The Renewable Resources

Wind

Wind power is the fastest growing energy resource in the world. Good wind areas, found on 6% of the land in the Western states, could supply more than five times the region's current electricity consumption. This emission-free resource is already being harnessed across the region, but at a fraction of its potential.

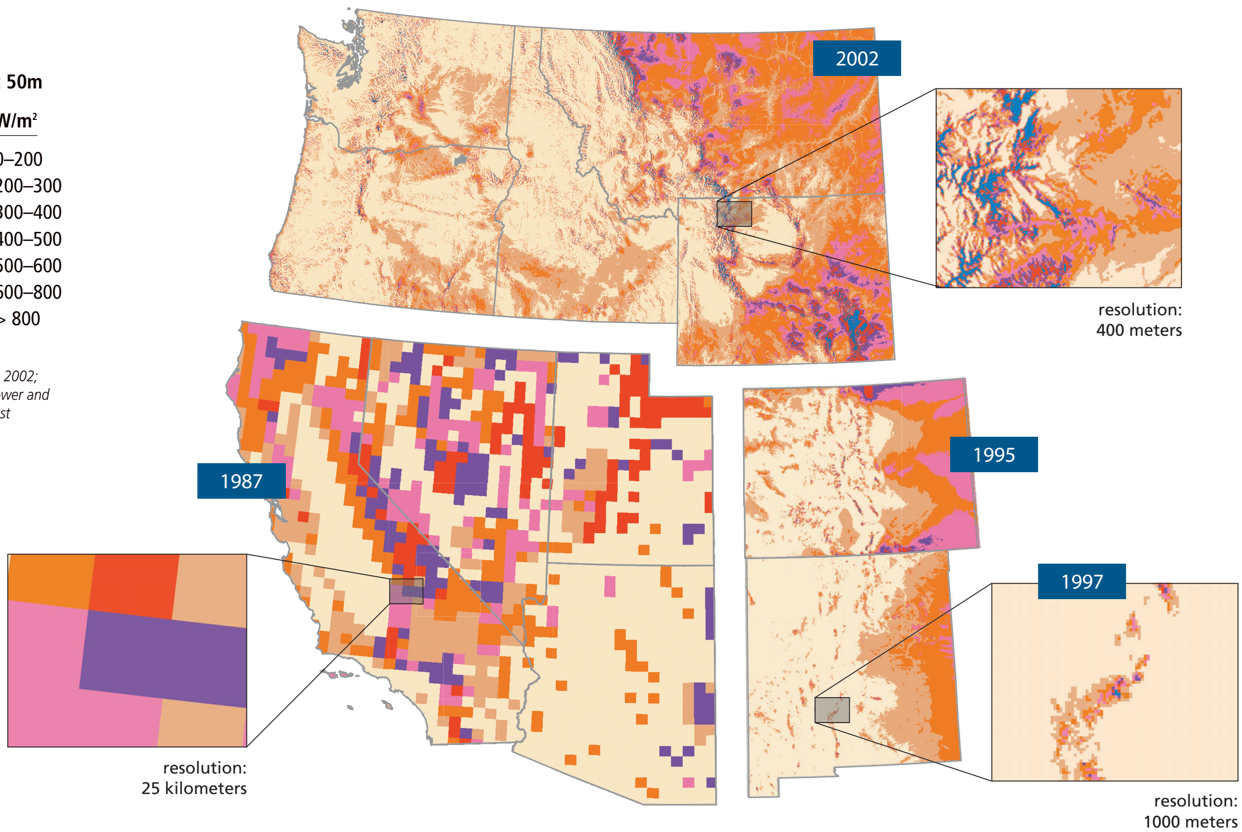
Wind resources adequate to power commercial wind farms are very site specific. Relatively small differences in the average wind speed have major impacts on energy production.

The energy potential in the wind is expressed by wind power classes ranging from 1 (least energetic) to 7 (most energetic). Each class is defined by a range of wind speeds and power densities, the expected watts per square meter of the blade swept area. Nearly 2,300 Megawatts of wind turbines are currently installed in the eleven Western states (according to the American Wind Energy Association).

Wind Power Density at 50m

Class	W/m²
1 Poor	0–200
2 Marginal	200–300
3 Fair	300–400
4 Good	400–500
5 Excellent	500–600
6 Outstanding	600–800
7 Superb	> 800

Data source: TrueWind/NWSEED 2002; Brower and Company 1997; Brower and Company 1995; Pacific Northwest Laboratory 1987



Wind Resource Maps: 1987 to 2002

Wind mapping techniques have improved significantly over the past 10 years. The 1987 Wind Energy Resource Atlas of the United States provided coarse approximations of wind resources. Although it was produced with the best methods available at the time, the 1987 atlas both underestimated and overstated wind resources for specific locations, as gridcell designations were only intended to represent well exposed areas. In the mid-1990s, updated techniques were used to produce maps for Colorado and New Mexico, increasing the resolution from 25 kilometers to 1 kilometer. Since 1997, wind mapping techniques have improved even further, and in 2002, updated maps were produced for Idaho, Montana, Oregon, Washington and Wyoming. The resolution is now 400 meters, a significant improvement over the old standard of 25 kilometers. The image above compares the most recent data for each of the eleven Western states.

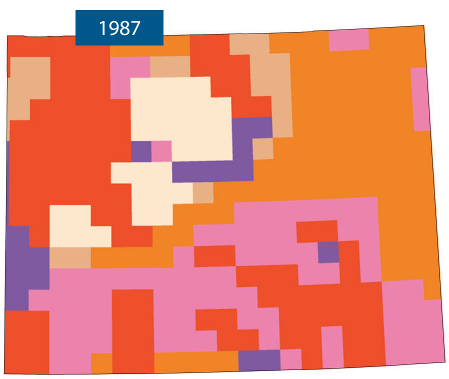
New Technology Provides Reliable Estimates of Windy Land Area

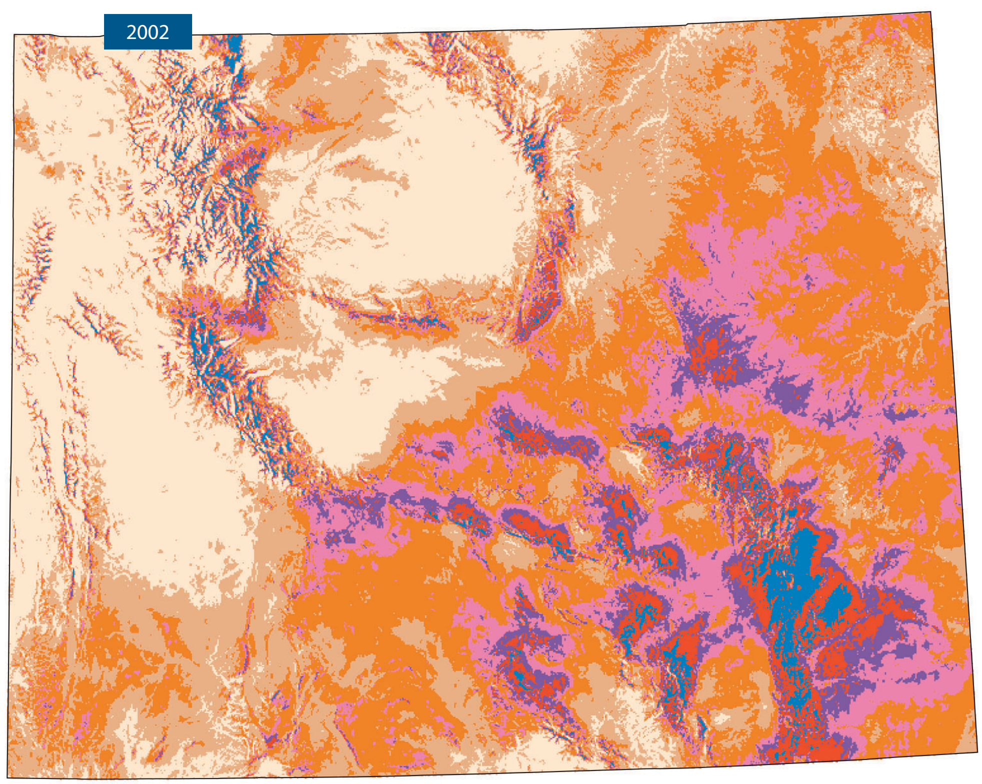
Improvements in wind resource mapping techniques can more accurately identify suitable areas for wind power development. This chart shows the estimated acreage of land suitable for commercial wind power development in each state. As wind resources in the rest of the Western states are mapped using the newest methods, clearer pictures of lands available for wind development will emerge.

Areas Available for Wind Development (Class 4 or Above)

State	1992 Pacific Northwest Laboratory Maps (acres)	2002 High-Resolution Data (acres)
Arizona	77,000	NA
California	729,000	NA
Colorado	6,005,000	NA
Idaho	479,000	814,000
Montana	10,576,000	17,351,000
Nevada	899,000	NA
New Mexico	1,129,000	NA
Oregon	912,000	1,183,000
Utah	366,000	NA
Washington	605,000	1,039,000
Wyoming	9,785,000	14,457,000

Source: Gridded State Maps of Wind Electric Potential, *Pacific Northwest Laboratory, 1992,* and *True Wind Solutions High-Resolution Wind mapping project for NorthwestSEED, 2002.*





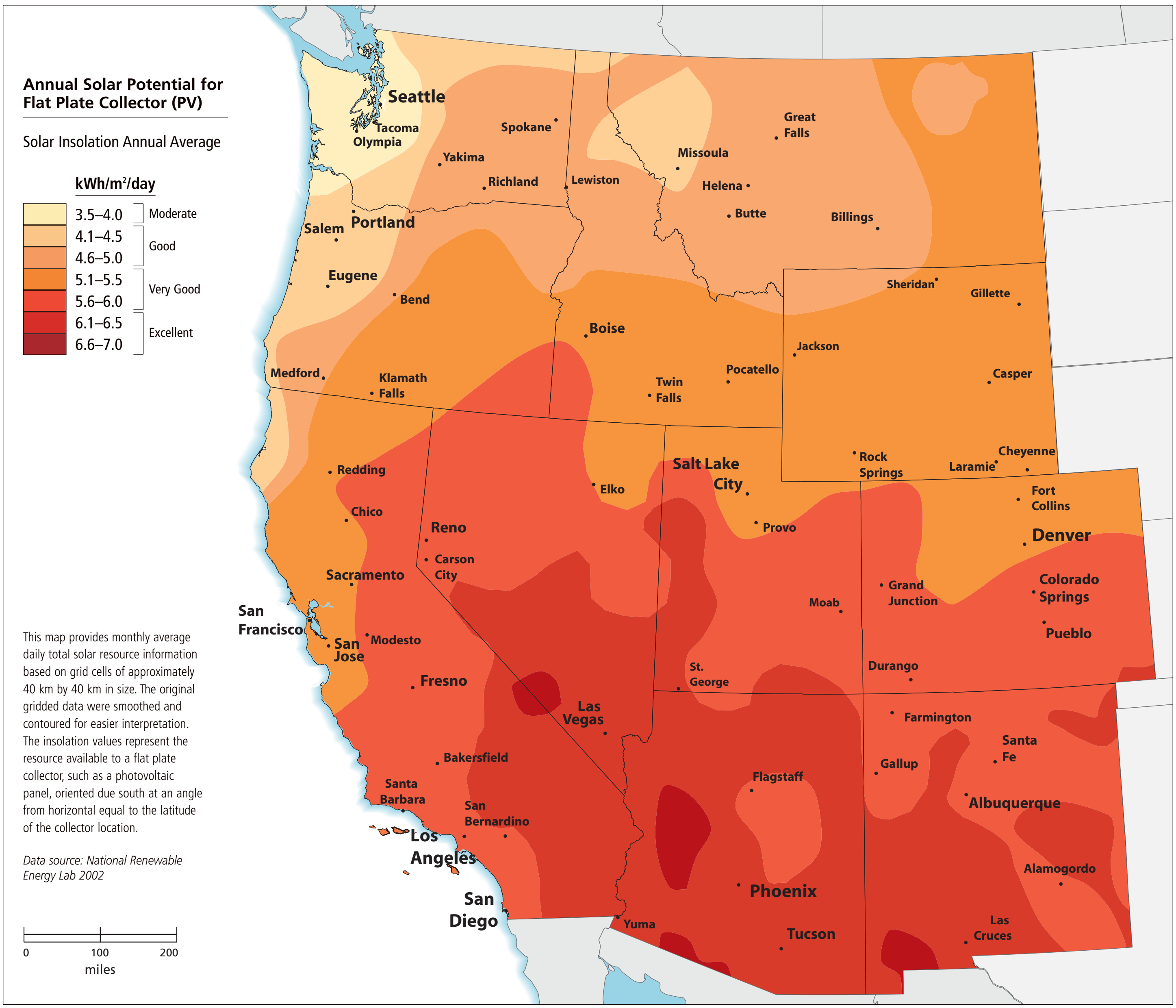
Wyoming 1987 and 2002

Wyoming is one of five states with an updated 2002 wind resource map. The 2002 map (right) shows far greater detail than the 1987 map (above). The dramatic difference can be attributed to a decrease in the spatial resolution, or "cell size," used to map the data. The newer data contain about 4,000 times more detail.

Solar

Solar energy is one of the most abundant natural forms of energy. Thousands of buildings across the West use passive solar design, solar hot water systems, photovoltaics, or other types of solar collectors to provide a portion of their energy. This map demonstrates the potential energy available for directly converting the sun's *light* into electricity using photovoltaics. Electricity can also be generated from the sun using concentrating solar technologies – those that turn the sun's *heat* into electricity.

At least 371 MW of solar power are currently installed in the West. Of this, 21 MW are photovoltaics and 350 MW are concentrating solar power.



This map provides monthly average daily total solar resource information based on grid cells of approximately 40 km by 40 km in size. The original gridded data were smoothed and contoured for easier interpretation. The insolation values represent the resource available to a flat plate collector, such as a photovoltaic panel, oriented due south at an angle from horizontal equal to the latitude of the collector location.

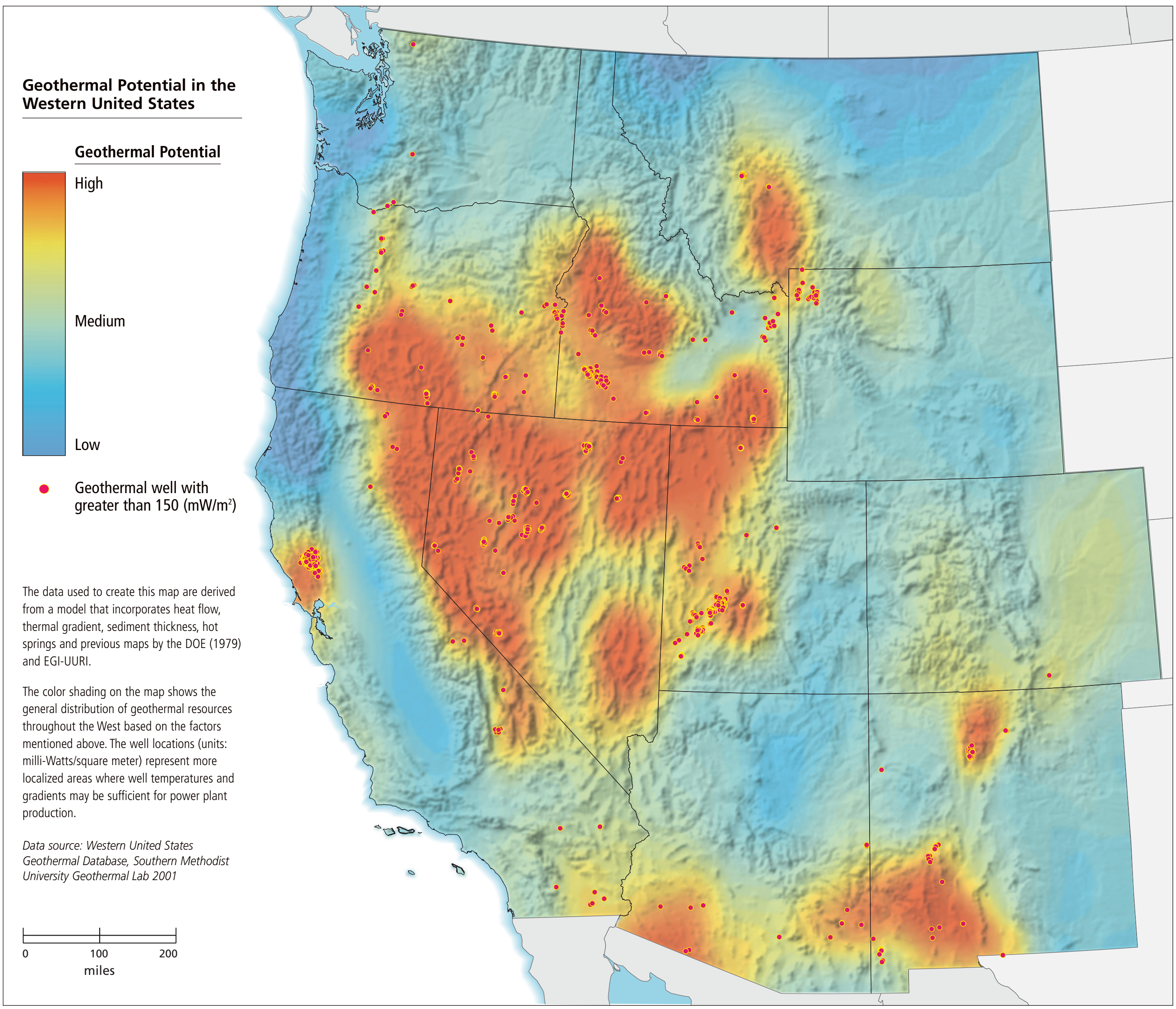
Data source: National Renewable Energy Lab 2002

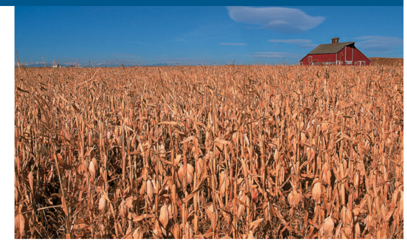
Geothermal

The potential for geothermal energy – heat from the earth – is significant worldwide. It is estimated that the uppermost six miles of the Earth's crust contains many times the energy of all oil and gas resources in the world. In the US, geothermal is found almost entirely in the West.

Geothermal is commonly used both for direct heating and cooling and to produce electricity. Geothermal heat pumps, which exchange heat between the earth and a home or business, are useful in most areas of the West and are not dependent on the same type of resources as large-scale geothermal electricity production.

There are 2,734 MW of geothermal power plants currently installed in the West.



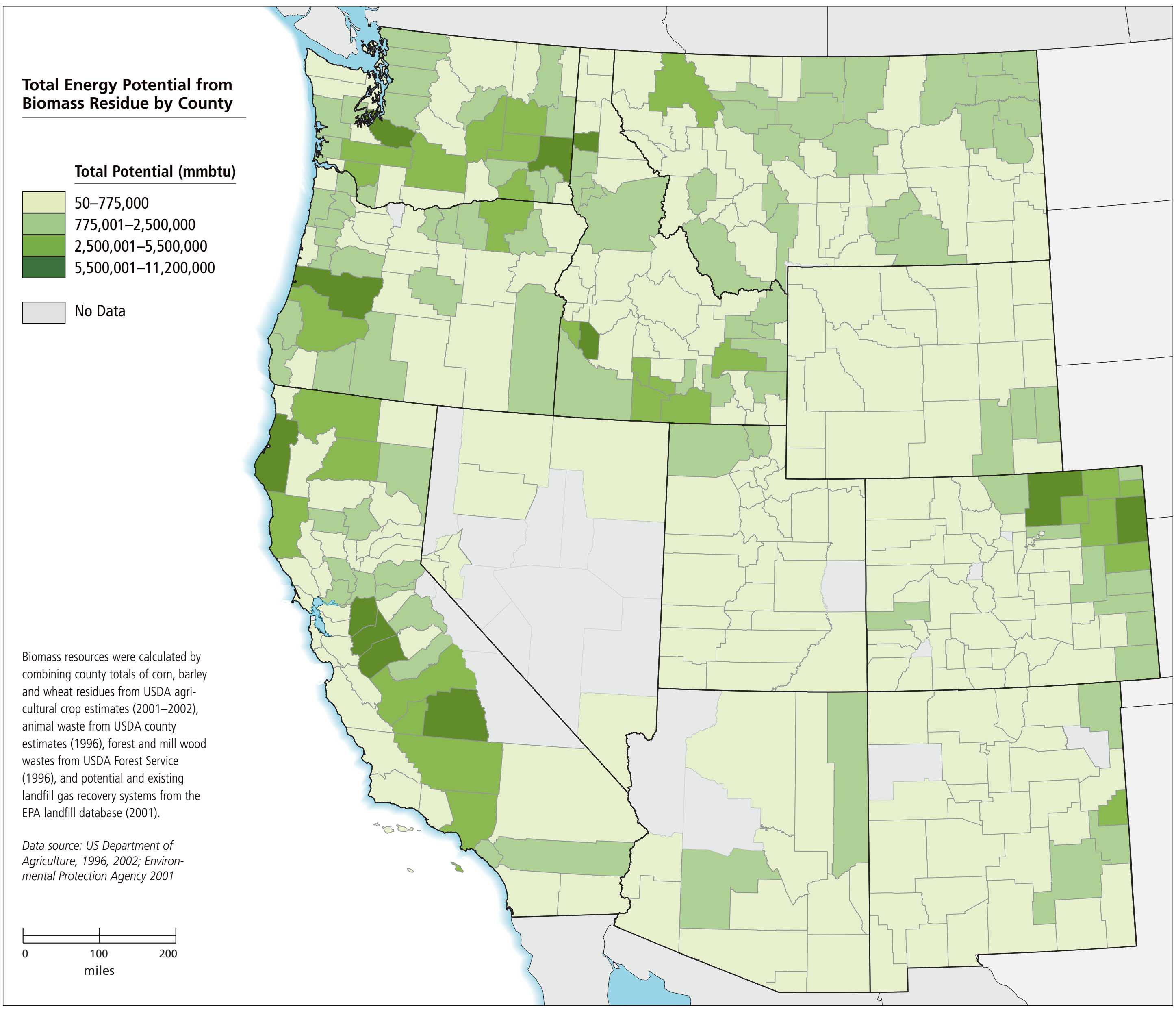


Biomass

Biomass energy (or bioenergy) uses organic materials such as agricultural and forest residues, animal waste, and landfill gas (methane) to produce electricity. Biomass can be used in its solid form for heating applications or electricity generation, or it can be converted into liquid or gaseous fuels, e.g., turning corn into ethanol for gasoline.

In many applications, biomass utilizes organic material that would otherwise be added to landfills or burned without capturing the embodied energy. Fast-growing, drought-resistant "energy crops" may become the biomass fuels of choice in the future. In the West their development is likely to be limited to less arid locales.

The eleven Western states currently have 1,747 MW of installed capacity of biomass.



Electric Generation Potential from Renewable Energy

Electricity generated by renewables today represents only a very small fraction of the total potential. Theoretically, available wind, solar, geothermal, and biomass resources could supply several times the West's electricity needs. Renewables can generate some of this electricity at competitive costs, especially from wind. Other resources will require appropriate policies to yield cost reductions, such as those expected for solar photovoltaics and biomass gasification, by accelerating market development and spurring widespread implementation to create economies of scale.

Given many unknowns about the pace of future technological progress and electricity market conditions, it is difficult to predict exactly how much of the region's electricity might ultimately be produced from renewables over the next few decades.

For each state, the table below shows indicative electricity generation potentials by resource, compared with the overall electricity consumption in the state. The table is followed by a description of how the estimates were calculated. Additional detail is provided in the Data Sources and Methodologies section. While generation production estimates can be compared across states for any given resource, the estimates for the different resources are not directly comparable. Each resource estimate is based on different assumptions and constraints. All are subject to major uncertainties. For instance, the geothermal estimates include high-temperature sites that may prove unexploitable due to competing land uses and more recent and inconclusive test drilling. However, the geothermal estimates do not include the lower-temperature resources that can now be tapped using binary cycle technology. Evaluating solar generation potential is also challenging, since the theoretical resource is vast and the achievable potential hinges on policy commitments, future cost reductions, and application approaches.

Electricity Production from Renewable Sources (Illustrative Potentials) Compared With Current Consumption (million MWh/yr)

State	Illustrative Potentials				Current (1999)
	Wind	Solar	Biomass	Geothermal	Electricity Consumption
Arizona	5	101	1	5	58
California	45	128	14	59	235
Colorado	601	83	4	0	41
Idaho	49	60	9	5	23
Montana	1,020	101	6	N/A	13
Nevada	55	93	1	20	26
New Mexico	56	104	0	3	18
Oregon	70	68	10	17	48
Utah	23	69	1	9	22
Washington	62	42	11	0	99
Wyoming	883	72	0	N/A	12
TOTAL	**2,869**	**920**	**57**	**118**	**594**

Wind

Wind calculations are based on "windy land area," defined as areas with an average wind power of Class 4 or greater. In general, wind regimes of Class 4 or higher are considered economically viable for utility-scale wind projects. However, because of terrain, land-use restrictions, or environmental sensitivities, not all windy land is suitable for wind energy development. In the estimates presented below, areas not suitable for wind power production were screened out. (Small-scale distributed wind turbine systems require less wind for economic viability and have been successfully installed in regimes as low as Class 2. Potential energy production from small-scale turbines located in lower class wind regimes, however, are not reflected in the table.) These estimates were developed using the most recent available data for each state (2002 for ID, MT, OR, WY and WA, 1997 for NM, 1995 for CO and 1987 for the others).

Solar

The amount of solar energy that strikes the United States is much greater than that needed to meet our foreseeable energy needs. To give an idea of the tremendous theoretical potential of solar power production, the estimates presented here show the amount of electricity that could be generated if solar photovoltaic systems were installed on 0.5% of each state's total land area. As the table (pg. 13) shows, even restricting solar development to this small percentage of total land would yield large generation potentials – in many cases more than the electricity currently consumed in the state. While solar's theoretical potential is enormous, the high cost of solar power – currently in the 25–30 cent/kWh range – limits the use of solar energy in most applications. If these potentials are to be realized solar costs must come down. Until costs are reduced, solar power is most likely to be developed in areas with high electricity costs, where solar's ability to generate during summer peak hours is most valued, and in off-grid applications, where the expense of electric line extensions make distributed solar technologies cost-effective.

Geothermal

Deriving comprehensive estimates for geothermal energy's potential is particularly difficult because geothermal heat lies buried, often at significant depth, and is not easily modeled and verified with available tools. Although temperature gradient maps like those shown on page 11 can show "hot spots" where conditions for effective power generation are most likely to occur, the geological conditions needed for actual power generation (hot fluids at high flow rates) cannot typically be determined without expensive on-site test drilling. Over the past two decades, test drilling activity has been limited, and where done, results are often proprietary. As a result, available knowledge on resources amenable to power generation has not increased significantly since the US Geological Survey published its widely cited Circular 790 in the late 1970s.

Advances in geothermal power technologies since that time have rendered some lower temperature resources more amenable to power generation. However, there are no comprehensive assessments of these resources to add to power production estimates.

For the purposes of power estimates presented here, we relied upon data developed for the US DOE's National Energy Modeling System (NEMS), a collection of estimated resources and development costs at approximately 50 sites in the Western US. These data were derived from the earlier USGS analysis and have been subsequently revised by geothermal experts. These estimates are still speculative. There is a significant difference of opinion in the geothermal field as to the total exploitable resource, especially given potential land-use conflicts at a number of sites.

Biomass

Biomass energy is widely used for power generation in the West, particularly from residues at paper and pulp mills and from methane captured at municipal landfills. The overall resource potential is far greater, as the region's extensive agriculture and forestry activities produce vast quantities of residues. While it would be neither environmentally or economically viable to use all of these materials for energy purposes, the sustainably exploitable resource is significant. For instance, up to 30–40% of crop residues, such as wheat stalks and corn stover, can be collected while leaving sufficient residues in the fields to maintain soil quality.

In addition to the solid biomass residues, landfill gas and animal wastes (with anaerobic digesters) generate methane that can be captured and burned in engines or microturbines. The table (pg. 13) shows the combined biomass resource from landfills and animal, crop and forest residues, in terms of total electricity generation potential.

The potential generation from these sources of biomass, presented above, represents a high estimate, since they reflect all available residues and assume that all landfills can generate electricity. However, these estimates do not reflect all potential sources of biomass energy, such as dedicated energy crops.