Renewable Energy: A Path Forward for Park City

Produced for Park City, Utah by:

Energy Dynamics Lab
Utah State University Research Foundation

and

Jon M. Huntsman School of Business
Utah State University

Micro Hydro
Microwind
Solar
Biomass/Biodigester
Natural Gas Vehicles
Intuitive Buildings

EDL | Energy Dynamics LABORATORY
Utah State University Research Foundation

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The Energy Dynamics Lab (EDL) and the Jon M. Huntsman School of Business (HSB) of Utah State University have combined resources to produce this feasibility study for Park City which looks at several areas of interest in renewable and sustainable energy projects. The study provides an overarching analysis of several projects to be considered by the Park City Mayor, the City Council, and city resident's to aid them in their efforts to reduce the city's carbon footprint and secure various forms of sustainable and renewable energy. This study is intended to help Park City make informed decisions in becoming a model for municipalities in Utah and across the west that face similar challenges and goals.

Five primary research projects and one special project were considered for the purposes of this study.

- Micro hydro
- Microwind
- Solar
- Biomass and biodigestion
- Natural gas bus transition

A special project discussion is included on the potential of using a high-end retail establishment in Park City to demonstrate and test the most advanced intuitive lighting system in the world.

This report provides a top-level analysis of each project area. The information is intended to help Park City hone in on its strategy for creating a portfolio of sustainable energy activities that will ultimately help Park City reduce its carbon footprint in an economically feasible fashion. The report is intended to help both the municipality and its residents identify areas in the renewable and sustainable energy sectors that warrant implementation or further study.

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1. Introduction

Park City currently has a goal to reduce its carbon footprint through the implementation of one or more sustainable energy projects. Previous studies have indicated that that the need for reduction of carbon emissions is vital to the economy of Park City due to the potential impact of climate change on the tourist economy that sustains the city.[1] In September of 2009, Stratus Consulting Inc. prepared a report entitled "Climate Change in Park City: An Assessment of Climate, Snowpack, and Economic Impacts" for the Park City Foundation. This report estimated that by 2030, more than 1,100 jobs could disappear resulting in $20.4 million in lost earnings due to the estimated decrease in annual snowpack due to greenhouse gas emissions.[2]

Despite these dire and dramatic predictions, the city has taken a thoughtful and conscientious approach, realizing that the only projects that will adequately reduce greenhouse gases are those projects that are economically feasible over the long term. To that end, EDL has engaged the Huntsman Business School Field Studies program to assess the financial feasibility of the projects studied. Certainly all of the projects studied for this report would reduce the city's carbon footprint, but given current technology and Park City's geographic location, not all of the projects were found to be financially viable.

Building on the strength of EDL's technology advancement charter, this report provides a current snapshot of some of the technologies available but also looks a bit into the future of sustainable energy. In doing so, Park City has information available to them that will allow them to make decisions based not only on the current financial viability of projects, but those projects in which near-term technology advancements may provide a better return on the city's investment.

While Park City has challenges ahead of them for implementing sustainable energy projects it also has unique resources and opportunities. Its high elevation, mountainous location offers abundant resources of certain kinds – notably solar, wind, and hydro. Conversely, the city experiences marked seasonal fluctuations with large temporal changes in the availability of solar, wind and hydro resources.

The wide annual range of temperatures and high elevation of Park City provides additional challenges. Technology developed at low elevation, temperate climate locations may not be suitable for Park City. Therein, however, exists a unique opportunity for Park City in being a model for similar cities across the west.

It also drives home the point that Park City's approach to a sustainable energy future will likely require a portfolio approach. This report is intended to help the city choose wisely from the many available technologies.

This study has also tailored the scenarios and case studies presented here to the somewhat unique nature of the Park City area. While resources for the projects described here are available across the United States, references and sources have been chosen, where possible, within the region. These reference and sources are familiar with both the assets and the challenges that are representative of these projects.

All communities will face similar challenges as they look for ways of meeting societal desires and government requirements for reducing greenhouse emissions and reliance on traditional energy. In engaging USU to assess both the technical and financial feasibility of sustainable energy projects, Park City has taken a proactive, calm, and thoughtful approach, and has positioned itself as a leader in addressing these problems as a municipality rather than relying solely on its citizens.

2. Micro Hydro

2.1 Overview

Hydropower systems are common along the Wasatch Front. Many communities along the front are able to generate much of their power using hydroelectric plants that capture the energy of the run-off from heavy winter snowpack. But large-scale hydro electric plants are costly, limited by available space and resources, and are environmentally disruptive. Smaller-scale hydroelectric technology, commonly referred to as micro hydro, has been available for more than 30 years. Micro hydro turbines can use preexisting infrastructure in culinary and irrigation water systems to produce economical renewable energy. Micro hydro is generally classified as those systems producing 100 kW of power or less.

In general, a micro hydro power system uses moving water from a channel, or pressurized pipeline to rotate a turbine

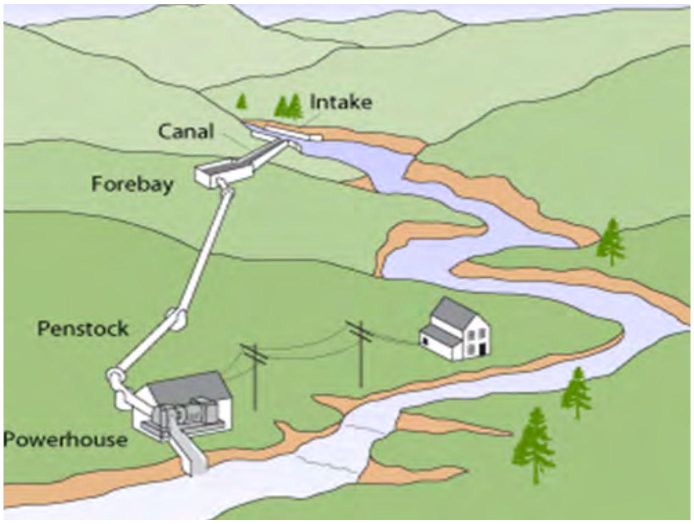


Diagram 1. Courtesy of U.S. Department of Energy

which spins a shaft. The motion of the shaft can be used to power an alternator or generator to generate electricity. Power from a micro hydro system can be used for mechanical processes, connected to a grid, or provide a standalone power source for off-grid applications. A well-located micro hydro system can generate up to 100 kW of electricity; 10 kW is sufficient to power a large home or a small business.[3]

Communities, particularly those in hilly or mountainous areas, often find themselves with the need to reduce overall water pressure coming from the source. Pressure reducing valves (or PRVs) reduce the pressure from source water to a pressure that is sufficiently low that it will not damage the community's hydraulic systems. At each PRV, hydroelectric energy is dissipated and the energy is wasted. Few PRVs, however, are suitable given the current state of the technology. The feasibility of any given site for a micro hydro application is predicated upon numerous parameters including: flow rate and variability, physical access to location, environmental impact, and proximity to the power grid.

While current technology constrains the number of PRV sites that are feasible, there exists great potential for tapping into an unrealized renewable energy source at many of these locations. Technological advancements have the potential to vastly increase this number.

This brief report on micro hydro looks at the current market and its limiting factors, analyzes projects being done in other Utah communities, and provides insight into the possibility of near-term technological advancements.

2.2 Current Market and Market Proposal

Park City has approximately 120 PRVs within its culinary and irrigation water supply system, and some of the main PRVs are potential candidates for micro hydro systems. Park City is also upgrading its water treatment capabilities with the installation of the Quinn's Water Treatment facility, which is in the final design stages before construction. The Quinn's treatment plant is a tremendous opportunity for Park City to design micro hydro technology into a planned facility, thereby avoiding the costs of retrofitting an existing facility.

Additionally, smaller PRVs at locations of more consistent flow have the potential for a smaller but reliable retrieval of wasted energy. The cost of micro hydro systems has limited these applications.

A major advantage of all micro hydro power generation systems over other renewable energy technologies is preexisting infrastructure. A community's culinary water system provides numerous possibilities for applying micro hydro technology to PRVs in existing pipelines without extensive environmental impact assessments and issues of site selection. For this reason, we recommend that Park City explores the unrealized potential of their existing system as a first step.

Beyond the community's culinary water system, there are micro hydro applications that may be feasible for private land owners in Summit County. In run-of-the-river micro hydro systems, water is diverted from the natural waterway and held in a penstock at a location that provides the proper head – or vertical drop – for the chosen turbine. Water is directed back to the stream after being run through the micro hydro system.

Cabins, resorts or farming operations with access to streams could potentially derive much or all of their power requirements from a run-of-the-river micro hydro system. A general scenario for a run-of-the-river micro hydro system is depicted in Diagram 1.

Typical run-of-the-river micro hydro system can generate up to 100 kW of electricity. With a large house, small business, or hobby farm requiring, on average, 10 kW for their operations, a micro hydro system has the potential to substantially or entirely reduce their dependence on traditional power sources.[4] Still, there are factors that require careful consideration when considering this approach.

The primary limitation for the use of micro hydro systems by private land owners is the suitability of the site. Many factors are considered when planning the construction of a micro hydro site. Flow rate and amount of head – or vertical drop – are the most important factors that limit the economic feasibility of a site. Distance from the power source to the location that the energy will ultimately be used is an important factor. The cost, availability, and integration of system components such as turbine, generator, batteries, controller, transmission line and pipelines, all require careful consideration. Additionally, permitting and impacts to the environment will eliminate or complicate some sites with acceptable stream characteristics.[5] While these smaller hydroelectric systems have a minimal impact on the environment compared to large-scale hydro electric plants, site assessment and environmental permitting will still be the greatest limiting factor for run-of-the-river micro hydro applications.

In general, for all applications the more head, amount of flow, and consistency of flow a site has, the more economically attractive that site becomes.[6] Site location also plays into the economics of a micro hydro system. Close proximity to power lines, 4000 feet or less,[7] make it feasible to sell power back to utility companies within the limits of net metering. For private land owner applications, the expense of transmitting power to the location in which the power will be used can be limiting. Every potential location requires independent investigation to verify the economic feasibility of the site.

2.3 New Technologies

Micro hydro systems have been available for several decades, but wide-spread, practical use of these systems has been limited by the economic feasibility of current turbine technology, retrofit of existing infrastructure to accommodate the system, and environmental permitting for run-of-the river sites.

The PRVs with the quickest return on investment are generally those with the highest head and flow rate – often the main PRV from the source. In communities that rely in part on snowpack for their water resources, these PRVs are also likely to experience the greatest fluctuations in flow rates.

Historically, micro hydro has been an expensive proposition for most applications. Current technology requires that for most applications, the turbine used in the system is calibrated to operate in a very narrow range of water flow so that 'clean' electricity enters the grid. During times of high or low water flows, water is diverted around the turbine to avoid damaging the turbine and to restrict low-quality electricity from entering the grid. This seriously restricts the use of micro hydro systems in mountainside communities which experience cyclical high and low water flows. While cost-effective micro hydro turbines exist, custom-calibrated turbines remain expensive, require detailed flow rate information, and have an extended lead time to purchase.

Realizing the limitations of the current technology and the potential of being able to retrieve wasted energy at the PRVs in culinary water supplies, former Pleasant Grove mayor, Mike Daniels, engaged several Utah-based companies such as WaterWorks Engineers, Power Innovations, and the Energy Dynamics Lab with the goal of developing and testing new micro hydro technologies and power generation systems that could ultimately change the landscape for micro hydro use, both in Utah and across the Intermountain West.[8] The concept has garnered broad support and 1M dollars in federal funding that will be matched with money and in-kind contributions from numerous sources.

2.3.1 Power Innovations

2.3.1.1 Overview of the Company

Power Innovations, a Lindon, Utah company founded in 1997, focuses on pioneering technology that will provide solutions for generating, storing, and managing AC power. The company's CEO, Robert Mount, is dedicated to developing these new technologies and has worked closely with Pleasant Grove, Utah. The company's Auto-regulated Mobile Power System known as AMPS, could be the foundation for technology that will broaden the use of more cost effective micro hydro technology.

2.3.1.2 Auto-Regulated Mobile Power System (AMPS)

AMPS was originally designed to generate five to ten kilovolts of clean, mobile power from combustion engines. The AMPS system consists of a custom alternator and a control management system, and is capable of generating high quality electricity over a wide range of inputs. The custom alternator allows for full power load to be generated on a combustion engine, whether idling or at full throttle.

2.3.1.3 Micro-Hydro Applications

Engineers at Power Innovations made modifications to the original AMPS system by developing a 12-volt system that could be suitable for very small micro hydro applications. With this new technology, micro hydro locations are no longer limited by varying flows and a less expensive, non-custom turbine could be used. The limiting factor then becomes the overall efficiency of the turbine, although the efficiency of most commercially available turbines is quite high – generally 85% or greater.

With AMPS technology, turbines can be placed in-line and upstream of existing or planned PRVs. The AMPS system recovers usable power from the spinning turbines. Power Innovations has created a six step model to illustrate the Hydro Power Generation process with their AMPS alternator.

1. **Inline Turbine** – Uses wasted hydro energy to spin the AMPS alternator.
2. **AMPS Alternator** – Generates power using rotational input. The generated power is constant even with inconsistent water pressure.
3. **AMPS PRV Dynamic Control** – Dynamically manages the alternator torque and power output to ensure de sired water pressure upon exiting the turbine.
4. **Q-GPM Grid Power Management System** – Accounts for generated power. Cleans and regulates the power to meet grid quality requirements.
5. **Power Grid Distribution Network** – The electricity is integrated into the power grid distribution network.
6. **City Buildings** – Offsets the city's electrical costs (work ing in conjunction with the power company).[9]

The AMPS 12-volt alternator is a compact 5.5 by 11 inches. Due to its small size, the AMPS technology could be placed at PRV stations where space is limited. The small size of AMPS components greatly increases the number of preexisting PRV sites that could feasibly be converted to a micro hydro system, and would save on the construction and housing cost that would be needed for a traditional system. PRV stations in manholes under streets and ski runs can be converted into micro hydro systems with the commercialization of this technology.

While the small envelope of the AMPS system vastly increases the number of accessible locations in which it could be used, engineers agree that the 12-volt system is too small to make economical use of the energy at most locations.

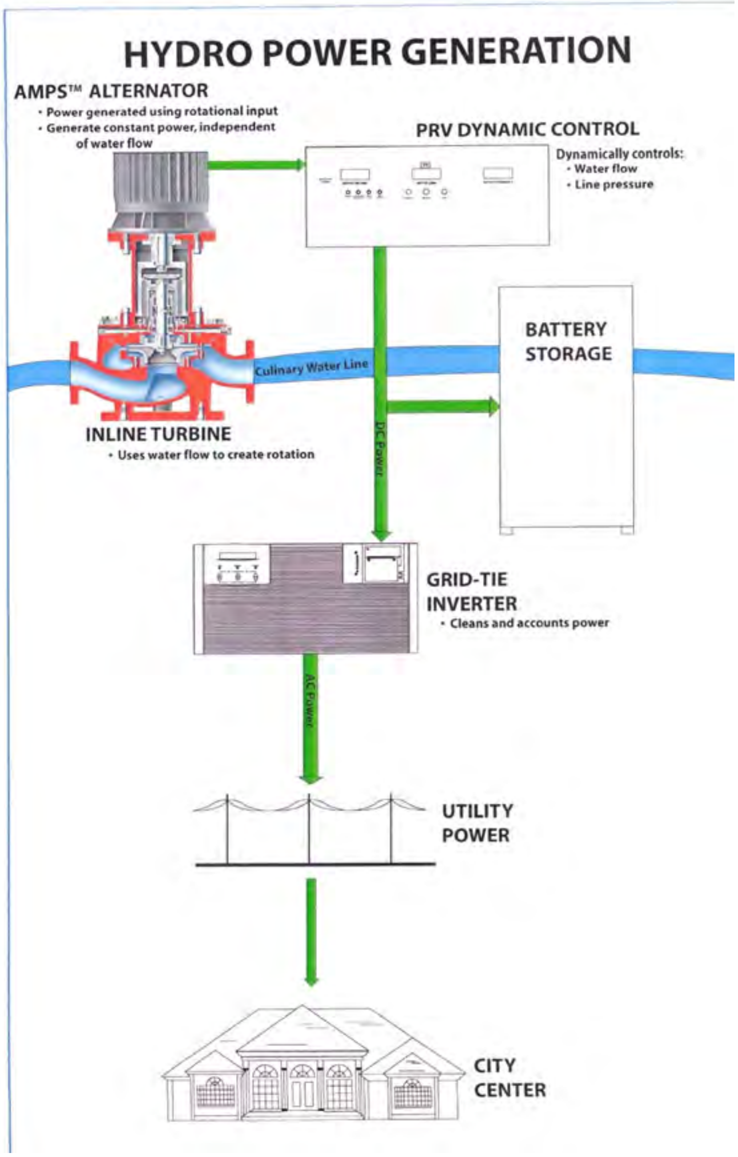


Diagram 2. Courtesy of Power Innovations

Power Innovations generally agrees with this assessment but is cautious about incurring the expense of developing a larger AMPS system until it is convinced that a robust market exists for the technology.[10]

2.4 Resources and Challenges

Mountainside communities, like Park City, with large winter snowpack accumulations are often good candidates for micro hydro power systems. These communities frequently have one or more sites that have the requirements of the current technology – a minimum of 200 feet of head and a

Park City PRV Nomenclature	Days of Flow at 95% Uptime (Assumption)	Potential Power(kWh)	Potential Annual Revenue	Gallons per Minute
Quinn's Water Treatment Facility	360	853,800	$51,125	2100
JSSD #1	230	345,000	$20,700	1000
JSSD #2	230	274,000	$16,400	1000
Daly	360	181,000	$10,900	600
Lowell Ave	230	141,000	$8,500	400
Mixing Vault	230	55.000	$3,300	400
Park Meadows	230	46,000	$2,800	400
Top of Main	230	44,000	$2,600	400

Table 1. Estimates of potential revenue available at selected PRVs in the Park City water system

minimum constant flow of approximately 600 gallons per minute.[11] Conversely, a challenge to these communities is the seasonal flow rate variations which can limit the applicability of current micro hydro technology.

Park City has approximately 120 PRVs in its culinary water system. While some of these sites may have the potential to be a source of renewable energy, many of the sites are run through the peaks but are shut off during non-peaks.[12] Park City, like most communities, has not yet undertaken an in-depth study of its water resources. Such a study would further refine the feasibility of PRVs for micro hydro applications by assessing flow rates, head, and suitability of the site.

Park City's most accessible resource for economical and renewable energy in the near term, is likely the Quinn's Water Treatment Facility. The planned location has both adequate head and flow rates, but most importantly has not been completed. Park City is in the fortunate situation of being able to incorporate a micro hydro project into a planned development thereby avoiding the high cost of retrofitting existing facilities. It is our strong recommendation that Park City continue its initial activities in including micro hydro turbines in the Quinn's construction. While the city has decided to temporarily wait in its planning to gauge where technological advancements are going, we believe that an application with current technology is likely to be valuable at the Quinn's location.

Table 1 shows potential for revenue available at a handful of Park City's PRV locations. None of these sites have been adequately studied to make an informed assessment of the expected revenue at these sites.

2.5 Cost and Return on investment

Cost of a micro hydro system can vary dramatically based on available infrastructure, system components, siting assessment and permitting requirements. Flow rates and seasonal variability affect the amount and quality of power realized and the potential for annual income.

2.5.1 Municipality

A very small-scale hydro power turbine can cost from $1000 - $20,000[13] depending on site location and electricity transmission requirements. These costs do not include site preparation or the infrastructure required to divert stream flows, house the equipment, and transmit the power.

As flow varies, the micro hydro turbine is set to lower than peak performance to optimize the energy output. Because the turbine isn't able to perform until a minimum flow is established and cannot take advantage of higher flows, the payback time for the micro hydro system can be of an economically prohibitive duration.

For a site that has adequate pressure and flow, such as the Quinn's Water Treatment Facility, micro hydro is an economically viable option to capture energy that is currently being lost at PRVs. While most of the existing PRV locations throughout the intermountain west do not have constant flows and are not economically viable candidates for current micro hydro technology, advances in micro technology that are expected in the near term could vastly increase the economic feasibility of this renewable energy source.

2.5.2 Private Land Owner

Unfortunately, micro hydro is not economically feasible for many private land owner applications because of water rights issues, environmental impacts, and current laws. Intermountain Wind and Solar and Gardner Engineering, however, both provide turnkey services for micro hydro applications given their individual situations.

2.6 Case Studies

2.6.1 Logan, UT

Logan, Utah, located at the mouth of Logan Canyon, is ideally situated for hydroelectric power. The city has positioned itself as a leader in the state of Utah with its foresight into the capture of lost energy at PRVs. In 2003, the City of Logan hired Stanley Consultants of Salt Lake City, Utah, to provide a more in-depth study of eleven sites within Logan's existing culinary and irrigation supply system as potential micro hydro sites. Four of the sites were located on Logan's canal system, while the other seven were preexisting PRV locations throughout the city. Due to varying flow rates, only one of the sites (700 North 275 East) showed a payback of less than 20 years, although four others were considered potentially viable.

Considering the variable flow rates, ranging from 1800 to 6100 gallons per minute, Stanley Consultants estimated that 800,000 kilowatt hours could be produced annually at the 700 N site. This would result in $47,200 of annual income for Logan City. The project was estimated to have a cost of $528,000 and a payback of roughly 12 years.[14]

The final cost of the project was $1.4 million. Logan City received funding for its project through the American Recovery and Reinvestment Act in 2009. Logan City received $675,000 from the government and a government loan of $725,000. The micro hydro project is expected to produce 750,000 kW hours a year which is the equivalent of $30,000 to $50,000. The expected simple payback will range from 14 to 24 years. The maintenance costs are estimated at $5,000. The life of the turbine is about 25-30 years depending on how much sediment is in the water.

The turbine will operate seven months out of the year based on flows. During the other months flow will be controlled by a traditional PRV. Canyon Hydro from Washington State is the manufacturer of the turbine and there is no warranty because Logan is installing it themselves.

Given advancements in technology, a second study of the four Logan sites identified as potentially viable in 2003, may give more favorable outcomes.

Logan has recently updated their 700 North PRV location in preparation for the installation of a micro hydro system. The project is slated for completion in 2010.

2.6.2 Pleasant Grove, UT

More recently, the city of Pleasant Grove hired Water Works Engineers to conduct a similar study of their city's potential for micro hydro projects. When the study's findings were published in the fall of 2009, the Battle Creek area was identified as having the best conditions for a micro hydro application with traditional technology. Pleasant Grove chose to look for additional technology that would allow for great power production at a low price.

Once again, given the variation in flow at the Battle Creek site, it was clear that large amounts of energy would be wasted throughout the year using traditional micro hydro technology. The inability to capture the energy from high and low flows inspired Pleasant Grove to look for newer technology that would allow for greater power production. The city discovered the AMPS technology described above and is now pursuing the use of the Battle Creek site as a potential testbed to incorporate the AMPS technology in conjunction with proven, commercially available micro hydro technology.

With the development of a system using the AMPS technology, Pleasant Grove believes it may be able to take advantage of many other PRVs in the city's culinary water system. The City estimates that it could produce 1,072,801 kilowatt hours of electricity annually. This would be enough energy to offset the current electrical consumption for all of the city's municipal buildings. Financially, the city expects a potential payback in as little as five years.[15]

Pleasant Grove has access to one million dollars in federal funding for a micro hydro system. Rather than installing a traditional system, the city is pursuing the installation of a fully functional test site that will integrate and test technological advancements such as AMPS and monitor the results. The city's ultimate goal is to use the test site to produce quantitative data that could be used to assess feasibility of PRV sites in communities along the Wasatch Front and throughout the west. The city anticipates having the full system installed by the end of 2010.

2.7 Funding Opportunities and Resources

Funding opportunities for micro hydro applications on a municipal level are limited. Logan City received funding for its project through the American Recovery and Reinvestment Act of 2009. Pleasant Grove received federally designated money for its micro hydro project. Rocky Mountain Power's Blue Sky Program began accepting applications for community-based projects in March 2010. They will continue accepting applications until May 14, 2010.

Table 2 illustrates some funding possibilities for residential and commercial applications.

Grove and Logan, can provide the city with informed infor mation on installation cost, potential for annual income, and return on investment.

Possible sites for new technology could also be identified during this process which could establish Park City as one of the forerunners in information gathering that has the potential to impact communities along the entire Wasatch front, draw notoriety to the city's commitment to a sustainable future, and drive the technology required to increase Park City's available PRV market.

Incentive	Type	Amount Residential	Residential Max	Amount Commerical	Commercial Max
Renewable Energy Systems Tax Credit	Wind, Solar, Hydro	30%	30%	30%	30%
Renewable Energy Systems Tax Credit (Corporate)	Wind, Solar, Hydro	25%	$2000	$0.35/kWh	$50,000
Renewable Energy Development Incentive	Wind, Solar, Hydro	100%	100%	100%	100%
Renewable Energy Systems Tax Credit (Personal)	Wind, Solar, Hydro	25%	$2000	$0.35/kWh	$50,000
Renewable Energy Sales Tax Exemption	Wind, Solar, Hydro	sales tax	100%	sales tax	100%

Table 2. Funding for micro hydro residential and commerical applications.

2.8 Summary

Park City has great potential for sustainable energy capture in the municipality's water supply. Several existing sites are likely candidates for existing technology and new technologies could greatly expand that potential.

The Quinn's Water Treatment Facility is an exceptional opportunity for the city to exploit micro hydro technology with the advantage of being in a position to incorporate micro hydro technology into the design of the facility, rather than having to retrofit existing infrastructure.

2.8.1 Recommendations

We recommend that the city moves forward in their initial plans to incorporate micro hydro technology into the Quinn's Water Treatment Facility. We believe that either a traditional micro hydro system, an experimental system, or a combination of both could provide a reliable and economical source of renewable energy.

We also recommend that a municipality-wide, in-depth analysis of the Park City water system be conducted to assess the feasibility of other sites in the city's water supply. Armed with data on flow rates and head, as well as number, location, and size of existing PRVs, local resources with experiential knowledge of communities such as Pleasant

Continued involvement and support of Blue Energy is recommended as advancements realized in the testbed planned for Pleasant Grove, are likely to ultimately benefit Park City.

For private land owners, this report can be used as a tool to access the local resources available to conduct micro-scale site assessments which can help inform the decision-making process.

3. Microwind

3.1 Overview

Wind energy is recognized as a high quality, renewable energy source. Wind is still free and abundant in North America. The wind has been harnessed for thousands of years to sail ships, pump water, grind grain, and countless other activities. Today, the term "wind energy" is often associated with the presence of very large turbines placed in high visibility areas such as open spaces or along ridgelines.

These large-scale (macro) wind turbines produce large amounts of green energy that can benefit entire communities and offset the nation's demand for electricity.

Capturing the energy from wind is not limited to large turbines, however, and resurgence in the application of micro wind technology is helping individuals, companies, and communities produce their own energy needs while reducing their impact on the environment.

In ideal situations, energy generated from micro wind turbines can be used to completely eliminate power received from the grid and may be sold back to the power companies when an excess of power is created.

For the purposes of this report, micro wind systems will be identified as any turbine less than 45 feet in height and with an energy production of less than 25 kilowatts, but sufficient to provide a significant offset to the power requirements of a house or business. Micro wind systems have some advantages over macro wind systems; the foremost being low up-front costs and lesser wind requirements.

For wind energy to be considered a reliable source for energy needs, it must be acquired in an economically sustainable manner that does not rely on long-term governmental financial aid. While most micro wind systems are not likely to provide quick payback periods given Park City's prevailing winds, advances in the technology could soon offer sustainable means of harnessing the power of the wind for individuals, companies, and communities.

3.2 Current State of the Art

3.2.1 Horizontal-axis Wind Turbines

The blades of horizontal-axis wind turbines spin on a horizontal axis and are similar in appearance to the large megawatt wind turbines. While smaller and far less obtrusive than large turbines, these small-scale turbines can still produce a significant amount of energy, and are a viable option for reducing dependence on traditional energy sources.

A company that has long realized the benefits of harnessing the wind's energy on a small scale is Southwest Wind Power. Southwest manufactures the SkyStream 3.7 kW wind turbine that is distributed locally by Intermountain Wind and Solar.

Wind Sail Receptor, Inc. of Boulder City, Nevada is another entry into the horizontal turbine market. The company is developing economically competitive products for both micro and macro wind applications.

Wind Sail Receptor Prototype
Photo courtesy of WindGen Energy

Wind Sail Receptor's prototype has caught the attention of several well-respected companies. WindGen Energy will soon distribute Wind Sail's small-wind product line, while Global Energy Technologies has contracted with company to distribute the large megawatt turbines. Deere and Company, also known as John Deere, have committed to investing in the Wind Sail Receptor turbines. The Chevron company has also shown interest in the Wind Sail Receptor technology and is negotiating a contract to team with Wind Sail Receptor, Inc.

SkyStream 3.7
Photo courtesy of Intermountain Wind and Solar

3.2.2 Vertical-axis Wind Turbines

Vertical-axis turbines are newer technologically but are gaining in popularity. What they lack in technological maturity they gain in aesthetic appeal and performance relative to many applications in which traditional horizontal-axis turbines are less suitable. This type of turbine requires a wind speed of only six miles per hour, is more capable of exploiting the inconsistent wind characteristics of in-city locations or areas of complex terrain, and can be placed at substantially lower heights than horizontal-axis turbines.

Vertical-axis Wind Turbine
Photo courtesy of WePOWER

Organizations as diverse as the consumer electronics giant BestBuy to National Geographic's headquarters in Washington, D.C. are capturing the energy potential of micro wind turbines.

3.2.2.1 A Possible Paradigm Shift in the Wind Turbine Industry

Wind Sail Receptor, Inc.

Wind Sail Receptor, Inc., based in Boulder City, Nevada, was founded by Richard Steinke in 2002. Steinke sought to develop a wind turbine that would address many of the shortcomings of traditional turbines. He envisioned a turbine that could operate at low wind speeds; incorporated durable, low-maintenance propeller blades; and could operate at speeds higher than most conventional turbines. The company has developed both micro and macro scale turbines.

Most turbines operate at wind speeds between 10 to 30 miles per hour and have a breaking system that initiates around 35 miles per hour to prevent the blades from being damaged. Conventional wind turbine designs are similar to aircraft propellers and allow a significant amount of wind to pass between the blades. The Wind Sail Receptor has substantially more surface area which allows it to harness a greater amount of the wind energy passing across its blades. The blades of the Wind Sail Receptor are made of a strong polyurethane, with a tear strength twice that of rubber. The shape and design of the blade allows it to commence spinning at wind speeds of roughly half that of traditional turbines at 5 miles per hour. The material of the blade allows the turbine to withstand wind speeds of over 65 miles an hour.

One of the many expenses involved in a macro scale wind turbine is the manufacturing costs. A 100 - 200 foot turbine blade typically takes up to 90 days to manufacture. This manufacturing time represents a significant lead time before a new, macro-scale wind turbine is operational. It is not unusual that a large turbine manufacturer will have a lead time of years for the installation of a new turbine.[16]

By comparison, the blade of a wind sail receptor is manufactured in 15 minutes. This production efficiency allows a responsiveness to changing requirements that is not possible in the manufacturing of utility-scale turbines. It also has implications in the time for repair. The time it takes to replace a damaged blade can vary widely, particularly if the repair necessitates that a replacement be manufactured. It is not unusual to see windmills with damaged blades sit idle for months. The cost of fixing blades on large windmills can cost up to $250,000. A wind sail receptor blade can be replaced in about 3 hours at a cost of around $5,000.

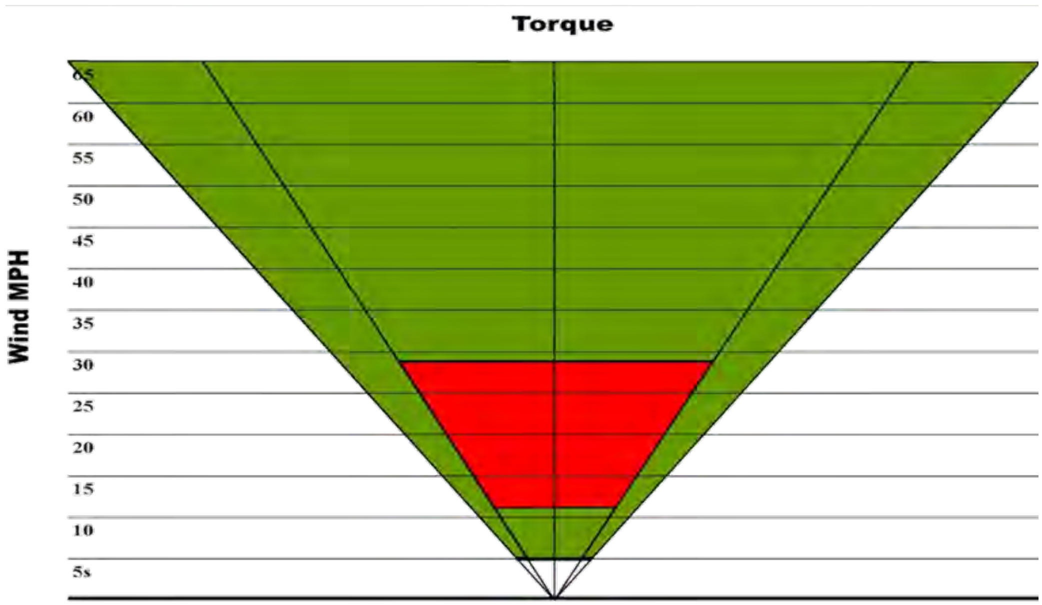


Diagram 3. Courtesy of Global Energy Technologiies

Due to the greater range of energy production, these new smaller turbines could have an improved payback time. The megawatt Wind Sail turbines can be placed at a height of 65 feet instead of the more cumbersome 200 feet. The micro size Wind Sail Receptors can be placed as low as 30 feet. The chart below shows the operating wind speeds of conventional wind turbines (in red) compared to the range of operating wind speeds for wind sail receptor turbines (in green).

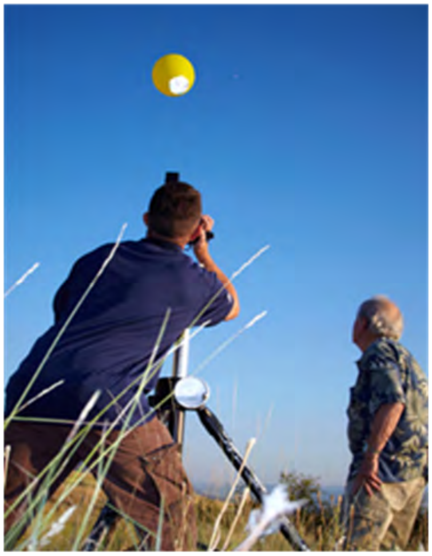
3.2.3 Wind Characterization

Wind characterization, or wind profiling, is the measurement of wind resources in a given area. The information gleaned from wind characterization studies help in situating wind turbines to realize optimum power production. Traditionally, anemometers placed on towers are used to characterize wind, but this gives little information about changes in the vertical column and can be expensive to install.

Geographical Information System (GIS) studies can be used to gain a landscape scale understanding of wind over a large area. The confluence of certain geological features dictates somewhat predictable wind patterns. This type of study can be used to narrow the focus for smaller scale studies when a large area requires surveying.

3.2.3.1 ValidWind™

ValidWind is a lidar-based balloon-tracking system used to measure wind power and stability. This new technology was developed at Utah State University's Center for Active Sensing and Imaging (CASI). ValidWind is portable and inexpensive and is ideal for assessing the local wind resources in communities with complex geographical terrains. Data gathered from ValidWind creates a 3D wind profile of a specific location. Unlike anemometers, small changes in the vertical column can be detected with the techniques used by ValidWind. This helps developers position turbines at an optimal height for power generation. This becomes increasingly important in situations where the physical location of a turbine is predetermined by either geological features or other structures, but there is some flexibility in the height that the turbine can be situated.



ValidWind™, a lidar-based balloon tracking system
Photo courtesy of Energy Dynamics Lab

3.3 Resources and Challenges

The Park City area has wind speeds that average 7 – 10 mph through most of the year.[17] With most micro scale wind turbines requiring approximately 5 mph to begin turning, the winds in Park City are conducive to operating micro wind turbines.

Codes within Park City proper and in Summit County are favorable for micro wind applications, as there is no distinction between micro and macro wind. The primary limiting factor to the use of wind turbines in Park City are height restrictions. According to the Park City municipal code, height restrictions are as follows:

- No structure may be erected to a height greater than twenty-eight feet (28') from existing grade. This is the zone height.[18] Wind turbines may extend above the maximum zone height subject to a visual analysis and conditional use approval by the Planning Commission of a small wind energy system. Height is measured from natural grade to the tip of the rotor blade at its height point.[19]

Park City Municipal Code has been written specifically for small wind energy systems in both the Recreation and Open Space District and the Community Transition District. These codes give general guidelines for micro-wind applications throughout Park City. All micro-wind applications require a Conditional Use permit.[20]

Summit County codes do not have information specific to micro wind applications. The county codes currently separate the application process into sections based on the overall height of the structure. If the structure is less than 45 feet and the transmission lines are less than 12 inches in diameter, than the structure would be considered a Utility

Facilities, Underground.[21] To proceed with installation of the system, a low impact permit would be required.[22] Low impact permits authorize uses and activities that are considered to have little or no impact on public health, safety, and general welfare.[23]

Any micro wind project in Summit County that exceeds an overall height of 45 feet is classified as Above-Ground Utilities,[24] and requires the filing of a conditional use permit.

The more challenging restrictions are those imposed by the covenants of local Homeowner's Associations and other local organizations that seek to prevent the placement of wind turbines in residential areas and along ridgelines.

The sub-freezing winter temperatures experienced by Park City are an additional challenge. While many of the turbine manufacturers we spoke with claimed that their turbines continue to spin in sub-freezing temperatures, it's a question that should be posed by anyone thinking of installing a micro wind turbine in the area. At worst, the economics of purchasing a micro wind system should consider that there may be times in which the turbine remains idle.

Although Park City has a substantial wind resource available for renewable energy, there remains some resistance to wind power within the community due to the potential for restricting views and the sound and turbulence associated with macro wind projects. The new advancements in micro wind technologies, however, provide attractive options and a pilot-scale demonstration project could alleviate some of those concerns.

3.4 Market

The market for micro wind applications in Park City is varied and depends more on the power needs of the user given current state policy. The information that follows gives a brief assessment of the types of turbines locally available and an estimate of the power needs they can address.

3.4.1 Residential Appications

New advancements in micro wind technology are opening up wind power for small-scale commercial and residential applications. Their small size reduces some of the aesthetic concerns and a correctly sited micro wind system could provide much of the electricity necessary to power a mid-sized home or small business.

The WePOWER Falcon Series is a great option for residential applications and are available in various sizes. The Falcon Series 3.4 and 5.5 kilowatt wind turbines are ideal for residential applications and have a great return on investment.

WindGen Energy will begin distribution of Wind Sail Receptor's 10 kW turbine in April of 2010. The Wind Sail Receptor technology may change the wind turbine market and make micro wind turbines more economically feasible because of a quick return on investment

Intermountain Wind and Solar is a turnkey company that sizes the project to the needs of the customer, allowing optimal use of available resources. Intermountain Wind and Power typically uses Southwest Wind Power's SkyStream turbine. Gardner Engineering also typically uses the SkyStream for their wind projects.

Photo courtesy of Intermountain Wind and Solar

Photo courtesy of Gardner Engineering

3.4.2 Municipal and Business Applications

For users that can take advantage of aggregate metering or businesses that have greater electricity demands, mid-sized turbines – between 10 and 25 kW – are readily available.

WePOWER's vertical-axis wind turbines are another great option for commercial and government applications. The variety of sizes and applications allow businesses to easily match WePOWER products with their specific needs.

WindGen Energy and Global Energy Technologies are both great options for municipal and business applications. Both companies are licensed distributors of the Wind Sail Receptor, Inc. WindGen Energy is the distributor for the 10, 15, and 25kW systems while Global Energy Technologies is the distributor for the 1MW system. The larger system is more applicable for utility companies but could be used by a municipality or business if there is sufficient capital to start a project of that size.

Southwest Wind Power's SkyStream, offered by both Intermountain Wind and Solar and Gardner Engineering, is also an option. However, it has a longer return on investment.

3.4.3 Ski Resorts and Commercial Applications

Global Energy Technologies will distribute the one megawatt Wind Sail Receptor turbine that can be placed as low as 65 feet and will cost approximately $1.5 million.[25] A turbine of this size could offset the electricity needs of resort operations while at the same time present a positive image.

WindGen Energy will also distribute the smaller versions of the Wind Sail Receptor technology. The sizes that may be applicable to ski resorts and other commercial entities in Park City are the 10 kW, 15 kW, and 25 kW models. All three models can be placed at 30 feet. WindGen Energy is still in the development stage for these turbines. They estimate the 10 kW turbine to cost around $10,000.[26]

The 5.5 and 12 kW Falcon Series vertical-axis wind turbines distributed by WePOWER, are also options for ski resorts and commercial applications. These turbines are large enough to make an impact on the overall carbon footprint, but small enough not to make a large visual impact.

The tables and scenarios listed in the following section illustrate representative costs, estimated time for payback in years, and possible subsidies available for small-scale wind projects. This information is intended to serve as a starting point for commercial entities or residents who are considering wind energy in their renewable energy plans.

3.5 Cost and Time to Payback

3.5.1 WePOWER Falcon Series

Tables 3 and 4 show the payback schedule for both a residential and commerical application.

WePOWER Falcon Series - Residential								
Model	Cost	Federal 30%	State 25% max $2,000	Cost after Incentives	Annual Energy Production (kWh)	Price per kWh	Annual Savings	Estimated Payback (Years)
1.2 kW	$11,850	$3,555	$2,000	**$6,295**	**424 - 706**	**$0.063**	$26.71-$44.49	142-236
3.4 kW	$29,850	$8,955	$2000	**$18,895**	**1,278 - 2,131**	**$0.063**	$80.51-$134.25	141 -235
5.5 kW	$44,250	$13,275	$2000	**$28,975**	**2,178 - 3,631**	**$0.063**	$137.21 - $228.75	127-211
12 kW	$78,750	$23,625	$2000	**$53,125**	**4,145 - 6,908**	**$0.063**	$261.14 - $435.20	122 - 203

Table 3. WePOWER Falcon Series - Residential

WePOWER Falcon Series - Commercial								
Model	Cost	Federal 30%	State 10% max $50,000	Cost after Incentives	Annual Energy Production (kWh)	Price per kWh	Annual Savings	Estimated Payback (Years)
1.2 kW	$11,850	$3,555	$830	**$7,465**	**424 - 706**	**$0.063**	$26.71-$44.48	168-280
3.4 kW	$29,850	$8,955	$2090	**$18,805**	**1,278 - 2,131**	**$0.063**	$80.51-$134.25	140 -234
5.5 kW	$44,250	$13,275	$3098	**$27,877**	**2,178 - 3,631**	**$0.063**	$137.21 - $228.75	122-203
12 kW	$78,750	$23,625	$5513	**$49,612**	**4,145 - 6,908**	**$0.063**	$261.14 - $435.20	144 - 190

Table 4. WePOWER Falcon Series - Commercial

3.5.2 WindGen Energy

Size: 10 kW, 15 kW, and 25 kW

Estimated Cost: $10,000 for the 10 kW unit

WindGen Energy will be the manufacturer and distributor of the smaller Wind Sail Receptors. An accurate assessment of cost, payback, and eventual return on investment cannot be accurately measured because the output and retail installation costs have not been solidified for these turbines. WindGen Energy will begin manufacturing the Wind Sail Receptors in April 2010.

3.5.3 Global Energy Technologies

Size: One Megawatt

Cost: $1.5 Million

Estimated Return on Investment: Three to five years depending on wind speeds, placement in Park City and eligibility for government subsidies. "If we built a 100 MW wind farm that operates 20 hours a day, the total production would be round 60,800 MWH or 60,800,000 KWH per month. If we assume a low average of just 5.5 cents per kilowatt hour, we should see a gross potential income per month of over $3.4 million dollars. Depending on the location, it's not unusual to see scenarios that provide complete payback for a wind sail receptor system within 3 years." Dave Gallagher, Global Energy Technologies, VP of Business Development.[27]

One factor that may extend the payback on WindGen's products compared to Global Energy Technologies' products is economies of scale. When Global Energy sells turbines, they will sell multiple turbines to utility companies. Costs will be minimized in this fashion due to economies of scale that won't be realized at present in individual sales for residential and commercial uses.[28]

3.5.4 Intermountain Wind and Solar (Southwest Wind Power's SkyStream)

Size: 3.7 kW

Cost: $18,000 to $20,000

Estimated Return on Investment: 25 to 30 years at wind speeds of 14.5 mph (higher than the 7 – 10 mph annual average for the Park City area) and yearly savings of $540

3.5.5 Gardner Engineering (Southwest Wind Power's SkyStream)

Size: 3.7 kW with a 45 foot tower

Cost: $18,000 to $20,000

Estimated Return on Investment: 25 to 30 years at wind speeds of 14.5 mph (higher than the 7 – 10 mph annual average for the Park City area) and yearly savings of $540

3.5.6 DeerPath Energy Company

Size: 3.7 kW Southwest Wind Power's SkyStream on light poles

DeerPath Energy specializes in Power Purchase Agreements, PPAs. This means that the customer has no upfront costs. DeerPath purchases, installs, and maintains all equipment throughout the life of the project. The customer simply signs a PPA for a determined number of years, either 10 or 20 years. DeerPath acts like a utility company, tracking the power generated and consumed by the customer and bills accordingly.[29]

3.6 Summary of Porcupine Ridge (Macrowind Case Study)

An Analysis of State-Level Economic Impacts from the Development of Wind Power Plants in Summit County, Utah

David J. Ratliff, Captain United States Air Force

Cathy L. Hartman, Ph.D., Edwin R. Stafford, Ph.D.

Center for the Market Diffusion of Renewable Energy and Clean Technology

Jon M. Huntsman School of Business, Utah State University 3560 Old Main Hill Logan, Utah 84322-3560 DOE/GO-102009-2918 October 2009

Summary:

The report on the economic impact of a possible wind power plant located on Porcupine Ridge in Summit County was released in October 2009.

Porcupine Ridge has the potential of producing up to 130 MW of wind capacity. Due to wind patterns, the majority of the electricity produced would be from 10 a.m. to 9 p.m. This energy production coincides with the peak energy demands found in the state of Utah. For this reason, the Porcupine Ridge project because ideally suited for not only meeting energy demands, but reducing the overall carbon footprint by reducing the need for natural gas-fired power generation.

If a 50 MW power plant was to be installed, it could generate:

- 51 onsite construction jobs with a payroll of nearly three million dollars
- $150,000 per year in land leases
- $800,000 per year in property taxes
- $631,000 of property taxes would benefit local school districts per year
- $240,000 yearly payroll for personnel costs
- $2.3 million yearly impact
- 10 year return on investment
- 80 percent financed through debt and 20 percent by corporate investors

The Porcupine Ridge project should be studied in greater detail by city councils, local businesses, and residents. The project would have a significant impact on all residents of Summit County.

3.7 Case Study

3.7.1 Palmdale Parking Lots

Palmdale, California, is joining other cities like Buffalo, New York, and Cleveland, Ohio, in the development of renewable energy in urban areas. Palmdale allows companies to install wind turbines on light poles in parking lots. This change in policy is helping companies generate renewable energy that can be used to run their businesses.

The city has been concerned over the aesthetics of wind turbines and has enacted policies that limit the height of the turbines to a maximum of 60 feet. According to the Assistant City Manager, Laurie Lile, the turbines must double as lighting structures and must be compatible in design and color with the existing light fixtures. The hope is that companies will be able to reduce their operating costs by installing the turbines.

Currently, the new Sam's Club in Palmdale is installing 17 turbines that will produce 76,000 kilowatts of clean energy every year. This will reduce the overall operating cost of the new company and reduce the strain on current utilities. Most residents of Palmdale are in support of the change in policy.

Park City may be able to implement a similar policy. Several businesses already have large parking lots and light poles. These companies would be able to harness wind power without adding additional structures to their sites. The poles may have to be updated in order to meet the structural demands of the wind turbines. The use of light poles and small wind turbines may also be a great alternative for municipal buildings and the resorts.

3.8 Summary

3.8.1 Recommendations

We recommend that the city procures a vertical axis turbine to install on a city-owned building. We encourage the city to situate the turbine in a location that is highly visible. A small public awareness campaign including signage and media involvement would help both city residents and tourists gain additional information about micro wind projects.

We also recommend the city compile previously obtained anemometer data along with information from local residents to identify potential sites for micro wind turbines. Once these sites have been identified, we recommend that the sites are further characterized using ValidWind to determine the optimal placement of turbines.

Continued development of the parkcitygreen.org website to include more comprehensive information about micro wind options is recommended. The wind site should include information such as the value of micro siting, contacts for local vendors and installers, information about city and county codes, and subsidy and rebate information. The message forum on the site could be used to organize a group of residents interested in wind power so that they might collectively approach a vendor for reduced pricing on multiple units.

3.8.2 Citizen Involvement

The key to the success of any change is the people that are impacted directly and indirectly by the project. Community involvement cannot be underestimated. There are many different ways for residents to get involved. The following are a few recommendations for Park City residents.

1. Join the Utah Wind Working Group to meet other sup porters and become educated about wind energy proj ects throughout the state. Visit their website http://geol ogy.utah.gov/sep/wind/uwwg/index.htm for more infor mation.
2. Visit Utah Clean Energy website http://utahcleanenergy.org for information about renewable clean energy. Utah Clean Energy also has free publications and training on a variety of clean energy sources.
3. Contact the Utah Public Service Commission to express concerns about renewable energy in the State of Utah, net metering, and aggregate metering.

Utah Public Service Commission
Heber M. Wells Building
160 East 300 South
Salt Lake City, UT 84114

http://www.psc.state.ut.us/

Phone: 801-530-6716
Fax: 801-530-6796
Hours: 7:00 - 6:00 Monday - Thursday, closed Fridays

4. Write or contact the members of the legislature subcom mittee Public Utilities and Technology Interim Committee:
    - Sen. Scott K. Jenkins, Co Chair
    - Rep. Michael E. Noel, Co Chair
    - Rep. Roger E. Barrus
    - Rep. Ralph Becker
    - Rep. Jim Bird
    - Rep. Melvin R. Brown
    - Sen. Mike Dmitrich
    - Rep. Janice M. Fisher
    - Rep. Lynn N. Hemingway
    - Sen. Mark B. Madsen
    - Rep. Steven R. Mascaro

3.9 Resources

3.9.1 WePOWER

WePOWER is a clean tech energy solution company that prides itself on their innovative ideas and industry break-through applications. WePOWER's vertical axis wind turbines are omnidirectional, require low maintenance, and are self regulated at high speeds.

WePOWER produces five vertical-axis wind turbines referred to as the Falcon Series. These are elegantly designed turbines with only three moving parts. They are free of vibration, and the manufacturer claims that the turbines continue to be operational in sub-freezing temperatures. Each turbine differs in size and output. The sizes of the turbines are 600 watts, 1.2 kilowatts, 3.4 kilowatts, 5.5 kilowatts, and 12 kilowatts. None of these turbines emit more than 32 decibels of sound which is comparable to that of a residential refrigerator.

The Falcon 600 W is an ideal size for agricultural pumps and to power similarly small farm operations. The Falcon 1.2 kW is optimal for agricultural uses and light residential use. The Falcon 3.4 kW turbine is excellent for light to medium residential use. The Falcon 5.5 kW turbine is best for medium residential and light commercial use. The Falcon 12 kW turbine is ideal for large residential and light to medium commercial use.

3.9.2 WindGen Energy

WindGen Energy is the licensed distributor for Wind Sail Receptor, Inc.'s smaller turbines. The sizes of the micro wind products are 10 kW, 15 kW, and 25 kW. The tentative availability of these products is April 2010. The estimated price for the 10 kW, horizontal-axis turbine is $10,000. These turbines produce less than 10 decibels of sound and will begin producing power at wind speeds of five miles an hour. The polyurethane blades of these turbines have been designed to withstand extreme temperatures and high wind speeds. The Wind Sail can be placed at a minimum height of 30 feet.

3.9.3 Global Energy Technologies

Global Energy Technologies is a licensed distributor of the one megawatt Wind Sail Receptor, Inc and is a turnkey company for large wind projects. These turbines can be placed at a height of 65 feet instead of several hundred feet like conventional wind turbines. These turbines need wind speeds of five miles an hour to commence spinning and can withstand wind speeds of 65 miles an hour. This wide range of operational speeds could mean a fast return on investment.

Braking systems on wind turbines tend to break and need constant maintenance to properly operate. Wind Sail Receptor technology does not have a braking system because the polyurethane blades can withstand high speeds. The estimated cost for a one megawatt turbine is around $1.5 million. The one megawatt turbine may be a viable option for area ski resorts given the anticipated power production. The size of this megawatt turbine is the size necessary for operation of the smallest chairlift tower at ski resorts. The megawatt Wind Sail Receptor is scheduled to be available in April 2010.

3.9.4 Intermountain Wind and Solar

Intermountain Wind and Solar offers turnkey solutions to customers that are considering the use of alternative energy to power their homes or businesses. They study every aspect of the process to install a solar, wind, or hydro system. For wind projects, Intermountain Wind and Solar specialize in Southwest Wind Power's SkyStream horizontal turbines but also use other brands depending on the needs of the customer and sizing of the system. They are based in Woods Cross, Utah, and are familiar with local challenges.

3.9.5 Gardner Engineering Alternative Energy Services LLC

Gardner Engineering Alternative Energy Services, LLC, is also a full design and build company. For wind projects, Gardner Engineering installs Southwest Wind Power's SkyStream product. Gardner Engineering is based in Ogden, Utah. Owner, Ken Gardner, is a board member of the Utah Solar Energy Association and Gardner Engineering has completed 18 solar photovoltaic projects since 2008 as well as four recent wind projects and four hydroelectric projects. Gardner Engineering handles all aspects of design, equipment supply, installation, and commissioning of energy systems. Gardner Engineering is fully licensed, NABCEP certified, insured, and bonded.

3.9.6 DeerPath Energy Company

Based out of Boston, Massachusetts, DeerPath Energy Company is a company that provides and sells power purchase agreements. Although power purchase agreements are a great way to start a renewable energy system, power purchase agreements are not allowed in the state of Utah except for government and non-profit entities (see HB145S02 from 2010 legislative session).[30] There may be legislation passed in the near future that will allow power purchase agreements for a broader range of groups in Utah. DeerPath specializes in urban wind farms that combine light poles and micro-wind turbines. DeerPath engineers, constructs, maintains, and sells the power generated by these urban wind farms to customers at competitive prices.

4. Solar Thermal and Solar Photovoltaic

4.1 Overview

Solar power is an abundant energy source in Utah and while many of the state's cities experience extended periods of inversion that negatively affects the use of solar during those times, Park City's altitude positions it above the worst of these inversions. When considering solar power, solar panels are generally the first thing that comes to mind. The photovoltaic, or PV, cells that are the workhorse of solar panels and tubes, capture sunlight and convert it into electricity or heat. Solar panels have been used to capture the sun's energy for decades, although there are limitations to their application. In recent decades the useful life of the solar panel has been over before a return on investment has been realized.

Other options for capturing energy from the sun exist beyond PV. The simplest of them, daylighting, is commonly overlooked. Solar thermal systems, in which the sun heats water that can then be used either directly or in radiant heating systems, are also gaining in popularity.

In 2009, prices of solar projects dropped dramatically due to market saturation of solar equipment and market entry of new companies and distributors. As companies emerge and compete, prices continue to drop. Two years ago, the price of an average 5 kW solar PV system was $45,000. A similar system today would cost about 33% less, or $30,000.

Given the current Utah policy, proper sizing to the needs of the user is critical to making the solar system economically viable. A consideration of shadows from other structures and objects should be taken into account as well.

Solar thermal and photovoltaic (solar panel) systems can be sized to fit any building or complex. These systems can also be sized to offset all or part of a utility bill, or to enhance an organization's image as being environmentally responsible. These systems can be sized from off-grid remote cabins to large on-grid complexes.

4.2 Current State-of-the-Art

4.2.1 Active Tracking Dual-axis Photovoltaic Systems

Active PV systems use an integrated sensor to track the sun thereby maximizing energy capture. Dual-axis allows the panel to rotate to the east, west, north, and south. Active systems are the most expensive because of the sensor and tracking components.[31]

Photo courtesy of Intermountain Wind and Solar

According to Kyle Hartman of Gardner Engineering, Gardner's photovoltaic dual-axis tracking systems are 30 percent more efficient than stationary systems. Solar panels with trackers and data loggers are the current state of the art for capturing the sun's energy and converting it to usable electric power. However, the efficiency of tracking systems as opposed to stationary systems has not been formally proven. The cost per watt of electricity generated by an active tracking system is approximately $2.50 to $3.00 more than that from stationary systems.[32] The current market price per watt is about $6.00 for stationary systems, so an active tracking system would cost somewhere between $8.50 and $9.00 a watt. An average five kW active tracking system would cost between $42,500 and $45,000. Still, some companies in the industry claim that a tracking system can realize a 20 – 40% increase in output over similarly-sized stationary systems.

Campbell Scientific of Logan, Utah is conducting a one year study to test a tracking system versus a fixed system, although results aren't expected until late 2010. The Campbell Scientific test system will use their data loggers in conjunction with tracking hardware from the Boomerang Group and solar panels from Intermountain Wind and Solar. Campbell has invested around $100,000 for this test system.[33]

Photo courtesy of Intermountain Wind and Solar

4.2.2 Passive Tracking Photovoltaic Systems

Passive tracking PV systems use two tubes of Freon, one on each side of the system, to adjust the angle of the solar panels. With the rotational movement of the sun, the Freon is heated at different rates, causing one tube to be warmer

Photo courtesy of Intermountain Wind and Solar than the other which pushes the Freon to the cooler tube, adding weight to that tube, and causing the panels to shift toward the sun.

Passive trackers cost less than active trackers, but produce less energy because it takes them longer to tilt toward the sun. In cold weather, the Freon takes longer to heat up, although according to Jack Matsen from Intermountain Wind and Solar, passive trackers are being used successfully in cold climate areas, such as Eden, Utah.

4.2.3 Stationary Photovoltaic Systems

Stationary systems maintain a fixed position and are situated such that their exposure to the sun is maximized. Generally they are angled to the south, although some systems lay flat. These systems are commonly seen on residential and commercial rooftops. The disadvantage of stationary photovoltaic systems is that their daily energy capture is limited to the periods of time that they are exposed to the sun, which varies by season. As the sun rotates, shadows from neighboring structures such as trees, chimneys or other buildings will also affect the systems productivity and can dramatically affect the realized return on investment of these systems. However, new microinverter technology can limit productivity losses by allowing PV arrays to remain productive even when some portions of the system are shaded.

Traditional solar energy installations deploy a single, centralized inverter to convert the DC output from multiple solar panels into AC power. New technological advancements have Microinverters are connected to each solar photovoltaic module. These modules produce more power than traditional modules because the microinverter for each module increases efficiency by minimizing energy losses. Enphase Energy claims that their microinverter system increases efficiency by 5 – 25%. Microinverters provide greater production in low-light conditions while they convert DC power to grid-compliant AC power. Each microinverter also collects and transmits performance information from their respective module to a website that the customer can access to monitor their system. The advantage of knowing the performance of each module allows the customer to understand what is preventing their system from maximizing power output. Information such as shade from nearby objects and fallen debris will be made available to the customer. Due to the fact that there are several inverters, there is no single point of failure and no central or string inverter to install or design. This makes the installation and design of the system simple and quick.

Photos courtesy of Gardener Engineering

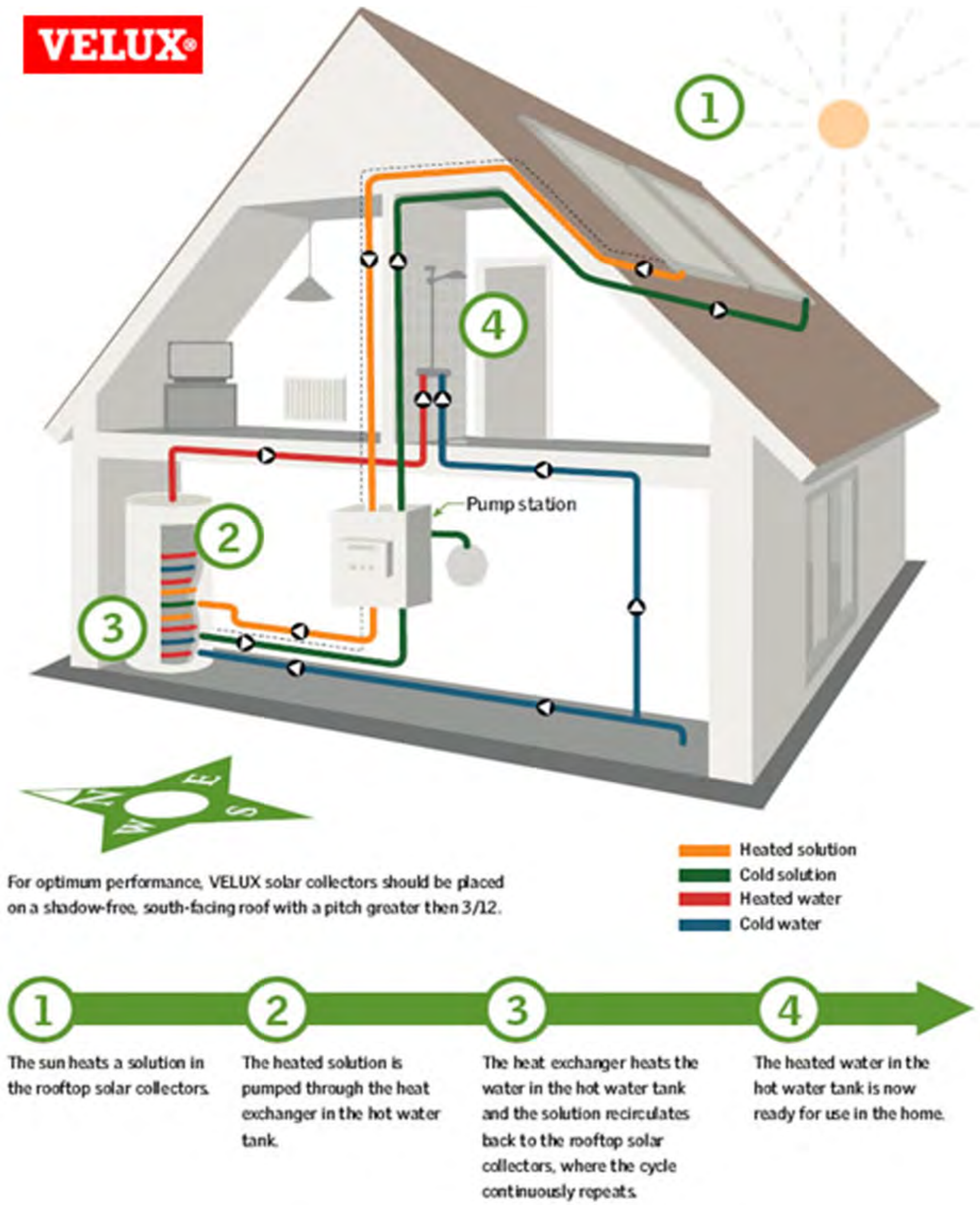
4.2.4 Solar Thermal Energy

Solar thermal systems are different than solar PV in that they do not convert solar energy into electricity. Solar thermal systems capture solar energy in the form of heat. These systems are classed into low, medium, and high temperature collectors. Low and medium collectors are primarily used to heat swimming pools or for residential and commercial hot water use. High temperature collectors can be used for radiant heating.

With the current tax credits and energy savings, solar thermal offers a faster return on investment when com-

Photo courtesy of Intermountain Wind and Solar pared to solar PV energy systems. Solar thermal also has a lower start-up cost than solar PV energy systems. For water heating applications, evacuated tube technology and flat solar panels are two choices. Evacuated tubes are a series of tubes that capture solar energy and can be used to heat water up to 400° F, which is sufficient to provide hot water needs or radiant heating. Flat plate collectors such as the Velux system shown below, are placed on a south-facing roof and require a pitch of greater than 3/12. These systems are capable of dropping heating bills by 50 to 80 percent depending on the size of the system and other environmental factors.[34]

Evacuated tube heat pipe collectors can attain higher temperatures more quickly than flat panels. One of the major challenges with solar-powered systems is storing the energy produced for times when there is little or no sunlight. Solar thermal systems can address some of this shortcom-



4.2.4.1 - How a solar panel hot water system works. Graphic courtesy of Utah Solar and Alternative Energy ing by being capable of storing thermal energy in the form of hot water for limited amounts of time.

4.3 Resources and Challenges

An enduring challenge of solar power is storing the energy harnessed by these systems. Solar power can only be generated during portions of the day and becomes problematic during extended periods of overcast weather. Proper maintenance including snow removal is critical for the proper functioning of solar panels.

While solar power can be stored in batteries, current battery technology requires a large system for residential use. The batteries have a short useful life and are expensive to replace. The production of large quantities of spent batteries can sometimes offset the environmental advantages of solar power. Battery storage for solar power is typically used for cabins and other off-grid locations.

Solar power can be stored in limited quantities and for limited time as hot water. Solar thermal technologies such as evacuated tubes and solar panel hot water systems are simple solutions for storing energy captured from solar power because hot water can be stored for several days.

Another solution to the storage problem is to use solar generated power during the day and sell the excess power not used during the day back to Rocky Mountain Power. If the system is sized correctly to the building, the net use of the building from the grid will be zero. For example, the homeowner will use power from the grid at night but during the day the system will rotate the meter backwards and credit the homeowner. This is called net metering because the net power usage by the consumer from the grid approaches zero. When an individual has several meters on a parcel of land they can use their credit on one meter to pay for other meters. This is called aggregate metering.[35]

Current Utah policy provides additional challenges to solar applications. Similar to the problems facing wind and hydro power, systems must be sized accurately for the intended application as a consumer cannot sell excess power to a utility beyond what is consumed. This is a distinct disadvantage for solar PV applications as the expense of these systems cannot be offset by the ability of the purchaser to sell excess power.

While Park City's high altitude and extended periods of clear days make solar a viable sustainable energy option for many applications, restrictive homeowner's associations can levy fines on their residents and have caused many homeowners to shy away from solar systems. Short winter days and the shadows cast by neighboring structures lengthen the period of time in which users can expect a payback for the system. Ironically, in the Park City area, the residences that are less affected by shadow from the town's infrastructure – those at higher elevations – are the residences that are more likely to be restricted by homeowner's associations.

Additionally, for communities like Park City in which many of the residences are second homes and are unoccupied for substantial portions of the year, the high upfront costs of solar technology makes it an unappealing investment.

4.4 Market

Historically, the use of solar power has been most attractive to businesses and organizations that reap the benefits by receiving government subsidies, can take advantage of aggregate metering, and desire to reap the less tangible benefits of promoting an 'eco-friendly' image.

Businesses with high demand for electricity, such as the ski resorts or hotels, may also find that solar power can be an economically feasible investment. The ski resorts in particular could take advantage of aggregate metering and have the open space to locate tracking-type solar systems. The hotels in town are an interesting and noteworthy example. Our preliminary look into this type of business shows that while most of the hotels within the city limits have sufficient demand for electricity and hot water that a solar PV or solar thermal application could be financially feasible, they lack adjacent open space for tracking solar systems and have insufficient roof area for traditional stationary PV or solar thermal panels to meet the needs of the hotel. In these cases, a solar application that can only offset a portion of the demand may not be economically viable given the cost of solar systems.

However, recent breakthroughs in solar panel technology, construction, and durability, indicate that the use of solar is becoming more cost effective. With advancements in panel technology and useful life, tracking systems that maximize the energy captured, solar thermal technologies for heat generation, corporate tax credits, governmental subsidies, and utility rebates; solar is more feasible than ever before; opening up the technology for more residential smaller-scale commercial applications.

4.5 Cost and Return on Investment

Costs of systems vary depending on size, output, brand, and complexity of tracking systems. Stationary 5 kW photovoltaic systems cost between $27,000 and $30,000.

The return on investment for solar systems is so heavily dependent on parameters out of the control of the installer, that many developers are reluctant to even provide averages or estimates. The payback for a system depends on the user's demands, weather and air quality, the possibility that a nearby structure could be erected that could cast shadows on the panel, and the end user's commitment to proper maintenance of the panels. Depending on the sizing of a system and the parameters just mentioned, a payback can be realized in six to eight years with government incentives and grants. Other systems can take 20 years or more to see a payback depending on environmental factors, size of system, and power usage of the individual. The warranty on most panels is around 25 years.

Current federal and state subsidies can offset as much as 40 percent for the purchase and installation of a solar PV or solar thermal system. Rebates from local utility companies are also available. Rocky Mountain Power pays $2 per watt of AC power up to $6,000 for residential applications and $30,000 for non-residential applications. For a solar thermal system, Questar Gas pays a maximum of $750.

4.5.1 Park City Historical Society

In the summer of 2008, a 5.04 kW photovoltaic stationary system was installed on the roof of the Park City Historical Society and Museum by Gardner Engineering. The system was financed almost entirely by the Rocky Mountain Power Blue Sky Program. Park City paid $2,000 in installation costs and the Blue Sky Program paid for the remaining $43,000. The Park City Historical Society and Museum pays about $1500 a month for their energy bill. The photovoltaic system was expected to offset their bill by about $200 and to pay for the cost to the museum in under two years.[36]

The 5.04 kW system was initially estimated to produce 810 kWh per month. On average, however, the system is producing less than 300 kWh per month. Several factors may have led to the difference in expected versus realized output including optimal placement and general maintenance of the panels. The difference in realized power generation dramatically affects the energy offset of the system and therefore the anticipated payback for the project.

At the current energy production rate, the payback for the Park City Historical Society and Museum will be nine years. Without the financial support from the Rocky Mountain's Blue Sky Program, the payback period for the museum would have been greater than 200 years.

4.6 Cost of Solar technology is Dropping

Table 5 illustrates the importance of adequately siting systems and the role of current subsidies in the economic viability of renewable energy projects. The project also provides a good baseline for evaluating how quickly the cost of current technology is dropping. The table below illustrates the actual costs of the system in 2008 and the amount the same system would have cost in 2009.

Project	Year Installed	Total Cost	Subsidies & Rebates	Cost to Owner
Park City Historical Society Museum	2008	$45,000	-	**$45,000**
Park City Historical Society Museum with Blue Skies	2008	$45,000	$43,000	**$2,000**
Park City Historical Society Museum	2009	$30,240	-	**$30,240**
Park City Historical Society Museum w/ current subsidies	2009	$30,240	$18,096	**$12,144**

Table 5. A comparison of actual 2008 costs for the Park City Historical Museum project and what a similarly sized system would have cost if purchased in 2009.

These two scenarios are examples provided to us by local vendors. The paybacks described are their best esimates for the situations described.

4.6.1 Payback for Businesses that Can Receive the Corporate Tax Credit

Gardner Engineering recently sold and installed a 15.72 kW solar photovoltaic system for $107,850 on a business. The business received a 30 percent subsidy from the federal government of $32,355, a 10 percent state subsidy of $10,375, a corporate tax credit of $25,365 (tax bracket of 28 percent), and a $30,000 rebate from Rocky Mountain Power.

After subsidies and rebates, the business paid $9,755. Given these estimates, Gardner Engineering has estimated that the business will see a payback in approximately five years.[37]

4.6.2 Solar Thermal Hot Water System

Bill Wilson from Utah Solar and Alternative Energy provided information about average costs of a solar thermal project installed on an average-sized home. The average cost of the solar thermal system is approximately $8,000. The Federal Government offers a subsidy of 30 percent so the customer in this example receives a federal subsidy of $2,400. With current state subsidies of $1,800 and a $750 rebate from Questar Gas Company the customer could offset over half of the cost of the system, leaving the customer with a total of $3,050 after the various subsidies. Mr. Wilson explained that a payback scenario for the example illustrated above is not practical without more information regarding the customer's gas use and what portion of that is attributed to heating of water.[38]

4.7 Funding Availability and Programs for Wind, Solar, and Hydro - Table 6 below is section 4.7.

4.8 Daylighting

Daylighting is the term describing the practice of using natural light to illuminate building spaces.[39] Buildings that employ daylighting practices can reduce their electricity consumption by using natural light instead of artificial electric light.

Several factors influence the proper implementation of daylighting in any building. Climate, location, orientation, and end use all play major roles in the proper integration of daylighting techniques. When done properly, daylighting can have a significant impact on the energy consumption of a building.

The Energy Center of Wisconsin worked with the Energy Resource Station in Ankeny, Iowa to determine potential savings from daylighting practices. The study compared the energy consumption of two rooms. The first room was configured to the standard configuration of most buildings. The room was equipped with energy efficient lighting and an HVAC system. The second room was reconfigured to implement new daylighting techniques and was also equipped with energy efficient lighting and an HVAC system. Energy consumption in both test rooms was monitored.

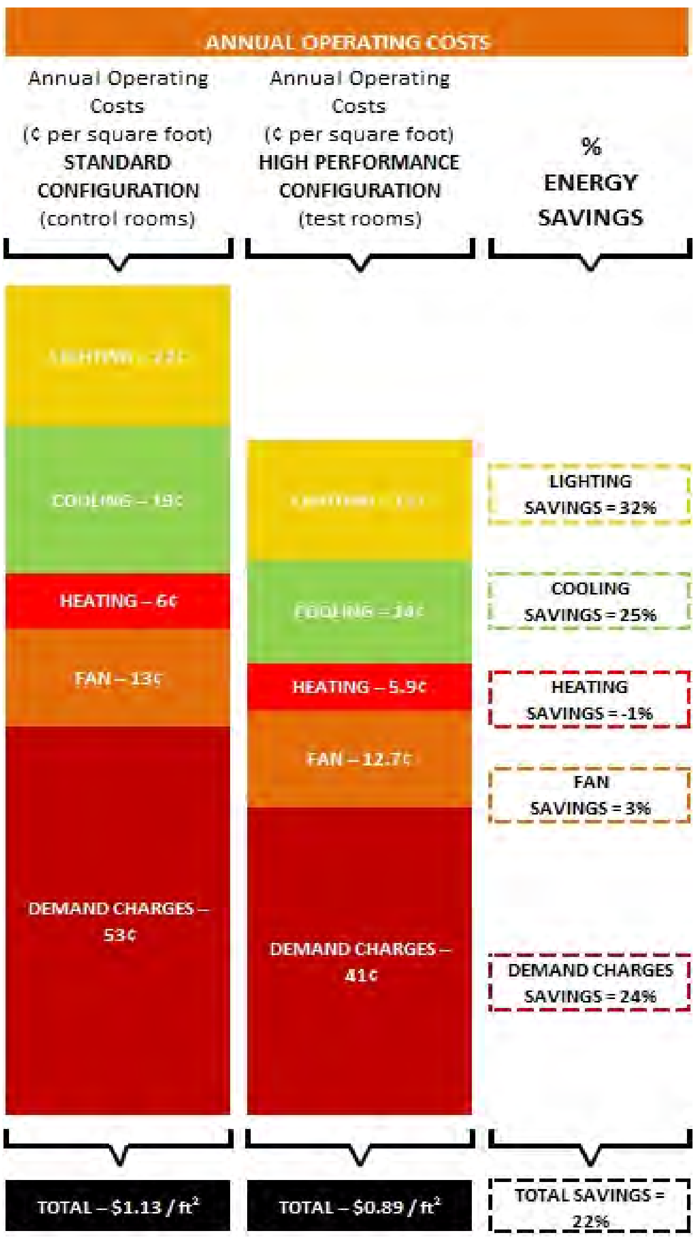
A comparison of energy consumption in the two rooms showed the dramatic impact of daylighting. The room configured to represent proper daylighting techniques

Incentive	Type	Amount Residential	Residential Max	Amount Commerical	Commercial Max
Renewable Energy Systems Tax Credit	Wind, Hydro, Solar	30%	30%	**30%**	**30%**
Renewable Energy Systems Tax Credit (Corporate)	Wind, Hydro, Solar	25%	$2,000	**$0.35 kWh**	**$50,000**
Renenewable Energy Development Incentive	Wind, Hydro, Solar	100%	100%	**100%**	**100%**
Renewable Energy Systems Tax Credit (Personal)	Wind, Hydro, Solar	25%	$2,000	**$0.35 kWh**	**$50,000**
Renewable Energy Sales Tax Exemption	Wind, Hydro, Solar	sales tax	100%	**sales tax**	**100%**
Questar Gas - Homebuilders Solar Assisted Gas Water Heating Rebate Program	Solar Water Heat			**$750**	**$750**
Quest Gas - Residential Solar Assisted Gas Water Heating Rebate Program	Solar Water Heat	$750	$750		
Rocky Mountain Power - Solar Incentive Program	Solar Photo-voltaics	$2 per Watt	$6,000	**$2 per Watt**	**$30,000**

Table 6. - **Section 4.7** - Funding Availability and Programs for Wind, Solar, and Hydro

had a 20% reduction in overall energy consumption even when compared to the use of energy efficiency lighting and cooling. The savings would likely be dramatically higher if compared with rooms that do not currently use energy efficient lighting and HVAC system.[40]

Incorporating daylighting practices into new building design is an economical way to significantly reduce energy consumption with minimal-to-no impact on the overall construction cost. Retrofitting existing buildings for daylighting can become an expensive proposal, however, and skylights or solar tubes are the most feasible way of incorporating daylighting into existing buildings. Skylights are best used in spaces that have no access to windows or are 25 feet or more away from windows. Current technology, however, limits this practice to top-level floors.



Properly designed daylighting has a lower light-to-heat ratio than the most efficient electric lights, filtering out 99% of the solar heat. Careful placement of windows, shading devices and low-transmittance glass make this possible. They provide the optimal amount of light while minimizing glare.

Daylighting has positive impacts both on building efficiency and the productivity of building occupants.

4.8.1 Fiberoptic Daylight

New technologies are developing in the daylighting industry. One such product is currently in the final stages of design. The Energy Dynamics Lab is participating in developing technology that will allow sunlight to be captured and "piped" into a building using fiberoptic cables. This makes it possible to illuminate sub top story floors with natural light.

This leading-edge technology will allow the benefits of natural light while providing them with "the same modularity, flexibility, convenience, and control that electric light does today."[41] Once commercially available, fiberoptic daylight will provide natural light for accent, directional, decorative, deep penetration, or task lighting.

Fiber Optics

4.9 Summary

When speaking of renewable energy, solar is likely the first that many people think about. The presence of solar panels on rooftops and in solar farms is a common and enduring sight. Despite solar technology being available for decades, wide-spread use of solar has been hindered by the high cost of the technology, limits to storage capabilities, appropriate sites to place the panels, opposition by those that oppose the aesthetics, and the time required for maintenance; the primary of these hindrances being the upfront costs and storage capabilities.

Park City has ample solar resources since during the majority of the year the city experiences bright sunny days free from inversion. Winter storms that bring overcast skies are generally short in duration. Extensive and substantial rebates are available to homeowners and businesses which help alleviate the higher cost of solar panel technology. There are substantial local resources that are familiar with local environments, resources, and restrictions.

While the cost of solar technology is currently dropping, it remains important to pay careful attention to the specific application and the proper siting and maintenance of these projects.

Solar is an attractive option for off-grid locations and businesses with high electricity demands. Solar panels are highly visible and for those who find them aesthetically unappealing this is a drawback; for those that can find value – either tangible or intangible – of an environmentally friendly image, it is a benefit.

4.9.1 Recommendations

We recommend that the leaders of Park City be active in their support of changes in Utah state policy that will be more accommodating for solar applications. Changes in the ability to meter or sell back to the utilities could make solar a more attractive proposition from a financial standpoint.

We recommend that all new city buildings incorporate daylighting in their design.

Continued development of the parkcitygreen.org website to include more comprehensive information about solar PV and solar thermal systems is recommended. The solar portions of the site should include information about the importance of proper siting of solar panels, contacts for local vendors and installers, information about city and county codes, and subsidy and rebate information. The message forum on the site could be used to organize a group of residents interested in solar power so that they might collectively approach a vendor for reduced pricing on multiple units.

We encourage the city to support or initiate workshops and working group meetings that will help homeowners and businesses access information that will help them make informed decisions about solar projects.

4.10 Resources

4.10.1 Intermountain Wind and Solar

Based in Woods Cross, Utah, offers active tracking, passive tracking, stationary, and solar thermal systems that they have installed in applications across Northern Utah.

4.10.2 Gardner Engineering Alternative Energy Services LLC

Gardner Engineering Alternative Energy Services, LLC in Ogden, Utah, is a full design and build company that offers active tracking and stationary solar systems. Gardner Engineering is owned by Ken Gardner who is a board member of the Utah Solar Energy Association.

4.10.3 Utah Solar and Alternative Energy

Park City's Utah Solar and Alternative Energy is a distributor and installer for SUNPOWER Corporation and Velux. Utah Solar distributes and installs solar photovoltaic systems, solar thermal heating systems, and passive solar daylighting skylights.

4.10.4 Rocky Mountain Power's Blue Sky Program

The Blue Sky program has been developed to give Rocky Mountain customers an option to invest in renewable energy technology. For $1.95 Rocky Mountain customers can purchase 100 kilowatt-hour blocks of energy. Although customers may not be using energy generated from renewable energy, the money from the Blue Sky Program helps develop small scale renewable energy projects.

These renewable energy projects reduce the overall carbon impact of power generation in the intermountain west. The majority of the renewable energy projects funded with revenue from the Blue Sky Program are wind and solar. Other renewable projects considered by the Blue Sky Program are biomass and micro hydro.

More than 490 million kilowatt-hours of energy were supported by Blue Sky customers through the funding of different projects throughout the region. The Blue Sky Program has funded numerous projects in Park City.

4.10.4.1 Park City Historical Society and Museum

Park City installed a 5.04 kW solar array on the roof of the Park City Historical Society and Museum. The renovation and design of this building make it a LEED certified building and the first photovoltaic system in downtown Park City. The solar project will be incorporated into the Museum exhibit exploring past mining technology and energy production. The project cost was $45,000 and was primarily financed by the Rocky Mountain Blue Sky Program.

4.10.4.2 Park City Ice Arena and Sports Complex

A 5.4 kW photovoltaic system was installed in September 2009 on the roof of the Park City Ice Arena and Sports Complex by Utah Solar and Alternative Energy and Johnson Controls, Inc. The project cost was $47,000 and was financed by the Rocky Mountain Blue Sky Program.

4.10.4.3 Park City Parks & Trails - Creekside Park Five kW Solar Array

The new Creekside Park is a multi-seasonal playground featuring a family picnic area, bicycle dirt jump park, walking trail, and sledding hill. The park will have a new restroom facility that will be equipped with a roof top solar array and educational display showing real time power generation to park visitors. The solar powered restroom facility is meant to be an educational piece to teach the public the importance of renewable and sustainable energy solutions. Estimated completion date for this project is spring 2010.[42]

5. BioDigestion of Biomass

5.1 Overview

The purpose of this portion of the study was to determine if waste products from dairy operations in Summit County could provide a renewable and sustainable source of energy – either as electricity for dairy operations, or as biodiesel or natural gas to fuel city vehicles or heavy equipment at resort operations. The study assumed that animal waste from four of the dairies in Summit County could be transported and combined at a single location for biodigestion into energy with a coproduct of high-quality fertilizer. Biodigestion of manure into energy has been a successful operation in several areas across the west, including Utah.

While anaerobic digestion of manure can produce a substantial amount of methane, researchers at agricultural schools such as Utah State University have shown that adding components such as algae or brown grease to the manure slurry can double or even triple methane production.

This study looked closely at a scenario in which algae could be used as an additive to dairy waste to increase the output of methane. In other communities along the Wasatch Front, high levels of phosphorous and nitrogen in their wastewater effluent will require remediation pending EPA-mandated reductions that are expected in the near term. Various strains of algae are efficient consumers of phosphorous, and the use of algae for bioremediation of high-nutrient effluent is a burgeoning field.

With this in mind, the original concept for biodigestion of dairy waste in Summit County included the use of algae to remedy the county's wastewater and then using the algae in the biodigestion of manure to increase methane yield. The concept assumed that the effluent from the Snyderville wastewater treatment plant would be similar to effluent of other wastewater treatment plants across the front and that ample nitrogen and phosphorous would be available for algae growth.

Initial investigations quickly showed that Summit County is one of the few counties on the front that does not grapple with excess phosphorous and nitrogen in their wastewater effluent. Given this, growing algae for the single purpose of increasing yield in a biodigestion process made little sense.

Other additives to the dairy waste are also capable of increasing methane production; one of these being brown grease – the waste grease that is captured in restaurant grease traps. Brown grease has been shown to triple methane production and with the ample number of restaurants in Park City, the financial assessment includes the addition of brown grease to the dairy waste to optimize methane output.

5.2 BioDigestion and Coproducts

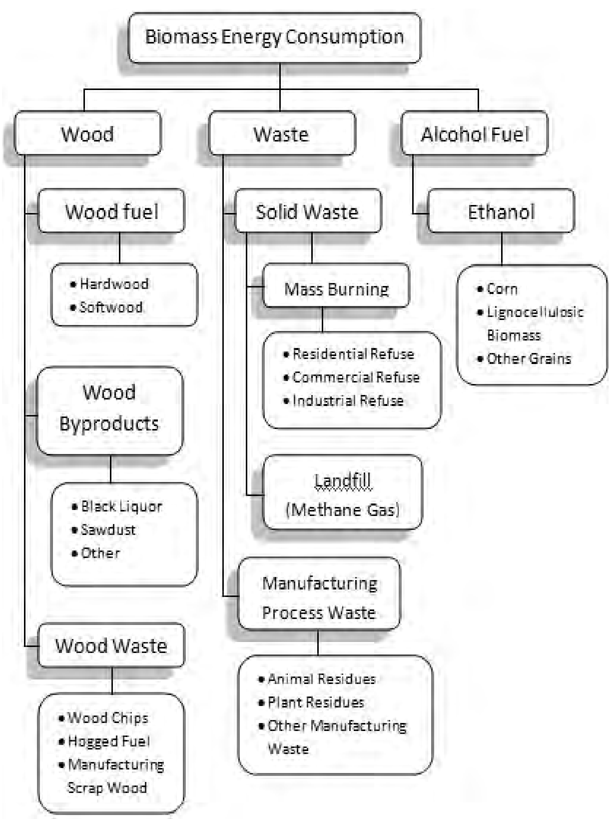
Biomass is a renewable source of carbon-based organic matter. Wood, dairy waste, and alcohol fuels are common sources of biomass. Through various methods, biomass can be turned into various forms of renewable energy. Biogas and biofuels are two possible derivatives of biomass.[43] Biomass can be converted by thermal conversion, or ortorrefaction, where heat is used to process biomass into forms of more efficient energy;[44] chemically treated by a process known as chemical conversion to derive biogas and other coproduct; or biochemical conversion, which breaks down the molecules that form the biomass by using a combination of biological factors. Anaerobic digestion, fermentation, and composting are all processes from which energy can be derived from biomass.

Liquid biofuels, either bioethanol or biodiesel, can be derived from plant matter. Bioethanol is produced by fermenting the sugars of plants, normally from sugar or starch crops. Cellulosic biomass is derived from plant materials such as algae and grasses. Through the bioreaction (digestion) process it can be turned into a bioethanol fuel. Biodiesel is made by chemically breaking down vegetable oils or animal fat in order to produce a fuel.[45]

A methane fuel, known as biogas which is similar in composition to natural gas, is produced by the breakdown of organic matter in the absence of oxygen. The composition of biogas produced from materials such as algae, manure, sewage, municipal waste, and green waste is primarily methane with small amounts of carbon dioxide.[46] Biogas from woody feed stocks is composed primarily of nitrogen, hydrogen, and carbon monoxide with trace amounts of methane.

5.3 Anaerobic Digestion

Utah State University has a long history in the basic research of anaerobic digestion and is familiar with northern Utah's climate and altitude. In this study we used technology and expertise developed at USU to analyze the feasibility of energy production through biomass digestion. This study focuses on the potential for using animal waste that could be used to either generate power for a farm, or to be used as a renewable fuel source such as biogas.



From afdc.energy.gov

5.4 Current State-of-the-Art

Researchers from Utah State University formed the spin-out company Andigen LLC, to apply leading-edge basic research in anaerobic digestion for use in real-world applications. Andigen has developed anaerobic digestion systems for dairy farms in the state of Utah and has a working knowledge of the start-up equipment required, as well as the operating and maintenance costs for biogas production through anaerobic digestion. Methane gas is the primary product of anaerobic digestion and subsequent to the removal of contaminant gases,[47] the biogas can be compressed for use in any vehicle or machinery that has an engine dedicated to compressed natural gas fuel.[48] Biofuel can also be derived through anaerobic digestion, but requires a slightly different process.

5.4.1 Biogas

Andigen LLC, spun out from the USU technology commercialization office in 2003,[49] designs and integrates large, anaerobic digestion capabilities for processing animal and food waste. Andigen's induced blanket reactor's (IBR) have a five-day processing time; significantly less than other commercially available anaerobic digestion systems. Additionally, Andigen systems are fully automated.

Andigen systems were originally designed for the treatment of agricultural waste, however, their systems can process many other forms of biomass, including: whey from cheese processing; algae; brown grease; and other green biomass compounds. While three primary biomass constituents were investigated as feedstock for biodigestion in this study; dairy waste, brown grease, and algae,[51] only dairy waste and brown grease were considered feasible for use in this type of project in Summit County.

The National Renewable Energy Laboratory uses the term "brown grease" to include trap grease, sewage grease, and black grease. One of the primary producers of brown grease is restaurants. In commercial kitchens, sinks are equipped with a grease trap which

Photos courtesy of Andigen [50]

slows the flow of hot water, allowing it to cool and separating it from the oil before it continues into the sewer system. The remaining waste grease is trapped in a tank. Service companies that provide maintenance of these traps, have several options for disposing of the grease including: dumping the grease in a landfill; burning the grease; composting the grease; and anaerobic digestion of the grease.[52]

Ongoing research at Utah State and Andigen LLC indicates that adding even small amounts (roughly ten percent of total biomass) of brown grease to dairy waste in the digestion process can increase the production of methane nearly threefold. Anaerobic digestion of biomass is heavily dependent on pH. Waste grease can act as a buffer for very acidic or basic biomass, allowing more efficient microbial digestion of the biomass. Addition of algae to the biodigestion process could theoretically double the methane production.

5.5 Resources and Challenges

The Ag offices of Summit County estimate that among the six dairies in the county there are a combined 750 dairy cows. Biodigestion projects with fewer cows have been successful but they were heavily subsidized.[53] Other operations that have been financially successful in the west have dairies with cows numbering in the thousands. Due to length of payback, the future of these dairies is an important factor in considering the feasibility of this project. Park City's efforts towards a 'buy local' approach to a sustainable community, could strengthen the future health of the Summit County dairies. Geographic distance of the dairies considered for this project is one of the greatest challenges to this project as the cost of transporting manure to a central location is high.

There are several forms of biomass other than dairy waste that can be used to generate biogas energy including brown grease, waste from ethanol production, whey used in the production of dairy products, algae, and other green waste. The primary form of biomass that would be feasible for use in Park City in addition to dairy waste is brown grease.[54]

Despite the small size of the community, Park City has a large number of restaurants that support the high annual influx of tourists. The more than 100 restaurants in the area generate a substantial amount of waste grease. At present, this grease is already recycled and is currently being converted to biodiesel. While it seems feasible that some portion of the waste grease could be used for biodigestion activities instead, the cost of transporting the grease to a second location will be burdened by the biodigestion project.

5.5.1 Transportation Costs

The primary challenge facing a biodigestion project near Park City is transportation distance. This includes the distance between the dairies, the distance required to transport brown grease from Park City to the project site, and then the need to transport the fuel back to the city for use. These transportation costs will greatly increase the payback time for a project of this magnitude.

5.5.2 Biogas Performance

While the concept of using sustainable and renewable biogas from waste materials is an appealing one, there are several factors to consider, including the cost of processing and transporting the biogas. There are also questions about the performance of biogas in general and in cold temperatures in particular.

The Deer Valley Ski Resort uses a mixture of 20% biodiesel during the summer and 5% in the winter in the machinery that operates at the resorts. The resort previously looked into using natural gas at their facilities but found areas of concern that are illustrative of the concerns of most end users that have considered biogas.

The cost of converting heavy machinery for gas use and the expense of constructing a filling station is restrictive. Additionally, equipment operators have concerns about the performance of natural gas in heavy machinery. While current technology has greatly improved the performance of natural gas engines, concerns about the lack of experience of machinery operators with less robust technology will be difficult to dispel.

Chris Anderson, who is responsible for maintenance of the machinery at the resort, indicates that natural gas decreases the power of converted engines. For example, an 800 HP engine would be decreased to 720 HP with a conversion from biodiesel to natural gas.[55] Given the resorts' need for top performance, the 65% performance value of biogas would be considered unsuitable for most applications. The reliability of biogas performance in cold temperatures is another noted concern.

5.6 Market

While our findings indicate that a biodigestion project spearheaded by the city has limited returns, it's useful to look at the potential market for products from a biomass biodigestion project. We identified several users for products from a biodigestion project. The dairies themselves could convert the gas to electricity and use it for operations on the farm, or the biogas could be used directly in machinery with natural gas fuel capabilities. Additional processing of the biogas to a refined gas could be used in natural gas vehicles; either by Park City's municipal fleet, one of the several resorts, or for resale to owners of CNG vehicles. Lastly, the remaining waste from the biodigestion process is in the form of a high quality fertilizer with lower phosphorous and nitrogen levels. As these nutrients are the primary concern in wastewater effluent along that Wasatch Front, there exists a market for this natural fertilizer in areas where high nutrient levels in wastewater effluent is a concern.

5.7 Cost

We focused our analysis on a biodigester fed with waste from 750 cows and supplemented with 10% brown grease. The following tables highlight our estimates of start-up costs as well as operating revenue and expenses for this operation. The revenue estimates are based off the sale of the biogas at commercial prices from September 2009.

Start-Up Costs

Product	Cost
Digester	$750,000
Scrubber	$112,000
Total	**$862,000**

Annual Biogas Revenue

Cows:	750
Bovine Biogas Production:	75 cu. ft. / day
Biogas Sale Price:	$9 per 1,000 cu. ft.
Biogas Efficiency Factor:	65%
Brown Grease Multiplier:	3x
Downtime / Loss	3%
Total Annual Revenue:	**$350,000**

Operating Income

Expenses	
Transportation & Vehicle Leasing	$150,000
Labor / Management	$100,000
Maintenance	$25,000
Utilities	$40,000
Total Operating Costs	$315,000
Revenue	$350,000
Net Income	***$35,000***

5.8 Return on Investment

The simple payback for the facility, including a scrubber, is approximately 25 years. Over the 20-year useful life of the equipment, our estimates for ROI range from 5-10%, depending on assumptions of cost/revenue inflation. The economics of this project suffer a significant negative impact from the transportation required to aggregate biomass from several dairies into a single location.

5.9 Funding Availability and Programs

Grants can be acquired through the United States Department of Agriculture. One such grant was acquired at Utah State University for the implementation of an anaerobic digester on a University farm. The grant program used was Small Business and Industry Grants.[56]

The organization Focus on Energy also aids municipalities in finding financing for biomass combustion as well as biogas and digesters. Though Focus on Energy's services are specifically offered to Wisconsin residents. They can be contacted at 1-800-762-7077.

The primary source for grants in the State of Utah is through the U.S. Department of Agriculture, Utah Rural Development Program, which offers assistance in Guaranteed Loan Programs, Intermediary Relending Programs, Rural Economic Development Loan and Grant Programs, Rural Business Enterprise Grant Programs, Rural Business Opportunity Grants, and Value-Added Agricultural Producer Grant Programs.

5.10 Case Studies of the Biomass Market

5.10.1 Wanner Pride n' Joy Dairy, Narvon, Pennsylvania

The Wanner Pride n' Joy Dairy is a 650-head dairy that produces a tanker truck of milk every 24 hours. Located in the heart of Pennsylvania Dutch country, the Wanners also operate a five-bedroom guest house on their working farm. In 2005, with the aid of a $367,412 grant sponsored by the Lancaster County Conservation District, the dairy installed an anaerobic biodigestion project to process manure from their dairy. The biodigester produces 967,000 kWh annually which is sufficient to meet the power demands for the entire farm as well as for those of a small community of approximately 100 homes. Beyond generating revenue, biodigestion of the manure also reduces the strong odor on the farm and creates a high-quality fertilizer that they use in their farming operations.

The entire project cost the farm $900,000. With the revenue generated and the grant from the county's conservation district, the Wanner's expect a payback of approximately eight years. Their project has been featured on CNN, NBC, and the Sundance Channel.

5.10.2 DeRuyter Dairy, Zillah, Washington

In Zillah, Washington, Dan DeRuyter operates the only manure digester in Eastern Washington, which is one of four in the state. DeRuyter project is a good example of a technology success that is losing money due to state policy restrictions.

DeRuyter's dairy has 3,000 cows and in Yakima County, Washington, his and other dairies are considered the primary culprit for nitrate contamination of the counties groundwater. Despite that the EPA has not officially pointed to dairies as the source of the problem, many dairy owners have taken a proactive approach in finding solutions. In 2007, DeRuyter installed a 1.2 megawatt capacity anaerobic digester on his farm at the cost of $3.8 million. At a contracted rate of 6.1 cents per kilowatt hour, DeRuyter's revenue from power sold to Pacific Power should be $1,700 per day, a revenue projection he used when performing the financial analysis for a return on investment for the project.

But a recent tariff that Pacific Power proposed, and was ultimately accepted, requires them to pay the contracted rate for only 1.0 megawatt of power. The proposed rate was intended to assure small start-up generators the revenue to cover their costs. For DeRuyter the excess energy production is wasted revenue until the state of Washington sets policies that will force the utility to pay contracted rates for longer periods and to greater levels. It's not an unprecedented policy. In neighboring Oregon, utilities are required to offer longer-term contracts and accept power from generators up to 10 megawatts.[57]

Many states are watching Washington closely as it grapples with the role that the state should play in forcing utilities to include renewable energy sources in their portfolios.

5.10.3 Seattle, Washington

In the population dense Northwest, Seattle is using a different form of biomass to offset its reliance on coal-fired electricity. Seattle transports by rail its many tons of household waste to the Columbia Ridge Landfill in Oregon. In December 2009, Waste Management Northwest began generating electricity from methane gas produced at the Oregon landfill. In January 2010, the City of Seattle announced a contract with Waste Management Northwest and the landfill to purchase all of the 5.78 megawatts of electricity being produced at the plant. Though the purchase of the methane generated electricity is only sufficient to power approximately 5,600 homes, the contract has enabled Seattle to stay at the forefront of the sustainability movement and continue its efforts towards providing reliable, renewable, and environmentally responsible power. The utility is the ninth largest in the U.S. and has the lowest customer rates of any urban utility. Seattle City Light achieved carbon neutral status in 2005 and was the first electric utility in the nation to do so.[58] Though the city is being charged $2.5 million annually by Waste Management Northwest, Seattle has been able to keep prices low for their utility users.[59]

5.11 Summary

As some of the case studies show, the principal concept of biodigesting waste materials as a source of renewable energy and coproducts can be a financially viable undertaking with the right circumstances. The scenario we investigated for Park City required too many costly transportation steps to prove prudent for the city at this time.

Still, the use of biogas from waste materials remains a technology that is quickly becoming more refined and affordable as basic science from universities and research and development laboratories is being applied to real-world applications. We anticipate that the technologies will develop at a rapid pace in the near future as there remains a strong interest in using various waste products to offset our use of traditional energy.

In Utah alone, academic institutions such as USU and privately held companies such as Ceramatec, are leading the way in technology related to biodigestion and biogas refinement. These technologies are expected to ultimately increase the efficiency of methane production and reduce the cost of biogas refinement to a form that will compete with natural gas resources.

Additionally, a biodigestion project at a single dairy was not closely examined and could prove feasible upon closer examination. Sustainable energy development in rural communities is receiving a growing interest from lawmakers and monies are flowing in for grants in rural energy development. As Park City continues its 'buy local' efforts, proactive dairy owner are likely to see the benefits of sustainable practices and biodigestion projects may pique their interest.

5.11.1 Recommendations

We recommend that the city engage the dairies to assess their interest in a biodigestion project. While it is unlikely that in the near term a biodigestion project in the county could directly benefit Park City, the continued health of small business owners in Summit County is important for many of the city's sustainable energy goals.

Several rural energy development grants are currently available and more are likely to be available in the future. A biodigestion project at one of the dairies that could offset the dairy's power demands could bring media attention to Summit County.

The above recommendations assume the continued existence and health of dairy farming operations in Summit County. We encourage the city to push forward with their efforts towards encouraging residents to buy local for a sustainable city. Those efforts will help ensure the continued prosperity of Summit County dairy operations.

6. Transition of Park City Bus Fleet to Natural Gas

6.1 Overview

The state of Utah lays claim to some of the lowest natural gas prices in the entire nation. State-mandated price controls have been in effect for several years and are expected to continue throughout at least the next ten years. Natural gas is also a low emissions alternative to diesel and gasoline and can help communities lower their greenhouse gas emissions.

With the thousands of annual miles that transit fleets log, converting a fleet to natural gas could be an effective way for municipalities to save money while reducing emissions and improving air quality.

This study looked specifically at converting or transitioning the Park City bus fleet from biodiesel to natural gas. It evaluated the feasibility of the project by looking at the costs associated with replacing or converting the fleet, installation of a filling station, and upgrades to the maintenance facility. It also considered Park City's actual bus maintenance and replacement schedule in conducting the study.

Initial inquiries quickly made it clear that converting existing vehicles to natural gas would be a costly endeavor and therefore the study focuses on a scenario in which the biodiesel buses in the Park City fleet would be phased out in favor of natural gas buses on the city's regular bus replacement schedule.

Description	"Clean Diesel"	Diesel-Electric	CNG[1]	CNG[2]
Purchase Price (40' Bus)	$ 340,000	$ 495,000	$ 400,000	$ 400,000
Net Cost w FTA Co-funding @ 80/83/83%	$ 68,000	$ 84,150	$ 68,000	$ 68,000
Yearly DGE Use based on 4.0/5.0/3.6 mpg	11,250	9,000	12,500	12,500
Fuel Cost/DGE - Non-taxed	$ 3.80	$ 3.80	$ 2.05	$ 2.45
Yearly Fuel Cost (before Fed Tax Credit)	$ 42,750	$ 34,200	$ 25,625	$ 30,625
Federal Fuel Tax Credit ($0.55/DGE)	—	—	$ (6,875)	$ (6,875)
Net Yearly Fuel Cost	$ 42,750	$ 34,200	$ 18 750	$ 23,750
Fuel Savings/Yr Compared to Clean Diesel:	—	$ 8,550	$ 24,000	$ 19,000
Fuel Savings/Yr Compared to D-E Hybrid	$ (8,550)	—	$ 15,450	$ 10,450
Battery Replacement Cost: 12-yr bus life:	—	$ 30-60K	—	—
12-yr life-cycle cost (net purch. + fuel):	$ 581,000	$ 540,000	$ 293,000	$ 353,000

Notes:

[1] Larger throughput station with better operational economies of scale: DGE = ~1.1 GGE; CNG price @ $2.05/DGE based on $9.00/Mcf = $1.24/DGE; LDC delivery to meter = $.15/DGE; Cost of compression = $.18/DGE; Station maintenance = $.18/DGE; Station capital investment/equipment = $.30/DGE

[2] Smaller throughput station with lesser operational economies of scale: DGE = ~1.1 GGE; CNG price @ $2.45/DGE based on $9.00/Mcf = $1.24/DGE; LDC delivery to meter = $.15/DGE; Cost of compression = $.26/DGE; Station maintenance = $.23/DGE; Station capital investment/equipment = $.57/DGE

Chart courtesy of NGV America.org

6.1.1 Natural Gas Fuel

Natural gas is an alternative to traditional fuels such as diesel and gasoline, and its use is becoming more widespread in the Unites States. Compressed natural gas, or CNG, is natural gas usually compressed to greater than 3,100 pounds per inch. Advantages of natural gas are that it is a cleaner burning fuel, costs less, and has a greater domestic availability. Worldwide, there are over 8 million vehicles powered by natural gas on the roads today. While US interest in natural gas vehicles has increased in reaction to increasing gasoline prices and a nation-wide interest in reducing dependence on foreign oil, only 6% of the vehicles on US roads are natural gas vehicles.

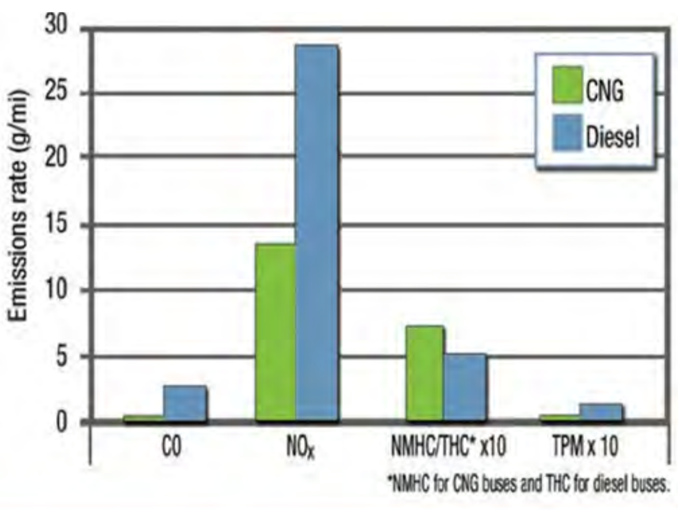
As cities and states across the US seek answers for increasing air quality problems and strive to reduce their contribution to greenhouse gas emissions, natural gas vehicles are increasingly being considered for mass transit and municipal fleets. Nationally there are more than 11,000 natural gas buses in service at 132 transit agencies and over the course of the past decade, more than 20 percent of new bus orders have been for natural gas buses.[60]

6.1.2 Clean Burning Fuel

Natural gas has long had a reputation for being one of the cleanest fuels in terms of emissions for transportation. Despite recent advances to diesel and gasoline fuels, testing shows that emissions of greenhouse gases are reduced in vehicles using CNG over diesel or gasoline.

For municipalities, this could mean big reductions in emissions and improvements to air quality when considering the in-use hours of their bus fleets. The results of a 2005 study conducted by the Washington Metropolitan Transit Authority for the Department of Energy, found that on average CNG buses reduced NOx emissions by 53%, total particulate matter (TPM) by 85%, and carbon monoxide (CO) by 89% compared with buses fueled by diesel.[61]

According to the Energy Information Administration (EIA) natural gas must go through a refinement or processing before it can be transported by pipeline for use in energy applications. The following are requirements that must be met before it is transported and consumed.[62]



Graphic courtesy of U.S. Department of Energy

- The heat content of natural gas must be within a specified range in British thermal units, generally 985 to 1085 per cubic foot.
- The hydrocarbon dew point of the gas must be sufficiently high that the gas wil not liquefy in pipelines.
- The gas must be free of compounds, such as hydrogen sulfide or carbon dioxide, that corrode pipelines
- Finally, the gas must be free of small particles and moisture

6.1.3 Fuel Costs

While fuel prices are notorious for their fluctuations, making reasonable assessments of operating costs into the future complicated, CNG currently costs significantly less than diesel. The National Institute of Standards and Technology has introduced the gasoline gallon equivalent (GGE) unit of measure to relate alternative fuels to gasoline. A GGE is the amount of alternative fuel it takes to equal the energy content of one liquid gallon of gasoline.[63]

The average price of CNG in Utah for the past three years is $0.76/gge compared to $2.71/gge for the biodiesel B-20 blend that is currently being used in Park City transit buses. This represents an approximate 70 percent decrease in fuel costs from converting from Biodiesel B-20 to CNG.[64] Utah municipalities considering vehicle conversions are currently at an advantage over other states, as price controls have positioned Utah with some of the lowest CNG prices in the nation[65] and are expected to remain so throughout the next decade.[66]

6.1.4 Domestic Supply

Natural gas prices are projected to remain stable over the coming years, even with accelerated demand. The Potential Gas Committee recently reported that the United States possesses a total natural gas resource base of 1,836 trillion cubic feet (Tcf) and a total available future supply of 2,074 Tcf. This equals about 100 years of supply as Americans consume an average of 22 Tcf of natural gas per year.[67] Looking into the future, advances in the production and refinement of biogas – a form of natural gas derived from biomass – will provide a renewable and sustainable supply of natural gas.

6.2 Current State-of-the-Art

6.2.1 Engine and Vehicle Technology

Cummins is the largest manufacturer of diesel and natural gas engines of greater than 200 hp. The diesel engine is a heavier duty engine designed for industrial, automotive and truck applications. A diesel engine takes in air at the beginning of the cycle, compresses it and then injects fuel into that compressed air. Diesel engines operate with compression ignition in which the heat of the compressed air lights the fuel spontaneously, eliminating the need for spark plugs. The compression of fuel and air is at a much higher compression ratio resulting in better efficiency and higher power.

The natural gas engine manufactured by Cummins is based upon the diesel platform. Although spark ignited much like a gasoline engine, the natural gas engine operates with much leaner air/fuel mixture. This means a significant reduction in emissions of the natural gas engine over diesel, while still conserving the diesel-like torque needed for the heavy duty applications required of buses, large trucks, and other heavy equipment. The main differences between a traditional diesel engine and a CNG engine are that the piston and ring pack, and the cylinder head and camshaft, require optimization specific to the use of natural gas.

Natural gas engines have the advantage of a spark ignition in that they run quieter than a diesel engine. The scheduled maintenance intervals and lifetime to rebuild are still similar to those of diesel engines.

Cummins claims a strong commitment to corporate responsibility and an integral part of their vision is to ensure that the development of their products leads to a cleaner and healthier environment. A new combustion system developed by Cummins is the stoichiometric combustion system. Previous lean-burning systems in which the air content was higher than stoichiometric caused higher emissions. Cummins' newer technology burns at a net zero mix of fuel to air. The new ISL G natural gas engine is a two-valve engine, compared to the 4-valve diesel engine, and is up to 10db quieter than a diesel. Importantly, it is also the only 2010 compliant EPA HD engine available today and therefore is the only engine that was considered in this study. This modern technology provides more torque at idle, more time at peak torque, improved fuel economy, and lower methane emissions, addressing several shortcoming of previous natural gas engines.

The fuel mileage of any vehicle is dependent on gearing, transmission, and vehicle application. Typically, a spark ignited CNG engine will have lower fuel economy than its diesel counterpart. This fuel efficiency is offset by lower natural gas fueling costs, resulting in lower fuel cost per mile.

In April 2003, under a competitive solicitation the National Renewable Energy Laboratory (NREL) awarded Cummins Westport Inc. an advanced development subcontract to develop an 8.9 L natural gas engine capable of meeting increased power ratings and reduced exhaust emissions. According to NREL, the power target was achieved, and torque and emissions targets were surpassed. The final ratings were 320 hp and 1,000 ft-lb peak torque.[68,69]

The range of a CNG powered bus generally is less than that of diesel powered buses due to the lower energy content of natural gas, requiring more frequent down time for fueling. Extra fuel tanks can increase range, but the additional weight may displace payload capacity. Natural gas vehicle horsepower, acceleration, and cruise speed are comparable with those of an equivalent conventionally fueled vehicle.[70]

6.2.2 Fueling Facility Impacts

Refueling of NGVs is easier and safer than refueling with diesel. The refueling nozzle simply connects to the receptacle on the bus and the tanks are ready to fill. When the tank is full, the dispenser automatically shuts off and is ready to be disconnected.

There are various options for refueling systems in a depot-based station. Based on the operations of the Park City bus fleet, a time fill system is recommended. The advantage of a time fill system is that the buses can be fueled overnight where the fuel is fed directly from the compressor to the buses' onboard storage cylinders (tanks). The system also has the capacity to top off a small number of buses throughout the day if needed.

Jeff Lucero, Project Manager at Vocational Energy CNG Fuel Systems, recommends two 200 SCFM compressors for Park City's fleet of 29 buses. This provides enough capacity to fill the fleet during off hours and allows for a back up in the case that one compressor should have a maintenance issue. Beyond this, a public fueling station, located blocks from the Park City public works office can produce 60 GGE of CNG per hour with a fast fill capability that could conveniently be used if needed.

6.2.3 Maintenance Garage Impacts

Transitioning vehicles in the Park City fleet will require modifications to the maintenance garages. The primary objective for modifying maintenance garages for CNG vehicles is to ensure that ventilation rates are high enough to rapidly disperse and dilute potential leaks. A basic ventilation rate that is the equivalent of exchanging the volume of air in the room six times over one hour is advised. Methane leak detectors should be installed in or above the service bays. Upon detection of a leak, the ventilation rate is increased twofold to twelve air exchanges per hour, and all doors are opened. CNG vapors are lighter than air and will eventually accumulate near the ceiling. Roof ventilators are desirable to dissipate any natural gas that may be released in the maintenance area. To mitigate fire hazards, a fail-safe backup plan is needed in the event of a power outage. This could be accomplished simply by opening all the garage doors. For specific requirements on maintenance facilities using CNG please see NFPA 88B - Standard for Repair Garages -1997 and NFPA 52 - Compressed Natural Gas Vehicular Fuel Systems Code – 2000.[71]

6.2.4 Safety

In general, NGVs are safer than vehicles powered by conventional fuels. The safety features associated with NGVs are magnified for delivery and long-haul trucks because of these vehicles' higher-than-average operation times. Should an accident occur, fuel ignition is less likely based on the following characteristics of natural gas and natural gas vehicles:

1. Should a collision occur, fuel is less likely to escape an NGV as natural gas fuel cylinders are significantly stronger than conventional fuel tanks.[72]
2. When natural gas does escape, the gas dissipates into the air instead of pooling on the ground like diesel and gasoline.
3. Natural gas has a higher auto-ignition temperature than either gasoline or diesel (1,076 degrees Fahrenheit for natural gas, which is greater than 536 degrees Fahrenheit for gasoline and 494 degrees Fahrenheit for diesel).[73]
4. The higher ignition temperature, combined with natural gas' narrow range of flammability (natural gas will not ignite in open air concentrations below approximately 5 percent or above 15 percent), means that the accidental ignition of natural gas is much less likely than the accidental ignition of diesel or gasoline.[74]
5. Natural gas does not leak into the groundwater.[75]

6.2.5 Conversion Kit Manufactures and Regional NGV Retrofitters

6.2.5.1 Cummins Westport

The Cummins Westport CNG bus engine is the only HD engine currently compliant with EPA standards for 2010. All of the buses below feature the 2010 compliant CWI ISL-G 8.9 L engine shown below. While these kits are available, we do not consider converting any of the Park City bus fleet due to the relatively high costs of conversion kits in comparison to the purchase of a new bus given the current federal and state subsidies.

Graphic courtesy of U.S. Department of Energy

CNS Engine (bus)
8.9 ISL-G 250-320
Website: http://www.cumminswestport.com
Sales: 604.718.8384

6.3 Resources and Challenges

Park City currently has an advantage compared to cities in other states when implementing CNG as an alternative fuel in any application, as Utah's natural gas prices are one of the lowest in the United States. Park City also has a bus fleet of varying ages that allows a staggered replacement of the existing fleet. Some community support is also apparent as fleet manager Darin Davis has had several requests to consider natural gas conversions of the fleet.

The altitude at which Park City is positioned and its annual temperature ranges have been expressed as a concern for considering a CNG bus fleet, according to Deputy Public Works Director Kent Cashel.[76] Park City's fleet is an integral part of the city's infrastructure in transporting huge numbers of tourists to the area's ski resorts, lodging and attractions throughout the year. The reliability of the fleet to operate on time without additional maintenance is, understandably, paramount to managers of the fleet.

Transit authorities in cities with climates similar to that of Park City have stated that colder temperatures and higher altitudes present no performance obstacles to CNG buses.[77] In an attempt to address these concerns, the authors of this report have identified several areas with similar geographic attributes and summarized their projects in the case studies below.

6.4 Costs

Converting the Park City bus fleet to CNG would require expenditures in three main areas. First, Park City would need to build a CNG pumping station (as described above). Next, minor renovations would be needed to the maintenance facility in order to guarantee the required ventilation rates. Finally, the buses themselves would need to be replaced or converted to run on CNG.

While CNG vehicle conversions are routine, reliable, and a cost effective solution for many applications, the current government subsidies for alternative fuel vehicles bring the net cost of purchasing a new CNG vehicle very close to the cost of converting existing Park City buses to CNG engines. Given this, we have developed a scenario in which existing buses running on biodiesel are replaced with CNG buses on the city's existing replacement schedule which replaces buses at the end of their 12-year operational lifetime.

The cost of establishing a CNG fueling depot initially seems substantial. Including the necessary renovations to the maintenance facility, the set-up cost is estimated at just under $1.2M. However, current federal subsidies could cover 80% of this expense,[78] leaving Park City's share at approximately $240,000.

To replace buses on the schedule shown below, a new biodiesel bus would cost the city approximately $340,000; $60,000 less than an equivalent bus equipped to run on CNG. Again, federal subsidies would currently cover up to 100% of the additional expense, as well as 80% of the base cost.[79] This leaves a required contribution from Park City of approximately $68,000 per CNG bus.

Reduced fuel costs allow a CNG bus fleet to operate at a substantially lower cost than an otherwise identical fleet of biodiesel-fueled buses. At present, the price of a gallon gas equivalent (GGE) of CNG is less than half the cost of an energy-equivalent amount of biodiesel. For Park City, the savings would eventually reach close to $200,000 annually. Given the current federal subsidies and lower operating costs, transitioning Park City's next generation of buses to CNG fueled buses is a financially attractive proposition. Despite the initial outlay for equipment purchases, government subsidies help the project realize an internal rate of return (IRR) of over 12%.

The bus replacement schedule is shown below, along with the relative cash flow requirements of CNG versus biodiesel buses

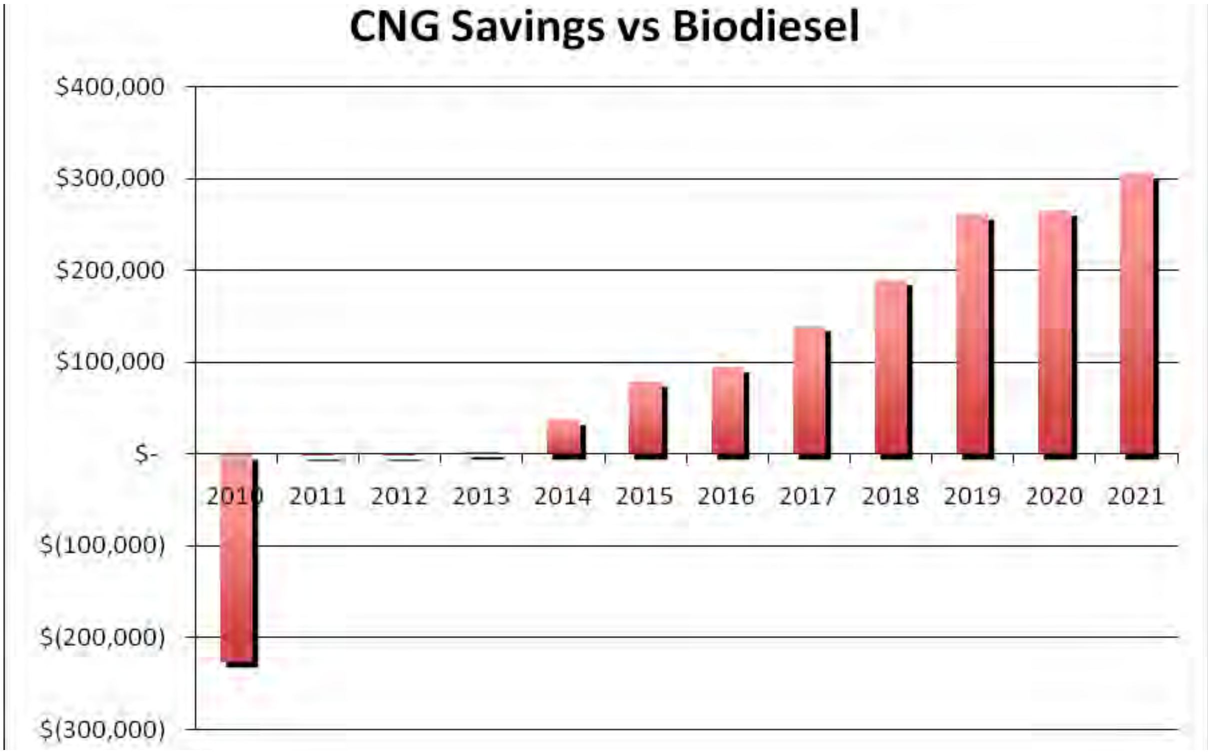
Assumptions:

29 bus fleet
30,000 miles per bus annually
No change in maintenance costs between the biodiesel and CNG
Average fuel prices in Utah from 2007-2009
Questar Gas: If price controls are lifted in Utah, CNG prices will not rise more than 20-30%
Capital Costs - $1.2 million
Station Maintenance - $24,500 annually
Compressor Electricity Costs - $17,600 annually
Discount Rate – 7%

Model Year	Number of Buses to be Replaced
2010	2
2011	0
2012	0
2013	3
2014	4
2015	1
2016	4
2017	4
2018	7
2019	0
2020	4
2021	0

Below is a comparison showing the cost savings of natural gas powered buses versus biodiesel. Based on this model CNG prices would have to reach close to $2.00/gge for biodiesel and natural gas buses to reach a similar life-cycle cost.

Description	Biodiesel	CNG
Purchase Price (40' Bus)	**$340,000**	$400,000
Net Cost w FTA Co-funding @ 80/83%	**$68,000**	$68,000
Yearly GGE Use based on 4/3.6 mpg	**7500**	8333
Fuel Cost/GGE	**$2.73**	$0.76
30% increase in CNG fuel cost added		$0.99
Yearly Fuel Cost	**$20,475**	$8,233
12-yr life-cycle cost (net purch. + fuel)	**$230,627**	$157,959



6.5 Funding Availability and Programs

The nation's current pursuit of solutions that can address both reliance on foreign oil and the greenhouse gas emissions that may contribute to global climate change, have opened a number of government and state programs that make natural gas vehicles an attractive avenue for reducing both costs and carbon emissions. While there is no guarantee that these programs and subsidies will remain available over the long term, the continued advancement of technology relating to alternative fuels and the nation's leaning towards more sustainable and renewable energy sources, give an indication that natural gas vehicles are a viable alternative.

6.5.1 Alternativie Fuel Vehicle Tax Credits

- EPAct Section 1341 (26 USC 30B) includes tax credits for dedicated alternative fuel vehicles (CNG included)
- Applies to vehicles placed in service after January 1, 2006
- Tax credits go to the purchaser of the vehicle
- Tax credit may be taken by seller if the buyer is a tax-exempt entity

6.5.2 Vehicle Purchase Tax Incentives

- An income tax credit to the buyer of a new, dedicated alternative fuel vehicle
- 50% of the incremental cost of the vehicle plus an additional 30% if the vehicle meets certain tighter emission standards
- Credit is effective for vehicles placed in service after December 31, 2005 and set to expire on December 31, 2010; Extensions of this credit are in various bills currently before Congress
- "Conversions" qualify if retrofit was done after December 31, 2005

6.5.3 Motor Fuels Excise Tax Credit

- 50 cent motor fuels excise tax credit is paid to the seller per GGE of CNG
- Credit began October 1, 2006; expiration extended until December 31, 2009; legislation before Congress is expected to extend end date
- Tax credit may be taken as excise tax credit, income tax credit, or direct payment, depending on circumstances

6.5.4 Fuel Station Tax Credit (IRS Form 8911)

- Equal to 30% of cost of alternative refueling equipment placed in service that year, up to $30,000
- Credit may be taken by seller if buyer is tax exempt entity
- Credit is effective on equipment placed in service after December 31, 2005 and was recently extended until December 31, 2010

6.6 Case Studies

6.6.1 Aggie Shuttle, Logan, Utah

The Utah State University bus system, Aggie Shuttle, located in Logan, Utah relies on 9 CNG powered buses to transport students to and from the university. USU sits at the foot of Logan canyon with an altitude of 4,775 feet, and is characterized by very cold winters and hot summers.

Aggie shuttle has been using CNG buses since 1999. Fleet manager Alden Erickson is very pleased with the fleet. He says the buses seem to operate well in Logan's cold climate. They have had some maintenance issues in the past but each new generation of engine has better technology which his drivers experience in performance. Erickson recommends a time-fill fueling station because less air enters the tanks allowing the buses to run for a longer period before refueling. He says with CNG fuel prices around $0.70 gge compared to around $2.60 for diesel, Aggie Shuttle sees significant cost savings and plans to continue the program into the future.[80]

6.6.2 Aggie Shuttle, Logan, Utah

Santa Fe, New Mexico, the largest city in New Mexico and the seat of Santa Fe County, sits at an altitude of 7,260. Annual temperature fluctuations range from an average low of 15° F in January and an average high of 86° F in July.

The City of Santa Fe currently operates 35 CNG-fueled transit style buses that have a combined mileage of over 5 million miles. Fleet and facilities manager, James Dillingham, say the CNG buses are reliable, have cleaner burning engines, require less frequent oil changes, and have lower fuel costs than diesel. The city purchased six new CNG buses in 2008 to replace older models and intends to continue using CNG buses in their fleet.[81]

6.6.3 Salt Lake City International Airport

The Salt Lake City International Airport is one of the largest airports in the west. Eighteen airlines operate from SLC International with daily scheduled departures exceeding 450. The airport is located within the city limits of SLC and is thereby subject to EPA's air quality nonattainment guidelines for particulate matter. The airport's Clean Fuel Program has put into service a fleet of nineteen CNG buses that operate year round, 24 hours a day. The airport fleet also operates 49 light-duty CNG vehicles and three CNG heavy-duty vehicles for its daily operations.

The airport's CNG fueling infrastructure is a combined effort of the U.S. Department of Energy's State Energy Program, Utah Clean Cities, Salt Lake City Corporation, Questar Energy Services, Utah Energy Office, Utah LP Gas, and Utah Hotel & Lodging Association. The fueling facility was positioned to accommodate the airport's CNG fleet as well as private ground transportation providers. It is open 24 hours a day and is also available to the public.[82]

6.7 Summary

Park City's transit system is a high-visibility way of showing the city's commitment to reducing emissions with a project that will also reduce costs to the city. Utah cities are at a distinct advantage when considering natural gas vehicles for their municipal fleet as state mandated price controls are expected to remain in effect for at least the next decade. It is likely that during this upcoming decade biogas, a renewable fuel that can be derived from waste products, will become a readily available and economical alternative to conventional natural gas.

While other vehicle technologies are also moving forward and hybrid-electric, or all electric buses are already available, we believe that there are some advantages to considering natural gas. These buses are still relatively costly and the technology remains at a somewhat nascent stage. Hybrid-electric buses are still higher in emission of greenhouse gases than natural gas, and the traditional method of generating coal-fired electricity is implicated in being a primary contributor of greenhouse gas emissions in the U.S.

Despite that the process of extracting natural gas is also a contributor to greenhouse gases, we believe that a vehicle fleet that is ultimately capable of using biogas, will be an economical alternative while providing an elegant solution in using biogas produced from waste materials.

6.7.1 Recommendations

In this report we have described a scenario in which the city could minimize the impacts of the upfront costs required to convert their bus fleet to natural gas. We recommend a phased approach to the transition of the city's fleet.

We suggest purchasing a single bus on the city's regular bus replacement schedule and then conducting a 6-month pilot program that will run over the winter months. This will allow drivers and maintenance personnel to familiarize themselves with the bus and provide input on performance and maintenance issues. The costs of installing a fueling facility will not be necessary during this phase of the project, as the local Top Stop station is a natural gas provider and the fueling bay will accommodate a city bus.

We recommend that a small public awareness campaign be conducted during the pilot project that will inform both residents and tourists of the city's efforts towards reducing both costs and emissions. The campaign could include signage on the NG bus, and dissemination of information at bus stops, regional print news, and brochures.

If the pilot program is considered successful, we recommend submitting requests for bid for the installation of a municipal CNG filling station and modification of the maintenance bays. With this information a more detailed study should be performed to provide current cash flow estimates.

6.8 Resources

6.8.1 Natural Gas Bus Manufacturers

6.8.1.1 El Dorado National

El Dorado National has been building buses for over 25 years. Since its inception it has been the largest volume producer of commercial buses in North America. They have focused much of their recent design and manufacturing resources on the development of alternative fueled buses including CNG.[83]

E-Z Rider ii: 30', 35'
Axess: 35: 40;
Escort RE/RE-A
Transmark RE
XHF

EZ-Rider ii
Photo courtesy of El Dorado National

Website: http://www.econline.com
Sales: 909.591.9557

6.8.1.2 Orion Bus/Daimler Commercial Bus

A collaborative effort between Ontario-based Orion International and US-based Daimler, these commercial buses have focused on alternative engine concepts since the early 90s. Orion/Daimler offers two lines of CNG buses; the Orion V and the Orion VII low.[84]

Orion V 32', 35', and 40'

Orion VII Low 32', 35', and 40'

Photos courtesy of Orion Bus

Website: http://www.orionbus.com
Sales: 303.460.3998

6.8.1.3 New Flyer

New Flyer offers a broad line of transit vehicles in Canada and the U.S.
The company's products include a wide range of products such as clean-running, fuel-efficient hybrid buses; zero-emission electric trolleys;

C/L30Lf: 30', 35', & 40'
Photos courtesy of Orion Bus

buses with alternative fuels, like hydrogen, CNG, and LNG; and clean diesel buses.[85]

Website: http://www.newflyer.com
Sales: 218.281.5752

6.8.1.4 North American Bus Industries

North American Bus Industries, Inc. produces a comprehensive line of innovative, heavy-duty transit buses from 31' to 60' (articulated) transit buses at its headquarters in Anniston, Alabama. North American Bus Industries prides itself on its environmentally responsible vehicles with CNG, hybrid-electric and clean diesel propulsion systems. The company also offers a suite of customer focused financing alternatives to help its customers optimize their budgets.[86]

Low Floor Bus: 31', 35', 40'

Standard Floor Bus: 40'

Metro 45C Composite Bus: 45'

BRT: 40', 42', 60', 65'

Photos courtesy of North American Bus Industries

Website: www.nabiusa.com
Sales: 256.831.4299

6.8.2 Certified CNG retrofitter

6.8.2.1 Go Natural CNG

Go Natural CNG is a Utah based company that is state certified as a CNG retrofitter. Go Natural installs EPA-certified CNG conversion kits manufactured by BAF and Baytech.179. Go Natural CNG also installs residential and commercial refueling infrastructure (for all fleet sizes). The company positions itself as an expert on CNG conversion and maintenance and prides itself on its effort to educate CNG consumers throughout the nation.

Contact: Tim Hunt
Phone: (801) 281-4766
Address: 2023 South 625
West Woods Cross, Utah 84087
Website: www.gonaturalcng.com

For additional information:

Alternative Fuels Data Center:
www.eere.energy.gov/afdc/fuels /natural_gas.html
www.eere.energy.gov/afdc/vehicles/natural_gas.html

NGV America: www.ngvc.org

Clean Vehicle Education Foundation:
www.cleanvehicle.org/index.shtml

7. Policy and Financing Issues

For many renewable energy solutions, favorable federal, state, and local codes and policies are necessary for new technologies to be implemented in a financially sustainable manner. Federal subsidies and funding is helping drive the transition to renewable energy sources, but this is not sustainable. States and local governments will likely need to put some pressure on the utilities that have had little competition in years past. The following section describes a few of the situations that exist in Utah that impact the economical implementation of sustainable energy projects.

7.1 Metering

7.1.1 Net Metering

Net metering is the term that refers to the practice of measuring the difference between the electricity consumed by a user, and the electricity generated by that same user. Net metering allows customers that install renewable energy generating technologies to sell energy back to the power company during times when not all of the on-site production is being consumed. When the customer has excess energy, that energy is made available to the electrical grid for others to consume. Customers receive credits from the utility – in Park City's case Rocky Mountain Power – for their excess power generation. These credits can be redeemed throughout the year. Net metering allows customers to offset part or all of their electricity requirements, by drawing on credit during times in which their demand exceeds the power generated on site.[87]

In order to install a net metering device, customers must meet all applicable codes, pass inspections, and sign a net metering agreement. The codes associated with net metering include the following:

- National Electrical Code ("NEC")
- National Electrical Safety Code ("NESC")
- The Institute of Electrical and Electronics Engineers ("IEEE") Standards
- Underwriters Laboratories ("UL") Standards
- All local, state and federal building codes

After passing code, customers will need to sign a net metering agreement. This agreement explains the legal obligations of both the customer and the utility company.

7.1.2 Aggregate Metering

Aggregate metering gives increased flexibility to customers with more than one meter. While net metering only applies to one meter, aggregate metering gives users with multiple meters the ability to net power generation against consumption in multiple locations.

Although currently Rocky Mountain Power does not allow for aggregate metering, this policy is under review. Even with a policy change, aggregate metering would be limited to one user only. For example, a community wind installation project would not be able to install a wind turbine and distribute the revenue from the turbine to multiple homeowners. The renewable power source would have to be owned by one power customer and that single customer would receive the aggregate metering advantage.

Large consumers, however, could benefit from a change in Rocky Mountain Power's policy. A school, for example, might have several power meters located on their campus. If the school were to install a turbine that produced enough electricity to power the entire campus, aggregate metering would allow the school to receive credit for the entire bill and not just for the energy produced or used by a single meter.

If Rocky Mountain Power were to adopt an aggregate metering policy, it would greatly benefit large power consumers that wish to develop renewable energy sources.

7.1.3 NetZero Metering

In either situation of either aggregate or net metering, the utility will not purchase more power than the customer consumes. Customers cannot profit from power generated on their property. This has implications for careful sizing of systems such as solar, wind, and hydro. No financial advantage can be taken by a customer whose system generates power in excess of what they will consume.

7.2 Power Purchase Agreements

Under current Utah law, Power Purchase Agreements are not available except to governments and non-profit entities (see HB145S02 from 2010 legislative session). Power Purchase Agreements (PPAs) are contracts between a power consumer and a producer to sell power at an agreed upon price for a predetermined time period. Power Purchase Agreements enable a third party to purchase and install the renewable energy projects, and gives the third party the right to sell the power gained from these renewable sources to customers.

These contracts typically have extra importance for the seller, as they provide evidence of future income to potential creditors. They are frequently used to provide credit support to entities that would not otherwise have a credit rating – such as special purpose entities created to help take advantage of tax incentives. PPAs can give governments and nonprofit organizations a vehicle by which they can take advantage of government rebates. On October 12, 2008, Utah's Public Service Commission created a docket for investigating PPAs. The docket was open for public comment through November 16th.

The proposed docket has received large support from Utah City mayors, including Park City's Mayor Dana Williams; cornerstone retailers such as Walmart; state energy partners, including Utah Clean Energy; and many other business and nonprofit organizations.

7.3 Tax Structures

For most of the renewable energy sources discussed in this report, Park City can improve the economic outlook by taking advantage of available tax credits. Due to the municipality's tax-exempt status, this requires the proper legal structure and a taxable partner – preferably one that is willing to provide up-front cash in exchange for the tax benefits.

In short, a special-purpose vehicle (SPV) must be created. Ownership of the SPV is nominally shared between Park City and its partner. The bulk of the funding, however, is provided by the taxable partner – essentially, this can be thought of as a loan to Park City. Using this capital, the new SPV buys whatever equipment is needed and leases it to Park City.

Initially, the partnership agreement directs all revenue into the SPV to the taxable partner. Accordingly, Park City's lease payments flow to the taxable partner. As these are revenues received for leasing equipment used to produce clean power, the partner is entitled to claim the federal Production Tax Credit (PTC) against this income. Accelerated depreciation rules for investments in renewable power allow the partner to get additional tax benefits. Park City, in exchange for the lease payments, enjoys the benefit of all the generated power. These payments are similar to the interest payments that Park City would have to make if it issued debt.

After a predetermined period of time, and after all tax benefits have been exhausted, an arrangement of this sort typically terminates with a final buy-out payment from the city. This can be compared to the final principal payment in a bond issue. Future revenues into the SPV are directed to Park City.

In aggregate, Park City's payments are very similar to the payments it would make if a bond were issued. The taxable partner's receipts mirror this. However, the tax credit means that the federal government is also making a contribution. This allows a structure whereby both the City and the partner receive favorable terms.

7.4 Specialized Bond Issues

7.4.1 Clean Renewable Energy Bonds

Clean Renewable Energy Bonds (CREBs) are defined within the Energy Tax Incentive Act of 2005. This structure provides a low-cost way for municipalities to issue debt to fund renewable energy projects. In lieu of interest payments, bondholders receive tax credits from the federal government. To be eligible for this program, projects must involve power generation from renewable sources. Smaller projects are given priority in the approval process, which makes this program a very good match for Park City's needs.

7.4.2 Qualified Energy Conservation Bonds

Qualified Energy Conservation Bonds (QECBs) are similar to CREBs from a financial standpoint - they are intended to be issued at face value, and tax credits take the place of interest payments. Unlike the federally-run approval process in place for CREBs, QECBs are approved at the state level. It is important to note that QECBs are designed to give priority to large municipalities (100,000+ persons), a fact which makes it unlikely for Park City to receive money through this program.

7.4.3 Property Assessed Clean Energy Bonds

Property Assessed Clean Energy (PACE) bonds are designed to fund homeowner-level renewable energy projects. In this structure, the municipality serves as a centralized borrower for homeowners who are looking to fund certain types of green projects. This allows the homeowners to borrow money at the tax- and credit-advantaged rate that the municipality enjoys. Repayment of these loans is accomplished through a line-item on the homeowner's property tax bill.

Two features make this structure safer for bondholders. Because the loan and project are attached to the house, they transfer to a new owner in the event of a sale. Secondly, because the payment is incorporated into property tax payments, it is senior to mortgage debt in the event of a default.

The PACE structure is legally ambiguous in Utah, however. While 17 states currently have legislation that explicitly allows this type of bond issue, a measure to allow PACE bonds was recently defeated in the Utah State Senate.

8. Special Project - Intuitive Buildings

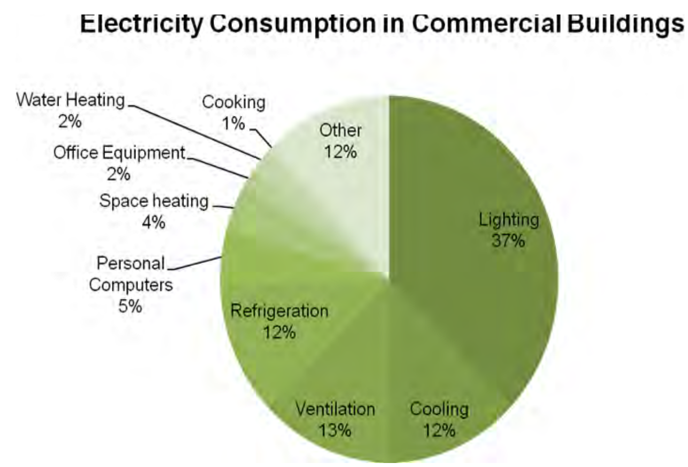
8.1 Overview

The bulk of the energy consumption in commercial buildings comes from the demands of lighting. Energy Secretary Steven Chu has indicated that a major focus of the current administration will be energy efficiency in buildings, both new construction and retrofits.

On average, lighting consumes nearly twenty percent of all electricity use in the United States, with lighting consuming twice that in commercial buildings. In the United States, a typical 50,000 square foot building costs on average $45,000 per year in illumination alone. It has been estimated that if all commercial buildings in the United States installed energy efficient lighting systems, a building's energy use for illumination could be reduced by forty percent.[88] The following chart represents average electricity use at a commercial site, with lighting equaling 37% of total electricity use.[89]

The Energy Dynamics Lab is conducting research that could prove to be a transformational change in the way that lighting is accomplished in commercial buildings. The Task-based Intuitive Lighting System, or TILS, is expected to reduce lighting consumption by fifty percent.

The TILS project uses low cost, commercially available video and LIDAR imaging sensors to assess and create images of occupants within a room. The images are sent to a centrally controlled computer system that will use software algorithms to interpret and predict the activities of the occupants of the room. The system then alters the room's lighting to be optimal for the activities performed by the occupants.



The development of the predictive lighting system is revolutionary in the field of energy and building efficiency. Though research has been and is currently being conducted concerning occupancy and efficient illumination, no other project is addressing task determination and task specific lighting. The project is receiving USTAR funding to advance this research to the commercialization phase.

One of the primary markets for TILS is the high-end retail market. Beyond implications for reduction in energy consumption, task-specific lighting has many other advantages. Human factors studies have shown that lighting can effect mood, appetite, and influence purchasing decisions to name a few.

Park City has several art galleries in which appropriate lighting is an integral part of successful sales. Realizing the potential in advancing this technology, two galleries in Old Town Park City, the Meyer Gallery and the Terzian Galleries, have expressed interest in becoming a testbed for the new TILS technology.

Meyer Gallery. Susan Meyer 435.649.6389

Terzian Galleries. Karen, info@terziangalleries.com 435.649.4927

9. The Wasatch Institute

While researching and investigating the several projects in this report, we realized the true extent of the portfolio of assets available at USU that could help drive transformational change in the way the nation looks at sustainable energy. Through this process we became fond of the idea of creating an Institute for renewable energy leadership. While Logan is a charming and quaint community, we believe that Park City has the access, infrastructure, recreational opportunities to attract leaders in the field of renewable energy to this location to come together to help find solutions for implementing sustainable energy solutions that protect our natural resources, our quality of life and our financial security.

The objective of such an institute might be to build the premier, international institute related to research, development, and implementation of sustainable energy technologies. This could be accomplished in several ways:

- Build an international consortium and think tank of leaders in academia and industry to lead research, development, deployment and commercialization.
- Conduct seminars, symposia, and workshops which will attract the brightest participants from an international pool to deepen knowledge, broaden perspective, and steer research and development and policy; thereby enhancing the capacity to solve the problems that world leaders face.
- Recruit top talent in the field to come to Utah for one to two-year periods, to deepen the knowledge base in Utah's institutions of higher education.
- Create opportunities for young-leader fellowships around the globe, which bring a selected class of proven leaders together for an intense multi-year program and commitment. The fellows become better leaders and apply their skills to significant challenges.
- Explore policy programs, which serve as nonpartisan forums for analysis, consensus building, and problem solving on a wide variety of issues.
- Public conferences and events, which provide a commons for people to share ideas and voice concerns.

By necessity, academic institutions across the state, nation, and world would be necessary to achieve such heady goals. But we believe that the relationship between Park City and USU provides a foundation for success. We also believe that Park City is an ideal location for showcasing new technologies and that city leaders are uniquely capable of setting an example of a synergistic approach to sustainable energy that cities across the west and the nation can model.

10. Summary

Although the exact economics of any specific project can be debated, it is clear that Park City's unique location makes a wide variety of renewable energy sources accessible. Unlike some cities that may have access to one or a few types of clean power, all of the technologies discussed above have the potential to provide Park City with a lasting source of clean, renewable energy. At the same time, none of these energy sources come with guarantees. Many factors might cause the realized power production to vary substantially from projections.

Before addressing the problems created by this uncertainty, it is useful to take a step back. Beyond doubt, we can say that the task of power generation has changed over the past several decades. Government – federal, state, and municipal – once had the relatively simple task of determining the answer to a single question: what power source will provide constituents with the cheapest energy?

In the Western US, the answer was frequently found in hydropower. Idaho, Oregon, and Washington all produce over 80% of their electricity from hydroelectric generators.[90] Utah, on the other hand, generates almost 90% of its power from coal.[91]

Yet, the days of simply looking for cheap electricity have ended. In our modern, carbon-conscious world, price is only one of a number of factors that must be considered when planning a new power source. Environmental concerns have risen to the forefront when choosing between power sources. Further, the level of discussion about "green" issues has changed as well. Broad, general discussions have been replaced by nuanced, informed debates. The case of hydropower provides an example. Dams were once considered clean and renewable source due to their lack of emissions. Now, the industry is under fire for displacing communities, harming local animal and fish species, and in some cases contributing to misuse of farmland or to the abuse of waterways.[92]

10.1 Energy as a Portfolio

Rather than looking at this as a challenge, we see the increased discussion of environmentally-conscious power as an opportunity for Park City. It highlights the idea that with power generation – as in finance – a portfolio approach is not only prudent, but necessary. Due to its unique position as a municipality that can draw on such a wide range of renewable resources, Park City is ideally situated to explore a portfolio approach to green power.

The benefits of this approach start with the bottom line: powering the city. Many of the technologies discussed in this report are subject to seasonal variation in availability. Combining several sources can reduce the vulnerability that a city faces when relying on a single source of power. Periods of reduced wind energy will, most likely, not coincide with diminished output from solar panels.[93] It is easy to envision an active management system in which, for example, water flows could be scheduled so that the electricity from micro hydro generation could help to fill shortfalls from wind and solar sources.

There are many, many more synergies between energy sources that could provide added benefits for a portfolio approach. Using local biomass to generate CNG for buses is one example. Other economies of scale could be as simple as sharing poles for photovoltaic panels and wind turbines, or as complicated as using mechanical energy from wind or hydro sources to clean snow from photovoltaic panels. The interactions are limited only by the ingenuity of the city and its employees.

10.2 Economics are Still Important

Although environmental factors have increased in importance, power generation still comes down to economic feasibility. While consumers may pay a small premium, ecologically-sound power generation is unlikely to be embraced if the rates are too high. Unfortunately, this can add a level of complexity to the decision faced by early adopters. The sound financial decisions of today might cause speculation when compared to future technological advances. Photovoltaic panels are one area where new products have vastly outperformed previous generations, and as discussed above, design changes have led to improved efficiency in alternate-fuel vehicles, wind turbines, and micro hydro generators.

A sizeable initial investment can compound the financial uncertainty of stepping into a green power project. Infrastructure, particularly in the form of power transmission lines, adds cost to remote sites. Detailed analyses of potential environmental impact and of the availability of a renewable power source also add cost to a project well before revenue starts coming in. And cutting-edge technology, while often promising, is equally unproven. Unanticipated expenses for maintenance or for customized installation of first-generation equipment can dramatically alter the financial picture.

10.3 Park City Can Change the Question

Because of its unique position and ability to draw on such a wide range of renewable energy sources, Park City can do more than just generate power for its own use; it can contribute to the way that practical research is conducted. Park City could establish its renewable energy efforts as a living lab, where different approaches to green power can be studied in an environment that is subject to real-world influences. To this end, we recommend adopting multiple technologies with an eye towards analysis and lessons learned rather than simply for power generation.

11. Acknowledgments

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Technology

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Utah State University Research Foundation