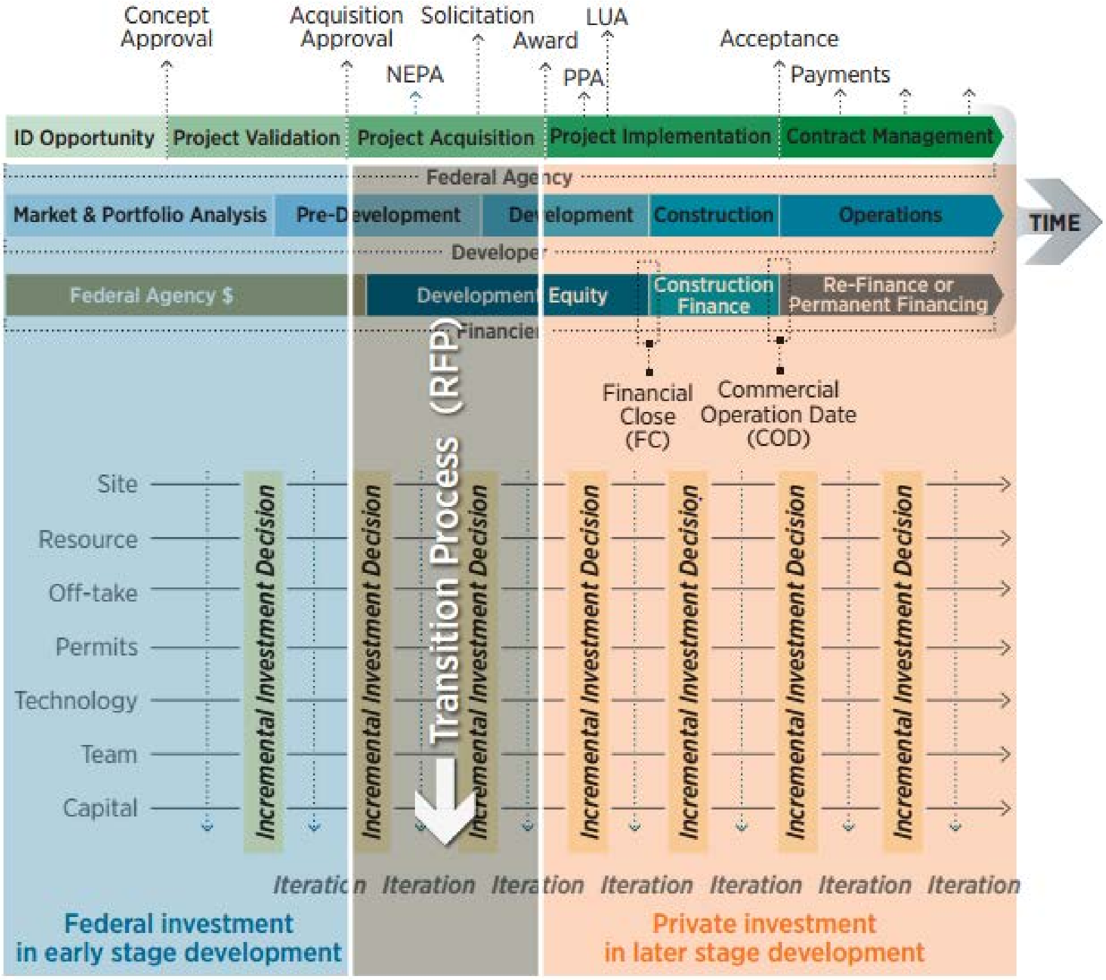

Figure 15. Project development process

Illustration from FEMP

2.2.2 Assumptions

Several GIS-based analyses were conducted to examine the developable acreage (primarily based on slope exclusions) for the PV, CSP, and wind resources at the top sites, as well as the proximity of all top sites to transmission substations with 69 kV or greater capacity. The exact capacity of the adjacent transmission substation is indicated in the GIS map for each site.

Acreage within a given distance from a substation was measured as site area covered within the given radius (1, 2, or 5 miles from the substation). This methodology is illustrated in the GIS maps included within each site evaluation. GIS shapefiles could not be gathered for four of the sites evaluated (Kansas City Plant, SPRU, National Energy Technology Laboratory [NETL], and the BPA Ross Complex); therefore, GIS maps are not included for these sites. The transmission data were gathered from the Ventyx Velocity Suite 2014.

2.2.3 Findings

In most instances, the top two potential projects with the lowest LCOEs for each technology (based on the portfolio analysis) were selected for an illustrative market barriers and opportunities analysis. In some instances additional potential projects per technology were analyzed, as time and resources allowed. Although these potential projects were deemed to be the most attractive based on the initial portfolio screening, many of the remaining potential projects also have strong techno-economic potential and may be equally developable. The development framework as demonstrated in Table 6 could be applied to the remaining sites to validate those projects' potentials. For each site, each major development consideration is given a qualitative color-coded rating based on the level of project risk. This rating system is coded into four separate bins:

- Green—acceptable project risk
- Yellow—significant uncertainty
- Red—infeasibility
- Gray—not evaluated.

For an acceptable project, risk is defined for the purposes of this high-level rating as the absence of any fatal flaws that would preclude development at the site, as well as the presence of promising site characteristics that might encourage a developer to proceed with deeper analysis of a project site. Projects were classified as yellow if there was significant uncertainty as to whether the site might be developable, or if there was a significant risk of discovering a fatal flaw later in the development process. Projects were classified as red if a fatal flaw had already been discovered and the sites were currently infeasible for development, although future changes in site conditions could change these results. Many categories are coded as yellow, consistent with the uncertainty inherent within the early stage development process. Table 6 summarizes these findings, and is followed by a detailed analysis of each site. Note that the modeled sizes listed in Table 6 are mutually exclusive; developing a CSP system on a piece of land would preclude installing PV on the same piece of land.

Table 6. Market Barriers and Opportunities Analysis Framework

Site – State	Technology	Modeled Size (MW)	Site Ownership & Control	Offtaker	Regulatory	Economics	Project Overview (Off-Site and On-Site Offtaker Considerations)
NNSS – NV	PV	100	Green	Yellow	Yellow	Yellow	**Off-site:** Given the 10-mile distance to the nearest grid interconnection point, only a very large project appears to be feasible. However, given the extensive land available and existing road infrastructure, the project could be viable at scale. **On-site:** There is low on-site load, and on-site power prices are lower than the estimated LCOE.
LANL – NM	PV	62.8	Green	Yellow	Yellow	Green	**Off-site:** Based on a previous site evaluation, roughly 400 acres were identified as "highly favorable" for PV development. The site has two 115-kV transmission lines, but transmission export capacity may be constrained due to on-site load growth. The site also has four endangered species and cultural resources, but a previous environmental review identified the sensitive areas. **On-site:** Two 1-MW arrays have already been developed, but on-site load growth may create a new opportunity.
Pantex Plant – TX	Wind	100	Red	Yellow	Yellow	Yellow	**Off-site:** The modeled LCOE of $42/MWh appears to be competitive; however, the site already hosts an 11.5-MW wind farm, and the availability of additional developable acres is uncertain. **On-site:** Barring new load growth, increasing capacity for on-site use would not be beneficial due to the lack of net metering.
Shirley Basin South – WY Disposal Site	Wind	50.9	Green	Green	Yellow	Green	**Off-site:** Up to 1,300 acres may be available for development. Based on GIS analysis of the site and its surroundings, about 1,184 of the total 1,527 acres are within a 2-mile radius of transmission substations that are larger than 69 kV. The modeled LCOE of $50/MWh appears to be competitive, but the additional costs of transmission access may be a limiting factor. **On-site:** There is no significant on-site load.

Site – State	**Technology**	**Modeled Size (MW)**	**Site Ownership & Control**	**Offtaker**	**Regulatory**	**Economics**	**Project Overview (Off-Site and On-Site Offtaker Considerations)**
SPRU – NY	Biomass	82.1	Red	Gray	Gray	Gray	**Off-site:** Development of a biomass project at the SPRU site is not likely, due to ongoing cleanup and site security requirements that would prevent new construction, as well as regular access for feedstock delivery. **On-site:** Not evaluated due to low onsite demand and project infeasibility.
FNAL – IL	Biomass	100	Yellow	Green	Yellow	Yellow	**Off-site:** 83% of the site is within 1 mile of a substation with a capacity of 69 kV or greater, and at least 500 acres may be available for development of an RE project. However, this land is reserved for future experiments, which would take priority over any RE development. **On-site:** On-site power purchase would not currently be an economically viable offtake option due to the site's low utility rate of $35/MWh.
Grand Junction – CO	LFG	6.8	Yellow	Yellow	Yellow	Yellow	**Off-site:** Up to 266 acres are potentially available for development at the site, but uncertainty still surrounds the potential costs associated with the construction and permitting of an 11-mile LFG pipeline delivery, as well as of transmission interconnection to the site. Based on GIS analysis, no transmission substations larger than 69 kV are within a 5-mile radius of the site. **On-site:** There is no significant on-site load.
Kansas City Plant (Bannister Road) – MO	LFG	2.5	Yellow	Green	Green	Green	**Off-site:** The site is 1.4 miles from the LFG resource. The pipeline path is not obstructed by geographical features and may potentially have a right-of-way path along a railway line. Uncertainty still surrounds the nature of the site's redevelopment and the permitting of pipeline delivery to the site. **On-site:** Not evaluated due to uncertainty of ultimate site use/demand.

Site – State	Technology	Modeled Size (MW)	Site Ownership & Control	Offtaker	Regulatory	Economics	Project Overview (Off-Site and On-Site Offtaker Considerations)
NETL – PA	LFG	2.5	Red	Yellow	Yellow	Red	**Off-site:** Numerous geographic and urban obstacles, including rivers and residential developments, would likely prevent the development of the required 6-mile LFG pipeline from being viable. **On-site:** Not evaluated due to project infeasibility.
BPA Ross Complex – WA	WTE	100	Red	Gray	Gray	Gray	**Off-site:** Fewer than 50 noncontiguous acres are available for development. This area is periodically used for equipment storage by the site. Based on discussion with the site contacts, the site does not appear to be suitable for RE development. **On-site:** Not evaluated due to project infeasibility.
ANL – IL	WTE	100	Yellow	Yellow	Red	Yellow	**Off-site:** The site is surrounded by a forest preserve and suburban residential areas, which may result in increased public scrutiny of any proposed projects. This land is also reserved for future experiments, which would take priority over any RE development. Whether sufficient feedstock and a viable offtaker are available is also still unknown. **On-site:** Biomass projects have previously been proposed and ultimately abandoned due to the poor economics surrounding the feedstock price and the site's low power prices of $42/MWh.
NNSS – NV	CSP	50	Green	Yellow	Yellow	Red	**Off-site:** Given the 10-mile distance to the nearest grid interconnection point, only a very large potential project would be feasible. However, the modeled LCOE of $200/MWh does not appear to be economically viable for a utility-scale PPA without additional incentives. **On-site:** There is low on-site load, and on-site power prices are lower than the estimated LCOE.

Site – State	Technology	Modeled Size (MW)	Site Ownership & Control	Offtaker	Regulatory	Economics	Project Overview (Off-Site and On-Site Offtaker Considerations)
LANL – NM	CSP	50	Red	Yellow	Yellow	Red	**Off-site:** Based on the limited availability of contiguous acreage with a slope of <3% (at most 245 acres) and the modeled LCOE of $200/MWh, a CSP project does not appear to be viable for this location. **On-site:** Not evaluated due to project infeasibility.
Shoal, NV, Site	Geothermal	N/A	Red	Yellow	Gray	Gray	**Off-site:** A discussion with the Navy, the site lessee, established that the site is not available for subsurface exploration, nor will it be opened in the foreseeable future. The site is currently used as a bombing range. **On-site:** Not evaluated due to project infeasibility.
Lakeview, OR, Disposal Site	Geothermal	N/A	Red	Yellow	Red	Gray	**Off-site:** The developable area of fewer than 40 acres would preclude development of a commercial-scale hydrothermal plant. The county's zoning requirements also specifically prohibit any drilling or construction of buildings. **On-site:** There is no significant on-site load.
NNSS – NV	Geothermal	N/A	Green	Yellow	Yellow	Gray	**Off-site:** Additional site-specific evaluations, including test wells, would be required to develop a reasonably accurate estimate of the hydrothermal potential. **On-site:** There is low on-site load, as well as low on-site rates.

Site – State	Technology	Modeled Size (MW)	Site Ownership & Control	Offtaker	Regulatory	Economics	Project Overview (Off-Site and On-Site Offtaker Considerations)
CNTA Site – NV	Geothermal	N/A	Yellow	Yellow	Gray	Gray	**Off-site:** Much more information is required to determine whether site UC-3 has a hydrothermal system (or systems) and this site's potential to achieve utility-scale power production. Based on GIS analysis, no transmission substations larger than 69 kV are within a 5-mile radius of the site. **On-site:** There is no significant on-site load.

2.2.4 Limitations

The rapidly changing nature of both electricity markets and the RE technologies evaluated in this report prevents a simple classification of projects into developable and undevelopable categories. Cost-reduction and technology innovations for many of these technologies have already resulted in exponential decreases in capital costs, and although a project may not be currently viable based on this screening analysis, sites with otherwise strong potential should be periodically evaluated for changes in the economic viability of the projects.

Not all of the development criteria summarized in Appendix D could be examined for each site. These development criteria were ranked in order of their relative positions within the development process, and as many of the early stage development criteria were addressed as possible. For example, although the site's geotechnical conditions could be an important fatal flaw in a project's development, this criterion is much more expensive in development time and money to examine than a question about the site's basic availability. Given that the full development framework could not be applied to each site, conclusions about each site's relative economic attractiveness are limited to the currently available information.

2.2.4.1 Photovoltaics

The following sections detail PV project development considerations at NNSS and LANL sites.

2.2.4.1.1 Photovoltaics at Nevada National Security Site

The portfolio analysis identified a PV project of 100 MW or larger as potentially viable for this location (100 MW was set as the maximum allowable size within the analysis). The project would likely require 500–1,000 acres of land and could potentially produce power at an LCOE of $82/MWh. Given the low site load, 10-mile transmission development requirement, and the presence of the desert tortoise, only a very large project would likely be able to absorb these additional costs and still generate an attractive return. However, given the extensive land available and road infrastructure, the project could be viable at scale. Areas 22 and 25 show the most potential and are highlighted in yellow in Figure 16.

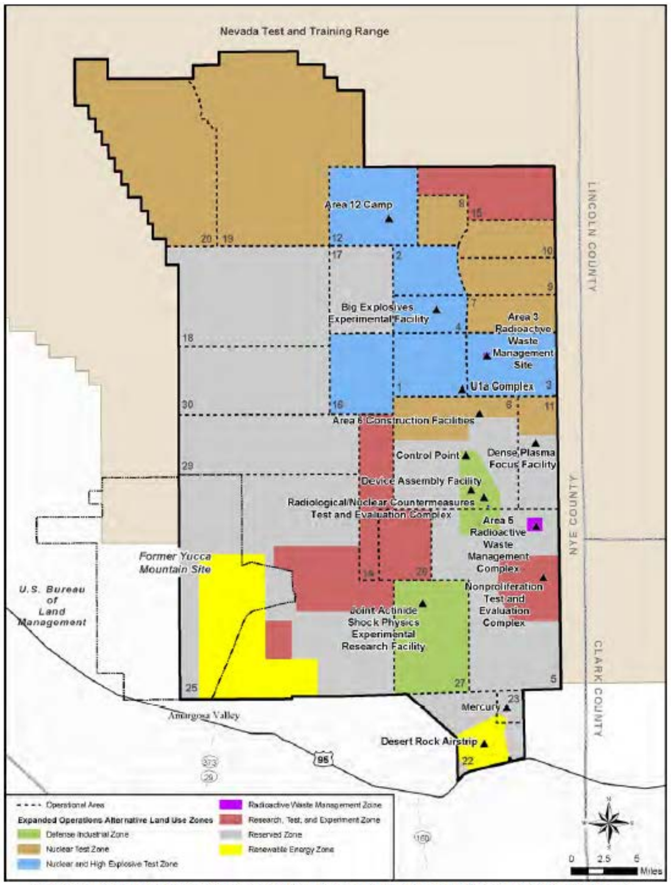

Figure 3–2 Nevada National Security Site Land Use Zones and Major Facilities Under the Expanded Operations Alternative

Figure 16. Nevada National Security Site site map

Source: DOE[42]

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[42] DOE/NNSA Nevada Site Office. 2013. "Final Site-Wide Environmental Impact Statement for the Continued Operation of the Department of Energy/National Nuclear Security Administration Nevada National Security Site and Off-Site Locations in the State of Nevada." Volume 1, accessed June 11, 2015, http://nnsa.energy.gov/aboutus/ouroperations/generalcounsel/nepaoverview/nepa/nnsssweis21413.

Table 7 provides a summary of PV project development considerations at NNSS.

Table 7. Description of PV at Nevada National Security Site

Location	Mercury, NV	
Technology	PV	
Size	100 MW (constrained by maximum allowable size)	
Mission	Previously called the Nevada Test Site, the site conducted numerous atmospheric and underground nuclear tests. The site now performs stockpile stewardship, environmental management, and research and development.	
Site Ownership & Control	Green (acceptable project risk)	• Up to 2,400 acres in Area 25 may be available for development. • Development in Area 25 would be allowable, but security would be a consideration. Development of low-water-use projects (such as PV) in Area 22 may be considered in the future.
Offtaker	Yellow (uncertain project risk)	• The project would likely need to install approximately 10 miles of 230-kV or 500-kV transmission lines and also perform upgrades at the closest substation. • No additional transmission upgrades are expected in Area 25.
Regulatory	Yellow (uncertain project risk)	• Full environmental analysis based on the proposed project would still be required. The DOE and BLM would make a determination of lead agency responsibility assignment. • Land use outside the mission of weapons testing would require NNSA and BLM approval. • The endangered desert tortoise species is present in this area, which could result in additional mitigation costs. The presence and location of cultural resources are unknown.
Economics	Yellow (uncertain project risk)	• The project's estimated LCOE at $82/MWh is above the current on-site power contract of $63/MWh through 2022. • The average retail price of electricity in Nevada was $92/MWh in March 2015.

Site ownership and control. The NNSS, previously known as the Nevada Test Site, was the testing grounds for numerous atmospheric and underground nuclear bomb tests, which were discontinued in the 1980s. The site comprises 775,680 acres of land, but based on the site-wide EIS conducted in 2013, primarily Area 25 has been determined to be suitable for solar development.[43] Area 25 contains 163,000 acres of land, of which the EIS has identified up to 2,400 acres that may be available for development under the No Action Alternative.[44] This developable area is located in the southwestern corner of the NNSS. Area 25 was previously considered for development of a 240-MW demonstration CSP project under an Expanded Operations Alternative, but this alternative was not selected. Area 22 is also considered as potentially developable, and the proximity of this area to U.S. Route 95 may also facilitate development in this second area. This area is considerably smaller, about 20,000 acres in total,

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[43] Ibid.

[44] Ibid.

has an operating airstrip, and has water use restrictions. The EIS states that "low-water-use renewable energy projects may be considered for Area 22 in the future," which would likely include PV technologies.

Based on GIS analysis of the site's potential slope exclusions, the site's slope within Area 25 would not be a limiting factor because the slope is less than 3% and contiguous (Figure 17). Area 22 may also be feasible for development but appears to include some areas of greater slope within the developable area.

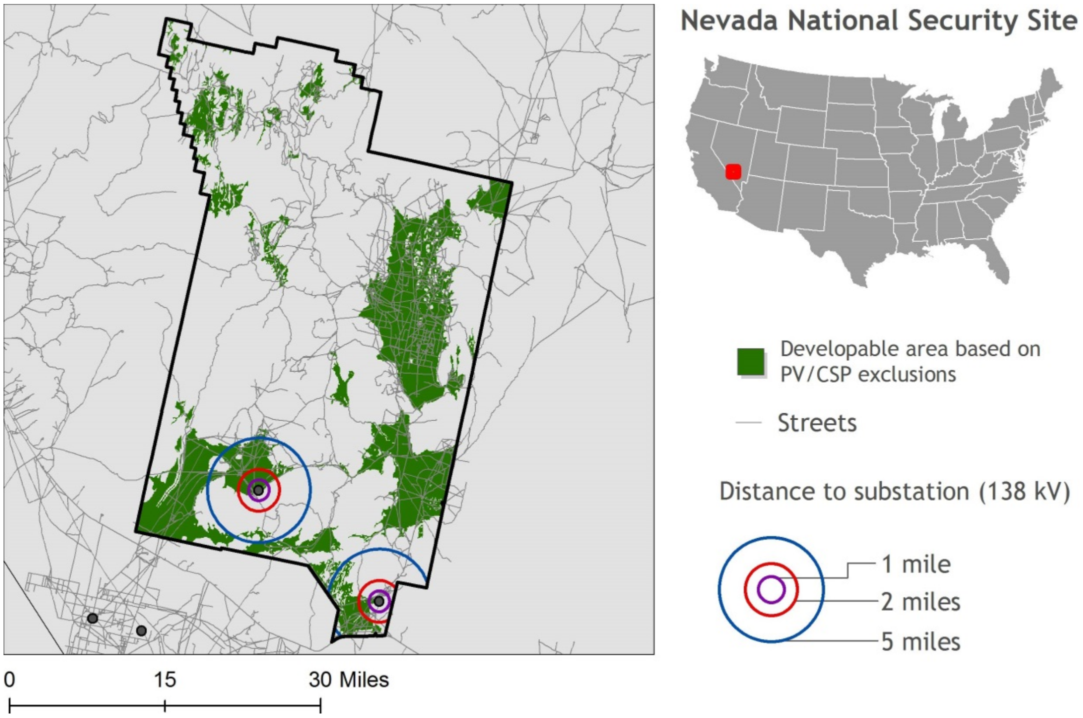

Figure 17. Nevada National Security Site geographic information system analysis map

Illustration by Jenny Melius, NREL

Offtaker. A potential offtaker for this power is NV Energy. This utility may be interested in power generation from this site as a part of its 100-MW 2016 RFP or as part of its future 25% by 2025 RPS goal. However, half of the 25% RPS goal must be met from efficiency or RE measures installed at residential locations. Given that the average retail price of electricity in Nevada was $92/MWh in March 2015, any significant additional costs for transmission or site-specific construction requirements may make the project uneconomic.[45]

Out-of-state PPA sales may also be feasible for larger-scale projects; however, the project will have to be competitive relative to in-state generation to overcome the additional cost of transmission.

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[45] U.S. Energy Information Administration, "Form EIA-826, Monthly Electric Sales and Revenue Report with State Distributions Report," accessed June 11, 2015 at http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a.

Based on the EIS performed at this site, the project would need to install approximately 10 miles of 230-kV or 500-kV transmission lines and to perform upgrades at the closest substation in order to interconnect the system for electricity export to an offtaker. However, development of transmission lines is costly; an illustrative example of the cost per mile for a 230-kV transmission line is $940,000–$960,000.[46] Whether additional transmission expenses would be required for development at Area 22 is unclear.

Regulatory. The primary regulatory requirements identified by this preliminary review include NEPA review (although the required level of review must be determined on a project specific basis), land use approval from NNSA and BLM, and an aquifer withdrawal impact analysis. These requirements do not constitute a comprehensive list, but are indicative of several major issues with developing the site.

Based on the EIS findings, there are multiple sensitive elements on the site, such as endangered species; therefore, the site would have to determine the required level of NEPA analysis on a project-specific basis. The DOE and BLM would make a determination of lead agency responsibility assignment.

Given the nature of the site, construction security would need to be considered, and land use outside the mission of weapons testing would require NNSA and BLM approval. Outstanding questions surround the legal framework of a site access agreement due to the current land withdrawal terms. Both the NNSA and BLM would be required to approve any site access agreement. Further, some stakeholders may claim that a project such as this is not compatible with the public land order(s) that provided the initial authority to administer the activities on a particular parcel of land.

Finally, any new NNSS water use will trigger aquifer withdrawal impact analysis by the U.S. Fish and Wildlife Service, U.S. Forest Service, State of Nevada, and Paiute Indian Nation.

Economics. Additional desert tortoise environmental mitigation and 10-mile transmission development costs would adversely impact the estimated LCOE of $82/MWh, although a project with sufficient scale may be able to absorb these costs.

2.2.4.1.2 Photovoltaics at Los Alamos National Laboratory, New Mexico

The portfolio analysis identified a PV project of 63 MW as potentially viable for this location (the project was constrained by the estimated transmission capacity). The project would likely require 315–630 acres of land (5–10 acres/MW) and could potentially produce power at an LCOE of $82/MWh. This site had the second largest potential capacity and lowest LCOE for PV of all sites screened. Based on discussion with the site contact, about 400 acres were identified as highly favorable for PV development. The site has two 115-kV transmission lines, but this transmission capacity may already be accounted for by significant anticipated growth in site demand. This may not preclude an on-site PV purchase option, but power sales off site may be constrained. Based on discussion with site contacts, most of the electricity generation in the

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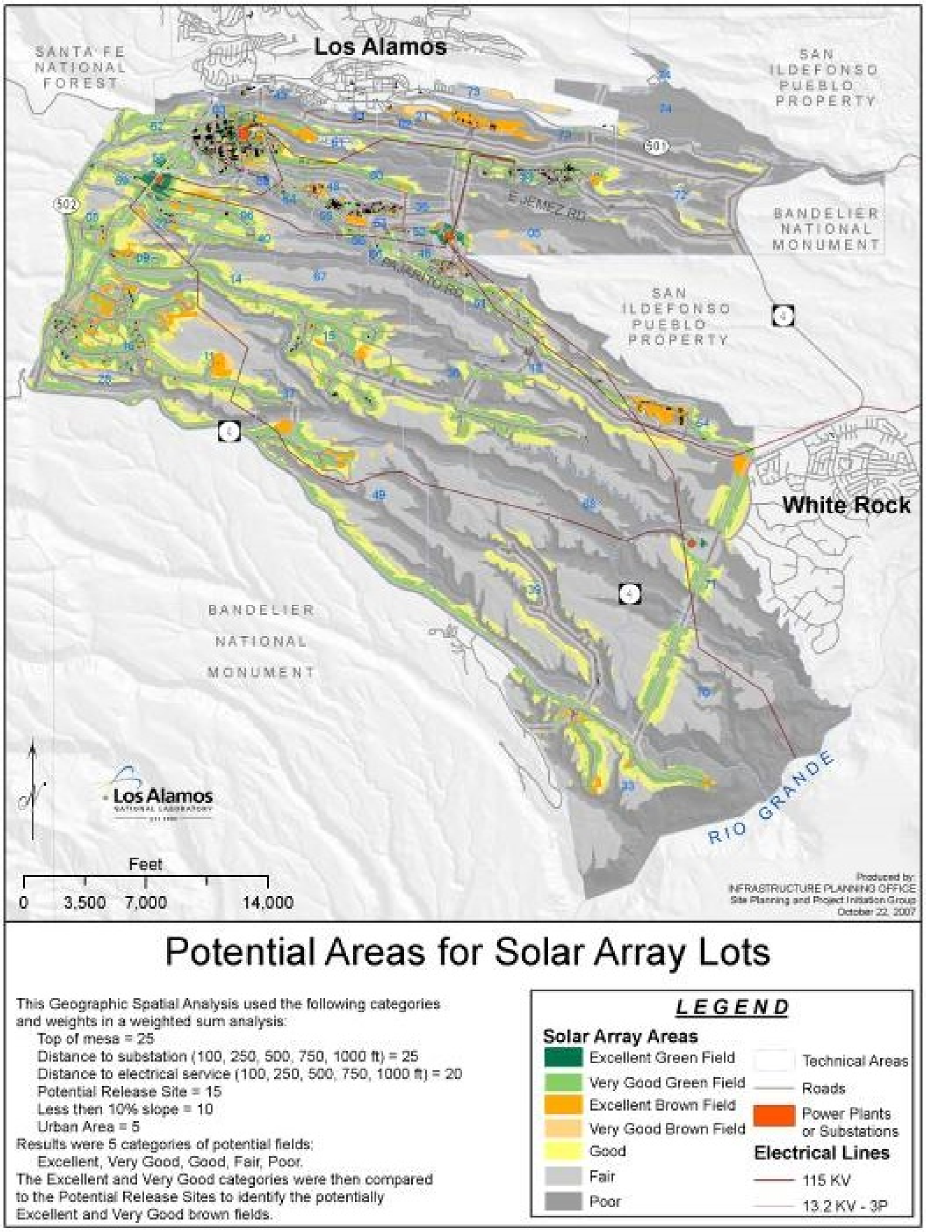
[46] Pletka, et al. 2014. *Capital Costs For Transmission And Substations.* Western Electricity Coordinating Council: Black & Veatch, February 2014, accessed at https://www.wecc.biz/Reliability/2014_TEPPC_Transmission_CapCost_Report_B+V.pdf.

LADWP power pool is already consumed by LANL, making the site the largest offtaker. Four endangered species are present on the site, but a previous environmental review was performed and two 1-MW arrays have already been developed. Although the project's estimated LCOE of $82/MWh is somewhat higher than the site's power rates, the project may still be viable in the future. A site map is available in Figure 18.



This Geographic Spatial Analysis used the following categories and weights in a weighted sum analysis:
Top of mesa = 25
Distance to substation (100, 250, 500, 750, 1000 ft) = 25
Distance to electrical service (100, 250, 500, 750, 1000 ft) = 20
Potential Release Site = 15
Less then 10% slope = 10
Urban Area = 5
Results were 5 categories of potential fields:
Excellent, Very Good, Good, Fair, Poor.
The Excellent and Very Good categories were then compared to the Potential Release Sites to identify the potentially Excellent and Very Good brown fields.

Figure 18. Los Alamos National Laboratory site map

Source: LANL

Table 8 provides a summary of PV project development considerations at LANL.

Table 8. Description of PV at Los Alamos National Laboratory

Location	Los Alamos, NM	
Technology	PV	
Size	63 MW (constrained by estimated transmission capacity)	
Mission	LANL is a major science and technology institution that emphasizes research about national security.	
Site Ownership & Control	Green (acceptable project risk)	• Based on a 2008 study of RE development potential, which was updated in 2015, about 400 acres are very attractive locations for solar development. Security concerns in some areas of the site make access more difficult. The 406 acres identified could be accessed by uncleared personnel. • The site has previously leased land to Los Alamos County for two 1-MW landfill solar demonstration projects that serve local residential loads.
Offtaker	Yellow (uncertain project risk)	• The site's current peak demand is approximately 70 MW and is expected to grow in the next 10 years. • As of the 2008 study, the site had the capacity to import an additional 25–30 MW of RE power to serve the site's electricity demand. • The site currently has two 115-kV lines. Although the projects are close to 13.2-kV lines, some additional transmission upgrades for megawatt-scale projects would likely be required.
Regulatory	Yellow (uncertain project risk)	• Full environmental analysis based on the proposed project would still be required. The DOE and BLM would make a determination of lead agency assignment on a project-specific basis. • The site is adjacent to the Bandelier National Monument, which could result in additional environmental review. • The site has four endangered species, archeological sites, and potentially contaminated sites that must be avoided. However, these areas have been identified in previous studies.
Economics	Green (acceptable project risk)	• The project's estimated LCOE of $82/MWh is above the current cost of power at the site at $67/MWh, but the likelihood of load growth at the site and the presence of existing 1-MW solar arrays indicate that new projects may be feasible.

Site ownership and control. LANL is a major science and technology institution with about 9,000 employees. The site comprises 28,000 acres of land, although only 500 acres, split across nine separate ground-mount locations, were determined to be usable, based on a 2008 site evaluation conducted by NREL.[47] The most promising of these locations was 114 acres divided into two adjacent lots.

Based on more recent discussion with the site contact, 400 acres appear to be highly favorable for solar development (Figure 19). Based on the GIS analysis of the site, slope constraints appear

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[47] VanGeet, Otto. 2008. *DOE Los Alamos National Laboratory (LANL)—PV Feasibility Assessment NREL Final Report*, National Renewable Energy Laboratory, Golden, CO. January 30, 2008.

to be a primary factor in the limited developable acreage. Of the total 26,263 acres on site, roughly 24%, or 6,300 acres of land had a slope of 5% or less. However, many of these 6,300 acres may not be favorable for solar PV development due additional factors, such as proximity to transmission, and lack of sufficient contiguous area. The acreage within close proximity to the southeastern transmission substation may be the most feasible area for development, due to its proximity to the White Rock housing development.

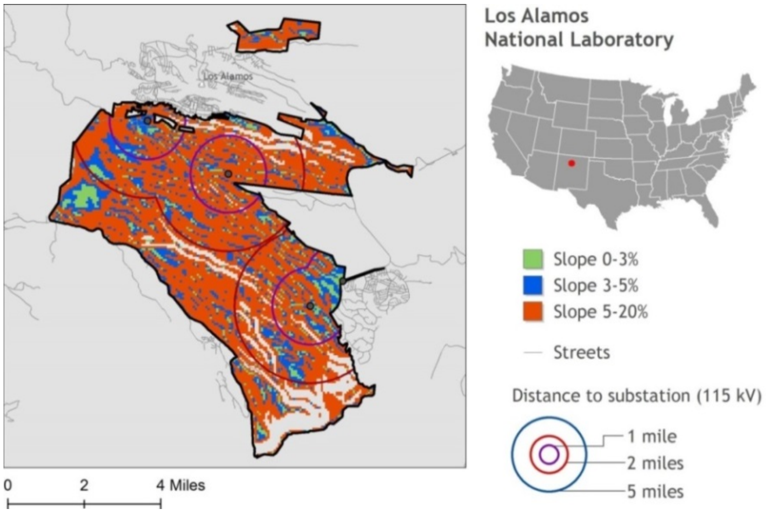

Figure 19. Los Alamos National Laboratory geographic information system analysis map

Illustration by Jenny Melius, NREL

Offtaker. Because the Los Alamos Department of Public Utilities' (LADPU) current cost of power is \$100/MWh for residential customers and \$67/MWh for commercial customers, and because 115 kV appears to be the highest transmission capacity outside the region, the LADPU appears to be the most likely offtaker.

The proposed project would be interconnected within the site's 115-kV transmission infrastructure. Based on the 2008 RE integration study conducted by LANL and updated in 2015, the site had the capacity to import an additional 25–30 MW of RE power to serve baseload power requirements. However, this transmission capacity may already be accounted for by significant anticipated growth in site demand. This may not preclude an on-site PV purchase option, but power sales off site may be constrained. Based on discussion with site contacts, most of the electricity generation in the LADWP power pool is already consumed by LANL, making the site the largest offtaker entity. The site currently has two 115-kV lines (Reeves and Norton lines). Although the potential project sites are close to 13.2-kV lines, some additional transmission upgrades for megawatt-scale projects would likely be required.

Regulatory. A more detailed NEPA analysis may be required because archaeological sites are present on some of the larger usable ground-mount areas, and four endangered species live on the site.[48] However, the site contact has confirmed that the 400 acres identified as highly favorable for solar development have no cultural resources. All sites are within 100 feet of a 13.2-kV line; whether additional transmission upgrades would be required depends on the sizes of the arrays installed. Based on site contact responses, previous projects have encountered issues with permitting water and air discharges, waste disposal, and environmental cleanup, but no issues were unresolvable in permitting the existing 2-MW PV site.

Economics. The project's estimated LCOE of $82/MWh is within the range of the LADPU's retail power rates, which are $100/MWh for residential users and $67/MWh for large commercial users.[49] The proposed project may be feasible through a PPA that is structured to undercut present power costs and increase at a fixed rate. The project's estimated LCOE is above the current cost of power at the site at $67/MWh, but the likelihood of load growth at the site and presence of existing 1-MW solar arrays indicates that new projects may be feasible.

2.2.4.2 Wind

The following sections detail wind project development considerations at Pantex Plant and Shirley Basin South sites.

2.2.4.2.1 Wind at Pantex Plant, Texas

The portfolio analysis identified a wind project of at least 100 MW as potentially viable for this location (100 MW was set as the maximum allowable size within the analysis). The project would likely require up to 3,000 acres of land (30 acres/MW) and could potentially produce power at an LCOE of $42/MWh. This site had the lowest LCOE for wind of all sites screened. The site already has an 11.5-MW wind farm in operation, although an expansion at the site may be feasible. Based on high-level GIS screening, this project could result in only 170 acres remaining undeveloped for future projects (Figure 20).

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[48] Hathlock, Charles D., et al. 2014, *Threatened and Endangered Species Habitat Management Plan for Los Alamos National Laboratory*, (LANL; March 25, 2014). accessed July 6, 2015 at http://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-14-21863.

[49] Leidos Engineering. 2014. *Electric Utility Cost of Service Analysis and Rate Study* (LADUP; November 2014) accessed July 14, 2015 at http://www.losalamosnm.us/utilities/DPUDocuments/DPU_BR141106-LADPU2014COSandRateDsgn-FINAL.pdf.

Figure 20. Pantex Plant site map, wind farm indicated in red

Illustration from Pantex Plant

Table 9 provides a description of wind project development considerations at Pantex Plant.

Table 9. Description of Wind at the Pantex Plant

Location	Amarillo, TX	
Technology	Wind	
Size	100 MW (constrained by maximum allowable size)	
Mission	The Pantex Plant is a nuclear weapons assembly and disassembly facility.	
Site Ownership & Control	Red (infeasible project risk)	• Up to 3,170 acres may be available for development. However, based on GIS analysis, only 1,670 acres would be suitable for wind development. When the 1,500 acres of current wind development is accounted for, limited acreage may remain for development. • The site already hosts an 11.5-MW wind farm, and the availability of additional developable acres is uncertain.
Offtaker	Yellow (uncertain project risk)	• The site has an 11.5-MW wind farm operating to reduce on-site load. The connection to the wind farm is sized at 15 MW. • Based on discussion with site contacts, the interconnection point to the 115-kV grid would be less than 10 miles from the site. • Based on GIS analysis of the site and its surroundings, about 1,184 acres of the total 1,527 acres is within a 2-mile radius of transmission substations larger than 69 kV.
Regulatory	Yellow (uncertain project risk)	• The original Federal Aviation Administration permitting process took approximately 3 years. • NEPA will be required; the level of analysis required is still uncertain.
Economics	Yellow (uncertain project risk)	• The modeled LCOE of $42/MWh appears to be competitive; however, wind PPA prices in the ERCOT region are currently significantly pressured due to oversupply.[50]

Site ownership and control. The Pantex Plant is a nuclear weapons assembly and disassembly facility. The site comprises about 18,000 acres of land; 12,000 acres are owned by DOE and 6,000 acres are leased to Texas Tech University. This land is primarily used as a safety and security buffer.[51] Up to 3,170 acres would be available for development at the site, and additional land would apparently be available to the south of the wind farm.

Based on GIS analysis, only a limited part of the site is available for development. However, the GIS shapefile boundary differs considerably from the provided site plan, so this shapefile may be out of date. The available acreage for wind development within the GIS analysis was 1,670. When the 1,500 acres of current wind development are accounted for, only limited acreage may remain for development (Figure 21).

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[50] Bailey, D. 2015. "Texas finds wind security in hedges," *WindPower Monthly*, April 30, 2015. Accessed July 6, 2015 at http://www.windpowermonthly.com/article/1344891/texas-finds-wind-security-hedges.

[51] DOE. *Pantex General Overview.* NNSA Pantex Plant fact sheet, accessed July 6, 2015 at http://www.pantex.com/about/Documents/Fact%20Sheet%20Docs/FS%20-%20General%20Overview.pdf.

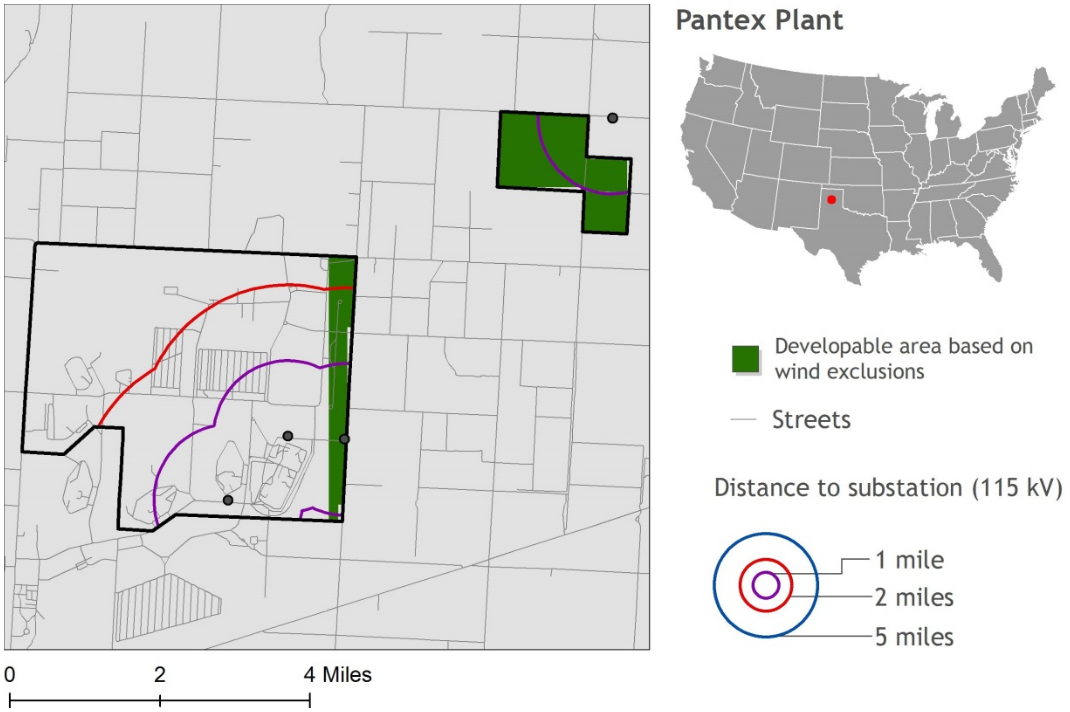

Figure 21. Pantex Plant geographic information system analysis map

Illustration by Jenny Melius, NREL

Offtaker. The proposed offtaker for this power is either the site load (if additional site load has not been met by the 11.5-MW wind farm) or a utility offtaker. The site load is already being met through an ESPC with Siemens Government Technologies Inc., so any additional wind project would need to pursue an off-site offtaker.

Concerning the viability for a PPA with an off-site utility, the interconnection and PPA price may be limiting factors. The site's interconnection point to the 115-kV grid is roughly 2 miles from the wind farm. Also, Texas is currently encountering limited demand for wind PPAs, which may preclude further development at the site in the near term.[52]

Regulatory. Although the original Federal Aviation Administration permitting process took approximately 3 years to receive a Determination of No Hazard to Air Navigation, future expansions at the site may be facilitated by this initial development work. More detailed NEPA analysis may be required because the site has environmental contaminants.

Economics. Additional due diligence was conducted on REopt assumptions to verify economics for this project. The availability of an additional revenue stream from REC sales was examined but does not appear to be currently viable due to oversupply concerns. As of June 16, 2015, REC prices were less than $1/MWh, with limited potential for future upswing. Due to relatively weak RPS requirements and strong growth in wind capacity, the current REC market is heavily

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[52] Bailey, D. 2015. "Texas finds wind security in hedges," *WindPower Monthly*, April 30, 2015. Accessed July 6, 2015 at http://www.windpowermonthly.com/article/1344891/texas-finds-wind-security-hedges.

oversupplied, although future policy changes to increase compliance obligations could create new demand.

2.2.4.2.2 Wind at Shirley Basin South, Wyoming

The portfolio analysis identified a wind project of 51 MW as potentially viable for this location (the size of this project was constrained by land availability). The project would likely require up to 1,530 acres of land (30 acres/MW) and could potentially produce power at an LCOE of $50/MWh. This site had the second-lowest LCOE for wind of all sites screened. Although the modeled LCOE of $50/MWh appears to be competitive, and the site appears to be available for development, the additional costs of transmission access may be a limiting factor. Maps of Shirley Basin South are in Figure 22 and Figure 23.

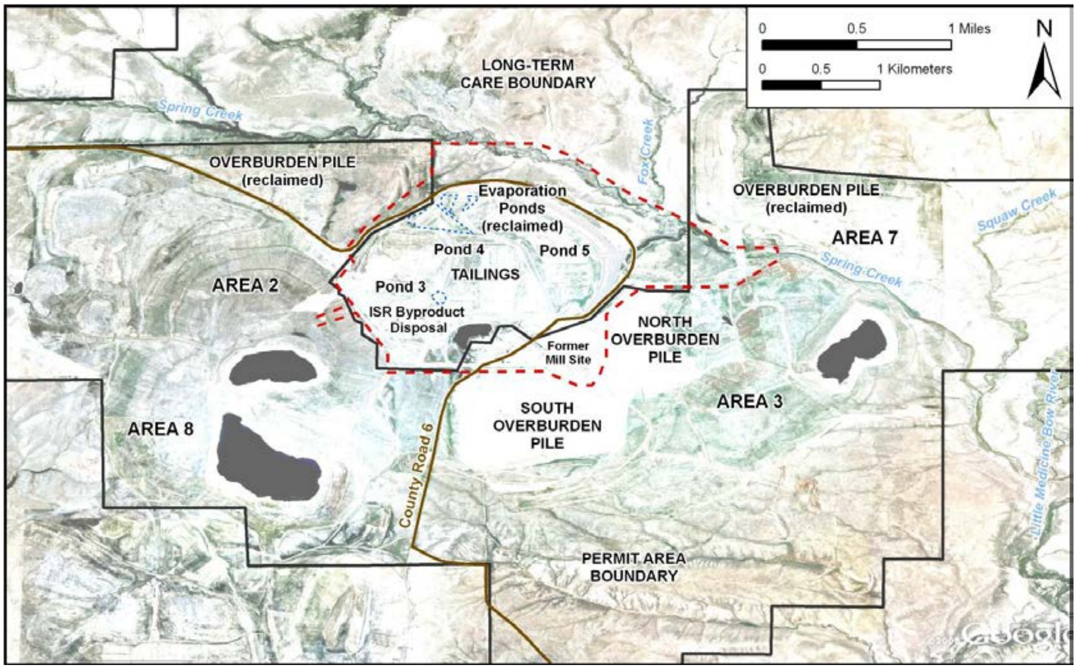

Figure 22. Site map of disposal cell in the southern end of the Shirley Basin South site

Source: Pathfinder Mines Corporation[53]

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[53] Pathfinder Mines Corporation. 1993. *Shirley Basin Mine Tailings Reclamation Plan*, Volume 2 (Mills, Wyoming, 1993), accessed August 2015 at http://www.nrc.gov/info-finder/decommissioning/uranium/is-pathfinder-shirley-basin.pdf.

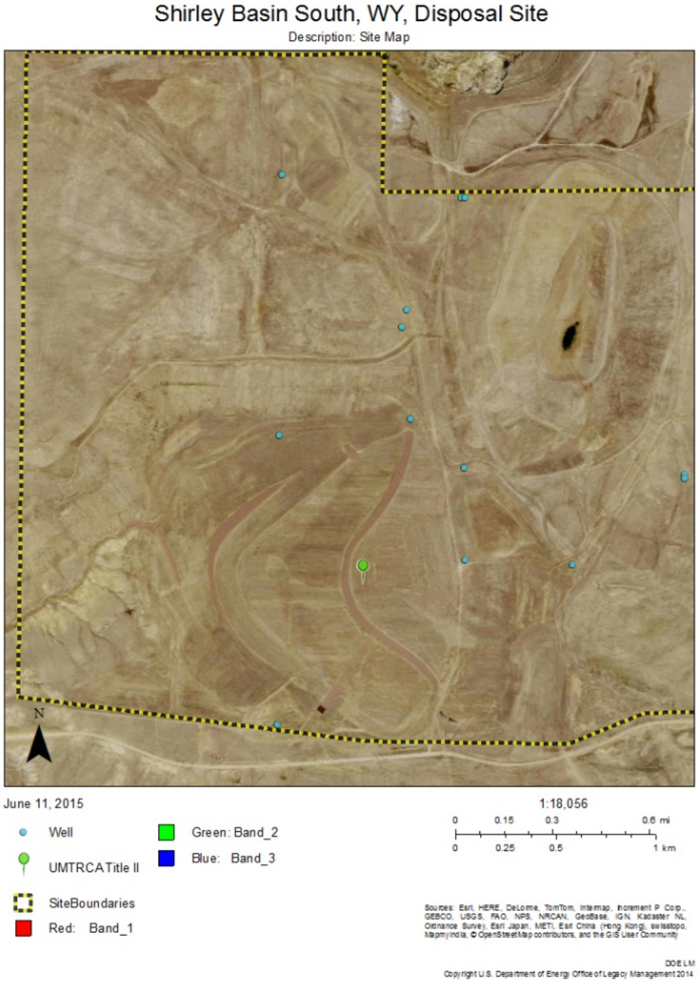

Figure 23. Shirley Basin South site map

Source: DOE[54]

Table 10 provides a description of wind project development considerations at Shirley Basin South.

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[54] "Geospatial Environmental Mapping System, Version: 2.4.6." DOE Office of Legacy Management, accessed July 20, 2015, at http://gems.lm.doe.gov/.

Table 10. Description of Wind at Shirley Basin South (Wyoming) Disposal Site

Location	Carbon County, WY	
Technology	Wind	
Size	51 MW (constrained by land availability)	
Mission	The Shirley Basin South site is a disposal site for radioactive tailings from a now-defunct uranium mill.	
Site Ownership & Control	Green (acceptable project risk)	• Up to 1,300 acres may be available for development. The site is fenced and access is via a public road. • Based on a GIS analysis of the site's slope, about 95% of the site acreage would be suitable for wind development. • A grazing license is currently in place and would require coordination with the licensee in the grazing area.
Offtaker	Green (acceptable project risk)	• Based on GIS analysis of the site and its surroundings, about 1,184 acres of the total 1,527 acres is within a 2-mile radius of transmission substations larger than 69 kV.
Regulatory	Yellow (uncertain project risk)	• The regulator for this site, the U.S. Nuclear Regulatory Commission (NRC), would need to approve a development plan in advance of its construction. • It is also likely the long-term surveillance plan (the site-specific compliance document) would need to be revised and approved by NRC in advance. • NEPA will be required; the level of analysis required is still uncertain.
Economics	Green (acceptable project risk)	• The modeled LCOE of $50/MWh appears to be very competitive. The additional costs of transmission access may be a limiting factor.

Site ownership and control. The Shirley Basin South site is a disposal site for radioactive tailings from a now-defunct uranium mill. The site comprises 1,527 acres of land, of which 142 acres includes the disposal cell. Based on a GIS analysis of wind-specific slope constraints, about 95% of the site acreage would be suitable for wind development (Figure 24).

The condition of the site includes unsealed road access and perimeter fencing. Two mine pits are also within the site boundary. One pit serves as a drainage basin directly east of the site. The other is in the northeast of the site and presents a sudden and notable change in topography over a short distance. Mine spoils are also located in the northwest of the cell and create a steep hill that may not be conducive to good wind patterns.

The disposal cell contains mill tailings with radiological contamination and is outside the considered available area. Construction hazards would include (but not be limited to) the cell, monitoring wells, a containment dam, diversion channels, and steep changes in typography (e.g., mine pit). Although vegetated, the northwest section of the site also has mine spoils.

Finally, a grazing licensee would need to be consulted before the project is developed.

Offtaker. The site has no significant load, so the offtaker would have to be off site and likely in a different state. Based on a recent NREL study, the states most likely to purchase this power would be Nevada and Utah due to the comparative cost advantage of Wyoming wind power compared to in-state resources.[55] However, the Chokecherry and Sierra Madre Wind energy project, which is projected to include two 1.5-GW phases, is currently under development and would pose significant competitive pressure to other projects pursuing out-of-state sales.[56]

The proximity, cost, and availability of transmission interconnection to the site will be major determinants of the project's viability. Based on GIS analysis of the site and its surroundings, about 1,184 acres of the total 1,527 acres is within a 2-mile radius of transmission substations larger than 69 kV (Figure 24 and Figure 25).

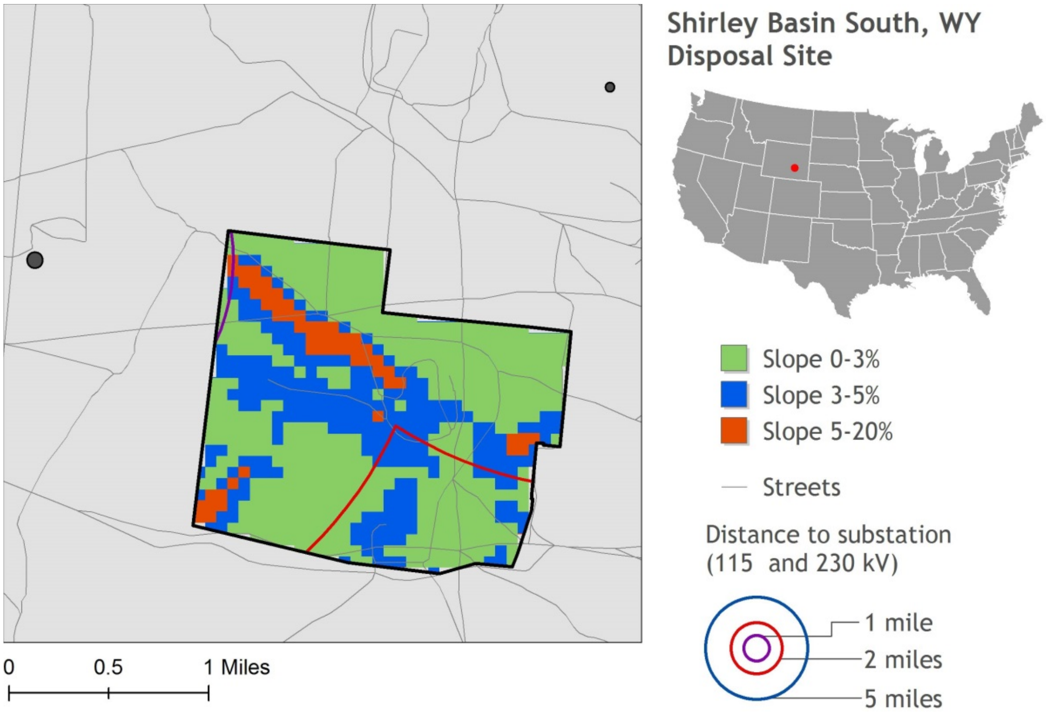

Figure 24. Shirley Basin South geographic information system analysis map

Illustration by Jenny Melius, NREL

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[55] Hurlbut, David J., Joyce McLaren, and Rachel Gelman. 2013. *Beyond Renewable Portfolio Standards: An Assessment of Regional Supply and Demand Conditions Affecting the Future of Renewable Energy in the West*. TP-6A20-57830, 2013, National Renewable Energy Laboratory, Golden, CO. http://www.nrel.gov/docs/fy13osti/57830-1.pdf.

[56] "Chokecherry and Sierra Madre Wind Energy Project." Carbon County Economic Development Corporation. 2012, accessed July 14, 2015, at http://www.ccwyed.net/chokecherry-sierra-madre.shtml.

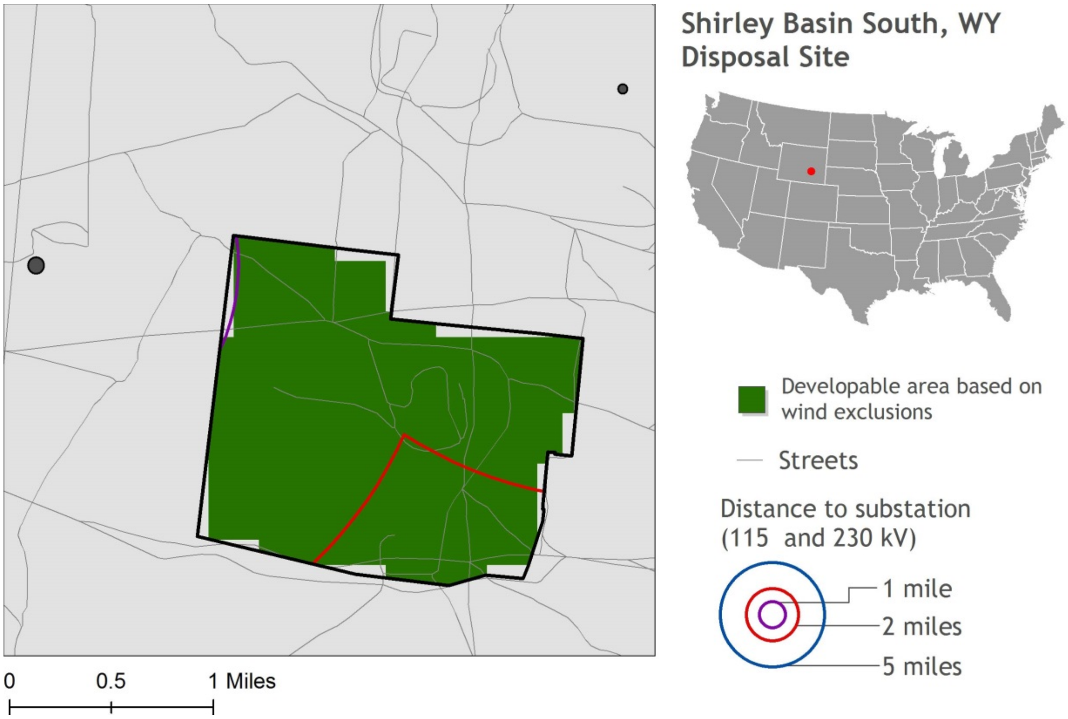

Figure 25. Shirley Basin South wind exclusions map

Illustration by Jenny Melius, NREL

Regulatory. No information is available to determine the level of NEPA analysis that will be required. Grazing licenses are in effect at the site, within the land boundary. No information about endangered species or cultural resources is available. The site would most likely require the approval of the NRC for project development as well. Neighboring land is primarily owned by BLM and by a commercial mine operator.

Economics. The modeled LCOE of $50/MWh appears to be very competitive. The additional costs of transmission access may be a limiting factor.

2.2.4.3 Biomass

The following sections detail biomass project development considerations at SPRU and FNAL sites.

2.2.4.3.1 Biomass at Separations Process Research Unit, New York

The portfolio analysis identified a biomass project of 82 MW as potentially viable for this location (the size of the project was limited by resource availability). The project would require about 40 acres of land and could potentially produce power at an LCOE of $91/MWh. However, after consultation with the site contact, the site does not appear to be developable, based on an ongoing cleanup mission (Figure 26).

Figure 26. Separations Process Research Unit site overview

Source: EDI[57]

Table 11 provides a description of biomass project development considerations at SPRU.

Table 11. Description of Biomass at the Separations Process Research Unit

Location	Niskayuna, NY	
Technology	Biomass	
Size	82 MW (constrained by feedstock resource availability)	
Mission	The SPRU site is an inactive laboratory for plutonium extraction research that is currently undergoing cleanup.	
Site Ownership & Control	Red (infeasible project risk)	- Development of a biomass project at the SPRU site is not currently feasible due to ongoing cleanup and site security requirements that would prevent regular access for feedstock delivery.
Offtaker	Gray (not evaluated)	- Not evaluated
Regulatory	Gray (not evaluated)	- Not evaluated
Economics	Gray (not evaluated)	- An LCOE of $91/MWh was estimated, but no additional analysis was performed due to site unavailability.

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[57] DOE. "DOE Small Sites, Separation Process Research Unit (SPRU) Staff Augmentation," (Edi), accessed at http://www.edi-nm.com/services-pdf/map-pdf/21_SF330%20DOE%20(Small%20Sites)%20SPRU_2010.pdf.

Site ownership and control. According to the SPRU website, "the Separations Process Research Unit (SPRU) is an inactive facility located at the Knolls Atomic Power Laboratory (KAPL) in Niskayuna, New York. Currently, decontamination and decommissioning (D&D) is taking place of two contaminated buildings (G2 and H2 buildings), seven inactive waste storage tanks located within H2 tank vaults, a pipe tunnel between G2 and H2, and associated contaminated soil."[58] During consultation with contacts at the site, NREL learned that the site is still undergoing cleanup, after which it will be a part of an ongoing security mission that would prevent the development of a biomass plant.

Offtaker. The most likely offtaker for this power would be National Grid. This utility could be interested in this power if RPS targets were expanded; however, the site does not appear to have a notable competitive advantage for development, given its environmental contaminants.

Regulatory. Because development of a biomass project at the SPRU site is not currently feasible due to ongoing cleanup and site security requirements that would prevent regular access for feedstock delivery, additional examination of the site's legal environmental requirements was not conducted.

Economics. Because development of a biomass project at the SPRU site is not currently feasible due to ongoing cleanup and site security requirements that would prevent regular access for feedstock delivery, additional examination of the site's economics was not conducted.

2.2.4.3.2 Biomass at Fermi National Accelerator Laboratory, Illinois

The portfolio analysis identified a biomass project of at least 100 MW as potentially viable for this location (100 MW was set as the maximum allowable size within the analysis). The project would require 50–100 acres of land and has a modeled LCOE of $97/MWh.

Based on further research, 83% of the site is within 1 mile of a substation with a capacity of 69 kV or greater. However, the site's available acreage is reserved for development of future experiments and is not currently available for renewable energy development. On-site power purchase would not currently be an economically viable offtake option because of the site's low utility rate of $35/MWh, but an off-site offtake may still be viable.

In 2008, NREL conducted an initial RE feasibility assessment to determine the potential for RE installations to offset the on-site load. This study concluded that thermal biomass used in a wood-fired boiler was the only potential option, with a payback of 21 years. According to site contacts, this option was seriously considered, but the price of the wood feedstock subsequently increased and resulted in the project becoming uneconomic. The primary factor cited in the electricity generation project's lack of competitiveness was the site's low utility rate ($35/MWh). FNAL also purchases RECs on a year-to-year contract in an amount equivalent to 3% of the total annual electricity use.

A site map is available in Figure 27.

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[58] DOE. 2013. "EM Marks Milestone at Separations Process Research Unit." Office of Environmental Management, March 7, 2013, https://energy.gov/em/articles/em-marks-milestone-separations-process-research-unit.

Figure 27. Fermi National Accelerator Laboratory site map

Source: FNAL[59]

Table 12 provides a description of biomass project development considerations at FNAL. Details follow the table.

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[59] "Fermilab Fact Sheets." DOE Fermi National Accelerator Laboratory, http://www.fnal.gov/pub/presspass/factsheets/pdfs/Fermilab_Site_Map.pdf.

Table 12. Description of Biomass at Fermi National Accelerator Laboratory

Location	Batavia, IL	
Technology	Biomass	
Size	100 MW (constrained by maximum allowable size)	
Mission	FNAL is a major science and technology institution; its research emphasizes particle physics and accelerator research.	
Site Ownership & Control	Yellow (uncertain project risk)	• The site comprises 6,811 acres of land that has significant existing uses. Although there are 500 acres of undeveloped land, this is reserved for future experiments, which would take priority over any RE developments.
Offtaker	Green (acceptable project risk)	• The site has been approached in the past about PV and biomass PPAs, but the lab's low power prices of $35/MWh have prevented projects from being economic. • Based on GIS analysis, about 5,800 acres, or 83% of the site, is within 1 mile of a substation with a capacity of 69 kV or greater.
Regulatory	Yellow (uncertain project risk)	• Based on discussion with site contacts, the site has several wetlands and one cultural resource (a Pioneer Cemetery). The site is also home to numerous birds, including several endangered species, which may result in more detailed NEPA analysis. • Air quality permitting will be required.
Economics	Yellow (uncertain project risk)	• On-site power purchase would not currently be an economically viable offtake option due to the site's low utility rate of $35/MWh, in comparison to modeled LCOE of $97/MWh. • Feedstock price and availability are still unknown.

Site ownership and control. The site comprises 6,811 acres of land that has significant uses. At this time it is uncertain whether 50 to 100 acres would be available for development of an RE project because this land is reserved for HEP experiments. Based on GIS analysis, 99% of the site has a slope gradient of less than 3%, which would be advantageous for the proposed project. Similar to other DOE laboratory sites, development on-site would be subject to some security considerations, but procedures are in place to facilitate this process.

Offtaker. The proposed offtaker for this power would be the on-site load and/or an off-site utility purchaser. Although the site's low power rate of $35/MWh is much lower than the LCOE of any of the modeled technologies, the site may be able to purchase a portion of the power at a premium if the project provided a sufficiently compelling research opportunity. That said, the site would probably be able to act as the sole offtaker in the near future. Based on GIS analysis, 83% of the site's area, or 5,770 acres, are within 1 mile of a 69-kV or larger substation (Figure 28).

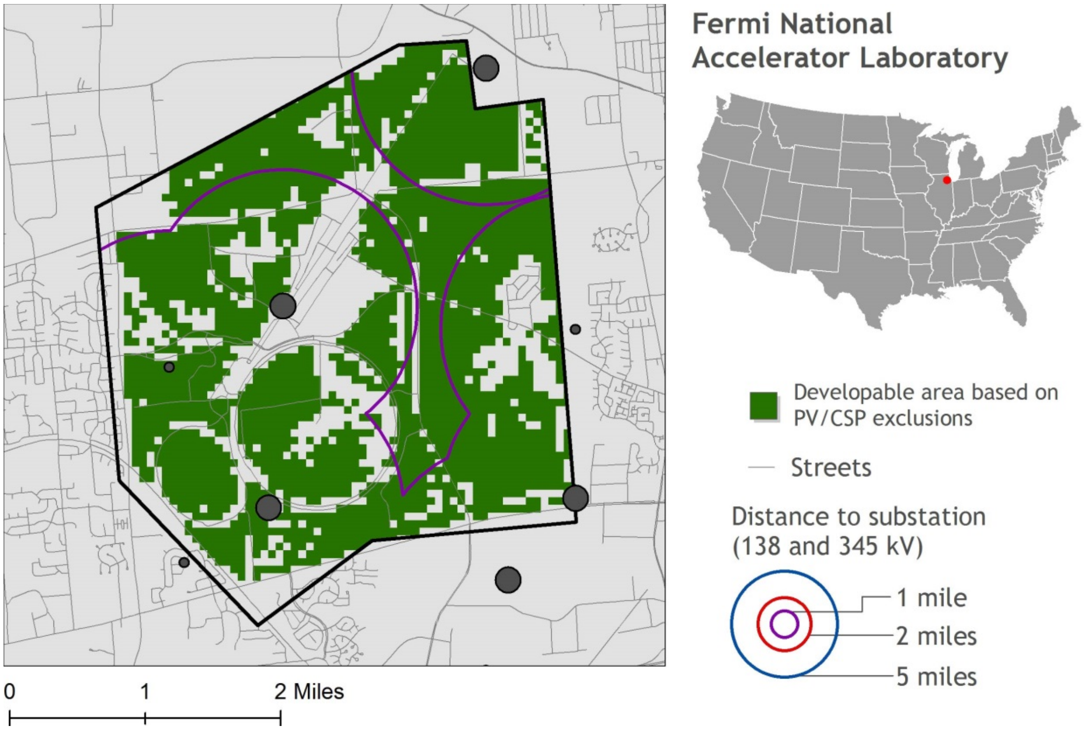

Figure 28. Fermi National Accelerator Laboratory geographic information system analysis map

Illustration by Jenny Melius, NREL

Concerning a utility offtaker, Illinois has already made significant process toward its 2020 RPS goals (82% of the total 2020 emissions target are already completed), which may limit demand for additional PPAs in the near term.

Regulatory. Based on discussion with site contacts, the site has several wetlands and one cultural resource (a Pioneer Cemetery). The site is also home to numerous birds, including several endangered species, which may result in more detailed NEPA analysis.

Economics. On-site power purchase would not currently be an economically viable offtake option due to the site's low utility rate of $35/MWh. Feedstock price and availability are still unknown.

2.2.4.4 Landfill Gas

The following sections detail LFG project development considerations at the Kansas City Plant, NETL, and Grand Junction Disposal sites. Appendix F examines the feasibility of LFG delivery pipelines to DOE sites.

2.2.4.4.1 Landfill Gas at Kansas City Plant, Missouri

The portfolio analysis identified an LFG project of 2.5 MW as potentially viable for this location (the system size was limited by resource availability). The project would require 5–10 acres of land and could potentially produce power at an LCOE of $91/MWh. Based on the analysis, development of an LFG project at this site appears promising, although uncertainty still surrounds the nature of the site's redevelopment and the permitting costs of an LFG pipeline to the site. Although construction of a pipeline is costly, construction of the plant on the DOE site would be required for the project to fit within the requirements of development on DOE land. A site map is available in Figure 29.

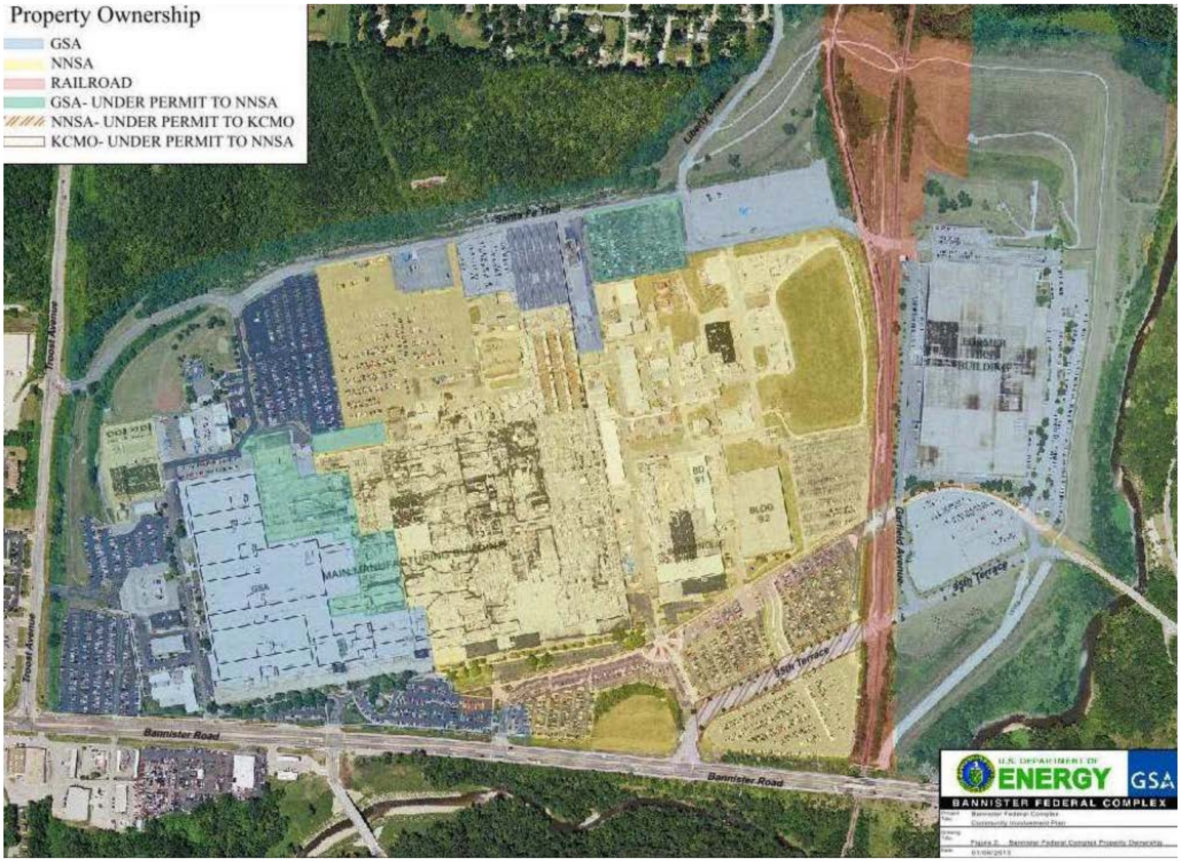

Figure 29. Old Kansas City Plant (Bannister Road) site map

Source: DOE and GSA[60]

Table 13 provides a description of LFG project development considerations at Kansas City Plant.

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[60] Department of Energy and General Services Administration. 2013. "Bannister Federal Complex Community Involvement Plan." June 2013, http://honeywell.com/sites/aero-kcp/SiteCollectionDocuments/June%202013%20BFC%20Community%20Involvement%20Plan%20Final.pdf.

Table 13. Description of Landfill Gas at the Kansas City Plant

Location	Kansas City, MO	
Technology	LFG	
Size	2.5 MW (constrained by resource availability)	
Mission	The Kansas City Plant is a manufacturing facility for nonnuclear material used in the U.S. nuclear arsenal. The plant recently relocated its operations from the original facility near Bannister Road to its new location near Botts Road.	
Site Ownership & Control	Yellow (uncertain project risk)	• The Bannister site was chosen for analysis because it is 1.4 miles from the LFG resource (Southeast Landfill), whereas the Botts site is 8 miles. The Bannister pipeline path is not obstructed by geographical features and may potentially have a right-of-way path along a railway line. • The Bannister site has up to 122 acres available for development, as well as a perimeter fence and access road.
Offtaker	Green (acceptable project risk)	• There may be future on-site demand if the Bannister site is redeveloped. There may also be off-site industrial or utility purchasers in close proximity to the site. The site has two independently fed 161-kV transmission lines, two 13.8-kV step-down transformers, and 63 100-MW substations.
Regulatory	Green (acceptable project risk)	• Air quality permitting will be required. • Right-of-way permitting may be required.
Economics	Green (acceptable project risk)	• There was a modeled LCOE of $91/MWh, but there is still uncertainty surrounding the nature of the site's redevelopment and the permitting of pipeline delivery to the site. These costs may significantly impact the project's overall competitiveness.

Site ownership and control. The Kansas City Plant is a manufacturing facility for nonnuclear material used in the U.S. nuclear arsenal. The plant recently relocated its operations from the original facility near Bannister Road to its new location near Botts Road. This new facility is 8 miles from the Southeast Landfill, whereas the original site is 1.4 miles away (Figure 30). Although the new site was examined for potential development, any LFG pipeline would have to traverse 8 miles of urban areas, which does not appear to be feasible.

During discussion with the site contact for the Bannister site, NREL learned that this site will apparently be redeveloped for a new use in keeping with the surrounding area, which is characterized by single and multifamily dwellings, commercial establishments, an industrial district, and public use land. The Bannister complex is much closer to the Southeast Landfill and a nearby railway might serve as a right-of-way path for the pipeline. Roughly 120 acres of the 300-acre complex is available for development with site road access.[61] Low hills surround much of the complex, and the site is situated in the Blue River Valley approximately 800 feet above sea level. A 500-year flood level protection system protects the federal complex.

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[61] NNSA. 2011. "Kansas City Plant at the Bannister Federal Complex." Presented at U.S. Department of Energy, June 9, 2011, http://honeywell.com/sites/aero-kcp/News-Events/Documents/KCP_Disposition_CAP2011.pdf.

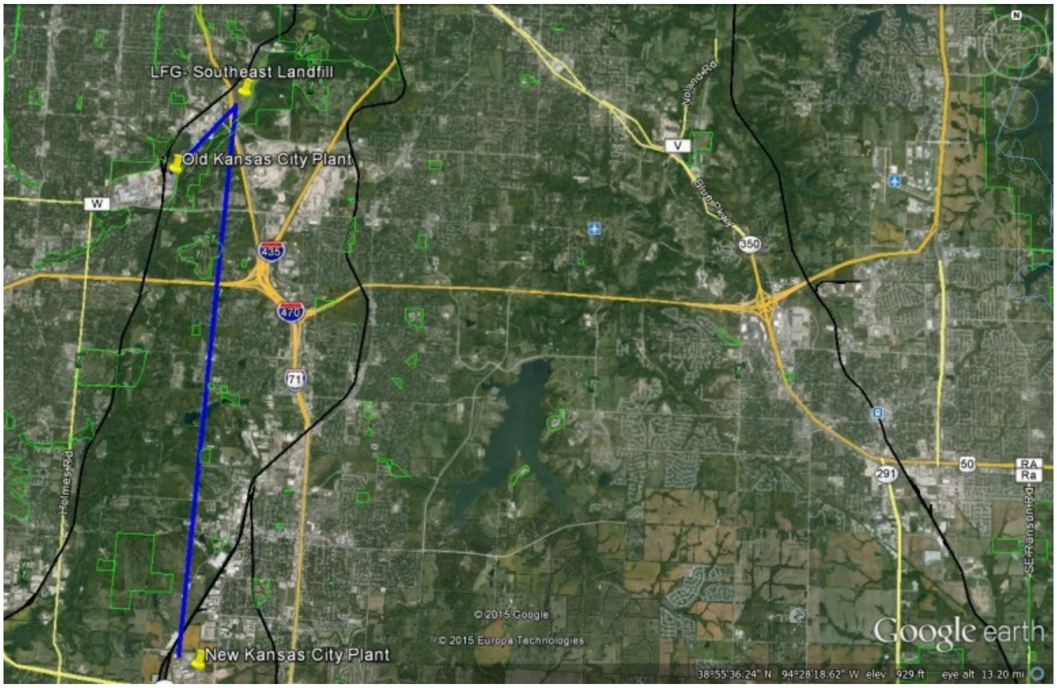

Figure 30. Comparison of landfill gas pipeline distance—Kansas City plant

Source: © 2015 Google Earth, alterations by Jenny Melius, NREL

Offtaker. The timing and future ownership of the Bannister complex would likely determine the viability for the system's production to meet an on-site load. Given the site's location in an urban area, industrial users, the local utility, or other entities may become offtakers. The site has two independently fed 161-kV transmission lines, two 13.8-kV step-down transformers, and 63 100-MW substations.[62]

Regulatory. Although the REopt analysis did include the cost of pipeline construction for delivery of the LFG, additional permitting work would probably be required to secure a right-of-way between the landfill and the project site. The site would also likely require an air permit, because the LFG plant would produce emissions. NEPA will be required; however, the level of analysis required is still uncertain.

Economics. Although the site's resource and economic potential appear promising, major uncertainty surrounds the potential costs associated with the construction and permitting of pipeline delivery to the site.

2.2.4.4.2 Landfill Gas at National Energy Technology Laboratory, Pennsylvania

The portfolio analysis identified an LFG project of 2.5 MW as potentially viable for this location (the system size was limited by resource availability). The project would require 5–10 acres of land and could potentially produce power at an LCOE of $86/MWh. Based on this analysis, numerous geographic and urban features would likely preclude the development of the required 6-mile pipeline. Although construction of a pipeline is costly, construction of the plant on the

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[62] Ibid.

DOE site would be required for the project to fit within the requirements of development on DOE land.

Table 14 provides a description of LFG project development considerations at NETL.

Table 14. Description of Landfill Gas at National Energy Technology Laboratory

Location	Pittsburgh, PA	
Technology	LFG	
Size	2.5 MW (constrained by resource availability)	
Mission	NETL is a major science and technology institution; its research emphasizes energy security.	
Site Ownership & Control	Red (infeasible project risk)	• The site has up to 63 acres available for development, although existing buildings may reduce the developable area. • The site is 6 miles from the LFG resource (Kelly Run Sanitary Landfill). The pipeline path is obstructed by geographical features such as rivers and hills, as well as urban features such as roads, railways, and residential developments.
Offtaker	Yellow (uncertain project risk)	• The on-site load and potential off-site offtakers are uncertain but were not evaluated in-depth due to the right-of-way obstructions. • Transmission capacity and proximity to the site is unknown.
Regulatory	Yellow (uncertain project risk)	• Air quality permitting will be required. • Right-of-way permitting will likely be required.
Economics	Red (infeasible project risk)	• There was a modeled LCOE of $86/MWh, but a 6-mile LFG pipeline would probably encounter significant permitting and construction challenges that would pose a significant risk to project completion.

Site ownership and control. NETL is a major science and technology institution; its research emphasizes energy security. The site has up to 63 acres available for development, although existing buildings may reduce the developable area. The site is 6 miles from the Kelly Run Sanitary Landfill. The pipeline path is obstructed by geographical features such as rivers and hills, and urban features such as roads, railways, and residential developments (Figure 31).

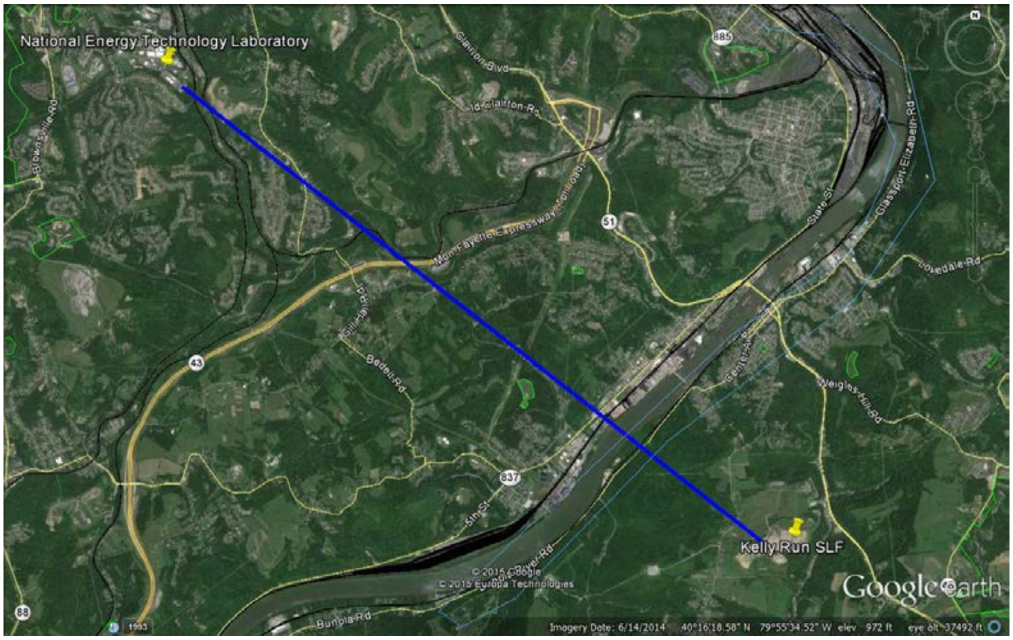

Figure 31. Landfill gas pipeline—National Energy Technology Laboratory

Source: © 2015 Google Earth, alterations by Jenny Melius, NREL

Offtaker. The proposed offtakers for this power were not evaluated in depth due to the limited feasibility of LFG delivery to the site. If a pipeline were pursued, additional analysis would be required to determine whether the on-site load would be sufficient to purchase power from the proposed project or whether the site's interconnection infrastructure would be sufficient for off-site sales.

Regulatory. Although the REopt analysis included the cost of pipeline construction for delivery of the LFG, additional permitting work would probably be required to secure a right-of-way through the various urban areas. The pipeline would also have to avoid boat traffic on the river. The site would also require an air permit, because the LFG plant would produce emissions. NEPA will be required; however, the level of analysis required is still uncertain.

Economics. An LFG pipeline would probably encounter significant permitting and construction challenges that would pose a significant risk to project completion.

2.2.4.4.3 Landfill Gas at Grand Junction, Colorado, Disposal Site

The portfolio analysis identified an LFG project of 6.8 MW as potentially viable for this location (the system size was limited by resource availability). The project would require 5–10 acres of land and could potentially produce power at a LCOE of $81/MWh. This site had the greatest capacity and lowest LCOE for LFG of all sites screened. Up to 266 acres are available for development; however, the LFG resource is located 11 miles from the site and uncertainty surrounds the potential costs associated with the permitting of 11 miles of LFG pipeline delivery. The site also has no current transmission interconnection that would be adequate for a megawatt-scale project. Although construction of a pipeline is more costly, construction of the plant on the DOE site would be required the project to fit within the requirements of development on DOE land. Site maps are available in Figure 32 and Figure 33.

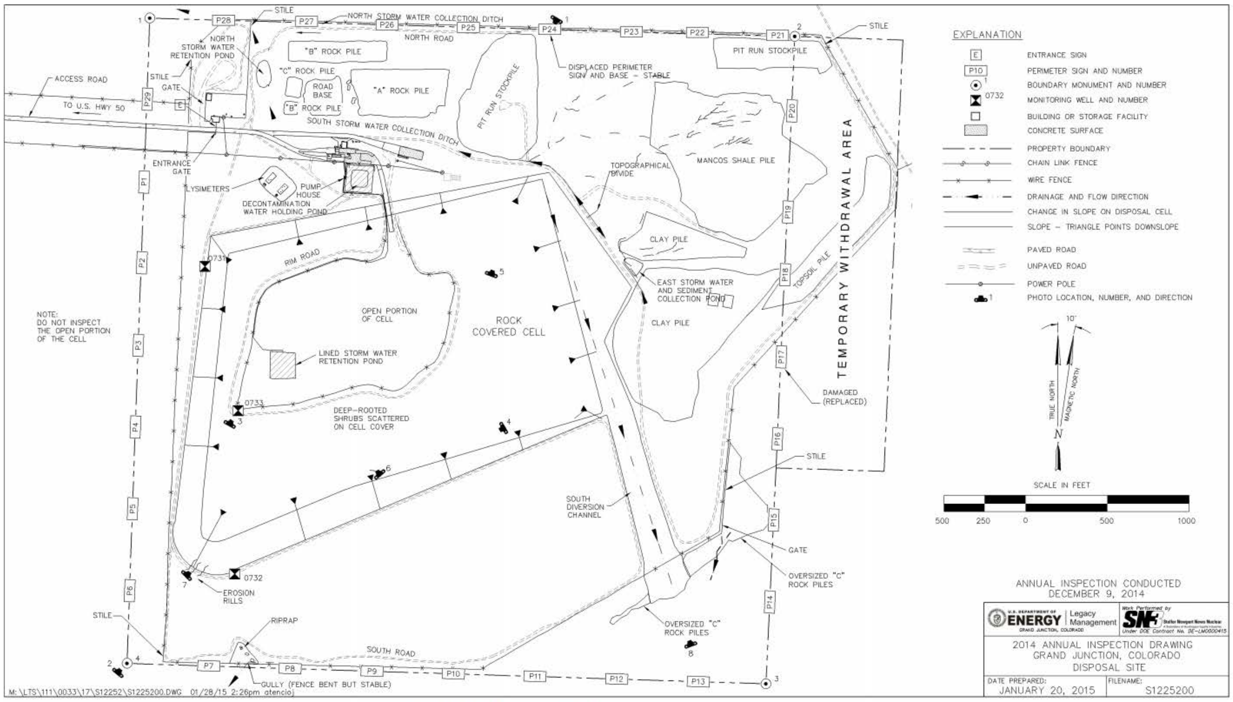

Figure 6-1. 2014 Annual Inspection Drawing for the Grand Junction Disposal Site

Figure 32. Grand Junction disposal site map

Source: DOE[63]

Figure 33. Grand Junction disposal site aerial view

Source: CLUI[64]

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[63] DOE, 2015. *2014 Annual Site Inspection and Monitoring Report*, Office of Legacy Management, March 2015, www.lm.doe.gov/Grand_Junction_DP/air_grj.pdf.

[64] "Grand Junction Disposal Cell," Center for Land Use and Interpretation, accessed July 20, 2015. http://clui.org/ludb/site/grand-junction-disposal-cell.

Table 15 provides a description of LFG project development considerations at the Grand Junction Disposal Site.

Table 15. Description of Landfill Gas at the Grand Junction Disposal Site

Location	Grand Junction, CO	
Technology	LFG	
Size	6.8 MW (constrained by resource availability)	
Mission	The site is a disposal cell for mill tailings from several cities and towns in the region where tailings were used for fill and construction material.	
Site Ownership & Control	Yellow (uncertain project risk)	• The site has up to 266 acres available for development, as well as a perimeter fence and access road. • The site is 11 miles from the LFG resource (Mesa County Landfill). The pipeline path is not obstructed by geographical features but does pass through BLM land.
Offtaker	Yellow (uncertain project risk)	• There is no on-site demand; the most likely offtaker for the power would be the City of Grand Junction or the utility, Xcel Energy. • Based on GIS analysis, no transmission substations larger than 69 kV are located within a 5-mile radius of the site. The site is currently interconnected to a 7.2-kV line.
Regulatory	Yellow (uncertain project risk)	• The project would require NRC approval before construction begins. • Right-of-way permitting through the surrounding BLM land would probably be required to reach the site. • Air quality permitting will be required.
Economics	Yellow (uncertain project risk)	• There was a modeled LCOE of $81/MWh, but there is still uncertainty surrounding the potential costs associated with the right-of-way permitting of LFG pipeline delivery and transmission interconnection to the site.

Site ownership and control. The Grand Junction disposal site (previously called the Cheney site) is 360 acres and is located about 18 miles southeast of Grand Junction. The BLM property surrounding the 360-acre site is used seasonally for grazing. The site is protected by a perimeter fence and a locked gate. The nearest residence is approximately 2 miles north of the site. The full 360 acres would not be developable, however, because the disposal cell currently comprises 94 acres.[65] The remaining 266 acres would still be more than sufficient for the modeled 6.8-MW LFG facility. Based on GIS analysis of the site's potential slope exclusions, its slope would not be a significant constraint to development, because more than 90% of the entire area has a slope less than 20%.

The site is 11 miles from the Mesa County Landfill. It apparently has no significant geographic obstacles to completing an LFG pipeline; however, permitting the right-of-way through 11 miles

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[65] DOE. 2015. "UMTRCA Title I: Grand Junction, Colorado, Disposal and Processing Sites." Office of Legacy Management fact sheet, May 27, 2015. www.lm.doe.gov/Grand_Junction_DP/Fact_Sheet_GJ.pdf.

of BLM land and lands with other potential ownership will likely result in additional costs (Figure 34). The site is immediately surrounded by BLM land, but the land ownership further along the right-of-way toward the landfill is uncertain. Although the modeled LCOE includes the pipeline construction cost, it does not factor in any permitting or right-of-way costs, which may significantly impact the project.

Figure 34. Grand Junction disposal site map (11 miles from landfill)

Source: © 2015 Google Earth, alterations by Jenny Melius, NREL

Offtaker. Given that the site is for disposal purposes only, it has no on-site load. The likely utility offtaker would be Xcel Energy, and the likely local offtaker would be the City of Grand Junction. However, based on GIS analysis, no substations larger than 69 kV are located within a 5-mile radius of the site. The site appears to have access to a 7.2-kV power line, so construction and right-of-way permitting of additional transmission would also be required for a megawatt-scale LFG project.[66]

Regulatory. The regulator for this site, the NRC, would need to approve a development in advance of its construction. Although the portfolio analysis included the cost of pipeline construction for delivery of the LFG, additional permitting work to secure a right-of-way through the surrounding BLM land would probably be required. The site would also likely require an air permit, because the LFG plant would generate emissions. NEPA will be required; however, the level of analysis required is still uncertain.

Economics. Although the site's resource and modeled LCOE of $81/MWh appear promising, major uncertainty surrounds the potential costs associated with the construction and permitting of pipeline delivery to the site.

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[66] DOE, 2015. *2014 Annual Site Inspection and Monitoring Report*, Office of Legacy Management, March 2015, www.lm.doe.gov/Grand_Junction_DP/air_grj.pdf.

2.2.4.5 Waste to Energy

The following sections detail WTE project development considerations at the BPA Ross Complex and ANL sites.

2.2.4.5.1 Waste to Energy at the Bonneville Power Administration Ross Complex, Washington

The portfolio analysis identified a WTE project of at least 100 MW as potentially viable for this location (100 MW was set as the maximum allowable size within the analysis). The project would require about 50 acres of land and could potentially produce power at an LCOE of -$25/MWh due to the additional revenue stream from tipping fees. However, fewer than 50 noncontiguous acres are available for development. The site periodically uses this area for equipment storage. Based on discussion with the site contacts, the site does not appear to be favorable for development.

Table 16 provides a description of WTE project development considerations at the BPA Ross Complex.

Table 16. Description of Waste to Energy at the Bonneville Power Administration Ross Complex

Location	Vancouver, WA	
Technology	WTE	
Size	100 MW (constrained by maximum allowable size)	
Mission	The Ross Complex serves as the control center for the generation and transmission of electricity throughout the Pacific Northwest	
Site Ownership & Control	Red (infeasible project risk)	• Fewer than 50 noncontiguous acres are available for development. The site periodically uses this area for equipment storage. • Based on discussion with the site contacts, the site does not appear to be favorable for RE development.
Offtaker	Gray (not evaluated)	• The WTE project would be co-located with a major switchyard, but additional concerns may arise that pertain to the project’s interconnection at the control center.
Regulatory	Gray (not evaluated)	• The site may be subject to more detailed NEPA analysis due to environmental contaminants. • Air quality permitting will be required. Also, the site is close to residential areas.
Economics	Gray (not evaluated)	• There was a modeled LCOE of $-25/MWh, based on tipping fee assumptions, but feedstock price and availability are still unknown.

Site ownership and control. DOE owns 250 acres of land at the site, which is administered by BPA. The Ross Complex serves as the control center for the generation and transmission of electricity throughout the Pacific Northwest. It is also a federal storage facility for BPA waste from operations in Washington, Oregon, Idaho, and Montana. After discussion with the site contacts, fewer than 50 acres of land appear to be available for development. The site includes a switchyard, environmental contaminant disposal areas, and BPA equipment. The site periodically uses the remaining area for equipment storage (Figure 35).

Figure 35. Bonneville Power Administration Ross Complex site map

Source: © 2015 Google Earth

Offtaker. Although the site does not appear to be viable due to limited available acreage for development, the fact that the site contains extensive interconnection equipment would likely facilitate physical interconnection. However, given the BPA's role as a balancing authority, additional concerns may arise that pertain to the project's interconnection at the control center.

Regulatory. Although the site does not appear to be viable due to limited available acreage for development, additional environmental permitting studies would likely be required due to environmental contaminants on site. Additional air quality permitting would be required, which may be exacerbated by the fact that the site is located in a residential area.

Economics. The economic viability of the project would be highly dependent on the tipping fee pricing and availability of usable waste streams. This availability was not examined further due to the site limitations already described.

2.2.4.5.2 Waste to Energy at Argonne National Laboratory, Illinois

The portfolio analysis identified potential for at least a 100-MW WTE project at an LCOE of -$5/MWh (due to tipping fees) at ANL (100 MW was the maximum size considered in this analysis). Based on GIS analysis, about 1,385 acres, or 35% of the site, is within 1 mile of a substation with a capacity of 69 kV or greater, which may enable the sale of power to an off-site entity. Sufficient feedstock at an economic price and a viable offtake will require further detailed review.

A site map is shown in Figure 36.

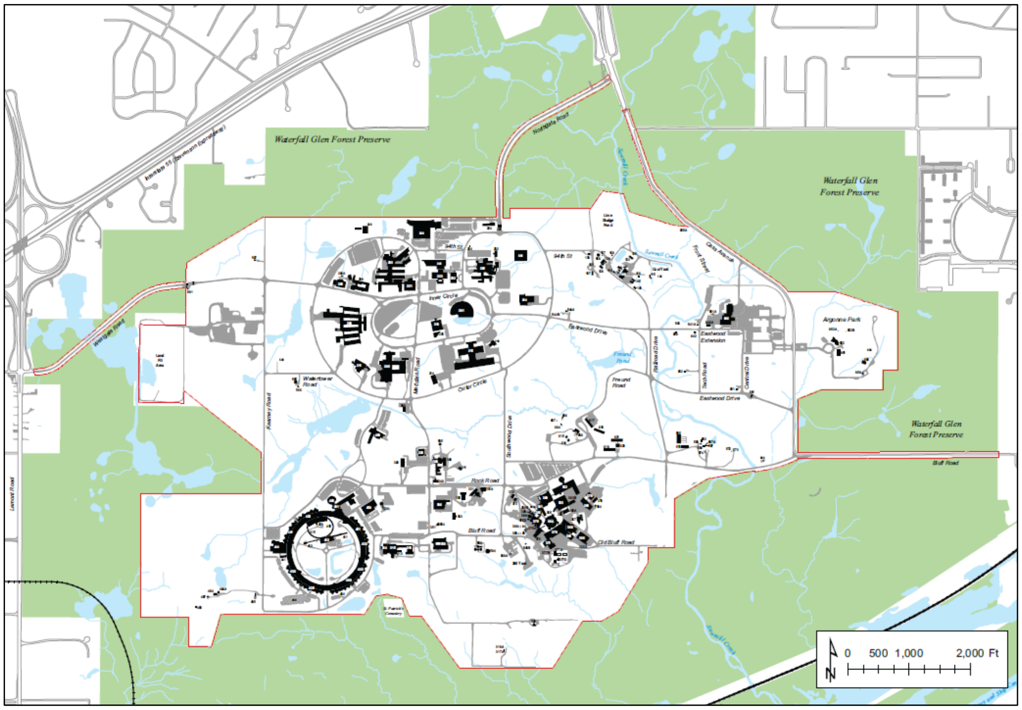

Figure 36. Argonne National Laboratory site map

Source: ANL[67]

Table 17 provides a description of WTE project development considerations at ANL.

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[67] "Map of Argonne National Laboratory," Argonne National Laboratory, accessed at http://www.anl.gov/sites/anl.gov/files/Argonne_Map.pdf.

Table 17. Description of Waste to Energy at Argonne National Laboratory

Location	Lemont, IL	
Technology	WTE	
Size	100 MW (constrained by maximum allowable size)	
Mission	ANL is a multidisciplinary science and engineering research center that spans 15 research divisions in clean energy, environment, technology, and national security.	
Site Ownership & Control	Yellow (uncertain project risk)	• Fewer than 500 acres might still be available for development in former building areas (east and 800 areas). However, this land is reserved for future experiments, which would take priority over any RE development. • Development on-site would be subject to some security considerations, but procedures are in place to facilitate this process.
Offtaker	Yellow (uncertain project risk)	• The site has been approached in the past about PV and biomass PPAs, but ANL's low power prices of $42/MWh have prevented economic development. • Based on GIS analysis, about 1,385 acres, or 35% of the site, are within 1 mile of a substation with a capacity of 69 kV or greater.
Regulatory	Red (infeasible project risk)	• The site is surrounded by a forest preserve and suburban residential areas, which may result in increased public scrutiny of any proposed projects. • Previous studies have not documented any endangered species on-site but did find some cultural resources. Approximately 30 wetland sites of about 1 acre each are scattered throughout the site. • Air quality permitting will be required.
Economics	Yellow (uncertain project risk)	• There was a modeled LCOE of $-5/MWh, based on tipping fee assumptions, but previously proposed WTE and PV projects were not pursued due to the site's low cost of power of $42/MWh. • Feedstock price and availability are still unknown.

Site ownership and control. ANL is a multidisciplinary science and engineering research center and comprises roughly 1,700 acres of forested land. Based on discussion with site contacts, fewer than 500 acres of land would be available for RE development, primarily in former building areas on the east end of the site. However, this land is reserved for future experiments, which would take priority over any RE development. Some site security concerns have been raised, including site access and safety controls that would apply to any construction contractors, but these processes are already well established. As indicated in Figure 36, the site already has paved site access roads. Site imagery indicates availability in the eastern section of the site, with limited vegetation and infrastructure.

Several previous RE projects have been constructed at the site, including a 0.1 MW PV array (for research purposes), a 10-kW wind turbine, and a ground-source heat pump. The site has also received 10 interested responses from a previous biomass RFI and attempted to develop a wood-fired biomass system, but this project was ultimately discontinued. Based on GIS analysis, the slope in the eastern part of the site appears to be less than 3% and would likely be able accommodate a WTE or biomass plant (Figure 37). Resource availability was not examined in greater detail due to regulatory obstacles described below.

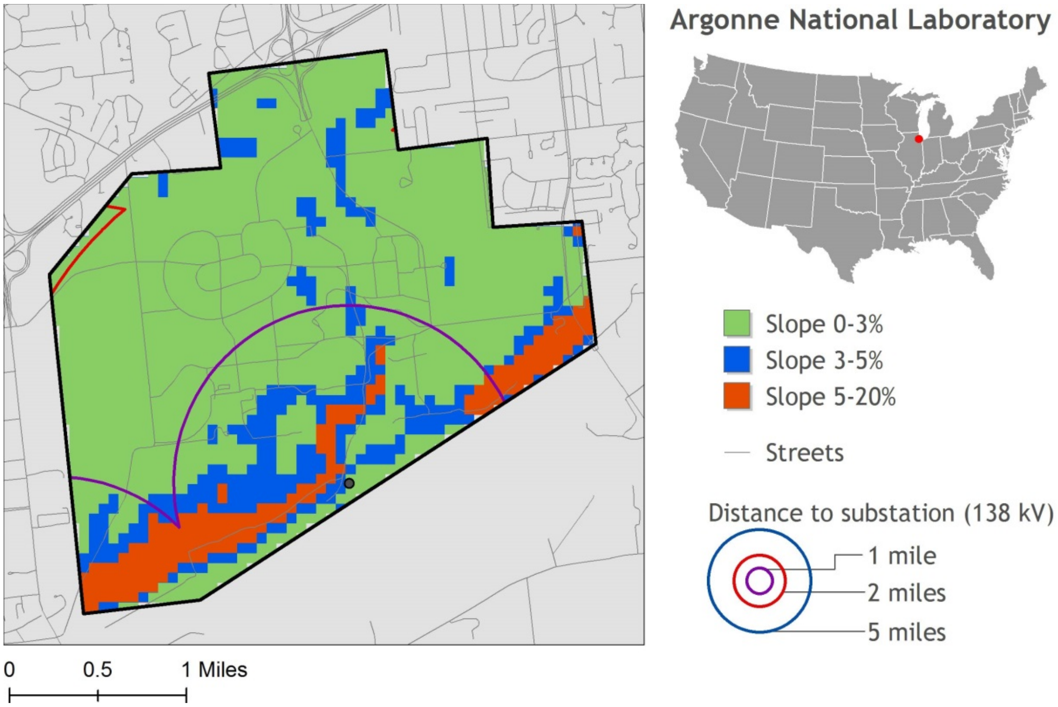

Figure 37. Argonne National Laboratory geographic information system analysis map

Illustration by Jenny Melius, NREL

Offtaker. Potential offtakers for this power would include on-site load, an off-site utility purchaser, or another nearby commercial/industrial user. Although the site's low power rate of $42/MWh is much lower than the LCOE of any of the modeled technologies, the site may be able to purchase a portion of the power at a premium if the project provided a sufficiently compelling research opportunity. However, the site probably would not be able to act as the sole offtaker in the near future. Concerning a utility offtaker, Illinois has already made significant progress toward its 2020 RPS goals; 82% of the total 2020 emissions target is already completed.[68] The viability of a nearby commercial/industrial user as an offtaker was not explicitly examined. Based on GIS analysis, about 1,385 acres, or 35% of the site, is within 1 mile of a substation with a capacity of 69 kV or greater. The entire site is within 2 miles of a substation with a capacity of 69 kV or greater.

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[68] Jeremy Richardson et al., "States of Progress: Existing Commitments to Clean Energy Put Most States on Track to Meet Clean Power Plan's 2020 Benchmarks" (presented at Union of Concerned Scientists, June 3, 2015), accessed July 6, 2015 at http://www.ucsusa.org/sites/default/files/attach/2015/06/states-of-progress-analysis-slide-deck.pdf.

Regulatory. The site is surrounded by a forest preserve and suburban residential areas, which may result in increased public scrutiny of any proposed projects. Although previous studies have not documented any endangered species, the site has some cultural resources. Approximately 30 wetland sites of about 1 acre each are scattered throughout the site. Because the project would generate emissions, air quality permitting will likely be required.

Economics. Previously proposed WTE and PV projects were not pursued due to the site's low cost of power of $42/MWh. Although an on-site agreement to purchase a part of the power generated may be feasible in the future, the project would most likely require an off-site offtaker. The economic viability of the project would also be highly dependent on the tipping fee pricing and availability of usable waste streams. This availability was not examined further due to the site limitations already described.

2.2.4.6 Concentrating Solar Power

The following sections detail concentrating solar power project development considerations at NNSS and LANL sites.

2.2.4.6.1 Concentrating Solar Power at Nevada National Security Site

The portfolio analysis identified a CSP project of 50 MW as potentially viable for this location (50 MW was set as the maximum allowable size within the analysis). The project would likely require 750 acres of land and could potentially produce power at an LCOE of $203/MWh. This site had the lowest LCOE for CSP of all sites screened. Development at the site appears to be constrained primarily by transmission access and the economics of the power produced, which does not appear to be economically competitive at this time. A site map is available in Figure 38.

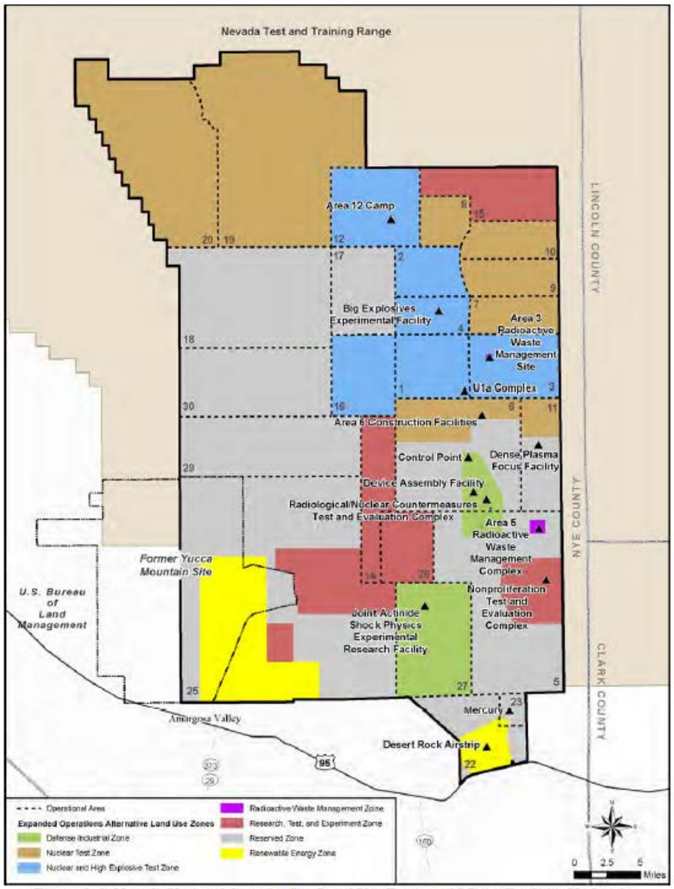

Figure 3–2 Nevada National Security Site Land Use Zones and Major Facilities Under the Expanded Operations Alternative

Figure 38. Nevada National Security Site site map

Source: NNSA[69]

Table 18 provides a description of CSP project development considerations at NNSS.

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[69] DOE/NNSA Nevada Site Office. 2013. "Final Site-Wide Environmental Impact Statement for the Continued Operation of the Department of Energy/National Nuclear Security Administration Nevada National Security Site and Off-Site Locations in the State of Nevada." Volume 1, accessed June 11, 2015, http://nnsa.energy.gov/aboutus/ouroperations/generalcounsel/nepaoverview/nepa/nnsssweis21413.

Table 18. Description of CSP at Nevada National Security Site

Location	Mercury, NV	
Technology	CSP	
Size	50 MW (constrained by maximum allowable size)	
Mission	Previously called the Nevada Test Site, the site conducted numerous atmospheric and underground nuclear tests. The site now performs stockpile stewardship, environmental management, and research and development.	
Site Ownership & Control	Green (acceptable project risk)	• Up to 2,400 acres may be available for development. • Development in Area 25 would be allowable, but security would need to be considered. Development of low-water-use projects in Area 22 may be considered in the future.
Offtaker	Yellow (uncertain project risk)	• Based on the EIS performed at this site, the project would be required to install approximately 10 miles of 230-kV or 500-kV transmission lines to interconnect the project, and would probably be required to perform upgrades at the closest substation. • No additional transmission upgrades are expected in Area 25.
Regulatory	Yellow (uncertain project risk)	• Full environmental analysis based on the proposed project would still be required. The DOE and BLM would make a determination of lead agency assignment on a project-specific basis. • Land use outside the mission of weapons testing would require NNSA and BLM approval. • The desert tortoise lives in this area, which could result in additional mitigation costs. The presence and location of cultural resources are unknown. • Any new water use would require aquifer withdrawal impact analysis by multiple agencies.
Economics	Red (infeasible project risk)	• Previously proposed CSP projects from the mid-1990s and 2004–2008 were ultimately uneconomic. • NNSS currently has an on-site power contract of $63/MWh through 2022. • Given that the average retail price of electricity in Nevada was $92/MWh in March 2015, compared to the estimated CSP LCOE of $203/MWh, there is currently limited economic potential.

Site ownership and control. The NNSS, previously known as the Nevada Test Site, was the testing grounds for numerous atmospheric and underground nuclear bomb tests that were discontinued in the 1980s. The site comprises 775,680 acres of land, but based on previous studies, Area 25 was selected as the primary area suitable for CSP development. Area 25 contains 163,000 acres of land, of which the previous EIS has identified up to 2,400 acres that may be available for development under the No Action Alternative.[70] The developable area is

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[70] Ibid.

located in the southwestern corner of the NNSS (Figure 38). Area 25 was previously considered for development of a 240-MW demonstration CSP plant under an Expanded Operations Alternative, but this alternative was not selected due to regulatory issues. The proximity of the developable area in Area 22 to U.S. Route 95 may also facilitate development in this second area, although it is somewhat smaller at about 20,000 acres, has an operating airstrip, and has water-use restrictions. The EIS states that "Low-water-use renewable energy projects may be considered for Area 22 in the future." [71] This may contribute to additional O&M costs for any completed CSP project, because water requirements may need to be met from off-site sources.

Based on GIS analysis of the site's potential slope exclusions, the site's slope within Area 25 would not be a limiting factor, because the slope is less than 3% and contiguous (Figure 39). Area 22 may also be feasible for development, but appears to include some areas of greater slope within the developable area.

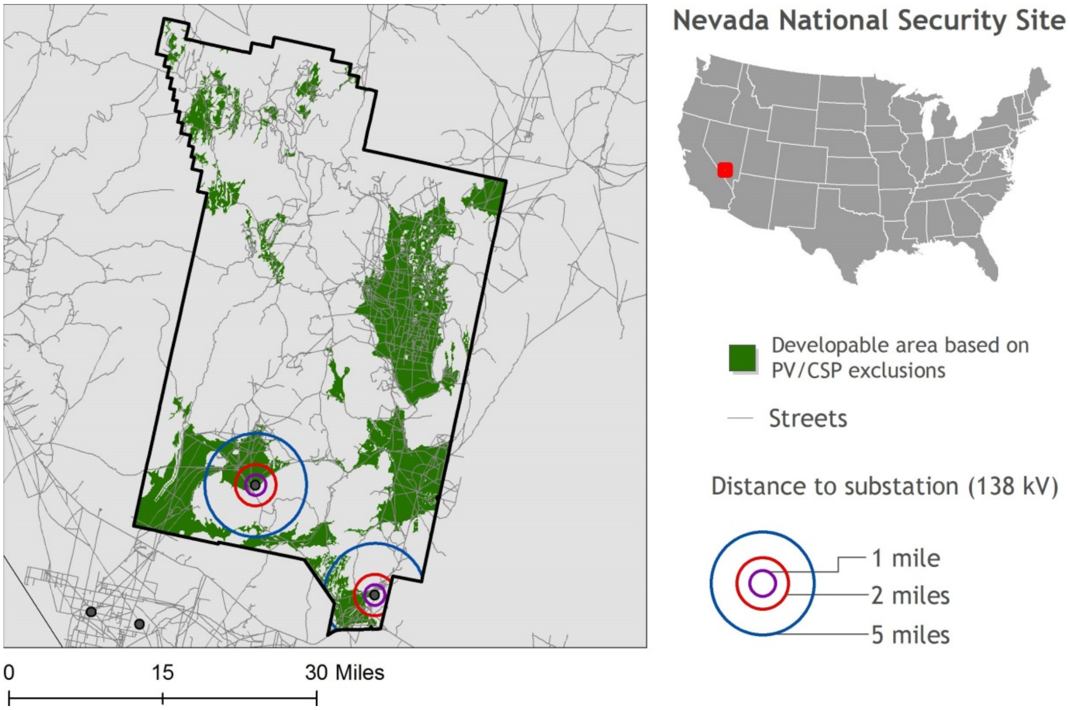

Figure 39. Nevada National Security Site geographic information system analysis map

Illustration by Jenny Melius, NREL

Offtaker. A potential offtaker for this power could be NV Energy. This utility may be interested in power generation from this site as a part of its 100-MW 2016 RFP or as part of its future 25% by 2025 RPS goal. However, half of the 25% RPS goal must be met from efficiency or RE measures installed at residential locations. Given that the average retail price of electricity in

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[71] Ibid.

Nevada was $92/MWh in March 2015, the project's modeled LCOE of $0.20 does not appear to be competitive at this time.[72]

Out-of-state PPA sales may also be feasible for larger-scale projects; however, the project will have to be competitive relative to in-state generation to overcome the additional cost of transmission.

Based on the EIS performed at this site, the project would be required to install approximately 10 miles of 230-kV or 500-kV transmission lines to interconnect the project, and would probably be required to perform upgrades at the closest substation. However, development of transmission lines is costly; an illustrative example of the cost per mile for a 230-kV transmission line is $940,000–$960,000.[73] Whether additional transmission expenses would be required to develop Area 22 is unclear.

Regulatory. The primary regulatory requirements identified by this preliminary review include NEPA review (although the required level of review must be determined on a project specific basis), land use approval from NNSA and BLM, and Aquifer Withdrawal Impact analysis. These requirements may not be a comprehensive list, but are indicative of several major environmental issues with developing the site.

Although the EIS examined many key sensitive criteria (desert tortoises, cultural resources, protected areas, etc.), the site's required level of NEPA analysis on a project-specific basis would have to be determined. The DOE and BLM would make a determination of lead agency responsibility assignment. Construction security would also have to be considered given the nature of the site, and land use outside the mission of weapons testing would require NNSA and BLM approval. Outstanding questions also surround the legal framework of a site access agreement due to the current land withdrawal terms. Both NNSA and BLM would be required to approve any site access agreement. Further, some stakeholders may claim that a project such as this is not compatible with the public land order(s) that provided the initial authority to administer the activities on a particular parcel of land.

Finally, any new NNSS water use will trigger aquifer withdrawal impact analysis by the U.S. Fish and Wildlife Service, U.S. Forest Service, State of Nevada, and Paiute Indian Nation.

Economics. Although the site appears to be developable, the high estimated LCOE for the proposed CSP project makes it uneconomic at this time.

2.2.4.6.2 Concentrating Solar Power at Los Alamos National Laboratory, New Mexico

The portfolio analysis identified a CSP project of 50 MW as potentially viable for this location (the project was constrained by the maximum allowable size). The project would likely require about 750 acres of land and could potentially produce power at an LCOE of $209/MWh. Based

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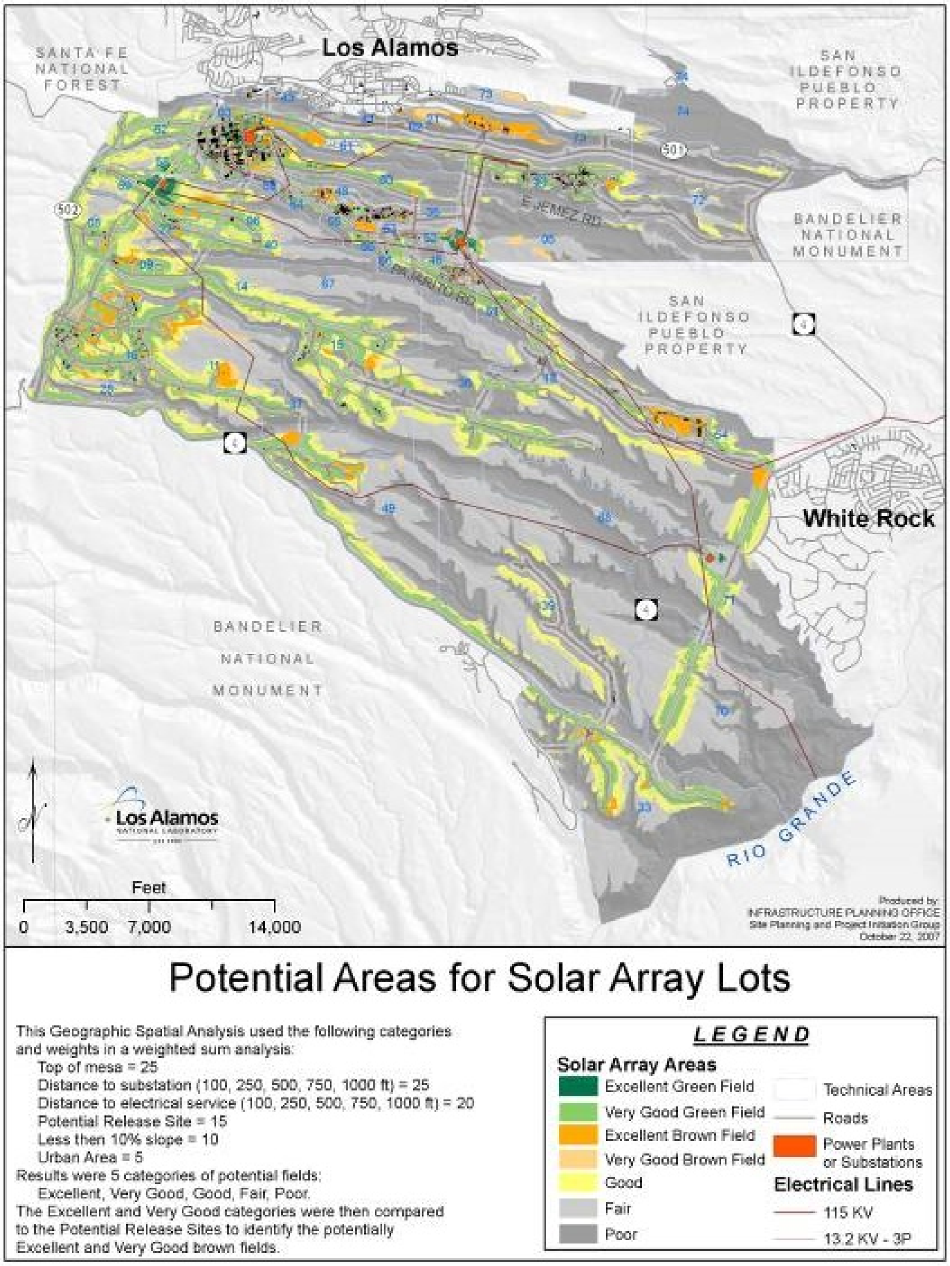
[72] U.S. Energy Information Administration, "Form EIA-826, Monthly Electric Sales and Revenue Report with State Distributions Report," accessed June 11, 2015 at http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a.

[73] Pletka et al., *Capital Costs For Transmission And Substations* (Black & Veatch, February 2014), accessed at https://www.wecc.biz/Reliability/2014_TEPPC_Transmission_CapCost_Report_B+V.pdf.

on the limited availability of contiguous acreage with a slope of less than 3%, a CSP project does not appear to be viable for this location. A site map is available in Figure 40.



Potential Areas for Solar Array Lots

This Geographic Spatial Analysis used the following categories and weights in a weighted sum analysis:
Top of mesa = 25
Distance to substation (100, 250, 500, 750, 1000 ft) = 25
Distance to electrical service (100, 250, 500, 750, 1000 ft) = 20
Potential Release Site = 15
Less then 10% slope = 10
Urban Area = 5
Results were 5 categories of potential fields:
Excellent, Very Good, Good, Fair, Poor.
The Excellent and Very Good categories were then compared to the Potential Release Sites to identify the potentially Excellent and Very Good brown fields.

Figure 40. Los Alamos National Laboratory site map

Source: Los Alamos National Laboratory[74]

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[74] William Jones and John Arrowsmith. *Renewable Energy Feasibility Study*, (LA-UR 08-07230 Los Alamos National Laboratory & Los Alamos County, 2008), accessed at https://www.losalamosnm.us/utilities/DPUDocuments/DPU_BR0904SolarEnFeasStdyApr.pdf.

Table 19 provides a description of CSP project development considerations at LANL.

Table 19. Description of Concentrating Solar Power at Los Alamos National Laboratory

Location	Los Alamos, NM	
Technology	CSP	
Size	50 MW (constrained by maximum allowable size)	
Mission	LANL is a major science and technology institution; its research emphasizes national security.	
Site Ownership & Control	Red (infeasible project risk)	• Based on discussions with site contacts, only 400 noncontiguous acres are very attractive locations for CSP development. These areas do not have <3% slope, which would preclude development of a CSP plant at the site.
Offtaker	Yellow (uncertain project risk)	• The site's current peak demand is approximately 70 MW and is expected to grow in the next 10 years. • The site's 13.8-kV transmission infrastructure would require an upgrade to export power from the proposed CSP project.
Regulatory	Yellow (uncertain project risk)	• More detailed NEPA review at the site may be required. The site has four protected species habitat sites, archeological sites, and potentially contaminated sites that must be avoided. However, these areas have been identified in previous studies. • The site is adjacent to the Bandelier National Monument, which could result in additional environmental review.
Economics	Red (infeasible project risk)	• Given the project's estimated LCOE of $209/MWh, the project is well outside the range of the Los Alamos Department of Public Utilities' retail power rates, which are $100/MWh for residential users and $67/MWh for large commercial users. A CSP project does not appear to be economic at this time.

Site ownership and control. LANL is a major science and technology institution with about 9,000 employees. The site comprises 28,000 acres of land; based on conversations with site contacts only about 400 noncontiguous acres are available as locations for CSP development. However, these areas do not have <3% slope, which would preclude development of a CSP plant at the site (Figure 41).[75] The most promising of these locations was 114 acres divided into two adjacent lots.

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[75] Otto VanGeet. *DOE Los Alamos National Laboratory (LANL)—PV Feasibility Assessment NREL Final Report*, (National Renewable Energy Laboratory, 2008).

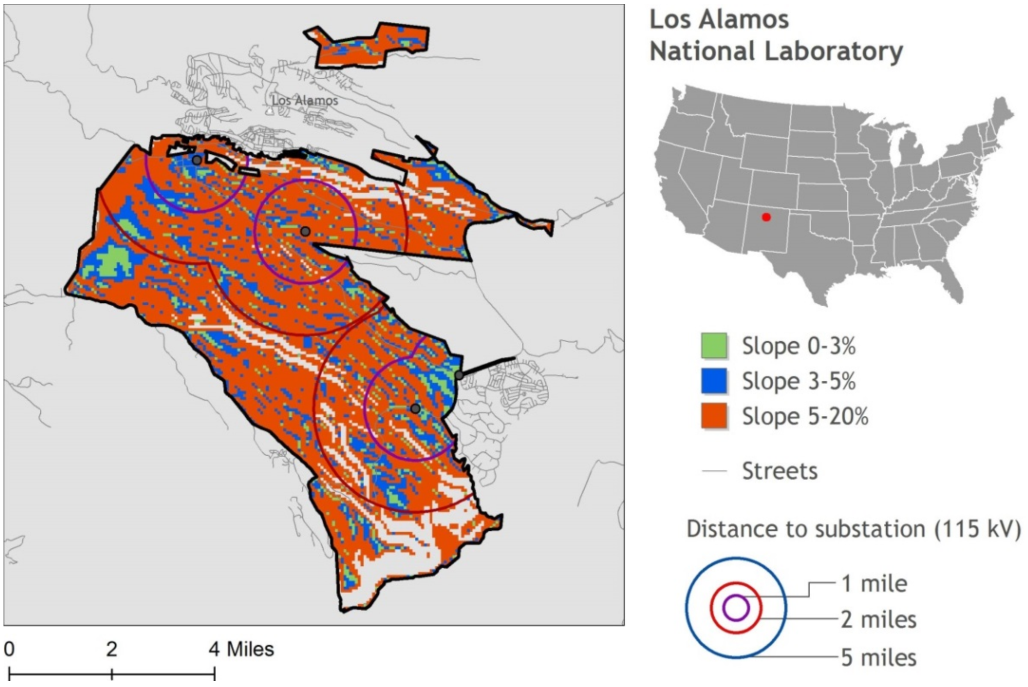

Figure 41. Los Alamos National Laboratory geographic information system analysis map

Illustration by Jenny Melius, NREL

Offtaker. Because the Los Alamos Department of Public Utilities' current cost of power is $100/MWh for residential customers and $67/MWh for commercial customers, and because 115 kV appears to be the highest transmission capacity outside the region, the LADPU appears to be the most likely offtaker.

The project would be interconnected within the site's 115-kV transmission infrastructure. Based on the 2008 RE integration study conducted by NREL for LANL, the site had the capacity to import an additional 25–30 MW of RE power to service baseload power requirements, although this is somewhat uncertain, given that the site may see substantial increases in loads for supercomputing applications. This transmission capacity may already be accounted for by significant anticipated growth in site demand. This may not preclude an on-site PV purchase option, but power sales off site may be constrained by the available transmission capacity. Based on discussion with site contacts, most of the electricity generation in the LADWP power pool is already consumed by LANL, making the site the largest offtaker. The site currently has two 115-kV lines (Reeves and Norton lines). Although the projects are close to 13.2-kV lines, some additional transmission upgrades for a megawatt-scale project would likely be required.

Regulatory. More detailed NEPA analysis may be required, because the site has archaeological sites on some of the larger usable ground mount areas, and four endangered species live on the site.[76] However, the site contact has confirmed that the site has no environmental or cultural

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[76] Charles D. Hathlock et al., *Threatened and Endangered Species Habitat Management Plan for Los Alamos National Laboratory*, (LANL; March 25, 2014), accessed July 6, 2015 at http://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-14-21863.

resources within the 400 acres identified as favorable for CSP development. All sites are within 100 feet of a 13.2-kV line; additional transmission upgrades would be required for a CSP plant due to the required economies of scale. Based on site contact responses, previous projects have encountered issues with permitting water and air discharges, waste disposal, and environmental cleanup, but no issues were unresolvable in permitting the 2-MW PV site.

Economics. Given the high estimated LCOE of $209/MWh for the proposed CSP project, a CSP project does not appear to be economic at this time.

2.2.4.7 Geothermal

The following sections detail geothermal project development considerations at Shoal, Lakeview Disposal, NNSS, and CNTA sites.

2.2.4.7.1 Geothermal at Shoal Site, Nevada

The portfolio analysis identified a potential geothermal project area based on USGS hydrothermal favorability estimates. After further discussion with site contacts, as well as the Navy Geothermal program, geothermal development was determined to be not possible at this site. Additional site-specific evaluations, including test wells, would be required to develop a reasonably accurate estimate of the hydrothermal potential. A site map is available in Figure 42.

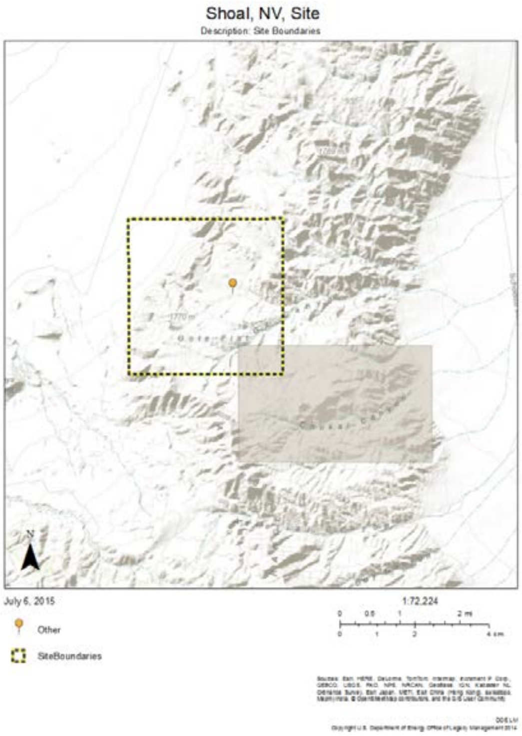

Figure 42. Shoal site map

Source: DOE[77]

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[77] "Geospatial Environmental Mapping System, Version: 2.4.6." DOE Office of Legacy Management, accessed July 20, 2015, at http://gems.lm.doe.gov/.

Table 20 provides a description of geothermal project development considerations at the Shoal Site.

Table 20. Description of Geothermal at Shoal, Nevada, Site

Location:	Shoal, NV	
Technology	Geothermal	
Mission	The shoal site was previously an underground nuclear test site and comprises 2,560 acres of withdrawn federal lands for long-term surveillance and maintenance.	
Site Ownership & Control	Red (infeasible project risk)	• Discussion with Navy contacts (the surface lessor) established that the site is not available for subsurface exploration, nor will it be opened in the foreseeable future.
Offtaker	Yellow (uncertain project risk)	• Based on GIS analysis, no transmission substations larger than 69 kV are located within a 5-mile radius of the site.
Regulatory	Gray (not evaluated)	• Not evaluated
Economics	Gray (not evaluated)	• Not evaluated

Site ownership and control. The site, previously an underground nuclear test site, comprises 2,560 acres of withdrawn federal lands for long-term surveillance and maintenance. The Shoal site is currently leased to the Navy, which uses it as a bombing range. It has been expressed to the Navy Geothermal Program Office[78] that the site will at no time be allowed to be explored or developed for geothermal energy.

As additional context, the surface was reserved to the U.S. Navy in 1999 for testing and training for tactical maneuvering. The Navy land withdrawal also includes restrictions to prevent drilling on the property, as well as a requirement of notification of drilling on adjacent BLM land. This restriction will prevent the development of any geothermal projects at the site.

Offtaker. Given that the site is not developable, limited analysis of offtake was performed. Based on GIS analysis, no transmission substations larger than 69 kV are located within a 5-mile radius of the site (Figure 43).

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[78] A. Sabin, personal communication with Mike Hillesheim, June 2015.

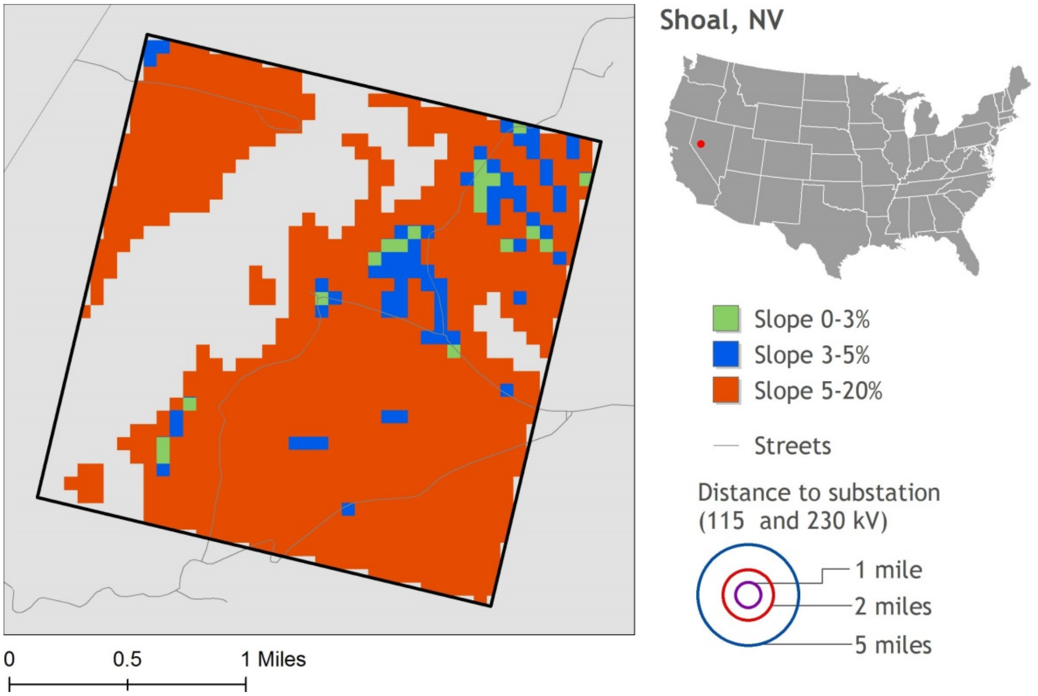

Figure 43. Shoal geographic information system analysis map

Illustration by Jenny Melius, NREL

Regulatory. Additional examination of the site's permitting requirements was not conducted.

Economics. Given the inherent uncertainty in the geothermal resource, an LCOE could not be calculated for the site. Additional examination of the site's economic feasibility was not conducted.

2.2.4.7.2 Geothermal at Lakeview Disposal Site, Oregon

The portfolio analysis identified a potential geothermal project area based on USGS hydrothermal favorability estimates. The Lakeview processing site is a former uranium-ore processing facility. The developable area is fewer than 40 acres; this precludes development of a commercial-scale hydrothermal plant (Figure 44). Given the inherent uncertainty in the geothermal resource, an LCOE could not be calculated for the site. Additional site-specific evaluations, including test wells, would be required to develop a reasonably accurate estimate of the hydrothermal potential.

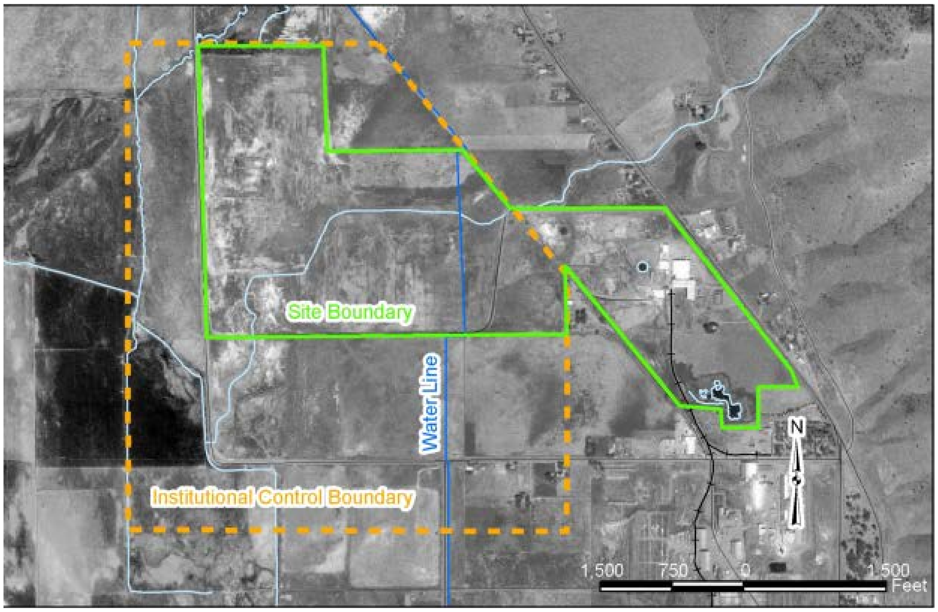

Figure 44. Lakeview disposal site cell map

Source: DOE[79]

Table 21 provides a description of geothermal project development considerations at the Lakeview Disposal Site.

Table 21. Description of Geothermal at the Lakeview, Oregon, Disposal Site

Location	Lakeview, OR	
Technology	Geothermal	
Mission	The Lakeview processing site is a former uranium-ore processing facility.	
Site Ownership & Control	Red (infeasible project risk)	• The developable area of fewer than 40 acres precludes development of a commercial-scale hydrothermal plant. • Strong evidence shows that a hydrothermal system with the potential for utility-scale power generation is present at depths greater than 4,000 feet; however, no confirmation wells have been drilled to verify this potential.
Offtaker	Yellow (uncertain project risk)	• Based on GIS analysis, no transmission substations larger than 69 kV are located within a 5-mile radius of the site.
Regulatory	Red (infeasible project risk)	• Discussion with site contacts revealed that a hydrothermal project would not be developable at the site due to Lakeview County zoning restrictions, which prohibit drilling and other land-disturbing activities at the site.
Economics	Gray (not evaluated)	• Not evaluated

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[79] DOE. 2015. "UMTRCA Title I: Lakeview, Oregon, Processing/Disposal Site." Office of Legacy Management fact sheet, January 31, 2015. www.lm.doe.gov/Lakeview/lakeview-factsheet.pdf.

Site ownership and control. The Lakeview processing site is a former uranium-ore processing facility. The site comprises 40 acres. However, these 40 acres are not entirely available for development, because part of the site is covered with contaminated uranium mill tailings. Further, although the site has an additional 258 acres, this land is not managed by DOE and is therefore outside the scope of the analysis. Finally, for access to the site, a perpetual Road Easement assigns a "permanent easement for the purpose of constructing and maintaining an access road solely for access to allow surveillance and monitoring of the cell and the test well site." This road easement may further limit the developable area of the site.

Resource. A known hydrothermal system underlies the site.[80] Currently, a near surface outflow plume of the system is being utilized for thermal, direct-use applications such as greenhouses, spas, and space heating. Strong evidence suggests that a deeper-seated hydrothermal system with the potential for utility-scale power generation is present at depths lower than 4,000 feet; however, no confirmation wells have been drilled to verify this. The primary constraint for developing the site is its size. At 40 acres the surface land area is too small to develop a utility-scale geothermal plant. Despite the small footprint of the geothermal power plant, more land is needed to support a well field that can provide enough hot water to achieve megawatt-scale generation. Land use and subsurface rights agreements with neighboring landowners would need to be obtained to achieve a viable project. Another challenge could be communicating that the development of the deeper system would not impact local use of the shallow, low-temperature resource.

Offtaker. The site has no significant load, so the proposed offtaker would have to be an off-site purchaser. Based on GIS analysis of the site and its surroundings, no transmission substations larger than 69 kV are located within a 5-mile radius of the site, which could result in additional project interconnection costs (Figure 45).

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[80] Hillesheim, Michael and Gail Mosey. 2013. *Feasibility Study of Economics and Performance of Geothermal Power Generation at the Lakeview Uranium Mill Site in Lakeview, Oregon*. TP-6A10-60251. National Renewable Energy Laboratory, Golden, CO. http://www.nrel.gov/docs/fy14osti/60251.pdf.

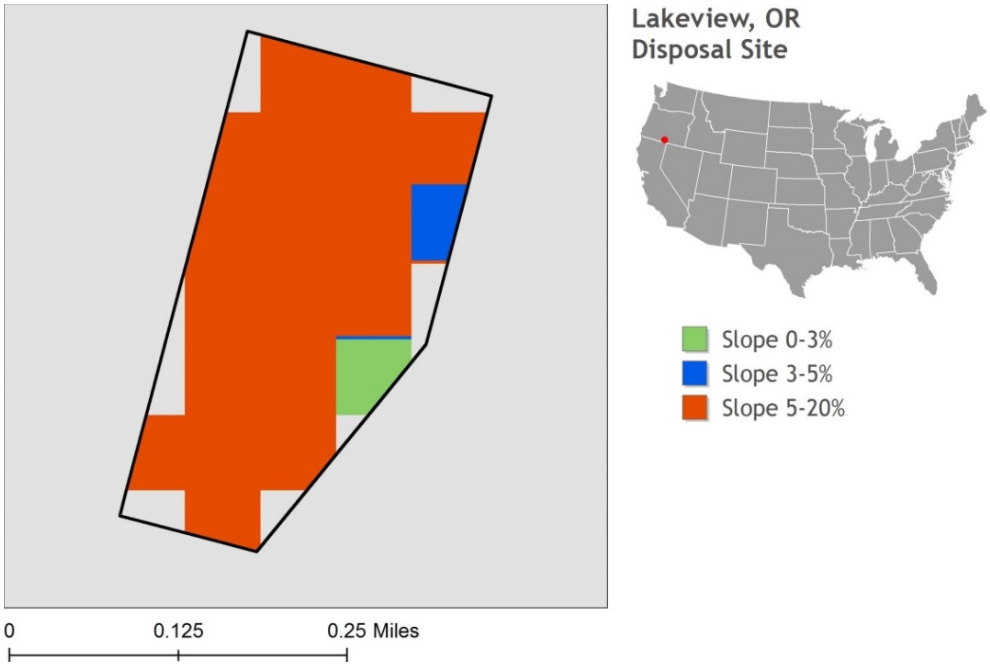

Figure 45. Lakeview geographic information system analysis map

Illustration by Jenny Melius, NREL

Regulatory. Based on discussion with site contacts, this site does not appear to be developable for geothermal energy production due to land use restrictions imposed by Lakeview County. Section 16 of the county zoning requirements (Waste Disposal, Inactive Uranium Mill Tailings Zone) state that "No land-disturbing uses or activities are permitted, including but not limited to mining, well drilling for stock water or any other use and soil disturbance in conjunction with livestock grazing that will jeopardize the integrity of the disposal cell."[81] Further, no buildings are allowed under the zoning permitted uses.

Economics. Given the inherent uncertainty in the geothermal resource, an LCOE could not be calculated for the site. Additional examination of the site's economics was not conducted.

2.2.4.7.3 Geothermal at Nevada National Security Site

The portfolio analysis identified a potential geothermal project area at the NNSS based on USGS hydrothermal favorability estimates. A previous EIS of the site has identified up to 2,400 acres as available for renewable energy development under the No Action Alternative. Given the inherent uncertainty in the geothermal resource, an LCOE could not be calculated for the site. A site map is available in Figure 46 (renewable energy zones depicted in yellow). Additional site-specific evaluations, including test wells, would be required to develop a reasonably accurate estimate of the hydrothermal potential.

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[81] "Lake County Zoning Ordinance." Adopted May 1980, accessed August 2015 at http://www.lakecountyor.org/government/docs/Lake_County_Zoning_Ordinance__Entire_Document_.pdf.

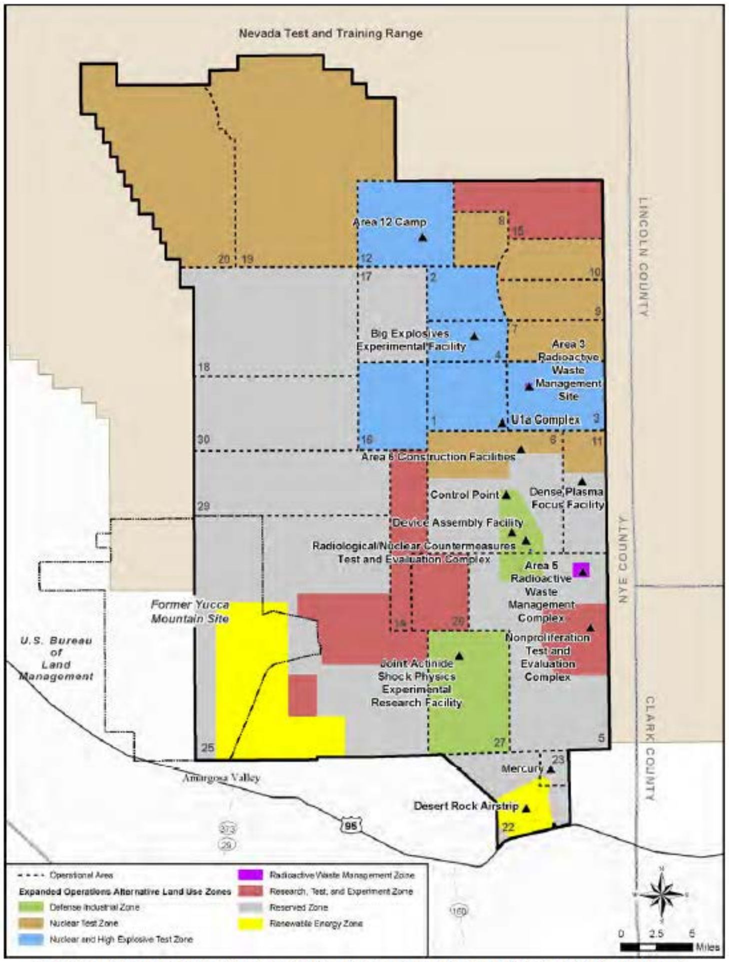

Figure 3–2 Nevada National Security Site Land Use Zones and Major Facilities Under the Expanded Operations Alternative

Figure 46. Nevada National Security Site site map

Source: NNSA[82]

Table 22 provides a description of geothermal development considerations at NNSS.

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[82] DOE/NNSA Nevada Site Office. 2013. "Final Site-Wide Environmental Impact Statement for the Continued Operation of the Department of Energy/National Nuclear Security Administration Nevada National Security Site and Off-Site Locations in the State of Nevada." Volume 1, accessed June 11, 2015, http://nnsa.energy.gov/aboutus/ouroperations/generalcounsel/nepaoverview/nepa/nnsssweis21413.

Table 22. Description of Geothermal at Nevada National Security Site

Location	Mercury, NV	
Technology	Geothermal	
Mission	Previously called the Nevada Test Site, the site conducted numerous atmospheric and underground nuclear tests. The site now performs stockpile stewardship, environmental management, and research and development.	
Site Ownership & Control	Green (acceptable project risk)	• Up to 2,400 acres may be available for development. • Development in Area 25 would be allowable, but security would need to be considered. Development of low-water-use projects in Area 22 may be considered in the future. • Much more information is required to determine the presence of a hydrothermal system (or systems) at the site, as well as their potential to achieve utility-scale power production.
Offtaker	Yellow (uncertain project risk)	• Based on the EIS performed at this site, the project would be required to install approximately 10 miles of 230-kV or 500-kV transmission lines to interconnect the project, and would probably be required to perform upgrades at the closest substation. • No additional transmission upgrades are expected in Area 25.
Regulatory	Yellow (uncertain project risk)	• Additional analysis of the subsurface ownership and leasing process would also be required, as this was not explicitly evaluated. • Full environmental analysis based on the proposed project would still be required. The DOE and BLM would make a determination of lead agency responsibility assignment. • Land use outside the mission of weapons testing would require NNSA and BLM approval. • The desert tortoise species lives in this area, which could result in additional mitigation costs. The presence and location of cultural resources are unknown. • Any new water use would require aquifer withdrawal impact analysis by multiple agencies.
Economics	Gray (not evaluated)	• Not evaluated

Site ownership and control. The NNSS, previously known as the Nevada Test Site, was the testing grounds for numerous atmospheric and underground nuclear bomb tests that were discontinued in the 1980s. The site comprises 775,680 acres of land, but based on previous studies, Area 25 was selected as the primary area suitable for renewable energy development. Area 25 contains 163,000 acres of land, of which the previous EIS has identified up to 2,400 acres that may be available for development under the No Action Alternative.[83] The developable area is located in the southwestern corner of the NNSS (Figure 46). The proximity of the developable area in Area 22 to U.S. Route 95 may also facilitate development in this second area, although it is somewhat smaller at about 20,000 acres, has an operating airstrip, and has

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[83] Ibid.

water-use restrictions. The EIS states that "Low-water-use renewable energy projects may be considered for Area 22 in the future." [84]

Based on GIS analysis of the site's potential slope exclusions, the site's slope within Area 25 would not be a limiting factor, because the slope is less than 3% and contiguous. Area 22 may also be feasible for development, but appears to include some areas of greater slope within the developable area.

Resource. The NNSS is located in an area of moderate probability for finding a hydrothermal system (Williams 2008). Additionally, thermal springs can be found on the site and local geologic factors (e.g., extensive faulting) are promising (UNR 2015). More detailed data for the site is scarce and/or difficult to obtain. Much more information is required to determine the presence (and specific location) of a hydrothermal system (or systems) at the sites, as well as their potential to achieve utility-scale power production.

Offtaker. A potential offtaker for this power could be NV Energy. This utility may be interested in power generation from this site as a part of its 100-MW 2016 RFP or as part of its future 25% by 2025 RPS goal. However, half of the 25% RPS goal must be met from efficiency or RE measures installed at residential locations. Geothermal systems' ability to provide baseload renewable electricity may also provide a competitive advantage for out-of-state PPA sales to utilities attempting to accommodate higher RE penetrations.

Based on the EIS performed at this site, the project would be required to install approximately 10 miles of 230-kV or 500-kV transmission lines to interconnect the project, and would probably be required to perform upgrades at the closest substation. However, development of transmission lines is costly; an illustrative example of the cost per mile for a 230-kV transmission line is $940,000–$960,000.[85] Whether additional transmission expenses would be required to develop Area 22 is unclear.

Regulatory. The primary regulatory requirements identified by this preliminary review include NEPA review (although the required level of review must be determined on a project specific basis), land use approval from NNSA and BLM, and Aquifer Withdrawal Impact analysis. These requirements may not be a comprehensive list, but are indicative of several major environmental issues with developing the site.

Although the EIS examined many NEPA sensitive criteria elements (desert tortoises, cultural resources, protected areas, etc.), the site would have to determine the required level of NEPA analysis on a project-specific basis. The DOE and BLM would make a determination of lead agency responsibility assignment.

Construction security would also have to be considered given the nature of the site, and land use outside the mission of weapons testing would require NNSA and BLM approval. Outstanding

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[84] Ibid.

[85] Pletka, et al., *Capital Costs for Transmission and Substations: Updated Recommendations for WECC Transmission Expansion Planning* (Black & Veath, February 2014), accessed at https://www.wecc.biz/Reliability/2014_TEPPC_Transmission_CapCost_Report_B+V.pdf.

questions also surround the legal framework of a site access agreement due to the current land withdrawal terms. Both NNSA and BLM would have to approve any site access agreement. Further, some stakeholders may claim that a project such as this is not compatible with the public land order(s) that provided the initial authority to administer the activities on a particular parcel of land.

Finally, any new NNSS water use will trigger aquifer withdrawal impact analysis by the U.S. Fish and Wildlife Service, U.S. Forest Service, State of Nevada, and Paiute Indian Nation.

Economics. Given the inherent uncertainty in the geothermal resource, an LCOE could not be calculated for the site. Additional examination of the site's economics was not conducted.

2.2.4.7.4 Geothermal at Central Nevada Test Area Site

The portfolio analysis identified a potential geothermal project area based on USGS hydrothermal favorability estimates. The project could have up to 2,560 acres of land available. Given the inherent uncertainty in the geothermal resource, an LCOE could not be calculated for the site. A site map is available in Figure 47. Additional site-specific evaluations, including test wells, would be required to develop a reasonably accurate estimate of the hydrothermal potential. Based on these strong initial results, additional analysis was conducted. This project is intended to be a merchant power plant with no energy sold to the DOE host site.

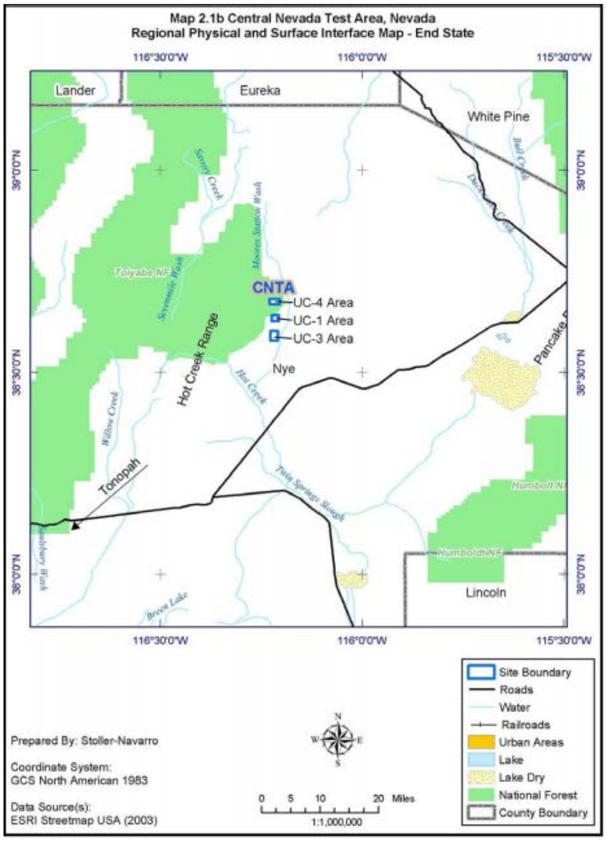

Figure 47. Central Nevada Test Area site map

Source: DOE[86]

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[86] DOE, *Central Nevada Test Area Environmental Management End State Vision, Final*, (U.S. Department of Energy, Washington, D.C., January 2005), www.lm.doe.gov/CNTA/CNT000007.pdf.

Table 23 provides a description of geothermal project development considerations at CNTA.

Table 23. Description of Geothermal at the Central Nevada Test Area Site

Location	CNTA, NV	
Technology	Geothermal	
Mission	The site, previously an underground nuclear test site, comprises 2,560 acres of withdrawn federal lands for long-term surveillance and maintenance.	
Site Ownership & Control	Yellow (uncertain project risk)	• The site, previously an underground nuclear test site, comprises three areas at a total of 2,560 acres of withdrawn federal lands for long-term surveillance and maintenance. • The site has three separate, noncontiguous areas: UC-1, UC-3, and UC-4. Based on slope and drilling restrictions, UC-3 appears to be the only viable site for development. Up to 845 acres are available at UC-3, although this area would be reduced by the area of the restricted sections. • Much more information is required to determine the presence of a hydrothermal system (or systems) at one or both sites, as well as their potential to achieve utility-scale power production.
Offtaker	Yellow (uncertain project risk)	• Based on GIS analysis, no transmission substations larger than 69 kV are located within a 5-mile radius of the site.
Regulatory	Gray (not evaluated)	• Additional environmental analysis requirements concerning the underground test areas would likely be required. • Additional analysis of the subsurface ownership and leasing process would also be required, because this was not explicitly evaluated.
Economics	Gray (not evaluated)	• Not evaluated

Site ownership and control. The site, previously an underground nuclear test site, comprises 2,560 acres of withdrawn federal lands for long-term surveillance and maintenance. BLM approves all surface land uses. Based on discussion with the site contacts, the total acreage is currently withdrawn from all forms of appropriation associated with mining laws and leasing, which would likely prevent the development of any geothermal resource at the site. Land-use restrictions that prohibit any activity that may alter the buried drilling mud/material are in effect at 11 smaller sections of the three sites; however, whether drilling would be allowed outside these 11 sections is unclear. These sections were used to dispose of contaminated drilling muds and because of groundwater monitoring wells installed to monitor contamination from the underground nuclear test at the site. That said, the land (which is mostly administered by BLM) is open to the public and used for livestock grazing and ranching. A small part of UC-4 is now managed by the U.S. Forest Service. Development of a solar project at the site may be feasible, although whether the leasing restrictions apply to surface uses at the site or only subsurface interests is unclear.

The sites are shown in greater detail in Figure 48.

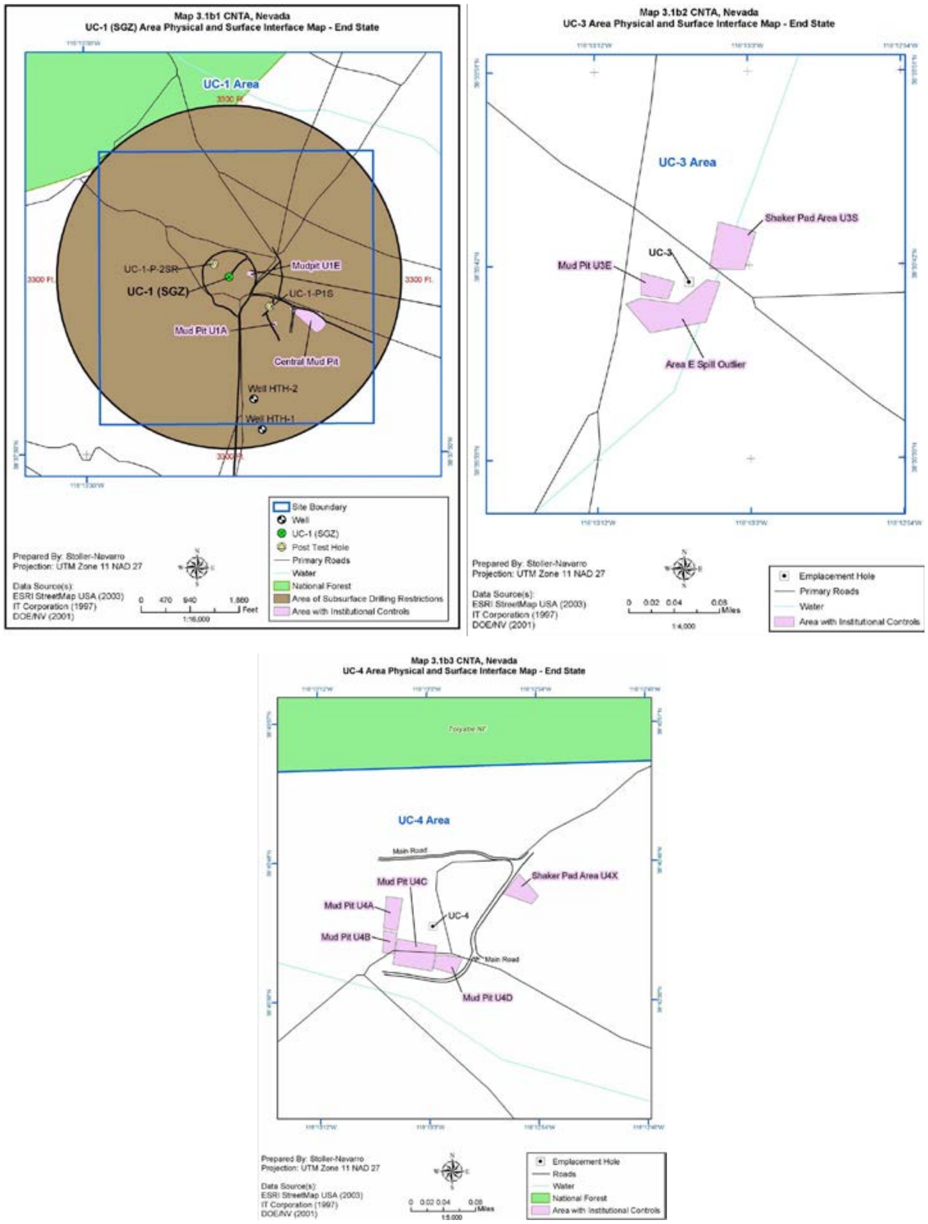

Figure 48. Detail of Central Nevada Test Area sites

Source: DOE[87]

Resource. The CNTA sites are located in areas of moderate probability for finding a hydrothermal system.[88] The three sites (UC-1, 3 and 4) are emplacement boreholes originally intended for underground nuclear testing, although only UC-1 was ever actually used for testing.

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[87] Ibid.

[88] C.F. Williams, et al., *Assessment of Moderate- and High-Temperature Geothermal Resources of the United States,* (fact sheet), (U.S. Geological Survey, September 2008), accessed at http://pubs.usgs.gov/fs/2008/3082/pdf/fs2008-3082.pdf.

Additionally, thermal springs can be found on both sites and local geologic factors (e.g., extensive faulting) are promising.[89] Detailed data for both sites are scarce and difficult to obtain. Much more information is required to determine the presence of a hydrothermal system (or systems) at one or both sites as well as their potential to achieve utility-scale power production.

Offtaker. The site has no significant load, so the proposed offtaker would have to be an off-site purchaser. However, interconnection to the project site may result in additional project costs; based on GIS analysis, no transmission substations larger than 69 kV are located within a 5-mile radius of the site (Figure 49).

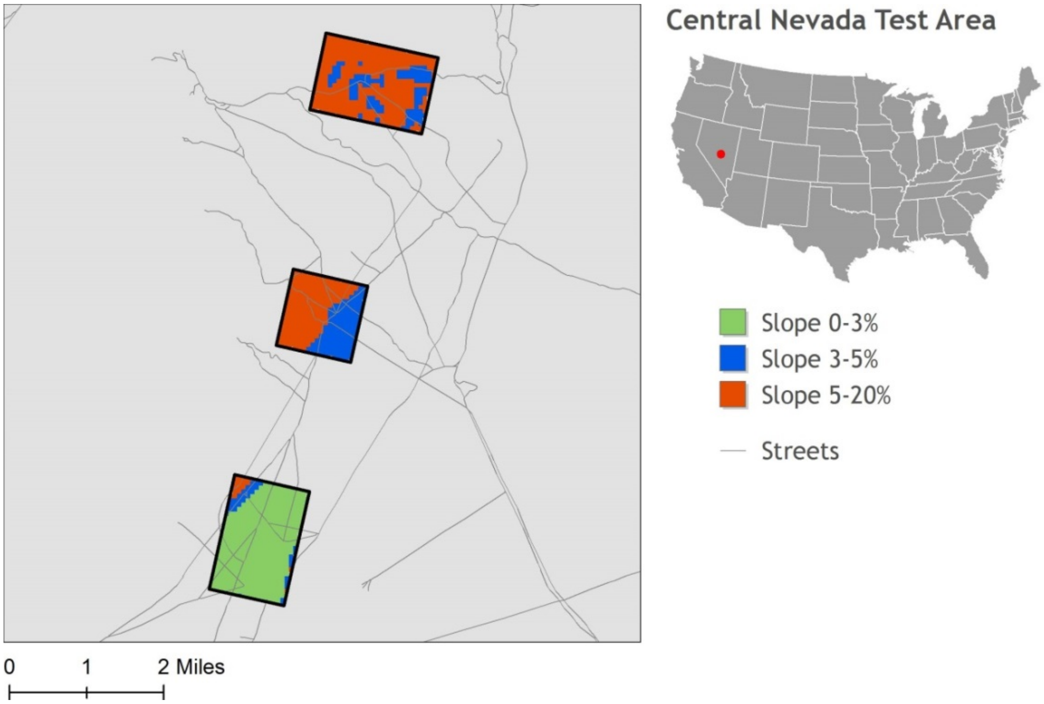

Figure 49. Central Nevada Test Area geographic information system analysis map

Illustration by Jenny Melius, NREL

Regulatory. Additional environmental analysis requirements concerning the underground test areas would likely be required. Additional evaluation of the subsurface ownership and leasing process would also be required, because this was not explicitly evaluated.

Economics. Given the inherent uncertainty in the geothermal resource, an LCOE could not be calculated for the site. Additional examination of the site's economics was not conducted.

2.2.5 Potential Next Steps

For the sites that were not excluded by any development criteria (e.g., no red categories) in Section 2.2.3, as well as for the remaining sites not specifically evaluated within the development framework, there are several potential next steps to pursue further development.

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[89] "Interactive Geothermal Map of Nevada," University of Nevada, Reno, accessed June 4, 2015 at http://www.nbmg.unr.edu/Geothermal/InteractiveMaps.html.

Although only the lowest LCOE sites were evaluated for this report, some of the other projects assessed in the portfolio analysis could be equally or even more viable for development. This would require a follow-up analysis to fully address the development criteria for the remaining 45 sites. These next steps were determined by consultation with project development professionals at NREL and from discussion with a private solar developer.

1. **Conduct a market barrier and opportunities examination of the remaining sites:**
    - Does the site have a comparative advantage? The DOE site should have a comparative advantage over other potential sites to attract interest from RE project developers. For example, a DOE site located in an already heavily developed area may be more attractive to developers due to the limited remaining developable land in that area, available transmission capacity from earlier development, and the proximity to potential offtakers. By contrast, a DOE site in a remote location may be less attractive than a private tract of land in the same area due to the additional regulatory requirements for development on federal land. Finally, a DOE site in a remote location may have no comparative advantage at all if no transmission access is nearby.
        - Is there private land adjacent to the site that would be developable? Is there a compelling reason for a developer to select the DOE site?
        - Is there transmission access close to the site? What is the rated capacity of this transmission?
    - Is there a potential market? If the DOE site appears to have a comparative advantage over nearby sites, the economic viability of RE power sales should examined. The demand for RE power, and the likely accompanying purchase price for that power, will be major determinants in the viability of any proposed project. For biomass and WTE projects, the accompanying feedstock price is equally, if not more important than the power pricing.
        - Does the utility accepting the interconnection of the DOE site have experience with integrating RE?
        - Is there demand for RE? This demand could be driven by state RPS requirements, local and state incentives, and the competitiveness of RE compared to the retail utility rate.
        - Interview potential utility offtakers to determine whether the proposed project is economically competitive with wholesale market pricing.
    - If there is an installation on the DOE site, would it be able to purchase any of the power from the proposed project? The availability of even a partial on-site load could be a competitive advantage for a DOE site over an undeveloped tract of land. The presence of prior environmental studies could be an additional advantage for a DOE site.

2. **Vet this subset of developable sites through contact with RE developers; for example, issue an RFI to collect information from interested developers.** If a project still appears to be viable after an iteration of the development process, an RFI should be issued to verify whether there is actual interest in the project. An RFI will typically include basic information about the site such as available acreage, topographic maps, and the approximate location of any transmission infrastructure. Any RFI should also request that interested parties identify any remaining information or outstanding questions should be addressed in a full RFP for the proposed development pathway (site access agreement, PPA, ESPC, or similar).
3. **Assuming that the site receives sufficient interest, issue an RFP, which will ideally include detailed site interconnection, analysis of sensitive environmental factors, geotechnical information, a detailed discussion of the RFP selection criteria, and timelines and criteria for the selection process.** To generate favorable responses to any RFP, additional application of the development framework would likely be required. In general, an RFP with a high potential for success would confirm the availability and location of transmission access, include a statement about environmental review requirements that identifies sensitive resources in the area, and include site energy consumption data (if the on-site load could be met with RE from the system). The framework developed above should establish a consistent and efficient means to examine the potential of DOE sites for future RE development.

3 Fossil Fuel Resource Analysis

Researchers from CSM screened the same 55 DOE sites considered in the RE screening analysis for their potential to produce oil, gas, or coal in commercial quantities. An initial screening of the sites was conducted; further market barriers and opportunity analysis for specific sites was not performed. Fossil fuel resources were examined only for extraction potential and not for commercial power potential.

3.1 Portfolio Analysis

A portfolio screening analysis was conducted for the 55 DOE sites to identify those which have potential to produce oil, gas, or coal in commercial quantities. The screening approach and findings are discussed in turn for oil and natural gas resources, and coal resources, followed by general limitations in the methods applied and potential next steps.

3.1.1 Oil and Natural Gas

3.1.1.1 Methodology and Screening Criteria

The portfolio screening analysis for oil or natural gas potential consisted of the evaluation of each of the 55 DOE sites against five criteria. A single assessment was done to identify either oil or gas potential. Relevant data needed to assess the criteria were gathered for each site, analyzed, and then summarized. Once this initial site assessment was performed, sites were screened out of consideration for more detailed analysis if any of the criteria were not met.

Given limitations in the resources and time available for analysis, this screening analysis did not attempt to estimate either the magnitude of the potential oil and gas resource that might be accessible from the site or the exploration and production costs associated with developing that resource.

The following criteria were applied in the screening. The rationale for the use of each criterion is described, along with the typical data sources used to assess them.

- **Is the site area larger than 160 acres?**

  The use of this screening criterion was based largely on an assumption that the predominant reservoir type likely to be developed from the sites would be unconventional and require long-reach horizontal drilling to develop. Such methods generally require large land positions. The bulk of current U.S. onshore reservoir development activity is occurring in unconventional plays.[90] Site acreage was included in site information that DOE provided for the sites.

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[90] While this criterion might exclude the consideration of conventional oil or gas potential, which generally require smaller land positions, such potential should be fairly evident in the immediate area, or it would be unlikely to occur in the foreseeable future. A play might eventually arise in the area, but for these small sites, it was considered preferable for DOE to simply to wait until approached to lease the land. A scenario like this did occur for the Rulison, Colorado, site, which has been transferred to private hands with site restrictions.

- **Is the site likely to be released for alternative use, or are there past or present activities that would most likely preclude its transfer?**

  Uses of some of the DOE sites, either entirely or in part, are restricted by statutes or prior activities. Information about such limitations was obtained from DOE for specific sites and combined with the authors' knowledge of these locations.

- **Is the site located in a sedimentary basin?**

  This criterion assumes sites that fall within identified sedimentary basins, especially those that have estimated or demonstrated oil and gas potential of all types (conventional and unconventional), are more likely to have potential for commercial quantities of oil and gas than sites that are not located in sedimentary basins. Data for the areal extent of sedimentary basins and their associated resource potential and production were obtained primarily from USGS open file or published resource assessments. For some sites, these USGS data sources were augmented with published reports produced by state geological surveys or bureaus, or other sources.

- **Is there active drilling or production in the basin?**

  This criterion extends consideration of geologic proximity to currently active drilling or production, under the assumption that this presence increases the likelihood of commercial deposits being present as well as industry interest being present to develop them. Data for drilling and production activity were obtained from USGS open file or published resource assessments as well as industry activity data sources. Conventional oil and gas and coal-bed methane gas drilling and production activity were included in this assessment.

- **Is there active drilling or production near the site?**

  This criterion further extends the consideration of drilling and production activity to proximity to the site, under the assumption that this presence further increases the likelihood of commercial deposits being present as well as industry interest being present to develop them. In other words, the inclusion of this criterion assumes that DOE might benefit from the extension of plays being pursued nearby into the area of some sites and that DOE would be unlikely to benefit from actively pursuing the development of such resources in the absence of an active play in the region. Data for drilling and production activity were obtained from published state or regional industry activity data sources.[91] Conventional oil and gas and coal-bed methane gas drilling and production activity were included in this assessment.

3.1.1.2 Findings

The individual findings for each site are described in Appendix G, in which the sites are categorized first by the screening criterion by which their consideration was eliminated, with the sites that were recommended for more complete evaluation listed at the end. Within these groupings, sites are listed alphabetically. Separate findings were not made for oil and natural gas.

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[91] For example, the Colorado Oil and Gas Conservation Commission website (http://cogcc.state.co.us) was a source for information on sites in Colorado.

Seventeen sites were screened out on the basis of inadequate acreage (first criterion above). These are listed in Table 24 in order of decreasing acreage.

Table 24. Sites Screened Out on the Basis of Area <160 Acres

Site	Location	Acreage
NETL	Morgantown, WV	136
Kansas City Plant	Kansas City, MO	136
Durango	Durango, CO	120
Gunnison	Gunnison, CO	115
Salt Lake City Disposal	Salt Lake City, UT	99
Burrell	Burrell, PA	73
NETL	Pittsburgh, PA	63
Slick Rock	Slick Rock, CO	61
NETL	Albany, OR	44
Lakeview	Lakeview, OR	40
Canonsburg	Canonsburg, PA	34
Naturita	Naturita, CO	27
Green River	Green River, UT	26
Spook	Spook, WY	22
Lowman	Boise, ID	18
Albany	Albany, OR	16
Parkersburg	Parkersburg, WV	16

Two sites, the Waste Isolation Pilot Plant (WIPP) and the Pantex facility, were screened out because DOE was unlikely to permit oil and gas drilling on these sites (second criterion above). The reservation of the WIPP site by a Land Withdrawal Act was intended to preclude human intrusion by drilling into the transuranic waste repository there, because this is the only release scenario in the performance assessment for WIPP.[92] Pantex is an extremely high-security facility and drilling on or under it is likely to present significant security challenges to the site.

Twenty-two sites were identified as low or very low priority because they were outside a sedimentary basin, on the edge of a sedimentary basin, or showed no evident oil and gas activity in the basin (third and fourth criteria above). These sites are listed in Table 25, sorted by acreage. Several of these sites are in areas of volcanic provinces with little likelihood of preserved organic material.

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[92] The Waste Isolation Pilot Plant Land Withdrawl Act, Public Law 102-579, as amended by P.L. 104-201. 1992–1996. H.R. 3230, 104th Congress; accessed July 17, 2015; https://www.nrc.gov/docs/ML1219/ML12198A074.pdf.

Table 25. Sites Screened Out for Being Outside of Sedimentary Basins, at the Edge of Sedimentary Basins, or in Basins with Little or No Oil and Gas Activity

Site	Location	Acreage	Priority	Notes
NNSS	Mercury, NV	775,680	V. Low	Inactive, hot basin; deep plays
SNL	Albuquerque, NM	193,000	Low	Inactive rift basin
Savannah River	Aiken, SC	180,000	Low	Not in active basin
Oak Ridge National Laboratory (ORNL)	Oak Ridge, TN	71,584	Low	Edge of Chattanooga Basin
INL	Idaho Falls ID	64,467	V. Low	Inactive basin; volcanic hot spot
LANL	Los Alamos, NM	28,000	V. Low	Hot basin, deep rock
Fermi	Batavia, IL	6,811	Low	Edge of Michigan Basin
BNL	Upton, NY	5,273	V. Low	Not in active basin
Paducah	Paducah, KY	3,556	V. Low	Outside Illinois Basin
Bluewater	Bluewater, NM	3,305	Low	Not in active basin
Livermore (two sites)	Livermore, CA	3,422	V. Low	Outside Sacramento Basin play
Central NV Test Site	Tonopah, NV	2,560	Low	Shot site; small field potential
Shoal	Fallon, NV	2,560	Low	Shot site; small field potential
ANL	Argonne, IL	1,700	Low	Edge of Michigan Basin
L-Bar	Seboyeta, NM	738	Low	Not in active basin
Moab	Moab, UT	439	Low	Inactive basin
Edgemont	Edgemont, SD	360	Low	Not in active basin
Ambrosia Lake	Grants, NM	315	Low	Not in active basin
Weldon Springs	St. Louis, MO	267	Low	Not in producing basin
BPA Ross Complex	Vancouver, WA	250	Low	Not in producing basin
SPRU	Schenectady, NY	200	Low	Edge of Appalachian Basin
Jefferson Accelerator	Newport News, VA	171	Low	Not in active basin

Drilling in the past or nearby was indicated at seven sites, but the wells were dry holes, permitted well locations were abandoned, or other indications suggested that nearby drilling targets do not persist into the site (fifth criterion above). These sites are listed in Table 26, sorted by acreage.

Table 26. Sites Screened Out Due to Lack of Active Drilling or Production Nearby in the Basin

Site	Location	Acreage	Priority	Notes
Shirley Basin	Casper, WY	1,527	Low	A few dry holes in vicinity
Monticello	Monticello, UT	995	Low	Single dry hole nearby
NREL	Golden, CO	640	Low	DJ Basin, no production nearby
Grand Junction	Grand Junction, CO	360	Low	Few wells, no production
Maybell West	Maybell, CO	250	Low	Wells and locations abandoned
Maybell	Maybell, CO	250	Low	Wells and locations abandoned
Rifle	Rifle, CO	205	Low	Edge of Piceance Basin activity

The remaining six sites were considered to have distinct potential for oil and gas production, although on varying development time scales. These sites are listed in Table 27.

Table 27. Sites Considered To Have Distinct Potential for Oil and Gas Production

Site	Location	Acreage	Priority	Notes
Hanford	Richland, WA	307,467	Medium	Limited prior oil and gas production in Columbia River Basin; recent interest (2009)
Portsmouth	Piketon, OH	3,556	Medium	Edge of Appalachian Basin
Falls City	Falls City, TX	744	High	Close to active production in Eagle Ford play
Gnome-Coach	Carlsbad, NM	680	Medium	Shot site; small radiologic exclusion area; Permian Basin oil and gas
Gasbuggy	Farmington, NM	640	Medium	Shot site; small radiologic exclusion area; San Juan Basin coal bed gas
Rio Blanco	Rio Blanco, CO	360	Medium	Shot site; small radiologic exclusion area; Piceance Basin tight gas

All were considered to have medium potential, except the Falls City, Texas, Uranium Mill Tailings Radiation Control Act (UMTRCA) site, which lies very close to active production in the Eagle Ford play,[93] an active unconventional oil and gas play, and within the liquids-rich part of

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[93] U.S. Energy Information Administration. 2014. *Updates to the EIA Eagle Ford Play Maps.* U.S. Department of Energy, accessed August 2015 at http://www.eia.gov/maps/pdf/EIA%20Eagle%20Ford%20Play%20update%2012-29-14.pdf.

this play.[94] This site is of particular interest and warrants evaluation as a current oil and gas leasing opportunity.

The Hanford site lies within the Columbia River Basin, where a few oil and gas wells have been completed, where the presence of gas has been documented in sedimentary rocks beneath the plateau basalts of the basin.[95] However, two episodes of exploration in the 1980s and 2000s failed to establish economic production in the basin, in part due to the challenges of drilling through the thousands of feet of hard basaltic rock to reach the sedimentary section. [96] The resources of the Columbia River Basin are unlikely to be produced in the readily foreseeable future and further detailed analysis of the site was deemed to be unwarranted at this time. However, given the likelihood that DOE will continue to hold the site for a long time period, some continued consideration of its gas potential may be warranted. Technology could potentially advance during that time, and substantial resources might someday be developed.

The Portsmouth site has not been fully evaluated. It lies at the edge of the Appalachian Basin.[97] While the site could participate in one of the recent gas/condensate shale plays in the basin, available play maps do not clearly include the site. Further analysis is needed to resolve this issue.

The other three sites were all originally selected to test the potential of nuclear devices to fracture sedimentary rock to accelerate the production of oil and gas trapped in relatively impermeable reservoirs. Each lies in a known sedimentary basin and therefore has the potential to be a productive area. The Rio Blanco site is most likely underlain by some gas resources, as drilling appears to have occurred relatively nearby.[98] The Gnome-Coach site is similarly close to drilling sites.[99] Given that the radiologic exclusions for these sites are significantly smaller than the aerial extent of the sites, they warrant further investigation to determine if some of the land could be leased for oil and gas drilling. Such an investigation could include a serious geologic prospect evaluation by personnel who are familiar with the regional plays in which they lie to determine the likelihood of oil and gas in commercial quantities underlie the sites.

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[94] Oil & Gas Journal Editors, "EIA estimates average Eagle Ford EUR at 168,000 bbl/well," *Oil & Gas Journal*, May 9, 2014, accessed August 2015; http://www.ogj.com/articles/2014/05/eia-estimates-average-eagle-ford-eur-at-168-000-bbl-well.html.

[95] Potential Gas Committee. 2015. *Potential Supply of Natural Gas in the United States; Report of the Potential Gas Committee, December 31, 2014*. Potential Gas Agency, Colorado School of Mines, Golden, CO.

[96] Montgomery, S.L., 2008. "New exploration concepts highlight Columbia River basin's potential," *Oil & Gas Journal* (January 14, 2008), v. 106, no. 2, accessed August 2015, http://www.ogj.com/articles/print/volume-106/issue-2/exploration-development/new-exploration-concepts-highlight-columbia-river-basinrsquos-potential.html.

[97] Ryder, R.T. 2008. *Assessment of Appalachian Basin Oil and Gas Resources: Utica-Lower Paleozoic Total Petroleum System*. U.S. Geological Survey Open-File Report, 2008:1287, 29 p.

[98] DOE. 2014. *Rio Blanco, Colorado, Site*. Office of Legacy Management fact sheet, Rio Blanco, Colorado.

[99] DOE. 2014. *Gnome-Coach, New Mexico, Site*. Office of Legacy Management fact sheet, Gnome-Coach, New Mexico.

3.1.2 Coal

3.1.2.1 Methodology and Screening Criteria

The portfolio screening analysis for coal potential consisted of the evaluation of each of the 55 DOE sites against three criteria. Relevant data needed to assess the criteria were gathered for each site, analyzed, and then summarized. Once this initial site assessment was performed, sites were screened out of consideration for more detailed analysis in the order the criteria are listed in below.

Given limitations in the resources and time available for analysis, this screening analysis did not attempt to estimate either the magnitude of the potential coal resource that might be accessible from the site or the exploration and production cost associated with developing that resource.

The following criteria were applied in the screening. The rationale for the use of each criterion is described, along with the typical data sources used to assess them.

- **Is the site located in a sedimentary coal-producing basin?**

  This criterion assumes sites that fall within identified sedimentary coal-producing basins of all types are more likely to have potential for commercial quantities of coal than sites that are not located in such basins. The CSM team relied primarily on the work of Warwick and Cahan, presented to the NAS Committee in May 2015,[100] to identify the DOE sites located in coal-producing basins. This analysis relied on data for coal-producing basins from USGS published open file reports.[101,102]

- **Is the site area larger than 160 acres?**

  The use of this screening criterion was based largely on an assumption that coal development would require large land positions. The 160-acre value was chosen to be consistent with the site acreage cut-off used for the oil and gas assessment above, but is considered very small as most coal mines cover very substantial acreage (e.g., up to tens of thousands of acres for large surface coal mines). Site acreage was included in site information that DOE provided for the sites.

- **Is the depth to the coal formation likely to be below 3,000 feet?**

  This depth is commonly considered a cutoff for the economic production of coal. Data for the depth of relevant producing coal formations were identified for a few sites based on USGS open file or published resource assessments. For the remainder of the sites, this determination was left for future, more detailed analysis.

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[100] Warwick, Peter D. and Steven M. Cahan. 2015. "Review of Coal and Geologic Carbon Dioxide Storage Resources Underlying DOE Lands," Presented at U.S. Geological Survey, May 21, 2015.

[101] East, J.A. 2013. *Coal fields of the conterminous United States: National Coal Resource Assessment updated version*. U.S. Geological Survey Open-File Report 2012-1205. one sheet, scale 1:5,000,000. http://pubs.usgs.gov/of/2012/1205/.

[102] Tewalt, S.J., S.A. Kinney, and M.D. Merrill. 2008. *GIS representation of coal-bearing areas in North, Central, and South America*. U.S. Geological Survey Open-File Report 2008-1257. http://pubs.usgs.gov/of/2008/1257/.

3.1.2.2 Findings

The individual findings for each site are described in Appendix G.

Thirty-six sites were identified by Warwick and Cahan as falling outside coal-producing sedimentary basins and were screened out on that basis (first criterion above).[103] These are listed in Table 28 in order of decreasing acreage.

Table 28. Sites Screened Out for Being Outside a Coal-Producing Sedimentary Basin

Site	Location	Acreage
NNSS	Mercury, NV	775,680
Hanford	Richland, WA	307,467
SNL	Albuquerque, NM	193,000
Savannah River	Aiken, SC	180,000
Oak Ridge National Laboratory (ORNL)	Oak Ridge, TN	71,584
INL	Idaho Falls ID	64,467
LANL	Los Alamos, NM	28,000
Fermi	Batavia, IL	6,811
BNL	Upton, NY	5,273
Portsmouth	Piketon, OH	3,556
Bluewater	Bluewater, NM	3,305
Livermore (2 sites)	Livermore, CA	3,422
Central NV Test Site	Tonopah, NV	2,560
Shoal	Fallon, NV	2,560
ANL	Argonne, IL	1,700
Shirley Basin	Casper, WY	1,527
L-Bar	Seboyeta, NM	738
Gnome-Coach	Carlsbad, NM	680
Moab	Moab, UT	439
Edgemont	Edgemont, SD	360
Ambrosia Lake	Grants, NM	315
Weldon Springs	St. Louis, MO	267
BPA Ross Complex	Vancouver, WA	250

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[103] The Warwick and Cahan analysis identified 12 additional DOE sites, not included in the 55 sites assessed in this report, that are located in coal-producing basins.

Site	Location	Acreage
SPRU	Schenectady, NY	200
Jefferson Accelerator	Newport News, VA	171
Gunnison	Gunnison, CO	115
Salt Lake City Disposal	Salt Lake City, UT	99
Burrell	Burrell, PA	73
Slick Rock	Slick Rock, CO	61
NETL	Albany, OR	44
Lakeview	Lakeview, OR	40
Naturita	Naturita, CO	27
Green River	Green River, UT	26
Lowman	Boise, ID	18
Albany	Albany, OR	16

Seven sites were screened out on the basis of inadequate acreage (second criterion above). These sites are listed in Table 29, in order of decreasing acreage.

Table 29. Sites Screened Out on the Basis of Area <160 Acres

Site	Location	Acreage
NETL	Morgantown, WV	136
Kansas City Plant	Kansas City, MO	136
Durango	Durango, CO	120
NETL	Pittsburgh, PA	63
Canonsburg	Canonsburg, PA	34
Spook	Spook, WY	22
Parkersburg	Parkersburg, WV	16

Of the remaining ten sites, two sites, Rio Blanco and Rifle, are known to be in areas where the coal formation (part of the Cretaceous Mesaverde Formation) are at depths much greater than 3,000 feet (third criterion above), which is commonly considered a cutoff for the economic production of coal. This third criterion was not evaluated for any of the additional remaining sites.

Eight sites in coal-producing basins remain that have not been eliminated from consideration for coal mining potential (coal resources may be present, but of unknown potential and cost to develop). These sites are listed in Table 30, in order of decreasing acreage. Assessment of the third criterion, depth to the coal-producing formation at the site, could be made for these sites with a moderate initial investment of time, as could other potential development factors, including whether coal mining operations would be permitted on the sites.

Table 30. Remaining Sites Not Screened Out for Coal Mining Potential

Site	Location	Acreage	Notes
Paducah	Paducah, KY	3,556	
Monticello	Monticello, UT	995	
Falls City	Falls City, TX	744	Tertiary lignite coal mined in vicinity. Mining could disturb the uranium mill tailings at the site, which could render unprospective unless the tailings could be relocated to another site.
Gasbuggy	Farmington, NM	640	
NREL	Golden, CO	640	Coal mining may not be permitted in such an urban area.
Grand Junction	Grand Junction, CO	360	
Maybell West	Maybell, CO	250	
Maybell	Maybell, CO	250	

The Falls City, Texas, site, noted above as having high potential for Eagle Ford oil/condensate/gas production, could also be evaluated to determine whether the Tertiary lignite coal produced at other mines in its area might have commercial potential there. The site's size and the presence of uranium mine tailings could also impact its coal commercial potential.

3.1.3 Limitations

The screening analysis summarized above was based only on resource data and maps available from the sources noted. No communication was made directly with the DOE sites to collect additional relevant information or validate the screening results. As noted above, given limitations in the resources and time available for analysis, this screening analysis did not attempt to estimate either the magnitude of the potential resource that might be accessible from the site or the exploration and production cost associated with developing that resource. Other criteria were used to identify sites for which this more detailed assessment might be warranted.

Further, the screening criteria for the potential presence of resources consider the viability of resource recovery primarily from the perspective of site size and geospatial proximity to existing production. Consideration was not given explicitly to environmental factors, including proximity to water sources or population centers, and post-extraction site reclamation, as well as to a range of potential end-use conflicts to safety and security concerns. These factors could be considered in a subsequent market barriers and opportunities analysis.

3.1.4 Potential Next Steps

Further analysis could be done to examine in more detail the small number of sites that remained after application of the screening criteria for both sets of analyses, to determine whether additional sites can be eliminated. This additional examination is especially applicable for the sites that were not evaluated for the depth to coal criterion. DOE could prepare a prospect evaluation of the Falls City site, and further assess whether the Gasbuggy,[104] Gnome-Coach, and Rio Blanco sites could be leased to companies that operate in the area. Additional work on the Portsmouth site could be done to assess its proximity to the Appalachian Basin and its recent gas/condensate shale play activity.

For the Hanford site, the potential of the basin has already been evaluated. Reconsideration of this site should be contingent upon advances in drilling technology that might enable development of the identified gas potential in sedimentary section underlying the basalt.

As with other sites, DOE could best prepare for such development by reviewing its own process for making land available to companies interested in leasing land, so that the agency can react quickly should an active play develop in an area. DOE might also find it useful to put a plan in place to review fossil fuel resource potential at its sites at regular intervals, to consider both improving extraction technology and potential expansion of industry activity. DOE might also consider offering favorable leasing terms to companies proposing to test novel technology for energy development on its sites (e.g., testing drilling technology at the Hanford site).

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[104] DOE. 2014. *Gasbuggy, New Mexico, Site*. Office of Legacy Management fact sheet, Gasbuggy, New Mexico.

4 Uranium and Thorium Resource Analysis

This report provides a high-level assessment of the potential for uranium or thorium commercial resource development on the same 55 DOE sites assessed for both RE and fossil fuel potential. These nuclear material resources were examined only for extraction potential and not for commercial power potential. Researchers from CSM[105] conducted an initial portfolio screening analysis in two stages. The first eliminated 36 of the 55 potential sites from consideration for nuclear resource development based on their distance from known resources (mines, mining claims, mining prospects, and sampling sites). The second stage of the screening process ranked the remaining 19 potential sites by assessing nearby mine production status and type of material production to identify the sites for a market barriers and opportunities analysis.

The market barriers and opportunities analysis performed by the CSM researchers on the top five potential nuclear resource sites considered the production history of the sites and adjacent mining operations. The analysis also considered ongoing mining projects that were being evaluated by mining companies in adjacent or inclusive areas relative to the DOE sites. This evaluation provides an overview of the public and commercial interest in these areas and indicates which sites could be worthy of further investment.

4.1 Portfolio Analysis

The screening for potential commercial nuclear mineral resource development considered all 55 DOE sites as described in Appendix A to ultimately produce a list of the top 5 sites with the greatest potential for recoverable uranium or thorium mineral resources. Figure 50 shows the locations of the 55 sites.

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[105] CSM was selected to perform the evaluation of the nuclear portion of the analysis in light of the university's interdisciplinary expertise in nuclear energy mineral resources and its emphasis on the nuclear fuel life-cycle and mineral resources.

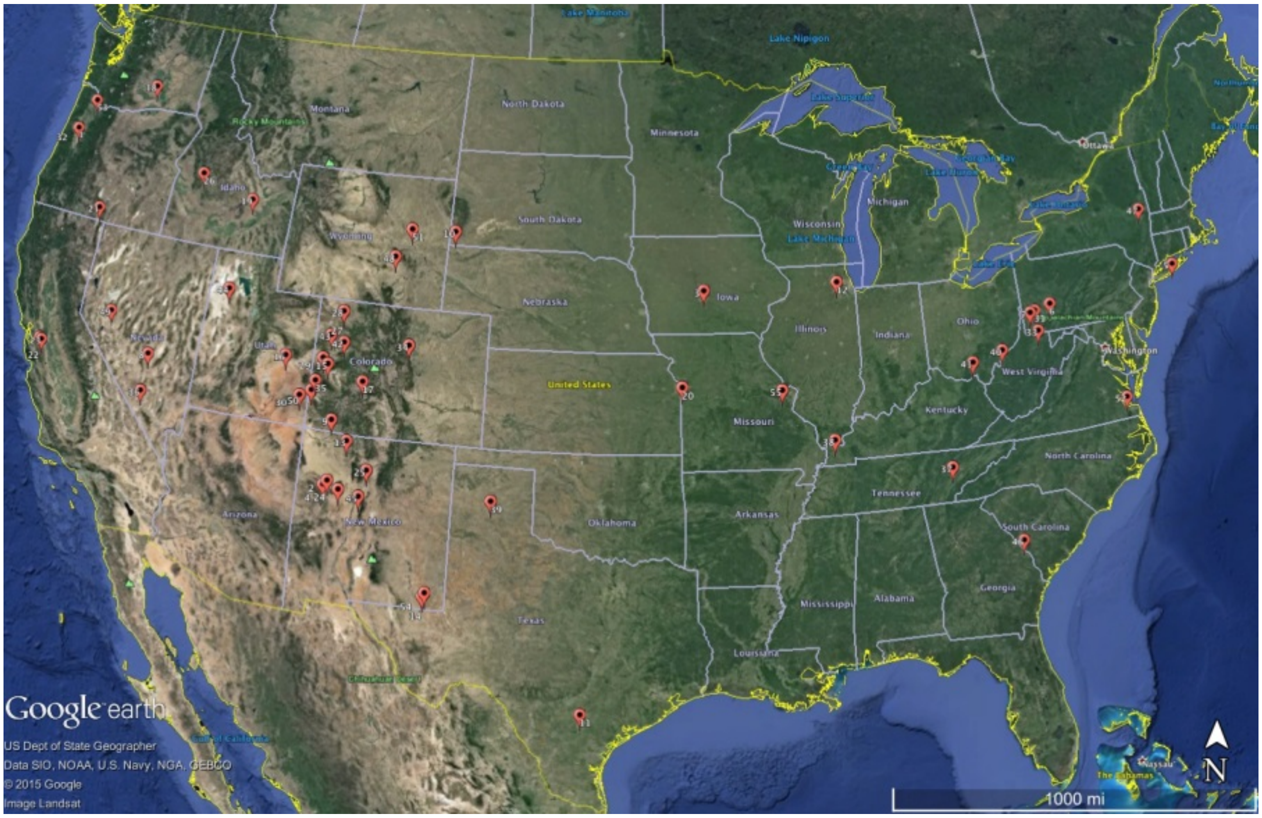

Figure 50. DOE sites considered for nuclear material resources potential

Source: © 2015 Google Earth, alterations by Jeremy Washington

4.1.1 Methodology

The first stage of the site screening relied heavily on data from both the USGS Mineral Resources Data System (MRDS) and from a national geophysical topographic survey[106,107] to produce an overview of nuclear material resource potential at all 55 DOE sites, specifically the potential presence of uranium or thorium.

The following information was gathered for the sites:

- Location with respect to known uranium provinces or regions
- Average uranium soil concentration and average thorium soil concentration
- Proximity to previous or current mining operations, claims, or site survey locations.

The uranium provinces are shown in Figure 51 as a demonstration of their prevalence across the United States. Differences in the map projections prevent the DOE sites and uranium provinces from being overlaid on a single map.

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[106] "Mineral Resources Data System (MRDS)," Mineral Resources On-Line Spatial Data, USGS, accessed August 2015, http://mrdata.usgs.gov/mrds/.

[107] Phillips, J.D., J.S. Duval, and R.A. Ambrosiak. 1993. *National geophysical data grids: gamma-ray, magnetic, and topographic data for the conterminous United States*.

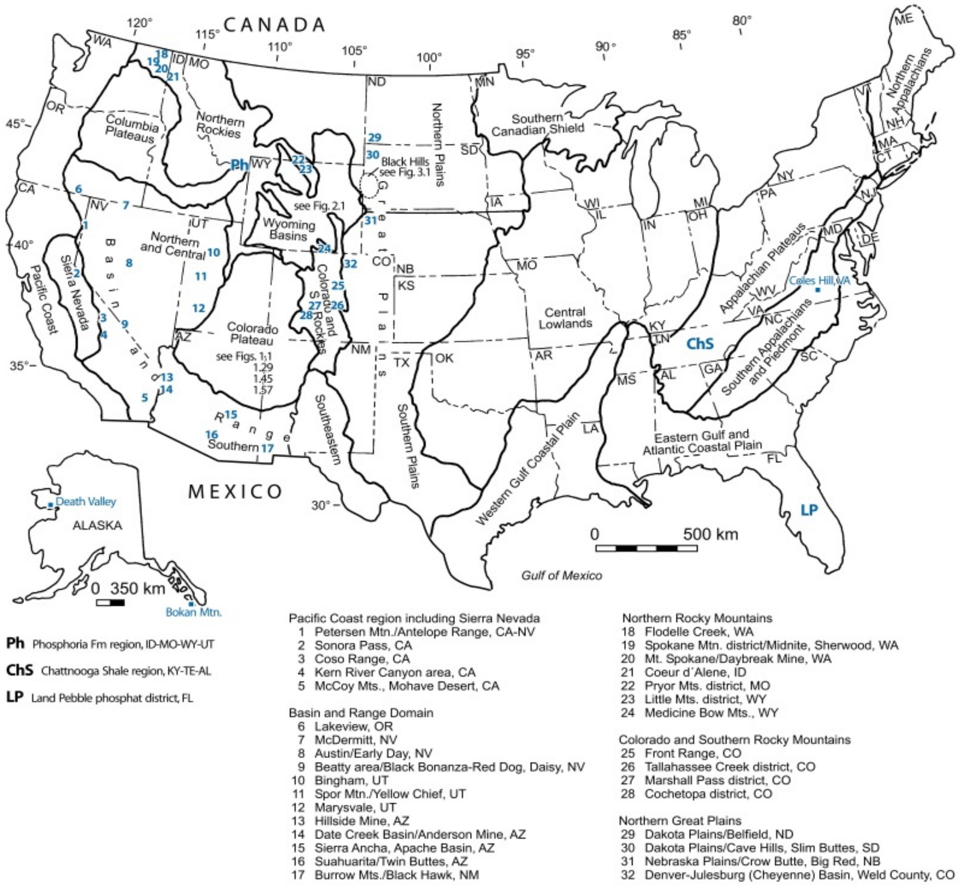

Figure 51. Uranium provinces and regions

Source: Dahlkamp 2010[108]

The average uranium soil concentration and the average thorium soil concentration were pulled from a national geophysical topographic survey. The uranium soil concentration (Figure 52) or equivalent uranium (eU) was determined from the upper 20–25 cm of the surface material by plane, at 400- to 500-ft altitude, with a gamma-ray detector tuned to bismuth-214. A similar method mapped the thorium concentration (eTh) with a detector tuned to the thallium-208 energy window (Figure 53).[109] The USGS provides these data as contour maps, separated data files, and Google Earth data files. Though the concentration of uranium or thorium in the soil does not correspond to a high probability of a uranium or thorium deposit, it may indicate a probability of local deposits.[110]

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[108] Dahlkamp, F.J. 2010. *Uranium Deposits of the World USA and Latin America, 1st ed*. (Springer-Verlag Berlin Heidelberg, 2010).

[109] Phillips, J.D., J.S. Duval, and R.A. Ambrosiak. 1993. *National geophysical data grids: gamma-ray, magnetic, and topographic data for the conterminous United States*.

[110] Dahlkamp, F.J. 2010. *Uranium Deposits of the World USA and Latin America, 1st ed*. (Springer-Verlag Berlin Heidelberg, 2010).

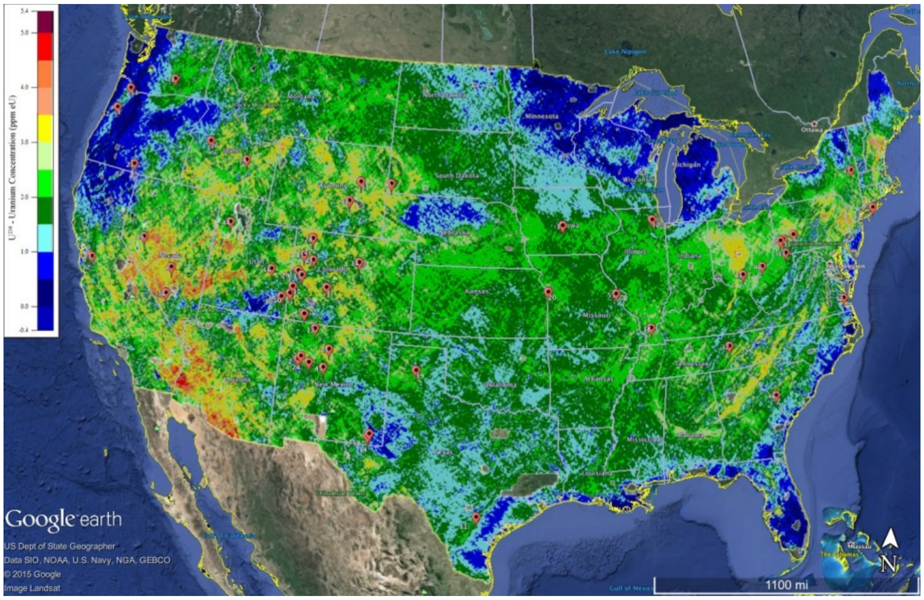

Figure 52. DOE sites and equivalent uranium concentrations

Source: © 2015 Google Earth, alterations by Jeremy Washington

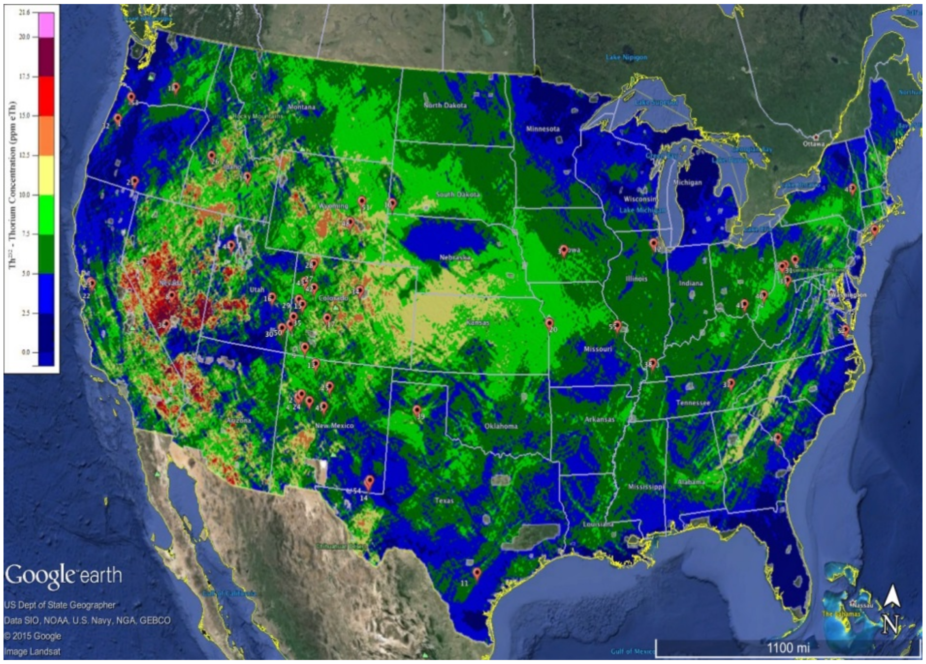

Figure 53. Potential DOE sites and equivalent thorium concentrations

Source: © 2015 Google Earth, alterations by Jeremy Washington

The sites that contained the keyword uranium or thorium were extracted from the USGS MRDS data and plotted with the DOE sites to determine proximity. Although the specific activity identified in the USGS data (mining operation, claim, or site survey) was eventually considered in the second screen of this portfolio analysis, the roles of the sites identified in the USGS database were unimportant to the initial screening process. While many of the DOE sites reside in a uranium province or region, the proximity to a previous or current mine, mill, claim, or survey was deemed a superior primary evaluation metric because it indicated previous or active mining in the area and therefore a higher likelihood of recoverable resources at the DOE site. A 15-mile maximum distance threshold was applied in the first screen as a reasonable compromise between identifying promising sites and eliminating sites with little commercial interest.

The second stage of the screening process considered the following information:

- The distance from the DOE site to the nearest two mines
- The current production status of each of these mines
- The primary material (commodity) that was produced at each mine.

Distance from the DOE site to the nearest two mines was used in this second screen instead of the more general distance to the nearest survey, claim, mill or mine used in the first screen. For the current mine production status, each mine was scored 1, 2, or 3 depending on its status of producer, past producer, or occurrence or prospect, respectively, based on data available from the USGS MRDS. This production status reflects the level of mining industry interest in the area.

The primary material produced at each of the nearby mines was based on USGS MRDS commodity production data. Mines that produced primarily uranium or thorium were assigned a 1; the mines with a secondary commodity of either uranium or thorium scored a 2; and the mines listed as having a tertiary commodity of either uranium or thorium scored a 3. This associated production of the local mines reflects the likelihood of nuclear resource production in a given locale.

Finally, the values assigned to each mine for commodities and production status were averaged with the distance from the mine to the DOE site to produce a numeric score for each DOE site. The DOE sites were then ranked by this metric score and then by the production status of the nearest mine. This second stage of the screening process was used to narrow the list of potential nuclear material sites to the top five sites, which were then further analyzed.

4.1.2 Assumptions

The most significant assumption used during the screening process for nuclear material resources at DOE sites was that the proximity to active uranium or thorium mines indicates the presence of uranium or thorium. The initial screening assumed the acreage of the site was unimportant and acreage was not factored into the evaluation. The DOE sites were assumed to be legally available for mining operations and to have access to the infrastructure required for mining operations.

4.1.3 Findings

The majority of the DOE sites in the western United States are within the Wyoming Basin, Colorado Plateau, and Columbia Plateau uranium provinces, and also within 30 miles of a uranium mine or claim. The first stage of the screening eliminated 36 of the DOE sites based on a maximum distance of 15 miles to a current mine, claim, mill, or survey site. The 15-mile threshold provided a reasonable compromise between identifying promising sites and eliminating sites with little commercial interest. Expanding the threshold to 35 miles would not have significantly changed the results of the screening. The eliminated sites, listed in Table 31, show no significant past or present activity in uranium or thorium extraction. The lack of commercial interest indicates a lack of nuclear material resources, a lack of economical nuclear material resources, or a legal or social barrier to the extraction of these resources. While the excluded sites are not in proximity to a uranium mine or claim, there still may be mines, claims, or sampling sites for other commodities in the USGS MRDS present in the area.

Table 31. DOE Sites Eliminated during the First Stage of the Screening

Site Name	Site Name
LLNL Main Campus	BNL
LLNL Site 300	SPRU
Grand Junction, CO, Disposal Site	Portsmouth Gaseous Diffusion Plant
Gunnison, CO, Disposal Site	Albany Site, OR, Site
Naturita, CO, Disposal Site	NETL
Rio Blanco, CO, Site	Burrell, PA, Disposal Site
INL	Canonsburg. PA, Disposal Site
ANL	NETL
FNAL	Savannah River Site
Paducah Gaseous Diffusion Plant	ORNL Site
Kansas City Plant	Pantex Plant
Weldon Spring, MO, Site	Salt Lake City, UT, Disposal Site
Gasbuggy, NM, Site	Thomas Jefferson National Accelerator Facility
Gnome-Coach, NM, Site	Hanford Site
WIPP	BPA Ross Complex
CTNA, NV Site	NETL
NNSS	Parkersburg, WV, Site

Of the 55 DOE sites assessed in the portfolio analysis, 19 are located within 15 miles of a previous or present uranium site listed on the USGS MRDS. Of these, 13 are listed as disposal sites, three are national laboratories, and three are sites with unlabeled purposes. The second-stage screening evaluated each of the remaining 19 DOE sites using Google Earth. Table 32 lists the summary data for the 19 sites. Table 32 includes the approximate distance to the nearest water source and the type of water source for future reference.

The second-stage screening identified the top five potential nuclear material resource sites based on the methods outlined in the methodology section (4.1.1) of this report.

Table 32. Sites Included in the Nuclear Resource Evaluation That Are within 15 Miles of an Existing Claim

Site	Acreage	Uranium Soil Concentration (ppm eU)	Thorium Soil Concentration (ppm eTh)	Distance to Nearest Uranium Mine or Claim (~ miles)	Distance to Water (~ miles)	Water Source
L-Bar, NM, disposal site	738.29	2.0–3.0	5.0–7.50	1	6.0	Lake
Edgemont, SD, site	360.00	3.0–3.5	7.5–10.00	2	2.0	River
Ambrosia Lake, NM, disposal site	314.97	2.5–3.5	5.0–7.50	1	25.0	Lake
Maybell West, CO, disposal site	250.36	3.5–4.0	7.5–10.00	1	2.0	River
Slick Rock, CO, disposal cell	61.25	2.0–2.5	5.0–7.50	1	2.0	River
Maybell, CO, disposal site	250.36	3.5–4.0	7.5–10.00	1	2.5	River
Falls City, TX, disposal site	744.15	1.5–2.0	5.0–7.50	1	5.0	River
Moab, UT, site	439.00	1.0–2.0	2.5–5.05	6	1.5	River
NREL	632.00	1.0–2.0	5.0–10.00	4	1.5	Reservoir
Bluewater, NM, disposal site	3,304.65	2.5–3.0	5.0–7.50	6	11.0	Lake
Rifle, CO, disposal site	205.00	2.0–2.5	7.5–10.00	2	2.0	Reservoir
Durango, CO, disposal site	120.06	1.5–2.0	5.0–7.50	6	0.5	Reservoir
Monticello, UT, disposal and processing sites	995.15	1.5–2.0	5.0–7.50	6	2.0	Reservoir
Shoal, NV, site	2,560.00	3.0–3.5	10.0–12.50	6	40.0	Lake
SNL Albuquerque	193,000.00	2.0–2.5	5.0–7.50	8	9.0	River
Green River, UT, disposal site	26.27	3.5–4.0	5.0–7.50	4	1.0	River
Lowman, ID, disposal site	18.08	1.0–1.5	5.0–7.50	12	1.0	River
LANL	28,000.00	3.0–3.5	7.5–10.0	12	9.0	River

Table 33 lists the metrics used to rank the top five sites, which are sorted first by the metric denoted in the last column of the table, average production status score and distance to nearest mine or claim, and then by the first metric, the production status score of the nearest mines. This second-stage screen assumes that sites closer to active mining operations are more likely to be located on a uranium ore deposit and therefore warrant further investigation. As seen in Table 33, sites in addition to the top five ranked well using this evaluation methodology.

Table 34 lists the five sites determined to have the best potential for commercial-scale nuclear resource development along with the site location and acreage. All the sites except Edgemont are listed as disposal cells for the long-term storage of mine tailings. While the Edgemont site is not listed as a disposal cell in the provided DOE database, visual analysis of satellite imagery indicates it is likely to serve a similar purpose.

Table 33. Metrics Used To Determine the Top Five Potential Nuclear Material Resource Sites

Site	Mine Rating Score	Production Status (closest mine)	Production Status (2^{nd}-closest mine)	Commodity Rank (closest mine)	Commodity Rank (2^{nd}-closest mine)	Average of Mine Rating and Distance to Claim/Prospect
L-Bar, NM, disposal site	4	Producer	Producer	1	1	2.5
Edgemont, SD, site	4	Producer	Producer	1	1	3.0
Ambrosia Lake, NM, disposal site	5	Producer	Past producer	1	1	3.0
Maybell West, CO, disposal site	6	Producer	Occurrence	1	1	3.5
Slick Rock, CO, disposal cell	6	Past producer	Past producer	1	1	3.5
Maybell, CO, disposal site	7	Past producer	Occurrence	1	1	4.0
Falls City, TX, disposal site	7	Occurrence	Past producer	1	1	4.0
Moab, UT, site	4	Producer	Producer	1	1	5.0
NREL	7	Producer	Past producer	1	3	5.5
Bluewater, NM, disposal site	6	Past producer	Past producer	1	1	6.0
Rifle, CO, disposal site	10	Past producer	Past producer	3	3	6.0
Durango, CO, disposal site	7	Past producer	Occurrence	1	1 (Th)	6.5
Monticello, UT, disposal and processing sites	8	Past producer	Past producer	1	3	7.0
Shoal, NV, site	8	Prospect	Occurrence	1	1	7.0
SNL Albuquerque	8	Occurrence	Occurrence	1	1	8.0
Green River, UT, disposal site	12	Prospect	Prospect	3	3	8.0
Lowman, ID, disposal site	5	Producer	Past producer	1	1	8.5
LANL	10	Past producer	Past producer	3	3	11.0

Table 34. Top Five Potential Nuclear Resource Sites

Site	State	Longitude	Latitude	Acreage
L-Bar, NM, disposal site	NM	–107.335	35.18765	738.29
Edgemont, SD, site	SD	–103.794	43.27354	360.00
Ambrosia Lake, NM, disposal site	NM	–107.799	35.40880	314.97
Maybell West, CO, disposal site	CO	–108.016	40.54456	250.36
Slick Rock, CO, disposal cell	CO	–108.864	38.05454	61.25

4.1.4 Limitations

The primary limitation to potential commercial development of the top five potential nuclear resource sites listed in Table 34 is the acreage of each site. The sites are likely to be on uranium deposits and are in proximity to known uranium deposits but are possibly too small to produce meaningful quantities of uranium ore. The process of mineral extraction would likely require the return of these sites to a local mining company to be incorporated into a larger operation on the land adjacent to these sites to make mineral extraction economically feasible.

4.1.5 Potential Next Steps

More data may be available about the sites that were not selected for further consideration. The most informative step that could be taken at all the DOE sites provided for this report would be to perform a mineral survey at each site to determine if any mineral resources of commercial interest are readily accessible. Access to this information could greatly revise the priority of investigation into each site. Although the present estimates are likely to identify sites that have a high probability of nuclear resources, only a site survey can confirm their presence.

4.2 Market Barriers and Opportunities Analysis

The purpose of this review is to develop a deeper understanding of each of the top five nuclear material resource sites identified in the portfolio analysis and determine if the extraction of nuclear resources is feasible at these locations.

4.2.1 Methodology

The market barriers and opportunities analysis on the top five potential nuclear resource sites provided by the screening process examined specific questions. Documentation from the UMTRCA provided the history and characteristics of each site. Local considerations such as stakeholder acceptance, current site conditions, and current commercial interest in the sites were studied by evaluating ongoing operations by mining companies that are planning operations or currently operating in the vicinity of the DOE sites.

4.2.2 Assumptions

An important assumption used during the market barriers and opportunities analysis for nuclear material resources at DOE sites was that the DOE sites were assumed to be legally available for mining operations and to have access to the infrastructure required for mining operations.

4.2.3 Findings

The L-Bar disposal site in New Mexico is located west of Albuquerque and previously operated adjacent to mines operated by the SOHIO Western Mining Company. The total mining area covered 120,000 acres, which provided 898,600 short tons of material to the mill operating on site. This material resulted in 2,218,800 pounds of triuranium octoxide (U_3O_8) with an average ore grade of 0. 123 wt %.[111] This value is low compared to higher-grade deposits in Australia and Canada, but is typical for historical American uranium deposits.

As of April 1, 2014, the L-Bar mine is currently part of the Cebolleta Uranium Project. This collaboration between Uranium Resources, Inc., Cibola Resources, and Neutron Energy contains the L-Bar and St. Anthony uranium mines in New Mexico. The St. Anthony mine has not yet been evaluated for potential resources; however, both this mine and the L-Bar site have reduced mineralization deposits.

The evaluation of the L-Bar site estimates the deposit to be 1,000 ft in length, with a 6 to 12 ft width, located at a depth of 200 to 700 ft.[112] Estimates of the in-situ recoverable resources vary across the site and are listed in Table 35. The site does not currently contain the infrastructure required to proceed with mining operations but is within 6 miles of two high-power transmission lines and an electricity substation. Although the collaboration has not yet evaluated any groundwater issues, the uranium deposit is above the water table; however, water for operations would likely have to come from groundwater sources.[113]

Finally, considering issues of manpower and construction equipment, the nearest city of significant population is Albuquerque (45 miles). Though the DOE portion of the L-Bar site is small compared to the overall area of interest in the Cebolleta project,[114] the addition of the DOE site may increase the access to uranium resources. The project is ongoing, so there is ample evidence of commercial interest in the area.

Table 35. In-Situ Inferred Mineral Resources for Cebolleta Project

Area	Cutoff	U_3O_8%	Tons (k)	Tons U_3O_8 (K)	U_3O_8 lb (k)
Area I-II-V	0.08	0.173	4,564	7,874.000	15,748
Area III	0.08	0.162	998	1.616	3,232

The Edgemont site in South Dakota operated from 1956 to 1972 under Mines Development, Inc. as a subsidiary of Susquehanna-Western, Inc., based in Chicago, Illinois. The operation was a milling site and processed ore from the Black Hills area of southwestern South Dakota and

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[111] Boyd, R.G., L.C. Jacobsen, E.K. Kopp, and J.H. Olsen. 1984. *South Sohio Operations Variable Ore Reserve Study & Revised Mine Plan*, February 1984. SOHIO Western Mining Company.

[112] Moran, A.V. and F. Daviess. 2014. *NI 43-101 Technical Report on Resources Cebolleta Uranium Project Cibola County, New Mexico, USA*. Uranium Resources, Inc. http://www.westwaterresources.net/docs/default-source/Technical-Reports/ni-43-101-technical-report-on-resources-cebolleta-uranium-project-cibola-county-new-mexico-usa---april-1-2014.pdf?sfvrsn=d06d29cf_0.

[113] Ibid.

[114] Ibid.

northeastern Wyoming.[115] The site is currently under the control of the UMTRA project, which has cataloged the quantity of uranium ore processed by the site and the cost of remediation (see Table 36). The total remediation cost includes the costs generated by site characterization, remedial action design, surveillance, maintenance, technology development, and project management.[116] The site has a significant history of uranium production and the area is currently undergoing processes to develop in-situ extraction infrastructure.

Table 36. Remediation of UMTRCA Title I Uranium Mill Sites Under the UMTRA Project Summary Table: Uranium Ore Processed, Disposal Cell Material, and Cost for Remediation as of December 31, 1999

	Uranium Ore Processed			**Remediation Project Cost**			
Remediation Project (Mill Site Name, State)*	Ore (Million Short Tons)	Uranium Production (Million Pounds U_3O_8)	Disposal Cell Remediated Material Volume (Million Cubic Yards)	Total Cost (Thousand U.S. Dollars) 02/09	Per Pound Produced (Dollars per Pound U_3O_8)	Per Unit of Remediated Material (Dollars per Cubic Yard)	Per Unit of Radiation Avoided (Dollars per Curie, ^{226}Ra)
Ambrosia Lake, NM	3.05	13.02	5.20	39,961	3.07	7.68	21,600.54
Edgemont, SD	1.98	6.86	3.00	5,411	0.79	1.80	10,267.55
Maybell, CO	1.76	4.03	3.50	63,528	15.75	18.15	139,621.98
Slick Rock, CO	0.63	2.68	0.86	50,428	18.82	58.84	288,160.00

Powertech Uranium Corp., also known as Azarga Uranium, is currently developing an in-situ leaching project in the Dewey and Burdock area. These towns are abandoned and approximately 20 miles to the northwest of the city of Edgemont. The operation has been granted an NRC permit as of June 10, 2014, and Azarga Uranium has reported its initial assessment on the available uranium resources (Table 37).[117] Though the site has significant interest from the Azarga Uranium Corporation, the general Edgemont community appears to oppose the project.[118,119]

Table 37. Dewey/Burdock In-Situ Leach Resources

	Measured	**Indicated**	**Inferred**
Size	1,585 t U	1,715 t U	1,357 t U
Ore Grade	0.28% U	0.18% U	0.042% U

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[115] DOE. 2001. *Edgemont, South Dakota, Disposal Site,* (fact sheet), Long-Term Surveillance and Maintenance Program, Grand Junction.

[116] "Uranium Mill Sites Under the UMTRA Project," EIA Nuclear & Uranium, accessed August 2015; http://www.eia.gov/nuclear/umtra/#a.

[117] Graves, D.H. and S. Cutler. 2015. *Preliminary Economic Assessment Dewey-Burdock Uranium ISR Project*. NI 43-101 Technical Report. Azarga Uranium, South Dakota, USA.

[118] Cook, A.J. 2015. "Uranium mining topic of Custer meeting." Rapid City Journal.

[119] Woster, K. 2012. "Edgemont area ranchers clash over proposed uranium mine." Rapid City Journal.

The Ambrosia Lake site in New Mexico has also been evaluated by the UMTRA project and the quantity of uranium ore processed as well as the remediation costs are listed in Table 36. The Ambrosia Lake site generated approximately 3.1 million tons of tailings and used nearly 0.4 million tons of those tailings to backfill the underground mines at the end of operations. The site processed uranium ore from 1958 to 1982 and began the remediation process in 1987, which continued through 1995.[120] The site is currently undergoing final site tailings reclamation, and groundwater corrective actions are no longer required of Rio Algom, which retains a possession only license.[121] At the time of this writing there appears to be no corporate interest in the extraction of nuclear resources at the Ambrosia Lake site, though at least one uranium mine is operating in the region (see Table 36).

The Maybell West site in Colorado is the third of the top five nuclear resource sites and falls under the purview of the UMTRA project. The site was owned and operated by Umetco Minerals Corporation from 1975 through 1982. The quantity of uranium processed and the cost of remediation for this site are shown in Table 36. Though the site is adjacent to a producing uranium mine there appears to be no significant commercial interest in resuming use of the site, which completed reclamation in 2005 and is currently under long-term surveillance by LM.[122] Ceding the subcell mineral rights to companies that operate adjacent mines may produce additional nuclear resources, but mining companies have not expressed the interest shown for the areas adjacent to the L-Bar and Edgemont sites.

The Slick Rock disposal cell in Colorado is the final site evaluated in the market barriers and opportunities analysis for nuclear resources. This site also falls under the purview of the UMTRA Title 1 project and the ore processed by the site as well as the remediation cost is listed in Table 36. Although the Slick Rock site historically processed the smallest quantity of uranium ore of the top five sites, it began operation as a uranium and vanadium ore processing facility in 1931.[123] The Slick Rock site operated under the control of Uranium Energy Corporation from 1957 to 1983 and processed uranium and vanadium from the Burro Mines.[124] Table 38 lists the historical production data for the Burro Mine.[125]

Table 38. Historic Production from the Burro Mine

Production Years	**lb U_3O_8**	**lb V_2O_5**
1957–1971	1,992,898	12,149,659
1971–1983	243,825	1,791,798
Total	**2,236,723**	**13,941,457**

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[120] DOE. 2001. *Ambrosia Lake, New Mexico, Disposal Site,* (fact sheet), Long-Term Surveillance and Maintenance Program, Grand Junction.

[121] "Rio Algom - Ambrosia Lake Site Summary," Nuclear Regulatory Commission, accessed August 2015; http://www.nrc.gov/info-finder/decommissioning/uranium/rio-algom-ambrosia-lake.html.

[122] DOE. 2015. *Maybell West, Colorado, Disposal Site*, (fact sheet), Legacy Management, Grand Junction.

[123] DOE. 2015. *Slick Rock, Colorado, Processing Sites and Disposal Sites*, (fact sheet), Legacy Management, Grand Junction.

[124] "Slick Rock Project," Uranium Energy Corp, http://www.uraniumenergy.com/projects/colorado/slick-rock/.

[125] Ibid.

The area surrounding the Slick Rock site is currently under preliminary evaluation for mineral extraction by Uranium Energy Corp., which has developed a summary of inferred resources in the adjacent area (see Table 39).[126] The mineral resources of the DOE-owned Slick Rock site are surrounded by the project area under assessment by Uranium Energy Corp. (Figure 54). These mineral resources are located in two deposits in the Uravan mineral belt and are currently planned to be extracted through traditional underground mining operations.[127] The project site is also bordered by lands from the Uranium Leasing Program (Figure 54).

Table 39. Summary of Inferred Mineral Resources for Slick Rock Project[128]

Cutoff Grade eU_3O_8%	Thousand Tons	eU_3O_8 (%)	Contained U_3O_8 (Mlb)	V_2O_5 (%)	Contained V_2O_5 (Mlb)
0.10	4,225	0.186	15.7	1.12	94.2
0.15	2,549	0.228	11.6	1.37	69.6
0.20	1,646	0.255	8.9	1.53	53.4
0.25	775	0.296	4.6	1.78	27.6
0.30	274	0.340	1.9	2.04	11.4
0.35	71	0.415	0.6	2.49	3.6
0.40	69	0.417	0.6	2.50	3.6

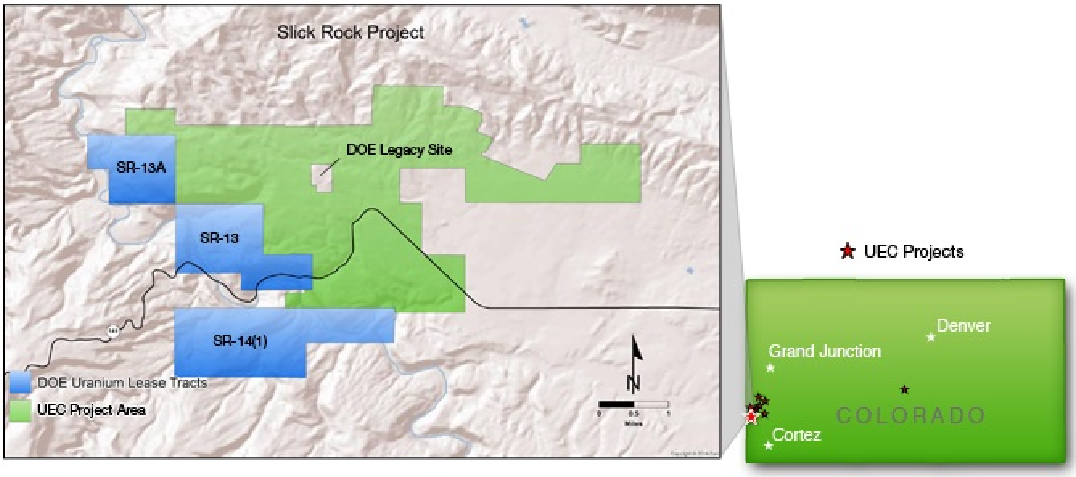

Figure 54. Uranium Energy Corporation's Slick Rock project

Interest in mineral extraction at the Slick Rock site is high as indicated by the reports from Uranium Energy Corporation.[129] This area of Colorado has traditionally been invested in mining operations and the local populace is likely to support ongoing and returning mining operations.

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[126] Beahm, D., B. Davis, and R. Sim. 2014. *Preliminary Economic Assessment Slick Rock Project Uranium/Vanadium Deposit*. Uranium Energy Corp. technical report, Corpus Christi, TX.
[127] Ibid.
[128] Ibid.
[129] Ibid.

4.2.4 Limitations

Factors that may significantly limit mineral extraction at these top five ranked DOE nuclear resource sites include the following:

- The support of the local public is a high priority for all nuclear operations. Without significant support from the local populace, most projects are unlikely to proceed.
- 10 CFR 40, Appendix A, Criterion 11, which is specific to the disposal cell sites. This law regulates the activities that may occur on land being used for the disposal of radioactive materials. The land is subject to an NRC license, which prohibits the disturbance of the disposal cell and may preclude mining activity.
- The size of each DOE site evaluated in the market barriers and opportunities part of the report may limit the usefulness of the site for mineral extraction unless it can be absorbed by adjacent acreage, such as in the case of the Slick Rock site.

Further analysis could also give explicit consideration to environmental factors, including proximity to water sources or population centers, and post-extraction site reclamation, as well as to a range of potential end-use conflicts and to safety and security concerns.

4.2.5 Potential Next Steps

Commercial development at any site would require a mineral survey to determine if nuclear resources are indeed present. Additionally, an inquiry with respect to 10 CFR 40 could be made to determine if mining operations can be performed at the disposal cell sites. If the disposal cells are unavailable for resource extraction, or the acreage proves to be too small to make resource extraction economical, the screening process revealed two national laboratory sites that have significant acreage and are within the top 18 sites in proximity to current mines, claims, mills, or survey sites.

Two national laboratory sites, SNL and LANL, would require extensive mineral surveys to determine if recoverable nuclear resources are present on the site. This would be the most important step to determine if mineral extraction could become feasible from an economic and infrastructure perspective.

Finally, the Uranium Leasing Program represents 31 lease tracts in the Uravan Mineral Belt in southwestern Colorado and is designed for the use of lands for mineral extraction. Currently, 29 lease tracts are active and two are permanently inactive. Figure 55 depicts these tracts, which may represent a superior investment in time and resources for the development nuclear material resources. DOE issued a final EIS for the Uranium Leasing Program in 2014, which indicates significant progress toward the addition of mines and infrastructure to these available lease tracts.[130]

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[130] DOE. 2014. *Final Uranium Leasing Program Programmatic Environmental Impact Statement.* No. DOE/EIS-0472. U.S. Department of Energy Legacy Management, Westminster, Colorado.

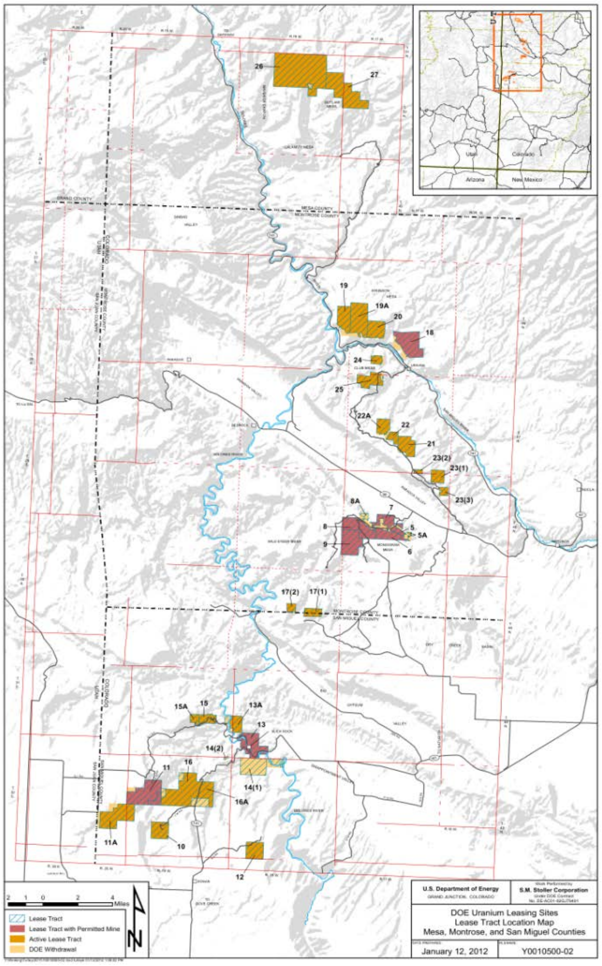

Figure 55. Uranium Leasing Program tract locations and status as of 2012

Source: U.S. Department of Energy[131]

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[131] DOE. 2014. *Final Uranium Leasing Program Programmatic Environmental Impact Statement*. (No. DOE/EIS-0472). U.S. Department of Energy Legacy Management, Westminster, Colorado.

5 Conclusions

This report summarizes an assessment of the potential for independent power producers to generate large-scale power on DOE lands and export that power into a larger power market, rather than serving on-site DOE loads. The analysis considered the potential for technologies for power production that are commercially viable at utility scale, including PV, CSP, wind, biomass, LFG, WTE, and geothermal technologies, as well as the availability of fossil fuels, uranium, or thorium resources for power production at 55 DOE sites. The methodology applied relied on LCOE as a primary screening metric, following the practice applied in previous assessments.

A high-level, portfolio-wide screening analysis of RE project potential determined techno-economic potential for at least one type of renewable energy technology at every site. The portfolio analysis considered the technical potential of geothermal, fossil fuels, and uranium or thorium resources: four sites showed good indication of hosting hydrothermal reservoirs, six sites were considered to have distinct potential for oil and gas production, eight sites in coal producing basins were not eliminated from consideration (because coal resources were present, but of uncertain potential), and nineteen sites were located within 15 miles of a previous or present uranium site listed on the USGS MRDS.

A market barriers and opportunities analysis methodology was developed and applied to the sites deemed most promising—via a techno-economic analysis—as illustrative examples of project development considerations and processes. In general, the top two projects with the lowest LCOE were selected for each RE technology evaluated, though for some technologies additional sites were analyzed as time and resources allowed. Nine of the seventeen potential projects evaluated contained one or more disqualifying criteria that would prevent development of the proposed technology at the site.[132] The most common disqualifying factors facing the sites were, in order: site unavailability, poor project economics, and permitting restrictions. Of the eight sites which were not excluded by disqualifying criteria, three sites merit further investigation for RE development due to their current relative economic attractiveness when compared with existing retail power rates: LANL, Shirley Basin South, and the Bannister Kansas City Plant. These sites could be candidates for an RFI to gauge development interest, but would require additional detailed analysis of the site's interconnection infrastructure, as well as the environmental impacts of a proposed project, prior to any RFI submittal. Finally, given the rapidly changing nature of the market conditions and technological improvements for many of these technologies, the offtake and economic viability of the examined projects are subject to change in the future and should be periodically re-evaluated.

Various DOE sites have successfully implemented both small- and large-scale RE projects, including PV at BNL and NREL, wind at Pantex, and biomass at the Savannah River Site as well as on-site mining of resources, such as the Uranium Leasing Program in Colorado. The PV project at BNL is the only known large system in the DOE complex which exports all power off site. In order to fully evaluate the potential for large-scale project development for power export

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[132] Projects without red color-coding in the market barriers and opportunities analysis summary in Table 6: NNSS (three sites), LANL, Shirley, FNAL, Grand Junction, Kansas City, and CNTA.

on DOE lands, it would be helpful to apply a project development framework—such as the market barriers and opportunities analysis framework—to a larger subset of sites, starting with those sites that show the highest techno-economic potential. While it was not in the scope of this report, DOE could also continue to pursue RE projects dedicated to serving on-site energy loads or to meeting research purposes.

This report also summarizes an assessment of the potential for commercial development of fossil fuel and nuclear material resources on these same 55 sites. While RE resources were examined for commercial power production potential, fossil fuel and nuclear material resources were examined only for extraction potential. For fossil fuel resources, a high-level screening for the potential presence of oil, gas, or coal resources was conducted. Further analysis could examine the small number of sites that were not screened out to determine whether additional sites should be eliminated. A more detailed market barriers and opportunities analysis that considered additional factors contributing to technical and economic viability could then be conducted for the most promising sites. For nuclear material resources, a two-step screening for the potential presence of uranium or thorium resources was performed, followed by a market barriers and opportunities analysis for the five highest-ranked sites that emerged from the screening. An important next step would be to perform a mineral survey at each of these sites to determine if nuclear resources are indeed present. An inquiry with respect to 10 CFR 40 could also be made to determine if mining operations can be performed at the disposal cell sites.

DOE can prepare for fossil fuel or nuclear material resource extraction development by reviewing its own process for making land available to companies interested in leasing land, so that the agency can react quickly should a resource be identified or a developer express interest in a particular DOE site. DOE may also wish to put in place a plan to review the potential of the resource at regular intervals, and might consider offering favorable leasing terms to companies proposing to test novel technology for energy development.

Each resource or technology screening was conducted independently; the use of lands for the development of one resource or technology would necessarily reduce the availability of those lands for other energy project development, and this consideration was not taken into account in this analysis. Further, given differences in the screening methodologies applied for renewable energy, fossil fuel, and nuclear material resources, it is not possible to compare opportunities between these types of resources.

Appendix A. U.S. Department of Energy Site Data

Table 40 lists all sites and site-specific information provided by DOE. All land area was assumed to be contiguous and available for energy project development.

Table 40. DOE-Owned Lands with Power Export Potential

Site	City	County	State	Program Office	Longitude	Latitude	Acreage
Albany, OR, Site	Albany	Linn	OR	LM	-123.12	44.62	16
Ambrosia Lake, NM, Disposal Site	Grants	McKinley	NM	LM	-107.80	35.41	315
Argonne National Laboratory (ANL)	Argonne	DuPage	IL	EM, SC	-93.65	41.72	1,700
Bluewater, NM, Disposal Site	Bluewater	Cibola	NM	LM	-107.95	35.27	3,305
Bonneville Power Administration (BPA) Ross Complex	Vancouver	Clark	WA	BPA	-122.66	45.66	250
Brookhaven National Laboratory (BNL)	Upton	Suffolk	NY	EM, SC	-72.87	40.86	5,274
Burrell, PA, Disposal Site	Burrell	Indiana	PA	LM	-79.24	40.43	73
Canonsburg. PA, Disposal Site	Canonsburg	Washington	PA	LM	-80.20	40.26	34
Central Nevada Test Area (CNTA), NV Site	Tonopah	Nye	NV	LM	-116.18	38.17	2,560
Durango, CO, Disposal Site	Durango	La Plata	CO	LM	-107.90	37.25	120
Edgemont, SD, Site	Edgemont	Fall River	SD	LM	-103.79	43.27	360
Falls City, TX, Disposal Site	Falls City	Wilson	TX	LM	-98.13	28.91	744
Fermi National Accelerator Laboratory (FNAL)	Batavia	Kane/DuPage	IL	SC	-88.26	41.83	6,811
Gasbuggy, NM, Site	Farmington	Rio Arriba	NM	LM	-107.21	36.68	640
Gnome-Coach, NM, Site	Carlsbad	Eddy	NM	LM	-103.87	32.26	680
Grand Junction, CO, Disposal Site	Grand Junction	Mesa	CO	LM	-108.34	38.90	360
Green River, UT, Disposal Site	Green River	Emery	UT	LM	-110.14	38.98	26
Gunnison, CO, Disposal Site	Gunnison	Gunnison	CO	LM	-106.85	38.51	115
Hanford Site	Richland	Benton	WA	EM	-119.52	46.56	307,467
Idaho National [Engineering] Laboratory (INL)	Idaho Falls	Butte/ Bingham/ Bonneville/ Jefferson	ID	EM, NE	-112.94	43.53	64,467
Kansas City Plant	Kansas City	Jackson	MO	NNSA	-94.55	38.86	136

Site	City	County	State	Program Office	Longitude	Latitude	Acreage
Lakeview, OR, Disposal Site	Lakeview	Lake	OR	LM	-120.43	42.29	40
Lawrence Livermore National Laboratory (LLNL) Main Campus	Livermore	Alameda	CA	NNSA	-121.70	37.69	640
Lawrence Livermore National Laboratory (Site 300)	Tracy	Alameda	CA	NNSA	-121.58	37.64	2,782
L-Bar, NM, Disposal Site	Seboyeta	Cibola	NM	LM	-107.33	35.19	738
Los Alamos National Laboratory (LANL)	Los Alamos	Sandoval	NM	EM, NNSA	-106.32	35.87	28,000
Lowman, ID, Disposal Site	Boise	Boise	ID	LM	-115.61	44.08	18
Maybell West, CO, Disposal Site	Maybell	Moffat	CO	LM	-108.02	40.54	250
Maybell, CO, Disposal Site	Maybell	Moffat	CO	LM	-107.99	40.54	250
Moab, UT, Site	Moab	Grand	UT	EM	-108.57	39.07	439
Monticello, UT, Disposal and Processing Sites	Monticello	San Juan	UT	LM	-109.33	37.85	995
National Energy Technology Laboratory (NETL)	Pittsburgh	Allegheny	PA	FE/ EERE/ Electricity Delivery & Energy Reliability	-79.98	40.30	63
National Energy Technology Laboratory	Albany	Linn	OR	FE/ EERE/ Electricity Delivery & Energy Reliability	-123.12	44.62	44
National Energy Technology Laboratory	Morgantown	Monongalia	WV	FE/ EERE/ Electricity Delivery & Energy Reliability	-79.98	39.67	136
National Renewable Energy Laboratory (NREL)	Golden	Jefferson	CO	EERE	-105.17	39.74	632
Naturita, CO, Disposal Site	Naturita	Montrose	CO		-108.76	38.36	27
Nevada National Security Site (NNSS)	Mercury	Nye	NV	NNSA	-116.19	36.99	775,680
Oak Ridge Site	Oak Ridge	Anderson/ Roane	TN	EM, SC	-84.32	35.93	71,584
Paducah Gaseous Diffusion Plant	Paducah	McCracken	KY	EM	-88.81	37.12	3,556
Pantex Plant	Pantex Village	Carson	TX	NNSA	-101.56	35.32	3,170
Parkersburg, WV, Site	Parkersburg	Wood	WV	LM	-81.69	39.25	16
Portsmouth Gaseous Diffusion Plant	Piketon	Pike	OH	EM	-83.00	39.01	3,708
Rifle, CO, Disposal Site	Rifle	Garfield	CO	LM	-107.80	39.61	205

Site	City	County	State	Program Office	Longitude	Latitude	Acreage
Rio Blanco, CO, Site	Rio Blanco	Rio Blanco	CO	LM	-108.37	39.79	360
Salt Lake City, UT, Disposal Site	Salt Lake City	Salt Lake	UT	LM	-113.11	40.69	99
Sandia National Laboratories (SNL) Albuquerque	Albuquerque	Bernalillo	NM	EM, NNSA	-106.53	35.06	193,000
Savannah River Site	Aiken	Aiken/Barnwell/ Allendale	SC	EM, NNSA	-81.74	33.35	180,000
Separations Process Research Unit (SPRU)	Niskayuna	Schenectady	NY	NR	-73.87	42.82	200
Shirley Basin South, WY, Disposal Site	Casper	Carbon	WY	LM	-106.17	42.36	1,527
Shoal, NV, Site	Fallon	Churchill	NV	LM	-118.39	39.20	2,560
Slick Rock, CO, Disposal Cell	Slick Rock	San Miguel	CO	LM	-108.86	38.05	61
Spook, WY, Site	Glenrock	Converse	WY	LM	-105.62	43.24	22
Thomas Jefferson National Accelerator Facility	Newport News	None (Independent City)	VA	SC	-76.48	37.10	171
Waste Isolation Pilot Plant (WIPP)	Carlsbad	Eddy	NM	EM	-103.79	32.38	10,240
Weldon Spring, MO, Site	St. Louis	St. Charles	MO	LM	-90.73	38.70	267

Appendix B. Renewable Energy Portfolio Analysis Results

Table 41 through Table 46 show the systems sizes, electricity produced, and LCOE for each technology at each site. The embedded Energy Resource Potential for DOE Lands workbook contains more detailed analysis parameters including:

- System Capacity (kW)
- System Installed Cost ($)
- NPV of ITC ($)
- NPV of MACRS ($)
- Unit Cost of Original Cost ($/kW)
- Annual O&M Costs ($/yr)
- O&M Unit Cost ($/kW)
- Area Required (acres)
- Assumed System Density (acres/MW)
- Electric Produced (kWh/yr)
- Electric LCOE ($/kWh)
- First Year Production Incentives ($)
- Average Capacity Factor (%)
- Limiting Factor

Figure 56 through Figure 61 show the results of the sensitivity analysis. The data behind these graphs can also be found in the embedded Energy Resource Potential for DOE Lands workbook.

- 1a. Lower Discount Rate
- 1b. Higher Discount Rate
- 2a. Lower Technology Cost
- 2b. Higher Technology Cost
- 3a. Higher Energy Output
- 3b. Lower Energy Output
- 4a. Lower LCOE Custom
- 4b. Higher LCOE Custom

The LCOEs for a single axis tracking PV system were calculated for all 55 sites and are shown in Table 41.

Table 41. PV LCOEs Sorted from Lowest to Highest

Site	System Capacity (kW)	Electricity Produced (kWh/yr)	Electric LCOE ($/kWh)	Limiting Factor
NNSS	100,000	199,323,398	$0.082	Max Size
LANL	62,842	125,515,279	$0.082	Transmission Capacity
SNL	100,000	192,934,148	$0.085	Max Size
L-Bar, NM, Disposal Site	84,595	163,212,642	$0.085	Transmission Capacity
CNTA, NV Site	84,824	163,266,003	$0.085	Transmission Capacity
Bluewater, NM, Disposal Site	94,158	179,970,674	$0.086	Transmission Capacity
Ambrosia Lake, NM, Disposal Site	45,000	86,011,601	$0.086	Land Availability
Shoal, NV, Site	100,000	188,073,786	$0.087	Max Size
Gasbuggy, NM, Site	84,090	157,866,806	$0.087	Transmission Capacity
Waste Isolation Pilot Plant (WIPP)	100,000	185,266,516	$0.088	Max Size
Gnome-Coach, NM, Site	57,098	105,783,475	$0.089	Transmission Capacity
Durango, CO, Disposal Site	17,143	32,183,233	$0.089	Land Availability
Moab, UT, Site	62,714	114,951,935	$0.090	Land Availability
Pantex Plant	100,000	182,060,274	$0.090	Max Size
Monticello, UT, Disposal and Processing Sites	37,494	68,612,534	$0.090	Transmission Capacity
Gunnison, CO, Disposal Site	16,429	30,527,060	$0.090	Land Availability
Grand Junction, CO, Disposal Site	51,429	91,844,177	$0.092	Land Availability
LLNL, Site 300	100,000	175,950,185	$0.093	Max Size
LLNL, Main	55,495	97,643,555	$0.093	Transmission Capacity

Site	System Capacity (kW)	Electricity Produced (kWh/yr)	Electric LCOE ($/kWh)	Limiting Factor
Slick Rock, CO, Disposal Cell	8,714	15,946,797	$0.094	Land Availability
Salt Lake City, UT, Disposal Site	14,143	25,060,337	$0.095	Land Availability
Maybell, CO, Disposal Site	35,714	59,995,498	$0.098	Land Availability
Naturita, CO, Disposal Site	3,857	7,069,937	$0.098	Land Availability
Green River, UT, Disposal Site	3,714	6,808,087	$0.098	Land Availability
Maybell West, CO, Disposal Site	31,682	53,221,766	$0.099	Transmission Capacity
Shirley Basin South, WY, Disposal Site	98,810	162,522,150	$0.100	Transmission Capacity
Rio Blanco, CO, Site	51,429	84,838,634	$0.100	Land Availability
Rifle, CO, Disposal Site	29,286	48,310,889	$0.100	Land Availability
INL	36,284	59,253,885	$0.101	Transmission Capacity
ORNL Site	100,000	144,810,939	$0.102	Max Size
NREL	90,286	144,440,932	$0.102	Land Availability
Edgemont, SD, Site	39,299	63,191,900	$0.103	Transmission Capacity
Lakeview, OR, Disposal Site	5,714	9,818,211	$0.103	Land Availability
Thomas Jefferson National Accelerator Facility	24,429	35,535,033	$0.104	Land Availability
Paducha Gaseous Diffusion Plant	100,000	142,545,366	$0.104	Max Size
Savannah River Site	100,000	155,684,584	$0.105	Max Size
Falls City, TX, Disposal Site	100,000	153,418,730	$0.107	Max Size
Spook, WY, Site	3,143	5,169,354	$0.110	Land Availability
FNAL	100,000	134,711,849	$0.111	Max Size
Hanford Site	80,268	118,576,314	$0.111	Transmission Capacity

Site	System Capacity (kW)	Electricity Produced (kWh/yr)	Electric LCOE ($/kWh)	Limiting Factor
Kansas City Plant	19,429	29,257,891	$0.111	Land Availability
Portsmouth Gaseous Diffusion Plant	100,000	134,013,399	$0.111	Max Size
ANL	100,000	132,809,850	$0.112	Max Size
Lowman, ID, Disposal Site	2,571	4,105,202	$0.114	Land Availability
Weldon Spring, MO, Site	38,143	53,459,493	$0.118	Land Availability
SPRU	28,571	38,702,884	$0.122	Land Availability
BNL	59,128	76,103,102	$0.128	Transmission Capacity
Canonsburg, PA, Disposal Site	4,857	6,217,396	$0.130	Land Availability
NETL, OR	6,286	8,397,002	$0.132	Land Availability
Burrell, PA, Disposal Site	10,429	12,274,624	$0.135	Land Availability
Albany, OR, Site	2,286	3,053,455	$0.136	Land Availability
BPA Ross Complex	35,714	43,002,213	$0.137	Land Availability
NETL, WV	19,429	21,868,449	$0.138	Land Availability
NETL, PA	9,000	10,355,488	$0.139	Land Availability
Parkersburg, WV, Site	2,286	2,632,977	$0.147	Land Availability

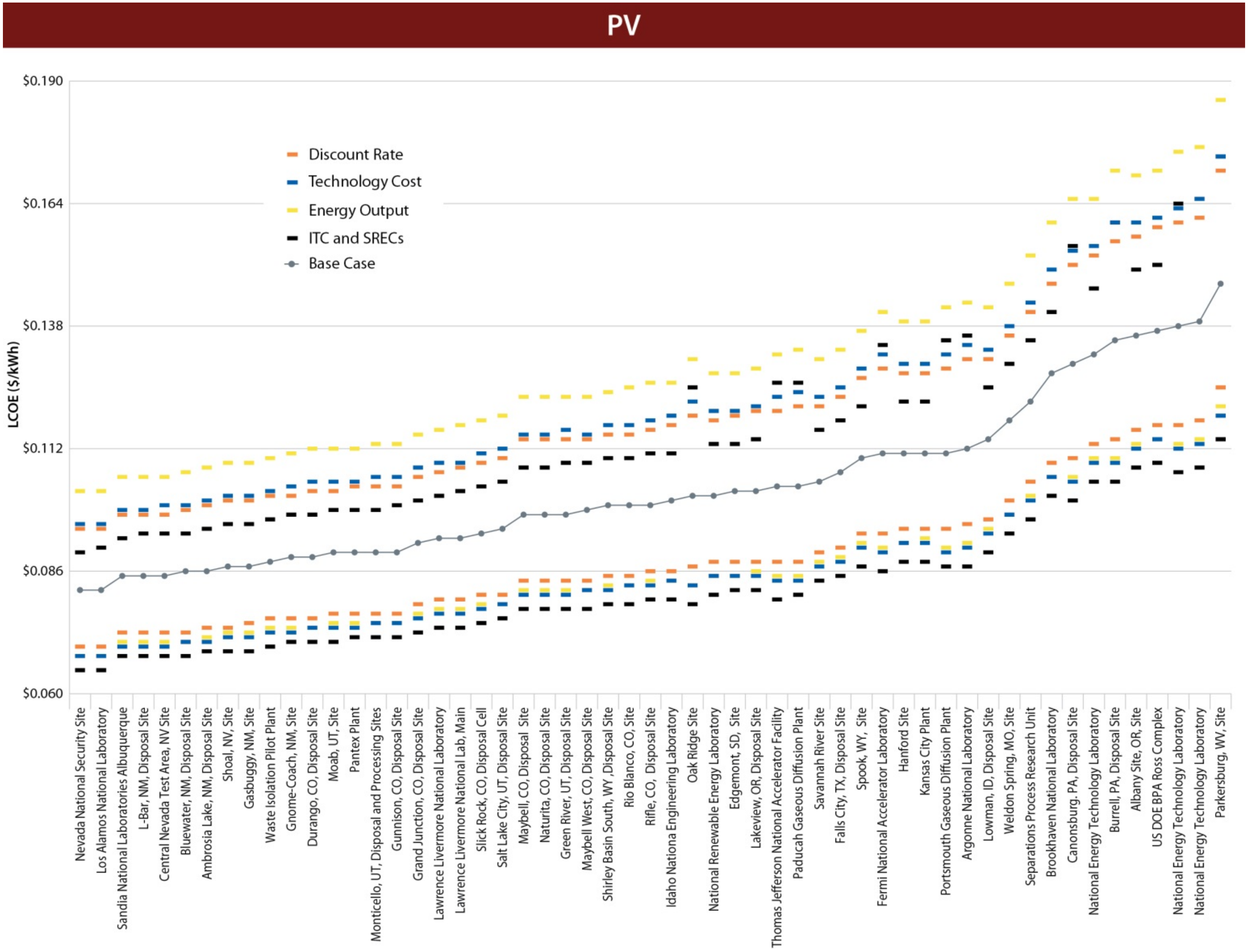

Figure 56. LCOE sensitivity analysis for PV

The LCOEs for wind projects were calculated at all 55 sites except one, which was located in a valley in Idaho where the wind resource was not strong enough for a wind project to be feasible. They are shown in Table 42.

Table 42. Wind LCOEs Sorted from Lowest to Highest

Site	System Capacity (kW)	Electricity Produced (kWh/yr)	Electric LCOE ($/kWh)	Limiting Factor
Pantex Plant	100,000	423,136,973	$0.042	Max Size
Shirley Basin South, WY, Disposal Site	50,900	182,797,461	$0.050	Land Availability
Gnome-Coach, NM, Site	22,667	81,050,614	$0.051	Land Availability
Edgemont, SD, Site	12,000	42,026,934	$0.052	Land Availability
Waste Isolation Pilot Plant (WIPP)	100,000	320,653,908	$0.056	Max Size
Kansas City Plant	4,533	15,548,148	$0.056	Land Availability
LLNL, Site 300	92,733	279,581,978	$0.059	Land Availability
FNAL	100,000	301,365,185	$0.059	Max Size
ANL	56,667	171,051,350	$0.059	Land Availability
Falls City, TX, Disposal Site	24,800	71,347,169	$0.063	Land Availability
BNL	59,128	165,411,084	$0.064	Transmission Capacity
Rio Blanco, CO, Site	12,000	33,332,789	$0.066	Land Availability
NREL	21,067	51,884,918	$0.074	Land Availability
Monticello, UT, Disposal and Processing Sites	33,167	80,071,488	$0.075	Land Availability
INL	36,284	84,910,382	$0.077	Transmission Capacity
Weldon Spring, MO, Site	8,900	21,243,341	$0.078	Land Availability
NNSS	100,000	225,489,684	$0.082	Max Size
Salt Lake City, UT, Disposal Site	3,300	8,117,874	$0.080	Land Availability
SPRU	6,667	15,251,876	$0.082	Land Availability

Site	System Capacity (kW)	Electricity Produced (kWh/yr)	Electric LCOE ($/kWh)	Limiting Factor
LANL	62,842	126,634,056	$0.089	Transmission Capacity
Spook, WY, Site	733	2,056,433	$0.092	Land Availability
Paducha Gaseous Diffusion Plant	100,000	192,812,344	$0.093	Max Size
Grand Junction, CO, Disposal Site	12,000	22,328,520	$0.099	Land Availability
Shoal, NV, Site	85,333	150,609,927	$0.101	Land Availability
Gasbuggy, NM, Site	21,333	38,057,052	$0.102	Land Availability
L-Bar, NM, Disposal Site	24,600	43,592,587	$0.102	Land Availability
Bluewater, NM, Disposal Site	94,158	160,881,885	$0.105	Transmission Capacity
Durango, CO, Disposal Site	4,000	7,186,079	$0.108	Land Availability
Savannah River Site	100,000	165,356,273	$0.108	Max Size
Thomas Jefferson National Accelerator Facility	5,700	9,965,165	$0.108	Land Availability
Moab, UT, Site	14,633	24,637,311	$0.108	Land Availability
BPA Ross Complex	8,333	13,880,227	$0.112	Land Availability
Burrell, PA, Disposal Site	2,433	4,211,976	$0.118	Land Availability
SNL	100,000	150,185,249	$0.119	Max Size
CNTA, NV Site	84,824	124,318,998	$0.122	Transmission Capacity
NETL, PA	2,100	3,547,748	$0.123	Land Availability
Portsmouth Gaseous Diffusion Plant	100,000	144,903,267	$0.123	Max Size
LLNL, Main	21,333	28,229,157	$0.137	Land Availability
Maybell West, CO, Disposal Site	8,333	11,280,506	$0.137	Land Availability
Maybell, CO, Disposal Site	8,333	11,280,506	$0.137	Land Availability

Site	System Capacity (kW)	Electricity Produced (kWh/yr)	Electric LCOE ($/kWh)	Limiting Factor
Hanford Site	80,268	103,405,014	$0.139	Transmission Capacity
NETL, WV	4,533	6,083,162	$0.143	Land Availability
Ambrosia Lake, NM, Disposal Site	10,500	13,032,062	$0.148	Land Availability
Gunnison, CO, Disposal Site	3,833	4,713,030	$0.158	Land Availability
ORNL Site	100,000	97,050,603	$0.184	Max Size
Slick Rock, CO, Disposal Cell	2,033	2,267,867	$0.188	Land Availability
Canonsburg, PA, Disposal Site	1,133	831,410	$0.319	Land Availability
NETL, OR	1,467	1,006,674	$0.323	Land Availability
Lakeview, OR, Disposal Site	1,333	905,879	$0.332	Land Availability
Albany, OR, Site	533	366,063	$0.391	Land Availability
Parkersburg, WV, Site	533	289,465	$0.495	Land Availability
Green River, UT, Disposal Site	867	436,007	$0.500	Land Availability
Rifle, CO, Disposal Site	6,833	2,556,873	$0.501	Land Availability
Naturita, CO, Disposal Site	900	413,488	$0.541	Land Availability
Lowman, ID, Disposal Site	N/A	N/A	N/A	Resource Availability

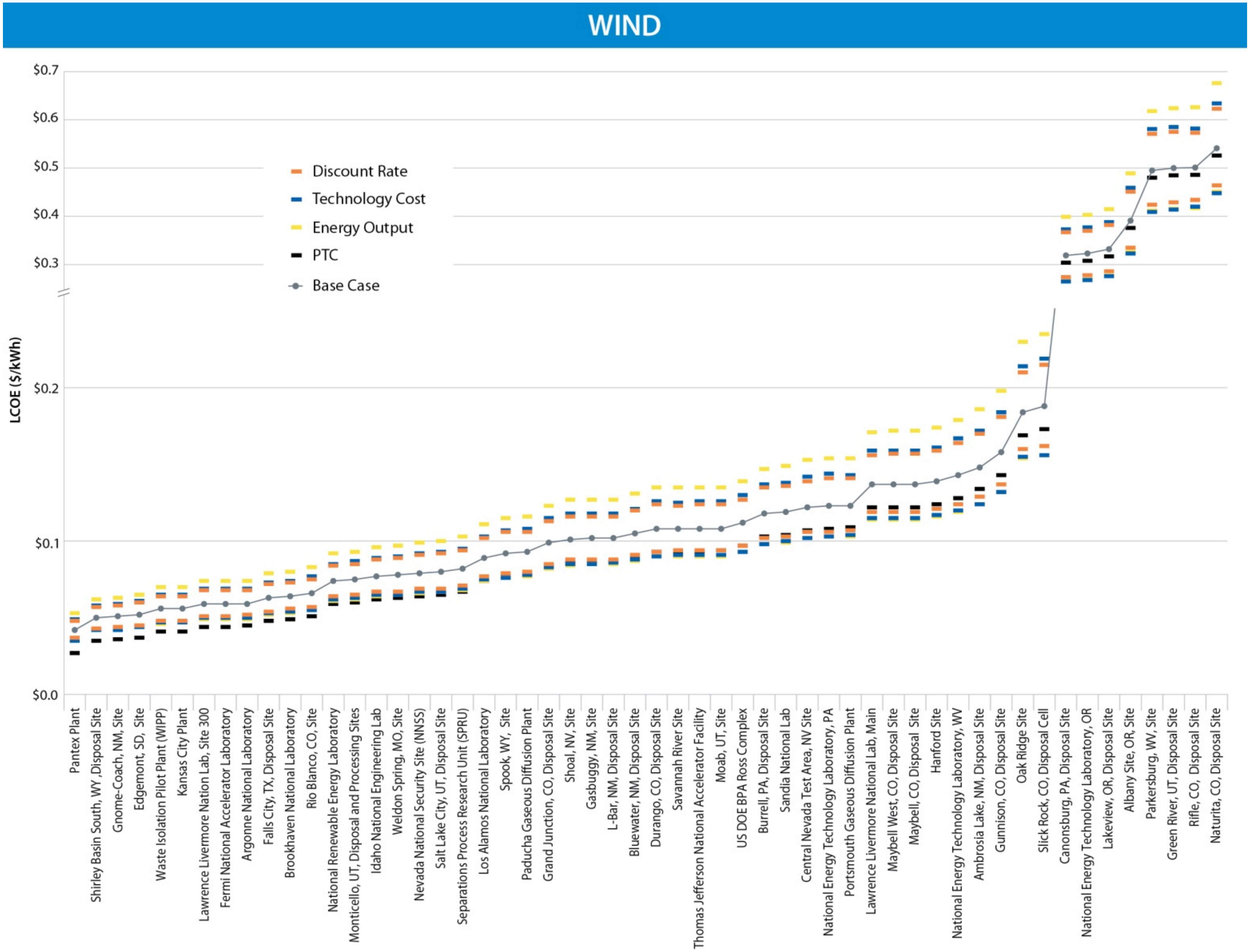

Figure 57. LCOE sensitivity analysis for wind

Biomass projects were evaluated at all 55 sites except three, which were located in parts of Nevada and Utah where no resource (feedstock) was available. The LCOEs are shown in Table 43.

Table 43. Biomass LCOEs Sorted from Lowest to Highest

Site	System Capacity (kW)	Electricity Produced (kWh/yr)	Electric LCOE ($/kWh)	Limiting Factor
SPRU	82,063	611,044,092	$0.091	Resource Availability
FNAL	100,000	744,600,000	$0.097	Max Size
ANL	100,000	744,600,000	$0.097	Max Size
Albany, OR, Site	52,624	391,838,304	$0.102	Transmission Capacity
NETL, OR	100,000	744,600,000	$0.102	Max Size
Savannah River Site	98,662	734,635,534	$0.102	Resource Availability
BPA Ross Complex	100,000	744,600,000	$0.103	Max Size
Paducha Gaseous Diffusion Plant	100,000	744,600,000	$0.105	Max Size
Kansas City Plant	75,634	563,168,439	$0.105	Resource Availability
Thomas Jefferson National Accelerator Facility	87,879	654,348,392	$0.106	Resource Availability
Weldon Spring, MO, Site	90,599	674,603,622	$0.107	Resource Availability
Portsmouth Gaseous Diffusion Plant	87,546	651,868,728	$0.107	Resource Availability
NETL, WV	72,950	543,186,899	$0.113	Resource Availability
Hanford Site	57,378	427,233,498	$0.113	Resource Availability
LLNL, Main	55,495	413,215,770	$0.113	Transmission Capacity
Burrell, PA, Disposal Site	55,257	411,445,880	$0.114	Resource Availability
LLNL, Site 300	58,423	435,015,764	$0.115	Resource Availability
NETL, PA	39,801	296,356,988	$0.117	Resource Availability
ORNL Site	42,497	316,435,521	$0.120	Resource Availability

Site	System Capacity (kW)	Electricity Produced (kWh/yr)	Electric LCOE ($/kWh)	Limiting Factor
BNL	42,825	318,877,231	$0.121	Resource Availability
Canonsburg, PA, Disposal Site	36,525	271,964,345	$0.122	Resource Availability
NREL	23,727	176,668,065	$0.127	Resource Availability
INL	32,387	241,155,782	$0.133	Resource Availability
Parkersburg, WV, Site	23,944	178,289,124	$0.139	Resource Availability
Pantex Plant	19,335	143,967,282	$0.147	Resource Availability
Falls City, TX, Disposal Site	12,029	89,565,641	$0.184	Resource Availability
Edgemont, SD, Site	9,856	73,391,314	$0.206	Resource Availability
Lakeview, OR, Disposal Site	8,652	64,424,039	$0.219	Resource Availability
Lowman, ID, Disposal Site	8,653	64,427,834	$0.219	Resource Availability
SNL	5,225	38,908,378	$0.246	Resource Availability
Grand Junction, CO, Disposal Site	5,998	44,660,946	$0.253	Resource Availability
LANL	3,885	28,928,151	$0.285	Resource Availability
Naturita, CO, Disposal Site	3,364	25,050,513	$0.295	Resource Availability
Durango, CO, Disposal Site	2,781	20,709,835	$0.318	Resource Availability
Gasbuggy, NM, Site	2,317	17,250,113	$0.337	Resource Availability
Slick Rock, CO, Disposal Cell	2,353	17,521,696	$0.339	Resource Availability
Rifle, CO, Disposal Site	1,722	12,823,407	$0.390	Resource Availability
Shirley Basin South, WY, Disposal Site	1,700	12,661,048	$0.392	Resource Availability
Monticello, UT, Disposal and Processing Sites	1,469	10,937,934	$0.425	Resource Availability
Gunnison, CO, Disposal Site	1,462	10,886,485	$0.427	Resource Availability

Site	System Capacity (kW)	Electricity Produced (kWh/yr)	Electric LCOE ($/kWh)	Limiting Factor
Waste Isolation Pilot Plant (WIPP)	817	6,082,346	$0.605	Resource Availability
Ambrosia Lake, NM, Disposal Site	174	1,298,872	$0.642	Resource Availability
Maybell West, CO, Disposal Site	130	968,250	$0.644	Resource Availability
Maybell, CO, Disposal Site	131	976,684	$0.644	Resource Availability
Gnome-Coach, NM, Site	398	2,961,681	$0.648	Resource Availability
Bluewater, NM, Disposal Site	551	4,100,302	$0.658	Resource Availability
Rio Blanco, CO, Site	383	2,854,988	$0.658	Resource Availability
Spook, WY, Site	111	826,555	$0.659	Resource Availability
L-Bar, NM, Disposal Site	25	185,131	$0.660	Resource Availability
Moab, UT, Site	543	4,043,793	$0.663	Resource Availability
Shoal, NV, Site	273	2,030,541	$0.665	Resource Availability
Green River, UT, Disposal Site	29	212,964	$0.666	Resource Availability
CNTA, NV Site	N/A	N/A	N/A	Resource Availability
NNSS	N/A	N/A	N/A	Resource Availability
Salt Lake City, UT, Disposal Site	N/A	N/A	N/A	Resource Availability

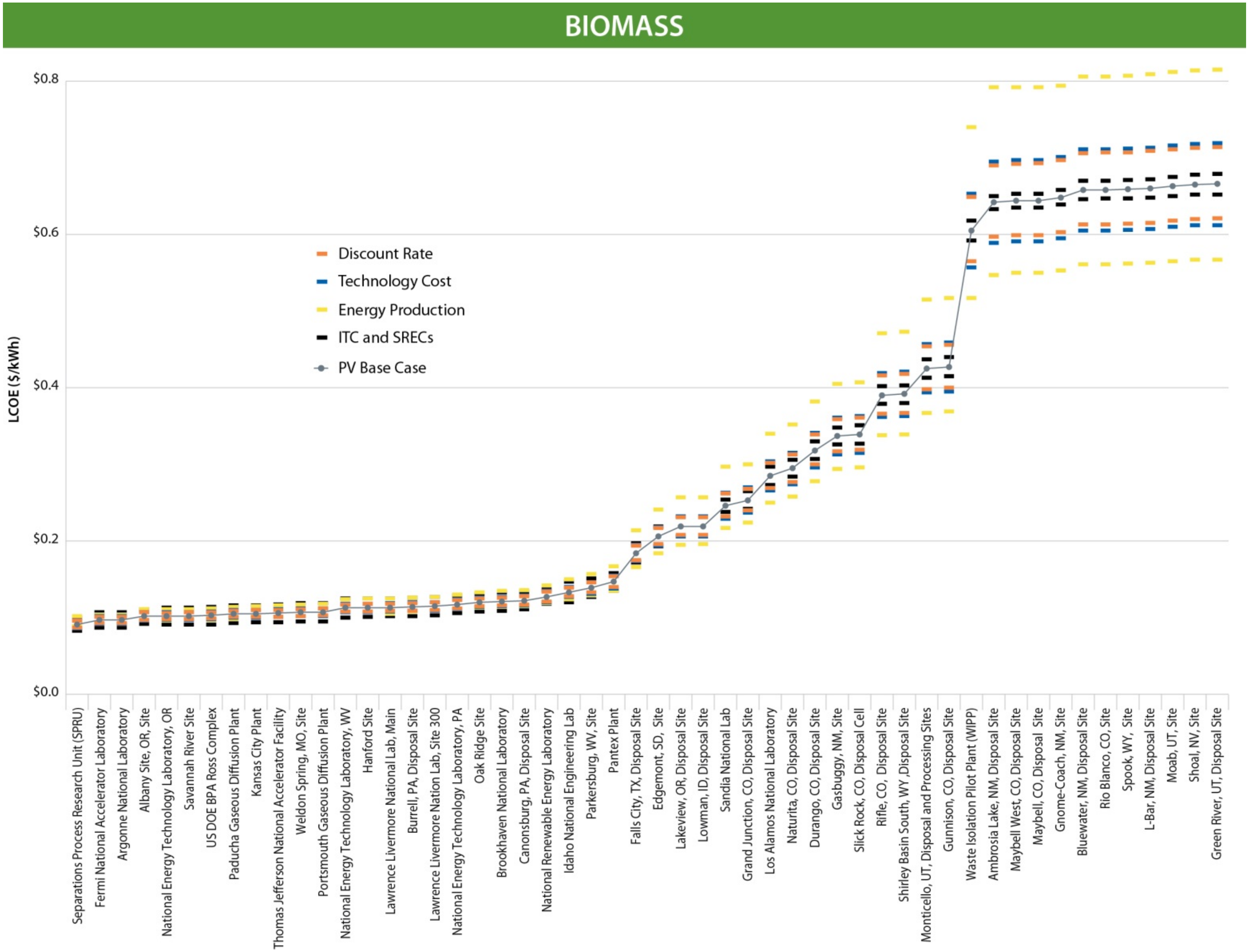

Figure 58. LCOE sensitivity analysis for biomass

The LCOEs for LFG were calculated at eight sites; the remaining 47 sites were not located within a 15 mile radius of a candidate landfill as identified by EPA's LMOP. The LCOEs are shown in Table 44.

Table 44. LFG LCOEs Sorted from Lowest to Highest

Site	System Capacity (kW)	Electricity Produced (kWh/yr)	Electric LCOE ($/kWh)	Limiting Factor
Grand Junction, CO, Disposal Site	6,760	50,340,476	$0.081	Resource Availability
NETL, PA	2,480	18,468,104	$0.086	Resource Availability
Kansas City Plant	2,470	18,393,636	$0.091	Resource Availability
Burrell, PA, Disposal Site	2,030	15,117,036	$0.092	Resource Availability
Portsmouth Gaseous Diffusion Plant	1,730	12,882,992	$0.093	Resource Availability
Parkersburg, WV, Site	2,610	19,436,190	$0.094	Resource Availability
ORNL Site	2,360	17,574,486	$0.104	Resource Availability
NREL	1,300	9,680,861	$0.108	Resource Availability
Albany, OR, Site	N/A	N/A	N/A	Resource Availability
Ambrosia Lake, NM, Disposal Site	N/A	N/A	N/A	Resource Availability
ANL	N/A	N/A	N/A	Resource Availability
Bluewater, NM, Disposal Site	N/A	N/A	N/A	Resource Availability
BNL	N/A	N/A	N/A	Resource Availability
Canonsburg, PA, Disposal Site	N/A	N/A	N/A	Resource Availability
CNTA, NV Site	N/A	N/A	N/A	Resource Availability
Durango, CO, Disposal Site	N/A	N/A	N/A	Resource Availability
Edgemont, SD, Site	N/A	N/A	N/A	Resource Availability
Falls City, TX, Disposal Site	N/A	N/A	N/A	Resource Availability
FNAL	N/A	N/A	N/A	Resource Availability

Site	System Capacity (kW)	Electricity Produced (kWh/yr)	Electric LCOE ($/kWh)	Limiting Factor
Gasbuggy, NM, Site	N/A	N/A	N/A	Resource Availability
Gnome-Coach, NM, Site	N/A	N/A	N/A	Resource Availability
Green River, UT, Disposal Site	N/A	N/A	N/A	Resource Availability
Gunnison, CO, Disposal Site	N/A	N/A	N/A	Resource Availability
Hanford Site	N/A	N/A	N/A	Resource Availability
IINL	N/A	N/A	N/A	Resource Availability
Lakeview, OR, Disposal Site	N/A	N/A	N/A	Resource Availability
LLNL, Main	N/A	N/A	N/A	Resource Availability
LLNL, Site 300	N/A	N/A	N/A	Resource Availability
L-Bar, NM, Disposal Site	N/A	N/A	N/A	Resource Availability
LANL	N/A	N/A	N/A	Resource Availability
Lowman, ID, Disposal Site	N/A	N/A	N/A	Resource Availability
Maybell West, CO, Disposal Site	N/A	N/A	N/A	Resource Availability
Maybell, CO, Disposal Site	N/A	N/A	N/A	Resource Availability
Moab, UT, Site	N/A	N/A	N/A	Resource Availability
Monticello, UT, Disposal and Processing Sites	N/A	N/A	N/A	Resource Availability
NETL, OR	N/A	N/A	N/A	Resource Availability
NETL, WV	N/A	N/A	N/A	Resource Availability
Naturita, CO, Disposal Site	N/A	N/A	N/A	Resource Availability
NNSS	N/A	N/A	N/A	Resource Availability
Paducha Gaseous Diffusion Plant	N/A	N/A	N/A	Resource Availability

Site	System Capacity (kW)	Electricity Produced (kWh/yr)	Electric LCOE ($/kWh)	Limiting Factor
Pantex Plant	N/A	N/A	N/A	Resource Availability
Rifle, CO, Disposal Site	N/A	N/A	N/A	Resource Availability
Rio Blanco, CO, Site	N/A	N/A	N/A	Resource Availability
Salt Lake City, UT, Disposal Site	N/A	N/A	N/A	Resource Availability
SNL	N/A	N/A	N/A	Resource Availability
Savannah River Site	N/A	N/A	N/A	Resource Availability
SPRU	N/A	N/A	N/A	Resource Availability
Shirley Basin South, WY, Disposal Site	N/A	N/A	N/A	Resource Availability
Shoal, NV, Site	N/A	N/A	N/A	Resource Availability
Slick Rock, CO, Disposal Cell	N/A	N/A	N/A	Resource Availability
Spook, WY, Site	N/A	N/A	N/A	Resource Availability
Thomas Jefferson National Accelerator Facility	N/A	N/A	N/A	Resource Availability
BPA Ross Complex	N/A	N/A	N/A	Resource Availability
WIPP	N/A	N/A	N/A	Resource Availability
Weldon Spring, MO, Site	N/A	N/A	N/A	Resource Availability

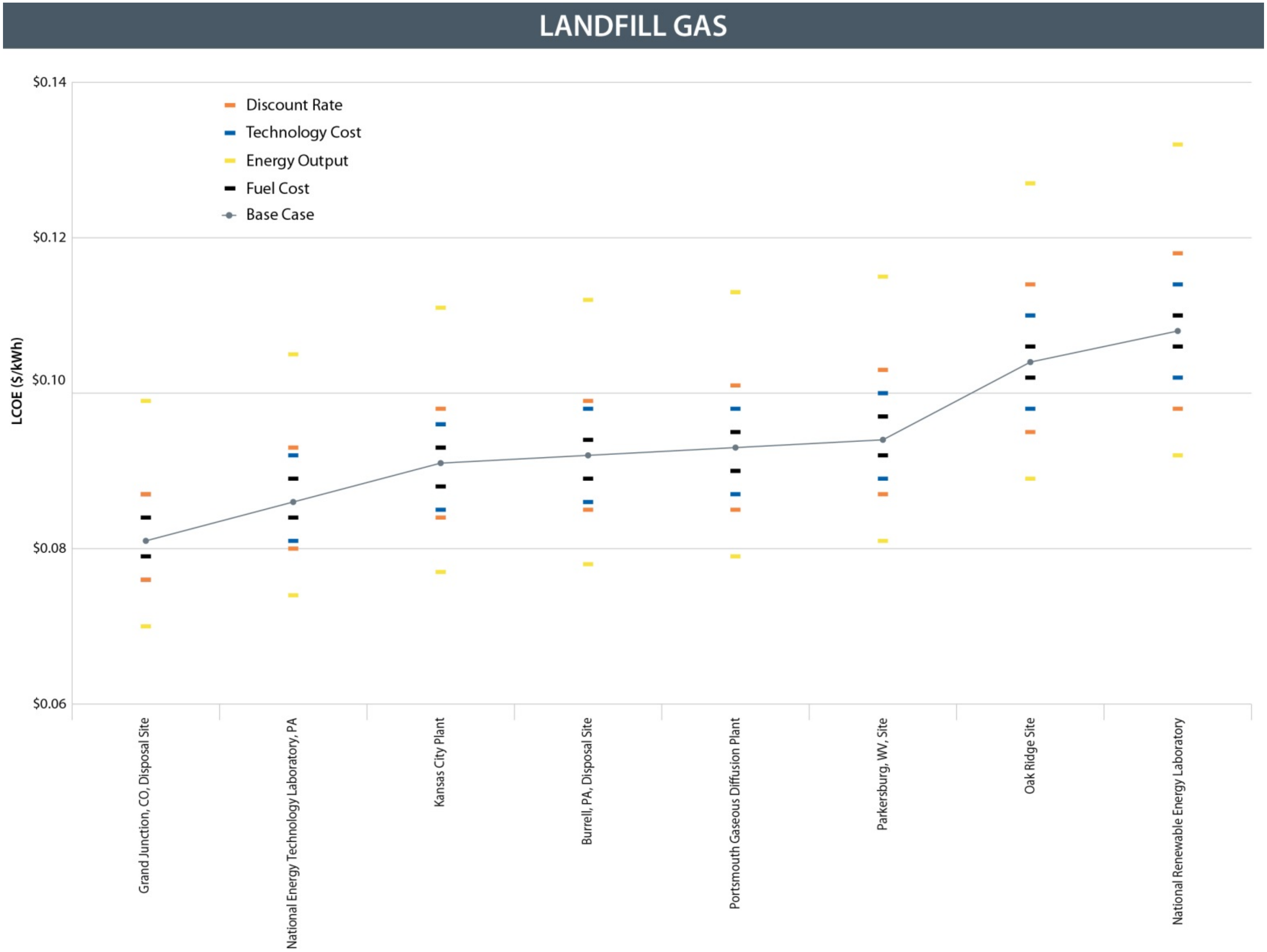

Figure 59. LCOE sensitivity analysis for LFG

WTE projects were evaluated all 55 sites except one, located in a remote part of Nevada where no resource (waste stream) was available. The LCOEs are shown in Table 45.

Table 45. WTE LCOEs Sorted from Lowest to Highest

Site	System Capacity (kW)	Electricity Produced (kWh/yr)	Electric LCOE ($/kWh)	Limiting Factor
BPA Ross Complex	100,000	744,681,600	-$0.025	Max Size
ANL	100,000	744,681,600	-$0.005	Max Size
Canonsburg, PA, Disposal Site	100,000	744,681,600	-$0.005	Max Size
FNAL	100,000	744,681,600	-$0.005	Max Size
LLNL, Site 300	100,000	744,681,600	-$0.005	Max Size
NETL, PA	100,000	744,681,600	-$0.005	Max Size
Thomas Jefferson National Accelerator Facility	100,000	744,681,600	-$0.005	Max Size
Kansas City Plant	91,994	685,063,475	-$0.003	Resource Availability
Weldon Spring, MO, Site	67,248	500,785,038	$0.005	Resource Availability
BNL	55,242	411,375,132	$0.008	Resource Availability
LLNL, Main	55,495	413,261,054	$0.012	Transmission Capacity
NREL	100,000	744,681,600	$0.020	Max Size
SPRU	41,300	307,553,891	$0.021	Resource Availability
Burrell, PA, Disposal Site	34,499	256,907,839	$0.035	Resource Availability
SNL	47,673	355,011,681	$0.048	Resource Availability
ORNL Site	32,465	241,761,244	$0.057	Resource Availability
NETL, OR	30,066	223,899,024	$0.060	Resource Availability
Albany, OR, Site	29,503	219,702,614	$0.061	Resource Availability
NETL, WV	21,805	162,376,782	$0.066	Resource Availability

Site	System Capacity (kW)	Electricity Produced (kWh/yr)	Electric LCOE ($/kWh)	Limiting Factor
Savannah River Site	25,923	193,047,225	$0.071	Resource Availability
Parkersburg, WV, Site	14,439	107,521,917	$0.091	Resource Availability
Pantex Plant	15,235	113,450,185	$0.122	Resource Availability
Portsmouth Gaseous Diffusion Plant	12,623	94,000,677	$0.127	Resource Availability
Grand Junction, CO, Disposal Site	12,383	92,214,926	$0.132	Resource Availability
Paducha Gaseous Diffusion Plant	10,858	80,856,263	$0.145	Resource Availability
Hanford Site	7,039	52,419,827	$0.147	Resource Availability
LANL	7,707	57,391,702	$0.185	Resource Availability
Durango, CO, Disposal Site	4,963	36,955,005	$0.250	Resource Availability
Falls City, TX, Disposal Site	4,371	32,553,288	$0.282	Resource Availability
Spook, WY, Site	128	955,537	$0.393	Resource Availability
Shirley Basin South, WY, Disposal Site	108	803,695	$0.393	Resource Availability
Rifle, CO, Disposal Site	2,744	20,435,413	$0.410	Resource Availability
CNTA, NV Site	140	1,041,510	$0.417	Resource Availability
Lowman, ID, Disposal Site	393	2,923,928	$0.417	Resource Availability
Moab, UT, Site	397	2,959,856	$0.417	Resource Availability
Monticello, UT, Disposal and Processing Sites	174	1,296,862	$0.417	Resource Availability
INL	332	2,473,533	$0.417	Resource Availability
Shoal, NV, Site	306	2,281,485	$0.417	Resource Availability
Salt Lake City, UT, Disposal Site	99	736,115	$0.417	Resource Availability
Green River, UT, Disposal Site	93	689,493	$0.417	Resource Availability

Site	System Capacity (kW)	Electricity Produced (kWh/yr)	Electric LCOE ($/kWh)	Limiting Factor
Edgemont, SD, Site	401	2,985,948	$0.424	Resource Availability
Lakeview, OR, Disposal Site	365	2,720,330	$0.433	Resource Availability
Maybell West, CO, Disposal Site	717	5,336,724	$0.442	Resource Availability
Maybell, CO, Disposal Site	1,009	7,511,277	$0.442	Resource Availability
Naturita, CO, Disposal Site	574	4,276,394	$0.442	Resource Availability
Slick Rock, CO, Disposal Cell	333	2,482,943	$0.442	Resource Availability
Rio Blanco, CO, Site	535	3,985,541	$0.442	Resource Availability
Gunnison, CO, Disposal Site	1,005	7,486,469	$0.442	Resource Availability
Bluewater, NM, Disposal Site	1,210	9,008,742	$0.447	Resource Availability
Gnome-Coach, NM, Site	1,213	9,029,273	$0.447	Resource Availability
L-Bar, NM, Disposal Site	600	4,471,436	$0.447	Resource Availability
Waste Isolation Pilot Plant (WIPP)	664	4,943,645	$0.447	Resource Availability
Ambrosia Lake, NM, Disposal Site	1,209	9,004,465	$0.447	Resource Availability
Gasbuggy, NM, Site	264	1,964,968	$0.447	Resource Availability
NNSS	N/A	N/A	N/A	Resource Availability

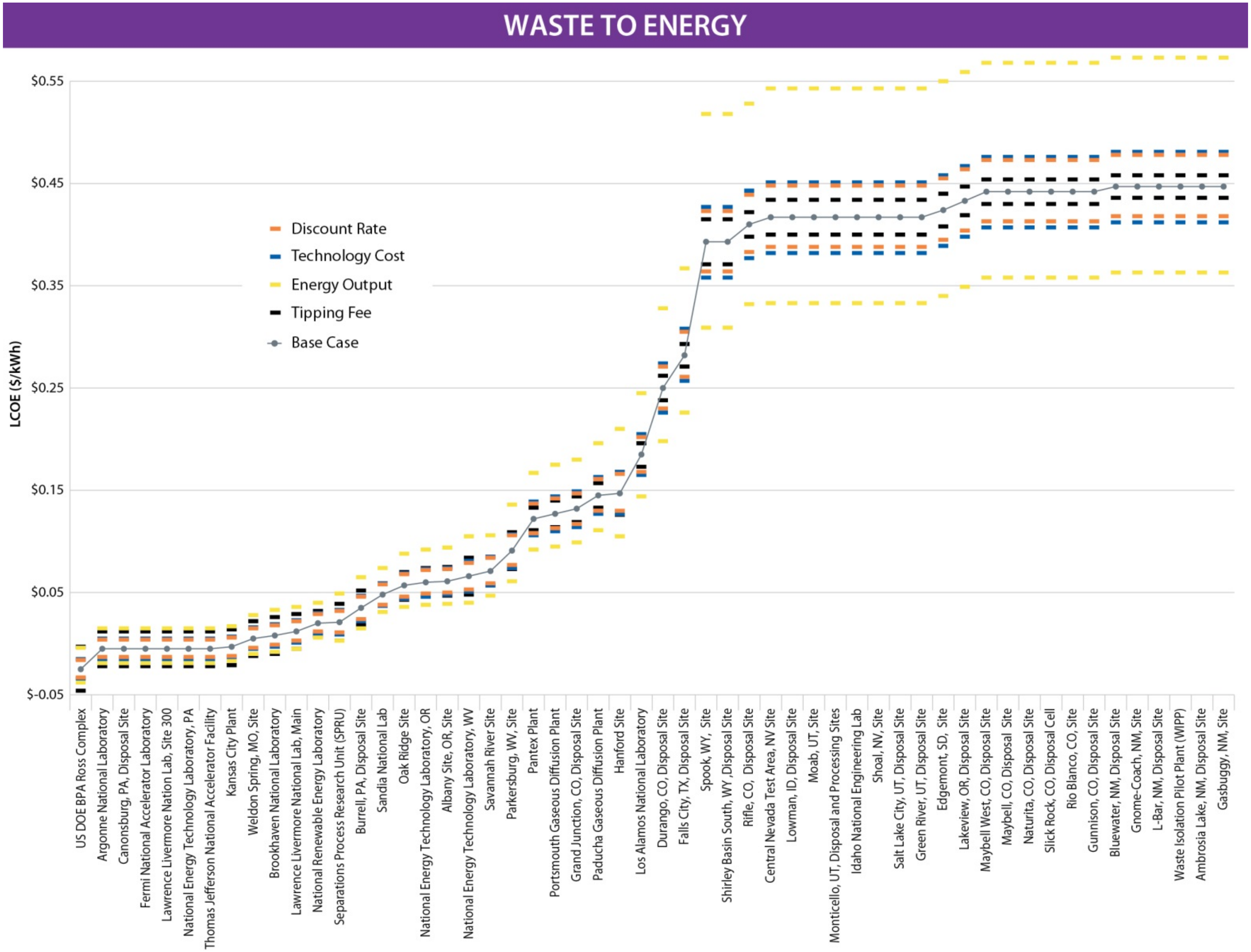

Figure 60. LCOE sensitivity analysis for WTE

The LCOE for CSP were calculated at 20 sites; the remaining 35 sites did not have sufficient land to host a 50-MW CSP plant, currently the minimum developable size. The LCOEs are shown in Table 46.

Table 46. CSP LCOEs Sorted from Lowest to Highest

Site	System Capacity (kW)	Electricity Produced (kWh/yr)	Electric LCOE ($/kWh)	Limiting Factor
NNSS	50,000	214,172,000	$0.203	Max Size
LANL	50,000	208,159,000	$0.209	Max Size
CNTA, NV Site	50,000	195,891,000	$0.222	Max Size
SNL	50,000	195,627,000	$0.222	Max Size
Shoal, NV, Site	50,000	195,332,000	$0.223	Max Size
Bluewater, NM, Disposal Site	50,000	191,013,000	$0.228	Max Size
Monticello, UT, Disposal and Processing Sites	50,000	188,530,000	$0.230	Max Size
WIPP	50,000	187,113,000	$0.232	Max Size
Pantex Plant	50,000	172,911,000	$0.251	Max Size
LLNL, Site 300	50,000	165,765,000	$0.262	Max Size
INL	50,000	145,077,000	$0.298	Max Size
Shirley Basin South, WY, Disposal Site	50,000	142,221,000	$0.304	Max Size
Hanford Site	50,000	131,558,000	$0.328	Max Size
Savannah River Site	50,000	126,058,000	$0.342	Max Size
Paducha Gaseous Diffusion Plant	50,000	110,146,000	$0.391	Max Size
ORNL Site	50,000	104,761,000	$0.411	Max Size
FNAL	50,000	96,219,100	$0.447	Max Size
BNL	50,000	95,239,900	$0.452	Max Size
ANL	50,000	93,413,400	$0.460	Max Size

Site	System Capacity (kW)	Electricity Produced (kWh/yr)	Electric LCOE ($/kWh)	Limiting Factor
Portsmouth Gaseous Diffusion Plant	50,000	87,125,400	$0.493	Max Size
Albany, OR, Site	N/A	N/A	N/A	Not Enough Land
Ambrosia Lake, NM, Disposal Site	N/A	N/A	N/A	Not Enough Land
Burrell, PA, Disposal Site	N/A	N/A	N/A	Not Enough Land
Canonsburg, PA, Disposal Site	N/A	N/A	N/A	Not Enough Land
Durango, CO, Disposal Site	N/A	N/A	N/A	Not Enough Land
Edgemont, SD, Site	N/A	N/A	N/A	Not Enough Land
Falls City, TX, Disposal Site	N/A	N/A	N/A	Not Enough Land
Gasbuggy, NM, Site	N/A	N/A	N/A	Not Enough Land
Gnome-Coach, NM, Site	N/A	N/A	N/A	Not Enough Land
Grand Junction, CO, Disposal Site	N/A	N/A	N/A	Not Enough Land
Green River, UT, Disposal Site	N/A	N/A	N/A	Not Enough Land
Gunnison, CO, Disposal Site	N/A	N/A	N/A	Not Enough Land
Kansas City Plant	N/A	N/A	N/A	Not Enough Land
Lakeview, OR, Disposal Site	N/A	N/A	N/A	Not Enough Land
LLNL, Main	N/A	N/A	N/A	Not Enough Land
L-Bar, NM, Disposal Site	N/A	N/A	N/A	Not Enough Land
Lowman, ID, Disposal Site	N/A	N/A	N/A	Not Enough Land
Maybell West, CO, Disposal Site	N/A	N/A	N/A	Not Enough Land
Maybell, CO, Disposal Site	N/A	N/A	N/A	Not Enough Land
Moab, UT, Site	N/A	N/A	N/A	Not Enough Land

Site	System Capacity (kW)	Electricity Produced (kWh/yr)	Electric LCOE ($/kWh)	Limiting Factor
NETL, PA	N/A	N/A	N/A	Not Enough Land
NETL, OR	N/A	N/A	N/A	Not Enough Land
NETL, WV	N/A	N/A	N/A	Not Enough Land
NREL	N/A	N/A	N/A	Not Enough Land
Naturita, CO, Disposal Site	N/A	N/A	N/A	Not Enough Land
Parkersburg, WV, Site	N/A	N/A	N/A	Not Enough Land
Rifle, CO, Disposal Site	N/A	N/A	N/A	Not Enough Land
Rio Blanco, CO, Site	N/A	N/A	N/A	Not Enough Land
Salt Lake City, UT, Disposal Site	N/A	N/A	N/A	Not Enough Land
SPRU	N/A	N/A	N/A	Not Enough Land
Slick Rock, CO, Disposal Cell	N/A	N/A	N/A	Not Enough Land
Spook, WY, Site	N/A	N/A	N/A	Not Enough Land
Thomas Jefferson National Accelerator Facility	N/A	N/A	N/A	Not Enough Land
BPA Ross Complex	N/A	N/A	N/A	Not Enough Land
Weldon Spring, MO, Site	N/A	N/A	N/A	Not Enough Land

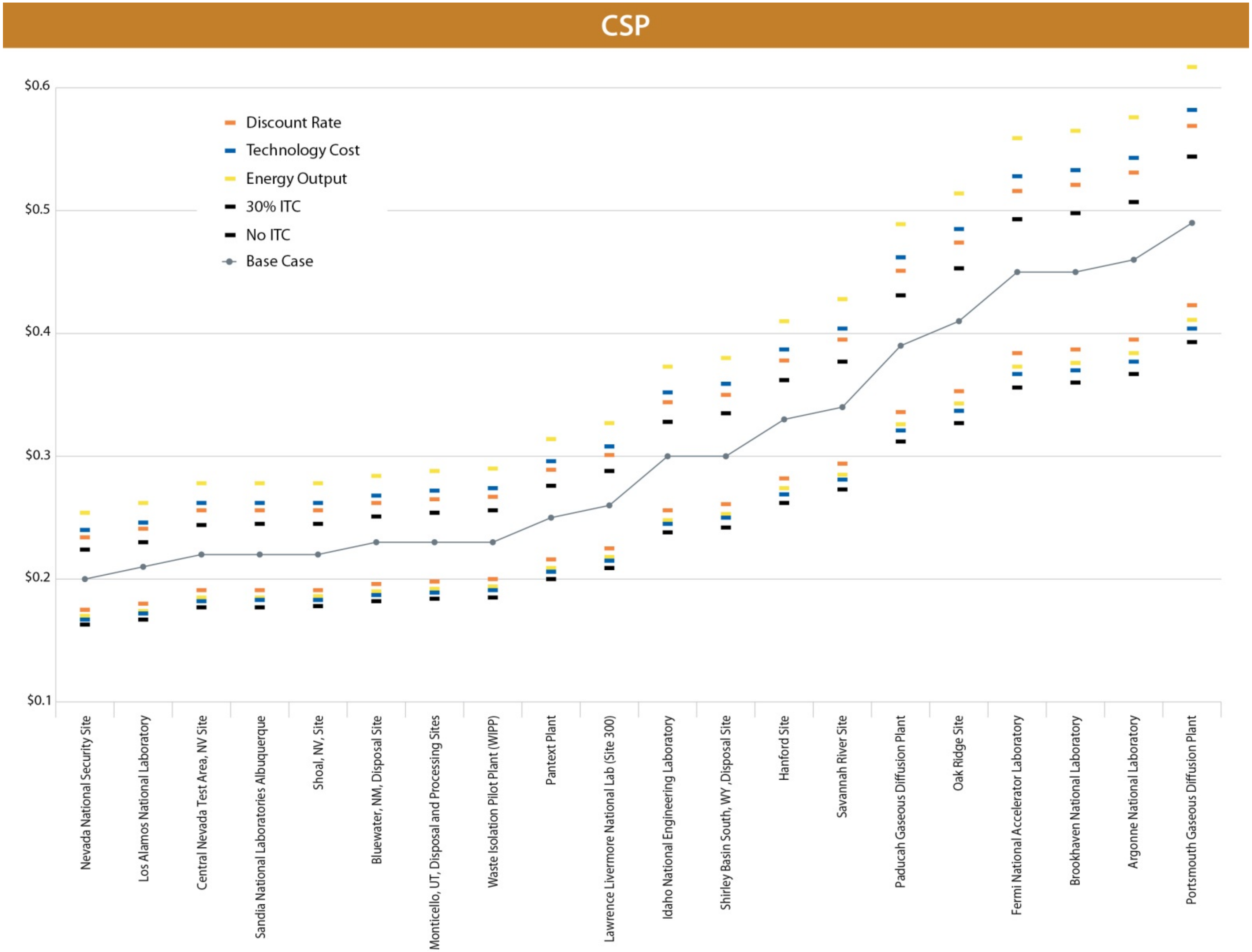

Figure 61. LCOE sensitivity analysis for CSP

Appendix C. Portfolio Analysis Assumptions

Table 47 through Table 56 describe the standard REopt technology assumptions. These assumptions and inputs are used in this analysis.

C.1 Portfolio Analysis Economic Models

C.1.1 REopt Economic Model

The economic cost-benefit analysis within NREL's REopt model is based on general economic theory. The approach and terminology is based on the work of Short et al. (1995),[133] and abides by the life-cycle cost methods and criteria for federal energy projects described in the Code of Federal Regulations 10 CFR 436, Subpart A, and which are detailed in NIST Handbook 135.

REopt applies code-based calculations in its cash-flow analysis. For this work, the LCOE is calculated from the total life-cycle costs (LCC[134]) and the electricity each project is predicted to generate over its useful life. LCC is the present value of all costs, after-taxes and incentives, associated with each option. LCC includes:

- Capital costs are overnight costs; i.e., all projects are completed at the end of Year 0 and produce energy starting in Year 1. No construction period, construction loan, or debt service costs are included in the model.
- O&M costs
- The costs of fuel (e.g., biomass feedstock) or WTE tipping fees collected for the project
- All applicable incentives made available by utilities, states, or federal government (ITC, PTC, and MACRS) are also applied.

Shown in Table 47, costs that occur in years beyond the base year (Year 0) are discounted using a present worth factor. An end of year discounting convention is applied. The present worth factor function includes accounting for annual cost escalations as needed. For example, in a nominal analysis, O&M costs are assumed to increase at the general inflation rate.

The primary economic inputs are:

- Analysis period
- Discount rate
- Developer's income tax rate
- General inflation rate
- Both tax and nontax-based incentives.

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[133] Short, Walter, et al. 1995. *A Manual for the Economic Evaluation of Energy Efficiency and Renewable Energy Technologies.* TP-462-5173. National Renewable Energy Laboratory, Golden, CO. https://www.nrel.gov/docs/legosti/old/5173.pdf.

[134] Total life-cycle cost has the meaning described in Short et al., and is abbreviated in that reference as TLCC.

The economic assumptions are:

- Capital costs are overnight costs; i.e., all projects are completed at the end of Year 0 and produce energy starting in Year 1. No construction period or construction loan is included in the model.
- One-year discounting periods; i.e., no midyear discounting sub periods.
- End-of-year cash flows.
- All projects have zero salvage value; i.e., analysis period = useful life.
- When tax benefits are considered, the system owner has sufficient tax appetite to capture all available tax incentives in their entirety.
- Nonfuel O&M and biomass, LFG, and WTE feedstock costs escalate at the general inflation rate.
- No sales tax, no insurance, and no property taxes are considered.
- No consideration of debt service coverage or reserve requirements.

Table 47. Costs Incurred After Year 0

Analysis Parameter	Value
Analysis Period (n)	25 years
Discount Rate (d), nominal	10%
General Inflation Rate[135]	0.5%

Reported LCOEs are in nominal dollars. O&M costs and feedstock costs are escalated at the general inflation rate.

C.1.2 System Advisor Model Economic Model

The financial model in SAM is based on the definitions and methods described in the work of Short et al. (1995),[136] the same reference used for REopt economics. SAM's economic model documentation is found at https://sam.nrel.gov/financial.

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[135] "Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis – 2014." NISTIR 85-3273-29, http://nvlpubs.nist.gov/nistpubs/ir/2014/NIST.IR.85-3273-29.pdf.

[136] Short, Walter, et al. 1995. *A Manual for the Economic Evaluation of Energy Efficiency and Renewable Energy Technologies.* TP-462-5173. National Renewable Energy Laboratory, Golden, CO. https://www.nrel.gov/docs/legosti/old/5173.pdf.

C.2 REopt Portfolio Analysis Technology Assumptions

Table 48. REopt Technology Assumptions

<table>
<thead>
<tr><th>Technology</th><th>Assumptions</th></tr>
</thead>
<tbody>
<tr><td>Photovoltaics</td><td>

PV technology consists of semiconductor devices that convert sunlight directly into electricity. The primary components are the PV array and the inverter. Rooftops, carports, and ground-mounted arrays are common mounting locations.
Fixed-axis PV systems are modeled to be oriented due south with tilt set to the site’s latitude; single-axis tracking systems are assumed to be installed in rows that run north-south and track the movement of the sun from east to west throughout the day. They are assumed to have no tilt to the south.
PV is constrained by available land.
NREL assumes PV requires 6 acres/MW for fixed-axis systems and 7 acres/MW for tracking systems.[137]
NREL assumes standard crystalline silicon panels with an average efficiency of 15%.
NREL assumes overall system losses to be 14% for soiling, electrical wiring losses, availability, etc.[138]
NREL assumes the inverter efficiency to be 96%.[139]
NREL assumes an annual performance degradation of 0.5% per year.[140]

</td></tr>
<tr><td>Wind</td><td>

Wind turbines have airfoils that translate the force or power in the wind to a rotational force that turns an electrical generator.
Preferred locations are areas of wide-open space to minimize air turbulence from surrounding buildings or trees.
Five representative wind turbines are modeled based on size and wind resource: small, medium, large class 1, large class 2, and large class 3.

<table>
<tr><th>Size</th><th>Small</th><th>Medium</th><th colspan="3">Large</th></tr>
<tr><td>Nameplate</td><td>10 kW</td><td>100 kW</td><td>3,000 kW</td><td>2,000 kW</td><td>1,800 kW</td></tr>
<tr><td>IEC Class (average wind velocity)</td><td>N/A</td><td>N/A</td><td>Class 1 (≥ 9 m/s)</td><td>Class 2 (7.5 m/s ≤ average wind speed < 9 m/s)</td><td>Class 3 (< 7.5 m/s)</td></tr>
<tr><td>Power Control Method</td><td>Stall</td><td>Stall</td><td>Pitch</td><td>Pitch</td><td>Pitch</td></tr>
<tr><td>Nacelle height assumed</td><td>30 m</td><td>50 m</td><td>80 m</td><td>80 m</td><td>80 m</td></tr>
</table>

15% losses are assumed for issues such as wake effects, electrical losses, and availability.
NREL assumes wind requires 30 acres/MW. Typical range for wind is 10–50 acres/MW.
The model uses a database of wind resource that is representative of the regional wind resource in the vicinity of the site. However, wind resource is highly sensitive to site-

</td></tr>
</tbody>
</table>

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[137] Sean Ong et al. 2013. *Land-Use Requirements for Solar Power Plants in the United States*, TP-6A20-56290. National Renewable Energy Laboratory, Golden, CO. http://www.nrel.gov/docs/fy13osti/56290.pdf.

[138] D.C. Jordan et al. 2010. “Outdoor PV Degradation Comparison.” Presented at the 35th IEEE Photovoltaic Specialists Conference Honolulu, Hawaii, June 20-25, 2010. http://www.nrel.gov/docs/fy11osti/47704.pdf.

[139] Ibid.

[140] Ibid.

<table>
<tr><th>Technology</th><th>Assumptions</th></tr>
<tr><td></td><td>specific features, and it should be verified before any investment decisions are made as part of project development due-diligence. NREL accesses the wind resource database using the site’s latitude and longitude and a search radius. The default search radius is 1 mile.</td></tr>
<tr><td>Biomass</td><td>

Biomass systems convert biomass feedstocks into heat and/or electricity. Four types of biomass combustion system can be modeled: 1) fully condensing turbine that generates electricity only; 2) CHP backpressure turbine that generates heat and electricity at a fixed ratio of electricity to thermal output; 3) CHP condensing turbine that can vary the ratio of thermal to electric output; and 4) standard combustion boiler that generates heat only.
For this analysis only type 1) systems were modeled.
Assumptions for electrical efficiency, thermal efficiency, availability, minimum turn down ratio, and fuel heat content of each system are:

<table>
<tr><th></th><th>Electric</th></tr>
<tr><td>Electrical efficiency</td><td>23%</td></tr>
<tr><td>Availability</td><td>85%</td></tr>
<tr><td>Assumed efficiency of existing heating system</td><td>80%</td></tr>
<tr><td>Min. turndown ratio</td><td>40%</td></tr>
<tr><td>Fuel heat content</td><td>9.2 MMBtu/ton</td></tr>
</table>

Biomass systems are not limited by land available in the model, though they will require some space (1-5 acres) for plant and feedstock storage.
NREL assumes the biomass resource within a 50-mile radius of the site is available to fuel the system.

</td></tr>
<tr><td>LFG</td><td>

LFG systems use methane gas generated by the anaerobic decomposition of carbon-based waste deposited in a local landfill to power an engine or boiler. Three types of LFG can be modeled: 1) internal combustion engine that generates electricity only; 2) CHP internal combustion engine with heat recovery system; and 3) standard combustion boiler that generates heat only.
For this analysis only type 1) systems were modeled.
Assumptions for electrical efficiency, availability, minimum turn-down ratio, fuel heat content, and maximum distance to landfill for each system are:

<table>
<tr><th></th><th>Electric</th></tr>
<tr><td>Electrical efficiency</td><td>33%</td></tr>
<tr><td>Availability</td><td>85%</td></tr>
<tr><td>Assumed efficiency of existing heating system</td><td>80%</td></tr>
<tr><td>Min. turndown ratio</td><td>30%</td></tr>
<tr><td>Fuel heat content</td><td>10.6 MMBtu/ton</td></tr>
<tr><td>Max. distance to landfill</td><td>15 miles</td></tr>
</table>

LFG systems are not limited by land available in the model, though the engine or boiler will require some space.
LFG for U.S. sites is evaluated for any site that has a candidate landfill designated by EPA’s LMOP within 15 miles of the site.
The model assumes the developer will pipe gas to the site, pay for piping and gas costs, and generate electricity on site. The model does not evaluate the feasibility of routing piping from the landfill to the site.

</td></tr>
</table>

<table>
<tr><th>Technology</th><th>Assumptions</th></tr>
<tr><td>WTE</td><td>

WTE systems convert municipal solid waste streams into energy. The model assumes the WTE systems are “mass burn.”
Four types of systems can be modeled: 1) fully condensing turbine that generates electricity only; 2) CHP backpressure turbine that generates heat and electricity at a fixed ratio of electricity to thermal output; 3) CHP condensing turbine that can vary the ratio of thermal to electricity output; and 4) standard combustion boiler that generates heat only.
For this analysis only type 1) systems were modeled.
Assumptions for electrical efficiency, derate (availability), minimum turn-down ratio, and fuel heat content of each system are:
<table>
<tr><th></th><th>Electric</th></tr>
<tr><td>Electrical efficiency</td><td>21%</td></tr>
<tr><td>Availability</td><td>85%</td></tr>
<tr><td>Assumed efficiency of existing heating system</td><td>80%</td></tr>
<tr><td>Min. turndown ratio</td><td>40%</td></tr>
<tr><td>Fuel heat content</td><td>10.4 MMBtu/ton</td></tr>
</table>

WTE systems are not limited by land available in the model, though they will require some space (3–10 acres) for plant and feedstock storage.
NREL assumes MSW within a 25-mile radius of the site is available to fuel the system.
The maximum WTE plant size that can be evaluated is 100 MW. Cost data are not available for larger plants.
WTE may be cost-effective in many locations but has high implementation barriers such as securing off-site waste streams, achieving community acceptance, and securing permits.

</td></tr>
</table>

C.3 System Advisor Model Portfolio Analysis Technology Assumptions

Table 49 describes the CSP technology assumptions used in SAM.

Table 49. SAM Technology Assumptions

Technology	Assumptions
CSP Power Tower[141]	• CSP power tower systems use numerous large, flat, sun-tracking mirrors, known as *heliostats*, to focus sunlight onto a receiver at the top of a tall tower. A heat-transfer fluid heated in the receiver is used to generate steam, which, in turn, is used in a conventional turbine generator to produce electricity. • A molten salt power tower system (BrightSource Heliostat LH-2.2, 539,654 m^2 total reflective area) is modeled and is assumed to be 50 MW net (55-MW power plant with 9% parasitic losses) and 96% availability. • NREL assumes the power plant is air-cooled. • The system is modeled to have 6 hours of thermal energy storage. • NREL assumes the system requires15 acres/MW[142]

C.4 Portfolio Analysis Cost Data

C.4.1 REopt Cost Data

This analysis used a cost dataset that is based on 2015 research, market data, and recently constructed RE projects. The costs in Table 50 reflect 2015 U.S. national averages and include assumed contracting costs for design, supervision and contingency. Grid improvement costs are not included. REopt uses a segmented system cost curve to account for the economies of scale realized when constructing larger systems. The marginal cost represents the cost to add the last, or incremental, unit of nameplate capacity to the system in each of the segments.

Table 50. REopt Standard Technology Cost Assumptions

Technology	Assumptions	Value
PV, Fixed Axis[143]	Marginal installation cost	\$2.54/Wdc for system size 0–200 kW
		\$2.01/Wdc for system size >200 kW–5 MW
		\$1.79/Wdc for system size >5 MW
	O&M cost	\$0.020/W-year
PV, Tracking[144]	Marginal installation cost	\$2.69/Wdc for system size 0–200 kW

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[141] Cost data are documented in the NREL publication, *Molten Salt Power Tower Cost Model for the System Advisor Model (SAM).* TP-5500-57625. National Renewable Energy Laboratory, Golden, CO. February 2013. http://www.nrel.gov/docs/fy13osti/57625.pdf.

[142] Land-use requirements for CSP are based on input from an NREL subject matter expert.

[143] PV costs for systems under 5 MW are from: DOE SunShot. 2014. "Photovoltaic System Pricing Trends." PR-6A20-62558. National Renewable Energy Laboratory, Golden, CO. http://www.nrel.gov/docs/fy14osti/62558.pdf. PV costs for systems greater than 5 MW are from: "Annual Technology Baseline and Standard Scenarios." NREL, http://www.nrel.gov/analysis/data_tech_baseline.html.

Technology	Assumptions	Value
		$2.18/Wdc for system size >200 kW–5 MW
		$1.95/Wdc for system size >5 MW
	O&M cost	$0.023/W-year
Wind Power[145]	Marginal installation cost	$88.00/W for system size 0–50 kW
		$2.38/W for system size >50–850 kW
		$1.75/W for system size >850 kW
	O&M cost	$0.035/W-year
Biomass[146] (All)	Fuel cost[147]	$0/ton on site
		$20.50/ton within a 25 mile radius
		$32.50/ton within a >25-50 mile radius
Biomass (Electric)	Marginal installation cost	$26.78/W for system size 0–713 kW
		$8.04/W for system size >713 kW–6.67 MW
		$1.83/W for system size >6.67 MW
	Marginal O&M Cost	$2.47/W-year for system size 0–713 kW
		$0.82/W-year for system size >713 kW–6.67 MW
		$0.15/W-year for system size >6.67 MW
LFG[148] (All)	Gas cost[149]	$1/MMBtu
	Piping cost	$346,200/mile
LFG (Electric)	Marginal installation cost	$5.65/W for system size 0–110 kW
		$2.56/W for system size >110 kW–3 MW

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[144] NREL cost models to be published indicated $0.15/W installed cost adder for tracking system and $3/kW/year additional O&M costs.

[145] Wind costs for systems <850 kW are derived from an internal cost estimating tool developed based on industry experience of NREL wind experts. Wind costs for systems >850 kW are from: "Annual Technology Baseline and Standard Scenarios." NREL, http://www.nrel.gov/analysis/data_tech_baseline.html. Wind O&M costs are from: Tegen, S. et al. 2013. *2011 Cost of Wind Energy Review*. TP-5000-56266. National Renewable Energy Laboratory, Golden, CO. http://www.nrel.gov/docs/fy13osti/56266.pdf.

[146] Biomass capital and O&M costs are derived from an internal NREL cost estimating tool developed based on industry experience of NREL biomass experts. Estimates are based on 2012 project cost research; technology costs have not changed significantly between 2012 and 2015.

[147] Biomass fuel costs come from NREL's Biomass Scenario Model (BSM) http://www.nrel.gov/analysis/bsm/. The costs in the BSM are based on personal communication with Jake Jacobsen, Idaho National Laboratory, December 2014. This cost includes the harvesting, collection, queuing and handling, storage, pre-processing, and transportation of woody biomass to the site. It should be noted that the cost to produce the biomass is assumed to be $0/ton.

[148] LFG capital and O&M costs are derived from EPA's 2012 LFGcost-Web V2.2 program. Technology costs have not changed significantly between 2012 and 2015. As of October 2017 the tool is located at http://www.epa.gov/methane/lmop/publications-tools/index.html.

[149] LFG fuel cost is estimated based on industry experience of EPA experts.

Technology	Assumptions	Value
		$2.41/W for system size >3 MW
	O&M cost	$0.250/W-year
WTE[150] (All)	Tipping fee[151]	Varies by state
WTE (Electric)	Marginal installation cost	$15.60/W for system size 0–2,520 kW
		$5.84/W for system size >2,520 kW–21 MW
		$3.69/W for system size >21 MW
	Marginal O&M cost	$2.44/W for system size 0–2,520 kW
		$0.36/W for system size >2,520 kW–21 MW
		$0.14/W for system size >21 MW

C.4.2 System Advisor Model Cost Data

Table 51 describes the CSP cost assumptions used in SAM.[152]

Table 51. SAM Technology Cost Assumptions

Technology	Assumptions	Value
CSP Power Tower[153]	Installation Cost	$6.30/Watt for system size 50 MW
	O&M Cost	$0.065/W-year
	Variable O&M Cost	$0.004/kWh

C.5 Portfolio Analysis Resource Data Sources

Renewable energy resource information is provided by NREL's GIS department.[154] This information is used in the RE technology equations to represent the magnitude of a renewable energy resource in the area. Data sets used in the analysis are described in Table 52.

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[150] WTE capital and O&M costs are derived from an internal NREL cost estimating tool developed based on industry experience of NREL WTE experts. Estimates are based on 2012 project cost research; technology costs have not changed significantly between 2012 and 2015.

[151] van Haaren, Rob, Nickolas J. Themelis, and Nora Goldstein. 2010. "The State of Garbage in America," *BioCycle*, October 2010. http://www.biocycle.net/images/art/1010/bc101016_s.pdf.

[152] "System Advisor Model (SAM)." NREL. https://sam.nrel.gov/.

[153] Performance data are documented in the NREL publication, *Molten Salt Power Tower Cost Model for the System Advisor Model (SAM).* TP-5500-57625. National Renewable Energy Laboratory, Golden, CO. February 2013. http://www.nrel.gov/docs/fy13osti/57625.pdf.

[154] "Geospatial Data Science." NREL, https://www.nrel.gov/gis/.

Table 52. REopt Resource Data Assumptions

Resource	Assumptions
Solar (for PV and CSP)	• Hourly solar radiation. Typical Meteorological Year 3 (NREL 2008). Represents 1,020 locations in the US. Derived from 1991–2005 National Solar Radiation Data Base.
Wind	• Hourly Typical Meteorological Year wind resource data for the United States is provided by AWS Truepower (2014). • Wind speed, wind direction, temperature, and air density are provided at 30, 50, 80, and 110 meters above ground level. • Dataset resolution is 20 km × 20 km.
Biomass	• Biomass resources (tons/year) available within 25 and 50 miles. • Derived from USDA, National Agricultural Statistics Service, 5 year average: 2003-2007; USDA, Forest Service's Timber Product Output database, 2007; U.S. Census Bureau, 2002 County Business Patterns; U.S. Census Bureau, 2000 Population data. • The biomass resource includes crop, forest, primary mill, and secondary mill. • Lookup point is buffered by selected radius. o If ≤10% of distributed county residue falls within the area, residue is disregarded (not assumed to be present for the analysis). o If >10% and ≤75% of distributed county residue falls with the area, that percentage of the county residue is used in the analysis. o If >75% of distributed county residue falls within the area, 100% of county residue is used in the analysis. • The resource is assumed to remain constant over the analysis period.
LFG	• Landfills that are candidates for energy generation are identified by EPA's LMOP (2012); only landfills within a 15 mile radius of the site are included in this analysis.[155] • LMOP estimates the potential gas production based on the landfill open and close date, waste in place, fill rate, and a first order decay model. • The resource is assumed to remain constant over the analysis period.
WTE	• The MSW resource available within a 25 mile radius is calculated by multiplying the population within a 25 mile radius by the waste generation per capita by state as described in the report *The State of Garbage in America (2010)*. [156] • MSW resource is estimated in tons/year; we assume the site can obtain 100% of this waste. • The resource is assumed to remain constant over the analysis period.

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[155] "Landfill Methane Outreach Program (LMOP)." EPA, http://www.epa.gov/lmop/.

[156] van Haaren, Rob, Nickolas J. Themelis, and Nora Goldstein. 2010. "The State of Garbage in America," *BioCycle*, October 2010. http://www.biocycle.net/images/art/1010/bc101016_s.pdf.

C.6 Transmission Line Capacity Approximation

Export of RE power may be limited by the physical capacity of the transmission line to the site or by operational reservations on the capacity of the line for other purposes. Both of these require detailed information to determine the actual limit on the line. For the purposes of this early screening we approximate the physical capacity of the line to carry power based on an approximate approach described in *Transmission Lines: Electricity's Highways*[157] and validated by comparison to the table in *The Wheeling and Transmission Manual*.[158] In order to estimate the power-carrying capacity of the line we need to know the length of the line, the voltage, and the number, type, and dimensions of the wire. But in this analysis, NREL geospatial data include only the length of the line and the voltage. In Table 53, for each voltage level we assume a type of conductor that is typical for that voltage and the associated surge impedance loading (SIL).

Table 53. Transmission Line Capacity Approximation

Voltage (kV)	Conductor (MCM)	SIL (MW)
72	266	13
138	477	49
230 Single	795	138
230 Bundle	2*795	188
345 Bundle	3*795	462
500 Bundle	4*795	1,051

The "Saint Clair Curve" was initially developed empirically in the 1950s and has been updated to accommodate longer lines and different configurations. The Saint Clair Curve reports how much power a line can carry in units of SILs as a function of the length of the line. Rather than read numbers off a printed curve, we use the following curve fit of the Saint Clair Curve:

$$\frac{MW}{SIL} = -0.789 * \ln(L) + 5.8786$$

Where L = line length in km

The result of this calculation is multiplied by the SIL for the voltage and line type to provide an approximate estimate of power-carrying capability of the transmission line to each site.

This simple method is validated by comparison to the detailed tables of The Wheeling and Transmission Manual, and found to agree within 10%. For example, for a 166km line at 138 kV, this simple method estimates 90 MW while the manual lists 100 MW. For a 333 km line at 500 kV, this method estimates 1362 MW while the manual reports 1320 MW. We must recognize

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[157] Kennedy, W.O. (Bill). 2013. "Transmission Lines: Electricity's Highways." Presented at IEEE-NCS, IAS/PES, January 22, 2013. http://sites.ieee.org/northern-canada-pesias/files/2013/01/Transmission-Lines-Presentation.pdf.

[158] Weiss, Larry, and Scott A. Spiewak. 1999. *The Wheeling and Transmission Manual*. Fairmont Press.

that this simple method to calculate line capacity is approximate and makes assumptions regarding missing information such as material and dimensions of conductors, and should be supplanted with more detailed analysis as information becomes available.

C.7 Financial Incentives

C.7.1 Investment Tax Credit and Modified Accelerated Cost Recovery System

Federal tax incentives including the ITC and MACRS are available to taxable entities. A 35% corporate tax rate is assumed to calculate the value of the ITC and MACRS. The capital cost used as the basis for MACRS is decreased by 50% of the value of the ITC.

At the time this analysis was conducted, the federal ITC for solar energy (including PV and CSP) was set to be reduced from 30% to 10% for projects implemented after 2016 (Table 54); thus the 10% value was used for this analysis. Because the ITC and MACRS are not available upfront, but rather are captured in out years, their values are discounted at the 10% rate.[159]

Table 54. ITC and MACRS Applied for Projects Installed After 2016

Technology	30% ITC	10% ITC	5-Year MACRS	7-Year MACRS
PV[a]		●	●	
CSP[a]		●	●	
Wind			●	
Biomass		●		●
LFG				●
WTE				●
Biomass heat				●
Solar hot water		●	●	
Solar ventilation preheat		●	●	

[a] At the time this analysis was conducted, the ITC had not been extended.

C.7.2 State and Local Incentives

In general, the system sizes evaluated in this report are too large to be eligible for many of the state and local incentives available, the exception is SRECs, for which a number of states have markets regardless of system size (Table 55). One SREC is equal to one MWh of solar electricity generated by PV. SRECs can be sold separately from the electricity generated, and their values are determined by market supply and demand mechanics. NREL received estimated SREC prices from a solar financing firm, SolSystems[160] in December 2014. We included the value of these in the LCOE analysis for applicable states. For states that have the option to sell into multiple markets, the highest SREC value was used. For states with different options for contract lengths

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[159] Based on input from an NREL financial subject matter expert.

[160] SolSystems: http://www.solsystems.com/.

(Table 56), the contract with the highest NPV was used (typically the longest contract with lower $/MWh).

Table 55. SREC Prices by State

State	State Has SREC Market	State Can Sell into PA SREC Market	State Can Sell into OH SREC Market
MA	✓		
DC	✓	✓	
NJ	✓	✓	
DE	✓	✓	
OH	✓	✓	
MD	✓	✓	✓
PA	✓	✓	✓
IL		✓ (ComEd only)	
IN		✓ (AEP only)	✓
KY		✓(AEP only)	✓
VA		✓	
WV		✓	✓
TN		✓ (AEP only)	
MI		✓ (AEP only)	✓
NC		✓ (Dominion only)	

Table 56. SREC Prices by State and Duration

Duration	MA SREC-I	MA SREC-II	DC	NJ	DE	OH	MD	PA
3-Year	$335	$255	$390	$195	$25	$35	$130	$39
5-Year	$315	$225	$300	$189	$15	$25	$86.6	$25
7-Year	$300	$175	$200	$165		$20		$20
10-Year	$270	$175	$175	$140				

C.8 Levelized Cost of Energy Calculation

The LCOE has the same units ($/kWh, $/MMBtu, $/therm, etc.) as utility purchased energy and can be thought of as the average cost of energy produced by an energy producing system. In the context of electricity generators, LCOE can also mean *levelized cost of electricity*.

When investing in commercially available systems with predictable performance and maintenance costs, a relatively accurate LCOE can be estimated for the useful life of the investment. The LCOE can then be used to compare alternative investments in energy-producing equipment or utility-purchased power.

The equation for LCOE is:

$$\mathrm{LCOE} = \frac{\sum_{=0}^{n} \frac{I_t \ + O\&M_t}{(1+d)^t}}{\sum_{=1}^{n} \frac{E_t}{(1+d)^t}}$$

Where:

I_t = Investment expenditure in year t, including the initial investment in year 0, plus any incentives and tax benefits that the project may realize (negative cost)
$O\&M_t$ = fuel and nonfuel operations and maintenance costs in year t
E_t = Energy produced in year t
d = Discount rate
n = Useful life of the system

The numerator is the life-cycle cost, the present value of all costs where the term I_t includes the initial investment (Year 0) plus any incentives and tax benefits that the project may realize (negative costs). The denominator is the energy produced over the useful life, similarly discounted. The concept of discounting energy production can be confusing so some think of LCOE as the *annualized costs of the project* divided by the annual energy produced. From that perspective, the discounting term in the denominator is not discounting the energy produced but rather amortizing, or annualizing, the life-cycle cost found in the numerator.

If the energy produced by a given technology is not constant from year to year (e.g., the declining energy production for PV systems due to age-related performance degradation), the energy produced also needs to be thought of in annualized terms. The general form of the LCOE equation addresses this.

The LCOE for energy produced by an RE system is a useful figure of merit; however, it is important to recognize that LCOE does not capture all the values a given system may offer. For example, the LCOE for a PV system could be lower than that predicted for a CSP system; however, the CSP system will be dispatchable and therefore have value to the electrical power system beyond just the annual useful energy it will produce. Thus, LCOE is a useful metric but it is incomplete and other factors should be considered when weighing the costs and benefits of alternatives.

C.9 Portfolio Analysis Tool Validation

C.9.1 REopt Validation

REopt economic calculations including present worth factors, treatment of tax incentives, inflation, and systems with declining annual energy output due to degradation were validated against standard spreadsheet cash flow calculations and results were also compared to economic analyses in NREL's SAM in 2012.

The wind power technology module was validated against Windographer, a commercial wind data analysis software package from AWS Truepower, in 2012. For a given wind resource data set, REopt wind turbine power production profiles were compared to Windographer's. The module was tested for multiple machines and hub heights to confirm that shear calculations and therefore power production estimates are accurate.

For PV power production profiles, REopt calls NREL's PVWatts through an application programming interface. PVWatts has been online since 1999. The PVWatts technical manual is available here: http://www.nrel.gov/docs/fy14osti/62641.pdf. PVWatts Version 5 was used in this analysis.

Biomass and WTE power plant modules are models of conventional steam power cycle and include an assumed heating value for the feedstock based on typical values for each type and average moisture contents. For a pure power plant configuration (not CHP) modeled for this work, a condensing type turbine is assumed. The prime mover modeled for LFG is a reciprocating engine generator. Biomass, WTE, and LFG modules are performance-based and assume standard conversion efficiencies to convert fuel inputs to power outputs. Modules were validated against NREL internal spreadsheet models from NREL experts and RETScreen International (http://www.retscreen.net/) in 2012.

C.9.2 System Advisor Model Validation

CSP is not included in REopt. NREL's SAM was used to model CSP performance and to calculate LCOE. SAM CSP power tower model documentation is found here: http://www.nrel.gov/docs/fy13osti/57625.pdf.

Appendix D. Renewable Energy Market Barrier and Opportunity Analysis Development Criteria

Table 57 through Table 60 provide descriptions of the development criteria used in the Market Barrier and Opportunity Analysis, and the sources used for their evaluation. For a full summary of relevant development criteria, refer to the FEMP Large-Scale Renewable Energy guide.[161]

Table 57. Site Ownership and Control Criteria

Site Ownership and Control Criteria	Description	Sources Used
Site Availability	Confirm that these acres are available for use for this purpose and that the site is on board with RE development.	Site Contact(s), Google Earth™
Vehicle or Labor Site Access	Verify that site access for both construction and O&M will be possible, and if there is suitable infrastructure to support heavy construction equipment.	Site Contact(s), Google Earth™
Existing Site Conditions (Google Earth)	Review imagery for shading, buildings, vegetation, and other potential development challenges.	Google Earth™
Existing Site Conditions (ArcGIS)	Check standard exclusions at each site (slope, soil conditions, etc.)	ArcGIS, Multi-Resolution Land Characteristics dataset
Neighboring Land Uses	Any neighboring land uses that could impede project? Additional adjacent land area for future development? Potential neighboring commercial offtakers?	Site Contact(s), LM Site Fact Sheets, existing site EIS reports, BLM land use maps
Competing Land Uses	Need to ensure that there are no competing land uses, and that the proposed project is the land's highest and best use.	Site Contact(s)
Resource Availability	The availability of a consistent stream of feedstock, at economically attractive tipping fees, are crucial for a biomass or WTE project .	Site Contact(s), ArcGIS, and Multi-Resolution Land Characteristics dataset. (Feedstock pricing not evaluated.)

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[161] DOE. 2013. *Developing Renewable Energy Projects Larger Than 10 MWs at Federal Facilities.* Federal Energy Management Program, DOE/GO-102013-3915. March 2013. https://energy.gov/sites/prod/files/2013/10/f3/large-scalereguide.pdf.

Table 58. Offtaker Criteria

Offtaker Criteria	Description	Sources Used
Identify Likely Offtaker (Utility, Wholesale Market, Adjacent Commercial Load)	Identify potential utility offtakers based on proximity/transmission constraints, examine wholesale market, and check for proximity of site to large commercial/industrial facilities.	Site Contact(s), Utility websites, Google Earth™
RPS Requirements	Verify renewable portfolio standards, track utilities' current progress.	Utility websites, DSIRE database
Proximity to Transmission	Check lat/long against proximity to transmission lines and substations and note distances.	ArcGIS, Ventyx transmission dataset
Interconnection Cost	Cost for interconnection application, system impact analysis, interconnection analysis, likely equipment requirements.	Utility websites (site-specific interconnection cost not evaluated in detail)

Table 59. Regulatory Criteria

Regulatory Criteria	Description	Sources Used
NEPA	Varying levels of analysis (categorical exclusion, environmental assessment, or environmental impact statement). Checked for sensitive elements below.	Site Contact(s), existing site EIS reports
Sensitive Elements	Email and ask if there are any endangered species, cultural resources, or environmental contaminants on-site.	Site Contact(s), existing site EIS reports
Land Disturbances	Identify any additional constraints or requirements associated with construction site work, verify any potential wetlands areas.	Site Contact(s), existing site EIS reports, ArcGIS, Multi-Resolution Land Characteristics dataset
Community Acceptance	News results search for previous projects in the region, ask site contact about important community stakeholders.	Site Contact(s)
Air Quality	Air quality permitting is an often costly permitting step; extensive air quality permitting requirements are a major development risk.	Site Contact(s), existing site EIS reports

Table 60. Economic Criteria

Economic Criteria	Description	Sources Used
Existing incentives	Check DSIRE for all existing incentives.	DSIRE database
REC Market	Check spot pricing for REC market, if applicable.	SRECtrade.com
Comparison with Retail Rates	Although retail rates are only a first-order estimate of the relative competitiveness of a proposed project, they can be a useful indicator of whether a project’s LCOE is at least below the retail rate.	Site Contact(s), utility websites
Competitive Pressure	Comparative attractiveness of the region to other developers. Highly competitive environments may discourage development at all but the best sites.	Utility websites, SNL Energy existing power plant database

Appendix E. Developable Acreage Exclusions for Utility-Scale Photovoltaic, Concentrating Solar Power, and On-Shore Wind

The development criteria for the PV, CSP, and wind resources are summarized in Table 61 and Table 62. Only PV, CSP, and wind resources were evaluated using a GIS approach due to their relatively large acreage requirements.

Table 61. Exclusions and Constraints for Utility-Scale PV and CSP

Exclusion Type	Criteria	Reference
Slope Exclusion	>3%	Lopez et al. (2012)
Contiguous Area Exclusion	<1 km^2	
Land Type Exclusion	Urban areas	ESRI (2004)
	MRLC[a]—water	MRLC (n.d.)
	MRLC—wetlands	
	BLM Areas of Environmental Concern	BLM (2009)
	U.S. Forest Service Inventory Roadless Area	USFS (2003)
	National Park Service lands	USGS (2005)
	U.S. Fish and Wildlife lands	
	Federal parks	
	Federal wilderness	
	Federal wilderness study area	
	Federal national monument	
	Federal national battlefield	
	Federal recreational area	
	Federal national conservation area	
	Federal wildlife refuge	
	Federal wildlife area	
	Federal wild and scenic area	

[a] Multi-Resolution Land Characteristics Consortium

Table 62. Exclusions and Constraints for On-Shore Wind Power

Exclusion Type	Criteria	Reference
Slope Exclusion	>20%	Lopez et al. (2012)
Distance Exclusion	<3 km distance to excluded area (does not apply to water)	
Land Type Exclusion	50% U.S. Forest Service lands (includes national grasslands, excludes ridge crests)	USGS (2005)
	50% U.S. Department of Defense lands (excludes ridge crests)	
	50% National Gap Analysis land stewardship Class 2, forest	CBI (2004)
	Airports	ESRI (2003)
	Urban areas	ESRI (2004)
	Land use/land cover, wetlands	USGS (1993)
	Land use/land cover, water	
	U.S. Forest Service Inventory Roadless Area	USFS (2003)
	National Park Service lands	USGS (2005)
	U.S. Fish and Wildlife lands	
	Federal parks	
	Federal wilderness	
	Federal wilderness study area	
	Federal national monument	
	Federal national battlefield	
	Federal recreational area	
	Federal national conservation area	
	Federal wildlife refuge	
	Federal wildlife area	
	Federal wild and scenic area	
	50% National Gap Analysis land stewardship Class 2, state and private lands equivalent to federal exclusions	CBI (2004)

Appendix F. Landfill Gas to Energy Pipeline Right of Way

All of the top LFG projects were examined at a high level for a basic potential disqualifier, right-of-way access for a delivery pipeline from the landfill resource to the proposed DOE site. Potential DOE sites were originally screened by proximity of 15 miles or less to the landfill resource; the top sites ranged from 6 to 14 miles. Although pipeline construction costs were factored into the original screening analysis, the impacts of the surrounding geography, infrastructure, and land uses were not considered. Table 63 lists these sites. Satellite imagery from Google Earth (Figure 62 through Figure 69) shows that many of these sites would likely be infeasible for development due to the obstruction of right-of-way access from existing commercial or residential development, waterways, and transportation infrastructure. A conceptual shortest potential route in blue is overlaid over this satellite imagery for emphasis; however, this may not be a viable route. Deviations from this shortest route could result in pipeline construction and permitting costs in excess of those modeled in the original screening, which could adversely affected the modeled electric LCOE of the projects.

Table 63. Sites That Are Likely To Be Infeasible

Site	System Capacity (MW)	Electric LCOE ($/MWh)	Distance to Landfill (miles)	Landfill Name within 15-Mile Radius of Sites
Grand Junction, CO, Disposal Site	6.8	$81	11	Mesa County Landfill, Grand Junction, CO
NETL, PA	2.5	$86	6	Kelly Run SLF, Elizabeth, PA
Kansas City Plant	2.5	$91	8	Southeast SLF, Kansas City, MO
Burrell, PA, Disposal Site	2.0	$92	7	Evergreen Landfill, Blairsville, PA
Portsmouth Gaseous Diffusion Plant	1.7	$93	6	Pike Sanitation LF, Waverly, OH
Parkersburg, WV, Site	2.6	$94	10	Northwestern Company Disposal Landfill, Parkersburg, WV
ORNL Site	2.4	$104	14	Matlock Bend Landfill, Loudon, TN
NREL	1.3	$108	8	Foothills Landfill, Golden, CO

Figure 62. Grand Junction, Colorado, disposal site

Source: © 2015 Google Earth, alterations by Jenny Melius

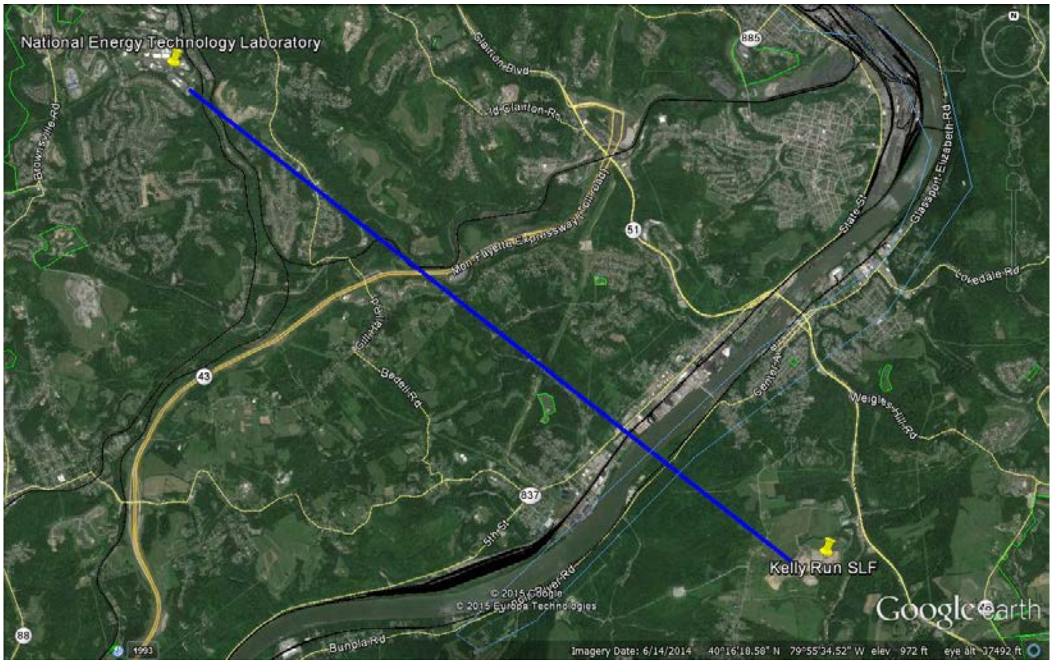

Figure 63. National Energy Technology Laboratory Pennsylvania site

Source: © 2015 Google Earth, alterations by Jenny Melius

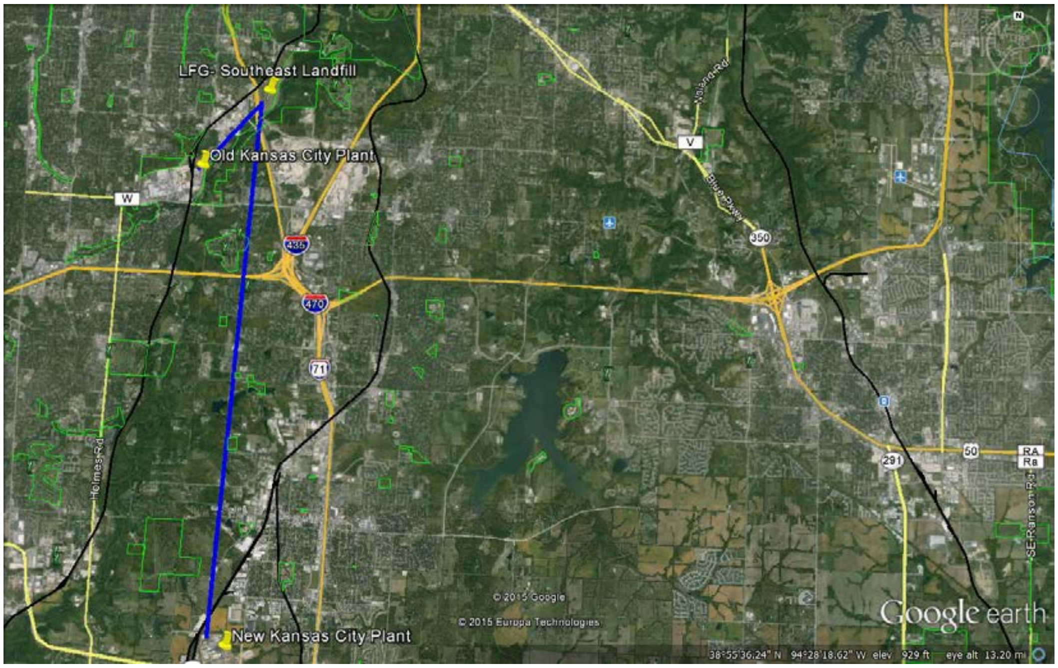

Figure 64. Kansas City plant

Source: © 2015 Google Earth, alterations by Jenny Melius

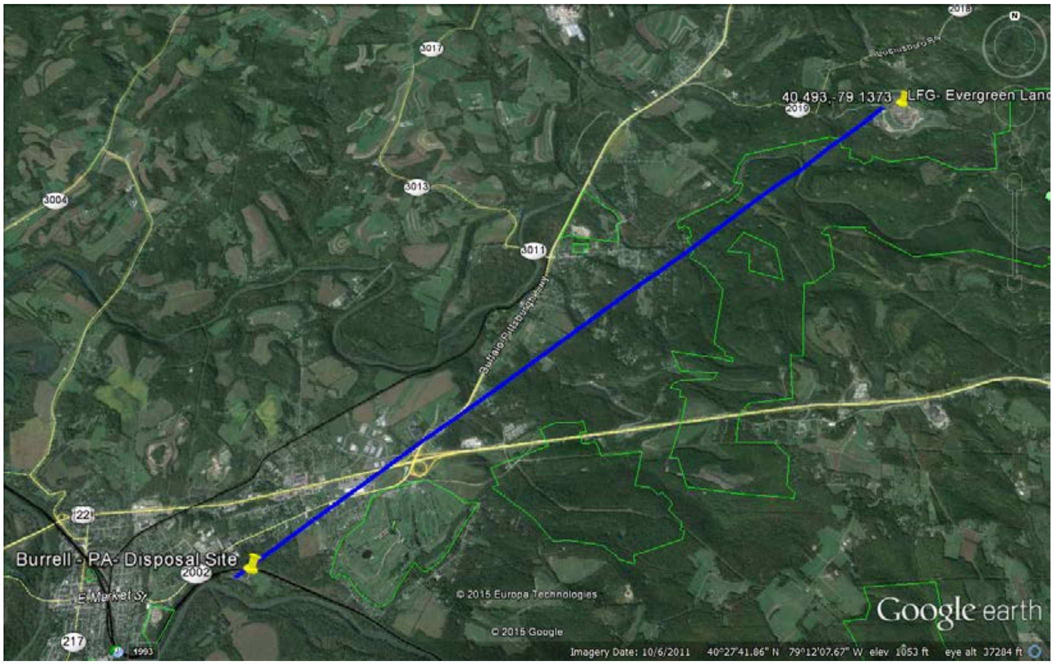

Figure 65. Burrell, Pennsylvania, disposal site

Source: © 2015 Google Earth, alterations by Jenny Melius

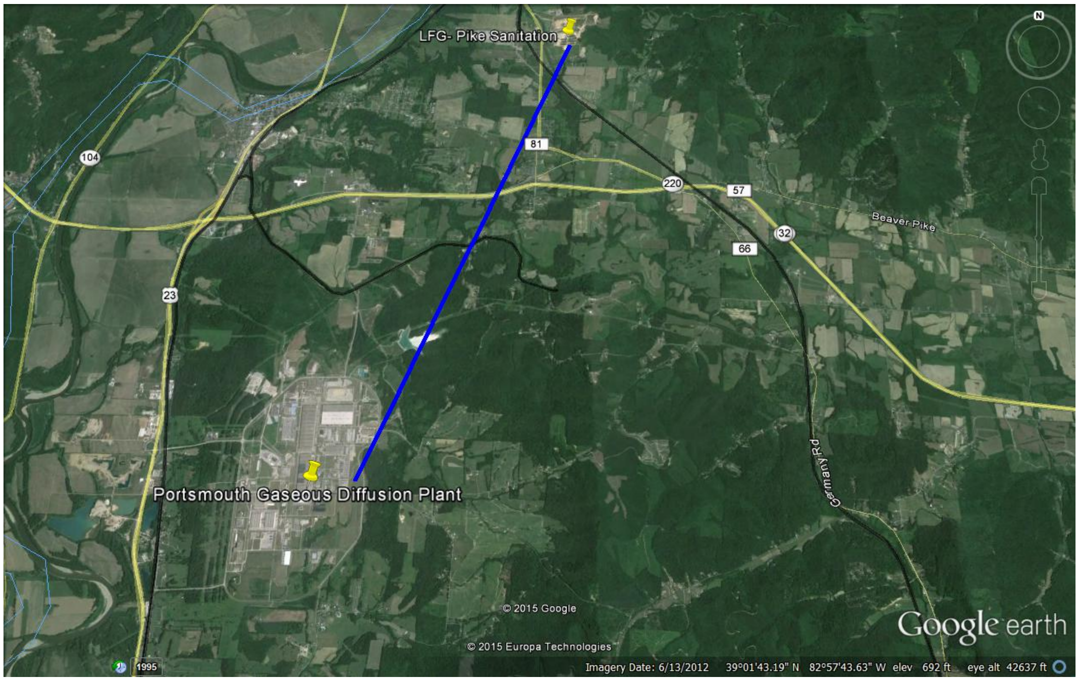

Figure 66. Portsmouth gaseous diffusion plant

Source: © 2015 Google Earth, alterations by Jenny Melius

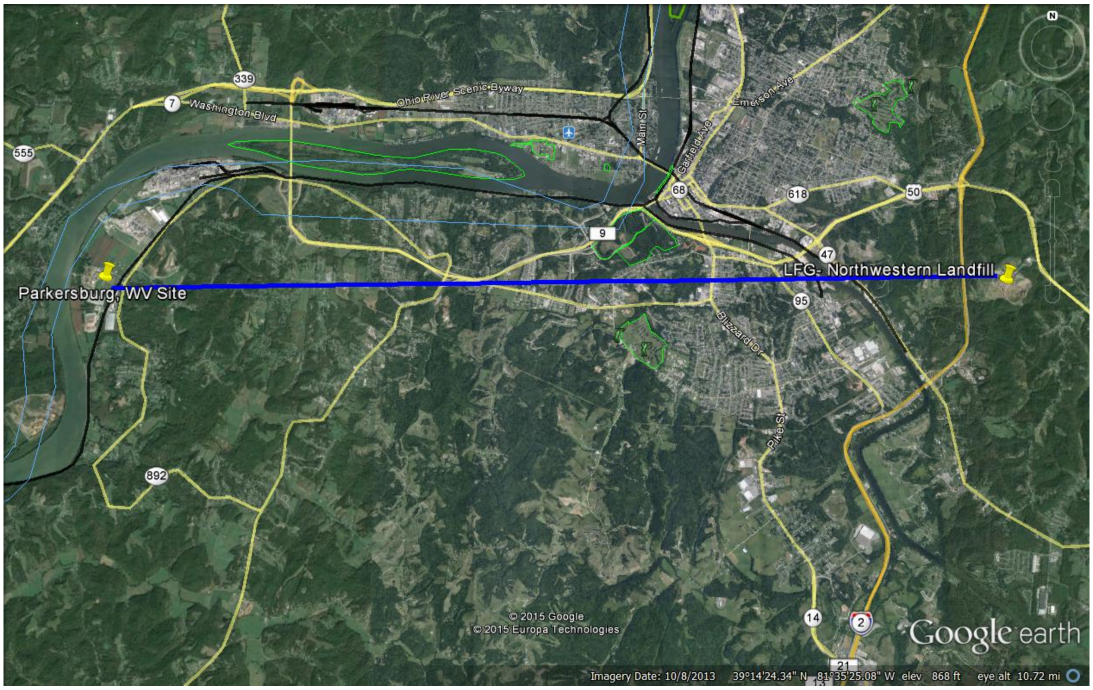

Figure 67. Parkersburg, West Virginia, site

Source: © 2015 Google Earth, alterations by Jenny Melius

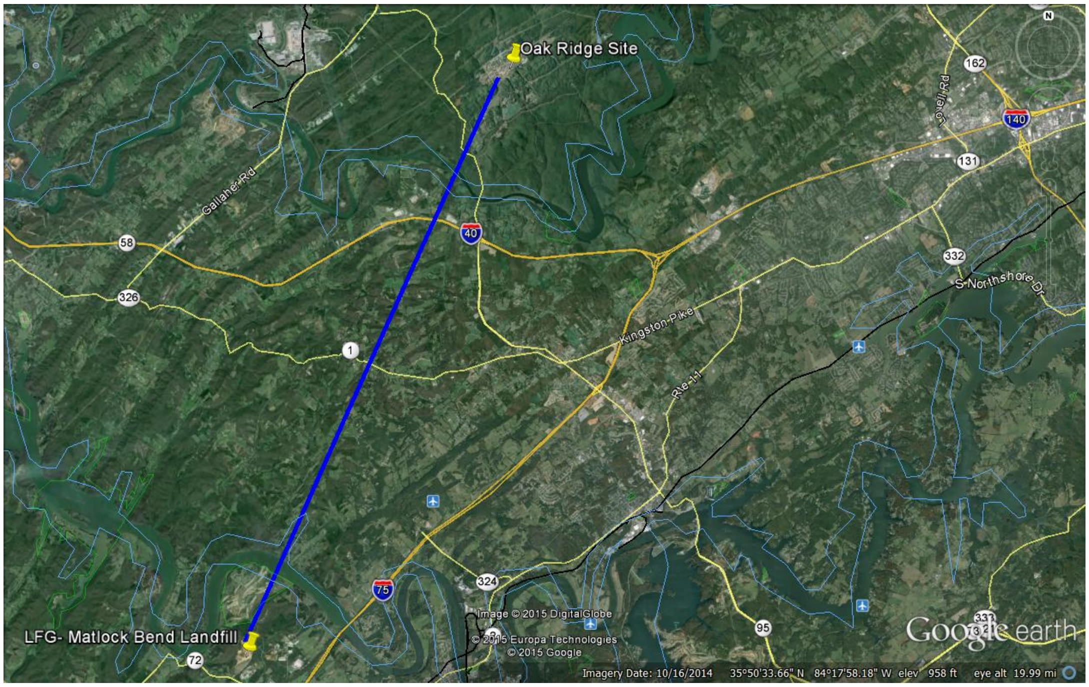

Figure 68. ORNL site

Source: © 2015 Google Earth, alterations by Jenny Melius

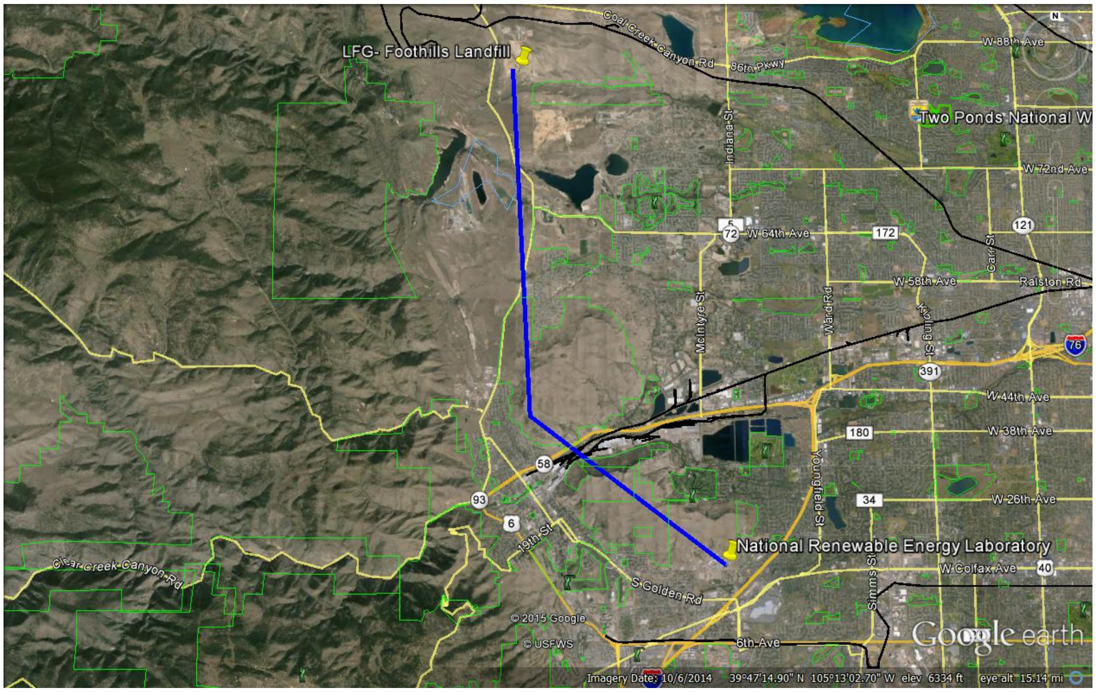

Figure 69. NREL site

Source: © 2015 Google Earth, alterations by Jenny Melius

Appendix G. Site Detail for Fossil Fuel Resource Analysis

The tables and maps in this section describe the results of the fossil fuel resource screening analysis conducted for the 55 DOE sites.

G.1 Fossil Fuel Resource Analysis Tables

Table 64 through Table 68 identify the location and site area (in acres), and provide a brief summary of the screening analysis results for each site (first for oil or gas, then for coal). Sites are grouped into five classifications:

- Sites with areas smaller than 160 acres, considered too small for effective development of unconventional oil or gas resources and for coal resources (17 in Table 64)
- Sites with potential land release issues (2 in Table 65)
- Sites not in sedimentary basins or in basins with no oil or gas activity (23 in Table 66)
- Sites with no nearby active oil and gas drilling or production (7 in Table 67)
- Remaining sites that passed the various screens (6 in Table 68).

While conventional oil and gas potential was also considered in some of the screening criteria, none of the 55 sites show significant conventional oil and gas potential based on this initial screening.

Table 64. Sites Smaller than 160 Acres

Site Name	**Albany, OR, Site (site #1)**
Location	Albany, Linn County, OR
Lat/Long	44.620188 N, 123.120777 W
Acreage	16
Write-up:	The Albany, OR, Site is not in a known oil and gas basin. *The site is not in a coal-bearing basin.*
Site Name	**Burrell, PA, Disposal Site (site #6)**
Location	Burrell, Indiana County, PA
Lat/Long	40.433059 N, 79.242531 W
Acreage	73
Write-up	The Burrell, PA, Disposal Site is located within the Appalachian Basin and has potential targets in the Utica-Lower Paleozoic Total Petroleum System (TPS, as defined by the USGS and the Marcellus TPS. For the Tuscarora Basin Center Assessment Unit (AU) (Utica), the mean results of assessed undiscovered technically recoverable gas are as follows: 2619.59 billion cubic feet of gas (BCFG) and 10.48 million barrels of natural gas liquids (MMBNGL). The estimated ultimate recovery (EUR) per well in the Tuscarora Basin Center AU is 0.010-4.0 BCFG, with a median of 0.070 BCFG.[162] For the Interior Marcellus AU, the mean fully risked estimates of undiscovered resources are as follows: 81,374 BCFG (gas fields) and 3,255 MMBNGL (gas fields).[163] Horizontal wells in the Marcellus typically produce 4 MMCFD, and at an 80-acre well spacing are expected to produce 2.5 BCFG over their lifetime.[164] The site is classified under UMTRCA Title I; restrictions should be considered. *The site is not in a coal-bearing basin.*

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[162] Ryder, R.T. 2008. *Assessment of Appalachian Basin Oil and Gas Resources: Utica-Lower Paleozoic Total Petroleum System*. U.S. Geological Survey Open-File Report, 2008:1287, 29 p.

[163] Coleman, J.L., et al. 2011. *Assessment of Undiscovered Oil and Gas Resources of the Devonian Marcellus Shale of the Appalachian Basin Province, 2011*. U.S. Geological Survey fact sheet, 2011, 3092.

[164] Soeder, D.J. and W.M. Kappel. 2009. *Water Resources and Natural Gas Production from the Marcellus Shale*. U.S. Geological Survey fact sheet, 2009, 3032.

Table 64. Sites Smaller than 160 Acres (continued)

Site Name	**Canonsburg, PA, Disposal Site (site #7)**
Location	Canonsburg, Washington County, PA
Lat/Long	40.256152 N, 80.199721 W
Acreage	34
Write-up	The Canonsburg, PA, Disposal Site is located within the Appalachian Basin and has potential targets in the Utica-Lower Paleozoic TPS and the Marcellus TPS. For the Tuscarora Basin Center AU (Utica), mean results of assessed undiscovered technically recoverable gas are as follows: 2619.59 BCFG and 10.48 MMBNGL. The EUR per well in the Tuscarora Basin Center AU is 0.010-4.0 BCFG, with a median of 0.070 BCFG.[165] For the Interior Marcellus AU, the mean fully risked estimates of undiscovered resources are as follows: 81,374 BCFG (gas fields) and 3,255 MMBNGL (gas fields).[166] Horizontal wells in the Marcellus typically produce 4 MMCFD, and at an 80-acre well spacing are expected to produce 2.5 BCFG over their lifetime.[167] The site is classified under UMTRCA Title I; restrictions should be considered. *The site is in a coal-bearing basin. However, at only 34 acres, this site has been screened out on the basis of small surface acreage.*
Site Name	**Durango, CO, Disposal Site (site #9)**
Location	Durango, La Plata County, CO
Lat/Long	37.248481 N, 107.903876 W
Acreage	120
Write-up	The Durango, CO, Disposal Site is located within the San Juan Basin. As of 2009 42.6 TCFG and 381 million barrels of oil [MMBO] of cumulative production have been recovered from San Juan Basin fields.[168] The site, however, is located north of the areas currently being drilled in the San Juan Basin and shows no active wells. The site is classified under UMTRCA Title I; restrictions should be considered. *The site is in a coal-bearing basin. However, at only 120 acres, this site has been screened out on the basis of small surface acreage.*

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[165] Ryder, R.T. 2008. *Assessment of Appalachian Basin Oil and Gas Resources: Utica-Lower Paleozoic Total Petroleum System*. U.S. Geological Survey Open-File Report, 2008:1287, 29 p.

[166] Coleman, J.L., et al. 2011. *Assessment of Undiscovered Oil and Gas Resources of the Devonian Marcellus Shale of the Appalachian Basin Province, 2011*. U.S. Geological Survey fact sheet, 2011, 3092.

[167] Soeder, D.J. and W.M. Kappel. 2009. *Water Resources and Natural Gas Production from the Marcellus Shale*. U.S. Geological Survey fact sheet, 2009, 3032.

[168] Fassett, J.E. 2010. *Oil and Gas Resources of the San Juan Basin, New Mexico and Colorado*. Edited by J.E. Fassett, K.E. Zeigler, and V.W. Virgil. Geology of the Four Corners Country: New Mexico Geological Society 61st Annual Fall Field Conference Guildbook, 2010, p. 181-196.

Table 64. Sites Smaller than 160 Acres (continued)

Site Name	**Green River, UT, Disposal Site (site #16)**
Location	Green River, Emery County, UT
Lat/Long	38.978164 N, 110.136749 W
Acreage	26
Write-up	The Green River, UT, Disposal Site is located within the Uinta Basin and has potential targets in the Phosphoria TPS and the Mancos/Mowry TPS. For the Paleozoic/Mesozoic AU (Phosphoria), the mean fully risked estimates of undiscovered resources are as follows: 6.29 MMBO (oil fields), 1.89 BCFG (oil fields), 48.04 BCFG (gas fields), 0.11 MMBNGL (oil fields), and 1.54 MMBNGL (gas fields). Resource estimates are not available for the Mancos/Mowry TPS, because the site does not lie within the specified assessment units.[169] The site is classified under UMTRCA Title I; restrictions should be considered. *The site is not in a coal-bearing basin.*
Site Name	**Gunnison, CO, Disposal Site (site #17)**
Location	Gunnison, Gunnison County, CO
Lat/Long	38.51 N, 106.846 W
Acreage:	115
Write-up:	The Gunnison, CO, Disposal Site is located just outside the Piceance Basin. The site is classified under UMTRCA Title I; restrictions should be considered. *The site is not in a coal-bearing basin.*
Site Name:	**Kansas City Plant (site #21)**
Location:	Kansas City, Jackson County, MO
Lat/Long:	38.862982 N, 94.546425 W
Acreage:	136
Write-up:	The Kansas City Plant is located within the Forest City Basin. 75,000 bbl of oil are produced annually from the basin.[170] *The site is in a coal-bearing basin. However, at only 136 acres, this site has been screened out on the basis of small surface acreage.*

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[169] USGS Uinta-Piceance Assessment Team. 2003. *The Uinta-Piceance Province—Introduction to a Geologic Assessment of Undiscovered Oil and Gas Resources*. U.S. Geological Survey Digital Data Series DDS-69-B. USGS Uinta-Piceance Assessment Team, Petroleum Systems and Geologic Assessment of Oil and Gas in the Uinta-Piceance Province, Utah and Colorado.

[170] Garstang, M. et al. 2007. *Oil and Gas in the Show Me State: The Geologic Column of Missouri*. 2007, v. 2, no. 1.

Table 64. Sites Smaller than 160 Acres (continued)

Site Name:	**Lakeview, OR, Disposal Site (site #22)**
Location	Lakeview, Lake County, OR
Lat/Long	42.286 N, 120.433 W
Acreage	40
Write-up	The Lakeview, OR, Disposal Site is not in a known oil and gas basin. The site is classified under UMTRCA Title I; restrictions should be considered. *The site is not in a coal-bearing basin.*
Site Name	**Lowman, ID, Disposal Site (site #27)**
Location	Boise, Boise County, ID
Lat/Long	44.08479 N, 115.606689 W
Acreage	18
Write-up	The Lowman, ID, Disposal Site is not in a known oil and gas basin. The site is classified under UMTRCA Title I; restrictions should be considered. *The site is not in a coal-bearing basin.*
Site Name	**NETL (site #31)**
Location	Pittsburgh, Allegheny County, PA
Lat/Long	40.300521 N, 79.977682 W
Acreage	63
Write-up	NETL is located within the Appalachian Basin and has potential targets in the Utica-Lower Paleozoic TPS and the Marcellus TPS. For the Clinton-Medina Basin Center AU (Utica), the mean results of assessed undiscovered technically recoverable gas are as follows: 10,832.70 BCFG and 108.33 MMBNGL. The EUR per well in the Clinton-Medina Basin Center AU is 0.010–1.2 BCFG, with a median of 0.080 BCFG.[171] For the Interior Marcellus AU, the mean fully risked estimates of undiscovered resources are as follows: 81,374 BCFG and 3,255 MMBNGL.[172] Horizontal wells in the Marcellus typically produce 4 MMCFD, and at an 80-acre well spacing are expected to produce 2.5 BCFG over their lifetime.[173] The site is located within the city limits of Pittsburgh and any municipal restrictions should be considered. *The site is in a coal-bearing basin. However, at only 63 acres, this site has been screened out on the basis of small surface acreage.*

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[171] Ryder, R.T. 2008. *Assessment of Appalachian Basin Oil and Gas Resources: Utica-Lower Paleozoic Total Petroleum System*. U.S. Geological Survey Open-File Report, 2008:1287, 29 p.

[172] Coleman, J.L., et al. 2011. *Assessment of Undiscovered Oil and Gas Resources of the Devonian Marcellus Shale of the Appalachian Basin Province, 2011*. U.S. Geological Survey fact sheet, 2011, 3092.

[173] Soeder, D.J. and W.M. Kappel. 2009. *Water Resources and Natural Gas Production from the Marcellus Shale*. U.S. Geological Survey fact sheet, 2009, 3032.

Table 64. Sites Smaller than 160 Acres (continued)

Site Name	**NETL (site #32)**
Location	Albany, Linn County, OR
Lat/Long	44.623157
Acreage	44
Write-up	NETL is not located within a known oil and gas basin. *The site is not in a coal-bearing basin.*
Site Name:	**NETL (site #33)**
Location	Morgantown, Monongalia County, WV
Lat/Long	39.67234 N, 79.9777347 W
Acreage:	136
Write-up	NETL is located within the Appalachian Basin and has potential targets in the Utica-Lower Paleozoic TPS and the Marcellus TPS. For the Tuscarora Basin Center AU (Utica), the mean results of assessed undiscovered technically recoverable gas are as follows: 2619.59 BCFG and 10.48 MMBNGL. The EUR per well in the Tuscarora Basin Center AU is 0.010-4.0 BCFG, with a median of 0.070 BCFG.[174] For the Interior Marcellus AU, the mean fully risked estimates of undiscovered resources are as follows: 81,374 BCFG and 3,255 MMBNGL.[175] Horizontal wells in the Marcellus typically produce 4 MMCFD, and at an 80-acre well spacing are expected to produce 2.5 BCFG over their lifetime.[176] *The site is in a coal-bearing basin. However, at only 136 acres, this site has been screened out on the basis of small surface acreage.*

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[174] Ryder, R.T. 2008. *Assessment of Appalachian Basin Oil and Gas Resources: Utica-Lower Paleozoic Total Petroleum System*. U.S. Geological Survey Open-File Report, 2008:1287, 29 p.

[175] Coleman, J.L., et al. 2011. *Assessment of Undiscovered Oil and Gas Resources of the Devonian Marcellus Shale of the Appalachian Basin Province, 2011*. U.S. Geological Survey fact sheet, 2011, 3092.

[176] Soeder, D.J. and W.M. Kappel. 2009. *Water Resources and Natural Gas Production from the Marcellus Shale*. U.S. Geological Survey fact sheet, 2009, 3032.

Table 64. Sites Smaller than 160 Acres (continued)

Site Name	**Naturita, CO, Disposal Site [site #35]**
Location	Naturita, Montrose County, CO
Lat/Long	38.36 N, 108.757 W
Acreage	27
Write-up	The Naturita, CO, Disposal Site is located within the Paradox Basin and has potential targets in the Paradox Formation TPS. For the Leadville McCracken AU, the mean fully risked estimates of undiscovered resources are as follows: 20 MMBO (oil fields), 60 MCFG (oil fields), 52 MCFG (gas fields), 8 MMBNGL (oil fields), and 1 MMBNGL (gas fields). For the Pennsylvanian Carbonate Buildups and Fractured Limestone AU, the mean fully risked estimates of undiscovered resources are as follows: 54 MMBO (oil fields), 81 BCFG (oil fields), 530 BCFG (gas fields), 6 MMBNGL (oil fields), and 1 MMBNGL (gas fields). For the Upper Paleozoic-Mesozoic Reservoirs AU, the mean fully risked estimates of undiscovered resources are as follows: 5 MMBO (oil fields), 20 BCFG (oil fields), 87 BCFG (gas fields), 1 MMBNGL (oil fields), and 1 MMBNGL (gas fields). For the Cane Creek Shale Gas AU, the mean fully risked estimates of undiscovered resources are as follows: 4,530 BCFG (gas fields) and 181 MMBNGL (gas fields). For the Gothic, Chimney Rock, Hovenweep Shale Gas AU, the mean fully risked estimates of undiscovered resources are as follows: 6,490 BCFG (gas fields) and 260 MMBNGL (gas fields).[177] The site is classified under UMTRCA Title I; restrictions should be considered. *The site is not in a coal-bearing basin.*

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[177] Whidden, K.J. et al. 2011. *Assessment of Undiscovered Oil and Gas Resources in the Paradox Basin Province, Utah, Colorado, New Mexico, and Arizona, 2011*. U.S. Geological Survey fact sheet, 2011, 3031.

Table 64. Sites Smaller than 160 Acres (continued)

Site Name	**Parkersburg, WV, Site (site #40)**
Location	Parkersburg, Wood County, WV
Lat/Long	39.250115 N, 81.685817 W
Acreage	16
Write-up	The Parkersburg, WV, Site is located within the Appalachian Basin and has potential targets in the Utica-Lower Paleozoic TPS and the Marcellus TPS. For the Clinton-Medina Basin Center AU (Utica), the mean results of assessed undiscovered technically recoverable gas are as follows: 10,832.70 BCFG and 108.33 MMBNGL. The EUR per well in the Clinton-Medina Basin Center AU is 0.010-1.2 BCFG, with a median of 0.080 BCFG.[178] For the Western Margin Marcellus AU, the mean fully risked estimates of undiscovered resources are as follows: 2,059 BCFG (gas fields) and 124 MMBNGL (gas fields).[179] Horizontal wells in the Marcellus typically produce 4 MMCFD, and at an 80-acre well spacing are expected to produce 2.5 BCFG over their lifetime.[180] *The site is in a coal-bearing basin. However, at only 16 acres, this site has been screened out on the basis of small surface acreage.*
Site Name	**Salt Lake City, UT, Disposal Site (site #44)**
Location	Salt Lake City, Salt Lake County, UT
Lat/Long	40.691 N, 113.111 W
Acreage	99
Write-up	The Salt Lake City, UT, Disposal Site is located within the Eastern Great Basin and has potential targets in the Paleozoic-Tertiary Composite TPS. For the Neogene Basins AU, the mean fully risked estimates of undiscovered resources are as follows: 827 MMBO (oil fields), 108 BCFG (oil fields) and 6 MMBNGL (oil fields).[181] The site is classified under UMTRCA Title I; restrictions should be considered. *The site is not in a coal-bearing basin.*

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[178] Ryder, R.T. 2008. *Assessment of Appalachian Basin Oil and Gas Resources: Utica-Lower Paleozoic Total Petroleum System*. U.S. Geological Survey Open-File Report, 2008:1287, 29 p.

[179] Coleman, J.L., et al. 2011. *Assessment of Undiscovered Oil and Gas Resources of the Devonian Marcellus Shale of the Appalachian Basin Province, 2011*. U.S. Geological Survey fact sheet, 2011, 3092.

[180] Soeder, D.J. and W.M. Kappel. 2009. *Water Resources and Natural Gas Production from the Marcellus Shale*. U.S. Geological Survey fact sheet, 2009, 3032.

[181] Anna, L.O., L.N.R. Roberts, and C.J. Potter. 2007. *Geologic Assessment of Undiscovered Oil and Gas in the Paleozoic-Tertiary Composite Total Petroleum System of the Eastern Great Basin, Nevada and Utah*. U.S. Geological Survey Digital Data Series DDS-69-L. U.S. Geological Survey Eastern Great Basin Assessment Team, Geologic Assessment of Undiscovered Oil and Gas Resources of the Eastern Great Basin Province, Nevada, Utah, Idaho, and Arizona.

Table 64. Sites Smaller than 160 Acres (continued)

Site Name	Slick Rock, CO, Disposal Cell (site #50)
Location	Slick Rock, San Miguel County, CO
Lat/Long	38.054538 N, 108.864253 W
Acreage	61
Write-up	The Slick Rock, CO, Disposal Cell is located within the Paradox Basin and has potential targets in the Paradox Formation TPS. For the Leadville McCracken AU, the mean fully risked estimates of undiscovered resources are as follows: 20 MMBO (oil fields), 60 MCFG (oil fields), 52 MCFG (gas fields), 8 MMBNGL (oil fields), and 1 MMBNGL (gas fields). For the Pennsylvanian Carbonate Buildups and Fractured Limestone AU, the mean fully risked estimates of undiscovered resources are as follows: 54 MMBO (oil fields), 81 BCFG (oil fields), 530 BCFG (gas fields), 6 MMBNGL (oil fields), and 1 MMBNGL (gas fields). For the Upper Paleozoic-Mesozoic Reservoirs AU, the mean fully risked estimates of undiscovered resources are as follows: 5 MMBO (oil fields), 20 BCFG (oil fields), 87 BCFG (gas fields), 1 MMBNGL (oil fields), and 1 MMBNGL (gas fields). For the Cane Creek Shale Oil AU, the mean fully risked estimates of undiscovered resources are as follows: 215 MMBO (oil fields) 193 BCFG (oil fields) and 15 MMBNGL (oil fields). For the Gothic, Chimney Rock, Hovenweep Shale Gas AU, the mean fully risked estimates of undiscovered resources are as follows: 6,490 BCFG (gas fields) and 260 MMBNGL (gas fields).[182] The site is classified under UMTRCA Title I; restrictions should be considered. *The site is not in a coal-bearing basin.*

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[182] Whidden, K.J. et al. 2011. *Assessment of Undiscovered Oil and Gas Resources in the Paradox Basin Province, Utah, Colorado, New Mexico, and Arizona, 2011*. U.S. Geological Survey fact sheet, 2011, 3031.

Table 64. Sites Smaller than 160 Acres (continued)

Site Name:	**Spook, WY, Site (site #51)**
Location:	Glenrock, Converse County, WY
Lat/Long:	43.238852 N, 105.622524 W
Acreage:	22
Write-up:	The Spook, WY, Site is located within the Powder River Basin and has potential targets in the Pennsylvanian-Permian Composite TPS, the Mowry TPS, and the Niobrara TPS. For the Minnelusa-Tensleep-Leo AU (Pennsylvanian-Permian), the mean fully risked estimates of undiscovered resources are as follows: 60.51 MMBO (oil fields), 2.83 BCFG (oil fields), 7.32 BCFG (gas fields), 0.10 MMBNGL (oil fields), and 0.44 MMBNGL (gas fields). For the Fall River-Lakota Sandstone AU (Mowry), the mean fully risked estimates of undiscovered resources are as follows: 64.05 MMBO (oil fields), 74.70 BCFG (oil fields), 574.51 BCFG (gas fields), 4.48 MMBNGL (oil fields), and 57.47 MMBNGL (gas fields). For the Muddy Sandstone AU (Mowry), the mean fully risked estimates of undiscovered resources are as follows: 47.34 MMBO (oil fields), 149.14 BCFG (oil fields), 248.77 BCFG (gas fields), 13.43 MMBNGL (oil fields), and 24.85 MMBNGL (gas fields). For the Frontier-Turner Sandstone AU (Niabrara), the mean fully risked estimates of undiscovered resources are as follows: 10.18 MMBO (oil fields), 40.47 BCFG (oil fields), and 2.91 MMBNGL (oil fields). For the Sussex-Shannon Sandstone AU (Niabrara), the mean fully risked estimates of undiscovered resources are as follows: 8.67 MMBO (oil fields), 8.09 BCFG (oil fields), and 0.65 MMBNGL (oil fields). For the Mesaverde-Lewis Sandstone AU (Niabrara), the mean fully risked estimates of undiscovered resources are as follows: 6.00 MMBO (oil fields), 8.41 BCFG (oil fields), and 0.59 MMBNGL (oil fields). For the Mowry Continuous Oil AU, the mean fully risked estimates of undiscovered resources are as follows: 197.61 MMBO (oil fields), 197.61 BCFG (oil fields), and 11.86 MMBNGL (oil fields). For the Niobrara Continuous Oil AU, the mean fully risked estimates of undiscovered resources are as follows: 226.67 MMBO (oil fields), 226.67 BCFG (oil fields), and 13.60 MMBNGL (oil fields). The site is classified under UMTRCA Title I; restrictions should be considered.[183] *The site is in a coal-bearing basin. However, at only 22 acres, this site has been screened out on the basis of small surface acreage.*

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[183] Anna, L.O.. 2010. *Geologic Assessment of Undiscovered Oil and Gas in the Powder River Basin Province, Wyoming and Montana*. U.S. Geological Survey Digital Data Series DDS-69-U. U.S. Geological Survey Powder River Basin Assessment Team, Total Petroleum Systems and Geologic Assessment of Oil and Gas Resources in the Powder River Basin Province, Wyoming, and Montana.

Table 65. Sites with Potential Land Release Issues

Site Name	**Pantex Plant (site #39)**
Location	Pantex Village, Carson County, TX
Lat/Long	35.3219400 N, 101.563610 W
Acreage	3170
Write-up	The Pantex Plant is located near the Anadarko Basin, but not within it. This is a high-security facility, so permission for exploration is considered unlikely. Further investigation is not recommended. *The site is* ***not*** *in a coal-bearing basin.*
Site Name	**WIPP [site #54]**
Location	Carlsbad, Eddy County, NM
Lat/Long	32.3750000 N, 103.791667 W
Acreage	10240
Write-up	The WIPP is located within the Permian Basin in the Delaware Basin subdivision. The New Mexico portion of the Permian Basin has 17 plays that are Ordovician to Permian in age. Cumulative production of 4456.69 MMBO in Mexico from the Permian Basin as of 2000, with 1.08% of the production taking place in 2000. There are several reservoirs with more than 1 MMBO cumulative production from the Delaware Mountain Group Basinal Sandstone Play that are in the vicinity of the site, though this play is currently in decline.[184] WIPP is a storage site for radioactive waste from the research and production of nuclear weapons. The Land Withdrawal Act prohibits oil and gas production, including directional drilling from outside the boundaries, on or below designated Land Withdrawal Act land (LWA: Lease Evaluation 1998). *The site is* ***not*** *in a coal-bearing basin.*

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[184] Broadhead, R.F., Z. Jianhua, and W.D. Raatz. 2004. *Play Analysis of Major Oil Reservoirs in the New Mexico Part of the Permian Basin: Enhanced Production Through Advanced Technologies*. New Mexico Bureau of Geology and Mineral Resources Open File Report 479.

Table 66. Sites Not in a Sedimentary Basin, Located at the Edge of a Basin, or in Basins with No Oil and Gas Activity

Site Name	**Ambrosia Lake, NM, Disposal Site (site #2)**
Location	Grants, McKinley County, NM
Lat/Long	35.408798 N, 107.799285 W
Acreage	315
Write-up	The Ambrosia Lake, NM, Disposal Site is not in a known oil and gas basin. The site is classified under UMTRCA Title I; restrictions should be considered. *The site is not in a coal-bearing basin.*
Site Name	**ANL (site #3)**
Location	Argonne, DuPage County, IL
Lat/Long	41°42'51.14"N, 87°58'57.01"W
Acreage	1700
Write-up	ANL is located at the edge of the Michigan Basin, and it is not in a productive area. *The site is not in a coal-bearing basin.*
Site Name	**Bluewater, NM, Disposal Site (site #4)**
Location	Bluewater, Cibola County, NM
Lat/Long	35.270623 N, 107.947483 W
Acreage	3305
Write-u:	The Bluewater, NM, Disposal Site is not in a known oil and gas basin. The site is classified under UMTRCA Title II; restrictions should be considered. *The site is not in a coal-bearing basin.*
Site Name	**BNL (site #5)**
Location	Upton, Suffolk County, NY
Lat/Long	40.8600000 N, 72.869580 W
Acreage	5274
Write-up	BNL is not located within a known oil and gas basin. Additionally, further exploration is unlikely with the New York statewide ban on hydraulic fracturing. *The site is not in a coal-bearing basin.*

Table 66. Sites Not in a Sedimentary Basin, Located at the Edge of a Basin, or in Basins with No Oil and Gas Activity (continued)

Site Name	**CNTA, NV, Site (site #8)**
Location	Tonopah, Nye County, NV
Lat/Long	38.17335 N, 116.181771 W
Acreage	2560
Write-up	The CNTA is located within the Eastern Great Basin and has potential targets in the Paleozoic-Tertiary Composite TPS. For the Neogene Ranges and other Structures AU, the mean fully risked estimates of undiscovered resources are as follows: 470 MMBO (oil fields), 61 BCFG (oil fields), 1,133 BCFG (gas fields), 4 MMBNGL (oil fields), and 50 MMBNGL (gas fields).[185] However, the small basins of the Basin and Range province have not been attractive targets for exploration. Hence, this site is not recommended for further investigation. However, DOE should consider any request for exploration efforts on the site. *The site is not in a coal-bearing basin.*
Site Name	**Edgemont, SD, Site (site #10)**
Location	Edgemont, Fall River County, SD
Lat/Long	43.273539 N, 103.794231 W
Acreage	360
Write-up	The Edgemont, SD, Site is not located within a known oil and gas basin. The site is classified under UMTRCA Title II; restrictions should be considered. *The site is not in a coal-bearing basin.*
Site Name	**FNAL (site #12)**
Location	Batavia, Kane/DuPage Counties, IL
Lat/Long	41.831944 N, 88.257222 W
Acreage	6811
Write-up	FNAL is located at the edge of the Michigan Basin, and it is not in a productive area. *The site is not in a coal-bearing basin.*

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[185] Anna, L.O., L.N.R. Roberts, and C.J. Potter. 2007. *Geologic Assessment of Undiscovered Oil and Gas in the Paleozoic-Tertiary Composite Total Petroleum System of the Eastern Great Basin, Nevada and Utah*. U.S. Geological Survey Digital Data Series DDS-69-L. U.S. Geological Survey Eastern Great Basin Assessment Team, Geologic Assessment of Undiscovered Oil and Gas Resources of the Eastern Great Basin Province, Nevada, Utah, Idaho, and Arizona.

Table 66. Sites Not in a Sedimentary Basin, Located at the Edge of a Basin, or in Basins with No Oil and Gas Activity (continued)

Site Name	**INL [site #19]**
Location	Idaho Falls, Butte/Bingham/Bonneville/Jefferson Counties, ID
Lat/ Long	43.5293800 N, 112.943500 W
Acreage	64467
Write-up	INL is not located within any known oil and gas basins. The bedrock is volcanic to a very substantial depth, and the heat flow is very high. There has been no drilling for oil and gas in the area. *The site is not in a coal-bearing basin.*
Site Name	**L-Bar, NM, Disposal Site (site #24)**
Location	Seboyeta, Cibola County, New Mexico
Lat/Long	35.187561 N, 107.334722 W
Acreage	738
Write-up	The L-Bar, NM, Disposal Site is not in a known oil and gas basin. The site is classified under UMTRCA Title II; restrictions should be considered. *The site is not in a coal-bearing basin.*
Site Name	**LLNL Main Campus (site #22)**
Location	Livermore, Alameda County, CA
Lat/Long	37.6880600 N, 121.704700 W
Acreage	640
Write-up	The LLNL Main Campus is located just outside the Sacramento Basin Province. *The site is not in a coal-bearing basin.*
Site Name	**LLNL (Site 300) (DOE) (site #23)**
Location	Tracy, Alameda County, CA
Lat/Long	37.6443000 N, 121.576660 W
Acreage	2782
Write-up	LLNL (Site 300) (USDOE) is located just outside the Sacramento Basin Province. *The site is not in a coal-bearing basin.*
Site Name	**LANL (site #25)**
Location	Los Alamos, Sandoval County, NM
Lat/Long	35.8739170 N, 106.318916 W
Acreage	28000
Write-up	LANL is not located within a known oil and gas basin. It occurs at the edge of a major volcanic caldera, with high heat flow and any sedimentary rocks located at great depth. *The site is not in a coal-bearing basin.*

Table 66. Sites Not in a Sedimentary Basin, Located at the Edge of a Basin, or in Basins with No Oil and Gas Activity (continued)

Site Name	**Moab, UT, Site (site #29)**
Location	Moab, Grand County, UT
Lat/Long	39.070682 N, 108.568677 W
Acreage	439
Write-up	The Moab, UT, Site is located within the Paradox Basin and has potential targets in the Paradox Formation TPS. The table shows the mean fully risked estimates of undiscovered resources for the entire basin.[186]

Assessment Unit	**Oil (MMBO)**	**Gas (MCFG)**		**NGL (MMBNGL)**	
	Oil Fields	**Oil Fields**	**Gas Fields**	**Oil Fields**	**Gas Fields**
Leadville McCracken	20	60	52	8	1
Pennsylvanian Carbonate Buildups & Fractured Limestone	54	81	530	6	1
Upper Paleozoic-Mesozoic Reservoirs	5	20	87	1	1
Cane Creek Shale Gas			4,530		181
Gothic, Chimney Rock, Hovenweep Shale Gas			6,490		260

However, the Moab site is remote from any of the productive areas of the basin, and is located in a high intensity recreation area unlikely to be opened for exploration in the foreseeable future.

The site is not in a coal-bearing basin.

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[186] Whidden, K.J. et al. 2011. *Assessment of Undiscovered Oil and Gas Resources in the Paradox Basin Province, Utah, Colorado, New Mexico, and Arizona, 2011*. U.S. Geological Survey fact sheet, 2011, 3031.

Table 66. Sites Not in a Sedimentary Basin, Located at the Edge of a Basin, or in Basins with No Oil and Gas Activity (continued)

Site Name	**NNSS, formerly Nevada Test Site (site #36)**
Location	Mercury, Nye County, NV
Lat/Long	36.985330 N, 116, 188400 W
Acreage	775680
Write-up	The NNSS is located within the Eastern Great Basin and has potential targets in the Paleozoic-Tertiary Composite TPS. For the Neogene Ranges and other Structures AU, the mean fully risked estimates of undiscovered resources are as follows: 470 MMBO (oil fields), 61 BCFG (oil fields), 1,133 BCFG (gas fields), 4 MMBNGL (oil fields), and 50 MMBNGL (gas fields).[187] NNSS has hosted 100 atmospheric nuclear detonation tests and 828 underground nuclear detonation tests (NNSS website); regulations should be considered when assessing future exploration. Most of the target horizons are deeply buried across most of the test site. The site includes at least one major volcanic caldera, indicating that geothermal gradients are likely to be high, and therefore, kerogen maturities are likely to be high, and potentially depleted of hydrocarbons. *The site is not in a coal-bearing basin.*
Site Name	**ORNL Site (site #37)**
Location	Oak Ridge, Anderson/Roane Counties, TN
Lat/Long	35.9333330 N, 84.316667 W
Acreage	71584
Write-up	ORNL is located within the Appalachian Basin and has potential targets in the Utica-Lower Paleozoic TPS, though the site is not located within any of the assessment units for the TPS. The site's location at the edge of the basin suggests it is an unlikely target for exploration. *The site is not in a coal-bearing basin.*
Site Name	**Paducah Gaseous Diffusion Plant (site #38)**
Location	Paducah, McCracken County, KY
Lat/Long	37.1201300 N, 88.811110 W
Acreage	3556
Write-up	The Paducah Gaseous Diffusion Plant is located within the Illinois Basin, though it is southwest of the known gas fields in the basin and is located at the edge of the basin. *The site is in a coal-bearing basin. The coal potential of the site has not been assessed.*

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[187] Anna, L.O., L.N.R. Roberts, and C.J. Potter. 2007. *Geologic Assessment of Undiscovered Oil and Gas in the Paleozoic-Tertiary Composite Total Petroleum System of the Eastern Great Basin, Nevada and Utah*. U.S. Geological Survey Digital Data Series DDS-69-L. U.S. Geological Survey Eastern Great Basin Assessment Team, Geologic Assessment of Undiscovered Oil and Gas Resources of the Eastern Great Basin Province, Nevada, Utah, Idaho, and Arizona.

Table 66. Sites Not in a Sedimentary Basin, Located at the Edge of a Basin, or in Basins with No Oil and Gas Activity (continued)

Site Name	**SNL Albuquerque (site #45)**
Location	Albuquerque, Bernalillo County, NM
Lat/Long	35.055288 N, 106.532813 W
Acreage	193,000
Write-up	SNL Albuquerque is not located within a known oil and gas basin. Several deep dry holes in the Rio Grande Rift near Albuquerque suggest a very low potential for hydrocarbons in the area. *The site is not in a coal-bearing basin.*
Site Name	**Savannah River Site (site #46)**
Location	Aiken, Aiken/Barnwell/Allendale Counties, SC
Lat/Long	33.3488800 N, 81.737780
Acreage	180000
Write-up	The Savannah River Site is located within the South Georgia Basin, though the basin has not been assessed and there is currently no drilling in the area. *The site is not in a coal-bearing basin.*
Site Name	**SPRU (site #47)**
Location	Niskayuna, Schenectady County, NY
Lat/Long	42.818391 N, 73.868963 W
Acreage	200
Write-up	The SPRU is located on the edge of the Appalachian Basin and has potential targets in the Utica-Lower Paleozoic TPS. The site, however, is not within any of the assessment units from the basin. Additionally, further exploration is unlikely with the New York statewide ban on hydraulic fracturing. *The site is not in a coal-bearing basin.*
Site Name:	**Shoal, NV, Site (site #49)**
Location:	Fallon, Churchill County, NV
Lat/Long:	39.201384 N, 118.387466 W
Acreage:	2560
Write-up:	The Shoal, NV, Site is not located within a known oil and gas basin. *The site is not in a coal-bearing basin.*
Site Name	**Thomas Jefferson National Accelerator Facility (site #52)**
Location	Newport News, Not in a County (Independent), VA
Lat/Long	37.095217 N, 76.484624 W
Acreage	171
Write-up	The Thomas Jefferson National Accelerator Facility is not located within any known oil and gas basin. *The site is not in a coal-bearing basin.*

Table 66. Sites Not in a Sedimentary Basin, Located at the Edge of a Basin, or in Basins with No Oil and Gas Activity (continued)

Site Name	**BPA Ross Complex (site #53)**
Location	Vancouver, Clark County, WA
Lat/Long	45.6616000 N, 122.657200 W
Acreage	250
Write-up	The BPA Ross Complex is not located within a known oil and gas basin. *The site is not in a coal-bearing basin.*
Site Name	**Weldon Springs, MO, Site [site #55]**
Location	St. Louis, St. Charles County, Missouri
Lat/Long	38.698168 N, 90.728274 W
Acreage	267
Write-up	The Weldon Springs, MO, Site is near the Illinois Basin, but not within it. *The site is not in a coal-bearing basin.*

Table 67. Sites with No Active Drilling or Production Nearby in the Basin

<table>
<tr><th>Site Name</th><th>Grand Junction, CO, Disposal Site (site #15)</th></tr>
<tr><td>Location</td><td>Grand Junction, Mesa County, CO</td></tr>
<tr><td>Lat/Long</td><td>38.902 N, 108.338 W</td></tr>
<tr><td>Acreage</td><td>360</td></tr>
<tr><td>Write-up</td><td>The Grand Junction, CO, Disposal Site is located within the Piceance Basin and has potential targets in the Mancos/Mowry TPS. The site, however, is not within any of the assessment units for the TPS. The site is classified under UMTRCA Title I; restrictions should be considered. No producing wells are near the site.
The site is in a coal-bearing basin. The coal potential of the site has not been assessed.</td></tr>
<tr><th>Site Name</th><th>Maybell West, CO, Disposal Site (site #27)</th></tr>
<tr><td>Location</td><td>Maybell, Moffat County, CO</td></tr>
<tr><td>Lat/Long</td><td>40.544556 N, 108.015615 W</td></tr>
<tr><td>Acreage</td><td>250</td></tr>
<tr><td>Write-up</td><td>The Maybell West, CO, Disposal Site is located within the Sand Wash Basin (Greater Green River Basin) and has potential targets in the Phosphoria TPS, the Mowry Composite TPS, the Niobrara TPS, the Hilliard-Baxter-Mancos TPS, and the Mesaverde TPS.[188] The table shows the mean fully risked estimates of undiscovered resources for the entire basin from that assessment.
<table>
<tr><th rowspan="2">Assessment Unit</th><th>Oil (MMBO)</th><th colspan="2">Gas (MCFG)</th><th colspan="2">NGL (MMBNGL)</th></tr>
<tr><th>Oil Fields</th><th>Oil Fields</th><th>Gas Fields</th><th>Oil Fields</th><th>Gas Fields</th></tr>
<tr><td>Phosphoria</td><td>16.6</td><td>32.2</td><td>1,350.70</td><td>1.2</td><td>40.6</td></tr>
<tr><td>Mowry</td><td>6.6</td><td>11.2</td><td>195.1</td><td>1.6</td><td>3.9</td></tr>
<tr><td>Niobrara</td><td>103.6</td><td>62.6</td><td></td><td>3.7</td><td></td></tr>
<tr><td>Hilliard-Baxter-Mancos</td><td></td><td></td><td>15.5</td><td></td><td>1</td></tr>
<tr><td>Mesaverde Conventional</td><td>2.3</td><td>18.8</td><td>36.9</td><td>0.7</td><td>0.4</td></tr>
<tr><td>Mesaverde Coalbed Gas</td><td></td><td></td><td>248.7</td><td></td><td>0</td></tr>
</table>
Although there are a number of well locations in the vicinity of the site, none has resulted in any production. Therefore, the site is considered to be unprospective for oil and gas production.
The site is classified under UMTRCA Title I; restrictions should be considered.
The site is in a coal-bearing basin. The coal potential of the site has not been assessed.</td></tr>
</table>

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[188] USGS Southwestern Wyoming Province Assessment Team. 2005. *The Southwestern Wyoming Province—Introduction to a Geologic Assessment of Undiscovered Oil and Gas Resources.* U.S. Geological Survey Digital Data Series DDS-69-D. USGS Southwestern Wyoming Province Assessment Team, Petroleum Systems and Geologic Assessment of Oil and Gas in the Southwestern Wyoming Province, Wyoming, Colorado, and Utah.

Table 67. Sites with No Active Drilling or Production Nearby in the Basin (continued)

Site Name	**Maybell, CO, Disposal Site (site #28)**
Location	Maybell, Moffat County, CO
Lat/Long	40.543859 N, 107.99287 W
Acreage	250
Write-up	The Maybell, CO, Disposal Site is located within the Sand Wash Basin (Greater Green River Basin) and has potential targets in the Phosphoria TPS, the Mowry Composite TPS, the Niobrara TPS, the Hilliard-Baxter-Mancos TPS, and the Mesaverde TPS.[189] The table shows the mean fully risked estimates of undiscovered resources for the entire basin, from that assessment.

Assessment Unit	**Oil (MMBO)**	**Gas (MCFG)**		**NGL (MMBNGL)**	
	Oil Fields	**Oil Fields**	**Gas Fields**	**Oil Fields**	**Gas Fields**
Phosphoria	16.6	32.2	1,350.70	1.2	40.6
Mowry	6.6	11.2	195.1	1.6	3.9
Niobrara	103.6	62.6		3.7	
Hilliard-Baxter-Mancos			15.5		1
Mesaverde Conventional	2.3	18.8	36.9	0.7	0.4
Mesaverde Coalbed Gas			248.7		0

Although there are a number of well locations in the vicinity of the site, none has resulted in any production. Therefore, the site is considered to be unprospective for oil and gas production.

The site is classified under UMTRCA Title I; restrictions should be considered.

The site is in a coal-bearing basin. The coal potential of the site has not been assessed.

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[189] Ibid.

Table 67. Sites with No Active Drilling or Production Nearby in the Basin (continued)

<table>
<tr><th>Site Name</th><th>Monticello, UT, Disposal and Processing Sites (site #30)</th></tr>
<tr><td>Location</td><td>Monticello, San Juan County, UT</td></tr>
<tr><td>Lat/Long</td><td>37.851103 N, 109.325213 W</td></tr>
<tr><td>Acreage</td><td>995</td></tr>
<tr><td>Write-up</td><td>The Monticello, UT, Disposal and Processing Sites are located within the Paradox Basin and have potential targets in the Paradox Formation TPS. The table shows the mean fully risked estimates of undiscovered resources for the entire basin.[190]
<table>
<tr><th rowspan="2">Assessment Unit</th><th>Oil (MMBO)</th><th colspan="2">Gas (MCFG)</th><th colspan="2">NGL (MMBNGL)</th></tr>
<tr><th>Oil Fields</th><th>Oil Fields</th><th>Gas Fields</th><th>Oil Fields</th><th>Gas Fields</th></tr>
<tr><td>Leadville McCracken</td><td>20</td><td>60</td><td>52</td><td>8</td><td>1</td></tr>
<tr><td>Pennsylvanian Carbonate Buildups & Fractured Limestone</td><td>54</td><td>81</td><td>530</td><td>6</td><td>1</td></tr>
<tr><td>Upper Paleozoic-Mesozoic Reservoirs</td><td>5</td><td>20</td><td>87</td><td>1</td><td>1</td></tr>
<tr><td>Cane Creek Shale Gas</td><td></td><td></td><td>4,530</td><td></td><td>181</td></tr>
<tr><td>Gothic, Chimney Rock, Hovenweep Shale Gas</td><td></td><td></td><td>6,490</td><td></td><td>260</td></tr>
</table>
The site is classified under UMTRCA Title I; restrictions should be considered.
The site is in a coal-bearing basin. The coal potential of the site has not been assessed</td></tr>
<tr><th>Site Name</th><th>NREL (site #34)</th></tr>
<tr><td>Location</td><td>Golden, Jefferson County, CO</td></tr>
<tr><td>Lat/Long</td><td>39.74084 N, 105.168528 W</td></tr>
<tr><td>Acreage</td><td>632</td></tr>
<tr><td>Write-up</td><td>NREL is located within the Denver Basin and has potential targets in Upper Cretaceous sandstones and shales, including the Niobrara.[191] There would likely be reluctance to drill at the NREL facility.
The site is in a coal-bearing basin. The coal potential of the site has not been assessed. There would be little likelihood that, even if the coal-bearing horizons were near the surface, which they probably are not, that coal mining would be permitted in such an urban area.</td></tr>
</table>

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[190] Whidden, K.J. et al. 2011. *Assessment of Undiscovered Oil and Gas Resources in the Paradox Basin Province, Utah, Colorado, New Mexico, and Arizona, 2011*. U.S. Geological Survey fact sheet, 2011, 3031.

[191] Higley, D.K., and D.O. Cox. 2007. *Oil and Gas Exploration and Development along the Front Range in the Denver Basin of Colorado, Nebraska, and Wyoming*. U.S. Geological Survey Digital Data Series DDS-69-P. Petroleum Systems and Assessment of Undiscovered Oil and Gas in the Denver Basin Province, Colorado, Kansas, Nebraska, South Dakota, and Wyoming—USGS Province 39.

Table 67. Sites with No Active Drilling or Production Nearby in the Basin (continued)

Site Name	**Rifle, CO, Disposal Site (site #42)**
Location	Rifle, Garfield County, CO
Lat/Long	39.614434 N, 107.801258 W
Acreage	205
Write-up	The Rifle, CO, Disposal Site is located on the edge of the Piceance Basin and has potential targets in the Mancos/Mowry TPS and the Mesaverde TPS. For the Piceance Basin AU (Mancos/Mowry), the mean fully risked estimates of undiscovered resources are as follows: 1,652.90 BCFG (gas fields) and 1.65 MMBNGL (gas fields).[192] For the Mesaverde TPS, the site is not within any of the AUs. However, the site lies on the edge of the basin, and although a number of wells have been drilled in the vicinity, the wells closest to the site have been dry holes. Nearby production is in more flat-lying rocks further out into the basin. The site is classified under UMTRCA Title I; restrictions should be considered. *The site is in a coal-bearing basin. The coal potential of the site has not been assessed. However, it is likely that the coal-bearing horizons are buried at far too great depth at the site for mining.*
Site Name	**Shirley Basin South, WY, Disposal Site (site #48)**
Location	Casper, Carbon County, WY
Lat/Long	42.363845 N, 106.174319 W
Acreage	1,527
Write-up	The Shirley Basin South, WY, Disposal Site is located within the Shirley Basin and has potential targets in the Phosphoria TPS and the Mowry-Hanna Composite TPS assessed by Dyman and Condon.[193] For the Tensleep-Casper Conventional Oil and Gas AU (Phosphoria), the mean fully risked estimates of undiscovered resources are as follows: 20 MMBO (oil fields), 20 MCFG (oil fields), 52 MCFG (gas fields), 740 MMBNGL (oil fields), and 1,550 MMBNGL (gas fields) For the Mesozoic-Cenozoic Conventional Oil and Gas AU (Mowry-Hanna), the mean fully risked estimates of undiscovered resources are as follows: 36 MMBO (oil fields), 89 MCFG (oil fields), 118 MCFG (gas fields), 8,910 MMBNGL (oil fields), and 2,360 MMBNGL (gas fields). No production has been established in the vicinity of the Shirley Basin site, and the site is considered unprospective for oil and gas production. The site is classified under UMTRCA Title II; restrictions should be considered. *The site is not in a coal-bearing basin.*

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[192] USGS Uinta-Piceance Assessment Team. 2003. *The Uinta-Piceance Province—Introduction to a Geologic Assessment of Undiscovered Oil and Gas Resources*. U.S. Geological Survey Digital Data Series DDS-69-B. USGS Uinta-Piceance Assessment Team, Petroleum Systems and Geologic Assessment of Oil and Gas in the Uinta-Piceance Province, Utah and Colorado.

[193] Dyman, T.S. and S.M. Condon. 2005. *2005 Geologic Assessment of Undiscovered Oil and Gas Resources, Hanna, Laramie, and Shirley Basins Province, Wyoming and Colorado*. U.S. Geological Survey Digital Data Series DDS-69-K. U.S. Geological Survey Hanna, Laramie, and Shirley Basins Province Assessment Team, Petroleum Systems and Geological Assessment of Undiscovered Oil and Gas, Hanna, Laramie, and Shirley Basins Province, Wyoming and Colorado.

Table 68. Sites with Potential for Oil and Gas Development

Site Name	**Falls City, TX, Disposal Site (site #11)**
Location	Falls City, Wilson County, TX
Lat/Long	28.905375 N, 98.132276 W
Acreage	744
Write-up	The Falls City, TX, Disposal Site is located within the Western Gulf Basin and has potential targets in the Eagle Ford Shale. The mean EUR for Eagle Ford Wells in Karnes County is 226,000 bbl among 975 wells.[194] The site is located within the oil window of the Eagle Ford Play. This is the highest-priority site in the DOE list, and it should be evaluated for its potential to produce from the Eagle Ford Formation. This would require significant effort, preferably by someone familiar with the play. The site is classified under UMTRCA Title I; restrictions should be considered. *The site is in a coal-bearing basin. The coal potential of the site has not been assessed. Tertiary lignite coal is mined in the vicinity. However, mining would disturb the uranium mill tailings at the site, which is likely to render the site unprospective unless the tailings could be relocated to another site. This should be considered only if the site is found to be prospective for the coal resources and large enough to warrant mining.*
Site Name	**Gasbuggy, NM, Site (site #13)**
Location	Farmington, Rio Arriba County, NM
Lat/Long	36.678031 N, 107.21023 W
Acreage	640
Write-up	The Gasbuggy, NM, Site is located within the San Juan Basin, in the northeast portion of the central basin. Cretaceous fields have produced 93% of the oil and 99% of the gas from the San Juan Basin; 78% of the gas and 99% of the oil are produced in New Mexico. There has been 42.6 TCFG and 381 MMBO cumulative production from more than 300 fields in the basin as of 2009, though many of the fields are nearing depletion.[195] Production is primarily from Upper Cretaceous sandstones and silty to sandy mudstones, though there has also been significant gas production from coal beds in the Fruitland Formation. This site was used to test the use of nuclear devices for stimulating natural gas production; subsurface intrusion is prohibited within 600 feet of the monument to a true vertical depth of 1,500–4,500 feet without the permission of the U.S. Government.[196] However, serious consideration should be given to more detailed evaluation of the site, as there appear to be oil and gas wells in the immediate vicinity, and the site is in a productive oil and gas basin. *The site is in a coal-bearing basin. The coal potential of the site has not been assessed.*

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[194] Oil & Gas Journal Editors, "EIA estimates average Eagle Ford EUR at 168,000 bbl/well." *Oil & Gas Journal*, May 9, 2014, accessed August 2015 at http://www.ogj.com/articles/2014/05/eia-estimates-average-eagle-ford-eur-at-168-000-bbl-well.html.

[195] Fassett, J.E. 2010. *Oil and Gas Resources of the San Juan Basin, New Mexico and Colorado*. Edited by J.E. Fassett, K.E. Zeigler, and V.W. Virgil. Geology of the Four Corners Country: New Mexico Geological Society 61st Annual Fall Field Conference Guildbook, 2010, p. 181-196.

[196] DOE. 2014. *Gasbuggy, New Mexico, Site*. Office of Legacy Management fact sheet, Gasbuggy, New Mexico.

Table 68. Sites with Potential for Oil and Gas Development (continued)

Site Name	**Gnome-Coach, NM, Site (site #14)**
Location	Carlsbad, Eddy County, NM
Lat/Long	32.263092 N, 103.869695
Acreage	680
Write-up	The Gnome-Coach, NM, Site is located within the Permian Basin, in the Delaware Basin subdivision. The New Mexico portion of the Permian Basin has 17 plays that are Ordovician to Permian in age. Cumulative production of 4456.69 MMBO in Mexico from the Permian Basin as of 2000, with 1.08% of the production taking place in 2000. There are several reservoirs with more than 1 MMBO cumulative production from the Delaware Mountain Group Basinal Sandstone Play that are in the vicinity of the site, though this play is currently in decline.[197] This site was used to test underground detonation of a nuclear device, and oil and gas leases are not permitted within the withdrawn area,[198] which is likely to be comparable to that for the Gasbuggy site. Serious consideration should be given to more detailed evaluation of the site, as there appear to be oil and gas wells in the immediate vicinity, and the site is in a productive oil and gas basin. *The site is not in a coal-bearing basin.*

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[197] Broadhead, R.F., Z. Jianhua, and W.D. Raatz. 2004. *Play Analysis of Major Oil Reservoirs in the New Mexico Part of the Permian Basin: Enhanced Production Through Advanced Technologies*. New Mexico Bureau of Geology and Mineral Resources Open File Report 479.

[198] DOE. 2014. *Gnome-Coach, New Mexico, Site*. Office of Legacy Management fact sheet, Gnome-Coach, New Mexico.

Table 68. Sites with Potential for Oil and Gas Development (continued)	
Site Name	**Hanford Site (site #18)**
Location	Richland, Benton County, WA
Lat/Long	46.5627 N, 119.5226 W
Acreage	307,467
Write-up	The Hanford Site is located within the Columbia River Basin and has targets in the Eocene Roselyn Formation as well as secondary targets in the Swauk/Manastash and Teanaway Formations and the Oligocene Wenatchee Formation. The site has undergone two rounds of drilling using modern methods, once in the 1980s and again in the 2000s. The BN 1-9 Test well drilled in the 1980s produced 5.1 MMCFD and 6 BCPD over a 62-day period. Drilling is made difficult by the presence of several thousand feet of the Columbia River Basalt that must be penetrated to reach the sedimentary basin. Montgomery estimated reserves as follows: 47.58 bcf per well in a volcanic reservoir with 320-acre well spacing; 39.46 bcf per well in a conventional reservoir with 640-acre well spacing; 14.73 bcf per well in a basin-center tight reservoir with 160-acre well spacing.[199] In addition, the Potential Gas Committee suggested the potential for 6,750 BCFG gas (most likely total estimate) in the Columbia Basin.[200] However, this is considered a very long-term prospect that would require significant advances in drilling technique and depletion of significant global resources more readily produced to become an attractive target for development. *The site is not in a coal-bearing basin.*
Site Name	**Portsmouth Gaseous Diffusion Plant (site #41)**
Location	Piketon, Pike County, OH
Lat/Long	39.0083330 N, 83.000000 W
Acreage	3,708
Write-up	The Portsmouth Gaseous Diffusion Plant is located within the Appalachian Basin and has potential targets in the Utica-Lower Paleozoic TPS. The site is not located within any of the AUs for the TPS and is west of the gas fields of the Clinton-Medina Transitional AU. Some additional evaluation of the potential of the site may be warranted. *The site is not in a coal-bearing basin.*

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[199] Montgomery, S.L. 2008. "New exploration concepts highlight Columbia River basin's potential," *Oil & Gas Journal*, January 14, 2008, v. 106, no. 2, accessed August 2015 at http://www.ogj.com/articles/print/volume-106/issue-2/exploration-development/new-exploration-concepts-highlight-columbia-river-basinrsquos-potential.html.

[200] Potential Gas Committee. 2015. *Potential Supply of Natural Gas in the United States; Report of the Potential Gas Committee, December 31, 2014*. Potential Gas Agency, Colorado School of Mines, Golden, CO.

Table 68. Sites with Potential for Oil and Gas Development (continued)

<table>
<tr><th>Site Name</th><th>Rio Blanco, CO, Site</th></tr>
<tr><td>Location</td><td>Rio Blanco, Rio Blanco County, CO</td></tr>
<tr><td>Lat/Long</td><td>39.792404 N, 108.367501 W</td></tr>
<tr><td>Acreage</td><td>360</td></tr>
<tr><td>Write-up</td><td>
<p>The Rio Blanco Site is located within the Piceance Basin and has potential targets in the Phosphoria TPS, the Mancos/Mowry TPS, and the Mesaverde TPS. Additionally, the site is located within the Sulphur Creek Gas field.[201] The table shows the mean fully risked estimates of undiscovered resources for the various AUs from the USGS study.</p>
<table>
<tr><th rowspan="2">Assessment Unit</th><th>Oil (MMBO)</th><th colspan="2">Gas (BCFG)</th><th colspan="2">NGL (MMBNGL)</th></tr>
<tr><th>Oil Fields</th><th>Oil Fields</th><th>Gas Fields</th><th>Oil Fields</th><th>Gas Fields</th></tr>
<tr><td>Phosphoria</td><td>6.29</td><td>1.89</td><td>48.04</td><td>0.11</td><td>1.54</td></tr>
<tr><td>Mowry/Mancos</td><td></td><td></td><td>1,652.90</td><td></td><td>1.65</td></tr>
<tr><td>Mesaverde Transitional</td><td></td><td></td><td>301.73</td><td></td><td>0.6</td></tr>
<tr><td>Mesaverde Sandstone</td><td></td><td></td><td>66.41</td><td></td><td>0.53</td></tr>
<tr><td>Mesaverde Continuous</td><td></td><td></td><td>3,064.27</td><td></td><td>9.19</td></tr>
</table>
<p>This site was used to test the use of nuclear devices for stimulating natural gas production; subsurface intrusion is prohibited within 600 feet of the monument to a true vertical depth of 1,500–4,500 feet without the permission of the U.S. government.[202] The remainder of the site, however, has substantial potential for gas production, and could be seriously considered for leasing, with due consideration of the restrictions.</p>
<p><i>The site is in a coal-bearing basin. The coal potential of the site has not been assessed. However, the coal formation is much deeper than 3,000 feet, and therefore unmineable.</i></p>
</td></tr>
</table>

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[201] USGS Uinta-Piceance Assessment Team. 2003. *The Uinta-Piceance Province—Introduction to a Geologic Assessment of Undiscovered Oil and Gas Resources*. U.S. Geological Survey Digital Data Series DDS-69-B. USGS Uinta-Piceance Assessment Team, Petroleum Systems and Geologic Assessment of Oil and Gas in the Uinta-Piceance Province, Utah and Colorado.

[202] DOE. 2014. *Rio Blanco, Colorado, Site*. Office of Legacy Management fact sheet, Rio Blanco, Colorado.

G.2 Fossil Fuel Resource Analysis Maps

The maps in Figure 70 through Figure 74 show DOE sites screened for fossil fuel resources, as well as gas and oil resources.

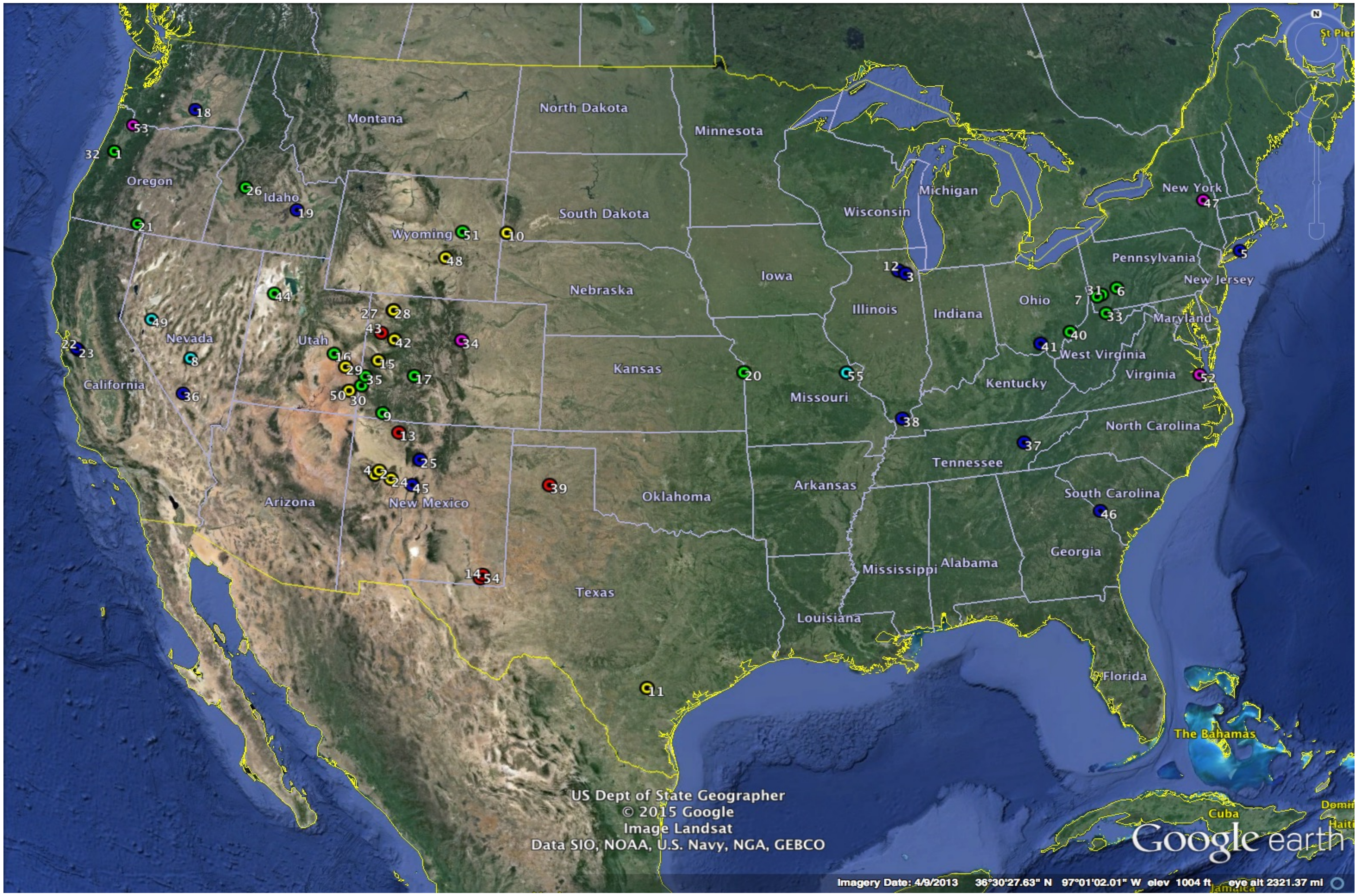
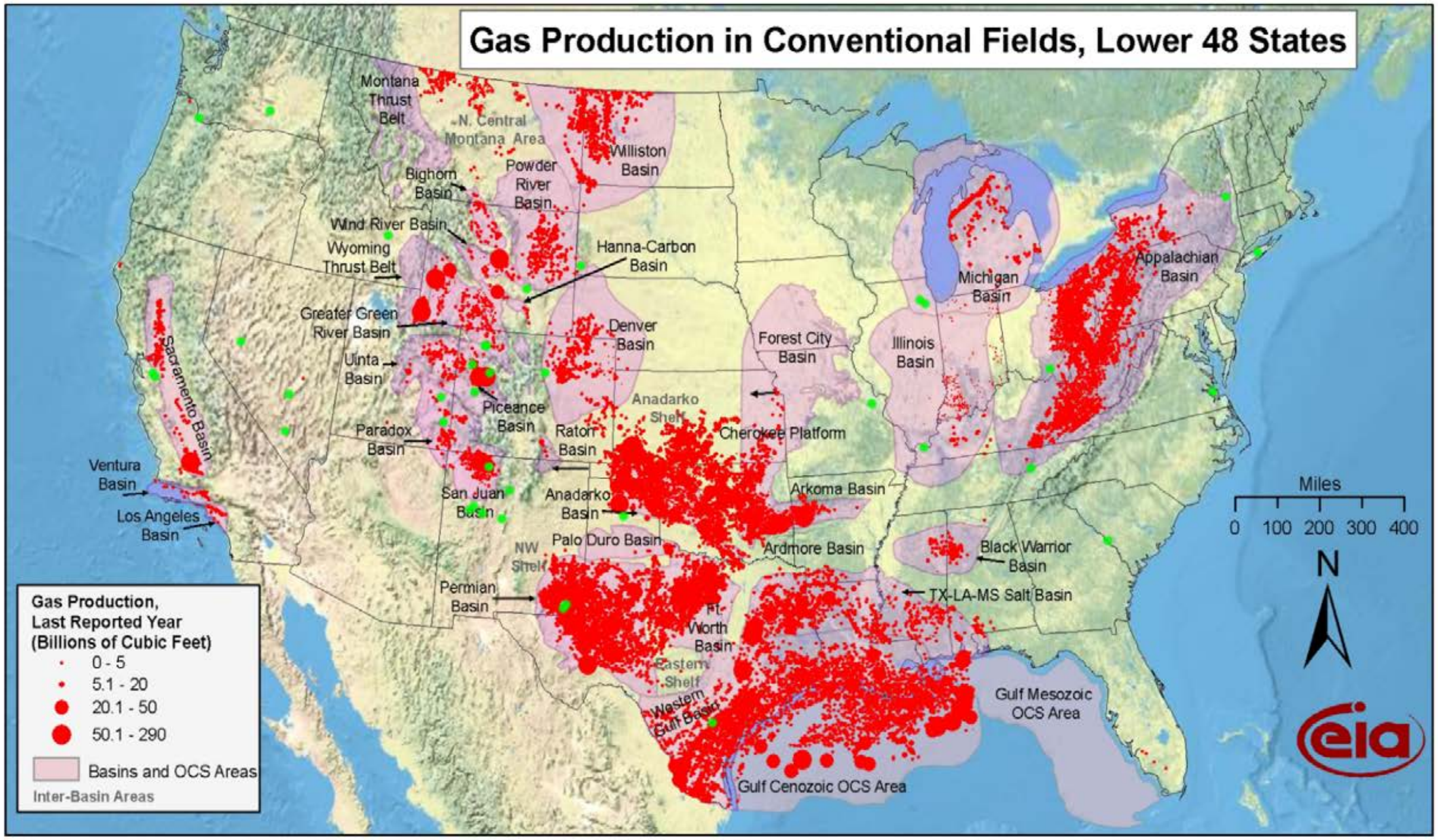


Figure 70. Locations of 55 DOE evaluated for this report

Source: © 2015 Google Earth, alterations by Jeremy Boak (CSM)



Source: Energy Information Administration based on data from HPDI, IN Geological Survey, USGS
Updated: April 8, 2009

Figure 71. Gas production in conventional fields of the contiguous 48 states

Source: U.S. Energy Information Administration[203]

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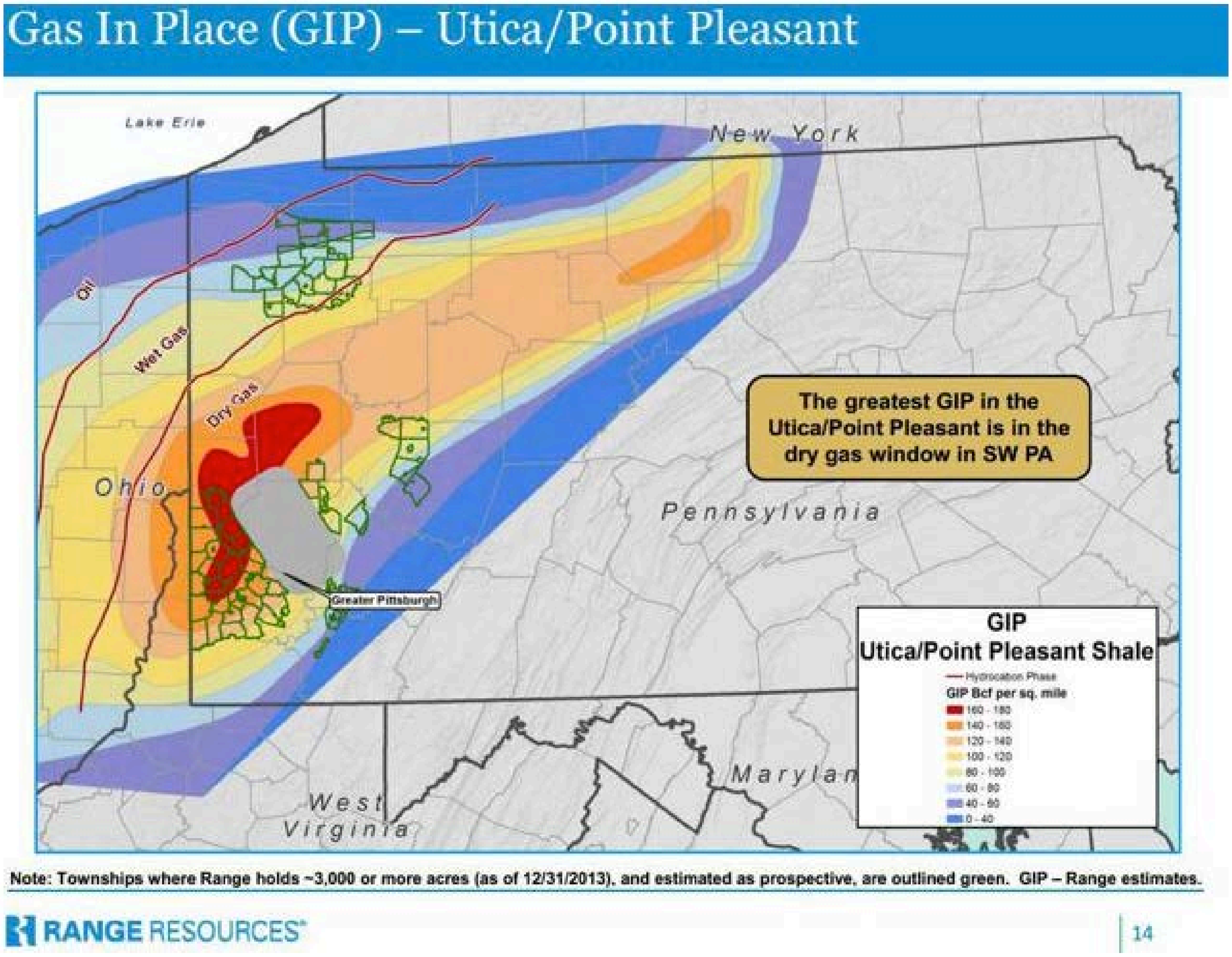
[203] U.S. Energy Information Administration. 2009. *Gas Production in Conventional Fields, Lower 48 States*. Accessed August 2015 at http://www.eia.gov/oil_gas/rpd/conventional_gas.pdf.



Gas In Place (GIP) – Utica/Point Pleasant

The greatest GIP in the Utica/Point Pleasant is in the dry gas window in SW PA

Note: Townships where Range holds ~3,000 or more acres (as of 12/31/2013), and estimated as prospective, are outlined green. GIP – Range estimates.

Figure 72. Map of gas-in-place in the Utica and Point Pleasant formations: Ohio, Pennsylvania, and New York

Source: Range Resources[204]

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[204] Zeits, R. 2014. "Shell's Deep Utica Discovery Opens A New Chapter For Northeast Gas." *Seeking Alpha*, September 4, 2014, accessed August 2015 at http://seekingalpha.com/article/2470225-shells-deep-utica-discovery-opens-a-new-chapter-for-northeast-gas.

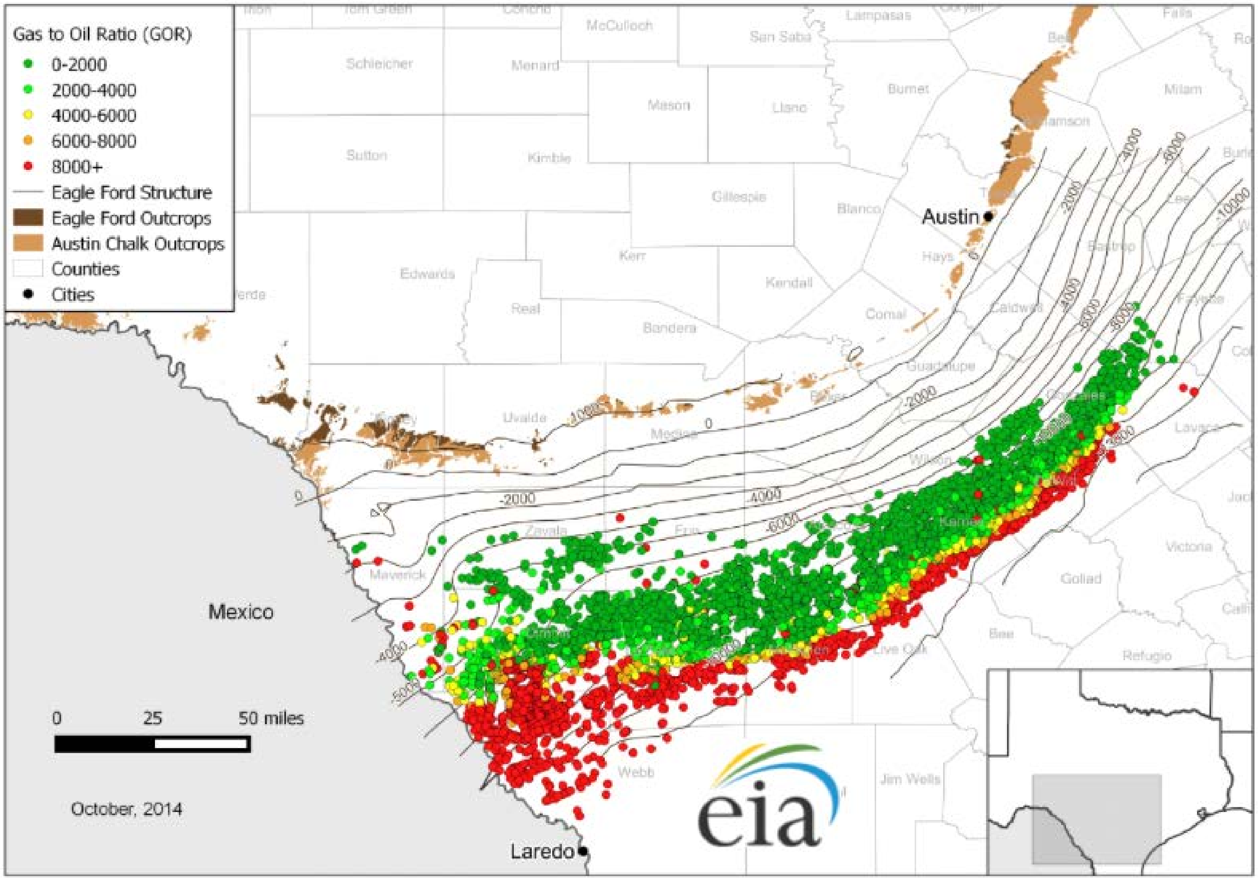

Figure 73. Initial gas-to-oil ratios of Eagle Ford wells (January 2000 to June 2014)

Source: U.S. Energy Information Administration[205]

In Figure 73, EIA calculates the initial gas-to-oil ratio (GOR) for each well using the second through fourth contiguous months of liquid and/or gas production. The first month of production may not represent full production and is, thus, not included in the GOR calculations.

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[205] U.S. Energy Information Administration. 2014. *Updates to the EIA Eagle Ford Play Maps.* U.S. Department of Energy, accessed August 2015 at http://www.eia.gov/maps/pdf/EIA%20Eagle%20Ford%20Play%20update%2012-29-14.pdf.

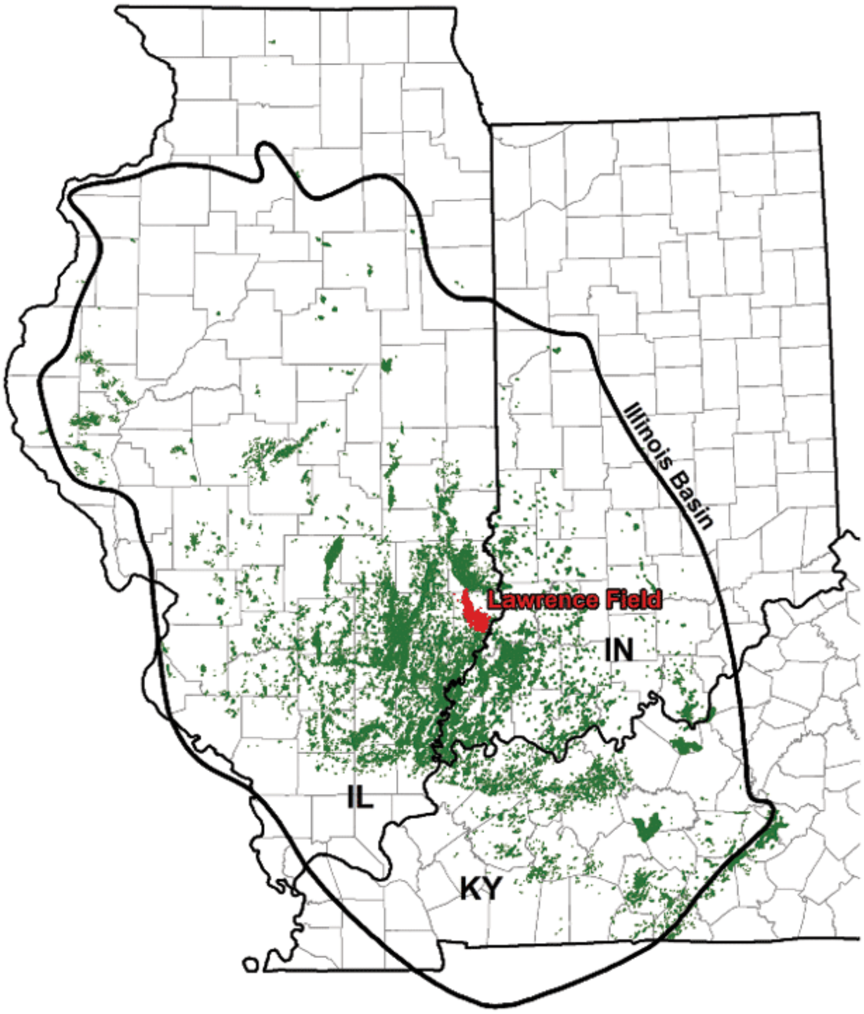

Figure 74. Location of the Lawrence Field in the Illinois Basin, showing the Basin boundary

Source: The American Oil & Gas Reporter[206]

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[206] Jikich, S. et al. 2012. "Illinois Applications Demonstrating Potential Of ASP EOR Technology." *The American Oil & Gas Reporter*, June 2012, accessed August 2015 at http://www.aogr.com/magazine/cover-story/illinois-basin-applications-demonstrating-potential-of-asp-eor-technology.