Solar Works for Oregon

The Vast Potential of Solar Power to Protect Our Environment and Create Jobs

ENVIRONMENT OREGON
RESEARCH & POLICY CENTER

Solar Works for Oregon

The Vast Potential of Solar Power to Protect Our Environment and Create Jobs

Travis Madsen and Jordan Schneider,
Frontier Group

Sarah Higginbotham,
Environment Oregon
Research & Policy Center

Summer 2012

Acknowledgments

Environment Oregon Research & Policy Center gratefully acknowledges Chris Dymond at enXco, Glenn Montgomery at the Oregon Solar Energy Industry Association, Jana Gastellum at the Oregon Environmental Council, John Audley at Renewable Northwest Project, Bob Jenks at the Citizens Utility Board, Imogen Taylor and Claire Carlson at Solar Oregon, Meghan Nutting at Solar City, Brian Pasko at the Oregon Chapter of the Sierra Club, and Chris Robertson for their insightful feedback on early drafts of this report. Additional thanks to Tony Dutzik and Elizabeth Ridlington at Frontier Group, and Rob Sargent and Bernadette Del Chiaro at Environment Oregon Research & Policy Center for advice and editorial assistance.

The generous financial support of The Energy Foundation and Tilia Foundation made this report possible.

The opinions expressed in this report are those of the authors and do not necessarily reflect the views of our funders or the experts who provided review. Any factual errors are strictly the responsibility of the authors.

Environment Oregon Research & Policy Center is a 501(c)(3) organization. We are dedicated to protecting Oregon's air, water and open spaces. We investigate problems, craft solutions, educate the public and decision makers, and help Oregonians make their voices heard in local, state and national debates over the quality of our environment and our lives. For more information about Environment Oregon Research & Policy Center or for additional copies of this report, please visit our website at www.environmentoregoncenter.org.

Frontier Group conducts independent research and policy analysis to support a cleaner, healthier and more democratic society. Our mission is to inject accurate information and compelling ideas into public policy debates at the local, state and federal levels. For more information about Frontier Group, please visit our website at www.frontiergroup.org.

Cover Photo: LL28 Photography
Layout: Harriet Eckstein Graphic Design

Table of Contents

Oregon has vast untapped potential for solar energy. Solar energy systems—like this rooftop solar photovolatic and solar water heating system—could meet 10 percent of Oregon's electricity needs and 6 percent of its water heating energy needs by 2025. Credit: Energy Trust, John Cunningham

Executive Summary

Oregon has vast untapped potential for solar energy. In the eastern two-thirds of the state, Oregon's solar resource rivals that of California's sunny Central Valley. Even in the often cloudy Willamette Valley, the sun still shines for far more over the course of the year than it does in Germany, which has the world's largest solar market.

Solar power can supply 10 percent of Oregon's electricity by 2025. At the same time, solar thermal power can reduce Oregon's energy use for water heating by 6 percent. This level of solar energy production could be achieved through a combination of rooftop solar photovoltaic panels, rooftop solar water heating systems, and utility-scale solar power stations.

Taking advantage of the state's solar energy potential would reduce Oregon's contribution to global warming and protect its environment. More solar power would also create jobs and boost manufacturing in Oregon. Putting policies in place to accelerate the growth of the solar energy market will allow Oregon to start reaping these benefits immediately.

Oregon sunlight is an enormous source of untapped energy potential.

- Utilizing all available rooftop space with suitable sun exposure, Oregon could technically install 10 gigawatts (GW) of rooftop solar photovoltaic (PV) power systems by 2025—which would generate about 20 percent of Oregon's forecast electricity use in that year. Rooftop solar provides unique advantages for the electricity system because the power is generated close to where it will be used, minimizing the need to invest in power lines and other infrastructure and increasing the reliability of electricity service.

- Oregon could feasibly develop almost 30 percent of that rooftop solar potential in the next 13 years. Doing so would yield 3 GW of local solar photovoltaic capacity by 2025. (See Figure ES-1.) This amount of solar power would generate the equivalent of nearly 6 percent of Oregon's annual electricity needs in 2025, or 3.3 billion kilowatt-hours (kWh). That is enough electricity to power 250,000 typical Oregon homes—or all the homes in the city of Portland.

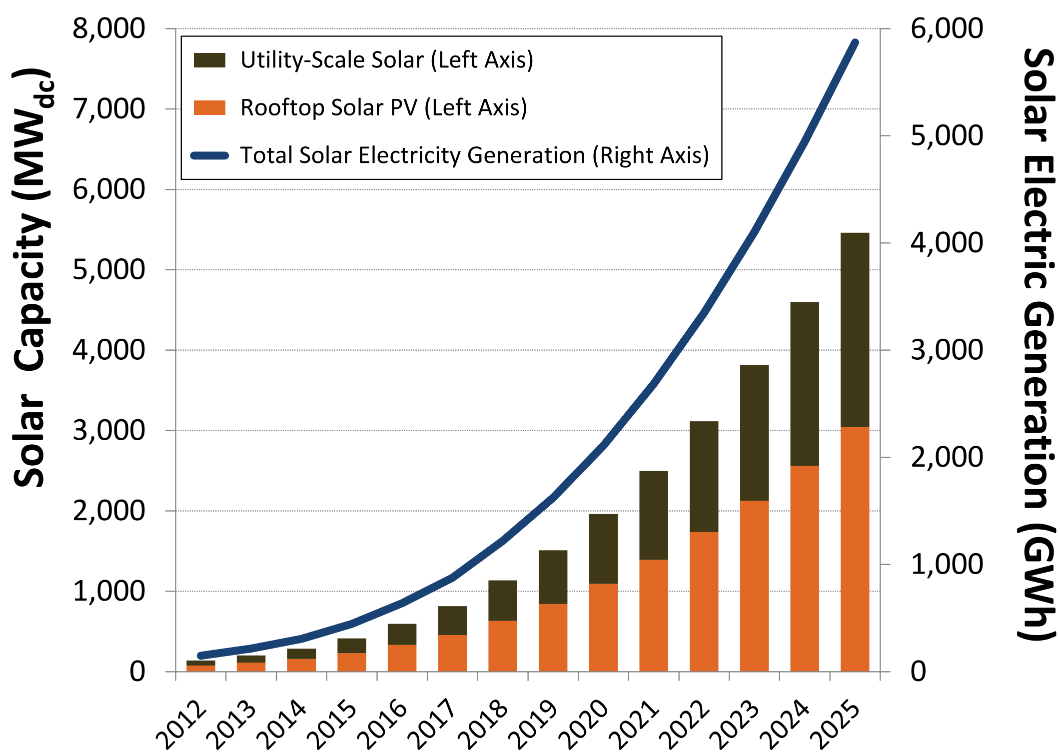
- New utility-scale solar power plants built on vacant land could generate another 3 billion kWh annually by 2025, bringing solar energy to 10 percent of Oregon's electricity supply.

- Installing rooftop solar water heating systems at the same pace as rooftop solar PV would yield 290,000 residential-scale systems and 16,000 commercial-scale systems by 2025. Those systems could capture enough solar energy to reduce Oregon's energy use for residential and commercial water heating by 6 percent, saving an additional 370 million kWh of electricity and 2 billion cubic feet of natural gas per year. That much energy could meet the full water heating needs of more than 150,000 Oregon households.

Solar energy prevents global warming pollution and protects Oregon's environment.

- At this rate of growth, by 2025 solar energy in Oregon would annually prevent 3.8 million metric tons of carbon dioxide pollution, reducing the state's contribution to global warming by nearly 8 percent in

Figure ES-1. Potential Solar Photovoltaic Market Growth in Oregon Through 2025



MW_{dc} stands for direct current megawatts, a measure of power generation capacity. GWh stands for gigawatt-hours, a measure of electricity output, in this case during a given year.

that year. This would be equivalent to eliminating the emissions from 730,000 passenger cars on the road today.

- Preventing global warming pollution is critical to ensure a stable environment. Unchecked, global warming threatens to increase average temperatures in Oregon by as much as 10° F by the 2080s. Temperature rise on this scale would reduce winter snowpack, threaten urban and rural water supplies, interfere with agriculture and salmon habitat, and create health threats—including increased air pollution, exposure to extreme heat and weather events, and introduction of new diseases. At the same time, global warming pollution is acidifying the ocean, threatening salmon and other ocean species.

Increasing the market for solar power in Oregon could make the state a leader in the regional solar power industry, create jobs and boost the state economy.

- Oregon's solar industry today employs 3,300 workers at 545 firms—and its solar job market is growing faster than in all but five other states.

- Oregon has already attracted at least six major solar technology manufacturers, including SolarWorld in Hillsboro, a company that employs more than 1,000 people at America's largest solar PV manufacturing facility.

- Expanding Oregon's solar energy market would create thousands of additional jobs in system manufacturing, and particularly in installation and maintenance—jobs that cannot be outsourced.

Oregon should enact policies to accelerate solar energy development.

- Oregon should set a goal of generating 10 percent of its electricity from solar energy by 2025, and a parallel goal of installing 300,000 residential and commercial solar water heating systems by 2025. The state could achieve these goals through a combination of expanded incentive programs (such as the program run by the Energy Trust of Oregon), a scaled-up CLEAN program (a "feed-in tariff"), and/or by expanding the solar carve-out in its renewable electricity standard.

- Oregon should standardize net-metering rules statewide and raise the net-metering cap to a minimum of 5 percent of utility peak aggregate demand—eventually eliminating the cap altogether. Net-metering should allow every individual, business or community that installs a solar energy system to earn fair compensation for the electricity they produce.

- Oregon should create a net-zero energy building code, requiring all new homes to generate the equivalent of their entire energy use annually by 2020, and all new commercial buildings by 2030.

- Oregon should reinvigorate state financing programs, such as the Residential Energy Tax Credits, and reinstate the Business Energy Tax Credit for a variety of renewable energy technologies.

Introduction

Oregonians care about the future. When it comes to protecting the state's environment and natural resources for future generations, the state has an admirable record.

Oregonians had the foresight to create the nation's most innovative and effective land-use laws, which have helped to preserve farmland and forests around major cities. The state passed one of the nation's first coastal access laws, giving citizens the ability to freely visit and appreciate the Pacific Ocean. The state also created one of the earliest "bottle bills," giving citizens an incentive to recycle drink bottles instead of littering or sending them to landfills.

Oregon continues to demonstrate leadership in the face of today's most serious environmental challenges. In particular, the state is working to reduce its contribution to global warming. Five years ago Oregon passed a strong renewable electricity standard which has driven the installation of 2,300 megawatts (MW) of renewable energy and generated over $5.4 billion in economic development. Workers have built massive wind farms in the Columbia River Gorge to generate pollution-free electricity. Architects in Portland are building super energy-efficient buildings, reducing the need to burn coal and natural gas. Planners are increasing low-impact transportation options, from rail lines to pedestrian- and bike-friendly communities, reducing Oregon's need for gasoline and diesel fuels. City parking meters are even powered by miniature solar panels.[1]

So, why doesn't Oregon have more solar energy systems on the free, open and unused rooftops of our buildings?

Solar energy is becoming an increasingly important part of the energy system around the world. For example, Germany is using solar power to help reduce its dependence on natural gas and nuclear power. In the month of December 2011, the German solar industry installed almost twice as many solar energy systems than the entire United States managed to complete during the entire year—and Germany did it at half the cost per kilowatt.[2] More than a third of the homes in Israel have solar water heating systems, and China has more solar water heating capacity than the rest of the world combined—helping to reduce these countries' dependence on electricity and natural gas.[3]

Solar energy is a clear area where Oregon can make greater progress toward its sustainability goals. The state needs to begin planning now for a future in which all of the state's electricity comes from zero-emission, renewable sources of power. Eventually, Oregon's electricity system may even become an important source of energy for transportation, providing power to recharge batteries in electric and plug-in hybrid-electric cars.

In order to make this vision a reality, however, Oregon must take bold action now to accelerate the deployment of distributed solar energy systems.

In this report, Environment Oregon Research & Policy Center examines the potential for solar power to contribute to Oregon's electricity and water heating needs. Further, the report examines the environmental and economic benefits of developing a stronger market for solar energy.

We conclude that solar energy can open the door for every citizen to play an important role in building a clean energy future for Oregon. The state has a significant opportunity to create jobs, reduce pollution, and decrease the risk posed by global warming for future generations.

Solar energy can open the door for every citizen to play an important role in building a clean energy future for Oregon. Credit: Sunlight Solar, Al Dertinger

Oregon Has Massive Untapped Solar Energy Resources

Sunlight is a massive energy resource that can help power Oregon's future. Capturing this energy can provide electricity and hot water for households and businesses across the state.

Solar power can supply 10 percent of Oregon's electricity and reduce water heating energy needs 6 percent by 2025. This level of solar energy production could be achieved through a combination of rooftop solar photovoltaic panels, rooftop solar water heating systems, and utility-scale solar power stations.

The Sun Shines on Oregon

Despite Oregon's reputation for cloudy weather, the sun shines on rooftops in the Willamette Valley for far longer over the course of the year than it does in Germany, which has the world's largest solar energy market. In the eastern two-thirds of the state, Oregon's solar resource rivals that of California's sun-drenched Central Valley. (See Figures 1 and 2.)

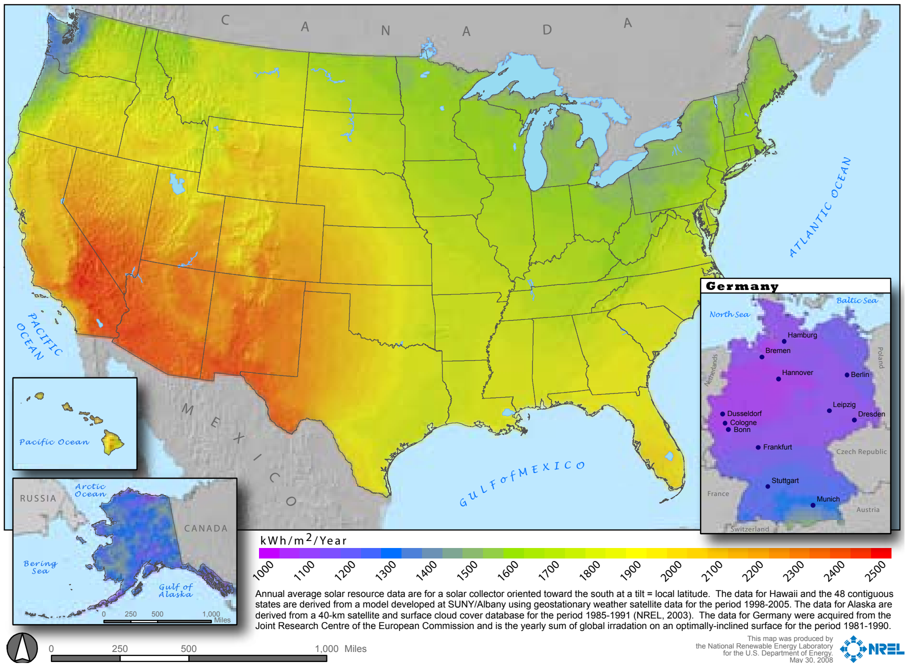
Solar resource quality at a given location can be measured by the average output of a solar photovoltaic panel over the course of a year. Output depends on the intensity of the sunlight reaching the panel, which varies from hour to hour with the weather and the passing of day and night, and from season to season with the angle of the sun and the length of the day.

In Portland, a one kilowatt solar panel using today's technology will capture enough sunlight to generate 1,018 kWh of electricity over the course of an entire year.[5] In other words, on average, the solar panel will generate electricity at full capacity about 12 percent of the time—a value called the panel's "capacity factor."[6] This value is typical of solar panels installed in Oregon's population centers as a whole.[7]

In comparison, the same solar panel in Bend would capture enough sunlight to deliver a slightly higher capacity factor of 15 percent.[8] And in the coastal town of Astoria, that solar panel would have a capacity factor of about 11 percent.[9]

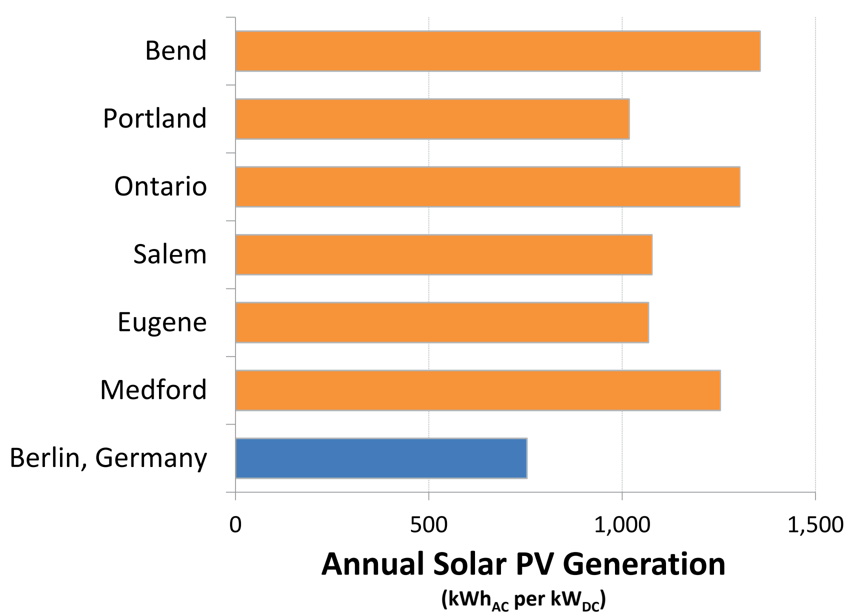
Oregon's solar resource compares favorably with other locations where solar energy is taking off. A one kilowatt solar panel in Germany—by far the worlds' most developed photovoltaic market—

Figure 1: Solar Energy Resources in Oregon far Exceed Those in Germany, the World's Largest Solar Market



Oregon receives a substantial amount of solar energy. The Willamette Valley is sunnier than Germany, which is the world's solar power leader. The eastern and southern expanse of Oregon receives as much sunlight as Sacramento, California—a center for solar energy development in the United States.

Figure 2: Solar Energy Resources Compared[4]



would deliver a capacity factor of about 9 percent.[10] And that same panel in Sacramento, California, would have a capacity factor of about 16 percent.[11] (See Figure 2.)

Rooftop Solar Energy Systems Work

Rooftop solar energy technologies turn sunlight into electricity and use solar heat to provide hot water for local consumption.

Solar photovoltaic (PV) panels capture the energy in sunlight and turn it into electricity. Buildings with rooftop solar PV systems are typically connected to the electric grid, which provides power during cloudy weather or at night and captures any extra electricity produced by the panels during periods of sunny weather. Since rooftop solar panels generate electricity close to where it will be used—and often at times of the day when demand for electricity is high and the cost of supplying electricity is also high—solar technology can reduce the need to invest in cross-country power lines and help increase the reliability of electricity service.

Utility-scale solar power plants can use photovoltaic technology or solar thermal technology. They can be installed anywhere with open land area, adequate exposure to sunlight, and access to a transmission line to deliver electricity to market.

Solar water heating systems use simple technology to capture solar energy and heat water for a home, commercial building, or factory. Tens of millions of households worldwide—particularly in Israel and China, but also increasingly in the United States—use solar water heating extensively.[12] Solar water heating systems work by preheating water before storing it in an insulated tank, reducing the amount of electricity or natural gas required to further heat the water to a usable temperature. In Oregon, solar hot water heating systems can cut the energy use of a standard water heater by half.[13]

Solar photovoltaic panels—like these installed on top of a parking garage in Hillsboro—turn sunlight into electricity. Credit: Flickr user born1945

Millions of Oregon Buildings Are Suitable for Solar Development

Empty rooftops represent a prime location to place solar energy systems.

Rooftop Solar Photovoltaic Panels

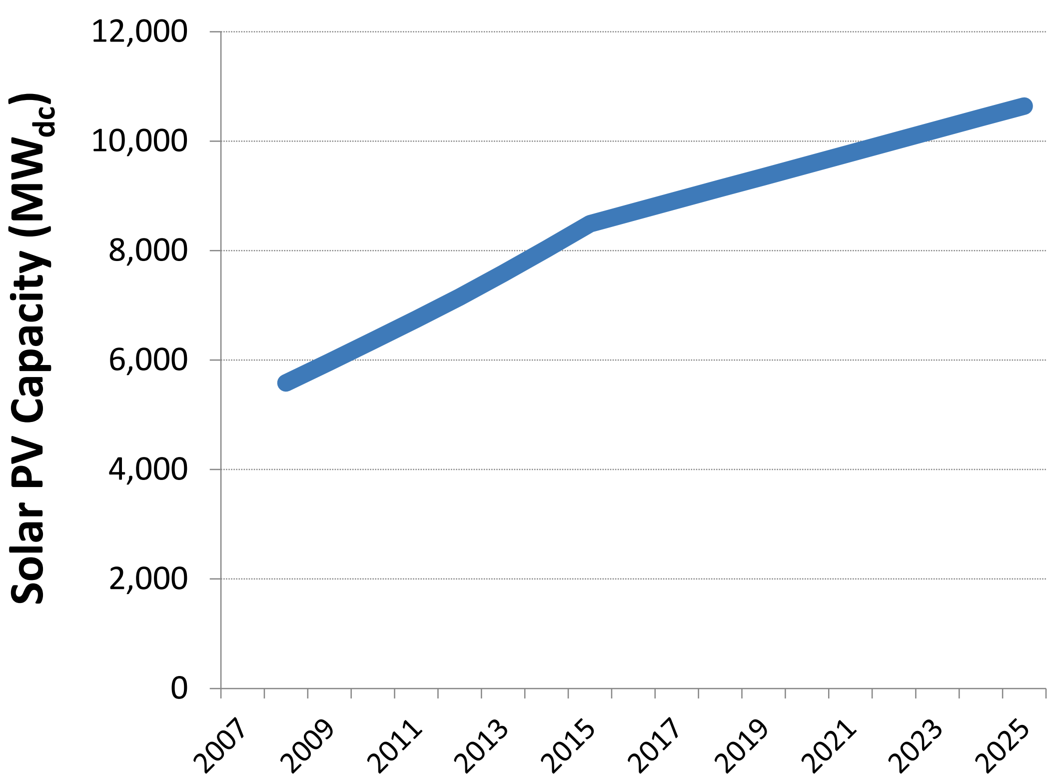
Solar photovoltaic panels produce the most power when they are placed on a roof with optimal sun exposure. Appropriate locations face south and are not shaded by trees or other objects for most of the day. A typical home solar installation ranges from 3 to 8 kilowatts (kW) in capacity, taking up 300 to 800 square feet of rooftop area.[14] Solar PV systems on commercial buildings can exceed 100 kW in size, especially on large warehouses.[15]

In 2008, the U.S. National Renewable Energy Laboratory estimated how much residential and commercial rooftop area in each state was appropriate for solar power development, taking into account shading, building orientation, roof structural soundness, and anticipated improvement in solar PV technology.[16] The agency calculated that Oregon rooftops could accommodate 7,152 megawatts (MW) of solar power capacity in the year 2012.[17]

Assuming that the pace of building new homes, warehouses and other buildings continues unchanged, and ignoring any potential for solar technology to improve beyond the year 2015, Oregon will technically be able support 10,600 MW of solar PV capacity on rooftops by 2025.[18] (See Figure 3.) Excluding the area required for full penetration of solar water heating systems, Oregon's technical rooftop solar PV potential would be about 10,000 MW.

That much solar photovoltaic capacity

Figure 3: Total Technical Rooftop Solar PV Potential in Oregon Based on Available Rooftop Area[20]



Empty, sun-exposed rooftops in Oregon can technically support 10 gigawatts (GW) of solar photovoltaic capacity—which could generate the equivalent of nearly 20 percent of the state's forecast electricity needs in 2025.

could generate more than 11 billion kilowatt-hours (kWh) of electricity—the equivalent of nearly 20 percent of Oregon's estimated annual electricity needs in that year.[19]

Rooftop Solar Hot Water Systems

Virtually any building with a need for hot water and a roof exposed to the sun can take advantage of solar hot water. The U.S. Department of Energy's National Renewable Energy Laboratory estimates that 55 percent of homes and 65 percent of commercial buildings in the Pacific Northwest have appropriate characteristics to support a solar hot water system.[21]

Moreover, solar water heating systems take up very little space. Solar water heating technology is simple and compact. A dark surface and liquid-filled tubes are enough to effectively capture the heat energy in sunlight.[22]

At full technical market penetration in 2025, Oregon could host more than 1 million residential solar hot water systems and 80,000 commercial-scale solar hot water systems. Those systems could save 1.3 billion kWh of electricity and 7.1 billion cubic feet of natural gas, the equivalent of the water heating energy needs of more than half a million Oregon residences.[23] Altogether, these systems would reduce Oregon's energy use for water heating by more than 20 percent.[24]

Subtracting the area required for solar hot water systems from the area available for solar photovoltaic panels would reduce Oregon's technical potential for solar PV by about 8 percent.

Utility-Scale Solar Power

Solar energy systems can also be placed on vacant land with adequate sun exposure—or on creative locations such as attached to utility poles—rather than on buildings. The technical potential for this type of solar energy in Oregon is limited only by the availability of appropriate locations and transmission lines to carry the electricity to market.

Oregon could install solar photovoltaic panels in ground-mounted arrays, along highways, on utility poles, or in other vacant spaces. In fact, the Oregon Department of Transportation has already begun to develop solar power installations along roadways it manages.[25] (See photo on page 11.) Utility-scale solar arrays are becoming increasingly large. For example, two ground-mounted photovoltaic projects in central California will add 800 megawatts of solar power capacity to the state's electricity grid.[26]

Oregon may also be able to take advantage of utility-scale solar thermal power technologies in the sunniest, driest parts of the state. Solar thermal power stations concentrate the heat of the sun to generate electricity.[27]

Solar Power Can Supply 10 Percent of Oregon's Electricity by 2025

Oregon has less solar energy infrastructure installed per person than the national average. At the end of 2010, Oregon had about 24 megawatts (MW) of solar photovoltaic capacity installed in total, or about 6 watts per resident.[29] In comparison, the national average is 7 watts per resident. Leading states, such as New Jersey and California, had five times as many watts per resident.[30]

What makes New Jersey and California different from Oregon is not so much the quality of their solar resources, but more the effectiveness of the policies these states have put into place to accelerate the market for solar power.

The main hurdle facing solar power in Oregon is the same hurdle facing any new energy technology—making it cost-competitive with established forms of energy generation that have benefited from decades of government and consumer investment and support.

In economic terms, solar PV primarily competes with new natural gas power plants, both of which are often called upon to meet the increasing demand for power on hot summer days, when demand for electricity tends to peak.

Two factors are making solar power increasingly competitive. First, solar electricity is perfectly suited to fill a growing niche in Oregon's electricity system. Second, the cost of solar photovoltaic technology is rapidly declining, making it increasingly attractive compared to other power alternatives Oregon could choose to maintain and enhance the function of its electricity system.

In 2011, the Oregon Department of Transportation installed nearly 2 megawatts of solar panels at the Baldock Safety Rest Area, south of Wilsonville on Interstate 5 in Clackamas County. The panels and power inverters were manufactured in Oregon by SolarWorld and PV Powered, Inc. Additionally, Oregon companies performed the design and installation work, including Aadland Evans Constructors, Moyano Leadership Group, Advanced Energy Systems, and Good Company.[28] Credit: Oregon Department of Transportation (DOT)

Solar Electricity Can Help Fill a Growing Need in Oregon's Electricity System

Solar power has unique attributes that can help fill a growing need in the regional electricity grid.

As Oregon grows and electricity use patterns change, we will need to find new sources of electricity capable of delivering power at different times. The Northwest Power and Conservation Council, an organization charged with planning for changes in the regional electricity system, notes that Oregon's population is expected to grow by nearly a third in the next two decades.[31] At the same time, demand for electricity in the summer at peak times is growing faster than demand for power overall, driven by increases in the use of air conditioning and consumer electronics.[32]

The hydroelectric power system is unlikely to provide more electricity than it does now—and it may provide less as global warming affects river flow patterns, or as salmon management plans require changes to dam operation. And given the likelihood of future laws limiting global warming pollution, new coal-fired power plants are unlikely to be built.[33]

Energy efficiency can meet a large fraction of Oregon's changing electricity needs at least cost and least risk.[34] Some additional needs will be met by renewable power sources—especially wind—that will be required to meet renewable electricity standards in three of the four Northwest states. However, Oregon's electricity system will still need additional resources—especially during periods of peak demand.[35]

Solar photovoltaic power is an ideal tool for this purpose. Solar PV can help to fill any gaps in the system's ability to respond to periods of peak demand, particularly on summer days. Solar increases the stability and reliability of the electricity grid.[36] Because solar PV generates the most electricity on hot summer days when demand for electricity tends to peak, it can help to increase summer system stability as part of a diverse network of generating resources.[37]

Solar PV provides value to all electricity consumers and to society as a whole in other ways, as well. For example:

- Local solar PV generates electricity close to where it will be used, reducing the need to invest in building and maintaining new power lines and reducing electricity losses that would occur if the power were transmitted over a long distance.[38]

- Because solar panels require no fuel, they are a very low-risk investment. Solar PV can act as an effective hedge against the possibility of short-term spikes or long-term increases in electricity prices.[39]

In 2025, Oregon rooftops will technically be capable of supporting more than 1 million residential solar hot water systems and 80,000 commercial-scale solar hot water systems—which would reduce statewide use of electricity or natural gas for water heating by 20 percent.

- Solar also benefits society at large by reducing global warming pollution.[40] (See page 18 for more discussion of the environmental benefits of solar power.)

Many of these benefits are not captured in the way utility companies have traditionally priced power. Policy reforms are required to ensure that the market appropriately recognizes the value that solar energy provides and compensates individuals and businesses who install solar panels.

The Northwest Power and Conservation Council notes in its latest planning document that "the region needs to devote significant effort to expanding the supply of cost-effective renewable resources, many of which may be small scale and local in nature." Launching a strong market for solar power is one way to meet that need.

Solar Photovoltaic Technology Is Becoming Increasingly More Cost-Effective

The increasing demand for solar technology here in the United States and around the world is rapidly driving down the cost for raw materials and for manufacturing. The installed cost of solar photovoltaic panels declined by 17 percent during 2010, partially as a result of increasing economies of scale in solar panel production.[41] In 2011, the wholesale market spot price of crystalline silicon PV panels dropped by half, falling from $1.80 to $0.90 per Watt, and the total installed cost of solar energy fell by at least 10 percent.[42] No other type of major power generation technology is achieving cost reductions at such a furious pace.[43] This mirrors consumer experience with cell phones, digital cameras, flat-screen televisions, and other modular electronic technologies, which have all rapidly become better and cheaper as manufacturers produce more devices.

Oregon has benefited from the downward trend in solar costs. In the solar PV program managed by the Energy Trust of Oregon, the average cost per Watt fell by more than a quarter from 2007 to 2010. (See Figure 4.) As the market for solar PV grows in Oregon, the state is likely to develop an increasingly competitive and efficient network of installation contractors, which will further reduce costs. For example, in Germany, with the world's most developed solar market, average installed costs for solar PV in the final quarters of 2011 were 50 percent less than in the United States.[44]

At the same time, overall electricity prices in Oregon have increased by nearly one-quarter since the year 2000, even after accounting for inflation.[45] A glut of shale gas entering the market may temporarily reduce upward pressure on electricity prices, but the long term trend toward more expensive energy is likely to continue, especially if state, regional or federal governments take more aggressive action against global warming pollution.[46] Solar makes an attractive hedge against increasing energy costs, since its up-front costs are predictable, and because sunlight is free.

Launching a Market for Rooftop Solar Power

With a sustained commitment to progress, Oregon can install 3 gigawatts of rooftop solar photovoltaic energy capacity and 300,000 solar water heating systems by 2025.

Reaching 3,000 megawatts (MW) of rooftop solar PV capacity by the year 2025 would roughly approximate what California and New Jersey achieved when those states were at a similar point in the

Figure 4: Solar PV Is Becoming More Affordable in Oregon[47]

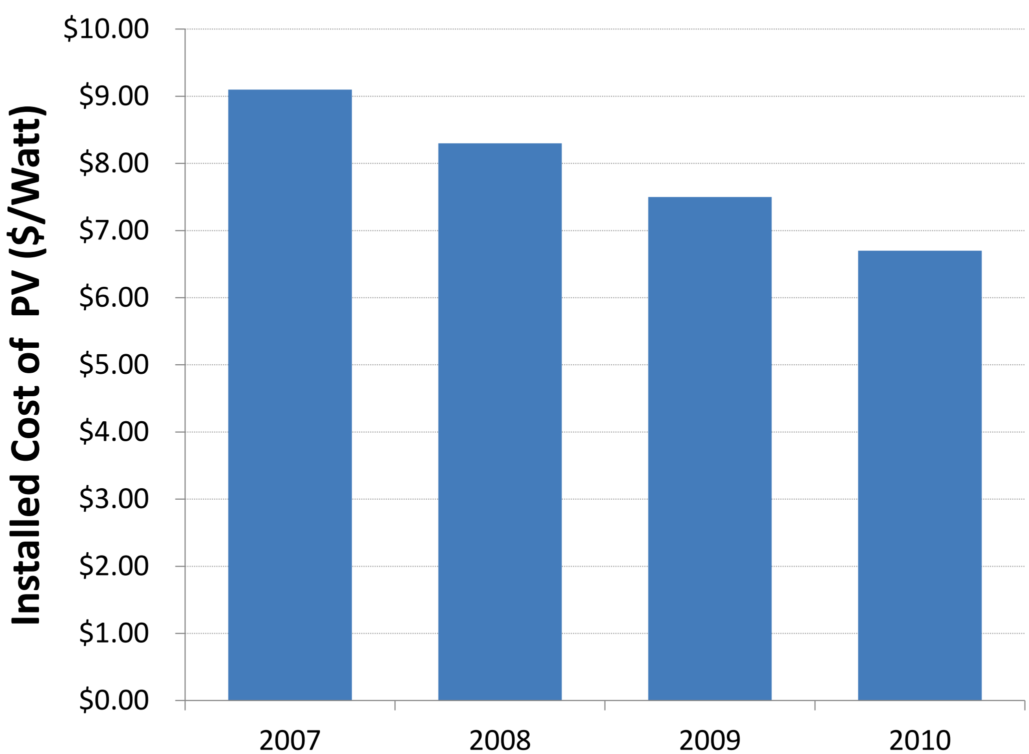
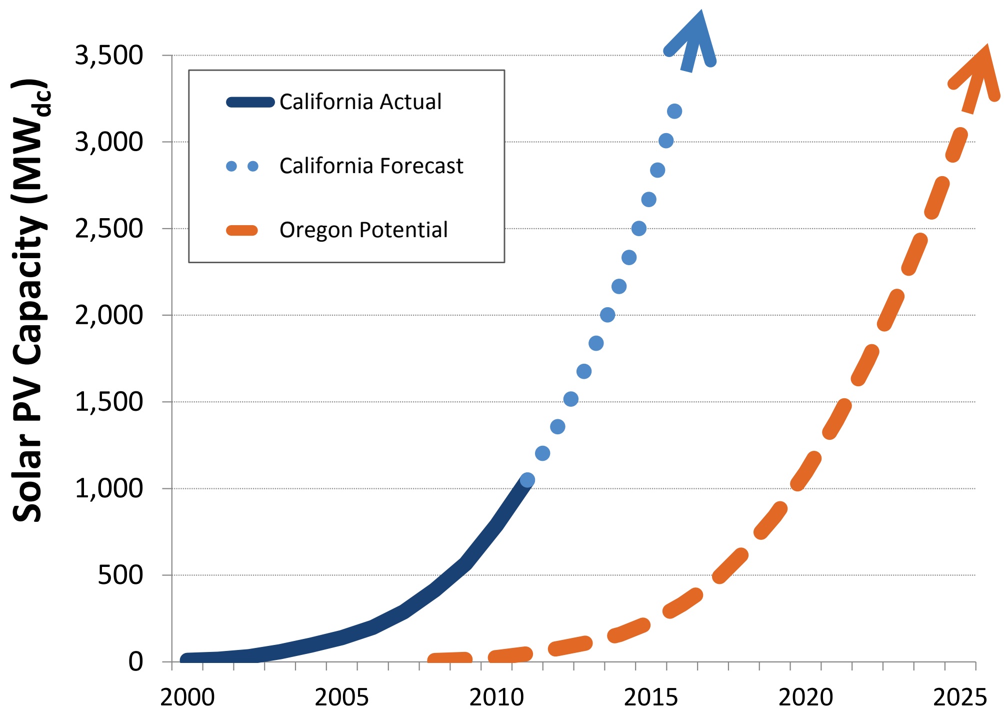


Figure 5: Oregon's Potential Rooftop Solar PV Development Trajectory Compared to California's Actual and Forecast Progress



development of their solar markets. (See Figure 5.) That much solar capacity would generate the equivalent of 6 percent of Oregon's anticipated annual electricity needs in 2025, or 3.3 billion kWh.[48] That is enough electricity to power 250,000 Oregon homes—or all the residences in the city of Portland.[49]

Achieving an equivalent market penetration for solar water heating in Oregon would yield 290,000 residential-scale and 16,000 commercial-scale solar water heating systems by 2025. At this level of development, solar water heating technology would reduce Oregon's water heating energy use by 6 percent, saving 370 million kWh of electricity and 2 billion cubic feet of natural gas per year.[50] That much energy could meet the water heating needs of more than 150,000 Oregon households.[51]

In total, this much solar energy capacity would use less than 30 percent of the state's available rooftop area suitable for solar development, leaving the state a great deal of room to continue expanding the solar energy market in the years beyond 2025.

Accelerating Development of Utility-Scale Solar

Solar development on vacant land at utility scale can also contribute to Oregon's solar-powered future.

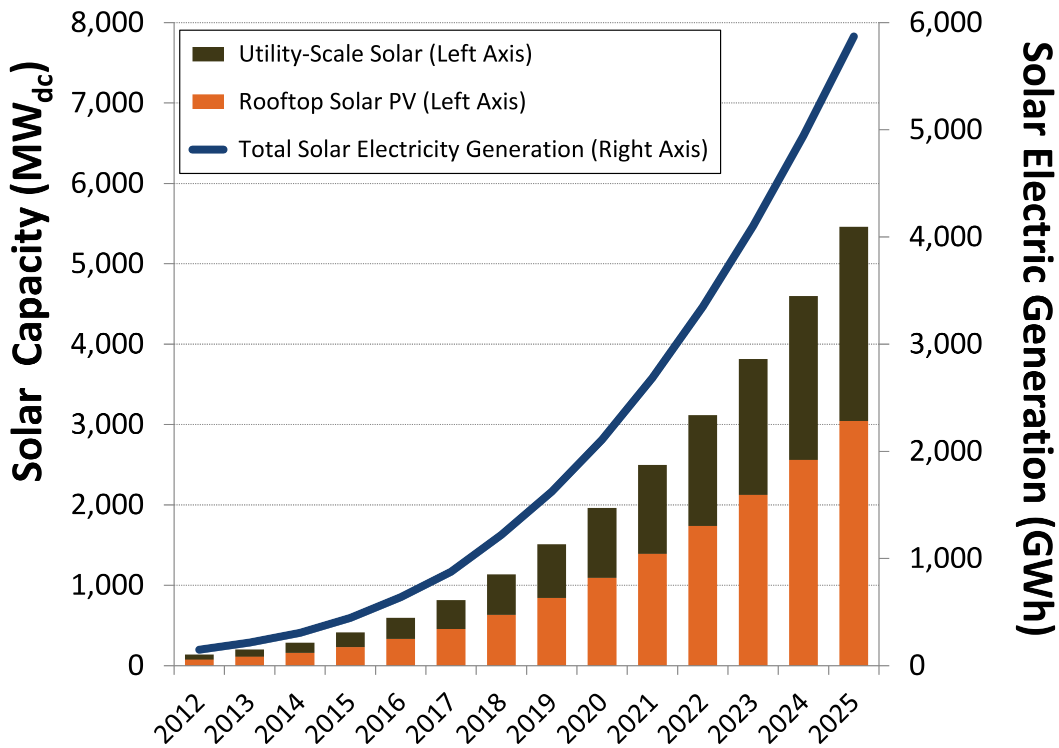
With appropriate policy support, Oregon could build enough new utility-scale solar power plants to reach a target of generating 10 percent of its electricity needs in 2025 through solar energy. On top of Oregon's potential for rooftop solar power, utility scale solar installations would need to generate another 3 billion kWh annually by 2025 to generate the equivalent of

10 percent of the state's annual electricity consumption. If the utility-scale solar took the form of ground-mounted photovoltaic panels on appropriate vacant land—the state would need to install about 2 to 2.5 gigawatts of capacity to achieve this level of performance, depending on location. (See Figure 6.)

The Role of Energy Efficiency

Energy efficiency can make Oregon's efforts to build a solar-powered future more effective. Getting more work out of every unit of electricity Oregon uses can increase the impact of solar energy development. For example, under a high-efficiency case forecast of Oregon's future electricity needs, the level of solar development evaluated in this report would reach 12 percent of electricity supply in 2025—as compared to 10 percent under the default case.[52] In other words, energy efficiency efforts can make renewable energy targets easier to reach.

Figure 6. Potential Solar Photovoltaic Market Growth in Oregon Through 2025



MW_{dc} stands for direct current megawatts, a measure of power generation capacity. GWh stands for gigawatt-hours, a measure of electricity output, in this case during a given year.

Solar Energy Protects Oregon's Environment and Strengthens the Economy

Solar energy prevents global warming pollution, helping to protect Oregon's environment for current and future generations. Increasing the market for solar power will also have benefits for the state's economy, creating jobs in manufacturing and installing solar energy equipment.

Global Warming Threatens Oregon

Oregon is vulnerable to the impacts of global warming, particularly due to the way the state's identity and economy are linked to its natural resources.

Human activities have already increased average temperatures in the Pacific Northwest by 1.5° F over the 20th century.[53] If emissions of heat-trapping pollution continue unchecked, Oregon temperatures could warm as much as another 10° F by the 2080s.[54]

Oregon-based experts—including Philip Mote and Kathie Dello at Oregon State University, and the hundreds of scientists and agency officials that participated in preparing the 2010 Oregon Climate Assessment Report and the 2010 Oregon Climate Change Adaptation Framework—have clearly spelled out the impacts our state is likely to face as a result of warming, including:

- Water supplies will become more limited. Warmer temperatures will cause more precipitation to fall as rain, rather than snow, affecting water availability. In the Northwest, more water is stored as snow than in reservoirs. Snow effectively holds precipitation in place during the winter, releasing it during the spring snowmelt. As more precipitation falls as rain, however, winter and early spring streamflows will increase and summertime streamflows will decrease.[55] This will reduce the availability of water for irrigation of farmland, for salmon, and for other water users.[56]

- The increased likelihood of droughts and heat waves will pose a threat to Oregon agriculture.[57] For example, over the course of the coming century, the Willamette Valley will become increasingly inhospitable for growing the pinot noir wine grape, one of Oregon's signature crops.[58] Other crops with narrow climate preferences will become increasingly difficult to grow, and Oregon farmers may have to switch to crops better adapted to a warmer climate.

- Oregon's oceans are also changing. Marine animals depend on the upwelling of nutrient-rich water to deliver food. Changes in the timing and size of the upwelling may affect animals' ability to reproduce, and may even cause some to starve. Already, changes in wind and currents have triggered near-shore upwelling every summer since 2002 that has caused a dead zone where fish and other animals cannot survive.[59] Simultaneously, global warming pollution is directly increasing the acidity of ocean waters. Acidification threatens to reduce the population of shelled animals, which could undermine the ocean food chain, reduce the availability of food for salmon, put many species at risk of extinction, and damage Oregon fisheries.[60]

- Erosion is likely to become more severe. The Pacific Northwest is expected to receive heavier winter rainfall. Experience with El Niño and La Niña events has shown that heavy rain saturates soils, causing landslides, and causes coastal flooding from overflowing rivers. Higher sea level will further increase coastal erosion.[61]

- Key Oregon natural resources will be damaged. Salmon will struggle with winter flooding, higher water temperatures, and declining summer water availability. Trees may grow faster due to increased precipitation, but forest fires are also expected to become more frequent.[62]

- Global warming is likely to harm human health. Hotter temperatures are likely to increase health-threatening air pollution levels and expose people to more extreme heat and weather events. The elderly, infants, the chronically ill, and outdoor workers are particularly vulnerable to increased risk of illness or death during extreme heat waves. Warmer temperatures are also likely to introduce new diseases and pests to Oregon's climate. For example, West Nile Virus, Hantavirus and Cryptococcus Gattii have all emerged recently in the Pacific Northwest.[63]

- Many of these impacts, including extreme weather events, are likely to harm roads, bridges, buildings and other key elements of Oregon's built environment as well.

Increased deployment of solar energy systems can reduce Oregon's dependence on fossil fuels and lessen its contribution to global warming. Credit: Oregon DOT

Solar Energy Prevents Global Warming Pollution

Increased deployment of solar PV panels and solar water heating systems can reduce Oregon's dependence on fossil fuels and lessen its contribution to global warming. Solar energy can replace fossil fuel combustion—especially natural gas—reducing the state's emissions of carbon dioxide, which is the leading pollutant driving global warming.[64]

In the Western Electricity Coordinating Council, the regional electricity grid of which Oregon is a part, energy sources used to meet daily peak electricity needs emit about 1,300 pounds of carbon dioxide pollution for every megawatt-hour of electricity generated.[65] In comparison, solar panels emit zero carbon dioxide pollution.

Generating 10 percent of Oregon's electricity from solar energy would enable a significant reduction in the state's contribution to global warming. By 2025, this much solar generation would annually prevent 3.5 million metric tons of carbon dioxide pollution per year.[66]

Reducing Oregon's energy use for water heating by 6 percent through solar hot water systems would additionally prevent 130,000 metric tons of global warming pollution from the electricity system, and 95,000 metric tons of global warming from natural gas consumption.[67]

Altogether, by 2025, Oregon could prevent 3.8 million metric tons of global warming pollution per year through increased deployment of solar energy systems. That amount of pollution is comparable to the annual emissions of 730,000 passenger cars.[68] Solar deployment at this level would reduce the state's projected energy-related global warming emissions in the year 2025 by 7.6 percent.[69] Solar power can contribute to meeting Oregon's goals of reducing global warming pollution to 10 percent below 1990 levels by 2020 and 75 percent below 1990 levels by 2050.[70]

Solar energy installation jobs cannot be outsourced.
Credit: Oregon DOT

Solar Energy Can Create Jobs and Strengthen Oregon's Economy

Increasing the market for solar power in Oregon could make the state a leader in the regional solar power industry, creating jobs and boosting the state economy. Oregon is already one of the nation's leading centers for solar technology design and manufacturing. Increasing local demand for solar power can create thousands of additional jobs in the clean energy industry.

With more than 3,300 Oregonians employed in its solar industry at 545 small and large businesses, Oregon currently has the eighth largest solar job market in the nation, according to The Solar Foundation's 2011 Solar Jobs Census.[71] That's a 284 percent increase since 2010, making Oregon the sixth fastest-growing solar job market in the country.[72]

Nationwide, more than half of all jobs in the solar industry are in system installation. Many more are in sales and distribution.[73] These kinds of jobs cannot be outsourced. As Oregon's solar market grows, so will local employment.

Oregon offers tax credits and loans to give solar manufacturing businesses an incentive to locate in the state.[74] Oregon is home to at least six major solar PV manufacturers, including SolarWorld, a German company that employs more than 1,000 people in Hillsboro, west of Portland.[75] The Hillsboro facility is capable of manufacturing 350 MW of solar PV modules per year, making it the largest solar panel factory in the United States.[76]

In 2011, a thin-film solar PV manufacturer, SoloPower, secured a lease for more than 200,000 square feet of industrial space in Portland, where it anticipates setting up two factories.[77]

Other solar manufacturers in Oregon include PV Powered (headquartered in Bend), Solaicx (with a silicon factory in Portland), Sanyo Solar (with a PV factory in Salem), and Sol-Reliant (a solar water heating system manufacturer and vendor in Portland).[78] Combined, annual revenues for these companies are expected to exceed $1.5 billion by 2015.[79] Oregon is also home to companies that are part of the solar supply chain, including FT Solutions, Oregon Crystal, SiC Processing, PV Trackers and Solar Bus Wire.[80]

Expanding the state's demand for solar energy systems could create thousands of additional jobs throughout Oregon's economy. Workers would be needed to design and manufacture solar energy system technology, to install solar energy systems on buildings, and to inspect and maintain systems periodically. A 2009 study from the University of California, Berkeley, concludes that every MW of solar capacity installed results in 25 job-years of employment in manufacturing, installation and maintenance of solar panels—although only the installation and maintenance labor is guaranteed to be local.[81]

Oregon's solar industry is now tied to growing markets in other states and around the world. For example, in April 2011, Portland-based Solar Nation completed the installation of what was at the time the nation's largest rooftop energy system, using solar panels made by SolarWorld in Hillsboro. But the system was located on top of a building owned by a property management firm in Edison, New Jersey.[82] While installations in other states benefit Oregon manufacturers, a steady market in Oregon would be even more beneficial for the local solar industry.

In addition to creating jobs directly in solar manufacturing, installation and maintenance, an expanded local solar power market would drive increased economic activity in other areas of the economy, including education, real estate and services.[83]

SolarWorld employs more than 1,000 people at its solar panel manufacturing facility in Hillsboro, west of Portland. Credit: Oregon DOT

SolarWorld's Hillsboro facility is capable of manufacturing 350 MW of solar PV modules per year, making it the largest solar panel factory in the United States. Credit: Oregon DOT

Policy Recommendations

Oregon now has the opportunity to build a stronger local market for solar energy systems. Solar energy technology costs are falling rapidly. Communities across the United States are turning to solar energy to fill a unique niche in their electricity systems. Solar energy can become an increasingly important part of local efforts to prevent global warming pollution and protect future generations. At the same time, solar energy can become an increasingly substantial force in our economy.

State leaders have started to invest in giving the solar industry a foothold in Oregon through renewable energy tax credits, favorable interconnection and net metering policies, a solar requirement within its renewable electricity standard, and a pilot "feed-in tariff" program. However, faced with a stifling $3.5 billion budget deficit, state legislators limited the funding available for renewable energy installations and manufacturing projects starting in 2010.[84]

Oregon should set ambitious goals for the future of solar power and launch new programs to achieve a bold vision. With every solar panel installed in the state, Oregon will reduce its contribution to global warming, increase the reliability of the electricity system, and stimulate the state economy.

Oregon should work to achieve its solar energy potential. New policies should:

Accelerate solar energy development.

- Oregon should set a statewide goal to generate 10 percent of its electricity from solar energy by 2025. The state should also aim to install 300,000 residential and commercial solar water heating systems by 2025.

- The state could achieve this goal through a variety of policy mechanisms, including an expanded incentive program, a scaled-up version of the pilot feed-in tariff program, or a scaled-up and modified solar carve-out within the state renewable electricity standard.

    - An expanded incentive program

could, for example, increase ratepayer funding available to the Energy Trust of Oregon to manage incentive payments to individuals and businesses who install rooftop solar energy systems, similar to the California Solar Initiative.[85] This program could be an effective vehicle to accelerate the growth of the market for both solar water heating systems and rooftop solar PV.

- A CLEAN program, also known as a feed-in tariff, sets fair and predictable prices for solar electricity produced and fed into the larger electricity grid, requiring all of the state's utilities to purchase solar-generated electricity fed into the grid at a set rate. Germany; Ontario, Canada; Gainesville, Florida; and most recently Palo Alto, California, have used this policy mechanism to encourage growth in the solar market. Oregon's pilot feed-in tariff program is limited to 25 MW, or April 2015, whichever comes first.[86] The program targets systems below 500 kW in size, including reserving 80 percent of the program for residential and small commercial systems. With a substantial expansion, this program could help drive the growth of the solar PV market to gigawatt-scale.

- Expanding the solar carve-out in the state's renewable electricity standard could also help advance Oregon's solar power infrastructure—particularly at utility-scale. Oregon's renewable electricity standard currently requires utilities to develop 20 MW (AC) of utility-scale solar PV systems by

Oregon should act to accelerate solar energy development. Credit: Bruce MacGregor

2020.[87] Not only is this target too low, but the enforcement date isn't soon enough to drive meaningful progress in the near term. The target should be increased along a more structured expansion schedule.

Allow all Oregon ratepayers to benefit from going solar.

- Net metering partially compensates solar energy system owners for the substantial benefits that they provide to other users of the electricity grid, including cleaner air, less global warming pollution, less need to finance the installation of new power plants or new transmission lines, and a more stable electricity grid. State leaders should enhance the value of net metering as an incentive for installing solar power, by taking the following steps:

  - Net metering is currently limited to 0.5 percent of a utility's peak aggregate demand. However, much more solar energy could be added to Oregon's electricity system without risking the stability of service. For example, solar power provided more than 3 percent of Germany's overall annual electricity consumption in 2011 without disrupting the electricity system.[88] The National Renewable Energy Laboratory concluded that the electric grid in the western United States could feasibly accommodate 5 percent solar and 30 percent wind energy.[89] Oregon's low net metering cap will prevent solar energy system owners from earning fair compensation for the benefits that their systems will provide to all ratepayers. Oregon should expand its net metering cap to a minimum of 5 percent, and eventually eliminate it altogether.

  - Oregon should standardize net metering rules across the state for all utilities, including the non-investor-owned utilities. At a minimum, net metering calculations must be done on an annual basis in recognition that solar energy systems are more productive in summer than in winter. Utilities that offer monthly net metering do not fairly recognize the value of solar energy as part of the electricity system.

- Oregon should facilitate solar energy system installations on multi-family buildings and systems owned by communities rather than individuals, where the value of system production must be distributed to multiple parties.

- Oregon should reinvigorate state financing programs, such as the Business Energy and Residential Energy Tax Credits, for a variety of renewable energy technologies.

Create a net-zero energy building code to increase the use of solar energy in new construction.

- Incorporating solar power into new buildings at the time of construction represents an enormous opportunity to grow Oregon's solar market. Ultimately, policy makers need to move beyond simple incentives to capture the full energy potential of new buildings. To achieve more, Oregon should require all new homes to include solar power—or other kinds of distributed renewable energy generation technologies—by no later than 2020, and all non-residential buildings by no later than 2030, through a net-zero energy building code requirement. Such a requirement would be consistent with the state's overall clean energy goals, as well as with steps that President Obama has ordered for federal buildings.[90] Moreover, the European Union will require net-zero energy construction for all new buildings beginning in 2019.[91]

Expand financing opportunities for solar energy systems.

- Other important policies can help ensure that homeowners or business owners who install solar energy systems maximize the return on their investments. Allowing on-bill financing could enable potential solar customers to install systems with no money down and low interest payments, as an ongoing part of the utility bill. These programs, such as the PAYS America program (Pay As You Save), harness future savings from renewable technologies or efficiency measures to pay the up-front cost of installation. They are especially promising for multi-family dwellings because they allow the payments to be attached to the utility meter, making the program attractive to renters, as well as property owners.

- Encouraging innovative leases or power purchasing agreements can further expand access to solar power by reducing or eliminating the upfront cost of an installation. For example, third party ownership—legalized in Oregon at the beginning of 2011—has been effective at expanding the pool of potential solar PV system owners.[92]

- The Property Assessed Clean Energy (PACE) program, which enables property owners to finance renewable energy and energy efficiency projects through local government loans that are paid back via property tax bills, should be reinstated. Oregon leaders should advocate for the program to be restored at the federal level.

Remove barriers to going solar at the local and state levels, including minimizing challenges with interconnection and permitting.

- Different jurisdictions across the state have varying permitting and interconnection procedures and fees, which can add unnecessary friction to the process of installing solar energy systems. State and local leaders should work to standardize procedures, minimize fees, and streamline the process of installing a new solar energy system and integrating it into the electricity grid.

Solar energy can become an increasingly important part of Oregon's effort to reduce global warming pollution, while simultaneously becoming a substantial force in our economy. Credit: Solar Oregon

Methodology

This analysis focuses on the potential for solar power on the rooftops of Oregon buildings and on vacant land. Electricity and hot water generated on top of buildings can be used locally, reducing the need for cross-country power lines and increasing grid efficiency and reliability. Utility-scale solar power installations on vacant land offer substantial additional potential.

Solar PV Potential

Technical

To estimate the total technical potential for rooftop solar PV in Oregon, we relied upon Rooftop Photovoltaics Market Penetration Scenarios, a report carried out by Navigant Consulting for the National Renewable Energy Laboratory.[93] Taking into account factors such as tree and other shading, roof tilt and orientation, and the room needed on roofs between solar panels and taken up by other objects such as chimneys and fan systems, Navigant estimated that 22 percent of residential roof space and 65 percent of commercial roof space in states with cool climates (such as Oregon) could be used for solar panels, on average.[94]

Navigant found that installing solar panels on all suitable residential and commercial rooftop space in Oregon in 2008 would result in 5,581 MW of solar power. Navigant also estimated total solar roof potential through 2015, based on a forecast for increasing rooftop space as new buildings are constructed.[95] Navigant also assumed that solar PV technology would increase in average efficiency from 13.5 percent in 2007 to 18.5 percent in 2015—meaning that the same amount of rooftop area could host a larger capacity of improved solar panels.

To estimate total solar PV potential in 2025, we extrapolated Navigant's trend of Oregon technical PV potential from 2007-2015, ignoring any potential for further improvement in solar technology beyond 2015. To the extent that solar PV technology moves beyond 18.5 percent efficiency, Oregon rooftops might be able to hold additional solar capacity.

We calculated that at 18.5 percent

conversion efficiency, installing the full 10,600 MW of Oregon's technical PV potential in 2025 would require approximately 550 million square feet of rooftop area.[96] Subtracting out the area required by solar hot water systems at full penetration (see below) would reduce area available for PV by 8 percent, yielding a total technical potential in 2025 of 9,800 MW.

We did not attempt to make an estimate of the technical potential for non-rooftop solar installations, which would be limited only by the availability of acceptable open land area with adequate sun exposure.

Achievable Vision

To lay out a vision for a future course of rooftop solar PV development for Oregon to pursue, we looked toward established rates of solar PV market growth that the states of New Jersey and California have demonstrated are possible. Using actual and forecast growth curves for solar in these states, presented visually in Figure 5 on page 14, we estimated that Oregon could achieve market growth as described in Table 1.[97]

Table 1: Potential Rooftop Solar PV Market Growth in Oregon, Based on Actual and Forecast Growth in California and New Jersey

Year	Growth Rate	Cumulative PV Capacity (MW)
2012	64%	77
2013	45%	112
2014	42%	159
2015	45%	231
2016	44%	332
2017	37%	454
2018	39%	632
2019	33%	841
2020	30%	1,093
2021	27%	1,391
2022	25%	1,736
2023	23%	2,126
2024	21%	2,562
2025	19%	3,042

We assume that non-rooftop, utility-scale solar development can generate another 3 billion kWh annually by 2025, bringing solar energy to 10 percent of Oregon's electricity supply. If the utility-scale solar took the form of ground-mounted photovoltaic panels, and were placed in areas with sun exposure comparable to the rooftop panels as described below, Oregon would need to install about 870 megawatts by 2020 and 2,400 megawatts by 2025 to achieve this target. (See Figure 6 on page 15.)

Energy Output

We calculated the energy output of solar PV panels in Oregon using a population-weighted state average annual electricity generation estimate of 1,075 kWh per kW, per the National Renewable Energy Laboratory's PVWatts tool.[98]

Solar Water Heating Potential

Technical

To calculate maximum market penetration for solar hot water systems, we first needed an estimate of the number of residential and commercial buildings that will exist in Oregon in 2025.

We estimated the number of housing units in Oregon in 2025 using data from the U.S. Census Bureau. Using 2008 estimates of population and housing units, we calculated a ratio of residents per household.[99] Holding this ratio constant, we then applied population projections to obtain an estimate of total housing units in 2025.[100]

We calculated the current number of commercial buildings in Oregon using estimates of the number of commercial buildings and the number of establishments per building in the Pacific census region, per the U.S. Department of Energy's Commercial Building Energy Consumption Survey.[101] Given that the Census reports that there are 108,040 commercial establishments in Oregon, we calculated that there are 90,159 commercial buildings in the state.[102] (The number of establishments per commercial building was listed as ranges in the Commercial Buildings Energy Consumption Survey—for example, two to five establishments per building. In order to be conservative in estimating the number of buildings, the highest number in the range was assumed when converting number of establishments to number of buildings.)

To project the number of business buildings in Oregon in 2025, we first calculated growth in commercial building space. We began with a 2004 Brookings Institution Metropolitan Policy Program report called Toward a New Metropolis: The Opportunity to Rebuild America. This report estimates the number of commercial workers by state in 2000 and 2030, and the building space that they require. To interpolate those figures for intervening years, we assumed that the percentage of the population engaged in commercial work (determined using the Brookings Institution commercial workers data and U.S. Census Bureau population projections) would change at a steady rate between 2000 and 2030. Then, we calculated the total square footage of building space that those commercial workers would require using the Brookings Institution estimates of space requirements per worker. We found that Oregon commercial building area is likely to increase 39 percent by 2025 relative to 2003. Assuming that average space per commercial building remains constant, in 2025, Oregon is likely to have 125,000 commercial buildings.

We assumed that 55 percent of residential buildings and 65 percent of commercial buildings in the Pacific region could install solar hot water systems, per the National Renewable Energy Laboratory.[103]

This yielded a maximum of more than 1 million residential solar hot water systems and 80,000 commercial-scale solar hot water systems in 2025. We calculated that at an average efficiency of heat capture of a solar hot water system of 55 percent (very conservative), and Oregon's average solar resources per our population-weighted PVWatts estimate described above, the state would require 45 million square feet of rooftop area to deliver the energy savings described.

Achievable Vision

We assumed that solar water heating systems could be installed in Oregon such that the state would achieve 29 percent of technical potential by 2025, in parallel with the rooftop solar PV trajectory described above.

Energy Output

We calculated the amount of energy that could be saved by solar hot water systems by assuming that a typical solar hot water system in Oregon could replace 50 percent of the energy used to heat water in a typical Oregon building, per the National Renewable Energy Laboratory.[104] We broke down energy saved into electricity and natural gas fractions by using the percent of residencial and commercial buildings in the Pacific census region that use electricity and natural gas to heat water, respectively, per the Residential Energy Consumption Survey and Commercial Building Energy Consumption Survey.[105] We then multiplied the number of systems by the average Pacific Region electricity or gas consumption per building for water heating, for residential and commercial buildings respectively, yielding savings in terms of kWh of electricity or cubic feet of natural gas.

Estimating Oregon's Future Electricity and Hot Water Energy Needs

Calculations for the equivalent percent of Oregon's future energy needs that solar output would represent were based on the following.

We derived an estimated value for 2025 electricity consumption in Oregon from the Northwest Power and Conservation Council, Sixth Northwest Conservation and Electric Power Plan, Chapter 3, February 2010. We scaled the percent change in regional power demand to Oregon using Oregon's 2010 electricity consumption, per U.S. Department of Energy, Energy Information Administration, 2010 State Electricity Profiles: Oregon, January 2012.

Oregon's anticipated water heating energy needs in 2025 were derived by multiplying the housing and commercial space increase forecast described above by the average electricity and natural gas consumption for water heating per residence or square foot of commercial building space, per the Residential Energy Consumption Survey and Commercial Building Energy Consumption Survey.[106]

Preventing Global Warming Pollution

We translated energy generation figures into global warming pollution as follows.

We assumed that energy generated by solar PV would primarily replace non-baseload electricity generation. In the Western Electricity Coordinating Council (WECC), Northwest Subregion, non-baseload electricity sources produce an average of 1,334 lbs of carbon dioxide per MWh.[107]

We assumed that electricity saved by solar water heating systems would not necessarily be timed to coincide with peak electricity demand, and therefore assumed that solar water heating would displace electricity at the total WECC Northwest pollution rate of 902 lbs of carbon dioxide per MWh.[108]

For natural gas, we assumed that every million BTU would prevent 53 kilograms of carbon dioxide pollution, per emission coefficients from the U.S. Department of Energy.[109]

Notes

1 City of Portland, Oregon, Procurement Services, *Green Purchasing Case Studies: Solar-Powered SmartMeters Streamline Portland's Parking*, June 2011.

2 Steven Lacey, "Germany Installed 3 GW of Solar PV in December – The U.S. Installed 1.7 GW in All of 2011," *Climate Progress*, 10 January 2012.

3 Bernadette del Chiaro and Timothy Telleen-Lawton, Environment California Research & Policy Center, *Solar Water Heating: How California Can Reduce Its Dependence on Natural Gas*, April 2007; AEE - Institute for Sustainable Technologies, *Solar Heat Worldwide*: *Markets and Contribution to the Energy Supply 2009*, May 2011.

4 U.S. Department of Energy, National Renewable Energy Laboratory, *PVWatts 2.0*, available at mapserve3.nrel.gov/PVWatts_Viewer/index.html.

5 Ibid.

6 Capacity factor calculated by dividing annual generation figure obtained from *PVWatts* by 365 days in a year and by 24 hours in a day.

7 The population-weighted average using *PVWatts* results for Portland, Bend, North Bend, Pendleton, Salem, Astoria, Eugene and Medford is 1,075 kWh per year per kilowatt of solar PV capacity. See note 4.

8 See note 4.

9 Ibid.

10 Ibid.

11 Ibid.

12 See note 3, Environment California Research & Policy Center.

13 P. Denholm, U.S. Department of Energy, National Renewable Energy Laboratory, *The Technical Potential of Solar Water Heating to Reduce Fossil Fuel Use and Greenhouse Gas Emissions in the United States*, March 2007.

14 Size based on data from the California Solar Initiative: California Energy Commission & California Public Utilities Commission, *California Solar Initiative Working Data Set*, 7 September 2011, available at www.californiasolarstatistics.ca.gov/current_data_files; Systems take approximately 100 square feet of roof area per kW, per: Solaris Blackstone, *Frequently Asked Questions*, downloaded from www.solarisblackstone.com/faq.html on 20 January 2012.

15 Ibid.

16 J. Paidipati, L. Frantzis, H. Sawyer, and A. Kurrasch, Navigant Consulting, Inc. for National Renewable Energy Laboratory, *Rooftop Photovoltaics Market Penetration Scenarios*, February 2008.

17 Ibid.

18 Based on a linear curve fit of the 2007-2015 technical potential trend in note 16. This initial trend assumes that solar PV technology increases from an average of 13.5 percent conversion efficiency in 2007 to 18.5 percent conversion efficiency in 2015 (meaning that a given area of panels could generate more electricity using better technology). Our projected technical potential curve ignores any potential for further improvement in solar technology beyond 2015, and is thus conservative.

19 See methodology for details.

20 See methodology for details.

21 See note 13.

22 Find Solar, *Solar Heating (Solar Thermal) Systems*, downloaded from www.findsolar.com/Content/SolarThermal.aspx, 7 August 2009.

23 Oregon average household water heating energy use: U.S. Department of Energy, Energy Information Administration, *2005 Residential Energy Consumption Survey: Total Consumption, British Thermal Units (Btu)*, Table WH4, 2009.

24 See methodology.

25 State of Oregon, Office of Innovative Partnerships and Alternative Funding, *Oregon Solar Highway* (factsheet), 17 March 2009.

26 David Sneed, "Solar Panels Sprouting on the Carrizo," *San Luis Obispo Tribune*, 5 February 2012.

27 For more details about solar thermal power and its potential, see Bernadette Del Chiaro, Tony Dutzik and Sarah Payne, Environment America Research & Policy Center, *On the Rise: Solar Thermal Power and the Fight Against Global Warming*, Spring 2008.

28 Oregon Department of Transportation, *Baldock Solar Highway Project Frequently Asked Questions* June 2011.

29 Including distributed systems on residential and commercial rooftops and central systems owned by electric utility companies. Larry Sherwood, Interstate Renewable Energy Council, *U.S. Solar Market Trends 2010*, June 2011.

30 Ibid.

31 Northwest Power and Conservation Council, *Sixth Northwest Conservation and Electric Power Plan: Plan Overview*, February 2010, p 2.

32 Ibid, p 7-8.

33 Ibid.

34 Ibid, p 3.

35 Ibid, p 7-8.

36 For example, analysts estimate that adding just 500 MW of solar PV capacity to the Northeast's power grid could have prevented the massive August 2003 blackout, which caused widespread disruption to business activity and $8 billion in economic damage. Richard Perez, State University of New York at Albany, et al., *New, Solar Power Generation in the US: Too Expensive, or a Bargain?*, April 2011; Richard Perez, et al., "Solution to the Summer Blackouts – How Dispersed Solar Power Generating Systems Can Help Prevent the Next Major Outage," *Solar Today* 19: 32-35 July/August 2005.

37 Ibid.

38 Richard Perez and T. Hoff, New York Solar Energy Industry Association and the Solar Alliance, *Energy and Capacity Valuation of Photovoltaic Power Generation in New York*, 2008.

39 T. Hoff, et al., Clean Power Research LLC, *The Value of Distributed Photovoltaics to Austin Energy and the City of Austin*. Final Report to Austin Energy (SL04300013), 2006.

40 See note 36, *New, Solar Power Generation in the US: Too Expensive, or a Bargain?*

41 Galen Barbose, Naim Darghouth, Ryan Wiser and Joachim Seel, Lawrence Berkeley National Laboratory, *Tracking the Sun IV: An*

Historical Summary of the Installed Cost of Photovoltaics in the United States from 1998 to 2010, September 2011.

42 "Spot price": GTM Research, "Polysilicon Prices Hit Record Low in 2011; Will Head Even Lower, Enabling $0.70/W PV in 2012," *GreenTech Media*, 25 January 2012; "10 percent": see note 41.

43 See comparison between the forecast cost of electricity from different technologies in: Joel Klein, California Energy Commission, *Comparative Costs of California Central Station Electricity Generation Technologies*, CEC-200-2009-017-SD, Draft Staff Report, August 2009.

44 See note 2.

45 Retail electricity costs per: U.S. Department of Energy, Energy Information Administration, *State Energy Data System, Table ET1: Primary Energy, Electricity, and Total Energy Price and Expenditure Estimates, 1970-2009, Oregon*, 30 June 2011. Corrected for inflation using the U.S. Bureau of Labor Statistics, *Consumer Price Index*.

46 Glut of shale gas: John Miller, "NW Power Group: Gas Glut to Cut Electricity Prices," *Bloomberg Businessweek*, 11 August 2011.

47 Data from the Energy Trust of Oregon, per note 41.

48 Assuming that the population-weighted average output of a solar panel in Oregon is 1,075 kWh per year per kW of capacity. (See note 7.) See methodology for estimated 2025 electricity consumption in Oregon.

49 Calculated using 2010 average annual residential electricity consumption in Oregon, per U.S. Department of Energy, Energy Information Administration, *2010 State Electricity Profiles: Oregon*, January 2012. Number of homes in Portland per U.S. Census Bureau, *State & County QuickFacts 2010*, downloaded from quickfacts.census.gov/qfd/states/41000.html on 7 January 2012.

50 See methodology.

51 See note 23.

52 Electricity demand forecasts: see note 31, Chapter 3. We scaled the percent change in regional power demand to Oregon using Oregon's 2010 electricity consumption. See Methodology.

53 K.D. Dello and P.W. Mote (eds), Oregon State University, Oregon Climate Change Research Institute, *Oregon Climate Assessment Report*, 2010.

54 University of Washington, Joint Institute for the Study of the Atmosphere and Ocean, Climate Impacts Group, *Climate Change Scenarios*, 1 August 2008, available from www.cses.washington.edu/cig/fpt/ccscenarios.shtml; see also note 53.

55 University of Washington, Joint Institute for the Study of the Atmosphere and Ocean, Climate Impacts Group, *Climate Impacts on Pacific Northwest Water Resources*, downloaded from cses.washington.edu/cig/pnwc/pnwwater.shtml, 26 October 2007.

56 See note 53.

57 Ibid.

58 Ibid.

59 Partnership for Interdisciplinary Studies of Coastal Oceans, *Policy and Outreach: Hypoxic Event Off Oregon Coast*, downloaded from www.piscoweb.org/outreach/topics/hypoxia, 20 June 2008.

60 Gwyneth Dickey, "Stanford Scientists Link Ocean Acidification to Prehistoric Mass Extinction," *Stanford Report*, 27 April 2010; Jennifer Langston, Sightline Institute, *Northwest Ocean Acidification: The Hidden Costs of Fossil Fuel Pollution*, November 2011.

61 University of Washington, Joint Institute for the Study of the Atmosphere and Ocean, Climate Impacts Group, *Climate Impacts on Pacific Northwest Coasts*, downloaded from cses.washington.edu/cig/pnwc/pnwcoasts.shtml, 26 October 2007.

62 University of Washington, Joint Institute for the Study of the Atmosphere and Ocean, Climate Impacts Group, *Climate Impacts in Brief*, downloaded from cses.washington.edu/cig/pnwc/ci.shtml#anchor3, 26 October 2007.

63 State of Oregon, *The Oregon Climate Change Adaptation Framework*, December 2010.

64 Leading pollutant: Intergovernmental

Panel on Climate Change, *Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, 2007.

65 U.S. Environmental Protection Agency, *eGRID2010 Version 1.1*, WECC Northwest subregion annual non-baseload CO_2 emission rate, downloaded from www.epa.gov/cleanenergy/energy-resources/egrid/index.html on 11 January 2012.

66 See Methodology.

67 See Methodology.
68 A typical vehicle emits 5.2 metric tons of carbon dioxide pollution per year. U.S. Environmental Protection Agency, *Emission Facts: Greenhouse Gas Emissions from a Typical Passenger Vehicle*, February 2005, available at www.epa.gov/otaq/climate/420f05004.htm.

69 Projected energy-related emissions in 2025 are on the order of 50 million metric tons of carbon dioxide, per the baseline emissions scenario from: Tony Dutzik, et al., Frontier Group and Environment America Research & Policy Center, *The Way Forward on Global Warming: Reducing Carbon Pollution Today and Restoring Momentum for Tomorrow by Promoting Clean Energy*, Summer 2011.

70 Jeremiah Baumann, et al., Frontier Group and Environment Oregon Research & Policy Center, *Global Warming Solutions: A Progress Report – Policy Options to Reduce Oregon's Contribution to Global Warming*, Spring 2009.

71 The Solar Foundation, *National Solar Jobs Census 2011: A Review of the U.S. Solar Workforce*, October 2011.

72 Ibid., and the Solar Foundation, *National Solar Jobs Census 2010: A Review of the U.S. Solar Workforce*, October 2010.

73 See note 71.

74 Bruce Laird, Oregon Business Development Department, *Oregon's Solar Advantage* (presentation), March 2011, downloaded from www1.eere.energy.gov/solar/sunshot/pdfs/pv_manufacturing_workshop_2011_march_laird.pdf.

75 Erik Siemers, "SolarWorld Consolidates U.S. Manufacturing in Hillsboro," *Sustainable Business Oregon*, published by the *Portland Business Journal*, 2 September 2011.

76 "350 MW": ibid. "Largest in the United States": SolarWorld, *Hillsboro, Oregon*, downloaded from www.solarworld-usa.com/about-solarworld/locations/hillsboro-oregon.aspx on 14 February 2012.
77 Christina Williams, "SoloPower Secures Portland Lease," *Sustainable Business Oregon*, published by the *Portland Business Journal*, 29 August 2011.

78 Oregon Global Warming Commission, *Report to the Legislature*, January 2009.

79 Ibid.

80 See note 74.

81 Study averaged job-creation results from three separate studies. Max Wei, et al., *Putting Renewables and Energy Efficiency to Work: How Many Jobs Can the Clean Energy Industry Generate in the U.S.?* 19 October 2009.

82 Erik Siemers, "Solar Nation Prefers Oregon but Faces Barriers to Work Here," *Sustainable Business Oregon*, published by the *Portland Business Journal*, 21 April 2011.

83 See note 81.

84 Advanced Energy Systems, *Is It Over?*, 11 April 2011, available at aesrenew.blogspot.com/2011/04/is-it-over.html.

85 Travis Madsen, Frontier Group, and Michelle Kinman and Bernadette Del Chiaro, Environment California Research & Policy Center, *Building a Brighter Future: California's Progress Toward a Million Solar Roofs*, November 2011.

86 U.S. Department of Energy, "Oregon Pilot Solar Volumetric Incentive Rates & Payments Program," *Database of State Incentives for Renewables and Efficiency*, 23 February 2012.

87 U.S. Department of Energy, "Oregon Renewable Portfolio Standard," *Database of State Incentives for Renewables and Efficiency*, 29 June 2011.

88 See also Pacific Northwest National Laboratory, *Large-Scale Wind and Solar Integration in Germany*, February 2010.

89 Michael Milligan and Debbie Lew, National Renewable Energy Laboratory, *Wind and Solar Integration into the Bulk Power System* (presentation), Solar and Wind Interconnection Workshop, 22 February 2012.
90 The White House, *Executive Order 13514*, 5 October 2009.

91 European Parliament, *All New Buildings to Be Zero Energy from 2019* (press release), REF.: 20090330IPR52892, 31 March 2009.
92 Easan Drury, et al., "The Transformation of Southern California's Residential Photovoltaics Market Through Third-Party Ownership," *Energy Policy* 42: 681–690, March 2012, available at dx.doi.org/10.1016/j.enpol.2011.12.047.

93 See note 16.

94 Ibid.

95 Ibid.

96 Based on converting annual solar output to BTU by multiplying by 3,412 BTU per kWh, then calculating how much surface area would be required to capture that much sunlight in a year given a population-weighted average solar resource in Oregon of 4 kWh/m^2/day (per *PVWatts* as described in note 7) at 18.5 percent conversion efficiency and adding an additional 25 percent to account for space required by ancillary equipment, per *Rooftop Photovoltaics Market Penetration Scenarios.*

97 For market growth rates, see: Travis Madsen, Frontier Group, and Michelle Kinman and Bernadette Del Chiaro, Environment California Research & Policy Center, *Building a Brighter Future: California's Progress Toward a Million Solar Roofs*, November 2011; and Larry Sherwood, Interstate Renewable Energy Council, *U.S. Solar Market Trends*, compiling statistics from the versions of this report published from 2008 through 2011, covering the years 2006 through 2010.

98 See note 7.

99 U.S. Census Bureau, Population Estimates Program, *2009 Population Estimates*, 20 July 2010, available at factfinder.census.gov/home/en/official_estimates_2009.html.

100 2008 estimates: U.S. Census Bureau, *Annual Estimates of the Resident Population for the United States, Regions, States, and Puerto Rico: April 1, 2000 to July 1, 2009 (NST-EST2009-01)*, December 2009. Future projections: U.S. Census Bureau, Population Division, *Interim State Population Projections*, 21 April 2005, available at www.census.gov/population/www/projections/projectionsagesex.html.

101 Commercial Buildings: Energy Information Administration, *2003 Commercial Buildings Energy Consumption Survey*, June 2006.

102 U.S. Census Bureau, *County Business Patterns*, 2009, available at censtats.census.gov/cgi-bin/cbpnaic/cbpsect.pl.

103 See note 13.

104 Ibid.

105 Number of households in Oregon: U.S. Census Bureau, *2010 U.S. Census*, May 2010; average energy used to heat water per household: Energy Information Administration, *2005 Residential Energy Consumption Survey— Table US14. Average Consumption by Energy End Uses*, *January 2009*; and number of households that use electricity and natural gas for water heating: Energy Information Administration, *2009 Residential Energy Consumption Survey—Table HC.1.11 Fuels Used and End Uses in Homes in West Region, Divisions, and States,* downloaded from 205.254.135.7/consumption/residential/data/2009/ on 11 January 2012; Energy Information Administration, *2003 Commercial Buildings Energy Consumption Survey*, June 2006.

106 Ibid.

107 See note 65.

108 Ibid.

109 U.S. Department of Energy, Energy Information Administration, *Voluntary Reporting of Greenhouse Gases Program Fuel Emission Coefficients*, 31 January 2011, available at 205.254.135.7/oiaf/1605/coefficients.html#tbl1.