Renewable Energy in the Rockies

Responsibly Using the Resources of the West

By Elizabeth Kolbe

THE 2008 COLORADO COLLEGE STATE OF THE ROCKIES REPORT CARD

Key Findings

•The Rockies region is home to world-class wind, solar, and geothermal energy resources.

•Five of eight Rockies states are among the top 15 windiest in the country.

•More than 97 percent of Wyoming's electricity supply currently comes from coal.

•86 percent of Idaho's electricity currently comes from hydropower.

•Energy usage in the Rockies is 9 percent lower than the U.S. average and consumers' monthly bill is 17 percent lower than the national average.

About the author: Elizabeth Kolbe (Colorado College class of 2008) is a student researcher for the 2007/08 State of the Rockies Project.

Introduction

The demand for energy in the United States has never been higher. As the population of the United States passes 300 million, American energy consumption continues to climb with cell phones, TVs, personal computers, and 1.86 children per family leaving the lights on late to finish reading Harry Potter.[1] However, political instability in energy-producing nations, rising energy costs, and increasing concern about climate change have prompted Americans to seek energy that is clean, cheap, and domestically produced. The drive to meet these terms has sparked public, economic, and governmental interest in renewable energy. The Rockies states are already major energy producers, home to some of the largest coal beds in the world and the nation's only natural gas fields with increasing production projections.[2] However, the Rockies are also capable of becoming a world-class production region for renewable energy.

The eight-state region is home to world-class wind, solar and geothermal resources, along with local hot spots for biomass potential. These resources qualify as renewable because they are essentially inexhaustible: they naturally replenish themselves as we use them. Occasionally "clean coal" and nuclear power are listed as renewable energy sources, but they will not be included as such in this report because coal and uranium are not replenishable on a timescale useful to humans. This report does consider hydroelectric power a renewable resource; nevertheless, most of the large rivers in the West have already been developed and there is little potential for expansion. As such, hydro's role in the energy mix of the Rockies will likely remain stable and will not be discussed further.[3]

Each person drawn to renewable energy is attracted by something different. For some, the promise of making money in a growing market is reason enough to act. But for the average person, supporting renewable energy may come with extra financial costs. So why do it? Why support a movement that until recently seemed to have trouble breathing in America's free market system?

National security has been on the minds of Americans and the tongues of politicians since 9/11/2001. As relationships with oil-rich nations remain tenuous, it is only sensible to end our dependence on that which has become unreliable. By fully understanding the wealth of our resources, we can formulate an energy policy to free our livelihood from the need to protect oil and gas interests overseas. Renewable energy can also mean energy independence for the individual. Living "off the grid" can empower individuals and local economies by freeing them from centralized infrastructure. This is especially true in the Rockies where people look to renewables to maintain their autonomy.

Still others see renewables as a way to make the world a better place. By implementing clean renewables, we directly combat global climate change (for more on climate change in the Rockies, see the *2006 State of the Rockies Report Card*). Whether or not humans are perpetuating climate change is no longer debatable. What is important is what we can do to slow the change of the Earth's climate. We emit a lot of greenhouse gases —somewhere on the order of 1.6 gigatons (3.5 trillion pounds) of carbon per year.[4] But according to a report by the American Solar Energy Society (ASES), coauthored by scientists at the National Renewable Energy Laboratories, the Massachusetts Institute of Technology, and the Rocky Mountain Institute, increased energy efficiency and the development of renewable energy resources can make large reductions in emissions. Although the authors of the ASES report remind the readers that uncertainties were present within their research, they were confident enough to say:

> The results strongly suggest, however, that energy efficiency and renewable energy technologies have the potential to provide most, if not all, of the U.S. carbon emissions reductions that will be needed to help limit the atmospheric concentration of carbon dioxide to 450 to 500 ppm.[5]

The authors assert that the concentration of CO2 noted in the quotation are the levels we must reach to maintain some semblance of the current biological, economic, and social order.

Lastly, we have a responsibility to our land and to our posterity. The Rockies region has a history of extraction, often devastating ecosystems and scarring the land (see section on Surface Water and Restoration in the *2008 State of the Rockies Report Card*). Renewable energy provides the Rockies a way to utilize our natural resources without causing harm to our environment. By maintaining a healthy environment and becoming ener-

Gas station, southeastern Utah © Charlie Kenyon gy independent we set an example for the future, providing generations to come with the beauty, resources, and opportunities that our ancestors have given us. Many people who dedicate their lives to renewables do it on moral grounds – they will not stand for environmental destruction any longer.

This chapter outlines current electrical generation and consumption trends, and the role of renewable energy in our current system. It also discusses the potentials of each renewable resource in the Rockies and the role governments and utilities play in moving our society toward a sustainable future.

Current Production – Trends

Between 1990 and 2006, electricity production grew from 3,185 to 4,250 terrawatt hours (see Figure 1).[6] This addition of 1,065 megawatt hours (MWh, equivalent to one million watts) represents a one-third increase in generation over 16 years. Consumption was not the only thing to increase. In nearly the same time period electricity rates increased just over one cent per kilowatt hour (KWh). (See Figure 2).[7] One cent may not seem significant, but the average U.S. home uses 938 KWh of electricity per month, so the heightened rates increase the average home's electricity bill by roughly $10 per month.

Mix Over Time

The power generation mix of the U.S. has been relatively constant since 1960. As generation capacity has increased, coal and natural gas have maintained their respective, and large, holds on the industry. The only changes in the generation mix over time occur with the entrance of nuclear power into the market. This occurred when hydro reached the limits of its capacity and the petroleum industry exited electrical generation to produce more auto fuel. Around 1990, renewables began to penetrate the industry, but even today are only a minute player in electrical generation.[8] (See Table 1.)

Figure 1
U.S. Electrical Production, Terawatt Hours, 1990-2006
Source: Energy Information Administration

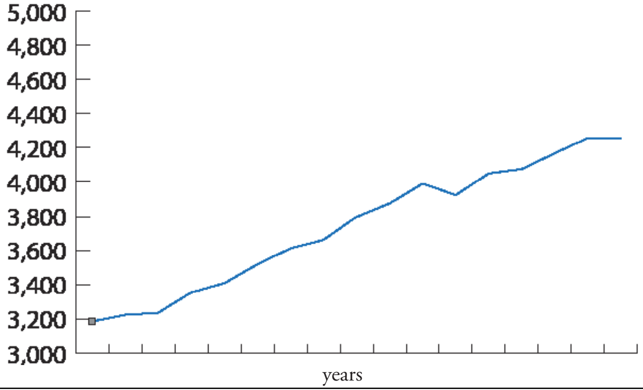
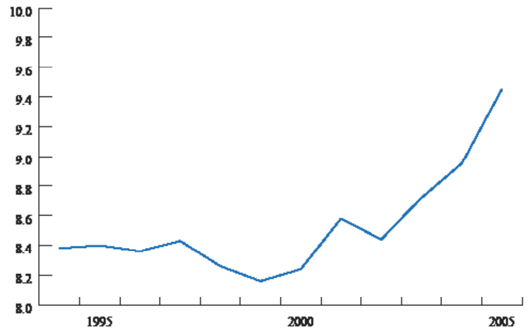


Figure 2
U.S. Residential Electricity Prices, Cents per Kilowatt Hour, 1994-2005
Source: Energy Information Administration



The Rockies region has seen coal-powered electricity skyrocket since 1960, decreasing the region's reliance on hydro, natural gas, and petroleum as electricity sources. As a group, renewable resources came to the Rockies markets later than the rest of the country. Geothermal accounted for just over 1,000 MWh of power by 1969, and wind brought only 2,000 MWh by 1989.[29] By comparison, a single, modern wind turbine can produce 4,000 MWh of power. Geothermal energy finally accounted for 1.5 percent of electricity in the Rockies starting in 1995.[10] (See Table 2.)

At the state level within the Rockies, some startling statistics emerge. Wyoming burns the highest percentage of coal, which fuels upwards of 97 percent of the state's electricity. Arizona does not reach the national average in coal consumption, but reaches well over the average in nuclear and natural gas. Idaho is the anomaly of the region. The state generates 86 percent of its power from hydroelectric sources, and nearly 1.5 percent from biomass.[11] Also important to note are the states' exports and imports of energy. The net imports and exports show how self-reliant a state can be for its energy needs. States whose power companies have to buy energy off the grid do so at a higher price, so self-sufficiency for power providers is economically attractive. As of 2004, only two of the Rockies states, Montana and Wyoming, were net exporters of electricity.[12]

Average Monthly Consumption and Costs

The Rockies states have relatively inexpensive energy, but we need to use it more wisely. The region finishes in the middle of the scale in per-household energy consumption for U.S. states. Although below the national average consumption of 938 KWh per month, the Rockies ranked fifth out of ten regions in 2005 at 852 KWh of energy consumed per household every month (Figure 3).[13] Simple steps can be taken to decrease energy use in the home. Many utilities offer energy-saving tips on

Table 1
U.S. Energy Generation Mix, 2005
Source: US Department of Energy, and Union of Concerned Scientists

Energy Source	Megawatt Hours	Percent of Total
Coal	2,013,178,838	50%
Hydroelectric Conventional	269,586,532	7%
Natural Gas	757,974,331	19%
Nuclear	781,986,365	19%
Other	4,748,646	0%
Other Gases	16,316,773	0%
Other Renewables	94,932,377	2%
Petroleum	122,521,953	3%

Table 2
Rockies Energy Generation Mix, 2005
Source: US Department of Energy, and Union of Concerned Scientists

Energy Source	Megawatt Hours	Percent of Total
Coal	221,279,564	63%
Hydroelectric Conventional	29,415,041	8%
Natural Gas	66,823,944	19%
Nuclear	25,807,446	7%
Other	125,589	0%
Other Gases	391,254	0%
Other Renewables	4,497,939	1%
Petroleum	614,863	0%

their websites, and some even sponsor conservation and efficiency workshops. A few ideas include switching to compact fluorescent lightbulbs, turning down water heaters, unplugging seldom-used appliances, and taking advantage of the West's arid climate to line-dry clothes.

Energy usage in the Rockies is nine percent less than the U.S. average rate, and, the Rockies consumer's monthly bill is 17 percent lower than the national average (Figure 4).[14] The gap between these percentages is created by the average cost (rate) of energy; rates in the Rockies are eight percent lower than the national average (see Figure 5). Looking at the region state-by-state, some interesting observations can be made (see Figures 6, 7, and 8).

Nevada and Arizona, the highest energy users after Idaho, pull up the regional average for monthly bills considerably, as they each average more than $90 per month. Given the two states' high prices and high consumption, this is not surprising. Nevada has the highest energy price rate and Arizona has the fourth highest rate in the region. In addition, they are the third and second largest consumers of energy in the region, respectively.[15] Homeowners and city planners in these states, as well as around the nation, should be asking themselves where they can reduce energy consumption. Undoubtedly, air conditioning is a major contributor to high energy use in these states. Instituting building codes with design standards aimed at reducing cooling needs would be a good first step for planners. Homeowners may look to simpler measures, such as installing ceiling fans and improving insulation and ventilation.

New Mexico residents are the most efficient users of energy. New Mexicans have the lowest average monthly consumption of any Rockies state, so despite paying the second-highest rates, they have the second lowest average monthly bill.[16]

Current Renewables Production

In the past five to ten years renewable resources have been increasingly utilized for electricity production. Utility companies are now implementing large wind farms, photovoltaic, geothermal, and concentrated solar facilities around the region. This trend comes, in part, from the utilities' effort to meet their Renewable Portfolio Standards (RPS), which identify the percentage of energy generated in the state that will be produced from renewable sources by a certain year. Wind is currently the leading installed renewable source in the Rockies

Figure 3
Monthly Household Residential Electrical Consumption in the U.S. by Census Division, 2005
Source: Energy Information Administration

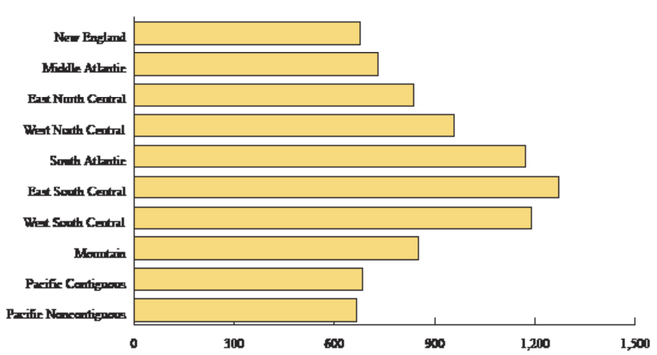


Figure 4
Electricity Consumption in Rockies States, all Sectors, MWh/yr, 2005
Source: Energy Information Administration

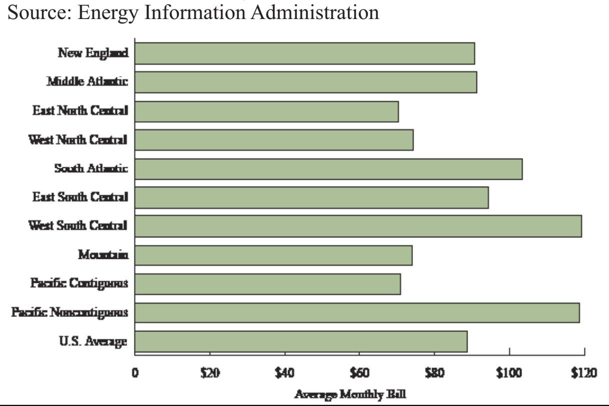


Figure 5
Average Monthly Residential Electricity Rate by Census Division, Cents per Kilowatt Hour, 2005
Source: Energy Information Administration

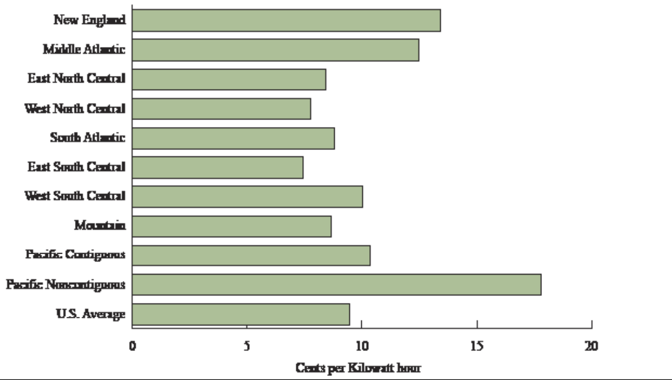


Figure 6
Average Monthly Residential Electricity Bill by Rockies State, 2005
Source: Energy Information Administration

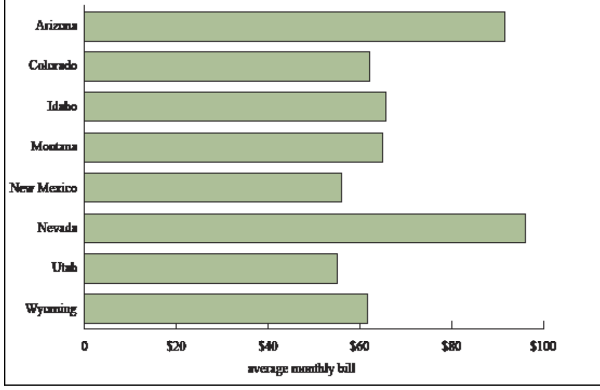


Figure 7
Average Monthly Residential Electricity Rate by Rockies State, Cents per Kilowatt Hour, 2005
Source: Energy Information Administration

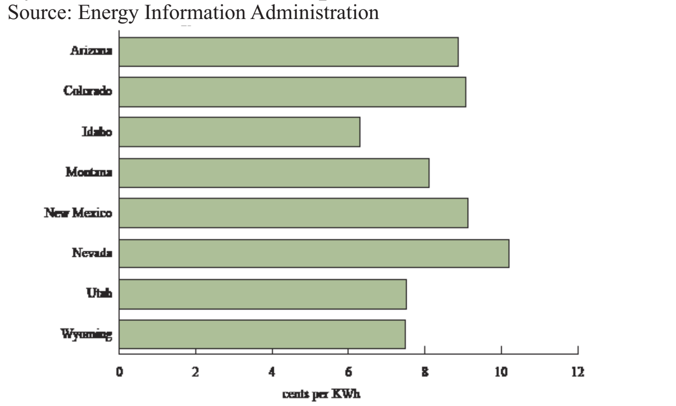
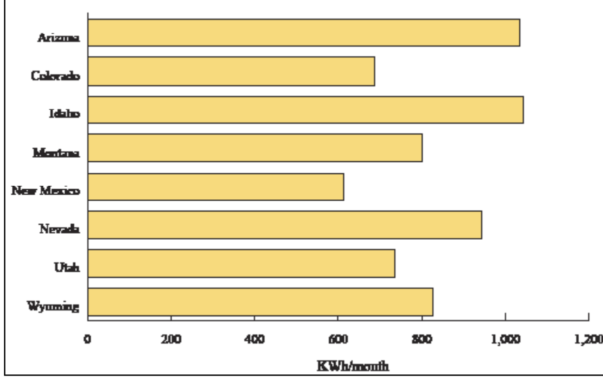


Figure 8
Monthly Household Residential Electrical Consumption in the Rockies by State, 2005
Source: Energy Information Administration



with 1,372 MW online, an electrical supply roughly equivalent to four or five coal-fired power plants.[17] Solar appears to have only a marginal contribution to date; however, many private solar systems are off-grid and while these are very important to the renewables movement, they are not included in this calculation. Home solar that is grid-tied can theoretically sell energy back to the system via net metering. This practice is financially important to the homeowner, but the amount of energy put into the grid is miniscule. A state-by-state breakdown of renewable energy generation can be seen in Table 3. The Rockies states are beginning down the renewables path, but have a long journey ahead of them.

Renewables Potential: Wind Resources

Wind power is usually broken into classes 1 through 7, where higher numbers indicate better wind. Generally, areas with class 3 wind or higher are good options for development (see Figure 9). The Dakotas are known for their consistent winds, but five of the eight Rockies states are among the top 15 windiest in the country.[18]

Magnifying the scale to the Rockies, it becomes apparent that the tops of mountains are often very windy but infeasible to develop because of limited access to roads and power lines (Figure 10). Nevertheless, the plains of Colorado, Wyoming, Montana, and eastern New Mexico are excellent places to install wind turbines. The top ten windiest counties, all registering in a wind power class between 4 (good) and 5 (excellent), lie along the front range of northern Montana and the plains of Wyoming.[19] The Rockies has ample class 3 wind resources; current facilities use just 0.3 percent of the region's wind potential.[20]

Solar Energy Resources

Based on the region's solar resources, it is in the best interest of Western states to aggressively develop solar energy. Figure 11: Annual Solar Resources of the Conterminous United States, shows annual solar energy resources across the country. The Rockies are highly distinguished; seven of the eight states register as superior solar resources, between 5,000 and greater than 6,000 kilowatt hours per square meter per day (KWh/m^2/day). (See Figure 12.)

Among the Rockies states, Arizona, New Mexico, and

Table 3
Installed Rewable Capacity by Rockies State (MW)
Source: Renewable Energy Atlas of the West, 2006

Resource Type	Arizona	Colorado	Idaho	Montana	Nevada	New Mexico	Utah	Wyoming
Wind	0.1	366.0	75.0	146	0.0	496.0	1.0	288.0
Solar (PV)	11.8	8.2	0.1	0.1	15.1	0.1	0.0	0.1
Solar (Thermal)	0.1	No data	0.0	0.0	64.0	0.0	0.0	0.0
Geothermal	0.0	0.0	0.0	0.0	346.0	0.0	39.3	0.0
Biomass	5.3	6.1	119.6	16.1	1.0	2.2	4.0	0.0
Total	17.3	380.3	194.7	162.08	426.1	498.3	44.3	288.1

Montana hold the greatest resources, each receiving the equivalent of over 100 million MWh/yr from the sun, nearly the equivalent amount of energy used by all three states combined in 2005.[21,22] Yuma and La Paz Counties of Arizona, and Luna County of New Mexico, are the top three sunniest counties in the Rockies. Residents of these counties would benefit from solar generation for their homes, and should urge electrical providers to utilize solar on a larger scale.

Solar energy development, however, should not be limited to the areas with the highest exposure. Compared with the rest of the country and most of western Europe, where solar is widely used, nearly the entirety of the Rockies receive superior sunshine (See Case Study: German Solar). The region's neglect of prime solar resources is striking when contrasted with other countries that pour research and capital into the development of relatively less lucrative renewable opportunities.

Currently, the solar energy market is dominated by photovoltaics (PV). PV systems are able to capture diffuse sunlight and convert it to electricity. These work best when installed facing south, but rotational axes can be installed in a variety of ways, usually on rooftops. Building integrated designs with PV cells, glass, or shingles is becoming more popular, especially in Germany, Japan, and Spain. In these countries, an emphasis is placed not only on the importance of renewable energy, but also on the aesthetics and beauty of the building. In the Rockies, this sort of energy is just starting to make its way into the market. It does not come easily, however. The Energy Company Xcel's solar financial rewards are lower for building integrated solar than rewards for conventional solar, and the technology is more expensive to purchase.

Another attractive quality of solar energy in the Rockies is that it can be easily implemented on the home, commercial, and utility scale. While solar fields installed by power companies can provide energy for thousands,

Figure 9
Wind Resources of the Conterminous United States
Source: National Renewable Energy Laboratory, US Department of Energy, 1987

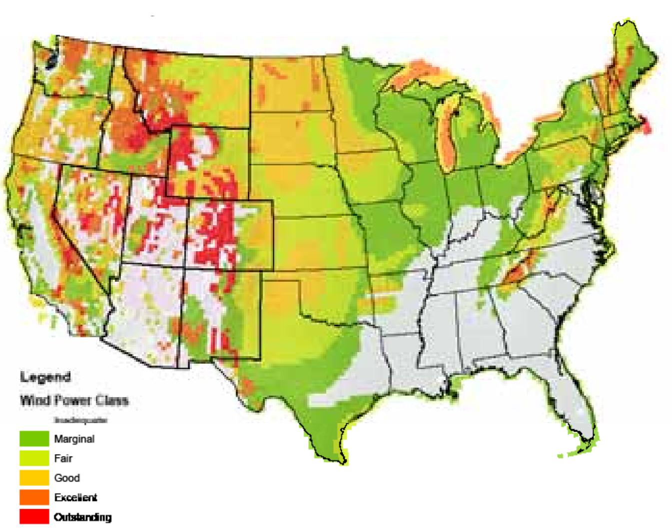


Figure 10
Wind Power Resource Potential in the Rockies (50 meter wind)
Source: TrueWind Solutions, provided by NREL

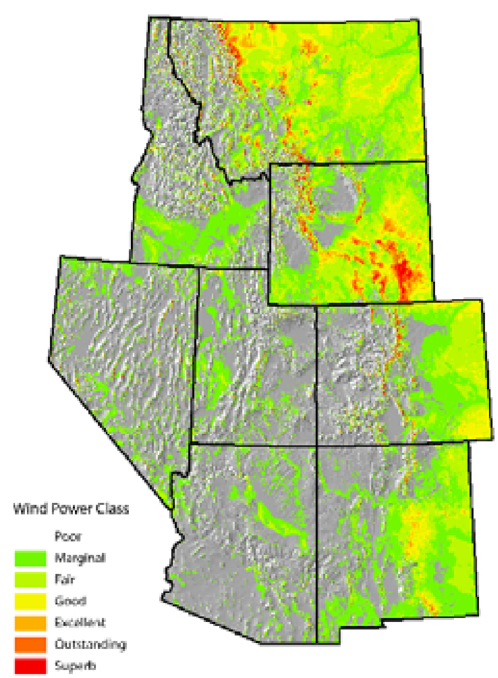
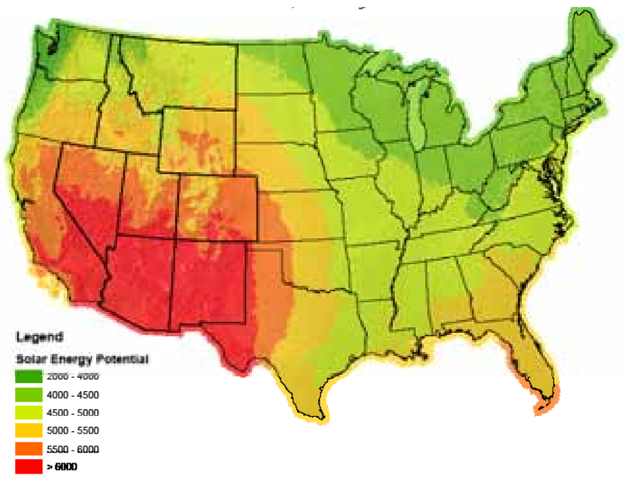


Figure 11
Annual Solar Energy Resources of the Conterminous United States (KWh/m²/day), Flat Panel Irradiance, South-Facing, Latitude Tilt
Source: Perez et al. (2002), Provided by NREL



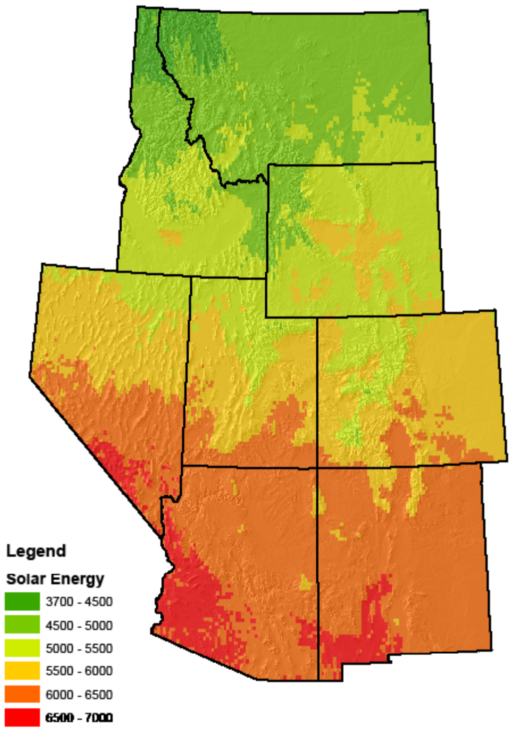
individual solar installations provide clean, renewable energy regulated solely by the home or business owner with the option of selling power back to the grid.

On the Horizon

Concentrated Solar Power, or CSP, is beginning to move into the U.S. market. Although still utilizing the sun, CSP works very differently than PV. CSP uses direct sunlight, mirrors, and a central collector to generate heat, and consequently, power. CSP holds a spatial advantage over PV: CSP uses five acres of land per megawatt of power produced, while PV, at best, requires 7.4 acres per megawatt.[23, 24]

The most common and cost-effective type of CSP is the parabolic trough, which is composed largely of concrete, steel, aluminum, and mirrors. Not including storage, the cost of building a CSP facility is $3.20-3.50 per watt.[25] The parabola is designed so that wherever the sun's rays hit, the light will be reflected directly onto a pipe filled with liquid. When the liquid is heated by the sunlight, it generates steam to move a turbine. This method of power generation is essentially the same mechanical technique as used by gas and coal-fired power plants, the only difference being that the energy to create the steam comes from the sun rather than a non-renewable resource. CSP can also be achieved with dishes or towers, but these methods are not yet proven on the market and, therefore, not as attractive to investors. Also, because CSP needs very direct sunlight, not all areas suitable for PV are suitable for CSP. Yet the best areas for PV are generally good places for CSP; counties with high solar resources should look into CSP development.

Figure 12
Annual Solar Energy Resources of the Rockies (KWh/m²/day), Flat Panel Irradiance, South-Facing, Latitude Tilt
Source: Perez et al. (2002), Provided by NREL



the U.S., CSP is most famously used in Boulder City, NV, at Nevada Solar One, which has a capacity of 64 MW. It is the third largest CSP facility in the world and generates enough power to cover the needs of more than 15,000 average households.[26] (See Case Study: Nevada Solar One.)

Biomass Resources

Biomass resources should not be confused with biofuel resources. The biomass resources in this section consist of crop residues (corn stalks), forest residues (trees from thinning), animal waste (methane digesters and water treatment plants), and landfill gas. The distillation process for ethanol and other *biofuels* is very different than the combustion process for electricity utilized by these resources. This section focuses on electricity generation with biomass and not biofuels. Biomass can be very effective when operating locally and diversely; there are dozens of ways to utilize biomass. In addition, most biomass not used for energy is thrown into landfills or released, uncombusted, into the atmosphere. Therefore, biomass energy is often a cost-effective and environmentally-responsible option. Figure 13: Annual Biomass Resources of the Conterminous United States, shows the biomass resources of the country broken down by state and county. Compared to the Midwest, the Rockies seem quite deficient in their quantity of biomass re-

Case Study: German Solar Comparison

The United States has the resources to be a world leader in solar power, but currently Germany is driving the market. Germany's sunshine, in the best places, is 33 percent less intense than Colorado's sun, yet the country installed 750 megawatts (MW) of solar power across 100,000 roof tops in 2006.[52,53] These numbers follow 600 MW of solar installations in 2004 and 750 MW of solar installations in 2005.[54] In all, Germany has installed 2,500 MW of solar energy.[55]

In the U.S., photovoltaics are tagged as too expensive. Germany sidesteps this problem by implementing "feed-in rates." Feed-in rates are the rate the utility company pays the owner of the solar system for the power that goes into the grid. The U.S.'s practice of net-metering is similar, but not as thorough. Net-metering only pays solar owners for the net power they generate; feed-in rates pay for all the power produced, even if it is used on-site. Plus, German feed-in rates are higher than American net metering. Jim Welch, President of Sun Electric Systems, sees feed-in rates as the best way to make solar competitive. It is simple, efficient, and easy to execute.

Solar Church, Germany
Implements vertical panel configuration
Photo Courtesy of Bella Energy

In Germany, normal solar collectors receive around 61 cents/kWh produced and building integrated solar receives 85 cents/kWh produced.[56] Essentially, Germany is paying a premium for ingenuity and architectural verve. As architects and engineers work together, new more efficient technology is often created. This serves as a potential driver to make solar more economically competitive, while at the same time making homes and buildings aesthetically pleasing and less susceptible to the vagaries of overcommitted centralized grids.

Illuminiertes Building, Germany
Uses architecturally integrated solar design
Photo courtesy of Bella Energy

sources. Small scale and localized biomass, however, is often very rewarding.

Maricopa County, Arizona, where Phoenix is located, stands out as a biomass hotspot (see Figure 14). This may seem peculiar given that Phoenix does not support much agriculture, but the beauty of biomass is its diversity and adaptability. The dense populations of Maricopa County generate waste that can be transformed to energy through landfill gas, wastewater gas, and urban wood residues. Other areas such as Las Vegas in Clark County, Nevada, boast similar resources from their waste.

Unlike Maricopa and Clark Counties, the top three counties in Idaho and Montana rely on residues from the timber milling industry for their biomass resources. Yuma County, Colorado, which is fifth best overall, benefits mainly from crop residues. On the national scale, and even on the regional scale, biomass does not appear to be a priority in the Rockies. On the local and municipal scale, however, the impacts of utilizing biomass should not be overlooked.

Geothermal Resources

Geothermal hot spots are normally caused by specific geologic features or seismic activity, but more generally geothermal heat resources are created by radioactive decay of elements in the Earth. A quick glance at Figure 15: Geothermal Resources of the Contiguous United States, shows that similar to solar resources, the Rockies stand out for geothermal resources. These resources represent huge assets to the region. The nature of geothermal power is intrinsically different than that of wind and solar. The latter sources are not constant: wind can stop blowing and the sun does not always shine. Conversely, geothermal is capable of handling large base loads of power needing a consistent, reliable supply. Figure 16: Rockies Geothermal Resources by County, illustrates the Rockies' geothermal resource potentials on the state and county level. With all of its resources, the Rockies are far behind in installed geothermal energy. The national capacity of geothermal facilities is 3,000 MW.[27] In the Rockies, geothermal electricity generation is most widely used in Nevada. Yet the state only has a capacity of 346 MW of geothermal power; a little less than one

Figure 13
Annual Biomass Resources of the Conterminous United States (tonnes per year)
Source: National Renewable Energy Laboratory, US Department of Energy

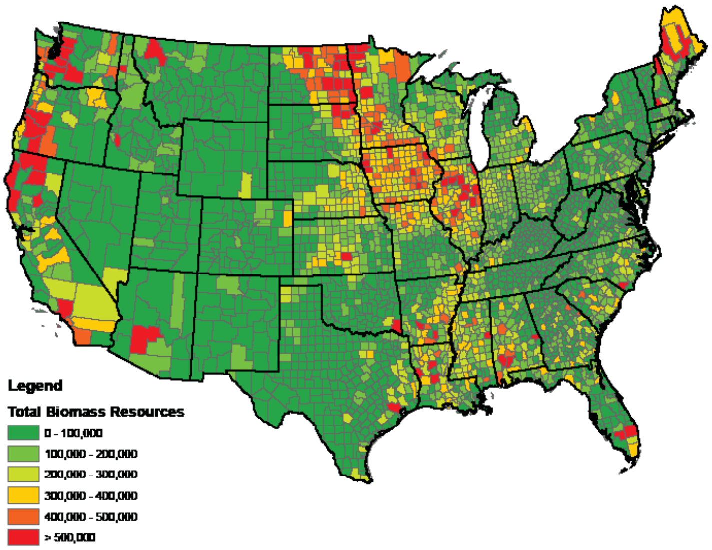
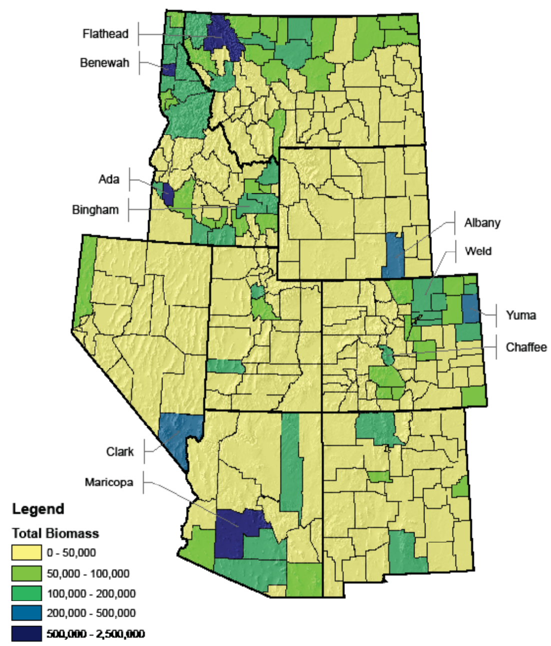


Figure 14
Cumulative Biomass Resources by Rockies County, 2005 (tonnes per year)
Source: National Biomass Assessment, NREL



coal-fired power plant in Pueblo, Colorado.[28]

While Nevada is currently the leader in developing geothermal energy in the Rocky Mountain West, other parts of the region provide more geothermal resources. Counties in Montana and Wyoming hold the greatest opportunity, yet portions of these counties lie within the boundaries of Yellowstone National Park and therefore will probably never be developed. This renders counties in the rest of the top ten, located around southern Idaho and northern Utah, very desirable for geothermal energy facilities.

Geothermal resources can be captured at the utility scale, but also at the residential scale. For utilities, geothermal energy is used to heat water to create steam that spins a turbine to generate power. Geothermal heat pumps, used in homes and businesses, are efficient in most parts of the United States because a direct geothermal heat source is not needed. Heat pumps take advantage of the stable temperatures underground to regulate the temperature of the building. To achieve this, pipes filled with a water-based fluid are coiled underground. The earth-insulated fluid is warmer in the winter and cooler in the summer, resulting in more comfortable living environments throughout the year. Curt Robinson, Executive Director of the Geothermal Resources Council, notes, "Ground source heat pumps are the Volkswagon of geothermal, bringing it to one's home, just like solar panels."[29]

Purchase example:

A homeowner in Iowa installed an Econar, a closed-loop geothermal system. The slinky system was composed of 3200 feet of ¾ inch plastic pipe buried 8-9 feet deep. The quote for the project was $13,350, and after the addition of an air filter came to $13,650. Alliant Energy provided a $2,285 rebate on the project. The couple expects to save 46 percent on their total utility bill. With an average yearly bill of $3,180, the cost of the heat pump will be repaid within eight years.[30]

Demand Side Management

One way utilities currently try to deal with peak demand issues is through Demand Side Management (DSM), which are programs that encourages energy conservation. DSM is especially sensitive to conserving energy during peak usage times. For example, turning down your air conditioner and not using the clothes dryer in the afternoon can greatly lessen the stress on utilities during peak hours. By lowering and normalizing the volume of energy needed, utilities, and therefore consumers, save money (see Figure 17).[32]

Conservation

Americans take pride in being visionary. However, we have traditionally focused our vision on the variety of ways in which we can have more of what we want. We define progress as more houses, more jobs, and more technology. Growth and development require changes and adaptations that consume energy. Looking ahead, we need to redirect our vision to answer the question of how we can use less—how we can conserve.

No new form of energy, or mix of energy, makes us more secure than not needing the energy in the first place. In all of our technologically progressive projections for the future, we have focused on meeting demand—not modifying our demand to accommodate our resources and infrastructure. Energy independence must mean more than weaning ourselves from foreign fossil fuels. It should also mean taking the system out of the clutches of a sprawling grid and infrastructure that races to keep up with growing consumption. By doing this, we could not only save money in our homes on our energy bills, but keep from investing millions of dollars towards the construction of unneeded power plants and infrastructure. Needing less can be far more liberating—and contribute more to our national security—than having more.

Intermittence

Although both wind and solar can make excellent additions to the energy grid, the variability in wind resources and sunshine prevents turbines and PV from supplying large base loads of power as reliably as coal-fired power plants. This "intermittence" is an ongoing problem for wind and solar energy. Turbines in most windy places will produce power some 70 percent of the year.[33] Unfortunately, the American expectation to receive unlimited power at *all* times renders 70 percent an underachievement.

This shortcoming should not cause wind and solar to be marginalized. Recent studies suggest that intermittence will have a far less negative impact on the grid than previously thought. Ron Lehr, former Chairman and Commissioner of the Colorado Public Utilities Commission, points out that Danish, German, Spanish, Irish, and English power system engineers are dealing with a much higher percentage of wind on their grids than the United States, without many storage concerns.[34] EnerNex's Wind Integration Study stated, "Many of the earlier concerns and issues related to the possible impacts of large wind generation facilities on the transmission grid have been shown to be exaggerated or unfounded by a growing body of research, studies, and empirical understanding gained from the installation and operation of over 6,000 MW of wind generation in the United States."[35] Among these studies is one performed for Xcel Energy, Colorado's largest energy provider. In 2010, it plans to install 1,500 MW of wind power to an area of Minnesota that only uses 10,000 MW of electricity, substituting 15 percent of power use to an "intermittent" resource.[36]

Intermittence has become exclusively associated with renewable energy. It seems people have forgotten what the failings of other types of energy could mean for the reliability of the grid. What would happen if foreign oil and natural gas imports were to cease? If we cannot safely store nuclear waste, what effect will that have on our national security? How secure are coal supply lines that stretch across the country? The intermittence of renewable energy is no reason not to push forward with its development; it simply emphasizes the need for diversity in energy generation. Just as our reliance on oil as the sole fuel of our automobiles causes environmental and political problems, a complete reliance on a single electrical power resource creates energy vulnerability. Energy is critically important to our national security and renewable, domestically-produced energy must be a top priority.

Figure 15
Geothermal Resources of the Contiguous United States (MW/m^2)
Source: SMU Geothermal Laboratory

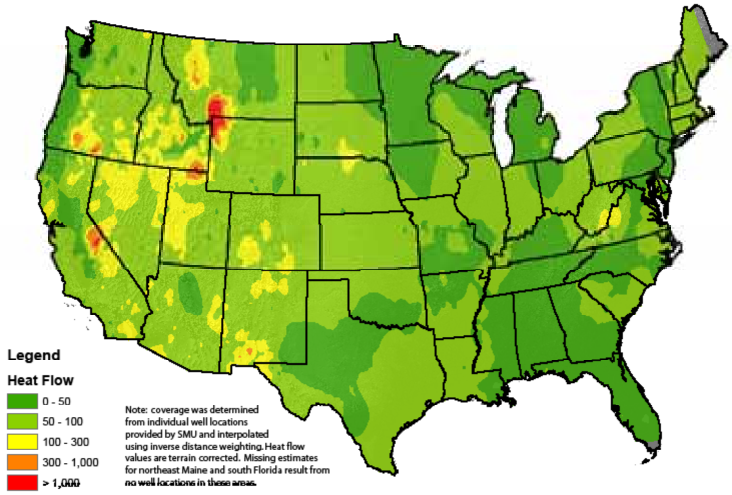


Figure 16
Geothermal Resources in the Rockies by County (MW/m^2)
Source: Calculated from SMU Geothermal Laboratory statistics

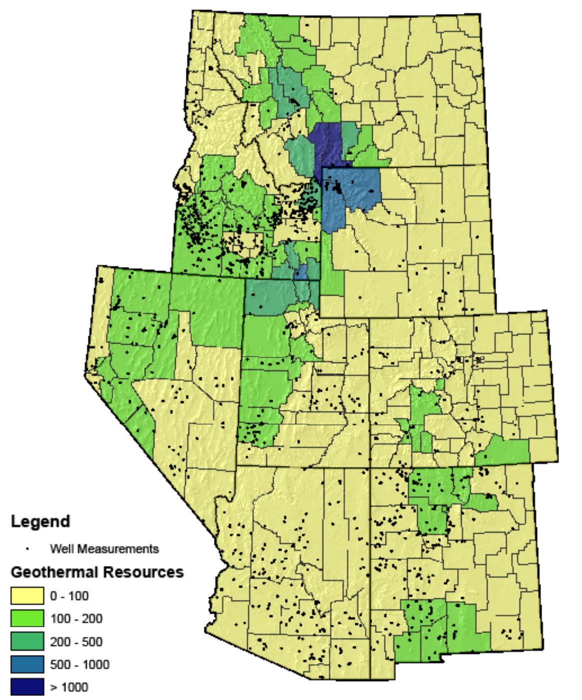
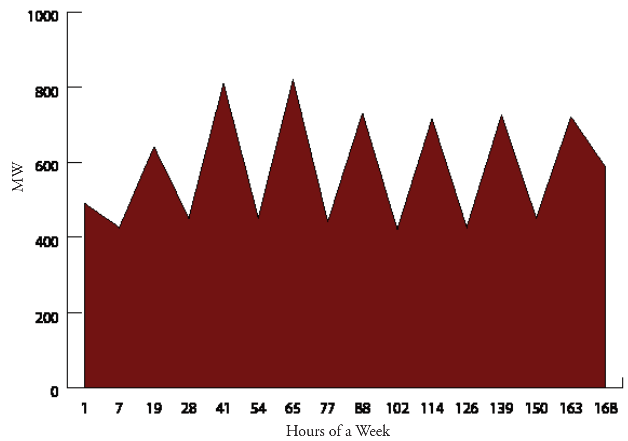


Figure 17
Hypothetical Utility Load Shape, MW, Peak Summer Week
Source: Estimated from Colorado Springs Utilities Data



Transmission

The transmission of electricity accounts for a huge effort by the energy industry, both geographically and financially. Three weakly interconnected grids cover the United States: the Western, Eastern, and Texas grids. For electricity to flow efficiently throughout the region, the grid must be updated to accommodate increased generation. Transmission lines are expensive. A common assumption about renewable resources is that they are far away from existing transmission lines and will require billions of dollars in new infrastructure; however, plenty of wind is available close to existing transmission lines.

As the region's infrastructure ages, policy makers are preparing for updates. In March of 2006, the Western Governors' Association's (WGA) Clean and Diversified Energy Initiative published a report of recommendations for updating what is becoming a heavily strained Western grid; they suggested eight major expansions. One example is the Frontier Line: stretching from California through Nevada and Utah to Wyoming, it is estimated to cost $3 billion.[37]

Currently, less than ten percent of the cost of electricity goes towards transmission.[38] With expensive infrastructure updates looming ahead, the WGA outlined several principles that should accompany the planning process.[39] To summarize, planners must be *proactive*, recognizing the needs of the future instead of building to suit what we currently have. The planning process must be *open* for public participation, recognizing needs of the many parties involved. The data used in making decisions must be *transparent*, and planning should be *comprehensive*, including demand and supply side management, as well as integration of new technologies [emphases in original].[40]

Also included in the recommendations was an emphasis on the importance of connecting to renewable energy resource sites in order to meet state Renewable Portfolio Standards. The WGA put priority on connecting to small generators (under 20 MW), for the timely cooperation of the federal government in the permitting process, and for the planning process to be region-encompassing.[41] In the past, individual utilities built lines when necessary. The WGA is calling for a regional plan for the future, creating an involved, comprehensive process to ensure stability for our electrical grids. Proponents of renewable energy should use this opportunity to ensure a place for renewables now and in the future.

Case Study: Nevada Solar One

The hot sun of Nevada is easy enough to notice, but when concentrated to 71 times its strength it produces temperatures up to 750 °F. These extreme temperatures are created by facilities like Nevada Solar One, the largest Concentrated Solar Power (CSP) facility in the world built within the last 16 years. Covering 400 acres, the facility uses 760 parabolic cylinder concentrators and 18,240 solar receivers.[51] The generation capacity of 64 megawatts will likely produce 130,000 MWh annually – enough to power more than 15,000 homes.

Beyond power production, the facility powers the economy. During the 16-month, $250 million construction that ended in June of 2007, 400 construction jobs were created along with 28 permanent jobs. Acciona Solar Energy, the developer, is a subsidiary of Spain's Acciona Energy, a company that is no stranger to the renewables business. Acciona is the largest supplier of wind energy in the world, having installed 4,500 megawatts across 169 wind farms in ten countries. They are also very active in solar, biomass, and biofuels production worldwide.

Nevada Solar One represents solar power operating on a utility-sized scale. CSP's efficient use of land and sun, cheap construction materials, and substantial energy capacity make it palatable for investors, consumers, and utilities alike. If other companies can follow the lead of Acciona, CSP can be an important contributor to the Rockies region's energy

Western Governors

In addition to their transmission report described above, the Western Governors' Association drafted a resolution in June 2006 entitled "Clean and Diversified Energy for the West." The resolution sets goals for the region's energy future, advocates several policies, and identifies ways clean and diversified energy would help the West. Although the WGA resolution identifies fossil fuels as the largest energy producer now and for the future, renewable energy, conservation, and efficiency play a large role in the policy recommendations. The major goals of the resolution include:

- •Additional development of 30,000 MW of clean energy by 2015 (75 percent of current production if generating at capacity at all times) from renewable energies, "clean coal" technologies, and advanced natural gas technologies.
- •A 20 percent increase in energy efficiency in western states by 2020.
- •An ability to meet the transmission needs of the West for the next 25 years.
- •Better position the western energy system to respond to new environmental challenges, including potential limitations on emissions.[42]

The Western Governors also include a section listing federal policies they would like to see implemented. Among these are increased tax incentives for renewables, increased national efficiency standards, adequate funding for technology research, and federal support of the transmission goals outlined in their Transmission Report (see Transmission Section, above).[43]

State Renewable Portfolio Standards

As an initial step, five of the eight Rockies states have adopted Renewable Portfolio Standards (RPS), which prescribe the percentage of energy generated in the state that will be produced from renewable sources by a certain year (See Table 4: Rockies Renewable Energy Portfolios by State).

Many of these standards have incremental percentage goals building up to the final target level. Colorado, for example, after passing Amendment 37 requiring 10 percent renewables by 2015, passed HB07-1281, requiring utilities to achieve 20 percent renewables by 2020, while meeting several deadlines along the way.

RPS target percentages, reporting, and enforcement vary greatly from state to state. For example, in Colorado, the Public Utilities Commission can only regulate Xcel Energy and Aquila, the publicly owned utilities. Municipal utilities, such as Colorado Springs Utilities and Fort Collins Utilities, are managed by their city councils, which are responsible for ensuring that they comply with standards. Furthermore, the Rural Electric Cooperatives, formed during the New Deal under Franklin Roosevelt, are not regulated. The RPS applies to them as well, but there is no enforcement.[44]

Many utilities initially developed Integrated Resource Plans to help them meet their RPS. An Integrated Resource Plan is defined as "a formal process by which utilities analyze the costs, benefits, and risks of *all* resources available to them—both supply-side and demand-side—with the ultimate goal of identifying a portfolio of resources that meets their future needs at lowest cost and/or risk."[45]

Utility incentives provided by the federal and state governments, utilities, municipalities, and non-profits are very effective in making renewable energy and conservation measures attractive and affordable to homeowners and businesses. Yet imperfect information often dissociates consumers from accessing what is available.

Social Movements, Signs of Change

Solar Energy International (SEI) is a non-profit educational organization based out of Carbondale, Colorado. Founded in 1991, it began by offering 12 classes each year that introduced about 250 people annually to renewable energy.[46] During the rest of the 1990s, interest in renewables and SEI's workshops steadily increased. After 2000, class and workshop enrollment began to sharply rise. In 2006, SEI offered 52 hands-on workshops and seven online courses, attracting 1,800 participants. Since 1991 more than 4,800 people have participated in SEI's Renewable Energy Education Programs.[47]

Table 4
Renewable Energy Portofolios by State
Source: US Department of Energy, and Union of Concerned Scientists

State	Percentage	Year	Organization Administering RPS
AZ	15	2025	Arizona Corporation Commission
CO	20	2020	Colorado Public Utilities Commission
MT	15	2015	Montana Public Service Commission
NM	20	2020	New Mexico Public Regulatory Commission
NV	20	2015	Public Utilities Commission of Nevada
WY	x	x	x
ID	x	x	x
UT	x	x	x

Note: Wyoming, Idaho, and Utah have not yet adopted renewable portfolio standards

“This is a national trend, not just a Colorado trend,” noted Johnny Weiss, Executive Director of SEI. Indeed, by running workshops in many states and offering online classes, SEI has helped people from all 50 states and 66 countries learn about renewable energy.[48]

Economics is always a factor. If people can save money with renewables the choice is easy. Currently, however, most progressive renewables represent a financial net loss. This does not seem to deter Weiss’s participants. Weiss added, “People who have installed solar on their homes in the past decade have done it for environmental and personal reasons…Renewables are seen as positive and constructive; they’re a personal statement.”[49] For some, investing in renewable energy generation may also reflect a desire to gain energy independence at the household level. In the case of a Hutterite community in Martinsdale, Montana, the incentive is economic gain, preservation of their autonomy, and the desire to implement the latest, and best technology (See Case Study: Martinsdale, MT, Hutterite Colony).

The Rights of Our Posterity

In his essay, “Law of the Land,” author David Orr calls for an amendment to the U.S. Constitution that would declare access to a healthy environment as a universal and timeless right. Part of his claim is that posterity has been greatly ignored by today’s society. Orr’s proclamation sounds bold, but it may also be reasonable: the State of Montana’s constitution already guarantees its citizens a fundamental right to a clean and healthful environment – a provision that was affirmed in a 1999 state Supreme Court decision.[50]

In thinking about energy, we must look to the future. As humans, how can we defend an energy system that deprives our great-grandchildren the opportunity to experience the world the way we, and those before us, have known it?

The Rocky Mountain West’s abundance of renewable resources is eclipsed only by its wealth of natural beauty: Yellowstone National Park, the Grand Canyon, the Sonoran Desert, Arches National Monument, the San Juan Mountains, the Gallatin River, to name a few. We need to focus our energy toward conservation and renewables to give future generations a chance not only to live, but to live well.

Huts with Solar Panels, Bear Basin Ranch, Westcliffe, Colorado
© Natalie Baumann

Endnotes and Citations

[1]“Table ST-F1-2000. Average Number of Children Per Family and Per Family With Children, by State: 2000 Census.” U.S. Bureau of the Census. http://www.census.gov/population/socdemo/hh-fam/tabST-F1-2000.pdf.
[2]Hall, Brian and Chris Jackson. April, 2007. “Energy Development in the Rockies.” *The 2007 State of the Rockies Report Card*. p. 70.
[3]Small hydro is often included in renewable standards, but also not included in this report.
[4]Kutscher, Charles F. January 2007. *Tackling Climate Change in the U.S.* American Solar Energy Society (ASES), p. 33.
[5]Kutscher, Charles F. p. 26.
[6]Statistical Review of World Energy 2007. http://www.bp.com/productlanding.do?categoryId=6848&contentId=7033471. A terawatt is one trillion watts.
[7]Energy Information Administration, From EIA-861, “Annual Electric Power Industry Report.”
[8]Table 7. Energy Consumption Estimates by Source, Selected Years, 1960-2004, United States. EIA
[9]“Table 12. Electric Power Sector Consumption Estimates, Selected Years, 1960-2004, United States.” State Energy Consumption, Price, and Expenditure Estimates (SEDS). Energy Information Administration. http://www.eia.doe.gov/emeu/states/sep_use/eu/use_eu_us.html.
[10]Energy Consumption Estimates by Source, Selected Years, 1960-2004, EIA. http://www.eia.doe.gov/
[11]Energy Consumption Estimates by Source, Selected Years, 1960-2004, States. EIA
[12]Energy Consumption Estimates by Source, Selected Years, 1960-2004, States. EIA
[13]U.S. Average Monthly Bill by Sector, Census. http://www.eia.doe.gov/
[14]Ibid.
[15]Ibid.
[16]Ibid.
[17]Numbers gathered from “Wind Energy Projects.” American Wind Energy Association. http://www.awea.org/projects/ and “Project Locator.” Interwest Energy Alliance. http://www.interwest.org/projects/default.aspx.
[18]“The Top Twenty States for Wind Energy.” 1991. American Wind Energy Association: Wind Energy Fact Sheet. http://www.awea.org/pubs/factsheets/Wind_Energy_An_Untapped_Resource.pdf Source: Pacific Northwest Laboratory.
[19]Calculated from NREL data.
[20]Kutcher, Charles. p. 13.
[21]Ibid.
[22]http://www.eia.doe.gov/cneaf/electricity/esr/table5.xls
[23]Mehos, Mark. June, 2007. Program Manager: Concentrating Solar Power. National Renewable Energy Laboratory Personal Phone Conversation with Author.
[24]Worked from www.nrel.gov/docs/fy04otsi/35079.pdf
[25]Mehos, Mark.
[26]Acciona Solar Power. June 7, 2007. “Acciona Connects to the Nevada Grid the World’s Largest Solar Thermal Plant in 16 Years.”
[27]Robinson, Curt. July 25, 2007. Executive Director of the Geothermal Resources Council. Personal Email Correspondence with Author.
[28]Project Locater. Interwest Energy Alliance. www.interwest.org/projects/default.aspx. 8/4/07. And Existing Generating Units in the United States by State, Company, and Plant, 2005. Energy Information Administration, Form EIA-860, “Annual Electric Generator Report.”
[29]Robinson, Curt.
[30]Kolbe, Kevin. August 9, 2007. Personal Interview with Author.
[31]www.wisconsinpublicservice.com/farm/terms.asp
[32]Richard Mignogna. June, 2007. Renewables Engineer, RPS Compliance Lead, Colorado Public Utilities Commission. Personal Telephone Correspondence with Author.
[33]Udall, Randy. Personal Telephone Correspondence with Author.
[34]Ronald Lehr. Attorney, AWEA Western Representative. Personal Email Correspondence with Author. 7/28/07.
[35]EnerNex Cooperation and Wind Logics, Inc. “Wind Integration Study: Final Report.” Sept. 28, 2004. p. 19. http://www.uwig.org/XcelMNDOCStudyReport.pdf.
[36]“Wind Integration Study: Final Report.” P. 20.
[37]Comments of the Wyoming Infrastructure Authority. “Considerations for Transmission Congestion Study and Designation of National Interest Electric Transmission Corridors”. February 2, 2006. p. 9. http://www.wyia.org/Docs/Comments/Comments percent20on percent20DOE percent20NOI percent20on percent20NIETC percent20from percent20WIA.pdf
[38]Ronald Lehr. June 22, 2007. Personal Email Correspondence with Author.
[39]The Western Governor’s Association (WGA) is a collection of Governors from the Western region (19 members) who work together to implement regional goals, share ideas and information, and form camaraderie with their neighbors.
[40]Draft Report of the Transmission Task Force. WGA Clean and Diversified Energy Initiative. March 2006. http://www.awea.org/policy/regulatory_policy/transmission_documents/WGA_TransmissionReport_3-2-06.pdf.
[41]Draft Report of the Transmission Task Force.
[42]*Clean and Diversified Energy for the West*. June 11, 2006. Western Governors’ Association Policy Resolution 06-10.
[43]*Clean and Diversified Energy for the West*.
[44]Richard Mignogna. June, 2007. Renewables Engineer, RPS Compliance Lead, Colorado Public Utilities Commission. Personal Telephone Correspondence with Author.
[45]Mark Bolinger and Ryan Wiser. Utility Integrated Resource Planning: An Emerging Driver of New Renewable Generation in the Western United States. http://repositories.cdlib.org/cgi/viewcontent.cgi?article=3908&context=lbnl
[46]Weiss, Johnny. August 2, 2007. Executive Director, Solar Energy International. Personal Phone Interview with Author.
[47]SEI 2006 Annual Report. Solar Energy International. Carbondale, CO.
[48]SEI 2006 Annual Report.
[49]Weiss, Johnny.
[50]France, Tom, 17 November 1999. “Having their Year in Court,” *Grist*. viewed online at http://www.grist.org/news/maindish/1999/11/17/france-montana/.
[51]“Introducing Nevada Solar One – Concentrating Solar Power.” Acciona Solar Power.
[52]Jim Welch. July 25, 2007. President, Sun Electric Systems, Inc. Personal Phone Conversation. With Author.
[53]Gipe, Paul. August 4, 2007. German Feed Laws Power Nation to New Renewable Record in 2006. 2/2/2007www.wind-works.org.
[54]Gipe, Paul.
[55]Gipe, Paul.
[56]Morris, Craig. “Much Ado about Germany.” *Solar Today*. Values are in U.S. dollars.

Case Study: Martinsdale, MT, Hutterite Colony

From the outside, the Hutterite colony near Martinsdale, Montana, doesn't seem especially progresssive. Sustained by farming, community members home-school their children only through ninth grade, attend church services nearly every day, and maintain gender roles from the 1920s. However, on a tour with the colony's financial director, Peter Wipf, it became clear that this Hutterite community was in some ways revolutionary.
We met Wipf at the base of the colony's Qualified Facility Hook-up wind farm. The system, new in 2006, is composed of 19 third-generation turbines from California. Despite their limited schooling, Hutterite boys are extremely proficient in mechanical operations. In two days, eight Hutterite men erected 11 of the turbines. The larger turbines took a bit longer, but all the work was done by the Hutterites. On the larger, 250-kilowatt machines, some of the blade technology is overseen by Montana Wind Works, on this day in the form of a high school biology teacher named Lewis Gunn.

Gunn sees his work with turbines as a hobby. His neighbor taught him how to work with turbines and he has been part of the wind company ever since. Gunn seemed to understand the importance of hands-on learning. Within five minutes of our meeting, he offered me his climbing harness and I was at the top of the turbine. I was covered in grease, but ecstatic to be looking across Montana from over a hundred feet in the air. For those who say wind turbines ruin the view, I would argue they are looking at the turbine from the wrong vantage point. Montana never looked better.

Wipf wanted to show us around the colony a bit more before taking us to the colony's off-grid turbine. While we walked, he answered our questions about agriculture, religion, technology, and Hutterite society. We learned that Hutterites are very musical; they perform a capella very often, and even though it isn't allowed, they sometimes play instruments. The colony is bilingual. To each other, they speak their traditional German dialect, but everyone spoke perfect English with us. Their religious philosophy is based mainly on two chapters of the Bible, Acts 1 and 2. Acts 2:45 says, "And (the Apostles) sold their possessions and goods, and parted them to all [men], as every man had need." The Hutterites live in accordance with this. Everyone works on the colony, but no one earns a salary. Money that is made by the colony is handled by the elder leaders.

Despite this communal approach, the Hutterites are very capitalistic in their endeavors. Wipf pointed out how important it was for the colony to keep on the cutting edge of technology. Without technology, they would not be able to compete in agricultural markets. The colony grows barley, wheat, yellow peas, and a variety of other crops. They are also a top producer of dairy cows, and their dairy products are sold to the regional dairy Meadow Gold. In fact, they are so proficient with agriculture, they are 90 percent self-sufficient for food. They only buy what they cannot produce as cheaply – namely beef.

We reached the colony's off-grid turbine. With a capacity of 65 kilowatts, the turbines often cover the needs of the entire colony. Wipf explained that because the Hutterites do all the electrical and mechanical work, the cost of the turbine was paid off in about a year and a half. The turbine was installed in December of 2003, and was the first of its kind in Montana's Wheaton County.

In addition to wind energy, the Hutterites have developed a heat-recapture system for their dairy and kitchen refrigeration units. The system is one of Wipf's proudest accomplishments, and the colony is in the beginning stages of acquiring a patent. In the colony building, where the women cook three meals a day, the excess heat is used for pre-heating water and heating buildings. In the dairy barn, the pre-warmed water is fed to the cows. This is doubly efficient for the colony. Because the cows do not have to use energy to warm the water, they require less calories, and subsequently, less feed.

After all they have accomplished, the Hutterites, true to their ethic, are not finished with their work in renewables. They plan to install two additional 150 kW turbines on the colony to sell power back to the grid. Also pending is a 75 megawatt wind farm development on their land by Horizon Wind Energy. The Hutterites, of course, will be doing all the mechanical, electrical, and installation work for these projects. When I asked Wipf how he got into wind, he said, "I've always been dreaming about wind."

Grading Renewable Energy Potential

Historically considered an inland energy colony of the United States, the eight-state Rocky Mountain West has for decades been exploited for its fossil fuel resources. With national interest turning toward renewable energy alternatives, what opportunities are available for counties in the region? This "Grading the Rockies" section of the *2008 State of the Rockies Report Card* examines the potential to develop wind, solar, geothermal, and biomass resources available in each of the 281 Rockies counties. The grades provided in this study only consider renewable potential, it does not account for the necessary infrastructure to store and deliver each county's collected renewable energy. Since the current infrastructure was built mostly to accommodate fossil fuel production, including this would not necessarily depict a particular county's ability to develop renewable energy. This analysis highlights which counties, when supplemented with the necessary labor and infrastructure, are best poised to take advantage of a renewable energy boom.

Methodology

Grades for geothermal potential were derived from geothermal heat flow data provided by the Southern Methodist University geothermal lab: http://www.smu.edu/geothermal/heatflow/heatflow.htm. Geothermal potential is measured by heat flow per unit area (mW/m^2).

The potential for biomass energy is calculated from a National Renewable Energy Lab (NREL) analysis that considers the following biomass sources: crop residues, forest residues, primary mill residues, secondary mill residues, urban wood waste, methane emissions from landfills, methane emissions from manure management, methane emissions from wastewater treatment plants, and dedicated energy crops. A more detailed description of these sources is located at: http://www.nrel.gov/gis/biomass.html.

Wind data is provided also by NREL. Wind resources for a given grid space are measured on a scale of one to seven, seven being the greatest resource potential. Wind speed is measured at 10 meters and 50 meters above ground to account for frictional effects on wind speed. A detailed table of this scale is provided below.

Classes of wind power density at 10 m and 50 m(a)				
Wind Power	10 m (33 ft)		50 m (164 ft)	
Class	Wind Power Density (W/m 2)	Speed (b) m/s (mph)	Wind Power Density (W/m 2)	Speed (b) m/s (mph)
1	0	0	0	
2	100	4.4 (9.8)	200	5.6 (12.5)
3	150	5.1 (11.5)	300	6.4 (14.3)
4	200	5.6 (12.5)	400	7.0 (15.7)
5	250	6.0 (13.4)	500	7.5 (16.8)
6	300	6.4 (14.3)	600	8.0 (17.9)
7	400	7.0 (15.7)	800	8.8 (19.7)
	1000	9.4 (21.1)	2000	11.9 (26.6)

Solar grades are also determined from data provided by NREL. These data show monthly average solar resources that can be collected by a flat plate collector and are described here: http://www.nrel.gov/gis/solar.html.

Solar Array at Nellis Air Force Base near Las Vegas, Nevada © David Amster-Olszewski

		Biomass		Solar		Wind		Geothermal	
State	County	Tonnes/year	Grade	Solar Energy Resource Potential (million MWh/year)	Grade	Mean Power Class	Grade	HF (mW/m2)	Grade
Arizona	Apache	20439.6	C+	58021.0	A	2.4	D	87.0	A
	Cochise	51675.3	B	27794.1	A	2.9	C-	81.7	A
	Coconino	33678.8	B-	65370.0	A	2.7	D+	53.2	A
	Gila	9831.8	C-	11421.7	B+	2.5	D	81.8	B
	Graham	22162.3	C+	17856.0	A-	2.8	C-	83.8	A-
	Greenlee	3002.9	D	2065.7	D	2.6	D	87.8	D
	La Paz	20234.7	C+	5387.7	C	2.2	D	83.3	C-
	Maricopa	515608.3	A	25857.3	A	2.7	D+	80.6	A
	Mohave	21141.5	C+	26193.2	A	2.5	D	89.7	A
	Navajo	155277.3	A	52835.0	A	2.4	D	71.6	A
	Pima	131454.6	A	39865.0	A	2.5	D	86.4	A
	Pinal	150765.0	A	26294.2	A	2.7	D+	76.7	A
	Santa Cruz	6785.3	D+	3684.6	D+	2.6	D	90.5	D
	Yavapai	26410.7	C+	22604.6	A	2.3	D	87.8	A
	Yuma	89560.3	A-	6455.0	C+	2.3	D	75.1	C-
Colorado	Adams	110052.4	A-	6334.6	C+	2.0	D	78.0	C
	Alamosa	72614.8	B+	3244.1	D+	3.5	A-	89.4	D
	Arapahoe	122320.7	A-	4311.5	C-	2.2	D	79.6	D+
	Archuleta	1512.7	D	2855.4	D	3.1	C+	87.7	D
	Baca	61942.3	B	8835.7	B-	3.1	C+	74.1	C+
	Bent	6073.7	D	8465.3	B-	2.7	D+	84.7	C+
	Boulder	42731.4	B-	1951.6	D	3.8	A	79.8	D
	Broomfield			180.1	D	2.0	D	76.1	D
	Chaffee	183509.1	A	827.7	D	3.6	A-		
	Cheyenne	22884.2	C+	9787.8	B	3.3	B+	74.9	B-
	Clear Creek	4226.7	D	520.7	D	3.7	A	82.0	D
	Conejos	10110.4	C-	2926.3	D+	3.1	C+	96.7	D
	Costilla	18689.9	C+	7050.2	C+	3.5	B+	94.9	C+
	Crowley	1150.2	D	4504.4	C-	1.8	D	92.2	C-
	Custer	1350.3	D	2506.3	D	3.5	B+	75.1	D
	Delta	9277.2	C-	2757.7	D	2.3	D	94.1	D
	Denver	68399.7	B+	800.9	D	1.7	D	78.4	D
	Dolores	3441.9	D	2121.4	D	2.7	C-	98.9	D
	Douglas	57510.8	B	3212.2	D+	2.3	D	78.6	D
	Eagle	6641.3	D+	1805.7	D	3.2	B	97.4	D
	Elbert	9012.2	C-	10249.4	B	2.5	D	86.5	B
	El Paso	95023.2	A-	9850.4	B	3.1	C+	89.0	B
	Fremont	7267.6	D+	4675.0	C-	3.0	C	78.3	D+
	Garfield	14840.1	C	5806.8	C	2.8	C-	70.2	C-
	Gilpin	493.0	D	295.9	D	3.7	A-		
	Grand	2995.5	D	2909.1	D+	3.3	B+	88.8	D
	Gunnison	3839.6	D	2855.8	D	3.2	B	106.3	D+
	Hinsdale	667.8	D	107.0	D	3.5	B+		
	Huerfano	3390.9	D	7079.6	C+	3.5	A-	97.1	C+
	Jackson	3009.5	D	3312.5	D+	3.4	B+	82.4	D
	Jefferson	68267.2	B+	3086.5	D+	3.2	B-	74.3	D
	Kiowa	6630.2	D+	9902.2	B	2.8	C-	81.2	B-
	Kit Carson	126771.4	A-	11753.4	B+	3.6	A-	69.1	B-
	Lake	1289.6	D	463.4	D	3.7	A-	106.1	D
	La Plata	6611.9	D+	5478.3	C	3.3	B	95.3	C
	Larimer	56382.0	B	5592.9	C	3.7	A-	79.2	C

		Biomass		Solar		Wind		Geothermal	
State	County	Tonnes/year	Grade	Solar Energy Resource Potential (million MWh/year)	Grade	Mean Power Class	Grade	HF (mW/m2)	Grade
Colorado (continued)	Las Animas	7576.6	D+	23165.2	A	2.9	C	103.2	A
	Lincoln	28329.6	C+	14358.2	B+	3.2	B	88.1	A-
	Logan	71773.7	B+	9781.4	B	3.4	B+	58.7	C+
	Mesa	38035.1	B-	4934.6	C	2.2	D	65.5	D+
	Mineral	2541.5	D			3.2	B-		
	Moffat	4336.0	D	10963.7	B	2.6	D	65.6	B-
	Montezuma	7980.2	D+	6580.6	C+	2.7	D+	77.6	C
	Montrose	21186.3	C+	3577.1	D+	2.2	D	117.1	C-
	Morgan	112868.4	A-	6978.1	C+	1.7	D	65.5	C
	Otero	12898.9	C	4818.6	C-	2.0	D	91.6	C-
	Ouray	6713.1	D+	1343.6	D	3.4	B+	133.3	D
	Park	2621.2	D	5222.9	C	3.5	B+	89.4	C
	Phillips	112099.3	A-	3595.6	D+	3.6	A-	65.0	D
	Pitkin	8084.9	C-	635.5	D	3.5	B+	91.4	D
	Prowers	29703.2	C+	9073.0	B-	3.1	C+	73.9	C+
	Pueblo	32650.6	C+	12170.3	B+	2.5	D	99.9	A-
	Rio Blanco	1746.7	D	4295.4	C-	2.5	D	65.6	D
	Rio Grande	70528.3	B+	1958.1	D	3.1	C+	93.9	D
	Routt	10374.0	C-	6551.7	C+	3.1	C+	86.1	C+
	Saguache	65416.8	B+	5214.4	C	3.3	B	88.8	C-
	San Juan	148.6	D	63.3	D	3.4	B+		
	San Miguel	2451.0	D	2522.7	D	3.3	B	108.1	D
	Sedgwick	73259.4	B+	2880.4	D	3.1	C+	68.8	D
	Summit	9187.4	C-	34.9	D	3.5	B+		
	Teller	3392.7	D	1578.4	D	3.1	C+	77.1	D
	Washington	85778.1	B+	13645.4	B+	3.0	C	63.9	B
	Weld	199644.2	A	14957.2	A-	3.1	C+	78.5	A-
	Yuma	368711.2	A	12630.0	B+	3.1	B-	66.2	B
Idaho	Ada	2232695.4	A	2748.8	D	2.2	D	151.4	C
	Adams	18085.6	C+	1905.9	D	3.0	C+	105.0	D
	Bannock	37809.2	B-	3935.6	C-	3.0	C	240.6	B+
	Bear Lake	5045.8	D	2847.8	D	2.7	D+	266.1	B
	Benewah	2336686.7	A	2729.2	D	2.6	D	75.1	D
	Bingham	171240.3	A	7752.9	C+	2.3	D	96.0	B
	Blaine	16908.1	C+	3012.4	D+	3.1	C+	69.0	D
	Boise	41622.4	B-	1282.1	D	2.8	C-	163.3	D
	Bonner	113172.7	A-	3941.5	C-	3.2	B	65.3	D+
	Bonneville	142871.3	A	4348.5	C-	2.7	D+	75.6	D+
	Boundary	61802.9	B	1639.7	D	3.2	B	80.5	D
	Butte	12879.5	C	1446.9	D	3.2	B	294.4	C
	Camas	3388.0	D	1858.6	D	2.6	D	170.0	D+
	Canyon	101941.0	A-	2870.0	D	1.8	D	103.3	D+
	Caribou	61065.4	B	4834.1	C	2.5	D	117.9	C+
	Cassia	125828.7	A-	5962.4	C+	3.0	C+	135.3	B
	Clark	10405.8	C-	2848.1	D	3.0	C	57.7	D
	Clearwater	143244.1	A	5355.0	C	2.9	C	73.3	C
	Custer	5661.9	D	1506.4	D	3.2	B-	111.4	D
	Elmore	59789.0	B	3159.8	D+	2.6	D	105.9	D+
	Franklin	12262.7	C	2028.0	D	2.6	D	912.2	A
	Fremont	110776.4	A-	3473.7	D+	3.0	C+	162.5	C+
	Gem	8748.4	C-	1727.5	D	2.2	D	132.1	D

State	County	biomass Tonnes/year	Grade	solar Solar Energy Resource Potential (million MWh/year)	Grade	Wind Mean Power Class	Grade	Geothermal HF (mW/m2)	Grade
Idaho (continued)	Gooding	35110.7	B-	1785.5	D	2.1	D	63.0	D
	Idaho	129653.4	A	6065.3	C+	2.9	C-	58.8	C-
	Jefferson	68193.1	B+	2709.6	D	1.7	D	47.0	D
	Jerome	72579.5	B+	1991.4	D	1.4	D	75.5	D
	Kootenai	117221.0	A-	3686.3	D+	2.9	C	70.1	D+
	Latah	163494.7	A	3903.1	C-	2.3	D	66.3	D+
	Lemhi	2785.2	D	1995.0	D	3.1	C+	76.3	D
	Lewis	84042.4	B+	2125.4	D	1.9	D	65.1	D
	Lincoln	15202.4	C	1589.8	D	1.4	D	51.1	D
	Madison	67928.7	B+	1824.6	D	2.1	D	82.9	D
	Minidoka	75219.5	B+	1949.1	D	1.2	D	65.4	D
	Nez Perce	98736.5	A-	3723.2	D+	2.3	D	68.4	D+
	Oneida	11977.5	C	2482.5	D	2.5	D	777.3	A
	Owyhee	30962.3	C+	8059.9	B-	2.6	D	104.1	B
	Payette	19299.3	C+	1497.7	D	1.6	D	87.4	D
	Power	84803.8	B+	4820.7	C-	2.8	C-	125.1	C+
	Shoshone	125016.0	A-	2305.0	D	3.2	B-	85.6	D
	Teton	33517.7	C+	1371.5	D	3.0	C	91.4	D
	Twin Falls	132186.4	A	4914.9	C	2.2	D	92.3	C
	Valley	34249.4	B-	2214.9	D	2.7	D+	122.7	D+
	Washington	13859.8	C	4372.7	C-	2.6	D	77.5	C-
Montana	Beaverhead	8742.7	C-	10337.2	B	3.3	B+	72.8	B
	Big Horn	34950.7	B-	23305.2	A	3.1	B-	53.8	A-
	Blaine	57206.1	B	15504.9	A-	4.0	A	38.8	B-
	Broadwater	20770.8	C+	3580.1	D+	3.1	B-	100.5	C-
	Carbon	12033.9	C	5702.3	C	3.7	A-	80.2	C
	Carter	6144.2	D+	11501.7	B+	3.3	B+	61.7	B-
	Cascade	80628.5	B+	10684.0	B	3.5	A-	93.5	A-
	Chouteau	130622.7	A	17191.0	A-	3.8	A	67.4	A-
	Custer	10228.6	C-	15442.8	A-	2.7	D+	52.2	B+
	Daniels	68166.2	B+	6206.1	C+	3.0	C+	52.8	C-
	Dawson	44744.3	B	10802.1	B	3.1	C+	55.1	C+
	Deer Lodge	7963.7	D+	1769.1	D	3.6	A-	87.5	D
	Fallon	5206.9	D	6960.4	C+	3.2	B-	58.0	C
	Fergus	70315.7	B+	16114.2	A-	3.4	B+	55.0	B+
	Flathead	2074657.0	A	4754.2	C-	3.6	A-	84.0	C
	Gallatin	63750.6	B	5838.6	C	3.3	B	1078.2	A
	Garfield	12849.8	C	16860.5	A-	3.1	C+	46.7	B
	Glacier	67786.4	B+	10874.4	B	4.2	A	151.4	A
	Golden Valley	2473.6	D	5239.4	C	3.6	A-	53.8	D+
	Granite	32451.8	C+	2539.5	D	3.2	B-	148.0	C-
	Hill	104413.9	A-	12613.0	B+	4.1	A	58.6	B
	Jefferson	10482.7	C	3388.8	D+	3.2	B-	84.7	D+
	Judith Basin	26459.8	C+	6392.6	C+	3.7	A	71.5	C
	Lake	48772.2	B	5547.8	C	3.5	B+	90.3	C+
	Lewis and Clark	44058.7	B	8275.5	B-	3.6	A-	181.3	A
	Liberty	58351.1	B	6373.6	C+	4.6	A	60.2	C
	Lincoln	106337.3	A-	1972.5	D	3.2	B-	79.5	D
	McCone	47644.1	B	10539.0	B	3.2	B-	51.6	C+
	Madison	12994.0	C	8492.9	B-	3.5	A-	101.9	B+
	Meagher	27394.2	C+	6548.9	C+	3.4	B+	103.6	B-
	Mineral	13931.4	C	477.1	D	3.4	B+		

State	County	Biomass Tonnes/year	Grade	Solar Solar Energy Resource Potential (million MWh/year)	Grade	Wind Mean Power Class	Grade	Geothermal HF (mW/m2)	Grade
Montana (continued)	Missoula	130588.9	A	4263.2	C-	3.2	B	110.1	C+
	Musselshell	13688.8	C	7904.6	C+	2.4	D	47.9	C-
	Park	11368.0	C	5350.2	C	3.5	A-	1102.5	A
	Petroleum	2082.0	D	4526.5	C-	2.6	D	46.1	D
	Phillips	34636.7	B-	13109.9	B+	3.1	C+	38.0	C+
	Pondera	100079.6	A-	6664.6	C+	4.1	A	89.3	C+
	Powder River	11320.5	C	11053.2	B	2.3	D	57.9	B-
	Powell	46013.8	B	5246.1	C	3.3	B	231.5	A-
	Prairie	6282.3	D+	5056.2	C	2.9	C	50.9	D+
	Ravalli	27113.6	C+	2487.6	D	3.3	B+	84.0	D
	Richland	49972.9	B	9343.3	B-	2.8	C-	55.1	C+
	Roosevelt	96006.8	A-	10468.0	B	2.3	D	54.5	C+
	Rosebud	27073.2	C+	21844.0	A	2.7	D+	49.0	A-
	Sanders	56110.6	B	5138.9	C	3.3	B+	82.9	C
	Sheridan	86734.3	A-	7130.9	C+	2.7	D+	56.0	C
	Silver Bow	5780.2	D	1569.4	D	3.3	B	83.8	D
	Stillwater	7807.1	D+	6970.3	C+	3.7	A-	112.0	B
	Sweet Grass	6973.2	D+	6561.5	C+	3.9	A	256.1	A
	Teton	78218.6	B+	8682.8	B-	4.0	A	160.2	A-
	Toole	81653.0	B+	8740.1	B-	4.4	A	51.5	C
	Treasure	11068.2	C	4637.4	C-	2.4	D	49.1	D
	Valley	81720.1	B+	13967.6	B+	2.9	C	47.1	B-
	Wheatland	8843.4	C-	6227.1	C+	3.6	A-	65.7	C
	Wibaux	7767.1	D+	3963.4	C-	3.2	B-	56.0	D
	Yellowstone	45635.6	B	11866.5	B+	2.3	D	49.2	C+
New Mexico	Bernalillo	95002.8	A-	5661.7	C	2.6	D	78.2	C-
	Catron	2154.8	D	12617.9	B+	2.4	D	82.8	B+
	Chaves	10427.4	C	22608.2	A	3.0	C	51.6	B+
	Cibola	7940.0	D+	18106.4	A-	2.8	C-	86.4	A-
	Colfax	13141.1	C	20948.2	A	3.1	C+	94.5	A
	Curry	67909.8	B+	8159.2	B-	2.5	D	68.3	C
	De Baca	390.8	D	13105.0	B+	3.2	B-	60.3	B-
	Dona Ana	37193.9	B-	5850.2	C	3.0	C+	170.3	B
	Eddy	13449.5	C	9915.1	B	3.8	A	43.6	C-
	Grant	3532.8	D	11918.7	B+	2.5	D	96.4	B+
	Guadalupe	607.9	D	17170.9	A-	3.7	A	69.0	B+
	Harding	119.6	D	11166.1	B	2.8	C-	72.6	B-
	Hidalgo	5424.1	D	11479.1	B+	2.9	C	90.2	B
	Lea	23852.9	C+	21616.6	A	2.2	D	45.3	B
	Lincoln	2546.8	D	16391.2	A-	3.1	B-	71.1	B+
	Los Alamos	1906.3	D	33.0	D	2.5	D		
	Luna	8015.5	D+	10414.6	B	2.8	C-	179.9	A-
	McKinley	9125.8	C-	27058.6	A	2.3	D	77.2	A
	Mora	2222.9	D	10120.1	B	3.3	B	104.7	B+
	Otero	110881.4	A-	11445.5	B+	2.8	C-	93.9	B+
	Quay	8419.7	C-	16804.8	A-	3.5	A-	72.4	A-
	Rio Arriba	104887.7	A-	14758.5	A-	2.6	D	87.2	A-
	Roosevelt	43794.8	B-	13954.6	B+	2.8	C-	49.7	C+
	Sandoval	13805.7	C	12521.3	B+	2.5	D	105.2	A-
	San Juan	35488.4	B-	23003.6	A	2.3	D	72.3	A-
	San Miguel	7701.3	D+	23656.5	A	2.9	C	76.4	A-
	Santa Fe	14055.1	C	8215.4	B-	2.9	C-	70.2	C

		Biomass		Solar		Wind		Geothermal	
State	County	Tonnes/year	Grade	Solar Energy Resource Potential (million MWh/year)	Grade	Mean Power Class	Grade	HF (mW/m2)	Grade
New Mexico (continued)	Sierra	1484.2	D	8544.4	B-	2.8	C-	106.5	B-
	Socorro	5570.3	D	16572.3	A-	2.7	D+	80.1	A-
	Taos	4485.3	D	5799.9	C	3.3	B+	103.7	C+
	Torrance	3070.1	D	17805.0	A-	3.3	B	61.0	B+
	Union	29674.7	C+	20823.9	A-	2.7	D+	68.9	A-
	Valencia	8626.2	C-	6009.5	C+	2.6	D	87.3	C
Nevada	Churchill	2814.3	D	4655.9	C-	2.7	D+	86.6	C-
	Clark	217348.2	A	5183.7	C	2.9	C	87.2	C-
	Douglas	10471.3	C	1270.3	D	3.3	B+	81.8	D
	Elko	10454.4	C	23228.5	A	3.0	C	106.1	A
	Esmeralda	203.5	D	1168.2	D	2.9	C	113.7	D
	Eureka	313.9	D	4407.5	C-	2.8	C-	97.6	C-
	Humboldt	6487.2	D+	8600.1	B-	3.0	C+	120.0	B+
	Lander	787.7	D	4152.0	C-	2.8	C-	124.8	C
	Lincoln	574.4	D	845.1	D	2.6	D	66.7	D
	Lyon	4893.6	D	3470.7	D+	2.7	D+	96.0	D+
	Mineral	679.7	D	2895.4	D	3.0	C	143.9	C-
	Nye	4454.7	D	2660.6	D	2.9	C	75.5	D
	Pershing	1063.9	D	7983.9	C+	2.8	C-	124.0	B+
	Storey	489.6	D	1389.8	D	2.1	D	120.1	D
	Washoe	59426.8	B	9830.1	B	2.9	C	94.8	B+
	White Pine	1279.5	D	2154.8	D	3.1	C+	99.6	D
	Carson City	16125.5	C	198.6	D	3.0	C+	90.3	D
Utah	Beaver	115701.1	A-	3069.2	D+	2.9	C	126.5	D+
	Box Elder	40581.4	B-	22401.5	A	3.1	C+	226.0	A
	Cache	28806.4	C+	2063.2	D	2.8	C-	608.1	A-
	Carbon	2997.8	D	3815.5	D+	2.7	D+	66.7	D
	Daggett	398.5	D	663.4	D	2.7	D+	59.1	D
	Davis	41226.4	B-	2839.2	D	2.8	C-	90.8	D
	Duchesne	4111.7	D	9401.5	B	2.9	C-	65.9	C+
	Emery	2557.1	D	4025.8	C-	2.8	C-	63.4	D
	Garfield	3028.5	D	2328.5	D	2.7	D+	74.5	D
	Grand	1203.6	D	5406.0	C	2.7	D+	60.4	D+
	Iron	6102.2	D+	7793.4	C+	2.4	D	103.8	B-
	Juab	1359.3	D	4892.1	C	2.7	D+	112.2	C
	Kane	2769.0	D	2784.9	D	2.7	D+	95.0	D
	Millard	10270.3	C-	8405.8	B-	2.9	C	109.9	B
	Morgan	1831.8	D	1866.8	D	2.6	D	70.6	D
	Piute	1247.4	D	827.8	D	3.2	B-	70.7	D
	Rich	845.6	D	3270.1	D+	2.6	D	173.2	C+
	Salt Lake	130324.6	A	2900.9	D	2.9	C	87.7	D
	San Juan	8456.9	C-	17282.3	A-	2.6	D	66.3	B+
	Sanpete	5518.1	D	3914.5	C-	3.1	C+	90.8	D+
	Sevier	8437.1	C-	1876.5	D	3.0	C	76.8	D
	Summit	7954.6	D+	4634.7	C-	2.9	C	63.0	D+
	Tooele	6333.5	D+	7944.5	C+	2.6	D	99.7	B-
	Uintah	12955.2	C	9013.9	B-	2.5	D	57.3	C
	Utah	62335.5	B	5760.7	C	2.9	C	105.8	C+
	Wasatch	3079.5	D	2338.4	D	2.5	D	84.7	D
	Washington	14711.7	C	3254.2	D+	2.9	C	85.0	D
	Wayne	1553.7	D	1311.1	D	2.6	D		
	Weber	29996.1	C+	1679.5	D	2.9	C	109.5	D

		Biomass		Solar		Wind		Geothermal	
State	County	Tonnes/year	Grade	Solar Energy Resource Potential (million MWh/year)	Grade	Mean Power Class	Grade	HF (mW/m2)	Grade
Wyoming	Albany	263639.5	A	16003.2	A-	4.5	A	48.6	B-
	Big Horn	13838.1	C	3476.4	D+	3.2	B-	60.4	D
	Campbell	4800.2	D	18998.7	A-	3.0	C	56.9	A-
	Carbon	7049.9	D+	18516.4	A-	4.1	A	55.4	B+
	Converse	1572.9	D	15260.6	A-	4.5	A	59.1	B+
	Crook	21724.1	C+	11991.4	B+	2.2	D	67.2	B
	Fremont	8257.9	C-	21147.0	A	3.9	A	64.3	A-
	Goshen	36965.7	B-	11397.6	B+	3.8	A	58.4	C+
	Hot Springs	1005.6	D	6087.4	C+	3.5	A-	68.2	C-
	Johnson	2741.2	D	14483.0	A-	3.5	A-	59.4	B
	Laramie	39334.6	B-	13813.8	B+	4.6	A	57.2	B-
	Lincoln	8565.2	C-	4996.2	C	3.0	C+	108.4	C+
	Natrona	9048.1	C-	15577.8	A-	4.1	A	60.8	B+
	Niobrara	1239.6	D	12545.3	B+	3.3	B	70.2	B+
	Park	22456.3	C+	7276.4	C+	3.7	A-	76.2	C+
	Platte	5519.4	D	10113.2	B	4.2	A	50.6	C
	Sheridan	7259.1	D+	9108.0	B-	3.3	B	57.8	C+
	Sublette	1282.2	D	5442.4	C	3.5	B+	73.1	C-
	Sweetwater	4623.6	D	15619.9	A-	3.2	B	58.6	B+
	Teton	10408.1	C-	470.6	D	3.3	B	89.8	D
	Uinta	2429.2	D	6362.8	C+	2.7	D	66.6	C
	Washakie	13785.7	C	3810.9	D+	3.0	C+	65.6	D
	Weston	4143.7	D	5047.0	C	2.7	D+	64.0	D+

Blank cells indicate instances where data are unavailable