

–FINAL DRAFT–
**Renewable Energy for Federal Land Management
Agencies in Southern Nevada**
A Collaborative Feasibility Study
Final Technical Report



by

**Yahia Baghzouz, Robert F. Boehm, Eric Wiemers,
Todd France, and Stephen E. Butterworth (NPS)**



**Center for Energy Research
University of Nevada, Las Vegas**

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National Park Service



U.S. Fish & Wildlife Service



USDA Forest Service

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Abstract

The National Park Service, the U.S. Fish and Wildlife Service, and the USDA Forest Service governmental agencies in southern Nevada have collaborated with the Center for Energy Research at the University of Nevada, Las Vegas, to explore the feasibility of becoming energy neutral by 2010. The three federal agencies have set a goal to offset their combined annual energy demand (currently supplied by local utility companies) with an equal amount of power produced by renewable energy sources.

The study results indicate that the three federal agencies above consume just over 3,000 megawatt-hours of electrical energy per year in and around the Las Vegas Valley. Upon researching various types of renewable energy, it was determined that wind, geothermal, and biomass technologies either failed to have sufficient resources available in southern Nevada or conflicted with the resource management philosophies of the federal agencies. Solar energy is the most abundant feasible source of renewable energy within the study area, and it was determined that a 1.5 megawatt fixed photovoltaic (PV) system is best suited for this project.

Among the numerous sites examined, the best location for this solar power plant was determined to be at the Southern Nevada Water Authority (SNWA) pumping station situated at the western shore of Lake Mead. SNWA has expressed interest in pursuing a Power Purchase Agreement with the federal agencies, whereby the renewable energy would directly feed the pumping station and SNWA would later reimburse the federal agencies for the energy consumed. The federal agencies would retain the credit for the renewable energy production. The preferred method for installing the solar power system is to mount PV panels on canopies over several flocculation and filtration basins within the pumping station facility. This site is not only secure, but it also has ample space for future expansion of a solar power plant. The proposed system will provide an opportunity for educational purposes, allowing for a model for future renewable energy plants in Nevada.

The proposed photovoltaic system is not as cost effective as the existing method of purchasing electricity generated by fossil fuels, but the federal commitment to reducing the impact of global climate change on America's public lands outweighs decisions based solely on financial rates of return. The project will demonstrate that the overall reduction in energy costs and ensuing benefits to the environment and society can counterbalance initial construction expenses. Installing a single PV system allows for the outsourcing of its operation, provides a much shorter construction to operation timeframe compared to the installation of several smaller systems, and will have minimal impact on protected lands. A single site PV arrangement will not be restricted under current state utility regulations.

The overall solution not only satisfies the energy neutral requirement, but also provides a new business plan model for the federal government, as well as other entities with non-centralized facilities, to achieve the benefits of renewable energy.

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Background

For the past several decades, Americans have relied heavily on fossil fuels to fulfill their energy demands. Currently, fossil fuels (coal, oil, and natural gas) deliver 85 percent of America's energy needs.¹ With the increased concern over the environmental impact resulting from the combustion of fossil fuels and the instability of foreign oil markets, the nation's electric utility companies and governmental agencies have shown renewed interest in the development and implementation of renewable energy sources.

Though rising energy costs have strained the American economy over the past few years, the entire costs of a fossil fuel-based society are indirect and difficult to calculate. Power plant construction, coal mining, oil drilling, and transmission line maintenance are expenses covered by the American consumer, but other, less quantifiable costs have farther reaching effects. These include lung damage caused by air pollution, degradation of the ecosystem due to strip-mining, and decreased fish populations caused by water pollution. Some citizens have argued for corrective pricing mechanisms (i.e., a carbon tax) to better account for the full costs of fossil fuels and to trigger the utilization of cleaner fuel sources. Until then, the following consequences must be absorbed by all of society.

Air Pollution

With coal power plants producing 49 percent of the nation's electricity and natural gas contributing another 20 percent, electricity production is currently the dominant source of air emissions in the U.S.² The 2006 U.S. Climate Action Report prepared by the U.S. Department of State asserts that carbon dioxide accounted for 85 percent of total U.S. greenhouse gas emissions in 2004, primarily due to transportation and electricity demands. According to the Environmental Protection Agency, fossil fuel-fired plants are responsible for:

- 67 percent of sulfur dioxide emissions;
- 40 percent of man-made carbon dioxide emissions;
- and 23 percent of nitrogen oxide emissions.³

On the world's stage, Americans fare poorly in energy conservation and emissions. With just 4.6 percent of the world's population, Americans use 21.7 percent of the world's energy. According to the Energy Information Administration, which has tracked carbon dioxide emissions caused by fossil fuel use, the U.S. produced 20.14 metric tons of carbon dioxide per capita in 2005. Comparatively, Germany (10.24 metric tons of CO₂ per capita), the United Kingdom (9.55), and Japan (9.65) produce about half the carbon emissions.⁴

According to the American Lung Association, an estimated 25 percent of Americans are breathing air that is hazardous to their health. Airborne particulates contribute to asthma and other respiratory illnesses, which are currently on the rise, especially among children. Increased health care costs and decreased worker productivity are other detriments of air pollution. Adverse health effects from fossil fuel combustion are attributable to the following pollutants:

Sulfur Dioxide

Produced by the oxidation of the available sulfur in a fuel, sulfur dioxide emissions, along with nitrogen oxides, are a key constituent of acid rain. Acid rain can damage buildings, reduce crop

production, and accumulate in lakes and rivers, at times making the waters too acidic to sustain plant and animal life.

Carbon Dioxide

A gas that traps heat in earth's atmosphere, carbon dioxide has been linked to global warming concerns. Since the inception of the Industrial Revolution, the amount of carbon dioxide in the atmosphere has increased by 25 percent, and is currently at its highest level in recorded human history.¹

Nitrogen Oxides

In combination with hydrocarbons (which are also released in mass quantities during the combustion of fossil fuels), nitrogen oxides form tropospheric ozone, a main component of smog. Exposure to smog can irritate the lungs, cause bronchitis and pneumonia, and decrease resistance to respiratory infections. Smog may also reduce crop yields.

Additionally, coal plants can release large amounts arsenic, a known carcinogen, and mercury, an extremely toxic byproduct that can have devastating effects on the human central nervous system.

Reducing air pollution in the Las Vegas Valley should hold high priority with the local federal agencies. Surrounded by mountains that may restrain the dispersion of airborne particulates, Las Vegas is situated near six of the nation's seven most polluted cities, all located in central and southern California.⁵ Considering the high volume of automobile and air traffic within the city, investing in clean energy sources is a necessity.

Water Pollution

The nation's water supply may be suffering long-term damage from the production of electricity. For example, oil-fired power plants and natural gas-fired boiler and combined cycle systems use large amounts of water for steam production and cooling. Fish and other aquatic life can be killed during the removal of cooling water from nearby lakes and rivers. Oil refineries and power plants release wastewater, often containing pollutants, into the local water supply. Likewise, oil drilling can harm the ecosystem, releasing pollutants into underground water supplies and surface water. During oil transport, spills may occur, further polluting the water that marine life and birds depend on for survival.

Though having a negligible effect on the atmosphere, nuclear power plants (currently supplying 19.4 percent of the nation's electricity) can damage the water supply. During the mining of uranium, the waste and rainwater runoff can filter into groundwater and neighboring bodies of water. The contaminants may include heavy metal contaminants as well as traces of radioactive uranium. Nuclear power plants consume vast amounts of water for cooling purposes and discharge water at higher temperatures back into the water supply, further harming the ecosystem.

Coal-fired power plants, the single largest source for electricity in the U.S., consume large amounts of water for cooling purposes and to produce steam. If the water used by a power plant is discharged back into a nearby river or lake, pollutants in the water may harm fish and plants.

During the coal mining process, large amounts of water are often used to remove impurities from the coal. At power plant sites, rainwater that falls on stored coal piles can flush heavy metals from the coal into adjacent bodies of water. These heavy metals may include arsenic and lead, both highly toxic compounds.

In order to create steam for its turbines, a typical 500-megawatt coal-fired plant extracts about 2.2 billion gallons of water from nearby bodies of water each year. The equivalent amount of water can support a city of approximately 250,000 people. During the intake process, the EPA estimates that as many as 1.5 million adult fish may become trapped against intake structures, many of them injured or killed.⁶

Located in the center of the Mojave Desert, millions of Las Vegas Valley residents and visitors depend upon the waters of Lake Mead and its source, the Colorado River. The Colorado River receives much of its water from the Rocky Mountains, but as of late, the Rocky Mountains and the Colorado River have been accumulating significantly less water than normal. During the past several years, changing precipitation patterns are causing more of the river's water to come as quickly-evaporating rain rather than slowly-melting snow. Consequentially, the Colorado River is filling less at the same time its demands are growing. Lake Mead's water level has fallen about 100 feet in the past six years, evident by the white band of mineral deposits discoloring the typically dark rocks surrounding the lake.⁷



Fig. 1: Lake Mead and its water level decrease.

Land Use

The amount of land used by an electricity-generating power plant varies widely depending upon the source of fuel. Nuclear power plants occupy 5 to 10 acres of land per rated megawatt. A coal-fired plant occupies about 19 acres of land per rated megawatt. In comparison, a geothermal field uses 1 to 8 acres per rated megawatt. Wind farms can be sited offshore or may occupy land that can be used for other purposes, such as cattle grazing and farming. Solar thermal systems occupy 5 to 10 acres per rated megawatt. Solar electric systems may have a negligible effect on the land because they can be affixed on top of existing structures or on land unsuitable for other uses.⁸

Often, the footprint of conventional power plants does not reflect the actual land required for electricity production. In the Appalachian Mountains, for instance, where a significant amount of the nation's coal is mined, entire mountaintops are often removed in order to expose the coal underneath. More than 300,000 acres of hardwood forests and 1,000 miles of streams have been destroyed during this process in West Virginia alone.⁶ Regarding worker safety, the dangerous coal mining industry is responsible for an average of 30 workers' deaths each year in the U.S.⁹

Though there are thousands of acres of unused land in southern Nevada, the ecosystem of the Mojave Desert is extremely fragile. Any ill-planned construction could alter natural washes and other features of the lands, severely affecting the sustainability of the region's flora and fauna.

Global Effects

The demands of the world's growing populations and economies, particularly in China and India where 37 percent of the world's population lives, are increasing energy costs and decreasing conventional fossil fuel sources. According to the International Energy Agency, China's demand for oil will equal that of the U.S. by 2030. Many experts believe global fossil fuel output is at or near its peak, meaning traditional energy supplies will soon be shrinking while demand continues to escalate. Of the collective 13 terawatts (13,000,000 megawatts) of steady energy consumed by the world, 85 percent is produced by fossil fuels. By the year 2050, it is estimated the world will need 30 terawatts of power, more than double the current output.¹⁰

Under the existing system, one billion tons of coal are mined in the U.S. every year to supply 320,000 megawatts of electrical power (the U.S. has one-quarter of the world's coal resources). Electricity demand is estimated to increase at a rate of 1.8 percent annually over the next 20 years. New coal-fired power plants, with a combined capacity of 100,000 megawatts, are one possible solution to supply the nation's power in the future.¹¹

Across the globe, many nations do not have the ability to supply their citizens with reliable energy. A lack of natural resources, undeveloped infrastructures, and political strife inhibit technological growth. An increase in renewable energy systems manufacturing in the U.S. will not only help Americans become energy independent, it will also expand U.S. markets in the renewable energy sector, thereby aiding in the stabilization of the world's energy market and the protection of the global environment. In doing so, the U.S. could help developing nations provide reliable electricity to communities without dependable energy sources and to those too distant from the electrical grid (an estimated 80 percent of Africans live in villages without access to electrical grids).¹⁰

Energy Neutrality

Over the past several years, Americans have increasingly supported renewable energy. Many pay a premium on top of their standard energy bills to support the development of renewable energy technology. According to the National Renewable Energy Laboratory, sales of renewable energy systems in voluntary markets increased 60 percent in 2004, and a further 40 percent in 2005.¹² Legislators have passed regulations mandating energy providers supply a predetermined percentage of their total energy output from renewable sources. Other laws provide tax rebates and financial incentives for companies and individuals who install renewable energy systems on

their property. There has been an upsurge in energy-efficient building by contractors and homeowners hoping to reduce emissions and energy costs.

In contrast to traditional power plants, where enormous facilities are centrally localized and provide power for large regions, renewable power sources have the versatility to either provide power to thousands of households or sized to match the needs of one specific user. In the case of solar and wind power, systems can be upgraded and enlarged incrementally to grow with increasing power demands. Should the nation invest in the development of smaller power networks, the potential for blackouts will be significantly reduced.

The overall objective of this study was to determine an appropriate location, size, and type of renewable energy generation system that is reliable, efficient, and economical. After determining the amount of electrical energy used annually by the three federal agencies in the Las Vegas Valley, renewable energy resources in southern Nevada were analyzed, and the best possible locations for a renewable energy power source were examined. An adequately-sized system needed to produce energy equal to that used by the three agencies has been determined.

Annual Electrical Energy Demand and Billing Structure

The National Park Service, the U.S. Fish and Wildlife Service, and the USDA Forest Service have facilities distributed across much of southern Nevada. The facilities receive most of their energy from Nevada Power, the state's largest investor-owned utility company. Also serving these facilities is a mix of municipal and locally managed utilities.

The Center for Energy Research at the University of Nevada, Las Vegas, collected monthly utility bills for each of the three federal agencies' locations during the 2005 billing period. The locations under study within the Lake Mead Recreation Area include only those in the state of Nevada (the eastern side of the Lake Mead Recreation Area in Arizona is not included in this project). As shown in Table I below, the National Park Service is the major power purchaser, consuming 90 percent of the three agencies' entire yearly energy use. In 2005, there were a total of 157 electric energy meters that registered 3,156 megawatt-hours. The total cost of the energy was \$290,800.

Table I: Yearly Energy Consumption and Associated Cost

Agency Name	Electric Power Provider	Number of Meters	Yearly Energy Use (2005)	Yearly Energy Cost (2005)
National Park Service	Overton Power District	26	505 MWh	\$46,700
	Nevada Power Co.	82	1,783 MWh	\$177,800
	Boulder City	7	550 MWh	\$34,000
Fish and Wildlife	Valley Electric	4	55 MWh	\$7,000
	Overton Power District	5	29 MWh	\$3,300
	Alamo Power	9	100 MWh	\$7,100
	Nevada Power Co.	9	45 MWh	\$5,400
USDA Forest Service	Nevada Power Co.	15	89 MWh	\$9,500
Total		157	3,156 MWh	\$290,800

Managing the actual energy among the three federal agencies proved to be challenging, as each of the 157 electric energy meters above is treated as an individual customer (different agencies pay their electric bills accordingly). The existing utility regulatory environment in Nevada would not support consolidating all three agency utility bills, nor would it permit offsetting energy use at the 157 different locations by one renewable energy facility.

In order to offset the electricity used by the three federal agencies, the following options were considered:

1. *Connect a renewable energy system to each of the existing 157 electric meters:*
This method was initially requested by Nevada Power. The system would operate under net-metering guidelines, whereby any excess electricity produced on a monthly or yearly basis would be purchased by Nevada Power. However, the time

needed to accomplish this task was projected to take more than 50 years. Installing and maintaining the 157 individual renewable energy systems would create an overwhelming workload for the agencies, which are already challenged to maintain the existing facility base.

2. *Connect renewable energy systems to the largest energy consumption meters only:* This option, also acceptable to Nevada Power, was rejected on the basis that the renewable energy systems would only benefit one agency and thus would not meet the goal of energy neutrality for all three agencies. However, this may be a viable option for agencies to pursue individually before the construction of new facilities or renovation projects.
3. *Install a single renewable energy system to feed the utility grid; use net-metering benefits for each agency:* This option, while logistically practical, is not permitted under current utility regulations. Nevada state laws allow public utilities to impose fees on net-metered systems greater than one hundred kilowatts. Total system size allowed for net-metering purposes is limited to less than one megawatt. These limitations would therefore not allow the agencies to meet their energy neutrality goal.
4. *Investigate a Power Purchase Agreement by utilizing a renewable energy facility sited on federal lands:* This method will allow a single renewable energy system to generate as much electricity as the three federal agencies consume annually. Under such an arrangement, the federal agencies are permitted to sell electricity generated by an agency-owned renewable energy system to a third party, while retaining the credit for the renewable energy production. The renewable energy produced by the proposed system will offset the utility-provided energy that the agencies will continue to consume. This option can be operational in a relatively short time frame (less than three years) and will create minimal additional workload for the agencies. This option was selected as the best available method.

Renewable Energy Policy for the Federal Agencies

The National Park Service, the U.S. Fish and Wildlife Service, and the USDA Forest Service, are guided in their efforts to reduce energy consumption and better conserve the environment through the Energy Policy Act of 2005 and by Executive Order 13424, established in January 2007. Excerpts from the federal guidelines, as they pertain to the three federal agencies in this report, are presented below.

The Energy Policy Act of 2005

SEC. 203. FEDERAL PURCHASE REQUIREMENT.

(a) REQUIREMENT.—The President, acting through the Secretary, shall seek to ensure that, to the extent economically feasible and technically practicable, of the total amount of electric energy the Federal Government consumes during any fiscal year, the following amounts shall be renewable energy:

- (1) Not less than 3 percent in fiscal years 2007 through 2009.
- (2) Not less than 5 percent in fiscal years 2010 through 2012.
- (3) Not less than 7.5 percent in fiscal year 2013 and each fiscal year thereafter.

Executive Order 13423 –

Strengthening Federal Environmental, Energy, and Transportation Management

Sec. 2. Goals for Agencies. In implementing the policy set forth in section 1 of this order, the head of each agency shall:

(a) improve energy efficiency and reduce greenhouse gas emissions of the agency, through reduction of energy intensity by (i) 3 percent annually through the end of FY 2015, or (ii) 30 percent by the end of FY 2015, relative to the baseline of the agency's energy use in FY 2003;

(b) ensure that (i) at least half of the statutorily required renewable energy consumed by the agency in a fiscal year comes from new renewable sources, and (ii) to the extent feasible, the agency implements renewable energy generation projects on agency property for agency use;

(c) beginning in FY 2008, reduce water consumption intensity, relative to the baseline of the agency's water consumption in FY 2007, through life-cycle cost effective measures by 2 percent annually through the end of FY 2015 or 16 percent by the end of FY 2015.

Sec. 3. Duties of Heads of Agencies. In implementing the policy set forth in section 1 of this order, the head of each agency shall:

(a) implement within the agency sustainable practices for (i) energy efficiency, greenhouse emissions avoidance or reduction, and petroleum products use reduction, (ii) renewable energy, including bioenergy, (iii) water conservation . . .

The development of the renewable energy sector relies on support from the federal government. Similar to the advancement of solar technology in the 1950s and 1960s, necessary to power NASA satellites, current support of renewable energy research is essential to ensure further innovation. By setting a goal to become energy neutral by 2010, the federal agencies in the Las Vegas Valley will exceed the minimum goals stated above while further spurring renewable energy development.

Renewable Energy Sources in Southern Nevada

Nevada has one of the largest capacities for renewable energy in the nation. Realizing the importance of developing the technology, Nevada legislators passed regulations requiring that renewable sources account for 15 percent of the state's electricity production by 2013. At least 5 percent of the energy must come from solar power.

There is no firm guidance according to federal energy policies regarding the selection of appropriate types of renewable energy. However, a number of criteria from other agency policies were taken into account. Figure 2 below shows the scope of the lands maintained by the federal government in Clark County, Nevada. The renewable energy potential of Nevada is detailed in the following pages.

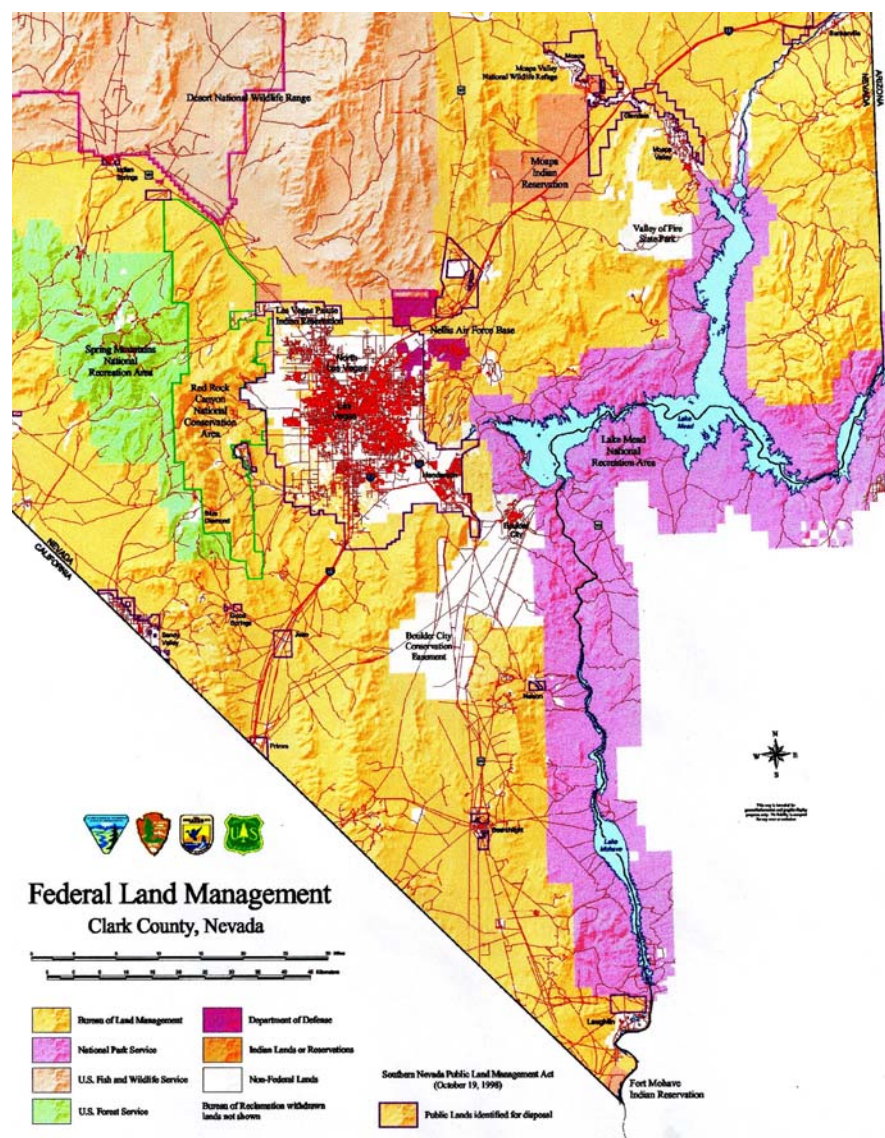


Fig. 2: Federal lands in Clark County, Nevada.

Hydroelectric Power

Hydroelectric power plants affect large tracts of land (in the case of the Hoover Dam, nearly 250 square miles of land were covered when Lake Mead was formed), and large-scale hydroelectricity is typically not considered renewable energy. Large dams have been shown to deplete fish populations, counter to the federal agencies' objectives. Hydroelectric plants under 10 megawatts have much less effect on waterways, providing a clean, renewable energy source for consumers near rivers. Scotty's Castle for instance, maintained by the National Park Service in Death Valley National Park, has been providing energy via Pelton water wheels since the 1930s. However, as the Colorado River is the only source in the Las Vegas Valley strong enough to supply water power, small-scale hydroelectric potential is very limited.



Fig. 3: Lake Mead and the Hoover Dam.

Geothermal Energy

Electricity produced by geothermal power creates very few emissions and has little adverse effect on the surrounding environment. Geothermal energy costs are often comparable to fossil fuel-produced electricity. Geothermal power can be available 24 hours a day, with average availabilities above 90 percent, compared to about 75 percent for coal-fired plants. However, since geothermal plants do remove heat from reservoirs of steam or hot water within the earth, geothermal energy may not technically be perpetually renewable. Additionally, the construction of a geothermal plant may require more land than the federal agencies wish to allocate and may cause a visual concern within federally protected lands.



Fig. 4: A geothermal plant in Dixie Valley, Nevada.

As shown below in Figure 5, geothermal energy is widely available in northern Nevada. Geothermal energy has been utilized in Nevada for more than two decades, and the state currently has more than 235 megawatts of installed capacity. Geothermal power has more room for growth in Nevada, but southern Nevada, in particular the Las Vegas Valley, has much less potential than other areas of the state.

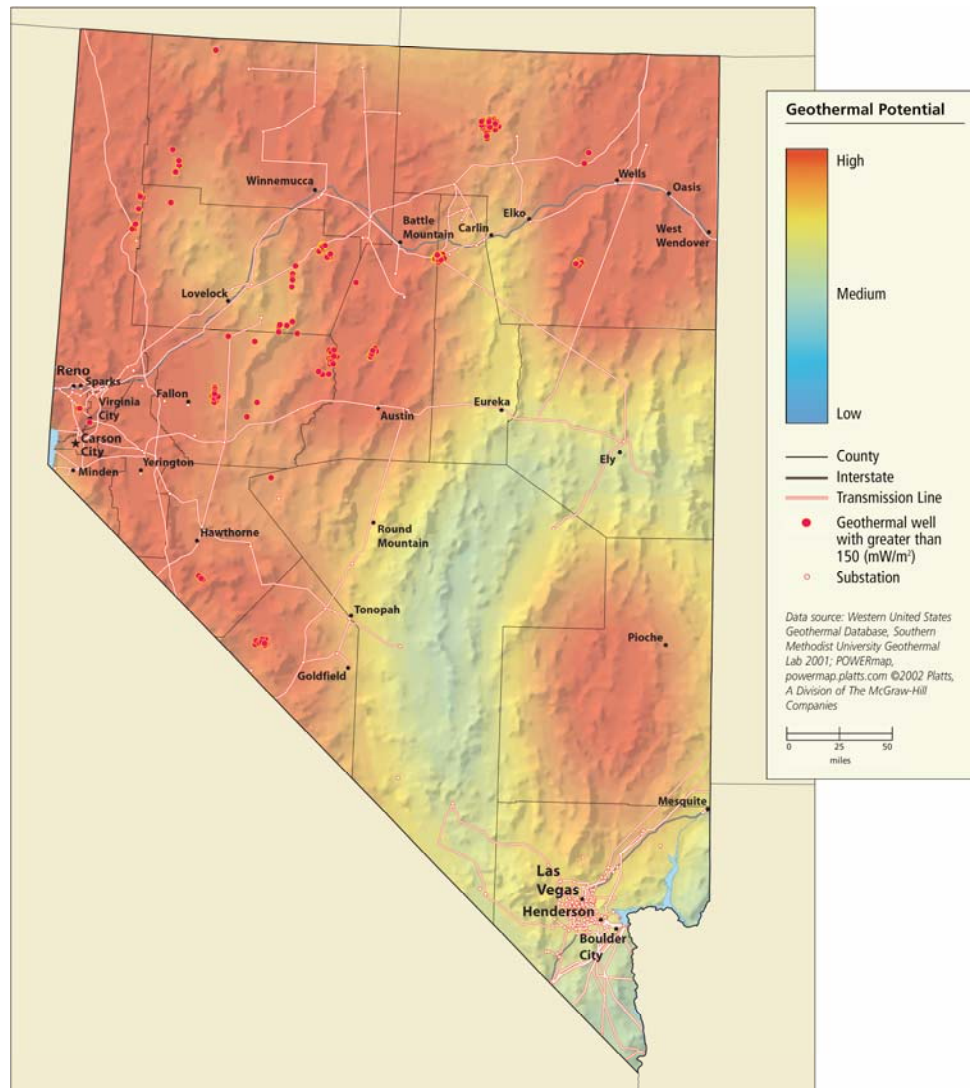


Fig. 5: Nevada geothermal energy potential.

Biomass Energy

Electricity generated from the burning of biological material, most commonly plant matter, has been proven to be an effective alternative energy method. Though causing far fewer detrimental consequences on the environment compared to the combustion of coal, biomass power plants do emit nitrogen oxides, sulfur oxides, and carbon dioxide. In addition, biomass requires large amounts of water, which may be discharged at higher temperatures and containing pollutants into nearby bodies of water, damaging plant and animal life. Biomass power plants may also require large areas of land. Due to its arid climate, Nevada does not produce a high volume of biomass

material suitable for large scale power generation. Figure 6 below shows biomass energy potential in Nevada.

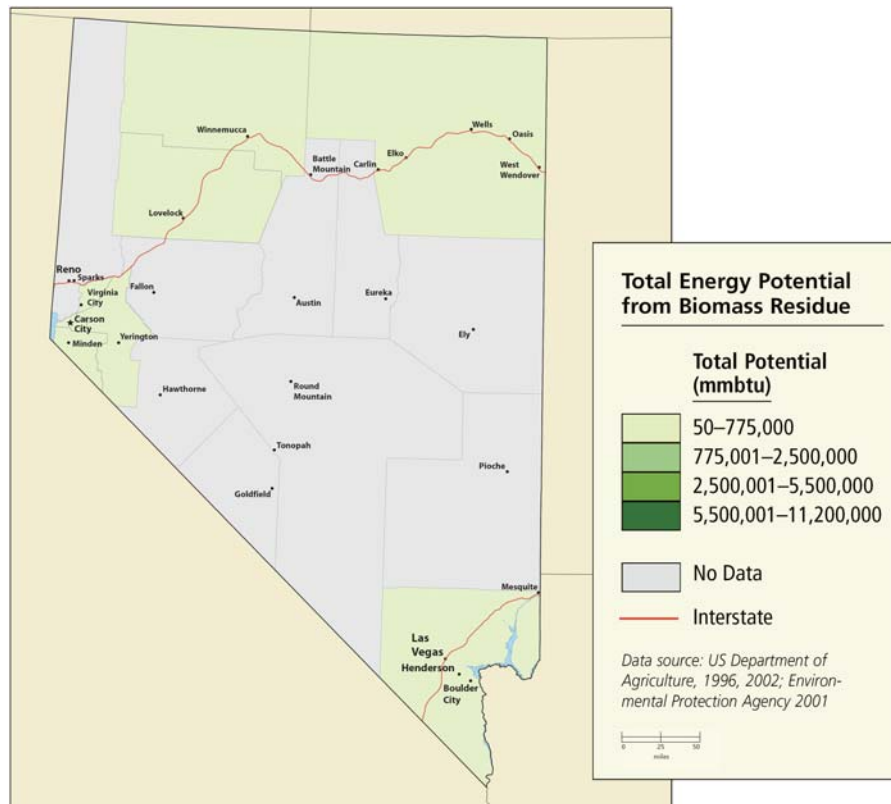


Fig. 6: Nevada biomass energy potential.

Wind Power

Energy from the wind has been harnessed for centuries and has of late come into an era of renewed interest and technological advancement; the U.S. Department of Energy hopes wind power will comprise 5 percent of the nation's electricity supply by 2020. Electricity can be generated by the wind relatively inexpensively and emission-free. Effects on land utilized by wind turbines can be minimal when the land is shared with other ventures. Although a viably proven renewable energy source, wind turbines require placement along open plains or atop ridges in order to utilize the most effective strength of the wind. As such, wind towers create a large visual concern for parks and wildlife refuges, running counter to the agencies' goal to keep federal land in its most natural state.

Counter to the popular belief that wind farms create an insurmountable hazard to birds and bats, modern wind turbines are responsible for an ever-shrinking amount of avian deaths. The Altamont Pass in northern California has nonetheless become a focal point of controversy between wind energy proponents and wildlife advocates. The 50-square-mile Altamont Pass Wind Resource Area is home to more than 5,000 wind turbines, most of which utilize outdated, fast-rotating turbine blades that are notorious for killing thousands of migratory birds as they fly through the area or hunt for prey. According to the California Energy Commission, an estimated

1,700 to 4,700 birds are killed each year in the Altamont Pass, many of them federally protected raptors.¹³

In comparison, bird and bat deaths due to collisions with utility transmission and distribution lines, automobiles, tall buildings, residential house windows, and communication towers have been estimated to reach into the hundreds of millions. A report by the National Wind Coordinating Committee has assessed wind turbine-related avian collision fatalities to represent between 0.01 to 0.02 percent of all avian collision fatalities annually in the U.S.¹⁴ Comparing wind turbine to oil industry effects on the bird population, one expert in wind power technology has estimated that the Altamont Pass Wind Resource Area would need to operate for 500 to 1,000 years in order to account for the same amount of bird deaths as the Exxon Valdez oil spill in Alaska's Prince William Sound.¹³

While recognizing the need to reduce turbine-related bird and bat deaths, wind farm developers are replacing outdated wind turbines with modern towers that utilize blades that rotate more slowly and generate 15 to 30 times more energy, requiring far fewer turbines to create the same amount of energy.



Fig. 7: Wind farm on the coast of Denmark.

Across much of Nevada, particularly in the Las Vegas Valley, wind resources are marginal at best (shown in Fig. 8 on the following page). Though many areas of Nevada do show promise for the installation of large-scale wind farms, the Las Vegas Valley has limited potential.

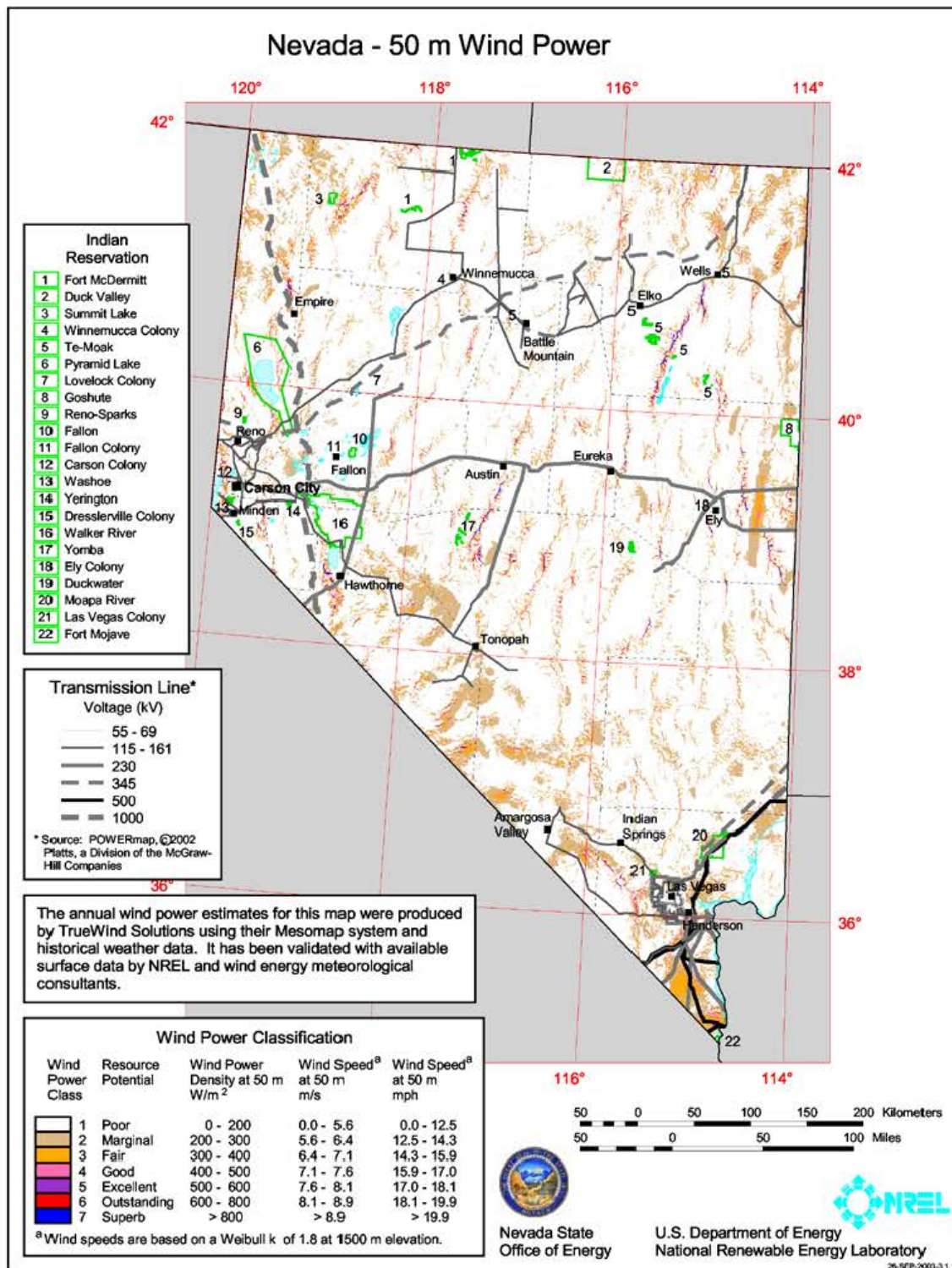


Fig. 8: Nevada wind power resource.

Solar Power

Solar power has been utilized for centuries, from the age of the Greeks and Romans who used passive solar techniques to heat their buildings and water, to 1839 when French physicist Edmond Becquerel discovered the photovoltaic effect, to the 1950s when NASA developed

photovoltaic panels for use in the Space Race. Since then, solar power has been further developed and harnessed to provide high quality energy with few or no undesirable consequences to the environment.

Solar power systems make little or no noise, emit zero emissions, require very little water for cleaning purposes, and typically have long lifecycles because they contain few or no moving parts. Generally constructed of modular, readily available materials, solar power plants are easier to site than conventional plants and can typically be built in a few years, or in as little as a few months. Conversely, coal and nuclear power plants require many years of planning and construction before coming on-line. The short lead times of solar power plants, and the ability to incrementally expand existing facilities, allow them to more suitably handle rapid increases in energy demands. As peak load demands increase during summer months with increased air-conditioner use, the need to construct additional generating capacity and upgrade transmission lines may be eliminated by locating renewable energy systems at the end of a distribution line. An additional benefit of renewable energy is the ability to construct many renewable systems near the site of the consumer. This practice of “distributed generation” avoids unnecessary transmission line construction and distribution power losses (rural electric utilities typically lose about 12 percent of the electricity sent over distribution lines).¹⁵

Even locations with moderate amounts of available sunlight are capable of producing energy from the sun. In Germany and Japan, where the available sunshine is much less than in the southwestern United States, solar power production is thriving. Thanks to generous tax rebates and incentives provided by their respective governments, Germany and Japan are leading the world in solar energy production. In 2005, the two countries each produced over 38 percent of the world’s total solar energy, with an installed solar capacity of 1,420 megawatts each. Solar power is highly competitive in Germany and Japan because average electric rates in the two countries hover around \$0.20 per kilowatt-hour, more than double the \$0.09 per kilowatt-hour average U.S. rate. California, with widely available sunshine and advantageous legislation, is responsible for about 13 percent of the world’s 3,705 megawatts of solar power, with an installed capacity of 479 megawatts as of 2005.¹⁶

According to the U.S. Department of Energy, sales of photovoltaic panels increased by 66 percent during 2004. That year, more than 1.6 million American homes received electric power from solar panels.¹⁰ The further development of PV technology may spur advancements in the automobile industry, as the utilization of solar energy to produce engine-powering hydrogen gas is currently under research. With many more renewable energy advancements on the horizon, thousands of technologically-advanced career opportunities are opening. In Germany for example, solar power is the second largest source of new jobs (after the automotive industry), employing about 200,000 people in the nation of 80 million.¹⁶

Clark County, home to Las Vegas, Red Rock Canyon, Spring Mountain National Recreation Area, acres of Desert National Wildlife Range land, and the western shore of Lake Mead, has a current population of nearly 1.8 million residents. The region is one of the nation’s fastest growing areas with an increase in population of 29 percent from 2000 to 2006.¹⁷ Additionally, nearly 40 million people visit Las Vegas each year. The population growth necessitates an easily

expandable energy system such as solar power. The following figures show solar resources in the world and in the U.S.

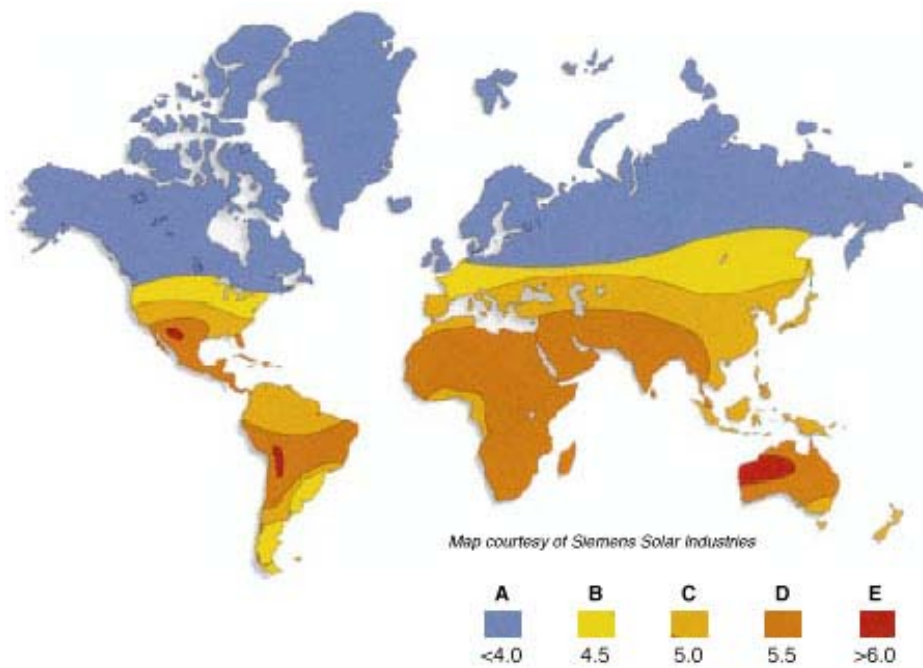
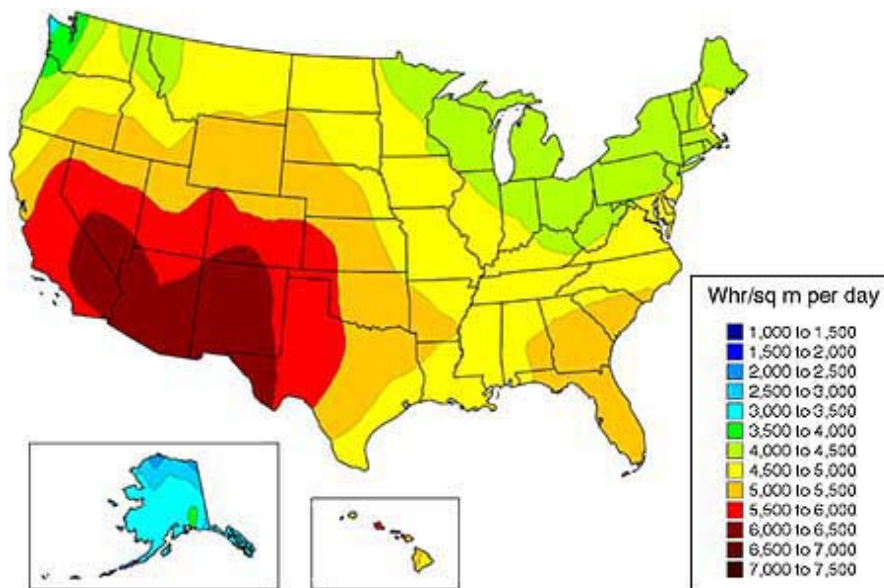


Fig. 9: World solar resource map (units are in kilowatt-hours per square meter per day).



Solar resource for a flat-plate collector

Fig. 10: U.S. solar resource map.

With high temperatures and more than 300 sunny days per year, Las Vegas has one of the most ideal solar resources in the world. The amount of available sunshine in Nevada is shown in Figure 11 below. Different types of solar power technologies are detailed in the next section.

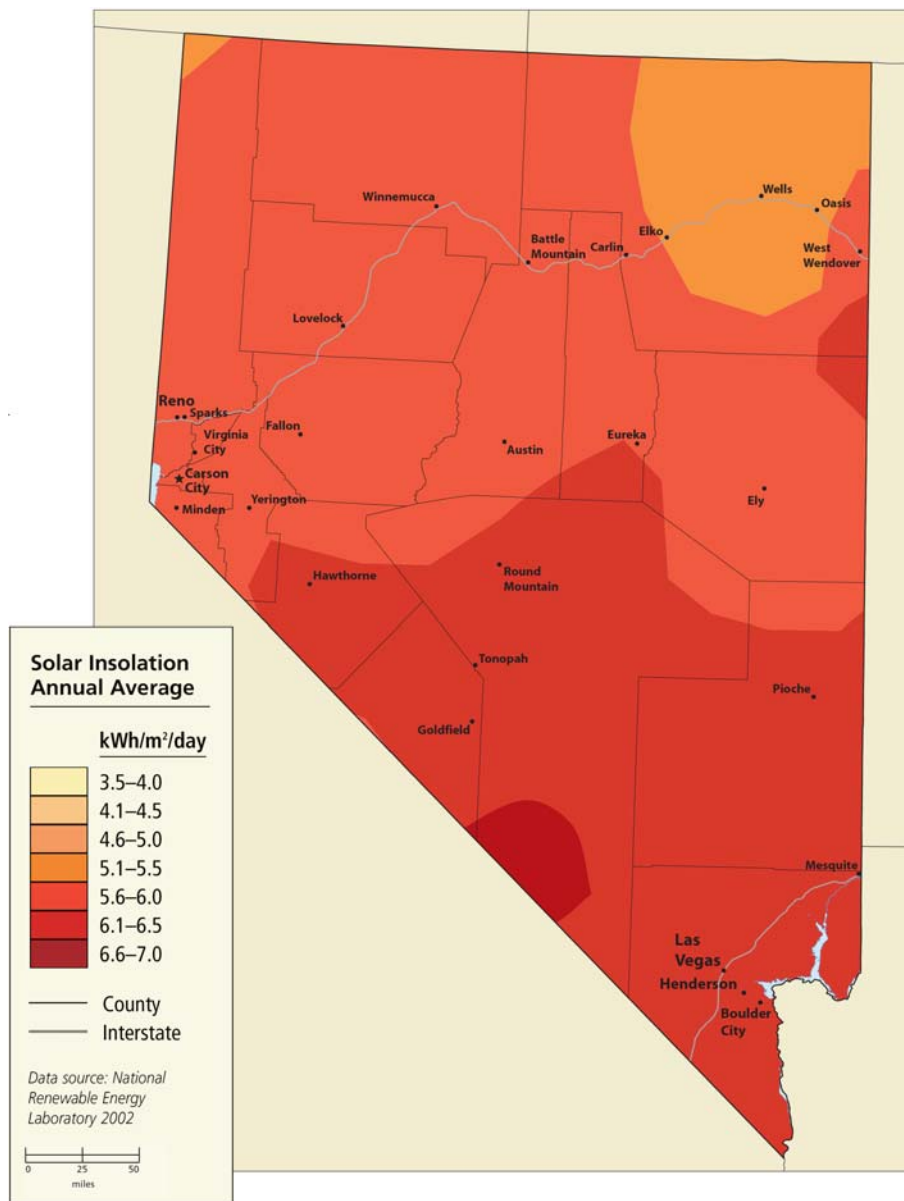


Fig. 11: Available sunshine in Nevada.

Types of Solar Power Technology

Listed below are several types of solar power technology that are currently in use or under development. Electricity-generating solar power technologies can be divided into two subgroups: concentrating solar thermal and solar electric power.

Concentrating Solar Thermal Power

Concentrating solar thermal power systems utilize heat from the sun to produce electricity. Power plants using this technology have been in use in California since 1984 and are currently the least expensive method for producing solar electricity. In the U.S., the Southwest is the most ideal locale for concentrating solar thermal power, as the technology produces the most electricity during the hottest part of the day, often the time of peak demand. Conversely, coal-fired and natural gas plants become less efficient during the hottest part of the day.

On average, current concentrating solar thermal power plants produce electricity at \$0.12 to \$0.14 per kilowatt-hour, a competitive price for high-demand peak periods.¹⁸ Below are three specific types of concentrating solar thermal power.

Concentrating Solar Power Dishes

A concentrating solar dish system uses mirrors to reflect all of the sunlight it receives onto a single focal point. At the focal point of the dish sits a Stirling engine or a steam engine that converts the heat into electricity. The high temperatures created by solar dish systems allow for increased efficiencies, but the systems require a dual-axis tracker to collect the sunlight, greatly adding to the cost and complexity of the system. Though showing promise of highly reliable energy at low costs, parabolic dish systems are still under development.



Fig. 12: Concentrating solar power dishes.



Fig. 13: The Solar Two power tower.

Solar Power Towers

Solar power towers utilize a field of mirrored panels, or heliostats, to track the sun and focus its rays onto a single receiver mounted atop a central tower. The concentrated sunlight is focused

onto a heat transfer fluid, such as molten salt, which is used to generate steam to drive electricity-producing turbines. Two experimental solar power tower systems were tested in the Mohave Desert in the 1980s and 1990s – the 10 megawatt Solar One and Solar Two demonstration projects. Europe's first commercial power tower, the 11 megawatt PS10 located in Spain, was recently completed.

Solar power towers have been proven to effectively generate clean electricity, but since so few have been built and tested, there is still much development to undertake. Furthermore, the physical nature of the power tower system design, with a tall receiver tower surrounded by a large array of mirrors placed in a circular pattern, may cause visual concerns within federal conservation lands.

Parabolic Troughs

A parabolic trough consists of a long curved mirror and a tube filled with a heat transfer fluid running along the mirror's focal point. The heat transfer fluid is used to heat steam in a standard electricity-producing turbine engine. Parabolic troughs are typically situated in parallel arrays for large energy output capabilities. These arrays are mounted along a north-south axis and are driven by motor to rotate east to west in an effort to track the sun, hence providing direct sunlight to the system.

Of all large-scale solar power systems in the U.S., parabolic troughs produce the most electricity by far. Five systems at Kramer Junction, California, rated at 30 megawatts each, two systems at Harper Lake, California, rated at 80 megawatts each, and a brand new 64 megawatt system in Boulder City, Nevada, are now in use. The California parabolic troughs are part of the Solar Energy Generating Systems, the largest solar power system of any kind in the world. As a testament to their development, solar trough output has increased by 35 percent while costs have dropped 40 percent.¹⁸ Currently, most parabolic trough plants are hybrid systems, meaning they use natural gas as a supplement to provide energy at night or during overcast days.

The U.S. Department of Energy has a goal to install an additional 1,000 megawatts capacity of concentrating solar power systems by the year 2010. With further technological advancements in conjunction with increased manufacturing, electricity produced by concentrating solar power could decline to \$0.07 per kilowatt-hour, a highly competitive price in today's market.¹⁹



Fig. 14: Solar trough array.

Solar Electric Power

Like concentrating solar thermal power, solar electric power comes in a wide variance of type and application. Currently, electricity produced from solar panels is more expensive than nuclear or fossil fuel power, but major advancements in photovoltaics and increasingly advantageous federal and state tax incentives have made solar electric power financially competitive with traditional energy sources. Listed below are several types of solar electric power.

Photovoltaic Panels

Photovoltaic panels employ the photovoltaic effect, creating direct current electricity after photons of light strike a semiconductor. When solar cells are connected in line to form modules and modules connected to form panels, solar power systems can create substantial amounts of electricity. Solar cells are typically comprised of monocrystalline or polycrystalline silicon. Though monocrystalline silicon cells are more efficient, they are also more expensive and not as readily available as the more commonly used polycrystalline silicon cells.

Installing photovoltaic panels in a fixed configuration is the simplest method to design and maintain because no moving parts are involved. Fixed panels can be mounted horizontally flat (zero-degree) or at an angle facing the southern horizon to better capture direct sunlight. Fixed panels are the most efficient when mounted at an angle equal to that of the location's latitude, but panels at a slight angle of just 10 to 15 degrees have significantly higher efficiencies than fixed zero-degree panels. Panels mounted at an angle tend to collect less dust particles than zero-degree panels, maintaining cleaner, more efficient panel surfaces that rainwater will easily run off. As a drawback, panels mounted at fixed angles will shade adjacent panels unless proper spacing is allotted. This spacing increases the overall footprint of the solar array. Shading effects drastically reduce panel efficiency.

In an effort to better capture direct sunlight, many large-scale photovoltaic systems are powered by tracking systems. Single-axis tracking arrays, which are typically mounted along a north-south axis, rotate from east to west over the course of the day. Like fixed arrays, panels can be mounted at zero-degree or southerly-facing angles.

Since PV panels are most efficient with direct sunlight, PV panels that perfectly track the sun, or dual-axis trackers, are the most efficient. However, the added cost and complexity of dual-axis trackers are often not worth the slightly higher efficiency benefit, and many large-scale facilities opt to use single-axis tracking systems.

Thin Films

There are many advantages to solar electric thin films, which are lighter and less expensive to manufacture than traditional crystalline solar cells. Rather than individual cells that must be mounted in frames and wired together, thin films are produced as complete, extremely thin modules that are attached to low-cost backings such as glass or plastic. Since thin films are flexible and can conform to the shape of the backing, they can be used in a variety of products. The public has shown a great interest in developing thin films, indicated by the stock price of First Solar, a thin-film manufacturing company, which has increased from an initial public offering price of \$20 in November, 2006, to a 2007 high of more than \$147. Though showing

promise for the future, thin films have a much lower efficiency than traditional silicon cells and thus are typically not used in large-scale systems.

Concentrating Photovoltaic

Concentrating photovoltaic systems utilize mirrors or lenses to reflect sunlight onto small, highly efficient solar cells. This technology focuses sunlight to concentrations from 250 to over 500 times the strength of standard sunlight. As a result, the systems require much less semiconductor material than standard PV panels. (The high cost of manufacturing semiconductor material is a significant factor in the expense of solar electricity.) However, concentrating solar photovoltaic systems require direct sunlight, and therefore dual-axis trackers, to produce electricity.

A concentrating photovoltaic system manufactured by Amonix, a California-based company, has shown great promise for this technology. Amonix systems are currently undergoing testing by the Arizona Public Service utility company and at UNLV's Center for Energy Research.



Fig. 15: An Amonix concentrating photovoltaic system.

Matters Specific to the Federal Agencies

Though solar power plants require a sizeable amount of land area, the ability to install solar power instrumentation atop or adjacent to existing structures or previously disturbed land makes solar power the best choice for this particular project. To avoid creating visual quality concerns, many types of solar power can be shaped to blend in with the landscape.

During the examination of different locations capable of housing a renewable energy system in the Las Vegas Valley, sites with preexisting structures held precedence due to their developed infrastructure. Were a renewable power facility to be built on previously undisturbed land, a road to the site would be required and transmission lines, either above ground or trenched through the land, would have to be run to the nearest grid connection point. The sheer cost of new roads and transmission lines could be prohibitive, and their construction conflicts with maintaining forests, refuges, and federal park lands in their original state.

Renewable Energy Experience

A leader in renewable energy use, the National Park Service uses bio-diesel fuel for more than 675 pieces of equipment and vehicles at 23 national parks and has over 700 photovoltaic applications installed.²⁰ One particular project shows the agency's commitment to and experience with solar power applications.

Glen Canyon National Recreation Area utilizes a 160 kilowatt photovoltaic/propane-hybrid power system that provides clean, dependable energy to the Dangling Rope Marina, estimated to save over \$2.3 million in fuel and maintenance costs over a 20-year period.²¹ Originally supported by diesel generators that ran 24 hours a day and consumed 65,000 gallons of diesel fuel each year, the hybrid system was installed in 1996 and upgraded two years later. In addition to generating less noise and eliminating the risk of a diesel fuel spill on the marina's Lake Powell, annual air emissions have been reduced by an estimated 665 tons of carbon dioxide, 11,840 pounds of nitrogen oxides, and 3,000 pounds of sulfur oxides.²² Installation and testing of the system was completed on schedule and within budget by Applied Power, which provided further system operation and maintenance training to National Park Service personnel. The reliability of the system was nearly perfect during its first year of operation, with availability at 99.6 percent. Further conservation measures, such as replacing electrical appliances with propane-fueled appliances and installing more efficient heat pumps, reduced the marina's electrical load 10 to 12 percent.²³



Fig. 16: Solar array at Glen Canyon National Recreation Area.

Potential Locations

Determining the location of the proposed renewable energy system was governed by the budgetary authority under the Southern Nevada Public Lands Management Act, which directs the expenditure of funds to projects on lands owned or managed by one of the federal partner agencies. According to the previously cited Executive Order 13423, renewable energy projects used by federal agencies are to be built on federal lands.

When the Bureau of Land Management, originally a fourth partner in the collaborative study, declined to participate in this project, lands within the Lake Mead National Recreation Area became a logical choice for the system site. The Lake Mead Recreation Area offers several sites with access to existing power transmission lines. Lands maintained by the U.S. Bureau of Reclamation were also considered. The layout of locations is presented in Figure 17 below, and the individual sites are discussed in detail on the following pages.

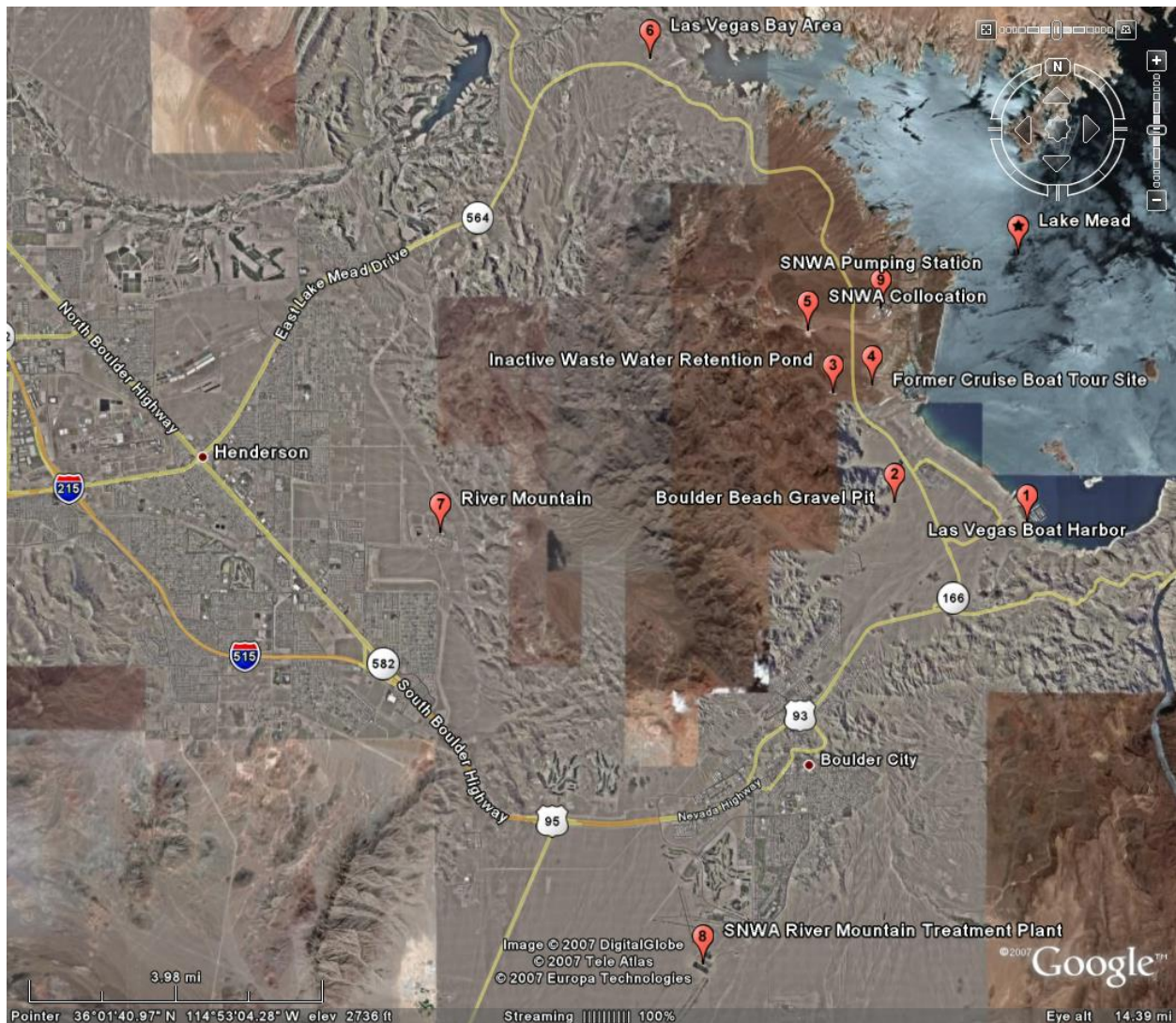


Fig. 17: Layout of potential sites.

Locations considered for a renewable energy site had to satisfy several prerequisites set by the federal land management agencies:

1. The site needed to be on or adjacent to previously disturbed land, so as to not disturb land still in its natural state.
2. The site needed to be accessible by road, so a new road would not need to be built for the facility's construction.
3. The site needed direct access to the electrical grid, so new transmission lines would not need to be installed.
4. In order to have maximum exposure to the sun's rays, the site could not be shaded by surrounding structures or terrain.

Further criteria required that the installation should be invisible to the visitors of the area such that it does not obscure or obstruct the natural beauty of the area. Security concerns such as preventing vandalism were priorities in the planning process.

Locations within the Lake Mead National Recreation Area

Location 1: Las Vegas Boat Harbor

(36° 01.589'N, 114°46.579'W; elevation: 1203 ft.)

This location (shown in Fig. 18) has the potential for secondary benefits that may be realized by installing solar panels in place of the existing shade structures (some structural shoring may be necessary). If a new installation is more desirable than refitting an existing one, the nearby parking area and fish cleaning station are candidates for shading structures. Furthermore, this location is unshaded by nearby mountains, especially at the docks. The only concern is the slope of the landing leading down to the waterline.

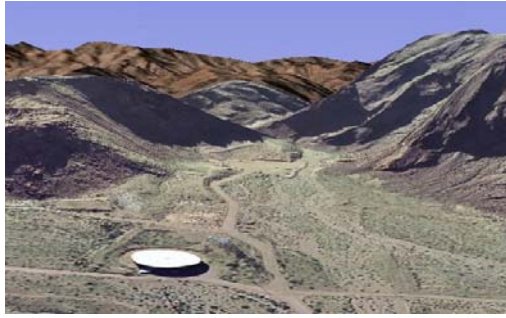


Fig. 18: Las Vegas Boat Harbor.

Location 2: Boulder Beach gravel pit

(36°01.844'N, 114°48.582'W; elevation: 1471 ft.)

This location (shown in Figs. 19 & 20), while desirable because it has been previously disturbed, has low solar potential due to the significant shading from the mountains to the west. (The image on the left below is taken from the east.)

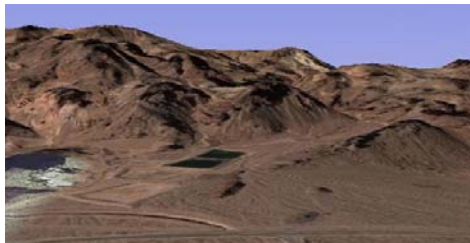


Figs. 19 & 20: Boulder Beach gravel pit.

Location 3: Inactive waste water retention pond

(36°03.163'N, 114°49.495'W; elevation: 1376 ft.)

This location (shown in Figs. 21 & 22), like the Boulder Beach Gravel Pit, is desirable because it is previously disturbed and somewhat disused. However, it also has shading from the mountains to the west, but to a lesser degree than the Boulder Beach gravel pit. (The image on the left below is the view from the east.)



Figs. 21 & 22: Waste water retention pond.

Location 4: Former cruise boat tour site

(36°03.274'N, 114°49.023'W; elevation: 1240 ft.)

Like the Las Vegas Boat Harbor, this location (shown in Fig. 23) is far from the mountains and near the waterline. This location is disused for boating purposes. The Clean Water Coalition has an installation here and may be receptive to joint involvement in the project and to an expansion that may include hydroelectric power. The Clean Water Coalition has entered into an agreement with the National Park Service for the use of this site.



Fig. 23: Former cruise boat harbor.

Location 5: SNWA collocation on disturbed land

(36°03.980'N, 114°49.270'W; elevation 1319 ft.)

This location (shown in Fig. 24) has great potential due to the remote proximity to the mountains to the west, the fact that the land is previously disturbed, and the security offered by its proximity to the existing Southern Nevada Water Authority installation. However, gaining access to this location may be problematic because it is protected as a matter of national security.



Fig. 24. SNWA collocation on disturbed land.

Location 6: Las Vegas Bay area

(36°07.213'N, 114°52.223'W; elevation: 1273 ft.)

This location (shown in Fig. 25) is close to the beach and far from the mountains. There is a set of two covered structures operated by a concessionary where boats are stored. This location has the potential for the secondary shading benefit.



Fig. 25: Las Vegas Bay

Locations Operated by the Bureau of Reclamation

Location 7: River Mountain

(36°01.471'N, 114°55.443'W; elevation: 2239 ft.)

The area outlined in red in Figure 26 below is an approximation of the land owned by the Bureau of Reclamation. A potential site is located at a facility situated near the center of the outlined area. The facility is surrounded by a 6 to 8 foot brick wall and is near power transmission lines. The Bureau of Reclamation is very receptive to renewable energy projects and may be a potential partner in any such venture. Due to its proximity to established residential areas, the potential for vandalism is high outside of the protected, walled-in area.

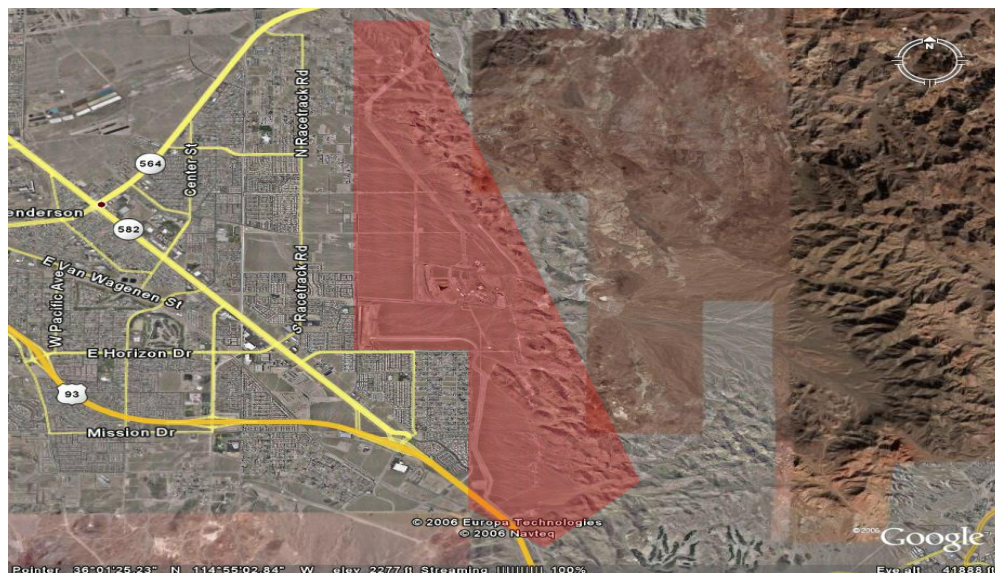


Fig. 26: River Mountain area.

A more detailed view of the current facility on the land managed by the Bureau of Reclamation is shown in Figure 27 below.



Fig. 27: River Mountain facility.

Location 8: SNWA River Mountain treatment plant
(35°56.347 'N, 114°51.435'W; elevation: 2068 ft.)

The WAPA-operated facility owned by the Bureau of Reclamation is a site with high potential due to the openness of the area and its proximity to the power substation (shown in Fig. 28). Accessibility makes the security of the location an issue, but not an insurmountable one.



Fig. 28: SNWA treatment plant and nearby power substation.

The Most Suitable Site

Location 9: SNWA pumping station

(36°04.199'N, 114°48.789'W; elevation: 1242 ft.)

The Southern Nevada Water Authority manages a pumping station located on State Route 166 in the Lake Mead National Recreation Area. The pumping station sits far enough away from surrounding mountains such that shading effects are negligible. The site is located about 1,200 yards from Lake Mead's western shore, thirty miles from downtown Las Vegas. The site is secure and well protected.

The Southern Nevada Water Authority has a proven track record of energy and water conservation. (SNWA is currently collaborating with the Center for Energy Research at UNLV on two projects: converting conventional engines to run on hydrogen, and developing a renewable hydrogen refueling station powered by photovoltaic panels.) SNWA has shown great interest in pursuing a renewable energy system to provide power to the pumping station.



Fig. 29: SNWA pumping station; the western shore of Lake Mead is on the right.

The SNWA pumping station offers acres of area suitable for solar power. All potential locations at the pumping station are above existing structures, meaning a solar energy system's effects on the land, as well as any visual concerns, would be minimal.

The pumping station offers five specific sites suitable for the installation of a solar energy system. Four sites are located above sets of flocculation basins and filtration tanks and have a total area of 155,000 square feet. The fifth site is located above an underground clear-well storage tank, which offers a total area of 210,000 square feet. Because there may be shading concerns at the fifth location, the areas above the flocculation basins and filtration tanks show the most potential at the pumping station. The pumping station is discussed in detail in the following section.



Fig. 30: Aerial view of SNWA pumping station; the shot is from the west looking east.

Plant Type, Size, and Cost

As previously described, the most suitable approach to produce renewable energy in the Las Vegas Valley is with solar power. With the exception of fixed photovoltaic panels, all solar power arrays require a motor-driven tracking system in order to follow the sun. Due to the additional weight and complexity of tracking systems, they are typically only suitable for ground installations (i.e., not on top of structures). The preferred area above the SNWA pumping station's flocculation basins and filtration tanks should be fitted with fixed photovoltaic panels.

In discussions with representatives from the Southern Nevada Water Authority, the preferred method of providing renewable energy to the pumping station is to construct carport-style canopies above the flocculation basins and filtration tanks; PV panels would then be mounted on top of the structures. The structures would not only provide a flat mounting surface for the PV panels, but would also provide shading benefits for the underlying water tanks. The shade would inhibit algae growth within the tanks, thereby reducing the amount of chlorine needed to sanitize the water. As a result, fewer chemicals would need to be removed from the water in order to produce clean drinking water. As a secondary benefit, the shade would reduce the amount of water that evaporates from the tanks.

The figures in this study were calculated assuming the panels are to be installed horizontally flat (at a zero-degree angle), which will provide the most amount of shade and make the installation process as simple as possible. This arrangement, while taking advantage of the most amount of area above the flocculation basins and filtration tanks, will reduce the amount of direct sunlight received by the panels. The specific arrangement of the photovoltaic panels will be researched further during the design phase of this project.

Sizing the System

According to Table I, the annual energy demand of the three federal agencies is 3,156 megawatt-hours. In order to produce this amount of electricity with fixed zero-degree photovoltaic panels, a size analysis was undertaken.

The industry average efficiency for photovoltaic modules is between 10 to 12 percent. High-quality panels may achieve higher efficiencies, such as SunPower Corporation's 210 Solar Panel, which is rated at a 16.9 percent efficiency. Large-scale production modules typically consist of 36 individual PV cells wired in parallel, and the modules are connected to form panels. Because PV panels produce direct current (DC) electricity, inverters are necessary to convert the electricity into industry-compatible alternating current (AC) electricity. Inverters typically have efficiencies from 90 to 95 percent. Including the transformers needed to handle the large electric load and losses from additional electronic equipment, the overall efficiency of large-scale systems is typically 20 to 25 percent below the module efficiency. Therefore if higher-quality PV panels are used (at an efficiency of 13.5 percent) and a 22.5 percent drop from module to system efficiency is assumed, then the overall efficiency of the PV system will be approximately 10.5 percent.

Sunlight strikes the earth's outer atmosphere at a strength of 1,367 watts per square meter. Reflection and other losses attributable to the atmosphere reduce the sun's power to about 1,000

watts per square meter on a cloudless day with the sun directly overhead. Table II below (obtained from NREL's *Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors*²⁴) shows the estimated monthly and yearly solar radiation available for different types of solar panels in the Las Vegas Valley. The figures vary according to tilt-angle and type of tracking system.

For a fixed zero-degree PV system, the annual average solar radiation received is 5.7 kilowatt-hours per square meter per day. This means that a 1 kilowatt peak capacity rated panel will produce 5.7 kilowatt-hours per day in the Las Vegas Valley (photovoltaic systems are rated in peak power output). Calculating the system rating size and required area yields:

$$\text{System Rating} : 3156 \frac{\text{MWh}}{\text{year}} \times \frac{1 \text{ kW}}{5.7 \text{ kWh/day}} \times \frac{1 \text{ year}}{365 \text{ days}} \times \frac{1 \text{ MW}}{1000 \text{ kW}} \times \frac{1000 \text{ kWh}}{1 \text{ MWh}} = 1.52 \text{ MW}$$

$$\text{Area Needed} : 3156 \frac{\text{MWh}}{\text{year}} \times \frac{\text{m}^2 \cdot \text{day}}{5.7 \text{ kWh}} \times \frac{1 \text{ year}}{365 \text{ days}} \times \frac{1000 \text{ kWh}}{1 \text{ MWh}} \times \frac{1}{0.105 \text{ efficiency}} = 14,447 \text{ m}^2$$

$$= 155,506 \text{ ft}^2$$

Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m ² /day), Uncertainty ±9%														
Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	3.0	4.0	5.4	6.9	7.8	8.4	7.9	7.2	6.2	4.7	3.4	2.8	5.7
	Min/Max	2.3/3.4	3.4/4.5	4.8/6.1	6.1/7.4	7.2/8.3	7.8/8.9	6.6/8.4	6.0/7.8	5.4/6.7	4.0/5.1	3.0/3.7	2.2/3.1	5.3/5.8
Latitude -15	Average	4.4	5.3	6.4	7.5	7.8	8.1	7.7	7.5	7.1	6.1	4.8	4.2	6.4
	Min/Max	3.2/5.3	4.4/6.1	5.6/7.3	6.4/8.0	7.2/8.3	7.6/8.6	6.5/8.2	6.2/8.2	6.1/7.7	5.0/6.7	4.0/5.4	3.1/4.8	5.9/6.7
Latitude	Average	5.1	5.9	6.7	7.4	7.3	7.4	7.1	7.2	7.2	6.6	5.5	4.9	6.5
	Min/Max	3.6/6.2	4.8/6.8	5.8/7.7	6.2/7.9	6.7/7.8	7.0/7.8	6.1/7.5	6.0/7.9	6.1/7.9	5.3/7.3	4.5/6.3	3.6/5.7	5.9/6.8
Latitude +15	Average	5.6	6.1	6.6	6.8	6.5	6.3	6.2	6.5	7.0	6.8	5.9	5.4	6.3
	Min/Max	3.8/6.8	4.9/7.2	5.7/7.6	5.7/7.3	5.9/6.8	6.0/6.7	5.3/6.5	5.5/7.2	5.9/7.6	5.4/7.5	4.7/6.8	3.8/6.2	5.7/6.6
90	Average	5.0	5.1	4.7	3.9	3.0	2.6	2.6	3.4	4.5	5.3	5.2	5.0	4.2
	Min/Max	3.4/6.2	4.0/6.0	4.0/5.4	3.3/4.1	2.8/3.1	2.4/2.7	2.4/2.7	2.9/3.7	3.8/4.9	4.2/5.9	4.1/6.1	3.5/5.8	3.7/4.5

Solar Radiation for 1-Axis Tracking Flat-Plate Collectors with a North-South Axis (kWh/m ² /day), Uncertainty ±9%														
Axis Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	4.6	5.9	7.8	9.8	10.9	11.6	10.8	10.1	9.0	7.1	5.1	4.2	8.1
	Min/Max	3.3/5.6	4.6/7.0	6.2/9.3	8.2/10.9	9.8/11.9	10.5/12.5	8.2/11.8	8.1/11.3	7.1/10.1	5.7/7.9	4.1/6.0	3.0/4.9	7.2/8.5
Latitude -15	Average	5.7	6.9	8.5	10.3	11.0	11.5	10.8	10.4	9.7	8.1	6.2	5.3	8.7
	Min/Max	3.9/6.9	5.3/8.2	6.9/10.2	8.5/11.4	9.9/12.0	10.4/12.4	8.2/11.8	8.4/11.7	7.7/10.9	6.4/9.1	4.9/7.3	3.7/6.2	7.7/9.1
Latitude	Average	6.2	7.3	8.8	10.2	10.6	11.1	10.4	10.3	9.8	8.6	6.7	5.9	8.8
	Min/Max	4.3/7.7	5.6/8.7	7.1/10.5	8.4/11.3	9.6/11.6	10.0/11.9	7.8/11.4	8.2/11.5	7.8/11.1	6.7/9.5	5.3/7.9	4.1/6.9	7.8/9.3
Latitude +15	Average	6.5	7.5	8.7	9.8	10.0	10.3	9.8	9.8	9.6	8.7	7.0	6.2	8.7
	Min/Max	4.4/8.1	5.7/9.0	7.0/10.4	8.1/10.9	9.0/11.0	9.3/11.1	7.3/10.7	7.8/11.0	7.6/10.9	6.7/9.7	5.4/8.3	4.3/7.3	7.6/9.1

Solar Radiation for 2-Axis Tracking Flat-Plate Collectors (kWh/m ² /day), Uncertainty ±9%														
Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
2-Axis	Average	6.6	7.5	8.8	10.3	11.1	11.8	11.0	10.5	9.8	8.7	7.1	6.3	9.1
	Min/Max	4.5/8.2	5.7/9.0	7.1/10.5	8.5/11.4	10.0/12.1	10.6/12.7	8.3/12.1	8.4/11.8	7.8/11.1	6.7/9.7	5.5/8.3	4.3/7.4	8.1/9.6

Table II: Las Vegas Valley Average Monthly and Yearly Solar Radiation

According to representatives with the National Renewable Energy Laboratory, the estimated cost of installing fixed PV arrays on the ground or on top of existing structures is around \$7 per rated watt. At this price, installing a system with a peak power generating capacity of approximately 1.5 megawatts will cost an estimated \$10.5 million. Installation of the carport-style mounting structures above the pumping station's flocculation basins and filtration tanks could increase the cost by an additional \$2 to \$4 per rated watt.

Installation at the SNWA Pumping Station

As noted earlier, the Southern Nevada Water Authority pumping station offers five specific areas capable of supporting photovoltaic power arrays. Figure 31 below shows the locations of the five potential sites at the pumping station.



Fig. 31: Locations of potential photovoltaic sites at the SNWA pumping station.

At location 1 are a set of two flocculation basins that measure approximately 350 feet by 100 feet (a total footprint area of 70,000 square feet). This area has a total peak capacity potential of approximately 700 kilowatts. The light poles that presently service the flocculation basins (see Fig. 32 on the following page) would need to be removed because the shading effects of the light poles would drastically reduce the panels' efficiency. New lights would need to be installed to the underside of the newly constructed carport-style canopies. To accommodate maintenance work on the basins, the PV system would need to be modular such that it could be temporarily removed. Because the basins are nearly identical, design costs should be minimal.



Fig. 32: Flocculation basin at the SNWA pumping station.

Locations 2 and 3 have two filtration tanks each, all four tanks measuring approximately 200 feet by 75 feet (a total area of 60,000 square feet). These locations have a total peak capacity potential of approximately 600 kilowatts. An array above the filtration tanks could be installed in a similar fashion as those above the flocculation basins.



Fig. 33: Filtration tanks at the SNWA pumping station.

At location 4 is a set of two filtration tanks measuring 125 feet by 100 feet each (a total footprint area of 25,000 square feet). Installation would be similar to that of the other sites. The two filtration tanks have a total peak capacity potential of approximately 250 kilowatts.

These four sites at the SNWA pumping station offer a total area of 155,000 square feet for a total peak capacity potential of approximately 1.55 megawatts. This matches well with required energy demand of the federal agencies.

Location 5, an alternative site situated above an underground clear-well storage tank, has 210,000 square feet of available area, with a total peak capacity potential of approximately 2 megawatts. However, power generation could be limited because this location is approximately twelve feet below surrounding structures and is shaded to the east and to the west.



Fig. 34: Site above the underground clear-well storage tank at the SNWA pumping station.

Emissions Reduction

Emissions reduced by the proposed system are based upon the reduction in utility-provided energy currently consumed by the SNWA pumping station. The pumping station presently receives its power from the Colorado River Commission. The actual emissions discharged during the production of the electricity that is consumed by the SNWA pumping station are unavailable. However, if the proposed solar power system were to replace electricity produced by a public utility, for example Nevada Power, emissions figures are available. According to electric utility emissions data collected by the Environmental Protection Agency, the following emissions are produced by the Nevada Power Company during electricity production:

- Nitrogen oxides: 2.814 pounds per megawatt-hour
- Sulfur dioxide: 0.462 pounds per megawatt-hour
- Carbon dioxide: 1857.857 pounds per megawatt-hour
- Mercury: 0.013 pounds per megawatt-hour²⁵

A renewable energy system, producing approximately 3,156 megawatt-hours of electricity each year that would replace an equivalent amount of electricity produced by Nevada Power, would therefore prevent the following emissions from entering the air annually:

- Nitrogen oxides: 8,881 pounds
- Sulfur dioxide: 1,458 pounds

- Carbon dioxide: 2,931 tons
- Mercury: 41 pounds

(It is important to note that these are not the actual amount of emissions that would potentially be saved by the proposed renewable energy system at the SNWA pumping station. These figures are presented in this report for educational purposes and for future reference only.)



Fig. 35: Aerial view of SNWA pumping station, looking to the east.

Size and Cost Variance

Many variables come into play when estimating a suitable photovoltaic system of this size. Listed below are several conditions that could marginally or significantly alter the system's energy output and cost.

System Efficiency

As previously stated, the efficiency of the entire photovoltaic system will depend upon several factors. The individual module efficiencies may vary by as much as 3 to 4 percentage points. This may seem trivial, but by incorporating thousands of PV modules into a large-scale array, the overall energy output will vary considerably depending upon the quality of the PV modules and the quality of the installation. The efficiencies of the inverters, transformers, and other electrical components will further affect the overall system performance. Dust and sand that may collect on top of the panels will slightly decrease their efficiency.

Available Sunlight

Again referencing Table II for fixed zero-degree flat-plate panels, the available sunlight can vary. The month of August, for example, offers solar radiation values between 6.0 and 7.8

kilowatt-hours per square meter per day, a variance of more than 20 percent. Additionally, the overall uncertainty of the figures in Table II is 9 percent.

Alternative Approaches

If the area above the flocculation basins and filtration tanks at the SNWA pumping station is deemed unsuitable to generate the required electricity needed, many alternatives do exist.

One alternative approach to reach energy neutrality would be to simply expand the system, installing additional panels above the underground clear-well storage tank. As previously mentioned, there are potential shading issues from surrounding structures at this area. However, with approximately 210,000 square feet of available area, this location should provide plenty of space for expansion.

If the area above the underground clear-well storage tank is deemed suitable to support the entire renewable energy system, fixed tilted or tracking photovoltaic panels could be installed, decreasing the total number of panels needed. Referencing Table II, panels tilted at an angle equal to the location's latitude receive the most sunlight (in the case of the Las Vegas Valley, about 36 degrees from horizontal). However, a high tilt angle causes shading concerns with adjacent panels, and more area is needed for proper spacing. Panels angled at 15 degrees less than latitude, in this case about 21 degrees, receive nearly the same sunlight as panels installed at latitude. Therefore, many large-scale systems compromise between panel tilt angle and spacing, installing the panels at about 20 degrees.

A dual-axis tracking photovoltaic system is not suitable for this area. The previously mentioned dual-axis tracking systems manufactured by Amonix, which focus sunlight on highly-efficient solar cells, would require more land than is available.

Installing PV panels, either fixed or single-axis tracking, above the underground clear-well storage tank will have a minimal effect on the environment. The land, which is unsuitable for most other structures, would not be disturbed by a photovoltaic array. The individual panels can be mounted on concrete footers placed directly atop the soil (no digging for a foundation is necessary). Installing the entire system at this site will not provide the shading benefits that accompany the potential system situated above the flocculation basins and filtration tanks, but the construction of the carport-style canopies would not be necessary. This measure would save an estimated \$3 million to \$6 million in initial construction costs.

In the future, the federal agencies should be mindful of new utility regulations, both on state and federal levels. Should the regulatory environment change in the coming years, the agencies should employ the best available method for taking advantage of any new laws. Seeking assistance from outside entities should be a considered option.

System Life Expectancy and Maintenance Costs

Because fixed panels require no moving parts and tracking systems rotate extremely slowly, photovoltaic systems are durable, reliable, and easy to maintain. PV panels come standard with 25 year warranties and typically last for 30 years or longer. Inverters should be required to have 10 year warranties and typically fail after 10 to 15 years. On average, PV panels lose less than one percent of their efficiency per year. (Assuming an initial 13.5 percent panel efficiency, the

panels would maintain efficiencies greater than 13.365 percent during their second year of operation).

System maintenance is minimal. Periodic washing will keep panel efficiency near peak performance. If a water supply is nearby, hosing off the panels once every few months is recommended. Vendors will provide service contracts if so desired, and can be looked into further during the preliminary design.



Fig. 36: Aerial view of SNWA pumping station, looking to the west.

Comparative Photovoltaic Systems

According to the U.S. Department of Energy, the nation's commercial sector now accounts for 60 percent of all newly installed photovoltaic capacity, up from 13.5 percent in 2001. California has seen the largest growth, now the second-fastest growing solar market in the world.¹⁶

Many photovoltaic systems comparable to the proposed system at the SNWA pumping station are currently in operation. Most of the nation's large-scale photovoltaic systems are located in the Southwest, particularly California, Nevada, and Arizona, where clear skies and advantageous financial incentives make solar power an attractive energy source. Aside from the environmental benefits and positive responses from consumers, companies utilizing renewable power are able to lock into predetermined electricity rates, allowing them to plan their finances far into the future and defray likely increases in utility energy rates. Brief summaries of several comparable systems are listed below.

Google Campus, Mountain View, California

As the largest corporate installation of solar panels in North America, Google's Mountain View Campus in central California uses a 1.6 megawatt photovoltaic system to generate 30 percent of the facility's peak energy demand. Generating enough electricity to power approximately 1,000 California homes, the facility's 9,212 polycrystalline silicon panels cover nearly all the roof space on the campus (197,000 square feet on top of existing buildings and carports). The polycrystalline silicon cells, manufactured by Sharp, average 12.8 percent efficiency. SatCon Technology Corporation supplied inverters with a 96 percent efficiency rating. The Mountain View facility in the San Francisco Bay area (which has about 15 percent less sunlight than the Las Vegas Valley) is estimated to generate 2,612 megawatt-hours per year, saving the company nearly \$400,000 in annual energy costs.



Fig. 37: Google's Mountain View Campus.

Installed by California company EI Solutions, the entire renewable energy system was installed on time and within budget. Beginning construction in November 2006 and finishing by May 2007, EI Solutions reduced the initial cost and simplified maintenance needs by using one type of PV module in all of the arrays. The photovoltaic panels are expected to save Google \$15 million over their 30 year lifespan, with a payback period of 7½ years (at which time the company will have saved enough in energy costs to recoup their initial investment). Although the financial details for the system were not released, it has been estimated that the system's installation cost was more than \$13 million before rebates and tax incentives.

Carbon dioxide emissions reduced by the renewable energy system are estimated at 3.6 million pounds per year, equivalent to the amount of carbon dioxide produced by cars driving a total 4.28 million miles.

Following Google's lead, several other companies have announced plans to install large-scale photovoltaic systems. Applied Materials of Santa Clara, California, announced in March 2007 that the company will install a 1.9 megawatt system on the rooftops of its complex in Sunnyvale, California. Wal-Mart has plans to install a combined 5.6 megawatts of PV panels on the roofs of 22 stores in California and Hawaii. Target and Kohl's are also preparing to install PV systems.¹⁶

Microsoft Silicon Valley Campus, Mountain View, California

Completed in April 2006, the SunPower subsidiary PowerLight installed 2,288 solar panels atop four Microsoft buildings in Mountain View, California. The 480 kilowatt system, which covers 31,000 square feet, provides 15 percent of the campus' energy needs. It is estimated that carbon-dioxide emissions will be reduced by 4,000 tons over the system's 30 year lifespan.²⁶



Fig. 38: Microsoft's Silicon Valley Campus.

FedEx Corporation, Oakland, California

Covering 81,000 square feet atop its hub at the Oakland International Airport, the FedEx Corporation has a 904 kilowatt photovoltaic system that provides 80 percent of the hub's peak energy demand. The PowerLight-installed system has exceeded its expected energy production by 9 percent, and has a projected payback period of 9 years. The system will reduce carbon-dioxide emissions by 10,800 tons over 30 years. Upgraded lighting systems, such as high efficiency fluorescent lighting, use half the electricity of the old fixtures. The renewable energy system received the EPA Green Power Leadership Award.²⁷



Fig. 39: The FedEx Oakland International Airport hub.

Elsinore Valley Municipal Water District, Lake Elsinore, California

The southern California public non-profit agency, in an effort to stabilize the municipality's utility bills in the wake of the California rolling blackouts, had a 765 kilowatt PV system installed above water district buildings and ground-mounted carports. The 3,960 solar electric tiles, installed by PowerLight, cover 57,000 square feet. Elsinore Valley officials plan to save \$7 million over the next 25 years in electricity expenses.²⁸



Fig. 40: Elsinore Valley Municipal Water District carports.

Ernest A. Love Field Airport, Prescott, Arizona

Begun in 2002 and currently still under construction, the solar power plant at the Prescott airport features two types of photovoltaic technology. Over 3.5 megawatts of single-axis tracking PV panels and more than 1.5 megawatts of dual-axis high-concentration PV panels are planned upon completion. Managed by the Arizona Public Service utility company, the projected energy output is 6,335 megawatt-hours per year, reducing carbon-dioxide emissions by 4,000 tons annually.²⁹

Nellis Air Force Base, North Las Vegas, Nevada

Completed in December 2007 after first breaking ground in June 2007, the 15 megawatt photovoltaic system at Nellis Air Force Base is the largest PV power system in North America. Consisting primarily of single-axis tracking panels installed at a 20-degree south-facing tilt angle (a limited number of panels are set at a zero-degree angle), the entire system covers 140 acres of land. The panels have a minimal effect on the grounds, as the land, much of it above a former landfill, is not suitable to house larger structures. The panels have been mounted on concrete footers placed directly atop the sand, making the entire system portable if necessary.

Sets of panels have been installed in line, allowing one motor to rotate several panels at once, simplifying the mechanics and decreasing the overall initial costs. The renewable energy system's 70,000 panels will produce enough electricity to cover 30 percent of the energy needs of the base, where 12,000 people work and 7,215 people live.



Fig. 41: Single-axis tracking solar panels at Nellis Air Force Base.

Nellis Air Force Base provided no up-front costs for the PV system. The Air Force agreed to a 20-year Power Purchase Agreement with MMA Renewable Ventures, a San Francisco-based company that will own, finance, and operate the system. MMA Renewable Ventures, which is leasing the land used by renewable energy system, will sell the electricity generated by the system back to the Air Force at a price set by the Power Purchase Agreement. With equity

investments from Citi and Allstate, and debt provided by John Hancock Financial Services, MMA Renewable Ventures will take advantage of a 30 percent federal tax credit.³⁰ The tax credit was passed in 2005 and expires at the end of 2007, though renewable energy proponents are pushing for an extension. MMA Renewable Ventures will also take advantage of accelerated depreciation schedules for solar power, an additional tax break.

Projected to cost more than \$100 million before state and federal rebates and incentives, MMA will sell solar renewable energy credits (RECs) to Nevada Power Company. Nevada Power will use the RECs to fulfill a Nevada state mandate requiring the public utility to obtain 20 percent of its power from renewable energy sources by 2015. Upon completion, the SunPower-built system will save the Air Force \$1 million per year in lower energy bills. Since the Air Force does not own the system and pays only for the electricity it is provided, maintenance responsibilities fall on MMA Renewable Ventures, which is thus motivated to keep the system operating as efficiently as possible.³¹

Financial Considerations

In order to best serve its citizens, the federal agencies are responsible for maintaining its facilities in an environmentally-friendly and economical manner. Referencing the Instructions for Implementing Executive Order 13423 (in the document *Strengthening Federal Environmental, Energy, and Transportation Management*), the objectives and duties of the federal agencies are detailed in the excerpts below.

Executive Order 13423, Section 1: It is the policy of the United States that Federal agencies conduct their environmental, transportation, and energy-related activities under the law in support of their respective missions in an environmentally, economically and fiscally sound, integrated, continuously improving, efficient, and sustainable manner.

In implementing the policy, goals, and objectives of E.O 13423, agencies shall apply the following overarching directives:

(3) Life-cycle costs. Each agency shall consider life-cycle costs and savings in planning and making determinations about investments in all capital assets, services, and procurements, which will lower the government's costs, achieve sustainable design principles, reduce energy and water consumption, and reduce the environmental impact/footprint of the government's operations as it implements its primary mission and improves the quality of service and effectiveness of government. In some cases, evaluation of life-cycle costs may result in a higher up-front cost with significantly lower maintenance costs, or longer life.

Achieving energy neutrality fulfills a stewardship goal, but there are additional fiduciary opportunities and mandates to address. Again, referencing Executive Order 13423, the federal agencies have been specifically directed to achieve the following performance objectives:

(a) improve energy efficiency and reduce greenhouse gas emissions of the agency, through reduction of energy intensity by (i) 3 percent annually through the end of FY 2015, or (ii) 30 percent by the end of FY 2015, relative to the baseline of the agency's energy use in FY 2003;

(b) ensure that (i) at least half of the statutorily required renewable energy consumed by the agency in a fiscal year comes from new renewable sources, and (ii) to the extent feasible, the agency implements renewable energy generation projects on agency property for agency use;

Estimated Initial Investment and Future Revenue Stream

Though a 30 percent tax credit is available to private firms installing renewable energy systems of this size, there are no financial incentives available to the three federal agencies. The initial cost of the system will be covered by funding specifically intended for this type of project and requires no payback. Therefore each agency will realize an immediate budget relief that can be used to provide more services to the public or better carry out stewardship responsibilities. Under a Power Purchase Agreement with the Southern Nevada Water Authority, the value of the energy produced by the photovoltaic system is estimated at \$60 per megawatt-hour. With an annual energy output of 3,156 megawatt-hours, the total revenue from the system is estimated to be \$189,360 per year. This represents 65 percent of the total yearly energy bill for the three federal agencies. Table III below details the revenue stream for each federal agency and associated power provider under the scenario above (using 2005 data).

Table III. Future Revenue Stream

Agency Name	Electric Power Provider	Proportional Cost	Proportional Revenue	Yearly Energy Cost (2005)
National Park Service	Overton Power District	16.1%	\$30,550	\$46,700
	Nevada Power Co.	61.1%	\$115,750	\$177,800
	Boulder City	11.7%	\$22,200	\$34,000
Fish and Wildlife	Valley Electric	2.4%	\$4,600	\$7,000
	Overton Power District	1.1%	\$2,210	\$3,300
	Alamo Power	2.4%	\$3,950	\$7,100
	Nevada Power Co.	1.9%	\$3,650	\$5,400
USDA Forest Service	Nevada Power Co.	3.3%	\$6,350	\$9,500
Total		100%	\$189,360	\$290,800

Again, the information provided in Table III can vary widely depending on the actual energy output of the system, the increase or decrease in energy demand of the federal agencies, the details of the Power Purchase Agreement between the federal agencies and the Southern Nevada Water Authority, and any future rate changes by the public utility providers.

Renewable Energy Credits and the Federal Agencies

The federal agencies will own the renewable energy credits generated by the proposed photovoltaic system; the RECs will not be sold to public utility companies, private corporations, or individual citizens. Although RECs sell for more than fossil fuel-produced energy on the open market (allowing the producers of RECs to profit from their sale), the federal agencies will retain the rights to the RECs, thus maintaining their obligation to operate in an energy neutral capacity. Were the RECs sold to a public utility for instance, the public utility would simply pass the premium rate on to consumers, thereby conflicting with the federal agencies' stewardship role.

Conclusion

To date, the efforts of the National Park Service, the U.S. Fish and Wildlife Service, and the USDA Forest Service, in collaboration with the Center for Energy Research at the University of Nevada, Las Vegas, have determined the following:

1. There exists sufficient renewable energy in southern Nevada to supply the power necessary to operate the various facilities in southern Nevada maintained by the three federal agencies.
2. Solar power is the preferred source of renewable energy in southern Nevada. Photovoltaic technology is the preferred method to capture that energy.
3. Installing individual renewable energy systems on a one system per one electric meter basis (or installing systems only at major energy consumption facilities) cannot achieve the energy neutral goal for each agency nor accomplish the goal within a short time frame.
4. Net metering a single large renewable energy system to offset the combined load of the three agencies is not permitted under the current regulation of utilities in the state.
5. Pursuing the Nellis Air Force Base example may reduce utility costs, but the federal agencies do not believe selling renewable energy credits to public utility companies, private entities, or individual citizens is a means for lowering expenses.
6. There are no financial incentives or rebates available to the federal agencies to offset the initial cost of the renewable energy system.
7. Pursuing a Power Purchase Agreement, using a government-owned renewable energy system, and selling the power to a third party is an acceptable method to achieve energy neutrality.

In the future, the three federal agencies will be required to:

1. Secure funding and authority to proceed.
2. Negotiate a Power Purchase Agreement with Southern Nevada Water Authority.
3. Negotiate an agreement between the National Park Service and Southern Nevada Water Authority to allow construction and operation of a renewable energy system within the Lake Mead National Recreation Area.
4. Award contracts for design and construction of the renewable energy system.
5. Watch for changes in the regulatory environment that may impact this effort.
6. Establish internal financial mechanisms to accept payments and make utility bills with appropriate fiscal controls, oversight, and audits.
7. Either expand the proposed renewable energy system or construct net-metered systems for all new facility development by any of the three agencies in order to maintain the energy neutral position.

Future Expansion

In the future, any new or renovated facilities in southern Nevada operated by federal land management agencies should incorporate sustainable building materials (such as wood approved by the Forest Stewardship Council) and sufficient renewable energy design features so as to support the energy neutrality goal. Supplementary possibilities for maintaining energy neutrality

in the years to come include expanding the proposed solar power system at the SNWA pumping station atop the clear well storage tanks, partnering with the Lake Mead Concession operations on covered slips and marinas, and the installation of individual renewable energy systems at future facilities.

The Zion National Park Visitor Center is an excellent example of an energy-efficient building that incorporates the natural features of the environment and protects the ecosystem. The National Park Service, in collaboration with the National Renewable Energy Laboratory, constructed the facility on previously disturbed land and erected many exhibits outdoors, thus reducing building materials and energy costs. Other features of the Zion Visitor Center include:

- photovoltaic panels to provide 30 percent of the buildings' power;
- energy efficient fluorescent lighting (no incandescent or halogen lights are used);
- clerestory windows to provide natural lighting (80 percent of the structure is lit by natural daylight);
- irrigation ditches to provide most of the water needed by the natural landscaping, thereby saving pumping energy and water treatment;
- natural ventilation provided by low inlet windows and high outlet windows operated by the facility's computer-controlled energy management system;
- structural insulated panels in the roof; foam insulation in the masonry wall cavities;
- Trombe walls to supply most of the building's heat;
- and passive down-draft cooling towers to help cool the building.

Instituting these energy efficient building methods, along with orienting the facility to best take advantage of the summer and winter sun, has reduced the Zion Visitor Center's energy use by more than 74 percent, allowing the National Park Service to save \$14,000 per year. The energy reduction saves 155 tons of carbon dioxide from entering the air each year. More facilities such as this will help sustain the nation's federal lands for years to come.³²

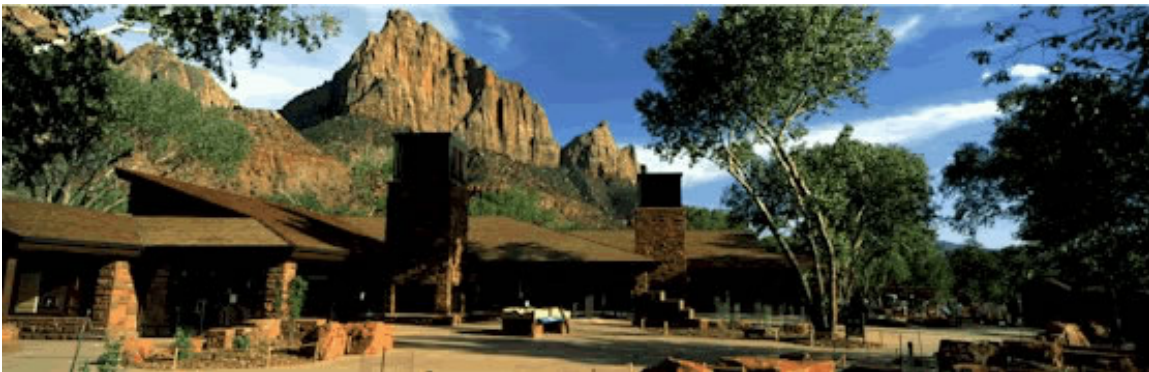


Fig. 42: Zion National Park Visitor Center.

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 Fig. 6: EnergyAtlas.org
 Fig. 8: National Renewable Energy Laboratory
 Fig. 9: Siemens Solar Industries
 Fig. 10: U.S. Department of Energy
 Fig. 11: EnergyAtlas.org
 Fig. 12: UNLV Center for Energy Research
 Fig. 13: U.S. Department of Energy
 Fig. 14: FPL Energy
 Fig. 15: Amonix
 Fig. 16: National Renewable Energy Laboratory
 Fig. 30: Southern Nevada Water Authority
 Fig. 35: Southern Nevada Water Authority
 Fig. 36: Southern Nevada Water Authority
 Fig. 37: EI Solutions
 Fig. 38: SunPower
 Fig. 39: SunPower
 Fig. 40: SunPower
 Fig. 41: Nellis Air Force Base
 Fig. 42: National Park Service

Appendix

Pertinent Meetings

This study has been a collaborative effort of discovery; the ultimate goal of having a single renewable energy site to offset the energy consumption of three federal agencies with facilities scattered over hundreds of square miles has never been attempted. Renewable energy technology was never the constraining issue. The overarching challenge came from the regulated world of utilities not keeping up with increasing awareness of utility customers as to opportunities created by flexible application of new technology. With that in mind, the study partners embarked upon a number of pivotal meetings which eventually led them to a preferred alternative. Documented below, is a list of meetings, participants, and outcomes.

Table IV. List of Pertinent Meetings

Timeframe	Participants	Outcome
July - August, 2006 NPS and UNLV begin preliminary discussions as to opportunities for collaborative effort	Bob Boehm, UNLV Steve Butterworth, NPS	Statement of Work CESU Agreement J8R07060020
Sept - Oct, 2006 Power data research	Eric Wiemers, UNLV Steve Butterworth, NPS	Identified utilities and utility billing history for 2005
October 16, 2006 First joint meeting	Bob Boehm, UNLV Yahia Baghzouz, UNLV Eric Wiemers, UNLV Steve Butterworth, NPS	Study direction and support re-evaluated and approved. NPS provided instruction to UNLV class
November 17, 2006 Examination of potential sites for renewable power facility	Eric Wiemers, UNLV Yahia Baghzouz, UNLV Jim Holland, NPS	Documented sites in around the Lake Mead NRA and evaluated site conditions.
January 2, 2007 Meeting with Nevada Power senior officials to explore mutual opportunities and secure management support	Bob Boehm, UNLV Yahia Baghzouz, UNLV Eric Wiemers, UNLV Lizette Richardson, NPS Steve Butterworth, NPS Thomas Fair, NPC Gregory Kern, NPC Bill Heck, NPC	The purpose of the study was presented, Nevada Power corporate strategy discussed, and the groundwork laid for follow on meetings to explore possible sites, single site generation treated as net-metered for all, and administrative details.
March 6, 2007 Working group follow up to Jan 2 meeting	Bob Boehm, UNLV Yahia Baghzouz, UNLV Lizette Richardson, NPS Steve Butterworth, NPS Bill Heck, NPV Nevada Power project staff	Nevada Power expressed that their preferred approach would be net-metered at each facility or specifically at higher load locations. A Power Purchase Agreement might be accomplished if site was at a distribution line and sized to less than 1 megawatt. NPS held to energy neutral, single site vision.

Timeframe	Participants	Outcome
March 8, 2007 Initial meeting with Southern Nevada Water Authority	Lizette Richardson, NPS Steve Butterworth, NPS Scott Krantz, SNWA John Evans, SNWA Gary Wood, SNWA, Gail Bates, CRC	Participants determined that the SNWA pumping site on Lake Mead offers potential locations for renewable energy within a secured facility. Further, SNWA offers flexibility to distribute revenue for any agency. A photovoltaic array could provide necessary shading potential for flocculation basins. Participants agreed to pursue this mutual interest.
March 23, 2007 On-site visit to Alfred Merritt Smith Water Treatment Facility on Lake Mead	Yahia Baghzouz, UNLV Eric Wiemers, UNLV Lizette Richardson, NPS Gary Wood, SNWA Jim Holland, NPS	Participants discussed site locations, size of systems, potential growth, mutual benefits, and how to cooperate and share data.
October 3, 2007 Meeting at UNLV Center for Energy Research	Steve Butterworth, NPS Todd France, UNLV	Participants discussed project in detail and decided how to best finalize the report. Decided initial report needed editing to encompass all of Task Agreement's objectives.
October 4, 2007 Nellis Air Force Base tour	Lizette Richardson, NPS Steve Butterworth, NPS Bruce Nyhuis, NPS Yahia Baghzouz, UNLV Todd France, UNLV	Toured new 15 MW PV system under construction at Nellis AFB. Participants learned first-hand about the PV technologies used and the agreement between Nellis AFB and MMA Renewable Ventures, the owner of the PV system. Finances were not discussed in detail, but overall contract among MMA Renewable Ventures, Nellis AFB, and SunPower (construction company) were presented.
November 9, 2007 Meeting between SNWA and NPS representatives	Bill Dickinson, NPS Lizette Richardson, NPS Scott Krantz, SNWA Pat Mulroy, SNWA Ron Zieger, SNWA	Discussed potential partnership in a joint, interagency PV project within the SNWA facility. An agreement was made to pursue the next phase – preliminary design to get a better understanding of the cost, operation and maintenance issues, and specific SNWA design requirements for the PV project.

Timeframe	Participants	Outcome
December 10, 2007 Meeting among representatives of NPS, FWS, and USFS	Steve Butterworth, NPS Lizette Richardson, NPS Hal Peterson, USFS Cynthia Martinez, FWS	Participants were briefed on the progress to date and current status. Participants received copies of the draft report and could later hold meetings with their respective managers regarding the nature and substance of the agreement, funding issues, and next steps needed to be taken by their agencies.