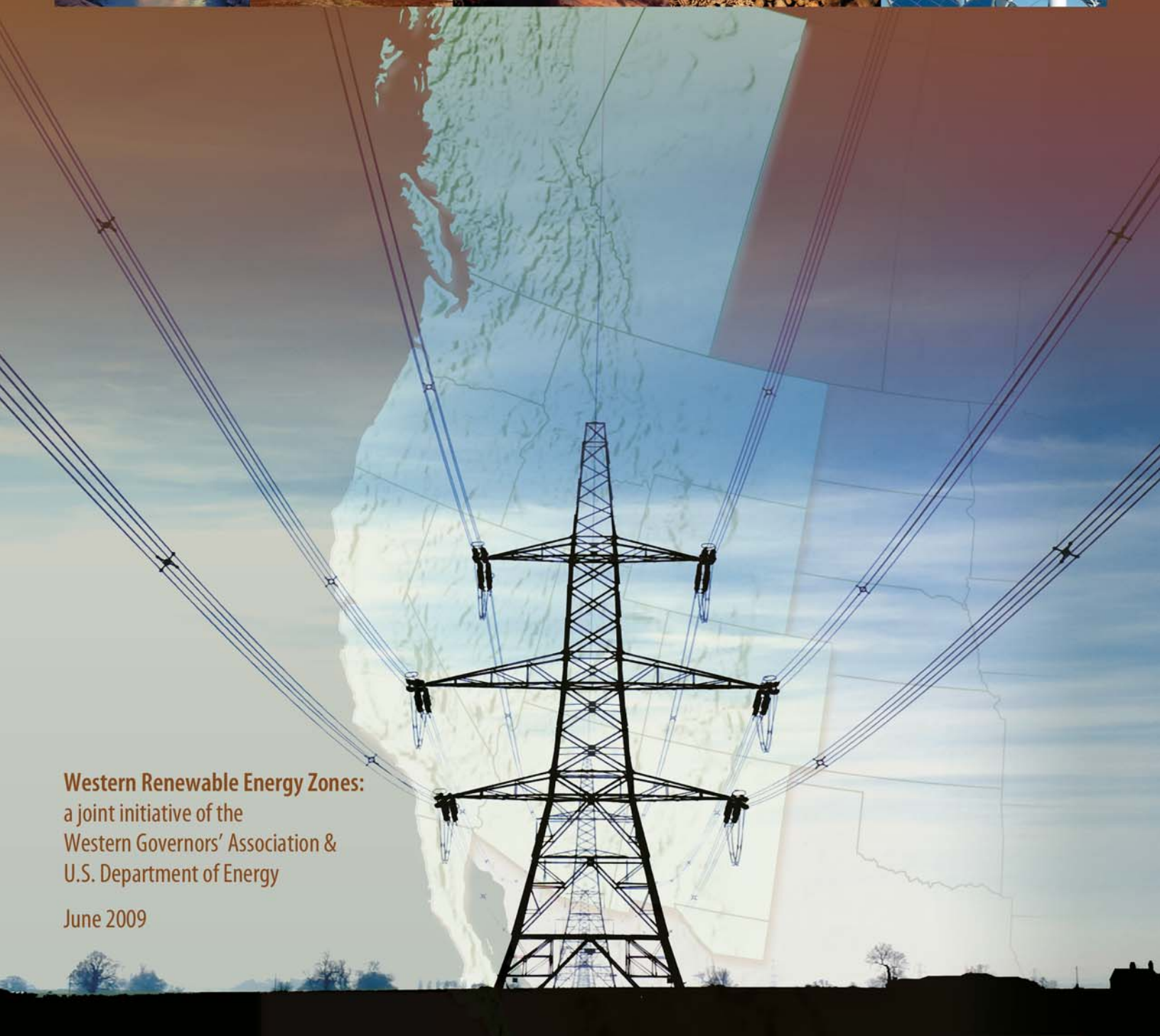
Western Renewable Energy Zones - Phase 1 Report

Mapping concentrated, high quality resources to meet demand in the Western Interconnection's distant markets



Western Renewable Energy Zones:
a joint initiative of the
Western Governors' Association &
U.S. Department of Energy

June 2009

Western Renewable Energy Zones Initiative

A joint initiative of the Western Governors' Association and U.S. Department of Energy

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Executive Summary

[1]The publication of "Western Renewable Energy Zones – Phase 1 Report" marks an historic turning point for the West and its energy future. In an effort to facilitate the construction of new, utility scale[1] renewable energy facilities and any needed transmission to deliver that energy across the Western Interconnection[2], the Western governors collaborated with the U.S. Departments of Energy, Interior and Agriculture, the Federal Energy Regulatory Commission, Canadian provincial premiers, and a diverse group of stakeholders that included renewable energy developers, tribal interests, utility planners, environmental groups and government policymakers to provide the analysis and tools to make this a reality.

This Phase 1 Report of the four-phase Western Renewable Energy Zones initiative achieves several important outcomes.

First, it takes important steps toward identifying the Western Renewable Energy Zones, those areas throughout the Western Interconnection that feature the potential for large scale development of renewable resources in areas with low environmental impacts, subject to resource-specific permitting processes. Initiative stakeholders developed and applied criteria to assess renewable resources across the region. They developed and applied a methodology to identify and characterize specific resource-rich areas that could become Western Renewable Energy Zones. This included screening out areas where development is prohibited or severely constrained by geography or by regulation or statutes. The stakeholders will continue to work toward refining Western Renewable Energy Zones by implementing additional screens that balance the benefits of renewable energy development with the need to protect wildlife and crucial habitat. This Phase 1 Report contains a map that reflects the accomplishments described above. They are discussed in greater depth in the body of the Report.

Second, this Report marks the completion of important work to assist evaluating various transmission strategies. The intention of the WREZ initiative is not simply to identify renewable energy zones in the Western Interconnection, but to facilitate the development of high voltage transmission to those areas with the potential for abundant renewable resources and low or easily mitigated environmental impacts. To this end, the WREZ initiative has created a modeling tool to evaluate the relative economic costs of renewable resources on a delivered basis, including transmission costs, from specific renewable resource areas to specific population (load) centers. The model also will calculate how much

[1] "Utility-scale" renewables is defined in this report to mean the potential to develop 1500 MW of solar or wind, or 500 MW of biomass, geothermal or hydropower generating capacity. This is large enough to support the construction of high voltage transmission lines to deliver energy to major load centers. Not included are customer-scale renewables, such as rooftop solar photovoltaics, geothermal heat pumps, small scale wind, or even solar photovoltaics installed at a utility substation level.

[2] The Western Interconnection is the name of the electricity grid that includes the states of Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming; the part of Texas near El Paso; the Canadian provinces of Alberta and British Columbia; and a small portion of northern Mexico in Baja California. It is overseen by the Western Electricity Coordinating Council (WECC).

theoretical energy could be supplied from the Western Renewable Energy Zones, once identified, to the load centers across the region.

Finally, this Report identifies the breadth of renewable energy potential across the Western Interconnection, beyond the potential that will be identified in the Western Renewable Energy Zones. The initiative recognizes that its work on regional development can and should be done in concert with more localized efforts to utilize the most cost effective renewable energy resources in the Western Interconnection. This Report aids that work.

Moving forward, the WREZ initiative will undertake a range of efforts to lay the foundation for promoting the efficient regional development, procurement and delivery of energy from renewable resource areas to multiple population centers throughout the Western Interconnection, while balancing important considerations, including state objectives and wildlife sensitivities.

Introduction

Transmission and Renewable Energy

In June 2006, the Western Governors' Association published "Clean Energy, a Strong Economy and a Healthy Environment," a report from the Clean and Diversified Energy Advisory Committee.[3] This report explained that while vast renewable resources exist throughout the West, many reside in remote areas without ready or cost effective access to transmission. Lack of cost effective transmission access was, and remains, the greatest impediment to the rapid development of utility-scale, renewable-rich resource areas.

This point was underscored at the National Wind Coordinating Collaborative Transmission Summit held in the fall of 2007. Identifying Western Renewable Energy Zones was one of the major concepts that emerged from the Summit.[4] This concept was ultimately developed as the WREZ initiative, a joint effort between the Western Governors' Association and the U.S. Department of Energy.

The WREZ Initiative Organization

The Western Governors' Association and U.S. Department of Energy launched the Western Renewable Energy Zones (WREZ) initiative in May 2008. Participating in the initiative are representatives from throughout the Western Interconnection, which includes 11 states, two Canadian provinces and areas in northern Mexico.

The WREZ charter[5] laid out four goals for the initiative:

1. Develop a framework for consensus among the states and provinces within the Western Interconnection on how best to develop and deliver energy from renewable resource areas to load centers.

3 Clean Energy, a Strong Economy and a Healthy Environment, Report of the Clean and Diversified Energy Advisory Committee to the Western governors, Western Governors' Association, June 2006.

4 "Increasing Renewable Energy in the Western Grid Summit," Summit Next Steps Memo, September 27-28, 2007. (http://www.nationalwind.org/events/summit/default.htm)

5 Western Renewable Energy Zones Charter, May 28, 2008.

While this initiative intends to assist the West's transmission efforts and renewable energy development, it is important to put the initiative in perspective.

The WREZ is intended to provide important information, but it is not intended to impinge on the legal authority or replace the regulatory role or requirements of any local, state, provincial, tribal or federal agency, including the environmental reviews necessary at any stage of a project.

In that respect, the WREZ was never intended to carry any legal or regulatory status once projects are proposed and permitted. The report in no way means to suggest that renewable resources inside a Qualified Resource Area or WREZ should be developed first, or that those outside of a WREZ should or cannot be developed.

Location of a project within a WREZ neither implies nor suggests any approval or disapproval of a specific pending or proposed renewable energy project, nor does it ensure or require that a transmission line will be built to a particular WREZ.

2. Generate reliable information for use by decision makers that supports the cost-effective and environmentally sensitive development of renewable energy in or near certain identified renewable energy zones, as well as the conceptual transmission plans needed to deliver the renewable energy to load centers.
3. Provide a foundation for interstate collaboration on commercial delivery of renewable energy to meet growing demand throughout the Western Interconnection.
4. Provide for the development of cost-effective renewable resources in order to promote the clean and diversified energy goals of the Western governors.

The WREZ initiative has been undertaken with an emphasis on **stakeholder involvement, public outreach, and transparency**. Participating stakeholders include public service commissioners and other state and provincial officials, load-serving entities, transmission owners, renewable energy developers, environmental organizations, Indian tribes, federal land use agencies and others. Members of the public and other interested parties have been given multiple opportunities to comment on the initiative's work products to date.[6]

Guiding the initiative is the **WREZ Steering Committee**, composed of governors, premiers and public utility commissioners. Officials from the U.S. Departments of Energy, Interior and Agriculture, as well as the Federal Energy Regulatory Commission, participate as ex officio members.

The Steering Committee appointed a **Technical Committee**, which is responsible for the day-to-day management of the initiative. The Technical Committee is composed of a wide variety of renewable energy and transmission experts, environmental groups, governmental agencies and representatives of three working groups described below.

The bulk of the effort has been accomplished by the three working groups reporting to the Technical Committee. Each working group is composed of a diverse array of stakeholders.

The **Zone Identification and Technical Analysis** (ZITA) working group was charged with developing the resource characteristics or criteria that would ultimately define the zones. By applying the technical screening criteria described below, ZITA identified areas for utility scale renewable energy development and combined that information with known restrictions relating to land use (including engineering limitations), regulatory mandates (or limitations) and environmental concerns.

The **Environment and Lands** (E&L) working group was responsible for categorizing the resource potential of zones based on land use, wildlife and other environmental considerations.

The **Generation and Transmission Modeling** (G&TM) working group was charged with two tasks:

1. developing a transparent and user-friendly model to enable load serving entities, regulators and others to evaluate the generating (bus-bar) cost,

[6] The internet version of this report contains hyperlinks to many of the primary documents generated during the process.

delivered cost (including transmission cost), and relative economic attractiveness of the renewable resources' delivered price of power coming from specific zones; and

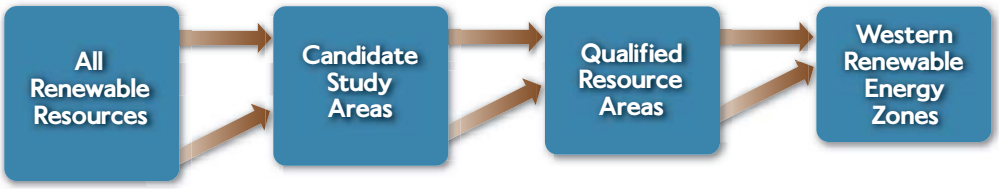
2. engaging the Western Electricity Coordinating Council (WECC), which oversees the transmission grid in the Western Interconnection, in a planning process to study transmission needed to move power from the zones to load centers.

Finally, the WREZ initiative recognizes that many states and provinces participating in the initiative have completed or are conducting their own assessments for renewable energy zones. These assessments are often aimed at addressing state or provincial goals for Renewable Portfolio Standards, economic development and the growing energy needs of their constituents. While the final products may differ, these state and provincial efforts and the WREZ initiative should be seen as complementary, each furthering the goal of cost effective and environmentally responsible renewable energy development locally and across the region.

The Path Toward Western Renewable Energy Zones

In Phase 1, the WREZ stakeholders engaged in the fundamental challenge and opportunity of the initiative: identifying Western Renewable Energy Zones that satisfy a diverse range of criteria to support large-scale transmission investment. To develop those criteria, the working groups established a process that evaluated promising resource areas through several steps.

The figure below shows the steps being taken by the initiative to move from identification of renewable resources to a WREZ. Presently, the initiative has indentified Qualified Resource Areas but not Western Renewable Energy Zones. The final identification will depend on the evaluation and public comment process relating to wildlife information and additional information from load serving entities.



Renewable Resources

The initial filter in evaluating the renewable energy resources was to identify those resources that met a threshold potential for commercial development. The resource review and application of the respective thresholds is outlined below.

The Zone Identification and Technical Analysis (ZITA) work group analyzed wind, solar, geothermal, biomass and hydropower resource potential by examining raw data and maps from the U.S. Department of Energy's National Renewable Energy Lab and Idaho National Research Lab, the Western Governors' Association Western Bioenergy Assessment, as well as Canadian renewable resource data obtained from a variety of sources.[7]

ZITA divided the Western Interconnection's renewable resources into two categories:

- **Primary** – Large amounts of renewable energy potential significant enough to define a Western Renewable Energy Zone's boundaries. These are the resources with the greatest near-term generation potential across the Western Interconnection.
- **Secondary** – Amounts of renewable energy potential small enough that the resource in itself would not define a Western Renewable Energy Zone's boundaries, but could be included in a WREZ once quantified.

Criteria for Primary Resources

Solar

Solar power will be a substantial component of renewable resources in the Western Interconnection. To identify the most promising locations for large-scale transmission projects that would serve utility-scale solar across the region, ZITA eliminated any location that received less than 6.5 kilowatt hours per square meter per day of direct normal insolation[8] (DNI) and had a terrain slope of greater than 5 percent. This slope minimum was further refined to 2 percent when the Qualified Resource Areas were created. These were accepted as the minimum conditions that must be met for an area to have a developable and cost-effective utility scale solar thermal resource based on currently understood solar technology. These areas were also considered viable for solar photovoltaics (PV) generation.

[7] British Columbia wind and hydropower data are from resource assessments performed by BC Hydro. The wind resource assessment quantifies the wind resource potential in the southern two-thirds of the province, and the assessments of hydropower quantify hydropower resources across the entire province. Alberta wind data are from the Alberta Electric System Operator queue and reflect wind projects planned by developers who are requesting access to the transmission grid. The Alberta data approximate the planned locations of these wind projects, but do not identify their precise spatial extent. Canadian discovered conventional geothermal data were obtained from the same dataset from GeothermEx that also quantified U.S. geothermal potential. British Columbia large and small hydropower data were obtained from BC Hydro and the BC Transmission Corporation. Alberta large hydropower data were obtained from Canadian Hydropower Developers and, indirectly, from a contact of TransCanada Energy.

[8] The rate of delivery of direct solar radiation per unit of horizontal surface.

Wind

The abundance of wind power throughout the West makes it one of the region's largest renewable resources. To identify the most cost effective and developable wind resources, ZITA only considered locations where the NREL wind power class is 3 or greater at 50 meters above the ground and the terrain slope is less than 20 percent. As wind power class increases so does the cost-effectiveness of that wind resource.

Conventional Discovered Geothermal

Steam power generated by heat from the earth continues to be an attractive resource in our region to generate clean base-load energy. ZITA included known, quantifiable resources that have been identified[9] already through commercial interest and current land leases as significant sources of conventional hydrothermal geothermal resource potential.

Canadian Hydro

Canada's significant, undeveloped, large conventional and small, run-of-river hydropower potential merited the inclusion of hydropower as a primary resource in Canada. Hydropower resource potential was used to identify QRA boundaries when it was large enough and occurred in high enough density to potentially define a WREZ.

Criteria for Secondary Resources

Biomass

When biomass is used for power generation, it is generally limited by fuel transportation costs to power plants typically sized under 50 MW. These biomass-fueled power plants are often necessarily close to supply, but may be geographically dispersed from one another, and generally do not require large new transmission to reach load centers. As such, biomass does not necessarily provide the same transmission infrastructure improvement opportunities as other renewable resources. Electricity can be produced from biomass fuels that include crops, crop byproducts, trees and residues from various tree plantations, such as pre-commercial-sized thinnings, beetle-kill pine forests and milled trees from forested lands.[10]

ZITA excluded certain types of biomass, including municipal solid waste (too urban for remote WREZ sites), manure (small generation potential per site) and dedicated "closed-loop" biomass crops (a resource currently of more interest in the East.) ZITA also recognized that most biomass traditionally has been used for heat generation, with electricity production as a value-added byproduct. ZITA estimated a third of biomass fuel is available for electricity generation.

Hydro

Given the small size and distributed nature of hydropower resources, the ZITA work group concluded that it was unlikely that these resources would be large

[9] By a technical consultant, GeothermEx.

[10] For details, "Resource Criteria," ZITA, WREZ, October 2008.

and dense enough to justify the creation of Western Renewable Energy Zones or significantly impact transmission planning (except in Canada). Hydro resources assessed in the U.S. include incremental additions of generating capacity to existing facilities, the installation of hydropower facilities at existing, non-powered dams, and power generation opportunities at irrigation projects. In Canada, small run-of-river hydro resources and large conventional resources that were not large enough to justify the creation of a WREZ on their own were considered as secondary resources. Pumped storage offers predictable electric generation, as well as the ability to supply critically needed integration services for variable resources, such as wind and solar, but was not assessed in this portion of the initiative. Also not addressed were ocean energy resources, such as wave and tidal energy generation, since the technologies to harness those abundant resources are in the early stages of demonstration and are not expected to be available for wide deployment for a decade or more.

Forming the Candidate Study Areas

The original NREL resource maps identified vast amounts of commercially viable renewable energy potential in the Western Interconnection, including more than two million megawatts of potential wind power resources and several million megawatts of potential solar energy resources. As a frame of reference, the peak load for the entire WECC in 2007 was approximately 150,000 megawatts. In order to reduce the large potential to only the best resources, some additional filtering was applied. This resulted in the Candidate Study Areas as described below.

Best Resources by State and Province

The WREZ initiative recognizes that geographic and resource diversity is an important component in creating a new clean energy infrastructure. Diversity can reduce transmission costs, load imbalances and energy security concerns. As a result, the ZITA working group sought to include in its analysis a robust combination of renewable resources within each state or province in the Western Interconnection to ensure creation of Western Renewable Energy Zones that reflect geographic and resource diversity.

To identify the highest quality and most cost-effective renewable resource areas across the region, ZITA set initial minimum resource quality thresholds for wind and solar. For wind, this was originally NREL wind power class 3 and above. For solar, it was a DNI level of 6.5 kilowatt hours per meter squared per day. Identifying the highest quality resources ensures that the resulting analysis focuses on areas with the potential to justify regional transmission investment.

In some states, the minimum resource quality thresholds did not provide sufficient focus on the best resources. Given the variations in wind power classes and solar DNI levels among states in the Western Interconnection, it was determined that the best of each resource type (e.g., solar, wind, geothermal) would be identified in each state and serve as the minimum resource class identified in that state. The underlying assumption for establishing these state-level criteria is that the best renewable energy resources are most economical to develop and will be developed first, subject to the availability of transmission. Further, it will benefit WREZs to have the most suitable resources used to determine their

economics, rather than to have all resources counted. For example, more than 50% of the best class 5 – 7 winds in the Western U.S. occur in southern Wyoming, making it a truly prolific resource base. By analyzing the most suitable resources in each state, the analysis facilitates a focus on areas with the potential to justify regional transmission and the associated financial investment.

In states with smaller amounts and lower quality renewable resources, it was necessary to reevaluate the minimum threshold for Candidate Study Areas. Idaho, for example, is projected to have only 7,917 megawatts of Class 4 and above wind. By including Class 3 wind in Idaho, the state's resources were expanded to 44,000 megawatts. While Idaho's wind resources may not appear to be as economically viable for justifying development of large regional transmission, they may be very valuable in meeting more localized demands, or serving as a way of using local resources, rather than participating in an interstate transmission line.

Canadian wind resources were not screened for resource quality because the Canadian wind resource assessment already took resource quality factors into account. The Canadian wind resource assessment relied on very detailed delineation of specific project sites from other studies or the location and capacity of planned projects in the system operator queue. These assessments already take into account resource quality so no further resource quality screens were applied in the WREZ process.

Quantifying Candidate Study Areas

Candidate Study Areas (CSA) resources were quantified so that areas with renewable energy resources could be compared, and the largest and most dense resource areas could be identified. Resource areas that did not meet a minimum threshold for inclusion in a Candidate Study Area cited above were excluded. A 50 square kilometer grid was laid over the Candidate Study Areas. The amount of screened renewable energy resource potential within each grid square was quantified, and grid squares were shaded based on the total megawatts of resource potential in each grid square. This allowed for a standard comparison across the study area based on the density of renewable energy resource in each grid square. This also highlighted when high density resource grids were contiguous to other resources, illuminating concentrations of total renewable resources for utility scale projects.

It is reasonable to expect that not all of the resource within a grid cell can 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, developability discounts were applied to the screened resources to account for the likelihood that within any grid square, only a portion of the total resource potential is developable. Based on the observation of renewable development in individual states with renewable energy zones, only 25 percent of the total available wind resource potential and 3.5 percent of the total available solar thermal resource potential would be expected to be developed within a respective QRA.[11] Because geothermal is

[11] These factors were based on empirical studies conducted during the Texas CREZ process and the California Renewable Energy Transmission Initiative (RETI) process. However, they should be considered within the context of any respective renewable energy zone.

typically a high capacity resource and has been identified in precise locations, there was no developability discount applied to the geothermal resource potential. The application of these development discounts creates a margin of safety that almost guarantees WREZs will realize sufficient development to justify a high capacity transmission line.

Refining to Qualified Resource Areas

The analysis conducted at this stage was meant to identify discrete areas for quantification of energy potential and to create boundaries around a geographic region that could justify the construction of regional transmission.

The ZITA working group determined that the minimum size of a Qualified Resource Area should be based on the electrical generating potential sufficient to justify at least a 500 kV alternating current transmission line: 1,500 MW for variable resources with moderate capacity factors, such as wind and solar.[12] ZITA also established a maximum size of approximately 100 miles from the geographic center of a Qualified Resource Area. ZITA concluded that a distance greater than this would unreasonably increase the costs of connecting to the transmission grid.[13]

The results of this analysis were geographic areas with at least 1,500 MW of high quality renewable energy within a 100 mile radius.

Statutory and Regulatory Exclusions

Statutory or regulatory limitations require that certain lands be excluded from the analysis of potential renewable development. E&L identified those federal lands where renewable energy development is precluded legally by relying on the U.S. Forest Service, U.S. Fish and Wildlife Service and the Bureau of Land Management to provide guidance on the lands they manage. These lands generally include U.S. National Parks, U.S. National Monuments, federally designated Wilderness Areas, and U.S. Forest Service primitive areas, to name a few.[14] E&L sought similar information from the appropriate Canadian federal and provincial ministries. Additionally, E&L solicited information from state land management agencies on state-owned lands where renewable energy development is precluded by statute or regulation.

Additional Geographic Exclusions

E&L also identified other categories of lands that should be excluded from analysis of potential renewable energy development due to the established purpose or policy direction for these lands. Among the lands included are BLM Areas of Critical Environmental Concern, state parks and state wildlife management areas.

[12] Geothermal and biomass resources have, on average, two to three times the capacity factor of wind and solar. To account for this when identifying QRAs, the capacity of these resources in a QRA counts triple when considering whether a QRA meets the 1,500 MW threshold. The actual amount of geothermal and biomass resource is quantified in the energy and capacity calculations. Due to the greater relative certainty of the developability of resources identified in Alberta and British Columbia, this minimum threshold was relaxed for wind resources in these provinces.

[13] Qualified Resource Areas, Selection Methodology, February 2009, ZITA, WGA.

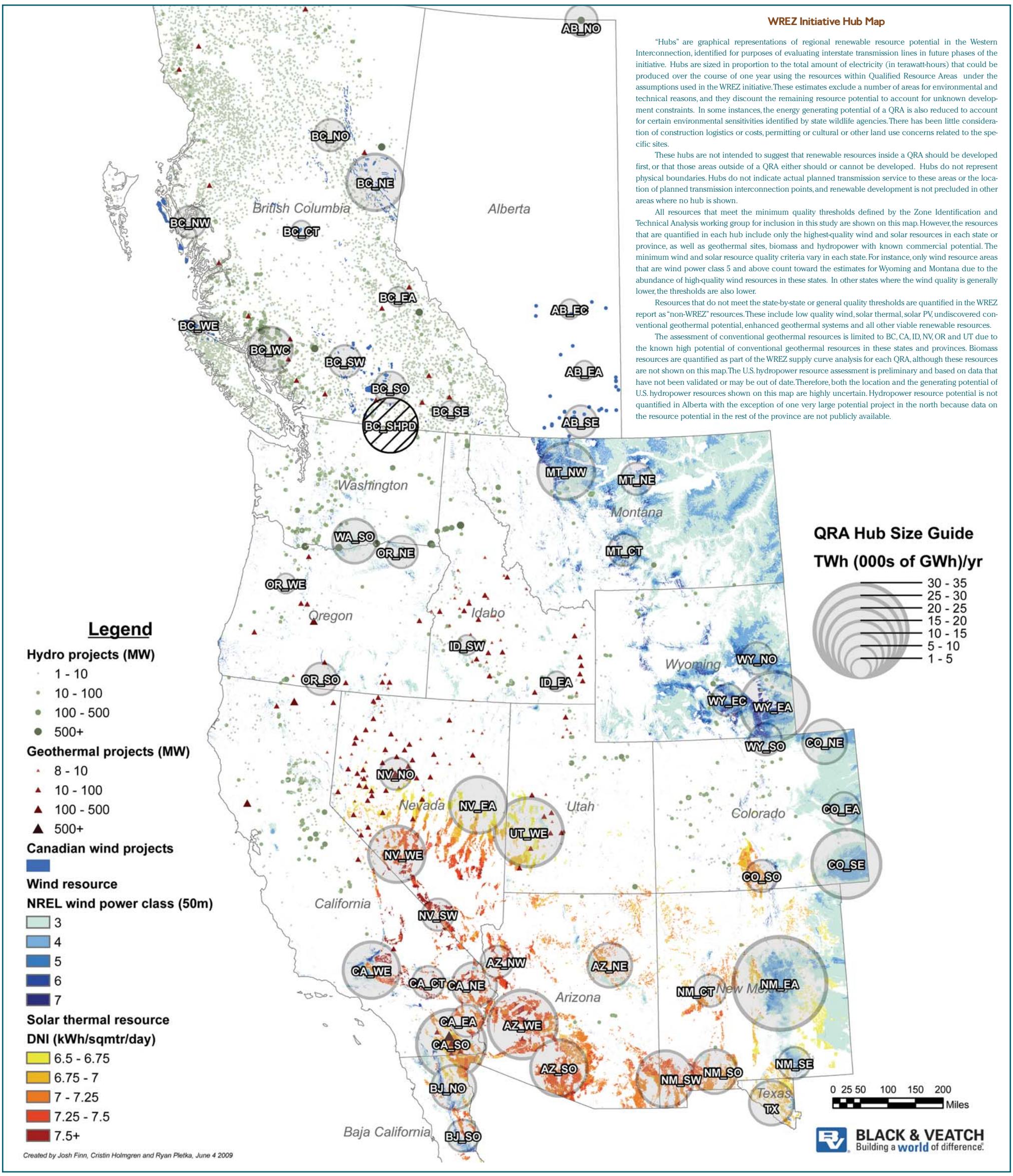
[14] Exclusion and Avoidance List, Environment and Lands Working Group and Western Governors' Wildlife Council.

About the WREZ Initiative Hub Map

To assist readers in fully understanding the WREZ Initiative Hub Map, a significant amount of supporting information is included in the tables and the endnotes at the back of this report. Additional information also is available on the WREZ Web site at: http://www.westgov.org/wga/initiatives/wrez/index.htm.

Particularly helpful are tables that quantify within each hub the energy generating capacity in megawatts and the theoretical annual energy generation in gigawatt-hours per year for the following resources: wind, solar, conventional discovered geothermal energy, small and large hydropower in Canada and incremental hydropower in the U.S. Undiscovered conventional geothermal resources are quantified in each state for which data are available, but not quantified, in the hub totals. Enhanced geothermal systems and other non-WREZ resources will be quantified in a followup report.

Hubs shown on the map are labeled by the abbreviation for each state and province, as well as the geographical area, such as NE for northeast.



WREZ Initiative Hub Map

"Hubs" are graphical representations of regional renewable resource potential in the Western Interconnection, identified for purposes of evaluating interstate transmission lines in future phases of the initiative. Hubs are sized in proportion to the total amount of electricity (in terawatt-hours) that could be produced over the course of one year using the resources within Qualified Resource Areas under the assumptions used in the WREZ initiative. These estimates exclude a number of areas for environmental and technical reasons, and they discount the remaining resource potential to account for unknown development constraints. In some instances, the energy generating potential of a QRA is also reduced to account for certain environmental sensitivities identified by state wildlife agencies. There has been little consideration of construction logistics or costs, permitting or cultural or other land use concerns related to the specific sites.

These hubs are not intended to suggest that renewable resources inside a QRA should be developed first, or that those areas outside of a QRA either should or cannot be developed. Hubs do not represent physical boundaries. Hubs 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 where no hub is shown.

All resources that meet the minimum quality thresholds defined by the Zone Identification and Technical Analysis working group for inclusion in this study are shown on this map. However, the resources that are quantified in each hub include only the highest-quality wind and solar resources in each state or province, as well as geothermal sites, biomass and hydropower with known commercial potential. The minimum wind and solar resource quality criteria vary in each state. For instance, only wind resource areas that are wind power class 5 and above count toward the estimates for Wyoming and Montana due to the abundance of high-quality wind resources in these states. In other states where the wind quality is generally lower, the thresholds are also lower.

Resources that do not meet the state-by-state or general quality thresholds are quantified in the WREZ report as "non-WREZ" resources. These include low quality wind, solar thermal, solar PV, undiscovered conventional geothermal potential, enhanced geothermal systems and all other viable renewable resources.

The assessment of conventional geothermal resources is limited to BC, CA, ID, NV, OR and UT due to the known high potential of conventional geothermal resources in these states and provinces. Biomass resources are quantified as part of the WREZ supply curve analysis for each QRA, although these resources are not shown on this map. The U.S. hydropower resource assessment is preliminary and based on data that have not been validated or may be out of date. Therefore, both the location and the generating potential of U.S. hydropower resources shown on this map are highly uncertain. Hydropower resource potential is not quantified in Alberta with the exception of one very large potential project in the north because data on the resource potential in the rest of the province are not publicly available.

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. 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 Web site 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 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.

Montana: The location and power potential of the Montana QRA hubs depicted on the WREZ Phase 1 Report Map above are based on the WREZ resource criteria of minimum Class 5 wind power potential, along with other criteria as specified in the WREZ process, including wildlife sensitivity areas. The Montana QRAs exclude only national parks, wilderness areas, state parks and other similar land areas identified in the WREZ process as being "statutory exclusion areas." Because the QRAs shown in Montana on the map reflect wind power of only class 5 and above, Montana's wind power potential is significantly higher than visually depicted. Montana has an AWEA-estimated 1,020,000 MW hours/year of wind power potential, class 3 and above. In keeping with permitting statutes, specific siting decisions about wind energy generation facilities in the vicinity of designated QRA hubs will be made by appropriate state and federal agencies. Montana's wind development plans will be shown in an addendum to the final WREZ Report.

Nevada: Nevada's Renewable Energy Transmission Access Advisory Committee (RETAAC), a stakeholder process, has completed two years of identifying renewable energy zones and transmission interconnection, including the review and ranking of land-use constraints. Development of zones or hubs must address land use constraints on a project specific level. The RETAAC Phase I report, December 2007, and Phase II report, June 2009, can be found at http://gov.state.nv.us/GibbonsEnergy/ and www.retaac.org.

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 WGA 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 New Mexico's wildlife sensitivity information, and include consultation with the New Mexico Department of Game and Fish and other relevant agencies for additional wildlife and environmental 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: Utah's hub designates the potential for high-quality renewable energy resources for transmission planning purposes. Development of resources, including consideration of wildlife and other resource values, will occur in accordance with the applicable existing federal, state and local reviews.

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.

Because these areas are not statutorily excluded from all development, the categorization of these areas does not represent a binding preclusion from future renewable development. However, it does reflect the intent of the federal and state agencies to extend special protection to them. Finally, E&L identified a number of areas that are significant when considering renewable energy development, but which could not be mapped in this effort either because data is unavailable or because the concerns are more appropriately handled at the project level.[15]

Finally, ZITA elected to exclude the following types of lands from consideration based on incompatibility with resource development:

- Wetlands/water bodies
- Surface mines
- Urban areas
- Airports
- Military lands[16]
- Excessively sloped areas[17]

WREZ Public Comment Period

A public comment period was held from February 2 to March 2, 2009 to receive feedback on a number of draft products from each working group. Documents were posted on the WGA Web site, including the QRA maps, technical and environmental exclusion areas, and the maps and figures developed for use in the transmission modeling exercise. Extensive outreach to tribal and local governments and relevant interest groups was conducted. Stakeholders were advised by e-mail of the opportunity to comment and WREZ participants were asked to inform their constituencies, as well.

More than 80 comments were received addressing one or more of the WREZ work products. WGA staff reviewed comments relevant to their working group or other facets of the initiative and proposed responses and adjustments to the draft materials based on the topics raised by the public. Topics raised included ZITA's technology cost assumptions and the development discounts. For the E&L, comments focused on additional areas for exclusion and the need to identify already disturbed lands that would be more appropriate for development. The GT&M modeling assumptions and the WECC study request also received comment. The proposed responses or adjustments proposed by staff were reviewed and approved by the respective working groups, the responses posted to the WGA Web site and the adjustments to the draft materials made.

All of the materials available for public comment, the comments received and the approved responses are posted on the WGA Web site at: http://www.westgov.org/wga/initiatives/wrez/comments.htm.

[15] *Significant Areas for Consideration Chart, Environment & Lands Working Group.*

[16] *Military airspace and operational areas were not considered for exclusion because they are a project level review requirement and were accounted for in the developability discounts.*

[17] *Greater than 2 percent for solar, 20 percent for wind.*

Incorporating Wildlife Sensitivity

The E&L working group was charged with categorizing the development potential of Qualified Resource Areas based on important wildlife habitat, sensitive ecosystems and other sensitive lands. To accomplish this goal, the working group coordinated its efforts with the Western Governors' Wildlife Council, whose members represent state wildlife agencies.[18] The state agencies provided information on crucial wildlife habitats and will continue to expand and refine that data. Ultimately, this information will be used to categorize Qualified Resource Areas based on their level of biological sensitivity and the level of mitigation needed to accommodate large-scale renewable energy development.

The Council requested wildlife data from agencies in 11 states and two Canadian provinces within the Western Interconnection.[19] The agencies were asked to provide information for crucial habitats and wildlife corridors, as well as sensitive ecosystems. A request for data also was made to the environmental community, academic institutions and industry.

A technical consultant developed a map showing the data layers and categorized them based on criteria developed by the Council[20] with input from E&L. The criteria used to prioritize wildlife values within each state or province related to impacts from renewable energy generation. Some states and provinces applied the criteria themselves and that information was included in the overall map. Once the initial round of mapping was completed, wildlife agencies reviewed them for accuracy, before sending them to the governors or premiers' offices for approval. Many of the maps have been completed, but some await additional reviews by other agencies.[21]

The Council's maps identify the level of wildlife sensitivity within the Qualified Resource Areas. This effort was meant to provide a broad screening-level assessment of development potential. The wildlife sensitivities were based on the best currently available data and the best professional judgment of the state wildlife agencies. Categorizations do not represent a binding action on development; the mapping effort by the Council was intended to indicate a prioritization of lands relative to wildlife in order to guide, from an overarching regional policy perspective, regional transmission investments to the areas with not only the best renewable resources, but also the least environmental conflicts. In addition, WREZ stakeholders expect this type of wildlife information will encourage appropriate and corresponding levels of mitigation when eventual development in an identified zone is proposed.

Once the state wildlife agencies, through the Council, provide wildlife sensitivity categorizations for all the QRAs, the E&L working group will review these

[18] For information on the members see the Western Governors' Wildlife Council Web site at www.westgov.org.

[19] The data request is available on the Western Governors' Wildlife Council Web site at www.westgov.org.

[20] The categorization criteria used by the Western Governors' Wildlife Council is available on their Web site at www.westgov.org.

[21] Wildlife sensitivity maps, and a description of the datasets that were categorized, that have been approved by governors for use in the WREZ are available on the Western Governors' Wildlife Council Web site at www.westgov.org.

categorizations with the Council and other WREZ stakeholders to clarify and, if appropriate, refine them. E&L and ZITA then will make recommendations on how to incorporate the wildlife sensitivity information in forming Western Renewable Energy Zones.

The Phase I Map

The Steering Committee chose to produce a map that demonstrates much of the work that has been accomplished to date. The map displays the raw renewable resources[22] across the Western Interconnection and accounts for agreed upon exclusions based on resource and environmental considerations. 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 was given the chance to review and modify its maps of Hubs in advance of this map's publication and inclusion in this 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. 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.

Given the continued work on wildlife sensitivities, it is premature to provide a final application of wildlife sensitivities on the Qualified Resource Areas. This will occur during completion of Phase 1 as described above.

The WREZ Initiative – Additional Tools

The intention of the WREZ initiative is not simply to identify Western Renewable Energy Zones in the Western Interconnection, but also to facilitate the development of high voltage transmission to those areas with abundant high-quality renewable resources and low environmental impacts. To this end, the WREZ initiative has developed a modeling tool for evaluating the relative economic attractiveness of costs of delivered renewable energy, including transmission costs, from specific renewable resource areas delivered to specific load centers. This section describes that modeling tool and discusses those efforts that will be the focus for future phases of the WREZ initiative.

Renewable Energy Generation and Transmission Model

The WREZ initiative has developed a publicly available modeling tool that will allow load-serving entities, regional planners, renewable energy developers, state and provincial regulators and other interested parties to estimate the

[22] *Available on the WGA Web site.*

relative economic attractiveness of delivering power from specific Western Renewable Energy Zones to existing load centers across the Western Interconnection. The model assists users in identifying robust renewable resource portfolios and the transmission required to deliver the renewable energy. More specifically, the model allows users to examine different renewable resource development scenarios by allowing them to test the relative economic attractiveness of different renewable resource choices under user-customized assumptions.

The WREZ's Generation and Transmission Modeling working group led the effort to develop this tool and to train utility planners, regulators and developers about its capabilities and how to use it. A usable version of the model, and more information on the development of the model, is available on the WREZ Web site. The model will continue to be refined during Phase 2 of the WREZ initiative and should be finalized by the end of Phase 2.

Non-WREZ Renewable Resources

While identifying and establishing transmission lines to hard-to-reach renewable energy resources is important, it is not the entire picture. The broader goal, as stated by the governors, 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."[23]

As this report notes, the West contains a significant amount of commercially viable renewable energy resources outside of the potential WREZs, and which have been identified through this process. Non-WREZ resources:

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

Non-WREZ renewable generation technologies fall into three general types:

- Wind, geothermal, biomass, landfill gas and anaerobic digestion, incremental and small hydro, utility-scale solar, and pumped storage that can assist wind and solar integration, that, while not concentrated enough or of high enough quality to justify major transmission infrastructure, they may result in regional transmission upgrades. These resources are, nevertheless, close enough to load centers to potentially be economically viable for local demand.
- Existing technologies, such as micro-hydro, biomass, distributed wind and solar PV[24], which by their natural characteristics are decentralized and distributed and afford limited opportunities for economies of scale, yet can be economically viable.
- Emerging technologies, such as enhanced geothermal, various types of advanced energy storage, tidal and ocean power, and next-generation solar PV that may become commercially competitive in the near future, even if today they are not, and could thus have an impact on transmission planning in the West, as well as more generally become part of the resource mix for the West.

[23] WGA, "Transitioning the West to Clean Energy and Energy Security," policy resolution 07-16 (2006)

[24] NREL, "Roof44 top Photovoltaics Market Penetration Scenarios", NREL/SR-581-42306 (Feb 2008), http://www.nrel.gov/docs/fy08osti/42306.pdf.

- While energy efficiency isn't a renewable source of electricity generation, it operates like one. As previously noted by the Western governors, "Energy efficiency is the easiest, least expensive and least controversial way to reduce energy demand." Like distributed generation, energy efficiency reduces the demand for all forms of utility generation and reduces pressure on existing and future transmission lines as well.

Each has its place in a comprehensive energy strategy and each contains some options that are less costly than others. Minimizing ratepayer impact involves utilizing the most cost-effective options from each category.

In-State or Province Utility Scale Renewable Resources

Wind, solar, and geothermal power can exist at utility scale, yet not in the concentrations or conditions sufficient to meet the criteria for a WREZ. California, Colorado, Arizona, New Mexico, Nevada, Utah and British Columbia are conducting or have completed their own state or provincial assessments of renewable energy resources. Unlike the WREZ, these efforts focus on ways to meet domestic renewable energy needs at the least cost to state or provincial electricity customers.[25] An in-state or province focus means that resource screens need not be as rigorous as those used to identify a WREZ. However, it is important to recognize how state or provincially initiated efforts can combine with the WREZ to create a system that can work to best utilize renewable resources in the West.

Future WREZ Initiative Work

This report summarizes the significant work and achievements to date during Phase 1 of the WREZ initiative, but work on the subsequent phases has already begun.

Completing Phase 1: Defining the WREZs

In 2009, the WREZ initiative will move from Hubs to the identification of Western Renewable Energy Zones by incorporating a screen for wildlife sensitivities on the existing Qualified Resources Areas.

Phase 2: Forging Transmission Plans

In Phase 2, the WREZ initiative will finalize the modeling tool that estimates the relative economic attractiveness of delivering energy from Western

[25] While California's Renewable Energy Transmission Initiative also looks at resources in surrounding states, the analytical objective is to identify resources that can help California meet its own renewable energy goals.

Renewable Energy Zones to specific load centers across the Western Interconnection. This modeling tool will be incorporated into the existing regional transmission planning processes to support new or existing transmission plans from Western Renewable Energy Zones to the region's load centers. In order to plan and support the permitting and construction of new transmission lines, there must, at a minimum, be close coordination among resource planners, transmission providers, sub-regional and interconnection-wide transmission planners, transmission developers, federal land use agencies, renewable developers, state, provincial and federal regulators, and environmental organizations. The introduction of the modeling tool and the identification of Western Renewable Energy Zones should facilitate this coordination.

Finally, transmission right-of-way or corridor siting is of the utmost importance to the timely development and delivery of renewable energy resources to market, as well as the protection of lands and wildlife resources. Therefore, an important component of Phase 2 will include a coarse-level environmental screening to recommend preferred locations for corridors and rights-of-way.

Phase 3: Coordinating Energy Purchasing from the WREZs

Aggregating demand for renewable energy can stimulate the development of commercial renewable generation and supporting transmission projects. Many municipal, cooperative, state, federal and provincial electric systems have renewable energy procurement goals and proposals to coordinate the purchasing cycles of regulated utilities already under discussion. Yet the mechanisms to integrate renewable energy targets into state or region-wide procurement remain to be developed. In Phase 3, stakeholders will work to bring state and provincial utility commissions, utilities and generators together to increase the coordination of power purchasing to facilitate development of a region-wide market for renewable power.

Phase 4: Fostering Interstate Cooperation for Renewable Energy Generation and Transmission

The WREZ initiative seeks to aggregate the regional demand for and supply of renewable energy to benefit the entire region. This will require addressing the political and regulatory obstacles to the permitting and construction of cross-jurisdictional transmission lines and renewable energy projects, as well as addressing any barriers to coordinated purchasing by load-serving entities. In pursuing solutions to these obstacles, Phase 4 will attempt to address cost allocation issues and opportunities to streamline and coordinate inter-jurisdictional permitting processes. In this phase, stakeholders will facilitate collaboration among the private sector and regulators to advance the goals of the WREZ initiative. While addressing these issues will be difficult, the viability of large-scale projects and our ability to meet Western Interconnection renewable goals in a timely manner, may hinge on resolving them.

WREZ on the Web

The Internet version of this report contains hyperlinks to key documents, the WREZ map and other supporting information, including the following:

- Western Electricity Coordinating Council Transmission Study Request
- Zone Identification and Technical Analysis Working Group Report and Products
- Environment and Lands Working Group Report and Products
- Generation and Transmission Working Group Report and Products
- State Renewable Energy Zone Identification Efforts
  - Arizona Renewable Resource and Transmission Identification Subcommittee (ARRTIS) of the Renewable Transmission Task Force (RTTF): http://www.azcc.gov/divisions/utilities/electric/Biennial.asp
  - California Renewable Energy Transmission Initiative (RETI): http://www.energy.ca.gov/reti
  - Connecting Colorado's Renewable Resources to the Markets: http://www.colorado.gov/energy/index.php?/utilities/senate-bill-07-91
  - Nevada Renewable Energy Transmission Access Advisory Committee (RETAAC): www.retaac.org
  - New Mexico Renewable Energy Transmission Authority (RETA): http://www.nmreta.org
  - Utah Renewable Energy Zone (UREZ) Task Force: http://geology.utah.gov/sep/renewable_energy/urez/index.htm
- Western Governors' Wildlife Council's Wildlife Sensitivity Maps
  - http://www.westgov.org/wga/initiatives/corridors/index.htm

View the full WREZ Phase 1 Report at:
http://www.westgov.org/wga/publicat/wrez09.pdf

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Western Renewable Energy Zones Initiative
Renewable Energy Generating Capacity Summary

Hub state/ prov	Hub 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	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**	**36.324947**	**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	125	e	0	260	1,081
ID	ID_SW	e	e	e	e	e	0	893	13	1	907	154	e	8	98	1,167
ID Total		**0**	**0**	**0**	**0**	**0**	**0**	**1,510**	**80**	**13**	**1,603**	**279**	**1,872**	**8**	**358**	**2,249**
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**
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	1,048	e	2	133	1,183
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**	**1,368**	**4,364**	**2**	**300**	**20,683**
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	225	e	0	91	9,196
UT Total		**4,786**	**2,178**	**237**	**0**	**0**	**7,202**	**1,516**	**133**	**29**	**1,678**	**225**	**1,464**	**0**	**91**	**9,196**
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
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_SHF	g	g	g	g	g	g	g	g	g	g	g	g	g	g	21,600[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***	***4,478***	***25,810***	***8,452***	***3,720***	***198,789***

CAPACITY (MW)

Western Renewable Energy Zones Initiative
Renewable Energy Generation Summary

Hub state/ prov	Hub 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	•	•	•	696	0	696	8,107	371	182	8,661	0	•	0	1,903	11,260
AZ	AZ NW	•	•	84	6,595	1,505	8,184	512	19	5	536	0	•	0	127	8,847
AZ	AZ SO	•	•	•	15,607	0	15,607	•	•	•	•	0	•	0	59	15,665
AZ	AZ WE	•	•	•	18,912	3,790	22,702	•	•	•	•	0	•	0	350	23,051
AZ Total		**0**	**0**	**84.32473**	**41,809**	**5,295**	**47,188**	**8,619**	**390**	**188**	**9,197**	**0**	**7,309**	**0**	**2,438**	**58,824**
CA	CA CT	•	•	1,191	2,123	2,069	5,383	2,850	561	134	3,545	0	•	0	83	9,011
CA	CA EA	•	•	2,375	3,615	158	6,148	522	53	14	589	0	•	0	83	6,821
CA	CA NE	•	•	2,836	6,693	1,407	10,937	1,199	202	7	1,407	0	•	0		12,344
CA	CA SO	•	•	6,937	915	83	7,934	1,170	376	429	1,976	11,074	•	8	142	21,134
CA	CA WE	•	•	1,139	2,984	2,717	6,840	3,093	2,239	3,282	8,615	0	•	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	•	•	0	0	0	0	•	6,640	0	6,640	0	•	0	50	6,689
CO	CO NE	•	•	0	0	0	0	•	10,904	623	11,527	0	•	0	94	11,621
CO	CO SE	•	•	0	0	0	0	•	23,836	109	23,944	0	•	0	120	24,065
CO	CO SO	•	•	4,617	326	0	4,943	•	303	299	602	0	•	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	•	•	•	•	•	0	1,515	182	38	1,735	1,034	•	0	1,936	4,704.756
ID	ID SW	•	•	•	•	•	0	2,189	36	4	2,229	1,079	•		728	4,036.080
ID Total		**0**	**0**	**0**	**0**	**0**	**0**	**3,705**	**217**	**43**	**3,965**	**2,113**	**13,119**	**0**	**2,663**	**8,741**
MT	MT CT	•	•	•	•	•	0	•	•	8,224	8,224	0	•	0	570	8,794
MT	MT NE	•	•	•	•	•	0	•	•	7,429	7,429	0	•	0	32	7,461
MT	MT NW	•	•	•	•	•	0	•	•	16,932	16,932	0	•	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	•	•	6,126	1,049	0	7,175	•	•	•	•	0	•	0	823	7,998
NM	NM EA	•	•	183	0	0	183	•	26,768	4,427	31,196	0	•	0	330	31,708
NM	NM SE	•	•	0	0	0	0	•	3,632	1,748	5,381	0	•	0	162	5,542
NM	NM SO	•	•	7,317	2,850	0	10,167	•	•	•	•	0	•	0	92	10,258
NM	NM SW	•	•	4,298	10,515	0	14,814	•	•	•	•	0	•	0	254	15,067
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	•	•	9,076	7,354	952	17,382	•	•	•	•	168	•	0	995	18,546
NV	NV NO	•	•	•	•	•	•	•	•	•	•	7,799	•	9	991	8,799
NV	NV SW	•	•	840	2,760	4,316	7,916	520	42	19	581	0	•	0	88	8,584
NV	NV WE	•	•	4,916	9,655	2,170	16,741	391	73	39	503	2,074	•	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	•	•	•	•	•	•	3,619	1,259	325	5,204	0	•	0	2,892	8,095
OR	OR SO	•	•	•	•	•	•	951	188	181	1,320	3,550	•	0	876	5,747
OR	OR WE	•	•	•	•	•	•	481	244	191	916	2,596	•	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	•	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	1,594	•	0	674	21,711
UT Total		**10,147**	**4,618**	**503**	**0**	**0**	**15,268**	**3,718**	**361**	**95**	**4,174**	**1,594**	**10,260**	**0**	**674**	**21,711**
WA	WA SO	•	•	•	•	•	0	6,295	1,635	295	8,225	0	•	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	•	•	•	•	•	0	•	•	24,570	24,570	0	•	0	35	24,605
WY	WY EC	•	•	•	•	•	0	•	•	8,801	8,801	0	•	0	0	8,801
WY	WY NO	•	•	•	•	•	0	•	•	9,606	9,606	0	•	0	41	9,647
WY	WY SO	•	•	•	•	•	0	•	1,670	4,457	6,126	0	•	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	•	•	•	•	•	0	[f]	[f]	[f]	4,044	0	•	0	713	4,757
AB	AB EC	•	•	•	•	•	0	[f]	[f]	[f]	2,146	0	•	0	907	3,053
AB	AB NO	•	•	•	•	•	0	[f]	[f]	[f]	0	0	•	6,307	1	6,308
AB	AB SE	•	•	•	•	•	0	[f]	[f]	[f]	7,389	0	•	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	•	•	•	•	•	0	[f]	[f]	[f]	1,953	0	•	10	905	2,868
BC	BC EA	•	•	•	•	•	0	[f]	[f]	[f]	0	224	•	437	250	911
BC	BC NE	•	•	•	•	•	0	[f]	[f]	[f]	11,389	112	•	4,953	811	17,265
BC	BC NO	•	•	•	•	•	0	[f]	[f]	[f]	5,730	0	•	420	588	6,738
BC	BC NW	•	•	•	•	•	0	[f]	[f]	[f]	3,159	224	•	1,984	632	5,999
BC	BC SE	•	•	•	•	•	0	[f]	[f]	[f]	252	224	•	508	447	1,432
BC	BC SHP[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	15,797[g]
BC	BC SO	•	•	•	•	•	0	[f]	[f]	[f]	4,786	224	•	630	815	6,455
BC	BC SW	•	•	•	•	•	0	[f]	[f]	[f]	3,630	112	•	717	1,204	5,663
BC	BC WC	•	•	•	•	•	0	[f]	[f]	[f]	0	1,419	•	12,546	949	14,914
BC	BC WE	•	•	•	•	•	0	[f]	[f]	[f]	3,205	0	•	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	•	•	7,026	2,218	30	9,274	•	2,058	3,110	5,169	0	•	•	•	14,443
BJ	BJ SO	•	•	1,022	1,218	117	2,357	•	1,668	2,078	3,745	0	•	•	•	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***	***33,509***	***180,876***	***31,243***	***27,698***	***561,527***

ENERGY (GWh/yr)

Endnotes Supporting Tables 1 and 2

[a] Only the best classes of wind and solar resources in each state were quantified. Quantifications for wind resources represent each state's minimum wind power class and higher, and for solar resources each state's minimum direct normal insolation level and higher. In Canada, renewable energy resources were quantified using a different methodology. It assessed resources at the site level as opposed to using raw resource data, therefore, the "best in state" criteria are not applied and Canadian resources are not discounted. Wind potential was not quantified in QRAs with less than 100 MW of total wind resource potential. Additional information is available on the Web at: http://www.westgov.org/wga/initiatives/wrez/zita/index.htm.

[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 at the state level with different levels of confidence. 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 and province. It is not captured in the QRA MW total, because these resources are not being quantified at the QRA level. U.S. estimates are from the U.S. Geological Survey, and Canadian estimates are from the Canadian Geothermal Energy Association.

[c] Data on undiscovered geothermal resources were not available for Baja California Norte and Texas at the time of publication.

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

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

[f] As noted above, a different resource assessment methodology is used to quantify the MW of renewable energy resources available in Canada. Data on the wind power class in British Columbia and Alberta are not available from this assessment. As a result, only the total potential of wind resources is shown here and are not broken down into different wind class categories.

[g] British Columbia voluntarily provided a hub on the British Columbia-Washington border to the WREZ process. This represents a 16,000 gigawatt-hour per year 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 when using the Generation and Transmission Modeling tool. The energy resources that make up this cost curve are not specified, therefore, they are not broken down by resource type or class. The generation available from this additional QRA is not included in the B.C. subtotal or the grand total on this table.

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