RENEWABLE ENERGY

A REPORT BY
THE LEAGUE OF WOMEN VOTERS OF WASHINGTON

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PREFACE

At the 2011 League of Women Voters of Washington (LWVWA) convention, the delegates authorized a proposed update of the 1977 LWVWA Energy Position, EN-6, which says in part:

> "The use of alternate energy systems such as on-site solar heating and recovery of energy from wastes should be actively encouraged."

The other relevant energy position, EN-5, says in part:

"When an energy source is chosen, the efficiency of the source selected should be an important consideration. The League favors research and development of such alternate power sources as solar, wind and tidal… ."

In addition, the League of Women Voters of the United States (LWVUS) declares in its Toolkit For Climate Action: "Global climate change is one of the most serious threats facing our nation and our planet today. Increasingly severe consequences are projected for more people and more regions of the world unless we act now -- as individuals, as communities, and as a nation. For its part, the League is calling for prompt action to cut this country's GHG emissions, freeze construction of new coal-fired power plants, invest in a new clean energy economy… ."

This report is based on a League of Women Voters of Washington study examining the various sources of renewable energy. We hope that it will provide a better understanding of renewable energy sources, their benefits, and the challenges surrounding their development – and that greater knowledge will encourage more effective decision-making regarding development and use of renewable energy.

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GLOSSARY

anthropogenic global climate change -- global climate change caused or produced by humans (chiefly through actions that release pollutants into the environment)

barrage installation -- an artificial barrier across a river or estuary to prevent flooding, to aid irrigation or navigation, or to generate electricity by tidal power

benthic community -- organisms that live in and on the bottom of the ocean floor

cogeneration (also called combined heat and power, or CHP) -- the use of a heat engine or a power station to simultaneously generate both electricity and useful heat

energy -- the ability to do work. It can be in many forms, such as heat, motion, chemical, pressure or vacuum. Units of measurement are kilowatt hours (kWh's), foot pounds, btu's, calories, etc.

generating capacity – the rated maximum power output of an energy source

geosynchronous earth orbit (GEO) -- an orbit that synchronizes with the earth's speed of rotation. For an observer at a fixed location on earth, a GEO satellite will always return to the same place in the sky at exactly the same time each day. Geostationary earth orbit (GSO) is a special type of GEO, in which a satellite is placed in orbit directly above the earth's equator at a precise height, so that it maintains the same position relative to the earth's surface (approximately 35,786 km or 22,236 mi above mean sea level)

gigawatt (GW) – a measure of electricity equal to one billion watts

kilowatt (KW) – a measure of electricity equal to one thousand watts

levelized cost of energy – the constant price per unit of energy that causes the investment to just break even

low head hydro -- hydroelectric power installations operating at lower water pressure or lower water height than would typically be found at a large dam

low impact hydro -- hydroelectric power installations whose environmental effects are relatively small. An example would be a dam holding back only a small quantity of water and having an outflow similar to the normal stream velocity, turbulence and flow continuity, thus having little effect on fish and wildlife. The term is also used for developments that increase hydroelectric capacity at existing dams and for hydroelectric production at water supply dams.

megawatt (MW) – a measure of electricity equal to one million wattsmicro-hydro -- referring to small scale hydroelectric power installations. Often assumed to be those less than 100 KW.

power -- the rate of use of energy. Units of measurement are watts, kilowatts, horsepower, etc.

pulping liquor (also known as black liquor) -- a thick, dark liquid that is a byproduct of the process that transforms wood into pulp, one of the steps in making paper

pumped hydropower – refers to facilities that use electricity, at "off peak" times when it is not needed to meet demand, to pump water from a lower reservoir into one at a higher elevation. When the water stored in the upper reservoir is released, it passes through hydraulic turbines to generate electricity. The off-peak electrical energy used to pump the water uphill is, in a sense, "stored" in the upper reservoir. In this way, two reservoirs in combination can be used to store large quantities of electrical energy for a long period of time.

venturi -- a funnel shaped inlet or bay which concentrates the tidal flow, resulting in high water velocity in the narrowed region

watt – the basic unit for measuring electric power

INTRODUCTION

Energy is the ability to do work. The current major sources of energy for our society are coal, oil, natural gas, nuclear power and hydroelectric dams. Of these sources, the first three are fossil fuels – that is, hydrocarbons or carbon derived from plants and animals from long ago. Renewable energy is energy that comes from sources other than fossil fuels.

This report discusses a wide variety of renewable resources including:

- wind (land-based and offshore)
- solar (photovoltaic and thermal)
- biomass
- biofuels
- wave
- tidal
- geothermal
- hydropower

The report also discusses related issues including:

- green power programs
- the electric power grid
- the smart grid
- energy integration

Background

Extensive research in the past few decades has clearly shown that earth's climate is warming and that a major cause of this warming is the increase of greenhouse gases such as carbon dioxide. The danger of sea level rising and other adverse effects of continued warming are the primary reason the LWVWA chose to study renewable energy. Conversion from use of fossil fuel to renewable energy sources would help slow the rate of increase of atmospheric carbon dioxide and therefore would decrease the rate of global warming.

The global average temperature increased by more than 1.4°F over the last century. According to the National Oceanic and Atmospheric Administration (NOAA), the decade from 2000 to 2010 was the warmest on record, and 2010 was tied with 2005 as the warmest year on record. Rising global temperatures have been accompanied by other changes in weather and climate. Many places have experienced changes in rainfall patterns,including more intense rain, more frequent and severe heat waves and droughts. The planet's oceans and glaciers have also experienced changes: oceans are warming and becoming more acidic, ice caps are melting, and sea levels are rising. All of these changes are evidence that the world is getting warmer.[1]

Some fluctuations in the earth's temperature are inevitable regardless of human activity. They result from natural phenomena such as decades-long ocean cycles. However, human activity plays a part, too. In November 2011, the International Energy Agency warned that if the world doesn't make significant progress toward phasing out its fossil fuel infrastructure by 2017, the world could lose forever its chance to avoid dangerous runaway climate change.[2]

Centuries of rising temperatures and seas lie ahead if the release of emissions from the burning of fossil fuels and deforestation continues unabated.[2] Increasing research, development and use of various commercial-scale renewable sources of energy, along with conservation efforts, may help mitigate these potentially devasting effects. Greater use of renewable energy, in addition to reducing atmospheric carbon dioxide, may have other benefits, including

- increasing energy independence
- potential reductions in air and water pollution
- reducing stress on the ecosystem
- a more distributed energy supply

The citizens of Washington state expressed their support for renewable energy with the passage of Initiative 937 in 2006. The Energy Independence Act (EIA) codified in RCW 19.285 requires that large utilities (25,000 customers or more) in Washington obtain 15 percent of their electricity from new renewable resources such as solar and wind by 2020 and undertake cost-effective energy conservation. Renewable resources eligible to meet this mandate are:

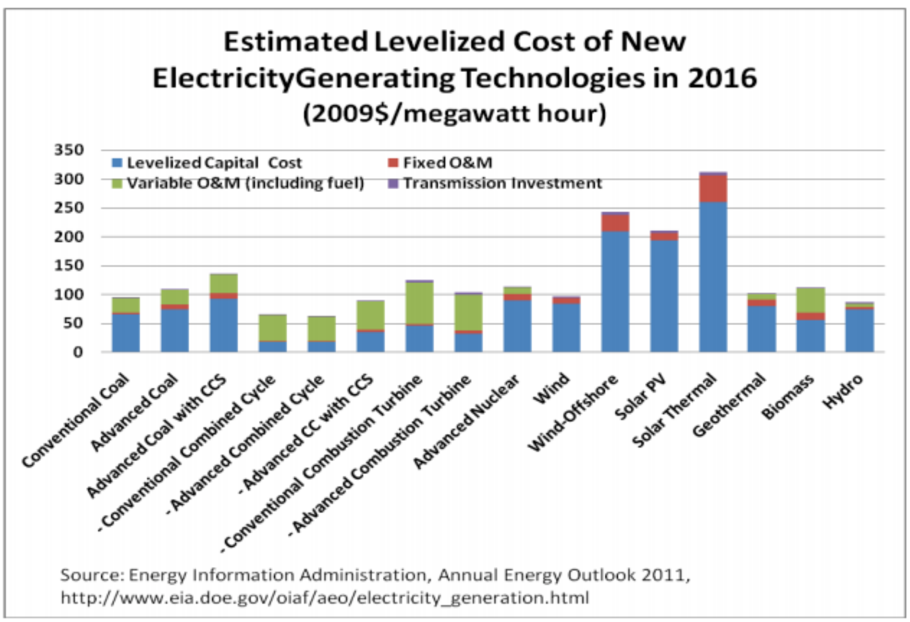
- Electricity from non-hydro renewables in facilities that begin operation after March 31, 1999
- Electricity produced as a result of efficiency improvements completed after March 31, 1999 at hydroelectirc generation facilities.
- Qualified biomass energy (organic by-products of pulping and the wood manufacturing process; animal manure; solid organic fuels from wood, forest or

field residues; untreated wooden demolition or construction debris; food waste and food processing residuals; liquors derived from algae; dedicated energy crops and yard waste). Qualified biomass does *not* include treated wood, wood from old growth forests or municipal solid waste.

Utilities must meet annual targets by 2020 with incremental steps of 3% by 2012 and 9% by 2016, along with undertaking cost-effective energy conservation (RCW 19.280). There are financial penalties for utilities who fail to comply and have a shortfall of megawatt-hours.

Costs

The expected future cost of each energy technology needs to be considered. In the chart below, the U.S. Department of Energy displays its estimates for the 2016 levelized costs of various energy sources, including fossil fuel sources and renewable sources.



The chart uses the terms "combined cycle," "CC," and "CCS," which may not be familiar to all readers. A combined cycle (CC) gas turbine plant has a gas turbine generator that produces electricity, but also uses the heat of its exhaust to make steam, which in turn drives a steam turbine to generate additional electricity. "CCS" is an abbreviation for "carbon capture and storage."

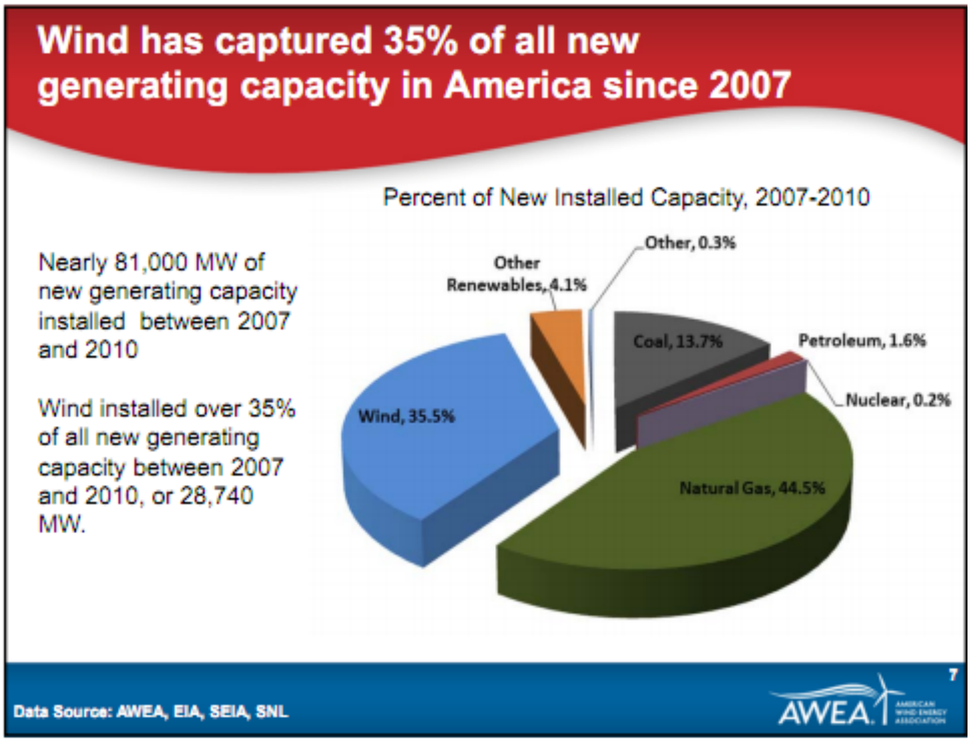
Costs will be discussed throughout this report, in relation to each renewable energy source. In most cases, especially with new and developing technology, many of the variables influencing cost are still in flux. In all cases, it has proven difficult to provide cost estimates which take into account savings from reduced impacts of burning fossil fuels. It is generally agreed, however, that these savings, though difficult to calculate accurately, are substantial.

WIND ENERGY

Commercial-scale land-based wind power has been second only to natural gas as a source of new electric power generation in the United States for the past five years, and is projected to make a major contribution to the nation's electrical energy production.

The modern era of generating electricity from utility-grade wind turbines began in the early 1980s, spurred on by generous federal and state financial incentives. Early machines, deployed primarily in California, were small and unreliable. The machines of today have rated capacities 15 to 20 times the capacity of the earlier machines and are reliable. The cost per kWh declined from 15-20 cents in 1980 to 7-9 cents in 2011.

A typical wind turbine is 200' tall, with rotor blade diameters of 260 – 280' and a life of 20-30 years, although with major component replacements, turbine life can be extended well beyond that time period. The primary raw materials include steel, copper and cement, with a small amount of rare earth materials used in the generators. All materials except the cement, which is used for the tower foundations, are recyclable, and the foundations might be either reused as is or modified to accommodate new turbine towers.



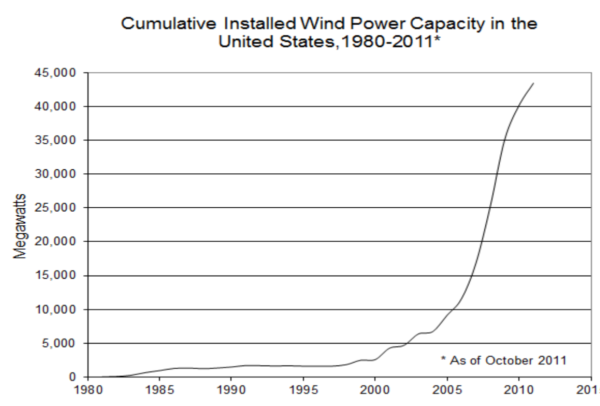
Capacity

As noted, commercial-scale land-based wind power has become a major energy source, going from nearly zero in 1980 to a capacity of close to 45,000 MW in 2011. In operation, wind turbines delivered about 352,000 GWh or 1.2 % of the total U.S. energy consumption for 2011. It is important to understand that the installed capacity is the rated maximum power that can be delivered by the wind turbines. The actual average energy that can be delivered in a year is 25% to 45% of this maximum power times the number of hours in a year, depending on the wind velocity and velocity variation as well as on the turbine and control system design.

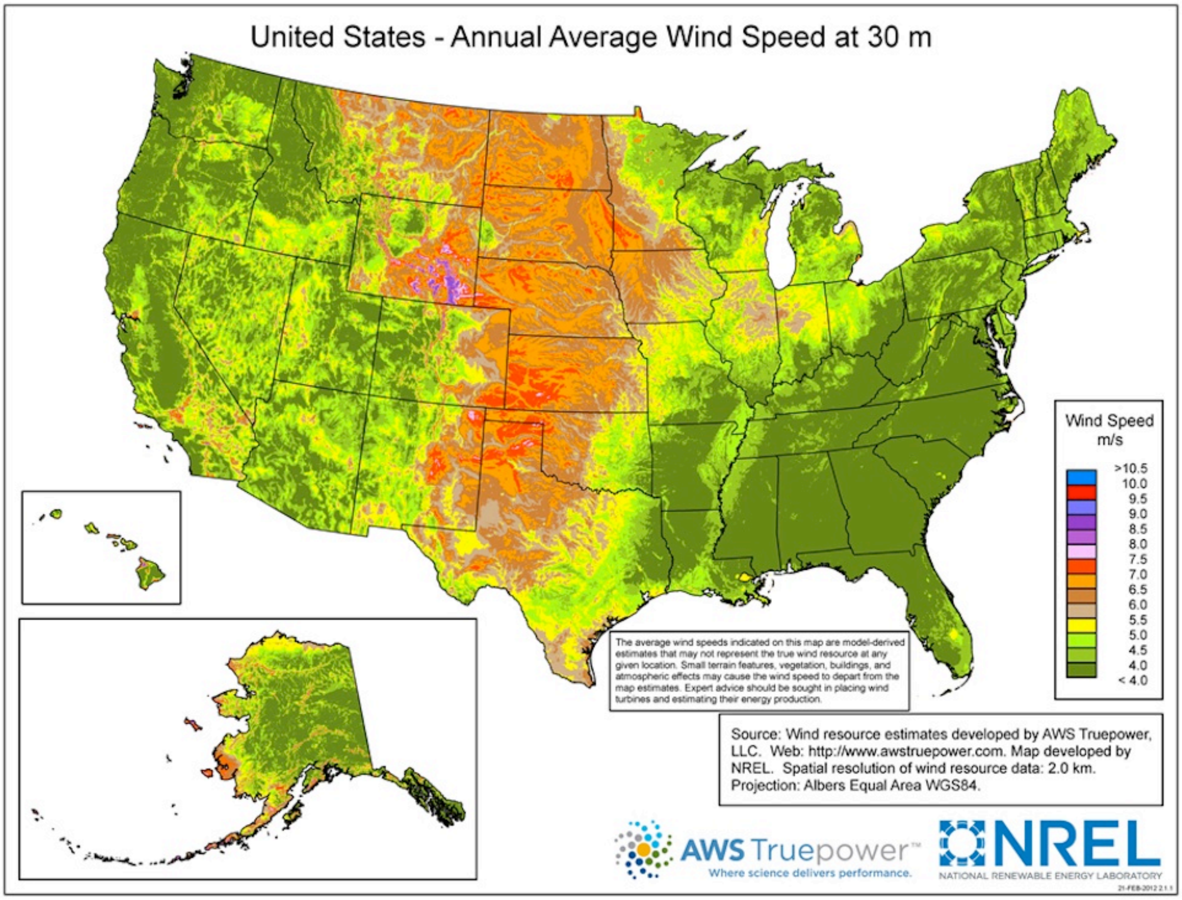
Despite those major increases in installed wind power, the current installed capacity, including offshore, is less than 0.4% of the potential maximum capacity. Wind power has the potential to become a significant portion of the electricity generation in the U.S., and the American Wind Energy Association has set a goal of wind power installed capacity achieving a 20% share of total U.S. electricity by 2030.[3]

Washington currently ranks sixth in the country for installed onshore wind power capacity. As of August 2012, projects in the state included, in megawatts: [4]

Existing projects	2,699 MW
Under construction	209 MW
Wind projects in queue	5,807 MW
Potential capacity	18,478 MW



Both Washington and the U.S. have a large potential for further development. The overall wind resource for the United States is depicted in the chart below:



Costs

Land-based wind energy has become more competitive than most other electrical energy sources, both renewable and non-renewable. This is due in part to increased cost of conventional coal resulting from recent stricter emissions requirements, and fewer new developable hydro resources. Wind energy remains more expensive than natural gas, though with the Production Tax Credit wind is within one cent per kWh of natural gas. The affordability of a wind turbine farm may depend strongly on the distance to a power grid with sufficient capacity to absorb the power generated, since extending the grid is expensive.

Federal Tax Incentives

The growth of wind energy installations in the U.S. is very dependent on federal tax incentives. There are two currently available to the industry:

- Production Tax Credit (PTC): currently pays the wind power station a 2.2 cents per kWh generated benefit for the first ten years of operation.
- Modified Accelerated Capital-Recovery System (MACRs): a system of rules and schedules for accelerated depreciation allowing a five-year depreciation schedule for all Investment Tax Credit eligible technologies.

The Production Tax Credit was due to expire at the end of 2012, but was renewed by Congress as part of end-of-year legislation to avert a “fiscal cliff.” Because wind energy projects typically take 2-4 years to develop and finance, the threat of expiration affected projections for installations in 2013, and American manufacturers saw a marked decrease in orders. The federal government has allowed PTCs to expire on three separate occasions since 1999, causing a boom-bust cycle that slowed

the installation of wind power stations and has had a related impact on the continuing growth of wind turbine manufacturing in the U.S.

Costs to the Consumer

Most utilities simply roll the cost of wind-generated electricity into their rates in the same way they include the cost of other generating sources. But some utilities give customers the opportunity to voluntarily pay a higher rate to encourage higher use of wind and other renewable technologies. These "green power" programs are described in more detail later in this report. The cost to the customer for voluntary participation in a green power program varies considerably throughout the country, depending on each utility's marketing strategy.

Reliability

Wind turbine suppliers typically guarantee that the machine will be available for generation 95% of the time, and typical field operations yield average availabilities of 97-98%. However, the wind doesn't blow all of the time, so the machines are neither always producing energy nor always at maximum capacity. Most turbines are in locations with sufficient wind to allow them to generate some amount of electricity between 60% and 80% of the time.

Given the variability of wind, the resulting capacity factor ranges from 25% to 45%, a dramatic improvement over first generation turbines. The energy payback period for a commercial wind turbine is now less than one year, even taking into account the energy required to mine, transport and process the raw materials used to manufacture the turbine and tower, as well as component manufacture, assembly and installation of the turbine.[5]

When contracting to purchase energy, utilities consider the variability of wind resources, by integrating them with other energy sources. When the wind is not blowing sufficiently, the utility relies more on its other production sources -- for example, natural gas, coal, or hydro.

Other

Because commercial wind installations tend to have tall towers and large rotor blade diameters, those installations can affect wildlife. Sounds and views are also affected, causing concern about possible decreases in property values. Wind energy development may also raise issues involving the electric power grid, including lack of adequate transmission lines and problems with grid integration.

Wildlife

Wind turbines can have an adverse impact on wildlife, especially birds and bats. Currently, wind turbines are estimated to cause less than three out of every 100,000 human-related bird deaths in the U.S., substantially lower relative to estimated total annual bird casualty rates.[6] [7]

By 2030, if the U.S. is to produce 20% of its electricity from wind, about 300,000 megawatts of wind capacity will be needed. At that level of production, it is likely that up to 1.2 million birds per year will be killed. However, it is important to note that this number represents only 0.03% - 0.08% of all birds killed by human structures and activities, a very small percentage when all factors causing bird deaths are considered.[8]

Other Environmental Effects

The primary objections to siting utility-grade wind turbines near population centers are visual, noise, and fear of loss of property value. The industry has tried to address each of these issues, with varying success. Objections to *visual impacts* are partially addressed by placing the turbines out of sight whenever practical and simply avoiding places such as wilderness areas altogether. National parks and monuments require the machines to be out of critical "viewscapes."

Noise impacts are reduced through the use of setback requirements calling for wind turbines to be sited a minimum distance away from homes. In general, wind turbines do not make a great deal of noise. But the sounds that wind turbines do make can be annoying to those who live nearby. Most modern wind turbines employ a variable speed rotor that is slowed down in the lower wind regimes to reduce noise. Rotor blades have also been refined to reduce trailing edge and tip noise. These measures have only been partially successful, and it seems inevitable that some people living near wind power stations will continue to feel adversely affected by noise from the turbines.

Property owners sometimes worry about the impact of wind development on *property values*, but most objective analyses have shown minimal, if any, impact from such development. Property values in the immediate area can be lowered if wind turbines intrude on the visual and/or ambient noise level in the area, or they can be increased if the land is part of the wind power station or a right-of-way for the plant's infrastructure. Many farmland owners have leased their land to the wind power station owners in return for annual lease payments. This has been a boon for hundreds of landowners who can still farm on 90% of the leased land, since the wind turbines and infrastructure take up less than 5% of the leased land.

Offshore Wind Energy

The National Renewable Energy Laboratory, the wind energy research and development laboratory for the U.S. government, estimates that the wind power potential in the U.S. includes not only 10,400,000 MW of onshore potential, but also 4,150,000 MW of offshore potential.[9] Based on relative current costs and the more challenging environment of offshore production, there are as yet no offshore installations in the U.S., although the Cape Wind project on Nantucket Sound has finished the permitting phase, is doing geological testing and hopes to begin cable work in 2013 and ocean construction in 2014 for a planned 130 turbine installation.[10]

SOLAR ENERGY

There is more energy delivered by the sun to the earth's surface in one hour than the amount consumed by the world's population in one year, according to Tony Thompson of REC Silicon, a Moses Lake producer of poly-silicon used in photovoltaic cells. The available energy from all other renewables added together is less than 1% of that available from solar energy alone.[11]

Solar electrical power is derived either directly, by capturing and converting the sun's energy to produce electricity (photovoltaic) or indirectly, by using sunlight to heat a fluid that can then be used to produce electricity.

Photovoltaic (PV) solar uses a device (cell) to convert solar rays into electricity. The cells, often made from some form of silicon, are configured into panels, 200-watt modules that can be connected together into arrays of 5 KW to 50 MW. Concentrator photovoltaic (CPV) solar converts sunlight into electrical energy through essentially the same process as conventional crystalline silicon or thin-film panels, but uses mirrors or lenses to concentrate sunlight onto tiny high-efficiency solar cells.

Thermal solar is used to heat swimming pools, and water and air in homes, businesses and communities. Concentrating thermal solar power (CSP) uses mirrors to concentrate solar radiation to a hot focus, which can then be used to superheat steam or another fluid and run a turbine for power generation. CSP projects are generally 5 MW or larger.

"Distributed solar" is a term used to describe solar installations that are site-specific, with the resulting electricity or heat used onsite. Under some circumstances, any excess electricity generated at the site can be transmitted to the electric grid.

Capacity

According to National Oceanic and Atmospheric Administration data measured at the stratosphere, we can estimate the average amount of sun continuously reaching the Earth's surface at 174 watts per square meter, which varies by latitude, season, cloud cover, and other factors. Daylight is necessary to produce energy from solar, and shade and debris adversely affect solar collection. While cloud cover may reduce the energy received, it will not eliminate it.

In the region from the southern tip of Greenland in the north to the outer rim of the Antarctic Circle in the south, where most of the energy demand is and where most of the solar energy generators would be constructed, the amount of continuous solar exposure is greater than the average for the entire planet, so the 174 watts per square meter is a valid and conservative value for estimating solar generation potential.

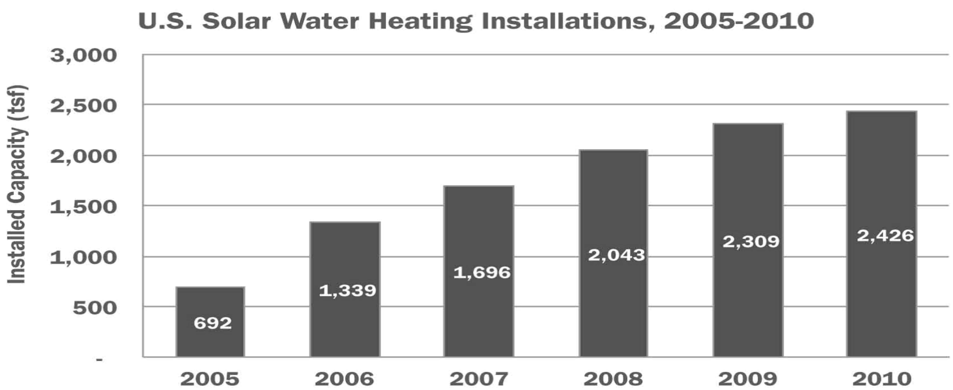
Unlike wind energy, solar is used widely in both small and large-scale projects. Its use is growing rapidly and is projected to increase seven-fold by 2035 as near term market growth results in lower system costs. The majority of the growth in solar is

with photovoltaics, a significant portion of which is in rooftop solar. There is also an increasing interest in free-standing arrays of photovoltaic panels that can track sunlight, and may produce enough power to serve an entire community. However, even with the strong growth in solar that is occuring at present, the technology is still expected to account for only a relatively small percentage of total electricity generation in the U.S. in 2035, reflecting the expiration of the 30% solar tax investment tax credit in 2016. Based on current law, the tax credit will then continue at 10%.

Solar PV panels are often installed on residential rooftops at a fairly small scale, and use an inverter to transform the direct current to an alternating current so that it can be used for household appliances and/or sent to the electrical grid. Such rooftop panels are environmentally benign, and are visually not too different from the roof itself. At this time, appliances account for roughly 20% of residential power usage, although electric cars may soon increase electrical usage for at least some number of households.

Solar Energy Industries Assn : Annual pv installed capacity by market segment 2005-2010[12]

Water heating is the second largest energy user in the average home and accounts for 14 – 25% of the average home's utility bills. A residential solar system can provide 60-70% of a home's annual hot water usage.



An advantage provided by residential or commercial solar panels is reduction of demand on the electrical grid, as well as lower costs to the consumer over time. This distributed generation also reduces efficiency losses from long-distance transmission of electricity. Disadvantages include relatively high installation costs that are usually borne by the property owner, and the loss of potential power due to the panels being shaded by trees and buildings, or being covered on occasion by snow or dirt.

While it is difficult to estimate worldwide home solar installations, global large-scale PV plant installations for 2011 may have topped 26 gigawatts (GW), with Germany and Italy leading.[13] Some examples are documented for large rooftop and plant installations worldwide, notably rooftop locations in Belgium, Italy, Spain, Germany and France.[14] Six GW of PV was installed in the Asia Pacific region in 2011.[15]

	2005	2006	2007	2008	2009	2010
Total	79	105	160	290	435	878
Utility	1	0	9	22	70	242
Non-Residential	51	67	93	190	208	372
Residential	27	38	58	77	157	264

In this country, most utility-scale land-based installations are of the concentrating thermal type, with a small number of concentrating photovoltaic. Many of these large solar installations are located in California.

Costs

Small-scale solar PV is inherently more expensive than large-scale PV, but its cost is comparable to large-scale concentrating solar installations. Already, solar power is competitive in a few select regions that have high electricity prices and a strong solar resource. The costs of solar have declined rapidly, dropping by 50% in 5 years. Solar installations are expected to last 30-50 years, though components will deteriorate over time.[16] Payback depends on the initial cost, the site, the nature of the system and the applicable financial incentives, and currently can be anywhere from 5 to 15 years. It has been calculated that for every $1 reduced in annual utility bills by solar, home value rises by $20.[17]
Many owners of homes in desert communities and other sunny locations who invest in rooftop solar find their electricity bills reduced to nearly nothing, sometimes including only administrative costs. In places where the local electric utility offers a buy-back program, homeowners installing rooftop solar may further reduce their net payment, or even realize a modest net gain, by sending any excess power they generate to the grid. To do this, they must first install an inverter that makes the power they send compatible with the grid.
Current incentives for solar in Washington include:[18]

- 30% federal tax credit (expires 2016)
- WA production incentive (15 cents per kWh, with annual limit) (expires 2020)
- Net metering credit for electricity sent back into the grid
- No sales tax for systems under 10 KW (expires 2013)
- 75% reduced sales tax for systems larger than 10 KW (expires 2013)
- Accelerated depreciation for businesses
- Renewable energy production incentive for utility companies
- Special incentives for community projects installed on local government property using panels and inverters made in Washington (expires 2020)

Other programs to encourage solar include:

- The SunShot Program: works to make solar energy technologies cost-competitive.[19]
- The Utility Solar Water Heating Initiative: a coalition of utilities and the solar thermal industry; works to increase the use of solar thermal technologies on a large scale.
- Database funded by the Department of Energy: "a comprehensive source of information on state, local, utility and federal incentives and policies that promote renewable energy and energy efficiency.[20]

Reliability

Because solar power is available during daylight hours only, finding effective ways to store the power that is generated is important. Recent papers issued by the Institute of Electrical and Electronics Engineers gives current thinking and efforts on storage technologies. The papers classify and describe three types of storage: [11]

- *chemical storage*: includes use of ammonia, hydrogen, or compressed air
- *mechanical storage*: relates to what is done with air or water, including pumped hydropower, to preserve its potential for releasing energy when needed
- *thermal storage*: entails ways to store heat in gravel, molten salt, or concrete, or by using a heat engine

Other

Large-scale solar power collections can be installed offshore or in space, as well as on land. For example, in India, a floating solar pilot project was begun at Walvan Lake in 2011, and the company intends a 400 MW installation once proven.[21] In this country, the Bureau of Ocean Energy Management oversees the exploration and development of the nation's offshore resources, and requires an environmental impact statement for offshore energy development.

Space Solar Power

Space Solar Power (SSP)[22] is the name commonly given to the concept, invented in 1968 by Peter Glaser, of deploying a system of satellites and ground receivers that would collect the sun's energy at geosynchronous earth orbit and beam that energy to earth for use. Building SSP is considered a challenge, both financially and technically. The International Academy of Astronautics has undertaken the first international assessment of SSP. They concluded that 10-15 years are required to complete a significant pilot, and 20-30 years to mature the technologies, including wireless power transmission.[23]

The options for wirelessly transferring power from the satellite to a receiver on the ground are

microwave and laser. Microwave Wireless Power Transfer (WPT) continues to be well funded in Japan. Of many entities working on SSP development, the leader is an eighteen company Japanese consortium at the Institute of Unmanned Space Experiment Free Flyer, with an estimated $21 Billion in funding. The Japanese group intends to launch a small test satellite in 2015, to test beaming power through the ionosphere using microwaves. A team at Kyoto University recently beamed microwave power from an airship.

Japanese researchers are targeting a one GW system, equivalent to a medium-sized atomic power plant, which would produce electricity at eight yen per kWh, six times cheaper than its current cost in Japan.[24] In addition, Chinese, European and a half dozen other start-up American and international companies are working to build SSP satellites. Astrium, Europe's largest aerospace company, and the University of Surrey, developer of the laser diode used in DVD players worldwide, are leading a plan to build a demonstration power satellite using infrared laser (in an eye-safe wavelength).[25] Boeing's Rocketdyne division received the sole source award for Marshall Space Flight Center's laser-photovoltaic WPT R&D in 2003. A private corporation in Everett, Washington intends to use existing high capacity solar cells in small satellites that can be wirelessly coupled to transmit energy using radio waves.

By collecting the solar energy at geosynchronous earth orbit (GEO), using a photovoltaic (PV) panel, SSP would collect about 9.6 times as much energy per day as the same PV panel would at an average location in the US (or Europe, Japan, or similar latitude), even when transmission loss from passing through earth's atmosphere is taken into account. All satellites at GEO receive continuous power, 24/7, except for 72 minutes in shadow at midnight during the spring and fall equinoxes. The energy received is independent of weather conditions at the receiving site, and is dispatchable, meaning that it can be distributed to locations within the satellite's field of view depending on real-time demand for power (and receiver locations). With mobile receivers, it could quickly provide power to disaster areas.

According to the U.S. Department of Energy, each kilowatt of solar electricity offsets up to 16 kilograms of nitrogen oxides, 9 kilograms of sulfur oxides, and 2,300 kilograms of carbon dioxide (CO_2) compared with coal plant emissions. However, the manufacturing process does contribute greenhouse gas emissions, and the materials often include rare-earth minerals as well as common material, namely types of silicon. According to a study co-authored by Stanford researcher Mark Z. Jacobson and UC-Davis researcher Mark A. Delucchi, we probably won't run into problems with the amounts of material needed to build solar collectors and other devices. They found that even materials such as platinum and the rare earth metals, the most obvious potential supply bottlenecks, are available in sufficient amounts. And recycling could effectively extend the supply. "For solar cells there are different materials, but there are so many choices that if one becomes short, you can switch," Jacobson said.[26]

BIOMASS

Biomass can easily be converted to energy and may well have been the first reliable energy source in human history. Biomass energy takes many forms and has been described in various ways. The American Council on Renewable Energy provides this definition: "Organic plant matter, known as biomass, can be burned, gasified, fermented, or otherwise processed to produce electricity, heat and biofuels for transportation. Bioenergy is another term for energy that is produced from biomass." [27]

Biomass is distinguished from fossil fuel products in that the carbon fixation in fossil fuels took place millions of years ago, sequestering carbon from the atmosphere, whereas biomass releases carbon and nitrogen that were recently removed from the atmosphere by the plants.

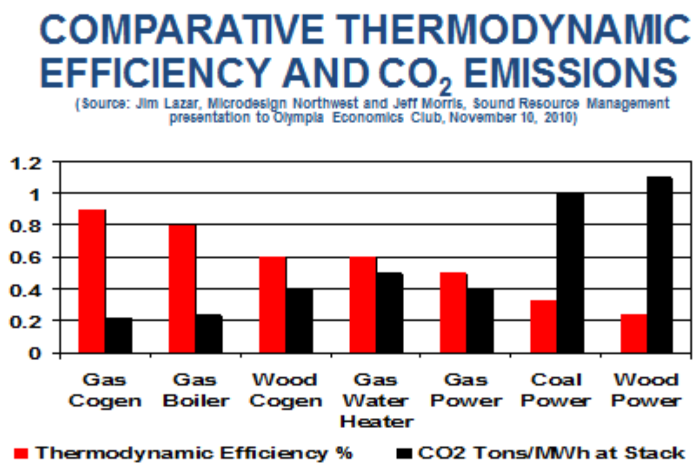
Biomass sources include wood and woody debris, agricultural crops, algae and other plants, garbage, agricultural waste, animal waste, pulping liquors (black liquor), and more. Biomass may be burned directly to produce heat for a variety of applications, including electricity generation in conventional steam plants. Starch, sugar and oil components may be extracted, fermented or otherwise processed to produce transportation fuels such as ethanol and diesel oil.

Biomass can be treated to produce gases that may be burned or used to produce liquid fuels. Because woody biomass can be used as fuel for steam production to generate electricity, it is viewed as a

potential partial replacement for other fuels, such as petroleum, coal and nuclear energy. Other plant materials, including agricultural wastes and domestic trash, can also be used for this purpose.

Capacity

Biomass of many types is widely available. Because Washington specifically, and the Pacific Northwest in general, have abundant forests on both public and private lands and a history steeped in logging tradition, the biomass discussion in this report will focus primarily on biomass derived from wood, woody debris (also called "slash"), and other forest products. A recently completed biomass supply assessment prepared for the Washington State Department of Natural Resources (DNR) by the University of Washington and TSS Consultants estimates that approximately 500,000 bone dry tons (BDT) were delivered to facilities in 2010 and 1 million bone dry tons could be economically extracted.[28]



Costs

The technology to convert biomass to electricity is readily available, but many factors influence the cost of biomass energy production. The U.S. Energy Information Administration puts the cost excluding any subsidies at $0.0995 - $0.133 per kWh, with an average of $0.1125 per kWh, depending on regional factors. The primary regional factor that influences the cost is the availability of, and competition for, wood and woody debris. The relatively high cost for wood combustion-generated electricity is a result of the low thermal efficiency (25-27%) of burning wood, which is lower than that of other conventional fuels used to produce electricity.[29] The energy efficiency of burning biomass also depends on the water content of the material (usually about 45%); green wood stocks with higher water content or fuels that include a high percentage of leaves or green needles will produce less energy per pound of fuel, and frequently require a supplementary fuel to begin the combustion process. This inefficiency can be reduced by using the waste heat (and extracting energy by condensing the smokestack water vapor) to dry the incoming feedstock. This is a form of cogeneration.

The cost of other renewable energy sources is declining, making energy from wood less competitive. The most recent contracts for purchases of renewable energy in California, the primary buyer for renewable energy, have declined to $0.089 per kWh. Without subsidies, it costs $0.1125 per kWh to produce electricity from wood combustion facilities.

New development of biomass-to-energy facilities is supported by federal tax credits (30% of capital costs and five-year depreciation) and low interest loans and grants from the U.S. government. The current federal legislation that provides for the 30% of capital cost tax credit is due to expire on December 31, 2013, but may be extended. In 2012, Engrossed Substitute Senate Bill 5575 passed in Washington state. This law makes biomass plants somewhat more financially attractive because it permits biomass facilities to sell the energy produced by burning pulping liquors as renewable energy.[30] This law also allows cogeneration biomass facilities that were in operation before March 31, 1999 to sell their electricity as renewable energy.

Reliability

Wood fired biomass plants (other than plants that are used exclusively for peaking power) have achieved capacity factors of 57% – 96%.[31] They are

considered "baseload" plants, since they can produce energy continuously. Many plants are cogeneration, combined heat and power, and as such may be shut down if the part of the plant that uses the heat (typically a mill) is shut down for maintenance. This explains why the capacity factors are lower than typical power generation facilities such as coal or natural gas.

<u>Other</u>

Long Term Viability of Woody Biomass -- The long-term viability of biomass combustion for producing electricity depends on the critical factors of protecting public health, achieving economic viability, having an adequate supply of biomass to ensure that facility feedstock needs do not result in environmentally damaging overharvesting practices, and ensuring that the operations do not have a significant negative impact on climate change.

Public Health Issues -- Air emission control devices used in biomass plants are subject to national requirements through the Clean Air Act that are enforced by the Environmental Protection Agency (EPA), usually through state and regional clean air agencies. Health organizations and even the EPA's Scientific Advisory Committee recognize that the current federal emission requirements are not sufficiently protective of human health.[32] [33] Some states, including Washington, have established air emission limits that are more stringent than required by the Federal Clean Air Act. However, many 'legacy' or older plants are grandfathered in and do not have to meet the latest standards. Construction of biomass facilities around the country has been opposed by health, medical, and citizen groups concerned that the current Clean Air Act and state regulations do not adequately address the health impacts of fine and ultrafine particulates. In December 2012, following a court order, the EPA updated its standards, adopting a stricter requirement for annual releases on fine particulates.

Economic Viability, Supply Adequacy and Forest Management - There is a complex relationship among the economic viability of woody biomass facilities, the adequacy and cost of the wood feedstock, and how forest management influences the supply of feedstock for the facilities. Facility size, overall number of facilities, location of facilities and supply of material to be burned are all factors that relate to future viability, and to the future health of the forests in which the facilities are located and/or from which the feedstock is gleaned. For woody biomass to work as an energy source without damage to the environment, there must be an adequate supply of feedstock that can be economically and sustainability recovered.

While increasing the feedstock supply to 1.3 million BDT would be adequate to supply approximately 33 MW of capacity, this could only be achieved at prices too high for economic viability for biomass production of electricity. In any case, even using the high extraction levels, the sources of supply show only a small potential for this technology, assuming that only waste wood is used.

There are no current regulations governing the location of biomass plants, but it would be important not to site them too close together. In a letter to Mason County Commissioners, Public Lands Commissioner Peter Goldmark outlined his concerns regarding the potential risk to forest health from locating woody biomass plants in overlapping feedstock areas.[34] It is important to note that the use of whole trees was not considered by the DNR study and has not been proposed by any of the new plant developers. Small projects designed to be supplied by sustainable feedstocks would be less likely to place undue pressure on forests or draw biomass resources away from other existing uses, and yet small facilities may not result in economies of scale, a concern for their financial viability. Woody biomass facilities that are associated with industries that create significant burnable waste, such as paper and lumber mills, are the most common current application of biomass plants in Washington state. There are 17 of these cogeneration plants in Washington. In addition, transportation costs of hauling feedstock are avoided.

Forest management is an important factor. In Washington, there is some statutory protection of forests; state DNR guidelines stipulate that feedstock will not be taken from old-growth forests and is defined as "by-products of current forest management activities, current forest protection treatments authorized by the agency, or the by-products of forest health treatment prescribed or permitted under Washington's forest health law."[35] DNR is currently examining the question of just how

much biomass must be left in the forests to ensure long-term forest health.
Washington State Department of Natural Resources (DNR) guidelines state that removing woody residuals of logging from the forest lessens the danger of wildfire, reduces losses from pest and disease outbreaks and makes for easier replanting, as well as creating more forest-based jobs. Alternatively, concerns have been raised that substantial development of this energy source could damage the environment and the health of forests, further stressing flora and fauna.[36]

Concerns regarding impacts to forest land may suggest the advantages of growing trees as a crop for dual uses of energy supply and timber production, and leaving the forests relatively untouched except for proper management practices necessary for their health. Plantation crops (tree farms) with short growing times have the double advantage of providing crops for use in biomass facilities and timber for other purposes, thus preserving forests while providing farms and agriculture with an opportunity to expand their operations. Greenwood Resources, Inc., with corporate headquarters in Portland, Oregon, has a large tree farm near Boardman, Oregon.[37] This farm grows poplar trees on previously less productive land in eastern Oregon and is part of the company's worldwide holdings that are harvested for timber and for renewable energy. Some concerns have been raised that this alternative has not been fully studied and could come with its own set of problems, relating to displacement of natural ecosystems, increased carbon emissions, loss of biodiversity, natural disasters, and replacement of existing ecosystems with genetically modified crops.[38]

Climate Change and Carbon Neutrality in Regard to Biomass

A major benefit of many forms of renewable energy is that they generally have a lower carbon impact than do fossil fuels, and thus could help combat climate change. Most renewable energy sources are considered clean. However, this is not necessarily true of biomass.

Woody biomass energy production creates carbon emissions in several ways: the actual burning of biomass in energy facilities; the loss of carbon sequestration from removal of forest products harvested for energy production; and carbon emissions from fossil fuels used in transporting feedstock to facilities for burning.

Washington state regulates a range of forest practice activities, including biomass harvesting, on both public and private lands, with the aim of protecting forests from overharvesting and other damaging practices which could reduce carbon sequestration capacity. One of its stated aims is to manage the forests in an ecologically sustainable manner. The Department of Natural Resources (DNR) has said that on state lands, biomass material will be harvested only pursuant to logging or other forest practice operations. State policy is that as long as the overall ability of the forests to sequester carbon is not diminished—e.g., the forests have a net *increase* in carbon sequestration capacity-- then biomass energy facilities are carbon neutral.[39]

A major debate at the heart of the discussion about biomass energy, then, is whether the process of creating that energy leaves the forests from which the biomass is drawn still able to sequester more carbon than is emitted in the energy production itself. There is vigorous and often heated debate within the scientific and academic communities on this question, with many players and many perspectives. Important considerations in attempting to sort out the key elements of the debate include:

- To what degree are whole trees (which sequester but also contain carbon) harvested for burning in energy production facilities? They are harvested on private lands and have been since the state was settled but are generally protected on public lands. If they are not part of the biomass feedstock, they retain the ability to sequester carbon even if woody debris is removed. The parts of the trees which are not used as biomass feedstock continue to hold carbon until they decompose or are burned. Yet denuding the forest of all debris through overharvesting could harm the health of the trees and of the forest overall.
- Slash piles that result from tree harvesting are often burned, but not as biomass for energy production. Which practice is preferable?
- EPA has not yet required carbon accounting from biomass facilities, but has been sued by environmental groups on this issue. The

outcome is uncertain. The state does not require carbon accounting either, but does pay attention to carbon sequestering capacity as noted.

- Many studies and reports base their analysis and findings on either nationwide or regional data which may not necessarily apply to the particular situation in Washington state. Washington *does* have laws protecting the forest, as noted elsewhere in this study.
- DNR's assumption is that if forests are not depleted, but are, instead, sustainably grown and harvested, the process including burning biomass for energy will be carbon neutral.
- The same activity may affect carbon sequestration capacity differently in the short and long term and this must be taken into account in making policy decisions.

The issue of carbon neutrality is vigorously debated because it is highly complex. And because it is so complex, it is almost impossible for the average citizen to sort through all the studies and counter studies and reports now available in order to be certain whether the data and assumptions used are accurate and applicable to Washington. The pending lawsuit against the EPA on carbon emissions may help resolve this as an outstanding issue.

Additional Biomass Energy Sources and Processes
Processing of municipal solid waste (MSW) in modern waste-to-energy facilities with multiple pollution controls is another source of bioenergy. Waste to energy is primarily a means of managing solid waste that also produces energy. The resultant ash is placed in landfills which results in a much smaller "demand" for solid waste disposal facilities. Additionally the release of methane gas from landfills is reduced. There are two such facilities in the Pacific Northwest. While EPA and other states define MSW as a renewable energy source, Washington state law does not include MSW as a renewable energy source, due to the fact that it was excluded from the list of renewables in the initiative passed by Washington citizens (discussed on p.4).

Anaerobic digestion (AD) of organic materials to produce biogas that can be used for power generation is considered renewable in Washington. Anaerobic digestion is a proven, well-tried and tested technology that meets the criteria of "closed-loop recycling and reuse." AD converts organic matter to biogas in the absence of oxygen, with nutrient rich fiber and liquid as by-products. Feedstocks for AD include sewage, animal manures, agricultural crops, animal by-products, organic wastes from industry (mainly from food processing) and the organic fraction of household waste. AD management of agriculture, commercial, and residential organic wastes is common in Europe and becoming more popular in the U.S., including Washington state.[40] Because of the early stage of development, the costs of energy and potential for this technology are not well established.
Pyrolysis is a pre-treatment for converting biomass to something that may be more useful. Pyrolysis heats up a material and converts it to charcoal plus volatiles and residue. Energy in the form of heat is required to do this. The only way to get energy out is to burn the output products of the pyrolysis. The only advantage to doing the pyrolysis rather than just burning the biomass is that these output products can be easier to work with and perhaps cleaner to burn [41] even though the same amount of CO_2 is produced as by burning the biomass itself without going through the pyrolysis process.
Producing electricity from wood using noncombustion processes such as pyrolysis holds the promise of reducing air emissions, including CO_2.[42] This technology is being used by a company in British Columbia, but the costs per kWh are considerably more expensive than combustion processes.

Regulatory Issues
A number of federal and state regulations apply to biomass energy development activities. For the most part, state laws and regulations do not apply to biomass energy development on tribal lands. Most federal regulations can be found in the Clean Air Act and the Clean Water Act (National Pollutant Discharge Elimination System (NPDES)). State regulations are found in State Environmental Policy Act (SEPA), NPDES, and Chapter 173-400 WAC - General regulation for air pollution sources. Currently, there are no pollution controls governing commercial CO^2 emissions.[42]

At this time, environmental regulation and accounting are fragmented in Washington, with some departments considering forest management practices, some air quality, some water quality, and some public health. While these impacts and many

others must be discussed in the EIS required with the permit application, it is not clear which regulatory agency or agencies will follow through, nor whether there is adequate communication, coordination or integration among the pertinent agencies.

BIOFUELS

There is a large ongoing effort to replace the petroleum based liquid fuels used in transportation with fuels made from biomass, i.e. with fuels made from plant materials or animal fats. The goal is to produce fuels that can be mixed with, or used in place of, gasoline or diesel.

There are two types of liquid biofuels in current use: ethanol and biodiesel. Since the 1970's gasoline engines in automobiles have been designed to use mixtures of gasoline and ethanol up to 10% without modification.[43] Biodiesel is easily substituted for diesel from fossil petroleum in diesel engines. Other liquid compounds made from plant material have been suggested for biofuel use, especially butanol, an alcohol with properties very similar to gasoline and 2,5-Dimethylfuran (DMF), a simple compound produced from the sugar fructose. Another avenue to biodiesel is to combine hydrogen and carbon monoxide from the breakdown of organic material to produce the long-chain hydrocarbon mixtures of diesel fuels.

Liquid biofuels are often referred to as first or second generation and occasionally as third generation. *First generation biofuels* come from crops where industrial level processes for extracting and converting sugar or starch to ethanol, or oil to diesel, are already available because of their use in the food industry. These crops include those high in sugar such as sugar cane and sugar beets. They also include crops high in starch, such as corn and wheat, where the starch is fairly easily broken down to its simple sugar components. The sugars are then fermented by yeasts to ethanol. A number of oil producing crops are used to produce biodiesel. These include soy beans, palm nuts, canola and the closely related rapeseed, and sunflower seed. Several other oil bearing seeds have been used, including the tropical tree Jatropha. The oils derived from these sources contain a mixture of fatty components and their energy content and usefulness depend on the mixture. Usually they must be chemically transformed to yield the best fuels.[44]

Second generation biofuels are derived from the major components of plant cell walls, cellulose and hemicellulose. The process requires breaking these two complex molecules into their component simple sugar molecules. The sugars are then fermented to ethanol. Currently, the breakdown of cellulose and hemicellulose is difficult. However, if economically viable ways to reduce them to their component simple sugars can be found, almost any plant material, including waste from agriculture and forestry, could be used to produce ethanol.

The definition of *third generation biofuels* seems to vary. Third generation biofuels usually include single celled organisms such as green algae and some fungi and bacteria which accumulate oils or sugars and are not grown as conventional crops. The term has also been used to describe production of liquid biofuels from multi-cellular seaweeds and production of hydrogen and other gasses from biomass of all types.[44 45 46]

It has generally been assumed by proponents that, if cropping and production are managed efficiently, biofuels can reduce greenhouse gas emissions from vehicles and also reduce many countries' dependence on imported fossil fuels. Biofuels are particularly important in developing fuels for transportation since they are portable and do not require large amounts of time to refill the vehicle, in contrast to electricity and natural gas. Substituting liquid biofuels for gasoline and diesel is also attractive because it requires little change in engines or the distribution system. In contrast, using electricity or liquefied gasses requires very different engines and distribution systems.

Liquid biofuels also have the advantage that most countries can produce at least some of the fuel they need, a major reason that many countries have been willing to subsidize their development and production. This will be particularly true if waste cellulose ethanol and algal biodiesel can be produced at a cost comparable to petroleum based gasoline and diesel.[44 46 47 48]

Currently a number of countries including the US, the European Union, Brazil, and China, mandate that 10—20% of the gasoline and diesel derived from

petroleum must be replaced with biofuels in the next 10 to 20 years.[44 45] This mandate has been quite successful and has not led to any serious problems, as cars and trucks have been designed to this standard since the 1970s.[43]

Airlines have successfully run test flights using blends of bio-fuels from algae despite some worries about the appropriateness of these oils for the manufacture of biodiesel.[47 49] Current vehicles will have to be modified to run on higher percentages of ethanol, butanol or on certain biodiesels, but these modifications are practical and well known.[45] Modifications necessary to use 2,5-Dimethylfuran are being explored but are expected to be minor.[50] Thus, if the base cost of petroleum continues to increase, biofuels can be competitive.

Capacity

Current production of ethanol and biodiesel is based on use of crops that are also used for food, because economical techniques for producing sugar for fermentation to ethanol or oils that can be converted to diesel are available from the food industry. These crops only grow well on the most fertile, well-watered agricultural land and usually require extensive weed control (just as for most other crops and plants) and separation of the sugar or oil containing portions from the rest of the plant. Thus, most authors consulted here argue that the use of corn, wheat, soybeans, etc. for fuels directly competes with use of the best land for food and probably is contributing substantially to a rise in food prices, especially in poorer countries. These crops also compete for scarce water resources. However, two studies based on recent data suggest that this has not been the case so far. Although 40% of corn is now used for ethanol, it has not substantially affected the amount available for domestic use and foreign export. [45]

There are two reasons for this surprising finding. First, the great majority of the corn and soybean crops is not used directly by humans for food but is used as animal feed to produce meat for humans. In this situation, it is the protein content of the seeds that is important; the sugars or oil are byproducts and actually produced in excess of demand for food. Conversion to fuel has raised the value of the byproducts and thus of the crops without lowering the amount of protein rich feed available. Secondly, yield in both crops has greatly increased in the last twenty years and is expected to continue to increase both through development of better stocks and use of already available efficient farming techniques such as no till farming and winter cover crops.[51 52]

There is debate within the scientific community about whether it would be physically impossible to produce enough biofuel to meet the current U.S. requirements for transportation, using first generation biofuels. Walker[45] calculates that replacing all currently needed transportation fuels with ethanol from corn in the U.S. would require 500 million acres of cultivatable land to produce the 800 billion liters of fuel now used. The U.S. has 473 million acres of cultivatable land. Similar problems are seen with the crops currently used for biodiesel.[47]

However, modeling by Dale[53] and his colleagues suggests that, with appropriate farming methods and use of byproducts, the U.S. could produce 400 billion liters of ethanol annually using 30% of total cropland, range and pasture without decreasing domestic food production or exports. According to this model, there would still be land available for biodiesel production. Although this prediction is more optimistic, both require converting grass or forest to cropland and large increases in agricultural efficiency.

If half or more of the biofuel needed must be imported, the most suitable land that could be used is in the tropics and supports rainforest or extensive grasslands. As natural death and regeneration occur, these lands tend to remove slightly more greenhouse gases than they release. Clearing these lands would increase the greenhouse gas problem and damage or decrease native plant and animal habitats and bio-diversity.

Although Dale's group would predict a greater proportion,[53] there seems to be a general concurrence among other sources that no more than 10-20 % of the transportation fuels used today can be sustainably produced from first generation biofuels. Demand in developing countries and population growth will increase, making maintenance of this percentage impossible without more efficient use of liquid fuels.[44 45 54] Limiting demand by using more fuel-efficient transportation

technologies will be very important in our future whether or not biofuels are to play a significant role in energy use.

A number of plants that produce oily seeds and will grow on poor soils with little water have been proposed as sources of biodiesel that would not compete with food crops for land and water and could be planted on cleared but degraded soils. China and India have promoted the use of the tree Jatropha and it has been widely planted. Unfortunately, while the trees do grow, they rarely produce seeds or seeds of good quality on marginal lands with limited water. Thus, what was supposed to be a boon for small farmers has become a disaster.[55]

Second and third generation biofuels may be more sustainable. Most sustainable would be converting plant wastes from forestry, agriculture and trash to ethanol. Although some wastes need to be returned to the soil to maintain nutrient and carbon quantities needed by the next crop, many are simply allowed to decay on site or in landfills, releasing greenhouse gasses without utilizing the potential energy available. Other sources are a variety of potential crops that can be grown on marginal or degraded land, some of which will also regenerate from the roots so there is no need for replanting. This prevents both soil erosion and carbon release from decaying roots. Fast growing trees, such as poplar and pine, as well as a variety of grasses, have been suggested. However, as with Jatropha, real world experiments that look at the costs and productivity are still lacking. Considerable research will be needed before non-food crops that can be grown on marginal land are economical for biofuel production.[43]

Use of green algae as a source of oil for diesel is also attractive. This is especially true in an integrated situation where the remaining plant material is used for ethanol and fuel to provide the energy needed for processing. Algae grow in water and can use wastewater and brackish water. This allows growth on non-arable land and may enable the utilization of nutrients in wastewater. To produce adequate amounts of oil, excess CO_2 is required. Waste CO_2 from electricity generating plants burning fossil fuels could be utilized.

Calculating from experiments under optimum conditions, from 0.3 to 2.7% of total global land would be needed to supply all of today's transportation fuel.[47] However, much development of strains and processes is still required to reach this goal at economically competitive costs.[47 48 56] Also, the areas with the most natural light and best year round temperatures are lacking in the water needed for large-scale production.

Large seaweeds have also been suggested as sources of biofuel. Recent breakthroughs in digesting the components of seaweed cell walls are very promising.[57] Seaweed is grown and harvested in a number of countries so techniques are available. However, large beds of seaweed are also important to a variety of fish and other animals used for human food. Use of seaweed on the scale necessary for significant biofuel production may not be sustainable.

At this time, few crops grown in Washington are suitable for biofuel production and those that are, wheat and canola, have higher market value as food. Future developments such as economical conversion of cellulose and hemicellulose to sugars may allow greater use of biological materials from Northwest states for biofuel production.[58]

Costs

Energy payback for first generation liquid biofuels is relatively low, with most fuels providing no more than three times the energy needed to produce them. In 2009-2011, costs for production were two to three times higher than those for petroleum. Since the amount of energy per liter or gallon of ethanol is 10 to 20% less than that of gasoline, the actual cost of substituting ethanol for gasoline was somewhat higher.[45] The exception is ethanol produced from plants with high sugar content such as sugar cane and sweet sorghum. These first generation fuels are only economically viable currently because of government subsidies and mandates.[44 54] Much research is still needed before biofuels from plant cell walls (second generation) or algae and seaweed (third generation) can be produced on an industrial scale, and it is very likely processing facilities will be complex.

In Brazil and China the cost is competitive with petroleum if the processing is carefully sited near

the plantations and the waste materials are burned to produce the heat and electricity used in processing. In the U.S. and Europe, where most ethanol comes from corn or wheat, production at competitive costs has been feasible only because of large government subsidies, although some have argued that increases in farming and processing efficiency in the U.S. can change this.[52]

In 2009-2011, production of ethanol from second generation sources was about ten times more expensive than production of gasoline, which then averaged about $2 per gallon.[44] If the technical problems can be overcome for second generation sources, the most optimistic prediction is that production costs of ethanol will be about twice production costs for petroleum based gasoline. However, production of ethanol from waste plant material could be competitive on a per volume basis with production from petroleum since farming costs would not be involved.[45 59]

The affordability of third generation biofuels is much debated. The cost of diesel from algae in pilot plants is stated to be two to three times more than that of diesel from petroleum at today's oil prices[48] or possibly up to 10 times more. It should be noted that these are commercial costs to produce the fuel and do not include costs to the environment or to human health for either fuel. Probably more important are the many technical problems to be overcome before industrial scale production is possible.[46 47 48 49]

Assuming that the two main goals of promoting replacement of fossil fuels with liquid biofuels are reduction in the use of fossil fuel and reduction in greenhouse emissions, one analysis [54] finds that the current policies are 14 to 31 times more expensive than reducing demand by imposing a 25 cent/gallon gasoline tax coupled with development of more energy efficient transportation. This analysis points out that because electric motors are about 7.5 times more efficient than internal combustion motors, utilization of electricity generated from wind and water for electric vehicles (including trains) may be much more cost effective than use of liquid biofuels and result in a greater reduction in greenhouse gases while having less impact on the environment.

Dr. Van Gerpen, on the other hand, contends that these arguments are flawed, for several reasons:

- Electric motors are only 2 to 3.6 times as efficient as liquid fuel engines.
- If the efficiency of the coal plant producing the electricity is included in the actual efficiency of using an electric motor to do work, the overall efficiency is 27 to 32% or about the same as for internal combustion engines.
- The use of electricity generated from wind and water is not really free since there are capital and operating financial costs as well as environmental 'costs' in producing and operating wind and water electric generating plants. These factors should be included when attempting to make a cost comparison of liquid biofuels with use of electricity.[43]

Reliability

Biofuels, including those from seaweed and algae, depend on crops. Thus, production levels will be affected by all the problems found with food crops: flooding, drought, insect and weed invasion, disease and the effects of global warming. This aspect has not been widely discussed in the literature but it could almost certainly be expected to bring realized amounts well below maximum calculated possible amounts. A global economy for biofuels which results in pricing based on world production and enables importation from anywhere in the world will likely help stabilize supplies from year to year, as it has done for food. The ease with which these fuels are stored will also help dampen yearly changes in supply.

Other

A major driver in developing liquid biofuels is the hope that their use will lower greenhouse gas emissions. Lowering greenhouse gas emissions is much more challenging than originally thought. Growth, harvest and transportation of all these crops are energy intensive, so that the energy obtained may, in a worst case scenario, actually be less than that used to produce the fuel, resulting in a net increase in greenhouse gas emissions.

However, under careful management of all aspects of production, ethanol from corn provides about 1.3 times the energy it consumes. In many ethanol-producing systems studied throughout the world, recoveries are from 0.9 (i.e. more energy is expended that recovered) to 3.0. The exception is

ethanol production from sugar cane in Brazil and China, where processing is done close to the fields and waste products are used for energy and fertilizer. These plants report an energy recovery of 8 times that expended.[44] Modern bio-ethanol plants are now using some of these techniques, so better energy recovery should be seen in the near future.[43]

Energy recovery has been somewhat better for biodiesel, with reported recoveries from 2.5 -3 for sunflower, soybean and rapeseed oils and up to 9 for palm oil.[44 60] A recent article finds that the energy recovery of biodiesel made from soybeans had improved to 5.5 based on data from 2006.[52] These studies are focused only on energy comparisons and therefore do not consider other relevant factors such as the costs of using water or land which would otherwise be used to grow food or, in the case of palm oil, has been converted from rainforest.

Since production of ethanol from plant cell walls (cellulose and hemicellulose) uses much more of the plant material, projections of the energy efficiency are considerably higher, ranging from 2 to 20.[44 60] However, these techniques are in development and the real costs are not known. Use of waste cellulose is assumed to be the most cost effective, since costs would only involve transport to the processing facility and the cost of processing; but these mixed materials may be more difficult to use.

Another serious problem is the destruction of native vegetation to provide land for biofuel crops, as most of the world's cleared farmland is already in cultivation for food. Even if the wood is utilized from a rainforest, the carbon released by decaying unusable vegetation and roots in the soil is enormous, greatly contributing to greenhouse gases. However, the argument for CO_2 release due to land use change is controversial and opponents of this theory have pointed out that the historical data show an apparent lack of any correlation between biofuel production and rainforest/grassland conversion.[51] In addition to these considerations there are also significant potential risks to forest health, animal and plant diversity, etc.
Biologists in several recent studies have estimated that it would take 400 years of use of land converted from rainforest for the production of biofuel to compensate for the carbon release, and 15 years to compensate for the release of carbon when native grassland is plowed,[38 61 62 63] although well managed grassland conversion to cropping in the U.S. could reduce this "pay back" period to 3 years.[64] Another problem is that continued removal of CO_2 from the air by either may be greater than the CO_2 fixed by the plantations that replace them. This appears to be true for Northwest forests as well.[65]

Converting natural lands to cultivation of single crops also has an enormous impact on biodiversity. This not only limits the plants that might be useful to humans, but also puts even more stress on migratory birds and other wild animals. Recent studies show that little attention has been paid to the effects of producing biofuels on biodiversity.[66] Both growth of the plant materials and their processing may require large quantities of water. This new use of fresh water will also have environmental effects though they are rarely discussed in the literature. Almost all reviews in the field stress the need for careful integration of crop growth and processing to recover as much energy as possible with as little environmental harm as possible. It is only with such careful management that any substantial reduction in greenhouse gas emissions seems likely.[44 45 46 53 65 67] Other economic considerations such as increased startup costs, labor costs, and the need for ongoing enforcement as well as resistance to government regulation may make it difficult to provide incentives that encourage appropriate management.

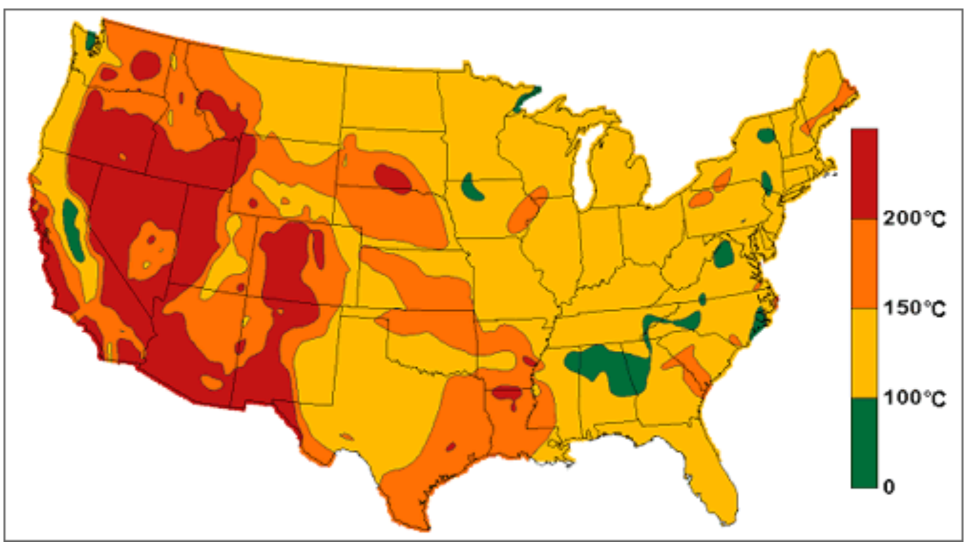
GEOTHERMAL ENERGY

Geo (earth) - thermal (heat) energy refers to energy that is generated by heat from the earth. Beneath the crust of the earth lies hot liquid rock called magma. Where the earth's crust is thin or cracked, hot water or steam comes to the surface through hot springs, geysers or steam, or from lava flowing from erupting volcanoes.

Such energy can come directly from wells or springs that produce heat energy, or indirectly from hot water that produces steam which in turn moves turbines. It can also be passive, as is seen in heat exchangers and heat pumps that capitalize on the difference between above ground and underground temperatures. "It is believed that the ultimate source of geothermal energy is radioactive decay occurring deep within the earth." [68]

To produce energy, this earth heat can be used in three main ways: pipe the hot water directly into buildings for heating; run the steam into an electrical power plant for power generation; and install heat pumps in homes and other buildings. Low and moderate temperature resources are either direct use or ground-source heat pumps. Direct use "involves using heat in the water directly (without a heat pump or power plant) for such things as heating of buildings, industrial processes, greenhouses, aquaculture… and resorts." In 2008, installed capacity of direct use systems totaled 470 MW, or enough to heat 40,000 average-sized houses.[68]

Ground-source heat pumps "use the earth or groundwater as a heat source in winter and a heat sink in summer. Using resource temperatures of 4C (40F) to 38C (100F), the heat pump, a device that moves heat from one place to another, transfers heat from the soil to the house in winter and from the house to the soil in summer. Accurate data is not available on the current number of these systems; however, the rate of installation is thought to be between 10,000 and 40,000 per year."[68] Heat pumps take advantage of the difference between above ground air and a constant underground temperature of around 54 degrees.



Geothermal Resource Map of the U.S.[69]

As a general rule, high temperature geothermal resources are used for the generation of electrical energy. Low temperature resources are simply not hot enough for electric power production. However, with the advancement in technology of geothermal power plants, some geothermal resources that are on the higher end of the low temperature threshold could be used to create power by utilizing what is called a binary geothermal plant. The 'binary' label indicates the use of a secondary fluid in the power plant that has a lower boiling temperature in which the lower temperature geothermal water heats the secondary fluid, vaporizing it into a gas that drives the turbine for power production. Low temperature resources are typically used for direct use applications such as heating & cooling, melting snow off sidewalks, and in greenhouses. [70]

In 2006, a Massachusetts Institute of Technology study presented a very optimistic finding for the future of geothermal energy:

"Geothermal energy from EGS [Enhanced Geothermal Systems] represents a large, indigenous resource that can provide base-load electric power and at a level that can have a major impact on the United States, while incurring minimal environmental impacts. With a reasonable investment in R&D, EGS could provide 100 GW or more of cost-competitive generating capacity in the next 50 years. … Most of the key technical requirements to make EGS work economically over a wide area of the country are in effect, with remaining goals easily within reach. This achievement could provide performance verification at a commercial scale within a 10- to 15-year period nationwide." [71]

Capacity

In the United States, eight states had geothermal installed capacity in 2011. Of the total, 3187

[redacted]

megawatts (MW), California alone produced 2615 MW. The other states are: Nevada (469 MW), Hawaii (43 MW), Utah (42 MW), Idaho (16 MW), Arkansas (0.73 MW), Oregon (0.28 MW), Wyoming (0.25 MW).[72]

Additional geothermal development is underway in the states cited above, and in seven more states: Arizona, Colorado, Louisiana, North Dakota, New Mexico, Texas and Washington. As can be seen from this list, most of the geothermal resources in the United States are found in the western states. Although the U.S. is the largest geothermal energy producer in the world, geothermal energy represents only 3% of the renewable-energy electricity consumption in the U.S.[72]

Washington State Department of Natural Resources (DNR) through its Geology & Earth Resources Division is currently sampling hot springs throughout the state to assess their geothermal potential. In addition, DNR with other state departments is now in the process of preparing a state geothermal resource plan. It is anticipated that the plan will be completed by the summer of 2013.

Geothermal Resources of Washington

DNR's project takes samples of hot springs and analyzes them for the elements found in the water, elements that indicate the sources of the water. These analyses can also be used to determine the temperature at depth for the possible geothermal reservoir. These facts will provide DNR with information about the potential for development of a geothermal resource.

Another current project is the drilling of five exploration wells in Washington. These are not for energy production facilities, but are being done to provide new data to the National Geothermal Database System (NGDS). This is part of a federal project in every state under the U.S. Department of

Energy; the project aims to develop a national accessible database concerning geothermal resources.

In thinking about the future of geothermal energy in Washington, Jeff Bowman, Geoscientist, DNR Geology & Earth Resources Division, offered this analysis:

> "There are several reasons why large scale geothermal energy production is not taking place in Washington. Probably one of the most significant reasons is the complex geology that is present in Washington. In most western states where geothermal resource development and energy production are taking place, the geology and therefore the large geothermal systems present are relatively simple. Most geothermal development taking place in the western states today is located in what is called the Basin and Range, where you have a series of valley's and ridges that continue for miles. If a geothermal resource was identified in one location, you can easily predict where another geothermal resource might be located, based on the consistent nature of the geology. Washington however is very complex, either the geology changes drastically over a short distance or there are multiple geologic processes going on in an area that a simple model cannot explain what is happening. This complex geology makes it difficult to understand any potential geothermal system.
>
> "Another obstacle that we deal with is the amount of meteoric water that is introduced to any potential geothermal resource. Some areas of Washington are subject to so much precipitation, that any surface manifestation of a possible geothermal resource is washed away and any water samples we collect to try and identify thermal properties are so diluted that the thermal signature is very faint.
>
> "One of the last major obstacles to overcome is the amount of public land (national parks, wilderness areas, etc.) that do not allow for certain activities to take place within their boundaries. With a majority of the Cascades located within these boundaries, it really limits the areas where exploration/development can take place. This also limits the areas where data can be collected which results in a lack of understanding of the geothermal potential of Washington."[70]

Bowman provides another example of issues in regard to geothermal data in Washington:

> "[I]n the area around Mt. Baker, there have only been two temperature-gradient measurements. Therefore, when the geothermal potential of Washington is modeled, those two data points carry a lot of weight and may be misleading to the potential of geothermal energy around Mt. Baker. This happens in a majority of the state except around populated areas. This relates to one of the goals for our geothermal project; research, compile, and make available all data related to exploration for geothermal resources. By filling in the data gaps, we will be able to get a better understanding of the geothermal potential within the state."[70]

At the present time there are no operating geothermal energy producing plants in Washington. However, the Geothermal Energy Association reports that Gradient Resources, a geothermal production company based in Nevada, is in Phase 1 of development of a 100 MW project at Mt. Baker.[72]

Ninety-seven percent of the state's low temperature geothermal wells are in the Columbia River Basin. Six counties have 83.5% of these wells: Adams (113 wells), Benton (1233 wells), Franklin (60 wells), Grant (118 wells), Walla Walla (113 wells), and Yakima (259 wells).

To date most Columbia Basin geothermal energy is the passive type relying on heat exchangers and heat pumps in homes. Some work so well that they generate electricity for the home. Presently, this passive type in homes is said to be the most feasible approach for developing geothermal resources in the state.[70] There are several kinds of financial, tax and other incentives available for installation of geothermal heat pumps at the local, county, state and/or national levels, as well as incentives offered by utility companies.

The number of homes with ground-source heat pumps in Washington is not currently known. This information may become available next year as part of DNR's geothermal project. "One of our [DNR's] goals is to compile information related to direct use application and heat pumps. We want to publish information regarding the numerous applications of direct use, who installs direct use systems, and some of the cost benefits associated with them."[70]

Oregon also currently has "no generation of electricity from geothermal sources" within the state. However, from the Oregon's Department of Energy website comes the news that U.S. Geothermal Inc. will be operating a 26 MW facility in 2012 in Neal Hot Springs in eastern Oregon. The following year Nevada Geothermal will have a 30 MW plant operating at Crump Geyser in central Oregon.[73]

Costs

Initial costs of construction of a geothermal power plant are high, but the elimination of fuel purchases brings the net cost significantly down. The high temperature geothermal resources (springs) in the Cascades are difficult to access and evaluate, and thus would be costly to develop. The cost to install geothermal heat pump systems in homes and other buildings is quite high, but the savings in lower electrical costs fairly quickly pays for that initial high cost.

On homeowner costs for a geothermal heat exchanger and pump system, an interview with the president of Earthheat, a provider of geothermal energy systems, provided this information.

- In recent years geothermal projects have been installed at Redmond high school and elementary school, Madison middle school in Seattle, a Bellevue Community College building, and Rachel Carson elementary school in Kirkland.
- A geothermal system in a 3,000 square foot house would cost about $700 to operate; a natural gas system for that house would cost about $6,000 a year.
- The U.S. Department of Energy says that ground-source heat pumps use 25-50% less electricity than conventional heating or cooling systems.
- A conventional natural gas system would cost about $10,000 to install; a geothermal system would cost about $15,000-$20,000 to install.
- A big advantage of a geothermal system is zero maintenance costs.
- In addition to the high cost to install, a geothermal system requires much greater space for installation than a natural gas system.[74]

Heat underlies the entire crust of the earth, but the means for extracting that heat becomes the issue in terms of cost and the degree of difficulty to bring that heat to the surface.

Reliability

Geothermal energy has the advantage that it is always available, unlike wind, solar or wave. Long term reliability depends on making sure the water sources are not depleted. It is also true that specific geothermal locations can be depleted through use over time.

Other

The advantages of geothermal energy are clear: little or no emissions, no use of fossil fuels, water used in the pipes is usually re-injected into the earth for heating and reuse, no use of added chemicals for most types of geothermal power plants .

A major concern about geothermal power plants is a possible connection between plant operations and induced seismic events. Such events have occurred at The Geysers in northern California, Pennsylvania, Switzerland, and Australia among other places. The evolving method called enhanced geothermal systems (EGS) involves breaking up the hot rock located at deeper levels than hot water and steam used in traditional methods. This process forces high-pressure water in to break up the rocks. More water is pumped in that absorbs the heat, produces steam that powers turbines that generate electricity.[75] That process is similar to hydraulic fracturing.

Other concerns include: potential loss of water if the water is not re-injected into the underground reservoir (some water is lost if steam is released into the air, and sometimes water is released into surface waters); such loss of water or a natural drying up of the underground water can lead to land subsidence; steam emissions may be harmful, including release of hydrogen sulfide (it smells like rotten eggs);

manufacturing of the system's components may use fossil fuels. The use of water in the enhanced geothermal systems method could be an issue depending on the source of water used in the fracturing process.

Any proposal for a geothermal energy-producing plant must be submitted to both Department of Ecology (DOE), which has jurisdiction over wells and groundwater, and to DNR, which has jurisdiction over geological state resources. If the proposal lies within a critical aquifer or recharge area, the plan must also be submitted to the Department of Health. A geothermal well application includes a well plan, the duration of the proposed extraction, the production goals as well as a State Environmental Policy Act (SEPA) report.

Wave Energy

Wave energy is ubiquitous throughout the world's oceans. For converting wave power to electrical energy, however, the highest intensity resource is concentrated along the west coasts of the world's continents, with wave power being more abundant in higher latitudes in both hemispheres.[76] The earliest commercial installations are likely to be within 1-3 miles of west coast shorelines near population centers. In the U.S., coastal Washington and Oregon are particularly suited for wave energy extraction.

- Wave energy converters are of three basic designs[77] normally involving floating buoys tethered to the ocean floor by flexible cable. These include:
- *Oscillating water column* in which a pocket of air is trapped in a partially enclosed buoy chamber, the air confined beneath a rigid vented lid above the water surface, by rigid buoy walls on the sides, yet fully open at the bottom to the oscillating water surface. Waves pushing up into the volume of air force air to vent out the top. Receding waves pull air back in. The moving air rotates a turbine built into the vent. Akin to a cup anemometer, the turbine always turns in the same direction regardless of whether air is being pushed out or pulled in, driving the generator.
- *Overtopping devices* use baffles or walls on the water surface to concentrate waves at a single point. The focused waves slop up and over a ramp into an open basin whose mean water level is higher than the surrounding ocean. Water from that basin is drained out through a turbine, turning a generator in a manner similar to low-head conventional hydropower.
- *Oscillating body devices* convert rocking, heaving, or pivoting physical structures to energy. A particularly promising design is called a point absorber, in which a spar, tethered by flexible cable to the ocean floor, contains generating coils wrapped around the end nearest the water surface. The buoy, containing an array of magnets, surrounds the spar's coils and while freely oscillating up and down in the waves generates a current in the coils. It is particularly promising in that it is a simple design with few moving parts and involves minimal loss of mechanical energy.

Capacity

Waves are widely available, of course. Devices to extract that energy are currently not. The first significant commercial deployment of wave energy devices in the United States is not expected for another five to ten years. The U.S. total available wave energy resource is estimated at 23 gigawatts, equivalent to approximately 2.2 percent of the nation's total installed energy generating capacity in 2010.[78] Eventually, however, it is expected that wave energy resources for the U.S. will be exploited to the level of local and perhaps even regional significance along the coasts of Oregon and Washington, and possibly Alaska, with wave parks generally located one to three miles off the Pacific coast.

Costs

Wave energy is not yet affordable. To date, offshore wave devices are producing electricity at costs far higher than competing renewables like wind and solar.[79] Costs reported from around the world have varied from 24 cents per kWh to 88 cents. A recent generation of Japanese devices is projected to deliver energy at around 19 cents per kWh,[80] but confirming data are not yet available. Ultimate cost is tentatively estimated by one knowledgeable researcher[81] at around 10 cents per kWh and among the more optimistic estimates of ultimate cost is a figure of 4.5 cents per kWh. Such estimates depend on a large number of unanticipated variables, and could be validated or invalidated by future testing and experience .

Reliability

The lack of experience with this new technology makes a definitive answer difficult. Nonetheless, marine buoys have been deployed for years with few unresolved problems. An oscillating water column device off the coast of India is reported as still "going strong" after ten years of continuous power generation.[82] Survivability through extreme wave events (e.g. 50-year storms) remains an active area of academic and industrial research and development.

The only potential threat to sustainability of the global wave resource involves macro-scale alterations to wind and wave patterns from global climate change. The mere act of extracting energy from wind waves is unlikely to have any measurable effect on the long-term availability of wave energy off U.S. coasts. Nonetheless, final disposition of wind energy transferred into the upper ocean remains a major unknown in global ocean circulation budgets.[83]

Other

Environmental Impacts

Potential environmental impacts have been perhaps the most widely anticipated yet unanswered questions of all, and are likely to remain so even after questions of design configuration are settled. To date, few answers have been forthcoming due to the lack of actual testing in marine environments and due to a lack of dedicated marine environments in which to test, i.e. sites that can be instrumented and monitored over extended periods of time.

The magnitude of impacts will depend on wave park size. Early commercial installations are likely to be small, in the range of 10 MW, sufficient for up to 2,500 homes. Such an installation in a facility similar to Ocean Power Technologies' proposed wave park off the coast of Reedsport Oregon, would involve approximately seventy 150-KW generators arrayed over a 30-acre site, 2.5 miles off the coast. Scaling that up to 100 MW, which some say can be expected in the future, would involve relatively fewer, but larger and more efficient, buoys.

Potential environmental impacts were enumerated at a workshop held at Oregon State University in 2007. Participants addressed:

- The physical environment including beach effects on sediment transport and wave erosion
- Impact on phytoplankton and forage fish species and attraction of larger predators
- Changes to the benthic community from changes in water circulation and currents
- Effects of lighting and above-water structures on marine birds
- Effects on marine mammals, in regard to possible entanglement in mooring cables

The workshop looked at many other potential impacts including those on near-shore ecology of energy absorbing structures, chemical effects, hard structures and lighting, acoustics, electromagnetic field effects, and system-view/cumulative effects. Finds of the workshop were tentative, not based on specific testing but on the cumulative experience of these 50 scientists in other settings.[84] Findings were more prescriptive than descriptive, setting out what environmental testing should be done before commercial deployment is attempted at any significant scale.

A small pilot project off the northwest coast of the Olympic Peninsula found that chains used to secure buoys scraped huge circles in the bottom sediments due to slack in the chains at low tide, an impact which is extremely destructive to the sea life on the floor of the ocean.[85]

Long Term Viability

Technically, there are no significant impediments to the ultimate commercial deployment of this technology save for the testing required to settle on a preferred design configuration. Ecological concerns await site testing but are not expected to be severe. Still, endangered species will require careful monitoring. Social concerns remain to be determined, but could arise around disruption of historic commercial and recreational fishing and shellfish harvesting in the areas of new wave parks.

As with tidal energy, the future of this technology seems to lie more in financial considerations than technical, ecological, or social. At present, the technology is not competitive cost-wise. Even removing existing subsidies to conventional energy is unlikely to make much difference.

TIDAL ENERGY

Tidal energy in the U.S. involves turbines typically located underwater to take advantage of four-times-daily tidal currents. Tidal energy differs from wave energy, which refers to the energy of the oscillating water surface.

One configuration that seems to have been settled on in the United States is the deployment of arrays of single stand-alone turbines on the seabed,[86] much like land-based wind farms, as opposed to the large structurally integrated barrage installations spanning major estuaries in Europe.[87]

Capacity

Barring technological breakthroughs not currently on the horizon, the potential for tidal power in the United States is restricted largely to three states – Alaska, Washington, and Maine[88] – where tidal currents are concentrated by somewhat rare hydrogeological features in inlets acting as venturis. Near these few locations, tidal energy has the possibility of becoming a locally important source of electricity, extracting on the order of 5-10% at full build-out, sharing the carbon-free renewable limelight near U.S. coasts with wind and wave, but of relatively minor statewide and even less national impact.[89] A constraint is that its periods of generation are limited to that fraction of the day when the tidal velocity is sufficiently great to turn turbines – typically ten hours a day with today's technology.

Professor Brian Polagye, a University of Washington tidal energy scientist, speculates that tidal technology today in terms of its expected development path is where wind energy was 30 years ago. One important difference is that the number of suitable sites for tidal energy is orders of magnitude smaller than it was for wind. Indeed, there remains a small but significant possibility that tidal energy will never be deployed to any substantial degree because of the relative advantages of competing technologies that don't have to be deployed and maintained under substantial depths of water – wave and offshore wind for example.

Costs

With the single exception of a long-operating tidal generator in France,[90] commercial deployments of large scale tidal generators are probably at least a decade away, though that expectation depends substantially on the relative cost trajectories of competing technologies, the presence or absence of subsidies both for conventional energy and for tidal, and federal support of hydrokinetic energy development and testing in general. Without substantial additional support, first commercial deployment could take significantly longer than a decade depending on the rate at which testing is done. Once deployed, the length of time to full build-out is estimated at about 50 years, although that, too, depends on the costs and advantages of competing technologies as well as on financial resources available in the economy at the time.

As with wave energy, the future of tidal seems to lie more in financial considerations than in technical, ecological, or social considerations. At present, the existing tidal energy generating plants are not cost competitive except for the one large scale generating plant built long ago in a very favorable location. However, finding good sites for such facilities, especially for tidal barrages, is extremely challenging. The difficulty and therefore cost of undersea construction leads to high capital costs for tidal energy plants. Even removing existing subsidies to conventional energy is unlikely to make much difference.

Reliability

The tides themselves are very reliable and consistent. The operating and generating equipment is similar to other large machinery such as turbines in hydroelectric dams and drive shafts, bearings and propellors for large ships so it is expected that the reliability of tidal power installations would be very good. The only tidal generating plant in Europe is the tidal barrage at Rance Estuary in the bay of Mont St. Michel in northern France. This plant has been operating since its construction in 1966. It is the only large scale tidal generating plant in the world and has a capacity of 240 MW, and an average output of 60 MW. Because tidal flow changes 4 times a day, the output is variable. However, the operational reliability is very high and the cost of power produced is competitive.[90]

It is possible that climate change may produce more frequent and more severe hurricanes which could affect tidal power plant operation. Moderate storm surges could produce useful currents, but very large

ones might cause damage and interruptions to operation.

Other

Concerning the environmental impacts of tidal power devices themselves, much testing will have to be done. It appears that the installation and operation phases of tidal arrays in Washington waters would produce relatively minor impacts, particularly if turbines are simply set down on the ocean floor without pilings or caissons. The major caution during these phases is the potential impact on populations of endangered species, such as southern resident killer whales, seals, sea lions, salmon, steelhead, and rockfish in Admiralty Inlet.[91]

A significant concern is the underwater noise generated by the turbines. In Admiralty Inlet there is sufficient ambient noise from shipping and marine traffic that a single turbine is not detectable more than a few hundred meters away. If this were scaled up to a 100-MW array, however, the story could be different and nobody knows what the impact would be. Operational tests to date suggest that large numbers of tidal turbines could exceed the threshold for annoyance of – hence avoidance by -- marine mammals, but would probably not reach the threshold for hearing damage or loss.[92]

There has been concern over the presence of high-voltage cables on the ocean floor and what harm they might do to living organisms. Eels, which navigate electromagnetically, have been briefly studied in Europe in this regard and appeared not to be greatly affected or at all damaged by such cables under a limited range of test conditions.[93]

The greater environmental impact is likely to come during decommissioning and removal of retired turbines. Vertical structures in the marine environment inevitably attract colonization and, over time, a complex stable community develops including free-swimming organisms that visit and feed on it or hide in it on a regular basis. Removal of such a long-standing structure could have an important negative impact on endangered species, particularly if it had become their preferred habitat during its deployment.

HYDROPOWER

Hydropower is simply power derived from the energy of falling water. In Washington, federally owned hydroelectric dams on the Snake and Columbia Rivers, administered by the Bonneville Power Administration (BPA), currently furnish nearly half of Washington's electric power needs—and use most of the productive dam sites.

Capacity

Largely because of the way the hydroelectric system developed, capacity (that is, the ability to meet peak-hour load) and flexibility (the ability to rapidly increase or decrease generation output) have not been significant problems to date. However, as power needs increase, the hydropower industry can work toward more efficiencies including, for example:

- Establishing metrics for measuring system flexibility
- Developing methods to quantify the flexibility of the region's existing hydro resources
- Improving forecasting of the region's future demand for flexible capacity
- Increasing the availability and use of dynamic scheduling
- Possibly upgrading communication and control facilities
- Adding pumped storage

The U.S. Department of Energy has started a program to renovate existing dams to increase electrical output. This can be done without significant changes to the dam itself and these upgrades are highly cost-effective.

Considerations for the future include micro-hydro, low impact hydro, and low head hydro. Micro-hydro is a term used for hydroelectric power installations that typically produce up to 100 KW of electricity. Micro-hydro is often just a small dammed pool, at the top of a waterfall, with several hundred feet of pipe leading to a small generator.

Micro-hydro installations can provide power to an isolated home or small community, or are sometimes connected to electric power networks. They can provide an economical source of energy without the purchase of fuel, and, when the power is used on-site, they eliminate loss of power during transmission. Micro-hydro systems complement photovoltaic solar energy systems because in many areas, water flow, and thus available hydropower, is highest in the winter when solar energy is at a

minimum. Micro-hydro environmental impacts are similar to those for large hydro except that they are smaller and more local and can be minimal in some cases.

The Low Impact Hydropower Institute (LIHI) is a non-profit 501(c)(3) organization dedicated to reducing the impacts of hydropower generation through the certification of hydropower projects that have avoided or reduced their environmental impacts pursuant to the Low Impact Hydropower Institute's criteria.[94] In order to be certified by the Institute, a hydropower facility must meet criteria in the following eight areas: river flows, water quality, fish passage and protection, watershed protection, threatened and endangered species protection, cultural resource protection, recreation, and facilities recommended for removal. The standards are typically based on the most recent, and most stringent, mitigation measures recommended for the dam by expert state and federal resource agencies, even if those measures aren't a requirement for operating. A hydropower facility meeting all eight certification criteria will be certified by LIHI, and will be able to use this certification when marketing power to consumers.

Costs

BPA markets hydroelectricity from dams and from the Energy Northwest nuclear plant to Northwest utilities at cost. According to NW Council member Phil Rockefeller,[95] "cost" may include some old debt from the failed nuclear power development project known as "WPPSS." But even with that, the overall result is that the availability of hydropower makes Washington's electric power very affordable.

Average statewide electricity prices over the past several years have been less volatile than petroleum or natural gas prices. Average statewide electricity prices have risen, increasing from approximately 5.5 cents/kWh in 2004 to more than 7 cents/kWh in 2008, then declined to 6.5 cents/kWh in 2010.[96] The power supply component of this is about 3 – 4 cents/kWh, with distribution and management making up the balance. New small hydro projects are estimated by the Northwest Power and Conservation Council to cost 6 – 9 cents/kWh. The Sixth Northwest Plan from this Council estimates that new hydropower, over the next 20 years, could produce about 200 average MW of additional power (compared with about 20,000 average MW of consumption).[97]

Reliability

Hydroelectric power is very reliable, except in years where water flows are reduced by drought or low snow-pack. The potential impact of global warming is unknown but it could increase water availability as glaciers melt or decrease it if drought is the result. Also, low water flows increase constraints on the operation of the hydro-system to meet fish requirements.

Other

Both large-scale hydroelectric and micro or low impact hydropower projects and plants are subject to many federal and state regulations. The Federal Energy Regulatory Commission (FERC) administers the numerous federal power acts including licensing, compliance, safety inspections and oversight during construction or modifications. Most of the regulations concern environmental impacts, clean water, fish and wildlife but there are also regulations about coordinating and controlling power distribution, effects on interstate commerce, navigation, etc. For small projects, some special conditions permit exemptions from some regulations.

At the Washington state level licenses and permits are required to insure compliance with state regulations on water resources, water rights, water quality and other environmental factors. Hydraulic project approval from the Department of Fish and Wildlife is required for any work in or near a stream. In addition, projects must conform to agreements and treaties with Native American tribes.

In addition to providing non-fossil fuel energy, the dams in the Columbia River Basin also have an extensive system of locks that allow ships and barges to pass easily from one reservoir pool to the next. Navigation reaches to Lewiston, Idaho. One of the main shipping commodities is wheat, mainly for export. In addition to hydroelectricity and shipping, the dams address a variety of demands including agricultural irrigation, flood control, recreation, salmon fishing, stream flow regulation, storage and delivery of stored waters, and reclamation of public lands and Indian reservation land. Fish ladders have been installed at some dam sites to help the fish

journey to spawning waters. Still salmon populations have declined dramatically.

As described in David Montgomery's book, King of Fish, the Columbia River Basin only supports about seven salmon for every fifty salmon the basin had supported 150 years ago. Also, only one or two of those seven fish are wild. While there are numerous competing uses of the Columbia River, Montgomery suggests that dam removal is necessary for restoration and recovery of salmon and the Save Our Wild Salmon website recommends removing the four lower Snake River dams, which the organization believes would enable salmon to rebound with more habitat and easier passage on their journey to the ocean.[98]

NW Council member Phil Rockefeller[95] noted that the Northwest Power Act of 1980 requires that hydropower facilities "protect, mitigate, and enhance" fish and wildlife. The 1938 Mitchell Act (which authorized the Secretary of the Interior to carry on activities for conservation of fishery resources in the Columbia River Basin) has been interpreted to mean that fish hatcheries are considered a form of mitigation. In response to an observation that salmon survived the last Ice Age and promptly re-established their run in the Toutle River after the Mt. Saint Helens eruption in 1980, Rockefeller said that NOAA considers salmon to be very adaptive, but the introduction of genetically uniform hatchery salmon may compromise the genetic diversity of wild salmon.[95]

Some dams need to be modified to become more salmon-friendly and to increase stock diversity. Additional ladders and more spill water would help increase the salmon return. According to an article by the Bonneville Power Administration, the Snake River dams are an important source of clean energy for the region and they believe the benefits of clean energy far outweigh those of river restoration.[98] The Elwha Dam (Olympic Peninsula) and the Bruton Dam (Yakima River tributary) removals will provide scientific information that may help resolve the cost-benefit debate.

Though dams significantly reduce the amount of salmon that return to the Pacific from the Columbia, they also play a large role in the amount of non-fossil energy produced in Washington. Because of the amount of hydropower Washington uses, its carbon footprint is one of the lowest in the country. The adverse impacts to salmon and the benefits of dams to the energy system will not be easy to reconcile. Considering the large number of stakeholders in the Columbia River Basin, solutions that satisfy all parties will be difficult to achieve. Compromises will be needed from all parties.

GREEN POWER PROGRAMS

Some utilities offer their customers the opportunity to voluntarily pay a higher rate to help underwrite higher use of renewable technologies. Utilities may give customers energy-saving devices and financial incentives to conserve energy. Citizens participating in these programs, known as "green power programs," may become more aware of where their power actually comes from.

Most green power programs do not actually involve acquisition of power by the utilities that sell it. Rather, the utilities purchase "renewable energy certificates" that represent the renewable attribute of power, which is then sold into the market as undifferentiated power. According to Dr. Schwartz, a policy expert for the NW Council, and Jim Lazar, Consulting Economist,[99] [100] Grant, Chelan, Douglas, Snohomish, Clark, and Pend Oreille PUDs all produce power; several other utilities have partial ownership rights to various hydro projects, but get the vast majority of their power from the Bonneville Power Administration. Also according to Dr. Schwartz,[99] hydropower, except for low impact hydro, does not qualify under green power programs.

According to Puget Sound Energy,[101] 909 businesses and 30,020 residents participate in its program. Vashon Island leads the region with the highest participation rate (12%). Other cities with the most green power program participants are: Olympia (3,794), Bellingham (3,792), Bellevue (1,929), Kirkland (1,709) and Bainbridge Island (1,103). Those who participate in PSE's program have a power content of 50% wind, 7% wood waste, 7% livestock methane, 24% landfill gas, 10% low impact hydro, and 2% solar.

Puget Sound Energy offers its customers voluntary choices of add-on costs for the renewable energy:

100% usage at $0.0125 per kWh, or
Block purchases starting at $4.00/month for 320 kWh, or

Large volume rate of $.006 per kWh

Seattle City Light offers its customers free energy kits (compact flourescent light bulbs and high performance efficient shower heads), rebates for purchase of energy efficient appliances and technologies, and a number of other energy-saving discounts and incentives.[102]

Avista, headquartered in Spokane, WA, has a green power program called Buck-a-Block, a voluntary rate program launched in 2002. By the end of 2011, participants purchased more than 70,000 MWh of emission-free renewable energy annually. Sources include wind, biomass and solar. By signing up, users get 300 kWh of renewable energy for just $1.[103]

In addition, Avista

- publishes an annual sustainability report that contains data on its CO_2 emissions, showing them to be among the lowest of the largest power producers in the country.[104]
- has an aggressive program to help people replace single pane windows and make other energy improvements.
- offers a renewable generation incentive (RGI) for Washington customers who install their own renewable energy systems, like solar panels, wind turbines or anaerobic digesters. To qualify, a system must be on the grid.

There is also a one-time energy efficiency incentive for such projects available to both Washington and Idaho customers. Pacific Power, headquartered in Portland, OR, has a Home Energy Savings Program that offers incentives for energy efficient lighting and ceiling fans, new appliances, recycling, heating and cooling, windows and insulation, and incentives for customers in Washington with new homes.[105]

THE GRID

The grid is the hardware and software that comprises our nation's electric power infrastructure. Our century-old power grid is the largest interconnected machine on earth, covering much of the United States, Canada, and a little of Mexico. It is 99.97 percent reliable, yet the .03 percent of outages costs Americans $150 billion annually. The grid still handles its primary function, providing electricity while keeping costs down,[106] but the increasing demands for electricity have produced a greater frequency of failures. There has been an underinvestment in transmission and distribution relative to demand: since 1982, growth in peak demand for electricity has exceeded transmission growth by nearly 25% every year. Additionally, regulations are sometimes in conflict and the process of approvals for new transmission and distribution infrastructure can be cumbersome, time-consuming and politically challenging.

THE SMART GRID

The U.S. Department of Energy has been charged with modernizing the grid. In the short term, they are promoting use of existing technology to reduce stress on the grid by improving monitoring capability, upgrading aging hardware, and involving the customer. There are pilot programs in Washington and other states to better understand the technology and psychology that will contribute to inventing the so-called "smart grid." The smart grid, which will take more than a decade to realize, injects flexibility into the grid using new hardware and software technologies that exploit the power of computing to provide near real-time information and automation. One huge change the smart grid will produce is that consumers will be transformed into active participants.

In 2009, the US Department of Energy stated that "67% of energy is wasted between generation and the consumer."[107] Some of this loss occurs because customer power needs are based on annual usage, so voltage is usually transmitted at the high end of the desirable range (126-114 for 120 volts) to ensure the end of the line receives adequate power. *Conservation Voltage Regulation* (CVR) reduces the voltage actually sent to users. Snohomish Public Utility District is the largest public utility district in Washington, and was one of six northwest utilities to pilot CVR, adding equipment to control and monitor voltage to deliver 117 volts, a 2.3 % cut in voltage that avoided 11,226 MWh/yr power loss for its customers.[108] The added equipment ensured that voltage was the same to every recipient along the line, and the change was not noticed by the customers.

Demand Response and Load Management

Bonneville Power Administration (BPA) has forecast capacity shortages for the Northwest in the near

future and has invested in various demonstration projects to test ways to reduce failure frequency: one project, *Demand Response and Load Management*, consisted of several pilots. The *Direct Load Control* pilot used volunteer residents served by Kootenai Electric Cooperative in Idaho, who received equipment that could accept a radio signal to direct the thermostat to reduce the temperature by three degrees during the winter afternoons or raise it during the summer. The changes could reduce the overall system load if the system approached maximum capacity. Similar pilots have been tested, and continue, with commercial and industrial customers. In Seattle, the Northwest Open Automated Demand Response Technology Demonstration Project showed that an automated system could modify the load requirement of commercial buildings during summer and winter highest load to reduce overall load on the system. Also, *Demand Pricing* pilots were designed to learn whether customers would voluntarily modify their energy usage if they could see their usage alongside electricity prices that varied during the day.

Variable Power Generation

Variable power generation, e.g. wind, solar and wave, has been problematic to a grid designed for fixed power generation. Additional transmission lines are being built by BPA to avoid stopping wind generation when the need to produce hydro power (to reduce water volume) causes a conflict. BPA is involved with several pilots to try to store variable power using capacitors, batteries and pumped storage hydro, among other methods. They have begun a feasibility study with Pacific Northwest National Laboratory to determine whether energy could be stored in the basalt rock along the Columbia River.[109]

Distributed generation

Distributed Generation is energy produced locally where it is primarily used. The source could be a wind turbine, solar panels on a home or business, biodiesel generators, or a combination of varied sources that might provide heat as well as power. *Microgrids* are electrical systems that include multiple loads and distributed generation resources that can consume or supply power to the grid or act as an electrical island, delivering power locally.

Washington requires utilities to accept, and compensate up to a point, excess electricity that goes onto the grid (net-metering). BPA has tested using distributed generation to augment power. It has also worked with an industrial user on the Olympic Peninsula that accepts excess power generated from wind, thereby relieving stress on the grid (load shedding).[110] Power forwarded to the grid must have voltage stability, quality, and reliability because the current grid is unable to respond to variation in a timely manner.

Pacific Northwest National Laboratory has also developed real-time tools to improve immediate information about a grid operator's control area as well as information about neighboring systems. Some power substations have the ability to black out a neighborhood when there is stress on the grid. The Laboratory developed a controller that was tested with clothes dryers and water heaters to reduce or stop power consumption when the wall plug registered less power than normal, which could be enough to prevent a neighborhood blackout.

Active Consumer Participation

Active participation by consumers is the antithesis of previous consumer experience with power. With the smart grid, a user can specify power requirements over the day in much the same way as a programmable thermostat. A user would have near real-time access to usage and cost and could modify consumption based on the information. The user could also specify to what degree its power could be reduced during grid stress. Each modification that deferred to the needs of the grid would have an economic benefit. Additionally, using smart meters (advanced metering infrastructure), the system can sample the user's consumption over the day, providing information to the system about demand, a concept that has met with resistance because of privacy concerns.

Pacific Northwest Smart Grid Demonstration Project Washington participates in the Pacific Northwest Smart Grid Demonstration Project, the largest of sixteen across the country, which involves 60,000 metered customers and became operational October 24, 2012. The project intends to test that all key functions of the future smart grid work as expected, and that the design is scalable. The demonstration will validate new technologies; provide two-way communication between distributed generation, storage and demand assets, and the existing grid infrastructure; quantify smart

grid costs and benefits; advance interoperability standards and cyber security approaches; and validate new business models.

More than 20 types of responsive smart grid assets will be tested across varying distribution sites operated by discrete utilities. The project includes residential, commercial, industrial, and irrigation customers. The demonstration will test and validate the ability to continuously coordinate the responses of smart grid assets. It will also be among the first to engage distributed control so that wind integration problems are reduced. The project will operate into 2015 with 75% of the installed smart grid assets left in place at the conclusion of the project.[111]

Aspects of the Smart Grid
The smart grid demonstrates these characteristics:

- Enables active participation by consumers
- Accommodates all generation and storage options and enables new products, services, and markets
- Provides power quality for the digital economy, optimizes assets and operates efficiently, and anticipates and responds to system disturbances (self-healing)
- Operates resiliently against attack and natural disaster

Assets
Assets are the technologies, devices, and equipment to modernize and automate electric transmission, distribution, and customer systems. Assets include in-home displays, programmable communicating thermostats, advanced metering infrastructure, communication systems, distribution automation equipment, and measurement units. In addition, other energy resource assets, such as distributed generators and energy storage devices (including batteries, flywheels, and plug-in electric vehicles) can provide functions that are enabled or improved when paired with smart grid assets.[112] Open architecture is used to allow ready access by new products and services.

Price Responsive Model
A *price-responsive model* would reflect power costs during the day as opposed to the fixed energy rates of the past. Price links the consumer to the power system: visibility enables a consumer to manage usage by choosing economically efficient offerings. Energy price and demand shaping will be used to make financial decisions not only related to energy consumption but also to energy production. If the price of energy is high then producing power locally and selling back to the grid may make good financial sense. If the price is low, the locally produced power might better be used locally. For industry, it could be an incentive to invest in renewable distributed generation.[113]

The pricing model might include revenue to specifically finance renewable resources. Pricing models will continue to receive much scrutiny and will be the target of research and pilot programs to ensure they are equitable and don't discriminate against disadvantaged populations.

Grid Response Time
Grid response time will improve enormously with the smart grid. Operators who manage today's grid have difficulty acquiring enough information to understand what is happening and primarily must sledgehammer fixes to relieve grid stress. The technology to automatically monitor and control small and large corrections with the smart grid will allow the system to sense and bypass input disturbances in real-time. This reduces today's problems from voltage instability, poor quality, and unreliability. It also reduces the impacts of natural or man-made disasters.

Environmental Benefits
Conversion to the smart grid can reduce energy consumption and postpone the need for new generation projects. It can also promote use of renewable resources by making it easier to attach them to the grid as well as provide incentives for investment.

Regulation
Flexibility is key to the success of the smart grid; energy policies and regulations must enable nimble adjustments to the governing of the smart grid for it to succeed. There are several bodies in Washington that affect smart grid use:

- Department of Commerce (Energy Office) develops Washington energy strategy and, when explicitly directed by the legislature, writes rules in Washington Administrative Code 194 for public utility districts to implement the laws.
- Public utility districts (PUDs) implement the laws, and the Washington State Auditor

audits the PUDs to ensure compliance with the regulations.

- Utilities and Transportation Commission provides guidelines to, and regulates rates and services of, private and investor-owned utilities, specifying regulations in Washington Administrative Code 480.[114]
- Washington State Legislature writes and enacts laws in the Revised Code of Washington (RCW).

There are multiple federal organizations that affect the smart grid:

- Department of Energy addresses issues of energy and the environment using science and technology.
- Department of Commerce promotes economic growth and sustainable development. National Institute of Standards and Technology is the technology agency within this department that works with industry to develop and apply technology, measurements, and standards.
- Federal Energy Regulatory Commission (FERC) is an independent agency that regulates energy services.
- United States Congress writes and enacts public laws.

The National Association of Regulatory Commissioners is a forum for states to collaborate on regulatory areas that affect each state. The association has joined with FERC to create *Smart Grid Collaborative*, which will try to develop regulation solutions appropriate for all of the states. Consistency will still be an issue because each state legislature might be involved in the process, and each state may have existing mandates regarding renewable resources that could affect pricing models. Washington has renewable resource mandates, found in the Energy Independence Act discussed on p. 4.

Advanced metering infrastructure (AMI), which includes the smart meter that can broadcast consumer usage to the utility, is an example of an area the collaborative has examined. Some of the issues to be addressed are:

- who may see AMI data that can identify the consumer,
- transparency (tell consumer what was stored, why, to whom provided),
- provide a means to dispute,
- access specifically granted by consumer to secondary use of data (beyond the utility),
- collection and storage of only what is reasonably necessary,
- retention of information only as long as reasonably necessary, and
- notification to the consumer of any security breach.

There are numerous areas of regulation that need to be addressed to produce a smart grid that appears seamless. The Northwest Power Pool consists of nineteen authorities that have discrete requirements to maintain balance between load and generation of power. Most of the pool members have signed on to an agreement to reduce their regulatory burdens, which will help the smart grid. The Energy Facility Siting Evaluation Council oversees siting for energy facilities within Washington, but interstate regulation is another area with potential conflicts: the approval processes for interstate transmission siting vary widely.

ENERGY INTEGRATION

The intermittent nature of wind, solar, wave and tidal energy limit the fraction of these sources that could be added to the current power grid system. Both maintaining grid stability and being able to meet peak load demands cause this limit. Modeling and operational power grid data show that about 20% or perhaps 30% of the system capacity can be from intermittent sources such as wind without causing stability problems or significant increases to the cost of electric energy.[115] [116] To be able to use a higher fraction of the intermittent sources, improvements must be made with a combination of measures such as:[117] [118]

1) Improving the adjustability of current energy sources
2) Adding fast response energy sources such as natural gas turbines to the power system
3) Developing and use of energy storage systems connected to the grid which can store excess energy and release it when needed
4) Constructing more and improved ties to the other regional power grids (for power export or import during regional over or under

supply of power)
5) Improving the grid network and its control and monitoring systems
6) Developing and using smart grid techniques such as remote or automatic load shedding for loads which can be turned off with no serious consequences (even for individual home appliances)

Most of these measures will require investments and operational costs which may increase the amount utilities will charge the consumers of electric energy.

CONCLUSION

There is no silver bullet for energy. The target is an energy supply that is sustainable, clean, affordable and sufficient. As this report shows, renewable energy sources are largely sustainable and are mostly clean. They are becoming increasingly affordable. If each energy source were fairly priced according to all factors, including development of new technology vs. mitigating harm from its use, alternatives would already be highly viable, even those for which technology is still in its infancy, because there would be greater motivation to concentrate on moving the technology forward at a faster rate. The future costs to our society of global warming will be huge and should be factored into the cost of coal, oil and natural gas energy production.

But are the renewable sources enough to do the job, and can we develop strategies to fully and efficiently utilize them? By now there is broad understanding of the serious problems with heavy reliance on fossil fuels for our energy needs. In the United States and many other parts of the world, citizens and governments are moving ahead to begin to reduce, if not eliminate, the use of this non-sustainable and polluting energy source.

But before this can be achieved, we need to identify and address impediments to expanding the use of renewable energy sources. This report has laid out the strengths and challenges with each of the main sources of renewable energy.

Wind energy is becoming cost competitive and it is clean. But transmitting wind energy from generating turbines to the grid where it is distributed is a major concern for this particular energy source, as is the variable nature of the wind itself. Other concerns include environmental effects and storage challenges.

Solar radiation epitomizes sustainability. It is the largest inexhaustible source available to us. Solar, particularly involving photovoltaic installations on rooftops, has seen rapid growth in recent years. Storage is as important in managing the generation of power from solar energy as it is for wind power. In areas of minimal sunshine, solar is not a viable source of energy.

Biomass as a source of power has difficult challenges which suggest a limited future, challenges relating to the impacts of emissions on public health, supply shortages (especially with woody biomass), costs and carbon impacts of transporting the feedstock to the facilities and concerns for the health of the forest. Other biomass sources have similar problems with emissions and other environmental impacts, and waste-to-energy (the burning of municipal solid waste to create energy) is not recognized as renewable by the Energy Independence Act, and hence by Washington law.

Biofuels are already in widespread use in transportation, as additives or substitutes for gasoline or diesel. They provide an easily transportable fuel that can use current distribution systems. Biofuels do release greenhouse gases. However, when growth and production are carefully managed, the release is compensated over time by the uptake of carbon dioxide by replacement plants. Ethanol and biodiesel are the two biofuels most likely to be used. Producing them from some food crops is well established but sources which do not compete with food production, are not as subject to seasonal variations in crop size and have a higher energy payback, such as wood, waste from agricultural and other sources and algae, require much more development. Even with the use of these sources, limits on available land will make it difficult to replace most of the fuel now used with biofuels.

Wave and Tidal actions are potential energy resources particularly for coastal Washington and Oregon. Both technologies are in early stages of development (with the lone exception of a 46 year old tidal energy facility in France), and currently costs are not competitive. Siting of tidal facilities and

environmental impacts of both wave and tidal facilities can present additional challenges. The number of viable sites is limited for tidal, so it not expected to be a significant fraction of U.S. energy production.

Geothermal resources, in the process of being mapped, are not expected to be of major significance in Washington because of lower heat levels found so far. Washington's complex geology also makes this an unlikely resource, and in any event siting would be challenging due to the large proportion of protected public land in what might otherwise be promising locations. Ground source heat pump systems in individual homes and businesses is a technology that shows some promise.

Hydropower from federally owned dams on the Snake and Columbia Rivers is a major source of energy in Washington, supplying nearly half of the state's electric power needs. Hydropower is relatively affordable and this has resulted in low electricity bills for its citizens relative to other states. Dams contribute to loss of salmon in the Columbia River basin, yet play a large role in reducing Washington's carbon footprint and benefit a broad variety of interests including agriculture, recreation and transport of goods on barges. Compromises must be reached which take into account both fish and other needs.

Green Power Programs are offered by some power utilities to encourage the use of renewable energy and to assist customers in making wise choices in their use of energy. These programs are voluntary, are being used by a growing number of customers, and thus having an increasing impact on use of renewables and on smarter use of electricity in general. Three examples of programs in the Northwest are highlighted in this report.

The Grid is the hardware and software that comprises our nation's electric power infrastructure, and thus deals with issues common to all sources. This report summarizes each of the major sources of renewable energy, but it also identifies overarching considerations and common problems which apply to all or nearly all these sources and affect our ability to make full and timely use of them. The topics common to all sources are described in the section on The Grid.

Smart Grid is a federal program which epitomizes the "silver buckshot" [119] approach. Its goal is to modernize the grid by making the most efficient use of existing power infrastructure and management tools in the short term, and by developing new hardware and software technologies in the longer term. The smart grid works on multiple strategies simultaneously, some of which feature a far greater degree of customer involvement, and will significantly increase the flexibility of the grid.

Energy Integration problems are among the most significant issues facing the grid as can be seen from examples throughout the report, particularly in the discussions of the grid and of the smart grid. Resolving integration problems is key to being able to maximize use of renewable energy sources, as the intermittent nature of most renewable energy sources poses major challenges in managing the grid. Measures to address this problem will add to customers' utility bills but are necessary for increasing use of renewable energy.

It is apparent from all the sections of this report that decreasing the consumption of fossil fuel by increasing use of renewable energy sources will be complex and slow. Although there has been remarkable progress already, this process is still at an early stage. Technical, engineering and political difficulties still remain. The research, development, engineering, subsidies and incentives to overcome these will require continued investment. However, in addition to the benefits of being able to use renewable energy, this investment will provide jobs and lead to the development of many marketable products and services.

Reducing carbon-based energy consumption by 50 to 80% over the next half-century could give a dramatic boost to the overall development and implementation of all forms of carbon-reduced or carbon-free energy. Possible approaches for accomplishing this important goal are primarily based on the concept of including the true long-term cost to society in the price that fossil fuel users pay. While not within the scope of this study, these approaches are now being widely discussed by policy makers and are receiving much attention in today's news. This discussion, along with continued progress in the development and use of renewable energy, provides cause for optimism in achieving a better energy future.

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