Biennial Assessment of the Fifth Power Plan

Assessment of Other Generating Technologies

November 7, 2006

The purpose of this paper is to assess recent developments regarding new electric power generating resources for use by the Pacific Northwest and the possible significance of these developments to the Fifth Northwest Electric Power and Conservation Plan. The focus is on developments occurring since adoption of the Fifth Plan. For completeness, this paper summarizes the findings of the assessments of coal, natural gas and wind power, covered in more detail in specific papers.

The paper begins with an overview of generating resource development since adoption of the Fifth Plan. This is followed by an assessment of changes to the commercial status, cost or performance of the litany of new generating resource options. The paper concludes with a summary table of key developments, their significance and possible Council responses.

Resource Development Activity

A new cycle of resource development has occurred since adoption of the Fifth Plan (Figure 1). The Plan foresaw little need for new capacity prior to 2010, and recommended no major resource acquisitions other than 500 megawatts of wind to help confirm the resource potential. However, nearly 1900 megawatts of new capacity primarily wind and natural gas has entered service or is are under construction since adoption of the Plan. Wind plant construction is driven by extension of the federal production tax credit, the California renewable portfolio standard and high natural gas prices. Current thinking is that the wind production tax credit is likely to be extended, possibly for several years, but at a declining rate. In combination with the aggressive 2010 target of the California, this will likely lead to a continued rapid rate of wind power development in the Northwest. A preliminary estimate prepared for the Northwest Wind Integration Action Plan project is for 1200 to 2200 megawatts of wind power development from 2007 through 2009.

The natural gas capacity additions shown in Figure 1 were under construction at the time of Plan adoption. An additional 170 megawatts of natural gas capacity for serving growing peaking capacity is planned for 2008. The coal resource appearing in 2006 is the 116-megawatt Hardin plant, located in eastern Montana.

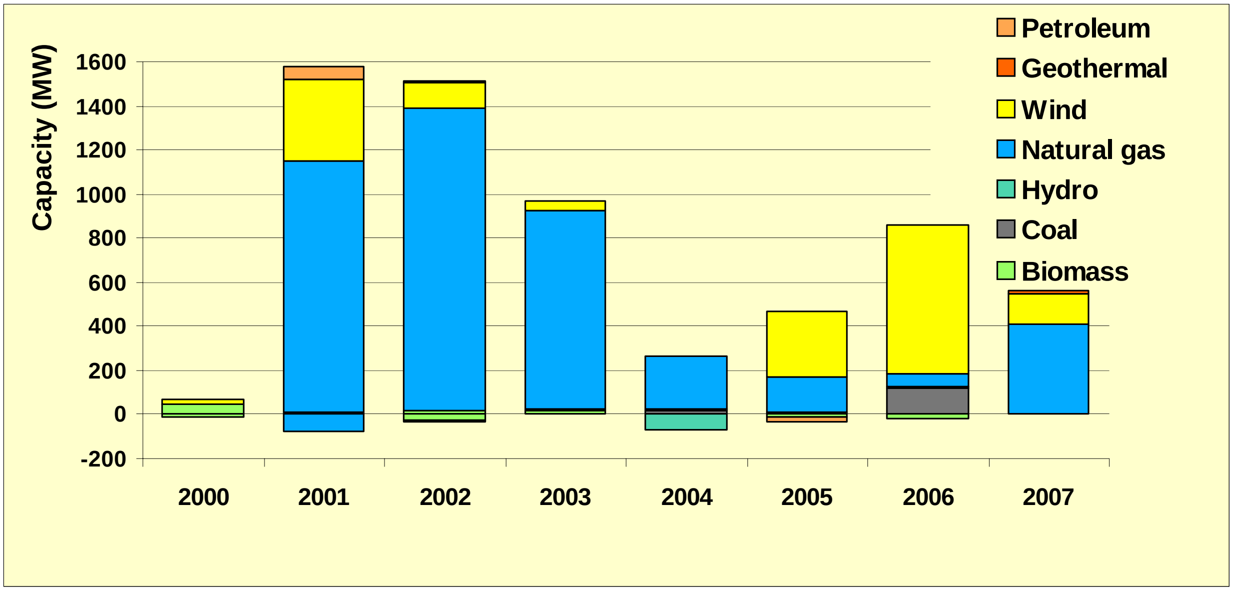

Figure 1: Pacific Northwest electrical generating capacity additions

Resource Status and Recent Developments

Biomass

Biomass generation currently represents about two percent (900 megawatts) of Northwest generating capacity. Though opportunities for expansion are diverse, the relatively high cost of new biomass capacity has resulted in only about 15 megawatts of new biomass generation since adoption of the Fifth Plan. The most feasible near-term uses of biofuels for electric power generation in the Northwest are expected to be landfill gas energy recovery, wastewater treatment plant and animal manure energy recovery and chemical recovery boiler upgrades. Other possible sources of biofuels include forest thinnings, agricultural field residues, municipal solid waste and energy crops. While available in large quantities in the Northwest, the high cost of generation using forest thinning residues may continue to constrain further development of this resource. It is possible that the development of processes for economically producing ethanol form cellulosic waste may divert forest residues to this application. Likewise, ethanol production may ultimately be the most economic use of agricultural field residues. Public opposition, high cost, and established municipal solid waste (MSW) disposal systems are likely to retard development of energy recovery from raw MSW. Much of the energy value of MSW, however, can be recovered by separating the clean combustible fraction for use as fuel. Though technically feasible, the estimated cost of producing electricity from dedicated hybrid cottonwood exceeds $100/MWh. The wood is more valuable as a fiber crop.

The most significant development regarding biofuels since adoption of the Fifth Plan has been acceleration of efforts to derive synthetic liquid fuels from energy crops and biomass residues.

Development of economic processes for converting cellulosic waste to ethanol could divert the fairly large bio-residue potential to liquid fuel production.

Coal

Coal-fired power plants represent about 14 percent (7560 megawatts) of Northwest generating capacity. Most of this capacity consists of large central station units completed between 1968 and 1986. Low coal prices, mature technology, limited availability of natural gas and nearly complete development of low-cost hydropower made coal a "resource of choice" during this period. Rising natural gas prices has renewed interest in coal-fired generation throughout North America. However, the choice of coal technology, fuel and site has become more complex. An array of technologies, carbon dioxide (CO_2) control policy, availability of petroleum coke, co-production options[1], mercury control, federal incentives, water and transmission availability and public perception all meld in the choice of coal technology, fuel and site. It is becoming evident that no single correct choice of technology or configuration exists for all situations.

The current status of coal-based generation is assessed in the paper *Assessment of Coal-fired Power Plant Planning Assumptions*. That assessment found: (1) advanced (super-critical) steam-electric coal technologies are entering the market more rapidly than anticipated; (2) the Fifth Plan capital cost assumptions for steam-electric technologies remain reasonable; (3) cost assumptions for integrated gasification combined-cycle (IGCC) power plants should be increased to account for the spare gasifier needed to achieve the availability expected of base load power plants; (4) availability assumptions for new coal technologies should be increased; (5) petroleum coke is becoming increasingly available as a fuel option for gasification plants; and (6) the efficiency of IGCC plants will be lower and the efficiency of supercritical steam-electric plants will be higher than previously thought.

Geothermal

The heat of the earth is naturally concentrated as hot water at certain near-surface locations, from which it can be economically captured and converted into electricity. Potential geothermal resource areas in the Northwest include deep vertical faults in the Basin and Range geological province in southeastern Oregon and Southern Idaho and shallow magmatic intrusions associated with Cascades vulcanism. Basin and Range geothermal resources have been developed for both power generation and for direct application in Nevada, Utah and California. The 13-megawatt phase I of the Raft River project in southern Idaho, when completed in 2007 will be the first commercial geothermal power plant in the Northwest.

Newberry Volcano, Oregon and Glass Mountain, California are the only Cascades structures offering geothermal potential not largely precluded by land use. Geothermal potential has been confirmed at Glass Mountain. Though projects have been proposed for these sites over the years, none have yet come to fruition. Overall Northwest geothermal potential is poorly understood. The estimate of the Fourth Power Plan, 340 to 3300 average megawatts with a most likely potential of 940 average megawatts, remains reasonable.

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[1] Co-production is the manufacture of electricity, hydrogen, and substitute natural gas, synthetic liquid fuels and other products from a common plant.

Only dated and uncertain geothermal cost information was available for the Fifth Plan. Because of this, and the uncertainty regarding Northwest potential, geothermal was not specifically included in the portfolio analysis. The developers of the Raft River project have recently published generic cost information that could be used to update the Council's estimates of geothermal cost and provide a sounder basis for considering geothermal in future portfolio analyses.

Hydropower

Though hydropower represents about 64 percent (33,560 megawatts) of Northwest generating capacity, most feasible sites have been developed. The remaining opportunities are for the most part small-scale and relatively expensive. In its Fourth Plan, the Council estimated that new sites might yield about 480 megawatts of additional hydropower capacity at $90 per megawatt-hour, or less. This capacity could produce about 200 average megawatts of energy. Some additional energy is available from upgrades to existing projects. The Council retained this estimate for the Fifth Plan, and concluded that few projects are expected to be constructed because of the high cost of developing most of the remaining feasible sites and the complex and lengthy licensing process. Overall, it appears unlikely that new hydroelectric development will be able to offset the loss of capacity and energy from expected removal of several older environmentally damaging projects.

The conclusion has largely been borne out. Three projects, totaling 25 megawatts of capacity have been brought into service since adoption of the Fifth Plan and no additional projects are currently under construction. While new hydropower is unlikely to become a major contributor to new resource needs, newer information is available regarding undeveloped hydropower potential. The Idaho National Laboratory (INL) as part of a nationwide assessment has identified 1315 sites in the four-state region with an undeveloped potential exceeding 8000 megawatts. Though it is not clear that this survey fully considered all constraints to development faced by new hydropower in the Northwest, the INL survey employed methods and information not available when the surveys upon which the Council's estimates are based were undertaken in the 1980s. A revised estimate of new Northwest hydropower potential could be prepared for the next power plan using the INL survey and other, more recent information.

Natural Gas

Natural gas combined-cycle power plants represent about 11 percent (5914 megawatts) of Northwest generating capacity. Simple-cycle units, valued for system reliability, regulation, load following and hydro firming, comprise about 3 percent (1654 megawatts) of Northwest generating capacity. Most of the combined-cycle capacity was completed between 1995 and 2004 when low natural gas prices and reliable, low-emission and efficient gas turbine technology made these plants the resource of choice. Higher natural gas prices have reduced the attractiveness of bulk power generation using natural gas and construction of only one large combined-cycle project has been initiated since 2001. That plant is the 399-megawatt Port Westward project, scheduled for completion in 2007.

The current status of natural gas power generation technologies are assessed in the paper *Assessment of Gas-fired Power Plant Planning Assumptions*. That assessment found: (1) the Fifth Plan assumptions regarding cost and performance of natural gas power plants remain representative of real-world experience; (2) possible needed capacity to maintain system reliability, and regulation and load following capability for the integration of wind power may result in the need for additional natural gas capacity prior to that identified in the Fifth Plan; (3) completion of currently suspended combined-cycle capacity may become attractive in the face of the cost increases being experienced for other new generating resources; and, (4) in view of the strongly cyclical market observed for natural gas and other new generating resources, future portfolio analyses might consider possible correlations between electricity market activity and resource capital costs.

Nuclear

At the time the Fifth Plan was prepared, future U.S. nuclear plants were expected to use advanced "Generation III+" designs such as the Westinghouse AP-1000. These are completely new designs employing passively-operated safety systems and factory-assembled standardized modular components. These features are expected to result in improved safety, reduced cost and greater reliability. In the Fifth Plan, the first North American Generation III+ plants were assumed to be operating by 2015, probably at southeastern sites, following which a decision might plausibly be made to proceed with construction with a new plant in the Northwest. That plant would see service by 2020 at the earliest. Because of the distant decision dates, a new nuclear option was not considered in the portfolio analysis and actions bearing on new nuclear plants were not included in the plan.

The Energy Policy Act of 2005 includes incentives for new commercial nuclear plants including a production tax credit, loan guarantees and insurance against construction delays. These incentives, plus high natural gas prices and greenhouse gas risk have motivated developers, mostly operators of existing nuclear facilities in southeastern United States to seriously consider construction of new nuclear capacity. As of August 2006, the Nuclear Regulatory Commission has received notices of interest for 27 potential new commercial nuclear projects. One, Constellation Energy has proceeded to order heavy components, but not for a Generation III+ plant. The components are for an enlarged (1600 megawatt) Generation III "evolutionary" design, an example of which is under construction in Finland. Another developer, NRG, has announced its intention to apply for a two-unit operating license for another evolutionary design, the General Electric Advanced Boiling Water Reactor, similar to units operating in Japan since 1996 and currently under construction in Taiwan. Generation III plants are refined versions of the current generation of nuclear plants. These developments suggest that the next U.S. plants will likely be evolutionary designs, rather than the full passively safe modular designs formerly thought to represent the next generation of U.S. plants.

The assumption that the earliest decision to proceed with construction of a new nuclear power plant in the Northwest would come no sooner than 2015 remains reasonable. Cost and performance assumptions for Generation III and III+ units and the proposed hydrogen co-production demonstration reactor at INL should be included in the next plan.

Ocean and Tidal Currents

The kinetic energy of flowing water can be used to generate electricity by turbines operating on similar principals to wind turbines, but more compact because of the greater density of water. Turbine energy yield is very sensitive to current velocity and little potential is available from the weak and ill-defined currents off the Northwest coast and in the Strait of Juan de Fuca. However, tidal currents of 3 to 8 knots occur locally in Puget Sound and estuaries along the Oregon and Washington coast could provide an economic source of energy as Tidal In-Stream Energy Conversion (TISEC) devices are perfected. A prototype machine was deployed at Race Rocks in British Columbia in September and the deployment of the first two turbines of a six turbine pilot plant in New York City's East River is planned for November. Twenty-nine requests for preliminary permits have been filed with the Federal Energy Regulatory Commission, including sites in the Tacoma Narrows, Deception Pass and the San Juan Islands. A feasibility study of the Tacoma Narrows site concluded that a commercial project could yield about 16 average megawatts at $72 to $90/MWh (2005 dollars, including federal production tax credit). Commercialization of this resource will require development and production of TISEC machines suitable for extended reliable and efficient operation under fully-submerged conditions. Other issues needing resolution include system integration, environmental impacts, installation and maintenance procedures, cost uncertainties and public acceptance. Though the potential Northwest resource would be of limited size (tens to low hundreds of average megawatts), TISEC plants would have predictable though intermittent output, low aesthetic profile and could provide local distribution system support. The resource should be more fully assessed in the next power plan. The current plan contains an action (GEN-17) supporting the development and commercialization of new renewable technologies such as wave power and TISEC.

Ocean Thermal Gradient

An ocean thermal energy conversion (OTEC) power plant extracts energy from the temperature difference that may exist between surface waters and waters at depth. Megawatt-scale OTEC technology has been demonstrated in Japan and Hawaii, but practical application of the technology requires a temperature differential of about 20^{o} C (36^{o}F), or greater. Temperature differentials of this magnitude are limited to tropical regions extending to 25 to 30 degrees of latitude. Ocean thermal temperature differentials in the Northwest range from 0 to 12^{o}C (0 - 20^{o}F) precluding operation of OTEC technology.

Petroleum

Petroleum-derived fuels such as propane, distillate and residual fuel oils are too costly for bulk electric power generation in the Northwest. Distillate fuel oil and propane are used as backup fuel, plant startup, for peaking or emergency service power plants and for power generation in remote areas. About 90 megawatts of capacity primarily fuelled by petroleum fuels are in service in the region.

Petroleum coke ("pet coke") is a solid carbonaceous residual product produced by thermal decomposition (cracking) of heavy residual oils during refining. This product consists mostly of carbon and small amounts of hydrocarbons, sulfur and ash and trace quantities of metals. Increasing use of heavier crudes and more efficient processing of refinery residuals has resulted in rapid growth in US and worldwide production of petroleum coke. Additional supplies are becoming available from Alberta oil sands synthetic crude production. Green coke[2] can be used directly as fuel, or further processed for use as a raw material for the manufacture of electrodes

[2] Coke directly from refinery coking units.

for the smelting of metals. A 65-megawatt cogeneration project at the Exxon Billings refinery uses petroleum coke as fuel.

Petroleum coke has a superior heating value compared to lower-rank coals and a very low ash content. However, most of the sulfur, inert materials and heavy metals present in the crude feedstock are concentrated in the coke, making it an environmentally unattractive fuel for conventional boilers. For this reason, petroleum coke has historically been priced at a discount to coal. An attractive approach for recovering the energy value of coke is to convert it to a synthetic fuel gas in a gasification plant. The sulfur can be removed from the raw synthesis gas using standard processes. Metals are embedded in the gasifier slag or removed in the syngas coarse particulate removal and scrubbing process. Some refineries now employ gasification plants to process coke into higher value products. Since release of the Plan, Energy Northwest has proposed constructing a 600-megawatt gasification combined-cycle power plant at Kalama on the lower Columbia River. The plant would use petroleum coke from Puget Sound refineries possibly in combination with other coke and coal supplies as feedstock.

Because of the increasing availability of petroleum coke and the availability of gasification technology to use this fuel, a forecast of the future price and availability of petroleum coke should be added to the next power plan.

Salinity Gradient Energy

Energy is released when fresh and saline water area mixed. Conceptually, the energy potential created by fresh water streams discharging to salt water bodies could be captured and converted to electricity. The technologies to do so are in their infancy, and it is not clear that current concepts would be able to operate off the natural salinity gradient between fresh water and seawater as present at the mouth of the Columbia and other rivers. Although the theoretical resource potential in the Northwest is substantial, many years of research, development and demonstration would be required to bring these technologies to commercial availability.

Solar

The best solar resource areas of the Northwest - the inter-mountain basins of south-central and southeastern Oregon and the Snake River plain of southern Idaho - receive about 75 percent of the solar energy received at the best Southwestern sites. However, because of latitude and climate, the Northwest solar resource exhibits strong summer seasonality. While desirable for serving local summer-peaking loads, the Northwest resource is not coincident with general regional loads. There has been no regional assessment resource potential, though it is likely there is sufficient developable resource to support any feasible demand[3].

The use of small photovoltaic arrays to generate electricity is widespread and has been encouraged in the Northwest by state incentive programs. While economic for small isolated loads, bulk photovoltaic power is currently much more expensive than power from competing sources. The present-day cost of bulk power from photovoltaics was estimated in the Fifth Plan to be $250 per megawatt-hour, compared to $33 - 46 per megawatt-hour for other bulk power

[3] An assessment developed by the Western Governor's Association Clean and Diversified Energy Initiative was limited to the deployment of central station solar thermal plants in the Southwest.

sources. Photovoltaic costs have historically declined at about 8 percent per year on average and capacity addition studies using the AURORA model suggested that bulk photovoltaic generation might become economically competitive in the Northwest about 2025 (and sooner in the Southwest) if this rate of cost reduction was sustained. Strong demand and increasing material costs have recently reversed the declining trend in photovoltaic prices. Module prices rose three percent in real terms between 2004 and 2005, though this is a modest increase compared with cost increases incurred by many other generating resources. Over the long-term, increasing demand should lead to increasing economies of production. Also, technology developments promise more efficient use of materials. These factors should lead to continued decline of photovoltaic costs over the long-term.

Solar thermal technologies employ concentrating devices to create temperatures suitable for driving thermal engines. Concentrating thermal technologies are currently less costly than photovoltaics for bulk power generation. They can also be provided with energy storage or auxiliary boilers to allow operation during periods when the sun is not shining. Concentrating solar thermal technologies require high levels of direct normal solar radiation for most efficient operation and are best suited for Southwest conditions. Over 350 megawatts of concentrating solar thermal capacity was constructed under favorable contracts in California during the 1980s. Following a 15-year hiatus, a one-megawatt plant was recently completed by Arizona Public Service Company. A much larger (65-megawatt) plant is under construction in southern Nevada.

Fifth Plan assumptions regarding solar generation remain consistent with long-term expectations.

Tidal Energy

Tidal energy can be captured and converted to electricity by means of hydroelectric “barrages” constructed across natural estuaries. These admit water on the rising tide and discharge water through hydro turbines on the ebb. The key requirement is a large mean tidal range, preferably 20 feet or more. Suitable sites with tides of this magnitude occur only in a few places worldwide where landforms amplify the tidal range. Economic development of tidal hydroelectric plants in the Northwest is precluded by insufficient tidal range.

Wave Energy

Three wave energy projects have been proposed in the Northwest. Each would initially consist of a small demonstration array of wave energy converters. These could be expanded to commercial-scale if the technology and site proves feasible. Though the technology is still in the pre-commercial stage, wave energy could be a major player in the Northwest. The theoretical wave power potential of the Washington and Oregon ocean coast is estimated to 3,400 - 5,100 megawatts for near-shore sites and 21,000 megawatts for offshore sites. Wave power converters are expected to have an efficiency of at least 12 percent, suggesting a technical potential of up to 2,500 megawatts, though only a portion of this potential is likely to be available because of navigational, aesthetic or ecological concerns. Wave power in the Northwest is winter peaking with a seasonal factor of 20. While the Council concluded that it is unlikely that commercial wave power projects will become widespread during the period of the Fifth Plan, development of the technology is accelerating and a full review of wave power cost and technical potential should be prepared for the next plan.

Wind Power

With completion of projects under construction, wind power will have grown to about 3 percent of regional capacity (1730 megawatts) for zero ten years ago. Factors contributing to the recent acceleration in the growth rate of wind include sustained high natural gas prices, climate change concerns, the federal production tax credit (PTC), and state renewable portfolio standards (RPS). Adoption of proposed RPS for Washington and Oregon would sustain current rates of development. For the Fifth Plan, the Council assumed 6000 additional megawatts of wind potential consisting of 1000 megawatts of committed resource and 5000 megawatts of discretionary resource. All 5000 megawatts of discretionary wind capacity were included in the recommended resource portfolio. The action plan recommended near-term development of 500 megawatts of wind power to resolve uncertainties associated with large-scale development of the resource. Actual development has greatly exceeded this recommendation.

Earlier this year, in response to Bonneville and utility concerns regarding significant cost increases, the Council released the paper *Assessment of Near-term Wind Power Plant Planning Assumptions*. That assessment found a 50 to 60 percent increase in wind project capital cost over the past four years principally from increased commodity and energy costs, a weak dollar and escalating demand for wind power equipment and services. These factors have been offset to some extent by higher capacity factors and somewhat more favorable financing. The focus of the paper was on short-term costs and the long-term persistence of higher costs was not addressed. Long-term effects are uncertain. Commodity and energy costs are historically cyclical and are likely to decline over the next several years as global production capacity is increased, substitutes introduced or currently strong demand weakens. A significant unknown is continuation of strong economic growth in East Asia.

A prolonged weak dollar should increase investment in domestic wind turbine production capacity, as would long-term extension of the PTC and broader adoption of state renewable portfolio standards. Continued strong demand should also increase the availability of specialized transportation and erection equipment and skilled construction and operating personnel. While political support for the PTC appears to be strong, extension at current levels will increasingly conflict with the federal budget deficit. Immediate termination of the PTC would suppress demand for a period, reducing costs. On net, wind capacity costs may remain high for the next several years, and then resume their historic downward trend. Offsetting this trend may be declining site quality. As better sites are developed, interconnection and integration will become increasingly expensive and wind quality may diminish.

Bonneville, the Council and the region’s utilities recently launched the Northwest Wind Integration Action Plan project. The initial phase of this project seeks to improve the understanding of the ability and cost of integrating the wind capacity expected to be developed within the next several years using existing system capabilities. A subsequent phase will identify the most cost-effective means of expanding transmission, load following and regulation capability to integrate the much larger amounts of wind capacity envisioned in the longer-term. The results of the project are expected to become available beginning in early 2007.

Transmission and Remote Resources

The Fifth Plan assessment of Alberta oil sands cogeneration was the first Council assessment of resource potential external to the Region. Though not included in the recommended portfolio, oil sands cogeneration was sufficiently attractive for the Council to recommend that additional study be undertaken of the transmission costs of importing power from remote locations. Since adoption of the Fifth Plan, the Northwest Transmission Assessment Committee (NTAC) of the Northwest Power Pool has undertaken several scoping studies of major transmission expansion options. Completed studies include Eastern Montana to Northwest load center corridors and Western Canada - Northwest - Southwest corridors. These studies have yielded better information regarding the cost, capacity and possible location of transmission to access remote resources. Assessments undertaken for the Western Governor's Association Clean and Diversified Energy Advisory Initiative have yielded new information regarding the cost and potential of new coal, wind, hydropower, biomass, combined heat and power, geothermal and solar resource potential in the West. The new transmission and resource information will provide the basis for expanding the scope of future Council resource assessments.

Summary of Recent Developments

Table 1 summarizes recent developments and new information regarding new generating resources. For completeness, the findings of the separate papers on coal, natural gas generation and wind power are included here. Items are listed in general order of priority with respect to possible near-term impacts on Plan recommendations.

Table 1: Summary of recent developments regarding new generating resources.

Development	Significance	Possible Council Response	Timing
Better information regarding coal-fired plant availability, efficiency and cost	Timing of coal in resource portfolio; technology recommendations.	Update coal-fired technology availability, efficiency and cost assumptions. Test effects on portfolio	Near-term
Wind development greatly exceeding levels called for in Plan	Sufficiency of integration capability Timing of non-wind resources	(1) Keep Wind Integration Action Plan project on fast track (2) Add assessment of system flexibility[4] augmentation options to plan	(1) Near-term (2) Following completion of Wind Integration Action Plan
Better information regarding wind cost and resource potential, transmission & integration	Role of wind in longer-term; need to secure transmission & integration capability.	Update wind power planning assumptions. Test effects on portfolio.	Following completion of Wind Integration Action Plan
Growing summer peak loads	Possible need for suitable supply or demand-side capacity in addition to energy-driven needs identified in Plan	Broaden assessment of system capacity needs and options	Next power plan
INL assessment of undeveloped hydropower	Possible expansion of estimated potential	Update estimate of new hydro potential	Next power plan
Increasing availability of petroleum coke	Inexpensive feedstock for IGCC plants	Forecast pet coke cost and availability Assess pet coke/IGCC plant cost and performance	Next power plan
Better information regarding remote resources and transmission	Expanded inventory of new resource options	Expand assessment of remote resource options	Next power plan
Notices of intent to license, equipment orders for new nuclear units; proposed co-production reactor at INL	Role of nuclear in longer-term	Update nuclear planning assumptions	Next power plan
Better information regarding cost of "CO2-ready" IGCC plants	Role of coal-fired plants in longer-term	Prepare estimates of the cost and performance of "CO2 ready" IGCC	Next power plan
Wave power demonstration projects	Role of wave power in longer-term	Update wave power planning assumptions	Next power plan
Tidal current power demonstration projects	Future role of tidal current power	Update tidal current planning assumptions	Next power plan

[4] "System flexibility" includes regulation (sub-hourly) and load following (hourly and longer) capability, provided by generating capacity and possibly by demand response measures.

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