The Energy Policy Institute

OPTIONS FOR MEETING ELECTRICITY DEMAND IN IDAHO

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The views expressed in this work are those of the authors and do not necessarily reflect the position or policy of the Center for Advanced Energy Studies.

Preface

Purpose of Document

The purpose of this document is to inform members of the public who are involved in a study of their preferences for ways that Idaho can meet future electricity demand. It is intended to provide only a baseline of information and was written to intentionally not lead the reader to specific conclusions. The study is being conducted by researchers at the Energy Policy Institute (EPI), part of the Center for Advanced Energy Studies (CAES). CAES is a collaboration of Boise State University, University of Idaho, Idaho State University, and the Idaho National Laboratory.

The information covers Idaho's electricity situation as well as several options for meeting future electricity demand. The advantages and disadvantages for five alternatives are discussed: *energy conservation and efficiency, fossil fuel electricity generation, hydropower electricity generation, nuclear electricity generation and non-hydro renewable electricity generation.*

While other forms of energy are important, this document will focus on **electricity**. It will not discuss issues relative to fuels (petroleum fuels, bio-fuels, etc.) used for transportation, space heating or process heat unless electricity is somehow involved.

How This Document is Organized and How it Should be Used

This document has been organized so that each section will build upon the information provided in the previous section. It describes:

1.) How the electricity system works;
2.) National perspective on electricity;
3.) Idaho's current electricity situation;
4.) Five choices for meeting electricity demand;
5.) Important factors to consider.

As you read this document, you will find two Appendices useful as a quick reference. The Appendices provide quick comparisons between the five electricity options.

1) Appendix I contains a set of 8 tables that summarize the advantages and disadvantages of the five different electricity options.
2) Appendix II contains a table that summarizes and compares research and development opportunities that could significantly improve each option.

Cited references will be posted on the Energy Policy Institute's website. The subscripted notations in the text indicate the reference used. Please go to: http://www.boisestate.edu/energypolicyinstitute/

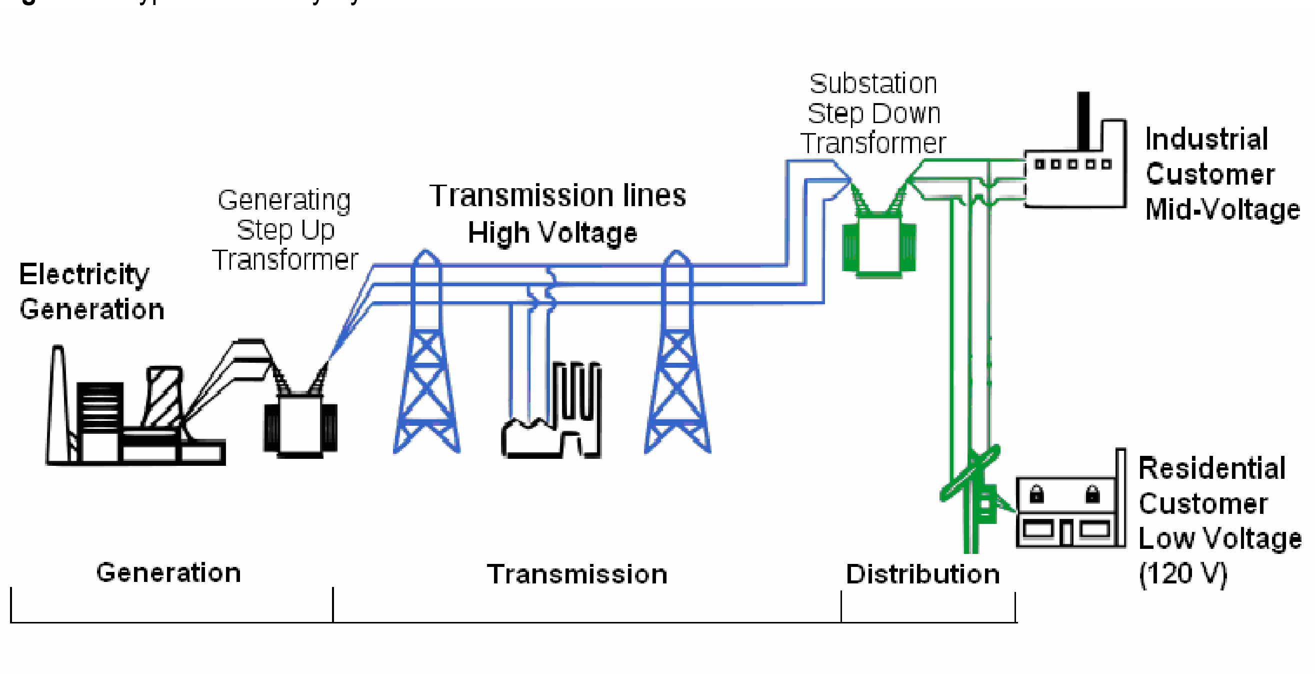
How the Electricity System Works

Electricity is one of the most widely used forms of energy. Electricity is flow of electrical power or charge. It is a secondary energy source, which means that we get electricity from the conversion of other sources of energy, like water, wind, coal, natural gas, sun, nuclear power and other natural sources, which are called primary sources. The energy sources that are used to make electricity can be *renewable* or *non-renewable*.

There are three parts to the system that provides consumers with electricity (See figure 1):

- electricity generation,
- transmission lines or the "grid,"
- the distribution system.

Figure 1: Typical Electricity System



Source: (U.S.-Canada Power System Outage Task Force, 2003)

Electricity generation is the process of converting non-electrical primary sources of energy into useable electricity. Although solar energy can be directly converted into electricity through photovoltaic panels, most electricity is produced by a rotating machine that drives a generator. These machines are typically driven by water (hydropower), wind, hot gases and, most commonly, steam. Steam for electricity is produced in several ways:

- From water that is boiled by burning either fossil fuels, biomass or by nuclear fission.
- From geothermal resources where hot water or steam under pressure in geothermal reservoirs in the earth's crust emerges from the ground and drives a turbine
- From a fluid heated by the sun (solar technologies that are not solar-photovoltaic)

Source: (Current Energy, 2005)

After power is generated, it has to be stepped up in voltage to make the transfer of electricity over large distances more efficient. This is because the further electricity is generated from the place it is used, the more electricity is lost in moving it; and stepping up the voltage lowers the amount of electricity lost. Today in the United States, most electricity is generated away from most cities and towns. It is moved to substations by large, high-voltage **transmission lines**, often supported by tall metal towers. In the United States, the network of nearly 160,000 miles of high-voltage transmission lines is known as the *grid*.

When power has moved closer to where it will be used, the electricity is moved through a local **distribution system** made up of a series of substations, transformers and lower-voltage power lines until it is used by the customer.

Now that we have reviewed how electricity is delivered to our homes, there are three very important things to keep in mind about how the system is operated.

1. Electricity cannot be generated and then stored for later use.
2. The supply of electricity must always equal the demand.

The power grid that supplies the electricity coming into your home or business is designed to maintain a constant balance between consumer demand and the amount being supplied by generators. When there is an increase in demand for electricity then there must be an increase in the supply. Because electricity can not be effectively stored, producers of electrical power must react immediately to increase supply when demand rises or customers could experience power outages.

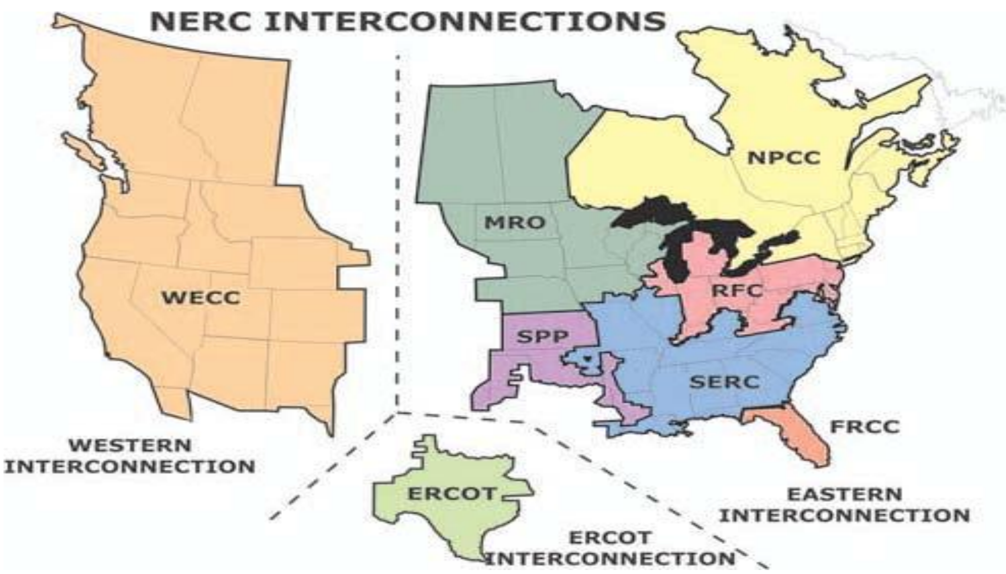
National Perspective of Electricity

There are a number of things to consider from a national and international perspective when exploring different options for meeting electricity demand in Idaho. They are:

1. The importance of a nationally/internationally interconnected electricity grid.
2. Issues with carbon emissions from burning fossil fuels and future national legislation.
3. National growth in demand for electricity.

The first issue to consider is that the electricity system is part of **an internationally interconnected grid**, not contained within state or national boundaries. As seen in figure 2, Idaho is part of the Western Interconnection, an electricity grid that encompasses Alberta and British Columbia, Canada, south into Mexico and from the West coast over the Rocky Mountains to the Great Plains. This region of the grid is also tied to the Eastern Interconnection with several very limited DC transmission lines.

Figure 2: Map of North American Electric Reliability Council (NERC) Interconnections



Source: (North American Electric Reliability Corporation, 2006)

Although having an Idaho only electricity system may seem like an attractive idea, the reality is that it would make electricity more costly, less reliable, less secure, and simply impractical for a number of reasons. Listed are a number of reasons why being part of a regionally dispersed grid is important:

- Idaho currently imports on average at least 50 percent of its electricity from outside the state. Without sources of electricity from outside the state, Idaho would not have sufficient electricity to meet current demand.
- Having multiple or redundant sources of electricity increases reliability. If one source goes down or is eliminated, there are others that can make up the difference. A diversity of resources decreases the risk that all will be unavailable at once.
- It allows wholesale markets and competition to develop among providers of electricity across a larger area that ultimately can reduce consumer costs.

- It can enable geographically remote generation sources such as renewables, to serve areas where electric supply is needed.

The second issue Idahoans needs to consider is the possibility of **future national carbon emission legislation** that could be imposed on our state. Whether or not one believes that changes in the Earth's climate are caused by humans, there may be legislation passed in the next few years that would either:

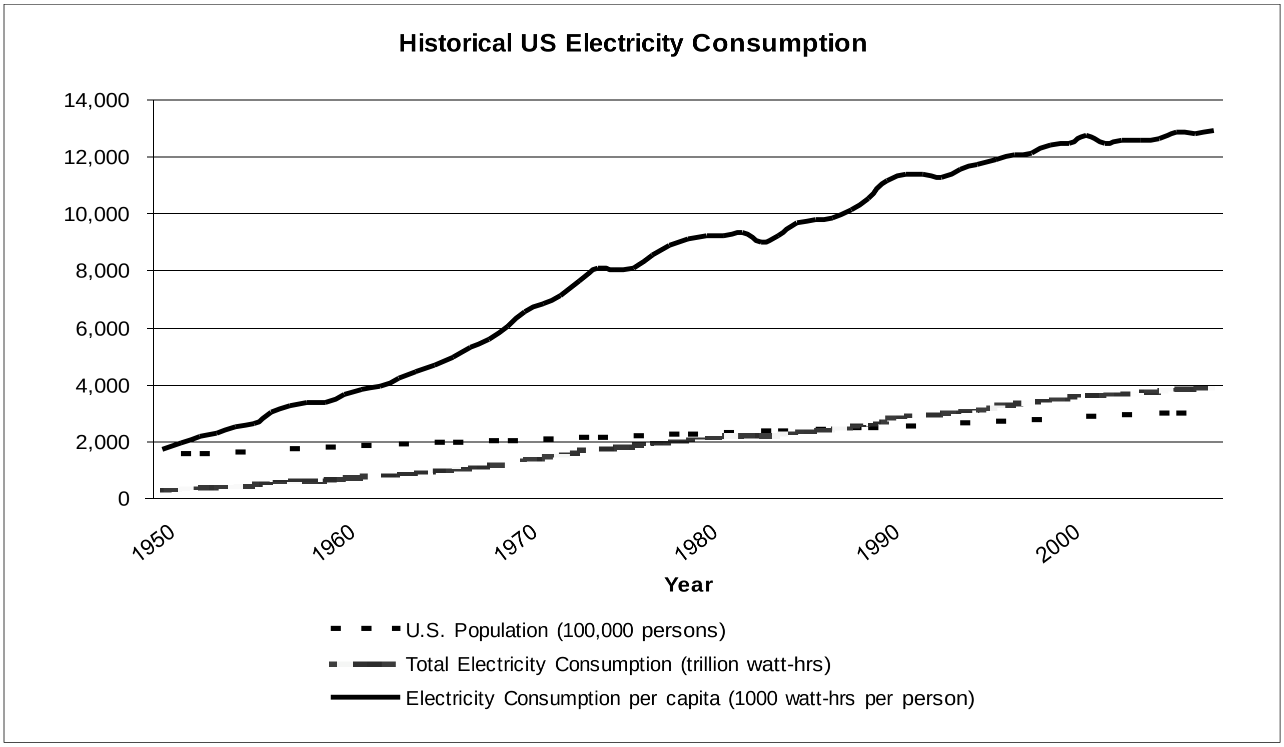
- promote renewable resources of generation that produce little or no greenhouse gases.
- increase the cost of greenhouse gas producing electricity generation sources (i.e. fossil fuels)

Promoting renewable sources of electricity that produce little or no greenhouse gases could come in the form of a national Renewable Portfolio Standard (RPS). This would impose a mandate that utilities buy a certain percentage of their electricity from renewable sources such as wind, solar, hydro, or geothermal. Nuclear is considered by many experts to be non-greenhouse gas producing, but it may not be included as a "renewable" source to fulfill national requirements for a national RPS. Similarly, hydropower projects with large dams forming extensive reservoirs that severely alter the flow of a river may not be included as a "renewable" source.

An increase in the cost of electricity generation that uses fossil fuels could come in the form of a "carbon tax" or as a "cap-and-trade" system. A carbon tax is a tax placed on the price of coal, natural gas or oil either purchased or consumed by an electric utility. A "cap-and-trade" is a system that would impose an overall limit or "cap" on the amount of greenhouse gases that can be produced nationally by providing emissions "allowances" to specific sources, such as investor-owned or public utilities. Emitters would then trade their allowances; some with unneeded allowances could sell them to sources that emit more then their allocation. Sources could also choose to reduce their emissions so as not to exceed their individual allowance. Cap-and-trade and carbon tax mechanisms effectively drive up the cost of carbon-based fossil fuels for generating electricity, also increasing the costs for consumers[82].

The third national issue that could impact Idaho has to do with the overall **increase in electricity demand in the U.S.** Figure 3 clearly shows that while the nation's population has been steadily increasing, the amount of electricity consumed per person has been increasing as well. And beyond traditional uses of electricity, future national legislation will likely promote cars, trucks and public transportation that are powered by electricity. If these trends continue, the United States will need to build electric generation facilities, find ways to conserve and use electricity more efficiently, or both. The growth in demand will put upward pressure on the price of fuel and capacity for generating electricity and accelerate depletion of non-renewable natural resources.

Figure 3: Historical consumption of electricity in the United States versus population growth



Sources: (Energy Information Administration-US Department of Energy, 2006; U.S. Census Bureau, 2002, 2007)

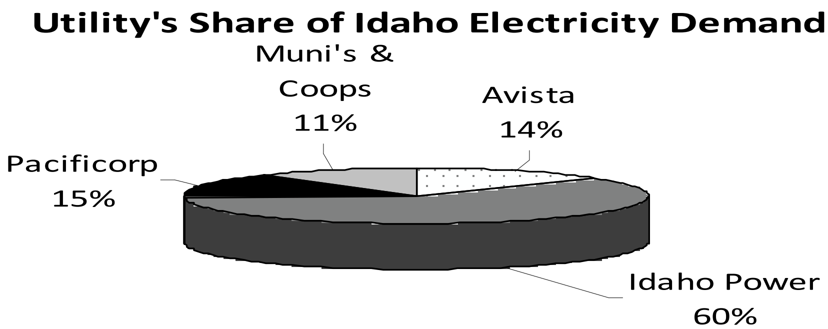
Understanding the inter-connectedness of the electricity system, potential federal legislation, and national demand trends will have an effect on Idaho's future choices for electricity. Our choices will also need to consider issues illustrated in the next section describing Idaho's current electricity situation.

Idaho's Current Electricity Situation

Overview

Figure 4 illustrates that three large investor owned utilities supply 88 percent of Idaho's electricity demand: Idaho Power, Avista, and Pacificorp. Idaho Power services the Treasure Valley and much of southern Idaho; Avista services northern Idaho; and the Rocky Mountain subsidiary of PacifiCorp services parts of eastern Idaho. There are smaller, local utilities owned by consumers (cooperatives or co-op's) and municipalities (muni's) that supply the more rural regions of the state.

Figure 4: Utility's share of Idaho electricity consumption



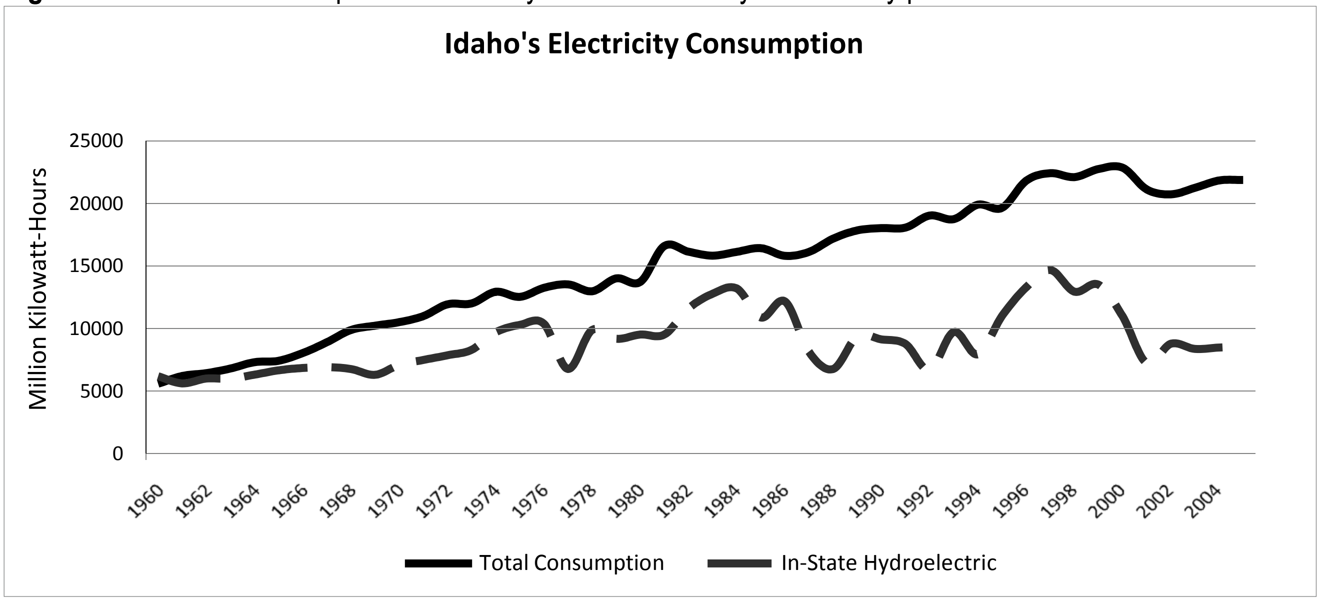
Source: (Idaho Legislature - E3 Consulting, 2007)

Idahoans currently consume approximately 23,600,000 megawatt-hours per year (MWh/yr) of electricity (2005) while only producing about 11,300,000 MWh/yr (2006) (Idaho Legislature - E3 Consulting, 2007). This means that Idaho currently imports a little over 50 percent of its electricity from outside the state. For illustration purposes, it would take either one or two new nuclear power plants, two or three new coal plants, about four Brownlee-sized dams, or 75 Wolverine Creek wind farms for Idaho to eliminate import of electricity into the state. There are no nuclear or coal plants in Idaho. Brownlee is the largest dam and Wolverine Creek is the largest windfarm (43 windmills) in Idaho. (Note: one megawatt-hour is equivalent to the amount of electricity used by ten-thousand 100-watt bulbs for 1 hour).

Idaho is currently facing an uncertain energy future. According to the U.S. Census Bureau, Idaho was the fourth fastest growing state in 2006-2007 and the sixth fastest growing state in 2007-2008 (U.S Census Bureau, 2008). That growth brings higher demand for electricity.

Idaho consumers, in 2007, on average paid the lowest retail electricity rates in the nation due to hydroelectricity sources. This may be at risk. Figure 5 shows how Idaho's in-state hydroelectricity generation is becoming a smaller percentage of the state's total consumption. Historically, as the state's consumption has grown, Idaho's utilities have historically chosen to source from relatively inexpensive coal plants in other states making Idaho's electricity consumption based less on hydropower. Current national policies may create financial disincentives for burning coal and natural gas making them more expensive. In addition, Idaho has long term contracts due to expire in the next several years with electricity suppliers in states that currently have higher electricity prices than Idaho. When contracts are re-negotiated, there is a risk that prices will reflect neighboring state's higher electricity prices.

Figure 5: Historical consumption of electricity versus in-state hydroelectricity production



Note: The year-to-year variation in hydroelectric production is dependent upon the quality of the water year.

Source: (Energy Information Administration, 2008g)

This will inevitably put upward pressure on electricity rates as we consume from sources that will be more expensive than in the past.

Additional issues and challenges that Idaho currently faces:

- Currently, Idaho does not have adequate transmission capacity to meet the potential for increased demand, especially if that demand is met by more importation from out of state. Transmission capacity in Idaho is operating at near- or full-capacity during periods of peak demand. As a result, Idaho will require additional transmission capacity to integrate diverse resources into its energy mix. As demand increases, it will put more strain on the existing transmission system, which can put Idaho at risk for potential outages.
- The amount of electricity produced by hydropower is dependent on how much water is available in a given year.
- Idaho is rich in renewable energy resources, but has no commercially viable deposits of coal, oil, or natural gas[31].

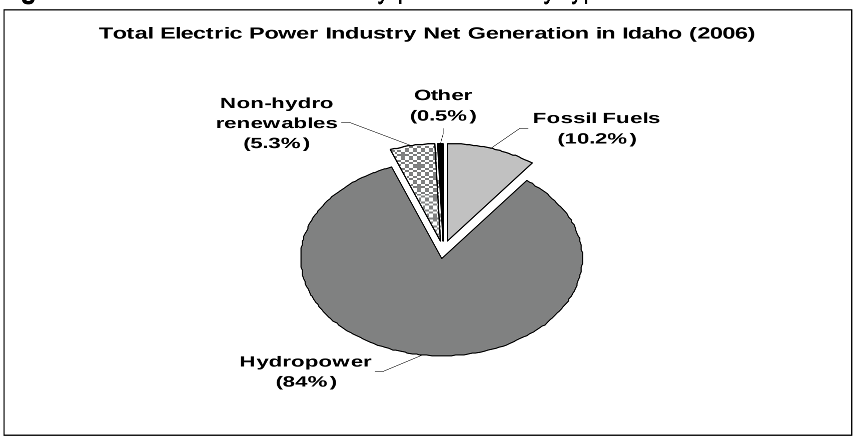
Electricity Production

There are currently three main types of electricity **production** within the borders of Idaho (figure 6):

1. hydropower generation
2. fossil fuel generation,
3. non-hydro renewable generation.

Hydropower is Idaho's dominant source supplying 84 percent of the total electricity produced in the state. Only 10.2 percent comes from **fossil fuels** of which 9.6 percent comes from natural gas. There are no utility oil-fired or coal-fired power plants in Idaho (Idaho National Laboratory, 2006). The little coal-fired generation the state does have (0.6 percent) is self-produced for owner consumption. Idaho also produces 5.3 percent of its total in-state production of electricity from **non-hydro renewable** sources. This includes 4 percent from biomass and 1.3 percent from wind power (Energy Information Administration, 2008c). There are several wind projects that are in different stages of development which may increase the percentage of wind. Idaho does have one operating geothermal power plant that began commercial operation in 2007 (not reflected in the graph), no commercial scale solar facilities and no **nuclear** power plants. However, during the last three years, there have been two companies that have been or are considering nuclear power plants in southwestern Idaho.

Figure 6: Total in-state electricity production by type in 2006

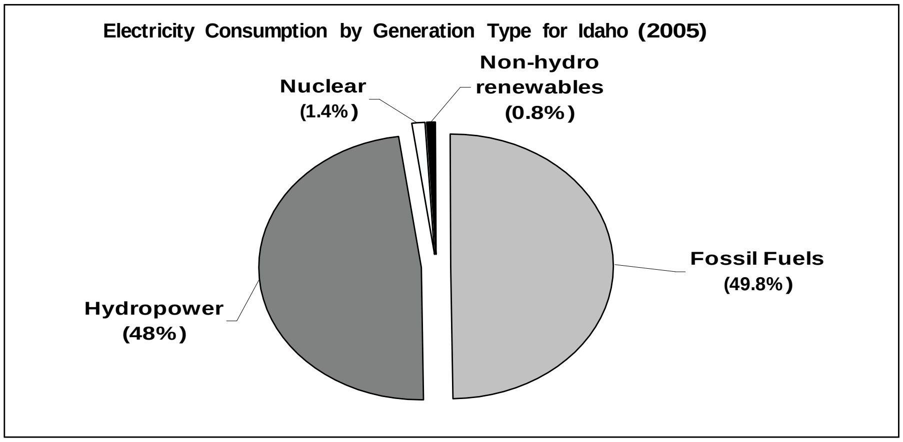


Note: Other category includes batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, tires and miscellaneous technologies.
Sources: (Energy Information Administration, 2008d, 2008i)

Electricity Consumption

Although hydropower is by far the largest *production* source in the state, depending on the quality of the water year, Idahoan's *consume* as much or more from fossil fuel sources (49.8 percent), than from hydro-power (48 percent). This is because Idahoans must import more than half of their electricity which includes 42 percent from coal fired power plants, all located outside the state. An additional 8 percent comes from gas-fired power plants making up the remaining fossil fuel consumption. Idahoans do consume about 1.4 percent of their electricity produced from a nuclear power plant in south-central Washington [31] and only 0.8 percent from non-hydro renewable sources. **Sources:** (Energy Information Administration, 2008h; Western Resource Advocates, Northwest Sustainable Energy for Economic Development, GreenInfo Network, Idaho Energy Division, & U.S. Department of Energy, 2002) (D. Solan, personal communication, January 28th, 2009).

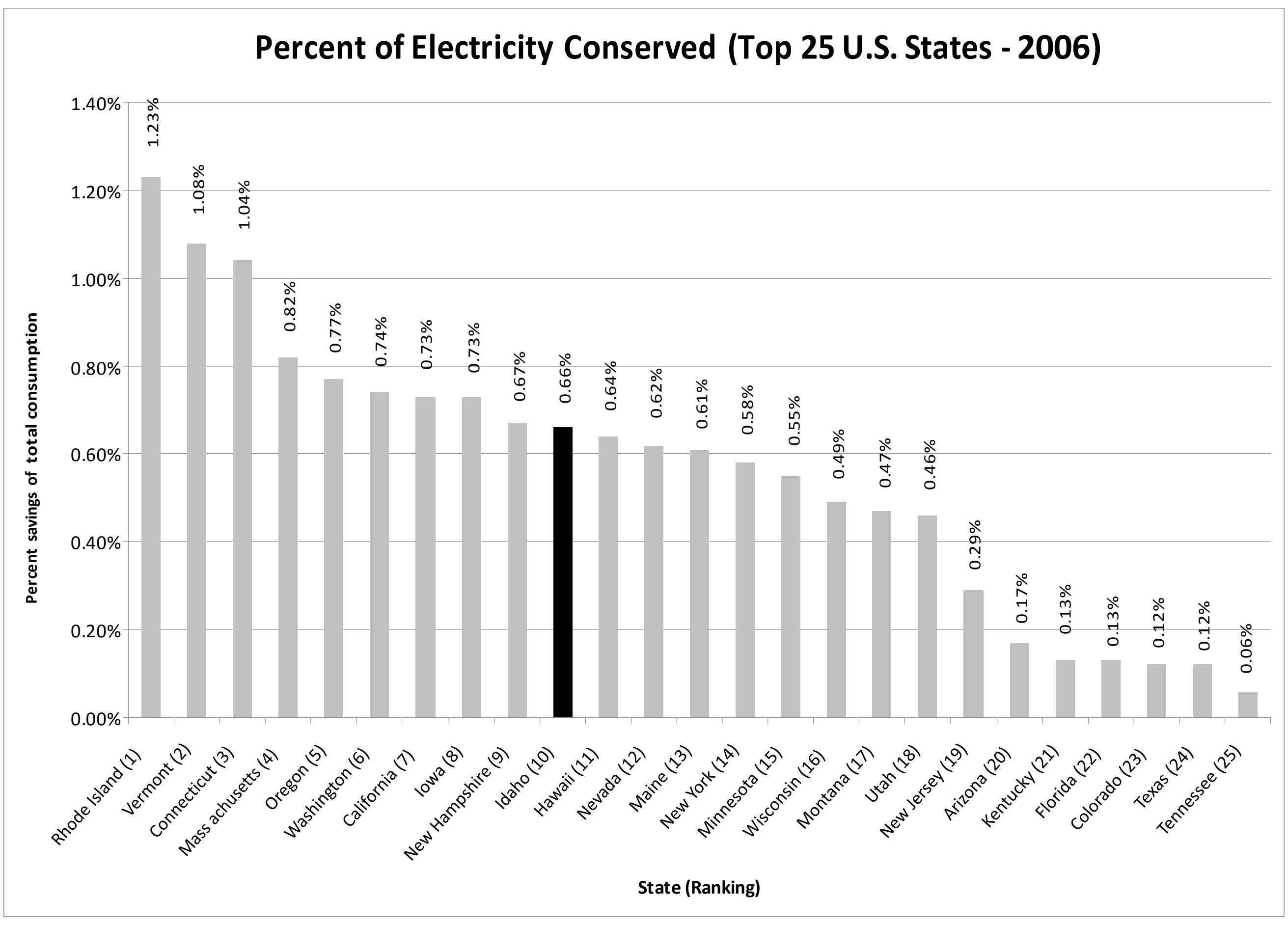
Figure 7: Total electricity consumption by generation type in 2005.



Source: (Idaho Legislature - E3 Consulting, 2007)

Another way the state and utilities have addressed electricity consumption is through conservation and efficiency measures. Most of Idaho's utilities plan for and invest in these measures and treat them as a resource to meet demand. Idaho's utilities saved approximately 151,000 MWh's or 0.66% of net total consumption in 2006 through energy conservation and efficiency measures (figure 8). For this period, Idaho ranked tenth compared to all other states.

Figure 8: State comparison of electricity conserved as a percent of total demand in 2006.



Source: (Eldridge et al., 2008)

Five Choices for Meeting Future Electricity Demand

Given the state's situation, Idahoans will need to make choices about how to handle future electricity demand growth. This study will explore five alternatives:

1. Energy Efficiency and Conservation
2. Fossil Fuels
3. Hydropower
4. Nuclear
5. Non-hydro Renewables

Energy Efficiency and Conservation

A 16-watt compact florescent bulb

"Energy efficiency is the use of technology that requires less energy to perform the same function. Energy conservation is any behavior that results in the use of less energy" (Energy Information Administration, 2008b). For example, a compact fluorescent light bulb (CFL) uses less energy than a regular incandescent bulb. They both produce the same amount of light, but the CFL is more ***efficient***. An example of energy ***conservation*** is when someone turns off the lights after leaving an empty room or turns the air-conditioner or furnace to a lower setting. Both result in less consumption of energy. ***Efficiency*** uses technology without sacrificing performance or comfort, while ***conservation*** requires us to be more careful in how energy is used so that less is wasted.

Electricity saved through energy conservation and efficiency can displace an equivalent amount of electricity that a utility would have to produce or buy from other utilities to meet demand.

There are two areas in the electricity system that energy conservation and efficiency can be implemented:

1. The supply-side.
2. The demand-side.

On the **supply-side**, utilities can upgrade their generation, transmission and distribution equipment. Better and newer equipment can make significant efficiency gains. Utilities can also make investments in the transmission and distribution system and find better ways to set up and run the grid. Electricity traveling down a wire suffers *line loss* caused by energy dissipating through the wire in the form of heat. From power plant to the customer, it is estimated that the United States loses approximately 10% of its total power through the electricity grid and the distribution system (National Council on Electricity Policy, 2004). Placing generation sources closer to where the electricity is used can lessen line loss. This allows utilities to meet more demand with the same amount of generation capacity.

On the **demand-side,** consumers can implement conservation and efficiency measures solely as a desire to reduce their utility bills. Most often, demand-side measures are motivated by government policies or through a utility program. There are two types of programs or policies.

1. *Conservation programs and policies.* These are aimed at reducing the energy required to accomplish a task. For example, utility conservation programs may subsidize (assist with a money contribution)

efficiency measures such as water heater blankets, energy- efficient light bulbs, and appliances for their customers. These subsidies are usually funded by the rates utilities are allowed to charge, usually approved by the Public Utilities Commission. An example of a conservation policy might be a tax credits passed by the state or federal government for making energy-efficient purchases (i.e., Energy Star appliances, insulation, etc.).

2. *Demand response programs and policies.* The goal is to reduce electricity demand during periods when electricity use is high (peak morning and evening hours) to keep the utility from having to use more expensive sources of electricity. These do not necessarily reduce overall usage. One example of a program is to employ devices that utilities can use to remotely shut off energy intensive equipment such as air conditioners and industrial motors. Customers may receive a benefit by allowing their utility to call upon these devices when they are needed. The Public Utilities Commission or state legislature can also develop a policy mandating a variety of rate-making mechanisms, such as Time-of-Use (TOU) rates, which encourages customers to use electricity when the cost of producing that electricity is least expensive during off-peak hours.

Advantages of Energy Conservation and Efficiency:

- **Fewer emissions:** By reducing carbon-emitting generating resources, fewer greenhouse gases and other pollutants are emitted into the atmosphere, reducing pollution.
- **Quickest to implement:** Conservation changes in households and business are the most simple to implement of the five alternatives discussed in this document.
- **Reduction on bills:** Energy- efficient products and energy conservation reduce the amount of energy used, thus reducing bills. Home upgrades can help reduce 25 to 30 percent of the costs; however, this reduction can be as high as 50 to 60 percent.
- **Sustainable use of resources:** With less than 5 percent of the population in the world, the U.S. uses 25 percent of the world's energy resources. Conservation and efficiency can encourage the smart use of our energy resources, and there can be a decrease on the reliance of imports for fossil fuels.
- **Incentives for implementation:** Incentives are available through utility programs and tax code to partially offset up-front investment by consumers.
- **Total cost:** Energy conservation and efficiency has the lowest levelized cost of all options discussed. On average, a utility can displace the same amount of new generation capacity for about half the cost.
- **Independent of fuel supply and cost:** Energy conservation and efficiency is not affected by fuel availability or price volatility.
- **Other benefits:** Implementing energy efficiency can provide jobs in manufacturing, construction, energy auditing, and installation.

Sources: (Energy Information Administration, 2008b; Energy Star, 2008; Environmental Protection Agency & U.S. Department of Energy, 2008; Idaho Office of Energy and Resources, 2008; Idaho Power, 2008a, 2008b; National Energy Policy Development Group, 2008; Northwest Power and Conservation Council, 2005)

Disadvantages of Energy Conservation and Efficiency**:**

- **Up-front costs:** Even though energy efficiency modifications may pay for themselves over time, consumers may not have sufficient funds to cover the up-front costs of improvements. The initial costs for energy efficient appliances or products could be a limiting factor for consumers.
- **Hazardous materials in some energy efficient devices:** Compact fluorescent light bulbs contain a small amount of mercury. Even though CFLs use less power and have a longer life, people may feel reluctant to changing their incandescent light bulbs to CFLs due to worries about disposal, potential air and water contamination or the unavailability of recycling facilities.
- **Increased indoor air pollution:** As air leaks are decreased in buildings, there is less air movement in and out to the environment. Therefore, there is increased accumulation of gases within buildings,

including carbon dioxide (from natural gas combustion), radon and off-gasing of carpets and cleaning solvents.

- **Uncertainty:** Voluntary actions by a large number of people are needed to obtain significant outcomes. In the case of energy efficiency and conservation, electricity consumers may not replace appliances for more efficient ones until their current appliances have reached the end of their useful life. In the case of demand response programs, a utility is relying on customer's actions to reduce load as opposed to increasing generation at a power plant that is operated by the utility.

Sources: (National Energy Policy Development Group, 2008) (D. Solan, B. Nielson, personal communication, January 28th, 2009) (S. Piet, personal communication, January 31st, 2009)

Research and Development Opportunities for Energy Conservation and Efficiency:
Increasing the adoption rates of energy conservation and efficiency measures by electricity consumers is one of the biggest opportunities for improvement. Significant improvements are needed in the technology of devices that use electricity; but there are already a number of energy efficient replacements available on the market. It is ultimately up to the consumer to turn off lights when not in use or replace electrical devices with more efficient ones. This problem is inherently a social one, dependent on attitudes, knowledge, and behavior.

Examples of research that could help policymakers and utilities improve consumer adoption rates include: 1.) investigation of innovative alternatives that could motivate the public to adopt energy conservation and efficiency measures; 2.) analysis of alternatives to find those most accepted by stakeholders and members of the public; and 3.) development of policy decision-making processes and education that build public and stakeholder commitment. Research in this area is relatively inexpensive compared to technology-based research, and the effect of some improvements could be felt almost immediately.

Fossil Fuel Electricity Generation


Castle Gate coal plant in Utah

Fossil fuel generation uses coal, oil or natural gas resources to create electricity. Fossil fuels are non-renewable sources of energy found beneath the Earth. Exploration, drilling, extraction and refining are necessary processes to obtain usable fossil fuels. Once fossil fuels are obtained, they are usually transported to power plants by ships, trucks, trains, oil tankers or pipelines. In the case of coal power for Idaho, several power plants are located at the mine site (out of state) and the electricity is transmitted through power lines into Idaho. When they are burned, fossil fuels usually heat water which produces steam, and the steam turns turbines that drive generators that produce electricity. **Sources:** (American Coal Foundation, 2007; Chughtai & Shannon, 1998; Discovering Fossils, 2008; Energy Information Administration, 2008a, 2008e; Environmental Protection Agency, 2007a, 2007b, 2007c; Idaho National Laboratory, 2006)

Advantages of Fossil Fuels:

- **Easy transportation:** Natural gas is transported to power stations relatively easily using existing pipelines. Natural gas is currently imported into the state through pipelines from Alberta, Canada and from southeast of the state.
- **Significant generation of electricity:** A single power station that burns coal or natural gas can produce large amounts of electricity.

- **Consistent supply of energy:** Fossil fuels are a controllable and predictable source of base-load electricity and can be used to integrate intermittent renewable resources. The U.S. has a 200-250 year supply of coal.
- **Flexibility:** Natural gas can be used for base load, intermediate, or peak power.
- **Total cost:** Current levelized cost of coal-fired and non-peaking gas fired generation are on par with other forms of base-load generation such as nuclear and hydropower.
- **Capital cost:** Initial capital investment cost ($575-$1,550/kW) for natural gas plants are relatively low.
- **Other Benefits:** Construction of plants and ongoing operation can increase jobs and the state and local tax base. Excess heat can be used as process heat for other applications beside electricity generation.

Sources: (Energy Information Administration, 2008h; Lazard, 2008) (D. Solan, personal communication, January 28th, 2009)

Disadvantages of Fossil Fuels:

- **Lack of Availability**: There are no commercially viable deposits of oil, natural gas, or coal in Idaho, although there are sources in surrounding states.
- **Total cost:** The levelized cost of natural gas fired generation used to meet peaks is the most expensive source of electricity but is necessary to balance variation in the system. Cost of coal will likely increase dramatically with legislation to limit carbon.
- **Capital cost**: Initial capital investment cost ($2,550-$5,350/kW) for coal plants are moderate to moderately high.
- **Fossil fuels are non-renewable resources:** Reserves of fossil fuels vary. There are still reserves of 200 to 250 years for coal in the United States; however, the availability of natural gas is much less certain. Once resources in an area are exhausted, different areas need to be drilled or mined in order to satisfy current demand. If known fossil fuel reserves diminish and demand remains high, prices will increase.
- **Emission of pollutants and greenhouse gases:** The process of combusting fossil fuels produces harmful emission, including carbon dioxide and sulfur dioxide. These contribute to environmental problems such as acid rain and climate change. Burning coal produces the largest amount of emissions per MWh produced for electricity generation, and is also associated with mercury emissions and contamination. In contrast, the combustion of natural gas produces the lowest amount of emissions for production of electricity from a fossil fuel.
- **Area requirements:** With the exception of natural gas plants, which are relatively small and can be placed in urban areas, large coal-fired power plants require up to four square kilometers of land. Surface mining disturbs larger areas than underground mining. Wildlife and plant habitats can be destroyed.
- **Responsiveness and leadtime:** Timeframe for siting large fossil fuel power plants can be lengthy (especially coal) due to environmental permitting, and NIMBY (not in my backyard) issues.
- **Undesirable presence:** Power generating plants are aesthetically displeasing and their establishment in areas close to neighborhoods is unwelcome. Gas can be highly explosive and must be handled properly.
- **Consumption of water and potential contamination:** Power plants often consume large amounts of water for steam production and cooling. Large quantities of water are used to remove coal impurities and the overall mining process can contaminate water. Aquatic life can be affected from all processes. In addition, drilling can cause contamination of underground water and runoff can affect surface waters.
- **Mining and extraction impacts:** The processes of drilling and extraction can leave harmful waste products. Solid waste (i.e., wastewater sludge, residues not completely burned, ash) and waste-water can contain high levels of contaminants. Drilling processes can contaminate ground and surface water. The only fossil-fired source that does not produce substantial amount of solid waste is natural gas.

Sources: (Environmental Protection Agency, 2007a, 2007b, 2007c; Lazard, 2008; U.S. Department of Energy & Energy Efficiency and Renewable Energy, 2008d, 2008e, 2008f; U.S. Geothermal Inc., 2007)

Research and Development Opportunities for Fossil Fuels:
In the United States, the building of fossil fuel electricity generation plants (especially coal) has slowed considerably given local opposition and the likelihood of legislation that may increase the cost of burning fossil fuels. Methods to capture and store gases that potentially warm the atmosphere from fossil fuel emissions present the most opportunity. There are a number of efforts under way to study how to capture and store carbon, but researchers are a number of years from making it commercially viable, even if there is sufficient funding (see Appendix II; Table 9).

Hydropower Electricity Generation


Brownlee Dam in Idaho

Hydropower uses natural or artificial water flow to create electricity. Electricity is generated when moving or falling water turns blades in a turbine, spins a generator, and produces electricity. When water is stored in a reservoir, it can be released to create electricity when demand is high[15]. Hydroelectricity plants can be large or small. Rivers with a high flow, or with a high drop, produce a large amount of energy.

Advantages of Hydropower**:**

- **Large amount of developed capacity:** Idaho has a significant amount of developed capacity of hydroelectric resources providing a predictable and controllable source of base-load electricity.
- **Low electricity rates:** Rates from hydro power are low because very high capital costs can be spread across a long useful life (50 years) of the asset and there are no fuel costs. Idaho's hydroelectric facilities have fully amortized capital costs.
- **No greenhouse gas emissions.** Operating a hydropower plant emits no greenhouse gases.
- **Time-tested technology:** Hydro technology has been proven and time-tested. Engineers can control the flow of water through turbines to produce electricity so long as they comply with other operating constraints for water rights, flood control, fish flows, recreation, transportation, etc.
- **Total Cost:** Hydropower has no fuel cost and Idaho's existing facilities have fully amortized capital costs.
- **Other benefits**: Impoundment hydropower creates reservoirs, providing recreational opportunities, but can change the natural landscape. Dams also help with water supply, irrigation and flood control. The construction of hydropower plants and their ongoing operation can increase jobs and the state and local tax base.

Sources: (U.S. Department of Energy & Energy Efficiency and Renewable Energy, 2008a)

Disadvantages of Hydropower:

- **Disruption of fish migration:** Salmon and other salmonids need to swim to the ocean and then return to their spawning grounds. Encountering impoundments/dams affects their migration and fish populations can decrease. Pressure changes, turbulence, and other types of stress from turbine passage or fish ladders may cause fish to get disoriented and may cause injury or death.
- **Dependence on water flows:** Dams depend on seasonal flows of water. In Idaho, water for hydropower largely comes from snowpack, which varies yearly. If there is a winter drought, hydropower plants may have to operate at reduced capacity. Early spring run-off may need to be "spilled" from dams without producing electricity to prevent flooding. A slow, late spring runoff scenario helps create more water for electricity generation, especially during seasonally-high demand periods.

- **Impact on local natural environment:** Hydropower facilities compete with other land uses. Natural sites could be affected and cause an impact on wildlife and plant habitat. Historical sites and local cultures could also be affected. The magnitude of the effect depends on the type of hydroelectric plant. Large hydroelectric plants with dams and reservoirs have large land use impacts while run-of-river plants have much smaller impacts.
- **Impact to the aesthetics of the area:** Dam and reservoirs change natural landscape (i.e., flowing rivers). Impact is much lower from run-of-river power plants.
- **Impact on water quality and flow:** Water in the reservoir is stagnant compared to a free-flowing river. Water-borne sediments and nutrients can be trapped, resulting in the undesirable growth and spread of algae and aquatic weeds". Low dissolved-oxygen downstream of the dam can be harmful to riverbank habitats.
- **Lack of location for new dam construction:** There are few potential sites for additional large-scale hydropower dams. The best locations have already been used and other potential locations are problematic due to the large amounts of land flooded for reservoirs. Further expansion is limited to the conversion of existing dams without generating capacity, the addition of more efficient turbines and/or generators to existing hydropower facilities, and the use of small sites with limited electricity capacity. There are other technologies that do not require large dams and impoundments (i.e., run-of-river plants).
- **Economic dislocation:** Dam could displace existing economic benefits (i.e., agriculture, white water rafting, etc.).
- **Catastrophic dam failure:** There is a small risk of dam failure causing potential property damage or even loss of life (e.g. Teton Dam disaster, 1976)

Sources: (U.S. Department of Energy & Energy Efficiency and Renewable Energy, 2008a, 2008b, 2008c)(D. Solan, personal communication, January 28th, 2009)

<u>Research and Development Opportunities for Hydropower:</u>

The biggest area of opportunity for hydropower-generated electricity is to eliminate or lessen the effect of dams on salmon migration and survival. Dams impede migration by blocking passage and by affecting water temperature and water quality, which impact migrating fish. A combination of solutions have been tried on many dams in the Columbia River System, including fish ladders and elevators, trapping and transporting fish around dams by truck, diverting fish away from turbines, installing fish-friendly turbines and increasing flow by releasing water to flush juvenile salmon downstream. Research is helping to improve these measures and determine effectiveness (see Appendix II; Table 9).

Nuclear Power Electricity Generation

Columbia Nuclear Plant in Washington State

Nuclear power uses uranium to create electricity. "Nuclear energy is energy in the nucleus (core) of an atom. Atoms are tiny particles that make up every object in the universe. There is enormous energy in the bonds that hold atoms together" (Energy Information Administration, 2007). Nuclear energy needs to be released from the atoms to produce electricity. Energy is released by a process called fission, where atoms are split apart to form smaller atoms (Energy Information Administration, 2007).

Uranium is the fuel normally used to produce the nuclear reaction. It is a non-renewable element found in rocks. "Nuclear plants use a certain kind of uranium, U-235, as fuel because its atoms are easily split apart"[11]. Mining, extraction and

Nuclear fuel pellet

processing (including enrichment) are necessary to obtain uranium in order to use it as fuel for nuclear electricity generation (Energy Information Administration, 2007). Processing produces one-half inch-sized fuel pellets that are stacked into fuel rods.

Fuel assemblies are located in the center of reactors at a nuclear power plant. The fission process produces heat that makes water boil to produce steam. This steam turns turbines that drive generators to produce electricity. At a cooling tower, the steam is turned back into water for re-use (Energy Information Administration, 2007). As nuclear fuel is used, radioactive waste accumulates, which slows the reaction process to the point that the fuel rods are no longer useful for producing electricity and need to be disposed and replaced.

Advantages of Nuclear:

- **Amount of energy:** The fission process allows for a large amount of energy to be released from a small amount of fuel. One pellet contains "the same amount of energy as 150 gallons of oil" (Energy Information Administration, 2007).
- **Efficiency:** Large amount of electricity can be generated with a small amount of fuel. Existing nuclear plants operate at more than 90 percent capacity on average (Nuclear Energy Institute, 2007).
- **Highly reliable:** The United States gets about 20 percent of its electricity from nuclear power providing a reliable source of base-load power. The U.S. has 104 operating nuclear power plants.
- **No greenhouse gas emissions:** Operating a nuclear power facility emits no greenhouse gases.
- **Total Cost**: Nuclear power is on par with other base-load forms of electricity generation such as coal and natural gas due to low fuel associated cost and plant efficiency.
- **Regulatory structure**: The U.S. Nuclear Regulatory Commission (NRC) regulates commercial nuclear power plants and other uses of nuclear materials through licensing and inspection. Nuclear power plants must pay into trust funds that will be used to decommission plants when their useful operating life is over and must pay a surcharge on fuel to offset disposal costs.
- **Other benefits**: The construction of nuclear plants and their ongoing operation can increase jobs and the state and local tax base. Excess heat can be used as process heat for other applications beside electricity generation.

Sources: (Alternate Energy Sources, 2008; Energy Information Administration, 2007; Lazard, 2008; U.S. Department of Energy, 2008).

Disadvantages of Nuclear:

- **Costly regulation:** The NRC enforces federal laws for operating nuclear power plants. These regulations increase cost, e.g., nuclear plants are forced to set aside funds for waste disposal and decommissioning of power plants when they stop operation. Other forms of power do not have to do these things.
- **Capital costs:** Technology and scale of plants require extremely high construction costs. Nuclear power requires the highest initial capital investment cost ($5750 to $7550 per kW) of all the electricity options discussed.
- **Storage of radioactive waste:** The most hazardous radioactive waste remains toxic for a very long time and is more than 10,000 times more toxic than the natural uranium ore that was mined to make the original fuel. There is currently no long term disposal or storage solution for radioactive waste.
- **Water use:** Nuclear power plants, like fossil fuel plants, require consumption of water. The amount of water needed depends on how efficient the plant is; however, the numbers are quite similar among all thermal power plants.
- **Connections to nuclear weapons**: Nuclear energy has been perceived as connected or related to the fabrication of nuclear weapons. However, uranium used as fuel (fresh or used) cannot be used in nuclear weapons, which requires highly-enriched weapons-grade uranium. All nuclear materials, weapon material

and existing weapons are guarded worldwide. The U.S. operates on a "once-through" process and does not recycle fuel because of cost and nuclear weapons proliferation concerns.

- **Responsiveness and lead time:** The length of time to obtain a license and to construct a nuclear power plant is highly uncertain and can range from 6 to 10 years, although new licensing processes are expected to reduce the length of time.
- **Area requirements:** Nuclear power generating plants require up to four square kilometers of land, slightly larger than coal or natural gas, but immensely smaller than wind or hydroelectric dams for the same amount of energy produced. Beyond this space, the Nuclear Regulatory Commission requires an area with relatively low population, which can be evacuated if needed.
- **Mining and extraction impacts:** Improper mining and extraction of uranium can contaminate local water supplies and can be a threat to worker health and safety.
- **Undesirable presence:** Power generating plants are aesthetically displeasing and their establishment in areas close to neighborhoods is unwelcome.
- **Perception of safety**: There is a public perception of insecurity regarding the potential for accidents or terrorist attacks U.S. nuclear power plants have an excellent safety record. The only major commercial power plant accident in 1979 was at Three Mile Island in Pennsylvania. This accident raised questions about adverse effects from radiation. However, after an extensive investigation, results showed that "in spite of serious damage to the reactor, most of the radiation was contained and that the actual release had negligible effects on the physical health of individuals or the environment" [74]. Control and operating training has been implemented in nuclear power plants to avoid potential accidents. In addition, this accident led to the establishment of the Institute of Nuclear Power Operations, through which the nuclear industry shares information on operational best practices.
- **Perceptions of trust**: There is an inherent lack of trust perpetuated by a legacy of secrecy and lack of transparency from Cold War era weapons programs.

Sources: (Johnson, 2008; Lazard, 2008; U.S. Nuclear Regulatory Commission, 2004; United States Nuclear Regulatory Commission, 2009) (D. Solan, B. Nielson, personal communication, January 28th, 2009) (S. Piet, personal communication, January 31st, 2009)

Research and Development Opportunities for Nuclear:

Perhaps the most common concern about nuclear power is radioactive waste. When nuclear fuel comes out of a nuclear power plant, it is over ten thousand times more toxic than the natural uranium ore that was mined to make the original fuel. If all the used nuclear fuel is disposed, it remains more toxic than uranium ore for almost a million years.

There are two approaches to deal with this waste, *direct disposal* or *recycle*. *Direct disposal* requires a geologic repository to isolate the material from air, land, and water. The U.S. does operate an underground repository located in several hundred million year old salt beds dedicated for government use. Disposal of U.S. commercial nuclear power used fuel is planned for Yucca Mountain, Nevada. Although a license application to construct the Yucca Mountain facility was submitted last summer, there is no guarantee the license will be granted or the repository built. If a license is ever granted, the Yucca Mountain geologic repository would be filled with the waste that that would exist at the time the repository opened and additional sites would be needed.

A *recycling* approach removes material useful as fuel from residual waste. The residual waste, less toxic than uranium ore in 1000 years, must still be disposed. The useful material is processed back into fuel to generate nuclear power. Other countries with the largest nuclear power programs (France, Japan, Russia) recycle used nuclear fuel. The U.S. recycle research program aims at recycling the used fuel in such a way as to achieve better waste savings with less concern about nuclear weapon production. (see Appendix II; Table 9).

Non-Hydro Renewable Electricity Generation

In this study, we will consider three non-hydro renewable energy sources to generate electricity:

1. Solar,
2. Geothermal,
3. Wind.

Solar electricity generation uses the light and radiant heat from the sun. A photovoltaic or solar cell is used to convert solar energy directly into electrical power. Solar thermal power plants produce electricity "when the heat from solar thermal collectors is used to heat a fluid which produces steam that is [then] used to power [a] generator" (Energy Information Administration, 2008f).

Solar Panels at Nellis Air Force Base

Geothermal electricity generation uses heat generated within the earth. This heat could be found "in the form of hot water, steam or rocks, near the surface of the earth's crust" (Western Resource Advocates et al., 2002). Electricity is generated either by steam directly from a geothermal reservoir or from hot water from a geothermal reservoir (usually below the boiling point of water) that is used to heat a liquid with a lower boiling point used to turn a turbine generator. In this sense, geothermal is similar to coal, natural gas, oil, or nuclear power plants - gases are heated to turn a turbine.

Raft River Geothermal Plant in Idaho

Wind electricity generation uses wind to generate electricity. When the wind blows, it turns blades on a wind machine. The blades are connected to a hub and shaft that turns an electric generator to produce electricity. A typical wind machine stands as tall as a 20-story building and has three blades that span 200 feet. "The largest wind machines in the world have blades longer than a football field" (Energy Information Administration, 2008j). Wind energy can be used to generate electricity and "the energy potential in the wind is expressed by wind power classes ranging from 1 (least energetic) to 7 (most energetic). "In general, wind regimes of Class 4 or higher are considered economically viable for utility-scale wind farms" (Western Resource Advocates et al., 2002).

Wolverine Creek Wind Turbines in Idaho

Solar Electricity Generation Advantages:

- **Renewable source:** Solar electricity uses sunlight, which is free and a non-depleting resource.
- **No greenhouse gas emissions:** Operating a solar energy facility emits no greenhouse gases.
- **No additional requirements:** Solar energy does not require water or any other resources (other than maintenance) to generate electricity.
- **Scalability:** Solar PV plants can be built in increments depending upon need.
- **Availability:** The output from a solar generation facility typically ramps up in the morning, peaks in the afternoon, and drops off in the evening which matches a utility's load shape during high use summer months.

- **Other benefits:** Implementing solar can provide jobs in manufacturing, installation, and operations resulting in increased state and local tax base.

Solar Electricity Generation Disadvantages**:**

- **Capital and total costs:** Very high capital cost ($4500 to $6300 per kW) of solar panels makes solar energy one of most expensive forms of electricity on a levelized cost basis. Although as the technology to produce panels gets less expensive, with zero fuel costs, many experts believe that it will become more competitive with other forms of generation.
- **Variable energy output:** Energy production varies due to night time and changing sunlight levels.
- **Large area requirements:** Large surface areas are needed to install solar panels in order to produce useful amounts of electricity.

Sources: (Idaho National Laboratory, 2006; Lazard, 2008)

Geothermal Electricity Generation Advantages:

- **Renewable source:** The Earth's core is continuously producing heat, providing an unlimited source of heat.
- **Clean energy:** Geothermal fields produce about 17 percent of the carbon dioxide that a relatively clean natural-gas-fueled power plant produces, and very little of the nitrous oxide or sulfur-bearing gases. Binary plants, which are closed-cycle operations, release essentially no emissions. Energy can be extracted without burning a fossil fuel such as coal, gas or oil. There is no need to transport resources or have facilities to process them.
- **Reliable and non-variable:** Geothermal energy is always available. Geothermal power plants have average availabilities of 90 percent or higher, against 75 percent for coal plants. It is a base-load electricity resource.
- **Scalability:** Facilities can be built in increments depending upon need.
- **Total cost:** Although initial capital costs are relatively expensive, high efficiency factors and zero fuel costs make geothermal electricity one of the most in-expensive forms of base-load power in terms of levelized cost.
- **Other benefits:** Implementing geothermal can provide jobs in manufacturing, installation, and operations resulting in increased state and local tax base.

Geothermal Electricity Generation Disadvantages**:**

- **Finding a suitable resource:** Finding a suitable geothermal resource for power generation is difficult. (Geothermal Energy Association, 2009). Investments of millions of dollars are required to confirm a commercially viable resource".
- **Capital costs:** Moderately high initial capital cost ($3000 and $4000 per kW) but has high efficiency and uptime.
- **Site location:** Location of sites with significant resources may not be close to transmission lines, electricity users, or located on protected land.

Sources: (Geothermal Energy Association, 2009; Idaho National Laboratory, 2006; Lazard, 2008) (B. Neilson, personal communication, January 28th, 2009)

Wind Electricity Generation Advantages**:**

- **Renewable source:** Wind generated electricity uses wind, which is a free and non-depleting resource.
- **Total cost:** "Wind energy is one of the lowest-priced renewable energy technologies available today, costing between $0.04 and $0.06 cents per kWh," where a high quality wind resource is available[67].

- **No additional requirements:** Wind energy does not require water or any other resources (other than maintenance) to generate electricity.
- **No greenhouse gas emissions:** Operating a wind turbine emits no greenhouse gases.
- **Scalability:** Facilities can be built in increments depending upon need.
- **Other benefits:** Implementing wind can provide jobs in manufacturing, installation, and operations resulting in increased state and local tax base.

<u>Wind Electricity Generation Disadvantages</u>**:**

- **Capital cost:** Even though the cost of wind power has decreased ($1900 to $2500 per kW), the installation of this technology requires a high initial investment to get an equivalent amount of power due to the intermittency of wind.
- **Effect on wildlife:** Birds and bats could be harmed or killed by wind machines and sage grouse habitat could be affected.
- **Intermittency of wind:** The wind does not blow all the time. Both can vary significantly or may not be available when power is needed. Wind energy is most available at night rather than when power is most needed during the day. Intermittency is problematic for utilities as other resources must be available on short notice if the wind suddenly stops blowing.
- **Area requirements:** Wind farms can have a large footprint since turbines need to be spaced far enough apart so that the turbulence produced does not affect other turbines. However, the space between the turbines can be used for other purposes, such as growing crops or as cattle range.
- **Undesirable presence:** Wind machines can be unwelcome due to visual impacts and noise produced by rotor blades. "Wind resource development may compete with other uses of the land," which can be more valued than electricity generation[23].
- **Site location:** Location of sites with significant resources may not be close to transmission lines, electricity users, or located on protected land.

Sources: (Idaho National Laboratory, 2006; Lazard, 2008) (B. Neilson, personal communication, January 28th, 2009).

<u>Research and Development Opportunities for Non-hydro Renewable Electricity Generation:</u>

One of the largest research and development opportunities for non-hydro renewable energy is the intermittent nature of wind and sun. Two areas of research could solve this problem. One potential solution could be the development of large batteries, which could store energy when it is being generated and release it onto the grid when needed. Battery technology of this size and scale doesn't exist. Even if these batteries were available, it could increase the cost of electricity, possibly significantly. Research to develop this type of battery technology will likely take years. Other potential solutions include pumped storage and the development of better forecasting tools.

Another method is to build enough geographically dispersed wind turbines and solar resources and connect them by a "smart grid" so that the electricity could be moved to wherever it is needed. Most of this technology is available, but there are opportunities to make it more affordable, to develop policies that standardize grid technology and to encourage utilities to make investments. The initial investment to create a national *smart grid* could run in the hundreds of billions of dollars (see Appendix II; Table 9).

Important Factors to Consider

There are a number of factors to consider when choosing different alternatives for meeting electricity demand. For simplicity, a set of categories have been developed that covers many of the important factors. Some are fairly objective (such as *cost*) while others are more subjective (such as *trust* or *harm to aesthetics*). Tables 1 through 8 in the Appendix I compare the advantages and disadvantages of each electricity alternative for the 8 different factors below.

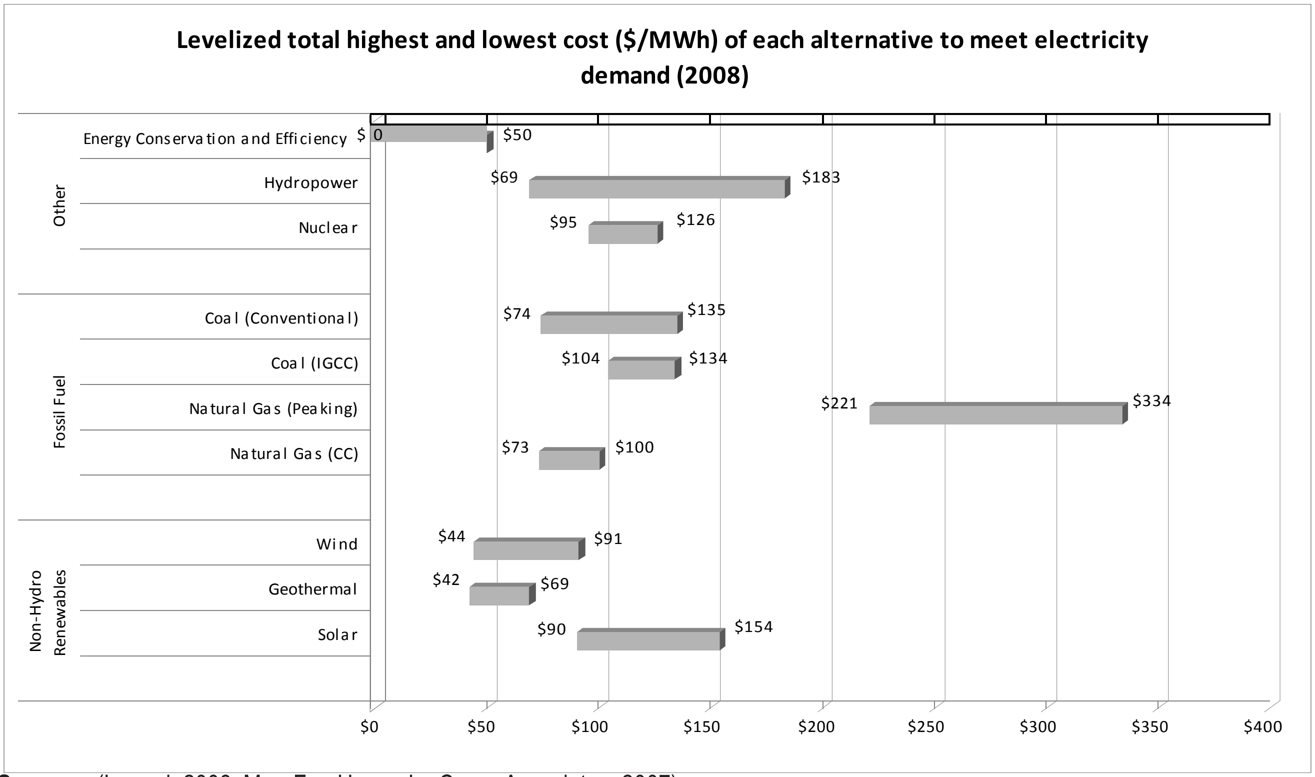
- **Safety and Security**: No personal harm, property damage or accidents as a direct result of human actions or naturally occurring events (See Appendix I; Table 1).
- **Reliability and Predictability:** The ability of an electricity option to perform consistently and maintain its functions both short-term and long-term and under normal and unexpected circumstances (See Appendix I; Table 2).
- **Trust:** An expectation that an electricity industry or regulating body will fulfill policies, ethical codes, laws and previous promises (See Appendix I; Table 3).
- **Harm to the Environment:** Harm to air, land, water, wildlife or other natural resources (See Appendix I; Table 4).
- **Cost:** Negative impact on taxes, government subsidies, bills paid directly to utilities by consumers, private investment, and/or reduction in property values (See Appendix I; Table 5).
- **Responsiveness and Adaptability:** Time to construct or add to electricity generation facilities; or ease with which an electricity option can change in order to meet temporary or permanent growth or reduction in electricity demand (See Appendix I; Table 6).
- **Harm to Aesthetics:** Negative impact on the way that something looks, sounds, smells (See Appendix I; Table 7).
- **Benefits:** Additional advantages and value resulting from a particular electricity option beyond the primary benefit of meeting electricity demand (See Appendix I; Table 8).

Economics

The definition of cost in the previous section is difficult to quantify for comparison. One proven method to get some measure of comparison is to develop a levelized cost of each different alternative for meeting electricity demand. Figure 9 illustrates a levelized cost for all of the alternatives under consideration in this study. It incorporates all operational costs (fuel, operations, and maintenance), as well as the upfront costs like capital costs distributed over every megawatt-hour (MWh) of electricity the generation source would produce or the efficiency measure would save over a fixed period (20 years).

In any cost analysis, assumptions need to be made that may favor one alternative over another. For example, the assumption of a 20 year timeframe may penalize technologies that have a demonstrated longer life span such as hydropower, coal, and nuclear, over technologies that have a shorter life. Although not entirely accurate, it can give a rough indication of what might happen to customer rates if a particular alternative is chosen over another that is equal in capacity. This is especially true in a regulated environment like most of Idaho, where cost is one of the factors used to determine consumer rates. A range of high and low costs are given to reflect differences in the size of facilities, technology, and fuel prices within each category.

Figure 9: Levelized total cost ($/MWh) for each alternative to meet electricity demand (2008)



Sources: (Lazard, 2008; Mon-Fen Hong - La Capra Associates, 2007)

Notes:

1. Required debt, equity return, capital structure, and economic life were held constant.
2. Investment cost, capacity factors, operating costs, fuel costs and federal tax incentives were differentiated as appropriate for each technology.
3. Renewable energy credits or carbon emission offsets and transmission costs were not considered.
4. Levelized cost for hydropower includes both small and conventional hydropower.
5. Integrated Gas Combined Cycle (IGCC) may allow for the capture of carbon dioxide if the technology is ever developed.
6. Peaking plants are only run during high demand periods of the day and not built for efficiency. Low efficiency and sporadic use is reflected by a significantly higher levelized cost.

Appendix I

Table 1: Safety and Security (advantages and disadvantages)**:** No personal harm, property damage, or accidents as a direct result of human actions or naturally occurring events.

SAFETY AND SECURITY	Energy Conservation and Efficiency	Fossil Fuels	Nuclear	Hydropower	Renewable
Advantages					
Disadvantages	~ Indoor pollution	~ Worker health and safety. ~ Natural gas is explosive	~ Radioactive material ~ Terrorist risk ~ Worker health and safety.	~ Potential dam failure.	

Appendix I

Table 2: Reliability and Predictability (advantages and disadvantages)**:** The ability of an electricity option to perform consistently and maintain its functions both short term and long term, under normal and unexpected circumstances.

RELIABILITY AND PREDICTABILITY	Energy Conservation and Efficiency	Fossil Fuels	Nuclear	Hydropower	Renewable
Advantages		~ Dependable high producing base-load source ~ Significant supply in US ~ Natural gas is easy to transport.	~ Highly fuel efficient ~ Dependable high producing base-load source.	~ Large generating capacity ~ Time-tested ~ Dependable high producing base-load source.	~ Renewable ~ Not dependent on fuel & water ~ Geothermal is highly available.
Disadvantages	~ Requires consumer behavior change.	~ No viable sources in Idaho ~ Nonrenewable ~ Natural gas price and supply fluctuate.		~ Variable water flow.	~ Sun & wind highly variable.

Appendix I

Table 3: Trust (advantages and disadvantages)**:** An expectation that an electricity industry or regulating body will fulfill policies, ethical codes, laws, and previous promises.

TRUST	Energy Conservation and Efficiency	Fossil Fuels	Nuclear	Hydropower	Renewable
Advantages			~ NRC inspects & regulates.		
Disadvantages			~ Public association with weapons programs		

Appendix I

Table 4: Impact to the Environment (advantages and disadvantages)**:** Harm to air, land, water, wildlife, or other natural resources.

IMPACT TO THE ENVIRONMENT	Energy Conservation and Efficiency	Fossil Fuels	Nuclear	Hydropower	Renewable
Advantages	~ Reduces GHG ~ Sustainable resource use		~ No GHG ~ Decommissioning trust fund	~ No GHG	~ No GHG
Disadvantages	~ Hazardous materials	~ GHG ~ High water use ~ Air, water, and solid waste contaminants. ~ Coal & oil have land requirements for plants	~ Waste disposal challenges ~ Land requirements for plants ~ Safety buffer required ~ High water use	~ Impacts to fish ~ Habitat loss ~ Impact to water quality and flow	~ Solar and wind have large land requirements ~ Wind has impact to birds

Appendix I

Table 5: Costs (advantages and disadvantages)**:** Negative impact on taxes, government subsidies, bills paid directly to utilities by consumers, private investment, and/or reduction in property values.

COSTS	Energy Conservation and Efficiency	Fossil Fuels	Nuclear	Hydropower	Renewable
Advantages	~ Reduces electricity bills ~ Cheaper than new generation ~ Not dependent on cost of fuel	~ Coal is Currently inexpensive ~ Natural gas plants are inexpensive to build	~ Total cost similar to other base load sources	~ No fuel cost ~ Inexpensive from existing dams	~ No fuel cost ~ Wind has tax incentives ~ Wind and geothermal have low total cost
Disadvantages	~ Up front costs to consumer	~ Potential carbon emission charges ~ Coal plants are moderately expensive to build	~ Highest initial cost ~ High cost of regulatory compliance		~ Moderate to high initial cost

Appendix I

Table 6: Responsiveness and Adaptiveness (advantages and disadvantages)**:** Time to construct or add to electricity generation facilities; or ease with which an electricity option can change in order to meet temporary or permanent growth or reduction in electricity demand.

RESPONSIVENESS AND ADAPTIVENESS	Energy Conservation and Efficiency	Fossil Fuels	Nuclear	Hydropower	Renewable
Advantages	~ Fast to implement ~ Utility and tax incentives	~ Natural gas is very versatile			~ Able to add increments of capacity
Disadvantages	~ Results depend on consumer behavior	~ Long lead time to build	~ Long lead time to build	~ Further expansion is limited	~ Locating geothermal sources expensive ~ Wind and geothermal have siting issues

Appendix I

Table 7: Harm to Aesthetics (advantages and disadvantages)**:** Negative impact on the way that something looks, sounds, smells.

AESTHETICS	Energy Conservation and Efficiency	Fossil Fuels	Nuclear	Hydropower	Renewable
Advantages				~ Reservoirs provide recreational areas	
Disadvantages		~ Aesthetically displeasing & unwelcome	~ Aesthetically displeasing & unwelcome	~ Changes to natural landscape	~ Wind is aesthetically displeasing & unwelcome

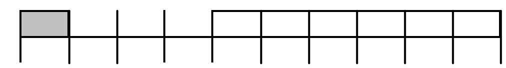
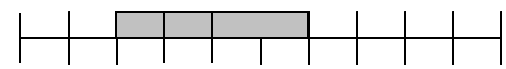
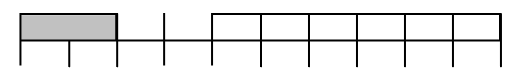
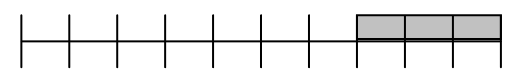
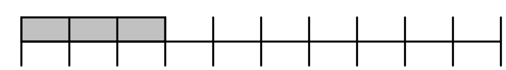
Table 8: Benefits (advantages and disadvantages)**:** Additional advantages and value resulting from a particular electricity option beyond the primary benefit of meeting electricity demand.

BENEFITS	Energy Conservation and Efficiency	Fossil Fuels	Nuclear	Hydropower	Renewable
Advantages	~ Increase jobs and tax revenue	~ Produce heat for non-electricity uses ~ Increase jobs and tax revenue	~ Produce heat for non-electricity uses ~ Increase jobs and tax revenue	~ Recreation ~ Increase jobs and tax revenue ~ Water supply and flood control	~ Increase jobs and tax revenue
Disadvantages				~ Displace existing uses and economic benefits	

Appendix II

This table summarizes a key research and development opportunity for each alternative that will help make it a viable for meeting future electricity demand. It summarizes the problem needing to be solved and if solved, the potential for improvement. Included is an indicator of the timeframe required for the improvement or technology to be commercially viable.

Table 9: Opportunities for Research and Development

Energy Alternative	Problem	Potential for Improvement	Time to Viability (opinion of expert panel)
Energy Conservation and Efficiency	**Low adoption rates of conservation and efficiency measures by consumers**	**In 2006, Idaho only conserved 0.66% of total consumption. The Northwest Power and Conservation Council's goal for western utilities is approximately 6% for 2013.**	 Currently Viable 100 years
Fossil Fuel Electricity Generation	**Efficiently capturing and storing gases (CO2) that potentially warm the atmosphere**	**If carbon can be captured and stored successfully from the emissions of burning coal, there is enough coal to supply current rates of consumption for approximately the next 200 years.**	 Currently Viable 100 years
Hydropower Electricity Generation	**Dam's effects on salmon migration**	**Without removal of dams, salmon migration levels will never return to pre-dam levels, although mitigation measures could partially restore them**	 Currently Viable 100 years
Nuclear Electricity Generation	**Lack of cost effective and secure method for radioactive waste disposal**	**If re-processing research is successful, Yucca Mountain would be the only waste repository needed this century.**	 Currently Viable 100 years
Non-Hydro Renewable Electricity Generation	**Intermittency issues with wind and solar sources of electricity generation**	**Combinations of energy storage, smart grid technology, and diversity of sources could allow Idaho to supplement capacity using renewable sources.**	 Currently Viable 100 years

Literature Cited:

Alternate Energy Sources. (2008). There are advantages of nuclear energy as there are challenges. Retrieved December 8th, 2008 from: http://www.alternate-energy-sources.com/advantages-of-nuclear-energy.html

American Coal Foundation. (2007). Converting coal into electricity. Retrieved September 25th, 2008 from: http://www.teachcoal.org/aboutcoal/articles/coalconvert.html

Chughtai, O., & Shannon, D. (1998). Fossil fuels and society. Retrieved September 26th, 2008 from: http://www.umich.edu/~gs265/society/fossilfuels.htm

Current Energy. (2005). Supply of and demand for electricity for California. Retrieved March 2009 from:http://currentenergy.lbl.gov.ca/

Discovering Fossils. (2008). What are fossil fuels? How do they form? Retrieved September 26th, 2008 from: http://www.eia.doe.gov/cneaf/electricity/epm/table2_6_a.html

Eldridge, M., Neubauer, M., Vaidyanathan, S., Chittum, A., Nadel, S., & York, D. (2008). The 2008 State Energy Efficiency Scorecard. Retrieved March 15, 2009 from: http://www.aceee.org/pubs/E086.pdf

Energy Information Administration-US Department of Energy. (2006). Annual Energy Review, Table 8.9 Electricity End Use, Selected Years, 1949-2006. Retrieved March 2009 from: http://www.eia.doe.gov/emeu/aer/contents.html

Energy Information Administration. (2007). Nuclear Energy (Uranium) - Energy from atoms. Retrieved December 8th, 2008 from: http://www.eia.doe.gov/kids/energyfacts/sources/non-renewable/nuclear.html

Energy Information Administration. (2008a). Electricity: A secondary energy source. Retrieved October 7th, 2008 from: http://www.eia.doe.gov/kids/energyfacts/sources/electricity.html

Energy Information Administration. (2008b). Energy efficiency. Retrieved October 4th, 2008 from: http://www.eia.doe.gov/kids/energyfacts/saving/efficiency/savingenergy.html

Energy Information Administration. (2008c). Geothermal Energy - Energy from the Earth's core. Retrieved December 7th, 2008 from: http://www.eia.doe.gov/kids/energyfacts/sources/renewable/geothermal.html

Energy Information Administration. (2008d). Idaho renewable electricity profile - 2006 Edition. Retrieved December 10th, 2008 from: http://www.eia.doe.gov/cneaf/solar.renewables/page/state_profiles/idaho.html

Energy Information Administration. (2008e). Natural gas, a fossil fuel. Retrieved October 9, 2008 from: http://www.eia.doe.gov/kids/energyfacts/sources/non-renewable/naturalgas.html

Energy Information Administration. (2008f). Solar energy - Energy from the sun. Retrieved December 7th, 2008 from: http://www.eia.doe.gov/kids/energyfacts/sources/renewable/solar.html

Energy Information Administration. (2008g). State energy profiles - Idaho. Retrieved December 7th, 2008 from: http://www.eia.doe.gov/emeu/states/hf.jsp?incfile=sep_use/eu/use_eu_id.html&mstate=IDAHO

Energy Information Administration. (2008h). State energy profiles - Idaho. Retrieved December 7th, 2008 from: http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=ID

Energy Information Administration. (2008i). State Total Electric Power Industry Net Generation, by energy source, 2006 (Publication. Retrieved December 10th, 2008 from: http://www.eia.doe.gov/cneaf/solar.renewables/page/state_profiles/rspt04id.xls:

Energy Information Administration. (2008j). Wind Energy - Energy from moving air. Retrieved December 7th, 2008 from: http://www.eia.doe.gov/kids/energyfacts/sources/renewable/wind.html

Energy Star. (2008). Idaho home performance with Energy Star. Retrieved November 17th, 2008 from: http://www.homeperformance.idaho.gov/

Environmental Protection Agency. (2007a). Electricity from coal. Retrieved September 22nd, 2008 from: http://www.epa.gov/cleanrgy/energy-and-you/affect/coal.html

Environmental Protection Agency. (2007b). Electricity from natural gas. Retrieved September 20th, 2008 from: http://www.epa.gov/cleanrgy/energy-and-you/affect/natural-gas.html

Environmental Protection Agency. (2007c). Electricity from oil. Retrieved September 22nd, 2008 from: http://www.epa.gov/cleanrgy/energy-and-you/affect/oil.html

Environmental Protection Agency & U.S. Department of Energy. (2008). Federal tax credits for energy efficiency. Retrieved March 2009 from: http://www.energystar.gov/index.cfm?c=products.pr_tax_credits

Geothermal Energy Association. (2009). Power plant costs. Retrieved February 8th, 2009 from: http://www.geo-energy.org/aboutGE/powerPlantCost.asp#cost

Idaho Legislature - E3 Consulting. (2007). *Idaho Energy Plan*.

Idaho National Laboratory. (2006). *Idaho's Energy Options*. Idaho Falls.

Idaho Office of Energy and Resources. (2008). Idaho Tax Deductions. Retrieved October 19th, 2008 from: http://www.energy.idaho.gov/Tax_Credits_website.pdf

Idaho Power. (2008a). Energy audit. Retrieved October 19th, 2008 from: http://www.energy.idaho.gov/Tax_Credits_website.pdf

Idaho Power. (2008b). Home products program. Retrieved October 20th, 2008 from: http://www.idahopower.com/energycenter/energyefficiency/YourHome/HomeProducts/default.cfm

Johnson, T. (2008). Challenges for nuclear power expansion. Retrieved March 3, 2009 from: http://www.cfr.org/publication/16886

Lazard. (2008). Levelized cost of enery analysis.

Mon-Fen Hong - La Capra Associates. (2007). Analysis of renewable energy potential in South Carolina. Retrieved March 18th, 2009 from: www.ecsc.org/newsroom/RenewablesStudy.ppt

National Council on Electricity Policy. (2004). Electricity Transmission A Primer. Retrieved March 2009 from: www.raponline.org/Pubs/ELECTRICITYTRANSMISSION.pdf

National Energy Policy Development Group. (2008). *Using energy wisely. Increasing energy conservation and efficiency*. Retrieved October 12th, 2008 from: http://www.whitehouse.gov/energy/Chapter4.pdf.

North American Electric Reliability Corporation. (2006). Map of North American Electric Reliability Council (NERC) Interconnections. Retrieved March 2009 from: www.nerc.com

Northwest Power and Conservation Council. (2005). The Role of Energy Efficiency in the Northwest Power and Conservation Plan. Retrieved March 2009 from: www.nwcouncil.org/energy/present/IdEnergyConf_101405_Eckman.ppt

Nuclear Energy Institute. (2007). U.S. Capacity factors by fuel type (Publication. Retrieved January 28th, 2009 from: http://www.nei.org/filefolder/US_Capacity_Factors_by_Fuel_Type_2.ppt:

U.S Census Bureau. (2008). Utah is fastest-growing state. Retrieved March 2009 from: www.census.gov/Press-Release/www/releases/archives/population/013049.html

U.S.-Canada Power System Outage Task Force. (2003). Blackout in the United States and Canada: Causes and Recommendations, April 2004 Figure 2.1. Basic Structure of the Electric System. Retrieved March 2009 from: news.findlaw.com/hdocs/docs/ferc/uscanrpt40504ch1-3.pdf

U.S. Census Bureau. (2002). No. HS-1, Population: 1900 to 2002. Retrieved March 2009 from: http://www.census.gov/compendia/satab/hist_stats.html

U.S. Census Bureau. (2007). The 2007 Statistical Abstract: The National Data Book. Tables 2 and 3. Retrieved March 2009 from: http://www.census.gov/compendia/statab/2007/population/national_estimates_and_projections.html

U.S. Department of Energy. (2008). The Global Nuclear Energy Partnership. Retrieved February 2nd, 2009 from: http://www.gnep.energy.gov/

U.S. Department of Energy, & Energy Efficiency and Renewable Energy. (2008a). Advantages and disadvantages of hydropower. Retrieved November 18th, 2008 from: http://www1.eere.energy.gov/windandhydro/hydro_ad.html

U.S. Department of Energy, & Energy Efficiency and Renewable Energy. (2008b). Advantages and disadvantages of wind energy. Retrieved November 17th, 2008 from: http://www1.eere.energy.gov/windandhydro/wind_ad.html

U.S. Department of Energy, & Energy Efficiency and Renewable Energy. (2008c). Hydropower research and development. Retrieved November 19th, 2008 from: http://www1.eere.energy.gov/windandhydro/hydro_rd.html

U.S. Department of Energy, & Energy Efficiency and Renewable Energy. (2008d). Idaho Energy Summary Fact Sheet. Retrieved December 5, 2008 from: http://apps1.eere.energy.gov/states/energy_summary_print.cfm?state=ID

U.S. Department of Energy, & Energy Efficiency and Renewable Energy. (2008e). Large wind technology. Retrieved November 19th, 2008 from: http://www1.eere.energy.gov/windandhydro/large_wind_tech.html

U.S. Department of Energy, & Energy Efficiency and Renewable Energy. (2008f). Wind energy systems integration. Retrieved November 19th, 2008 from: http://www1.eere.energy.gov/windandhydro/wind_sys_integration.html

U.S. Geothermal Inc. (2007). Raft River Project. Retrieved December 8th, 2008 from: http://www.usgeothermal.com/RaftRiverProject.aspx

U.S. Nuclear Regulatory Commission. (2004). Three Mile Island Accident (Publication. Retrieved August, 2008 from: http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.pdf:

United States Nuclear Regulatory Commission. (2009). Determination of exclusion area, low population zone, and population center distance. Retrieved March 7th, 2009 from: http://www.nrc.gov/reading-rm/doc-collections/cfr/part100/part100-0011.html

Western Resource Advocates, Northwest Sustainable Energy for Economic Development, GreenInfo Network, Idaho Energy Division, & U.S. Department of Energy. (2002). Renewable Energy Atlas of the West - Idaho State Edition (Publication. Retrieved October 21st, 2008 from: http://www.energyatlas.org/downloads/ID_booklet.pdf: