

# A Range of Energy Sources for a Diverse Energy Portfolio

## Executive Summary

*UAMPS is a joint action agency that provides comprehensive wholesale electric energy, on a nonprofit basis, to community-owned power systems throughout the Intermountain West. The UAMPS membership represents members from Utah, Arizona, California, Idaho, Nevada, New Mexico, Oregon and Wyoming.*

Fueled by growing global population increases and an increase in per capita consumption, the demand for energy is steadily increasing tending to make for volatile energy prices. One strategy to counter this potential volatility is to manage an energy portfolio around predictable usage, supply stability, and resource diversity.

Each energy source has its advantages and disadvantages with regard to the extraction or collection of the resource, the generation of electricity from the resource, and the delivery of the electricity to the market. A combination of energy sources is required to offset the adversities of each resource, because no single resource provides a complete and comprehensive solution. Maintaining a diverse energy portfolio will ensure that consumers will be less susceptible to rate fluctuations and have consistent and reliable electric energy delivered to their homes and businesses into the distant future.

This paper provides some fundamental information about coal, natural gas, wind, hydropower, solar, and geothermal energy resources. This paper details advantages, disadvantages, and energy costs for each of the resources.

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## Introduction

Fueled by growing global population increases and an increase in per capita consumption, the demand for energy is steadily increasing tending to make for volatile energy prices. One strategy to counter this potential volatility is to manage an energy portfolio around predictable usage, supply stability, and resource diversity.

Broadening the range of energy sources within an electricity provider's portfolio to include demand side management and renewable resources like wind and solar, along with the necessary thermal generation sources, will ensure that utilities meet future demand while controlling costs, ensuring reliability, and promoting a clean environment.

Understanding how each resource produces electricity provides the ability to match each resource against load needs. The origin of each resource and the process by which energy is transferred into electricity is given. The advantages and disadvantages of each resource and their best use within an energy portfolio (base, intermittent, or peak load) are also given, as is the cost of each resource per kilowatt hour. Costs (cents/kWh) are all costs including capital cost, operating and maintenance costs, and financing costs. Exceptions are explained where appropriate.

## Coal

Coal is a sedimentary rock; in its purest form it is composed of primarily of carbon and hydrogen. The energy in coal comes from the energy stored in plant remains buried by mud and water deep below the earth's surface for millions of years.

Coal, currently the largest source of fuel for electricity generation worldwide, is extracted using two different methods. Surface mining is used when coal is located less than 200 feet underground and underground mining is used when coal is

located deeper in the ground. The majority of coal used in the U.S. is mined via surface mining because surface mining is more cost effective than underground mining. Once the coal has been extracted using either method, it is transported to power plants. The coal at this point costs approximately 1.2 cents /kWh of the total costs.

Once at the power plant, the coal is pulverized and injected in to a high heat and pressure boiler to make steam. The steam is run through a series of high to low pressures turbines, which drive an electric generator. This process costs approximately 1 cent/kWh for a total cost of 2.2 cents/kWh. Taking into account the capital and financial costs brings the total cost to approximately 4 cents/kWh.

This is not the end of the story. The waste products, combustion gases, ash and heat, from the above process must be captured and disposed. The Clean Air Act requires that each combustion gas be identified and removed in a specified amount. Land use permits require that the solid waste products of the combustion cycle, mainly ash, be captured and stored such that they never leave the plant site. Heat remaining in the water is piped to cooling towers and evaporated into the atmosphere. This increases the cost of the electricity by another 0.5 cents/kWh bringing the cost of the electricity to 4.5 cents/kWh.

### *Advantages of Coal*

From an economic perspective, coal fired generation can be provided at a lower cost to the consumer when compared to other resources. The U.S. has the world's largest known coal reserves with an estimated 276.9 billion short tons (Energy Information Administration (EIA) 2008). The abundance of coal reserves in the United States contributes to the stability of cost over time.

The technology to convert coal to electricity is well advanced

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thus there are numerous vendors in this market to insure competitive pricing. The design of coal plants are based upon continuous use for 30 to 50 years.

Coal fired generation will continue to be a large part of our energy portfolio given new advances in clean coal technology intended to further reduce environmental impacts and increasing efficiencies of the resource.

### *Disadvantages of Coal*

Coal is a rock and therefore, requires approximately half of its corresponding electric costs to be in capital investment. The physical plants endure a lot of wear and tear because of this rock and therefore, require constant up keep and replacement.

Future air quality requirements will increase the current 0.5 cents/kWh in an exponential manner if carbon dioxide and other greenhouse gases are regulated

Coal plants are designed to run 24 hours a day for years thus they do not integrate well with intermittent wind and solar resources.

### *Energy Portfolio for Coal*

Coal works best as base load given its relatively low cost and consistent availability. Coal can also be used to support the intermittencies of renewable energy sources in a diverse energy portfolio.

Cost per kilowatt hour (cost/kWh) is \$0.03–\$0.045 (in 2008 dollars) (ERCOT 2005).

## **Natural Gas**

Natural gas is a fossil fuel formed in a geologic process similar to that forming coal, in which the organic matter that existed in ecosystems millions of years ago is compressed under the pressure of the earth. Natural gas is found one to two miles below the earth's crust (United States Department of Energy

(USDOE) 2007) and is odorless, colorless, and tasteless.

Once seismic surveys determine the location of a source of natural gas, drilling begins and the gas is extracted. Refining is then required to separate the pure methane gas from petroleum liquids and contaminants (Natural Gas Supply Association 2004). After refining is complete, the natural gas is transmitted through a network of pipelines to the power plant. The cost of electricity from the natural gas at this point is approximately 5 cents/kWh.

Gas fired generation comes in two forms: simple cycle and combined cycle. Simple cycle means that the natural gas is ignited under pressure and directed through a hot gas turbine, which in turn drives an electric generator. Combined cycle starts as a simple cycle but, the resultant hot exhaust is captured in a steam boiler to produce electricity in the same manner as coal generation discussed above. This process adds about a penny per kilowatt-hour.

The waste product from natural gas generation is primarily heat, thus no incremental costs. Adding in the capital and financing costs the price of electricity is 7 cents/kWh.

### *Advantages of Natural Gas*

A new natural gas plant can be constructed in a relatively short time and at about half the cost of a coal project.

Natural gas burns cleaner than other fossil fuels, such as oil or coal. The combustion of natural gas emits roughly 30% less carbon dioxide than oil and just under 45% less than coal (Natural Gas Supply Association 2004). California has exempted natural gas generation in its latest environmental laws.

The clean nature of burning gas allows gas-fired generation to be placed closer to load centers thus avoiding transmission investment.

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Current IRS rules allow for financial management of price volatility unlike coal.

Gas plants integrate well with coal, wind, and solar resources.

### *Disadvantages of Natural Gas*

The price of natural gas is subject to wide fluctuations in price. Price volatility is often due to high demand. According to the EIA, natural gas prices will increase sharply after 2016 when the cost of developing the remaining natural gas reserves increases sharply (EIA 2008).

Gas plants are not design to last as long as coal plants so costs tend to increase over time.

### *Energy Portfolio for Natural Gas*

Natural gas may be used to serve all load needs but, given its cost it is best as an intermittent or peak load supply.

Cost/kWh is \$0.05–\$0.07 (ERCOT 2005).

## Wind

Wind is actually a form of solar energy in that irregularities in the earth's surface and the rotation of the earth cause uneven heating of the atmosphere by the sun. The direction and speed of the wind is influenced by the earth's terrain, bodies of water, and vegetation.

The generation of electricity occurs when wind turbines transfer kinetic energy in wind to mechanical power or electricity. As the wind turns the blades, a shaft in the turbine spins, which connects to a generator that transfers the electricity. The amount of electricity generated by the turbine is dependant on the density and speed of wind.

Estimates of wind resources are expressed in terms of wind power classes ranging from 1 to 7 (Figure 1). Each class represents a range of mean wind-power density or equivalent mean speed at specified heights above ground. Wind-power density,

measured in watts per square meter, signifies the amount of energy potential for energy conversion by a wind turbine at the site. The standard for measuring wind speed is based on sea level conditions. To maintain the same wind-power density as that found at sea level, wind speed generally increases 5% for every 5,000 feet of elevation gain (American Wind Energy Association 2007). Areas designated as having a wind-power class of 4 or greater are suitable for wind-generated electricity using today's technology.

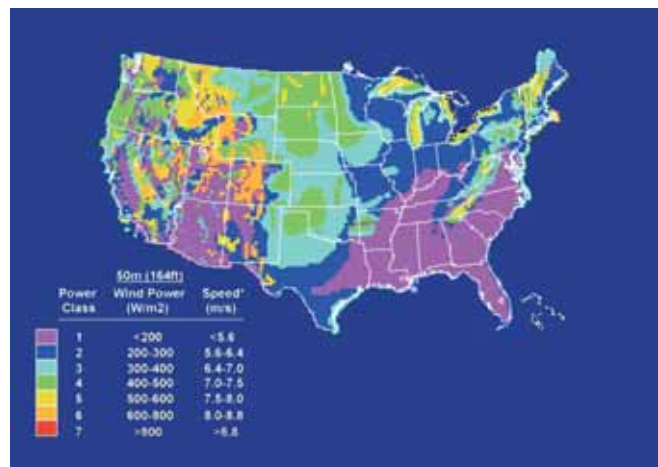


Figure 1. Annual wind power resource and wind power classes for the contiguous United States. \*Speed at sea level mean density. Source: USDOE 2005a.

### *Advantages of Wind*

Wind power is one of the least expensive renewable energy sources available today. The initial investment in wind technologies is similar to that for coal at \$2,000–\$2,500 per kW.

Wind power is beneficial because it is a renewable energy source without emissions.

Wind power can be an economic benefit to rural areas because the turbines, which have relatively small footprints, can be built on farms and ranches while still allowing for traditional farming and ranching practices.

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Wind and gas fired generation can be integrated into a beneficial relationship.

### *Disadvantages of Wind*

When compared to thermal energy-generating sources wind power may not be as cost competitive. This is due to the amortization of the capital investment over low annual output. Wind produces approximately one third the amount of energy that a coal plant does given almost identical capital costs.

Because the wind does not blow consistently and predictably, it cannot always be relied upon to meet demands when electricity is needed.

### *Energy Portfolio for Wind*

Wind energy is best suited to accommodate intermittent loads.

Cost/kWh is \$0.04– \$0.06 (USDOE 2005a).

## **Hydropower**

To understand hydropower it is important to first know some basic principles behind the hydrologic cycle. Solar energy heats up water, which causes it to evaporate. The water vapor condenses into clouds and falls back to the earth's surface in the form of precipitation. The water flows back into rivers and oceans where it evaporates and begins the cycle once again.

The energy from flowing water can be channeled and transferred into mechanical energy. The amount of available energy is determined by the flow and gradient of the flowing water body. More energy is available when flows and gradients are higher and steeper, respectively. Hydroelectric facilities convert the energy from flowing water into electricity by pushing water through a pipe (increasing the pressure) to deliver it to turbines, which rotate electric generators (Idaho National Laboratory 2005).

### *Advantages of Hydropower*

Similar to wind energy, hydropower is generated domestically so there is no need to rely on overseas providers. Hydropower plants have low maintenance and operation costs, and hydropower is generally available when needed. The flow of water through the turbines can produce electricity on demand. Hydropower is a renewable energy source because the water cycle is endless and constantly recharged. Another environmental advantage is that hydropower is a clean energy source that produces no emissions.

### *Disadvantages of Hydropower*

While maintenance and operation costs are relatively low and stable over time, the initial construction of a hydroelectric plant can be costly. Costs can vary widely depending on the location of the plant, ability to transfer generated electricity to the end user, and environmental mitigation requirements.

There are no new sites to develop.

### *Energy Portfolio for Hydropower*

Hydroelectric power can be used to accommodate base, intermediate and peak loads because it is generally accessible on demand.

Cost/kWh is \$0.07–0.10 (Hunter 2008).

## **Solar**

Light energy from the sun is converted to electric energy through photovoltaic (PV) technologies and thermal collectors. The PV cells are made of semiconductor material, and when connected together they form PV modules, which range in size and power output (USDOE 2005b). Together with electrical connections, mounting hardware, and batteries that store solar energy when the sun is not shining, the modules create a PV system that transfers light energy into electrical electricity.

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## Advantages of Solar

The generation of solar power does not depend on fuel; therefore, there is no fuel cost to generate power in areas that are off-grid. Other economic advantages include investment credits, rebates, and sales and property tax waivers that exist in 48 states to encourage consumers to use solar energy (USDOE 2005b). Recent increases in development of new solar-generated power technologies have employed over 20,000 people. These jobs are high-tech and high-value, and this number could increase as the demand for solar power also increases (USDOE 2005b).

Like wind and hydropower, solar power produces no emissions or byproducts. In fact, every kilowatt of PV electricity produced annually offsets 16 kilograms of nitrogen oxide, 9 kilograms of sulfur oxide, and 2,300 kilograms of carbon dioxide (USDOE 2005b). From a land-use perspective, solar plants can be built in "brownfields," on rooftops, in parking lots, and on vacant lands in otherwise-congested urban environments.

## Disadvantages of Solar

The initial investment in the materials to generate solar electricity is costly. The levelized cost per kWh (approximately \$0.30) is considerably higher than those of fossil fuels and other renewables (USDOE 2006a). Solar electricity is dependant on weather and location, often precluding large-scale use in areas that do not have consistently clear weather patterns. Also, large amounts of land are required per unit of generation when compared to other resources.

The manufacturing of PV cells involves the use of toxic materials and chemicals.

## Energy Portfolio for Solar

Solar PV power works best as for intermittent loads and can also offset peak load times, especially in summer months.

Cost/kWh is \$0.30 (USDOE 2006a).

## Geothermal

Geothermal energy is generated at the earth's core approximately 4,000 miles below the surface as the slow decay of radioactive particles release heat. Most of the geothermal reservoirs are found along major plate boundaries where earthquakes and volcanoes are concentrated, especially in an area called the Ring of Fire, which rims the Pacific Ocean. The majority of geothermal reservoirs in the United States are located in Alaska, Hawaii, and Western states. California generates the most geothermal electricity (EIA 2008).

Geothermal reservoirs are accessed by drilling wells that measure one mile or more into the earth (see Figure 2). The energy from the steam and hot water (usually between 122 degrees and 482 degrees F) is extracted from the earth by production wells and is used to generate electric power using traditional power-plant technologies including turbines, generators, and heat exchangers (USDOE 1998).

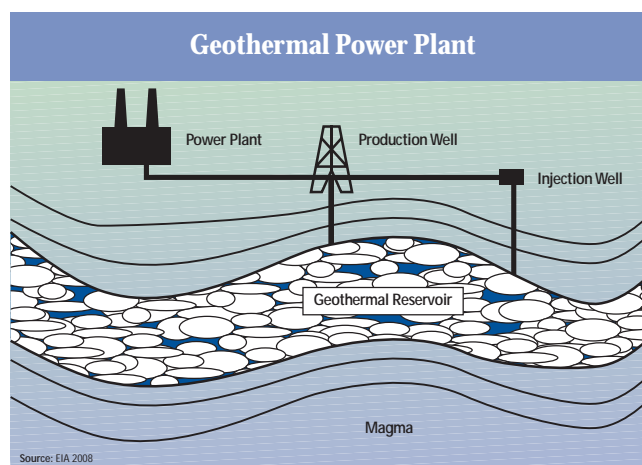


Figure 2. Geothermal power plant. Source: EIA 2008.

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## ***Advantages of Geothermal***

Given the low cost per kWh, geothermal power is priced competitively with non-renewable energy sources. Geothermal energy is responsive and available 24 hours a day. Geothermal power plants have average abilities to generate power 90 percent of the time or higher. Comparatively, coal plants generate power 75 percent of the time (USDOE 2006b). Because the power is produced domestically, our dependency on foreign oil is minimized.

Geothermal energy is a renewable resource because there is an almost unlimited amount of heat generated at the earth's core. As with other renewables, geothermal energy is extracted without burning fossil fuels and produces very few emissions. Geothermal fluids produce one sixth the carbon dioxide that a natural gas-fueled power plant produces and very little sulfur bearing gases or nitrous oxide (USDOE 2006b).

Geothermal power plants have small environmental footprints. Land requirements are minimal compared to coal, wind, and solar facilities. Once wells and associated power plants have been completed, other land uses can occur within the same area. For example, the Imperial Valley in Southern California produces 400 MW at 15 geothermal plants and is one of the most productive agricultural areas in the world (USDOE 2006b).

## ***Disadvantages of Geothermal***

The geology in the United States is such that only a few sites exist in the United States with temperatures high enough to allow for geothermal power production. Once determined feasible, the initial construction costs of geothermal facilities are high. The initial cost for the field and power plant would be approximately \$2,500 per installed kW for a larger plant and \$3,000–\$5,000 for a smaller plant (USDOE 2006b).

Some geothermal plants produce solid material waste that requires disposal in approved sites. Some of the extracted solids (zinc, silica, and sulfur) are sold on the market, making the extraction of the energy resource more economical. Land subsidence can occur upon extraction of large amounts of fluid from beneath the earth's surface. However, the spent geothermal fluids can be reinjected to help prevent land instability.

## ***Energy Portfolio for Geothermal***

Geothermal energy is best used as a base load.

Cost/kWh is \$0.08 – 12 (USDOE 2006c).

## **Summary**

Demand for energy is continually increasing at the global, national, and local levels. In order to meet increasing demand, we need to look at a broad range of energy sources. Today, it is important to maintain diversity in our energy sources so that we do not become too dependant on any one source. Recent advances in technology have made renewable energy resources—wind, solar, and geothermal—feasible and priced competitively.

Each energy source has its advantages and disadvantages with regard to the extraction or collection of the resource, the generation of electricity from the resource, and the delivery of the electricity to the market. A combination of energy sources is required to offset the adversities of each resource, because no single resource provides a complete and comprehensive solution. Maintaining a diverse energy portfolio will ensure that consumers will be less susceptible to rate fluctuations and have consistent and reliable electric energy delivered to their homes and businesses into the distant future.

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