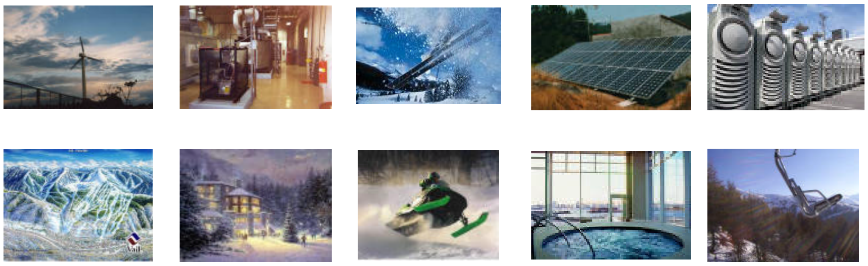
THE ROLE OF DISTRIBUTED ENERGY RESOURCES IN OPTIMIZING ENERGY USE FOR SKI AREA OPERATIONS



Final report on the feasibility of using Distributed Energy Resources for optimizing energy management for Aspen and Vail Mountain ski area operations

Submitted to:

The Colorado Governor's Office of Energy Management and Conservation and the U.S. Department of Energy Denver Regional Office

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Table of Contents

1 Introduction and Objectives ... 3
  1.1 Motivation ... 3
  1.2 Objectives and Approach ... 4
  1.3 Limitations ... 4
2 Energy Management Initiatives within the US Ski Industry ... 5
  2.1 Environmental Charter ... 5
  2.2 Energy Usage for Ski Area Operations—Industry Trends ... 5
  2.3 Energy Management Initiatives at Ski Resorts ... 6
3 Overview of Distributed Energy Resources (DER) ... 7
  3.1 Energy Efficiency, Active Energy Management, and DER ... 7
  3.2 DER Equipment and Technologies ... 7
  3.3 Summary of DER Characteristics ... 15
  3.4 Challenges and Issues Associated with DER Adoption ... 17
  3.5 Economic Benefits of DER ... 21
  3.6 Dispatchability ... 24
4 Energy Analysis for Aspen and Vail Mountain Operations ... 26
  4.1 Aspen ... 26
  4.2 Vail Mountain ... 27
5 DER Opportunities at Aspen and Vail Mountain Ski Areas ... 31
  5.1 CHP Opportunities ... 31
  5.2 Chair Lift Opportunities ... 33
  5.3 Snow Making Opportunities ... 35
  5.4 Microhydro at Ski Areas ... 36
  5.5 Stand-alone Combustion based DR systems ... 36
  5.6 Integrating Renewable Energy ... 37
6 Capturing the Benefits of Integrated Energy Management ... 38
  6.1 Systems Approach ... 38
  6.2 DER as Benefits Multiplier ... 40
  6.3 Capturing Intended Energy Savings ... 42
  6.4 Conclusions ... 42
7 Acknowledgements ... 43
  7.1 Financial Support ... 43
  7.2 Case Study Participation ... 43
  7.3 Research, Analysis, and Report Preparation ... 43

1 Introduction and Objectives

This study explores the role that Distributed Energy Resources (DER) can play towards optimizing energy management at U.S. ski resorts. Results are based on a compilation of existing DER practices across the industry as well as a more targeted analysis of potential opportunities for two Colorado ski resorts: Aspen Skiing Company and Vail Mountain. This study is based on energy consumption data collected through prior energy assessments and from monthly billings from energy providers. It was outside the scope of this study to collect new data for a complete quantitative DER analysis. Instead, the study focused on examining the adoption of mature DER technologies and active energy management within ski area operations enhancing energy efficiency and increasing the adoption of renewable energy.

1.1 Motivation

1.1.1 MOTIVATION FOR SKI RESORTS

Over the past three years, the National Ski Areas Association (NSAA) has been working with over 173 individual ski areas to develop and quantify its environmental charter, called Sustainable Slopes, as a collection of environmental best practices for ski area owners and operators. NSAA membership accounts for over 90% of the industry in terms of skier visits and Sustainable Slopes participation accounts for 73% of the industry. Although four of NSAA's twenty-one major sustainability principles are energy related, it was found over the past three years that energy related solutions were among the least implemented, while their impact on sustainability was considered by resorts to be among the most significant.

Related to sustainability, the industry is also motivated by threats of global warming and its projected impacts on U.S. Ski Resorts. As a result, NSAA in partnership with the Natural Resources Defense Council is starting its third year of its "Keep Winter Cool" campaign.

At the same time, major ski areas have been evaluating renewable energy projects from sources such as wind, microhydro, and Combined Heat and Power (CHP). Several preliminary energy audits have also been conducted at different sites to establish energy use patterns and to establish baselines for projects. However, the lack of a comprehensive study of how distributed energy resources (energy efficiency, metering and monitoring, CHP, and renewables) can be coordinated to meet energy conservation and sustainability targets has limited the adoption of solutions in this area.

Aspen and Vail are particularly motivated to explore the possible benefits of a systems approach to energy management that includes DER. They are currently leading the industry in researching and implementing on-site electric generation from renewables. Aspen has recently implemented a microhydro project and Vail is actively researching installation of four wind turbines at the top of Vail Mountain. Both resorts also have a full-time environmental coordinator. Aspen also has taken a leadership position regarding climate change and the McCain Lieberman Climate Act. The company has initiated the industry's first climate policy and emissions reduction targets.

1.1.2 MOTIVATION FOR US DEPARTMENT OF ENERGY

The US DOE has been actively involved in developing and demonstrating distributed energy technologies, energy efficiency, and energy optimization technologies for a number of years. DOE is interested in facilitating the adoption of innovative energy technologies in new and broader market segments. The ski industry has many similarities to industrial plants that DOE is used to serving: pumps, compressors, water treatment plants, large electric motors (lifts), buildings (HVAC, lighting, plug loads), etc. are commonly found in ski area operations. However, the seasonal nature of the industry and its focus on recreation and the quality of the skiing experience presents unique challenges for proactive energy management unlike other energy intensive industries. DOE is interested in facilitating the development of replicable energy efficiency, renewable energy, and energy optimization solutions leveraging DER for this unique industry segment that is heavily dependent on electricity for its primary business operations.

Additional factors such as a high profile industry that has significant contact with consumers (2 million+/year at Aspen and Vail alone), many of who are executives of energy-intensive industries presents attractive education and marketing opportunity for DOE. The ski industry also has a well-organized trade association, the National Ski Areas Association (NSAA), poised to disseminate results industry-wide through the programs and resources supporting its environmental charter – Sustainable Slopes. The NSAA network includes an extensive supply chain, including manufacturing facilities that may be targets of DOE assistance through its Industrial Assessment Centers.

Although skiing is perceived as a luxury sport, the mountain communities as a whole benefit from active energy management by resorts. Resorts tend to dominate local utility load profiles. The adoption of better energy management at resorts and the incorporation of clean DER technologies can result in significant system benefits for the local utility. Deferral of transmission and distribution upgrades due to better utilization of the existing system and the minimization of spot purchase of electricity for system balancing needs can lower costs for all utility customers including residential and small business customers.

Supporting the development of innovative energy management in ski resorts in rural mountain communities has the potential to significantly further DOE's objectives of promoting energy efficiency and the adoption of cleaner distributed energy resources in energy intensive industries. A nominal investment in sharing some of the financial risks with early adopters in the industry could lead to technology and economic validation and significant market penetration down the road.

1.2 Objectives and Approach

The primary objective of this study is to gain a better understanding of the role that distributed energy resources and integrated energy management can play in increasing the economic benefits that can realized through energy efficiency and renewable energy projects at ski resorts. A secondary objective is to familiarize ski industry stakeholders with the field of distributed energy resources and to introduce energy efficiency and renewable energy stakeholders to the unique energy management needs and opportunities for ski resort operations. This study accomplishes these objectives by:

- Presenting the current status of energy management initiatives within the US ski industry,
- Presenting an overview of the field of distributed energy resources,
- Analyzing energy usage patterns at Aspen and Vail from existing data,
- Reviewing current or planned renewable energy and energy efficiency projects at Aspen and Vail,
- Identifying DER well-matched with the energy needs and seasonal nature of ski resort operations, and
- Evaluating the role that DER can play in enhancing economic benefits through integrated energy management

1.3 Limitations

The scope of this study was limited to the evaluation of distributed energy resources for ski area operations based on existing energy use data. While prior studies where made available by both participating ski resorts, it was found that they were based on aggregate monthly consumption data. The Green Room database maintained by the National Ski Areas Association, also served as a valuable resource for national trends based on self-reported data by the member resorts. The conclusions drawn in this report are therefore limited by available data and are qualitative in nature. They point out specific areas where a more detailed analysis could lead to significant energy conservation, optimization, and renewable energy utilization opportunities.

2 Energy Management Initiatives within the US Ski Industry

2.1 Environmental Charter

Every year, millions of people visit ski areas across North America to enjoy snow sports and to experience the natural beauty of the mountains. These visitors place a high priority on environmental concerns. The National Ski Areas Association (NSAA) and its member resorts have committed to improving environmental performance in ski areas. This commitment is detailed in the Sustainable Slopes Environmental Charter for Ski Areas adopted in June 2000. The Charter states:

> "The ski industry has an opportunity to be leaders among outdoor recreation providers and other businesses in promoting environmental awareness and striving to be a model of sustainable development."

The Charter includes 21 specific principles that focus on a variety of topics, including energy use for facilities, snowmaking and lifts, as well as issues of water conservation and waste reduction. Approximately 175 ski areas have endorsed this Charter. NSAA produces an annual report to gauge the endorsing resorts' progress towards implementing the principles of the Charter. Additionally, NSAA administers a web-based collection of environmental measures, The Green Room, compiled by resorts that describe innovative actions being taking to implement the Charter principles.

In 2003, NSAA also introduced a *Keep Winter Cool* campaign that highlights the effects of global warming on winter recreation. The campaign also highlights the opportunities that resorts have to address the unique challenge that global warming presents to resorts. In general, snowpack is projected to be significantly reduced by global warming. In fact, snowpack reduction of over 50% is likely over coastal mountains such as the Cascades, while projections are near 30% for inland mountains such as the Rockies. In the Cascades, the average snowline will move up from about 3,000 feet to 4,100 feet, and snow will disappear about one month earlier. Within the next 15 years, ski resorts with base elevation below 4,000 feet may be significantly affected by the shortening of the ski season, and when snow disappears at the base of the chair lifts.

2.2 Energy Usage for Ski Area Operations—Industry Trends

According to a 2002 report administered by the Colorado Department of Public Health and Environment (CDPHE), the majority of energy usage by ski resorts is electrical. Other common types of energy usage at resorts include propane, natural gas, gasoline and diesel. For two case studies referenced in the 2002 CDPHE report, ski resort buildings had the largest usage of energy; chair lift and snowmaking operations were also significant, but smaller, energy usages. Based on a 2003 NSAA report, electrical usage by reporting resorts was estimated to be 500,000–600,000 MWh/yr. This usage estimate represents about 45% of the ski resorts that endorse the NSAA's Environmental Charter and does not include non-endorsing or non-member resorts. Of those reporting NSAA resorts, the average kWh usage of a resort is 7 million kWh/yr. If the averages reflected in this data hold true for the remaining 55% of the NSAA resorts, electrical energy usage for resorts nationwide could exceed a 1,000,000 – 1,200,000 MWh/yr level.

Ski resorts are often served by rural electrical associations (REAs) or electric cooperatives due to their remote location. Although the resorts are likely the largest power consumer of a rural utility company, they are often at the end of long feeders. This situation is often conducive to inconsistent service from their utility providers and incurs higher transmission and distribution enhancement costs.

It is clear from the results of the NSAA charter over the past several years that resorts recognize the benefits of energy management, including increased monetary savings, reduced environmental impacts, increased positive public image, and reduced regulatory liability. At the same time, ski resorts often have limited operations budgets and very little in-house energy management capabilities. It is no surprise then, that resorts also consistently regard energy management as the greatest source of untapped opportunity.

2.3 Energy Management Initiatives at Ski Resorts

2.3.1 ENERGY EFFICIENCY

Data submitted by individual resorts for the 2003 Sustainable Slopes report, indicated that reporting resorts are collectively saving about 52,000 MWh/yr in energy efficiency strategies, or approximately 9% - 10% of total electric energy consumed.

Example strategies reported for achieving these reductions include:

- Window upgrades and lighting retrofits in buildings
- Programmable thermostats
- Heating system upgrades/retrofits in buildings
- Efficient office equipment (computers, printers, copiers, etc.)
- Energy star clothes washers
- Building energy management systems
- Timers on heaters in lift shacks
- Motor upgrades for lifts and harmonics filtering
- VFDs for pump motors for snowmaking
- Gravity fed snowmaking systems
- More efficient snowmaking guns
- Repairing leaks in compressed air lines
- Energy efficient compressors and compressor upgrades

2.3.2 RENEWABLE ENERGY

From initial results of the 2004 NSAA report, only eight reporting results currently have some form of onsite renewable energy generation in place. The on-site applications tend to be very small projects such as solar-powered ticket scanners, PV on composting toilets, or PV on bus shelters. The most significant new on-site renewable generation project is the micro-hydro project recently installed by Aspen Ski Company that is discussed in further detail later in this report. Roughly one third of reporting resorts on the other hand are purchasing green power from their local utility and/or green tags from a separate entity.

2.3.3 CURRENT ENERGY MANAGEMENT STRATEGIES AT SKI RESORTS

Figure 1 highlights the publicly reported energy management and renewable energy strategies being employed by ski resorts today, as reported to NSAA via the Sustainable Slopes program and/or the Green Room database.

Strategy	Project	Resort(s)
Curtailment	Interruptible Service	Breckenridge
Demand Management	Demand Management System	Alyeska; Belleayre; Bromley; Jackson Hole; Winter Park
On-Site Renewables	Micro-hydro	Aspen
On-Site Renewables	PV - Composting Toilets	Breckenridge
On-Site Renewables	PV - Ticket Scanner	Breckenridge
On-Site Renewables	PV - bus shelter	Canyons
Heat Recovery	Waste energy from snowmaking used to heat buildings	Snow Summit
Cogeneration	30 kW/hr microturbine (pilot project)	Blue Mountain (Ontario)
Peak Load Shaving	Back-up engines for lifts	Arapahoe Basin; Aspen; Keystone; Vail; Waterville Valley
Peak Load Shaving	Back-up engines for snowmaking	Belleayre

Figure 1: Energy Management and Renewable Energy Initiatives at Ski Resorts

3 Overview of Distributed Energy Resources (DER)

3.1 Energy Efficiency, Active Energy Management, and DER

Energy efficiency, energy management, and distributed energy resources each have their place as strategic tools for improving functional, environmental, and financial performance. The key is understanding when and where to apply them. Assessment of the technologies and strategies they comprise is also critical to capturing benefits without compromise.

While not the primary subject of this report, energy efficiency by design is an essential strategic first step: Reducing the loads and peak demands that will need to be managed, served by DER and/or utility energy sources, and paid for has unquestionable environmental and economic benefits. The ideal unit of energy is the one that you never needed to use and paid little or nothing to save. And, nearly every element of buildings and other resort facilities has some impact on energy consumption and/or peak demand. Integrated energy efficiency measures in building design, construction, and systems, for example, have been demonstrated in numerous cases to save 40–80% of energy consumption and associated costs over their conventional counterparts. Return on investment (ROI) easily exceeds 10–20% and can be well over 100% (*i.e.,* when payback, including cost of capital, is within less than one year). While energy efficiency is indeed often a matter of specifying high-performance materials and premium-efficiency equipment, maximizing performance *and* ROI is more often than not a function of effectively integrated whole-system design.

Active energy management complements energy efficient design and equipment, capturing further savings through operational strategies and enabling technologies. Tools include systems automation, DERs matched to specific peak loads, and energy or thermal storage. Building automation systems, for example, are becoming relatively commonplace in large commercial facilities as means of efficiently using installed equipment to meet thermal comfort, lighting, and other demands. Appropriate DERs can address specific peak loads. Various storage and distributed generation technologies can be employed to shave, manage, or displace peak loads. Again, good design and knowing where and when to use available strategies are critical to successful implementation.

Once facilities have been designed, built, or otherwise set up to run efficiently, distributed energy resources (DERs) can be used to reduce the environmental impact of remaining energy consumption, more efficiently serve those loads, reduce the demands that the utility provider must meet, and reduce the costs associated with peak demands. Which of these roles a DER can play depends on the particular technology involved. The potential and challenges associated with representative technologies are discussed below, following a more general discussion of related benefits and issues.

3.2 DER Equipment and Technologies

The full range of distributed energy resources and technologies includes various forms of renewable energy, clean generators, combined heat and power systems, and various forms of energy storage.

Renewable distributed energy resources include wind, micro-hydroelectric, solar-electric (PV), solar-thermal, biomass, and biogas generators or collectors. The first four of these, as they are most applicable in this case, are covered below.

Clean combustion-driven generators comprise mainly natural gas reciprocating engines and turbines, but also can include units run on biomass and biogas. Again, just the former options are covered here, as the latter tend to make sense principally when an appropriate industrial feedstock is available (such as the spent grain used to run generators at the New Belgium brewery in Ft. Collins, CO) or at a landfill location where methane can be captured as fuel.

Combined heat and power (CHP) systems integrate combustion-driven generators, heat exchangers, and even heat-driven cooling to offer exceptionally efficient provisioning of electric power and thermal comfort. There are also emerging micro-CHP systems using Stirling engines, fuel cells, and hybrid solar-electric/thermal collectors.

Finally, energy storage technologies present options for storing either electrical or thermal energy. Storage can save excess electrical or thermal energy from a DER for later use or displace an energy or thermal load over time to smooth out demand peaks. Technologies include electrochemical batteries and flow cells, electromechanical flywheels, and phase-change materials such as ice for "coolth" and eutectic salts for heat.

The following sections describe some of the leading DER technologies in more detail and Table 2 summarizes the main characteristics of various DER technologies and their applicability at ski resorts.

3.2.1 WIND

While wind energy is generally very competitive and provides a high return on investment (ROI) for many locations in the eastern plains of Colorado, the front range and mountain regions tend to have less than desirable wind resources. While a turbine can provide some power even where wind is intermittent, ROI becomes questionable and the benefits of competing technologies start to look more attractive. That said, there might be some exceptional locations where a particular site offers useful wind resources. Generally these will be where landforms capture thermal currents or, by constriction of air currents, cause an accelerating venturi effect. It is almost always worth placing an anemometer on a temporary tower to record actual conditions—preferably for a full year to account for seasonal variations—before investing in a wind turbine. This would be even more important in a site believed to have exceptional characteristics relative to the surrounding region.

For sites where wind resources are appropriate, the cost of grid-tied wind energy over a 25-year system life can be as low as 4–7¢ per kWh for a 20-kW turbine (2–2.5¢ per kWh is generally achieved only with larger—*e.g.,* 600-kW— utility-scale turbines or unusually good sites) and more like 10–20¢ per kWh for smaller turbines in the 1–10 kW range. Again, cost per unit energy produced is highly dependent on average wind speed available at the site.

If a ski-area site were determined to have wind resources worth harnessing, visual impact might still present a challenge. However, where relatively small systems are concerned, this is more a psychological than physical barrier, as even an 80-ft tower will tend to "disappear" against the sky or backdrop of trees as seen from more than a hundreds yards or so away. The appeal of renewable energy is also a motivator for ski-area operations where wind turbines can be "featured" to highlight environmental stewardship.

Grid-tie vs. energy storage, typically in batteries, to buffer variability of wind also needs to be worked out, but is a fairly straightforward matter to be dealt with for off-grid remote locations or where back-up power during a utility outage confers a significant advantage. In the context of a ski resort, a stand-alone system with batteries would be used only to serve a small load in a remote location. A larger grid-tied system would be more likely to fit in on a high ridge at the top of a lift line where wind resources might be adequate and yet considerable infrastructure would already be in place.

3.2.2 MICRO-HYDROELECTRIC

Micro-hydroelectric technology has the potential to offer low-cost renewable energy where sufficient flow and head (difference in height between the head pipe source and the turbine) are available. Micro-hydroelectric is variously defined as having a power output of between about 10 and 200 kW (more by some definitions).

Peak power output per dollar invested in micro-hydroelectric equipment is typically much higher than for other renewable energy technologies. However, if power is available only half of the year and peaks for only a couple of months, for example, the technology cost advantage can be significantly diminished or even eliminated. The economics of a given installation are highly dependent on having a site where adequate head can be harnessed at reasonable cost and with an acceptable level of environmental impact. In other words, adequate flow must be present, the grade must be sufficient to provide adequate head over a reasonable distance, and there must be an acceptable path for installation of the head pipe or penstock. Although Aspen and Vail Mountain ski areas do not have access to anything more than seasonal alpine creeks, they do have man-made reservoirs for snow making purposes fed by snow melt. The reservoirs are maintained at higher elevations to provide the necessary head for snow making activities. In addition, water rights are not an issue since ski resorts are already using the water for snow making purposes.

Maintenance costs of about 5% of installed cost per year are a significant factor relative to wind and solar—*e.g.,* on the order of $40,000 (total) over a twenty-five year system life for a system averaging 50-kW output as compared to a small fraction of that number over the same period for a properly design and installed grid-tied PV array. This difference in maintenance costs results largely from the mechanical nature of hydroelectric systems and the wear caused by sand and grit in the water. Given all of these considerations, the cost per kWh of micro-hydroelectric energy can range anywhere from 3–30¢ per kWh.

3.2.3 SOLAR PHOTOVOLTAICS

While typically the most capital-intensive of the technologies described here, solar photovoltaics (PVs) are indeed a clean, reliable, and sometimes even cost-competitive means of generating renewable energy. Even after counting their considerable embodied energy, the environmental benefits of using PVs to provide services in a remote location or to offset coal-fired generation of electricity have both tangible and perceptual value. Among DERs, PVs stand out as attractive tools for bringing attention to renewable energy. Depending on equipment, type of installation, system size, and location, energy costs for well-designed grid-tied PV systems range from 15–25¢ per kWh (based on a 25-year system life). Very small systems can easily run more like 30¢ per kWh. In the mountain region of Colorado, with a somewhat lower average amount of sun than much of the Southwest, getting down to 18–20¢ per kWh would require a relatively large array and low-cost building-integrated design using a simplified approach to panel installation.

The most cost-competitive PV applications are generally those serving a relatively small load in a remote location where the cost of bringing in electricity over wires would be significant. Where renewable energy is particularly important to a project owner and both wind and hydroelectric resources are relatively limited, grid-tied PVs can once again be a cost-competitive option.

PVs can also be used to displace peak midday summer air conditioning loads in grid-tied applications, but are considerably more capital-intensive than other peak-shaving options, such as ice storage. Public relations value might therefore be an important consideration in choosing to install PVs as a combined renewable energy and peak shaving system. Income from the sale of renewable energy credits (RECs) should also be considered. Unfortunately, at this time, there are no local or regional solar REC programs that might offer higher value per unit energy (see §3.5.4).

Single and multi-crystalline PVs are most appropriate where space is limited, such as a stand-alone powered device or small building in a remote location. A small panel of crystalline PVs can produce enough power to run communications devices, lighting, weather monitoring instruments, or other low-power equipment. A small set of batteries, charged when the sun is shining, can provide power at night or under dense cloud cover. The principal benefits of stand-alone remote power installations such as this are continuous power availability and avoidance of the costs and environmental impacts with bringing power to the site through wires.

All types of PVs can also be used in grid-tied configurations on building roofs, facades, parking structures, parking shading devices, or as supported by dedicated structures. The most cost-effective installations of crystalline PV panels, however, are typically on flat roofs where the panels can be secured to simple wedge-shaped aluminum boxes or insulative panels that simply sit on the roof. These installations are simple, relatively inexpensive, and can be done without roof penetrations. Unfortunately, ski area facilities are much less likely to have flat roofs than are other types of commercial buildings. Still, high-output crystalline PVs may have appropriate application as either integrated with building façade architecture or on structures mounted between rows of cars in parking lots—though these are higher-cost installations. Considerations for parking lot installations would include stout enough free-standing structures to manage snow loads, space for the pile up of snow shed by the panels, and plowing around their support structures.

Amorphous silicon PVs produce less power per unit area. There are, however, many advantages of amorphous PVs, especially the triple-junction variety, which would be worth considering in the context of ski area operations.

To begin with, amorphous PVs are generally less expensive per unit area, so, assuming roof space is not a constraint, cost per unit peak *power* is already fairly close to that of the crystalline technologies. They are tolerant of partial shading from partly cloudy skies, which on a small area of a crystalline panel reduces the output of the whole panel. They continue to produce power even though a few inches of snow cover (responding to non-visible portions of the solar spectrum that are more readily transmitted through snow). They are much less affected by the heat of the summer sun, which lowers the output of crystalline PVs considerably for every degree in surface temperature rise. Each of these contributes to average real-world energy production that us higher than the comparison of peak power per unit area or cost would suggest. With robust rubber-like form and greater tolerance of summer heating, amorphous PVs do not require cumbersome and costly glass covers, rigid mounting frames, and offset hardware to for protection and cooling. And, they're available as roofing shingles or in rollout sticky-backed panels intended for mounting directly on the surface of sloped metal roofing.

Amorphous silicon might therefore be more readily installed on ski resort facilities, which tend to have sloped rather than flat roofs and which are likely to receive significant snow from time to time. The same characteristics also make amorphous PVs potentially better suited to use on existing buildings with sloped metal roofs–which are fairly common in ski areas.

3.2.4 SOLAR THERMAL

Solar thermal collectors are a good fit for lodging facilities with significant year-round demand for hot water, including showers, saunas, and laundry facilities. They are particularly well suited to heating swimming pools, as the pool largely obviates the need for hot water storage (though a backup heat source maybe required to assist the solar thermal system under extended conditions of heavy cloud cover). Solar thermal collectors are generally not economically viable for seasonal heating loads.

While there might come a time when active solar thermal systems offer a hedge against rising natural gas prices, even for space heating, conserving heat though energy-efficient design, materials, glazing, etc., will most likely remain a better investment for the foreseeable future.

3.2.5 MICROTURBINES AND OTHER CLEAN COMBUSTION TECHNOLOGIES

Microturbines, usually burning natural gas, are appropriate for loads on the order of 30–400 kW. For high-duty-cycle applications (*i.e.,* the opposite of intermittent operation for backup power) below about 100 kW, microturbines tend to provide better overall performance than reciprocating engines. The efficiency of micro-turbines, which falls between that of gasoline and diesel internal combustion engines, will always be limited by the minimum clearances—regardless of scale—for spinning turbine blades in an enclosure. However, they do run cleaner than diesel and gasoline engines of similar capacity. In theory, microturbines, with many fewer moving parts, should also be a good bit less expensive to maintain than similar capacity reciprocating engines—especially when compared to diesel engines. While that has proven true for their larger scale brethren (see below), industry reports on the cost of maintaining this relatively new technology have thus far been somewhat mixed. Therefore, solid backing of microturbine-based systems and installations is important to ensuring cost-effective operation. Microturbines have the added advantage of higher exhaust temperatures that make them better suited to CHP applications.

For larger applications requiring several hundred kW to multiple MW, the choice is usually between a reciprocating engine and a combustion turbine. As compared to combustion turbines, natural gas or diesel reciprocating engine generator sets typically have higher efficiencies and more readily tolerate load variations, high altitude, and high ambient temperatures. They also do not require high-pressure gas, and they can start within 10 seconds, which is important in standby applications. On the other hand, combustion turbines are much lighter, take up much less space, and are less expensive to maintain. Like the microturbines described above, the higher exhaust temperatures of combustion turbines are also better suited to CHP applications.

Gas-fired equipment, in general, is much cleaner than diesel-fired. And, gas-fired combustion turbines are often, but not always, cleaner burning than reciprocating natural gas engines. However, because emissions vary so much from one model to the next and with the emissions controls employed, it's best to compare the products capable of meeting project-specific power requirements.

There are two main types of reciprocating engines: compression-ignited and spark-ignited. Spark ignition engines, while less efficient, are typically cheaper than their diesel counterpart. Either type of engine can burn natural gas or other gaseous fuels (dual fuel operation for compression ignition engines), such as propane or biogas. Dual-fuel engines are also available in which natural gas and diesel fuel can be used alternately. Dual-fuel engines maintain power output in the event of a failed natural gas supply, and yet decrease emissions relative to running just on diesel.

Combustion turbines can also run on gaseous fuels, liquid fuels, or dual-fuels. Combustion turbines are typically clean burning and produce fewer emissions than many gas engines. Ordering a dual-fuel option adds costs to the unit compared to single-fuel systems. Combustion turbine efficiency is substantially lower than reciprocating engine efficiency, in most cases.

3.2.6 COMBINED HEAT AND POWER

Combined heat and power systems, also referred to as cogeneration, save energy by more efficiently serving both electrical and thermal loads with a single integrated system. Most CHP systems use turbines and reciprocating engines of various sizes fitted with specialized heat exchangers and even heat-driven cooling technologies to offer exceptionally efficient provision of electric power and thermal comfort or hot water. There are also emerging micro-CHP systems using Stirling engines, fuel cells, and hybrid solar-electric/thermal collectors.

A typical mid-sized CHP system (in the 200 kW to 5 MW range) in an onsite application where year-round electrical and thermal loads are present—for which thermal loads could include hot water, space heating, or space cooling, or any combination thereof—can save approximately 25% of primary fuel energy when compared to separate systems. This assumes that the separate systems would use a gas boiler for heat and hot water loads plus a typical mix of grid electricity sources. The comparison would actually tend to be even more favorable in Colorado where most power comes from conventional coal-fired plants. One of the advantages onsite CHP systems have is that there are no transmission and distribution (T&D) losses. This accounts for about 5-10% of the savings. Most of the rest of the overall efficiency gain is a function of recovered heat energy, despite average electric power generation being of equal of lesser efficiency that a typical power plant. (The latter comparison depends on whether the CHP uses a turbine or reciprocating engine and whether the power plant is conventional coal-fired technology or combined-cycle natural gas. However, this has limited bearing on the comparative efficiency of the integrated CHP system, since losses from less efficient power generating technology are being captured as useful thermal energy.)

In the case of turbine-driven generators, heat is collected from working fluids, such as steam or hot combustion gases, that have just passed through an electric turbine. In the case of reciprocating engine-generators, external combustion Stirling-cycle generators, and high-temperature fuel cells, both cooling water and exhaust are tapped as heat sources. For high-efficiency, low-temperature (*i.e.,* PEM) fuel cells, even when using a natural-gas reformer, only the cooling water may have enough heat in it to be worth extracting. In the case of PV/T technology, heat is collected either via liquid cooling of the PV cells themselves, integrated heat-collecting elements within concentrator array, or air flowing over the cells. With the one exception of air-cooled PVs, for which the available hot air might only be useful as a contribution to space heating, recovered heat can be used to provide a variety of services. It might, for example, be used to provide domestic hot water, heat a swimming pool or occupied space, or drive a cooling system. And, heating and cooling services can alternately be provided by the same sources of "waste" heat. Cooling is then provided by steam-turbine-driven chillers, steam-fired absorbers, and direct-fired absorbers and desiccant cooling systems.

Applications for primary energy conversion technologies within CHP systems generally follow the same general guidelines as would apply to their use as stand-alone generators, with the added consideration that the ratio of electric power generated to heating/cooling provided differs from one technology to the next:

- A combustion turbine plus an absorber or steam-turbine driven chiller would be suited to providing greater than 1MW power plus 500 or more tons cooling capacity (averaging 0.5–0.6 ton/kW);
- A gas-fired reciprocating internal combustion engine plus an absorber or desiccant cooling would be appropriate to provide 100 kW to 3 MW power and 30-1,200 tons cooling (averaging 0.3–0.4 ton/kW);
- A microturbine(s) plus an absorber or desiccant cooling would be appropriate to provide 30–400 kW power and 12–200 tons cooling capacity (averaging 0.4–0.5 ton/kW);
- A fuel cell(s) with natural gas reformer plus an absorber would be appropriate to provide 5–50 kW and 1–10 tons cooling (averaging ~0.2 ton/kW);
- A Stirling engine(s) plus an absorber would be appropriate to provide 1–250 kW and 0.2–75 tons cooling (averaging 0.2–0.3 ton/kW);
- A direct-hydrogen fuel cell plus an absorber might be appropriate to provide 1–50 kW and 0.1–5 tons cooling (averaging ~0.1 ton/kW);

Gas turbines will generally provide the best heat recovery and highest thermal output per unit primary energy. Gas-fired reciprocating engines will be somewhat more efficient in terms of electricity produced per unit primary energy and will maintain that efficiency more effectively under part-load conditions, high ambient temperature, and at high elevations. Microturbines provide many of the desirable attributes of larger gas turbines, simply at a much smaller scale.

Small proton-exchange-membrane (PEM) fuel cells, also still a bit pricey at ~$3,000/kW electric, offer high combined CHP efficiency, excellent thermal recovery, and low emissions in 5-kW increments with roughly 2:1 ratio of thermal to electrical output. These units may still incur additional costs for fuel reformers. Due to manufacturing cost and fuel availability issues, many of the PEM manufacturers have put off production of residential and small commercial units to focus on building products for UPS applications.

Larger (250-kW), high-temperature, solid-oxide fuel cells are relatively exotic, and still quite pricey, but offer extremely low emissions and all-around efficiency. Stirling engines, only just now coming to market in 1-kW to 100-kW capacities, offer high efficiency at full or part load, very low emissions, and potentially good heat recovery.

Solar PV-thermal (PV/T) panels, just now moving from R&D toward commercial availability, are a bit unusual among possible CHP technologies. PV/Ts should improve the real-world efficiency of standard PVs by removing heat that otherwise degrades the power output of the PVs: Typical PVs convert 10–12% or so of incident solar energy into electricity, reflect another ~20%, and absorb the remaining ~70%. Absorption of that energy can reduce electrical output by 20% or more on a hot summer day. If, instead, that heat is carried away by a liquid flowing through tubes on the back of the PV panel, the degradation of electrical output should be significantly reduced. And, while the thermal efficiency of the PV/T collector will be a good bit less than that of a dedicated solar-thermal collector, the manufacturing cost and roof area required should both be significantly less than for separate PV and thermal collectors.

From an economic perspective, the strongest commercial applications for CHP systems tend to be those with beds—*i.e.,* hotels, resorts, and hospitals. The key is to have relatively consistent year-round electric and thermal loads matched to the relative electrical and thermal capacities of the chosen CHP technology. CHP systems with high return on investment will tend to be designed and sized to meet the base thermal load. CHP can thus be thought of as a thermal technology that just happens to produce a handy byproduct of electricity. Corresponding electric power output will be a function of the selected CHP technology. Technology selection will be a function of scale, desired mix of electric and thermal outputs, and specific project goals, such as emissions reduction.

Another important determinant of economic value for CHP is the price of grid power and, especially, the difference between prices for grid power and natural gas (referred to as “spark spread”). Because natural gas is a primary energy source, it's generally a good bit cheaper per unit energy than electric power from the grid (which may, in part, be the product of gas-fired power plants). Spark spread will tend to remain consistent, regardless of rising natural gas prices, in regions where a significant fraction of electricity is generated in gas-fired plants. However, spark spread may shrink with rising natural gas prices in regions, such as Colorado, where most electricity is from coal-fired plants.

Standby charges, which are assessed by a utility to meet electric demands if and when the CHP system is offline, can be pivotal in determining the economic viability of a CHP system. For example, if considering a CHP system with 1MW output in a representative application, no standby charge might allow power production at about 4.3¢ per kWh. An annual standby charge of $75/kW would extend the payback period from around 4 years to 6 years. An annual standby charge of $150/kW would extend the payback period to almost 11 years. An annual standby charge of $300/kW would effectively eliminate the prospects for return on investment.

The good news is that a CHP system that operates during periods subject to high demand charges can also be used to reduce peak demand (via reduction of base load), and thus the associated charges.

3.2.7 ENERGY STORAGE TECHNOLOGIES

Energy storage technologies present options for storing either electrical or thermal energy. Storage can save excess electrical or thermal energy from a DER for later use or displace an energy or thermal load over time to smooth out demand peaks. Technologies include electrochemical batteries and flow cells, electromechanical flywheels, and phase-change materials such as ice for "coolth" and eutectic salts for heat.

While they also may provide benefits as a backup resource, energy and thermal storage of significant capacity are more often used to shave or manage peak demands. If peak shaving is the aim of storing energy and the peaking load is thermal, a thermal storage system should always be considered before electrical energy storage.

Batteries

Electrochemical batteries are relatively low-density and high-cost way to store energy. Traditionally, batteries have been the solution for moderate capacity short-term storage, as in uninterruptible power supply (UPS) systems, and for higher-capacity long-term storage, as in stand-alone PV systems. Unfortunately, they are among the least cost-effective and most problematic elements of such systems. They are costly per unit energy stored, have limited life, take up large volumes of space, are heavy to transport and secure/support, and come with relatively high maintenance costs. When used in large packs, they also require sophisticated monitoring technology to ensure that a failed cell does not pull the whole pack down.

There are a variety of deep-cycle battery chemistries, each with particular advantages: Lead-acid generally has the lowest up-front cost, but relatively high lifecycle cost because of high maintenance and short life; Nickel-iron is more robust, and can be rebuilt several times over, but is still high maintenance and even more voluminous to house and massive to transport or handle; Nickel-cadmium has advantages for high-power applications and where space is limited or lower mass has value, but is not much longer lived than lead-acid and comes with added upfront and disposal costs; Nickel-metal-hydride is perhaps the most robust, high-performance, and environmentally benign of these, but also the most costly and least available. There are a broad range of options, and costs, within each chemistry type, especially lead-acid. The very least expensive batteries tend to be far less reliable, require more maintenance, and have a much shorter useful life. The most expensive batteries may be hard to justify except in the most critical power quality and reliability applications.

The vast majority of significant energy storage applications, such as stand-alone PV or wind energy systems, use one or another variety of lead-acid battery. First costs for good quality deep-cycle, valve-regulated, lead-acid batteries are typically around $110 per kWh. Charging, control, and monitoring equipment will be required as well, and can easily add $1,000 per kW rated power. A DC-to-AC inverter would also be required for applications other than PV, small wind systems, and very small micro-hydro systems, all of which already require an inverter for grid-tied operation. While they are more or less a known quantity, batteries are still an expensive way to store energy.

Flywheels

Flywheels are essentially electromechanical batteries—storing kinetic rather than chemical energy. Both high-speed and "low-speed" designs have been demonstrated to be far more efficient, more reliable, and offer lower life-cycle cost than electrochemical batteries. High-speed flywheels (operating up around 100,000 rpm) offer very high-density energy storage when compared to batteries. So-called "low-speed" flywheels (operating at around 6,000–10,000 rpm) offer a potentially low-cost means of buffering highly transient loads (such as the demand spike generated when and electric motor-driven AC compressor or heat pump starts up) at end-use locations. As such, these low-speed flywheels can remove very brief demand spikes that are often on the order of 10 times the base load they are buffering. There are, unfortunately, very few commercial flywheels on the market, and these are mainly towards the high-speed end of the range and intended for uninterruptible power supply (UPS) applications wherein not all that much energy is stored.

A flywheel-based UPS operates at an efficiency rating of 97% as compared to typical battery-based systems that are usually rated between 86% and 90% efficient. The few available commercial products have been demonstrated to be more reliable than battery based systems. A flywheel-based UPS also has a smaller footprint than an equivalent battery-based UPS and, unlike batteries, can operate effectively at high ambient temperatures. One installation that upgraded from battery-based UPS for their IT system was able to re-purpose an entire battery room and lower their HVAC demands, capturing immediate cost savings. They are also able to avoid the recurring cost and risk of removing and disposing of toxic lead-acid batteries every 3 years. Overall lifecycle cost looks better with the flywheel-based UPS.

Flow Cells

Flow cells are rather like batteries where the electrolyte is stored as liquid in alternating tanks depending on their state of charge (i.e., chemical state). The electrodes themselves are relatively much smaller, as the electrolyte only needs to flow over their surface area as charge is added or removed. Though still relatively immature, flow cells are said to make sense for a variety of massive industrial and utility-scale operations and in certain niche applications in the 200–500-kWh range. In either case, they will tend to be most useful where fluctuations in energy supply or demand are regular and fairly extreme. For this reason, they appear to be a potentially competitive means for both peak shaving and for intermittent renewable energy sources, such as wind and solar. While improving availability, and thus offsetting or potentially eliminating standby charges and/or investment in "spinning reserves," it should be kept in mind that storage always adds to the capital-cost challenges that renewables already face as grid-dependent systems.

Thermal Storage

Ice storage uses otherwise idle nighttime chiller capacity to make ice, which is then melted as needed during the day, to permit use of a downsized chiller and to reduce peak power demand. Ice storage has been shown to be a cost-effective in large commercial facilities with refrigerative mechanical cooling systems where cooling loads are significant throughout most of the year. However, strictly seasonal cooling loads, depending on relative peak demands and utility rate structures, may not justify it if the ice storage equipment itself sits idle too much of the time. Ice storage for peak shaving, among the most viable forms of energy storage in commercial buildings, may not therefore be economically viable for ski resorts with limited and very seasonal cooling loads.

Phase-change heat storage uses low-melting-point eutectic salts and similar materials to efficiently and effectively store useful quantities of heat energy within a reasonable volume and at reasonable cost. Generally, heat storage is viable for two kinds of applications: where large quantities of heat are added and removed in repeating process cycles (usually industrial applications); and where there is a short-tem peak demand for heat (*i.e.*, a rapid infusion) that can be met by a dramatically downsized heat source if the phase change material is "charged," like a capacitor, and then allowed to dump its stored energy into the application.

Ground-source or water-source heat pumps are yet another means of moving thermal energy in an out of storage. In this case the storage medium is most often the earth but can also be a pond. Because they can transfer thermal energy from or to the ground, they can provide heating, cooling, and/or demand management with respect to the provision of those services. They can also, when used in a common-loop system, efficiently transfer heat from a cooling load to a heating load, thus saving energy and managing peak loads. When extracting heat from the ground, a heat pump is actually harnessing a low-level geothermal renewable energy resource. And, good heat pumps can extract, deposit, or otherwise relocate about four times as much thermal energy as they consume in electrical energy (referred to as a coefficient of performance or COP of 4.0). Keep in mind, however, that seasonal heating loads alone, which can be satisfied by a less costly boiler using primary energy rather than electricity, may not justify the use of a heat pump. In other words, a heat pump with a COP of 4.0 running on electricity that represents just 25% of the energy in the primary fuel consumed at the power plant (after generation plus T&D losses) is hardly much better than a good condensing boiler running at 92–96% efficiency. But, even such high-tech boilers are limited just to making heat, so even modest cooling load could start to make the heat pump look like a better option. Add in the potential for use as a thermal transfer and demand management tool, and the heat pump starts to look like an interesting and unique opportunity.

3.3 Summary of DER Characteristics

Figure 2 summarizes the main characteristics of major DER technologies, their benefits and limitations, and their applicability to ski resort operations.

Figure 2: Summary of DER characteristics and their applicability at ski resorts

WIND		
CHARACTERISTICS	**BENEFITS AND LIMITATIONS**	**SKI RESORT APPLICABILITY**
Relatively mature and widespread technology	Relatively low cost where wind resource is plentiful	Insufficient wind resource in most of CO mountain region
Small footprint and exceptionally minimal other impacts	Potentially available all seasons and times of day, but would require storage if to be depended upon to produce at a given time	Small turbines may be appropriate on some elevated sites or in path of regular diurnal thermal currents
Uses free natural resource	Unpredictable and limited in most of the CO mountain region	Requires measurement of wind resource at site
Intermittent power	Seen by some as visually intrusive	Typically uses 50–80-ft tower
	4–7¢ per kWh for a 20-kW turbine and ~10–20¢ per kWh for smaller turbines in the 1–10 kW range	
MICRO-HYDRO		
CHARACTERISTICS	**BENEFITS AND LIMITATIONS**	**SKI RESORT APPLICABILITY**
Relatively mature and widespread technology	Low-cost renewable energy where water flow and head are adequate	Potentially applicable to serve modest summertime loads
Moderate impacts	Could shave some summer demand	Potential historic reference
Uses free natural resource	Potentially constant output during limited months of operation	Natural river flows not available during winter peak energy consumption
Extreme seasonal variation: late-spring, early-summer peak	Installation and operation of larger systems can adversely affect riparian ecosystems and biota	Systems capable of making substantial power may have excessive impact
	3–30¢ per kWh, depending on site, resource, climate variables, etc.	Water storage for snow making could be used for small system

PHOTOVOLTAICS		
CHARACTERISTICS	**BENEFITS AND LIMITATIONS**	**SKI RESORT APPLICABILITY**
Exceptionally mature niche technology	High cost first cost with low operating cost and many benefits	Building integrated base area and mountaintop locations
Minimal impact		Remote off-grid locations
Uses free natural resource	Highly predictable seasonal output and semi-predictable daily output	Possible contribution to year-round consumption
Moderate variability of daily heat output; no nighttime output	Significant cost to buffer output variability via storage; in some cases grid connection is an option	In sync with modest summer air conditioning loads
	Very low maintenance	Readily integrated with architecture
	18–20¢ per kWh for relatively large (~100–250 kW) systems with low-cost building-integrated design	Limited space compatible with least expensive BIPV installation scenarios
SOLAR-THERMAL		
CHARACTERISTICS	**BENEFITS AND LIMITATIONS**	**SKI RESORT APPLICABILITY**
Semi-mature niche technology	Moderately high first cost, some maintenance, reasonable ROI	Well suited to serve relatively constant year-round loads
Minimal impact	Visual impact presents challenges	Need to be visually integrated
Uses free natural resource	Highly predictable seasonal output and semi-predictable daily output	Mountaintop restaurant kitchen and restrooms
Moderate variability of daily heat output; no nighttime output	Variable output can be buffered at reasonable cost with storage tank	Lodging domestic and service hot water (showers, sinks, hot tubs, pool, laundry, etc.)
	Note generally cost-effective for seasonal loads (i.e. space heating)	
GENERATORS		
CHARACTERISTICS	**BENEFITS AND LIMITATIONS**	**SKI RESORT APPLICABILITY**
Mainly very mature technology	Potential for peak-shaving value through demand management	Low-cost emergency backup
	Energy cost can be competitive, depending on load profile and utility demand charges	Possible tool for managing otherwise unavoidable peaks in energy demand
	Low-emission generator sets can be cleaner than coal-fired utility power	Potential for "hybrid-electric" lifts using separately located generator (CHP even better)
	Efficiency is generally lower than with all other options	See CHP below
	More valuable as component of CHP	
COMBINED HEAT & POWER (CHP)		
CHARACTERISTICS	**BENEFITS AND LIMITATIONS**	**SKI RESORT APPLICABILITY**
Typically integrating mature technologies, but not always	Potentially significant energy and cost savings (~25%) if matched to a suitable application	Potential to serve significant loads at base area (lifts, lodging, and other facilities)
Technology dependent range of emissions and noise impacts	Good return on investment (ROI) may require year-round electric and thermal loads	Cost-effective (year-round) application may require CHP with heat-driven cooling
Quiet, low-emission natural-gas-fired	Some systems can present complex control challenges or require	CHP could serve lodging (heating, hot water, cooling,

options available	significant maintenance	and dehumidification) plus food-service refrigeration
Capable of providing heat, cooling, and electric power	Interconnection issues and standby charges can eat into ROI	Hotels rank among most cost-effective commercial CHP applications
	Power at 4–5¢ per kWh, plus heat	
OPTIMIZATION, DEMAND MANAGEMENT, AND ENERGY STORAGE		
CHARACTERISTICS	**BENEFITS AND LIMITATIONS**	**SKI RESORT APPLICABILITY**
Wide range of technologies and strategies	Vast potential, many opportunities and options, but low-hanging fruit may already have been picked	Building design, materials, construction, HVAC, lighting, service hot water, and fixtures
Reduction in demand by design, technology selection, and/or load management	In many cases, energy-efficient design, construction, and technologies also yield superior performance	Facilities commissioning, re-commissioning, efficient operation, and load management automation
Reduces overall impact in proportion to both energy savings and avoided demand	Potential for exceptional return on investment, though results are often highly dependent on proper design and implementation	Optimization of food-service equipment and operation (refrigeration and ventilation) and laundry equipment
Use of energy storage where appropriate	Some high-ROI strategies require significant capital investment	Synergistic applications with CHP systems
Frees up otherwise wasted energy	Often only feasible with new construction or major renovations	If high demand charges, even electrical storage could fly
Frees up both grid generating and T&D capacity	Other than ice storage for shaving cooling demands, and possibly common-loop water/ground-source heat pumps, most energy "storage" technologies are cost-effective only where high value is placed on power quality and reliability.	May not have sufficient or consistent enough cooling loads to make ice storage economically viable

3.4 Challenges and Issues Associated with DER Adoption

3.4.1 TECHNICAL BARRIERS

The challenges facing DER technologies are consistent with their respective maturity—technologies such as fuel cells, Stirling engines, and some exotic photovoltaics are still in the early stages of demonstration, deployment and field-testing. Other technologies such as reciprocating engine or gas turbine based CHP systems and thermal storage technologies are extremely mature with very limited technology risk. The maturity of other DER technologies such as wind fall in between although wind turbine technology is fast becoming a very mature field in its own right. In general, for the majority of commercial applications there are several mature technologies to select from without having to manage the risk associated with adopting emerging technologies. This section provides a brief overview of the technical barriers facing some DER technologies.

Fuel cells have run into challenging cost barriers as a function of membrane technology development, platinum loading, and the sheer number of cells, and thus separate component layers of precision fabricated materials, that must be stacked up to provide desirable voltages for most applications. Diesel engines continue to suffer from NOx and particulate emissions issues—while still generally higher than other prime movers, these have both been reduced, by over 80% for on highway applications, over the last several decades. Additionally, new technologies are expected to further reduce these emissions levels by another order of magnitude. Although microturbine Nox emissions are typically quite low, they suffer from physical limits to efficiency when compared to larger turbines. The holy grail of exceptionally low-cost amorphous PVs has eluded more than a dozen well-funded teams—many of whom have given up. (At least one group, Colorado State University in Ft. Collins, still appears to be making noteworthy progress, despite exceptionally limited funding.)

While the optimization of wind turbines has made their production of power on a relatively large scale very competitive, their adoption on that scale is constrained by the need for firm capacity (continuous availability of power output). To overcome the inconsistent nature of wind, lower-cost turbines and large-scale storage technologies have to be developed such that they can compete, as a package, against conventional power sources. Large-scale flow-cell technology has been shown to be competitive for load management on an otherwise conventional grid, but not as part of a package deal to improve the viability of wind energy. Distributed small-scale wind power has the advantage of avoiding transmission & distribution losses, but is still hampered by the lack of cost-effective storage, which brings us to batteries.

Battery technology always seems to be five years away from a dramatic reduction in cost per kWh. Indeed, there has been stunning progress in battery mass and form factor for portable applications and both peaking power and reliability for hybrid-electric vehicular applications. Bulk storage of electrons in batteries, however, is still prohibitively expensive for all but a few niche applications. Battery life, toxic hazards, and maintenance costs are part of this technical ball & chain. And, flywheels, the electromechanical alternative to batteries so far share the attribute of being commercially viable for critical backup power applications, but generally not for storage sufficient to bridge the availability of inconsistent wind and solar resources. The limiting technical factor for flywheels with significant energy capacity is reasonable containment in case of catastrophic failures wherein massive amounts of energy must be dissipated in fractions of a second.

Although many of the DER technologies face some remaining technical hurdles, the technologies covered in this report have progressed at least far enough to be commercially viable in a range of niche applications. This fact offers some sense of perspective: The technical barriers sited here are mainly barriers to mass adoption, but certainly not barriers to technical performance or their commercial use in well-designed applications that are appropriately matched to the strengths of the respective technologies.

3.4.2 COMMERCIAL AND ECONOMIC BARRIERS

Commercial barriers to adopting DER technologies include the need for well-trained engineering staff to maintain the equipment, the need for physical space for the equipment, substantial costs associated with permitting and licensing, and the presumption that all new technologies are unreliable until proven otherwise over a substantial period of time. On top of those, there is the challenge of selling project concept to CFOs and CEOs who are typically unfamiliar with the benefits of investing in DER technologies. Each of these barriers can be formidable.

While in-house engineering expertise is not necessary, because equipment O&M can be outsourced, the required expertise may be hard to come by in some locations and outsourcing may prove to be relatively expensive for small operations. Regarding physical space for the equipment, available commercial space can be very limited where floor-space is closely tied to revenue and some DERs—especially those requiring storage of electrochemical energy, hot water, or ice—can have a substantial footprint. Licensing requirements and interconnection with the utility can entail long and complicated administrative processes with high associated costs. The requirement for DER technologies to stand the test of time sets up a chicken-&-egg problem: Positive industry experience with any new technology requires industry adoption and use of that technology over and extended period. Getting buy-in from key decision makers is a similar challenge in that it often requires numerous solid examples of actual return on investment.

The most common economic barrier to DERs—renewables in particular—is high cost per unit energy when compared to the grid. The other relatively common economic concern—particularly for fuel cells and microturbines—is uncertain maintenance costs (which should, for these technologies, be very competitive or even much lower that for most conventional technologies, but have yet to demonstrated as such with any consistency). However, economic competitiveness is improving steadily, and even more so when technology selection, system design, and implementation are appropriately optimized. However, this optimization requires interdisciplinary technical expertise that is not readily available.

Social economic benefits and other non-financial benefits may also have to be valued for a given DER project to be deemed worthwhile. Those include, for example, avoided environmental impacts, improved power quality and reliability, and corporate stewardship.

The applications in which DER technologies are most likely to be competitive from a purely economic perspective are remote power, demand management, and CHP. Remote applications for renewable energy systems often avoid high costs associated with extending power lines from the grid. Demand management through storage, controls, and other strategies stand to reduce utility bills significantly where high peaks can be mitigated on a sufficiently consistent basis. Combined heat and power can be advantageous where both the electrical and thermal energy can be efficiently and consistently put to use.

3.4.3 REGULATORY ISSUES

Energy, environment, and utility regulations have a significant impact on the viability of energy projects. Benefits are positive where productivity, efficiency, and clean technologies are encouraged and extremely negative where incumbent utilities are allowed to exert their monopoly power through draconian interconnection rules and standby charges with no counterbalancing market alternatives. Some of the applicable regulatory issues are discussed below.

Wind

If the wind output is for on-site use alone by the asset owner, state-level regulations regarding renewable energy are less applicable. If the energy output will be put on the grid, the project will require a power purchase agreement from the utility. From a regulatory standpoint, that kind of power purchase will either be encouraged by the purchasing utility if it part of an RPS (renewable portfolio standard), or it will be neutral to discouraged if there is no renewable requirement for the utility. In Colorado, there is no RPS, but there is a ballot initiative. The sponsors (Environment Colorado, a division of CoPIRG) of the ballot initiative in Colorado (which calls for 10% of retail energy sold by six utilities and coops in the state to be from renewable energy resources by 2014) needed roughly 100,000 signatures by August 2 to get on the ballot. Over 110,000 signatures were turned in to the Secretary of State with a final count awaited at the time of writing potentially making Colorado the first state in the US to vote on renewable energy. The RPS would also apply to other renewable energy resources. In Nevada, for comparison, the goal is 15% by 2012.

Siting is another regulatory hurdle for wind energy. The project first has to be sited in a good wind site, from a technical and economics point of view, and if that location has either scenic value, or is located far away from the grid, it can stop the project from going forward. Public resistance can be a significant market barrier in pristine areas, as well. If it is on federal land, the project will have to be approved by the US Fish and Wildlife department, which looks at multiple ecological issues including avian impacts and impacts on other species.

Another regulatory issue is at the federal level: will the US Congress approve the federal renewable energy production tax credit (worth 1.8 cents per kilowatt-hour generated by wind and biomass)? The energy bill of which it is a part just passed in the House, and is going to the Senate at time of writing. If it does get enacted, it will likely be part of a bill that includes additional tax breaks for coal-bed methane. For more information, see www.thomas.loc.gov.

Micro-Hydro

Siting and licensing are the primary regulatory issues associated with micro-hydro. The primary constraint is permitting controls by the Federal Energy Regulatory Commission (FERC). High development costs attributed to project and site evaluation procedures for FERC licensing have slowed small hydro development in the U.S. to a crawl. The application procedure requires a complete engineering analysis of the project and an environmental impact statement describing the effect the project would have on fish, water quality, wildlife, geology, soils, botanical resources, recreation, land use and socioeconomic values.

Solar

Few regulatory issues apply to solar energy technologies. Some states have a program that allow for a write down of costs associated with PV installation costs, through a systems benefit charge, but Colorado does not have that program. There are proposals in the National Energy Bill, which has not passed Congress. Under the proposed legislation now in committee, a company can receive a tax credit for investments in PV.

CHP and Reciprocating Engines

The most important regulatory issue for CHP and reciprocating engines is air emissions. The Air Quality Control Commission, a non-PUC, state-level regulatory body, regulates air emissions in Colorado.

Annual emissions over 2 tons of any criteria pollutants requires an air pollution notice to be filed. The notice tells the Commission about the project, technology, emission rates, etc. The company has to pay annual fees, which would be low for small emission amounts. If a company emits over 10 tons of NOx, SOx or CO, a state "construction permit" is required. If over 100 tons is emitted, then the company is required to get a Title 5 "operating permit" (Title 5 of the 1990 Clean Air Act). These permits are granted under the Federal Operating Permit Program, managed by the state. For PM10 and VOCs, the permit threshold (at which point a permit is needed) is 5 tons per year. If the company or site is located in a non-attainment area, it can be difficult to get these permits. The Denver metro area is currently labeled as "attainment management." At one point, Aspen was labeled non-attainment for PM10.

Emergency backup generators (which typically operate on diesel) are regulated by EPA rulings that are implemented by the State. There are some exemptions, but those are contingent on the units being used for emergency backup. Units operating at less than 260 horsepower are exempt. Units operating greater than 260 HP and less than 737 HP, and operating no more than 250 hours per year, are also exempt. Units operating at 1,840 HP and no more than 100 hours per year are exempt. Permits are required for anything else. A unit running in parallel with the grid, as a peaking unit for example, would be regulated like any other emitting unit.

3.4.4 INTERCONNECTION ISSUES

Interconnection issues often present significant hurdles for DE producers. From the customer perspective, the main concern is protecting DER equipment from dirty grid power—spikes and brownouts that can wreak havoc on electrical and electronic components. For the utilities, compatibility with operation and maintenance of the grid is the primary concern. Though it has not proven to be an issue for the vast majority of DERs, utility representatives often argue that their T&D equipment will have to be upgraded to deal with customers' excess power. Until DERs represent a significant fraction of power on the grid, this concern may be unwarranted. And, while grid maintenance, and worker safety in particular, is a very real concern, a customer with grid-tied renewable energy or CHP system has ample and generally affordable options for preventing their power from feeding into the grid when the grid is de-energized. This is commonly known as anti-islanding or islanding, wherein either the DER shuts down with the grid, as a preventative measure, or disconnects from it so as to continue providing onsite power when the grid has failed.

Local utility buyback rates are closely tied to interconnection issues and can present similar challenges. Under PURPA Title 2, which largely drove the markets for clean energy projects in the 1980s and 1990s, utilities were required to purchase power from qualifying facilities (QFs) that generated certain types of clean energy. However, barriers still remain: interconnection costs can be high due to expensive hardware required on the utility side, and the terms of using the grid as backup power or virtual storage are sometimes unclear and unfavorable.

In practice, according to the CHP industry for example, grid managers have attempted to "gold-plate" the interconnect in ways that added significant cost. Utilities buying back power have also been known to bargain perhaps a bit too hard on standby power rates and standby capacity charges. PURPA was intended to address these issues by requiring utilities to offer prices based on avoided costs. Generally, in today's utility environment, avoided costs are much lower than average rates on most systems, so QFs end up in extensive bargaining sessions in an attempt to secure reasonable buyback rates. And, there is now an amendment in the pending Congressional energy bill that would relax the requirement to buy power from QFs at avoided cost. The requirement to buy back would still exist, but the rates may be even less attractive than they already are.

3.4.5 INCUMBENT OR RESISTANCE-TO-CHANGE BARRIERS

While the human desire to make life easier is often the mother of invention, it is even more often the source of stagnation. Owners, designers, engineers, installers, and facility managers more often than not go with what they know: “tried and true solutions” that have been used for decades and seem to work well enough. Unfortunately, the accepted norms for what constitutes working “well enough” are often abysmal. Furthermore, performance is often measured with inappropriately narrow metrics, such as first cost per unit of peak cooling capacity for an HVAC system or cost per kWh, sans demand charges and externalities, for utility power. These tendencies typically lead to ignorance of better performing technologies and designs, lack of accounting for whole-system performance, lack of integration, and selection of old technologies and methods as known quantities, even when decidedly inferior. Thus accepted levels of performance—environmental, functional, and financial—generally lag well behind available options.

3.5 Economic Benefits of DER

3.5.1 NET METERING

Net metering provides means of selling excess power at any given time into the utility grid. This enables use of the grid as virtual storage without losing the value of energy generated onsite. Because a grid-tied arrangement is generally much less costly than provision of on-site energy storage, net metering is economically beneficial when the onsite generation is intermittent, such as is the case for wind and solar-photovoltaic (PV) power. Given that these renewable sources are not always producing when one wants the power, some form of “storage” can be a useful enabler.

Net metering can also be beneficial when operation of an onsite generator, co-generation, or combined heat & power (CHP) system is producing excess electricity either because the demand for heat is determining its output or because operation at very low fraction of peak load to serve a fluctuating need would be inefficient. For example, ski area lodging may have an unusually high demand for hot water at certain times of day that might, given the quantity involved, make storage of that much hot water impractical or inefficient (because the large volume of water in storage would have to be kept hot all the time). A large boiler might thus be used to handle the need. If a CHP system were used instead to meet the thermal load, capturing its benefits would require the extra electricity generated during the elevated demand for heat to be used or sold. A net metering arrangement would allow the excess power to be sold, thereby helping to pay for the services otherwise provided by the CHP system.

The purchase price per kWh or value of this “sale” is set in advance by the utility. For small net metering quantities, a meter may simply be allowed to run in reverse, thus making the buying and selling prices equal. For larger distributed energy producers, prices paid are typically closer to wholesale rather than retail. The amount paid above wholesale, if any, will tend to be based either on the DER’s round-the-clock availability, such as is the case for hydroelectric power, or its coincidence with midday summer air conditioning loads, such as is the case for PV power. The latter, however, is more common in dense and/or lower elevation urban areas. It is less likely to be a factor in higher-elevation mountainous areas where air-conditioning loads tend to be relatively lower and evening/night loads relatively higher.

3.5.2 HOLY CROSS ELECTRIC

Rural electric co-ops, such as Holy Cross Electric (HCE), are exempt from portfolio standards that require10% renewables by 2010 in 1% annual increments. HCE has nonetheless adopted a goal of 10% renewable energy by 2010.

HCE has an informal program of working with customers who wish to develop distributed energy resources. Projects are managed by HCE on a case-by-case basis. The favored renewable energy technologies are wind and micro-hydro. PV is generally considered by Holy Cross to be overly expensive and poorly matched to their load profiles (because it is available only during daylight hours and not during their evening periods of peak demand), but they will work with customers who wish to build PV as well.

HCE has provided net metering with equal buy & sell prices for somewhat larger-than-typical PV installations (20-kW) and has indicated a willingness to provide a similar arrangement, but with closer-to-wholesale DE purchase prices, for much larger installations (*e.g.,* 200-kW PV).

HCE also has a program called The Local Renewable Pool, which includes micro-hydro, PV, and small-scale wind power. Under this program, HCE currently buys power from two micro-hydro producers within their system at avoided cost of production plus a small premium related to reduced demand (about 6.5¢ per kWh total). HCE expects to enter into a limited number of additional agreements of this nature.

3.5.3 DEMAND MANAGEMENT, PEAK SHAVING, AND LOAD SHAPING

Good design, distributed energy generation, automated demand management, and energy or thermal storage technologies can all be employed to shave peak electric power demands. These strategies can smooth the load profile seen by the utility or onsite renewable energy system either by meeting a portion of peak demand with another onsite resource or by displacing that demand over time. Peak demand is most often a function of midday air conditioning loads or intermittent commercial and industrial process loads. Peak demand for the Aspen and Vail Mountain ski area operations is profiled in §4.

The specific tools of demand management and peak shaving include energy efficiency through effectively integrated design (as discussed at the beginning of §3), automation technology, DERs, and storage technologies. Integrated design, typically aimed at reducing energy consumption in general, can also target peak loads, such as unwanted afternoon solar gain. Avoiding unwanted cooling loads through integrated design, materials, and construction is nearly always cost effective. The cost-effectiveness of reducing or eliminating other types of loads depends on project variables such as climate, program, site, and related design elements. Sophisticated digital building automation systems offer a reliable and often cost-effective means of controlling equipment to more efficiently provide services. This can include running a fan at optimal speed, staging the operation of equipment so each item is running as close as possible to peak efficiency, or simply opening a damper to bring in more fresh air when the outdoor temperature is in a desirable range (referred to in HVAC jargon as an economizer). DERs, individually described below, are best suited to demand management applications when the timing of their energy output corresponds to an onsite peak demand.

Reducing or displacing peak power demand reduces utility demand charges, reduces transmission and distribution (T&D) losses during peak-demand periods, and helps utilities avoid expansion of T&D and generating capacity. Demand charges are typically in the range of $10–15 per kW peak over a predetermined baseline. In cases where monthly demand charges are set for a given customer based on their highest peak demand during the entire year, and that particular demand peak is well above what is otherwise typical for the customer, peak shaving can provide substantial savings. In other words, depending on the utility rate structure, reducing a peak load that occurs only in one season can reduce demand charges for the entire year.

Reducing peak demand can also be used to improve the financial feasibility of distributed energy systems, especially those with a relatively high cost per kW power output. For example, it may be cheaper to optimize a building, system, or load for a 20% lower peak demand than to buy a 20% larger PV array and inverter. This will be especially true when the efficiency, peak shaving, or load management scheme can reduce peak demand below a threshold corresponding to a smaller or larger incremental equipment size. In the case of an inverter, for example, avoiding the jump to the next larger increment in equipment size will not only save a significant first-cost increment, it will save energy by avoiding part-load operation of an oversized piece of equipment.

Similarly, optimizing a heating or cooling load for a given size of combined heat & power (CHP) system may be cheaper, and more efficient, than installing the next size larger CHP device. While not all equipment operates most efficiently at maximum load, part-load operation of oversized equipment is a common source of significant loss. The amount of lost efficiency at part load depends on the particular system or technology.

3.5.4 RENEWABLE ENERGY AND EMISSIONS CREDITS

Renewable energy credits (RECs) can be sold to offset a portion of the cost of installing a renewable energy system. Selling RECs differs from selling excess power to a utility in that one is selling credits based on how much renewable energy was produced, regardless of whether any of it was provided to the grid as excess. Basically, the owner of the renewable energy system is being paid to displace other less desirable energy sources. Depending on the market, the payment may be collected from energy users within the community or region or across the nation. In any case, RECs represent a transfer of funds from those who wish to support renewable energy to those harnessing it.

The value of RECs depends significantly on the scale and type of market. Generally, only wind, solar-electric, and micro-hydroelectric power production qualify for RECs. (Certification by the Low-Impact Hydropower Institute is usually required for hydroelectric RECs to be salable in the marketplace.) As utility scale wind energy is the most prevalent renewable nationwide, national REC markets tend to pay something like 2.5¢ per kWh for any and all types of renewable energy production. In other words, one generally has to compete with other sources in a given market. On the local scale—at the other end of the spectrum—markets are often much less competitive among types of renewables and tend to place a higher value on those that bode well for the community. For example, there are local REC markets in the Northeastern U.S. that pay as much as 25¢ per kWh (ten times the national market price) for solar RECs, as local use of solar energy is seen as directly benefiting people within that local market. Unfortunately, Colorado has yet to foster any regional or local REC markets. So, for the time being, RECs from renewable energy produced in Colorado can be sold only to national markets where prices are set by large-scale wind energy.

The price paid for RECs also depends on the type of contract with the REC trader. A spot-price or short-term contract will tend to fetch lower prices, initially, but have the flexibility to reap the rewards of higher prices if and when the market is willing to pay them. Long-term contracts—*e.g.,* ten years—will, on the other hand, lock in a higher initial price per REC, but lack the flexibility to capture any improvements in market prices.

There is no regulation or offset program or emission credit trading specifically for emissions in Colorado. The State has approved Regulation Number 5, a mechanism for banking emissions and credits for criteria pollutants (NOx, SOx, CO, VOCs and PM), but EPA has not yet approved the State's regulation. There are a couple examples of companies that have gotten emission credits for VOCs and have been able to buy them as offsets (under Regulation Number 7, which applies to Denver metro area, which was the only area in non-attainment for ozone), but there are very few examples of offset/credit trading in Colorado.

PM10 particulate emissions are the most significant air-quality challenge for Colorado ski towns. Aspen adopted a number of measures to mitigate the PM10 problem, including restriction of wood burning and attempts to reduce or constrain vehicular traffic volume to control the problem. All the communities that were in PM10 non-attainment zones have been re-designated as attainment areas. Colorado mountain towns have not been in non-attainment for other criteria pollutants.

3.5.5 ENVIRONMENTAL BENEFITS

Most DERs have the potential to provide truly meaningful environmental benefits. While some benefits such as displacement of coal-fired power from the utility may not appear to accrue directly to the DER operator, implementing renewable, clean, and efficient systems has public relations value with real depth. It can also serve to reinforce a local and corporate culture of stewardship. And, studies of the Northeastern U.S. during the recent regional power blackout demonstrate that air quality, as measured both by distance of visibility and with air samples, is dramatically improved within a matter of days and even hours when a regional coal-fired power plant is shut down. Environmental benefits, while difficult to measure, might thus be more directly enjoyed by ski area patrons and locals than one might think.

The flip side of this are the local environmental concerns related to DER in the context of ski area operations, which include air quality, noise, visual impact, fragile alpine ecosystems, riparian corridors, and wildlife habitat. Capturing the benefits of DERs thus requires cognizance of potential DER-related impacts. Because many DERs are relatively benign, and each has situations to which it is better suited, the concerns that come into play can often be overcome through thoughtful selection of appropriate technologies and strategies.

Although the environmental benefits of better energy management are qualitatively recognized by business managers, the translation of those benefits into quantifiable economic or other business metrics often become a roadblock to the implementation of otherwise attractive energy projects. Very few projects will be authorized on environmental considerations alone; at best, they make a four-year payback acceptable instead of three. Quantifying and articulating the benefits, risks, and tradeoffs involved in clean energy projects is probably the most challenging part of successfully getting projects authorized.

3.5.6 SYSTEM OPTIMIZATION

System optimization for energy efficiency spans design, equipment specification, and operation. Optimization of mechanical and electrical systems saves energy and money that would otherwise be thrown away without providing any benefit whatsoever. System design—be it for renewable energy production or combined heat & power—needs to match anticipated loads and be integrated with all other systems or flows with which it interacts. Equipment needs to be sized to meet loads as predicted by careful modeling and/or thorough calculations rather than simplified engineering “rules of thumb,” which tend to result in costly and inefficient oversizing. Pipes and ducts need to be designed, sized, and routed to minimize friction and pumping losses. High-efficiency electric motors with adjustable speed drives should be specified where significant and frequent part-load operation would otherwise waste energy. Equipment within a given system, such as PV panels and inverters or CHP heat sources and absorption cooling, needs also to be matched carefully to avoid oversizing and inefficient part-load operation.

Operational strategies can provide real-time optimization of system efficiency through load management, control of duty cycles, control of motor speeds for pumps, compressors, and fans, and timely utilization of natural resources (*e.g.,* fresh air) and integrated passive systems (*e.g.,* desirable solar gain in winter or daylighting in conjunction with electric lighting). Each of these contributes to compounding savings within a system—quite the opposite of the compounding losses we’re so accustomed to tabulating.

Very often it is difficult to exactly match the availability of a particular resource with an appropriate load or storage system. The best approach then is the creation of pools of generation, storage, and load shedding capabilities that have specific characteristics such as granularity, dispatchability, aggregation, limited notification, and real-time verifiability. “Virtual” resources with these capabilities can be used effectively, with the right communication and control infrastructure, to optimize energy consumption, purchase, generation, and storage. This method of system optimization remains virtually untapped primarily due to the systems approach it requires and the limited experience that most providers have in this area.

3.6 Dispatchability

Capturing the financial benefits of DERs requires that they’re available when needed. If not, losses and costs associated with storing and retrieving or selling and buying back energy can easily soak up or completely overshadow potential for return on investment. Dispatchability, like availability, can also have a significant effect on the price a utility is willing to pay for power exported to the grid. If it’s not available when they need it, the value is much less. If it’s available on demand, the value is higher.

Energy sources that are controllable in terms of providing the required output on demand are considered dispatchable. While some projects may require only matching DER output to predictable or consistent demand, others will require dispatchability in order to provide timely services and financial benefits. Then there are projects intending to export significant quantities of energy to the grid, which, in order to be of value to the grid, will need to produce power when the grid needs it most, and perhaps even be able to do so in response to a control signal from the utility.

All of the technologies presented in this report that convert primary fuel energy to electric power and/or thermal energy are dispatchable. When they are needed, they can simply be turned on by a control signal. Most technologies that convert primary energy are also controllable in terms of level of output, with the ratio of peak output to minimum output referred to as “turn-down ratio.” It is rare, outside of heat-energy intensive industrial applications, that it makes sense to design or operate a DER consuming primary energy in a manner that produces significantly more power than can be consumed onsite.

Renewable DERs, on the other hand, are generally not dispatchable without some form of storage: The sun shines during daylight hours, and less so on cloudy days; The wind blows when weather patterns facilitate it; Water flows down hill when snow melts or after rainfall. Because we lack control over these events and generally want to get as much as we can from an investment in technology, it makes sense to capture and convert as much energy as we can, given the variable input of sun, wind, or water flow. But the output of these systems is only controllable or dispatchable to the extent that it can be stored and later retrieved on demand.

Thermal storage of water heated by solar thermal collectors is relatively cost-effective, and thus often a practical means of making this particular renewable resource dispatchable. Because electrical storage for PV, wind, or micro-hydro adds cost and reduces efficiency, the cases where it is worth using are generally those where high value is placed on demand management, power quality, power reliability, or avoidance of a costly utility grid extension. Flow-cells appear to be among the most economical and dispatchable forms of electrical storage, but are still relatively immature and thus available in a very limited number of sizes. Damming a water flow can be a cost-effective form of storage, but more often than not it is an environmentally damaging one. Pumped storage—*i.e.,* moving some water up to a higher location—to buffer the daily or seasonal output of micro-hydroelectric power may be somewhat less economical than a dam, but is also usually much less damaging as it can avoid flooding a complex and fragile riparian ecosystem. Other renewable sources, such as wind energy, can also be couple with pumped storage. Still, all of these storage options come at a cost that may or may not be justified by the availability and dispatchability provided.

All demand-management technologies, including those discussed above in relation to renewables, are, by definition, dispatchable. Ice is used to store “coolth” until it is needed, and then tapped for output on demand. Like batteries and flywheels, only with practical applications on a larger scale, flow-cell technology can be used to demand on a utility grid scale or for an onsite DER. With any storage technologies, the limit of dispatchability is a function of peak output and available rate of change in output. In other words, when the rate-of-output limit is reached, even though there may be ample energy still in storage, systems will have to resort to grid power to meet additional demands.

One future possibility for dispatchable non-industrial distributed conversion of primary energy is the remotely controlled use of parked hydrogen fuel cell powered automobiles connected to a stationary reformer. The reformer converts natural gas to hydrogen and provides it to grid-connected automobiles for electricity production. Its waste heat supports building HVAC and hot water services. This would allow the use of a reformer plus otherwise idle assets to generate heat and power on demand—as independently dispatchable outputs—and thus also CHP-based energy cost savings and potential revenue. While some years down the road, this scenario can have significant financial potential for all parties involved—mainly because we’re accustomed to buying expensive vehicles and allowing their short-lived conventional gasoline engines to sit idle most of the time as they steadily lose market value. Building owners (via CHP benefits), utilities (via demand management), and society (through reduced environmental costs) would also reap economic rewards. This scheme also offers a synergistic bridge between the introduction of stationary and mobile hydrogen applications.

4 Energy Analysis for Aspen and Vail Mountain Operations

4.1 Aspen

Aspen Ski Company (ASC) owns and operates the four distinctive mountains of Aspen, Aspen Highlands, Buttermilk and Snowmass. Snowmass will be the focus of this analysis since it is the largest of ASC's mountains at a little over 3,000 skiable acres. The information utilized in this analysis comes largely from a 1999 baseline analysis that was completed, in part, for the *Greening Your Ski Area Handbook.*

In 1999, all four mountains served just over 1.2 million skiers. (For an order of magnitude perspective on distribution among the four mountains, Snowmass served approximately 650,000 skiers in 2002.) Snowmass is provided electrical service by Holy Cross Energy and natural gas from K-N Energy. In 1999, costs for all four ASC mountains were approximately $1.9 million for electricity, providing service to buildings, snowmaking operations, lifts and miscellaneous electric loads. Similarly, natural gas costs were $472,700 for service to buildings of the four mountains.

The utility metering and billing structure at ASC allows for select energy usage characterization specific to Snowmass Mountain. In particular, natural gas is metered separately for the buildings of Snowmass Mountain. The monthly cost for natural gas at Snowmass during winter months is approximately $3,000 according to the 1999 baseline data. Natural gas costs were based on an average cost of $0.48/therm.

The electrical metering structure employed at ASC segregates the building usage between the four mountains' buildings. According to 1999 data, electrical use for Snowmass Mountain buildings totals about 2,150 MWh/yr or about $150,000/yr. Figure 3 depicts the baseline monthly electrical costs for the buildings at Snowmass Mountain.

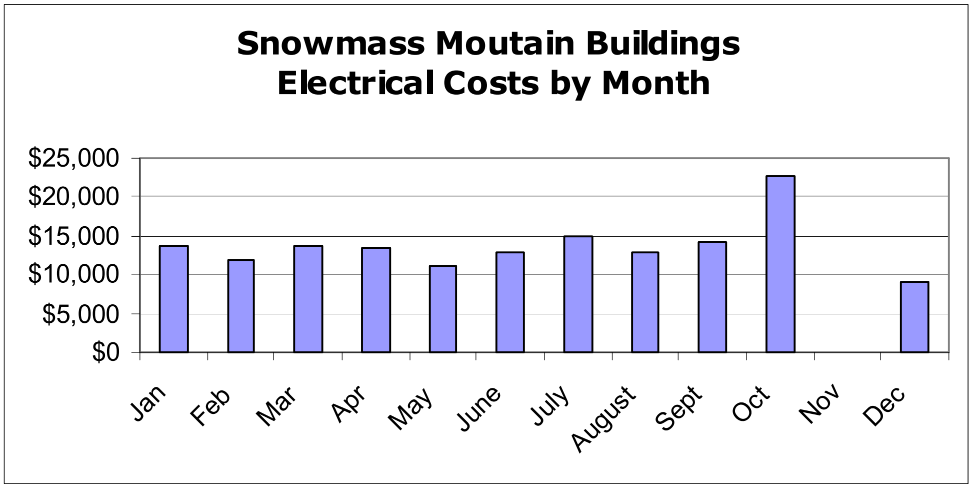


Figure 3: Baseline monthly electrical costs for the buildings at Snowmass Mountain

The operations served by the electrical and natural gas utilities at the four ASC mountains can be subdivided into three primary categories: facilities, lifts, and snowmaking. Lifts are described in Figure 4. Note that the potential demands are based on the nameplate ratings of the equipment, not actual meter readings.

Figure 4: Energy Demand from Lift operations at Snowmass Mountain

DESCRIPTION OF LIFTS			
DESCRIPTION	AVERAGE HORSEPOWER (HP)	TOTAL HORSEPOWER (HP)	POTENTIAL DEMAND (MW)
Lifts 21 total	322	6,763	5.0

The breakout of usage for electricity by service for all ASC mountains is shown below in Figure 5. As Figure 5 demonstrates, the top contributor to annual usage is lifts, although the distribution across lifts, snowmaking, and buildings is largely equal.

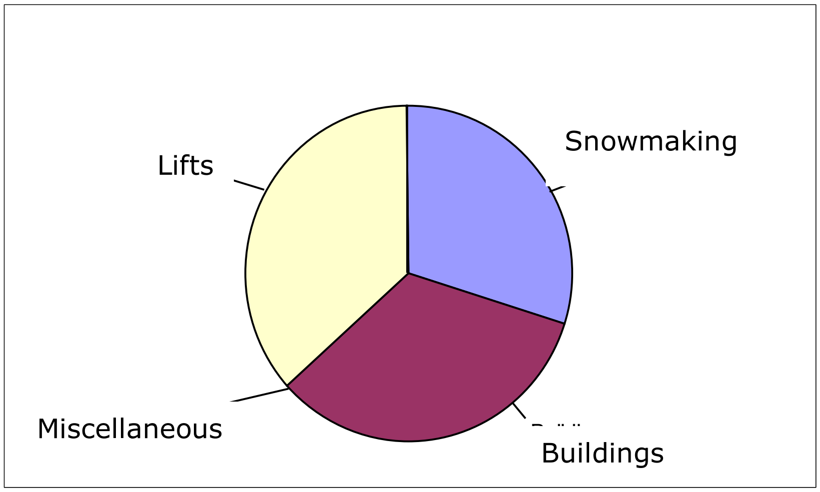
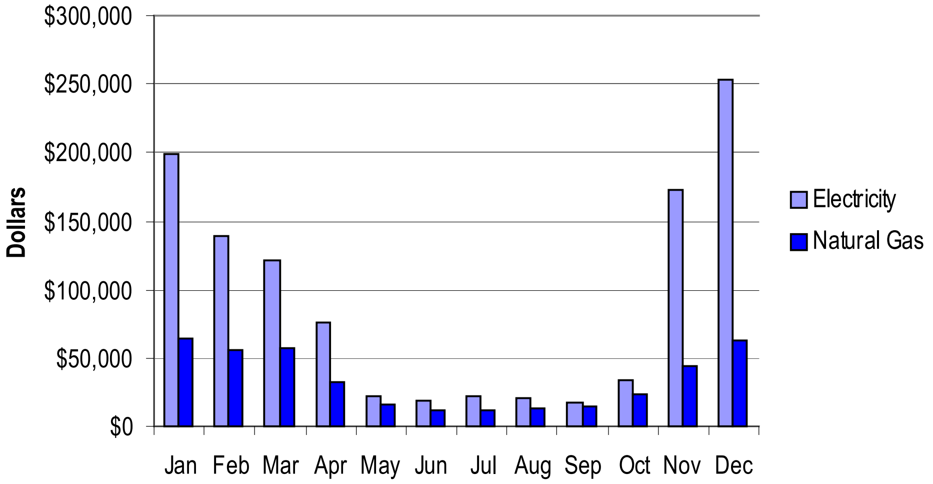


Figure 5: Aspen Ski Company electrical cost distribution by use

4.2 Vail Mountain

In 2002 Vail Mountain served approximately one and half million skiers. Vail's on-mountain facilities, lifts, and snowmaking operations obtain electricity from Holy Cross Energy and natural gas from Tiger Gas. The baseline monthly costs for each of these energy sources are shown in Figure 6.

Figure 6: Monthly cost for electricity and natural gas at Vail Mountain



The information utilized in this analysis comes largely from a Comprehensive Energy Analysis prepared for Vail Mountain by CMS Viron Energy Services in December of 2002. Vail Mountain made this document available in order to facilitate the development of this report.

In 2002, Vail spent approximately $1,098,451 on electricity and $407,266 on natural gas for use in on-mountain operations. Natural gas costs were based on an average cost of $0.6361/Therm from Tiger Gas. The monthly totals were determined from separate meters at the on-mountain facilities, as indicated in the detailed facilities and equipment breakdown in Table 7.

The electrical metering structure employed on Vail Mountain makes a detailed energy usage characterization difficult. Currently, on-mountain facilities and operations for both Vail Mountain and Beaver Creek Resort share a single primary meter. Though submeters exist, they are not read. This makes a breakdown of energy usage for individual operations challenging.

For internal billing purposes, the operations staffs at Vail and Beaver Creek have collaboratively developed a baseline energy breakdown for lifts, snowmaking and facilities at each resort. The authors of this report utilized Viron's equipment audit results to perform an energy balance for Vail facilities and equipment and found the usage and peak demand results to be of similar magnitude to the internal baseline. Given that Vail's staff has a better understanding of their processes and scheduling, their internal baseline numbers are used through the rest of this analysis, unless otherwise noted.

Based on the baseline energy breakdown from fiscal year 2001 through 2002, Vail Mountain uses approximately 18,469,317 kWh annually for on-mountain facilities, lifts and snowmaking. Billing from the utility is based on a rate structure that includes a fixed monthly Customer Service Charge of $5,944, a Demand Charge of $15.91/kW, and an Energy Charge of $0.028/kWh.

The operations served by the electrical and natural gas utilities at Vail Mountain can also be subdivided into three primary categories: facilities, lifts and snowmaking. Facilities includes all on-mountain restaurants, customer services buildings and the gondola building at Eagle's Nest. Note that base area facilities like One Vail Place, the Lodge at Vail and Golden Peak are not included, as these do not fall under the single primary electric meter discussed above. None of the included facilities have overnight accommodations. A detailed description of each facility can be found in Figure 7, while lifts and snowmaking are described in Figure 8. Note that the potential demands are based on the nameplate ratings of the equipment, not actual meter readings.

FIGURE 7: DESCRIPTION OF FACILITIES

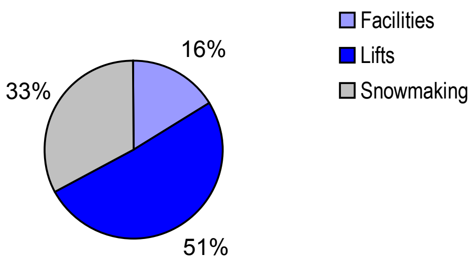
NAME	DESCRIPTION	SIZE (SQ. FT.)	POTENTIAL DEMAND			
			NATURAL GAS (MBH)	HEATING AND WATER DIST. (KW)	VENT. (KW)	LIGHTING (KW)
Eagle's Nest	Top of Eagle Bahn Gondola	27,673	>6,434	15.1	20.8	104.8
Game Creek Club and Chalet	Restaurant and club	11,287	>4,087	8.8	18.1	25.5
Mid Vail	Restaurant and services	34,793	>6,000	5.2	32.6	44.4
Two Elk	Restaurant and services	29,900	7,552	7.9	31.7	30.7
Wildwood	Restaurant and services	9,497	1,490	0	2.2	10.0
Buffalos/ PHQ	Restaurant, services, Patrol HQ	N/A	1,535	1.5	3.4	10.4

Data not available for appliance loads

FIGURE 8: DESCRIPTION OF LIFTS AND SNOWMAKING			
DESCRIPTION	AVERAGE HORSEPOWER (HP)	TOTAL HORSEPOWER (HP)	POTENTIAL DEMAND (MW)
Lifts 9 fixed, 14 detachable, 9 tow, 1 gondola	457	15,075	11.2
Snowmaking			
17 pump motors	379	6,450	4.81
13 compressor motors	369	4,800	3.58

As Figure 9 demonstrates, the overall contribution to annual usage is dominated by the lifts and then by snowmaking, despite the very short season in which snowmaking equipment is operated.

Figure 9: Annual Energy Consumption by Operation at Vail Mountain



Figures 10 and 11 show the monthly usage and demand profiles. Note that the profiles are exactly the same since Vail operations uses the same percentages to calculate baseline numbers for demand and usage.

Figure 10: Monthly Energy Usage by operation at Vail Mountain

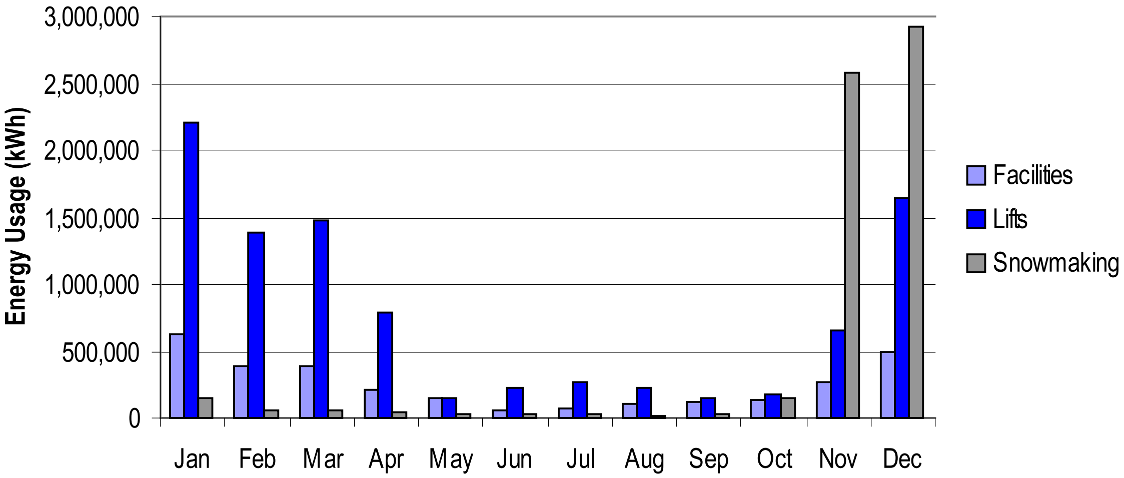
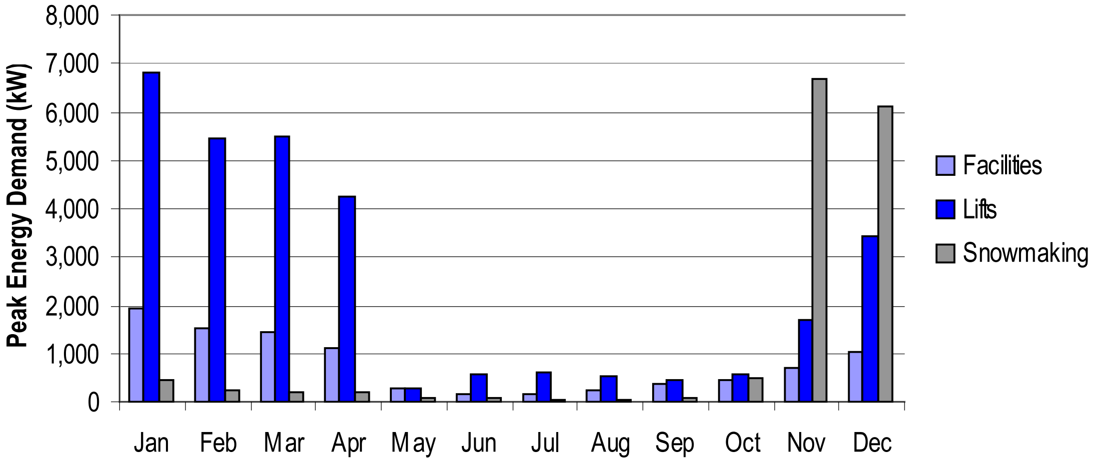


Figure 11: Monthly peak demand by operation at Vail Mountain



On average, with Demand Charges and fixed Customer Service Charges included, Vail Mountain is paying $0.0595/kWh.

Some of the other key metrics helpful for evaluating the energy component of ski area operations are presented in the table below (Figure 12). They offer a glimpse of the metrics that have to be kept in mind as fundamental drivers for evaluating energy projects for ski area operations.

	FACILITIES	LIFTS	SNOWMAKING
System	26.7kWh/sq ft	NA KWh/skier/vertical-ft	13,428kWh/acre
Visitation	1.96kWh/skier-visit	6.07kWh/skier-visit	3.96kWh/skier-visit

Figure 12: Annual Energy Intensity By Operation

5 DER Opportunities at Aspen and Vail Mountain Ski Areas

DER and CHP opportunities at ski areas are significant and technically feasibly. However, as is frequently the case, the difficulty is in creating an economically attractive package that meets the ski industry's technical requirements, the skier's desire for a pleasant experience on the slopes (noise, visual impact, etc.), as well as providing a high level of environmental stewardship.

The ski industry, and communities in which they are located, have done a great job in expanding from a five month ski season to now include many summer activities and in some cases approaching a year round vacation destinations. While activities are increasing beyond the ski season, the energy use at these areas is still very heavily winter dominated due to nearly continuous lift operating during the winter days and early season snow making activities at night as was previously indicated in §4.

Ski areas are scattered across the US with the largest concentrations in New England and the mountain states of the west. In addition to the geographical diversity, non-uniformly distributed natural resources such as wind and solar, physical characteristics (size, number of lifts, energy requirements, etc.), and the specific interests of the management and staff at specific ski areas, the consideration and selection of DER and CHP technologies will vary from one ski area to another. Additionally, many ski areas are served by rural electric cooperatives. Each electric utility has its own rate structures, peak demands, and current availability of capacity to serve the local ski area. These too may drive the decision to consider DER/CHP and possibly the choice of prime mover technology.

However, even with these differences there are significant energy use pattern similarities throughout the ski industry and therefore opportunities for DER and CHP. All make snow early in the ski season, all run lifts on nearly the same time schedule, required space and domestic water heating and electrical requirements are, on a daily cycle, coincident, and many are the single largest energy consuming entity in their respective community.

As discussed previously, ski area energy use can be divided into three primary areas, facilities, lifts, and snowmaking. Each of these provides different opportunities for DER or CHP. Chair lifts and snow making may provide some overlapping opportunities since they are primarily drive power and typically out of phase with each other, lifts operate during the day while snowmaking is primarily done at night. These two operations, lifts and snow making, make up the bulk of the energy consumption at ski areas, on the order of 80% or more during some months. The drive power required by these systems could be electricity provided by the utility or generated on site by any number of the technologies previously discussed in §4. The energy use in the various facilities, while much smaller than the other two operations, often provides an opportunity with both economic and environmental benefits in that both the electricity and thermal energy produced by a CHP system can be utilized during the winter months, thus reducing total energy consumption. Opportunities for each of these are discussed in the following sections.

5.1 CHP Opportunities

While the bulk of the energy used at ski areas is to drive the motors that operate chair lifts as well as air compressors and water pumps for snow making, these operations primarily require mechanical or electrical energy only. The various facilities at ski areas including lodges, restaurants, shops, ticket sales offices, maintenance facilities and others not only require electricity for lighting, cooking, operating the HVAC fans, pumps and other equipment, but also require space and water heating during the majority of the operating season. Additionally, ski areas are frequently high in the mountains where the climate is considerably harsher than at lower elevations, increasing the need for space heating. Average temperatures throughout the ski season are frequently in the teens and 20s Fahrenheit, with record lows of -30F and lower being common. Even well designed, insulated, and constructed building envelopes have significant heat losses in these climates. Add to this the infiltration heating requirements that result from open doors to accommodate the near steady stream of skiers entering and leaving these facilities, large glass areas so the guests can soak up the mountain views, and the heating loads are substantial. And this is the opportunity for CHP.

As mentioned previously, there is a wide array of packaged CHP systems available in capacities from a few kWs to multi-megawatt electrical capacities and with a variety of prime mover technologies. These systems are also often available with absorption chiller options. There are cooling requirements during the summer months in these areas. However, they are typically fairly modest and of short duration. This combination tends to decrease the economic viability of using absorption chillers compared to their lower cost electric vapor compression counterparts. Figure 13 presents general prime mover capacity ranges as well as electrical and thermal efficiencies.

Figure 13: Capacity range and electrical and thermal efficiencies of packaged CHP systems

Prime Mover	Electric Capacity	Electrical Efficiency	Thermal Capacity[1]
Reciprocating engine	~5 kW to 5 MW	20% to 43%	4,000 to 9,000 Btu/kWh
Microturbine	30 kW to 200 kW	17% to 25%	5,500 to 12,000 Btu/kWh
Gas Turbine[2]	300 kW to 10 MW	14% to 36%	4,500 to 16,500 Btu/kWh
Stirling Engine	1 kW to 100 kW	13% to 30%	5,000 to 17,000 Btu/kWh
Fuel cell	5 kW to 250 kW	30% to ~60%	3,500 to 6,000 Btu/kWh

[1] All systems were expected to have a maximum overall (electric + thermal) efficiency of 80%.

[2] Gas turbines larger than 10 MW are readily available. However, this is expected to be about the largest capacity that a ski area might employ.

Source: Manufacturers data.

Electricity can be fed into the grid or used in grid-isolated applications while the thermal energy provides space and water heating. During the summer, when space heating requirements are small, but perhaps still exist during the nights and early morning, appropriately sized (perhaps multiple units) and controlled CHP system can operate efficiently and provide savings year round.

5.1.1 COGENERATION PROJECT AT BLUE MOUNTAIN, ONTARIO

Although no CHP projects have been implemented at Vail or Aspen yet, it is valuable to describe a cogeneration project at Blue Mountain, Ontario in more detail here.

The pilot project at Blue Mountain Resorts included a load following, grid-connected, 30 kilowatt (expandable to 90 kilowatt) micro-turbine. If grid power is lost, the unit shuts down and restarts only 20 minutes after grid power is restored. In Blue Mountain's case, a 480-volt to 600-volt step-up transformer was needed to tie into the switchgear. Also included was a stand-alone heat exchanger to change the turbine exhaust into thermal energy to heat the resort's domestic hot water. All of this is monitored, through the web, by a system that logs gas consumption, electrical output, water flow rates, and temperature in and out of the heat exchange. Blue Power, which owns and financed this pilot project, has determined with data gathered to this point that an additional 60 kilowatt may be justifiable. The micro-turbine supplies 30 kilowatt of electrical energy and provides approximately 55 kilowatt of thermal energy to heat the resort's domestic hot water and laundry facilities. This represents approximately 85 percent fuel conversion efficiency. The Capstone micro-turbine the resort uses has a relatively small footprint and low emissions ranging from 2 to 9 parts per million of NOx at 15 percent O2 at full load. Although the unit runs on natural gas, the turbines can be designed to run on propane, diesel, kerosene, oil field flare-gas, and biogas with energy content as low as 350 British thermal units per cubic foot. The resort will not have true cost or energy savings numbers until the micro-turbine has operated for at least a year. However, preliminary efficiency ratings are very promising.

5.2 Chair Lift Opportunities

Chair lift operations are required to have a backup source of power that can run the lift to at least get the passengers off in case of an emergency. Physical characteristics of nearly 350 lifts located at ski areas throughout Colorado were analyzed and of this number, 325 had provided data concerning their back up power capabilities. The predominant back up system is a diesel engine connected via V-belts, chain, gear drive, or driveshaft to the speed-reducing gearbox. Additionally, a few gasoline engines are used, typically on smaller lifts. Engine capacities varied depending on the vertical gain and length of the lift as well as the chair spacing, ranging from relatively small (less than 50 hp) to well over 1000 hp, exceeding 2,500 hp in one case with the average power rating of just over 250 hp. However it should be noted that this value is skewed lower than might be expected by the large number of smaller lifts, well over 1/3 of the total lifts had back up systems rated at 100 hp or less, providing less than 5% of the total hp of all lifts. At the other end of this spectrum are the units of greater than 500 hp. While these units account for only 90 lifts, about 28% of the population, they account for 66,000 hp or more than 75% of the total power.

Based on energy usage for a limited number of lifts, operating hours, etc. the capacity factor of a lift was determined to be between 50% and 75% of the rated capacity. Therefore, in a peak shaving scenario where it is only considered to utilize existing onsite engines with capacities greater than 500 hp, and being conservative and derating these by 50% for capacity factor, a small number of lifts could provide significant demand reduction opportunities.

Using Vail as an example, and not including the Eagle Bahn Gondola since its motors are considerably larger than any others in the data sample, there are 12 lifts with back up engines 500 hp or larger, totaling 8,950 hp and averaging nearly 750 hp each. Assuming a conservative capacity factor of 50% this results in nearly 4,500 hp or 3.3 MW of electrical demand reduction.

While this is not an electrical generator connected to the grid, it may prove valuable to discuss this with the local utility in order to coordinate efforts. Depending on when the utility sets its peak relative to the ski area's peak, and the electrical demand charge rate and structure, in some cases for both the facility's peak and the utility's peak, engine operating hours may be minimized through careful coordination and monitoring of the electric utility and ski facility demand. As an example (but not at a ski area) of this type of host site and utility coordination, in a real world situation a company intended to operate 3 gensets totaling 2.25 MW for peak shaving. It was expected that the gensets would be operated on the order of 1,000 hours over 3 to 4 summer months to reduce the demand. This had to be done with no genset outages or that portion of the month's demand saving would be lost. After discussions with the utility, who was interested in this project due to their own capacity constraints, the gensets were operated for approximately 100 hours to achieve a similar demand charge savings at considerably lower cost to the host site. And the utility allowed for a limited number of unscheduled outages that would not have been possible otherwise.

One must note that this opportunity is not without a price. There will be additional fuel to be purchased, increased maintenance costs, costs associated with setting up the operating strategy, as well as ongoing monitoring, and perhaps even utility coordination even though this is not a generator drive. Different operating permits will very likely be required as well as possibly increased sound attenuation around the engine and, depending on the operating hours and air district, perhaps some form of emissions control system.

An additional opportunity that would increase flexibility would be the use of a genset as the source of back up power for lifts rather than mechanical drives. There are, as there always is, both pros and cons to this approach. A mechanical drive does provide a mechanism for lift operation not only in the event of a utility power outage but also in the event of a drive motor or virtually any other mechanical failure up to, but not including the gearbox.

Since mechanical drives are directly connected to their load they can provide power only to that dedicated load. Using generators allows, with appropriate wiring, the use of a genset in one location to power a system in a different location. Among other things this approach could provide added redundancy to the back up systems for chair lifts in the event of a utility outage and simultaneously the engine located in that lift not starting—an unlikely, but possible combination of events.

An alternative, although more costly, would be for the lift manufacturers to develop hybrid drive systems for their lifts. These systems have been developed and are commercially available in the HVAC industry in the form of packaged gas engine/electric motor-driven chiller/generator sets. In this case, the chiller can be driven by the engine or by electric motor with the choice depending on the real time price of natural gas and electricity. Additionally, the engine can be used to drive the motor, which is also a generator, either independent of, or in parallel with the chiller. The entire system, engine, motor/generator, chiller are mounted in-line on a single skid. These systems can be configured as CHP systems as well. Replacing the chiller with a connection to the lift gearbox would seem to be a relatively straightforward "next step" for energy efficiency and operating cost reductions in the ski industry.

This opportunity would likely be most cost effective in applications with larger drive motors, say 500 to 600 hp and larger. There are several possible approaches to this.

New lift installations: Coordination with the lift manufacturer will be required in order to purchase the lift with an optional genset (hybrid drive) rather than the standard engine and mechanical drive. This could be purchased as a complete system from the lift manufacturer with their full system warranty.

Retrofit: install a packaged genset with appropriate switchgear so that in the event of a utility outage the utility electrical connection is opened and the generator connection is closed on the lift. This open transition connection ensures the genset is isolated from the grid, similar to typical backup generator installations. This option is only useful in the event of an electrical outage and will not prove useful in the event of a motor or mechanical failure. If space is available it may be possible to modify the existing system and install a genset hybrid drive in the lift enclosure. This option would provide either electrical or mechanical capabilities and thus be more flexible than the genset alone, but with a higher first cost.

Between 1999 and 2003 there were 159 chair lifts installed in the US, averaging 32 per year but the installations were more heavily weighted to 1999 when 49 lifts were installed. Since then, the general trend currently has been declining numbers of installations until 2003, which showed an increase over the previous year. Motor horsepower data is not available for these lifts but the trend is to larger carrying capacity with an average of 4 seats. The average hp requirements per lift are therefore expected to be increasing. If it is can be assumed that the average capacity for lifts installed prior to 1999 is 3 seats (estimated) per chair and is 4 seats per chair as is the case for the new lifts (1999 to 2003) and assuming the average length and vertical rise are similar to the existing stock of lifts, it can be expected that the average motor horsepower would similarly increase. Therefore the average power requirements of lifts installed between 1999 and 2003 would be on the order of 325 hp. It is therefore estimated that approximately 52,000 hp (38 MW electric equivalent) were installed during the 5 year period. This averages approximately 10,000 hp or just under 8 MW of potential electric generating capacity installed per year in the ski industry.

In addition to the choice of drive type, mechanical or electrical, alternative fuel options are also available. The choices will depend on factors such as fuel availability and cost and whether or not existing engines are being used or new engines are being purchased.

Natural gas/LPG engines: Rather than using diesel engines as the back up power source, natural gas or LPG engines can be use. If onsite fuel storage is required either a small CNG or LPG/air storage facility would be needed.

Dual fuel engines: As an alternative to diesel engines, dual fuel engines are an option. Dual fuel engines are compression ignition (diesel) engines that utilize natural gas or other gaseous fuel (such as LPG, landfill gas, etc.) as a substantial part of the total energy required by the engine. These can be purchased from a number of manufactures and in some cases diesel to dual fuel conversions can be made by the engine manufacturer to achieve very high natural gas substitution rates – in some cases in excess of 95% natural gas. Alternatively, there are a number of aftermarket conversion kits available for just about any engine. However, aftermarket conversions generally have considerably lower natural gas substitution rates, on the order of 50% to 80% of the energy content. Diesel fuel supplies the remaining 20% to 50%, which is required for ignition. Engines can be switched from diesel to dual fuel and back while operating under load so if the natural gas supply is interrupted there is a transparent switch to diesel fuel. Benefits obtained from conversion of a diesel engine to dual fuel are:

- Reduced operating costs – This varies depending on the relative price of diesel fuel and natural gas. As fuel prices vary the most cost effective fuel can be used.
- Reduced engine maintenance costs – Oil change intervals can often be extended.
- Lower emissions – SOx and particulates are generally reduced approximately in proportion to the fraction of natural gas used. NOx reductions are dependant on the specific engine as well as natural gas substitution rate.
- Extended operating hours for a given supply of diesel fuel – Assuming a 75% natural gas substitution rate a dual fuel genset can operate 4 times as long on a tank of diesel fuel as the same engine operating on straight diesel fuel.
- Use of other diesel-like fuels – Currently the most common such fuel is biodiesel. This is often used as a mixture of 20% biodiesel and 80% petrodiesel and is referred to as B20 and is a “fill and go” fuel meaning that generally there are no engine modification required to use biodiesel. Older engines may require replacement of some plastic and rubber components. Other fuels include emulsion diesel fuel, which generally consists of 80% diesel fuel, 20% water, and a very small amount of surfactant to stop separation of the diesel/water mixture. NOx and particulate reductions of 20% to 30% and 50 to 60%, respectively, are possible with emulsion fuels.

5.3 Snow Making Opportunities

Snow making is very energy intensive and generally occurs fast and furiously for short periods of time just prior to and soon after opening of the ski area, primarily in the months of November and December. Snow making typically occurs at night when the ambient temperatures are the lowest, increasing snow making efficiency and since this is out of phase with chair lift operations it will avoid further increases in demand charges. However, individual utilities have set up a variety of rate structures to capture these industry specific load profiles as they see fit.

Energy used for snow making during November and December can approach or even exceed total energy use during all other individual months of the year. It is interesting to note that monthly electric demand resulting from snowmaking is frequently comparable to the electric demand incurred from chair lift operations. However, as the snowmaking operations are reduced later in the ski season, the lift usage increases, as does the demand. As an example, the electric demand set as a result of snowmaking at Vail during November and December ranged between 6 and 6.5 MW while chair lift operations during January, February and March ranged from about 5.5 MW to nearly 7 MW. The opportunity here, then, is that since the lifts are required to have a backup source of power and considering the opportunities proposed in the previous section “Chair Lift Opportunities” (i.e. using gensets rather than mechanical drives) the same asset could be utilized for multiple purposes. This approach requires significant planning, design, and implementation efforts by a number of parties, but offers significant benefits to those willing to make the necessary investments.

There are a variety of options for interconnecting the chair lift power generation assets for other uses. These could be specific gensets connected to specific loads such as a compressor or pumping station, or depending on the genset capacity, individual compressors or pumps within a station with these units connecting to each other via open transition switches and therefore always remaining off-grid. Alternatively, all appropriate gensets could be connected together and this “virtual power plant” be connected to larger load centers such as entire compressor and pumping stations. Starting sequences would need to be monitored to avoid under voltage and frequency tripping that could be caused by attempting to start too many motors simultaneously. While this approach allows for more efficient asset utilization and greater operational flexibility it is also a somewhat more expensive option since a number of gensets would need to be synchronized. This option could also function independent of the grid thus avoiding interconnection issues and costs but it may prove cost effective to utilize the grid since the wiring for all facilities, lifts, and snowmaking equipment is already in place.

5.4 Microhydro at Ski Areas

There are several components required for a successful microhydro project. These include an adequate water supply, substantial elevation drop between water supply and turbine/generator, a delivery system connecting the water supply and the turbine, and of course the turbine/generator itself. It may be surprising to many ski area operators but, to a large extent, they may have three of these already. The first two of these, water and elevation, are found in the snow making water that is frequently surface water, stored at higher elevations than the base of the ski area. The third requirement is the snow making piping system itself. While the existing piping is not necessarily going to start and end at exactly the right location on every mountain, it is possible that a substantial portion of the piping system is usable for this application.

While three of the four items may already be in place there may still be substantial costs associated with utilizing this resource. The turbine and generator as well as electrical switchgear and possibly transformers will need to be purchased. Additionally, a building to house this equipment will be required. Piping additions and modifications, control systems and possibly a variety of permits will be needed. Studies, evaluations, and engineering designs will be required and all cost money.

However, where circumstances are right there can be an opportunity to provide renewable energy at a fraction of the cost of typical renewable energy projects, reduce the environmental impact caused by electricity generation, and have a reasonable economic return on investment.

To date this opportunity has had very little attention. One project is at Snowmass Mountain, owned by Aspen Skiing Company. This system utilizes existing 10 inch diameter pipes initially installed for snowmaking. A facility was built to house the turbine and 115 kW generator. The system is expected to generate approximately 250,000 kWh of electricity annually with a simple payback on the order of 6 years. Other similar opportunities exist at Aspen as well as at many, and perhaps most, ski areas throughout the US although there are no solid estimates as to the potential of this resource. Resource assessment, development of site screening criteria, and a proven track record of early adopters are needed to accelerate the adoption of microhydro projects at ski resorts.

5.5 Stand-alone Combustion based DR systems

The ability to extract value from existing, under utilized assets can prove cost effective and improve reliability in many situations. However, the approaches discussed above may not be applicable in all instances or simply may not appeal to operations mangers for a variety of reasons. Alternatives to modifying existing systems and potentially significant construction costs associated with the addition of electrical switchgear, rewiring, etc. adding new combustion based onsite generation capacity can achieve similar demand reductions.

Large capacity gensets can be installed on a temporary or permanent basis. Mobile rental units with capacities well in excess of 1 MW are readily available from a number of manufacturer's distributors as well as independent rental companies. Rental units are typically powered by diesel engines but some natural gas fueled units are available. Gensets are trailer mounted and are available with all required cabling, appropriate transformers, interconnection equipment as well as fuel tanks, set up, start up, and even onsite operating and maintenance for larger projects. This approach would require coordination with the local utility and might be especially appropriate where the ski area has access to a single point connection.

As an example, several years ago during the summer of 1999, Caterpillar provided ComEd in Chicago with trailer mounted, diesel fueled generator sets totaling 100 MWs of peaking capacity. These were connected to the grid at utility substations.

Alternatively, rather than renting a genset, these units can be purchased. When purchased the owner has full access to the unit at any time it is needed but also has full responsibility for it as well. Both options have advantages and disadvantages as listed in Figure 14.

Figure 14: Comparison of renting vs. owning Combustion based DER

	RENT	OWN
Advantage	• Opportunity to "try it out" at a modest cost. • Only pay for it when needed. • Off balance sheet. • Saves money each year or the unit would not be installed. • Flexibility in use – may not rent in some years.	• Lower LCC – greater ROI than renting. • Available any time, including unexpected outages. • Can operate as many hours as desired. • Install only once rather than each year. • Can be installed in a CHP configuration if annual operating hours justify the cost. This will further reduce LCC. • Potential for CHP conversion
Disadvantage	• May not be the lowest cost option. • Not available when not rented but desired as in unexpected utility outages. • Time and expense to set up and prepare for shipping. • Limited operation without incurring cost penalty	• Fairly expensive asset that is used relatively few hours per year. • Depending on financing, cash flow may not be positive for several years. • Total responsibility for everything.

Installing a DER system primarily for peak shaving during snowmaking and chair lift operating hours may have other advantages and secondary benefits as well. If the unit is to be operated enough hours per year, adding heat recovery heat exchangers to the water jacket and exhaust system, making this a CHP system, can provide substantial space and water heating capabilities and reduce total energy costs. While heat exchangers to recover the available thermal energy are relatively inexpensive, it is likely the thermal loads are not adjacent to the genset. Therefore the thermal energy would need to be distributed through a small district heating loop to the end users—with an associated construction cost. Depending on the system electrical capacity and thermal requirements of the ski area facilities currently being heated, unheated or minimally heated buildings, perhaps maintenance areas, can cost effectively be heated, increasing worker comfort and very likely productivity. Additionally, if there is excess heat available, a glycol piping loop can be installed when new sidewalks are being poured. Relatively low temperature hot water circulating through the sidewalks melts snow and eliminates the formation of ice. This not only reduced labor costs of clearing the snow, it also reduced the likelihood of injury and potential lawsuits from visitors slipping and falling as a result of less than perfectly clear sidewalks.

5.6 Integrating Renewable Energy

While wind, solar energy, and other renewable energy sources may be predictable as to when and in what quantity they will be available, one of the ever-present issues is the intermittency of their availability. In many cases storage is a possibility for both thermal and electrical energy as was previously discussed. Large scale battery systems are being used in a few utility scale peaking projects and very large hot and chilled water storage tanks are frequently used with district energy systems. However these can add significantly to the overall cost of the system, reducing the economic viability of such projects.

Opportunities to firm up the capacity of renewable energy projects do exist and may make them more economically attractive. Rather than over sizing renewable projects and utilizing storage to cover loads during periods when the resource is not available, down sizing these project to a more modest scale and utilizing combustion based technologies, such as reciprocating engine DER and CHP systems as discussed above, to carry the loads during periods of unavailability either as a result of the lack of resource or due to maintenance downtime, firm capacity can be achieved. This strategy maximizes the utilization of the renewable resource while reducing its first cost. This approach reduces the use of combustion based technologies and meets the goal of reducing purchased energy while assuring the sought after electric demand reduction.

6 Capturing the Benefits of Integrated Energy Management

6.1 Systems Approach

Existing central power plants deliver electricity to end user facilities at an overall fuel-to-electricity efficiency in the range of 28 –32% representing a loss of around 70% of the primary energy provided to the generator. Since the majority of the primary energy comes from fossil fuels, the environmental impact of the portion lost as waste heat is quite significant.

Increasing the efficiency of energy conversion and increasing the contribution of renewable energy to serving loads are two obvious ways of mitigating the adverse environmental impact of fossil fuels. However, since the primary business of the ski industry—efficiently moving people uphill and providing excellent skiing conditions throughout the season—are heavily dependent on relatively cheap electricity, energy related projects seldom get implemented due to the unfavorable economics associated with more environmentally friendly alternatives. This situation is especially true when the benefits of energy related projects are calculated solely on the basis of avoided kWhs at the tariff offered by the utility. Typically, projects such as energy efficiency upgrades or the installation of wind turbines evaluated as stand alone projects fail to get implementation approval due to unacceptably long payback periods. The challenge in successfully implementing these projects lies in capturing multiple value streams to bring project ROI in line with corporate expectations. An integrated approach to energy efficiency, renewable energy, and energy optimization has the potential to create and capture significantly more benefits than that created by individual efficiency or renewable projects alone. Section 5 presented a number of ways in which DER can be leveraged for optimizing the energy needs of ski resort operations. This section focuses on how to integrate them so that project benefits can be maximized.

The selection of DER has to match the unique energy needs of ski resorts (highly seasonal with winter peaks and summer valleys, peaks from snow making at night and lifts during the day, and energy needs about equally split between facilities, snowmaking, and lift operations). The following DER options are feasible based on available data and the analysis conducted so far.

- CHP for the heat needs of resort facilities with electricity as a byproduct for operations
- CHP (electric) used to balance wind or hydro resources with thermal storage for excess heat
- Wind turbines for renewable energy with pumped hydro for storage
- Pumped hydro system matched with the water storage and flow requirements of snow making
- Rental natural gas reciprocating engine for emergency reserve (peak management and n+1 redundancy)
- Modular load shedding capabilities for lift operations (switching to backup engines) and facilities (configured for shedding non-critical loads on demand)
- Energy efficiency upgrades to reduce base load

The detailed analysis required for appropriately sizing the resources and determining optimal configuration for best return on investment was beyond the scope of this study. This study is therefore limited to a qualitative analysis that serves to highlight the options and potential benefits of a DER-integrated energy project.

Based on prior studies and currently available data, the Vail and Aspen ski areas have the potential to implement CHP, wind, and pumped hydro, at 400-500kW installed capacity each. In addition, a modular load shedding strategy, using lifts and facilities loads, should be able to reliably provide 500kW of sheddable loads. Factoring in energy efficiency upgrades that reduce demand by another 500kW, the total peak reduction potential can be estimated to be as high as 2.5MW. Finally, a 500kW natural gas genset (seasonal rental) can be used to achieve n+1 reliability (if any one DER option fails an alternative is available to immediately compensate). Assuming that only 3 of the 4 DER alternatives works out to be viable at any one resort and assuming that one block of 500kW is held in reserve for n+1 reliability, DER still has the potential to serve up to 2MW of the peak demand of 8MW.

While any one DER resource alone cannot reliably provide the 2MW demand reduction due to significant variability in their availability at any given time (with the exception of the dedicated peaking generator), by using a mix of resources in smaller, modular configurations matched with specific loads, the required availability and reliability can be achieved providing certainly to benefit streams. The added burden is that the various resources have to be integrated using an automated infrastructure in order to reliably capture potential benefits.

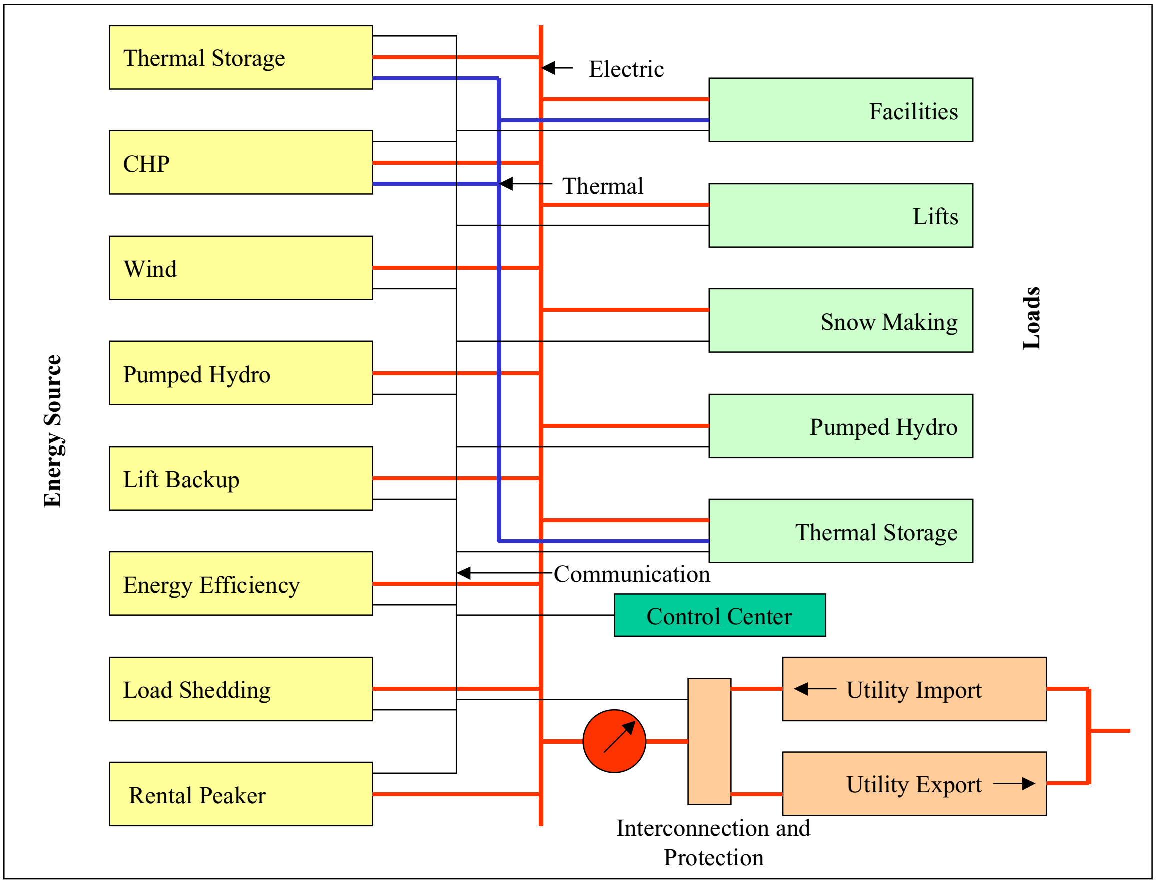


Figure 15: Schematic of integrated energy management system

Figure 15 shows a schematic representation of the integrated energy system for a ski resort. The main characteristics of the system are:

1. The DER are sized into modular units that provide n+1 redundancy
2. The switchgear has to be enhanced to provide appropriate interconnection and protection functions
3. The system can be viewed as a microgrid with closely matched local generation and loads
4. Renewable energy is broadly incorporated
5. A communication and control system is installed for operations coordination
6. While efficiency upgrades provide base demand reduction, active energy management provides peak demand management capabilities
7. System has the capability for islanded operation and automatic reconnection back to the grid
8. Individual assets are small, aggregate portfolio of DER is large

9. CHP with thermal storage is used to manage demand fluctuations
10. Pumped hydro (using existing snow making facilities) enables energy to be stored, particularly excess wind energy

The main benefits that the integrated system can provide are:

1. Peak demand reduction
2. Reduction in energy purchase
3. Increased utilization of renewable energy
4. Enhanced utilization of existing assets
5. Use of thermal storage to smooth the daily peaks and valleys in energy consumption
6. Generate nearly free electricity for summer on-mountain activities
7. Defer transmission and distribution expansion charges as resort operations continue to grow
8. Reduce fossil fuel based energy consumption (kWh/skier-visit)
9. Reduce environmental footprint from an energy perspective
10. Enable the export of energy, standby capacity, and renewable energy to the utility
11. Generate additional revenues in the form of renewable credits and tax incentives
12. Use excess heat from CHP operations for resort enhancements such as heated sidewalks
13. Provide full visibility into energy and operations facilitating better system management
14. Implement major enhancements such as switchgear, CHP systems, and monitoring and control infrastructure as part of current redevelopment activities at the resorts

6.2 DER as Benefits Multiplier

A major concern in taking an integrated approach incorporating multiple distributed energy resources is weather the total benefits generated has the potential to exceed the sum of the benefits of individual projects leading to a better return on investment.

The best way to evaluate this issue is to compare the DER-integrated project to more conventional projects of the same size. The table below (Figure 16) compares the value streams that can be monetized from the 2MW integrated project (discussed in §6.1) to an energy efficiency upgrades project and wind project of the same capacity.

Value Stream	DER-integrated Project (2MW aggregate capacity)	Wind Project (2MW rated)	Energy Efficiency Project (2MW name-plate demand reduction)
Reduction in kWh purchased	Yes. Can be controlled based on economic criteria	Yes. Limited to periods of wind availability. Cannot regulate production very well	Yes. Reduction through enhanced equipment efficiency
Reduction in demand charges	Yes. Demand can be capped reliably	No	Yes, but limited to upgraded equipment. Cannot actively manage demand threshold
Renewable credits	Yes	Yes	No

Tax incentives	Yes	Yes	Some
Nearly free electricity for summer activities	Yes	Yes	No
Fuel arbitrage	Yes	No—but uses zero cost fuel during wind availability	No
Sale to Utility of kW, kWh, renewable energy	Yes, can enter into firm contracts that have much higher value	kWh—yes. kW—no. Renewable energy—lower value non-firm contracts	No
T&D deferral	Yes	No—since the resource does not reliably decrease demand	Limited since overall demand reduction cannot be guaranteed
Heat source for resort operations	Yes	No	No
Increased optionality	Yes, resources can be re-purposed depending on changing needs	No	No

Figure 16: Benefits comparison between DER-integrated vs. conventional projects

As the benefits analysis in Figure 16 indicates, a DER-integrated project can tap into a broader set of benefits than stand alone projects by leveraging cross synergies between assets and enhancing overall reliability through redundancy (e.g., optional use of CHP w/ thermal storage for firming non-firm resource). In addition to capturing a broader set of benefits, DER-integrated projects also lead to higher value for the benefits created (e.g., Firm renewable energy and firm capacity are valued much higher than their non-firm equivalents). Two other key benefits that are not immediately obvious from the table are higher utilization of smaller assets and the leverage obtained by using existing assets for new purposes.

The challenge now moves to the cost side—can a DER-integrated project be deployed at or below the cost of implementing stand-alone projects of similar magnitude? Although it is impossible to correctly answer this question without much more project-specific details, we can infer certain trends from available project cost data. The table below (Figure 17) shows some representative costs for various DER technologies.

Technology	Investment Cost Range ($/W)	Generating Cost Range (cents/kWh)
Diesel Genset	0.4-0.8	4.0-26.0
Microturbine	0.5-1.0	4.5-7.0
Wind	0.8-2.0	3.0-8.0
Small Hydro	0.8-1.2	5.0-10.0

Figure 17: DER technology and corresponding investment and generating cost range

A mean investment cost of around $1/W is typical for mainstream DER technologies with considerable variation in fuel and long-run marginal operating costs. These projects also tend to have payback periods in the 6-10 year range. DER-integrated projects are based on similar technologies with three exceptions: i) existing assets are used wherever possible, ii) additional automation and information technologies are needed to operate the system optimally, and iii) reliability is achieved with redundancy, which incurs additional cost. Given these cost tradeoffs, it is reasonable to assume that DER-integrated projects will have installation and operating cost structures comparable to stand alone projects. Since greater benefits can be captured with comparable investments, the payback scenario for DER-integrated projects will be more attractive than single-purpose projects of the same magnitude.

6.3 Capturing Intended Energy Savings

Capturing savings related to energy efficient design, energy management, and proper operation of distributed energy systems requires that performance be measured both when new facilities are brought on line and periodically over time. Preferably an independent third party—a commissioning agent—hired by the facility owner should carry out this task. Commissioning ensures that building design, equipment, and controls are functioning as intended. Commissioning of new construction typically improves performance and easily pays for itself in saved energy. Given this favorable cost-benefit relationship, commissioning is also increasingly being used to provide routine operational check-ups over time.

Commissioning is typically sufficient for capturing the benefits of static energy efficiency improvements. However, when active DER and dynamic energy management is brought into the picture, it becomes essential to augment initial commissioning with an automated infrastructure that can ensure that the system continues to operate as planned—especially those involving manual processes or operator actions.

Dynamic energy management is also dependent on a robust automation infrastructure that can be programmed to operate correctly without requiring ongoing manual supervision. Automation will also ensure that operating thresholds can be set for the system with exception based alarming providing the mechanism for alerting appropriate personnel if the system drifts into modes where benefits are being lost (such as peak demand exceeding preset levels). An appropriate automation and information infrastructure will provide an “operations dashboard” that will allow appropriate personnel to continuously track key business and performance metrics and ensure that goals are met and benefits fully captured.

6.4 Conclusions

Strategically integrating DER into ski area operations has the potential to substantially improve the cost-benefit structure of energy projects. With careful design, ski area operators can lower their energy bills, increase the use of renewable energy for their operations, minimize growth related T&D expansion expenditures, and fully take charge of one of the most basic ingredients needed for their business operations.

Final decisions regarding the economic viability of DER-integrated projects will have to be determined based on project-specific details. However, in the case of ski area operations, two major requirements—availability of DER resources well matched to local operations and scale of operations large enough to allow the development of a viable DER portfolio—are both met. In the case of both Aspen and Vail Mountain ski areas, there is also a substantial amount of planned facilities redevelopment underway. This situation creates a unique window of opportunity for integrating DER into ski area operations for minimizing the costs of retrofitting new solutions into existing facilities, capturing the full benefits of integrated energy management, and positioning Aspen and Vail as the leading adopters of renewable energy and energy optimization for ski area operations.

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7.2 Case Study Participation

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7.3 Research, Analysis, and Report Preparation

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