

## Chapter 5 Description of Resources Modeled

While developing this Plan, NorthWestern considered a number of possible resource options for inclusion in the supply portfolio. Typically, the resource can be described by the fuel source (Coal, Natural Gas, Wind, etc.) and the technology utilized to convert the raw fuel supply into electricity. This chapter contains qualitative descriptions of the resources considered for this Plan. Note that a few of these resources, such as Tidal and Wave power, were not ultimately included in the modeled portfolios based on their current lack of availability as a tested and reliable source of power. Future procurement plans will continue to evaluate advances in generation technology and will modify the resources evaluated as appropriate. This chapter also briefly discusses a regulation resource. Volume 2, Chapter 5 includes a paper containing a more detailed discussion of NorthWestern's growing urgency for regulation resources and the steps NorthWestern is undertaking to fulfill this need.

### Resource Descriptions

Fuel: Coal

Technology: Pulverized – Conventional (Includes sub- and super-critical)

Pulverized coal plants provide a very large part of the electrical production in the United States today with unit sizes ranging from around 100 to over 700 MW. These plants burn coal to produce steam, which generates power under a variety of boiler/plant configurations. Although newer technology has significantly reduced emission such as NO<sub>x</sub> and SO<sub>x</sub> from these types of plants, current greenhouse gas and mercury concerns will significantly limit new coal plant construction, and create uncertainty regarding the total cost of such power resources as requirements to mitigate for GHG and mercury are likely in the near future.

Fuel: Coal

### Technology: Integrated Gasification Combined Cycle (IGCC)

IGCC plants are plants where a carbon based feedstock, such as coal or petroleum coke (a by-product of oil refining) are first gasified and then used as the primary fuel in a combined cycle plant. While combined cycle technology and gasification processes are in widespread commercial use, the combination of the two for power generation is not. There are two plants currently in operation in the United States – the 262 mw Wabash River Repowering IGCC in Indiana and the 250 mw Tampa Electric Polk Power Station in Florida. An example of a gasification process not tied to power generation is the Coffeyville Resources nitrogen plant in Kansas, built in 2001, which gasifies petroleum coke to produce nitrogen fertilizer.

### Fuel: Coal

#### Technology: Coal-Oxy (Oxy-Fuel Pulverized Coal Combustion)

A report issued from MIT titled “The Future of Coal” describes this technology as:

This approach to capturing CO<sub>2</sub> from pulverized coal units involves burning the coal with ~95% pure oxygen instead of air as the oxidant. The flue gas then consists mainly of carbon dioxide and water vapor. Because of the low concentration of nitrogen in the oxidant gas (95% oxygen), large quantities of flue gas are recycled to maintain design temperatures and required heat fluxes in the boiler, and dry coal-ash conditions. Oxy-fuel enables capture of CO<sub>2</sub> by direct compression of the flue gas but requires an air-separation unit (ASU) to supply the oxygen. The ASU energy consumption is the major factor in reducing the efficiency of oxy-fuel PC combustion<sup>1</sup>.

The captured CO<sub>2</sub> can be sequestered underground or in some other sequestration process. Although no Oxy-Fuel clean coal plants are in operation, Sask Power of Canada has recently announced plans to construct a

---

<sup>1</sup> Pages 29-30, “The Future of Coal”; Dr. James Katzer, et al., 2007.

demonstration project, has identified two potential construction sites, and has set 2012 as a projected on-line timeframe.

Fuel: Natural Gas

Technology: Simple Cycle Combustion Turbine (“SCCT”)

Primarily used for meeting peak demands and intermediate cycling, SCCTs provide a significant portion of the U.S. power supplies. Their quick start capability, relatively low capital cost and short lead times to construct make them a very attractive resource in times of resource uncertainty. Depending on their configuration, most units are less than 100 MW in size. These units can be easily developed as dual fuel units in the event of natural gas supply shortages or interruptions.

Technology: Generic Regulating Resource

Regulating resources are included in the Portfolio Analysis from the load-serving perspective. However, Volume 2, Chapter 5 includes a discussion paper regarding NorthWestern’s need for such a resource and an estimate of the size of the need. The estimated quantity of regulation varies between portfolios only to the extent that renewable portfolio standards are met with alternatives other than wind generation. The scope of this Plan is not intended to provide the analysis supporting the selection of a regulating resource and determining the operational and site specific costs. However, it is important from a portfolio perspective to capture the energy contribution and a proxy of the cost components of the regulation resource when developing the longer-term resource plan. The energy contribution from regulation resources to the default load portfolio is expected regardless of whether the unit is owned and operated by NorthWestern or the output is simply contracted by NorthWestern.

The generic regulation resource broadly represents the types of resources the utility may acquire as the result of the separate procurement and analytical efforts underway. The generic regulation resource will be modeled as must-run

and will be set to dispatch at approximately 50% of installed capacity, representing the need to have both upward and downward dispatch capability and thus the expected long-run quantity of energy contributed to the portfolio. While the exact intra-hour and hourly dispatch will be dictated by the transmission group, this appears to be a reasonable projection based on the continuous need for regulation services and a dispatch level that allows the unit to be regulated up or down within the hour. Due to the dispatch logic, the regulating resources will not be directly comparable to other peaking resource options that are modeled as economically dispatched. All the portfolios developed for intrinsic and stochastic analyses incorporate these regulation resource related assumptions.

Fuel: Natural Gas

Technology: Combined Cycle Combustion Turbine (“CCCT”)

A CCCT electric generation plant consists of one or more natural gas fired combustion turbine generators whereby the exhaust and waste heat from the combustion process is recovered and routed through a steam generator to increase generation output and plant efficiency. Plant sizes typically range from 350 to 600 MW and are used primarily for base load generation.

Fuel: Natural Gas

Technology: Combined Heat and Power (“CHP”)

A CHP plant is a thermal plant, typically a CCCT that is combined with an industrial process that can use the waste heat. The use of waste heat constructively improves the efficiency and economics of the overall power generation process. CHP is in widespread use and is a proven technology.

Fuel: Oil Sands

Technology: Combined Heat and Power

The oil sands are deposits of oil mixed with sand in northern Alberta which require processing prior to refining. A cogeneration plant located in this region could use locally available natural gas as the primary fuel for electric generation, and supply waste heat to the refining process for the oil sands. While the fuel and an energy intensive host are readily available, new electric transmission facilities would be required to transmit the output of these plants to NorthWestern's service territory.

Fuel: Natural Gas

Technology: Fuel Cells

Similar to a battery, fuel cells generate electricity by means of an electrochemical process. Fuel cells come in a variety of technologies of which proton exchange membrane is one of the most popular. Fuel cell sizes range from very small up to approximately 1 MW in size. Fuel cells emit no air pollutants or greenhouse gases.

Fuel: Natural Gas/Fuel Oil

Technology: Backup Generation

Backup generation represents at-site standby generation that is used to support high priority customer loads (e.g. hospitals, high tech) in the event of disruption of utility service. Increased coordination of these generators is being utilized by utilities to support extreme peak demand events on their system. The majority of these generators are powered by diesel engines which limits their operation due to air quality limitations. Individual generators range in size from 100 kW to over 2 MW.

Fuel: Wind

Technology: Wind

Commercial wind generators currently range in size from around 1 to 3 MW per unit. Wind generators are generally arranged in a series of farms to capture

economies of scale with some farms having total installed capacity of several hundred megawatts. Annual average capacity factors for wind projects typically average between 25% to 40%, but Montana is fortunate to have a robust wind resource and sites have been identified that have annual capacity factors in excess of 40%. Recent experience with the Judith Gap Project indicates that capacity factors at this level are reasonable.

Wind project generation is valued primarily due to its status as a renewable resource with no emissions and due to the free cost of the fuel source once the facility has been constructed. Due to their intermittent nature, wind resources are viewed primarily as an energy resource rather than a capacity resource. In this manner, they act to displace other more expensive variable cost forms of generation. The Northwest Resource Adequacy Forum has determined, however, that 15% of the installed generating capability of wind farms can be counted as capacity. This finding has recently been challenged based on analysis performed by the Wind Integration Forum, a group of utilities and other stakeholders that are working to analyze and understand the challenges associated with integrating wind generation in the Northwest.

The Wind Integration Forum has issued a report titled "The Northwest Wind Integration Action Plan" ("NWIAP"). This NWIAP identified nearly 1,400 MW of installed and currently operating wind generation in the Northwest with an anticipated total of 3,800 MW by 2009.

The NWIAP states that there appears to be no significant barrier to regionally integrating up to 6,000 MW of installed wind generation, although there is significant cost uncertainty related to this level of integration activity. The NWIAP also concluded that transmission limitations, rather than integration limitations, may pose a significant barrier to continued Northwest wind development beyond the 3,800 MW anticipated to be online by 2009. Due to the relatively low cost of wind generation relative to other forms of renewable generation, and the

adoption of renewable portfolio standards in most western states, it can be anticipated that wind development will continue to advance in the region.

Fuel: Geothermal

Technology: Flash, Binary Cycle

A geothermal generating plant produces power from either the direct or indirect use of geothermal fluid to produce steam. Geothermal plants are considered a renewable resource and therefore are growing in popularity. Geothermal development opportunities are somewhat limited in the Northwest. The fixed cost of this type of project is quite high compared to alternative resource options.

Fuel: Biomass

Technology: Conventional

Biomass generation includes the use of combustible material left over from production and/or human consumption to produce electricity. Sources of fuel for biomass generation include wood waste from logging, agricultural residue, lumber by-products, municipal solid waste, landfill gas and animal manure. Biomass facilities are usually located near population centers and provide advantages in reducing transmission costs and impacts. Biomass generation facilities are relatively small in size (less than 15 MW) but have relatively high generation availability.

Fuel: Solar

Technology: Photovoltaic

This technology produces electricity through the direct conversion of sunlight through the use of photovoltaic cells and panels. Although photovoltaic panels costs have fallen substantially, costs still far exceed other forms of generation. Photovoltaic's application is used primarily in a limited manner to provide power to remote or isolated areas.

Fuel: Solar

### Technology: Thermal

Solar thermal technology utilizes the concentration of the sun's energy to produce heat, which can ultimately be used for power production. Solar thermal plants generally take one of three forms – the concentration of the sun's energy using a parabolic dish, a parabolic trough, or an array of reflectors that focuses the sun's rays onto a central tower. Although small-scale demonstrations have been developed, this technology is not mature enough to provide significant large-scale power generation in the near future.

### Fuel: Uranium

#### Technology: Nuclear

The pressure to address carbon emissions from power production is leading to a potential resurgence of nuclear power plant construction. The US nuclear power industry was essentially halted following the mishaps at Three Mile Island in 1979. The appeal of nuclear is that the only atmospheric emission is water vapor, thus addressing the climate changes issue while providing a steady baseload power output on a large scale. The environmental trade-off, however, is the still unanswered question about the long-term disposal of the radioactive waste associated with a plant. Additionally, the public remains skeptical about the safe operation of such plants and concerned about the potential exposure to radioactive material.

Despite these issues, the NRC regulates over 100 existing nuclear power plants currently in operation for power production<sup>2</sup>. Additionally, a number of utilities, particularly on the East coast, have started the nuclear application process. While advances have been made in nuclear reactor technology over the last 30 years, NorthWestern has decided that inclusion of nuclear resources in the portfolio analysis would be premature at this time.

### Fuel: Tidal Power

---

<sup>2</sup> From [www.nrc.gov/reactors/operating.html](http://www.nrc.gov/reactors/operating.html)

### Technology: Various

These projects utilize the movement of water as a result of tidal power to generate electricity. There are a few examples of tidal projects that are constructed by blocking an estuary that utilize conventional turbine technology to generate electricity. The La Rance project in France is the largest at 240 MW and utilizes horizontally mounted bulb turbines for generation. It was constructed in the 1960s and is still in operation. Environmental concerns related to tidal barrages make it unlikely that this form of tidal power will be utilized in the U.S.

In 2006, EPRI published studies on the use of Tidal In-Stream Energy Conversion (TISEC). TISEC does not require a barrage, but is based on an open turbine construction, which in many cases resembles an underwater wind tower. Other potential designs include a shrouded turbine, with the shroud guiding the tidal flow through the blade, a helical blade design, or a vertical axis turbine. No commercial applications of these designs exist at this time, but a few pilot projects do exist. Marine Current Turbines, Ltd (MCT) constructed a single 300 kW experimental prototype off the coast of England and Verdant has installed prototypes in the East River in New York. Verdant is currently in the process of installing 6 more test units in the East River.

EPRI's study included an assessment of 7 sites in North America for commercial scale TISEC development, along with a cost projection based on information obtained from MCT. Three sites were identified on the West Coast – San Francisco Bay, Tacoma Narrows, and Knik Arm in Alaska. EPRI found that the Tacoma Narrows site had a commercial production capability of 121 GWh per year (13.8 aMW), which would be produced by 68 0.7 MW turbines (approximately a 30% capacity factor). Their estimates of commercial scale costs for this project are \$103 million for total plant cost with a yearly levelized O&M cost of \$3.8 million. At \$3.8 million, the O&M rate is \$31.4/MWh. The costs for the Golden Gate project were estimated to be significantly lower, mainly because the capacity factor at that project was estimated to be over 50%.

Tacoma Power has received a 3-year study permit from FERC for the Tacoma Narrows site, and worked cooperatively with EPRI in the Tacoma Narrows portion of their study. They are proceeding with more detailed study work related to the site.

Recently, Snohomish PUD has also received FERC permits to study seven other sites in the Puget Sound as potential TISEC development sites.

Fuel: Wave Power

Technology: Various

Wave power is a second form of potential power generation from ocean power and is also in the experimental stage. Potential forms of generators include oscillating water columns, overtopping barriers with turbines, floating devices that absorb wave energy at a single point, and long floating attenuators that absorb wave energy over the length of the device. The Pelamis wave generator is an attenuator generator built by Ocean Power Delivery Ltd. The Pelamis is currently being deployed off the coast of Portugal with 3 units (representing 2.25 MW) having been put into operation as the first phase of a project slated to reach 22.5 MW at completion. A 0.75 MW unit has also been undergoing testing off the coast of Scotland and in February plans were announced to build a wave farm, but the scope of the project is not clear. Other developers of wave technology include AWS Ocean Energy with their AWS (Archimedes Wave Swing – an oscillating water column), the WaveDragon (an overtopping device), Ocean Power Technology's floating buoy device, and Oceanlinx's (formerly Energetech) oscillating water column. All of these companies have deployed prototypes for testing purposes. In April, Oceanlinx announced plans to build a 15 MW wave park off the coast of Oregon and are seeking FERC permits. The Florence Wave Park will be expandable to 100 MW and will sell its power through power sales agreements with local utilities.

In September 2005, EPRI published a summary report titled “Offshore Wave Power Feasibility Demonstration Project”. EPRI reviewed the wave potential on the coast of the U.S. and worked up cost projections for the Pelamis unit deployed at different sites in the U.S. and the Oceanlinx unit analyzed for deployment in California only. The Oregon deployment of the Pelamis is estimated to cost \$235M for 180 units producing 300,000 MWh/yr, with an annual O&M cost of \$11M. A 10-year retrofit cost of \$23M was also estimated. The California deployment of the Oceanlinx technology was estimated to cost \$235M for 152 units (also producing 300,000 MWh/yr), with O&M costs at \$11M and a 10-year retrofit of \$15M. It should be noted that the EPRI study figured the average power flux at the Oregon site at 21.2 kW/m compared to the California power flux of 20.0 kW/m, meaning that the Oregon wave energy is, on average, stronger than the California site.

Fuel: Compressed Air Energy Storage

Technology: Various

Compressed Air Energy Storage (CAES) is a technology that has been in production, albeit only in two locations, for some time. The first was the 290 MW Huntorf plant in Germany, which was constructed in 1978, and the second was the 110 MW plant in Mackintosh, Alabama, which came on line in 1991. A third plant, rated at 2,700 MW, is slated for construction in Ohio.

CAES plants store energy by using electric compressors to pressurize underground storage caverns, which may occur naturally or be the result of abandoned mining or oil extraction operations. The compressed air can then be used in a couple different ways. One way is to generate using an air driven turbine-generator. Alternatively, and apparently more efficiently, the compressed air can be used to feed a natural gas fired combustion turbine and eliminate or minimize the need to consume fuel to compress air that is normally brought in the intake at ambient pressure. Reportedly, up to two-thirds of the energy consumed in CTs is used to compress the intake air rather than produce electricity. The net

effect on the turbine is a marked reduction in the heatrate. Of course, the CAES cycle is not 100% efficient, so there are losses to account for. The most straightforward manner would be to evaluate the resource contribution based on the ratio of energy input compared to energy output combined with the value of the energy input compared to the energy output. The energy output in a combined CAES/Natural Gas fired CT would be the energy output attributable to the heatrate improvement caused by the use of the CAES. Also, to the extent the CAES can support ancillary products, those values for reserves and regulation should be factored into the analysis.

Information about the efficiency of the CAES units is somewhat sketchy, as much of the recent literature is focused on combined Wind/CAES/Natural Gas CT and do not tend to break out the incremental components. Samir Succar of the Princeton Environmental Institute, in a presentation made in 2005, lists the "Round Trip Efficiency" as 82%. It appears from his calculations that this is the incremental contribution of the CAES in a hybrid CAES/Natural Gas CT.

#### Fuel: Hydro

#### Technology: Pumped Storage

Pumped Storage is similar in nature to CAES in that the power purpose of the facility is to store/reshape electrical power. The typical configuration for a pumped storage facility is a dual reservoir (upper and lower) with a set of pump/generators that can alternately pump water uphill from the lower reservoir to the upper and generate while releasing water from the upper reservoir to the lower. The technology is well-proven and feasible but requires the identification of a suitable site which to develop. Regionally, the Bonneville Power Administration operates pumped storage facilities at Banks Lake. These pump generators were put in place mainly to pump irrigation water from Lake Roosevelt (the lake impounded by Grand Coulee dam) up into Banks Lake, which serves as the head of the Bureau of Reclamation's irrigation project in Eastern Washington. The facility, however, was constructed with pump/gen units that can also

generate power when called upon. There may be sites in Montana suitable for this sort of development and with growing restrictions on the region's existing hydro-electric system, the need for new flexibility will grow. Pump Storage facilities have a round-trip efficiency similar to a CAES, in that about one-third of the energy total is sacrificed in round-trip efficiency losses (one storage and release cycle). In other words, for every 3 MWh used to pump water, you only get about 2 MWh back out on the generation cycle. This means that the generated energy needs to be 50% more valuable than the energy stored to add value in the reshaping of the energy.