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CEATI INTERNATIONAL Inc.
1010 Sherbrooke Street West, Suite 2500
Montreal, Quebec, Canada H3A 2R7
Website: www.ceati.com

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TECHNOLOGY REVIEW:
QUANTIFYING THE NON-ENERGY BENEFITS OF HYDROPOWER

Prepared by
GEI Consultants, Inc.
Lake Oswego, Oregon, USA

Principal Investigators
John, J. Pizzimenti, Ph.D., Project Manager
Darryll Olsen, Ph.D., Resource Economist

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Technology Coordinator
Alistair Wilson, P.Eng

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ABSTRACT

North American hydro power owners have historically been competing in a world of relatively inexpensive carbon-fuelled electricity from coal and gas. New U.S. energy policies on the licensing and operation of hydro plants have been increasingly trading energy and ancillary benefits of hydro for non-energy benefits including difficult-to-monetize benefits for endangered species and fish passage. Many small hydro projects have non-energy benefit costs that exceed the value of the energy generated. For example, the FERC (Federal Energy Regulatory Commission) licensing process no longer uses water resource economics and costs to make judgements in these trade-offs, but simply subtracts energy benefits to fill requested but unmeasured non-energy trade-offs.

The rapid growth of wind energy favoured by federal policies has led to the use of hydropower to firm wind generation, diminishing hydro's capacity to provide reserve power. This threatens the reliability of all electrical transmission. This technology review report explains the problem and monetizes the values of energy and non-energy benefits in comparable (2008) dollars. Properly communicated and explained, it will make policy makers, utility managers and regulators aware of this growing problem. It offers the opportunity to more appropriately value the unique contribution hydropower can make toward a better total North American energy policy.

Keywords:
Hydroelectric Power, Non-Energy Benefits, Federal Energy Regulatory Commission, Ancillary Electrical Benefits, Water Resource Economics, Hydropower Regulatory Policy

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EXECUTIVE SUMMARY

Stated succinctly, politicians, legislators, and regulators of all stripes frequently undervalue or casually take for granted hydro project benefits. Those who regulate hydro project operations often lose sight of the broad value base that brought the projects into being and continues to make them highly valuable assets. The erosion of sound economic policy applied to hydro has its roots in the 1980's, a time when electric power, especially hydropower in the Pacific Northwest, was abundant, relatively cheap and reliable. There was an exaggerated platitude at the time that public power at 1.5-3 mils was "too cheap to meter." It is no longer cheap and its future reliability is becoming questionable.

The first order of sound business, or policy, is to ensure that all benefits are quantified—and the "balance sheets" are prepared. This report will quantify the benefits and communicate these benefits as financial assets that can be readily displayed to boards of directors, legislators, and regulators. Project benefits take the form of both market and non-market values.

From the market perspective, the most pronounced economic benefit from hydro projects is energy or electric power. Closely related, and different from most other sources of energy supply, is hydropower's ability to rapidly change the amount of electricity being delivered (dispatched) into a power system in seconds, minutes, hours, days or weeks. This ability has major benefits commonly referred to as "ancillary" electrical benefits. These are quite special to hydroelectric power.

Because most hydropower systems are able to store water (hence have potential energy and water supply available on call), hydropower provides significant sources of other societal benefits linked to water supply. Pump stations at hydro project reservoirs serve irrigation, municipal, and industrial water supplies which form the very basis of a viable economy. Reservoirs also provide flood control.

Hydropower projects host another very broad set of non-market societal benefits within the recreational and environmental sectors. These can take the form of opportunities for active recreation (boating, swimming, fishing), passive recreation (hiking, sightseeing, bird watching) and fish and wildlife enhancements dictated by both federal (such as the Endangered Species Act) and provincial (local) mandates. These types of benefits often are non-market in character in that regulations require hydropower to provide the opportunities, facilities, lands, access, water supply, safety and the operations and maintenance costs to facilitate social benefits. The costs of these benefits appear to be "free" to the public. Relicensing trends show the costs for new license hydropower are nearly as much and sometimes more than the energy the project produces. Thus society, wittingly or not, is trading energy and capacity benefits for the very installations that make some of the "free" benefits possible and electricity reliable.

In the United States, the Federal Energy Regulatory Commission (FERC) regulates and mandates many of the resource allocations hydropower owners must meet. Similar organizations and policies exist in Canada and other developed nations. It is beyond the scope of this study to assess all international hydropower regulations. Suffice to say that the US and Canada have highly regulated hydropower resources and reflect tradeoffs and potential economic consequences that can be compared elsewhere. The World Commission on Dams suggests that in third world countries, inadequate attention to socio-economic conditions is a significant issue.

In the United States, current FERC protocols on economic valuation are no longer based on national economic development (NED) accounting or conventional water resources economics. Instead, an avoided-cost approach determines net energy benefits, without considering the direct net benefits of specific "non-energy" measures from each economic sector. The general approach is that hydro should pay for other types of project benefits (mitigation), until the energy costs are equal to the avoided costs of other power resources (coal, etc.). From FERC's perspective, the project owner should be indifferent, as long as the hydro project costs are equal to or less than the avoided cost. FERC even licenses projects whose energy is less than the avoided costs leaving the question of decommissioning to the owner. This approach tends to undervalue or erode the energy benefits and increase or overvalue the non-energy benefits of all energy sources, but especially hydro. This study uncovered costs of both "applying" and "living with" new licenses issued by FERC along with the non-energy trade-offs. The costs for mandatory (agency) conditions increase the cost by 300 percent. FERC itself made the startling observation that process costs of obtaining a license are nearly 30 percent of the actual non-energy trade-offs implemented.

Largely due to the growing complexity surrounding regulatory actions (federal laws trumping federal laws) and growing environmental regulations, the hydro industry has difficulty in effectively communicating societal value of hydro "electrical" benefits. Despite efforts of the National Hydropower Association, the Canadian Hydropower Association, the International Hydropower Association, other advocacy groups, and their many educational outreaches, the erosion of hydropower energy benefits is real. Part of the problem is communicating complexity of ancillary benefits in the face of half-truths of environmental benefits and society's expectation of "free" non-energy benefits.

So what are the economic benefits and the trade-offs? This report presents numeric tables for three distinct regions in North America that present monetary value ranges inherent to hydro projects for the energy and non-energy benefits of each region. The values are defined; the sources are public information and documented in a bibliography. The data are also displayed in graphical form depicting all the values inherent in a typical hydroelectric project and the weighted contribution of hydro to those values.

In summary, there are many societal values linked with hydropower. The original value (energy) is being transformed into other societal values at the cost to energy supply primarily by changes in federal laws and regulations. Because energy is the oldest market and arguably the most liquid of these various benefits, it is easily valued but unwittingly valued against generic energy from coal or traded for non-energy benefits whose values are veiled, unrecognized and mostly un-monetized. Collectively, all these represent the total benefits ascribed to hydro projects.

Within the bounds of energy policy, decision makers including FERC and other regulatory bodies should resist making unsubstantiated trade-offs between economic sectors. To avoid these policy or regulatory pitfalls, hydro project managers must shine a bright light on project benefits (monetized values), and how economic sector trade-offs affect social well-being of society as a whole. Monetizing benefits and communicating them effectively is a major step toward that end. This report identifies and quantifies values and markets in three regions of the North American electrical grid.

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North American hydro project owners and operators have historically been competing in a world of moderately priced carbon-based energy from oil, coal, and gas; and via other mid-range cost power resources such as conservation and load response measures. At the same time, hydro power operators have suffered increasing energy benefit trade-offs from non-energy benefits at their projects, with little recognition received for the true economic values or impacts at play. Concurrently, greater demands have been placed on the dispatch and use of hydropower resources.

In addition to their facile dispatch characteristics, hydro projects provide tangible social benefits in areas related to water supply, fisheries, recreation, navigation, irrigation, and other environmental goods. Hydro power is usually the power system operator's first choice for dispatching resources to serve reserve power needs, or providing an increasing demand for load-following capability where variable supply renewable resources are involved. The impact to hydro power from these "reserve" and "environmental" benefits comes both in the form of lost opportunity costs, usually "hidden" to ratepayers in generally higher power costs, and in internal power system savings and marginal power cost sales. It is often a mixed accounting ledger at best.

Yet it is fundamentally necessary to ensure that all the entries on the "balance sheet" are made, otherwise poorly informed decisions will be rendered and net social welfare and equity will be unnecessarily lost. Failure to make and recognize proper resource values will cost nations, regions, and households real money.

Conveying hydro projects' value to net social welfare and equity is an important objective of this technology review report. The direct route to pursue this objective is through the explicit monetization of project benefits and associated values—turning products and services into market-based dollars. There are well developed and technically respected methods to do so, which are reviewed and applied within this report.

2.0 ISSUES AND REGULATORY-POLICY IMPLICATIONS

Stated succinctly, politicians, legislators, and regulators of all stripes frequently undervalue or casually take for granted hydro project benefits. Those who govern hydro project operations often lose sight of the broad value base that brought the projects into being and continue to make them highly valuable assets. The erosion of sound economic policy has its roots in the 1980's, a time when electric power, especially hydropower in the Pacific Northwest, was abundant and relatively cheap. A combination of political and economic shocks led to major pieces of legislation that began to trade these hydropower reserves. The Electric Consumer Protection Act (1987) reduced FERC's diminishing powers to balance energy and environment. FERC licensing has become a contentious, protracted and expensive "group think" with powers shared by multiple agencies and the public. This caused an escalation of the costs of licensing, changing regulations and the led to diminishment of energy and capacity hydropower resources that are increasingly traded for social benefits (c.f. FERC 2001). The Energy Policy Act (1992), likewise, affected transmission and capacity to deliver energy and expunged regulated markets leading to a complex of differences among regions, transmission areas and states. These two laws and the ensuing complex of regulatory changes together with a larger population demanding more energy from a diminishing and more constrained resource led us to where we are today.

Prevalent issues affecting the recognition hydro project benefit quantification are expressed below.

2.1 Adequate Valuation and Monetization

Economists will argue that the best way to measure equitably the benefits (and costs) of public and private purposes is through monetization—converting the purpose or item into a universal measure of value: money. Hydro project benefits are no different than other public and private resources used by individuals and society to obtain net social welfare (subsistence, prosperity, and happiness). As a matter of sound public policy, it is through explicit quantification and careful accounting of benefits (and costs) that decision makers and resource managers guide their decisions.

So the first order of sound business, or policy, is to ensure that all benefits are quantified—and the "balance sheets" are prepared. This report will quantify the benefits and respect (organize) these benefits as financial assets that can be readily displayed to boards of directors, legislators, and regulators. The report can be used to help policy makers understand that we have gradually traded many of the electrical benefits available to the public for non-electrical ones, but without monetization.

2.2 Adequate Consideration of All Direct Net Social Benefits

Project benefits take the form of both market and non-market values. From the market end of things, the most pronounced economic benefit from hydro projects is energy or electric power. Closely related but different from most other sources of energy supply is hydropower's ability to rapidly change the amount of electricity being delivered (dispatched) into a power system in seconds, minutes, hours, days or weeks. This ability has major benefits commonly referred to as "ancillary" electrical benefits. These benefits have become monetized in electrical markets as a result of the Energy Policy Act of 1992. This is a benefit of rapidly increasing importance unrecognized by most of society and one in which we are incurring greater diminution at significant risk to the reliability of the system.

Because most hydropower systems are able to store water (hence have potential energy and water supply available on call), hydropower provides significant sources of other societal benefits linked to water supply. Pump stations at hydro project reservoirs serve irrigation, municipal, and industrial water supplies which form the very basis of a viable economy. Here the water supply markets (availability and delivery costs) dictate product types and values. Thus, hydropower often has the direct societal benefit of providing water supply. It is important to recognize that some reservoirs are constructed primarily for water supply, and hydropower is an ancillary benefit to that primary economic need. But in many cases, the two provide coequal benefits, or water supply is the ancillary or secondary benefit. Proper economic analyses recognize these facts.

Reservoir storage can also provide the opposite benefit of water supply, and that is to protect against too much water by controlling floods. Flood control economics are factored into societal benefits separately and are often linked with hydropower in large storage reservoirs. Often, flood control benefit is traded for other benefits including power generation and endangered species, water quality and aquatic habitat protection (see below).

Hydropower projects host another very broad set of non-market societal benefits within the recreational and environmental sectors. These can take the form of opportunities for active recreation (boating, swimming, fishing), passive recreation (hiking, sightseeing, bird watching) and fish and wildlife enhancements dictated by both federal mandates (Endangered Species Act; Electric Consumer Protection Act, National Environmental Policy Act, Clean Water Act) or state and local regulations that afford similar protections. These types of goods often are non-market in character in that the regulations require hydropower to provide the opportunities, facilities, lands, access, water supply, safety and the operations and maintenance costs to enable the public to enjoy these benefits. The costs of these benefits appear to be "free" to the public. These environmental benefits have been growing rapidly since passage of the Electric Consumer Protection Act and seem to some to be burgeoning out of control. In Appendix A, we present an example where the environmental benefits consume over one-third of the energy benefits in a recent FERC License. Review of FERC license conditions reveal many examples where the energy benefits have been completely consumed by the restoration of environmental benefits leading to a net societal loss from the projects. In some cases, the costs to the owners are so great as to lead to decommissioning. Thus society, wittingly or not, is trading energy and capacity benefits for the very installations that make some of the "free" benefits possible.

One of the most recent "societal benefits" attributable to hydropower is its ability to reduce carbon emissions that are potentially affecting climate change. This is another most recent benefit and nascent market place driven by new federal laws responding to concerns over global warming and its link to carbon emissions. There are a few limited market places for trading of carbon allowances and being converted to monetary form. An interesting fact is that despite an "Armageddon-like" press, the market for carbon credits appears extremely weak as of August 2009.

In short, there are many societal values linked with hydropower. The original value (energy) is being transformed into other societal values at the cost to energy supply, primarily by changes in federal laws and regulations. Because energy is the oldest market and arguably the most liquid of these various benefits, it is the most easily valued. These other benefits are less liquid, less visible, less easily monetized. None of the market or non-market value benefits should be neglected or discounted. They represent the total benefits ascribed to hydro projects. This report will help identify and quantify the values and markets for all these benefits.

2.3 Adequate Consideration of Electric Power Ancillary Benefits

The versatile nature of hydropower capacity and energy makes it an unmatched resource for meeting variable demand conditions and scheduled and regulated loads; and a formidable back-up for unscheduled emergency conditions. With increasing power resource constraints and costs, the value of hydro project ancillary power products is becoming more apparent.

For example, increasingly low capacity-factor and variable generation resources—such as wind power—are significantly diminishing the availability of hydropower resources for generation reserve services (load-following, spinning and non-spinning reserves). While wind power may act as a contributor to energy—perhaps like demand response resources—it does not viably contribute to capacity. Consequently, either load-following and/or reserve resources must be dedicated to wind, eliminating existing hydro power resources for reserve dispatch.

The need for greater load following capability, or reserve peaking capacity, also becomes more necessary as residential demand becomes a large share of system loads. Large blocks of manufacturing or industrial base loads are being displaced by growing residential loads, with more disparate system load peaks.

Whenever possible, power managers turn to hydro power to acquire the ancillary power products required to meet these system demands. One other common energy supply, namely natural gas fired turbines, has the ability to provide short term (peak) energy similar to hydropower. But they have few of the other benefits of hydro, and due to the rising fuel costs have become increasingly less competitive with hydro. Furthermore, there are few places that gas that can match hydropower in capacity. What gas offers over hydropower is a more rapid permitting process because it has less affect on natural rivers, which is a resource of diminishing availability which the public places value. However, hydropower has lower carbon emission than gas fired turbines.

2.4 Misapplications of Water Resources Economics

In the United States, the Federal Energy Regulatory Commission (FERC) regulates and mandates many of the resource allocations with which hydropower owners must comply. Similar organizations and policies exist in Canada and other developed nations. Current FERC protocols on economic valuation are not directly based on national economic development (NED) accounting or conventional water resources economics. The agency uses an avoided-cost approach to determining project power benefits, without considering the direct net benefits of specific “mitigation” measures from each economic sector. We suspect this same approach is used in Canada and wherever “environmental mitigation” is considered the “cost” of doing business, without assessing the benefit in economic terms. The general approach is that power should pay for other types of project benefits (or mitigation), until the project (power) costs are equal to the avoided costs of other power resources. From FERC’s perspective, the project owner should be indifferent, as long as the hydro project costs are equal to or less than the avoided cost.

This approach tends to undervalue or erode power (or project) benefits and increase or overvalue mitigation costs. For example, if the mitigation costs for a project do not equitably match its mitigation benefits, then simply adding costs that must be off-set by power benefits reduces the overall direct net benefits to society. Or constraints are placed on power production that not only reduce firm power benefits, but affect ancillary power benefits that may not be adequately taken into account by the regulators. The story is even more onerous for many marginal existing small projects, because an owner is faced with even larger costs to “decommission” an uneconomic project. This is less than a zero sum game for hydropower and national energy policy.

FERC is not alone in engaging in this practice, but their project “cost-effectiveness” approach is more explicitly visible. In several regions, project operation costs—costs to society—are veiled from monetization by Endangered Species Act or other federal acts such as the Clean Water Act provisions, where neither the true costs of mitigation effectiveness nor power impacts is transparent to decision makers or rate payers.

2.5 The Cost of Inattention to All Hydro Project Values

Largely due to the growing complexity surrounding regulatory actions—and its corresponding perceived political and “anti-environmental image”, the hydro industry has difficulty in effectively communicating societal value of hydro “electrical” project benefits. Despite efforts of National Hydropower Association, Canadian Hydropower Association, International Hydropower Association, and many educational efforts, the erosion of hydropower energy benefits is real. Part of the problem is the complexity of understanding the technical challenge of delivering safe reliable power in the face of half-truths and hidden costs that dams are bad and kill fish and destroy rivers. It is especially difficult when electricity prices are low and reliability is high.

The basic answer to this growing problem is that the stakes are too high to not bring these economic realities and the trade-offs into clearer focus. Sound public or societal fiscal policy will not manifest from incomplete information. Rate payers and their elected representatives should be given a full accounting of how hydro project benefits affect their fiscal well-being from both environmental and energy perspectives.

Within the bounds of energy policy, decision makers including FERC and other regulatory bodies should resist in making unsubstantiated trade-offs between project-affected economic sectors. To avoid these policy or regulatory pitfalls, hydro project managers should shine a bright light on project benefits, and how economic sector trade-offs affect social well-being. Monetizing benefits and communicating them effectively would a major step toward that end.

3.0 NON-ENERGY BENEFITS OF HYDRO—SOME DEFINITIONS AND CLARIFICATIONS

In general, there are two major groups of energy benefits from hydro: those that directly provide power (electricity) for the end user; and those that help maintain and deliver power and keep the power system grid in working order (generally called "ancillary" benefits). And then there are non-energy benefits that utilize the fuel (water) or its storage for other purposes and hence reduce or trade off reliability or availability of electrical energy, capacity or efficiency. We call this second group "non-energy benefits." Non-energy benefits are useful to society but do not all have the same market values and liquidities Categories of benefits range from use of water for out of river purposes (water supply) to instream environmental benefits to flood control both can be beneficial for downstream protection of human and wildlife habitats. There is a third type of newly conceived non-energy benefit which emerges from government regulations imposed on utility portfolios to reduce carbon emission. Nascent markets now exist to buy carbon credits from generators of non-carbon emitting resources (wind, solar, geothermal, and hydro).

Ancillary Benefits – Background and Basic Definitions

FERC defined six ancillary services as a result of the Energy Policy Act of 1992:

- Reactive Power: Voltage Control is the energy needed to maintain the transmission system in a ready (charged) condition to transmit power. Such power can be produced and absorbed by generators and the transmission system and reduces available energy for other purposes
- Loss Compensation: the energy and capacity that is lost and must be replaced within the transmission system as it is delivered from generator to user. Analogous to leaks in a water supply system, energy losses vary by time and location.
- Scheduling and Dispatching: Scheduling is the anticipated use of energy and capacity to pre-determined locations. Dispatching is the actual "real time" allocation of that energy and capacity to meet load in designated service areas. Differences can create inefficiencies in the market place.
- Load Following: the continuous balancing of resources versus load under control of transmission providers accomplished by increasing / decreasing generation. FERC suggests this control should be under control of Regional Transmission Providers
- System Protection: the reserve energy needed to maintain the transmission system in the face of large unscheduled outages from unit failures or transmission failures. It differs from load following which balances large aggregated minor changes versus isolated incidents of large changes. The former changes slowly allowing time to react and easily maintain proper line voltages; the latter happens rarely but can shock the system and cause major outages (brownouts or blackouts) across wide areas. Spinning and non-spinning reserves are the primary tools or services of System Protection. They must be held for emergency purposes like a bank account and therefore have a marginal cost.
- Energy Imbalance: the difference between the energy generated and the energy delivered (metered). Methods of compensation are arbitrary and not universally accepted.

- Black Start: is not defined as an ancillary resource however it is critical to restoring power to a grid after a local or regional outage occurs. Black start is the ability to restart electrical transmission without local power from the grid. Generally, it comes from diesel generators that can open gates at hydroplants and start and electrify turbine-generators. Because hydro requires only small generators to black start by opening water conductors (coal plants and nuclear plants would require much larger capacities), hydro becomes the "match" that can "restart the furnace" when the fire has gone out. It is unclear whether this "service" has any market value, but it clearly has societal benefits and costs including: capital cost of the equipment, the O&M costs, and storage and use of fuels.

There are a number of ways to slice or define ancillary electrical benefits, and existing markets reflect the above FERC definitions but have evolved, as markets do with maturity, since the regulations were enacted. Actually, ancillary benefits vary by region and political boundaries reflecting the local markets and regulations. Controversies exist for ancillary services among public power providers, municipalities, rural cooperatives, independent power producers, utilities, electrical consumers, regulators and the public including: precise definitions; how much service is needed to maintain reliability; whether that service can and should be provided in a competitive marketplace or should be regulated; whether sellers or providers can be outside a buyer's transmission service area; and whether the services provided can be accurately and fairly metered and applied to the end users' equitably. Differences among states and regions complicate the use, delivery, pricing and opportunities in the marketplace for these services within and among areas. It may be one of the larger societal issues as we overburden existing resources. Nonetheless, there are markets and prices for services which we will define and show monetary values in the final sections of this report.

3.1 Ancillary Costs Estimated by Models

Ancillary and non-power benefits trade availability and efficiency of generating and transmission equipment. Plant optimization software can compute and recommend how to efficiently dispatch and load the units in a plant to meet the plant's base point (plant contribution to system load with these non-energy factors). If units in the plant are on Automatic Generation Control or AGC, optimum utilization of the plant is unlikely unless the optimization software can automatically (theoretically) move all of the units dynamically. This is unlikely, so the result is reduced plant efficiency and loss of revenue. Further, spinning reserve, vars, voltage control, and environmental and water management constraints affect operating flexibility and reduce hydro's ability to efficiently extract energy from water resources.

The cost of an Ancillary Benefit is estimated by comparison with optimized operation that produces the same amount of energy and capacity without these constraints. The value is estimated by comparison with the costs of the same services provided by non-hydro facilities in the system. Thus, the operation's optimization software at the plant and system levels is an essential tool for determining the cost (and hence minimum theoretical market value) of these services. Although the cost does not determine the market, if a generator knows his costs, he can determine if he wants to trade off the other benefits if he has such choices. In some cases, local or regional legislation commands, especially public projects like the Federal Columbia River Power System to meet specific services regardless of the market place. BPA will attempt to optimize such transactions but this does not necessarily mean it is doing it cost-beneficially; only cost-effectively.

3.2 An Increasingly Expensive and Diminishing Resource: Energy from Hydropower

Relicensing studies for FERC projects routinely use computer models to estimate the energy costs of non-power constraints. Unfortunately, the industry is unable to place these costs into their rate bases because we have (at least in some areas) moved to a "competitive" or deregulated energy market place, but one in which the generating assets are highly regulated by the licensing process. Thus, every time FERC or any government agency mandates a new "non-energy benefit" in a license, such as an increased minimum flow, there is no way the owner or operator can recover the cost because it becomes a "free" benefit to the customers. Energy, which has a market value, is traded for fish or recreation whose economic values are not usually monetized and balanced with the energy traded. Unfortunately, this places hydropower energy supply on an increasingly uneven and "downward sloping" playing field with other energy sources. The trade-offs are supposedly negotiated in the licensing process, but many if not all of the final conditions are mandatory from a participating regulatory agency, if not FERC itself. And again, there is no "economic value" associated with the trade-off for energy; only a tacit and "supposedly free" societal value. Of special note in our example FERC project (Appendix A), the agency's request discontinuation of ancillary benefits. These would convert nearly two-thirds of the project benefits to a non-energy benefit intended to reduce stranding juvenile fish. FERC rejected this agency's recommendation in issuing the new license. The cost of operating Priest Rapids in the new license has expanded from $69 million annually to over $146 million annually, most of which emanates from the list of environmental requirements in the new license (Appendix B). The net value of the hydropower benefits declined about 25%.

4.0 RECENT FERC LICENSING COSTS AND TRADE-OFFS ASSOCIATED WITH NON-ENERGY BENEFITS

We perused recent examples of new licenses issued by FERC. The final conditions for the license are published along with the estimated costs associated with all the non-energy benefits in the Federal Register. Additionally, FERC has estimated the costs of obtaining the license as well and these are not trivial (Section 603, Energy Act of 2000). Prior to the passage of the 1987 Electric Consumer Protection Act, FERC "balanced" the energy and non-energy benefits based on "recommendations" from outside agencies and the public. After 1987, new regulations permitted non-energy focused agencies (U.S. Forest Service, National Marine Fisheries Service and U.S. Fish and Wildlife Service, and State Water Quality agencies) to dictate the licensing study process and final FERC license conditions; hence balance was suddenly shifted away from energy to non-energy values. Unfortunately, the non-energy benefits were not evaluated by standards of water resource economics that developed these resources in the first place.

4.1 FERC Examples of Energy Trade-offs for Non-Energy Values

We selected the Priest Rapids Development (FERC No. 2114), an 1898 MW development on the mid-Columbia River to illustrate a real world example of the process of trading non-energy benefits for energy benefits including ancillary benefits (Appendix A). This 1893 MW project, initially licensed in 1955, received a new license in April 2008 from FERC. Environmental costs of 120 items are tabulated on 11 pages and cost aggregately $123 million annually for a 30 year period. The total energy benefits are $350 million, leaving a net $227 million. Translated into MWh values for the project, the total energy value of the project is $38/MWh and the net value of the project energy with operating under the license conditions is $23/MWh or a net environmental/operating cost of $15/MWh or nearly 40 percent of the energy. Since about 10 million of the annual operating costs are not environmental, the trade-off is approximately $14/MWh or 36 percent of the energy value.

4.2 Ancillary Benefits at Priest Rapids and Potential Costs

Ancillary Benefits were examined in this license proceeding by two agencies who requested that the project forego load following to protect fish. FERC rejected this request and explained in its Order Issuing License why it is denying modification of this electrical benefit as follows:

"92. CRITFC and Alaska DFG recommend that the licensee maintain a daily flow fluctuation range of 10 thousand cubic feet per second (kcfs) in the Hanford Reach to reduce stranding and entrapments during the fall Chinook salmon rearing period. While…such a limitation would likely result in lower levels of juvenile fish stranding…it would reduce the project's ability to provide regional electrical system support and load-following capability and would reduce annual generation by 1,320 MW. …The cost of replacement power would be approximately $136 million per year. …the restriction requested by CRITFC and Alaska DFG are not warranted."

Comment: This one ancillary benefit of load following, had it been eliminated, would have doubled the environmental cost from $123 million to $259 million, resulting in a trade off of an additional $16/MWh to a net project electrical benefit $7/MWh, a figure approaching zero net-energy benefits for a 1994 MW plant.

4.3 FERC Licensing Costs and Affects on Energy Benefits

Pursuant to the Energy Act of 2000, FERC evaluated the cost and effects of licensing on energy from hydropower projects (FERC, 2001). There are two costs: the cost of "studies" and "process" in a new license and the cost to implement the changes. The "study-process" costs average $2.3 million or $85/kW; the implementation costs average $212/kW. Pre-filing costs (studies and agency consultation costs) run as high as $39 million (North Umpqua Project); and $20 million (Hells Canyon Project). Combined, they add an average of $297/ kW to the burden of operating hydropower plants. Projects with mandatory conditioning average 300 percent higher in costs than those without mandatory conditioning. The average generation loss per license is 1.59 percent and the average capacity loss per license is 4.06 percent. The net present value (npv) of licensing is $4.22/kW. The average FERC costs (burden) are $0.93/kW and the average agency burden to licensing is $0.25/kW. Combined, the npv of these agencies' burden is $3.33/kW. FERC itself noted that it is startled that the process costs are nearly 30 percent of the actual non-energy benefits implemented. The trend is that hydropower net energy values are decreasing and being traded for process costs, which in turn are trading energy benefits for non-energy benefits.

5.0 SO WHAT ARE THE ECONOMIC BENEFITS?

The economic benefits of hydro projects are tied to several important economic sectors. These include: a broad array of electric power products; stable access to water supplies for the irrigation, municipal, and industrial demands; diverse recreational activities; flood control; water borne commercial navigation; and several indirect environmental goods and services. Figures 5-1 and 5-2 provide a "synthetic" example of the energy and non-energy benefits of a "hypothetical" hydroelectric project in North America. The values for each benefit reflect the detailed data that follow. But the proportion of each in the example is arbitrary because they do not represent any one plant or average condition. For example, not all projects will have navigation benefits. Each facility will have a different and unique combination of energy and non-energy benefits. Later in the report, we provide a specific example (1994 MW Priest Rapids Development) of the costs and benefits of all the energy, ancillary and non-energy benefits (Appendices A and B). It will be possible to analyse specific projects for individual plants as a follow up study should sponsors desire.

While the numeric tables that follow estimate more precisely the monetary value ranges inherent to hydro projects (across broad regions), Figure 5-1 conveys more simply the multiple economic benefits offered by medium-scale projects sited throughout the U.S. and Canada. This "example" might represent a 500 megawatt, run-of-the-river (limited storage) project that: 1) offers boating and fishing opportunities for both flat-water and flow-regulated conditions; 2) provides irrigation water for about 20,000 acres; 3) is used for shallow-draft barge river navigation transportation; 4) supplies drinking water and industrial cooling water to local municipalities; 5) provides firm and non-firm power products for daily loads, scheduled regulation requirements—all to meet native and intersystem loads; and 6) is increasingly called upon to firm-up "renewable" resources or displace other power resources that have larger "carbon footprints."

For this "example" hydro project, the proportional economic benefits from each sector are depicted in Figure 5-2. Here the contributions of both market value sectors (power and water supply) and non-market sectors (recreation and some environmental benefits) can be considered. Although every hydro project possesses a different proportional mix of economic benefits, hydropower usually dominates the benefit scale, typically followed by water supply and recreation values.

For any specific project, more detailed table values may be used to assess site-specific benefits—both in terms of benefit types and value levels, and proportional benefit contributions among sectors. Or more refined benefit values can be determined for a site-specific project. Again, individual owners can modify this example to match their own plant or portfolio of hydroelectric projects. Such an example then could be used to lobby regulators or legislators to change the ways they value the assets and benefits in the licensing process.

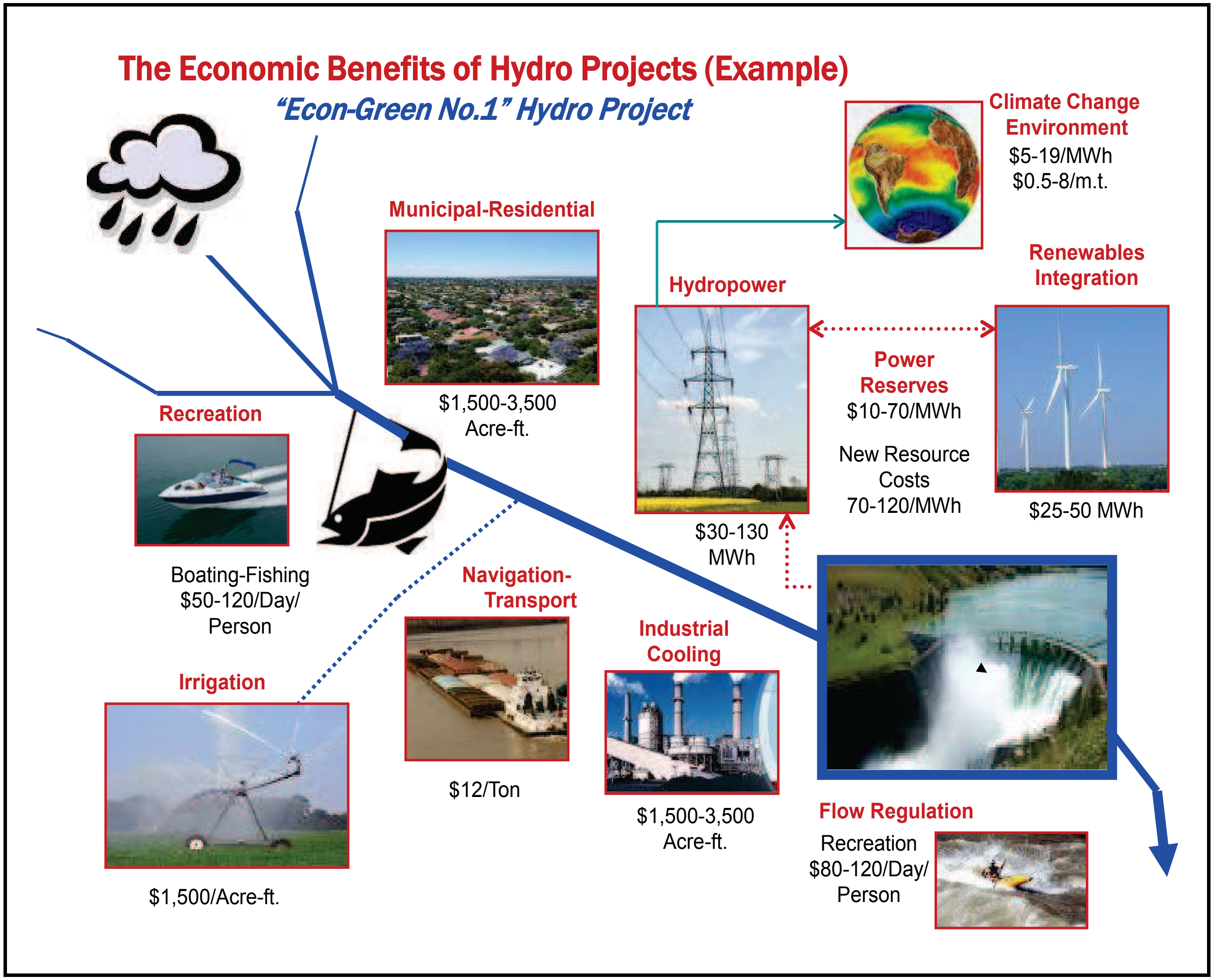

Figure 5-1 Economic Benefits of Hydro Projects-Example

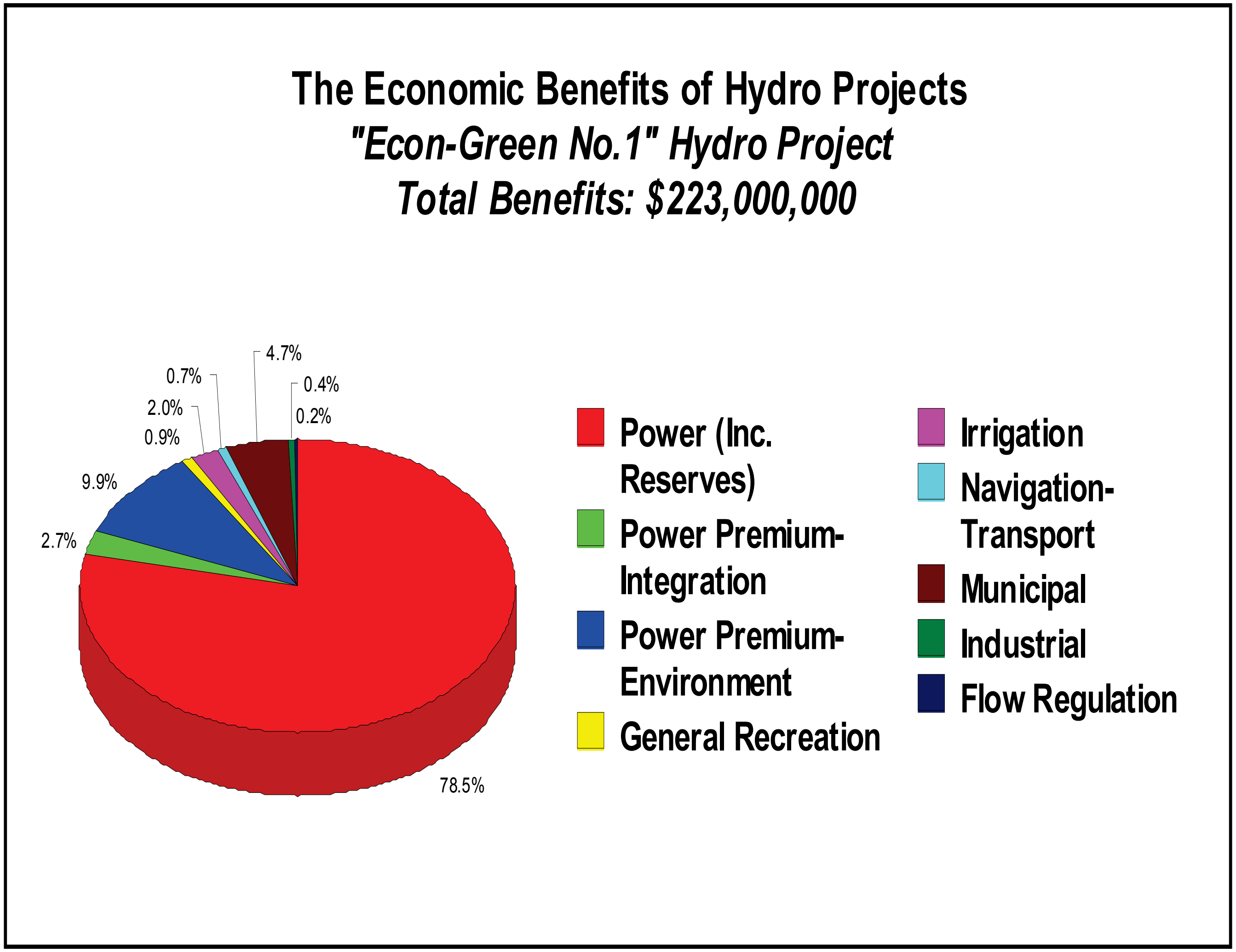

Figure 5-2 Economic Benefits of Hydro Projects-Example

6.0 TABLE VALUES AND INFORMATION

6.1 Economic Values and Data Sources

The economic values displayed within the tables below are principally derived from the sources listed in the following, selected bibliography/literature review. This review includes formal publications, and specialized technical papers from agency, academic, and private sector reports, studies, and technical documents. All of the literature reviewed or cited is publicly available per university libraries, internet websites, or from direct requests to indicated sponsors.

Also, where possible and data allow, estimates are reflective of regional conditions. This allows for a more appropriate application to specific hydro projects throughout the U.S. and Canada.

6.2 Economic Assumptions and Descriptions in the Data Tables

<u>Constant 2008$</u>: The economic values are adjusted to 2008 dollars (2008$) from their reference or published base year, using the U.S. Bureau of Economic Analysis GDP implicit price deflators (www.bea.gov). This adjustment seeks to present comparable values to today's dollars, even though substantive changes in value, within a specific economic sector, may occur over time.

<u>Present Value and Discount Rates</u>: Where applicable, a present value estimate is used to bring the cumulative stream of future annual values (monetary benefits) to one present value, reflecting today's dollars. Among other things, this allows for different costs and benefits to be compared equitably over time; or it can bring sharply into focus the magnitude of the benefit (or cost) stream.

Two items determine net present value: 1) the time horizon of the benefit or cost stream; and 2) the discount rate applied to each future year. Based on a recent review of hydro project life-cycle and financial costs, a 40-year net present value period is adopted here; with a 3 percent real discount rate, representing a "social rate of time" perspective toward monetary benefits and costs. A social rate of time perspective is applied in order to better capture a "true" social perspective toward hydro project benefits, thus respecting inter-generational equity considerations. In effect, more weight is given to future benefits than would occur under a strict "financial return" perspective, where a higher discount rate would be employed.

<u>Direct Net Values</u>: Both market and non-market values are expressed in terms of direct net value, unless specified as regional economic income (secondary values) or some other measure. Direct net values (national economic development (NED) account values) depict measures of direct net economic efficiency or net social welfare gain to the direct (national) economic base. They are related to the direct economic sectors (or actors) involved, and compose the drivers to other economic sectors within the economy: usually buying or selling goods and services to the direct sector. Direct net values affect the net national economy—regardless of a project's regional location—while secondary (income) values tend to focus on local or regional impacts. Consequently, NED accounting is based on direct net value.

Direct net values all have one key characteristic in common: they reflect an individual's, or societal, willingness-to-pay for a specific good or service. This is true for goods and services either measured monetarily within market transactions (such as hydropower or irrigation water supply), or for items that require non-market valuation techniques to ascertain a dollar value (such as sport fishing or boating).

Secondary or Regional Economic Values: Secondary or regional income (or employment) values take into account direct and secondary income effects related to a specific area, whether national or regional in scope (regional economic development, RED accounting). Secondary effects take into account the impacts to local and regional economies derived from changes to the direct net economic sectors (and values). For example, the direct net value per day for the recreational sport fishing sector may be about $100 (direct net value attributed to national economic development), but the total regional income impacts of the actual spent dollars may be about $200/day. The direct net value represents net economic benefits to the sport fisher alone (quantified in dollar terms), while the secondary value identifies the fisher's spent dollars and their multiplier effect throughout the regional economy.

NED and RED Values: National planners or agencies are principally interested in net economic benefits to society, whereas regional economic values are of most interest to state and local governments, and regional income beneficiaries—particularly when federal funds or regulations for projects are involved. The presence of NED benefits ensures that a net economic gain to society has occurred, and RED benefits usually mean that some regional location (or economic subsector) is the recipient of said direct and secondary income benefits within the broader society. Consequently, NED values hold project (or public agency) decision makers to a higher level of "discipline" than RED values, when making decisions including a hierarchy of economic analyses and impact assessments.

6.3 Economic Sector and Value Description

The table values refer to common economic sector designations within the technical literature. This includes the following sectors:

Recreation: The recreation sector is composed of several activities, such as sport fishing, flat water recreation, sight-seeing, and other forms of recreation related to hydro project reservoirs. Recreation (or sport) values presented here are based on non-market valuation estimates using various forms of either contingent valuation (CVM) methods (survey-willingness to-pay techniques) or travel cost (TCM) models (relying on survey and other data sources). These CVM or TCM estimates attempt to simulate market-like transactions, where willingness-to-pay can be measured for various recreation (sport) activities.

CVM estimates attempt to define net wiliness-to-pay for an activity through direct survey questions and arcane statistical techniques. TCM attempts to build a demand curve for an activity with expenditures for the trips estimated. Within either method, the value to be determined is an expression of net value (consumer surplus) to those participating in the activity.

Even for the same types of sport activities, the value ranges can vary greatly depending on location and recreation quality. Consequently, we attempt to clarify some of the value range distinctions where warranted.

Land Management: The land management values are presented as either the capital value or annual lease value of the land per acre affected by (controlled by) reservoir development. This can include land for direct sport use, or for residential recreation opportunities.

Irrigation: The irrigation values depicted here are based on dollars per acre-ft. of beneficially used water. They primarily represent either market value for water right transfers (sales), or the value equated to irrigation resulting from the capital land price difference between irrigated versus non-irrigated ground. Also, some estimates reviewed are based on farm enterprise/production budgets for some locations, taking into account an average net value (return) to ownership assigned to irrigation (water).

Flood Control: Flood control economic values are based on the avoided damages per flood event, per acre-ft. of available flood control storage. These estimates are difficult to make and are usually general in nature; they should be considered as a "lower range" estimate. No attempt is made here to project these values over time (frequency) with multiple events, which would increase the net present value of the flood control benefits.

Two key factors govern the value assigned to flood control benefits: 1) the value of properties, goods, and services prevented from damage (avoided cost); and 2) the volume of water assigned for flood control benefits. In some cases, the latter estimate may be based on a percentage of active (reservoir) storage available, or the incremental amount of emergency storage available from a run-of-the-river project.

Municipal: These value estimates are expressed in dollars per acre-ft. Municipal water supply values are based on two features: 1) the cost of purchasing alternative water supply sources or water rights from irrigated agriculture; or 2) the costs of delivering water to municipal demand from existing or new hydro project reservoirs (for example, an inter-basin pipeline project). This provides a two-staged value range.

It also should be noted that conservation practices are usually adopted first, prior to either water market purchases or building new water delivery systems; but conservation is seldom a stand-alone option for meeting increasing water demand.

Industrial Cooling: These value estimates are expressed in dollars per acre-ft. Industrial cooling water costs (value) are usually equal to or less than the municipal water supply costs (value). Industrial cooling may have the same point of withdrawal as a municipal pump station, but it may not necessarily be using treated potable water. So being, the general value is best reflected in a range between irrigation and municipal water values.

Navigation/Transportation: Water-borne navigation (NED) values are usually based on the (avoided) alternative cost of transportation for industrial and commercial products. This is usually derived from either rail or truck freight rates for specific regions. For example, on the Columbia-Snake River system, water-borne navigation (NED) values reflect the avoided costs of higher rail or trucking rates from the Inland Washington, Oregon, and Idaho region to the Portland distribution and receiving centers; and the estimated costs of new, supporting transportation infrastructure.

Climate Change/Environmental Values: These values are usually assigned as "costs", within NED type analyses, and are "imbedded" within the value of the resource power value: society's willing-to-pay for a specific power resource. However, these values are portrayed here to define, to some degree, the intangible, net environmental benefits gained from hydro project operations.

Power (Energy-Low Load Hours): The power values depict near-term acquisition conditions. Energy values are based on scheduled resources used to meet minimum load demands during a specified low-load period (low-load hours of the system), separate from resources dispatched for peak system demand needs. This represents the base load over a specific time, or seasonal, period.

Hydropower projects are usually used to meet some level of base load demand, along with other integrated projects within the system.

Power (Energy-Demand Peaking): The power values depict near-term acquisition conditions. Peaking power resources (values) are scheduled resources used to meet daily and weekly, high-load hour demands. These resources are also used to meet demands during high-load periods of the year that are primarily driven by weather conditions, but sometimes power or transmission outages or other economic factors affecting the load. Sources to meet peak loads typically include hydropower projects, gas combustion turbines, and system market purchases.

Large conventional storage and pump-storage hydropower projects are often used for meeting peak power demands. They have operational flexibility to supplement base loaded coal-fired and nuclear power plants that are inefficient sources to vary output. In most systems, hydropower projects are integrated into a multiple resource system and provide both base load and peaking power. Increasingly, hydropower is being used to "firm" new wind and solar generation because of its unpredictable or limited temporal availability. You cannot dispatch wind if it is not blowing or solar when it is dark. Contracts to dedicate hydro to these resources are subtracting from its capacity to serve other purposes such as transmission stability and system back up. To the extent that other environmental requirements from hydro are restricting ability to "peak" on demand (cf. FERC 2001), these too are constraining the availability of "on peak power." As this problem evolves, the market place will change. Although wind currently accounts for less than 3 percent of U.S. energy, projections are for rapid growth in the next few years. In 2007, there were less than 17,000 MW of wind; currently that number has nearly doubled to nearly 30,000 MW. Conventional hydropower provides about 78,000 MW (7 percent) of the U.S. energy. Hydropower capacity is not growing anywhere near as rapidly as wind.

Power (Demand-Capacity): The dollar value per installed kW of power to meet a maximum load. The value (cost) reflects an ability to meet load, regardless of whether the resource is being fully dispatched to full operating capacity.

Power (Load Shaping): Load shaping involves the management of resources to conform to meeting specific loads, and it can involve a single project operation or often augmenting other power resource projects. It is considered as a fixed, yet flexible, resource capability separate from meeting peak power demands.

Hydropower projects are particularly suitable for load shaping needs, as this usually requires marginal changes to storage/flow releases. In recent years, load shaping for the integration of wind resources has been met with available hydropower resources (where flexibility allows).

Power Reserves (Spinning): Spinning reserves are generating capacity available on demand (within minutes or fractions of minutes) and can be scheduled (or unscheduled) resources (generators) already integrated or operating within the power system; or power resources capable of being immediately retracted or redirected from servicing other system loads (such as some types of limited, interruptible power contracts). Most power systems must secure some spinning reserves from their own power resources.

Non-spinning reserves are generating capacity that is "off-line" but capable of system integration within minutes.

Hydropower projects often may have some available spinning reserve capability depending on demand and water conditions. So being, the value of the spinning reserve power is the opportunity cost of dispatching (real-time) the power elsewhere; or at a minimum, the operators internal capital/variable costs of operation spread over the period of power dispatch. An often overlooked aspect of spinning reserves and peaking operations are the additional risks of unplanned unit outages of those peaking units themselves from the additional wear and tear of start stop operations. The revenue stream loss plus the reduced system capacity during outage repairs can be very substantial, albeit highly infrequent and unpredictable. Along with restoration costs, these are not trivial when the unit's sizes are of multiple hundred MW capacities. Thus this is another "benefit" in which the true cost may be veiled by the infrequency of outages.

Power Reserves (Supplemental): Supplemental reserves refer to available on demand resources that can be made operational with a short time period (about one hour). This can be considered as a scheduled (or unscheduled) resource, and can include available project capacity or real-time market purchases. Supplemental reserves may be dispatched to replace spinning reserves. Hydropower projects can be particularly useful for providing supplemental reserves, as well as spinning reserves.

Depending on overall system demands, the value of the power is the opportunity cost of dispatching (real-time) the power elsewhere.

Power (New Resources): In some systems, serving new load growth (demand) may be valued at a "new resource" rate, reflecting the marginal power costs of actually constructing new power projects, or securing future, long-term power supply contracts through market purchases.

Non-firm hydropower can be sold at what amounts to "new resource" rates depending on system, or inter-system, market conditions.

Power (Market Hedging): Power values related to hedging usually refer to long-term (multi-year) power sales contracts secured to avoid the purchase costs of presumably more expensive resources in the near future. For example, a power purchaser may "lock-in" today a resource power rate that exceeds current marginal power costs with an expectation that future year costs will significantly escalate. This type of market hedging activity is common among all types of power users.

Power (Voltage Stability-Control): Measured as an ancillary service to maintain voltages within safe and economically viable ranges, accounting for voltage control costs is becoming more important among systems with large-scale transmission (power market) inter-ties, and where highly variable (or erratic) power resources are integrated into an established power system—like the introduction of new wind resources. Among other actions, providing for adequate system voltage control can require additional reserve capacity to provide additional voltage support capacity, and resources to meet real-time contingency operating conditions. The actual resource costs "assigned" directly to voltage control can vary greatly, and must be separated from resource costs assigned more directly to load following.

Hydropower can be, and is, used to provide voltage stability for regional power system inter-ties, and for the integration of substantial new wind power resources.

6.4 Benefit Transfers and Economic Valuation

A fundamental assumption underlying an application of the table economic values to regional (or other areas) is that of consistent "benefit transfers." This assumption holds that the economic values derived from one type of economic activity are representative of other, generally similar types of economic activity—although location, timing, and other features may differ. While the specific applicability of benefit transfers is often debated within the technical economic literature, the approach is generally accepted as a conventional (necessary and pragmatic) practice for economic valuation studies and various economic impact assessments. Benefit transfers assume that the value derived from the same kind of economic activity in one area is roughly equivalent to the values exhibited in another area.

Figure 6-1 BC-Hydro and Northwest-West Region

Figure 6-2 BC-Hydro and Northwest-West Region

Tables of Economic Values for Energy and Non-Energy Hydro Resources in the Pacific Northwest and British Columbia Region.

Economic Sector	Direct Net Value	Annual Value Net Value	Annual Regional Income $	Direct Net Present Value $
Recreation: Sport Fishing	$118/Day (High-Range) $46/Day (Low Range)	$118/Day (High-Range) $46/Day (Low Range)	$150-210/Day (Mid-Range, Direct-Sec.)	NA
Boating and General Flat-Water Recreation; and Other Reservoir-Related Activities	$89-108/Day (High Range) $41/Day (Low Range)	$89-108/Day (High Range) $41/Day (Low Range)	$100-200/Day (Mid-Range, Direct-Sec.)	NA
Land Management	$10,000-30,000/Acre (Mid-Range)	$700-2,200/Acre (Lease)	NA	$10,000-30,000/Acre (Mid-Range)
Irrigation	$1,125-1,500 Acre-ft. (Cap.)	$130 (Annual Lease)	$840Acre-ft. (Annual)	$1,125-1,500 Acre-ft. (Cap.)
Flood Control	>$260/Acre-ft.	>$260/Acre-ft.	>$500/Acre-ft.	NA

Table 6-1 Recreation, Land Management, Irrigation and Flood Control Benefits of Hydropower

Primary Sources: FERC 2007; USBR 2006, 2008; USACE 2002, 2005; UW 2004; Loomis 2004; Olsen, et al., 1992, 1994; Pacific NW Project 2008.

Economic Sector	Direct Net Value	Annual Value	Annual Regional Income $	Direct Net Present Value $
Municipal	$1,125-3,500 Acre-ft. to $7,000 Acre-ft.	$130/Acre-ft. (Lease)	>$100,000/ Acre-ft.	$1,125-3,500 Acre-ft. to $7,000 Acre-ft.
Navigation/ Transportation	> $10/Ton	> $10/Ton	------	> $10/Ton
Industrial Cooling	$1,125-3,500 Acre-ft.	$130/Acre-ft. (Lease)	>$100,000/ Acre-ft.	$1,125-3,500 Acre-ft. to $7,000 Acre-ft.
Climate Change/ Environment	$5-10/MWh	$5-10/MWh	Annual Dir. Net: $30-60 Million Per 1,000 MW Installed Cap.	Present Value-- Annual Dir. Net: $650 Million to $1.3 Billion Per 1,000 MW Installed Cap.

Table 6-2 Municipal, Navigation, Industrial, and Environmental Benefits of Hydropower

Primary Sources: FERC 2007; USBR 2006, 2008; USACE 2002, 2005; UW 2004; Loomis 2004; Olsen, et al., 1992, 1994; Pacific NW Project 2008.

Economic Sector	Direct Net Value	Annual Value	Approx. Annual Value/1,000 MW Installed Capacity	Direct Net Present Value $
Energy (LLH)	$37-52/MWh	$37-52/MWh	$265 Million (Energy-Demand)	$6.3 Billion (Energy- Demand)
Energy (Peak HLH)	$45-57/MWh	$45-57/MWh	$265 Million (Energy-Demand)	$6.3 Billion (Energy- Demand)
Demand	$1.50-2.40/kW/m	$1.50-2.40/kW/mo	$265 Million (Energy-Demand)	$6.3 Billion (Energy- Demand)
Reserves (Spinning)	$9-57/MWh	$9-57/MWh	______	______
Reserves (Supplemental)	$9-57/MWh	$9-57/MWh	______	______
Back-Up Load Shaping	$23-58/MWh (Energy)	$23-58/MWh (Energy)	______	______
Back-Up Load Shaping	$1.90-2.80/kW/mo (Demand-Cap.)	$1.90-2.80/kW/mo (Demand-Cap.)	______	______
Market Hedging (Flat)	> $45-51/MWh	> $45-51	______	______
NR Energy (LLH)	$32-60/MWh	$32-60/MWh	______	______
NR Energy (LLH)	$44-84/MWh	$44-84/MWh	______	______
NR Demand	$1.50-2.75/kW/mo	$1.50-2.75/kW/mo	______	______
Voltage Control Stability	= > $0.50-3/MWh	= > $0.50-3/MWh	______	______

Table 6-3 Energy and Electrical Ancillary Benefits of Hydropower

Primary Sources: BPA 2009; NPPC 2009; Energy News Data 2009; NRU 2009.

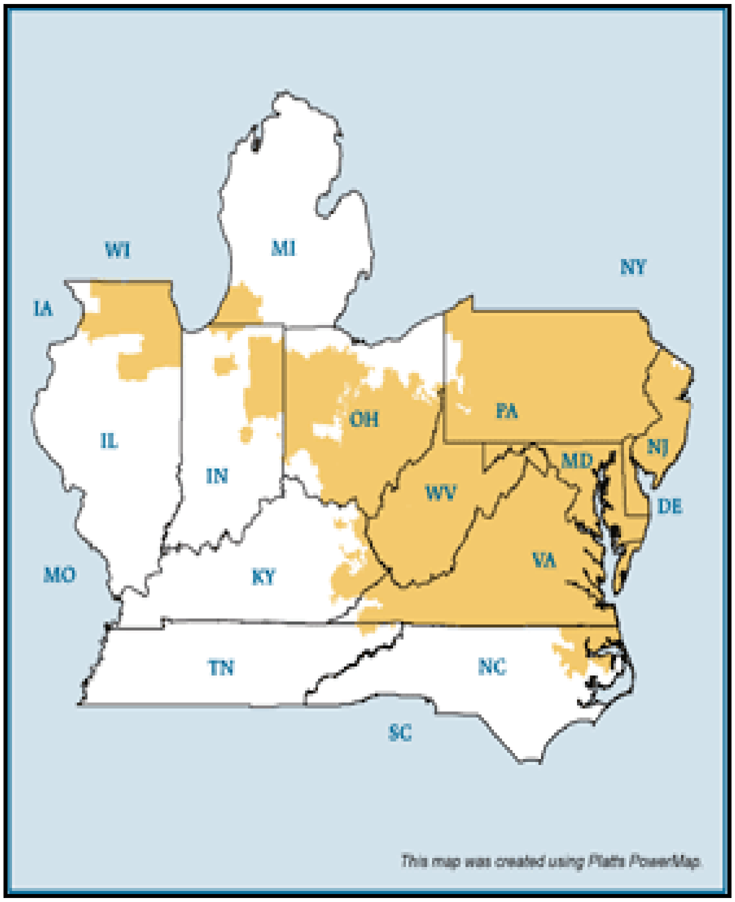

Figure 6-3 PJM Region

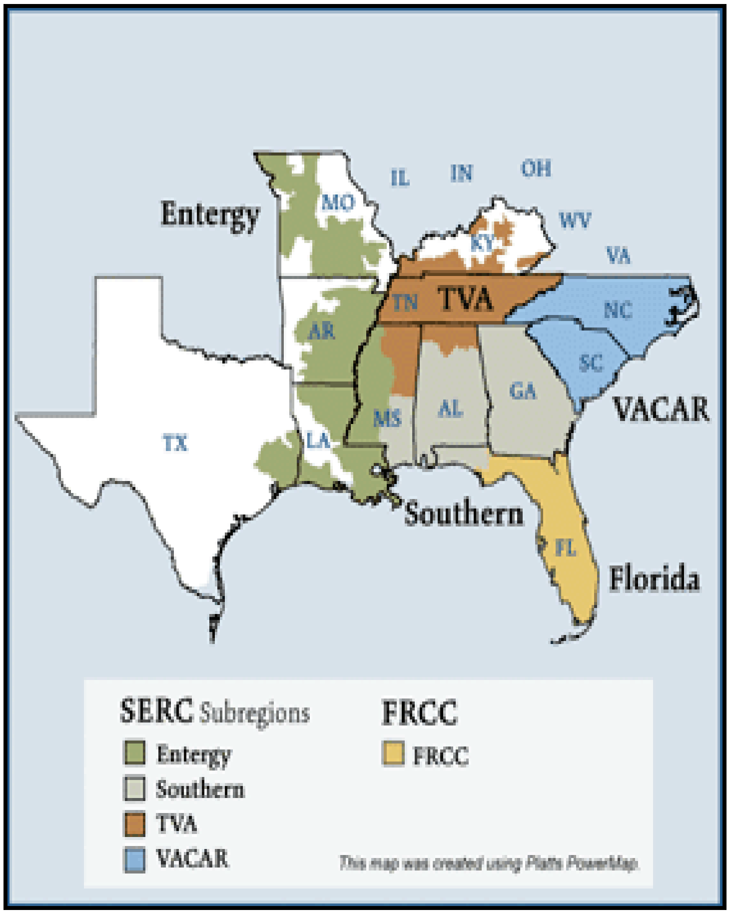

Figure 6-4 Southeast Region

Tables of Economic Values for Energy and Non-Energy Hydro Resources in the PJM and Southeast Regions.

Economic Sector	Direct Net Value	Annual Value Net Value	Annual Regional Income $	Direct Net Present Value $
Recreation: Sport Fishing	$100/Day (High-Range) $30/Day (Low Range)	$100/Day (High-Range) $30/Day (Low Range)	$80-160/Day (Mid-Range, Direct-Sec.)	NA
Boating and General Flat-Water Recreation; and Other Reservoir-Related Activities	$80-120/Day (High Range) $30/Day (Low Range)	$80-120/Day (High Range) $30/Day (Low Range)	$60-150/Day (Mid-Range, Direct-Sec.)	NA
Land Management	$10,000-40,000/Acre (Mid-Range)	$700-3,000/ Acre (Lease)	NA	$10,000-30,000/Acre (Mid-Range)
Irrigation	NA Acre-ft. (Cap.)	NA (Annual Lease)	$NA (Annual)	$NA Acre-ft. (Cap.)
Flood Control	>$260/Acre-ft.	>$260/Acre-ft.	>$500/Acre-ft.	NA

Table 6-4 Recreation, Land Management, Irrigation and Flood Control Benefits of Hydropower

Primary Sources: U.S. Dept of Interior/Census Bureau 2008, FERC 2007; USBR 2006, 2008; USACE 2000, 2003, 2002, 2005; UW 2004; Loomis 2004; Olsen, et al., 1992, 1994; Pacific NW Project 2008.

Economic Sector	Direct Net Value	Annual Value	Annual Regional Income $	Direct Net Present Value $
Municipal	$2,500-3,500 Acre-ft.	$275-385 (Lease)	>$100,000 /Acre-ft.	$1,125-3,500 Acre-ft. to $7,000 Acre-ft.
Navigation/ Transportation	> $10/Ton	> $10/Ton	------	> $10/Ton
Industrial Cooling	$2,500-3,500 Acre-ft.	$275-385 Acre-ft. (Lease)	>$100,000 /Acre-ft.	$1,125-3,500 Acre-ft. to $7,000 Acre-ft.
Climate Change/ Environment	$5-10/MWh	$5-10/MWh	Annual Dir. Net: $30-60 Million Per 1,000 MW Installed Cap.	Present Value-- Annual Dir. Net: $650 Million to $1.3 Billion Per 1,000 MW Installed Cap.

Table 6-5 Municipal, Navigation, Industrial, and Environmental Benefits of Hydropower

Primary Sources: FERC 2007; USBR 2006, 2008; USACE 2000, 2003, 2002, 2005; UW 2004; Loomis 2004; Olsen, et al., 1992, 1994; Pacific NW Project 2008.

Economic Sector	Direct Net Value	Annual Value	Approx. Annual Value/1,000 MW Installed Capacity	Direct Net Present Value $
Energy (LLH)	$30-70/MWh	$30-70/MWh	$140 Million (Energy-Demand)	$3.3 Billion (Energy- Demand)
Energy (Peak HLH)	$55-125/MWh	$55-125/MWh	$140 Million (Energy-Demand)	$3.3 Billion (Energy- Demand)
Demand (Capacity)	$2.50-4.00/kW/mo	$2.50-4.00/kW/mo	$140 Million (Energy-Demand)	$3.3 Billion (Energy- Demand)
Reserves (Spinning)	$15-130/MWh	$15-130/MWh	———	———
Reserves (Supplemental)	$15-130/MWh	$15-130/MWh	———	———
Back-Up Load Shaping	$40-130/MWh (Energy)	$40-130/MWh (Energy)	———	———
Back-Up Load Shaping	$3.00-5.00/kW/mo (Demand-Cap.)	$3.00-5.00/kW/mo (Demand-Cap.)	———	———
Market Hedging (Flat)	$50-100/MWh	$50-100/MWh	———	———
NR Energy (LLH)	$40-70/MWh	$40-70/MWh	———	———
NR Energy (HLH)	$55-125/MWh	$55-125/MWh	———	———
NR Demand	$2.50-4.00/kW/mo	$2.50-4.00/kW/mo	———	———
Voltage Control Stability	= > $0.50-3/MWh	= > $0.50-3/MWh	———	———

Table 6-6 Energy and Electrical Ancillary Benefits of Hydropower

Primary Sources: FERC, Market Oversight Data, 2009; EIA, Power Markets, 2009; Platts

Figure 6-5 New York (NYISO) Electric Region

Tables of Economic Values for Energy and Non-Energy Hydro Resources in the New York ISO Region.

Economic Sector	Direct Net Value	Annual Value Net Value	Annual Regional Income $	Direct Net Present Value $
Recreation: Sport Fishing	$100/Day (High-Range) $30/Day (Low Range)	$100/Day (High-Range) $30/Day (Low Range)	$80-160/Day (Mid-Range, Direct-Sec.)	NA
Boating and General Flat-Water Recreation; and Other Reservoir-Related Activities	$80-120/Day (High Range) $30/Day (Low Range)	$80-120/Day (High Range) $30/Day (Low Range)	$60-150/Day (Mid-Range, Direct-Sec.)	NA
Land Management	$10,000-40,000/Acre (Mid-Range)	$700-3,000/Acre (Lease)	NA	$10,000-40,000/Acre (Mid-Range)
Irrigation	NA Acre-ft. (Cap.)	NA (Annual Lease)	$NA (Annual)	$NA Acre-ft. (Cap.)
Flood Control	>$260/Acre-ft.	>$260/Acre-ft.	>$500/Acre-ft.	NA

Table 6-7 Recreation, Land Management, Irrigation and Flood Control Benefits of Hydropower

Primary Sources: U.S. Dept of Interior/Census Bureau 2008, FERC 2007; USBR 2006, 2008; USACE 2002, 2005; UW 2004; Loomis 2004; Olsen, et al., 1992, 1994; Pacific NW Project 2008.

Economic Sector	Direct Net Value	Annual Value	Annual Regional Income $	Direct Net Present Value $
Municipal	$2,500-3,500 Acre-ft.	$275-385 (Lease)	>$100,000 /Acre-ft.	$1,125-3,500 Acre-ft. to $7,000 Acre-ft.
Navigation/ Transportation	> $10/Ton	> $10/Ton	------	> $10/Ton
Industrial Cooling	$2,500-3,500 Acre-ft.	$275-385 Acre-ft. (Lease)	>$100,000 /Acre-ft.	$1,125-3,500 Acre-ft. to $7,000 Acre-ft.
Climate Change/ Environment	$5-10/MWh	$5-10/MWh	Annual Dir. Net: $30-60 Million Per 1,000 MW Installed Cap.	Present Value-- Annual Dir. Net: $650 Million to $1.3 Billion Per 1,000 MW Installed Cap.

Table 6-8 Municipal, Navigation, Industrial, and Environmental Benefits of Hydropower

Primary Sources: FERC 2007; USBR 2006, 2008; USACE 2002, 2005; UW 2004; Loomis 2004; Olsen, et al., 1992, 1994; Pacific NW Project 2008.

Economic Sector	Direct Net Value	Annual Value	Approx. Annual Value/1,000 MW Installed Capacity	Direct Net Present Value $
Energy (LLH)	$45-70/MWh	$45-70/MWh	$310 Million (Energy-Demand)	$7.2 Billion (Energy- Demand)
Energy (Peak HLH)	$70-130/MWh	$70-130/MWh	$310 Million (Energy-Demand)	$7.2 Billion (Energy- Demand)
Demand (Capacity)	$2.50-5.00/kW/mo	$2.50-5.00/kW/mo	$310 Million (Energy-Demand)	$7.2 Billion (Energy- Demand)
Reserves (Spinning)	$10-130/MWh	$10-130/MWh	———	———
Reserves (Supplemental)	$15-130/MWh	$15-130/MWh	———	———
Back-Up Load Shaping	$40-130/MWh (Energy)	$40-130/MWh (Energy)	———	———
Back-Up Load Shaping	$3.00-5.00/kW/mo (Demand-Cap.)	$3.00-5.00/kW/mo (Demand-Cap.)	———	———
Market Hedging (Flat)	$50-100/MWh	$50-100	———	———
NR Energy (LLH)	$50-80/MWh	$50-80/MWh	———	———
NR Energy (LLH)	$60-130/MWh	$60-130/MWh	———	———
NR Demand	$3.00-5.00/kW/mo	$3.00-5.00/kW/mo	———	———
Voltage Control Stability	= > $0.50-3/MWh	= > $0.50-3/MWh	———	———

Table 6-9 Energy and Electrical Ancillary Benefits of Hydropower

Primary Sources: FERC, Market Oversight Data, 2009; EIA, Power Markets, 2009; Platts Data, 2009; and General Industry Information.

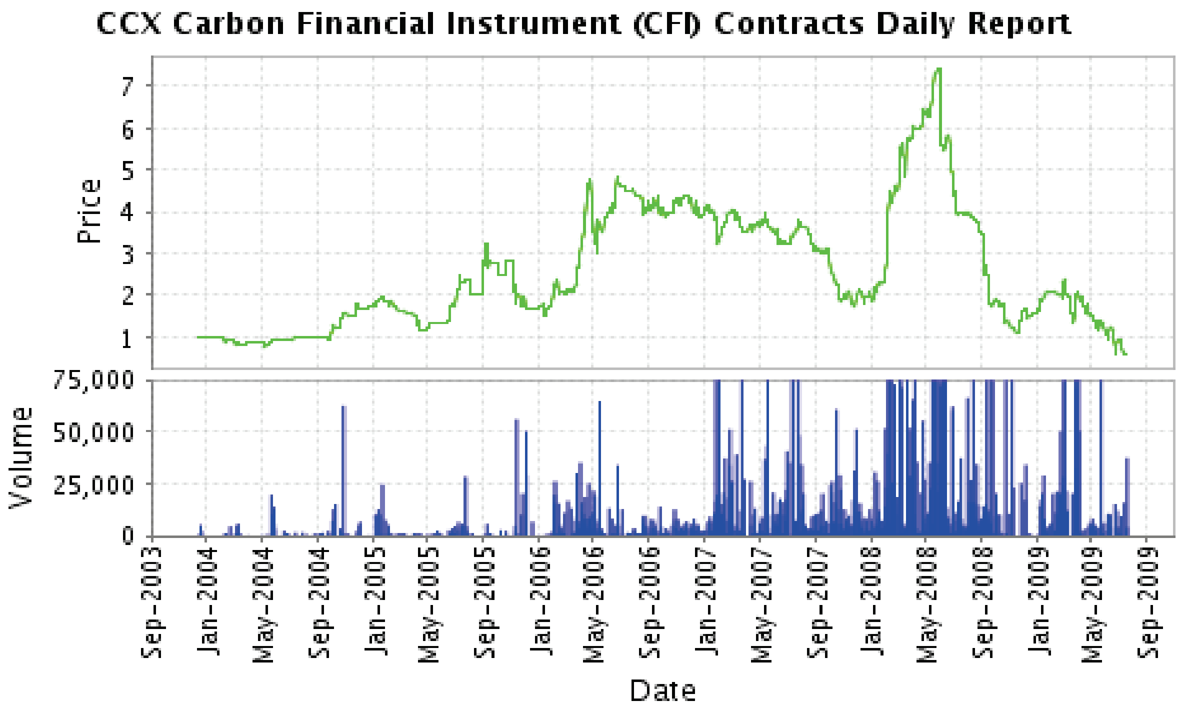

Figure 6-6 CO_2 Allowances Value ($/ton)

Source: Chicago Climate Exchange, July, 2009

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Note: This is the second of two volumes of case studies by David Pearce (Emeritus Professor of Economics, University College London, UK) that illustrate how environmental economists place values on environmental assets and on the flows of goods and services generated by those assets. The first volume Valuing the Environment in Developing Countries illustrates methodologies and applications of valuation techniques in the developing world; this volume concentrates on developed or 'wealthy' nations where the first examples of economic valuation of the environment were carried out. This important book assembles studies that discuss broad areas of application of economic valuation – from amenity and pollution through to water and health risks; from forestry to green urban space. In doing this, in his last book, the late David Pearce brings together leading European experts, contributors to some two dozen case studies exploring the frontiers of economic valuation of natural resources and environmental amenity in the developed world.

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severe options, there is a 27% loss of capacity among the least to most environmentally protective alternatives. Including both environmental and other costs, the 2020 MW economically viable resource is reduced between 62% and 72% of its theoretical potential of 2020 MW.

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APPENDIX A.
FERC ECONOMICS ANALYSIS METHOD EXAMPLE

Citation: Priest Rapids Hydroelectric Development, Public Utility District No. 2 of Grant County, Washington (USA). Project No. 2114-116; Order Issuing New License; Federal Energy Regulatory Commission, 123 FERC 61,049; Issued April 17, 2008. *Key points* are underlined for emphasis.

A.1 Project Economics

175. In determining whether to issue a new license for an existing hydroelectric project, the Commission considers a number of public interest factors, including the economic benefits of project power. Under the Commission's approach to evaluating the EIS at 3-4 and 383-84. Project No. 2114-116 - 55 - economics of hydropower projects, as articulated in *Mead Corp.*, the commission uses current costs to compare the costs of the project and likely alternative power with no forecasts concerning potential future inflation, escalation, or deflation beyond the license issuance date. The basic purpose of the Commission's economic analysis is to provide a general estimate of the potential power benefits and the costs of a project, and of reasonable alternatives to project power. The estimate helps to support an informed decision concerning what is in the public interest with respect to a proposed license. *Comment: Note that there is no economic evaluation of the public interest factors.*

176. In applying this analysis to the Priest Rapids Project, we have considered two options: Grant PUD's proposal and the project as licensed herein. As proposed by Grant PUD, the levelized annual cost of operating the project is $134.2 million or $14.85/megawatt-hour (MWh). The proposed project would generate an estimated average of 9,039,634 MWh of energy annually. When we multiply our estimated average generation by the alternative power cost of $38.69/MWh, we get a total value of the project's power of $349.7 million. To determine whether the proposed project is currently economically beneficial, staff subtracts the project's cost from the value of the project's power. Therefore, in the first year of continued operation, the project would cost $215.5 million or $23.84/MWh, less than the likely alternative cost of power. *Comment: These costs are simply subtracted from the marginal value of the project's power and if power values remain above the marginal value of regional power, the project is adjudged to be "economically viable." FERC will award a license whether it is economically viable or not. This differs from its practice of not awarding licenses to projects that did not exceed the value of regional power pre-ECPA (1987)*

177. As licensed herein with the mandatory conditions and staff measures, the levelized annual cost of operating the project would be about $133.1 million or $14.73/MWh. Based on an estimated average of 9,039,634 MWh as licensed, the project would produce power valued at $349.7 million when multiplied by the $38.69/MWh value of the project's power. Therefore, the project power would cost $216.6 million, or $23.96/MWh, less than the likely cost of alternative power. *Comment: After subtracting a total cost of operating the project of $133 million annually in mostly public interest factors (see next section for list of environmental expenditures), from the value of the power ($350 million) or more than a third of the energy benefits, the project is deemed "economic" and in the public interest.*

A.2 Final Environmental Impact Statement for the Priest Rapids Project

Citation: Final Environmental Impact Statement for the Priest Rapids Hydroelectric Development, Public Utility District No. 2 of Grant County, Washington (USA). Project No. 2114-116; Federal Energy Regulatory Commission, dated November 17, 2006. Issuance number 20061117-4002.

4.0 DEVELOPMENTAL ANALYSIS

In this section, we look at the Project's use of the Columbia River for hydropower purposes to see what effect various environmental measures would have on the Project's costs and power benefits. Consistent with the Commission's approach to economic analysis, the "power benefit" of the project is defined as the cost of obtaining the same amount of energy and capacity using the likely alternative generating resources available in the region. The "power value" is the unit cost of the selected alternative generating resource and is usually expressed in terms of dollars per megawatt hour ($/MWh) for energy and dollars per kilowatt-year ($/kW-yr) for capacity. The combined value (or cost) of energy and capacity can also be expressed in terms of $/MWh for a given amount of energy and capacity. Reducing the cost of licensing alternatives to an average cost per unit of electricity generated provides a convenient metric for assessing the public benefit of the project for power production.

In keeping with Commission's policy as described in Mead, our economic analysis is based on current electric power cost conditions and does not consider future escalation of fuel prices in valuing the hydropower project's power benefits.[115] Our analysis includes: (1) an estimate of the net power benefit of the Project for each of the licensing alternatives, and (2) an estimate of the cost of individual measures considered in the EIS for the protection, mitigation and enhancement of environmental resources affected by the Project.

To determine the net power benefit for each of the licensing alternatives, we subtract the cost of producing power at the Project from the total power benefit, which, as we said above, is the cost of obtaining the same amount of power using a likely alternative source of power. For any alternative, a positive net annual power benefit indicates that the Project costs less than the current cost of alternative generation resources; a negative net annual benefit indicates that project power costs more than the current cost of alternative generation resources. The net benefit helps to support an informed decision concerning what is in the public interest with respect to a proposed licensing alternative, or proposed license condition. However, project economics is only one of many public interest factors the Commission considers in determining whether, and under what conditions, to issue a license.

In the comprehensive development section, we use the estimated cost of individual measures to help us decide if the environmental benefit to the resource (usually described in qualitative, or non-dollar valuation terms) justifies the cost of the measure. For this purpose, we convert the capital and annual cost of individual measures to equal annual amounts spread over a 30-year period of analysis.

[115] See Mead Corporation, Publishing Paper Division, 72 FERC 61,027 (July 13, 1995). In most cases electricity from hydropower would displace some form of fossil-fuelled generation, in which fuel cost is the largest component of the cost of electricity production.

4.1 POWER AND ECONOMIC BENEFITS OF THE PROJECT

For the Project, we assume the energy value is similar to the cost of purchasing the equivalent generation from BPA at its new resource rate for firm power.[116] Using the average of the monthly high and low load hourly energy rates for BPA customers buying power for all 5 years of the 5-year rate period, we calculate an average energy value of $34/MWh. We use BPA's new resource capacity demand rate schedule to value the project's 1,535,000 kW of dependable capacity at $24 per kW per year (kW-yr). Using the average energy value of $34/MWh and a capacity value of $24/kW-yr, the combined power value is $39/MWh based on the current average annual net generation of 8,608,799 MW.

The current cost economic analysis is not entirely a first-year analysis in that certain costs, such as major capital investments, would not be expended in a single year. The maximum period we use to annualize such costs is 30 years. Also, some future expenses, such as taxes and depreciation, are known and measurable and are, therefore, incorporated in our cost analysis.

FERC's Table 39 reproduced below summarizes the assumptions and economic information we use in our analysis. Most of this information was provided by Grant PUD in its license application. We find that the values provided by Grant PUD are reasonable for the purposes of our analysis. Cost items common to all alternatives include: taxes and insurance costs; net investment (the total investment in power plant facilities remaining to be depreciated); relicensing costs; normal O&M cost; and Commission fees.

[116] Power Administration, 2002 Wholesale Power Rate Schedules (Revised May 2004).

Parameter	Value	Source
Existing Capacity/Net Dependable Capacity:		
Wanapum (MW)	1038/842	
Priest Rapids (MW)	855/805	Grant PUD[a]
Total (MW)	1,893/1,647	
Proposed Capacity/Net Dependable Capacity:		
Wanapum (MW)	1038/842	
Priest Rapids (MW)	956/900	Grant PUD[a]
Total (MW)	1,994/1,742	
Existing Average Annual Generation:		
Wanapum (MWh/yr)	5,121,289	
Priest Rapids (MWh/yr)	4,558,338	Grant PUD[b]
Less Rock Island Tailwater benefit	-639,993	
Total (MWh/yr)	9,039,634	
Proposed Average Annual Generation:	5,121,289	
Wanapum (MWh/yr)	5,258,690	
Priest Rapids (MWh/yr)	-626,301	Grant PUD[b]
Less Rock Island Tailwater benefit	9,753,677	
Total (MWh/yr)		
Energy value	$34/MWh	Grant PUD/staff[c]
Capacity value	$24/kW-year	Staff[c]
Overall cost of money	7 percent	Grant PUD/Staff
Discount rate	7 percent	Staff
Term of financing	20 years	Staff
Period of analysis	30 years	Staff
Annual Operation & Maintenance cost	$35,745,586	Grant PUD/staff[e]
Net Investment	$416,904,355	Grant PUD[f]

Table 39. Summary of key parameters for economic analysis of the Priest Rapids Project (Source: as noted).

[a] From Exhibit B of license application; net dependable capacity is based on summer flow and load conditions.

[b] From Exhibit B of license application; adjustment compensates for Wanapum reservoir encroachment at Rock Island Project's tailwater.

[c] Based on BPA's new resource energy and capacity rate schedule.

[e] From Grant PUD's 2004 Annual Report: $17,606,837 for Wanapum (p. 140) and $18,138,749 for Priest Rapids (p.109).

[f] Net plant investment estimated by staff from information contained in Grant PUD's 2004 Annual Report; includes total plant investment less accumulated depreciation for Priest Rapids and Wanapum ($142,029,777 and $160,886,947, respectively), plus costs for construction in progress ($62,107,121) and licensing costs ($51,880,510), all as of December 31, 2004.

4.2 COMPARISON OF ALTERNATIVES

Table 40 summarizes the annual cost, power benefits, and annual net benefits for the three alternatives considered in this final EIS: no-action, Grant PUD's proposal, and the staff alternative.

	No Action	Grant PUD's Proposal	Staff Alternative
Installed capacity (MW)	1,893	1,994	1,994
Annual generation (MWh)	9,039,634	9,753,677	9,753,677
Annual power value ($/MWh and mills/kWh)	$329,546,000 38.28	$377,346,000 38.69	$377,346,000 38.69
Annual cost ($/MWh and mills/kWh)	$69,341,000 8.06	$146,722,690 15.04	$145,669,980 14.93
Annual net benefit ($/MWh and mills/kWh)	$260,205 30.22	$230,623,310 23.64	$231,676,020 23.75

Table 40. Summary of the annual cost, power benefits, and annual net benefits for three alternatives for the Priest Rapids Hydroelectric Project (Source: staff).

4.2.1 No-Action Alternative

Under the no-action alternative, the project would continue to operate as it does now. On July 23, 2004, the Commission issued an order[117] amending Grant PUD's license and authorizing the replacement of the 10 turbines at the Wanapum development with ten new, upgraded turbines over a period of about 8 years. The order authorized the replacement of one turbine, followed by a study to test the effect of the advanced turbine design on fish passage survival. Replacement of the remaining 9 turbines would be allowed to proceed only after the Commission informed the licensee that test results were satisfactory. On October 11, 2005, Grant PUD filed a report on fish survival through the first installed turbine and, subsequently, on December 14, 2005, the Commission issued an order[118] authorizing the installation of the remaining nine advanced design hydro turbines. The new turbines increase the capacity of each turbine generator set by 13.8 MW. The Commission's order approving the installation of the remaining 9 turbines increased the authorized capacity of the Wanapum Development from 900 to 1,038 MW. Grant PUD expects to replace the remaining 9 turbines at the rate of about one every 9 months. The capacity and average annual generation for the no-action alternative in this final EIS represents the conditions after replacement of all approved turbine units at the Wanapum Development. Likewise, the cost of the Wanapum turbine replacements is included in the no-action alternative. Grant PUD estimates it will cost $124,630,387 to replace the Wanapum turbines with the advanced design turbines.

Under the no-action alternative, the planned replacement of the 9 remaining turbines at the Wanapum Development would occur, but Grant PUD would not replace the turbines at the Priest

[117] 108 FERC 62,075 (2004).

[118] 113 FERC 62,205 (2005)

Rapids Development or implement new environmental measures. Upon completion of the approved turbine replacements at Wanapum, the project would have a total authorized installed capacity of 1,893 MW and annually generate an average of 9,039,634 MWh of electricity. Based on our estimate of the current cost of replacing this amount of power with no consideration of inflation over the 30-year period of our analysis, the average annual power value of the project under the no-action alternative would be $346,876,000 (about $38.4/MWh). The average annual cost of producing this power would be $78,380,000 (about $8.7/MWh), resulting in an average annual net benefit of $268,495,000 (about $29.7/MWh).

4.2.2 Grant PUD's Proposal

Grant PUD proposes to replace the 10 existing turbines at the Priest Rapids development with the same advanced turbine design being used for the Wanapum Development. Based on its assessment of the remaining useful life of the existing Priest Rapids turbines, Grant PUD proposes to replace the turbines beginning in 2017 and extending through 2023. The total cost of Priest Rapids turbine replacement is estimated at $155,374,804. We include this cost and the resulting capacity and generation increases in the proposed action alternative. Upon completion of the replacement of all 10 turbines, the total capacity at the Priest Rapids development would increase from 855 to 955.6 MW, the rated capacity of the existing generators.

Upon completion of the proposed turbine replacement upgrades at both developments, the total Project capacity would increase to about 1,994 MW, an increase of about 225 MW from the current installed capacity of 1,768.8 MW. With a total capacity of 1,994 MW, a dependable capacity of 1,742 MW and an average annual generation of 9,753,677 MWh, the Project would have an annual power value of $377,346,000 ($38.69/MWh), an annual production cost (levelized over the 30-year period of our analysis) of $146,722,690 ($15.04/MWh), and an annual net benefit of $230,623,310 ($23.64/MWh).

4.2.3 Staff Alternative

The staff alternative includes the same developmental upgrades as Grant PUD's proposal and, therefore, would have the same capacity and energy attributes. Based on a total capacity of 1,994 MW, a dependable capacity of 1,742 MW and an average annual generation of 9,753,677 MWh, the Project would have an annual power value of $377,346,000 ($38.69/MWh). Since the staff alternative includes costs of additional measures, the annual production cost (levelized over the 30-year period of our analysis) is about $145,669,980 ($14.93/MWh), yielding an annual net benefit of about $231,676,020 ($23.75/MWh).

4.3 COST OF ENVIRONMENTAL MEASURES

Certain measures proposed by Grant PUD and other parties would affect project economics because they can increase the production cost by requiring new capital expenditures or additional annual costs for O&M. Other measures would affect the project's power production capability or average annual generation.

APPENDIX B. COST OF ENVIRONMENTAL MEASURES PROPOSED BY GRANT PUD, FERC STAFF, OR OTHERS

Citation: Cost of environmental protection, mitigation and enhancement measures proposed by Grant PUD, resource agencies, others, and staff for the Priest Rapids Hydroelectric Project (Source: Grant PUD, 2003a, modified by staff.)

B.1 FERC Environmental Cost Example – Priest Rapids

For measures where all or a portion of the cost is based on the cost of replacing project power benefits, the amount and assumed value of foregone power is given in the table footnotes. Measures that do not greatly affect the project economics or have unknown costs are not listed in the table.

Environmental Measure	Recommending Entities	Capital and One-time Costs	Annual Costs, Including O&M	Total Annualized Cost
Water Quantity and Quality				
TDG and GBT monitoring (part of Water Quality Monitoring Plan)	Grant PUD, Staff	N/A	$48,000	$48,000
Temperature monitoring plan(part of Water Quality Monitoring Plan)	Grant PUD, Staff	N/A	$140,000	$140,000
Aquatic macrophyte monitoring plan (called AIS plan in Terrestrial Resource section and part of Water Quality Monitoring Plan)	Grant PUD, Staff, Washington DFW	N/A	$25,000	$25,000
Nuisance aquatic macrophyte removal (part of AIS and Water Quality Monitoring Plans)	Grant PUD, Staff, Washington DFW	N/A	$7,000	$7,000
Zebra mussel monitoring (part of AIS and Water Quality Monitoring Plans)	Grant PUD, Staff, Washington DFW	N/A	$2,000	$2,000
Tailrace pumping to replace gravity fishway attraction water supply	Grant PUD, Staff	$3,676,450	N/A	$296,000
Aquatic Resources				
Develop a detailed fishery operations plan	CRITFC, Staff	$7,500	N/A	$600

Environmental Measure	Recommending Entities	Capital and One-time Costs	Annual Costs, Including O&M	Total Annualized Cost
Adult trapping facilities at Priest Rapids	Settlement Parties[1], Staff	$980,878	$5,000	$84,000
Hatchery effectiveness monitoring	Settlement Parties[1], Staff	N/A	$100,000	$100,000
Fishways automation, improvements and junction pool modifications	Settlement Parties[1], Staff	$2,700,000	N/A	$217,600
Video fish counting systems at both dams	Settlement Parties[1], Staff	$1,250,000	$200,000	$300,700
Downstream bypass system at Wanapum dam	Settlement Parties[1], Staff	$26,874,403	$11,124,864[3]	$13,290,000
Sluiceway spill for fallback at Priest Rapids and Wanapum dams	Settlement Parties[1], Staff	N/A	$2,204,370[2]	$2,204,370
Study of Wanapum gate seals	Staff	$50,000	N/A	$4,030
Northern pikeminnow removal program	Settlement Parties[1], Staff	N/A	$199,990	$199,990
Gatewell exclusion screen study	NMFS, Staff	$100,000	N/A	$8,060
Avian predator control program	Settlement Parties[1], Staff	N/A	$166,520	$166,520

Environmental Measure	Recommending Entities	Capital and One-time Costs	Annual Costs, Including O&M	Total Annualized Cost
Biological assessment and management plan program development and ancillary facilities	Settlement Parties[1], Staff	$9,000,000	$200,000	$925,300
Priest Rapids habitat mitigation fund	Settlement Parties[1], Staff	N/A	$1,096,550	$1,096,550
Habitat mitigation plan (part of habitat mitigation fund)	Settlement Parties[1], CRITFC, Staff	$5,000	N/A	$430
Adult PIT-tag facilities at Priest Rapids dam	Settlement Parties[1], Staff	$319,830	$10,000	$35,800
Anadromous fish monitoring and evaluation studies	Settlement Parties[1], Staff	N/A	$2,000,000	$2,000,000
Spill at both dams for downstream passage	Settlement Parties[1], Staff	N/A	$18,000,000 (temporary)	Unknown
Fall Chinook spawning habitat modifications at Wanapum dam	Settlement Parties[1], Staff	N/A	$50,000	$50,000
Hanford Reach Agreement	Settlement Parties[1], Staff	N/A	$4,346,610	$4,346,610
Bull trout monitoring plan	Washington DFW, Staff	$5,000	N/A	$430

Environmental Measure	Recommending Entities	Capital and One-time Costs	Annual Costs, Including O&M	Total Annualized Cost
Fishway telemetry study (part of the Pacific lamprey management plan)	Interior, Washington DFW, Staff	$200,000 (four instances at $50,000 each)	N/A	$16,100
Modify diffusion chambers on fishways at Priest Rapids to improve adult lamprey passage	Grant PUD, Staff	$219,122	$10,000	$27,700
Priest Rapids and Wanapum fishways	Settlement Parties[1], Staff	N/A	$771,690	$771,690
Fishway stranding protocol (part of the Pacific lamprey management plan)	Interior, Staff Washington DFW	$5,000	N/A	$430
White sturgeon management plan	Interior, CRITFC, Washington DFW, Staff	N/A	$50,000	$50,000
Final white sturgeon conservation aquaculture plan	Staff	$7,500	N/A	$600
Spring Chinook hatchery supplementation program	Settlement Parties[1], Staff	$10,722,172	$700,000	$1,564,000
Summer Chinook hatchery supplementation program	Settlement Parties[1], Staff	$8,756,339	$800,000	$1,505,000
Priest Rapids hatchery fall Chinook program	Settlement Parties[1], Staff	$11,754,801	$881,166	$1,828,000

Environmental Measure	Recommending Entities	Capital and One-time Costs	Annual Costs, Including O&M	Total Annualized Cost
Sockeye hatchery feasibility or alternative program	Settlement Parties[1], Staff	$12,119,304	$218,834	$1,195,000
Steelhead hatchery supplementation program	Settlement Parties[1], Staff	$3,870,181	$200,000	$511,900
Acclimation and broodstocking facilities	Settlement Parties[1], Staff	$9,939,694	N/A	$801,000
White sturgeon restoration & enhancement program	Grant PUD, Staff	$1,905,368	$150,000	$303,550
Priest Rapids fisheries forum	Washington DFW, Staff	N/A	$5,000	$5,000
Crab Creek/Burkett Lake enhancement plan	Staff	$20,000	N/A	$1,720
PIT tag detection at Wanapum	CRITFC, Alaska DFG	$319,830	$10,000	$35,800
Study of peaking effects on passage	CRITFC	$200,000	N/A	$16,100
Adult fallback and kelt passage studies	American Rivers	$500,000-$1,000,000	N/A	$40,300-$80,590
No Net Impact fund	Settlement Parties[1]	N/A	$1,112,500	$1,112,500
Flows to protect rearing fall Chinook salmon (10 kcfs fluctuation limit)	CRITFC Yakama	$46,200,000[4]	$112,500,000[4]	$136,000,000

Environmental Measure	Recommending Entities	Capital and One-time Costs	Annual Costs, Including O&M	Total Annualized Cost
Annual orthophotographic spawning surveys	Interior, CRITFC, Alaska DFG	$100,000	N/A	$8,060
White Bluffs spawning surveys	Umatilla, Alaska DFG	$20,000	N/A	$1,720
Spawning behavior studies	Interior, CRITFC, Alaska DFG	$200,000	N/A	$16,100
Primary and secondary production studies	Interior, CRITFC	$450,000	N/A	$36,200
Conduct annual stranding and entrapment surveys in Hanford Reach	CRITFC, Alaska DFG	N/A	$150,000	$150,000
Develop and implement a bull trout management plan	Interior, Washington DFW	$575,000	N/A	$46,300
Pacific lamprey studies	Interior, CRITFC, Washington DFW	$1,200,000	N/A	$96,720
Lamprey management plan – Hydraulic study	Interior	$100,000	N/A	$8,060
Lamprey management plan – Modifications to fish ladders	Interior	$700,000	N/A	$56,400
Alternative lamprey passage methods – dedicated fishway	Interior	$2,000,000	Unknown	$161,200

Environmental Measure	Recommending Entities	Capital and One-time Costs	Annual Costs, Including O&M	Total Annualized Cost
Alternative lamprey passage methods – capture and haul	Interior	N/A	$80,000	$80,000
Lamprey biologist	Washington DFW	N/A	$30,000	$30,000
Regional coordination and white sturgeon biologist	Washington DFW, Interior, CRITFC	N/A	$30,000	$30,000
Columbia basin hatchery funding	Grant PUD	$1,000,000	$100,000	$180,600
Pikeminnow removal/resident fish study	CRITFC	$600,000 (3 year study)	N/A	$48,300
Gatewell exclusion screens at both dams	Grant PUD	$500,000	$20,000	$60,300
Trophic dynamics study	Washington DFW	$750,000	N/A	$60,430
Terrestrial Resources				
Development of Wildlife Habitat Management Plan which includes:	Staff	$2,000 every 5 years	N/A	$960
Lower Crab Creek management plan	Grant PUD, Staff	$7,200,000	$30,000	$610,200
Colockum, Whiskey Dick, and Quilomene wildlife areas enhancements	Grant PUD, Staff	$2,000,000	$70,000	$231,200
Land acquisition fund for wildlife areas	Grant PUD, Staff	$1,000,000	N/A	$80,600

Environmental Measure	Recommending Entities	Capital and One-time Costs	Annual Costs, Including O&M	Total Annualized Cost
Fire suppression program	Grant PUD, Staff	N/A	$60,000	$60,000
Perch pole and duck box maintenance	Grant PUD, Staff	N/A	$15,500	$15,500
Fund Washington DFW operation and maintenance of wildlife area lands ($15/ac)	Washington DFW	$0	$1,494,750	$1,494,750
Fund replacement of Crescent Bar habitats	Washington DFW	$2,160,000	$36,000	$673,000
Habitat mitigation projects: a) Royal Lake excavation project; b) Crab Creek water diversion project; and c) Lower Crab Creek farm ground renovation project	Washington DFW	a) $181,000 b) $230,000 c) $126,000	a) $5,000[5] b) $5,000 c) $5,000[5]	a) $15,000 b) $ 19,000 c) $10,000
Habitat acquisition fund	Washington DFW	$4,500,000	N/A	$363,000
Wildlife Habitat Monitoring and Information & Education Program	Washington DFW, Staff	$15,000[5]	N/A	$1,000
Transmission line avian protection measures	Grant PUD, Staff	$500,000	N/A	$40,300
Northern wormwood conservation plan	Grant PUD, Staff	N/A	$40,000	$40,000
Transmission line RTE botanical protection	Grant PUD, Staff	N/A	$7,000	$7,000
RTE plant monitoring programs	Grant PUD, Staff	N/A	$35,000	$35,000
RTE plant research programs	Grant PUD, Staff	N/A	$13,500	$13,500

Environmental Measure	Recommending Entities	Capital and One-time Costs	Annual Costs, Including O&M	Total Annualized Cost
Bald eagle perch and roosting tree enhancements	Grant PUD, Staff	N/A	$17,500	$17,500
Implement AIS plan (as proposed by Grant PUD in Water Quality) with 3 additional components: Identifying and recommending any additional measures for detecting future AIS infestations, detailed information and education program, and implementation schedule	Washington DFW, Staff	$10,000[5]	$7,000	$8,000
Cultural Resources				
Implementation of the HPMP, associated additional Staff-recommended tasks, and maintain cultural resource management facilities	Grant PUD, Staff	$20,000,000	$3,750,000	$5,362,000
Recreation Resources				
Implementation of Recreation Plan which includes:	Grant PUD, Staff	N/A	$26,000	$26,000
Interpretation and education plan	Grant PUD, CRITFC, Staff	$86,100[6]	$8,000	$14,930
Recreation monitoring (including recreation monitoring on 748.8 acres of BLM-administered land in the Project area)	Grant PUD, BLM, Staff	$225,000[7]	N/A	$21,150
Dispersed recreation site maintenance/ management	Grant PUD, Staff	$15,000	$3,000	$4,200

Environmental Measure	Recommending Entities	Capital and One-time Costs	Annual Costs, Including O&M	Total Annualized Cost
Airstrip site (New)	Grant PUD, Staff	$7,892,500	N/A	$636,000
Apricot orchard boat launch	Grant PUD, Staff	$156,400	$2,000	$14,600
Beverly sand dunes OHV park	Grant PUD, Staff	$5,000	$3,000	$3,400
Buckshot ranch boat launch	Grant PUD, Staff	$42,200	$1,500	$4,900
Crab Creek corridor	Grant PUD, Staff	$452,320	$8,000	$44,450
Crescent Bar	Grant PUD, Staff	$1,800,850	$12,500	$157,600
Desert Aire	Grant PUD, Staff	$705,450	$3,250	$60,100
Frenchman Coulee boat launch	Grant PUD, Staff	$224,100	$1,500	$19,600
Getty's cove	Grant PUD, Staff	$511,750	N/A	$41,240
Huntzinger Road boat launch	Grant PUD, Staff	$684,000	$3,000	$58,100
Huntzinger Road fishing access site	Grant PUD, Staff	$88,500	$2,000	$9,100
Kittitas County boat launch	Grant PUD, Staff	$138,900	$15,000	$26,200
Wanapum dam lower boat launch	Grant PUD, Staff	$64,000	$3,000	$8,100
Mattawa RV park (New)	Grant PUD, Staff	$830,410	$2,500	$69,400
Priest Rapids park (New)	Grant PUD, Staff	$656,500	$11,000	$63,900

Environmental Measure	Recommending Entities	Capital and One-time Costs	Annual Costs, Including O&M	Total Annualized Cost
Quilomene dune and bay/West Bar	Grant PUD, Staff, CRITFC, Yakama	N/A	$3,000	$3,000
Rocky Coulee	Grant PUD, Staff	$193,700	$6,000	$21,600
Sand Hollow – North	Grant PUD, Staff	$127,000	$3,000	$13,200
Sand Hollow – South	Grant PUD, Staff	$1,223,500	$13,000	$111,600
Shoreline below Priest Rapids dam	Grant PUD, Staff	$96,000	$3,000	$10,700
Sunland estates boat launch	Grant PUD, Staff	$90,900	$6,000	$13,300
Sunland estates day-use area (New)	Grant PUD, Staff	$412,500	$4,000	$37,200
John Wayne pioneer trail river crossing (50% of total capital cost)	Grant PUD	$445,000	N/A	$35,900
Vantage area trail	Grant PUD, Staff	$67,250	$5,000	$10,400
Wanapum dam upper boat launch	Grant PUD, Staff	$71,400	$3,000	$8,800
Vernita bridge boat launch	Grant PUD, Staff	$500,000	N/A	$40,300
Wanapum dam heritage center	Grant PUD, Staff	$112,000	$4,000	$13,000
Wanapum dam overlook	Grant PUD, Staff	$66,500	$2,000	$7,400
Wanapum dam picnic area	Grant PUD, Staff	$80,900	$4,000	$10,600

Environmental Measure	Recommending Entities	Capital and One-time Costs	Annual Costs, Including O&M	Total Annualized Cost
Wanapum recreation area	Grant PUD, Staff	$1,853,300	N/A	$149,300
In a final Recreation Plan, include a provision (*e.g.*, signs) at Quilomene Dune and Bay to address wake size by boaters	CRITFC, Yakama, Staff	$3,000	N/A	$240
Provide funding for 1 FTE to Washington DFW enforcement program and 1 FTE to be divided equally between Grant PUD and Kittitas County Sheriff's offices; continue to provide a boat at Wanapum dam for local law enforcement officers.	Grant PUD	N/A	$100,000	$100,000
Provide funding for 2 FTE law enforcement officers to Washington DFW and funding for 0.5 FTE each to Kittitas and Grant County sheriffs	Washington DFW	N/A	$270,000	$270,000
Provide to Washington DFW $73,500 for a reservoir patrol vessel, $2,200 for a trailer, and replace on 10-year cycle	Washington DFW	N/A	$18,000	$18,000
Provide funding to Kittitas County for 1 Sheriff Deputy, 2 staff (May-Oct), and a vessel	Kittitas County	N/A	$100,000	$100,000
Dredge and lengthen the Kittitas County boat launch at Vantage	Kittitas County, Public Works, Pat Kelleher, Staff	$200,000[8]	N/A	$16,100
Fund 100% of the restoration and maintenance of the Beverly Bridge (John Wayne Pioneer Trail)	Washington DNR, Pat Kelleher, IAC	$890,000	$26,000	$102,540

Environmental Measure	Recommending Entities	Capital and One-time Costs	Annual Costs, Including O&M	Total Annualized Cost
Land Use				
Shoreline Management Plan	Grant PUD, Staff, Pat Kelleher	N/A	$300,000	$300,000

[1] Settlement Parties include: Grant PUD, NMFS, Interior, Washington DFW, the Yakama, and the Colville.
[2] Based on the cost of replacing 59,578 MWh of power at $37/MWh.
[3] Based on the cost of replacing 300,672 MWh of power at $37/MWh.
[4] Based on the cost of providing 1,320-MW Simply Cycle Combustion Turbine for operation from March 1 - June 15 and gas prices of $4/MMBtu (currently gas prices are over $6/MMBtu). See, also pages 57-58 of Grant PUD's July 8, 2005 letter responding to Interior's recommended terms and conditions.
[5] Staff estimated cost.
[6] Cost includes 2 interpretive displays/kiosks of $13,000 each.
[7] Required every 12 years at $75,000/survey; assumed by staff to occur 3 times over the 30-year period of our analysis.
[8] Grant PUD estimated cost from draft Recreation Plan.