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Western Renewable Energy Zones, Phase 1: QRA Identification Technical Report

Subcontract Report
NREL/SR-6A2-46877
October 2009

Ryan Pletka and Josh Finn
Black & Veatch Corporation
Overland Park, Kansas

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1.0 Executive Summary

Black & Veatch is pleased to provide this report on the Western Renewable Energy Zones (WREZ) initiative Phase 1 Qualified Resource Area identification process to the National Renewable Energy Laboratory. This report describes the identification and economic analysis of Qualified Resource Areas (QRAs) and "non-REZ" resources. These data and analyses will assist the Western US in its renewable energy transmission planning goals. The economic analysis in this report produced the input data for the WREZ Generation and Transmission model, which is a screening-level model to determine the optimal routing for and cost of delivering renewable energy from QRAs to load centers throughout the Western Interconnection.

This report is the final Black & Veatch deliverable for the Phase 1 portion of the WREZ initiative. In June 2009 the Western Governors' Association accepted the Western Governors' Association WREZ Phase 1 Report in which the QRAs were mapped and the entire WREZ Phase 1 process was explained in general. That same month the Lawrence Berkeley National Laboratory released the WREZ Generation and Transmission Model (GTM), which was also developed by Black & Veatch. This report details the assumptions and methodologies that were used to produce the maps and resource analyses in the WGA report as well as the economic data used by the WREZ GTM. This report also provides the results of the non-REZ resource analysis for the first time in the WREZ initiative.

1.1 Development of WREZ QRA Identification Methodology

In Phase 1 of the WREZ initiative, QRAs were defined as areas of high quality and dense renewable energy resources with enough capacity to potentially justify the construction of a high voltage transmission line for interstate transmission of renewable energy. QRAs needed to meet size, resource quality, environmental and technical criteria. The WREZ Zone Identification and Technical Analysis (ZITA) working group developed the economic and technical criteria to identify QRAs. The WREZ Environment & Lands (E&L) working group developed the environmental criteria to identify QRAs.

Black & Veatch used these two sets of criteria in geospatial analyses of the entire WREZ study area to filter vast renewable energy resource potential to the highest quality and most developable renewable energy resources. The resulting resource areas were called Candidate Study Areas (CSAs). The screening criteria developed by the ZITA and E&L working groups are detailed in Chapters 3.0 and 4.0 and maps of the CSAs are shown in Figure 3-1 and Figure 3-2.

Fifty-three QRAs were identified across the WREZ study area, with nearly 200,000 MW of renewable energy resources theoretically capable of generating over 560 terawatt hours (TWh) of energy per year.[1] Over 2,200,000 MW of non-REZ resources were also identified across the study area. To put these estimates in perspective, the entire WECC peak load in summer 2007 was 150,000 MW.[2]

1.2 Identification of Qualified Resource Areas

Once the CSAs were identified, resources were grouped and analytical boundaries were defined around them. The resources inside these boundaries were quantified and became the basis for WREZ QRAs. The resources that did not meet the WREZ resource criteria or fell outside QRA boundaries were counted as non-REZ resources and quantified separately.

The WREZ study identified nearly 200 GW of potential renewable energy resources within 53 QRAs in the WREZ study area and over 1,200 GW of non-REZ resource potential. Wind and solar constitute the majority of WREZ resources . Biomass, geothermal and hydropower also provide a significant amount of the cost-effective energy resources inside QRAs. The majority of the non-REZ resources are from solar photovoltaics and enhanced geothermal systems (EGS) resources.

A map of all the WREZ QRAs and qualifying WREZ resources, showing the final boundaries of QRAs as identified in the QRA analysis detailed in Chapter 3.0 is shown in Figure 5-1. Note that the QRA boundaries are analytical and not legal; they do not necessarily reflect areas that may be off limits to development due to local restrictions or because of site-specific environmental sensitivities. Capacity and energy summary tables by resource and by QRA are provided in Appendix B. Non-REZ resources identified across the WREZ study area are quantified in Table 5-1. The non-REZ analysis for each resource is detailed in Chapter 5.0.

1.3 Economic Analysis of QRAs

Once QRAs were identified, the cost of generation was calculated for every resource in every QRA as a levelized cost of generating power over the life of the resource on a $/MWh basis. These estimates exclude long-distance generation costs,

[1] British Columbia provided a 54th QRA representing a shaped renewable energy product to load serving entities (LSEs) at the British Columbia-Washington border. This QRA is shown in the hub map and selectable in the GTM model. However, it was developed independently of the Black & Veatch/NREL QRA analysis outlined here, so it is not characterized here.

[2] WREZ Zone Identification and Technical Analysis Working Group, Step 2: Filtering resource data into Candidate Study Areas, Available: http://www.westgov.org/wga/initiatives/wrez/zita/Step2.pdf, 2009.

which are modeled and added in the GTM module. Performance, economic and financing assumptions were developed for each technology by the ZITA working group and Black & Veatch. These were used in a cost of generation model developed by Black & Veatch to create generation supply curves for all QRAs. These curves show the amount of annual energy generation theoretically available at a particular price point. Supply curves for all QRAs are shown in Appendix A.

The cost of energy varied among technologies and within each technology. There were many factors that contributed to this variation. However, the most significant driver of cost variation was variation in the quality of the renewable energy resources across different areas. In general, higher quality resources had lower costs per MWh.

2.0 Introduction

Black & Veatch presents the WREZ Phase 1 Qualified Resource Area Identification Technical Report for the National Renewable Energy Laboratory (NREL). The objective of this report is to document the process used in the WREZ initiative to identify "Qualified Resource Areas" (QRAs), or areas with high concentrations of high quality renewable energy resources across the Western Interconnection. This introductory section includes some background to this initiative, a discussion of the objective of this report, its general analytical approach and the report's organization.

2.1 Background

Phase 1 of the Western Renewable Energy Zones (WREZ) study was undertaken by NREL and the Western Governor's Association (WGA) to identify areas of the Western Interconnection (Western Electricity Coordinating Council or WECC) that have both the potential for large scale development of renewable resources and low environmental impacts.[3] The WREZ Charter sets forth the overarching objective of the WREZ project:

> To develop transmission plans of service to priority zones to facilitate the environmentally sensitive development of the most cost-effective renewable resources located in the Western Interconnection. The project will evaluate all feasible renewable resource technologies that are likely to contribute to the realization of the goal in WGA policy resolution 6-10 for the development of 30,000 megawatts of clean and diversified energy by 2015, but may not include all such resources in the WREZ. The WREZ is intended to complement all the efforts related to implementing WGA policy, including development of a mix of clean and diverse energy resources and having a secure, reliable interstate transmission network that can move all generated electricity to markets.

[3] Western Governor's Association, Western Renewable Energy Zones Charter, Available: http://westgov.org/wga/initiatives/wrez/wrez-charter.pdf, May 2008

Figure 2-1. The Western Interconnection.

Phase 1 of the study engaged a diverse range of stakeholders to make decisions about the study direction and the criteria used in the technical and economic analysis.

The followings states and provinces were part of this study

• Alberta • Arizona • Baja California Norte • British Columbia • California • Colorado • Idaho	• Montana • Nevada • New Mexico • Oregon • Texas (El Paso area) • Utah • Washington • Wyoming

Decisions were first approved by small technical working groups and then reviewed and finalized by WREZ leadership committees. The working groups involved in the QRA identification process were the Environment & Lands (E&L) working group (in collaboration with the Western Governor's Wildlife Council or WGWC) and the Zone Identification and Technical Analysis (ZITA) working group. Another working group, the Generation and Transmission Modeling working group created the WREZ Generation and Transmission Model (GTM), which is not described in depth here. The WREZ initiative leadership committees consisted of two levels: the WREZ Technical Committee, which was staffed by representatives from the states and provinces from each WREZ work group and from the range of stakeholders interested in energy issues in the West; and the WREZ Steering Committee, comprising governors of the 11 Western states within the Western Interconnection (or their designees), public utility commissioners from each of those states and the Premiers of British Columbia and Alberta.[4]

[4] Western Governor's Association, About the WREZ, Available: http://westgov.org/wga/initiatives/wrez/index.htm, May 2008

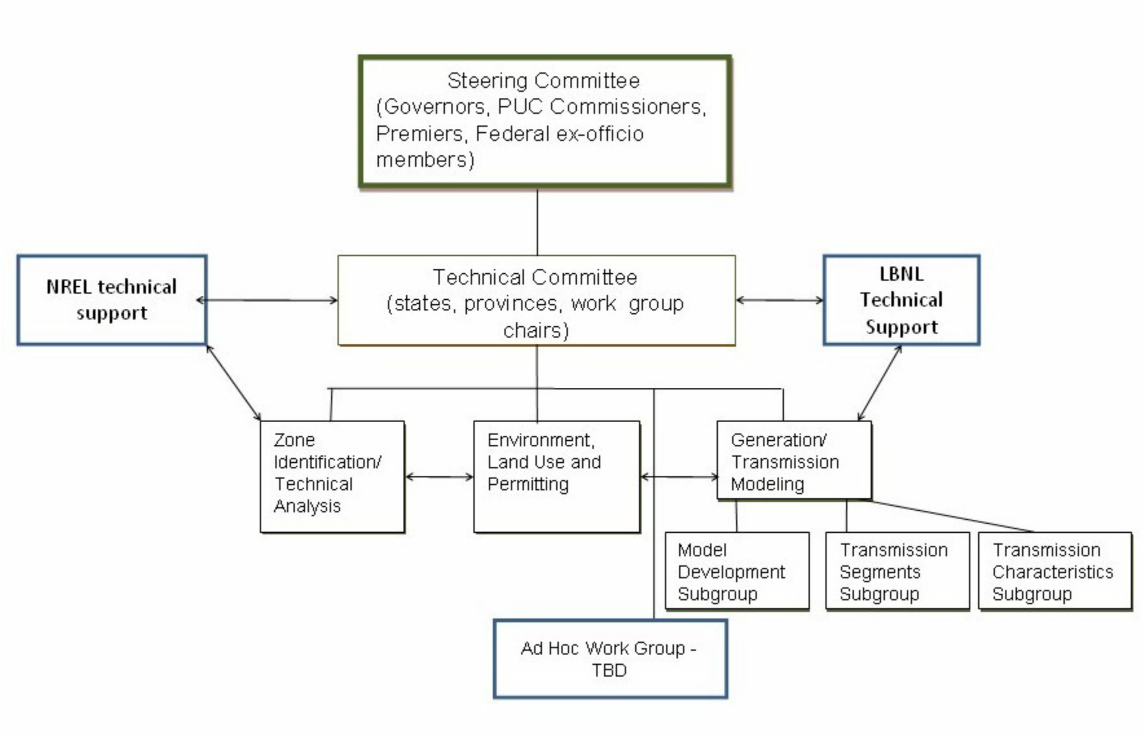

Figure 2-2. WREZ Working Group and Leadership Organizational Chart.[5]

Black & Veatch was retained to provide technical guidance and perform the analytical tasks necessary to identify and analyze the economics of renewable energy resources within the QRAs, which are precursors to Western Renewable Energy Zones. The WREZ Phase 1 report was approved by the WREZ Technical and Steering committees in late Spring 2009, and accepted by the Western Governor's Association in June 2009.

Note that although the study was funded and undertaken by governmental agencies and leaders, it does not impinge on the legal authority or replace the regulatory role or requirements of any local, state, provincial, tribal or federal agency.[6]

2.2 Objective

This technical report describes the QRA and supply curve analyses and presents the results from these analyses in detail. The supply curve analysis performed by Black & Veatch was an input to the WREZ GTM, which calculates the cost of delivering renewable energy from QRAs to load centers throughout the west. The supply curve

[5] Western Governor's Association, About the WREZ, Available: http://westgov.org/wga/initiatives/wrez/index.htm, May 2008

[6] Western Governor's Association, Western Renewable Energy Zones - Phase 1 Report, Available: http://www.westgov.org/wga/publicat/WREZ09.pdf, June 2009

analysis results shown in this report include the cost of generation plus the cost of delivering electricity from a QRA to the transmission system. The technical assumptions used in this analysis are documented in this report and also available in the original format documented by Black & Veatch for the ZITA working group on the project web site: *http://westgov.org/wga/initiatives/wrez/zita/index.htm*.

2.3 Approach

The WREZ Phase 1 study analyzed the economics of 54 QRAs with potential for high quality biomass, geothermal, hydropower, solar and/or wind energy generating potential across the WECC. These areas were identified after taking into account technical constraints (such as land slope) and minimum resource quality considerations developed by the ZITA working group. The identification and analysis of these areas also took into account environmental exclusions identified by the E&L working group and the WGWC. The Phase 1 study also quantified "non-REZ" resources: renewable energy resources that were of a lower quality and/or were located outside of the boundaries of the QRAs.

2.4 Report Organization

Following this Introduction, this report is organized into the following sections:

- **Section 3 – Methodology and Assumptions:** This section describes the methodology and assumptions used to identify and analyze the economics of QRAs.
- **Section 4 – Resource Characterization:** The WREZ Phase 1 study identified nearly 200,000 MW of biomass, geothermal, hydropower, solar and wind resources in QRAs across the WREZ study area. This section discusses the methodology used to characterize these resources. It also presents the results of the non-REZ resource analysis.
- **Section 5 – QRA and Non-REZ Analysis Results:** 54 Qualified Resource Areas were identified in the WREZ analysis. This section presents the results of this analysis at the QRA level.

2.5 Data Sources

Data sources used in this report include the following:

- California Energy Commission, An Assessment of Biomass Resources in California, PIER Collaborative Report 500-01-016, California Biomass Collaborative, 2006

- Fuchs, Mark and Frear, Craig et al, Biomass Inventory and Bioenergy Assessment: An Evaluation of Organic Material Resources for Bioenergy Production in Washington State, Washington Department of Ecology, Available: http://www.ecy.wa.gov/biblio/0507047.html, 2005
- Personal communication with Matthew Good, Alberta Department of Energy, August 2009
- Macdonald, A.J., Inventory of Wood Biomass from Harvesting Residues and Non-Merchantable Forests in Alberta, FPInnovations, November 2007.
- Milbrandt, Anelia, A Geographic Perspective on the Current Biomass Resource Availability in the United States, 2005, NREL Technical Report NREL/TP-560-39181.
- National Land and Water Information Service, Biomass Inventory and Mapping Tool, Agriculture and Agri-Food Canada, Available: http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1226509218872&lang=eng, April 2009
- Western Governor's Association Biomass Task Force, Strategic Assessment of Bioenergy Development in the West, Available: http://westgov.org/wga/initiatives/transfuels/index.html, 2008
- BC Hydro, Green Energy Study for British Columbia; Phase 2: Mainland, Report No. E44. Chapter 5.2: Geothermal Energy, pp. 18-22, 2002
- Broad-based assessments of geothermal potential (such as the USGS assessment of 1979, currently being updated; the CEC-PIER report of 2004; the WGA study of 2006)
- Data cited in a Personal Communication between Alison Thompson at the Canadian Geothermal Energy Association and the Western Governor's Association, February 2009
- Fairbank, B. D., and R. I. Faulkner, Geothermal resources of British Columbia. Geological Survey of Canada, Open File 2526, 1992
- Personal communications with Jacob DeAngelo at the USGS on November 10, 2008
- Personal communication with Sue Bonnyman at the BC Ministry of Energy, Mines and Petroleum on November 1, 2008
- Government of British Columbia (2007). Geothermal resources map. http://www.em.gov.bc.ca/Geothermal/GeothermalResourcesMap.htm
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- Williams, Colin F., Reed, Marshall J., Mariner, Robert H., DeAngelo, Jacob, Galanis, S. Peter, Jr., Assessment of Moderate- and High-Temperature Geothermal Resources of the United States: U.S. Geological Survey Fact Sheet 2008-3082, 2008

- Kutscher, C., Cosentaro, D. "Assessment of Evaporative Cooling Enhancement Methods for Air-Cooled Geothermal Power Plants." Presented at the Geothermal Resources Council Annual Meeting, Reno, NV. September 22-25, 2002. NREL/CP-550-23294.
- NREL TMY2 Data, Available at: http://rredc.nrel.gov/solar/old_data/nsrdb/tmy2/
- BC Hydro, 2008 Long Term Acquisition Plan Appendix F1 Resource Options Database (RODAT) Sheets, Available: http://www.bchydro.com/etc/medialib/internet/documents/info/pdf/2008_ltap_appendix_f8.Par.0001.File.2008_ltap_appendix_f8.pdf, 2008
- Engineering News Record, Building Cost Index History, Available: http://enr.ecnext.com/coms2/article_echi090601bldIndexHist, 2009
- Idaho National Laboratory, Estimation of Economic Parameters of U.S. Hydropower, Available: http://hydropower.inl.gov/resourceassessment/index.shtml, 2003
- Kerr Wood Leidal Associates Ltd., Run-of-River Hydroelectric Resource Assessment for British Columbia, Available: http://www.bchydro.com/etc/medialib/internet/documents/info/pdf/2008_ltap_appendix_f5.Par.0001.File.2008_ltap_appendix_f5.pdf, 2007
- Personal communication with Edward Higginbottom, Senior Strategy Advisor, British Columbia Transmission Corporation, January 2009
- Personal communication with Bevan Laing, Senior Manager, Generation, Infrastructure Policy, Government of Alberta Department of Energy, May 2009
- Personal Communication with Edward Higginbottom, Senior Strategy Advisor, British Columbia Transmission Corporation and Allan Woo, BC Hydro, February 2009
- Personal communication with Kathy Lee, Senior Resource Planning Engineer, BC Hydro, February 2009
- Western Governor's Association, WREZ Technology Assumptions for Supply Curve Analysis, Available: http://westgov.org/wga/initiatives/wrez/zita/Technology%20Assumption%20-%20Supply%20Curve%20TCversion.pdf, January 2009
- Blair, et.al., Modeling Photovoltaic and Concentrating Solar Power Trough Performance, Cost, and Financing with the Solar Advisor Model, available: www.nrel.gov, accessed: June 2008.
- R. Bird and C. Riordan, Simple Spectral Model for Direct and Diffuse Irradiance on Horizontal and Tilted Planes at the Earth's Surface for Cloudless Atmospheres, available at: www.nrel.gov, accessed: June 2008.
- Perez, et.al., SUNY Satellite Solar Radiation model, available at: www.nrel.gov, accessed: June 2008.

- NREL's GIS team, High Resolution National Solar Photovoltaic and Solar Thermal GIS data, available at: www.nrel.gov, accessed: June 2008.
- NREL Wind Resource Maps, available at: http://www.eere.energy.gov/windandhydro/windpoweringamerica/wind_maps.asp, accessed: March 6th, 2008
- NREL Mesoscale Wind Data, Available: mercator.nrel.gov/wwsi/
- BC Hydro, BC Wind Data Study, Available: http://www.bchydro.com/planning_regulatory/energy_technologies/wind_energy/wind_data_study.html, May 2009
- CanWEA and SEED, SE Area Wind Power Projects – Transmission Connected, received from Claude Mindorff or Mainstream Energy, November 2008.

2.6 Use and Purpose of this Report

The WREZ Phase 1 Qualified Resource Area Identification Technical Report is not a resource assessment. This report identifies areas of the WECC that might qualify as Western Renewable Energy Zones. This analysis was based on very specific criteria developed for the WREZ initiative. As such, the WREZ data are not recommended for direct use in other analyses and caution must be used when they are used for other purposes. The data produced by this study are not appropriate for site-level analysis. The data in this study might not even be appropriate for other high level planning studies, depending on the goals of the study.

Many simplifying assumptions went into the WREZ study that make the data inappropriate for other analyses. For example wind capacity factors were averaged across very large areas. A single capacity factor was assigned to all wind potential in each NREL wind power class 3 through 7. The weighted average of these capacity factors was calculated for areas of land in QRAs and the resulting capacity factor was assigned to all of the wind resources in those areas. This methodology tends to flatten out the variability in wind capacity factors across the QRAs. Low and high capacity factor wind resources that might exist in the QRAs are not captured by this methodology and the variation in generation cost among wind resources is relatively small. This methodology works well for zone identification and high-level transmission planning, but it is inappropriate to compare the capacity factors calculated in this analysis to the capacity factors of specific planned or existing projects in the same areas.

3.0 Methodology and Assumptions

This section describes the methodology Black & Veatch used to identify QRAs, quantify the resources inside their boundaries, and calculate the cost of generating and delivering energy to the transmission system. The general guidelines and specific assumptions to be used in this methodology were developed by the ZITA and E&L stakeholder working groups, with guidance from Black & Veatch, NREL and others.

3.1 QRA Development Process

QRAs are areas of high quality and dense renewable energy resources, which have enough resources to potentially justify the construction of a high voltage transmission line for interstate transmission of renewable energy. QRAs must meet a number of specific size, resource quality and environmental and technical criteria, which are detailed below.

QRAs were identified based on the location, density and size of renewable energy resources across the WREZ study area. For some resources, QRA identification involved paring down large-scale, raw resource data to just the developable areas and selecting the best areas from among them. This was the general process for wind, solar and biomass, for which renewable resource data were available for the entire study area. When large-scale, raw resource data were not available, project-specific data were available. In these cases, these data were assumed to represent the developable resource potential for a resource, and were used to determine the extent of the QRAs. This was the general process for geothermal and hydropower across the study area as well as wind in Canada, for which appropriate large scale resource assessments were not available but assessments of specific potential projects were available.

3.1.1 Resource Characterization

The first step in the QRA development process was to identify a set of qualifying renewable energy resources. The ZITA group chose renewable energy resources of a large enough magnitude, high enough quality and dense enough dispersion to potentially justify the construction of a 500 kilovolt (kV) transmission line to transport energy across state/provincial lines. The specific criteria for each renewable energy resource considered are described in Chapter 4.0.

A parallel process was undertaken by ZITA, E&L and the WGWC working groups to identify all areas where renewable energy development cannot or should not occur, according to the guidance provided by the working groups. These environmental and technical exclusions were combined using GIS software and these exclusion areas were removed from the renewable resource datasets when applicable. This exclusion process was iterative and continued throughout the QRA analysis as new data became available and working group decisions about exclusion areas changed.

3.1.2 Candidate Study Areas

The qualifying solar and wind resources identified resulted in areas that were too large to analyze from a transmission perspective. These large areas were reduced to areas with only the highest quality resources. This process resulted in "Candidate Study Areas" (CSAs), and "ensured the identification of the best resources available for use on a regional scale and to meet more localized needs."[7]

Resource quality criteria were applied to wind and solar to generate CSAs. For wind and solar resources in the US, the wind power classes considered varied by state. Given the variations in wind power classes and solar DNI levels among states in the Western Interconnection, it was determined that the best quality resources of each resource type would be identified in each state and serve as the minimum resource class identified in that state in the analysis. These thresholds are discussed further in Chapter 4.0. The WREZ CSA maps for wind and solar are shown below.

[7] Western Governor's Association, WREZ-Zone Identification and Technical Analysis, Available: http://westgov.org/wga/initiatives/wrez/zita/index.htm, January 2009.

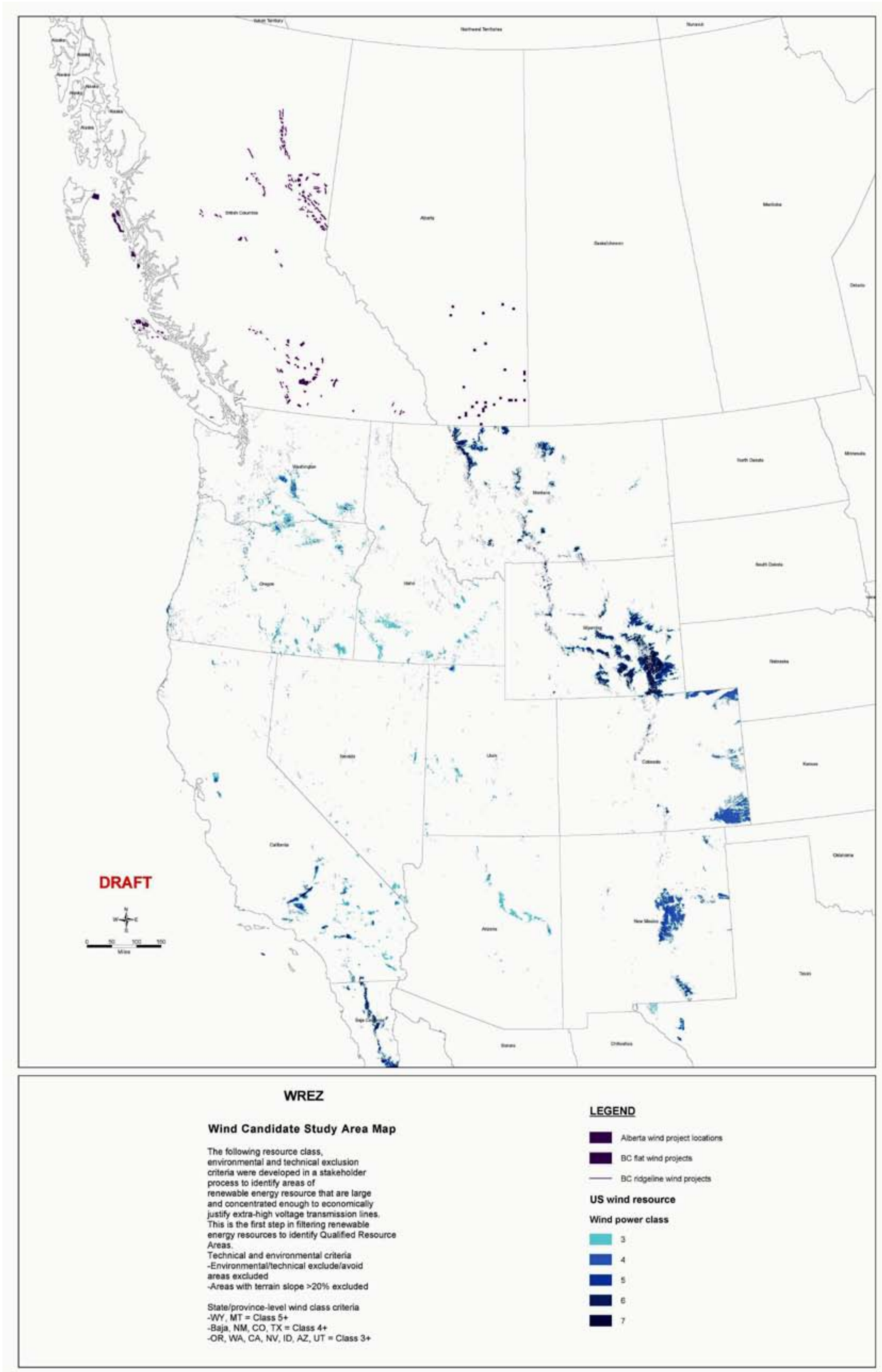

Figure 3-1. Wind Candidate Study Area Map.

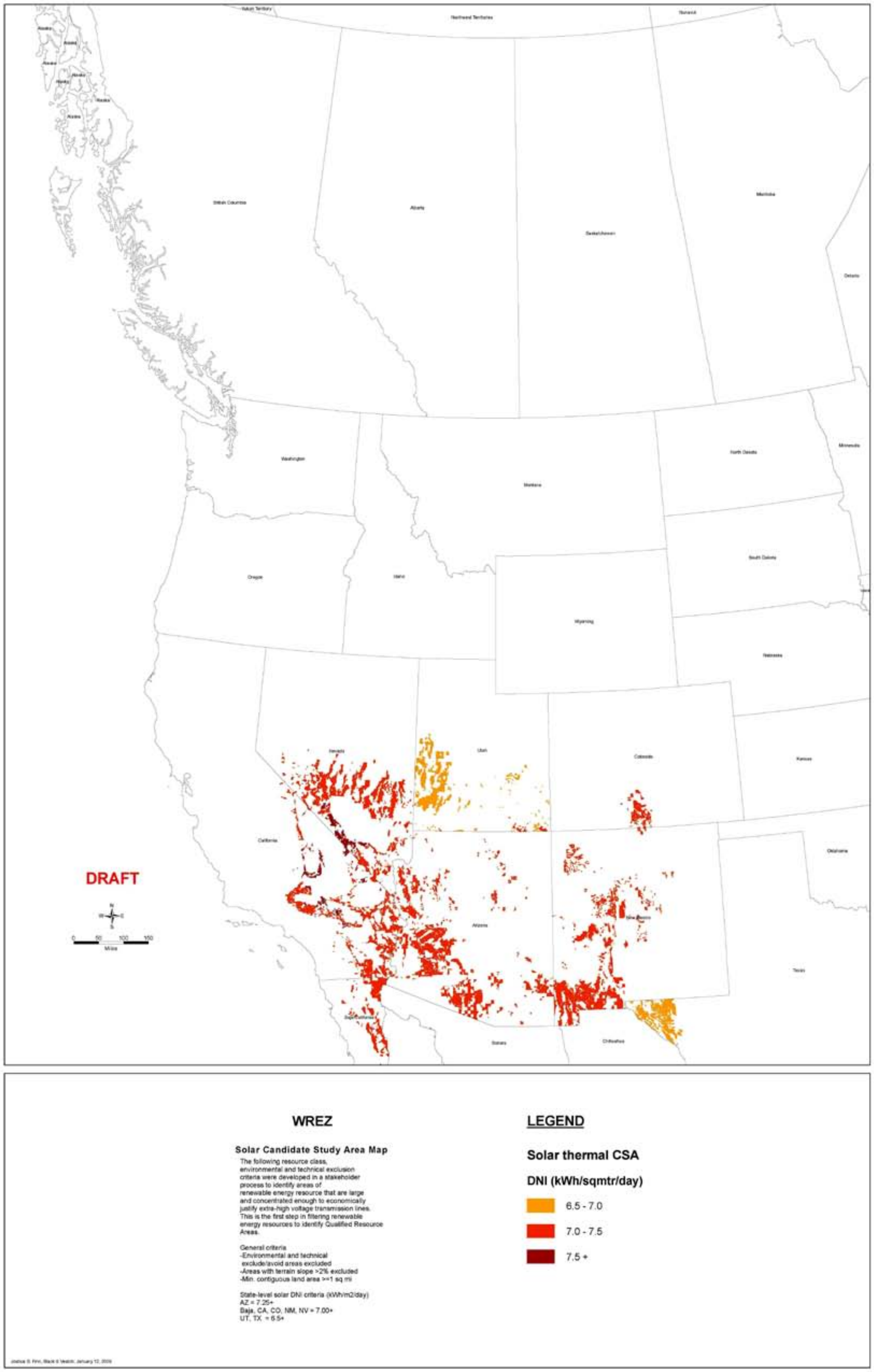

Figure 3-2. Solar Candidate Study Area Map.

Resource quality criteria were also applied to the other resources assessed in WREZ. For biomass, only certain types of biomass feedstocks were considered. For geothermal, resource quality screening was done to generate the data provided to the WREZ process by GeothermEx. For hydropower, only certain types of potential projects were considered and screened out of the data. These resource quality thresholds and the resource subtypes considered are discussed further in Chapter 4.0.

3.1.3 QRA Identification

Once the CSAs were identified and the exclusion areas were removed, resources were grouped and boundaries were defined around them. Resources were grouped based on minimum and maximum QRA size criteria developed by the ZITA working group. According to the ZITA working group, a QRA had to be less than 100 miles across and have at least 1,500 MW of developable potential (500 MW for biomass, geothermal and Canadian resources). QRA size criteria are discussed in greater depth below.

3.2 Technical and Environmental Exclusion Areas

Black & Veatch used a series of exclusion screens to filter out land and resources that would not be appropriate for development and should not be part of the WREZ resource analysis. Technical and land use exclusion areas were defined by the ZITA working group. Environmental exclusion areas were defined by E&L and WGWC working groups.

It is important to note that the purpose of these exclusions was for QRA identification and not to recommend specific project siting and land use decisions. Also, it should not be assumed that areas where there are no exclusions are appropriate for siting plants. All actual project development will need to proceed through all local, state, and federal permitting processes; WREZ does not supersede judgments to be made by these authorities. Additionally, much of the land identified as part of this assessment is privately owned. WREZ does not intend to interfere with the decisions of private land owners in any manner.

3.2.1 Resource Quality, Technical and Land Use Exclusions

The ZITA group developed technical, land use exclusions as well as resource subtype and quality criteria. The technical and land use exclusions only applied to only wind and solar resources in the US. Biomass, geothermal, hydropower and Canadian wind resources across the WECC were identified using data produced in other studies.[8]

[8] See Chapter 4.0 for the sources of all resource data.

The exclusions applied to wind and solar either did not apply to these resources, or it was determined that these studies took into account technical and land use exclusions comparable to those applied to wind and solar resources in the US. The technical and land use exclusions applied to wind and solar in the US included highly sloped areas, urban areas, water bodies, areas with a very small contiguous area for solar as well as some military lands.

Military installations were excluded from consideration for wind and solar, after much discussion among ZITA group stakeholders. Originally, certain military flyways were considered to be exclusion areas for wind and solar because it was presumed that project development in these areas was precluded by law. However, after discussion with military representatives it was determined that it was appropriate to exclude military installations but not military flyways because development in these areas is not precluded by law.

3.2.2 Developability Screening

It was reasonable to expect that not all of the resource within a given area can actually be developed. Various constraints, such as land ownership, presence of structures, local zoning restrictions or other factors will limit the "developability" of even the most high quality resources. For this reason, various developability screens were applied to the resources to account for the likelihood that within any area, only a portion of the total resource potential is developable. The application of these discounts also created margin of safety that significantly increases the likelihood that WREZs will realize sufficient development to justify a high capacity transmission line.

In some cases, it was possible to estimate developability screens and discounts for different areas or sites based on the specific factors affecting the developability of each resource. In other cases this level of analysis was not possible given the scope of the study and broad developability discounts were applied to screened resource potential. Developability screens and discounts are discussed below and in further depth in Chapter 4.0.

Wind and Solar

The developability of wind and solar in specific areas could not be studied in WREZ given the screening level of the study and the vast areas with high quality wind and solar resources. To account for unknown and unpredictable developability constraints, it was assumed that only a fraction of all the land with wind and solar resource potential in the US would be developable. These percentages were estimated by the ZITA working group, and wind and solar resource potentials were discounted to those percents. For wind, it was assumed that 25 percent of the screened area would be developable. This discount for was based on industry experience from other regional wind studies. For solar, it was assumed that 3.5 percent of the land would be developable. Given the lack of industry experience and empirical data on the percentage of potential solar projects that are actually developed, this was chosen somewhat arbitrarily through consensus of the ZITA working group stakeholders.[9]

Wind and solar are the two largest renewable energy sources in the WREZ study and they are the only resources that were pared down from raw resource data based on explicit technical, environmental, resource quality and developability screens. The resource quality, technical and land use screens for these two resources area summarized below.

Table 3-1. Resource Quality, Technical and Land Use Exclusions for Wind and Solar.

	Solar	**Wind**
Resource quality	Varies by state	Varies by state
Terrain slope (percent)	Greater than 2	Greater than 20
Min. contiguous square acres	640	N/A
Water bodies	Yes	Yes
Urban areas	Yes	Yes
Military restrictions	Installations excluded	Installations excluded
Percent of land developable	3.5	25

Source: WREZ ZITA working group, Available: *http://westgov.org/wga/initiatives/wrez/zita/index.htm*

Biomass

Different developability discounts were applied to biomass resources, dependent on the nature of the feedstock data. For biomass feedstock data that was not screened based on cost, it was assumed that only one third of the available biomass resources across the WECC could be used for power generation. This estimate was developed in previous Black & Veatch work, as part of the California Renewable Energy Transmission

[9] While 3.5 percent is an arbitrary percentage, it does result in resource densities (MW/sqmi) that are comparable to the discounted wind potential. Further, the QRA sizes based on a 3.5 percent discount are typical several GW, which seems to be an appropriate scale to represent opportunities for large-scale transmission.

Initiative.[10] This estimate is also supported by analyses by NREL and state agencies and was vetted with biomass industry stakeholders in WREZ.[11,12]

For some biomass feedstocks a collection cost supply curve was available, based on the amount of biomass available at various price points. For these feedstocks, it was determined that all biomass resources of the types considered that cost $80/dry ton or less to collect would be assessed. This was determined to be the maximum collection cost acceptable by plant developers.

Geothermal

Estimation of the amount of electricity that could be generated at various geothermal sites was based on industry experience and applied to estimates of the heat that can be recovered as electrical energy from a site. Uncertainty was handled by a probabilistic approach that yielded a range of possible generation values and associated probabilities. The modal value of the probability distribution was considered the "most likely value" of generation potential for the project concerned. This assessment of the developable geothermal potential was carried out for Black & Veatch for the WREZ study by a subcontractor, GeothermEx.

Hydropower

Three approaches to developability discounts were applied to hydropower resources in the US and Canada, dependent on the data source used. In the US, potential hydropower projects were identified using the INL Hydroelectric Resource Economics Database (IHRED) in which potential projects were assigned a "suitability factor" of 0.1, 0.25, 0.5, 0.75 or 0.9. These suitability factors reflected the probability that a project site would be acceptable for development given environmental and other developability factors.[13] Only projects with a suitability factor of 0.5 or greater were considered.

For Canadian run of river hydropower projects, developability discounts were not applied explicitly. However, the study that provided the data on these potential projects estimated the costs of projects in remote or difficult to develop areas to be extremely high. This rendered these projects' costs of energy so high in the supply curve analysis

[10] Black & Veatch, California Renewable Energy Transmission Initiative Phase 1B, Available: http://www.energy.ca.gov/reti/index.html, January 2009.
[11] Oregon Department of Energy, Oregon's Biomass Energy Resources, available: http://oregon.gov/ENERGY/RENEW/Biomass/resource.shtml, 2007.
[12] Milbrant, Anelia, A Geographic Perspective on the Current Biomass Resource Availability in the United States, National Renewable Energy Laboratory, December 2005
[13] Conner, Alison M. et al, U.S. Hydropower Resource Assessment Final Report, Idaho National Laboratory, 1998.

that they could never be cost effective when compared with the other resources assessed in WREZ. This had the effect of screening certain projects for developability.

The developability of impoundment hydropower projects in Canada was already vetted by the organizations that provided the data to Black & Veatch and it was determined that all Canadian impoundment hydropower projects that went into the analysis were developable.

3.2.3 Environmental Exclude and Avoid Areas

Environmental exclusion areas were identified by the E&L working group. They fall into the following three categories:

1. **Environmental Exclude** areas were those areas where development is precluded by law or policy, such as national parks and wildlife areas.
2. **Environmental Avoid** areas were areas excluded from consideration by consensus of the E&L and WGWC working groups for environmental reasons, although development is not legally precluded in those areas.
3. **Wildlife Avoid** areas were areas of crucial wildlife habitat that states decided should be excluded from the analysis.

Note that the wildlife avoid area analysis is not complete for WREZ, but some wildlife avoids were incorporated into this analysis at the request of various participating states. Both Environmental Exclude and Environmental Avoid areas were excluded from the resource analysis. For more information on the E&L work group's analysis and full lists of excluded lands, see the Environment & Lands Working Group Phase 1 Report and the WREZ Environment & Lands Working group web site.[14,15]

[14] WREZ Environment & Lands Working Group, Phase 1 Report, Western Governor's Association, Available: http://westgov.org/wga/initiatives/wrez/enviro/products/EL%20Phase%201%20Report%20FINAL.pdf, June 2009

[15] Western Governor's Association, WREZ Environment and Lands Work Group Web Page, Available: http://westgov.org/wga/initiatives/wrez/enviro/index.htm, June 2009

Table 3-2. Environmental Exclusion Categories.

Exclusion Type	Description	Examples
Environmental Exclude	Law or policy precludes development in these areas	• National monuments • State parks • Roadless areas • Designated wilderness areas
Environmental Avoid	E&L group decided these areas should not be included in QRAs for various environmental reasons	• Visual resource management areas • Conservation mitigation banks • Wildlife management areas
Wildlife Avoid	State agencies requested these areas were not included in QRAs due to wildlife sensitivities	• Sensitive wildlife habitat

Source: WREZ Environment & Lands Working Group, Phase 1 Report, Western Governor's Association, Available: http://westgov.org/wga/initiatives/wrez/enviro/products/EL%20Phase%201%20Report%20FINAL.pdf, June 2009.

3.2.4 Removing Exclusion Areas

Once technical and environmental exclusion areas and resource quality criteria were defined, exclusion areas were removed from the appropriate renewable energy resource datasets using GIS software. The resulting datasets quantified only the resources that were not located in exclusion areas, and which met the applicable resource quality criteria. These made up the developable renewable energy resources that were quantified in the QRA analysis.

Figure 3-3 and Figure 3-4 are examples of this GIS exclusion analysis. These figures show the process of eliminating exclusion areas from raw wind potential in central Montana and the process of eliminating exclusion areas from raw solar thermal potential on the Nevada, Arizona and California borders.

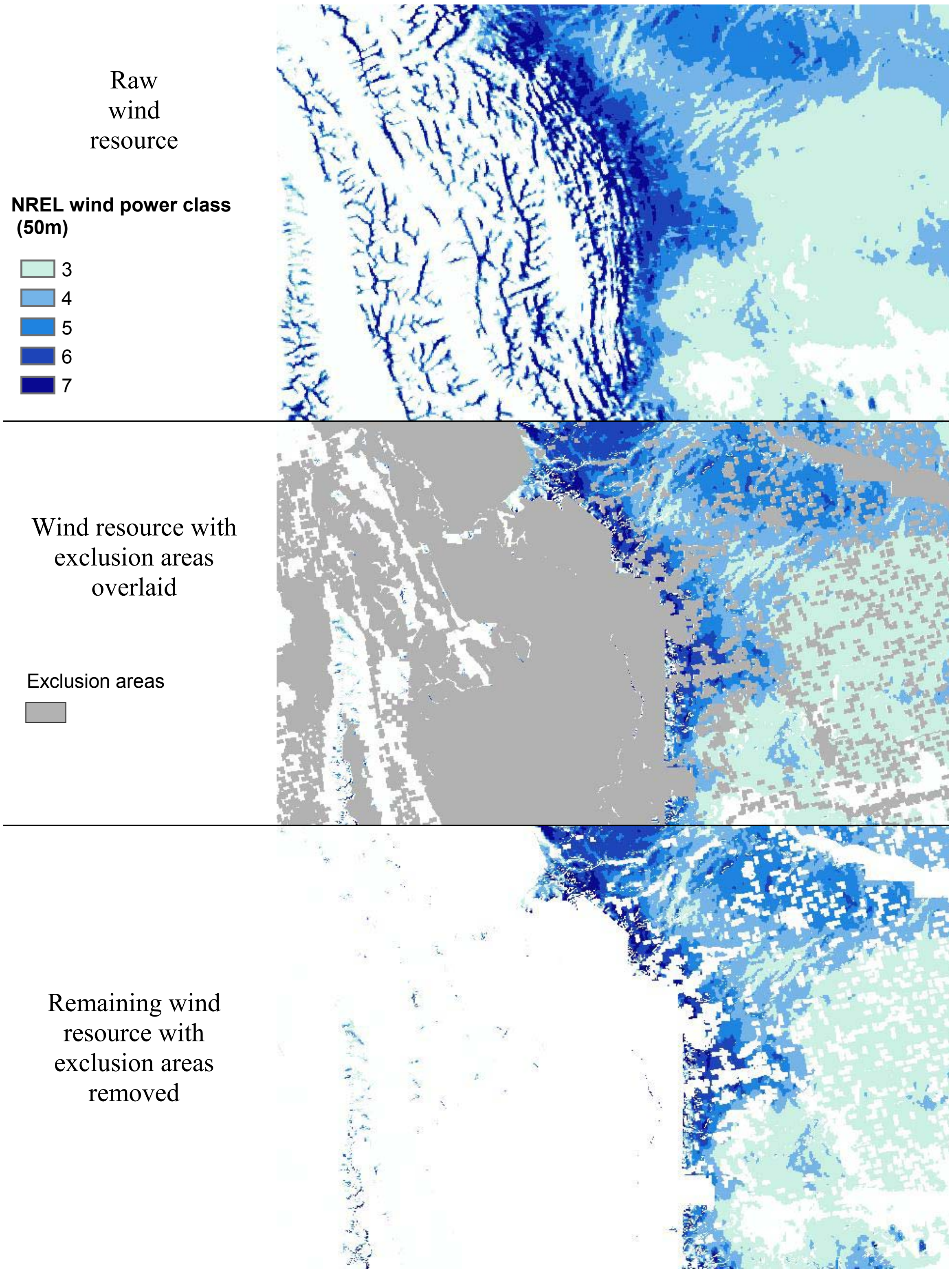

Figure 3-3. Example Exclusion Area GIS Analysis for Wind.

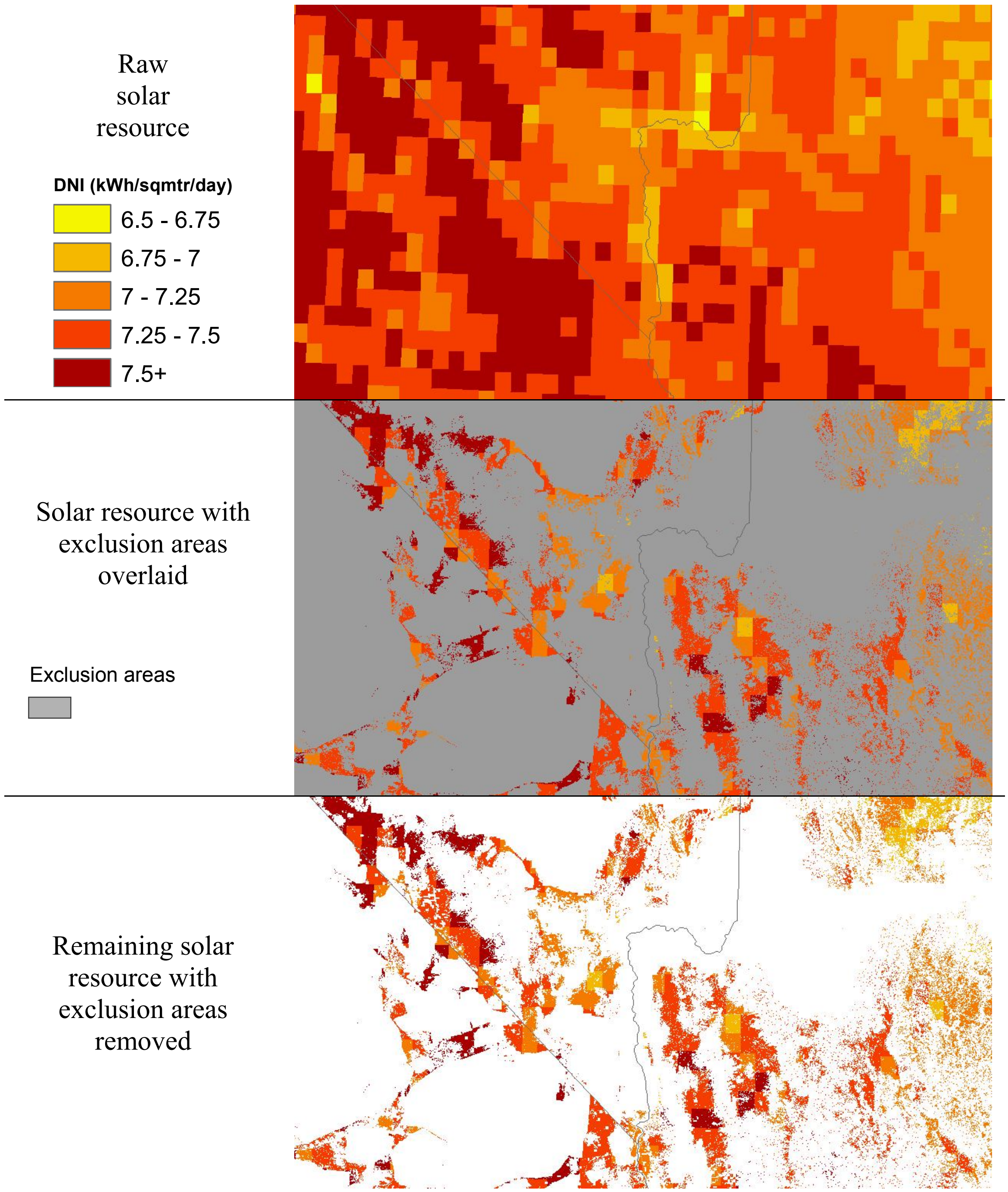

Figure 3-4. Example Exclusion Area GIS Analysis for Solar.

3.3 Qualified Resource Area Identification

After the raw resource datasets had been filtered for applicable exclusions, resource quality criteria and applicable developability discounts were applied, QRAs were identified using GIS software based on minimum and maximum QRA size criteria developed by the ZITA working group. This was a dynamic process. New exclusion area data were received at various points during the study and working groups discussed and tested various approaches to resource discounts. Additionally, resources were added to the analysis. As a result, QRAs were re-drawn multiple times over the course of the study.

At the request of the WREZ Steering Committee, the QRAs were eventually converted into "hubs," which are graphical representations of the magnitude of all WREZ resources quantified in each QRA. Hubs were sized in proportion to the total amount of electricity (in terawatt-hours) that the qualifying resources in the QRA are likely to produce during a typical year. Each state and province participating in the WREZ initiative was given the chance to review and modify its maps of hubs in advance of the hub map's publication and inclusion in the WGA's WREZ Phase 1 report.[16] The hub map is shown in Chapter 5.0.

3.3.1 Grid Square Analysis

In order to compare resources across large areas and select QRAs, a grid of 50 square kilometer squares (approximately 7 km on a side) was overlaid on the entire WREZ study area. Using the resource datasets filtered for applicable exclusions, the amount of screened renewable energy resource potential within each grid square was quantified. Grid squares were shaded based on the total MW of resource inside them. This enabled Black & Veatch to compare areas across the WREZ study area based on the density of renewable energy resources.

The following three figures show how the GIS grid square analysis was carried out. The wind and solar resource potential across the entire study area is quantified in each grid square and the squares are shaded to show varying density of resource potential across the area.

[16] Western Governor's Association, Western Renewable Energy Zones - Phase 1 Report, Available: http://www.westgov.org/wga/publicat/WREZ09.pdf, June 2009

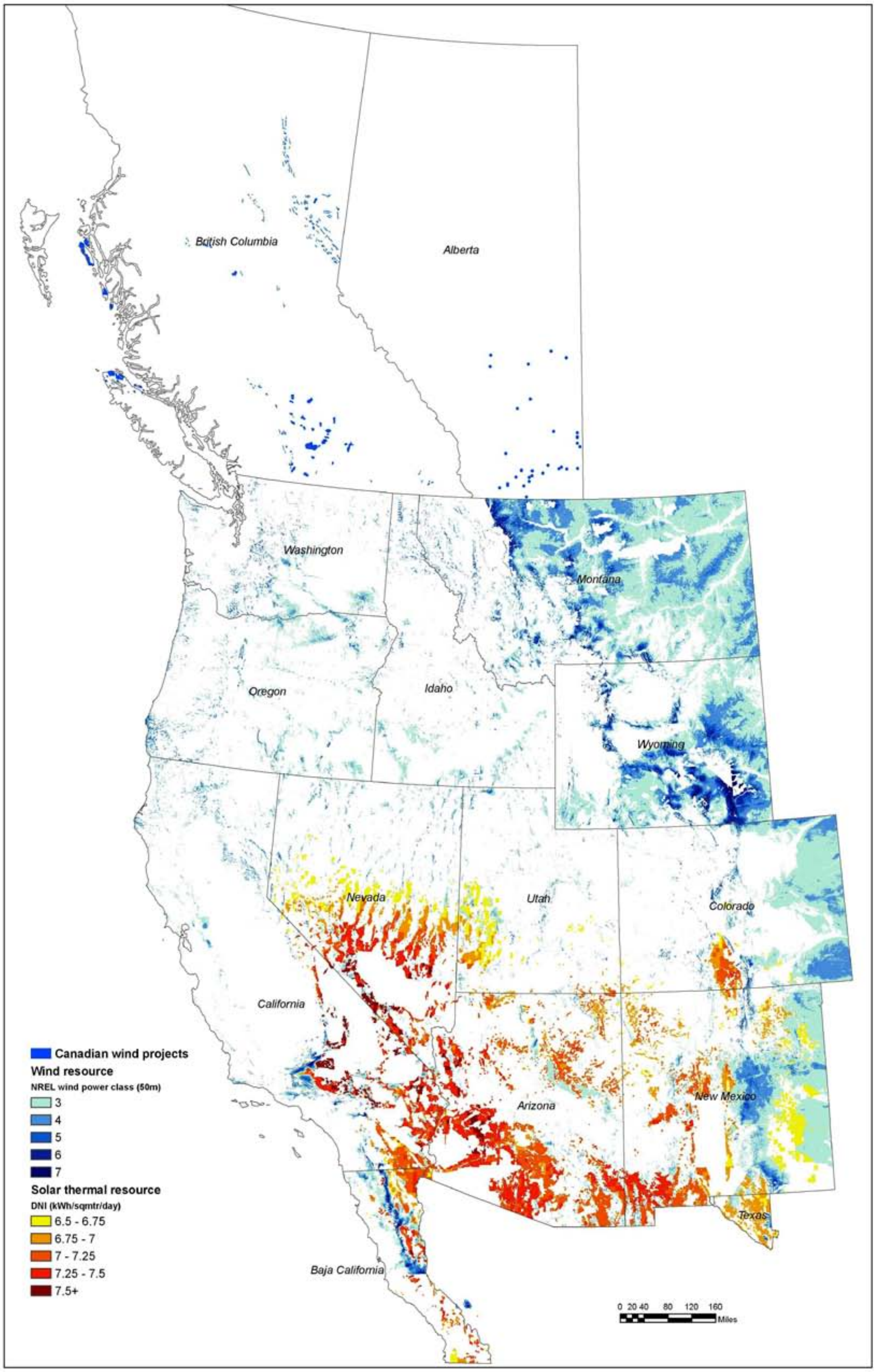

Figure 3-5. Wind and Solar Resources Screened for Exclusions.

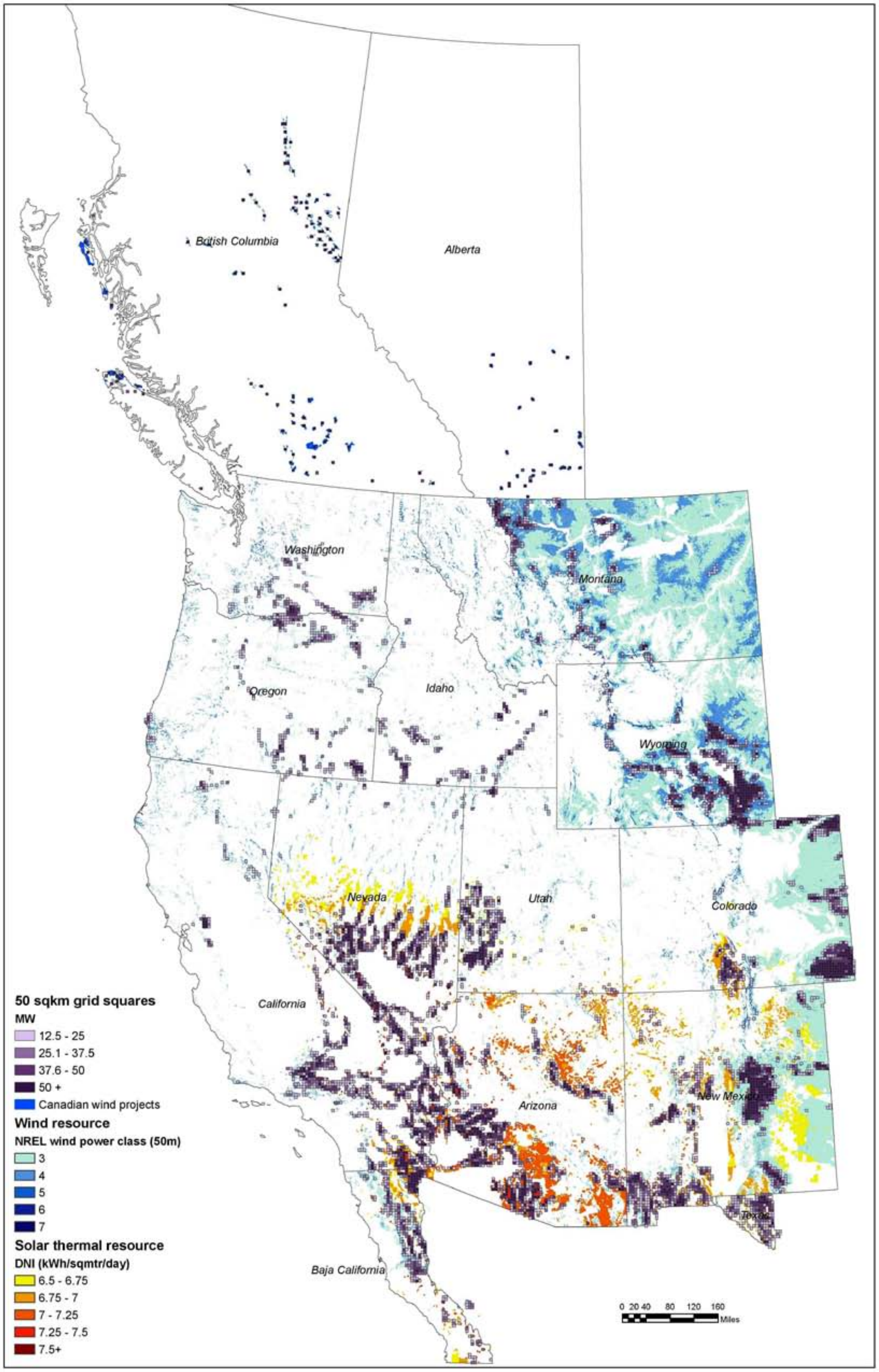

Figure 3-6. Grid Squares Overlaid on Wind and Solar Resource.

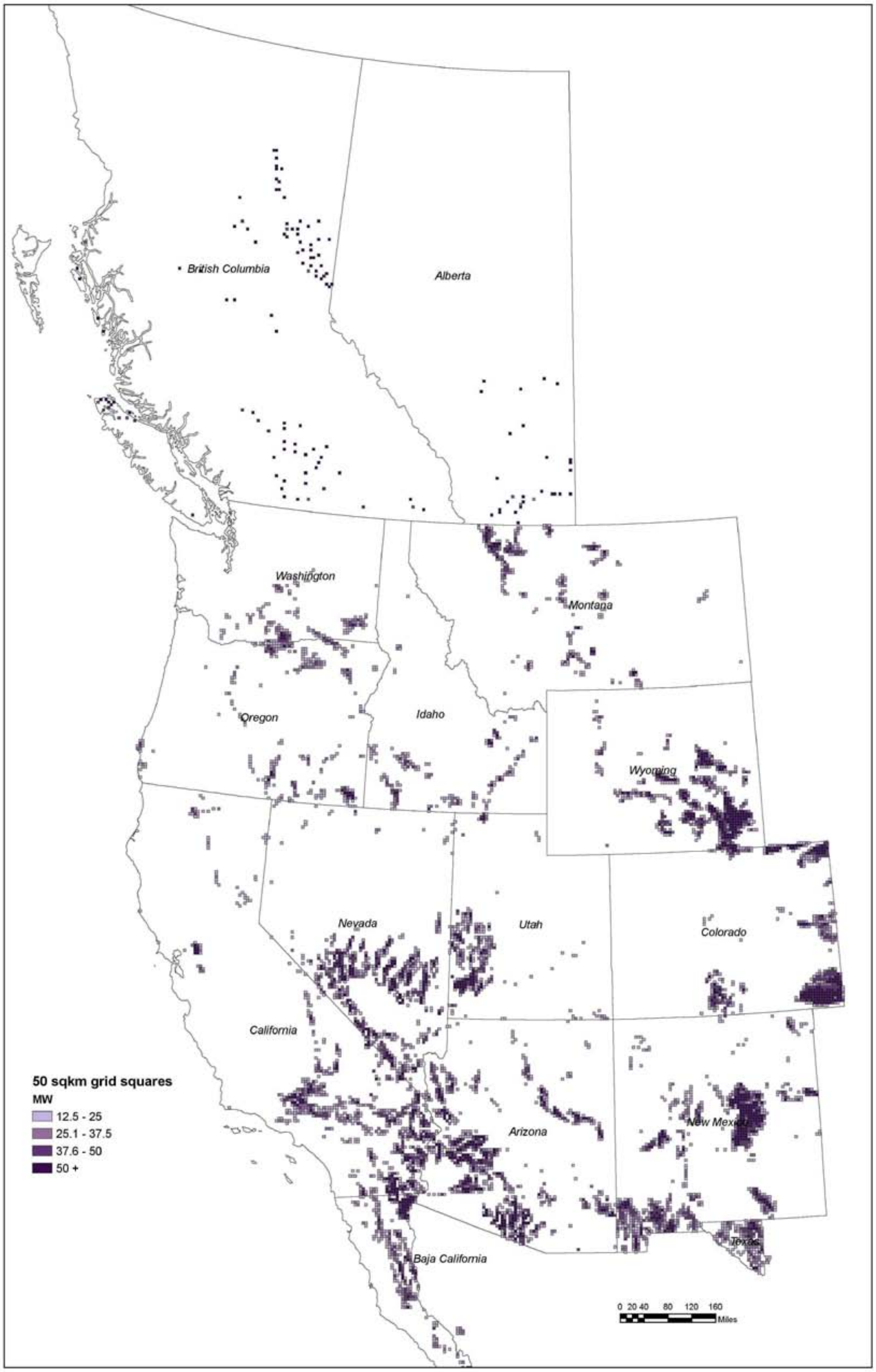

Figure 3-7. Grid Squares Quantifying Wind and Solar Resource.

3.3.2 QRA Selection

QRAs were defined as blocks of grid squares that met the resource and size criteria developed by the ZITA working group. Criteria were applied and visualized using GIS software.

QRA-Defining Resources

The ZITA work group anticipated that while certain resources would have enough potential in an area to justify the creation of a QRA on their own merits, others would be of interstate interest only if they were part of a QRA based on the merits of other stronger resources. QRA-defining resources were called "primary resources" and resources that would be quantified in a QRA if it was created for other resources were called "secondary resources."

- **Primary resources** are resources with high quality resource potential across an area that is small enough to qualify as a QRA to potentially justify the construction of a 500 kV transmission line. These resources can define a QRA's area.
- **Secondary resources** are resources that generally do not have enough resource potential across an area small enough to qualify as a QRA to justify a 500 kV transmission line. These resources were quantified only when they fell inside the boundaries of a QRA created for primary resources, to the extent they were not excluded under E&L criteria.

Minimum QRA Size

The minimum QRA size was based on electricity generating potential. A minimum QRA size of 1,500 MW was used because it is the approximate minimum capacity required to justify the construction of a 500 kV transmission line.

An exception to this criterion was made for geothermal resources. QRAs made up of only geothermal resources could be as small as 500 MW. Geothermal has on average two to three times the capacity factor of variable wind and solar resources, which means it can produce two to three times as much energy over the course of a year as wind or solar. As a result, it was determined that a geothermal resource could justify a QRA with 500 MW of potential.

An exception was also made for British Columbia and Alberta. Resources in these provinces were identified based on project development activity and site-level resource assessments, rather than large-scale resource maps. There is higher certainty that these resources will be developed than those identified in the United States. To account for this difference in likelihood of development of resources and to ensure QRAs in the United States and Canada were comparable, this refinement in the MW thresholds was made.

Maximum QRA Size

The maximum QRA size was based on geographical extent, rather than generating capacity. A maximum QRA size of approximately 100 miles around from a QRA's center was used. A larger area would increase the estimated levelized cost of a hypothetical collector system to more than $10/MWh, which the ZITA working group concluded would be the maximum cost that a project developer would be willing to incur for grid interconnection.

In order to determine this maximum, the costs of different collector line distances were calculated for wind and solar assuming a standard plant capacity and capacity factor for each technology, a single per MW-mile cost for a 115 kV collector line, and a generation project life of 20 years. Using these assumptions, the distance from a project to its collector substation could be as much as 100 miles before the cost of the collector line exceeded $10/MWh.

QRA Selection Process

QRAs were selected using a GIS map of the shaded grid squares and the GTM working group's transmission corridors. In many cases, isolated contiguous clusters of resource large enough to be QRAs were easily identified. In other cases, contiguous clusters of resource needed to be broken into multiple parts or multiple smaller clusters needed to be combined to form a QRA exceeding the minimum MW size threshold.

When a contiguous cluster of grid squares covered too large an area to be a single QRA, it was divided generally based on its position in relation to transmission lines. A point was selected on the nearest transmission line and a radius of 100 miles from that point was measured. All of the grid squares that fell within that radius were considered the extent of that QRA. The remaining grid squares in the large contiguous cluster of resource was considered one or more QRAs. When a contiguous cluster of grid squares larger than 200 miles across intersected multiple transmission lines, multiple anchor points were used to break up the cluster. In a small number of cases, a very dense and very large QRA was partitioned into smaller areas that still greatly exceeded the minimum threshold of 1,500 MW.

In several cases, there were not enough grid squares in a single contiguous block to meet the minimum size threshold. In these cases several separate clusters were aggregated to meet the minimum MW size threshold while still staying within the 200 mile size constraint.

Once QRAs were identified based on primary resources, the secondary resource potential was quantified when it fell inside QRA boundaries. In a few cases, when a QRA's primary resource potential was not great enough to meet the minimum size criteria, it was supplemented with secondary resource potential.

Creating "Hubs"

Once QRAs were quantified, they were visualized as "hubs" for the WGA WREZ Phase 1 report, as mentioned above. The hubs were created by creating a point at the centroid of the collection of grid squares that made up each QRA. These points were then sized-ramped on the map based on the estimated total TWh/yr energy production of each QRA. States and provinces were then given the opportunity to move the location or eliminate hubs for the final hub map. This hub map is shown in Chapter 5.0.

3.4 Economic Analysis of QRAs

Once QRAs were identified, a cost of generation for each resource within each QRA was evaluated, which included the cost of generation tie lines required to deliver energy from theoretical plants to the transmission system.

3.4.1 Generation Cost

The cost of generation (including the generation tie line) was calculated as a levelized cost of generating power over the life of the resource. The cost of generation was calculated on a $/MWh basis, allowing the resource in question to be compared with disparate resources types with different costs and operating over different time periods. It was calculated using a simple financial model that considers the project from the point of view of a developer, including the developer's direct costs, charges and incentives, as well as an expected rate of return on the equity. Specifically, it considered:

- Operations and maintenance costs
- Fuel costs (as appropriate)
- Cost of equity investment in capital
- Cost of financing capital
- Taxes, including investment and production credits

Other costs, such as insurance, property taxes, development fees, interest during construction, and debt service reserve funds are included within these major categories. Black & Veatch strived to make the model as simple as possible while still maintaining an appropriate level of accuracy for comparing the relative generation cost of different projects employing different renewable energy technologies. The simplifying assumptions allowed the model to serve its analytical purpose and still be streamlined enough to evaluate hundreds of projects. Because of the simplifications, the model was not intended to simulate the exact financial performance of any one project. Use of the model in this way would be inappropriate.

Line items and calculations in the Cost of Generation Calculator are outlined below. A screenshot of the calculator is included in Figure 3-8.

- **NPV for Equity Return**: A cost of equity is assumed as part of the financial assumptions. This number is treated as a hurdle which the project must reach. The project must generate sufficient income from power sales to obtain this return on equity. The Net Present Value (NPV) for Equity Return discounts all cash flows associated with the project by this prescribed return to generate a present value. If this metric is zero, the project is returning exactly the prescribed amount to equity investors. Higher values mean that the project generates too much money, and lower values mean that it does not generate enough.
- **Levelized Cost of Generation**: The actual cost of generation used in the model escalates over time. The levelized cost of generation is the constant cost (no escalation) that produces the same net present value as the actual modeled costs of generation over the life of the project. This single metric is the main output of the model.
- **Annual Generation**: The annual generation for the project is calculated based on an 8,760 hour year, the project capacity and the assumed capacity factor.
- **Cost of Generation**: The Year one cost of generation is chosen such that the NPV for Equity Return is zero. Costs of generation in later years are escalated by the assumed value.
- **Fixed Operations and Maintenance**: Fixed O & M is calculated from the assumed dollars per kilowatt of capacity per year, the project capacity and the assumed escalation value.
- **Variable Operations and Maintenance**: Variable O & M is calculated from the assumed dollars per megawatt-hour, the annual generation and the assumed escalation value.
- **Fuel Cost**: Annual generation, net plant heat rate, fuel cost and annual escalation of fuel cost determine the annual fuel cost for the project.
- **Debt Service**: Mortgage-style principal and interest payments are calculated for the proportion of the project that is assumed to be financed, the debt rate and the term of the financing.

- **Tax Depreciation**: Depreciation of project assets are calculated for tax purposes. These numbers are based on the Modified Accelerated Cost Recovery System (MACRS) depreciation schedules. Multiple depreciation schedules (5, 7, 15 or 20 years) can be applied to a single project.
- **Production Tax Credit (PTC)**: The production tax credit is modeled using three parameters: the dollars per megawatt-hour credit, the annual escalation of the credit, and the duration of PTC availability in years.
- **Investment Tax Credit (ITC)**: ITC eligible projects are credited the prescribed percent of their capital costs in year one.
- **Taxes**: Projects pay an all-in combined tax rate on their taxable income (operating revenue less operating expenses and depreciation) and are credited for applicable tax credits (PTC and ITC).
- **Total**: These are the cash flows associated with the project, including the equity investment portion of the overall capital costs (accounted for as a single value in year zero).

Cost of Generation Calculator

All inputs are in blue.

Technology Assumptions	
Project Capacity (MW)	200
Capital Cost ($/kW)	$2,400
Fixed O&M ($/kW)	$60
Fixed O&M Escalation	2.5%
Variable O&M ($/MWh)	$0
Variable O&M Escalation	2.5%
Fuel Cost ($/MBtu)	$0
Fuel Cost Escalation	2.5%
Heat Rate (Btu/kWh)	0
Capacity Factor	30%
Misc Revenue ($/MWh)	$0
Misc Escalation	2.5%
Degradation	0%

Financial/Economic Assumptions	
Debt Percentage	60%
Debt Rate	6.50%
Debt Term (years)	15
Economic Life (years)	20
Percent 5-year MACRS	100%
Percent 7-year MACRS	0%
Percent 15-year MACRS	0%
Percent 20-year MACRS	0%
Energy Price Escalation	2.5%
Tax Rate	40%
Cost of Equity	7.75%
Discount Rate	6.982%

Incentives	
PTC ($/MWh)	$0
PTC Escalation	0.0%
PTC Term (years)	10
ITC	30%
ITC Depr Basis	85%

Outputs	
NPV Equity Return	$0
LCOE	$77.28

77.28228087

Calculations		
Cap Cost		$336,000,000
	0	
	0	-225030298.3
	5	-207420608.5
slope		3521937.959

Year	1	2	3	4	5	6	7	8	9
Annual Generation (MWh)	525,600	525,600	525,600	525,600	525,600	525,600	525,600	525,600	525,600
Power Price	$63.89	$65.49	$67.13	$68.81	$70.53	$72.29	$74.10	$75.95	$77.85
Misc Revenue	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total Operating Revenue	**$33,582,626**	**$34,422,192**	**$35,282,746**	**$36,164,815**	**$37,068,935**	**$37,995,659**	**$38,945,550**	**$39,919,189**	**$40,917,169**
Fixed O&M	$12,000,000	$12,300,000	$12,607,500	$12,922,688	$13,245,755	$13,576,899	$13,916,321	$14,264,229	$14,620,835
Variable O&M	$0	$0	$0	$0	$0	$0	$0	$0	$0
Fuel Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0
Operating Expenses	**$12,000,000**	**$12,300,000**	**$12,607,500**	**$12,922,688**	**$13,245,755**	**$13,576,899**	**$13,916,321**	**$14,264,229**	**$14,620,835**
Interest Payment	$13,104,000	$12,562,113	$11,985,004	$11,370,382	$10,715,810	$10,018,691	$9,276,259	$8,485,569	$7,643,484
Principal Payment	$8,336,721	$8,878,608	$9,455,717	$10,070,339	$10,724,911	$11,422,030	$12,164,462	$12,955,152	$13,797,237
Debt Service	**$21,440,721**	**$21,440,721**	**$21,440,721**	**$21,440,721**	**$21,440,721**	**$21,440,721**	**$21,440,721**	**$21,440,721**	**$21,440,721**
Tax Depreciation - 5	$81,600,000	$130,560,000	$78,336,000	$47,001,600	$47,001,600	$23,500,800	$0	$0	$0
Tax Depreciation - 7	$0	$0	$0	$0	$0	$0	$0	$0	$0
Tax Depreciation - 15	$0	$0	$0	$0	$0	$0	$0	$0	$0
Tax Depreciation - 20	$0	$0	$0	$0	$0	$0	$0	$0	$0
Taxable Income	($73,121,374)	($120,999,922)	($67,645,757)	($35,129,855)	($33,894,229)	($9,100,731)	$15,752,970	$17,169,391	$18,652,850
PTC	$0	$0	$0	$0	$0	$0	$0	$0	$0
Taxes	**($29,248,550)**	**($48,399,969)**	**($27,058,303)**	**($14,051,942)**	**($13,557,692)**	**($3,640,292)**	**$6,301,188**	**$6,867,756**	**$7,461,140**
Total ***(134,400,000)***	***29,390,454***	***49,081,439***	***28,292,828***	***15,853,348***	***15,940,151***	***6,618,331***	***(2,712,680)***	***(2,653,518)***	***(2,605,527)***
MACRS Depreciation Schedules									
5	0.2	0.32	0.192	0.1152	0.1152	0.0576	0	0	0
7	0.1429	0.2449	0.1749	0.1249	0.0893	0.0892	0.0893	0.0446	0
15	0.05	0.095	0.0855	0.077	0.0693	0.0623	0.059	0.059	0.0591
20	0.0375	0.07219	0.06677	0.06177	0.05713	0.05285	0.04888	0.04522	0.04462

Year	10	11	12	13	14	15	16	17
Annual Generation (MWh)	525,600	525,600	525,600	525,600	525,600	525,600	525,600	525,600
Power Price	$79.79	$81.79	$83.83	$85.93	$88.08	$90.28	$92.54	$94.85
Misc Revenue	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total Operating Revenue	**$41,940,098**	**$42,988,600**	**$44,063,315**	**$45,164,898**	**$46,294,021**	**$47,451,371**	**$48,637,655**	**$49,853,597**
Fixed O&M	$14,986,356	$15,361,015	$15,745,040	$16,138,666	$16,542,133	$16,955,686	$17,379,578	$17,814,067
Variable O&M	$0	$0	$0	$0	$0	$0	$0	$0
Fuel Cost	$0	$0	$0	$0	$0	$0	$0	$0
Operating Expenses	**$14,986,356**	**$15,361,015**	**$15,745,040**	**$16,138,666**	**$16,542,133**	**$16,955,686**	**$17,379,578**	**$17,814,067**
Interest Payment	$6,746,663	$5,791,550	$4,774,353	$3,691,040	$2,537,310	$1,308,589	$0	$0
Principal Payment	$14,694,058	$15,649,171	$16,666,368	$17,749,681	$18,903,411	$20,132,132	$0	$0
Debt Service	**$21,440,721**	**$21,440,721**	**$21,440,721**	**$21,440,721**	**$21,440,721**	**$21,440,721**	**$0**	**$0**
Tax Depreciation - 5	$0	$0	$0	$0	$0	$0	$0	$0
Tax Depreciation - 7	$0	$0	$0	$0	$0	$0	$0	$0
Tax Depreciation - 15	$0	$0	$0	$0	$0	$0	$0	$0
Tax Depreciation - 20	$0	$0	$0	$0	$0	$0	$0	$0
Taxable Income	$20,207,079	$21,836,036	$23,543,922	$25,335,193	$27,214,578	$29,187,097	$31,258,077	$32,039,529
PTC	$0	$0	$0	$0	$0	$0	$0	$0
Taxes	**$8,082,832**	**$8,734,414**	**$9,417,569**	**$10,134,077**	**$10,885,831**	**$11,674,839**	**$12,503,231**	**$12,815,812**
Total	***(2,569,810)***	***(2,547,550)***	***(2,540,014)***	***(2,548,566)***	***(2,574,664)***	***(2,619,874)***	***18,754,846***	***19,223,718***
MACRS Depreciation Schedules								
5	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
15	0.059	0.0591	0.059	0.0591	0.059	0.0591	0.0295	0
20	0.04461	0.04462	0.04461	0.04462	0.04461	0.04462	0.04461	0.04462

Figure 3-8. Example Generation Cost Calculation for a Wind Project.

3.4.2 Financial Assumptions

The financial assumptions used in the cost calculation for WREZ resources in this study are shown below.

Table 3-3. Financing Assumptions.

Technology	Economic Life	Debt : Equity	Debt Term	Interest Rate	Equity Cost	Tax Life*
Biomass	20	60/40	15	7.5%	15%	7
Geothermal	20	60/40	15	7.5%	15%	5
Hydro	30	60/40	15	7.5%	15%	20
Solar PV	20	60/40	15	7.5%	15%	5
Solar Thermal	30**	60/40	25**	7.5%	15%	5
Wind	20	60/40	15	7.5%	15%	5

Source: Black & Veatch analysis for Phase 1 of the WREZ Initiative.

Notes:

* 5-year MACRS depreciation schedules are applied to all Canadian resources except for impoundment hydropower, to which the 7-year MACRS depreciation schedule is applied. This is done to approximate Canadian accelerated depreciation schedules, which are not modeled precisely. This is described below.

**The ZITA working group decided that the economic life and debt term for solar thermal technologies should be 30 and 25 years respectively, based on stakeholder input.

The economic life is the useful life of the project from the developer's perspective. The twenty year assumption for most technologies is a common term for a power purchase agreement. This is consistent with the assumed ownership structure. Hydroelectric power facilities generally have a longer life, and their economic life is extended.

The financing assumptions are the same for all technologies. It is a representative structure for the financing of renewable energy projects: 60 percent debt financed over 15 years at a rate of 7.5 percent and 40 percent equity at a cost of 15 percent. This results in a weighted average cost of capital of 10.5 percent. The debt term and rate are appropriate with the 20 year economic life and prevailing interest rates.

The cost of equity is an approximation of the return on investment that a renewable energy project investor would require, taking into account the rate of return that an investor could receive on a comparable investment. It is understood that the cost of equity varies between technologies and projects based on the perceived risk and innumerable other factors. In the absence of a generally accepted set of assumptions, however, Black & Veatch did not see adequate justification for assuming differences.

The tax life is the depreciation schedule for project assets. Tax incentives permit accelerated depreciation for most renewable projects as described further in the next section.

There are several additional assumptions that are made to support the economic analysis:

- Combined federal and state income tax rate: 40 percent (US/Canada) 28 percent (Mexico)
- Discount rate: 10.5 percent
- General inflation: 2.5 percent

3.5 Renewable Energy Financial Incentives

A number of financial incentives are available for the installation and operation of renewable energy technologies. The incentives available to new renewable energy facilities and those that were applied to WREZ resources in the economic analysis are briefly discussed below.

3.5.1 U.S. Federal Government

The predominant federal incentive for renewable energy has been offered through the U.S. tax code in the form of tax deductions, tax credits, or accelerated depreciation. An advantage of this form of incentive is that it is defined in the tax code and is not subject to annual congressional appropriations or other limited budget pools (such as grants and loans). Tax-related incentives include:

- Section 45 Production Tax Credit (PTC)
- Section 48 Investment Tax Credit (ITC)
- Accelerated depreciation

The Section 45 PTC is available to private entities subject to taxation for the production of electricity from various renewable energy technologies. The income tax credit amounts to 1.5 cents/kWh (subject to annual inflation adjustment and equal to 2.1 cents/kWh in 2009) of electricity generated by wind, solar, geothermal, and closed-loop biomass. The credit is equal to 0.75 cents/kWh (inflation adjusted, equal to 1.0 cents/kWh in 2009) for all other renewable energy technologies. A problem with the credit is the ever-present threat of expiration, which promotes boom and bust building patterns. The PTC was recently extended in February 2009 to the end of 2012 for wind and the end of 2013 for all other resources as part of HR 1, the American Recovery and Reinvestment Act (ARRA, or the "Stimulus Bill").

Major provisions of the Section 45 PTC are presented in Table 3-4.

Table 3-4. Major Production Tax Credit Provisions.

Resource	Eligible In-service Dates	Credit Size*	Special Considerations
Wind	12/31/93 - 12/31/12	**Full**	None
Biomass			
Closed-Loop	12/31/92 - 12/31/13	**Full**	Crops grown specifically for energy
Closed-Loop Cofiring	12/31/92 - 12/31/13	**Full**	Only specific coal power plants; based on % of biomass heat input
Open-Loop	Before 12/31/13	Half	Does not include cofiring
Livestock Waste	Before 12/31/13	Half	>150 kW.
Poultry Waste	10/22/04 - 12/31/13	**Full**	Incorporated with "livestock waste" with the American Jobs Creation Act of 2004
Geothermal	12/31/99 - 12/31/13	**Full**	Cannot also take investment tax credit
Solar	10/22/04 - 12/31/13	**Full**	Cannot also take investment tax credit; eligibility expired Dec. 31, 2005
Small Irrigation Hydro	10/22/04 - 12/31/13	Half	No dams or impoundments; 150 kW-5 MW
Incremental Hydro	10/22/04 - 12/31/13	Half	Increased generation from existing sites
Landfill Gas	8/8/05 - 12/31/13	Half	Cannot also take Sec. 29 tax credit
Municipal Solid Waste	10/22/04 - 12/31/13	Half	Includes new units added at existing plants

Source: Black & Veatch research.

Notes:

* All PTCs are inflation-adjusted and equaled $21/MWh ("Full") or $10/MWh ("Half") in 2009.

The Section 48 ITC effectively offsets a portion of the initial capital investment in a project. The Energy Policy Act of 2005 modified the ITC to include additional resources and increased the credit amount. While utilities originally were not eligible to receive the ITC, the extension of the ITC passed in 2008 changed this wording to allow utilities to claim the ITC if they have a tax burden. In addition, ARRA expanded the eligibility to a broader range of resources. The ITC provisions are now:

- Solar – Eligible solar equipment includes solar electric and solar thermal systems. The credit amount for solar is 30 percent for projects that come online prior to December 31, 2016; otherwise, it is 10 percent.
- Geothermal – Geothermal includes equipment used to produce, distribute, or use energy derived from a geothermal deposit. The credit amount for geothermal is 30 percent for plants that come online prior to December 31, 2012., but cannot be taken in conjunction with the PTC.

- Wind – Units must be placed into service by December 31, 2012.
- Biomass, LFG, hydro, and anaerobic digestion – Units must be placed into service by December 31, 2013.

One major non-tax related incentive to come from the ARRA is a new renewable energy grant program. Project owners with a tax burden can receive a grant after the project is placed into service equal to 30 percent of the project's capital cost. Projects must begin construction by the end of 2010, and must be placed into service by 2012 (wind), 2016 (solar), or 2013 (all other eligible resources). If the grant is utilized, the project cannot apply the benefits of the PTC or ITC. Since this program will largely have an impact similar to that of the 30 percent ITC program, it is not modeled separately in the financial pro forma.

The language of the PTC extension does not allow claiming of both the PTC and the ITC. Project developers must choose one or the other. For capital-intensive solar projects, the ITC is typically more attractive. The ITC also interacts with accelerated depreciation, as discussed further below.

Section 168 of the Internal Revenue Code contains a Modified Accelerated Cost Recovery System (MACRS) through which certain investments can be recovered through accelerated depreciation deductions. There is no expiration date for the program. Under this program, certain power plant equipment may qualify for 5-year, 200 percent (i.e., double) declining-balance depreciation, while other equipment may also receive less favorable depreciation treatment. Renewable energy property that will receive MACRS includes solar (5-year), wind (5-year), geothermal (5-year), qualifying hydropower (5-year) and biomass (7-year). Typically, the majority of the project capital cost, but not all, can be depreciated on an accelerated schedule. However, for biomass, only the boiler portion of the plant receives MACRS (about 60 percent of the project cost). The ARRA included a "bonus depreciation" allowance for most qualified renewable energy facilities that allowed 50% depreciation during the first year of operation provided that the facility commenced operation in 2009.

The accelerated depreciation law also specifies that the depreciable basis is reduced by the value of any cash incentives received by the project, and by half of any federal investment tax credits (e.g., the ITC). This provision has the effect of lowering the depreciable basis to 95 percent for projects that receive the 10 percent ITC and 85 percent for projects that take the 30 percent ITC.

The cost of generation for all US resources was modeled assuming they received the 30 percent ITC and the appropriate MACRS depreciation.

3.5.2 State Financial Incentives

All U.S. states within the WREZ study area have incentives for renewable energy projects. Black & Veatch reviewed the incentives and concluded that none would have a substantive effect on the analysis. Therefore, for the sake of simplicity, the assessment does not include state incentives.

3.5.3 Canadian Incentives

The Canadian federal government has two applicable incentive programs for renewable energy. First, it offers an accelerated depreciation program for renewable energy, the Capital Cost Allowance (CCA) 43.2. This incentive grants geothermal, wind and small hydropower resources a 50 percent declining accelerated depreciation benefit. It grants conventional, large hydropower a 30 percent declining accelerated depreciation benefit. In each case, the depreciation rate is halved for the first year. Black & Veatch determined that the Canadian 50 percent CCA accelerated depreciation schedule and the 30 percent CCA for renewable energy have a similar effect on the net present value of a project as the US MACRS depreciation schedules. As a result, all technologies that qualify for the 50 percent CCA were modeled with the 5-year MACRS depreciation schedule, and all technologies that qualify for the 30 percent CCA were modeled with the 7-year MACRS depreciation schedule.

The federal government also offers the EcoENERGY incentive for Renewable Power program. It was, however, determined by the WREZ ZITA working group that the EcoENERGY incentive would soon expire and was not applicable to this analysis. The only incentives that were applied to Canadian renewable energy resources were the MACRS 5-year depreciation schedules that mimic the CCA schedules.

3.5.4 Mexican Incentives

Mexico has several incentives for renewable energy development including 95 percent one-year accelerated depreciation, potential for Kyoto Protocol Clean Development Mechanism carbon credits at rates not available to U.S. projects, favorable export credit treatment from organizations such as the U.S. Export Import Bank, and other incentives.[17] The potential for Clean Development Mechanism credits were not modeled directly, because it was determined to be outside the scope of this project.

However, the 95 percent 1 year depreciation was mimicked using the models for the US incentives. It was determined that this could be mimicked by granting Mexican projects zero depreciation but providing them a tax credit in the first year equal to 95 percent of their tax liability.

3.5.5 Future Term and Nature of Incentives

The future of financial incentives is a source of uncertainly in the analysis. The extension of both the PTC and ITC as part of the ARRA now has the PTC expiring at the end of 2012-2013 and the 30 percent ITC/grant program expiring at the end of 2012, 2013, or 2016, depending on the technology. These incentives have a substantial impact on the cost of generation from renewables. It was accepted by stakeholders in the WREZ ZITA working group process that all incentives will, in general and in some form, be available to renewable energy projects over the term of this study. The decision of the ZITA working group was to assume that existing financial incentives extend in their current form throughout the study period.

3.6 Non-REZ Resources

It is important to quantify not only the resources that meet the specific criteria developed to identify QRAs, but also other resources that might help achieve the broader goals of the WREZ initiative. The overarching goal of the WREZ initiative is "to improve the balance and overall adequacy of renewable and traditional energy resources in a manner that will strengthen economic growth, promote energy price stability, mitigate environmental impact, maximize reliability and result in an abundance of diversified resource supplies."[18] Pursuant to that goal, this report quantifies renewable energy resources that may be significant and commercially viable even though they may lie outside of a QRA. The economics of these resources are not assessed and they are not included in the supply curve analysis. These resources are referred to as non-REZ resources. Non-REZ resources

- May not require extra-high voltage transmission in order to be economically viable;
- Primarily serve load in the same locality, state, province or utility service area; and
- Do not need to be concentrated in one place to be developed.

The specific qualities and types of non-REZ resources are described for each resource type in Chapter 4.0. Non-REZ resources are also quantified and summarized in this chapter as well as in Chapter 5.0.

[17] Personal communication from James Walker, Asociados Panamericanos, April 23, 2008
[18] Western Governor's Association, Western Renewable Energy Zones - Phase 1 Report, Available: http://www.westgov.org/wga/publicat/WREZ09.pdf, June 2009

4.0 Resource Characterization

This section describes the WREZ resources resource assessment, QRA identification and the non-REZ resource assessment process for biomass, geothermal, hydropower, solar, and wind resources in WREZ.

4.1 Biomass

This section details Black & Veatch's approach to the identification of biomass direct fired projects for the purposes of WREZ analysis. WREZ biomass was considered a secondary resource and was quantified when it could theoretically be located inside of QRA boundaries created for primary resources (geothermal, some hydro, solar, wind). Some biomass resources have been characterized in almost every QRA. This section discusses the methodology used to characterize the resources suitable for biomass direct firing technology. The general approach was to identify potential biomass resource potential based on the availability of different feedstocks.

4.1.1 Resource Assessment Methodology

Biomass resources are unique in the WREZ analysis: while the resource is generally distributed over a large area, the biomass fuel can be transported to the point of best use. This allows for a high degree of siting flexibility. For example, biomass projects can be sited near existing transmission lines with available transfer capacity. Projects can also be sited to avoid environmentally sensitive areas. At about 1 acre per MW, the physical footprint of biomass plants is relatively low. For these reasons, the resource assessment methodology for biomass focused on the amount of biomass fuel available to a particular QRA and did not identify specific locations of theoretical projects.

Slightly different resource assessment methodologies were used in the US and Canada because the data available were different. No biomass resources were identified in Baja, due to lack of data.

US

For US QRAs, county-level biomass feedstock data from NREL, the Western Governor's Association (WGA), the California Biomass Collaborative (CBC) and the Washington State Department of Ecology (WA ECY) were used as the basis for identifying the total amount of biomass that could be used for fuel for power generation across the western US.[19,20,21,22] The feedstock types assessed, which were chosen by the WREZ ZITA working group, included agricultural residues (orchard/vineyard, field/seed crop, vegetable crop, and food/fiber), forest residues (forest thinnings and slash, and mill residues), and urban wood waste. Forest and agricultural data used in this study came from the WGA report, orchard and vineyard residue data came from the CBC and WA ECY reports and urban wood waste data came from the NREL report.

The WREZ study set out to include a number of specific biomass resources that were thought to be newly available and potentially not captured in large-scale resource assessments. These included mountain pine beetle kill wood, vineyard and orchard residues, piñon juniper removals and green waste sites located in forest communities on US Forest Service land. It was determined that the WGA dataset included pine beetle kill wood and piñon juniper removals, as well as resources available from USFS green waste sites in the US. Reliable pine beetle kill data were not available for British Columbia and Alberta although significant time and effort was put into developing a sound methodology to assess these resources. Finally, it was determined from communications with the British Columbia Forest Service that it could not be reliably estimated given the data available and scope of this project.[23] Data on vineyard and orchard residues was collected for Washington and California, where these resources were thought to have the greatest impact.

Technically Available Potential

After discussion with biomass stakeholders, Black & Veatch determined that not all theoretically available biomass feedstock capacity would be available for power generation. It was assumed that one-third of the theoretical feedstock capacity quantified in the NREL, CBC and WA ECY biomass data would be available for power generation. The remainder was assumed to be unavailable or used in competing markets such as for mulch, biofuels, and other purposes.

The WGA report quantified the amount of biomass available at various costs and the amount of resources available at a particular price point was used as the basis for

[19] Milbrandt, Anelia, A Geographic Perspective on the Current Biomass Resource Availability in the United States," 2005. NREL Technical Report NREL/TP-560-39181.
[20] Western Governor's Association Biomass Task Force, Strategic Assessment of Bioenergy Development in the West, Available: http://westgov.org/wga/initiatives/transfuels/index.html, 2008
[21] California Energy Commission, An Assessment of Biomass Resources in California, PIER Collaborative Report 500-01-016, California Biomass Collaborative, 2006
[22] Fuchs, Mark and Frear, Craig et al, Biomass Inventory and Bioenergy Assessment: An Evaluation of Organic Material Resources for Bioenergy Production in Washington State, Washington Department of Ecology, Available: http://www.ecy.wa.gov/biblio/0507047.html, 2005
[23] Personal communication with Adrian Walton, Landscape Ecologist at the BC Forest Service, April, 2009.

identifying the amount of biomass available for power generation. Instead of discounting the total resource potential in this dataset, it was assumed that only biomass available at or below $80 per ton would be economically viable for power production. That constraint was assumed to reduce the gross potential to the realistically available potential in a way that was comparable to the two thirds discount applied to the other datasets.

The resulting resource potentials from all the datasets were assumed to be the amount of "technically available" biomass in the study area. The technically available biomass of each feedstock category by county was converted to a MW potential using the heating value for each fuel identified in the CBC study, a heat rate of 13,650 BTU/kWh, and an 85 percent capacity factor. This method defined the capacity (by county) across the western United States.

QRA-Level Assessment

The technically available capacity contained in each county located in and near each QRA was assigned to that QRA using GIS software. A 50-mile buffer was created around QRA boundaries in GIS. The distance that would be required to transport the biomass inside the QRA plus 50 miles was assumed to be the maximum distance that biomass resources could be hauled to a power plant before transportation costs would make collecting the feedstock uneconomic. These buffers were intersected with the county-level biomass data, producing a table indicating which QRA buffers overlapped which counties. In many cases, a single county was overlapped by multiple QRA buffers. Using this table and the visualization of the 50 mile buffers over the counties in GIS, the automatic matching of counties to QRAs was refined using the following rules:

- Counties were assigned to QRAs when they appeared to fall entirely or mostly inside of a QRA's buffer.
- When multiple QRA buffers overlapped a single county, that county was assigned to the QRA whose buffer overlapped the majority of its area.
- If multiple QRAs overlapped the majority of one county, the QRA with the greatest overlap was assigned that county. If multiple QRAs had buffers that overlapped all or most of a county the QRA located within the same state as that county was always assigned that county.
- In cases where two QRA buffers overlapped all or equal amounts of that county in the same state, the QRA that had fewer counties assigned to it was assigned this county.

Plant-Level Assessment

Once the total amount of biomass potential was estimated for each QRA, this potential was broken out into theoretical plants of different sizes and utilizing the different feedstock types (agricultural residues, forestry residues, urban wood waste), based on the amount of MW from each type of feedstock in each QRA. Plants were no larger than 100 MW in size. This was determined to be the maximum economically developable plant size given the biomass resources available.

When possible, different plants were created for different feedstock types. For QRAs with multiple feedstock types, each type was assigned to a single plant where sufficient feedstock was available. Of the counties assigned to each QRA, plants were located in the county with the highest density of the resource type. More than one fuel type was used in a single plant only when multiple types were available and the amount of each resource was less than 10 MW. Resource types were also combined if only a small amount of a resource was available, i.e. several resources less than 5 MW were combined with larger plants. All resources were combined for QRAs with very limited resources.

The resulting dataset contained theoretical plants of different sizes utilizing different feedstock types assigned to QRAs. These theoretical plant-level data were used to analyze the economics of biomass resources in these QRAs. This is discussed in depth below.

Canada

For Alberta and British Columbia QRAs, biomass feedstock data from Agriculture and Agri-Food Canada's Biomass Inventory Mapping and Analysis Tool (BIMAT) was used as the basis for identifying the total amount of biomass that could be used for fuel for power generation across those provinces.[24] BIMAT is an online mapping tool that enables users to quantify the amount of biomass resources in a certain area in various sites across Canada. Users select a site location, a search radius around each site, and the types of biomass resources to be quantified. The program then returns the dry tons per year of each type of biomass available in that search radius around the site. The feedstock types assessed, which were chosen by the WREZ ZITA working group, included crop residues (barley, wheat, flax, oats and corn), forest residues (soft and hardwood roadside harvest and mill residues), and urban wood waste. All biomass data for Canada came from BIMAT.

[24] National Land and Water Information Service, Biomass Inventory and Mapping Tool, Agriculture and Agri-Food Canada, Available: http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1226509218872&lang=eng, April 2009

Technically Available Potential

After discussion with stakeholders, it was concluded that one-third of the theoretical feedstock capacity quantified in the BIMAT data would be available for power generation. The remainder was assumed to be unavailable or used in competing markets such as for mulch, biofuels, and other purposes.

QRA-Level Assessment

As mentioned above, the distance that would be required to transport the biomass inside the QRA plus 50 miles was assumed to be the maximum distance that biomass resources could be hauled to a power plant before transportation costs would make collecting the feedstock uneconomic. The Canadian biomass assessment sought to quantify biomass resources within a radius of 50 miles around the edge of each QRA. Since users are only allowed to choose a central location around which to collect biomass resources in the BIMAT tool, Black & Veatch estimated the size of the circle required based on the size of the Canadian QRAs. These radii were then used in the BIMAT tool to quantify the amount of resources inside of each. These resources were then attributed to that QRA.

Plant-Level Assessment

The same methodology was used to break biomass resources into theoretical plants in Canada as was used in the US. The resulting dataset contained theoretical plants of different sizes utilizing different feedstock types assigned to QRAs. These theoretical plant-level data were used to analyze the economics of biomass resources in these QRAs. This is discussed in greater depth below.

Biomass Resource Map

A map of all biomass resources assessed in the US for WREZ is shown below in Figure 4-1. This map shows theoretical biomass generating potential in MW at the county level. Generating potential was calculated based on county level estimates of the amounts of different types of biomass resources available for power production annually. Estimates of the amount of feedstock available were discounted to reflect technical potential and converted to generating potential using the US biomass resource assessment assumptions described above.

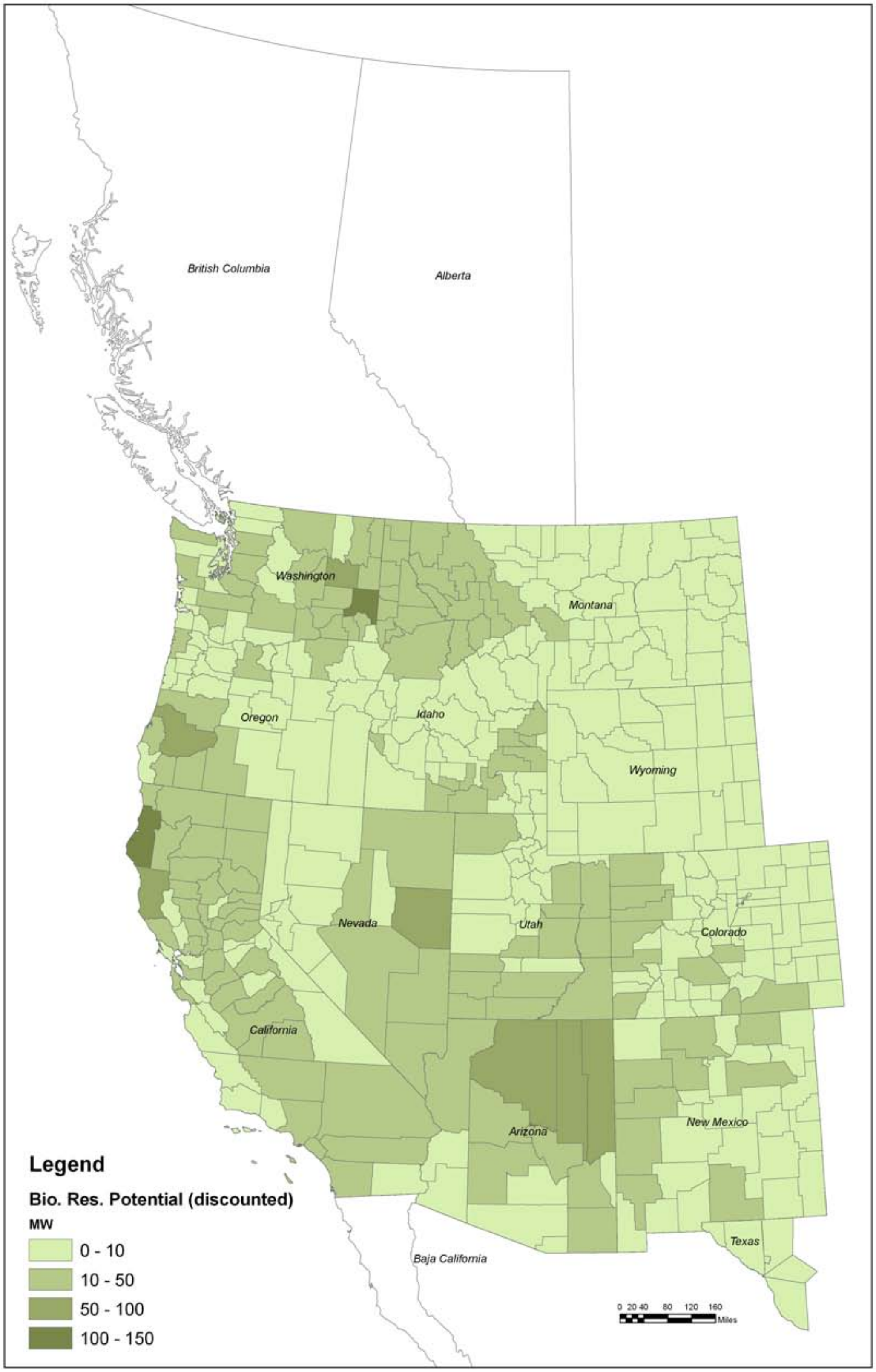

Figure 4-1. Biomass Resource Map.

4.1.2 Resource Supply Curve Characteristics

Combustion of biomass fuel was assumed to take place in a stoker or fluidized bed steam generator with a standard steam power cycle. Assumed emissions control equipment included selective non-catalytic reduction (SNCR) for NOx control and a baghouse/electrostatic precipitator for particulate control. This combination represents conventional technology which has been proven over many years of operation. The assumptions that went into the biomass supply curve economic analysis for this type of plant are detailed below.

Capital Cost

Capital cost for the projects considered (3 to 100 MW) ranged from around $3,400 to around $6,000/kW, based on a review of recent cost estimates performed by Black & Veatch. The capital cost is inclusive of generation tie-line and interconnection costs. This range is wider than the range anticipated by the WREZ ZITA working group due to the fact that the analysis identified some theoretical plants that are smaller than the smallest plants the working group anticipated.

Operations & Maintenance

Operations and maintenance (O&M) costs ranged from around $24/MWh to $52/MWh. This range is somewhat wider than the range anticipated by the WREZ ZITA working group due to the fact that O&M costs tends to increase as plant size decreases, and the WREZ analysis identified some theoretical plants that are smaller than the ZITA group anticipated.

Fuel Cost

Estimates of the cost of different biomass fuel feedstocks were developed from data supplied by the Green Power Institute, updated to 2009 costs, and adapted for the resources identified in the CBC report. Costs for each resource can be found in Table 4-1. Transportation costs were calculated assuming that fuel would not be collected further than 100 miles from the center of the county in which the plant was located. The assumed collection distance was the radius around this theoretical plant location containing 50 percent of the total fuel, assuming the fuel was evenly distributed across the circle around the plant.

Table 4-1. Biomass Fuel Cost (Undelivered).		
Resource	**Energy Content (BTU/bdt)**	**Collection Cost (Undelivered), $/bdt**
Agricultural Residues	7,790	30
Forest Thinnings/Slash	8,500	41
Urban Wood Waste	7,179	20
Mill Residues	8,597	29

Heat Rate

The heat rate varied based on the moisture content of the fuel, with a low of 14,000 BTU/kWh used for urban wood waste (12 percent moisture) to 15,780 BTU/kWh for forest residues (40 percent moisture). These fell within the range expected by the WREZ ZITA working group.

Production Profile

A capacity factor of 85 percent was applied to all projects. The generation profile was assumed to be flat. This assumption was developed by the WREZ ZITA working group.

4.1.3 Results

The WREZ biomass analysis identified over 3,700 MW of potential biomass capacity and over 27 terawatt-hours (TWh) of theoretical annual generation in QRAs across the study area. All states and provinces have some biomass potential, except for Baja. Alberta, British Columbia, Oregon and Idaho have the greatest WREZ biomass resources. Arizona, Nevada and New Mexico also have significant biomass resources, due to the potential availability of piñon-juniper trees, which have expanded beyond their historic range and may provide significant biomass resources in the Southwestern US.[25] Data on biomass for Baja were not available.

Economic Analysis

The levelized cost of energy of biomass resources across the WREZ study area ranged from $103/MWh to $165/MWh. The high end of this range is higher than expected by the largely because smaller plants generally produce more expensive energy

[25] Western Governor's Association Biomass Task Force, Strategic Assessment of Bioenergy Development in the West, Available: http://westgov.org/wga/initiatives/transfuels/index.html, 2008

and some plants are smaller than originally anticipated by the WREZ ZITA working group. Table 4-2 summarizes the biomass performance and economic results. Figure 4-2 is a supply curve of biomass resources in QRAs across the WREZ study area.

Table 4-2. Summary of Biomass Performance and Economics Results.

Performance	
Net Plant Capacity (MW)	3 to 100
Net Plant Heat Rate (HHV, Btu/kWh)	14,000 to 15,780
Capacity Factor (percent)	85
Economics	
All-In Capital Cost ($/kW)	3,400 to 6,000
Fuel Cost ($/MBtu)	1.40 to 2.40
Variable O&M Cost ($/MWh)	24 to 52
Levelized Cost of Energy ($/MWh)	103 to 165
Source: Black & Veatch analysis for Phase 1 of the WREZ Initiative.	

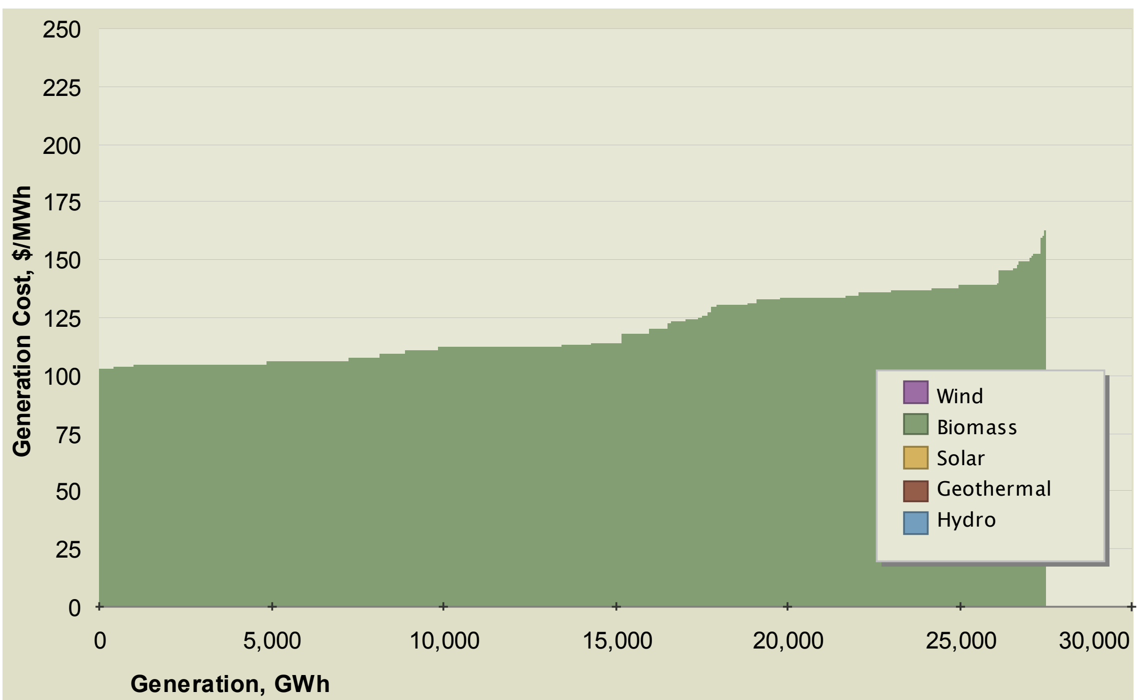

Figure 4-2. WREZ Biomass Supply Curve.

4.1.4 Non-REZ Resources

Non-REZ biomass resources were assessed as the biomass resources that met the REZ resource criteria, but were not quantified in QRAs. In some states, all of the biomass resources were assumed to be delivered into QRAs. As a result, not all states have remaining resources to quantify in the non-REZ analysis.

There are nearly 2,000 MW of non-REZ biomass resources across the Western Interconnection. These resources are mostly made up of forestry and agricultural residues.

Table 4-3. Non-REZ Biomass Resources by State/Province, MW

State	Ag Residues	Forestry Residues	Urban Wood Waste	TOTAL
California	117	468	65	650
Colorado	16	178	9	204
Idaho	23	182	0	206
Montana	0	164	0	170
New Mexico	0	9	0	12
Oregon	0	187	0	190
Utah	12	179	9	200
Washington	124	170	21	315
Wyoming	10	24	0	35
Alberta	*	220+**	*	220+**
British Columbia	20**	880**	*	900**
Baja	*	*	*	*
Grand Total	***322***	***2,661***	***104***	***3,102***

Source: Black & Veatch analysis for Phase 1 of the WREZ initiative; Macdonald, A.J., Inventory of Wood Biomass from Harvesting Residues and Non-Merchantable Forests in Alberta, FPInnovations, November 2007; Ralevic, Peter and Layzell, David B., An Inventory of the Bioenergy Potential of British Columbia, BIOCAP Canada Foundation, November 2006.

Note:

* Data on non-REZ biomass not available.

** Based on province-wide estimates of residues created by merchantable biomass harvest.

4.1.5 Data Sources

- California Energy Commission, An Assessment of Biomass Resources in California, PIER Collaborative Report 500-01-016, California Biomass Collaborative, 2006
- Fuchs, Mark and Frear, Craig et al, Biomass Inventory and Bioenergy Assessment: An Evaluation of Organic Material Resources for Bioenergy Production in Washington State, Washington Department of Ecology, Available: http://www.ecy.wa.gov/biblio/0507047.html, 2005
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- National Land and Water Information Service, Biomass Inventory and Mapping Tool, Agriculture and Agri-Food Canada, Available: http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1226509218872&lang=eng, April 2009
- Peter Ralevic and David B. Layzell, An InventoryWestern Governor's Association Biomass Task Force, Strategic Assessment of the Bioenergy Potential of British Columbia, BIOCAP Canada Foundation, November 2006
- Western Governor's Association Biomass Task Force, Strategic Assessment of Bioenergy Development in the West, Available: http://westgov.org/wga/initiatives/transfuels/index.html, 2008

4.2 Geothermal

This section details the approach to the identification of conventional hydrothermal geothermal resources in QRAs and quantifies the estimated potential of undiscovered resources and Enhanced Geothermal Systems (EGS) potential at the state level based on other studies. Recent studies of resource potential suggest that geothermal resources might have the potential to generate large quantities of renewable energy in the next 10 to 20 years. Based on updated research there may be geothermal energy potential available on the order of a hundred thousand megawatts or more in the Western Interconnection.

Geothermal was considered a primary resource in WREZ when it occurred in large enough quantities and a dense enough dispersion across an area to justify the creation of a QRA. Only known, quantifiable geothermal sources of conventional hydrothermal potential were considered WREZ resources. These were called "discovered conventional geothermal" resources in the WREZ process. Conventional hydrothermal geothermal resources that could not be associated with a specific site, but were thought to exist across a broad area were called "undiscovered, conventional geothermal" resources. These resources were quantified as non-REZ resources at the state/province level and were not included in the supply curve analysis. Non-REZ geothermal resource also included EGS resources, which are discussed in greater depth in the "Non-REZ Resources" section.

4.2.1 Resource Assessment Methodology

The geothermal resource assessment for WREZ was completed by GeothermEx, except for the generation tie-line analysis and production profile analysis, which were completed by Black & Veatch. Input from the private sector, research institutions and government agencies was used to compile a resource map and power production table that shows the varied and significant potential of geothermal resources across the Western Interconnection.

Estimation of geothermal generation potential for specific areas has relied on volumetric estimation of heat in place wherever sufficient information was available to justify this approach. The methodology has been described in detail in a study of California and Nevada geothermal resources for the CEC PIER program (GeothermEx, 2004). In brief, the heat-in-place approach entails estimation of the area, thickness, and average temperature of the geothermal resource. Recovery factors that are based on industry experience are applied to estimate the proportion of heat that can be recovered as electrical energy over an assumed project life of 30 years. Uncertainty in the input parameters is handled by a probabilistic approach that yields a range of possible generation values and associated probabilities. The modal value of the probability distribution is considered the "most likely value" of generation potential for the project concerned.

Where there is insufficient resource information to apply the heat-in-place method, estimates of generation potential have been made by analogy to better-known projects in similar geologic environments. If the only public information about a project is that it contains geothermal leases or has been the subject of a geological reconnaissance study, the project size has been estimated at a minimum size of 10 MW (gross). Larger estimates of capacity can be justified even in the absence of published resource data if there is evidence of active geothermal development efforts. For certain large volcanic centers in northern California, Oregon, and southern British Columbia, capacities of 50 MW (gross) have been estimated based on potentially favorable geologic conditions, even in the absence of current development efforts.

Treatment of Undiscovered Geothermal Resources

Undiscovered conventional geothermal resources were not identified with this approach and were not included in the supply curve analysis. For the purposes of near-term transmission planning, it is not possible to accurately and reliably quantify the locations of undiscovered conventional potential. However, estimates have been made of the undiscovered conventional potential at the state and province level by the USGS and Canadian researchers. These estimates are shown in the "Results" section below.

Geothermal Resource Map

A geothermal resource map is shown below in Figure 4-3. This map shows the location of specific potential projects assessed in WREZ as well as areas of "Geothermal Favorability." Geothermal favorability is a concept used by the USGS that the ZITA working group decided to use as a qualitative measure of the likelihood of undiscovered conventional geothermal and EGS resource potential in an area. Geothermal favorability data are used in the map below to show in general where undiscovered conventional geothermal and EGS resources might be located. These data are from the USGS and the British Columbia Ministry of Energy, Mines and Petroleum.[26]

[26] Personal communications with Jacob DeAngelo at the USGS on November 10, 2008 and Sue Bonnyman at the BC Ministry of Energy, Mines and Petroleum on November 1, 2008; Williams, Colin F., Reed, Marshall J., Mariner, Robert H., DeAngelo, Jacob, Galanis, S. Peter, Jr., 2008, Assessment of Moderate- and High-Temperature Geothermal Resources of the United States: U.S. Geological Survey Fact Sheet 2008-3082,

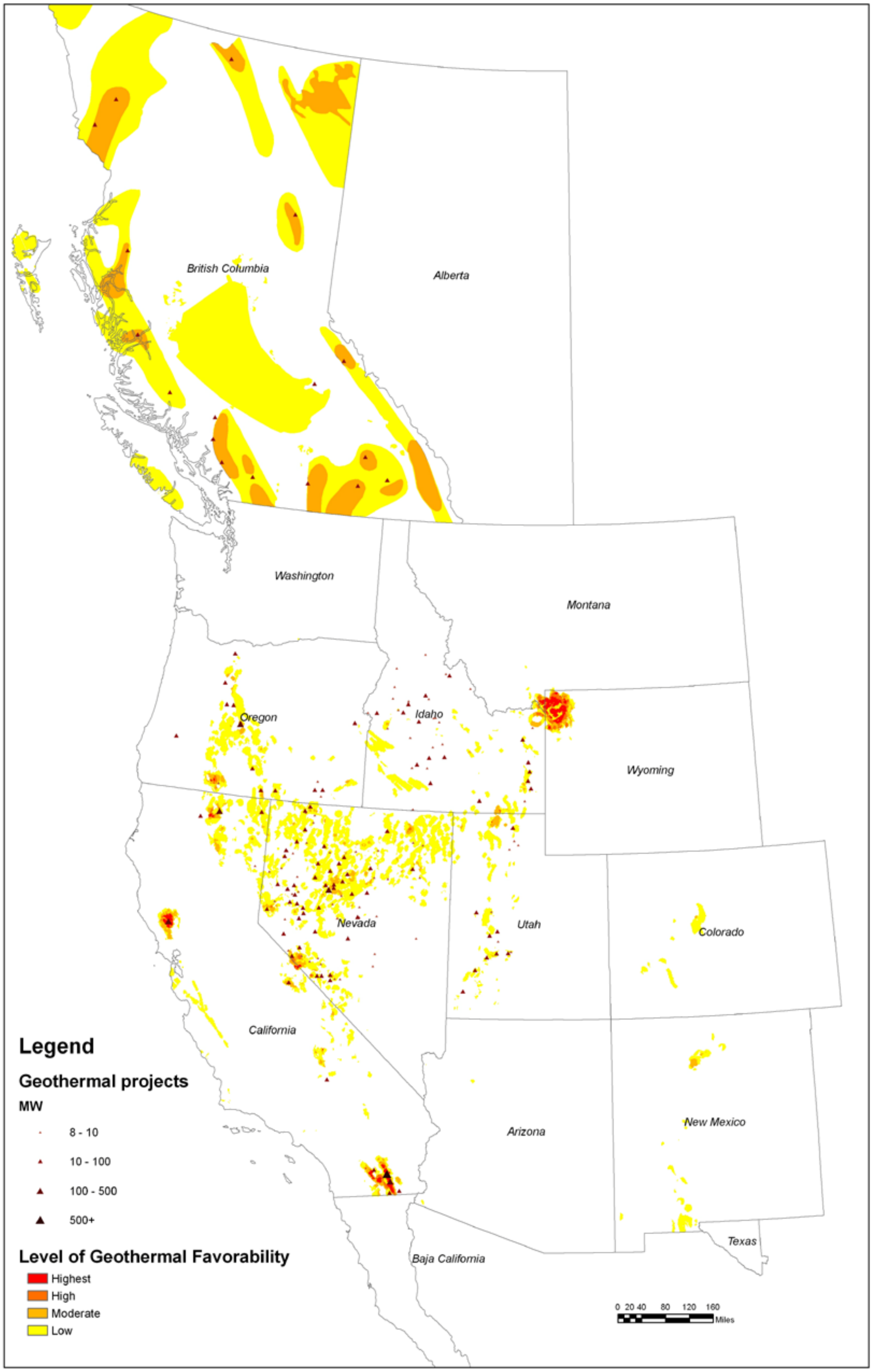


Figure 4-3. Geothermal Resource Map.

4.2.2 Resource Supply Curve Characteristics

Characterization of capital and operating costs for geothermal projects was based as much as possible on industry experience. The costs of drilling and plant equipment have risen markedly in recent years. A comparison of cost estimates from the CEC-PIER report with actual development costs as of 2008 indicates that the CEC-PIER estimates have escalated by about 20 percent.[27] Moreover, a correlation of the CEC-PIER cost estimates with estimated capacities has shown generally higher costs per kW installed for smaller projects. This correlation between cost and project size has been used to estimate the cost of projects not considered by the CEC-PIER study, and the 25 percent escalation factor has been used to express all project costs in 2009 dollars. For British Columbia, a 30 percent escalation factor has been applied to account for development challenges associated with colder climate and rugged topography.

Capital Cost

This analysis has yielded capital cost (including generation tie-line cost) estimates ranging from around $4,140 to $13,400/kW (net) installed. This variation was due to a number of factors, but primarily due to plant size. Generation tie-line costs also affected the capital cost of geothermal projects, most dramatically for smaller projects.

Generation tie-line costs were calculated for each geothermal project and added to their capital costs. These costs were calculated for each project based on the distance from the location of each project to the nearest substation at least 115 kV in size. The interconnecting generation tie-lines were assumed to be various voltages, which were chosen and the costs for which were estimated based on Black & Veatch's experience with transmission facilities of varying sizes. The generation tie-line costs for geothermal plants ranged from less than $20/kW to $1,900/kW for very small projects located in remote areas.

Operations & Maintenance

Operating costs have been estimated to range generally from $27 to $42/MWh (net), with higher costs characterizing the smaller project sizes. The operating cost estimates include site costs, general and administrative overhead, workovers, royalties, and insurance.

[27] Broad-based assessments of geothermal potential (such as the USGS assessment of 1979, currently being updated; the CEC-PIER report of 2004; the WGA study of 2006)

Production Profile

Initial capacity factor estimates for potential geothermal resources were assumed to be 90 percent for flash plants and 80 percent for binary plants. The operating characteristics of dry cooled binary plants are subject to ambient temperature considerations. Plant output decreases with increases in ambient temperature. The effect of ambient temperature on plant output was taken into consideration when developing a production profile for these plants. The ambient temperature effect on dry cooled geothermal plants was modeled by an NREL study and was applied to WREZ geothermal resources. [28] Figure 4-4, taken from the NREL study, shows the modeled effect of ambient temperature on dry cooled binary plant output.

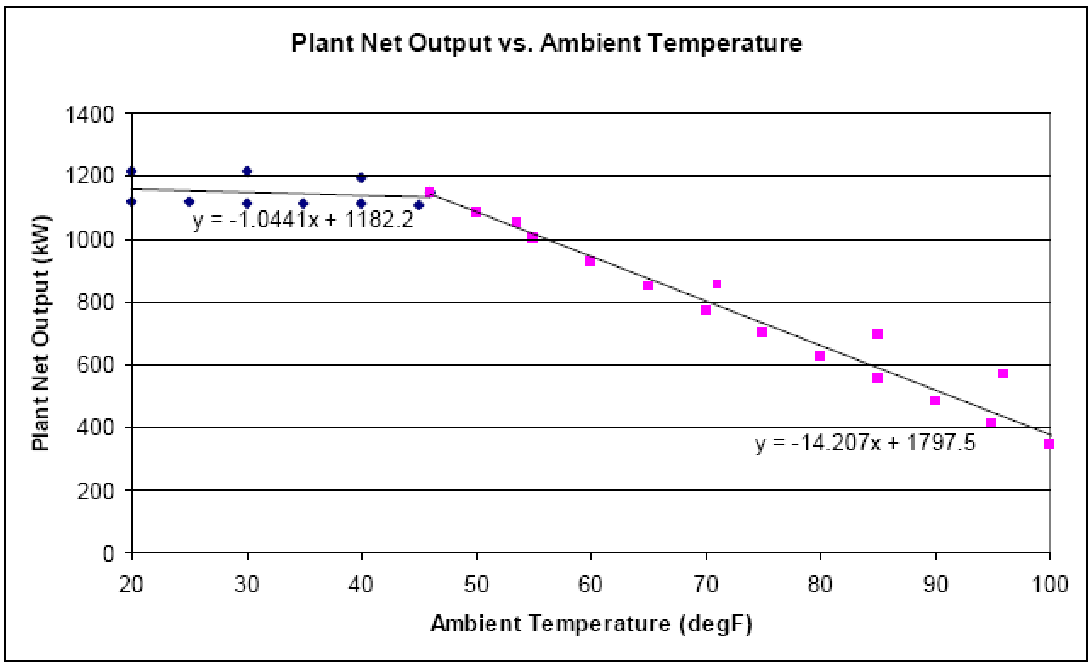


Figure 4-4. Plant Output vs. Ambient Temperature

Ambient temperature information for each potential site was collected from NREL TMY2[29] data, and the functions from the above figure were applied to determine expected plant output as a percentage of nameplate capacity.

[28] Kutscher, C., Cosentaro, D. "Assessment of Evaporative Cooling Enhancement Methods for Air-Cooled Geothermal Power Plants." Presented at the Geothermal Resources Council Annual Meeting, Reno, NV. September 22-25, 2002. NREL/CP-550-23294.

[29] NREL, Natoinal Solar Radiation Data Base, Available: http://rredc.nrel.gov/solar/old_data/nsrdb/tmy2/, 2009

After the implementation of the above ambient temperature methodology, plant capacity factor was scaled to the 80 percent assumed capacity factor for dry cooled binary plants.

4.2.3 Results

Over 4,470 MW of conventional, discovered geothermal resources were identified in QRAs across the WREZ study area, with a total theoretical annual capacity of over 33 TWh per year. These geothermal resources are located in British Columbia, California, Idaho, Nevada, Oregon and Utah. The analysis of conventional, discovered geothermal resources was limited to these states and provinces due to the known high potential of conventional geothermal resources in these areas.

Economic Analysis

The levelized cost of energy of conventional discovered geothermal resources across the WREZ study area ranged from $75/MWh to $203/MWh. Smaller projects and projects in remote areas were the most expensive, while larger projects and projects nearer to transmission infrastructure tended to be less expensive. Table 4-4 summarizes the geothermal performance and economic results. Figure 4-5 is a supply curve of geothermal resources in QRAs across the WREZ study area.

Table 4-4. Summary of Geothermal Performance and Economics Results.

Performance	
Capacity Factor (percent)	80 to 90
Economics	
All-In capital Cost ($/kW, including gen. tie line cost)	4,143 to 13,404
Gen. Tie Line Cost ($/kW)	20 to 1,900
Variable O&M Cost ($/MWh)	27 to 42
Levelized Cost of Energy ($/MWh)	75 to 203
Source: Black & Veatch analysis for Phase 1 of the WREZ Initiative.	

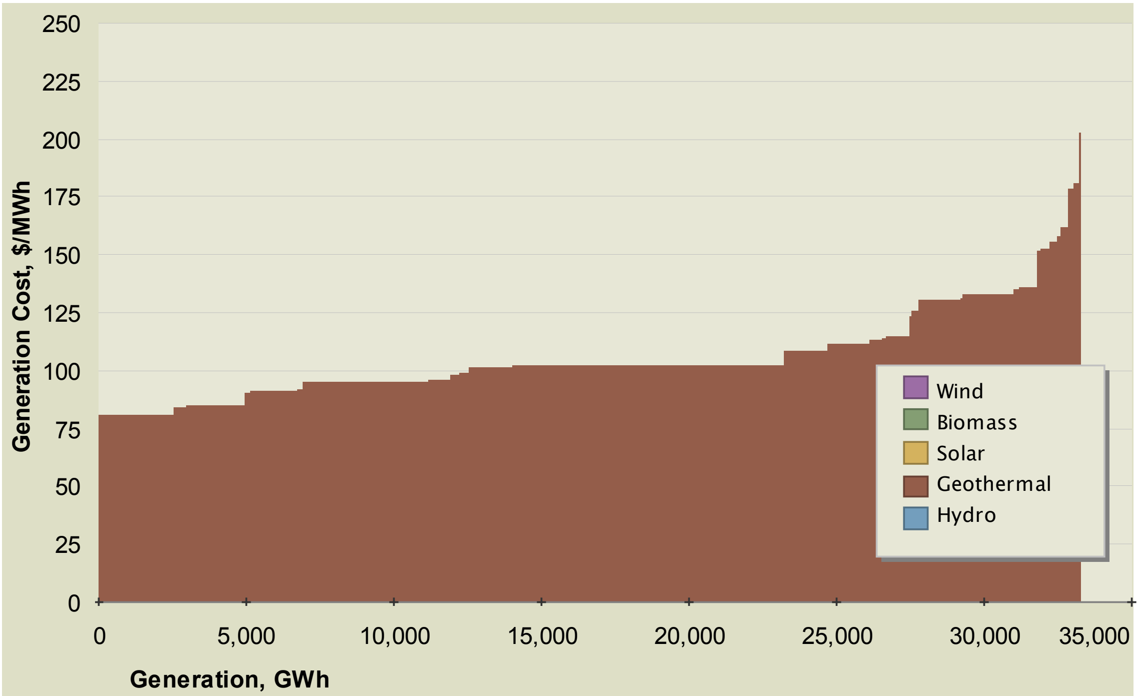


Figure 4-5. WREZ Geothermal Supply Curve.

4.2.4 Non-REZ Resources

Non-REZ geothermal resources consisted of undiscovered conventional geothermal potential as well as EGS potential. Over 31,000 MW of undiscovered, conventional geothermal resources were identified for this study. The general location and magnitude of these resources were estimated based on estimates of the USGS and various research efforts in Canada. These resources could become WREZ resources if the resource potential at specific project sites was quantified. However, site-level data were not available for this assessment so these resources are considered non-REZ resources.

The following describes the approach to EGS resources for WREZ. It was written collaboratively by WREZ stakeholders and is paraphrased below. This excerpt is from the WREZ Zone Identification and Technical Analysis Work Group Resource Criteria Approved by the WREZ Technical Committee at its October 2008 Meeting, available on the Western Governor's Association website[30]:

> Resource assessments for identifying QRAs focus on conventional geothermal resources with a high degree of resource certainty. A large potential also exists for Enhanced Geothermal Systems (EGS), known direct-use sites (which are also small power

[30] Available: http://westgov.org/wga/initiatives/wrez/zita/resource%20criteria.pdf

opportunities), and co-production opportunities in oil and gas fields using available data. These opportunities and future potential are regarded here as non-REZ resources, as their economic viability do not depend on the existence of a QRA.

Significant utility-scale EGS development may be 10 years or more from widespread commercial deployment, but the recent infusion of interest and investment will lead to near term development and its pace cannot be accurately predicted at this point in time. Its eventual pace of development may be determined by how fast cost-reductions follow from added experience in the development and operational aspects of EGS projects. Estimates by the Massachusetts Institute of Technology of near-term development of EGS sites, however, show economic potential within the range of other advanced technologies, ranging from 10 cents/kWhr to about $1/kWhr depending mostly upon the depth of the resource. This would indicate that prime EGS opportunities should be defined as part of the WREZ process, since their cost and timing may well be within the idealized goals for new renewable development.

It is recognized that various research efforts have estimated the generating potential of EGS resources in the US in the hundreds of thousands of MW. The potential of EGS resources in California alone is estimated to be as high as 67,600 MW. These resources would greatly increase the geothermal potential. As additional information is learned about the quantity, quality and location of these resources, it should be included in future transmission studies. At the state level, the estimated potential of EGS resources is quantified below.

Non-REZ resources are quantified at the state/province level in the table below.

Table 4-5. Non-REZ Geothermal Resources by State/Province, MW.

State	Undiscovered Conventional Geothermal Resources	Enhanced Geothermal Systems
Arizona	1,043	54,700
California	11,340	48,100
Colorado	1,105	52,600
Idaho	1,872	67,900
Montana	771	16,900
New Mexico	1,484	55,700
Nevada	4,364	102,800
Oregon	1,893	62,400
Utah	1,464	47,200
Washington	300	6,500
Wyoming	174	3,000
Alberta	500	*
British Columbia	5,260	*
Grand Total	***31,570***	***517,800***

Sources: Williams, Colin et al, Assessment of Moderate- and High-Temperature Geothermal Resources of the United States: U.S. Geological Survey, 2008; Data cited in a Personal Communication between Alison Thompson at the Canadian Geothermal Energy Association and the Western Governor's Association, February 2009.

Note:

* Data on the amount of resource potential from Enhanced Geothermal Systems not available for British Columbia and Alberta.

4.2.5 Data Sources

For the purposes of the WREZ study, geothermal resources have been identified from a variety of public domain information, including government assessments of geothermal potential, research papers and maps by universities and national labs, industry publications and press releases, leasing records, and direct responses from geothermal developers to solicitations for information. The following data sources were used:

- BC Hydro (2002). Green Energy Study for British Columbia; Phase 2: Mainland. Report No. E44. Chapter 5.2: Geothermal Energy, pp. 18-22.

- Broad-based assessments of geothermal potential (such as the USGS assessment of 1979, currently being updated; the CEC-PIER report of 2004; the WGA study of 2006)
- Data cited in a Personal Communication between Alison Thompson at the Canadian Geothermal Energy Association and the Western Governor's Association, February 2009
- Fairbank, B. D., and R. I. Faulkner (1992). Geothermal resources of British Columbia. Geological Survey of Canada, Open File 2526.
- Personal communications with Jacob DeAngelo at the USGS on November 10, 2008
- Personal communication with Sue Bonnyman at the BC Ministry of Energy, Mines and Petroleum on November 1, 2008.
- Government of British Columbia (2007). Geothermal resources map. http://www.em.gov.bc.ca/Geothermal/GeothermalResourcesMap.htm.
- Southern Methodist University (2008). Western Geothermal Areas Database. http://smu.edu/geothermal/georesou/resource.htm.
- Williams, Colin F., Reed, Marshall J., Mariner, Robert H., DeAngelo, Jacob, Galanis, S. Peter, Jr., 2008, Assessment of Moderate- and High-Temperature Geothermal Resources of the United States: U.S. Geological Survey Fact Sheet 2008-3082
- Kutscher, C., Cosentaro, D. "Assessment of Evaporative Cooling Enhancement Methods for Air-Cooled Geothermal Power Plants." Presented at the Geothermal Resources Council Annual Meeting, Reno, NV. September 22-25, 2002. NREL/CP-550-23294.
- NREL TMY2 Data, Available at: http://rredc.nrel.gov/solar/old_data/nsrdb/tmy2/

4.3 Hydropower

Different types of hydropower were considered eligible for WREZ based on their location. The ZITA group decided to treat hydropower differently in Canada and the US based on input from various stakeholders. In Canada, all hydropower potential, including large new dams, small run-of-river projects and additions of new power generating capabilities to existing dams, were quantified and considered in the WREZ economic analysis. In the US, only incremental upgrades at powered dams or additions of power to non-powered dams were considered.

4.3.1 Resource Assessment Methodology

The hydropower resource assessment relied on previous studies and assessments of hydropower potential across the WREZ study area. These studies and assessments identified the location and capacity of potential hydropower projects or upgrades. Using these data, hydroelectric potential was mapped using GIS software so that the amount of potential inside QRA boundaries could be quantified, or QRAs could be created based on the locations of these resources. Hydroelectric potential was identified in the US and Canadian portions of the WREZ study area, but was not identified in the Baja portion of the study area due to lack of data.

When hydroelectric resources that met the WREZ screening criteria were identified and attributed to a QRA, they were attributed to a grid square (see Chapter 3.0 for an in-depth description of the grid square analysis methodology). When the initial GIS analysis was completed, there were often multiple potential projects located in individual grid squares. The way the GIS analysis was set up, it was necessary that only one hydroelectric cost and capacity were attributed to each grid square. In order to account for this, projects that fell in the same QRA and had a per MWh levelized cost of energy within $25 of each other were grouped together and reassigned to the same grid square. The capital and operating costs of all of the hydropower resources in each grid square were then calculated as the annual generation-weighted average costs of all the hydroelectric resources in that grid square.

US

Hydroelectric potential has been previously assessed across the United States by the U.S. Department of Energy Idaho National Laboratory (INL) as part of the INL Hydroelectric Resource Economics Database (IHRED) database. This database identified the location and potential generation capacity of various potential hydroelectric sites.[31] Because hydroelectric resources were classified as secondary resources in the US, potential hydropower projects were quantified when they met the criteria set forth by the WREZ process and were located inside the boundaries of a QRA created for other resources. Hydroelectric resources in the US portion of the WREZ study area met the following criteria:

- Potential hydroelectric projects that add power generation to an existing dam with or without hydroelectric generating capacity were considered, but potential projects involving the construction of new dams or diversions were not. As a result, all undeveloped potential hydroelectric sites in the US, such as potential run-of-river sites, were not considered.
- Only projects identified in the INL database with a Project Environmental Suitability Factor (PESF) of 0.5 and greater were considered. The PESF values developed by INL rate each potential hydroelectric site in the database based on its likelihood of development given environmental constraints. A PESF value of 0.5 means that environmental concerns have moderate effect on likelihood of development.

Canada

Various assessments of hydroelectric potential in Canada were available to the WREZ process. A study published by engineering firm Kerr Wood Leidal (KWL), of small, run-of-river hydroelectric potential in BC, was used to identify these resources.[32] These data were supplemented by data from the British Columbia Transmission Corporation (BCTC) that identify additional run-of-river hydroelectric potential in provinces that are not captured by the KWL assessment.[33] Data on new large conventional dam hydroelectric and upgrades to existing dams in BC assessed by BC Hydro in their 2008 Long Term Acquisition Plan were also used.[34] Data on a single large run-of-river hydroelectric project in Northern Alberta was identified by BCTC were also used. This single project was the only hydroelectric project identified in Alberta.

All of these hydroelectric resources were assessed as WREZ resources. Small projects were treated as secondary resources. Projects that fell inside the boundaries of a

[31] Hall, Douglas G., et al, Estimation of Economic Parameters of U.S. Hydropower, Idaho National Laboratory, 2003, Available: http://hydropower.inl.gov/resourceassessment/index.shtml
[32] Kerr Wood Leidal Associates Ltd., Run-of-River Hydroelectric Resource Assessment for British Columbia,, Available: http://www.bchydro.com/etc/medialib/internet/documents/info/pdf/2008_ltap_appendix_f5.Par.0001.File.2008_ltap_appendix_f5.pdf, 2007
[33] Personal communication with Edward Higginbottom, Senior Strategy Advisor, British Columbia Transmission Corporation, January 2009
[34] BC Hydro, 2008 Long Term Acquisition Plan Appendix F1 Resource Options Database (RODAT) Sheets, Available: http://www.bchydro.com/etc/medialib/internet/documents/info/pdf/2008_ltap_appendix_f8.Par.0001.File.2008_ltap_appendix_f8.pdf, 2008

QRA identified based on other resources were quantified in that QRA. Very large hydroelectric projects or dense clusters of small projects were treated as primary resources. These represented enough potential to justify QRAs. In these cases, QRA boundaries were defined based on the location of these resources.

Hydropower Resource Map

A map of all hydropower resources assessed in WREZ is shown below in Figure 4-6. This map shows potential run of river hydropower projects in British Columbia, potential large impoundment hydropower sites in Alberta and British Columbia and potential additions of power to powered and non-powered dams in the US. Potential sites have been filtered to exclude those located in applicable environmental, land use and technical exclusion areas and size and color ramped based on their capacity.

Figure 4-6. Hydropower Resource Map.

4.3.2 Resource Supply Curve Characteristics

Hydroelectric generation is regarded as a mature technology, is already established throughout the US and Canada, and is not expected to experience any significant technical advancement due to its already high reliability and efficiency. Turbine efficiencies and costs have remained somewhat stable, but construction techniques and their associated costs continue to change. Capacity factors are highly resource dependent and can range from 10 to more than 90 percent, although typically range from 40 percent to 60 percent. Capital and operating costs also vary widely with site conditions.

Due to the mature nature of traditional hydroelectric technology, it was assumed that capital, operations and maintenance costs that have been established in earlier studies only need to be escalated to current year dollars (2009$) for the calculation of a project-level levelized cost of energy.

Capital and Operating Costs

For hydroelectric resources in the US, the IHRED database provided capital and operating cost information for every potential project, assessed in 2003 dollars. These project costs were taken from Federal Energy Regulatory Commission (FERC) Form 1, and were assumed to include all owner's costs. These costs were escalated to 2009 dollars using the Engineering News-Record building costs index.[35] Based on Black & Veatch experience, this index tracks the escalation of skilled labor and materials costs that are incurred in the construction and operations and maintenance of hydroelectric plants over time with accuracy acceptable for use in the WREZ evaluation. The ratio of the ENR 2009 and 2003 index values was 1.29; this factor was used to escalate IHRED 2003 costs to 2009 dollars.

Canadian hydroelectric cost information came from multiple sources. Cost information was provided for each small run-of-river hydroelectric project identified in the KWL study. Cost information for large BC hydroelectric projects came from the BC Hydro Resource Options Database sheets. Cost information for the single large Alberta hydroelectric project came from a personal communication with a representative from the Alberta Department of Energy with knowledge about that project.[36]

[35] Engineering News Record, Building Cost Index History, Available: http://enr.ecnext.com/coms2/article_echi090601bldIndexHist, 2009

[36] Personal communication with Bevan Laing, Senior Manager, Generation, Infrastructure Policy, Government of Alberta Department of Energy, May 2009

Cost information on the small run-of-river hydroelectric potential projects provided by BCTC was not available. Using the cost data in the KWL study, costs were estimated for each of these potential projects. Certain components of project costs were based on the capacity of each project. Other components were site-specific and estimated by KWL using GIS software. This GIS analysis was not available to Black & Veatch, so to account for these location-based cost components, for each BCTC project a KWL project was identified nearby using GIS software. It was assumed that the BCTC project would have the same cost per kW for each location-based cost component as the nearby KWL project. KWL's operations and maintenance costs were also location-based and were estimated for each BCTC project using GIS software and data in the KWL report.

All costs for Canadian resources were escalated to 2009 dollars using the ratio of the ENR building costs index in 2009 and the ratio in the year in which the costs were originally estimated. All costs were also adjusted to reflect the Canadian-US exchange rate, based on input from BCTC and BC Hydro.[37] This exchange rate was 78.15 US cents to the Canadian dollar.

Production Profile

Most hydroelectric sites are not susceptible to the same diurnal variation of resource availability as other renewable energy resources, such as wind and solar. For this reason, only monthly profiles (12x1) were used in the assessment of hydroelectric resources in the WREZ study area. For US projects, the INL IHRED database provided hydroelectric resource production profiles for each project.

BC Hydro provided Black & Veatch with hydroelectric resource production profiles for some of the projects identified in the KWL study, although production profiles for each individual KWL project were not available.[38] An average of the production profiles available for projects in each transmission region was taken. This average production profile was applied to all the KWL and BCTC run-of-river hydroelectric projects located in each region. BC Hydro also provided Black & Veatch with one of the production profiles for one of the large hydropower projects.

4.3.3 Results

The WREZ hydropower analysis identified over 8,400 MW of potential hydropower capacity and over 31 TWh of theoretical annual generation in QRAs across the study area. The vast majority of this resource potential is located in BC and Alberta.

[37] Personal Communication with Edward Higginbottom, Senior Strategy Advisor, British Columbia Transmission Corporation and Allan Woo, BC Hydro, February 2009

[38] Personal communication with Kathy Lee, Senior Resource Planning Engineer, BC Hydro, February 2009

In the US, some potential was also identified in QRAs in California, Idaho, Nevada, Oregon and Washington. Approximately half of the total hydropower capacity identified consists of small, run-of-river hydropower plants in BC and Alberta, and the other half consists of impoundment plants in BC and US resources. Over half of the theoretical annual generation comes from BC run-of-river projects. Individual hydropower plant size ranged from less than 1 MW for small, run-of-river projects to 1,800 MW for the very largest run-of-river project. Capacity factors ranged from 2 percent for to 60 percent. The 2 percent capacity factor applied only to a capacity project in BC, which is a planned project to serve capacity needs, rather than generate energy year round.

Economic Analysis

The levelized cost of energy of hydropower resources across the WREZ study area ranged from \$19/MWh to \$1,860/MWh. Capital costs ranged from \$641/kW for an incremental addition of power to a dam in Washington State to over \$200,000/kW for a very small run-of-river project in a remote and potentially difficult to develop area of BC. Fixed and variable O&M costs displayed a similarly wide variation in costs.

The costs of US hydropower and Canadian impoundment hydropower fall within the ranges of anticipated costs identified by the ZITA working group early on in the WREZ process.[39] The main factors affecting cost variations among these projects are project size and whether a project is an upgrade to an existing dam with or without power or a completely new build. Larger projects are cheaper to build. If a project is an upgrade to an existing power station, it is much less expensive than a project that requires a new dam and/or power station.

Cost variations among Canadian run-of-river hydropower projects are due primarily to the locations of these projects. Projects located in remote areas on terrain on which it is difficult to build are very expensive, often with capital costs over \$10,000/kW. Projects that are located in areas that are more easily accessed and easier to build have costs that fall within the ranges initially expected by the ZITA group.

Table 4-6 summarizes the hydropower performance and economic results. Figure 4-7 is a supply curve of hydropower resources in QRAs across the WREZ study area

[39] Western Governor's Association, WREZ Technology Assumptions for Supply Curve Analysis, Available: http://westgov.org/wga/initiatives/wrez/zita/Technology%20Assumption%20-%20Supply%20Curve%20TCversion.pdf, January 2009

Table 4-6. Summary of Hydropower Performance and Economics Results.[a]

Resource Type[b]	US Hydropower	Canadian Run of River Hydropower	Canadian Impoundment Hydropower
Performance			
Net Plant Capacity (MW)	2 to 544	<1 to 1,800	900 to 1,000
Capacity Factor (percent)	53 to 60	22 to 68	2 to 58
Economics			
All-In Capital Cost ($/kW)	652 to 3,680	3,057 to >200,000	640 to 4,500
Gen. Tie Line Cost ($/kW)[c]	N/A	N/A	N/A
Fixed O&M Cost ($/kW-yr)	7 to 27	0 to 4,803	6 to 37
Variable O&M Cost ($/MWh)	8 to 28	0 to 12	0 to 1
Levelized Cost of Energy ($/MWh)	19 to 85	100 to >1,000	112 to >400

Source: Black & Veatch analysis for Phase 1 of the WREZ Initiative.

Notes:

[a] All costs and capacity factors shown here are for individual potential plants assessed, prior to classifying them in QRA and technology cost bins for the final cost of energy analysis.

[b] See above for a description of each type of hydropower.

[c] Generation tie line costs were not calculated for any potential hydropower projects. The capital cost data either included this cost, or a generation tie line was assumed not to be necessary because resources were additions of power to dams already served by transmission.

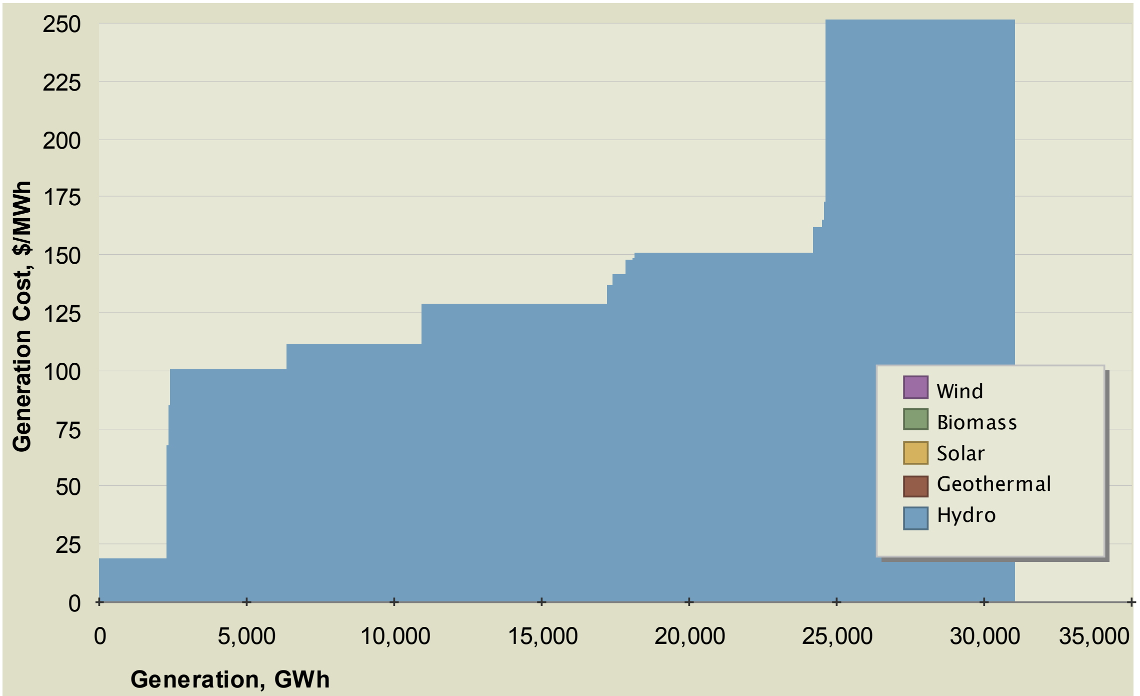


Figure 4-7. WREZ Hydropower Supply Curve.
Generation costs over $250/MWh not shown on chart.

4.3.4 Non-REZ Resources

Non-REZ hydropower resources are based on the data provided to the WREZ study for consideration and fell outside the boundaries of QRAs. This assessment is limited in Alberta because almost no data on non-REZ hydropower resources in that province were available.

There are 20,385 MW of non-REZ hydropower resources across the WREZ study area. Of the total non-REZ hydropower resources, 10,570 MW are incremental additions of power to powered or non-powered dams in the US, 9,714 MW are small, run of river hydropower resources in British Columbia and 100 MW are impoundment hydropower resources in Alberta.

Table 4-7. Non-REZ Hydropower Resources.

State/Province	US Hydropower	Canadian Run of River Hydropower	Canadian Impoundment Hydropower*
Arizona	72		
California	2,298		
Colorado	359		
Idaho	1,222		
Montana	574		
Nevada	29		
New Mexico	53		
Oregon	2,003		
Utah	456		
Washington	3,003		
Wyoming	502		
Alberta		**	100
British Columbia		9,714	
Grand Total	***10,570***	***9,714***	***100***

Sources: BC Hydro, 2008 Long Term Acquisition Plan Appendix F1 Resource Options Database (RODAT) Sheets, 2008; Idaho National Laboratory, Estimation of Economic Parameters of U.S. Hydropower, 2003; Kerr Wood Leidal Associates Ltd., Run-of-River Hydroelectric Resource Assessment for British Columbia, 2007

Notes:

* Only data on impoundment hydropower projects that were provided to the WREZ study that did not fall inside QRAs were considered here.

** Data were not available on run of river hydropower potential in Alberta, although resource potential might exist.

4.3.5 Data Sources

- BC Hydro, 2008 Long Term Acquisition Plan Appendix F1 Resource Options Database (RODAT) Sheets, Available: http://www.bchydro.com/etc/medialib/internet/documents/info/pdf/2008_ltap_appendix_f8.Par.0001.File.2008_ltap_appendix_f8.pdf, 2008
- Engineering News Record, Building Cost Index History, Available: http://enr.ecnext.com/coms2/article_echi090601bldIndexHist, 2009
- Idaho National Laboratory, Estimation of Economic Parameters of U.S. Hydropower, , 2003, Available: http://hydropower.inl.gov/resourceassessment/index.shtml

- Kerr Wood Leidal Associates Ltd., Run-of-River Hydroelectric Resource Assessment for British Columbia, Available: http://www.bchydro.com/etc/medialib/internet/documents/info/pdf/2008_ltap_appendix_f5.Par.0001.File.2008_ltap_appendix_f5.pdf, 2007
- Personal communication with Edward Higginbottom, Senior Strategy Advisor, British Columbia Transmission Corporation, January 2009
- Personal communication with Bevan Laing, Senior Manager, Generation, Infrastructure Policy, Government of Alberta Department of Energy, May 2009
- Personal Communication with Edward Higginbottom, Senior Strategy Advisor, British Columbia Transmission Corporation and Allan Woo, BC Hydro, February 2009
- Personal communication with Kathy Lee, Senior Resource Planning Engineer, BC Hydro, February 2009
- Western Governor's Association, WREZ Technology Assumptions for Supply Curve Analysis, Available: http://westgov.org/wga/initiatives/wrez/zita/Technology%20Assumption%20-%20Supply%20Curve%20TCversion.pdf, January 2009

4.4 Solar

Solar is a primary resource in the WREZ study area. QRA boundaries were defined based on the location of large amounts of high quality solar resource. The solar resource assessment approach was to quantify solar resource potential across the WREZ study area and reduce it to an assumed developable potential by removing lands that are undevelopable. A single solar resource dataset was available for the entire WREZ study area in the form of large scale solar resource maps from NREL. Various resource quality constraints were applied to these data and various environmental and technical exclusions were removed. A discount factor was applied to the remaining resource potential and the amount of resource potential in each grid square was quantified.

4.4.1 Resource Assessment Methodology

The solar resource assessment identified solar resources potentially developable as utility-scale solar projects. A direct normal insolation (DNI) level of 6.5 kWh/m^2/day was assumed to be an appropriate overall minimum DNI threshold that could be cost-effectively developed on a utility scale, although higher minimum DNI level thresholds were applied to solar resources in different states. This differentiation was made due to the vast disparities in the quality and quantity of solar resources across the western US and Baja. States such as Arizona and New Mexico have large quantities of potentially developable, high quality solar, while states such as Colorado and Utah have lower quality resources. A minimum threshold was applied in an effort to focus the analysis on resources that would most likely be developed for export across state lines.

Table 4-8. Minimum Solar DNI Level by State.

State/Province	Minimum DNI Level Considered in WREZ Analysis (kWh/m^2/day)
Arizona	7.25
Baja California	7
California	7
Colorado	7
New Mexico	7
Nevada	7
Utah	6.5
Texas	6.5

Certain areas were assumed to be undevelopable for solar resources. It was assumed that it would be too expensive to develop solar on land with a terrain slope greater than 2 percent, so areas with these slope characteristics were excluded from the solar resource analysis. Water bodies, urban areas and military bases were assumed to be undevelopable and were excluded from consideration. Certain other areas were excluded in accordance with recommendations from the E&L working group.

To calculate the solar resource capacity potential (in MW) inside each grid square in the WREZ study area, it was assumed that each square kilometer of eligible solar DNI level resource contained 38.6 MW of generation potential, based on Black & Veatch research. Using this assumption, the acreage of each eligible, solar DNI level in each grid square was quantified and converted to generating capacity. The solar generating capacity quantified in each grid square was discounted by 96.5 percent to account for unknown developability constraints and to simplify the modeling for resource planning.

This discount factor was vetted and agreed upon by the ZITA group stakeholders, although it was somewhat arbitrary. While it was necessary to create a discount of some sort to account for these unknown constraints, there was limited empirical data and industry experience on which to base this discount. In lieu of an empirical approach, the discount was developed by consensus by the ZITA working group. This factor yields a rough parity between the best solar resource areas and the best wind resource areas with respect to the amount of capacity developable on tracts of similar size. Stakeholders decided that this discount was large enough to both account for developability constraints and make the results of the resource assessment useful for resource planners. No discount or a less severe discount could have resulted in millions of MW of resource potential across the WECC, rather than tens of thousands.

Due to the fact that multiple types of solar technology are suitable for each developable area, multiple types of solar were modeled for each area. As a result, users of the GTM model can select which type of solar technology they would like to model for each solar resource area. Users cannot double count the resource by selecting multiple technologies for a single resource, but they can choose which technology they would like to use to convert a certain amount of resource into electricity. Each of these technologies has different performance and economic characteristics, which are detailed below.

Solar Resource Map

A map of all WREZ solar resources assessed is shown below in Figure 4-8. This map shows solar resources at DNI levels 6.5 kWh/m^2/day and above for US states and Baja Mexico filtered for applicable environmental, land use and technical exclusion areas.

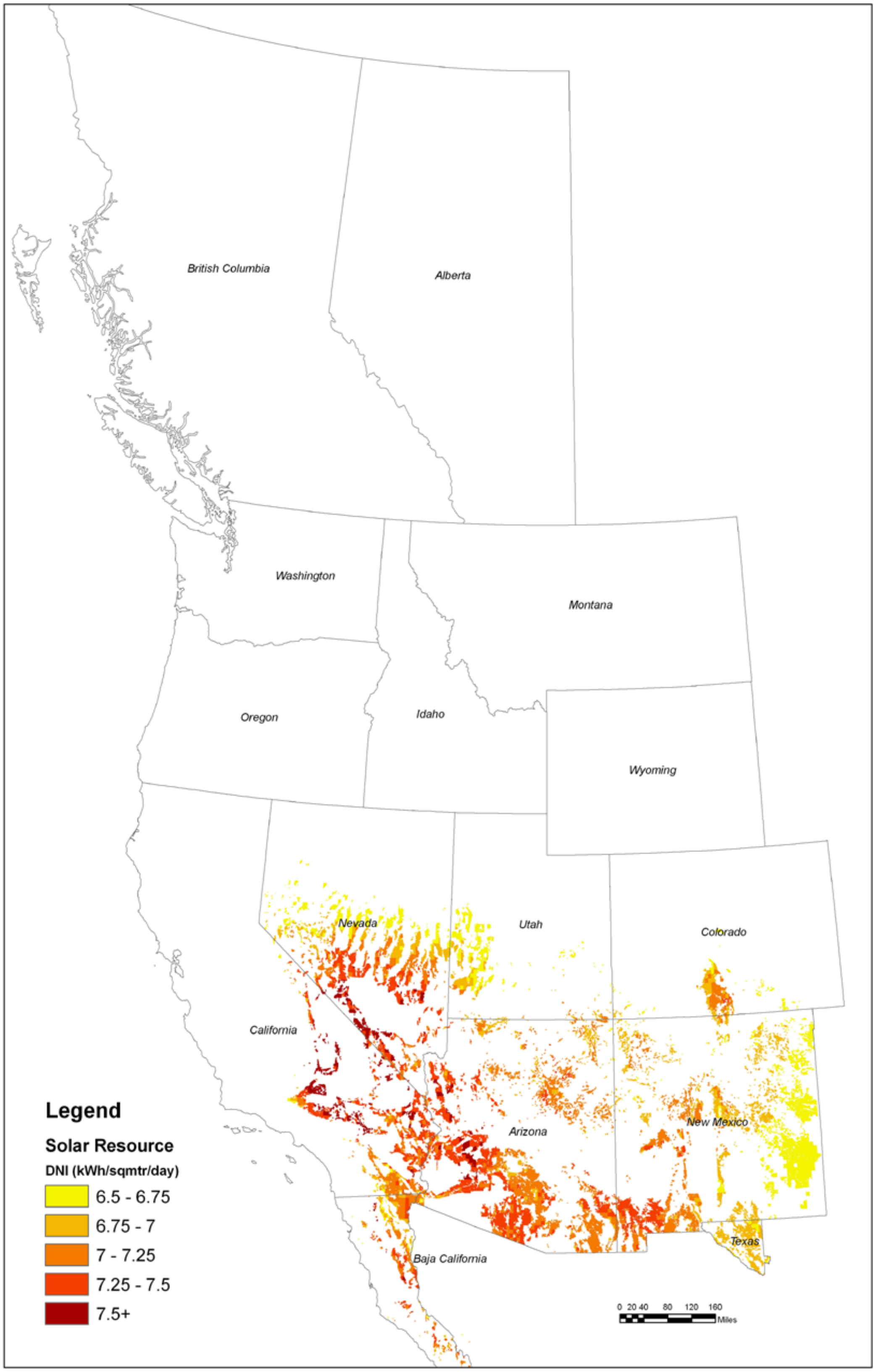


Figure 4-8. Solar Resource Map.

4.4.2 Resource Supply Curve Characteristics

Six different types of solar technology were modeled as part of the WREZ analysis so that users of the WREZ Generation & Transmission model can select which of these technologies they want to model. These six technologies included four types of parabolic trough concentrating solar thermal technologies: dry-cooled with no storage, dry-cooled with six hours of thermal storage, wet-cooled with no storage and wet-cooled with six hours of thermal storage. They also included two types of solar photovoltaic (PV) technology: fixed-tilt thin film and tracking crystalline. Areas that were appropriate for solar thermal development were also appropriate for all large scale solar development. For this reason, areas that fit the criteria for solar thermal are characterized as each type of solar thermal and each type of solar PV.

The solar resource in each grid square was individually characterized to determine its levelized cost of energy. The following section outlines the assumptions that were made in the characterization of solar projects.

Capital and Operating Costs

A capital cost and generation tie line (gen-tie) cost were assigned to all solar technologies in all QRAs across the WREZ study area. Capital costs were based on an assumed 200 MW project size. A base capital cost of per kW was assumed to be typical of the all-in cost per kW of each type of solar technology across the WREZ study area. This cost was based on Black & Veatch industry experience with real and planned solar projects and solar industry stakeholder input through the WREZ initiative.

Generation tie-line costs were calculated for solar resources in each QRA and added to the capital cost. These were calculated for each QRA based on the average distance from the centroid of each grid square to the nearest substation at least 115 kV in size. The interconnecting gen-tie lines were assumed to be 115 kV with a maximum line loading of 200 MW and a base cost of $750,000 per mile. This cost was based on Black & Veatch experience with transmission facilities of this size. The generation tie-line costs for solar resources from each QRA ranged from approximately $45/kW to $250/kW for QRAs located in very remote areas.

Fixed operations and maintenance costs were also assessed for each technology and used in the cost of generation calculations. Table 4-9 shows the base capital and operating cost assumptions for each solar technology, not including generation tie-line costs.

Table 4-9. Solar Technology Costs Used in the WREZ Analysis.

	Base Capital Cost ($/kW)	Variable O&M Cost ($/kW-yr)
Solar Thermal Dry-Cooled No Thermal Storage	5,300	66
Solar Thermal Dry-Cooled 6 Hrs Thermal Storage	7,600	66
Solar Thermal Wet-Cooled No Thermal Storage	5,100	66
Solar Thermal Wet-Cooled 6 Hrs Thermal Storage	7,400	66
Solar Thin-Film Fixed PV*	4,500	50
Solar Crystalline Tracking PV*	5,700	65

Source: Black & Veatch research for Phase 1 of the WREZ Initiative.

Notes:

* Solar PV values on a kWe and net AC basis.

Production Profile

Thermal and photovoltaic technologies each had its own production profile methodology.

Solar Thermal

All solar thermal projects were modeled as parabolic trough plants either dry or wet cooled and with or without storage. A production profile was created for various DNI levels throughout each QRA and assigned to all resources in that QRA within that DNI level. In order to do this, the median DNI level was found for each QRA grid square containing solar resources. Each QRA grid square containing solar resources was assigned one of five DNI level "buckets" from 6.5 to greater than 7.5, with breaks of 0.25 $kWh/m^2/day$. A 12x24 production profile was then calculated for the centroid of all of the grid squares in each of these buckets in each QRA. This profile was then assigned to all grid squares in that bucket in that QRA. The capacity factor was derived as the arithmetic mean of each profile.

Solar Photovoltaic

For solar PV technologies, 12x24 production profiles and capacity factors were calculated for each QRA's centroid and applied to all resources inside that QRA. For a solar photovoltaic project, capacity factor is the ratio of its AC delivered energy over a year and its AC energy output if it had operated at full nameplate capacity the entire time.

Black & Veatch used data and models developed by the National Renewable Energy Laboratory (NREL) as a basis for the capacity factor analysis for photovoltaic modules. NREL provided high resolution solar irradiance data in GIS format. This data included global horizontal, latitude tilt and direct normal monthly irradiance values for 10km x 10km grid squares. NREL derived the solar irradiance data from many years of satellite images covering the United States.

Black & Veatch used a proprietary tool to calculate energy production. The inputs for this tool included the NREL solar irradiance data, temperature data, geographical location, day and hour. The tool outputs average hourly energy production by month for both tracking crystalline silicon and fixed tilt thin film technologies.

Figure 4-9 and Figure 4-10 show examples of the daily energy generation profiles for single axis tracking and fixed tilt technologies. A single axis tracking system produces more energy in the mornings and afternoons than a fixed tilt system. The example daily energy generation profile in Figure 4-9 shows a July profile for crystalline and thin film. The thin film generation peak is above the crystalline peak for two major reasons. The first is that thin film has a lower temperature coefficient, which means that it suffers less from mid-day high temperatures than crystalline. The second is that the fixed tilt angle of thin film is more optimally pointed toward the sun than the flat horizontal tilt of crystalline at mid-day.

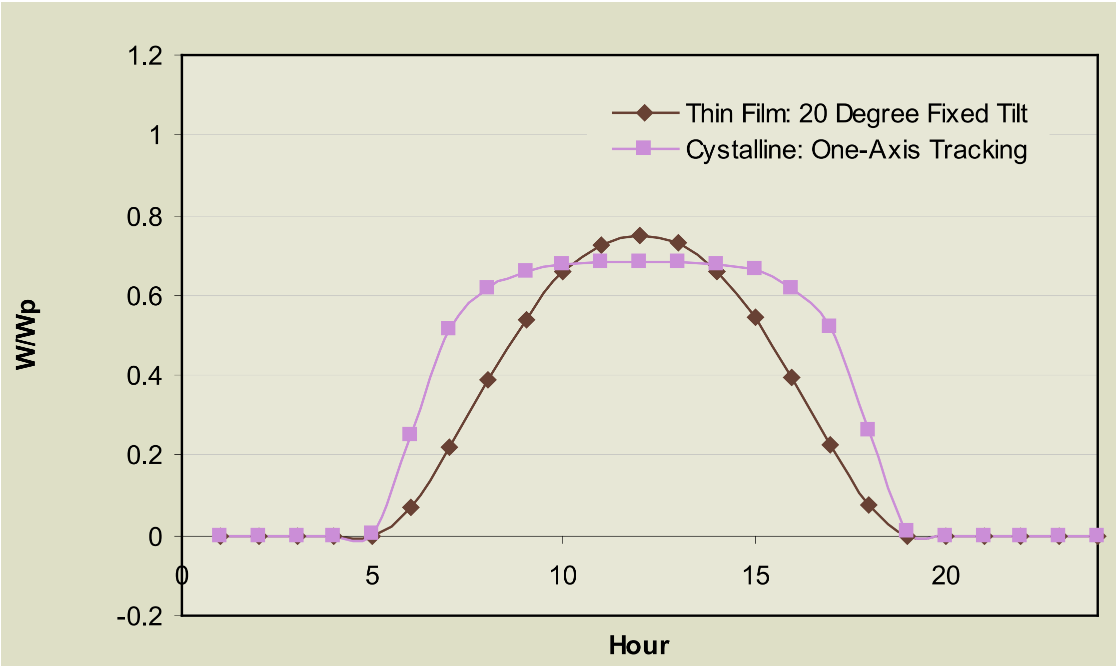


Figure 4-9. Example Energy Output from Tracking Crystalline and Fixed Tilt Thin Film (July).

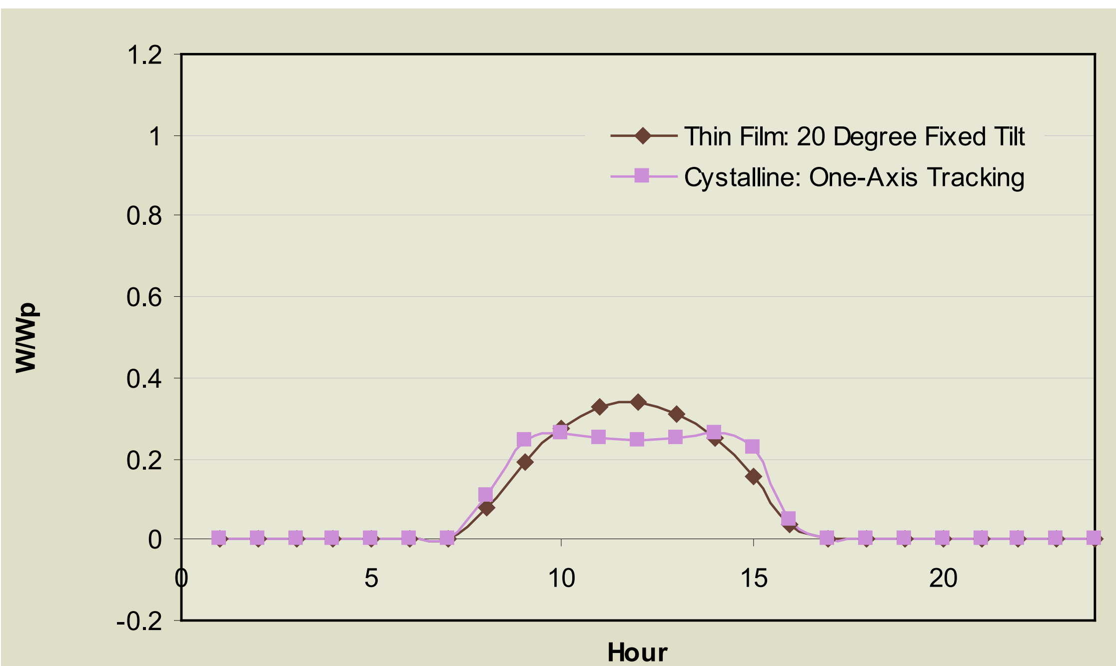


Figure 4-10. Example Energy Output from Tracking Crystalline and Fixed Tilt Thin Film (December).

4.4.3 Results

Over 86,000 MW of developable solar resources were identified in QRAs across the WREZ study area, with a total theoretical annual capacity of 190 to 270 TWh per year, dependent on the solar technology.[40] Of this resource potential, over 40,000 MW were between DNI levels of 7.25 and 7.5 kWh/m^2/day, over 26,000 MW were between 7.0 and 7.25, and the remainder fell into the other DNI classes. Of the states with solar resources, Arizona, California and Nevada had the most resource potential and the highest theoretical annual generation.

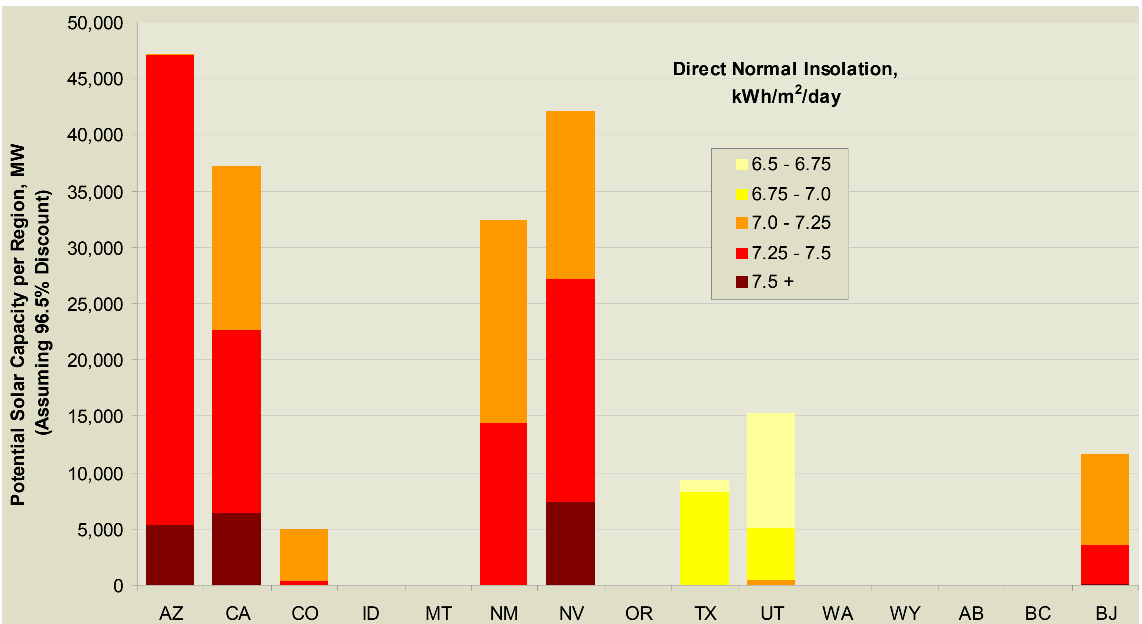


Figure 4-11. WREZ Solar Capacity by State/Province and DNI Level.

Economic Analysis

The levelized cost of energy of solar resources across the WREZ study area ranged from $148/MWh to $312/MWh. The levelized cost of energy varies across the WREZ study area and across different solar technologies. Wet cooled solar thermal with storage tends to produce the cheapest energy, while tracking crystalline PV tends to produce the most expensive energy. Variation in capacity factor and variation in capital costs due to different assumed generation tie-line lengths among QRAs have the greatest effects on the cost of generation of solar energy within technologies. Variation in tax incentives available for solar in the US and Mexico also have an effect on the cost of

[40] Some solar technologies assessed in this study have higher capacity factors than others, resulting in variation in annual generation potential.

energy from solar resources. Capital costs, including generation tie-lines, ranged from $4,546/kW to $7,852/kW. Capital costs vary from the base costs shown above due to variation in the average length of generation tie lines across QRAs.

Table 4-10 summarizes solar performance and economic results. Figure 4-12 is a supply curve of dry-cooled solar thermal resources with six hours of storage in QRAs across the WREZ study area.

Table 4-10. Summary of Solar Performance and Economics Results.

Resource Type	ST Dry No Storage	ST Dry 6 hrs Storage	ST Wet No Storage	ST Wet 6 hrs Storage	Fixed Thin-Film PV*	Tracking Cryst. PV*
Performance						
Capacity Factor (percent)	20 to 28	29 to 39	22 to 30	29 to 42	22 to 27	26 to 31
Economics						
All-in Capital Cost ($/kW, including gen. tie line cost)	5,346 to 5,552	7,646 to 7,852	5,146 to 5,352	7,446 to 7,652	4,546 to 4,752	5,746 to 5,952
Gen. Tie Line Cost ($/kW)	46 to 252	46 to 252	46 to 252	46 to 252	46 to 252	46 to 252
Fixed O&M Cost ($/kW-yr)	66	66	66	66	50	65
Levelized Cost of Energy ($/MWh)	168 to 291	162 to 284	152 to 269	148 to 269	176 to 284	191 to 312

Source: Black & Veatch analysis for Phase 1 of the WREZ Initiative.

Notes:

* All values for solar PV on a kWe, and net AC basis

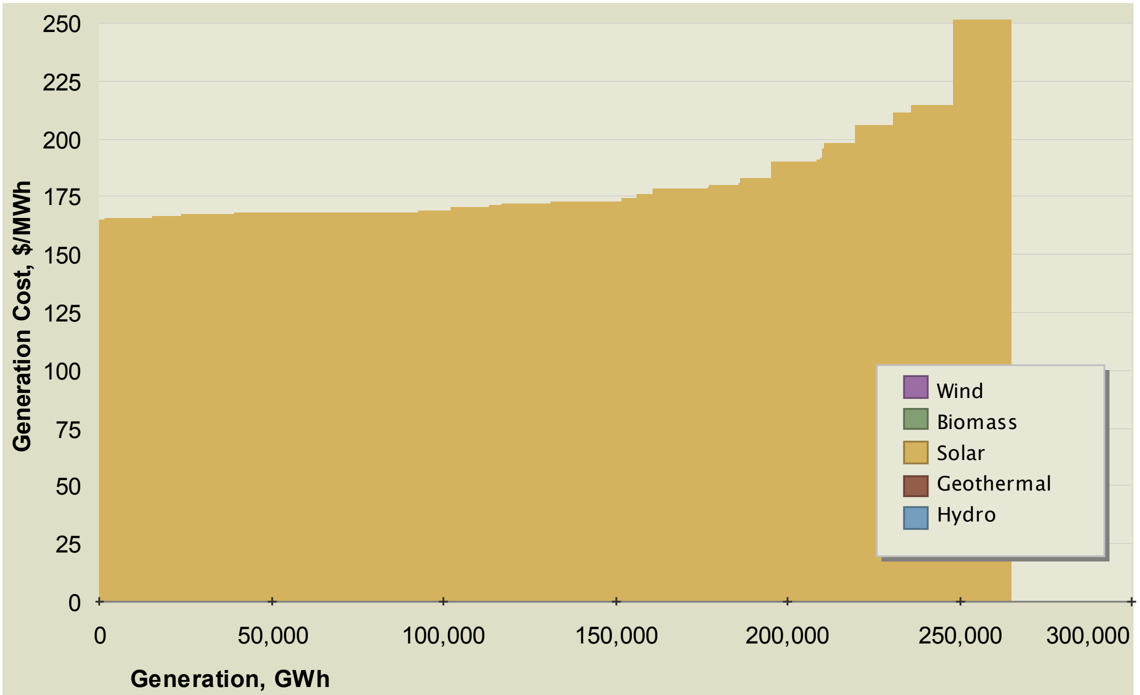


Figure 4-12. WREZ Solar Thermal Supply Curve.

4.4.4 Non-REZ Resources

There are over 416 GW of non-REZ solar thermal resources and over 750 GW of non-REZ solar photovoltaic resources across the WECC. These estimates exclude all applicable environmental and technical screens and apply a 96.5 percent discount factor to all solar resources. Solar thermal resources were quantified at DNI levels of 4.5 $kWh/m^2/day$ and above and solar photovoltaic resources were quantified at all global horizontal insolation (GHI) levels.

The greatest non-REZ solar thermal resource potential is in Colorado, Nevada and California. Note that the majority of the non-REZ solar thermal resources in these and almost every state (except for Baja and New Mexico) fall in the 4.5-6.5 $kWh/m^2/day$ DNI range. This range is below the minimum DNI level of resources considered REZ resources.

The greatest non-REZ solar photovoltaic resource potential is in New Mexico, Montana and Arizona. These resources were not classified into different GHI “buckets,” but their mean GHI levels were calculated, and are suggestive of the overall quality of the non-REZ resource in each state. Although Montana has among the highest non-REZ solar photovoltaic resources, it has among the lowest mean GHI levels, which suggests that it has poorer solar photovoltaic resources than other states.

Table 4-11. Non-REZ Solar Thermal Resources, MW by State/Province.*

State / Province	DNI level (kWh/m²/day)						TOTAL
	4.5-6.5	**6.5-6.75**	**6.75-7.0**	**7.0-7.25**	**7.25-7.5**	**7.5-7.5 +**	
Arizona		179	4,298	29,216	8,013	229	41,935
California	46,102	486	1,908	1,549	2,053	2,471	54,569
Colorado	56,023	1,174	2,592	743	21		60,553
Idaho	24,784						24,784
Montana	38,153						38,153
New Mexico	12,059	19,556	13,056	4,381			49,052
Nevada	38,040	7,361	7,009	2,652	2,012	245	57,319
Oregon	19,056						19,056
Texas		172	766				938
Utah	27,000	1,259	761	339			29,359
Washington	5,160						5,160
Wyoming	27,437						27,437
Alberta	1,104						1,104
British Columbia	**	**	**	**	**	**	**
Baja	1,395	941	2,315	1,744	1,023	67	7,485
Grand Total	***296,313***	***31,128***	***32,705***	***40,624***	***13,122***	***3,012***	***416,904***

Source: NREL's GIS team, High Resolution National Solar Thermal GIS data, available at: www.nrel.gov, accessed: June 2008.

Notes:

* Includes only resources not already quantified in the WREZ resource analysis. Resources were quantified after removing all environmental exclude and avoid areas, assuming 38.6 MW per square km of DNI and a 96.5 percent developability discount.

** Data not available.

Table 4-12. Non-REZ Solar Photovoltaic Resource by State/Province.*

State/Province	TOTAL MW All GHI Levels**	Mean GHI Level $kWh/m^2/day$
Arizona	86,989	5.5
California	29,355	5.2
Colorado	47,083	4.9
Idaho	25,794	4.4
Montana	123,085	3.9
New Mexico	126,150	5.4
Nevada	41,217	5.0
Oregon	48,689	4.4
Texas	11,951	5.7
Utah	33,955	4.9
Washington	30,613	3.9
Wyoming	84,025	4.5
Alberta	25,501	3.6
British Columbia	20,985	3.4
Baja	17,994	5.7
Grand Total	***753,384***	***N/A***

Source: NREL's GIS team, High Resolution National Solar Photovoltaic GIS data, available at: www.nrel.gov, accessed: June 2008.

Note:

* Includes only resources not already quantified in the WREZ resource analysis. Resources were quantified after removing all environmental exclude and avoid areas, assuming 38.6 MW per square km of GHI and a 96.5 percent developability discount.

** Estimates of non-REZ solar PV potential and solar thermal potential are mutually exclusive. It was assumed that non-REZ PV could be built anywhere non-REZ solar thermal could be built, so the non-REZ solar thermal potential was subtracted from the non-REZ PV potential, so as not to double count the potentially available resources.

4.4.5 Data Sources

Data sources used in this analysis included:

- Blair, et.al., Modeling Photovoltaic and Concentrating Solar Power Trough Performance, Cost, and Financing with the Solar Advisor Model, available at: www.nrel.gov, accessed: June 2008
- R. Bird and C. Riordan, Simple Spectral Model for Direct and Diffuse Irradiance on Horizontal and Tilted Planes at the Earth's Surface for Cloudless Atmospheres, available: www.nrel.gov, accessed: June 2008
- Perez, et.al., SUNY Satellite Solar Radiation model, available: www.nrel.gov, accessed: June 2008
- NREL's GIS team, High Resolution National Solar Photovoltaic and Solar Thermal GIS data, available: www.nrel.gov, accessed: June 2008

4.5 Wind

The assessment of wind resources across the WREZ study region was based on three different wind resource datasets. A single, consistent wind power dataset was not available for the entire WREZ study area. In the US and Baja California Norte, Mexico ("Baja"), wind resource potential was quantified across large areas and reduced to an assumed developable potential. Large scale wind power maps from NREL were used for the entire US portion of the WREZ study area. The Canadian wind resource analysis identified specific planned or theoretical projects. A study of wind resources across the lower two thirds of British Columbia (BC) by BC Hydro was used to identify BC wind resources.[41] In Alberta, data on planned wind projects that have applied for transmission interconnection from the Canadian Wind Energy Association (CanWEA) and the South Eastern Energy Developers (SEED) were used to identify resources in the province.[42]

It was not possible to assess wind resources in BC and Alberta using the same methodology used in the US. Wind power data for the majority of British Columbia were created as part of the BC Hydro wind study, but consultation with the study's authors revealed these data were consistently inaccurate in some regions. As a result, they were not comparable to the NREL data used for the US assessment without adjustments. These adjustments could not be made at the level of resolution of the US WREZ wind power analysis; but needed to be made at the project level. The WREZ process accepted this different resource assessment methodology because it provided the most accurate data possible for BC. Wind power data were not available for Alberta, so the resource assessment was based on planned wind projects.

In light of the fact that the US and Canadian resource assessment approaches are fundamentally different, efforts were made to ensure the comparability of the results. The US assessment quantified the wind power potential across large areas and removed the resource potential located on technically undevelopable lands, areas where development would not be economically feasible and areas where development was not feasible due to statute, regulation or environmental sensitivity. The remaining potential was then discounted to reflect unknown development constraints, and the fact that only a fraction of developable wind resources in an area have historically been developed. The BC and Alberta resource assessments used data for specific delineated theoretical (in BC) or planned (in Alberta) projects. These assessments represent specific potential projects

[41] BC Hydro, BC Wind Data Study, Available: http://www.bchydro.com/planning_regulatory/energy_technologies/wind_energy/wind_data_study.html, May 2009

[42] CanWEA and SEED, "SE Area Wind Power Projects – Transmission Connected," received from Claude Mindorff or Mainstream Energy, November 2008.

that already take many developability constraints into account. As a result, the resource potential identified in the Canadian assessments was not discounted at all.

4.5.1 Resource Assessment Methodology

US / Baja

The US and Baja wind resource assessment identified wind resources potentially developable as utility-scale wind projects. NREL wind power class 3 was assumed to be an appropriate overall minimum wind power threshold that could be cost-effectively developed on a utility scale, although higher minimum wind power class thresholds were applied to wind resources in different states. This differentiation was made due to the vast disparities in the quality and quantity of wind resources across the western US and Baja. States such as Montana and Wyoming have large quantities of potentially developable, high quality (Class 5) wind, while states such as Utah and Washington may not. A minimum threshold was applied in an effort to focus the analysis on resources that would most likely be developed for export across state lines.

Table 4-13. Minimum Wind Power Class by State.

State/Province	Minimum Wind Power Class Considered in WREZ Analysis
Montana	5
Wyoming	5
Baja California Norte	4
Colorado	4
New Mexico	4
Texas	4
Arizona	3
California	3
Idaho	3
Nevada	3
Oregon	3
Utah	3
Washington	3

Certain areas were assumed to be undevelopable for wind resources. It was assumed that it would be too expensive to develop wind on land with a terrain slope greater than 20 percent. Areas with these slope characteristics were excluded from the wind resource analysis. Water bodies, urban areas and military bases were assumed to be undevelopable and were excluded from consideration. Areas designated as environmental "exclude" and "avoid" areas by the Environment and Lands (E&L) working group were also excluded.

To calculate the wind resource capacity potential (in MW) inside each grid square for the US portion of the WREZ study area, it was assumed that each square kilometer of eligible wind power class resource contained 5 MW of generation potential. Using this assumption, the amount of land by wind class in each grid square was quantified and converted to generating capacity. As discussed in Chapter 3.0, the wind power capacity identified in each grid square was discounted by 75 percent to account for unknown developability constraints. This discount factor was agreed upon by the ZITA group stakeholders as representative of experience in the wind industry.

Canada

British Columbia Resource Potential Identification Approach

The British Columbia wind resource analysis relied on the projects delineated in the BC Hydro wind data study. Black & Veatch received GIS data on project locations, capacity factors and annual generation profiles for each project from BC Hydro.[43] Consultation with BC Hydro staff revealed that these BC projects already took into account a number of technical and developability exclusions. For this reason, none of the technical and developability exclusions that were applied to the rest of the WREZ study area were applied to the BC projects. These projects also took into account a number of environmental exclusions. An analysis of where these projects intersected with the environmental exclusions developed by the environment and lands group for WREZ was conducted. There were a few places where overlap did occur. BC Hydro was made aware of these overlaps, adjusted the affected projects and provided revised GIS and capacity data to Black & Veatch for the final analysis.

Alberta Resource Potential Identification Approach

The Alberta wind resources analysis relied on project locations and capacities provided in a memorandum by the Canadian Wind Energy Association (CanWEA) and the South Eastern Energy Developers (SEED), in Alberta. Black & Veatch received latitude and longitude coordinates for each of 36 projects identified in this memorandum. Unlike the British Columbia projects, these project locations were approximate and showed the general locations of projects. CanWEA and SEED advised Black & Veatch

[43] Personal communication with Magdalena Rucker, Energy Planning, BC Hydro, May 2009

that these projects were far enough along in their development that technical and developability exclusions did not need to be applied. Any apparent overlap with environmental exclusions of the GIS dataset was likely due to the approximate nature of the project coordinates. Any observed overlaps were brought to the attention of the CanWEA and SEED data coordinator, Claude Mindorff of Mainstream Energy[44] to determine whether the projects in question did actually fall inside these environmental exclusion areas.

In British Columbia and Alberta, the MW potential of projects was attributed to the grid square in which the centroid of each project was located. Wind resource potential in British Columbia and Alberta was not discounted, as is explained above.

Wind Resource Map

A map of all wind resources assessed is shown below in Figure 4-13. This map shows wind resources class 3 and above for all US states and Baja Mexico filtered for applicable environmental, land use and technical exclusion areas. It also shows the location of the Canadian wind projects that were assessed.

[44] Personal communication with Claude Mindorff, Vice President of Business Development, Mainstream Renewable Power LLC, March 2009

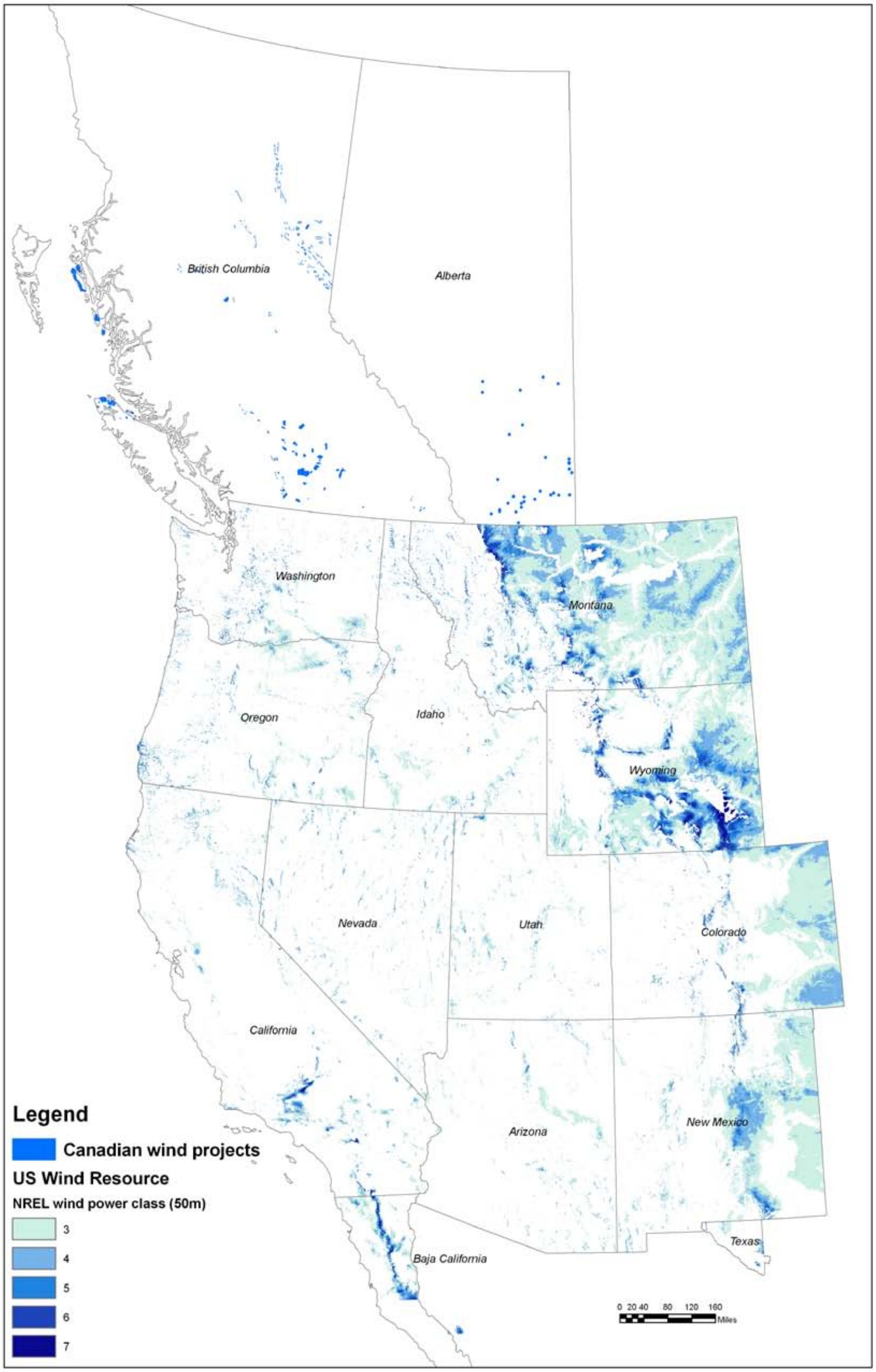


Figure 4-13. Wind Resource Map.

4.5.2 Resource Supply Curve Characteristics

Capital Cost

A capital cost and generation tie line (gen-tie) cost were assigned to all wind resources across the WREZ study area. Capital costs were based on an assumed 100-200 MW project size. A base cost of $2,300 per kW was assumed to be typical of the all-in cost per kW of wind resources across the WREZ study area. This cost was based on Black & Veatch industry experience with real wind projects of this size and wind industry stakeholder input through the WREZ initiative.

Generation tie-line costs were calculated for wind resources in each QRA and added to the capital cost. These were calculated for each QRA based on the average distance from the centroid of each grid square to the nearest substation at least 115 kV in size. The interconnecting gen-tie lines were assumed to be 115 kV with a maximum line loading of 200 MW and a base cost of $750,000 per mile. This cost was based on Black & Veatch experience with transmission facilities of this size. The generation tie-line costs for wind resources from each QRA ranged from approximately $40/kW to $400/kW for QRAs located in very remote areas.

Operating Costs

Operations and maintenance costs were assumed to be $60 / kW-year. This cost was calculated from Black & Veatch industry experience with projects of a similar size.

Capacity Factor

To calculate the annual wind energy generating potential (in GWh/yr) inside each grid square, a capacity factor was calculated for each grid square. A representative capacity factor was assigned to each wind power class, as shown in Table 4-14. In the US, the capacity factor for each grid square was calculated as the capacity-weighted average capacity factor of the wind power classes in each grid square. In British Columbia and Alberta, capacity factors were provided for the specific projects identified by BC Hydro and CanWEA/SEED. These were attributed to the grid squares in which the centroid of each projects was located.

Table 4-14. Assumed Wind Capacity Factor by Wind Class.	
Wind Power Class	**Capacity Factor (percent)**
Class 3	28
Class 4	31
Class 5	35
Class 6	40
Class 7	42
Source: Black & Veatch analysis for Phase 1 of the WREZ initiative.	

Production Profile

Production profiles were created for US wind resources using NREL mesoscale modeled data within 50 miles of the centroid of each initial QRA.[45] These profiles were used to determine the capacity and energy value of wind energy, based on the resource available in each of the WREZ QRAs in the WREZ Generation and Transmission Model. The NREL data represent output from 30 MW wind projects. Although the modeled projects were 30 MW, the resulting annual production profiles were appropriate for application to all wind resources in the WREZ.

Black & Veatch calculated average 12x24 output profiles from the mesoscale data. Each of the resulting 12x24 average output profiles had an inherent capacity factor. However, the inherent capacity factor may not have the same value as the capacity factor calculated for the wind resource within a given renewable energy zone. In some cases, the average output profiles needed to be scaled to match the calculated project capacity factor.

Scaling the 12x24 average output profiles to reflect a calculated resource capacity factor could not be accurately performed by multiplying each value in the profile by a uniform scaling factor. Doing so may produce values exceeding the 30 MW maximum power output for the modeled project. For example, if the NREL mesoscale average output for a site is 20 MW at a given time period (e.g. January at midnight) and the inherent capacity factor is 30 percent, then any calculated resource capacity factor scaled greater than 45 percent (1.5 scaling factor) would cause the value for that same time period to exceed the 30 MW ceiling.

The WREZ data arrays were capped at 30 MW. By using the uniform scaling method described above, the energy in excess of the cap would be discarded, and the actual capacity factor for the wind profile, scaled with a uniform approach, would be less than the desired value of 45 percent.

[45] Mesoscale data were taken from the NREL Western Wind and Solar Integration Study.

In order to accurately calculate a scaled capacity factor a different method was used. Power output that would have been in excess of the 30 MW ceiling was distributed proportionately across the remaining values in the array which did not exceed the cap, using conditional (if, then) logic. The resulting profile respects the 30 MW project maximum power output while generating a profile that produces the desired overall capacity factor.

4.5.3 Results

Over 95,000 MW of developable wind resources were identified in QRAs throughout the WREZ study area, with a total theoretical annual capacity of nearly 270 terawatt-hours (TWh) per year. Of this resource potential, more than 15,300 MW were NREL wind power class 3, more than 31,000 MW were class 4, and more than 23,000 MW were class 5 and above. An additional 18,000 MW of resource was identified in Canada with no assigned NREL wind power class. Colorado, Wyoming and British Columbia QRAs have the highest wind resource potential of all states and provinces in terms of developable capacity. Wyoming, Colorado and New Mexico QRAs have the highest annual generation potential. The QRAs with the highest capacity and those with the highest annual generation are different because wind resources have different capacity factors across QRAs. Note that QRAs labeled with a certain state/province name sometimes cross state boundaries.

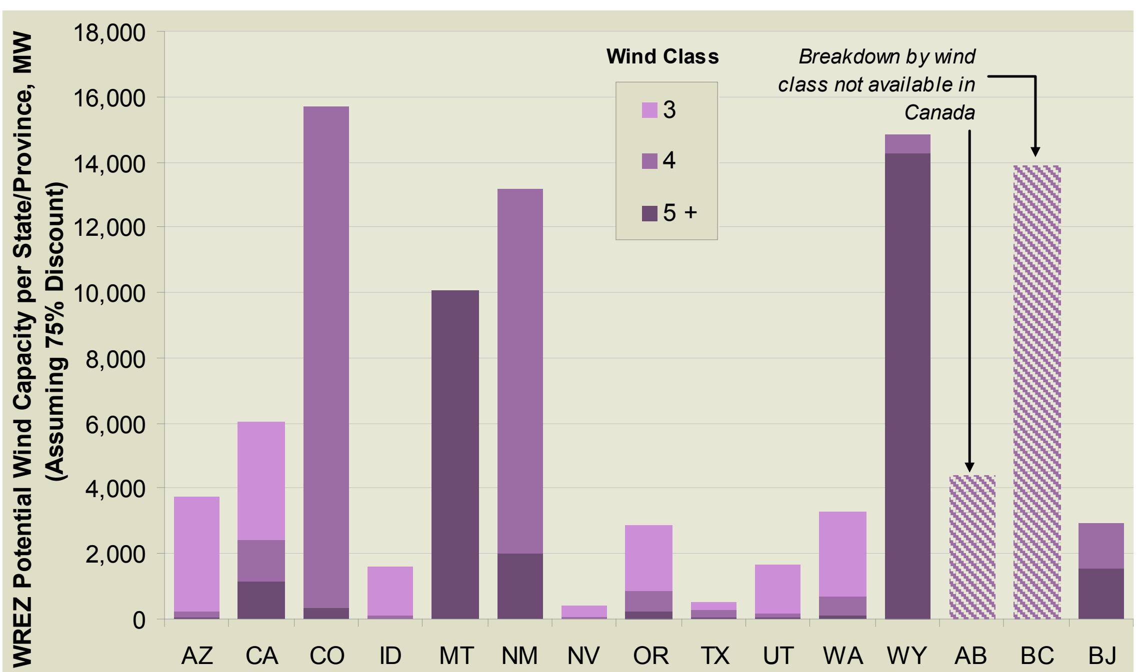


Figure 4-14. WREZ Wind Capacity by State/Province and Wind Power Class.

Economic Analysis

The levelized cost of energy of wind resources across the WREZ study area ranged from $71/MWh to $204/MWh. The levelized cost of energy varies across the WREZ study area due to variation in capacity factor, variation in capital costs due to different assumed generation tie-line lengths among QRAs and different tax incentives available for wind in the US, Canada and Mexico. Capital costs, including generation tie-lines, ranged from $2,347/kW to $2,671/kW and fixed operating costs were assumed to be $60/kW-yr for all wind resources. Capital costs vary from the base $2,300/kW cost due to variation in the average length of generation tie lines across QRAs.

Table 4-15 summarizes the wind performance and economic results. Figure 4-15 is a supply curve of wind resources in QRAs across the WREZ study area.

Table 4-15. Summary of Wind Performance and Economics Results.

Performance	
Capacity Factor (percent)*	21 to 40
Economics	
All-In capital Cost ($/kW, including gen. tie line cost)	2,347 to 2,671
Gen. Tie Line Cost ($/kW)	47 to 371
Fixed O&M Cost ($/kW-yr)	60
Levelized Cost of Energy ($/MWh)	71 to 204

Source: Black & Veatch analysis for Phase 1 of the WREZ Initiative.

Notes:

* The maximum capacity factor is less than the maximum assumed wind capacity factor by wind class in Table 4-14 because, as mentioned above, the economic analysis is performed at the cost bin level and the capacity factor of wind resources in each cost bin is the weighted-average capacity factor of all wind resources in that cost bin. The minimum is lower because some of the Canadian modeled projects had capacity factors at this level.

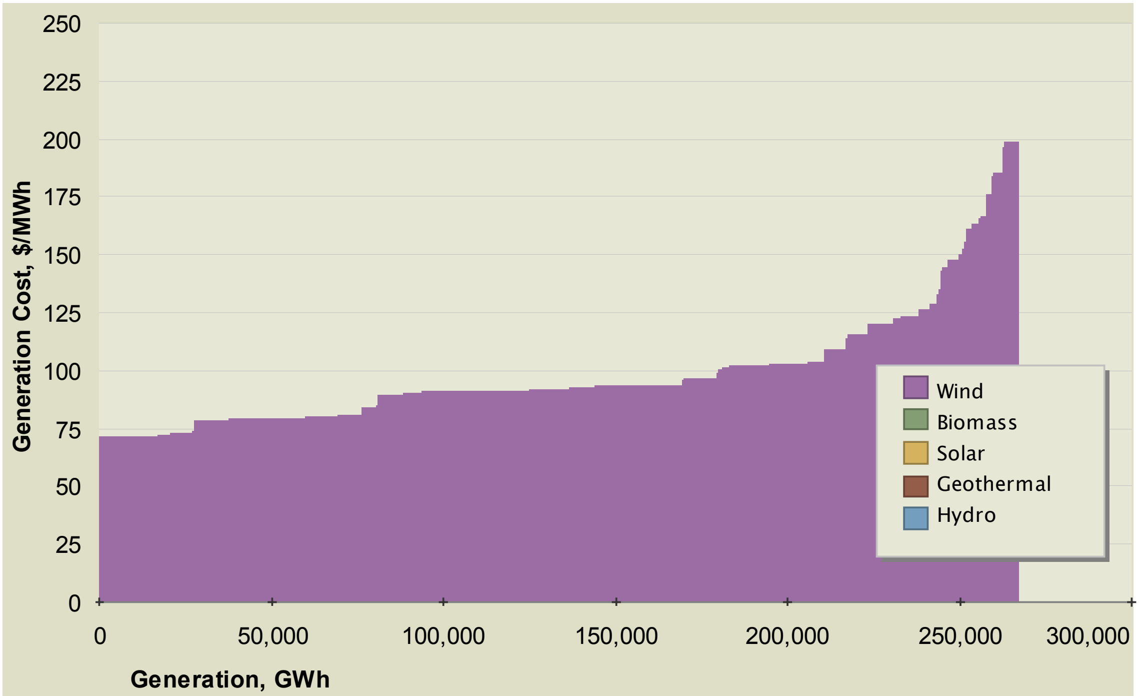


Figure 4-15. WREZ Wind Supply Curve.

4.5.4 Non-REZ Resources

Non-REZ wind resources were assessed for the entire WREZ study area. In the US, all wind resources at NREL wind power class 3 and above that were not already quantified in the WREZ resource analysis were considered non-REZ wind in all states in the US and Baja. This analysis identified over 470,000 MW of non-REZ resources, after applying a 75 percent developability discount. In Canada, non-WREZ wind resource data were provided by two other studies, and these data were not broken out by wind class. The majority of the non-REZ resources were concentrated in a few states/provinces. Over 440,000 MW of these class 3 wind resources were in Alberta, Colorado, Montana, New Mexico and Wyoming. The non-REZ analysis also quantified nearly 100,000 MW of class 4 and over 17,000 MW of class 5 and above wind resources.

Table 4-16. Non-REZ Wind Resources, MW.[a]

State / Province	Class 3	Class 4	Class 5+	TOTAL
Arizona	1,924	293	121	2,338
California	5,134	1,434	694	7,262
Colorado	54,855	2,860	910	58,625
Idaho	5,170	623	329	6,122
Montana	141,308	52,113	2,590	196,011
New Mexico	60,827	4,333	697	65,857
Nevada	3,046	671	352	4,069
Oregon	7,796	1,419	654	9,869
Texas	364	35	23	422
Utah	1,588	377	224	2,189
Washington	2,618	811	496	3,925
Wyoming	65,251	32,362	10,175	107,788
Alberta	b	b	b	120,000
British Columbia	b	b	b	3,800[c]
Baja	5,176	708	285	6,169
Total	***355,057***	***98,039***	***17,550***	***594,446***

Source: NREL Wind Resource Maps, available at: http://www.eere.energy.gov/windandhydro/windpoweringamerica/wind_maps.asp, accessed: March 6th, 2008; Personal communication with Matthew Good, Alberta Department of Energy, August 2009; Personal communication with Magdalena Rucker, BC Hydro, September 2009.

Notes:

[a] This chart includes NREL wind power class 3 and above resources that are not quantified in the REZ analysis.

[b] Non-REZ WREZ wind resource data not available by wind power class.

[c] Non-REZ wind data were taken from a much more refined analysis that delineated specific projects not originally identified in QRAs. Because it is closer to an estimate of non-REZ developable potential, non-REZ wind resources in BC are much smaller than those of many other states and provinces in the study.

4.5.5 Data Sources

Data sources used in this analysis included:

- NREL Wind Resource Maps, available at: http://www.eere.energy.gov/windandhydro/windpoweringamerica/wind_maps .asp, accessed: March 6th, 2008
- NREL Mesoscale Wind Data, Available: http://www.nrel.gov/wind/integrationdatasets/western/methodology.html
- BC Hydro, BC Wind Data Study, Available: http://www.bchydro.com/planning_regulatory/energy_technologies/wind_energy/wind_data_study.html, May 2009
- CanWEA and SEED, "SE Area Wind Power Projects – Transmission Connected," received from Claude Mindorff or Mainstream Energy, November 2008.
- Personal communication with Matthew Good, Alberta Department of Energy, August 2009

5.0 QRA and Non-REZ Analysis Results

Fifty-three QRAs were identified across the WREZ study area, with nearly 200,000 MW of renewable energy resources theoretically capable of generating over 560 terawatt hours (TWh) of energy per year.[46] Over 2,200,000 MW of non-REZ resources were also identified across the study area. To put these estimates in perspective, the entire WECC peak load in summer 2007 was 150,000 MW.[47]

This section presents maps generated for the WREZ analysis, a summary of the QRA and non-REZ analyses and a brief discussion of the renewable energy resources quantified in the analyses. A supply curve for each QRA was generated and is provided in Appendix A. Capacity and energy summary tables by resource and by QRA were generated and are provided in Appendix B.

5.1 QRA Maps

Two main maps resulted from the WREZ process. The WREZ QRA map shows the precise locations of the QRA boundaries identified in the QRA analysis. The WREZ hub map was created to represent resource concentrations in a general way through the visual image of hubs. The hub concept is explained in greater detail in Chapter 3.0.

5.1.1 WREZ QRA Map

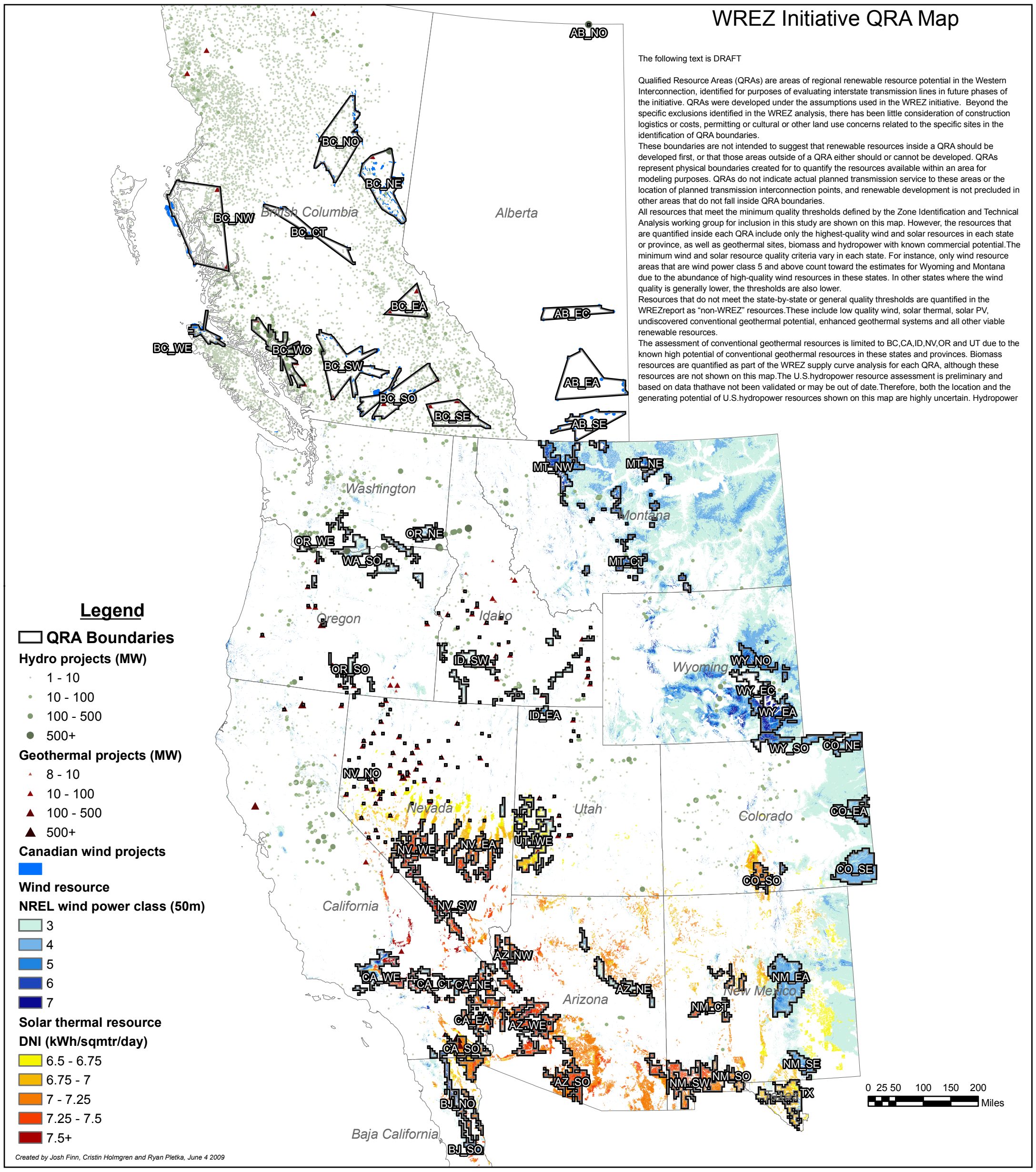
The WREZ QRA map shows the final boundaries of QRAs as identified in the QRA analysis detailed in Chapter 3.0. It also shows the resources that were quantified in the QRA analysis as well as all other WREZ resources that met the minimum quality criteria for inclusion in the WREZ analysis after environmental and technical exclusion areas were removed. In an effort to keep the map simple and uncluttered, biomass resources are not shown. Biomass resources are shown in the biomass resource map in Chapter 4.0.

Note that QRA boundaries were developed to quantify the resources in an area for a screening level analysis. These boundaries are not intended to suggest that renewable resources inside a QRA should be developed first, that those areas outside of a QRA either should not or cannot be developed, or that a tract just inside a QRA boundary is superior to an adjacent tract that has similar characteristics but happens to be outside the

[46] British Columbia provided a 54th QRA representing a shaped renewable energy product to load serving entities (LSEs) at the British Columbia-Washington border. This QRA is shown in the hub map and selectable in the GTM model. However, it was developed independently of the Black & Veatch/NREL QRA analysis outlined here, so it is not characterized here.

[47] WREZ Zone Identification and Technical Analysis Working Group, Step 2: Filtering resource data into Candidate Study Areas, Available: http://www.westgov.org/wga/initiatives/wrez/zita/Step2.pdf, 2009.

boundary. QRAs represent conceptual analytical areas created to estimate the resources available within an area for modeling purposes. They do not indicate actual planned transmission service to these areas or the location of planned transmission interconnection points, and renewable development is not precluded in other areas that do not fall inside QRA boundaries.



Notes on Each State/Province

Alberta: Wildlife and land-use concerns are addressed on a project specific basis through the environmental impact assessment process.

Arizona: Arizona's "hubs" represent areas of high-quality renewable energy resources for purposes of evaluating interstate transmission lines. This representation is not intended to suggest that renewable development should occur solely within these "hubs." Proper site selection for renewable energy generation facilities and associated transmission lines within and outside these "hubs" should include consultation with the Arizona Game and Fish Department and other relevant agencies for wildlife and environmental information. Stakeholders are participating in Arizona's Renewable Transmission Task Force (RTTF) process to more precisely evaluate identified renewable energy zones and develop appropriate transmission plans. Further information is available at http://www.azcc.gov/divisions/utilities/electric/Biennial.asp.

British Columbia: British Columbia's map includes 10 hubs, representing the province's 10 Qualified Resource Areas. British Columbia's map also includes a separate hub on the British Columbia-Washington border that represents a 16,000 gigawatt-hour shaped energy product. The intention of this additional hub and associated cost curve is not to represent a specific product offered to LSEs at the border, but to illustrate the benefits of a shaped and firmed decarbonized energy product to encourage further discussion. The hubs for British Columbia do not include environmental review beyond the criteria applied to date in the WREZ process, and have not been approved by the Premier of British Columbia because the province has been in an election campaign. As such, the hubs and exclusions are subject to change.

California: Stakeholders are working within California's Renewable Energy Transmission Initiative (RETI) to more precisely identify renewable development potential in renewable-rich areas, environmental concerns, and transmission plans of service for these areas. Please refer to the RETI website at http://www.energy.ca.gov/reti for additional information about renewable development potential in and around California, and the transmission planning efforts currently underway.

Colorado: The Colorado hubs reflected the in this map represent remaining renewable energy potential after screening for environmental and wildlife concerns. Full information on the Qualified Resource Areas and wildlife data are available on the Western Governors' Wildlife Council web site.

Idaho: These hubs are based on those portions of the Qualified Resource Areas (QRAs) in Idaho as defined by the Western Governors Association that can provide for renewable energy development with fewer impacts to elk and deer winter range, sage grouse and Idaho's species of greatest conservation need. These hubs are not meant to indicate that renewable energy will be developed at or near these locations. There has been little consideration of construction logistics or costs, permitting or cultural or other land use concerns related to the specific sites, except for wildlife presence which may have high sensitivity.

Montana: Montana's hubs are currently draft and may be revised in the printed report. Footnote forthcoming.

Nevada: Footnote forthcoming.

New Mexico: New Mexico's map depicts high-quality renewable energy resource hubs identified using the criteria applied to date in the WREZ process. Anyone interested in these areas for development purposes should also view all information available on wildlife sensitivity within the Qualified Resource Areas on the Western Governors' Wildlife Council web site. Proper site selection for renewable energy generation facilities and associated transmission lines should include careful planning to avoid, minimize or mitigate impacts to crucial wildlife habitats and connectivity corridors as indicated in NM's wildlife sensitivity information.

Oregon: Hubs reflect the high-quality renewable energy resources identified after screening for environmental and wildlife concerns, including big-game and non-game migratory corridors; habitat for rare plants and animals; Greater sage-grouse habitat; and Conservation Opportunity Areas (COAs) identified in the Oregon Conservation Strategy. Within each of the hubs, there remains some overlap with sensitive wildlife areas, although areas risking the greatest impacts have been avoided. COAs can be useful to guide project siting and offer opportunity to direct mitigation efforts. Finer-scale information on all of the hubs is available for consultation at the project scoping phase, and full information on the Qualified Resource Areas and wildlife sensitivity is available on the WGA web site.

Utah: Footnote forthcoming.

Washington: Hubs reflect the high-quality renewable energy resources identified after screening for environmental and wildlife concerns. Full information on the Qualified Resource Areas and wildlife sensitivity is available on the WGA web site. Washington may revise this map after public review and comment.

Wyoming: Wyoming has not established WREZs or QRAs. Renewable project proposals and transmission will be evaluated on a case-by-case basis. Wyoming's hubs represent areas of high-quality wind resources and are designated solely for purposes of modeling the cost of delivered electricity to load centers. This representation is not intended to suggest that renewable development should be precluded elsewhere in the state or that significant conflicts do not occur in the vicinity of the Wyoming hubs.

Figure 5-1. WREZ QRA Map.

5.1.2 WREZ Hub Map

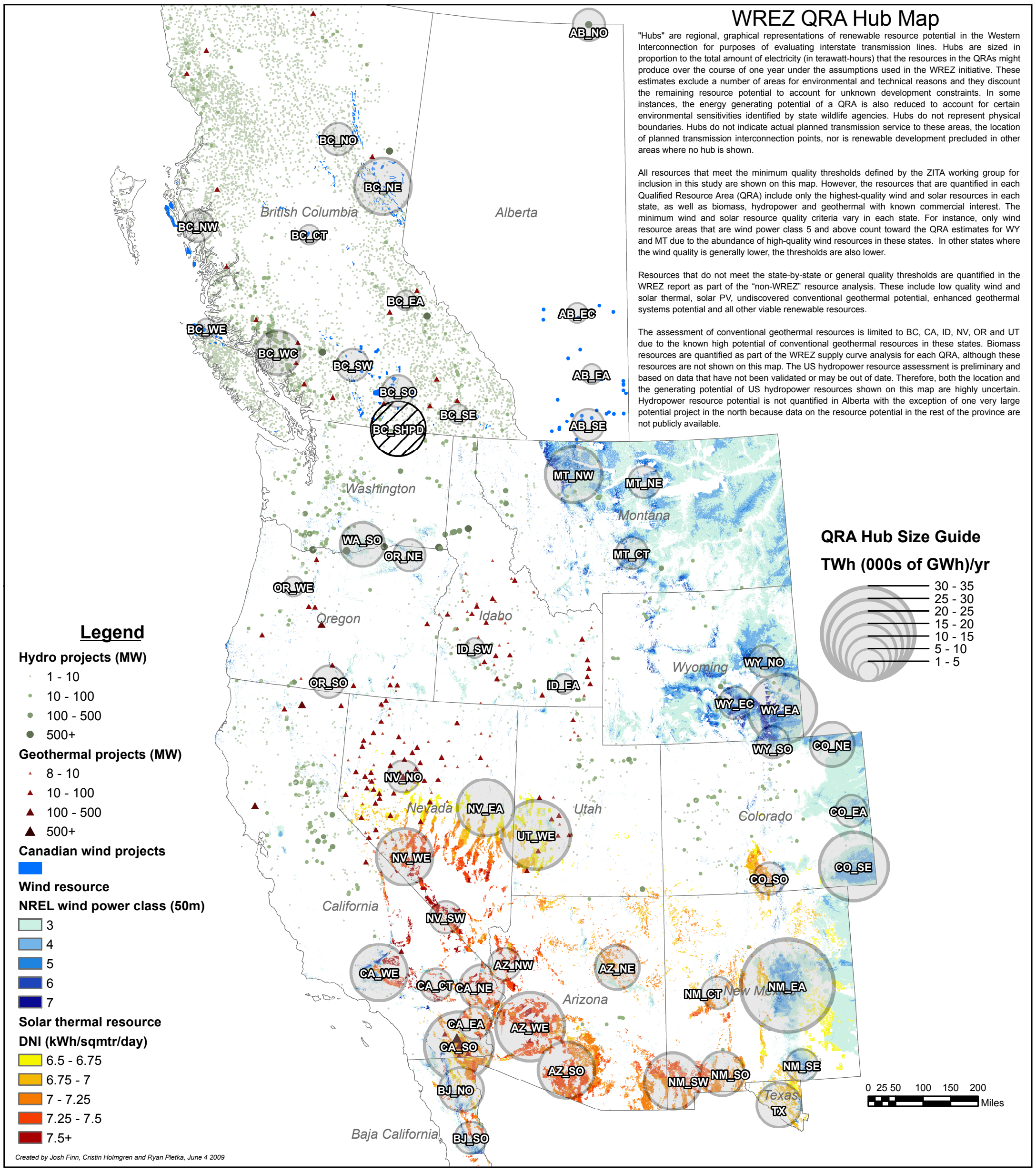
A second map was produced for the WREZ technical committee to display the raw renewable resources across the WECC after taking into account applicable exclusions. The map represents resource concentrations that may be most cost-effective for regional transmission through the visual image of "hubs", or general areas of high renewable resource concentration. Each hub is sized to represent the estimated amount of annual energy the area could potentially produce.

Each state and province involved in the WREZ initiative was given the chance to review and elect to remove or change the physical location of its hubs in advance of the hub map's publication and inclusion in the WREZ Phase 1 report. States and provinces were

> …invited to reduce or eliminate any hubs based on their interpretations of their wildlife categorizations. Their actions and their reasoning are reflected in footnotes [on the hub map]. The data and interpretation of that data will be vetted in the WREZ working groups in 2009 to complete the Phase 1 process of identifying Western Renewable Energy Zones.[48]

Changing the location of a hub did not change the location of the QRA used to proxy the amount of resource potential. It only changed the visual appearance of the hub map.

[48] Western Governor's Association, Western Renewable Energy Zones - Phase 1 Report, Available: http://www.westgov.org/wga/publicat/WREZ09.pdf, June 2009



Notes on Each State/Province

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Arizona: Arizona's "hubs" represent areas of high-quality renewable energy resources for purposes of evaluating interstate transmission lines. This representation is not intended to suggest that renewable development should occur solely within these "hubs." Proper site selection for renewable energy generation facilities and associated transmission lines within and outside these "hubs" should include consultation with the Arizona Game and Fish Department and other relevant agencies for wildlife and environmental information. Stakeholders are participating in Arizona's Renewable Transmission Task Force (RTTF) process to more precisely evaluate identified renewable energy zones and develop appropriate transmission plans. Further information is available at http://www.azcc.gov/divisions/utilities/electric/Biennial.asp.
British Columbia: British Columbia's map includes 10 hubs, representing the province's 10 Qualified Resource Areas. British Columbia's map also includes a separate hub on the British Columbia-Washington border that represents a 16,000 gigawatt-hour shaped energy product. The intention of this additional hub and associated cost curve is not to represent a specific product offered to LSEs at the border, but to illustrate the benefits of a shaped and firmed decarbonized energy product to encourage further discussion. The hubs for British Columbia do not include environmental review beyond the criteria applied to date in the WREZ process, and have not been approved by the Premier of British Columbia because the province has been in an election campaign. As such, the hubs and exclusions are subject to change.
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Idaho: These hubs are based on those portions of the Qualified Resource Areas (QRAs) in Idaho as defined by the Western Governors Association that can provide for renewable energy development with fewer impacts to elk and deer winter range, sage grouse and Idaho's species of greatest conservation need. These hubs are not meant to indicate that renewable energy will be developed at or near these locations. There has been little consideration of construction logistics or costs, permitting or cultural or other land use concerns related to the specific sites, except for wildlife presence which may have high sensitivity.
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Figure 5-2. WREZ Hub Map.

5.2 Summary of QRA Analysis Results

While not a resource assessment in the strictest sense, the WREZ QRA analysis demonstrates how renewable energy resources are distributed across the WECC in addition to creating data for the transmission modeling. The analysis also provides some data on general costs of generation for different renewable energy technologies in different areas across the WECC.

5.2.1 Resource Analysis

Areas in the Southern area of the WECC lower latitudes tend to have significant solar energy resources. Areas to the east tend to have the largest and highest quality wind resources. Biomass resources are the greatest in areas with dense forests, such as the Pacific Northwest states and British Columbia, however there are also significant biomass resources in areas of Arizona, where piñon pine and juniper removals provide a large feedstock. Hydropower resources make up a significant portion of British Columbia and Alberta's REZ resource potential as a result of the fact that more types of hydropower resources were considered in Canada than anywhere else. Washington State also has significant hydropower resources, due to the potential from upgrading a single large dam along the Columbia River. Figure 5-3 and Figure 5-4 below show renewable energy capacity and energy by state across the WREZ study area.

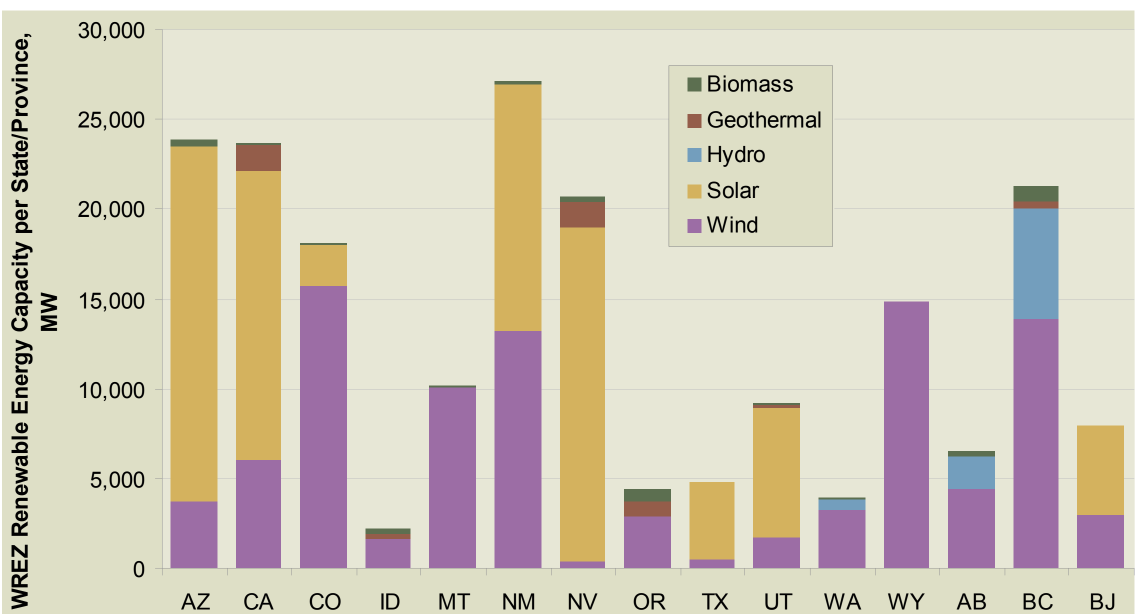

Figure 5-3. WREZ Renewable Energy Capacity by State/Province.

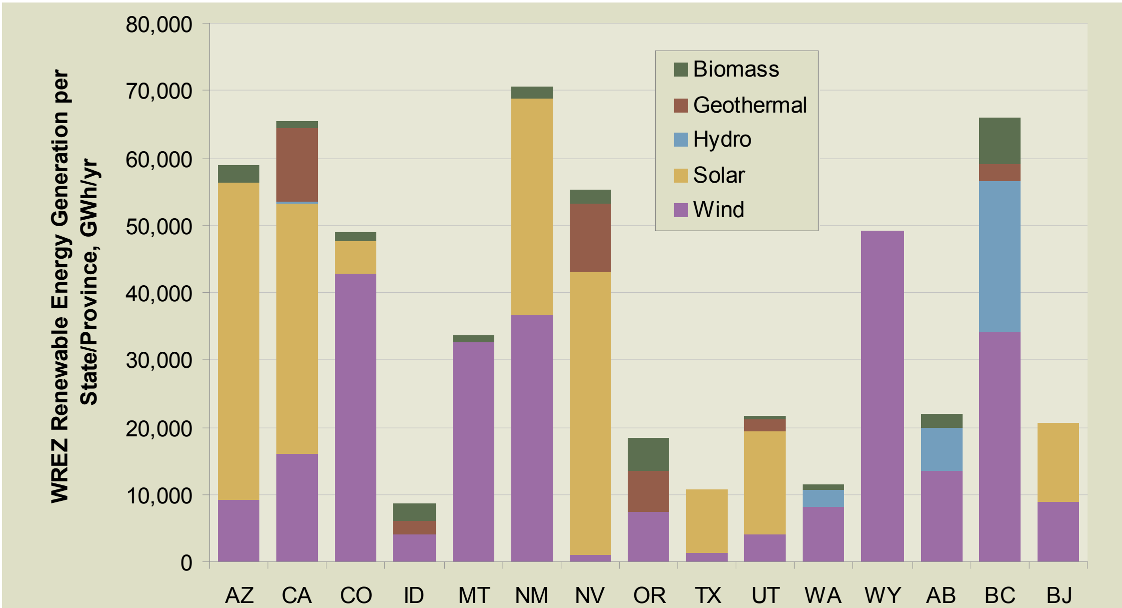

Figure 5-4. WREZ Annual Renewable Energy Generation by State/Province.

5.2.2 Economic Analysis

Supply curves were generated for each QRA in the WREZ study area. An example supply curve showing the generation cost including generation tie lines of the resources identified by Black & Veatch for the BC_NE QRA can be seen in Figure 5-5. Supply curves for all QRAs and are provided in Appendix A.

The example supply curve for BC_NE shows that there is a large amount of renewable energy potentially available in this QRA: over 17,000 GWh/yr. Resources within this QRA have differing economics, based largely on resource type as well as factors that vary among different resources of the same type. Variation in cost among wind resources in this QRA is caused by variation in capacity factors. Variation in hydropower costs is largely related to the suitability or unsuitability of particular areas for development within the QRA. In the supply curve, the cost of this energy rises as demand increases. There are almost 6,000 GWh/yr of wind energy potentially available at a cost of $110/MWh, and about 12,000 GWh/yr of wind and hydro potentially available below a cost of $125/MWh. There are some even higher cost biomass, geothermal, wind and hydropower resources.

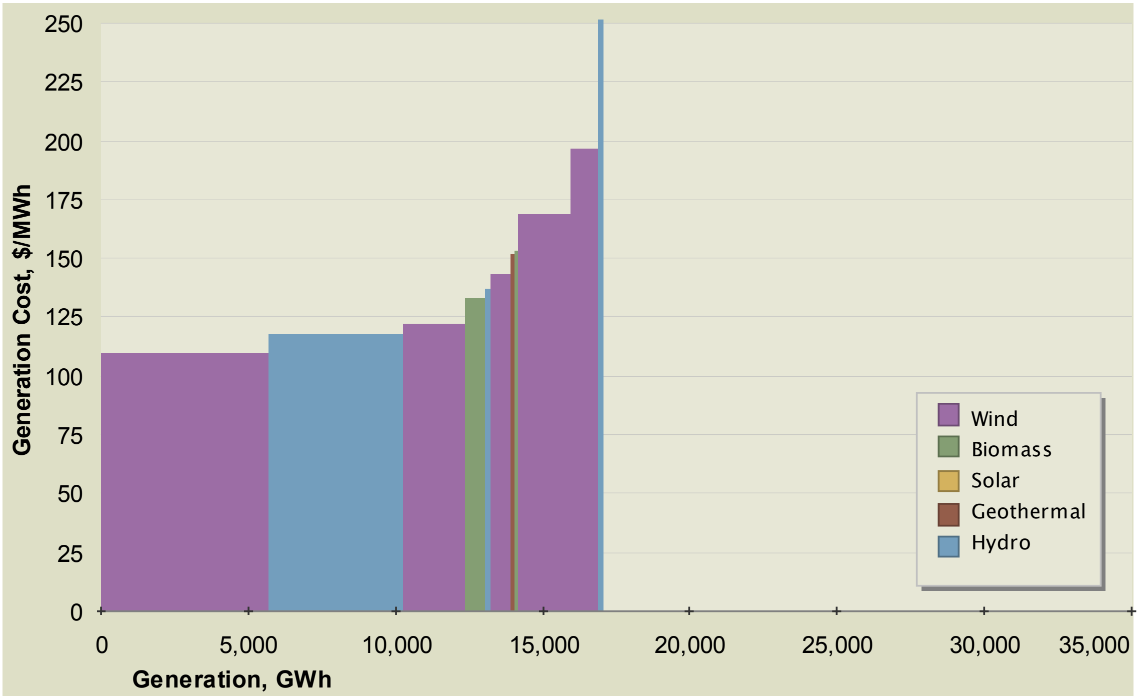

Figure 5-5. BC_NE QRA Supply Curve.
Generation costs over $250/MWh not shown on chart.

There are a number of factors that contribute to variation in the cost of generation of REZ resources across WREZ study area, but it is mostly due to the quality of the renewable energy resources in different areas. In general, higher quality resources have lower costs per MWh. Different types of sub technologies within one technology category also have different costs. For instance, energy from new, run-of-river hydropower projects tends to cost more than energy from incremental additions of capacity to existing hydroelectric dams and energy from dry-cooled solar thermal plants tends to have higher costs than energy from wet-cooled solar thermal plants. Other factors, such as the incentives available and the distance from a QRA to the transmission system also contribute to this variation in cost across the study area.

Readers and users of the data produced in this study should keep in mind that the quality of the cost data generated by the WREZ project is completely reliant on the quality of the assumptions used. Users of the Generation and Transmission model are invited to adjust cost assumptions for various resources as they see fit. Cost results from the default assumptions developed for WREZ are presented in Appendix A of this report.

5.3 Summary of Non-REZ Resource Analysis Results

Over 2,200 GW of non-REZ resources were identified across the WECC. This is over 14 times the WECC's peak load in 2007. Of this total, solar PV made up the largest proportion with over 750 GW. Geothermal, wind and solar thermal combined made up another 1,400 GW. The majority of the non-REZ solar thermal resources are of a lower quality than those assessed in the WREZ resources analysis. The same is true of wind, the majority of which is in Montana, Wyoming and Colorado and of wind power classes lower than those assessed in the WREZ resource analysis. The majority of non-REZ geothermal potential is EGS potential.

While non-REZ resources are fairly well distributed across the WECC, with most states and provinces having over 100 GW of non-REZ resource potential, some states and provinces have much smaller amounts. For instance, Texas has an order of magnitude fewer non-REZ resources than most other states. The Canadian provinces in the WECC also have markedly fewer non-REZ resources than the majority of the other states. In Texas, the small amount of non-REZ resources is largely due to the fact that only the El Paso area was considered, as it is the only part of the state within the WECC footprint. Alberta had significant data availability issues: Data on non-REZ hydropower and geothermal were not available for Alberta. Data on non-REZ wind in British Columbia were significantly more refined and represent additional, lower-quality developable potential. As a result, there appears to be significantly less non-REZ wind in British Columbia. These discrepancies between the US non-REZ assessment and the Canadian non-REZ assessment likely resulted in an underestimation of the non-REZ resources in these provinces.

Table 5-1. Non-REZ Resources by State/Province, MW.*

State / Prov	Bio	Geo	Hydro	Solar Thermal	Solar PV**	Wind	TOTAL
AZ		55,743	72	41,934	86,989	2,338	187,077
CA	650	59,440	2,298	54,569	29,355	7,262	153,574
CO	204	53,705	359	60,553	47,083	58,625	220,528
ID	206	69,772	1,222	24,784	25,794	6,122	127,900
MT	170	17,671	574	38,153	123,085	196,011	375,663
NM	12	57,184	53	49,052	126,150	65,857	298,309
NV	0	107,164	29	57,320	41,217	4,069	209,799
OR	190	64,293	2,003	19,056	48,689	9,869	144,100
TX				939	11,951	422	13,312
UT	200	48,664	456	29,360	33,955	2,189	114,823
WA	315	6,800	3,003	5,160	30,613	3,925	49,816
WY	35	3,174	502	27,437	84,025	107,788	222,961
AB	220	500	100	1,104	25,501	120,000	157,425
BC	900	5,260	9,714		20,985	3,800	36,859
BJ				7,485	17,994	6,169	31,648
Grand Total	***3,102***	***549,370***	***20,385***	***416,906***	***753,386***	***594,446***	***2,343,794***

Source: Black & Veatch analysis for Phase 1 of the WREZ Initiative.

Note:

* See Chapter 3.0 for a more in-depth discussion and analysis of the non-REZ resources for each resource type.

**Estimates of non-REZ solar PV potential and solar thermal potential are mutually exclusive. It was assumed that non-REZ PV could be built anywhere non-REZ solar thermal could be built, so the non-REZ solar thermal potential was subtracted from the non-REZ PV potential, so as not to double count the potentially available resources.

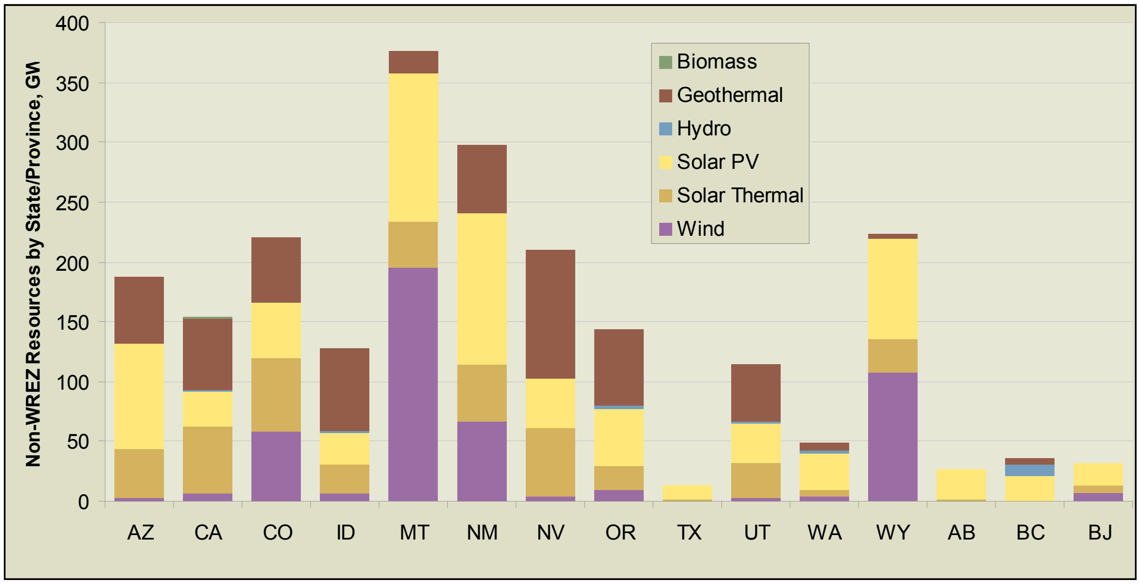

Figure 5-6. Non-REZ Resources by State/Province.

Appendix A. QRA-Level Supply Curves

WREZ QRA Supply Curves

This appendix to the WREZ Phase 1 Report presents supply curves for 53 WREZ QRAs developed for the WREZ initiative (the BC_SHPD supply curve is not presented here). For each QRA, the theoretical annual energy generation in gigawatt-hours per year (GWh/yr) is plotted against the cost of generating that electricity and delivering it to the transmission system via a generation tie-line on a dollars per megawatt-hour ($/MWh) basis. These curves show the amount of energy theoretically available from each QRA at various price points.

The data contained here do not represent a true resource assessment of the renewable energy resources of the Western Interconnection. These supply curves contain data that has been generated as part of a screening-level generation and transmission modeling exercise for the WREZ initiative. They have been analyzed in order to meet the specific needs of this project and other uses of these data might be inappropriate. Many simplifying assumptions have been made in order to produce an assessment of this scale that can be easily and realistically modeled at the screening level.

Notes on Supply Curves

1. All costs are in 2009 US dollars
2. Costs over $250/MWh are not shown on supply curves because the vast majority of the resources have a cost of generation below this level.
3. All solar resources modeled here are dry-cooled solar thermal technology with six hours of thermal storage, the default technology assumption chosen by the WREZ ZITA group. Five other solar technologies were also modeled and can be selected by users of the WREZ Generation & Transmission Model.
4. Various economic and financial assumptions were used to generate these supply curves. These are detailed by technology in the Black & Veatch WREZ Phase 1 technical report.
5. Generation cost includes the cost of a generation tie line to deliver electricity from the plant to the transmission system. Generation tie line costs are calculated differently for different technologies. The methodologies for costing these lines are detailed in the WREZ Phase 1 Technical Report.
6. The theoretical annual generation in each QRA supply curve does not always match precisely with the theoretical annual generation for each QRA reported in the WREZ Phase 1 Report. In some cases, such as for solar thermal technology, slightly different capacity factor assumptions were used in each analysis, which cause discrepancies in their outputs.

Supply Curves

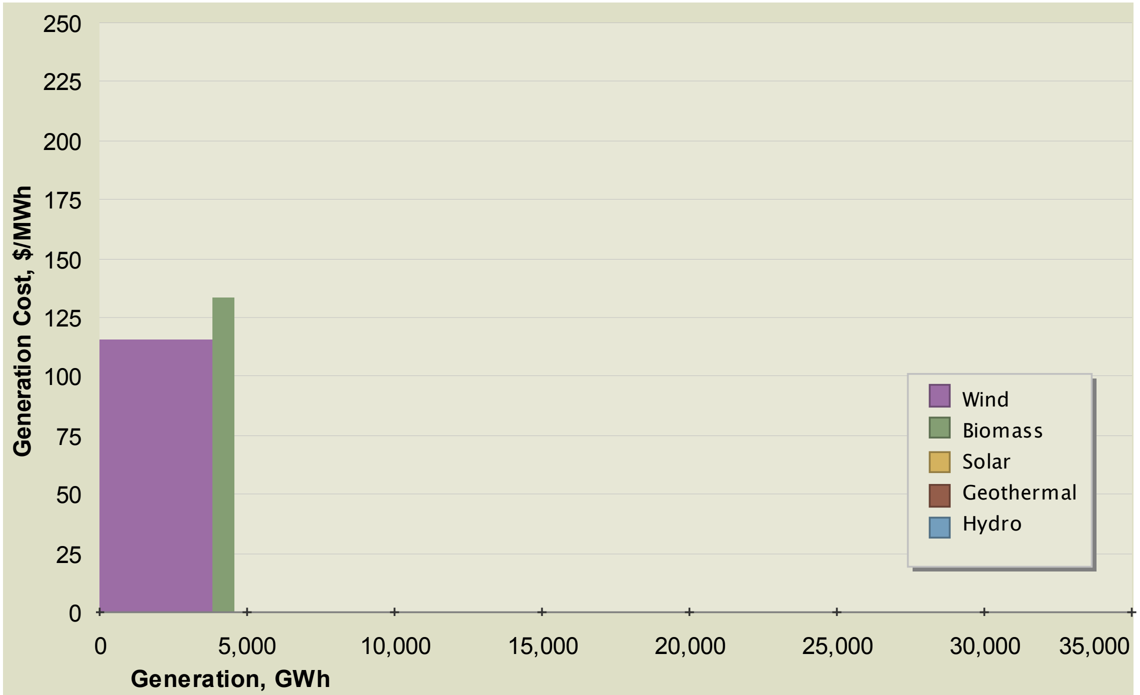

Figure A-1. AB_EA QRA Supply Curve

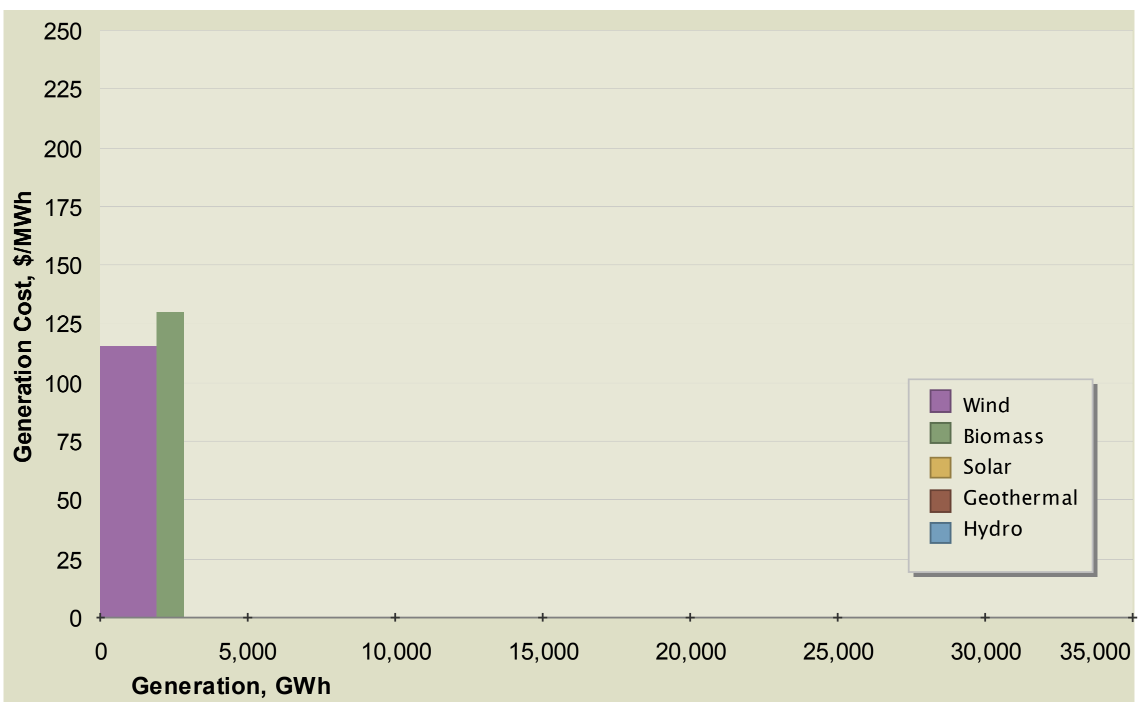

Figure A-2. AB_EC QRA Supply Curve

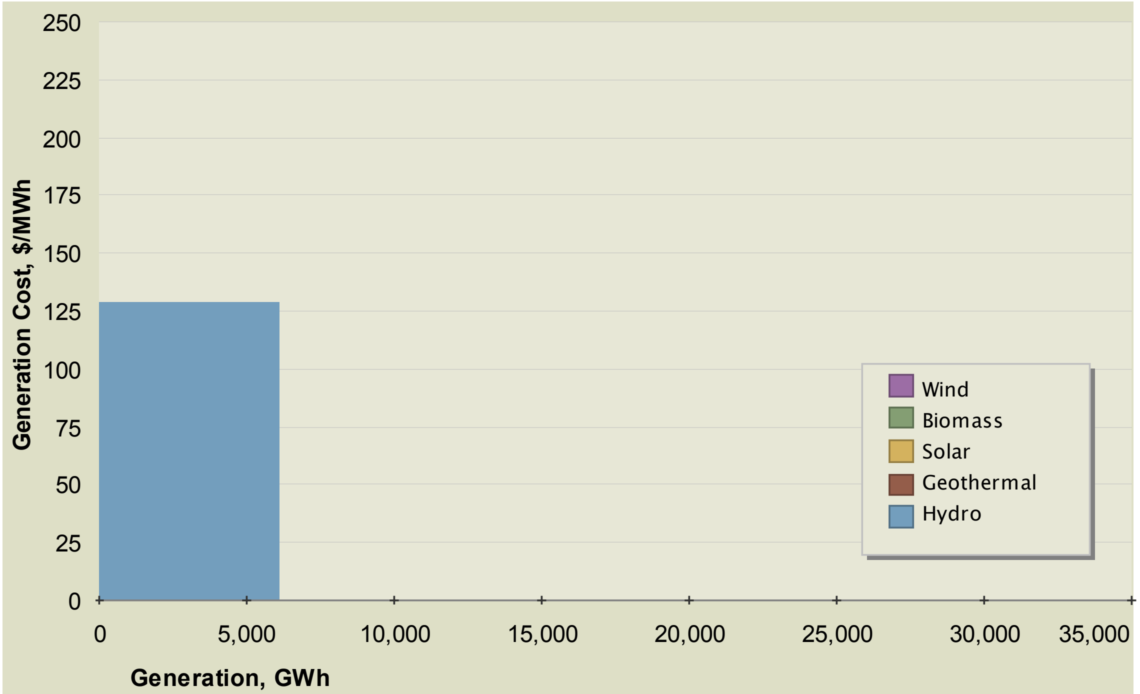

Figure A-3. AB_NO QRA Supply Curve

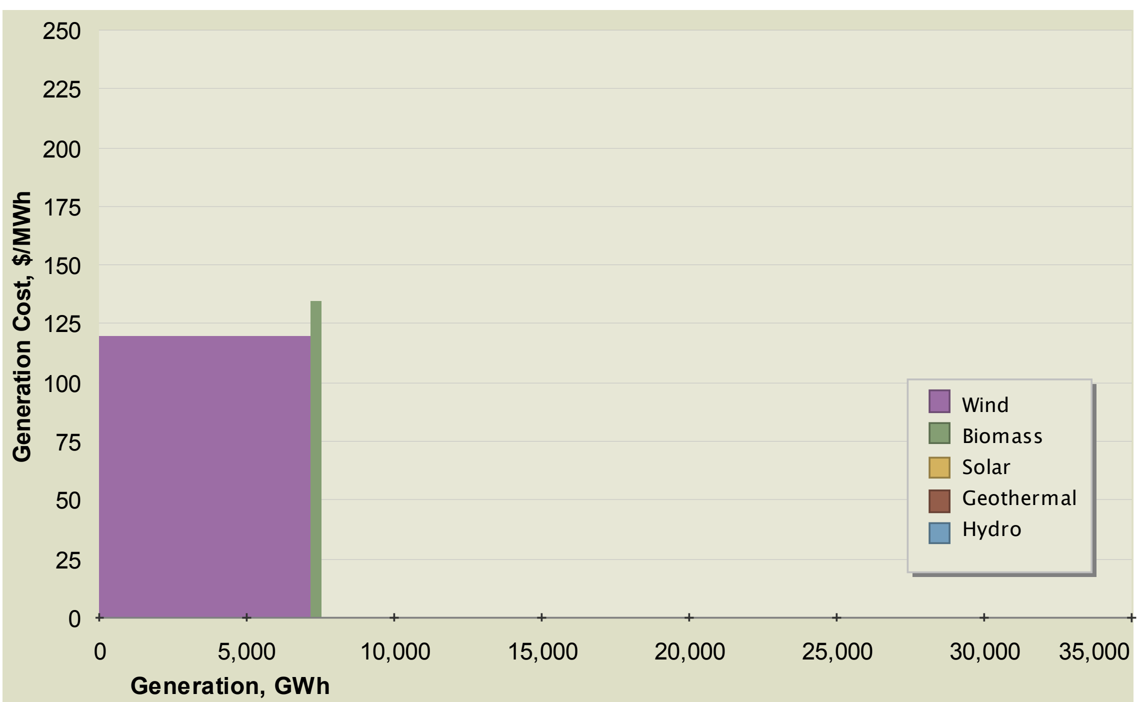

Figure A-4. AB_SE QRA Supply Curve

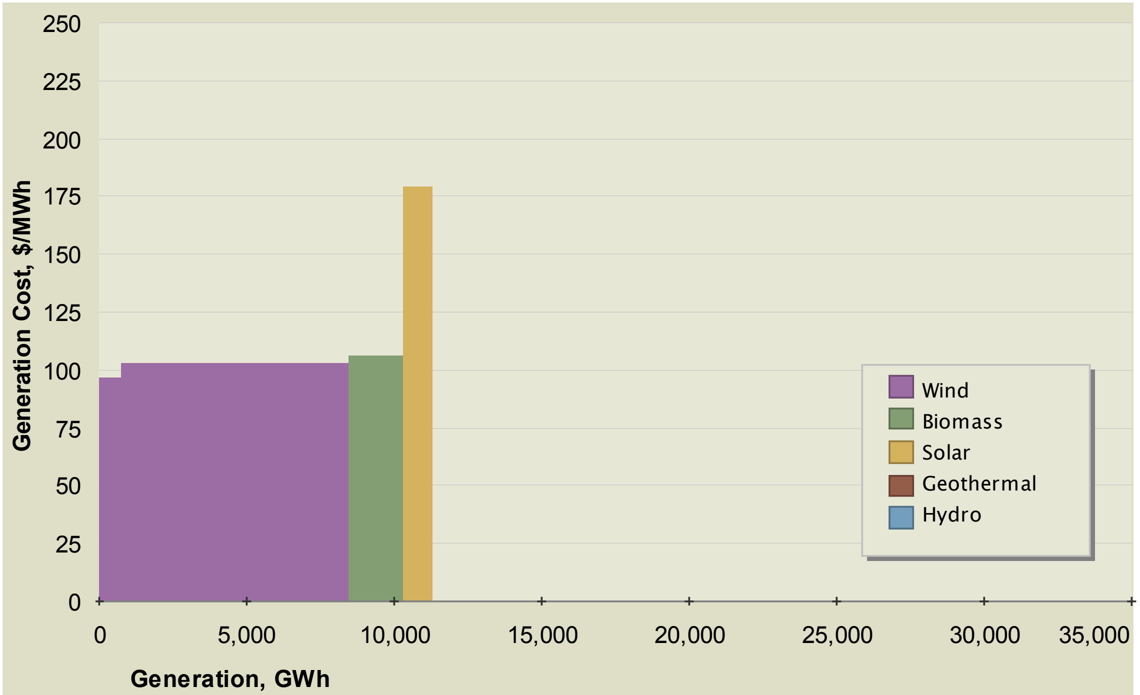

Figure A-5. AZ_NE QRA Supply Curve

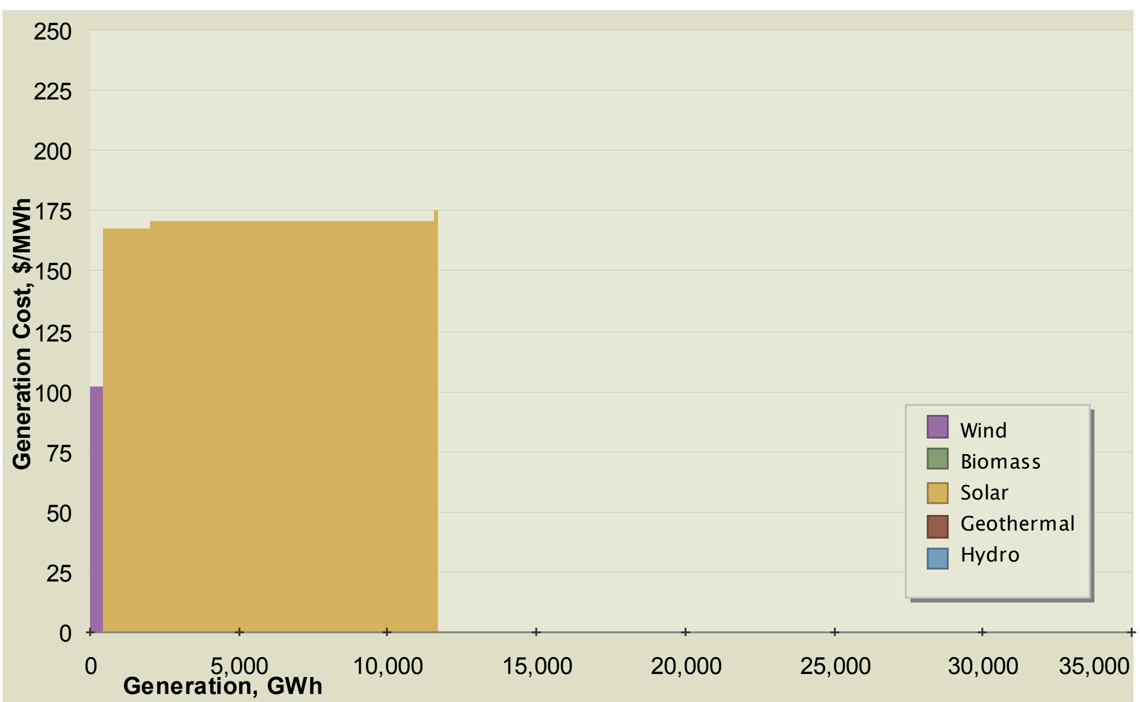

Figure A-6. AZ_NW QRA Supply Curve

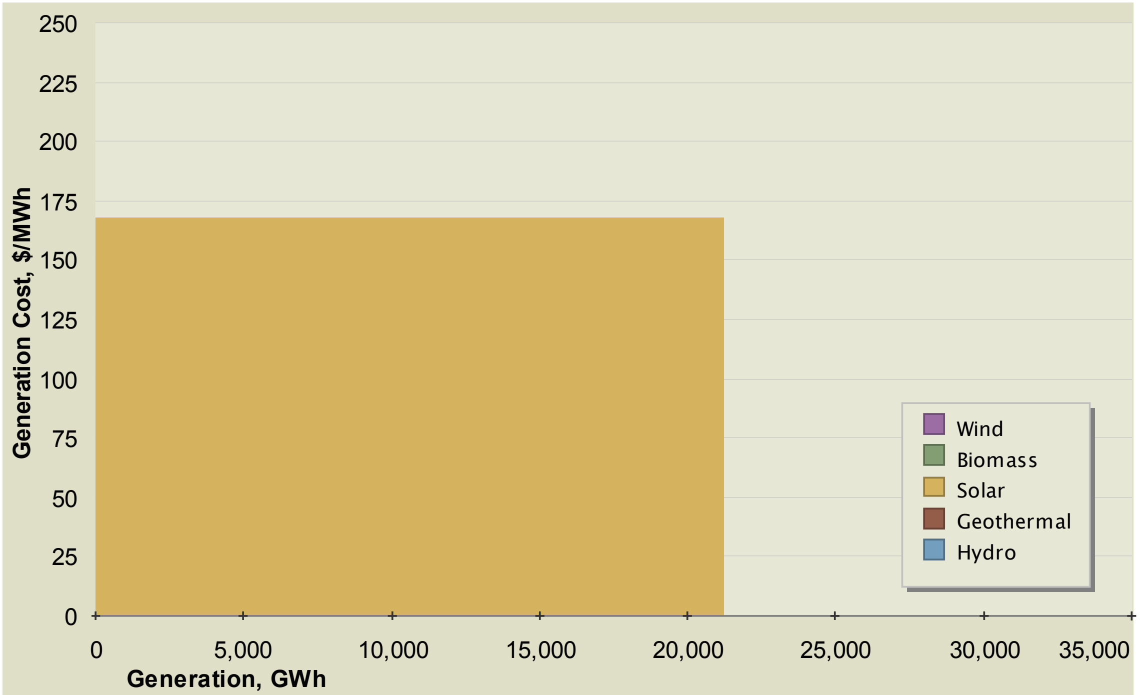

Figure A-7. AZ_SO QRA Supply Curve

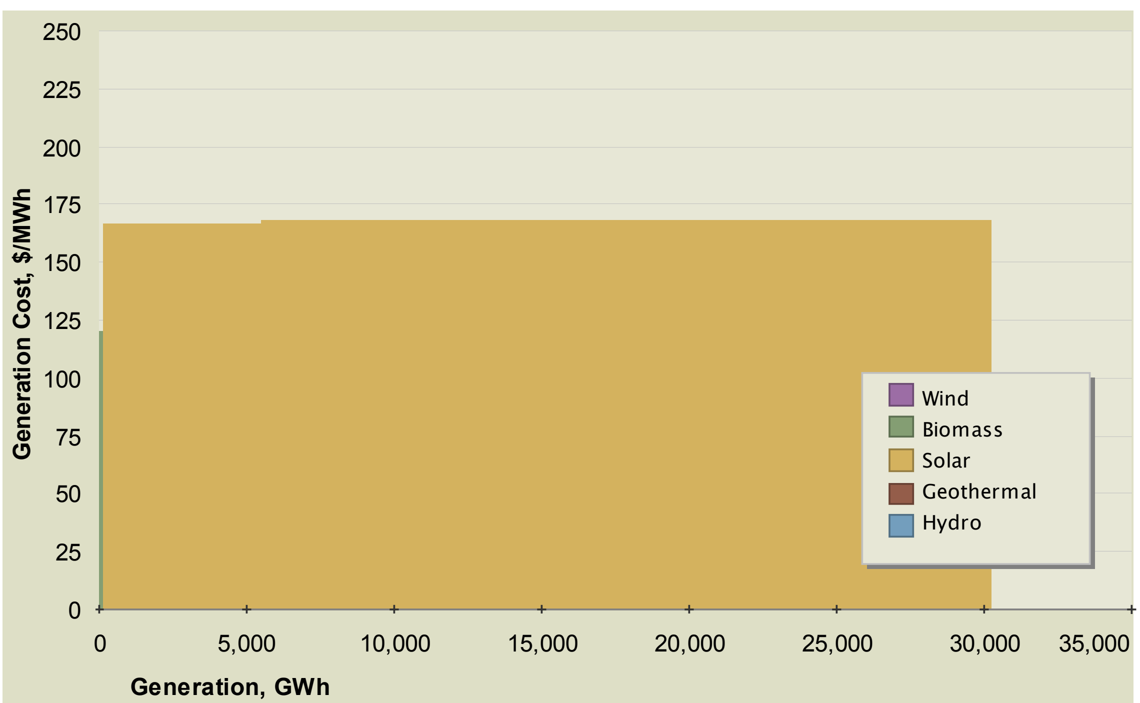

Figure A-8. AZ_WE QRA Supply Curve

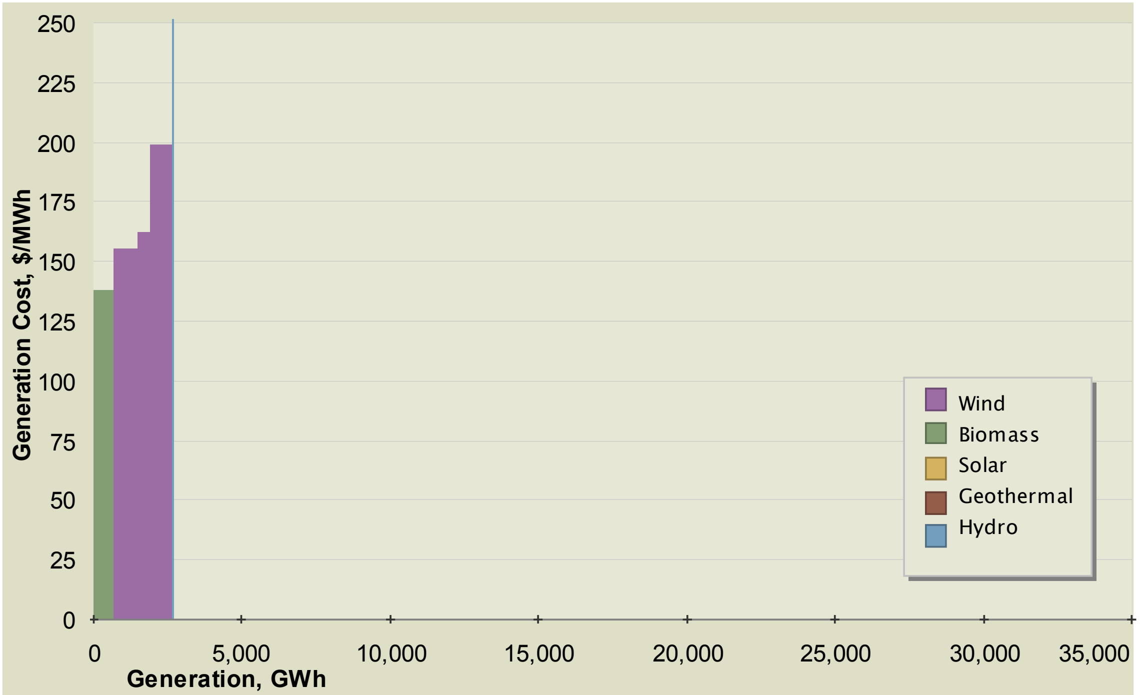

Figure A-9. BC_CT QRA Supply Curve
Generation costs over $250/MWh not shown on chart.

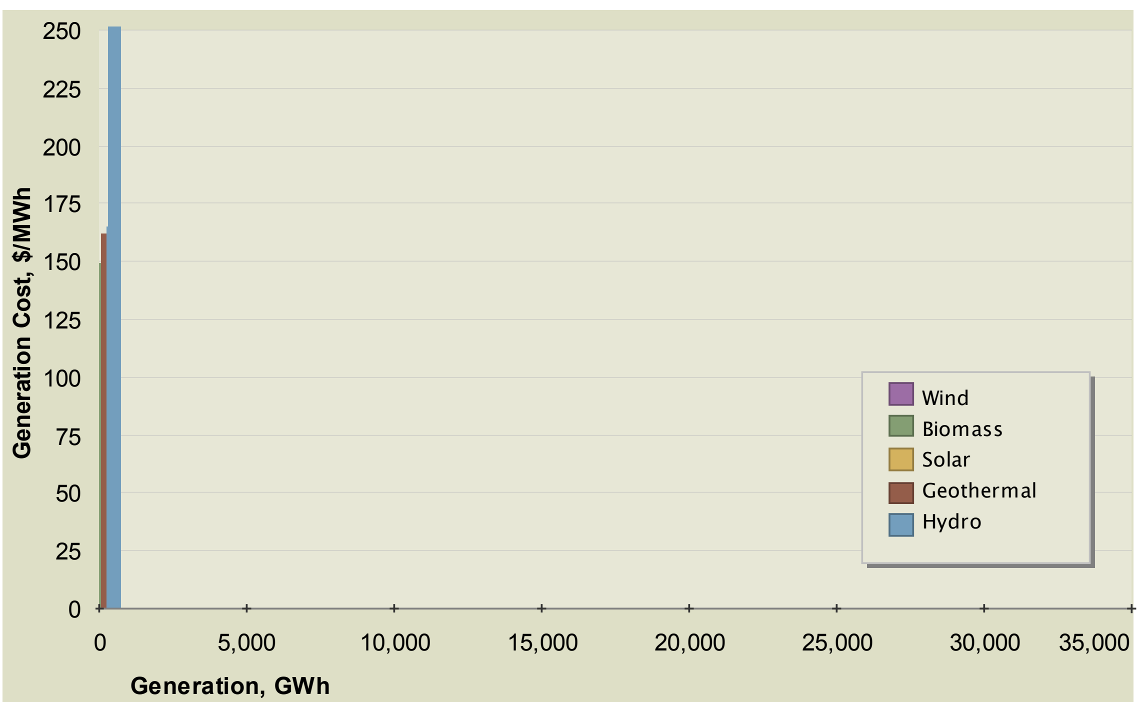

Figure A-10. BC_EA QRA Supply Curve
Generation costs over $250/MWh not shown on chart.

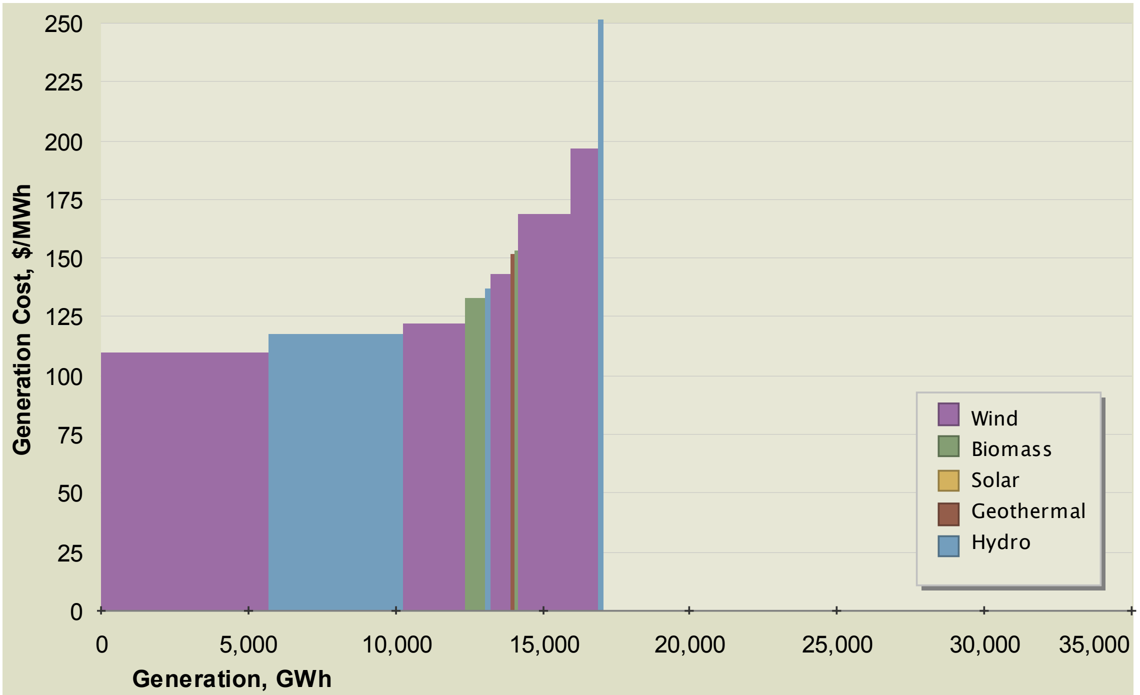

Figure A-11. BC_NE QRA Supply Curve.
Generation costs over $250/MWh not shown on chart.

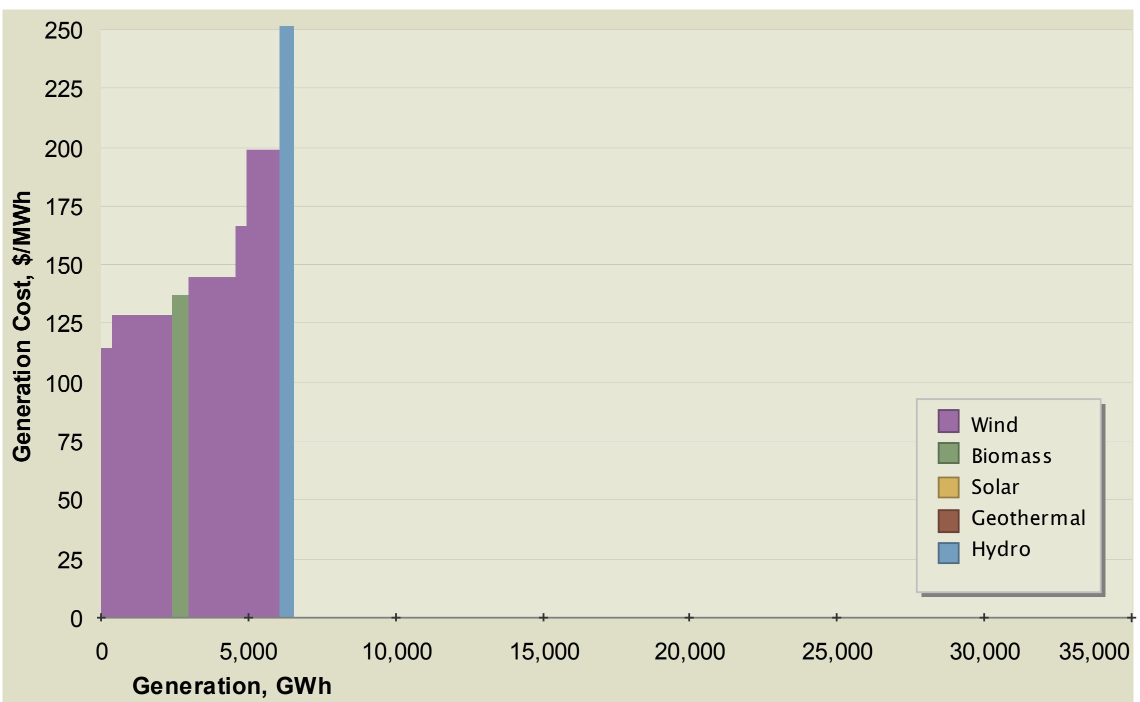

Figure A-12. BC_NO QRA Supply Curve.
Generation costs over $250/MWh not shown on chart.

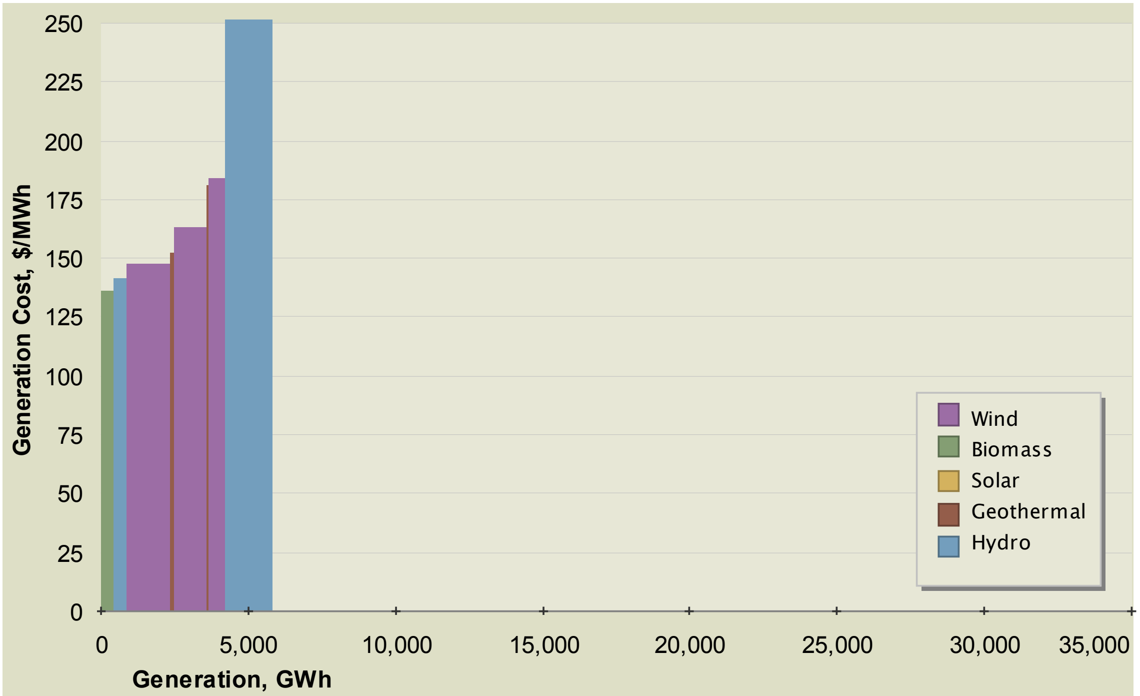

Figure A-13. BC_NW QRA Supply Curve.
Generation costs over $250/MWh not shown on chart.

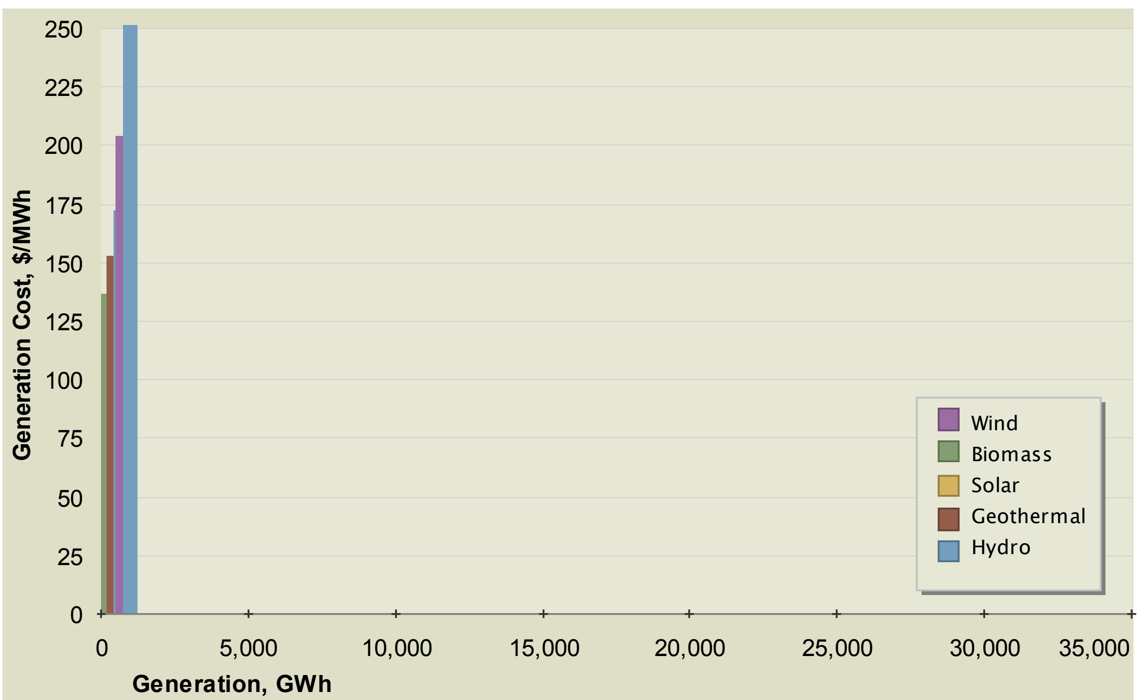

Figure A-14. BC_SE QRA Supply Curve.
Generation costs over $250/MWh not shown on chart.

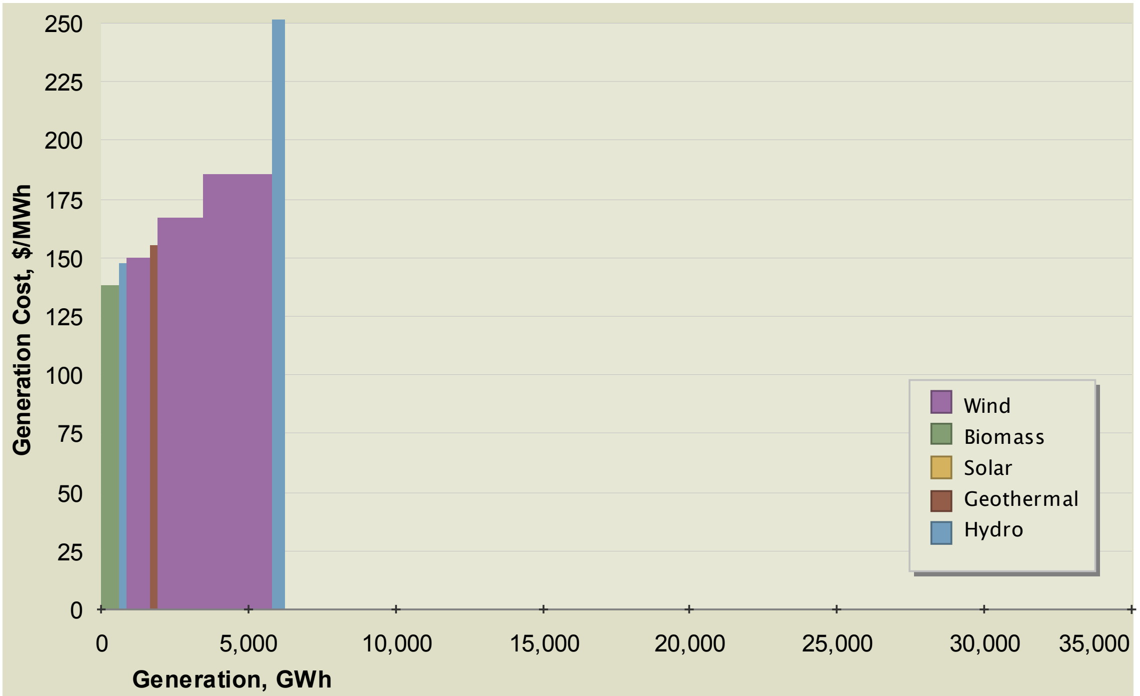

Figure A-15. BC_SO QRA Supply Curve.
Generation costs over $250/MWh not shown on chart.

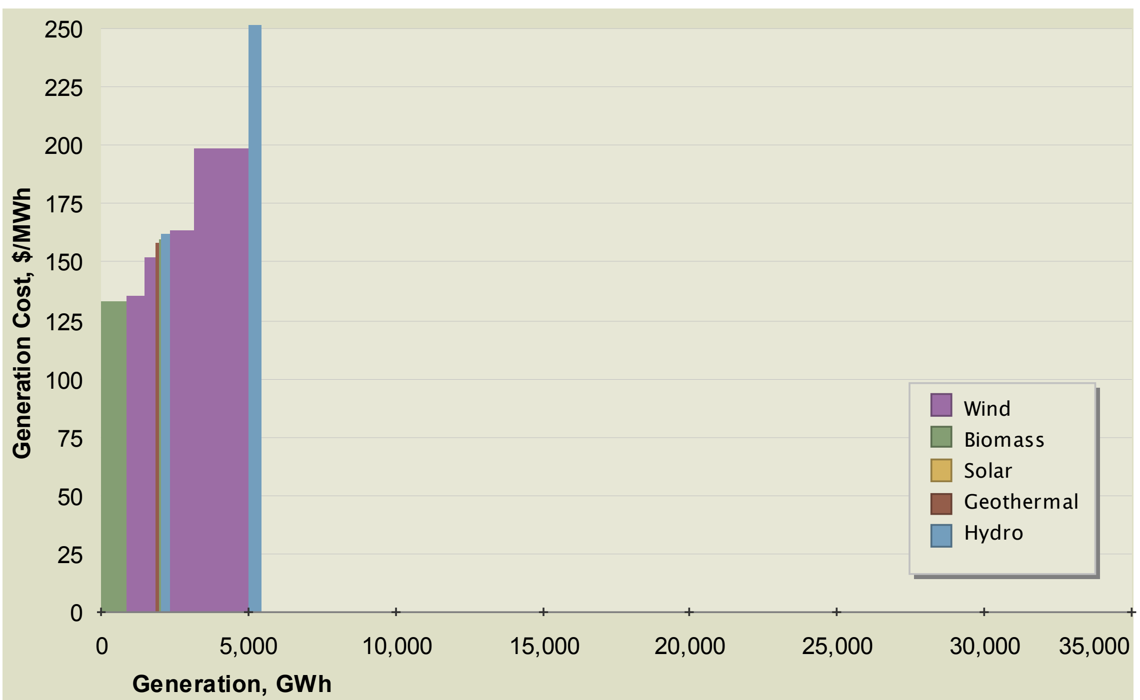

Figure A-16. BC_SW QRA Supply Curve.
Generation costs over $250/MWh not shown on chart.

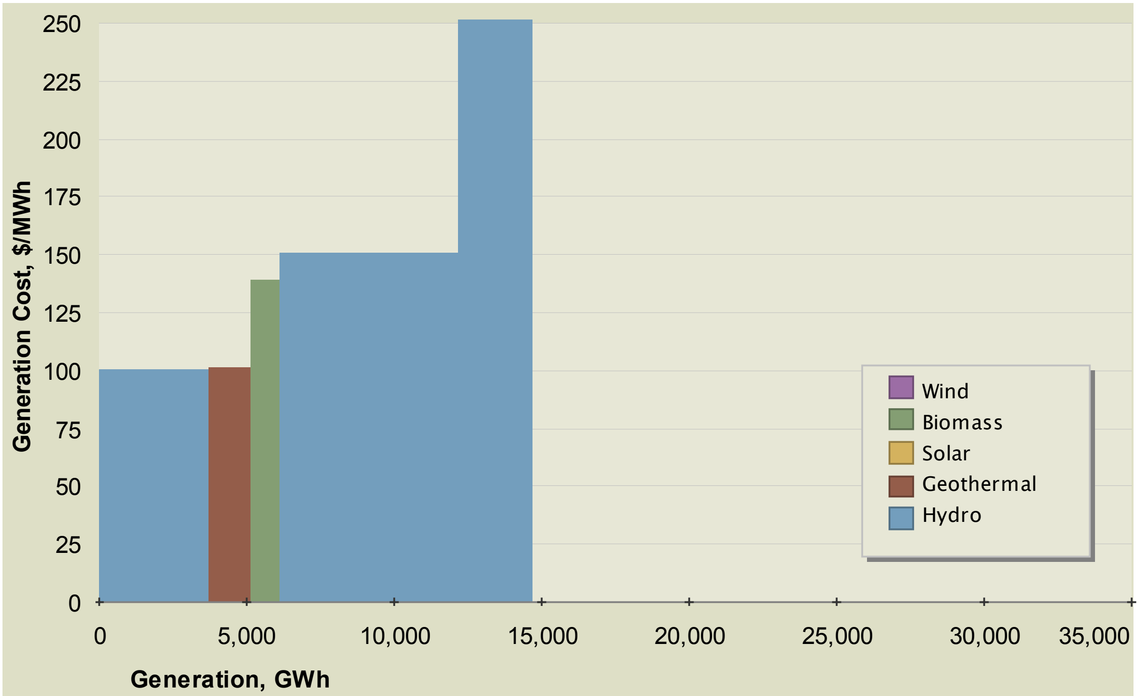

Figure A-17. BC_WC QRA Supply Curve.
Generation costs over $250/MWh not shown on chart.

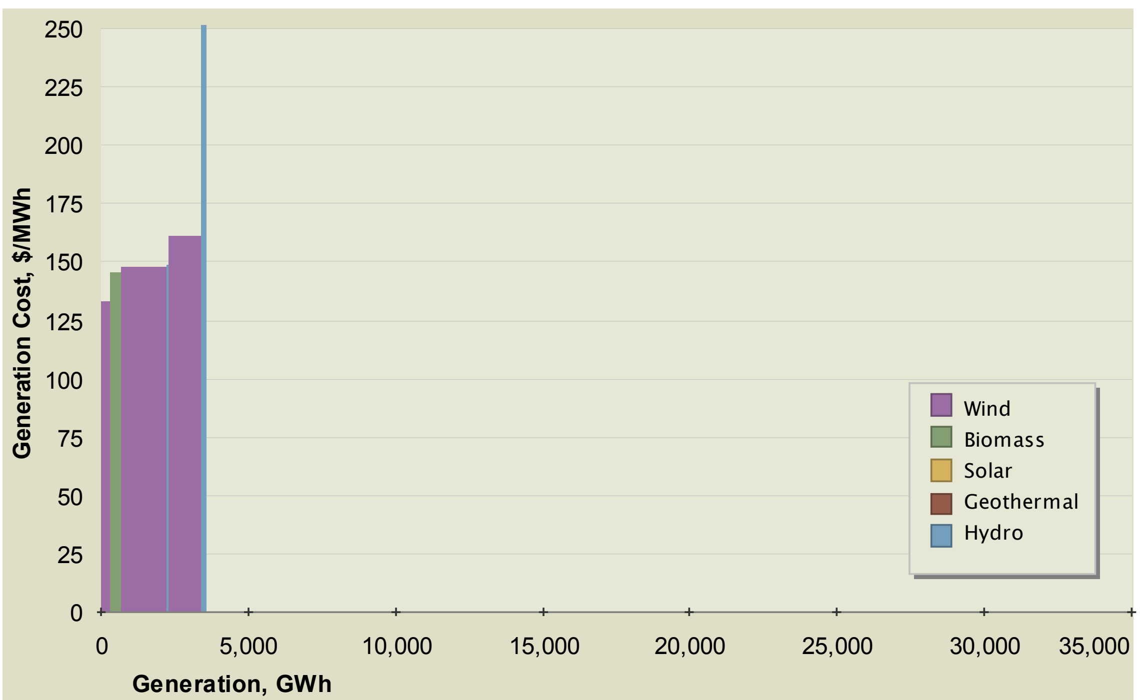

Figure A-18. BC_WE QRA Supply Curve.
Generation costs over $250/MWh not shown on chart.

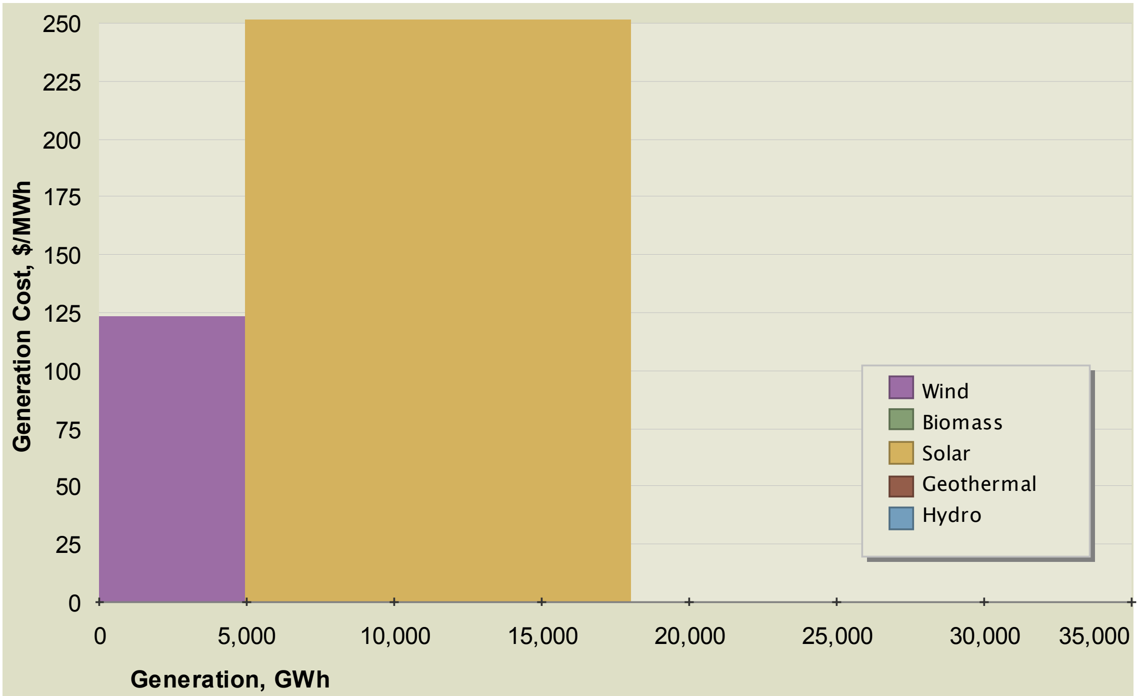

Figure A-19. BJ_NO QRA Supply Curve.
Generation costs over $250/MWh not shown on chart.

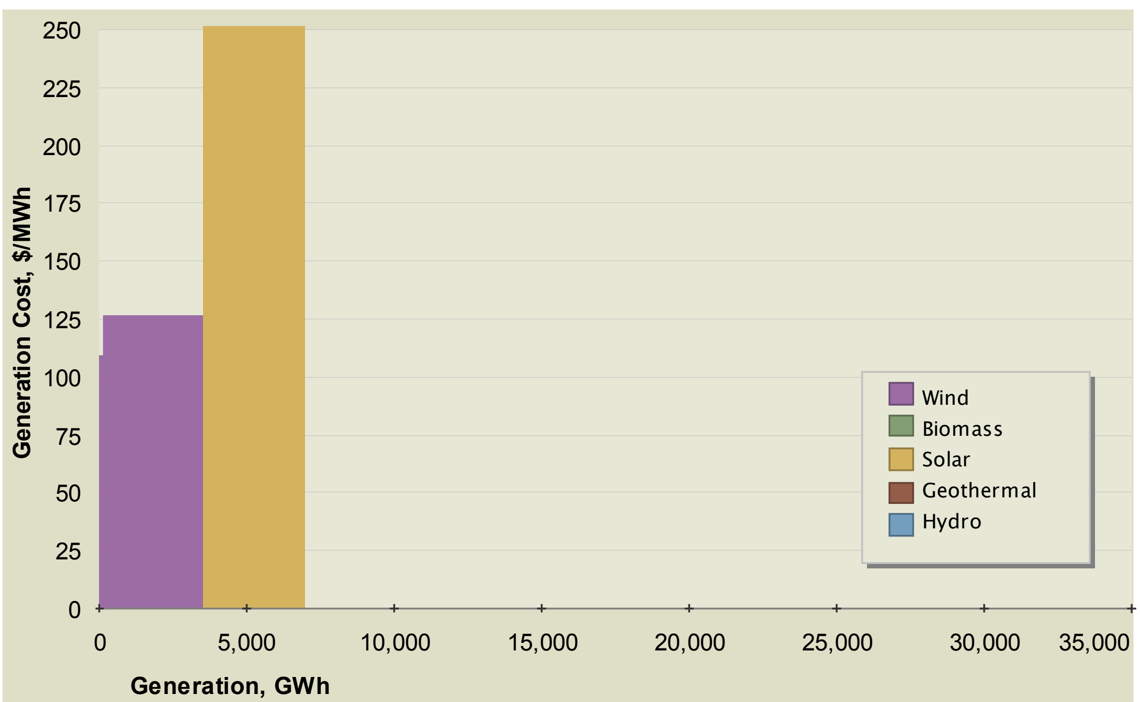

Figure A-20. BJ_SO QRA Supply Curve.
Generation costs over $250/MWh not shown on chart.

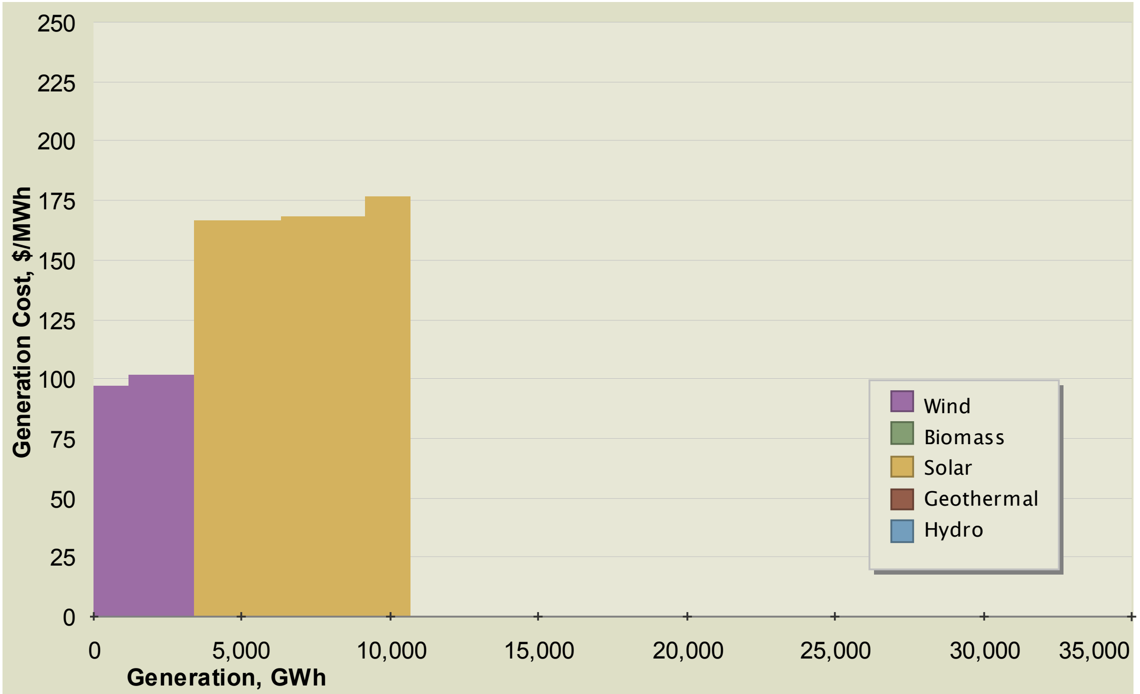

Figure A-21. CA_CT QRA Supply Curve.

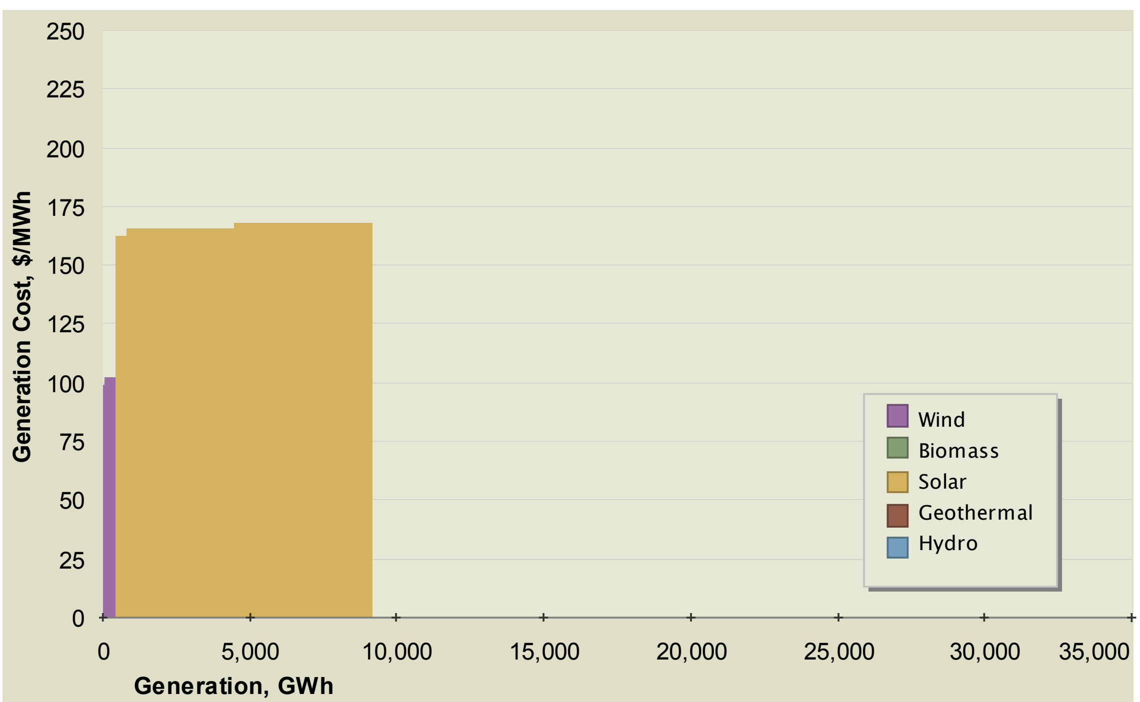

Figure A-22. CA_EA QRA Supply Curve.

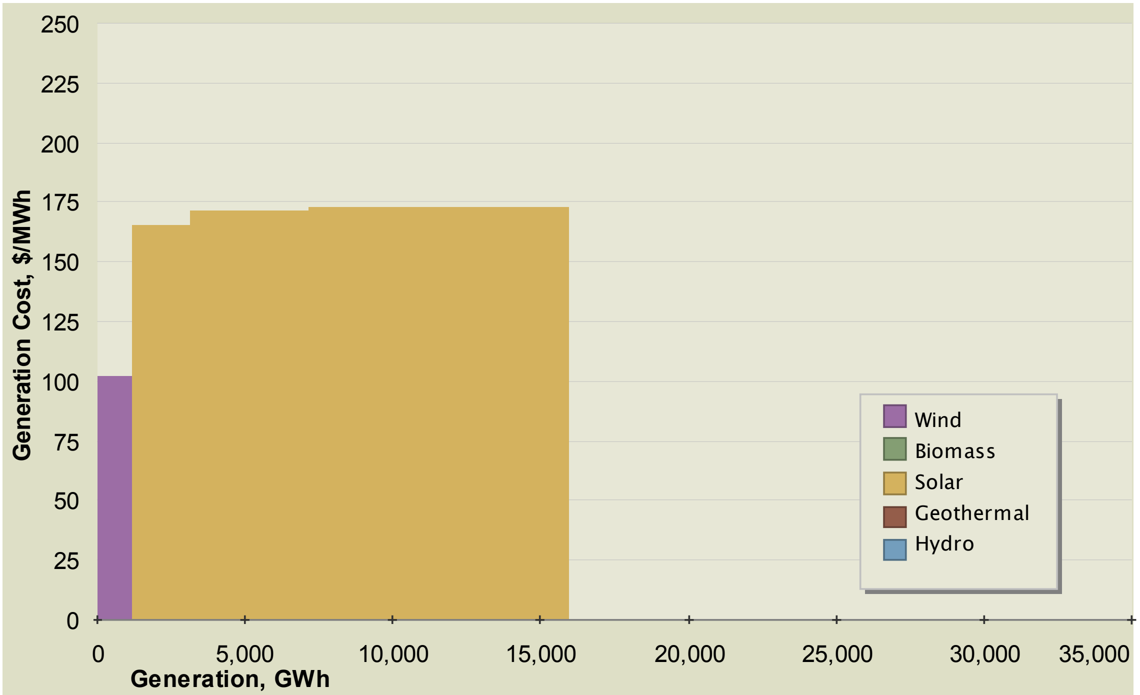

Figure A-23. CA_NE QRA Supply Curve.

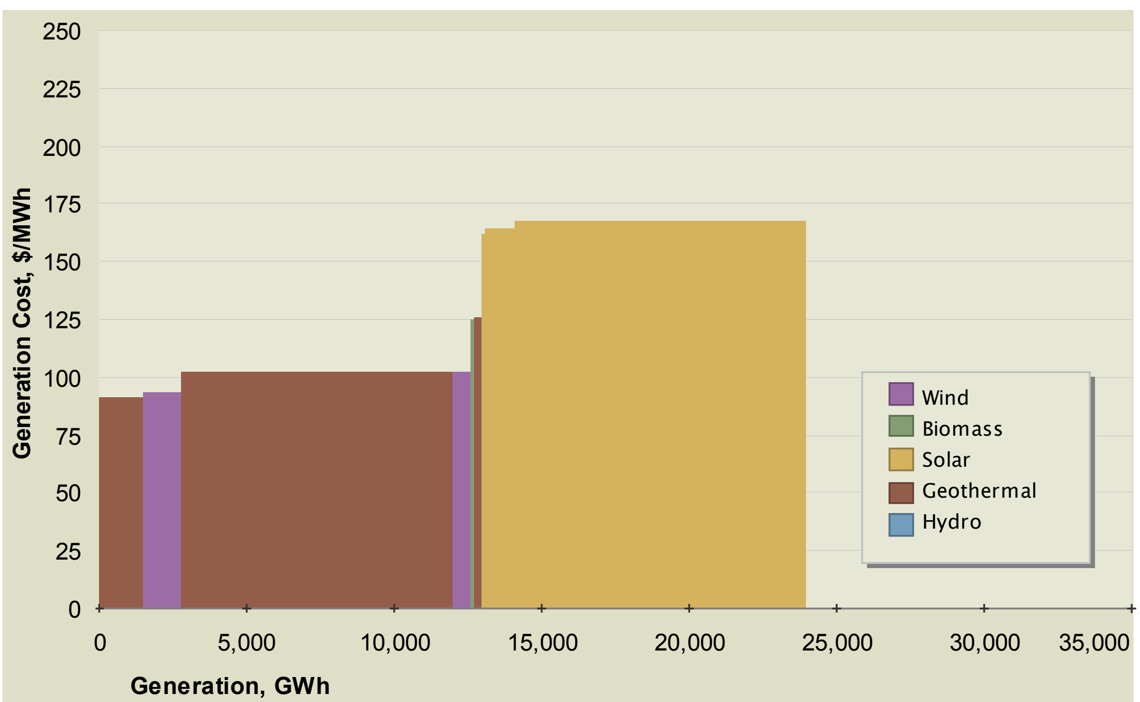

Figure A-24. CA_SO QRA Supply Curve.

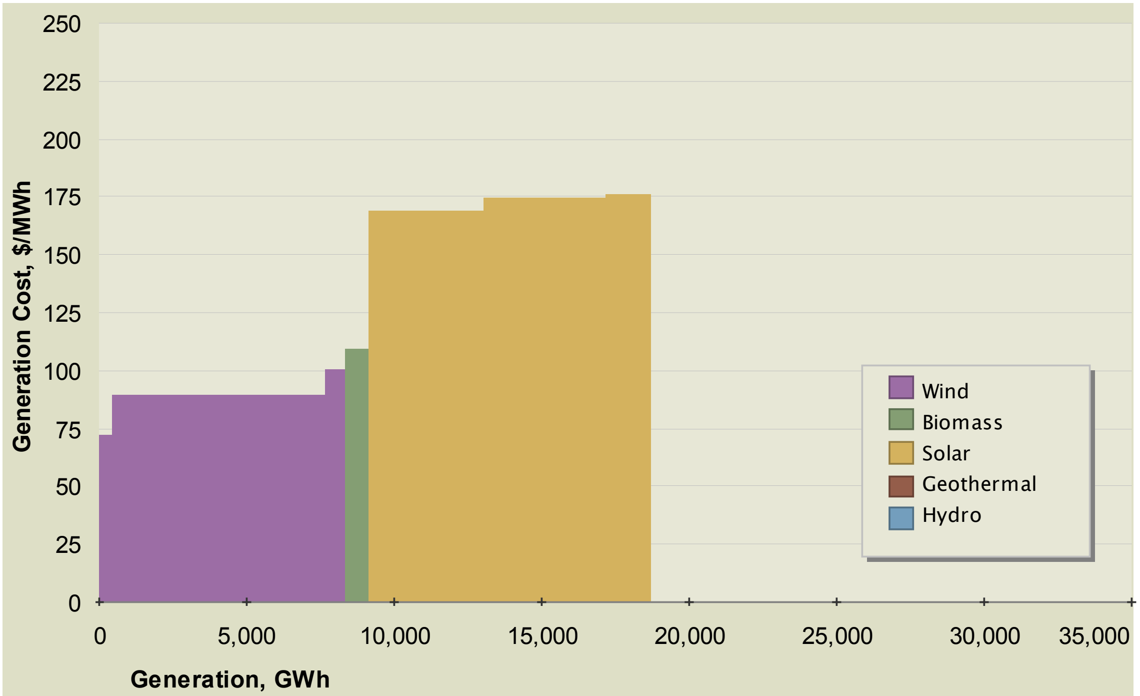

Figure A-25. CA_WE QRA Supply Curve.

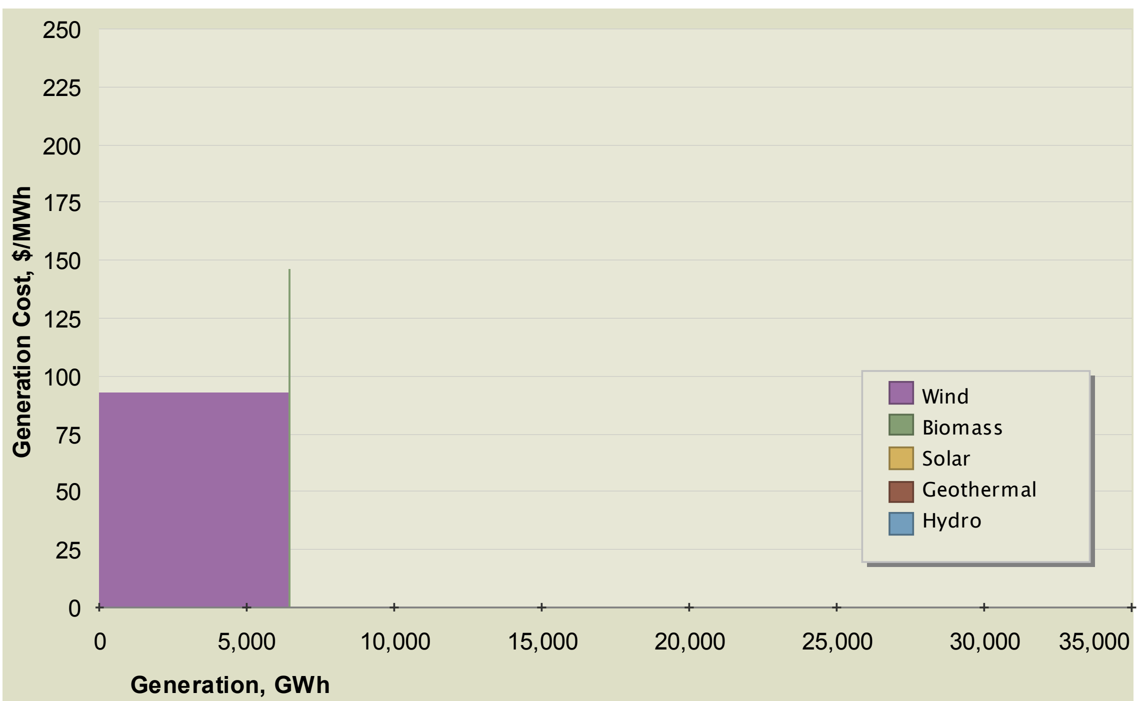

Figure A-26. CO_EA QRA Supply Curve.

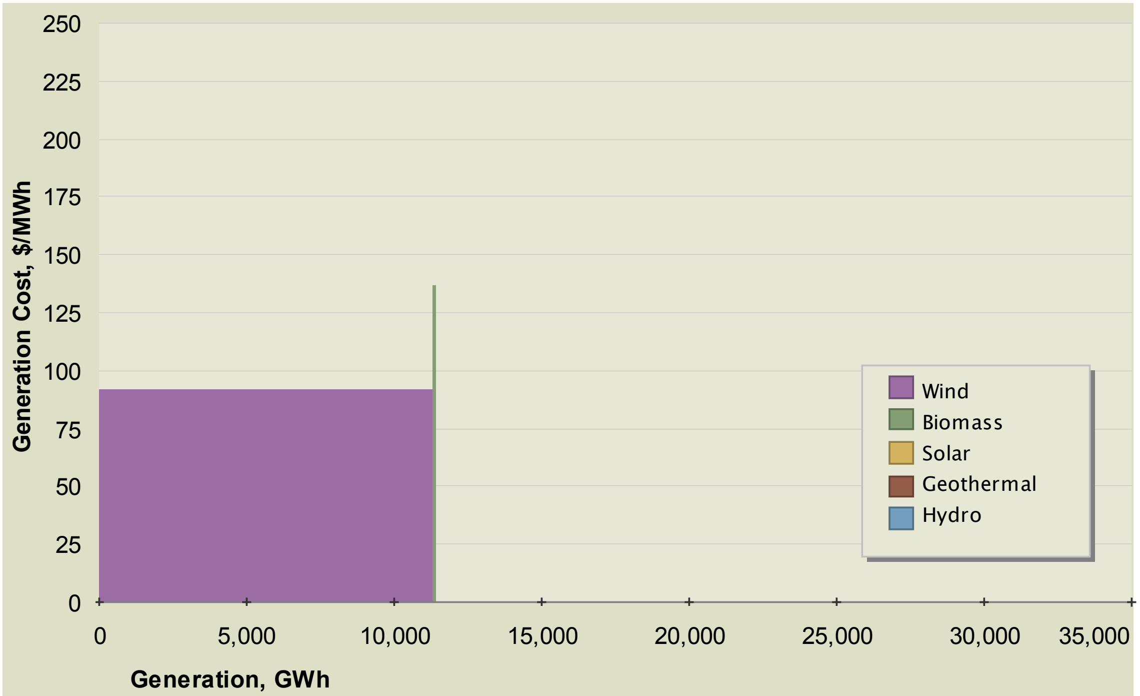

Figure A-27. CO_NE QRA Supply Curve.

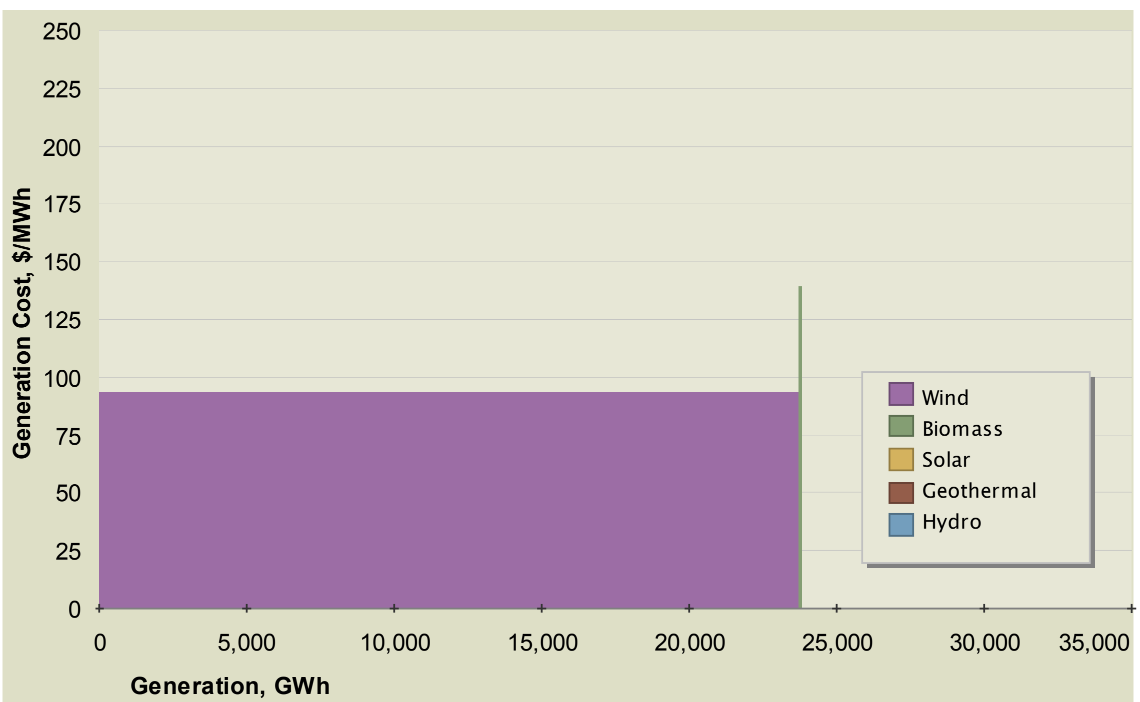

Figure A-28. CO_SE QRA Supply Curve.

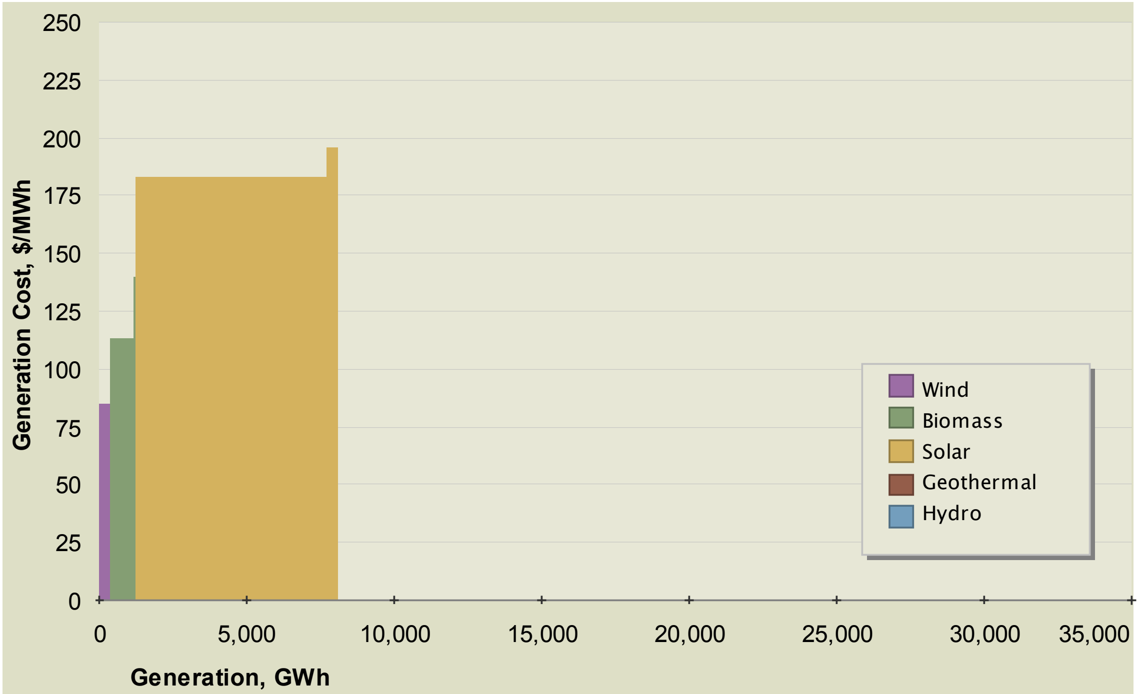

Figure A-29. CO_SO QRA Supply Curve.

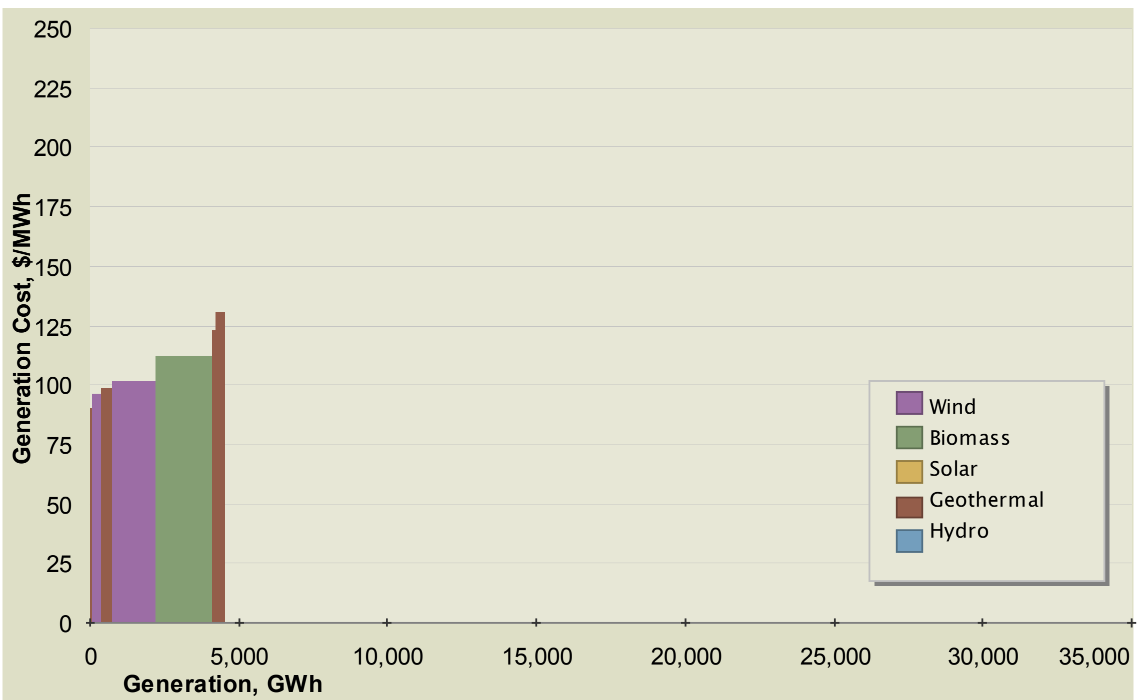

Figure A-30. ID_EA QRA Supply Curve.

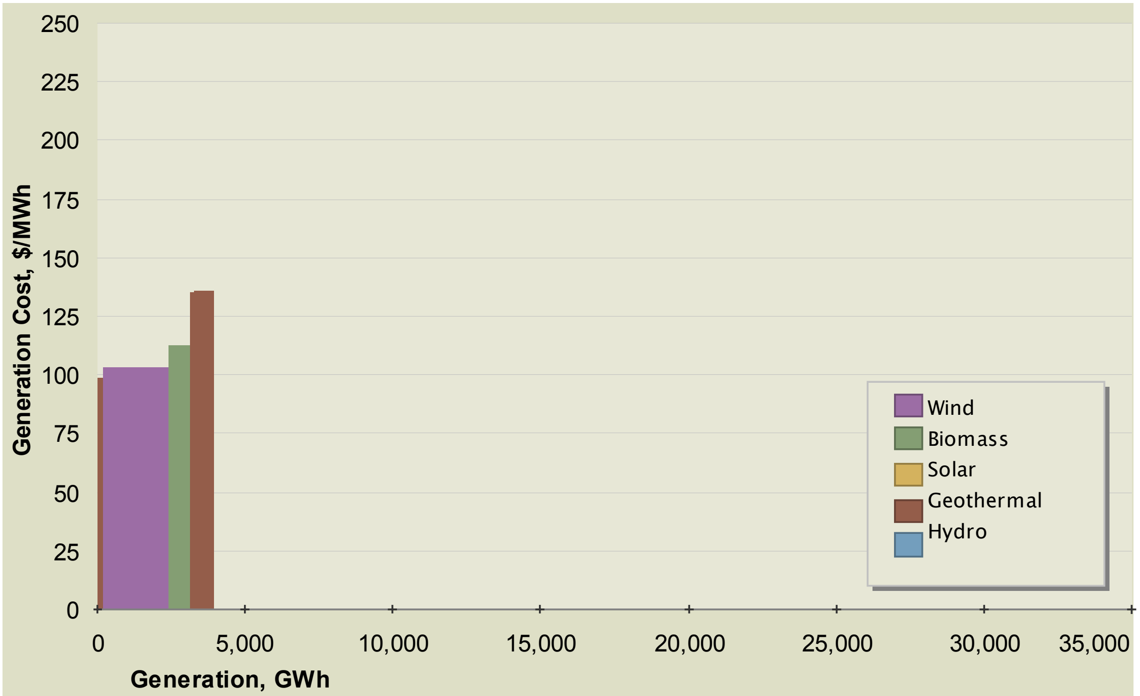

Figure A-31. ID_SW QRA Supply Curve.

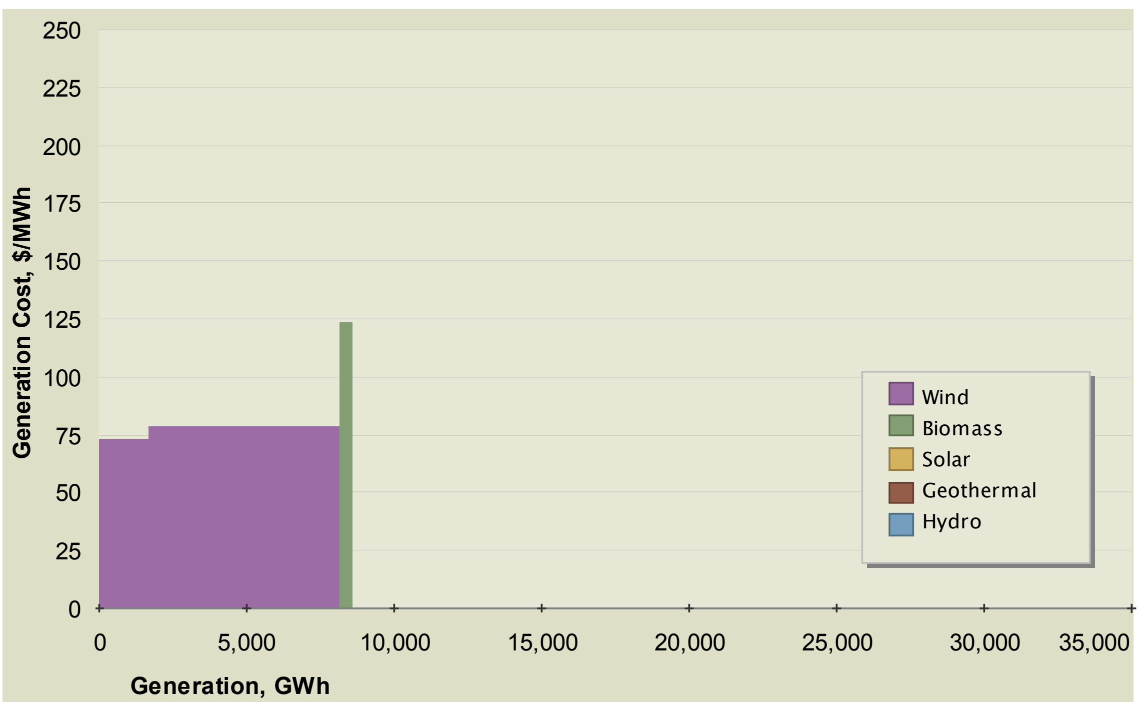

Figure A-32. MT_CT QRA Supply Curve.

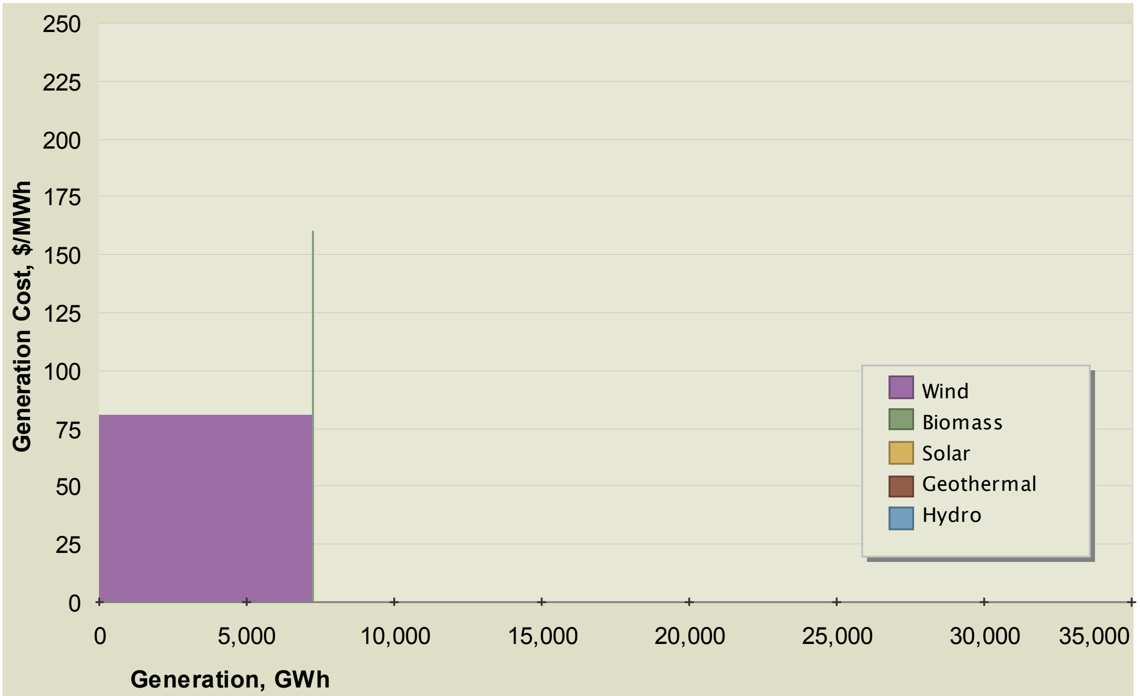

Figure A-33. MT_NE QRA Supply Curve.

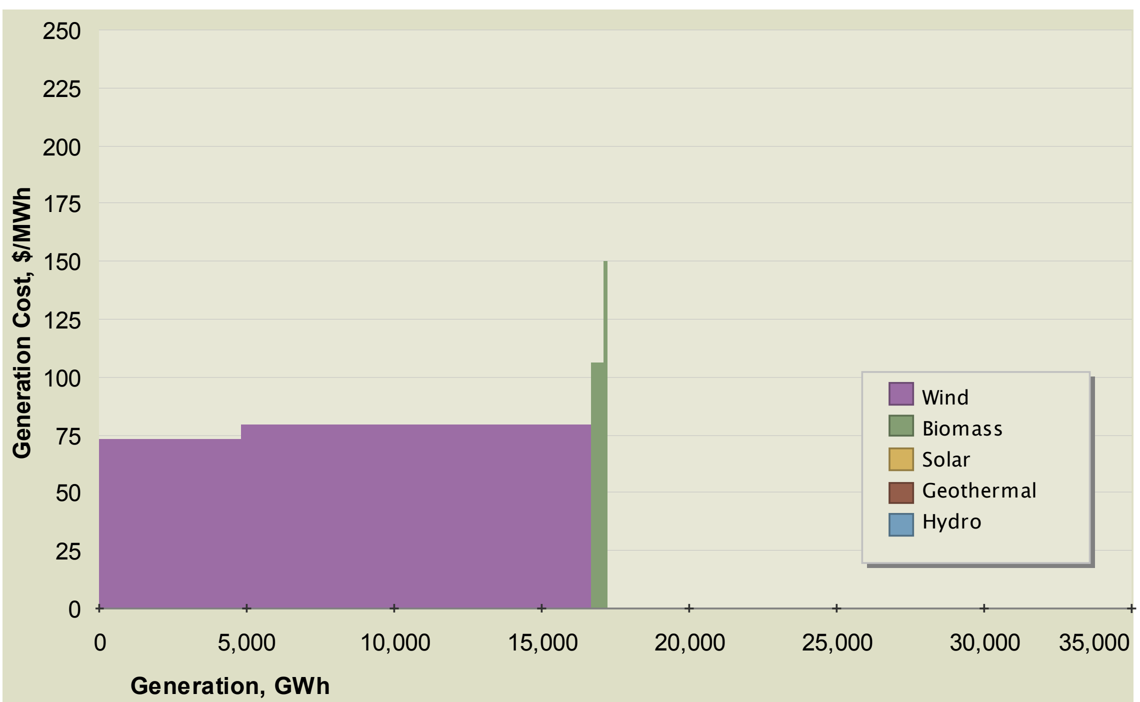

Figure A-34. MT_NW QRA Supply Curve.

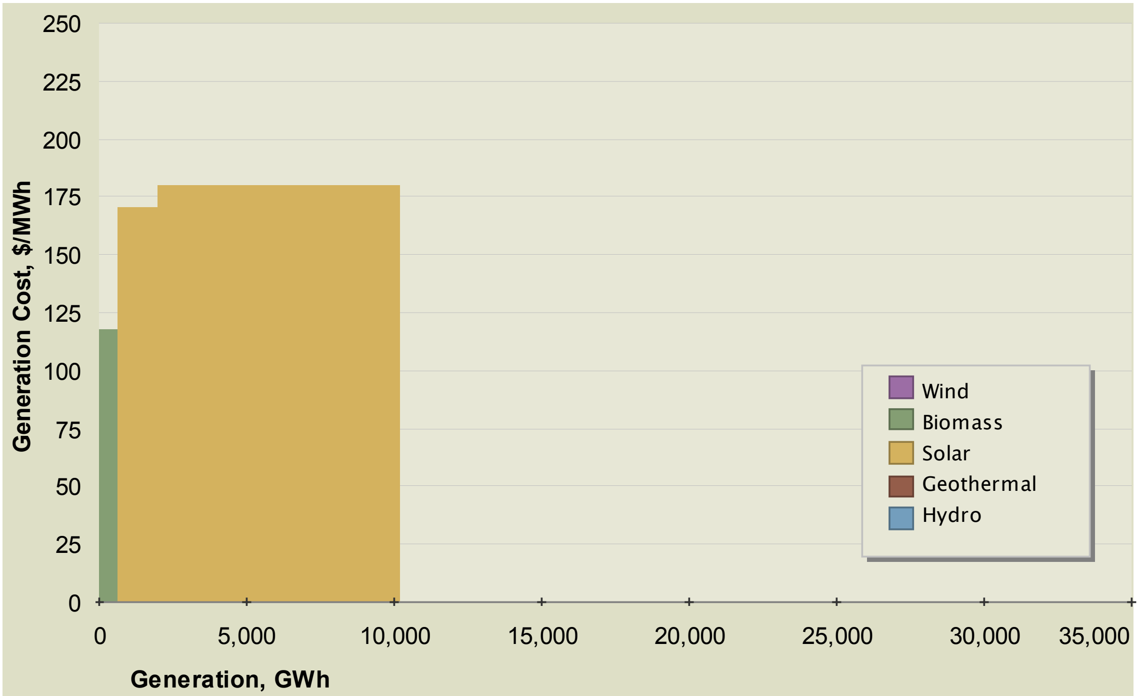

Figure A-35. NM_CT QRA Supply Curve.

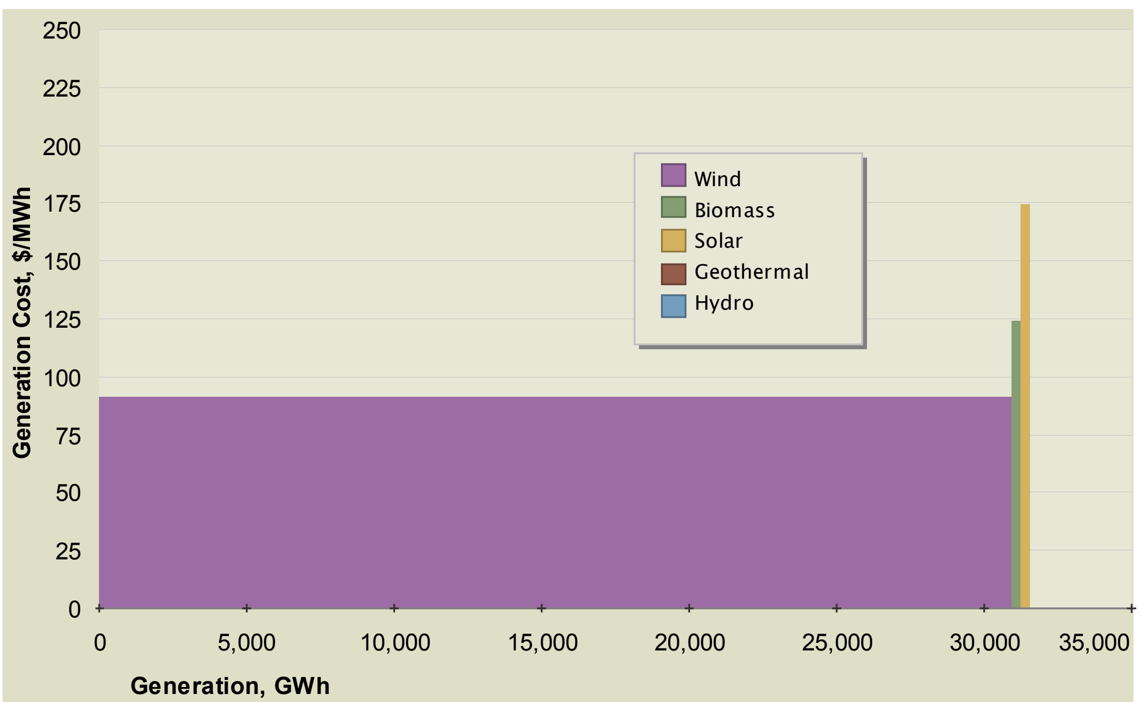

Figure A-36. NM_EA QRA Supply Curve.

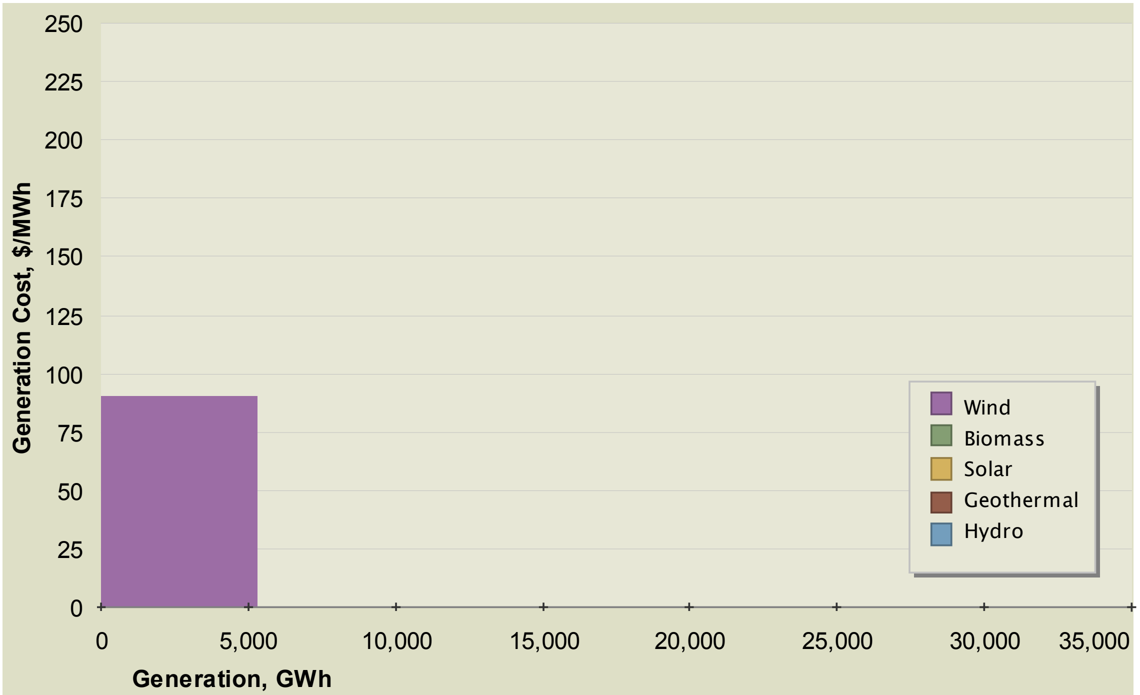

Figure A-37. NM_SE QRA Supply Curve.

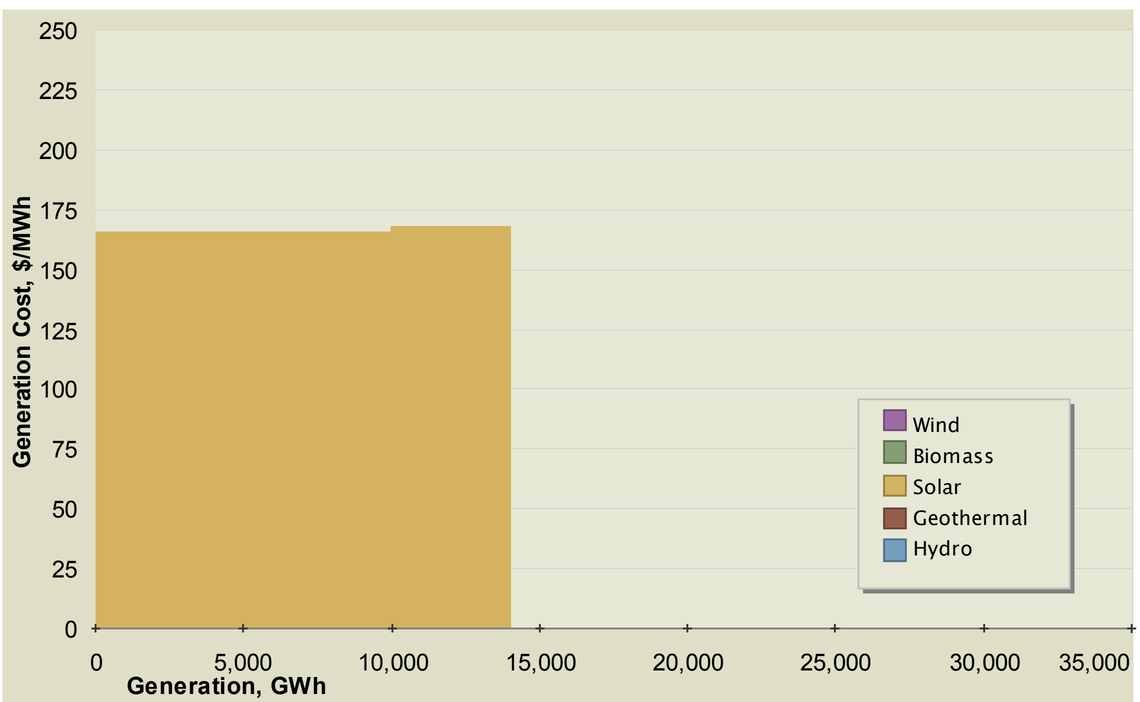

Figure A-38. NM_SO QRA Supply Curve.

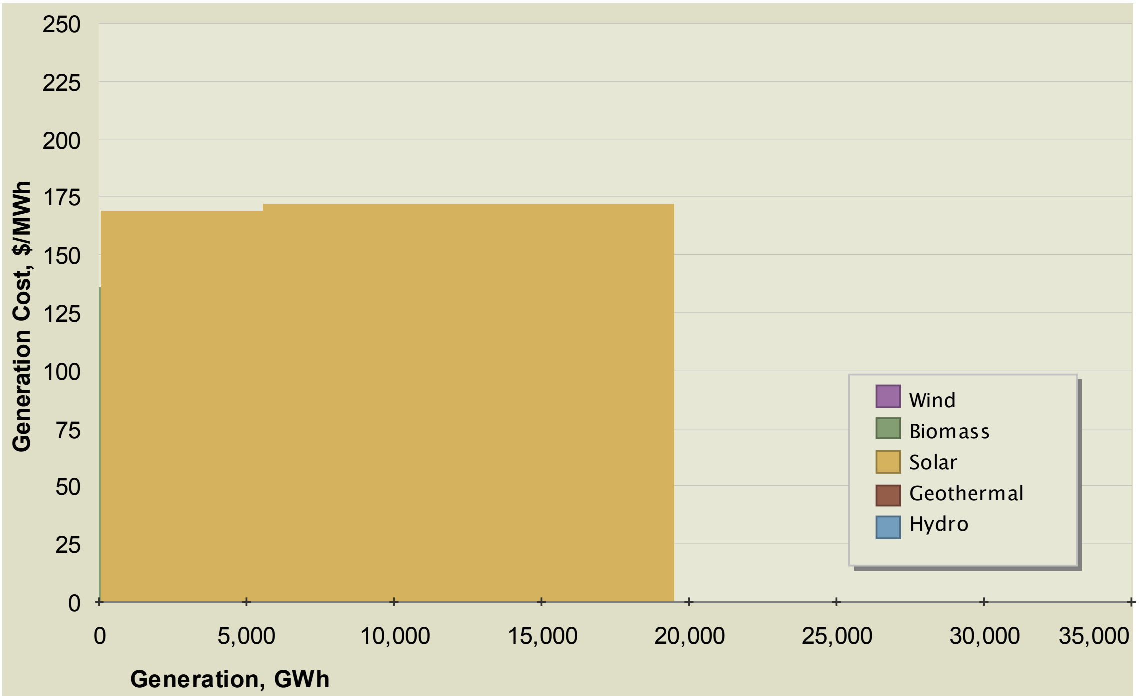

Figure A-39. NM_SW QRA Supply Curve.

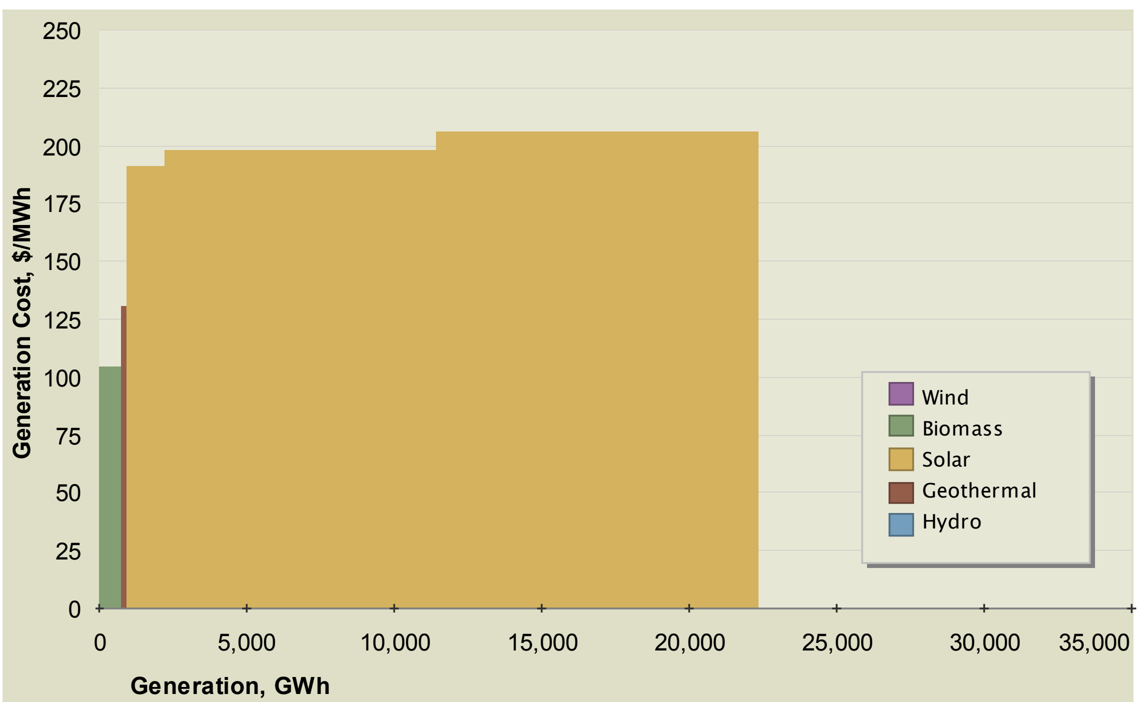

Figure A-40. NV_EA QRA Supply Curve.

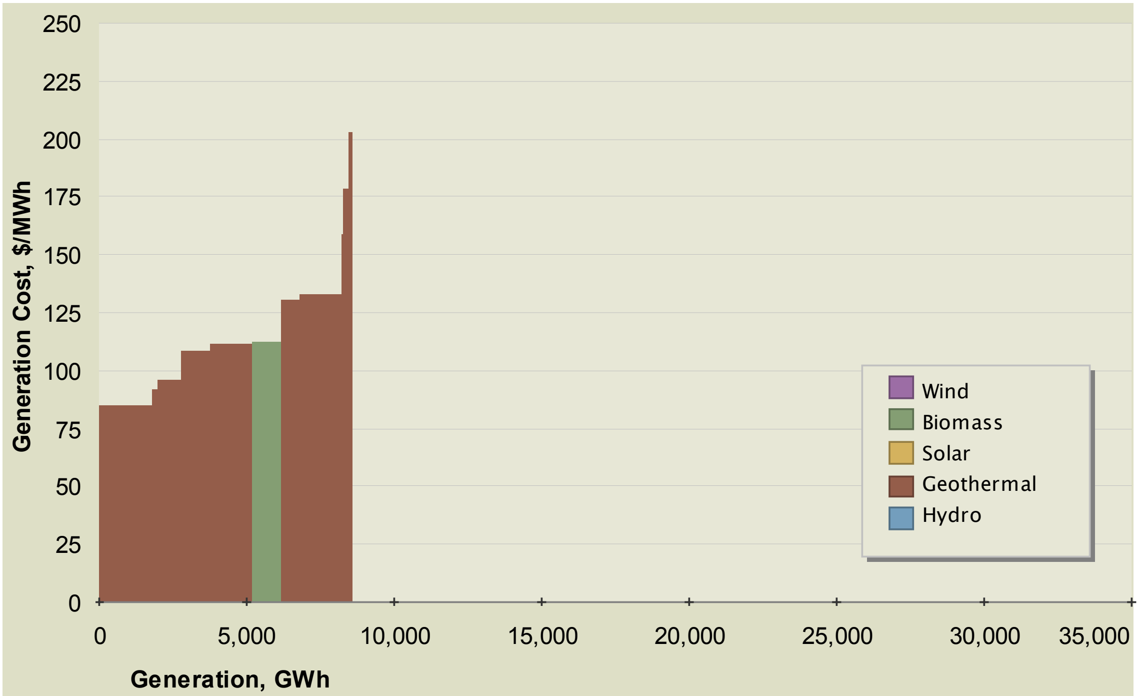

Figure A-41. NV_NO QRA Supply Curve.

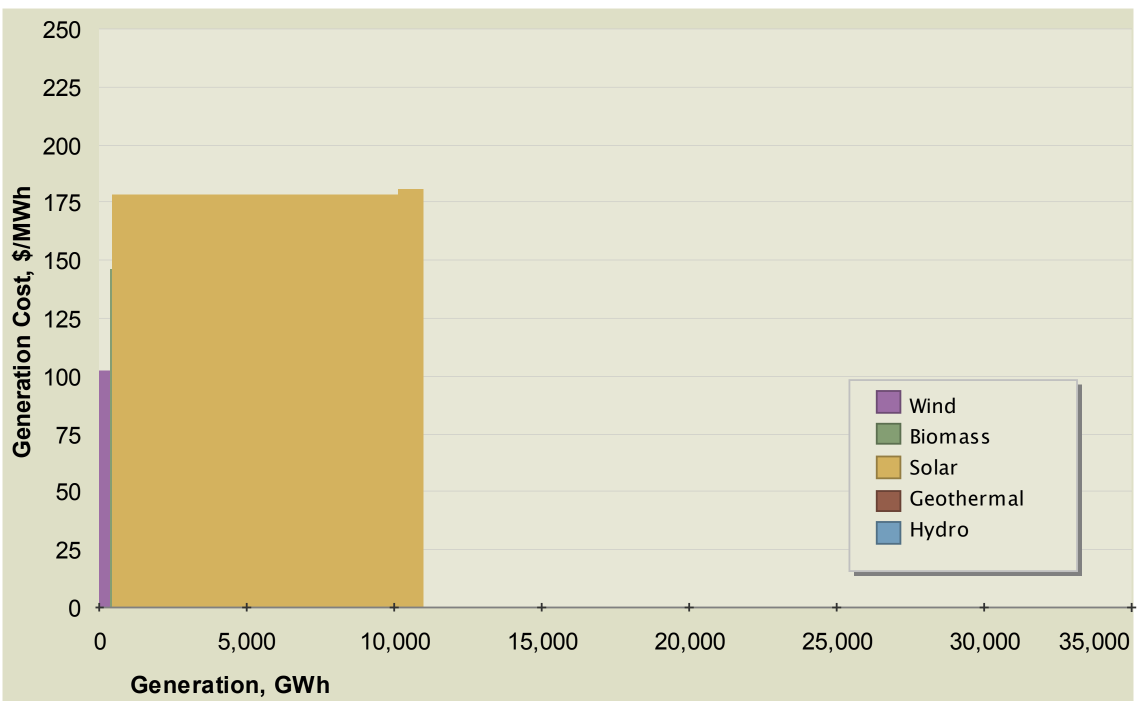

Figure A-42. NV_SW QRA Supply Curve.

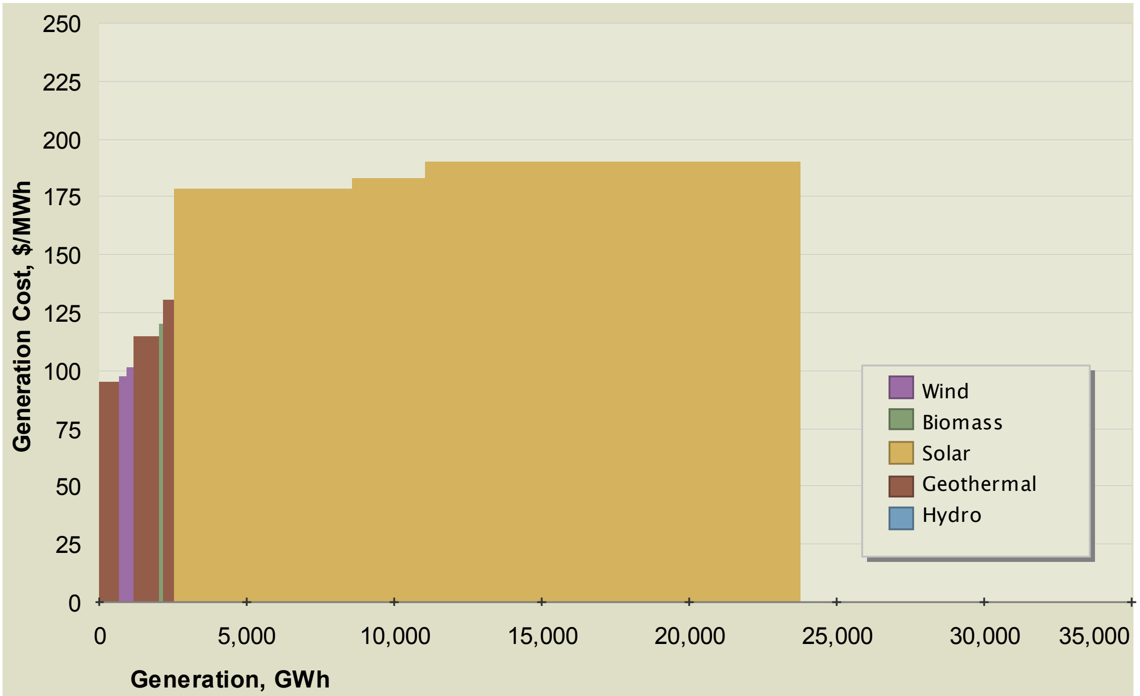

Figure A-43. NV_WE QRA Supply Curve.

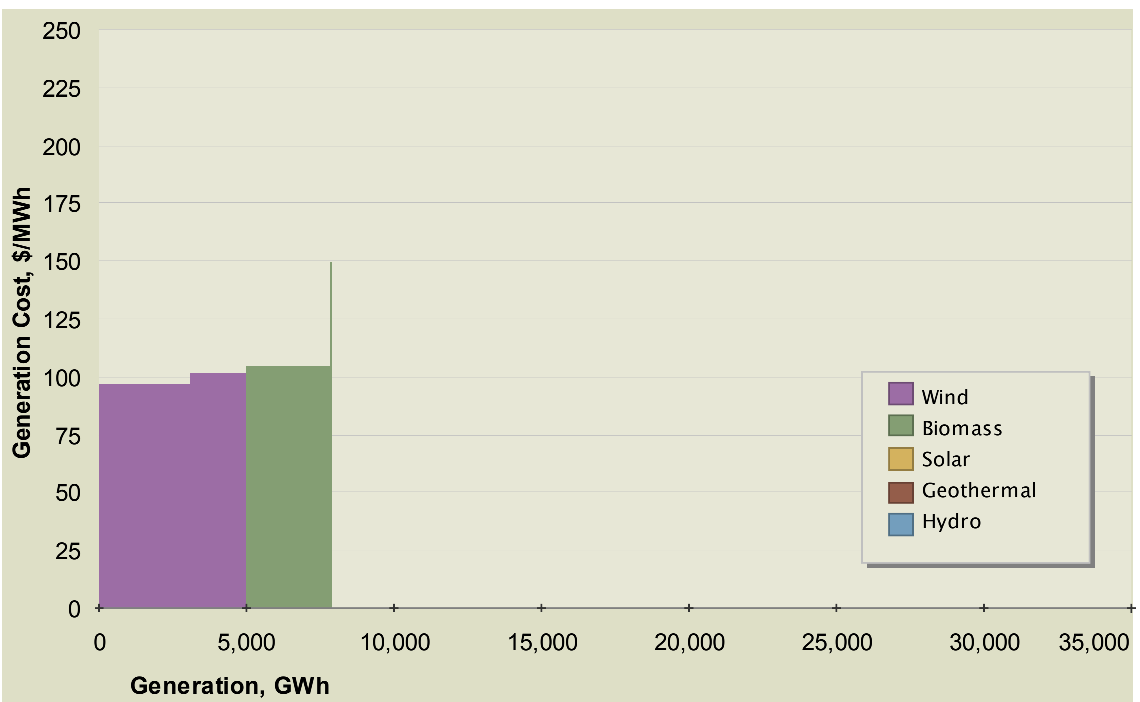

Figure A-44. OR_NE QRA Supply Curve.

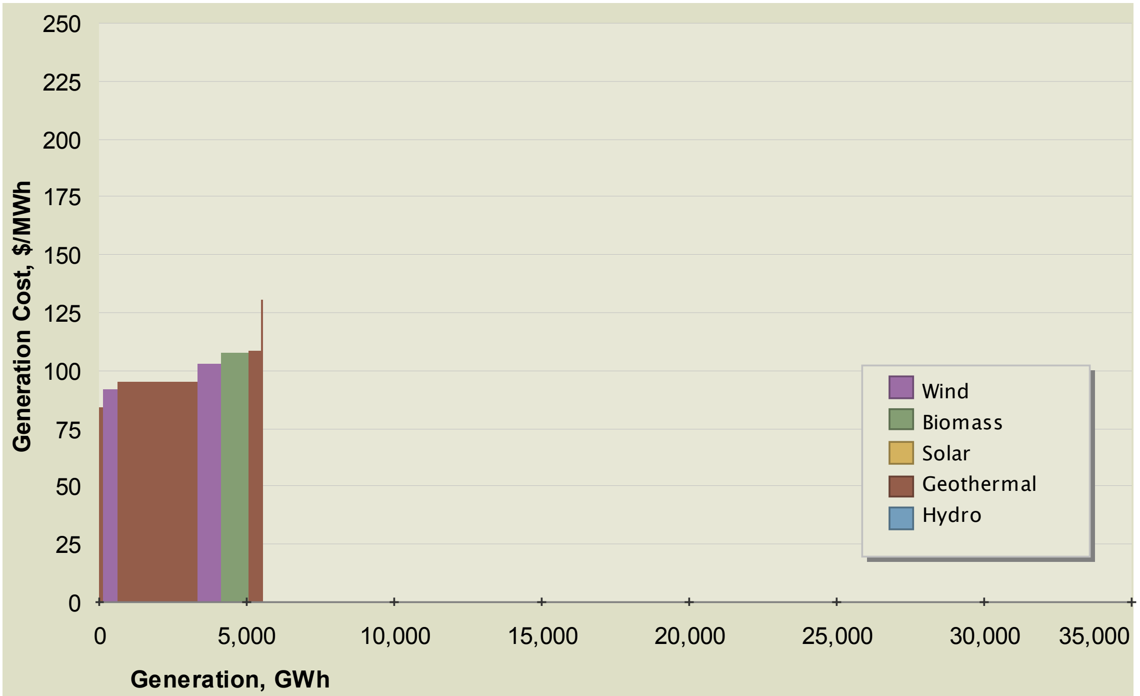

Figure A-45. OR_SO QRA Supply Curve.

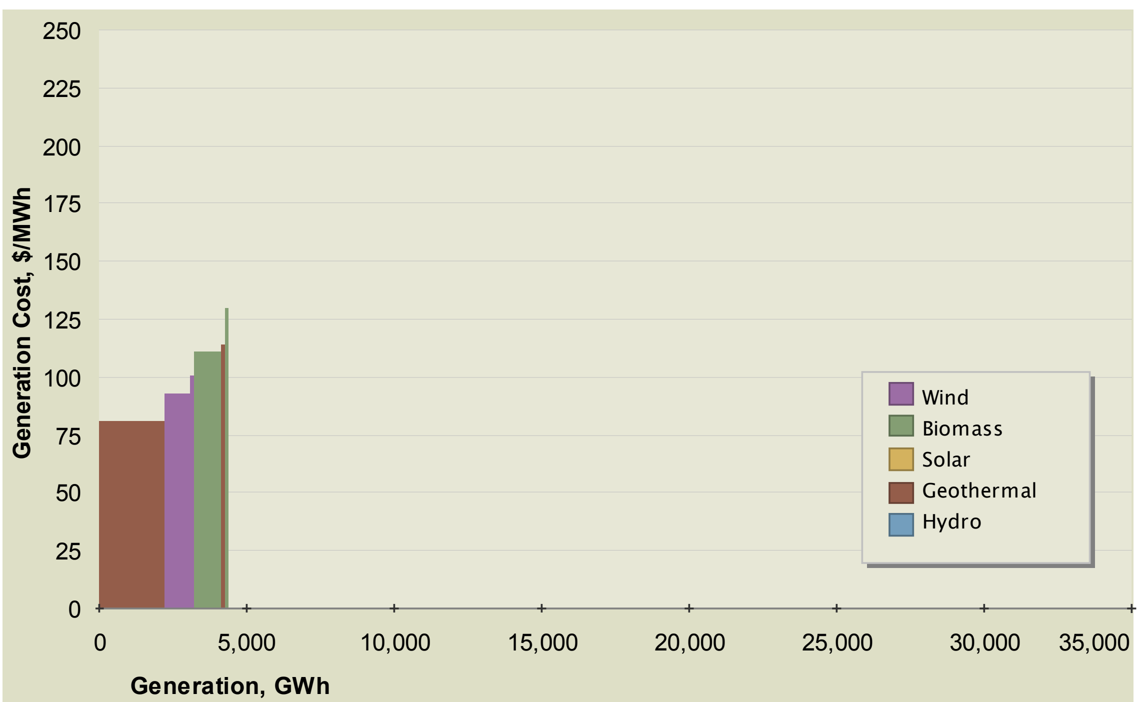

Figure A-46. OR_WE QRA Supply Curve.

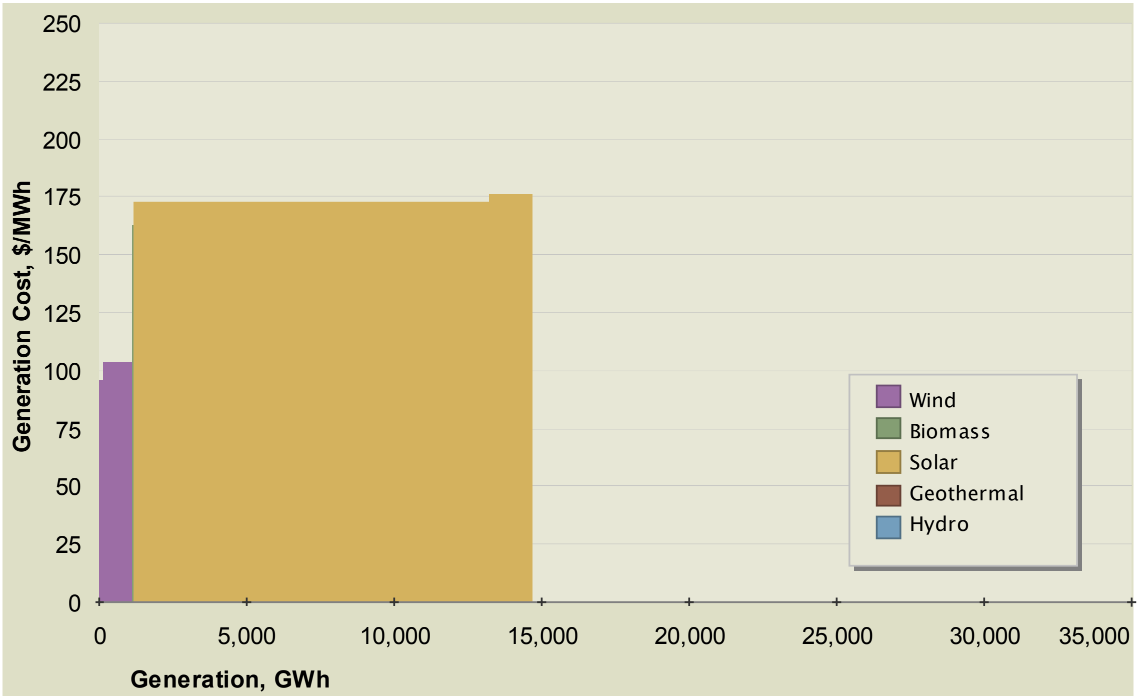

Figure A-47. TX QRA Supply Curve.

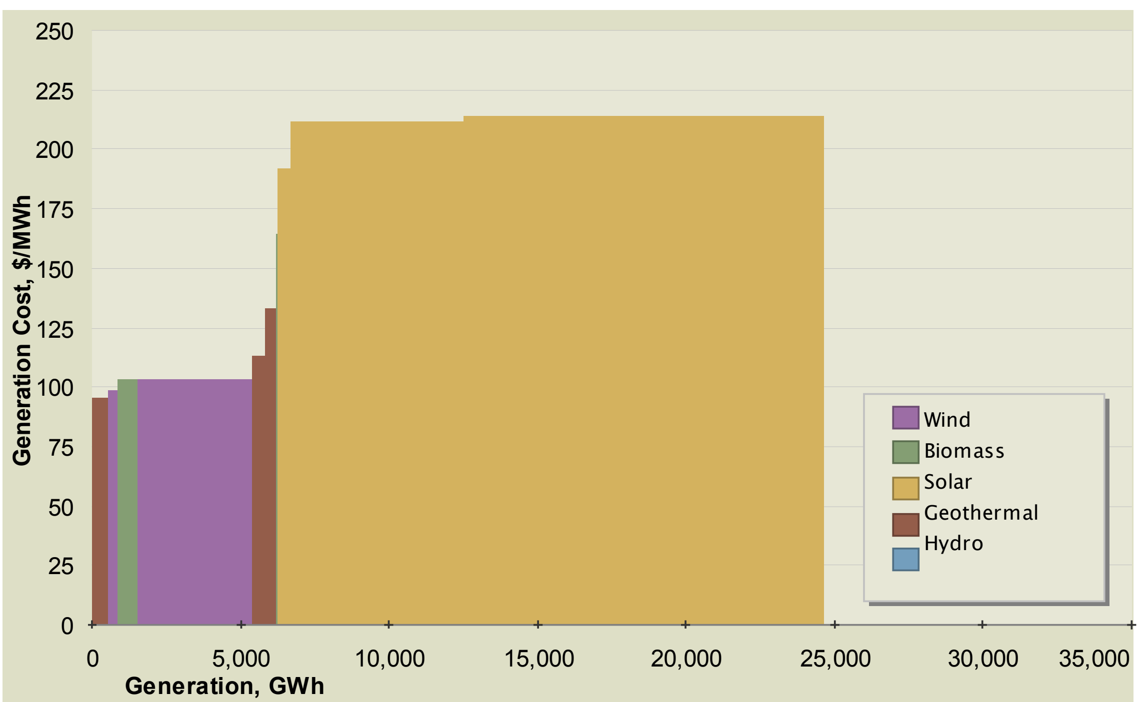

Figure A-48. UT_WE QRA Supply Curve.

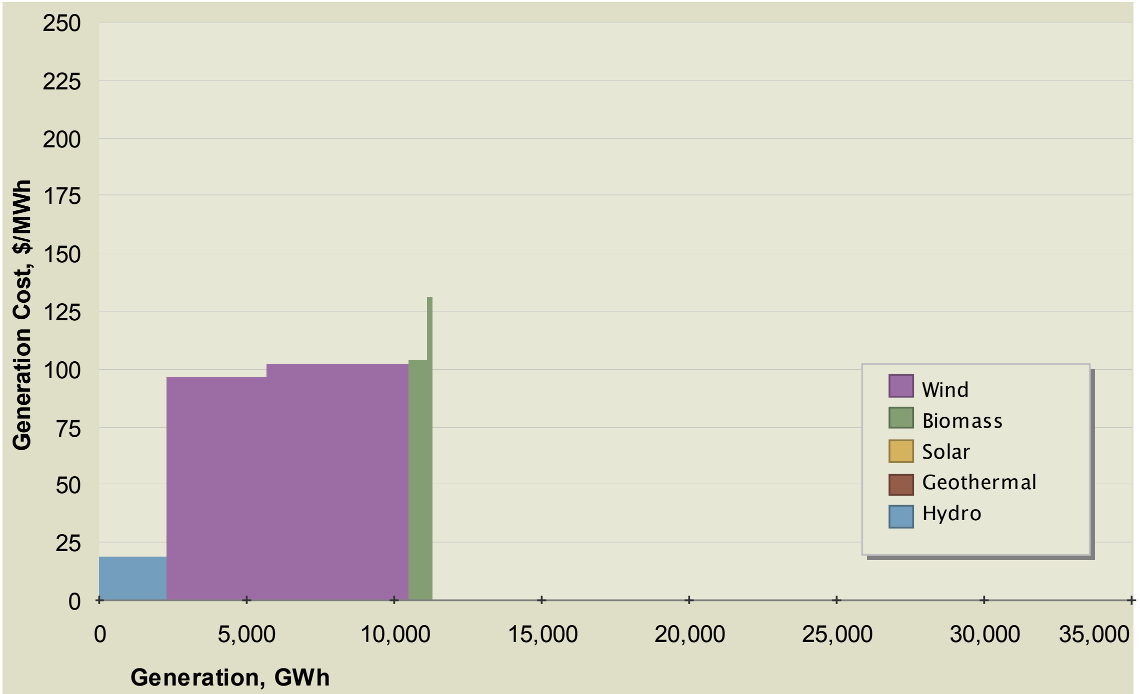

Figure A-49. WA_SO QRA Supply Curve.

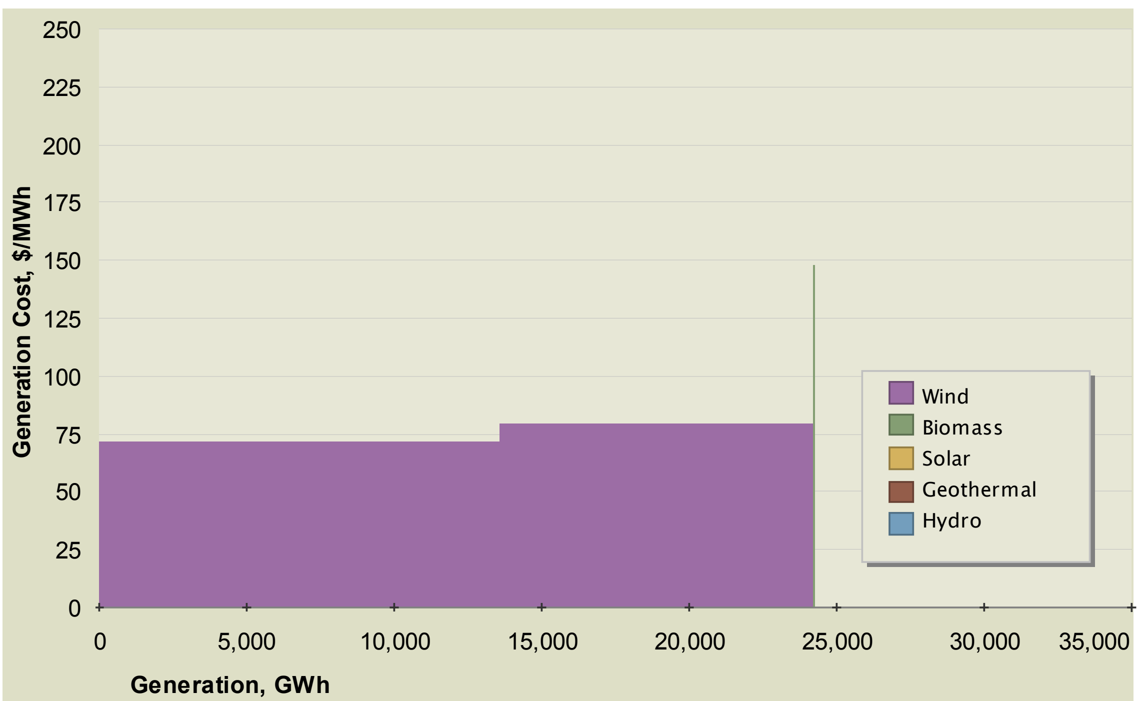

Figure A-50. WY_EA QRA Supply Curve.

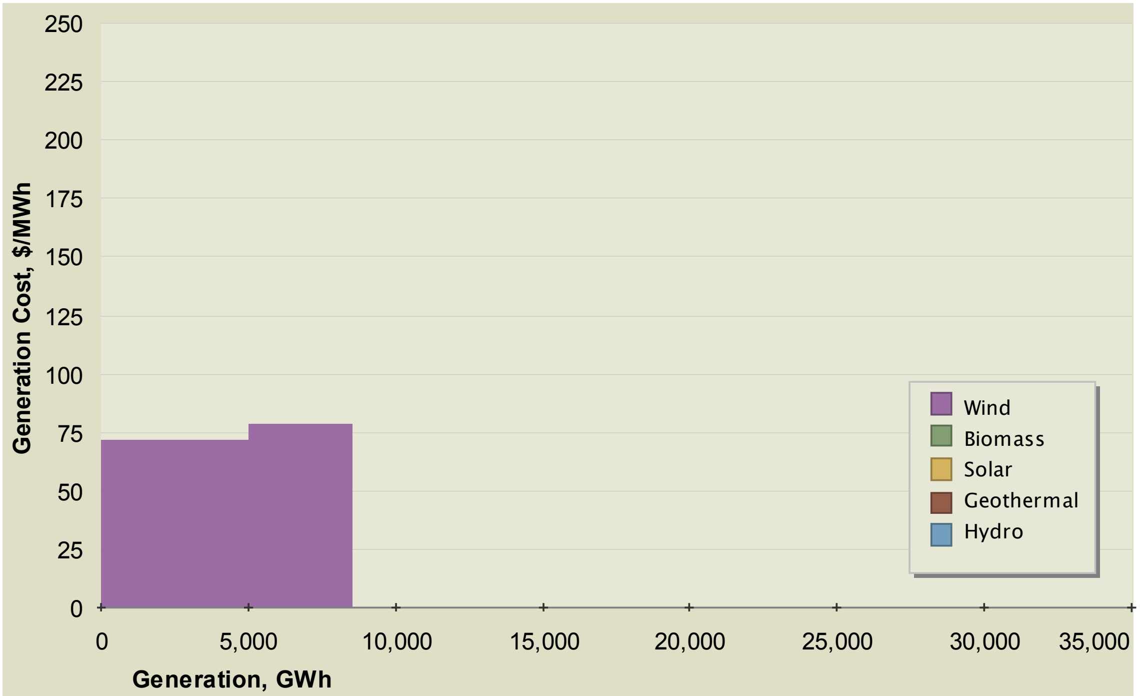

Figure A-51. WY_EC QRA Supply Curve.

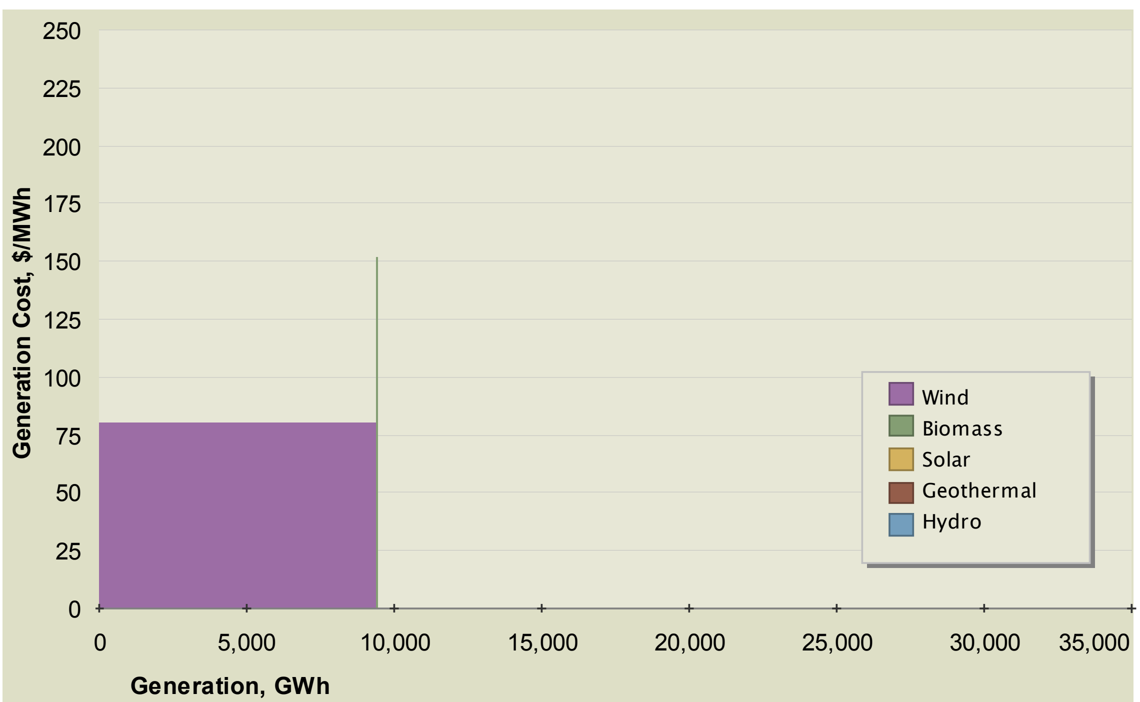

Figure A-52. WY_NO QRA Supply Curve.

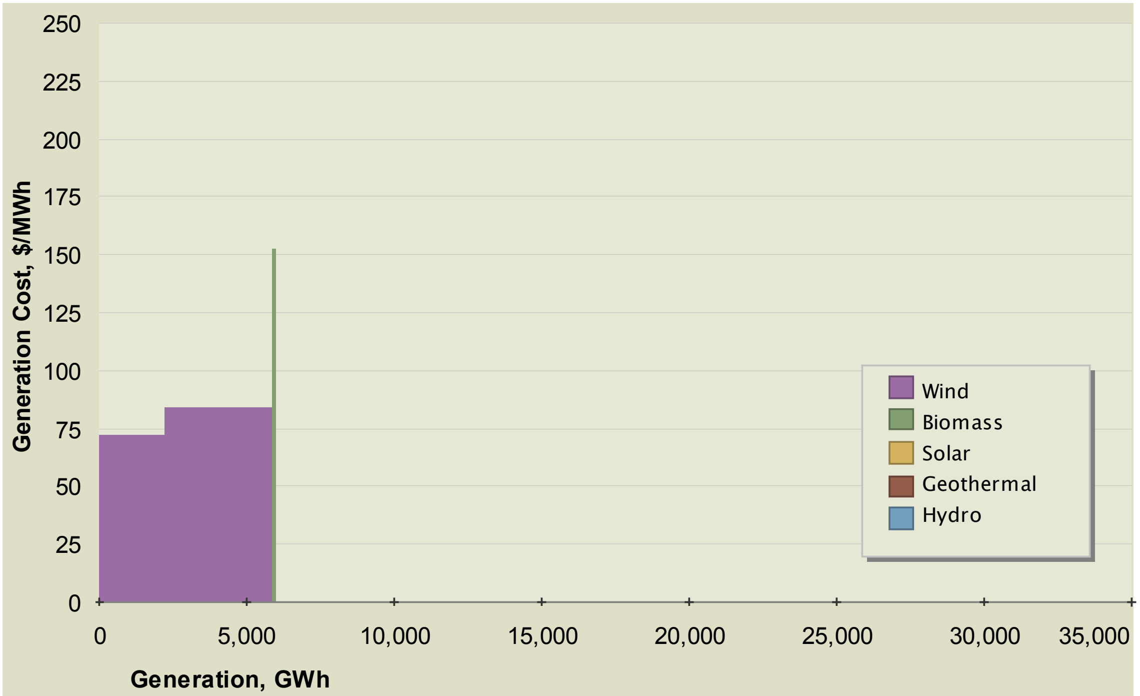

Figure A-53. WY_SO QRA Supply Curve.

Appendix B. QRA Capacity and Energy Summary Tables

Western Renewable Energy Zones
Qualified Resource Area (QRA)
Renewable Energy Resource Summary Tables
September 30, 2009

The following two sets of tables quantify the energy generating capacity in megawatts and the theoretical annual energy generation in gigawatt-hours per year for each of the following resources in each QRA: wind, solar, conventional discovered geothermal energy resources, run of river and large impoundment hydropower resources in Canada and incremental hydropower resources for the US. Undiscovered geothermal resources are quantified in each state for which data are available, but are not quantified in the QRA totals. Enhanced geothermal systems and other non-REZ resources are not quantified in these tables.

The first set of tables quantifies QRA capacity and annual energy generation after developability discounts have been applied to wind and solar resources. These are described in further depth in the WREZ Phase 1 QRA Identification Technical Report and in the notes below. The second set of tables quantifies QRA capacity and annual energy generation with no developability discounts applied to wind and solar.

Exclusions

Areas that by law or regulation are precluded from renewable energy development have been excluded. For example, renewable energy resources located inside national parks that lie inside QRA boundaries are not quantified here. Areas that fail to meet a number of technical criteria, such as terrain slope, have also been excluded from this analysis. The analysis has taken into account all avoid/exclude areas for which the E&L had data at the time of its completion. It has taken into account the effect of wildlife avoid and high sensitivity areas in three states, which requested that their wildlife avoid areas be excluded from the analysis: Colorado, Idaho, Oregon and Washington.

Developability Discounts

In addition to the environmental and land use exclusions mentioned above, various constraints, such as land ownership, the presence of structures, local zoning restrictions or other factors will limit the "developability" of renewable energy resources. For this reason, developability discounts were applied to total resource potential in the US to account for the likelihood that within any area, only a portion of the total resource potential is developable. After all other filters and exclusions have been applied, the remaining wind and solar resource potential are discounted to 25 and 3.5 percent of their total potential respectively. These discounts were not applied to Canadian resources, as the Canadian data had already taken similar factors into account.

These discounts are only applied in the first set of tables. They are not applied in the second set.

QRA Size Criteria

Areas must meet minimum and maximum size criteria in order to be considered QRAs. A QRA must be an area with a radius no greater than 100 miles and contain at least 1,500 MW of wind, solar or large hydropower after all exclusion criteria and developability discounts have been applied. QRAs that are composed largely of geothermal resources can be as small as 500 MW. A different methodology was used to quantify resource potential in Canada, so Canadian QRAs can be less than 1,500 MW.

QRA Labels

QRAs are labeled based on their state and the region of the state in which the majority of their area is located. Many QRAs overlap state boundaries. As a result, the totals for each state in the table below do not correspond exactly with the total MW quantified in that state in QRAs in the WREZ process.

NOTES:

[a] In the US, only the best classes of wind and solar resources in each state are quantified. In each state, only wind resources of that state's minimum wind power class and higher and solar resources of that state's minimum direct normal insolation level and higher are quantified. In Canada, renewable energy resources were quantified using a different methodology, which assessed resources on the site level, rather than using raw resource data so "best in state" criteria were not applied and Canadian resources were not discounted. For more information, please visit the public comment package Zone Identification and Technology Analysis working group web page.

[b] Undiscovered geothermal resources are believed to exist in certain areas because of the presence of geologic systems that have been correlated with geothermal resource potential in other areas. This undiscovered potential has not yet been quantified at specific locations where a geothermal plant could be built, but it can be estimated on the state level at different confidence intervals. As a result, these resources are not quantified at the QRA level or included in the economic modeling of QRAs. When undiscovered geothermal potential is believed to exist in a QRA, it will be noted even though it will not be quantified. The mean estimated potential from these resources by state is quantified in this table by state/province. It is not captured in the QRA MW total, because these resources are not being quantified at the QRA level. US estimates are from the USGS, and Canadian estimates are from CanGEA.

[c] Data on undiscovered geothermal resources were not available for Baja California Norte and Texas.

[d] Small and large hydropower was quantified in Canada. Incremental additions to powered or non-powered dams were quantified in the US.

[e] These resources may exist, but they were not quantified in this study.

[f] As noted above, a different resource assessment methodology was used to quantify the MW of renewable energy resources available in Canada. Data on the wind power class in British Columbia and Alberta were not available from this assessment. As a result, only the total MW

of wind resource is shown here, and these resources are not broken down into different wind class categories.

[g] British Columbia voluntarily provided a QRA hub on the British Columbia-Washington border to the WREZ process. This represents a 16,000 gigawatt-hour shaped energy product that British Columbia could provide to load serving entities (LSEs) at the border. The intention of this additional hub and associated cost curve is not to represent a specific product offered to LSEs at the border, but to illustrate the benefits of a shaped and firmed decarbonized energy product to encourage further discussion. This hub and its energy and production profile will be selectable in the GTM model. The energy resources that make up this cost curve are not specified, so they are not broken down by resource type or class here. The generation available from this additional QRA is not included in the BC subtotal or the grand total on this table.

QRA state/ prov	QRA Name	Solar thermal MW by DNI level (kWh/sqmtr/day)[a]						Wind MW by wind power class[a]				Geothermal MW		Hydro MW[d]	Biomass MW	Total MW
		6.5 - 6.75	6.75 - 7.0	7.0 - 7.25	7.25 - 7.5	7.5 +	SOLAR TOTAL	3	4	5 +	WIND TOTAL	Discov-ered	Undis-covered[b,c]			REZ-only
AZ	AZ_NE	[e]	[e]	[e]	309	0	309	3,305	137	57	3,499	0	[e]	0	256	4,064
AZ	AZ_NW	[e]	[e]	36	2,841	648	3,525	209	7	2	217	0	[e]	0	17	3,760
AZ	AZ_SO	[e]	[e]	[e]	6,623	0	6,623	[e]	[e]	[e]	[e]	0	[e]	0	8	6,631
AZ	AZ_WE	[e]	[e]	[e]	7,766	1,556	9,322	[e]	[e]	[e]	[e]	0	[e]	0	47	9,369
AZ Total		**0**	**0**	**36**	**17,539**	**2,204**	**19,780**	**3,514**	**144**	**59**	**3,717**	**0**	**1,043**	**0**	**327**	**23,824**
CA	CA_CT	[e]	[e]	500	891	868	2,259	1,162	207	41	1,410	0	[e]	0	11	3,680
CA	CA_EA	[e]	[e]	1,035	1,575	69	2,679	213	20	5	237	0	[e]	0	11	2,927
CA	CA_NE	[e]	[e]	1,213	2,862	602	4,676	489	74	2	565	0	[e]	0	0	5,241
CA	CA_SO	[e]	[e]	2,977	392	36	3,405	477	139	129	744	1,434	[e]	2	19	5,604
CA	CA_WE	[e]	[e]	508	1,331	1,212	3,050	1,261	825	1,000	3,085	0	[e]	0	106	6,241
CA Total		**0**	**0**	**6,232**	**7,051**	**2,786**	**16,069**	**3,602**	**1,264**	**1,176**	**6,042**	**1,434**	**11,340**	**2**	**147**	**23,693**
CO	CO_EA	[e]	[e]	0	0	0	0	[e]	2,445	0	2,445	0	[e]	0	7	2,452
CO	CO_NE	[e]	[e]	0	0	0	0	[e]	4,016	203	4,218	0	[e]	0	13	4,231
CO	CO_SE	[e]	[e]	0	0	0	0	[e]	8,777	36	8,813	0	[e]	0	16	8,829
CO	CO_SO	[e]	[e]	2,151	152	0	2,303	[e]	112	92	203	0	[e]	0	118	2,624
CO Total		**0**	**0**	**2,151**	**152**	**0**	**2,303**	**0**	**15,350**	**330**	**15,679**	**0**	**1,105**	**0**	**153**	**18,135**
ID	ID_EA	[e]	[e]	[e]	[e]	[e]	0	618	67	12	696	201	[e]	0	260	1,157
ID	ID_SW	[e]	[e]	[e]	[e]	[e]	0	893	13	1	907	128	[e]	8	98	1,141
ID Total		**0**	**0**	**0**	**0**	**0**	**0**	**1,510**	**80**	**13**	**1,603**	**329**	**1,872**	**8**	**358**	**2,299**
MT	MT_CT	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	2,527	2,527	0	[e]	0	77	2,604
MT	MT_NE	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	2,337	2,337	0	[e]	0	4	2,341
MT	MT_NW	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	5,194	5,194	0	[e]	0	66	5,261
MT Total		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**10,059**	**10,059**	**0**	**771**	**0**	**147**	**10,206**
NM	NM_CT	[e]	[e]	2,679	459	0	3,138	[e]	[e]	[e]	[e]	0	[e]	0	110	3,249
NM	NM_EA	[e]	[e]	83	0	0	83	[e]	9,857	1,433	11,290	0	[e]	0	44	11,418
NM	NM_SE	[e]	[e]	0	0	0	0	[e]	1,338	557	1,894	0	[e]	0	22	1,916
NM	NM_SO	[e]	[e]	3,128	1,219	0	4,347	[e]	[e]	[e]	[e]	0	[e]	0	12	4,359
NM	NM_SW	[e]	[e]	1,784	4,365	0	6,149	[e]	[e]	[e]	[e]	0	[e]	0	34	6,183
NM Total		**0**	**0**	**7,675**	**6,042**	**0**	**13,718**	**0**	**11,195**	**1,989**	**13,184**	**0**	**1,484**	**0**	**223**	**27,124**

CAPACITY (MW)

QRA state/ prov	QRA Name	Solar thermal MW by DNI level (kWh/sqmtr/day)[a]						Wind MW by wind power class[a]				Geothermal MW		Hydro MW[d]	Biomass MW	Total MW
		6.5 - 6.75	6.75 - 7.0	7.0 - 7.25	7.25 - 7.5	7.5 +	SOLAR TOTAL	3	4	5 +	WIND TOTAL	Discov-ered	Undis-covered[b,c]			REZ-only
NV	NV_EA	[e]	[e]	4,079	3,305	428	7,812	[e]	[e]	[e]	[e]	24	[e]	0	134	7,970
NV	NV_NO	[e]	[e]	[e]	[e]	[e]	[e]	[e]	[e]	[e]	[e]	1,088	[e]	2	133	1,223
NV	NV_SW	[e]	[e]	369	1,212	1,895	3,475	212	16	6	233	0	[e]	0	12	3,720
NV	NV_WE	[e]	[e]	2,142	4,207	946	7,294	160	27	12	198	296	[e]	0	22	7,810
NV Total		**0**	**0**	**6,590**	**8,724**	**3,268**	**18,582**	**371**	**42**	**18**	**431**	**1,408**	**4,364**	**2**	**300**	**20,723**
OR	OR_NE	[e]	[e]	[e]	[e]	[e]	[e]	1,476	464	104	2,043	0	[e]	0	388	2,431
OR	OR_SO	[e]	[e]	[e]	[e]	[e]	[e]	388	69	54	511	501	[e]	0	118	1,130
OR	OR_WE	[e]	[e]	[e]	[e]	[e]	[e]	196	90	57	343	331	[e]	3	140	817
OR Total		**0**	**0**	**0**	**0**	**0**	**0**	**2,059**	**623**	**215**	**2,897**	**832**	**1,893**	**3**	**646**	**4,378**
TX	TX	461	3,809	7	0	0	4,277	208	235	64	507	0	[e]	0	3	4,787
TX Total		**461**	**3,809**	**7**	**0**	**0**	**4,277**	**208**	**235**	**64**	**507**	**0**	**0**	**0**	**3**	**4,787**
UT	UT_WE	4,786	2,178	237	0	0	7,202	1,516	133	29	1,678	375	[e]	0	91	9,346
UT Total		**4,786**	**2,178**	**237**	**0**	**0**	**7,202**	**1,516**	**133**	**29**	**1,678**	**375**	**1,464**	**0**	**91**	**9,346**
WA	WA_SO	[e]	[e]	[e]	[e]	[e]	0	2,566	602	92	3,260	0	[e]	544	101	3,905
WA Total		**0**	**0**	**0**	**0**	**0**	**0**	**2,566**	**602**	**92**	**3,260**	**0**	**300**	**544**	**101**	**3,905**
WY	WY_EA	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	7,257	7,257	0	[e]	0	5	7,262
WY	WY_EC	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	2,594	2,594	0	[e]	0	0	2,594
WY	WY_NO	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	3,063	3,063	0	[e]	0	5	3,069
WY	WY_SO	[e]	[e]	[e]	[e]	[e]	0	[e]	615	1,324	1,939	0	[e]	0	6	1,945
WY Total		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**615**	**14,239**	**14,854**	**0**	**174**	**0**	**16**	**14,869**
AB	AB_EA	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	1,319	0	[e]	0	96	1,415
AB	AB_EC	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	700	0	[e]	0	122	822
AB	AB_NO	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	0	0	[e]	1,800	0	1,800
AB	AB_SE	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	2,410	0	[e]	0	51	2,461
AB Total		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4,429**	**0**	**0**	**1,800**	**268**	**6,497**
BC	BC_CT	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	902	0	[e]	4	122	1,027
BC	BC_EA	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	0	32	[e]	1,076	34	1,142
BC	BC_NE	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	4,081	16	[e]	1,006	109	5,212
BC	BC_NO	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	2,176	0	[e]	87	79	2,342

CAPACITY (MW)

QRA state/ prov	QRA Name	Solar thermal MW by DNI level (kWh/sqmtr/day)[a]						Wind MW by wind power class[a]				Geothermal MW		Hydro MW[d]	Biomass MW	Total MW
		6.5 - 6.75	6.75 - 7.0	7.0 - 7.25	7.25 - 7.5	7.5 +	SOLAR TOTAL	3	4	5 +	WIND TOTAL	Discov-ered	Undis-covered[b,c]			REZ-only
BC	BC_NW	e	e	e	e	e	0	f	f	f	1,285	32	e	572	85	1,974
BC	BC_SE	e	e	e	e	e	0	f	f	f	138	32	e	165	60	396
BC	BC_SHP	g	g	g	g	g	g	g	g	g	g	g	g	g	g	3,000[g]
BC	BC_SO	e	e	e	e	e	0	f	f	f	2,300	32	e	196	109	2,638
BC	BC_SW	e	e	e	e	e	0	f	f	f	1,744	16	e	198	162	2,119
BC	BC_WC	e	e	e	e	e	0	f	f	f	0	180	e	2,737	127	3,044
BC	BC_WE	e	e	e	e	e	0	f	f	f	1,318	0	e	50	53	1,421
BC Total		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**13,943**	**340**	**0**	**6,092**	**939**	**21,315**
BJ	BJ_NO	e	e	3,015	952	13	3,980	e	758	925	1,684	0	e	e	e	5,664
BJ	BJ_SO	e	e	439	523	50	1,012	e	614	639	1,253	0	e	e	e	2,264
BJ Total		**0**	**0**	**3,454**	**1,475**	**63**	**4,991**	**0**	**1,372**	**1,564**	**2,937**	**0**	**0**	**0**	**0**	**7,928**
Grand Total		***5,247***	***5,988***	***26,382***	***40,982***	***8,322***	***86,921***	***15,347***	***31,654***	***29,846***	***95,219***	***4,718***	***25,810***	***8,452***	***3,720***	***199,029***

QRA state/ prov	QRA Name	Solar thermal GWh/yr by DNI level (kWh/sqmtr/day)[a]						Wind GWh/yr by wind power class[a]				Geothermal GWh/yr		Hydro GWh/yr[d]	Biomass GWh/yr	Total GWh/yr
		6.5 - 6.75	6.75 - 7.0	7.0 - 7.25	7.25 - 7.5	7.5 +	SOLAR TOTAL	3	4	5 +	WIND TOTAL	Discov-ered	Undis-covered[b,c]			REZ-only
AZ	AZ_NE	[e]	[e]	[e]	696	0	696	8,107	371	182	8,661	0	[e]	0	1,903	11,260
AZ	AZ_NW	[e]	[e]	84	6,595	1,505	8,184	512	19	5	536	0	[e]	0	127	8,847
AZ	AZ_SO	[e]	[e]	[e]	15,607	0	15,607	[e]	[e]	[e]	[e]	0	[e]	0	59	15,665
AZ	AZ_WE	[e]	[e]	[e]	18,912	3,790	22,702	[e]	[e]	[e]	[e]	0	[e]	0	350	23,051
AZ Total		**0**	**0**	**84.3247**	**41,809**	**5,295**	**47,188**	**8,619**	**390**	**188**	**9,197**	**0**	**7,309**	**0**	**2,438**	**58,824**
CA	CA_CT	[e]	[e]	1,191	2,123	2,069	5,383	2,850	561	134	3,545	0	[e]	0	83	9,011
CA	CA_EA	[e]	[e]	2,375	3,615	158	6,148	522	53	14	589	0	[e]	0	83	6,821
CA	CA_NE	[e]	[e]	2,836	6,693	1,407	10,937	1,199	202	7	1,407	0	[e]	0		12,344
CA	CA_SO	[e]	[e]	6,937	915	83	7,934	1,170	376	429	1,976	11,074	[e]	8	142	21,134
CA	CA_WE	[e]	[e]	1,139	2,984	2,717	6,840	3,093	2,239	3,282	8,615	0	[e]	0	786	16,241
CA Total		**0**	**0**	**14,477**	**16,330**	**6,434**	**37,241**	**8,834**	**3,432**	**3,867**	**16,132**	**11,074**	**79,471**	**8**	**1,095**	**65,550**
CO	CO_EA	[e]	[e]	0	0	0	0	[e]	6,640	0	6,640	0	[e]	0	50	6,689
CO	CO_NE	[e]	[e]	0	0	0	0	[e]	10,904	623	11,527	0	[e]	0	94	11,621
CO	CO_SE	[e]	[e]	0	0	0	0	[e]	23,836	109	23,944	0	[e]	0	120	24,065
CO	CO_SO	[e]	[e]	4,617	326	0	4,943	[e]	303	299	602	0	[e]	0	875	6,421
CO Total		**0**	**0**	**4,617**	**326**	**0**	**4,943**	**0**	**41,683**	**1,031**	**42,714**	**0**	**7,744**	**0**	**1,139**	**48,796**
ID	ID_EA	[e]	[e]	[e]	[e]	[e]	0	1,515	182	38	1,735	1,448	[e]	0	1,936	5,119
ID	ID_SW	[e]	[e]	[e]	[e]	[e]	0	2,189	36	4	2,229	897	[e]		728	3,854
ID Total		**0**	**0**	**0**	**0**	**0**	**0**	**3,705**	**217**	**43**	**3,965**	**2,345**	**13,119**	**0**	**2,663**	**8,973**
MT	MT_CT	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	8,224	8,224	0	[e]	0	570	8,794
MT	MT_NE	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	7,429	7,429	0	[e]	0	32	7,461
MT	MT_NW	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	16,932	16,932	0	[e]	0	494	17,427
MT Total		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**32,585**	**32,585**	**0**	**5,403**	**0**	**1,097**	**33,682**
NM	NM_CT	[e]	[e]	6,126	1,049	0	7,175	[e]	[e]	[e]	[e]	0	[e]	0	823	7,998
NM	NM_EA	[e]	[e]	183	0	0	183	[e]	26,768	4,427	31,196	0	[e]	0	330	31,708
NM	NM_SE	[e]	[e]	0	0	0	0	[e]	3,632	1,748	5,381	0	[e]	0	162	5,542
NM	NM_SO	[e]	[e]	7,317	2,850	0	10,167	[e]	[e]	[e]	[e]	0	[e]	0	92	10,258
NM	NM_SW	[e]	[e]	4,298	10,515	0	14,814	[e]	[e]	[e]	[e]	0	[e]	0	254	15,067

ENERGY (GWh/yr)

QRA state/ prov	QRA Name	Solar thermal GWh/yr by DNI level (kWh/sqmtr/day)[a]						Wind GWh/yr by wind power class[a]				Geothermal GWh/yr		Hydro GWh/yr[d]	Biomass GWh/yr	Total GWh/yr
		6.5 - 6.75	6.75 - 7.0	7.0 - 7.25	7.25 - 7.5	7.5 +	SOLAR TOTAL	3	4	5 +	WIND TOTAL	Discov-ered	Undis-covered[b,c]			REZ-only
NM Total		**0**	**0**	**17,924**	**14,414**	**0**	**32,338**	**0**	**30,400**	**6,176**	**36,576**	**0**	**10,400**	**0**	**1,659**	**70,573**
NV	NV_EA	[e]	[e]	9,076	7,354	952	17,382	[e]	[e]	[e]	[e]	168	[e]	0	995	18,546
NV	NV_NO	[e]	[e]	[e]	[e]	[e]	[e]	[e]	[e]	[e]	[e]	7,799	[e]	9	991	8,799
NV	NV_SW	[e]	[e]	840	2,760	4,316	7,916	520	42	19	581	0	[e]	0	88	8,584
NV	NV_WE	[e]	[e]	4,916	9,655	2,170	16,741	391	73	39	503	2,074	[e]	0	161	19,479
NV Total		**0**	**0**	**14,832**	**19,769**	**7,438**	**42,039**	**911**	**115**	**58**	**1,083**	**10,041**	**30,583**	**9**	**2,235**	**55,408**
OR	OR_NE	[e]	[e]	[e]	[e]	[e]	[e]	3,619	1,259	325	5,204	0	[e]	0	2,892	8,095
OR	OR_SO	[e]	[e]	[e]	[e]	[e]	[e]	951	188	181	1,320	3,550	[e]	0	876	5,747
OR	OR_WE	[e]	[e]	[e]	[e]	[e]	[e]	481	244	191	916	2,596	[e]	16	1,040	4,567
OR Total		**0**	**0**	**0**	**0**	**0**	**0**	**5,051**	**1,691**	**698**	**7,439**	**6,146**	**13,266**	**16**	**4,808**	**18,409**
TX	TX	1,001	8,275	15	0	0	9,291	510	639	197	1,346	0	[e]	0	26	10,663
TX Total		**1,001**	**8,275**	**15**	**0**	**0**	**9,291**	**510**	**639**	**197**	**1,346**	**0**	**0**	**0**	**26**	**10,663**
UT	UT_WE	10,147	4,618	503	0	0	15,268	3,718	361	95	4,174	2,702	[e]	0	674	22,818
UT Total		**10,147**	**4,618**	**503**	**0**	**0**	**15,268**	**3,718**	**361**	**95**	**4,174**	**2,702**	**10,260**	**0**	**674**	**22,818**
WA	WA_SO	[e]	[e]	[e]	[e]	[e]	0	6,295	1,635	295	8,225	0	[e]	2,531	754	11,509
WA Total		**0**	**0**	**0**	**0**	**0**	**0**	**6,295**	**1,635**	**295**	**8,225**	**0**	**2,102**	**2,531**	**754**	**11,509**
WY	WY_EA	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	24,570	24,570	0	[e]	0	35	24,605
WY	WY_EC	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	8,801	8,801	0	[e]	0	0	8,801
WY	WY_NO	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	9,606	9,606	0	[e]	0	41	9,647
WY	WY_SO	[e]	[e]	[e]	[e]	[e]	0	[e]	1,670	4,457	6,126	0	[e]	0	41	6,168
WY Total		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1,670**	**47,434**	**49,104**	**0**	**1,219**	**0**	**117**	**49,221**
AB	AB_EA	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	4,044	0	[e]	0	713	4,757
AB	AB_EC	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	2,146	0	[e]	0	907	3,053
AB	AB_NO	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	0	0	[e]	6,307	1	6,308
AB	AB_SE	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	7,389	0	[e]	0	376	7,765
AB Total		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**13,579**	**0**	**0**	**6,307**	**1,997**	**21,883**
BC	BC_CT	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	1,953	0	[e]	10	905	2,868
BC	BC_EA	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	0	224	[e]	437	250	911

ENERGY (GWh/yr)

QRA state/ prov	QRA Name	Solar thermal GWh/yr by DNI level (kWh/sqmtr/day)[a]						Wind GWh/yr by wind power class[a]				Geothermal GWh/yr		Hydro GWh/yr[d]	Biomass GWh/yr	Total GWh/yr
		6.5 - 6.75	6.75 - 7.0	7.0 - 7.25	7.25 - 7.5	7.5 +	SOLAR TOTAL	3	4	5 +	WIND TOTAL	Discov-ered	Undis-covered[b,c]			REZ-only
BC	BC_NE	e	e	e	e	e	0	f	f	f	11,389	112	e	4,953	811	17,265
BC	BC_NO	e	e	e	e	e	0	f	f	f	5,730	0	e	420	588	6,738
BC	BC_NW	e	e	e	e	e	0	f	f	f	3,159	224	e	1,984	632	5,999
BC	BC_SE	e	e	e	e	e	0	f	f	f	252	224	e	508	447	1,432
BC	BC_SHPD	g	g	g	g	g	g	g	g	g	g	g	g	g	g	15,797[g]
BC	BC_SO	e	e	e	e	e	0	f	f	f	4,786	224	e	630	815	6,455
BC	BC_SW	e	e	e	e	e	0	f	f	f	3,630	112	e	717	1,204	5,663
BC	BC_WC	e	e	e	e	e	0	f	f	f	0	1,419	e	12,546	949	14,914
BC	BC_WE	e	e	e	e	e	0	f	f	f	3,205	0	e	167	393	3,766
BC Total		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**34,104**	**2,540**	**0**	**22,372**	**6,994**	**66,010**
BJ	BJ_NO	e	e	7,026	2,218	30	9,274	e	2,058	3,110	5,169	0	e	e	e	14,443
BJ	BJ_SO	e	e	1,022	1,218	117	2,357	e	1,668	2,078	3,745	0	e	e	e	6,102
BJ Total		**0**	**0**	**8,048**	**3,436**	**146**	**11,631**	**0**	**3,726**	**5,188**	**8,915**	**0**	**0**	**0**	**0**	**20,545**
Grand Total		***11,147***	***12,893***	***60,500***	***96,085***	***19,313***	***199,939***	***37,642***	***85,959***	***97,853***	***269,138***	***34,849***	***180,876***	***31,243***	***27,698***	***562,867***

ENERGY (GWh/yr)

QRA state/ prov	QRA Name	Solar thermal MW by DNI level (kWh/sqmtr/day)[a]						Wind MW by wind power class[a]				Geothermal MW		Hydro MW[d]	Biomass MW	Total MW
		6.5 - 6.75	6.75 - 7.0	7.0 - 7.25	7.25 - 7.5	7.5 +	SOLAR TOTAL	3	4	5 +	WIND TOTAL	Discov-ered	Undis-covered[b,c]			WREZ-only
AZ	AZ_NE	[e]	[e]	[e]	8,836	0	8,836	13,222	546	229	13,997	0	[e]	0	256	23,088
AZ	AZ_NW	[e]	[e]	1,038	81,166	18,522	100,726	835	28	7	869	0	[e]	0	17	101,612
AZ	AZ_SO	[e]	[e]	[e]	189,226	0	189,226	[e]	[e]	[e]	0	0	[e]	0	8	189,234
AZ	AZ_WE	[e]	[e]	[e]	221,882	44,463	266,344	[e]	[e]	[e]	0	0	[e]	0	47	266,391
AZ Total		**0**	**0**	**1,038**	**501,110**	**62,985**	**565,132**	**14,056**	**574**	**236**	**14,866**	**0**	**1,043**	**0**	**327**	**580,326**
CA	CA_CT	[e]	[e]	14,277	25,463	24,807	64,546	4,647	827	165	5,639	0	[e]	0	11	70,196
CA	CA_EA	[e]	[e]	29,562	45,005	1,966	76,533	851	79	18	947	0	[e]	0	11	77,491
CA	CA_NE	[e]	[e]	34,648	81,759	17,193	133,599	1,955	297	9	2,260	0	[e]	0	0	135,860
CA	CA_SO	[e]	[e]	85,053	11,214	1,015	97,282	1,909	554	515	2,978	1,434	[e]	2	19	101,714
CA	CA_WE	[e]	[e]	14,507	38,018	34,618	87,143	5,045	3,298	3,999	12,342	0	[e]	0	106	99,590
CA Total		**0**	**0**	**178,046**	**201,458**	**79,598**	**459,103**	**14,406**	**5,055**	**4,705**	**24,166**	**1,434**	**11,340**	**2**	**147**	**484,851**
CO	CO_EA	[e]	[e]	0	0	0	0	[e]	9,780	0	9,780	0	[e]	0	7	9,787
CO	CO_NE	[e]	[e]	0	0	0	0	[e]	16,062	810	16,872	0	[e]	0	13	16,885
CO	CO_SE	[e]	[e]	0	0	0	0	[e]	35,109	142	35,251	0	[e]	0	16	35,267
CO	CO_SO	[e]	[e]	61,462	4,340	0	65,802	[e]	447	366	813	0	[e]	0	118	66,732
CO Total		**0**	**0**	**61,462**	**4,340**	**0**	**65,802**	**0**	**61,398**	**1,319**	**62,717**	**0**	**1,105**	**0**	**153**	**128,672**
ID	ID_EA	[e]	[e]	[e]	[e]	[e]	0	2,471	267	47	2,786	201	[e]	0	260	3,247
ID	ID_SW	[e]	[e]	[e]	[e]	[e]	0	3,570	52	5	3,628	128	[e]	8	98	3,862
ID Total		**0**	**0**	**0**	**0**	**0**	**0**	**6,042**	**320**	**52**	**6,414**	**329**	**1,872**	**8**	**358**	**7,109**
MT	MT_CT	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	10,109	10,109	0	[e]	0	77	10,185
MT	MT_NE	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	9,349	9,349	0	[e]	0	4	9,353
MT	MT_NW	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	20,777	20,777	0	[e]	0	66	20,844
MT Total		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**40,235**	**40,235**	**0**	**771**	**0**	**147**	**40,382**
NM	NM_CT	[e]	[e]	76,554	13,111	0	89,665	[e]	[e]	[e]	0	0	[e]	0	110	89,775
NM	NM_EA	[e]	[e]	2,382	0	0	2,382	[e]	39,429	5,731	45,160	0	[e]	0	44	47,586
NM	NM_SE	[e]	[e]	0	0	0	0	[e]	5,350	2,226	7,576	0	[e]	0	22	7,598
NM	NM_SO	[e]	[e]	89,376	34,814	0	124,191	[e]	[e]	[e]	0	0	[e]	0	12	124,203
NM	NM_SW	[e]	[e]	50,980	124,714	0	175,694	[e]	[e]	[e]	0	0	[e]	0	34	175,728
NM Total		**0**	**0**	**219,292**	**172,639**	**0**	**391,931**	**0**	**44,779**	**7,957**	**52,736**	**0**	**1,484**	**0**	**223**	**444,890**
NV	NV_EA	[e]	[e]	116,549	94,428	12,229	223,205	[e]	[e]	[e]	0	24	[e]	0	134	223,363
NV	NV_NO	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	[e]	0	1,088	[e]	2	133	1,223
NV	NV_SW	[e]	[e]	10,539	34,621	54,137	99,297	847	62	23	933	0	[e]	0	12	100,242
NV	NV_WE	[e]	[e]	61,195	120,194	27,017	208,405	638	107	47	792	296	[e]	0	22	209,515
NV Total		**0**	**0**	**188,283**	**249,243**	**93,382**	**530,908**	**1,485**	**169**	**70**	**1,725**	**1,408**	**4,364**	**2**	**300**	**534,343**
OR	OR_NE	[e]	[e]	[e]	[e]	[e]	[e]	5,902	1,855	414	8,172	0	[e]	0	388	8,560
OR	OR_SO	[e]	[e]	[e]	[e]	[e]	[e]	1,551	276	216	2,044	501	[e]	0	118	2,662
OR	OR_WE	[e]	[e]	[e]	[e]	[e]	[e]	784	359	230	1,372	331	[e]	3	140	1,847

CAPACITY (MW)
Solar and Wind Not Discounted

QRA state/ prov	QRA Name	Solar thermal MW by DNI level (kWh/sqmtr/day)[a]						Wind MW by wind power class[a]				Geothermal MW		Hydro MW[d]	Biomass MW	Total MW
		6.5 - 6.75	6.75 - 7.0	7.0 - 7.25	7.25 - 7.5	7.5 +	SOLAR TOTAL	3	4	5 +	WIND TOTAL	Discov-ered	Undis-covered[b,c]			WREZ-only
OR Total		**0**	**0**	**0**	**0**	**0**	**0**	**8,237**	**2,490**	**860**	**11,588**	**832**	**1,893**	**3**	**646**	**13,069**
TX	TX	13,162	108,834	196	0	0	122,192	832	942	255	2,029	0	[e]	0	3	124,224
TX Total		**13,162**	**108,834**	**196**	**0**	**0**	**122,192**	**832**	**942**	**255**	**2,029**	**0**	**0**	**0**	**3**	**124,224**
UT	UT_WE	136,753	62,240	6,783	0	0	205,776	6,063	532	117	6,712	375	[e]	0	91	212,954
UT Total		**136,753**	**62,240**	**6,783**	**0**	**0**	**205,776**	**6,063**	**532**	**117**	**6,712**	**375**	**1,464**	**0**	**91**	**212,954**
WA	WA_SO	[e]	[e]	[e]	[e]	[e]	0	10,266	2,408	367	13,040	0	[e]	544	101	13,685
WA Total		**0**	**0**	**0**	**0**	**0**	**0**	**10,266**	**2,408**	**367**	**13,040**	**0**	**300**	**544**	**101**	**13,685**
WY	WY_EA	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	29,028	29,028	0	[e]	0	5	29,033
WY	WY_EC	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	10,376	10,376	0	[e]	0	0	10,376
WY	WY_NO	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	12,253	12,253	0	[e]	0	5	12,258
WY	WY_SO	[e]	[e]	[e]	[e]	[e]	0	[e]	2,459	5,298	7,757	0	[e]	0	6	7,763
WY Total		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2,459**	**56,955**	**59,415**	**0**	**174**	**0**	**16**	**59,430**
AB	AB_EA	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	1,319	0	[e]	0	96	1,415
AB	AB_EC	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	700	0	[e]	0	122	822
AB	AB_NO	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	0	0	[e]	1,800	0	1,800
AB	AB_SE	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	2,410	0	[e]	0	51	2,461
AB Total		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4,429**	**0**	**0**	**1,800**	**268**	**6,497**
BC	BC_CT	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	902	0	[e]	4	122	1,027
BC	BC_EA	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	0	32	[e]	1,076	34	1,142
BC	BC_NE	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	4,081	16	[e]	1,006	109	5,212
BC	BC_NO	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	2,176	0	[e]	87	79	2,342
BC	BC_NW	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	1,285	32	[e]	572	85	1,974
BC	BC_SE	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	138	32	[e]	165	60	396
BC	BC_SHPD	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	3,000[g]
BC	BC_SO	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	2,300	32	[e]	196	109	2,638
BC	BC_SW	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	1,744	16	[e]	198	162	2,119
BC	BC_WC	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	0	180	[e]	2,737	127	3,044
BC	BC_WE	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	1,318	0	[e]	50	53	1,421
BC Total		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**13,943**	**340**	**0**	**6,092**	**939**	**21,315**
BJ	BJ_NO	[e]	[e]	86,153	27,193	363	113,709	[e]	3,032	3,702	6,734	0	[e]	[e]	[e]	120,442
BJ	BJ_SO	[e]	[e]	12,531	14,939	1,432	28,902	[e]	2,456	2,555	5,011	0	[e]	[e]	[e]	33,914
BJ Total		**0**	**0**	**98,684**	**42,132**	**1,795**	**142,611**	**0**	**5,488**	**6,257**	**11,745**	**0**	**0**	**0**	**0**	**154,356**
Grand Total		***149,915***	***171,075***	***753,784***	***1,170,922***	***237,760***	***2,483,456***	***245,546***	***506,460***	***477,538***	***325,758***	***4,718***	***25,810***	***8,452***	***3,720***	***2,826,103***

CAPACITY (MW)
Solar and Wind Not Discounted

QRA state/ prov	QRA Name	Solar thermal GWh/yr by DNI level (kWh/sqmtr/day)[a]						Wind GWh/yr by wind power class[a]				Geothermal GWh/yr		Hydro GWh/yr[d]	Biomass GWh/yr	Total GWh/yr
		6.5 - 6.75	6.75 - 7.0	7.0 - 7.25	7.25 - 7.5	7.5 +	SOLAR TOTAL	3	4	5 +	WIND TOTAL	Discov-ered	Undis-covered[b,c]			WREZ-only
AZ	AZ_NE	[e]	[e]	[e]	19,892	0	19,892	32,430	1,484	729	34,643	0	[e]	0	1,903	56,439
AZ	AZ_NW	[e]	[e]	2,409	188,418	42,998	233,825	2,047	75	22	2,144	0	[e]	0	127	236,096
AZ	AZ_SO	[e]	[e]	[e]	445,901	0	445,901	[e]	[e]	[e]	[e]	0	[e]	0	59	445,960
AZ	AZ_WE	[e]	[e]	[e]	540,344	108,279	648,623	[e]	[e]	[e]	[e]	0	[e]	0	350	648,973
AZ Total		**0**	**0**	**2,409**	**1,194,555**	**151,276**	**1,348,241**	**34,477**	**1,559**	**751**	**36,788**	**0**	**7,309**	**0**	**2,438**	**1,387,467**
CA	CA_CT	[e]	[e]	34,017	60,671	59,107	153,796	11,399	2,245	535	14,179	0	[e]	0	83	168,058
CA	CA_EA	[e]	[e]	67,848	103,291	4,512	175,651	2,086	214	57	2,358	0	[e]	0	83	178,093
CA	CA_NE	[e]	[e]	81,038	191,228	40,212	312,478	4,794	807	28	5,629	0	[e]	0		318,106
CA	CA_SO	[e]	[e]	198,188	26,131	2,364	226,683	4,682	1,504	1,718	7,904	11,074	[e]	8	142	245,811
CA	CA_WE	[e]	[e]	32,532	85,257	77,634	195,423	12,374	8,957	13,130	34,461	0	[e]	0	786	230,670
CA Total		**0**	**0**	**413,624**	**466,577**	**183,830**	**1,064,031**	**35,335**	**13,727**	**15,467**	**64,530**	**11,074**	**79,471**	**8**	**1,095**	**1,140,737**
CO	CO_EA	[e]	[e]	0	0	0	0	[e]	26,560	0	26,560	0	[e]	0	50	26,609
CO	CO_NE	[e]	[e]	0	0	0	0	[e]	43,618	2,491	46,109	0	[e]	0	94	46,203
CO	CO_SE	[e]	[e]	0	0	0	0	[e]	95,343	435	95,778	0	[e]	0	120	95,898
CO	CO_SO	[e]	[e]	131,910	9,314	0	141,224	[e]	1,213	1,196	2,410	0	[e]	0	875	144,509
CO Total		**0**	**0**	**131,910**	**9,314**	**0**	**141,224**	**0**	**166,733**	**4,123**	**170,857**	**0**	**7,744**	**0**	**1,139**	**313,220**
ID	ID_EA	[e]	[e]	[e]	[e]	[e]	0	6,062	726	154	6,942	1,448	[e]	0	1,936	10,325
ID	ID_SW	[e]	[e]	[e]	[e]	[e]	0	8,757	142	17	8,917	897	[e]		728	10,541
ID Total		**0**	**0**	**0**	**0**	**0**	**0**	**14,819**	**868**	**171**	**15,858**	**2,345**	**13,119**	**0**	**2,663**	**20,867**
MT	MT_CT	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	32,894	32,894	0	[e]	0	570	33,465
MT	MT_NE	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	29,715	29,715	0	[e]	0	32	29,747
MT	MT_NW	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	67,729	67,729	0	[e]	0	494	68,223
MT Total		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**130,338**	**130,338**	**0**	**5,403**	**0**	**1,097**	**131,435**
NM	NM_CT	[e]	[e]	175,030	29,976	0	205,006	[e]	[e]	[e]	[e]	0	[e]	0	823	205,829
NM	NM_EA	[e]	[e]	5,216	0	0	5,216	[e]	107,072	17,710	124,782	0	[e]	0	330	130,328
NM	NM_SE	[e]	[e]	0	0	0	0	[e]	14,528	6,994	21,522	0	[e]	0	162	21,684
NM	NM_SO	[e]	[e]	209,043	81,428	0	290,472	[e]	[e]	[e]	[e]	0	[e]	0	92	290,563
NM	NM_SW	[e]	[e]	122,811	300,436	0	423,247	[e]	[e]	[e]	[e]	0	[e]	0	254	423,501
NM Total		**0**	**0**	**512,100**	**411,840**	**0**	**923,941**	**0**	**121,601**	**24,704**	**146,304**	**0**	**10,400**	**0**	**1,659**	**1,071,904**
NV	NV_EA	[e]	[e]	259,326	210,106	27,210	496,641	[e]	[e]	[e]	[e]	168	[e]	0	995	497,804
NV	NV_NO	[e]	[e]	[e]	[e]	[e]	[e]	[e]	[e]	[e]	[e]	7,799	[e]	9	991	8,799
NV	NV_SW	[e]	[e]	24,004	78,854	123,302	226,160	2,079	168	75	2,322	0	[e]	0	88	228,570
NV	NV_WE	[e]	[e]	140,450	275,859	62,007	478,315	1,565	291	156	2,012	2,074	[e]	0	161	482,561
NV Total		**0**	**0**	**423,779**	**564,818**	**212,518**	**1,201,115**	**3,643**	**459**	**231**	**4,334**	**10,041**	**30,583**	**9**	**2,235**	**1,217,735**
OR	OR_NE	[e]	[e]	[e]	[e]	[e]	[e]	14,477	5,037	1,300	20,814	0	[e]	0	2,892	23,706
OR	OR_SO	[e]	[e]	[e]	[e]	[e]	[e]	3,804	751	725	5,280	3,550	[e]	0	876	9,706
OR	OR_WE	[e]	[e]	[e]	[e]	[e]	[e]	1,922	975	766	3,663	2,596	[e]	16	1,040	7,315

ENERGY (GWh/yr)
Solar and Wind Not Discounted

QRA state/ prov	QRA Name	Solar thermal GWh/yr by DNI level (kWh/sqmtr/day)[a]						Wind GWh/yr by wind power class[a]				Geothermal GWh/yr		Hydro GWh/yr[d]	Biomass GWh/yr	Total GWh/yr
		6.5 - 6.75	6.75 - 7.0	7.0 - 7.25	7.25 - 7.5	7.5 +	SOLAR TOTAL	3	4	5 +	WIND TOTAL	Discov-ered	Undis-covered[b,c]			WREZ-only
OR Total		**0**	**0**	**0**	**0**	**0**	**0**	**20,203**	**6,763**	**2,791**	**29,757**	**6,146**	**13,266**	**16**	**4,808**	**40,727**
TX	TX	28,593	236,440	426	0	0	265,460	2,041	2,558	786	5,385	0	[e]	0	26	270,871
TX Total		**28,593**	**236,440**	**426**	**0**	**0**	**265,460**	**2,041**	**2,558**	**786**	**5,385**	**0**	**0**	**0**	**26**	**270,871**
UT	UT_WE	289,905	131,945	14,380	0	0	436,230	14,870	1,445	381	16,697	2,702	[e]	0	674	456,302
UT Total		**289,905**	**131,945**	**14,380**	**0**	**0**	**436,230**	**14,870**	**1,445**	**381**	**16,697**	**2,702**	**10,260**	**0**	**674**	**456,302**
WA	WA_SO	[e]	[e]	[e]	[e]	[e]	0	25,179	6,538	1,181	32,898	0	[e]	2,531	754	36,183
WA Total		**0**	**0**	**0**	**0**	**0**	**0**	**25,179**	**6,538**	**1,181**	**32,898**	**0**	**2,102**	**2,531**	**754**	**36,183**
WY	WY_EA	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	98,281	98,281	0	[e]	0	35	98,316
WY	WY_EC	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	35,205	35,205	0	[e]	0	0	35,205
WY	WY_NO	[e]	[e]	[e]	[e]	[e]	0	[e]	[e]	38,425	38,425	0	[e]	0	41	38,466
WY	WY_SO	[e]	[e]	[e]	[e]	[e]	0	[e]	6,679	17,827	24,506	0	[e]	0	41	24,547
WY Total		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**6,679**	**189,738**	**196,417**	**0**	**1,219**	**0**	**117**	**196,534**
AB	AB_EA	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	4,044	0	[e]	0	713	4,757
AB	AB_EC	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	2,146	0	[e]	0	907	3,053
AB	AB_NO	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	0	0	[e]	6,307	1	6,308
AB	AB_SE	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	7,389	0	[e]	0	376	7,765
AB Total		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**13,579**	**0**	**0**	**6,307**	**1,997**	**21,883**
BC	BC_CT	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	1,953	0	[e]	10	905	2,868
BC	BC_EA	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	0	224	[e]	437	250	911
BC	BC_NE	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	11,389	112	[e]	4,953	811	17,265
BC	BC_NO	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	5,730	0	[e]	420	588	6,738
BC	BC_NW	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	3,159	224	[e]	1,984	632	5,999
BC	BC_SE	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	252	224	[e]	508	447	1,432
BC	BC_SHPD	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	15,797[g]
BC	BC_SO	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	4,786	224	[e]	630	815	6,455
BC	BC_SW	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	3,630	112	[e]	717	1,204	5,663
BC	BC_WC	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	0	1,419	[e]	12,546	949	14,914
BC	BC_WE	[e]	[e]	[e]	[e]	[e]	0	[f]	[f]	[f]	3,205	0	[e]	167	393	3,766
BC Total		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**34,104**	**2,540**	**0**	**22,372**	**6,994**	**66,010**
BJ	BJ_NO	[e]	[e]	200,750	63,363	846	264,959	[e]	8,234	12,440	20,674	0	[e]	[e]	[e]	285,633
BJ	BJ_SO	[e]	[e]	29,200	34,811	3,336	67,347	[e]	6,671	8,310	14,981	0	[e]	[e]	[e]	82,328
BJ Total		**0**	**0**	**229,950**	**98,174**	**4,182**	**332,306**	**0**	**14,904**	**20,751**	**35,655**	**0**	**0**	**0**	**0**	**367,961**
Grand Total		***318,499***	***368,385***	***1,728,578***	***2,745,280***	***551,806***	***5,712,547***	***150,569***	***343,836***	***391,412***	***933,500***	***34,849***	***180,876***	***31,243***	***27,698***	***6,739,837***

ENERGY (GWh/yr)
Solar and Wind Not Discounted

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14. ABSTRACT *(Maximum 200 Words)*
This report describes the Western Renewable Energy Zones (WREZ) Initiative Phase 1 Qualified Resource Area identification process, including the identification and economic analysis of Qualified Resource Areas (QRAs) and “non-REZ” resources. These data and analyses will assist the Western US in its renewable energy transmission planning goals. The economic analysis in this report produced the input data for the WREZ Generation and Transmission model, which is a screening-level model to determine the optimal routing for and cost of delivering renewable energy from QRAs to load centers throughout the Western Interconnection. In June 2009, the Western Governors’ Association accepted the Western Governors’ Association WREZ Phase 1 Report in which the QRAs were mapped and the entire WREZ Phase 1 process was explained in general. That same month the Lawrence Berkeley National Laboratory released the WREZ Generation and Transmission Model (GTM), which was also developed by Black & Veatch. This report details the assumptions and methodologies that were used to produce the maps and resource analyses in the WGA report as well as the economic data used by the WREZ GTM. This report also provides the results of the non-REZ resource analysis for the first time in the WREZ initiative.

15. SUBJECT TERMS
Western Renewable Energy Zones; WREZ; qualified resource areas; QRAs; Western Governors' Association; Generation and Transmission Model; NREL; Lawrence Berkeley National Laboratory; LBNL; renewable energy resources; transmission; Black & Veatch

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