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Energy Efficiency, Water Efficiency, and Renewable Energy Site Assessment:

Mendenhall Glacier Visitor Center, Juneau, Alaska

James Salasovich, David LoVullo, and Alicen Kandt

Produced under direction of the U.S. Forest Service by the National Renewable Energy Laboratory (NREL) under Interagency Task No. WFHV.1000.

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Office of Energy Efficiency & Renewable Energy
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Strategic Partnership Project Report
NREL/TP-7A40-65673
January 2016

Contract No. DE-AC36-08GO28308

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Preface

The U.S. Forest Service, as part of ongoing efforts to reduce energy use and incorporate renewable energy technologies into its facilities, engaged the Department of Energy's National Renewable Energy Laboratory to conduct an energy efficiency and renewable energy site assessment at the Mendenhall Visitors Center in Juneau, Alaska. This report documents the findings of this assessment and provides site-specific information for the implementation of renewable energy technologies and energy and water conservation measures.

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Abbreviations and Acronyms

AC	alternating current
ACU	air conditioning units
AEL&P	Alaska Electric Light and Power
AHU	air-handling unit
Ah	ampere-hours
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAS	building automation system
Btu	British thermal unit
CAV	constant air volume
CFL	compact fluorescent lamp
cfm	cubic feet per minute
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
DCV	demand-control ventilation
DDC	direct digital control
DOE	U.S. Department of Energy
EE	energy efficiency
ECM	energy conservation measure
EISA	Energy Independence and Security Act
EO	executive order
EPAct	Energy Policy Act
FEMP	Federal Energy Management Program
ft^2	square feet
FY	fiscal year
GHG	greenhouse gas emissions
gpf	gallons per flush
gpm	gallons per minute
GSHP	ground source heat pumps
HPS	high pressure sodium
HVAC	heating, ventilation, and air conditioning
kW	kilowatt
kWh	kilowatt-hour
LED	light-emitting diode
LEED	Leadership in Energy and Environmental Design
M&V	measurement and verification
MGVC	Mendenhall Glacier Visitor Center
MMBtu	one million British thermal units
MWh	megawatt-hour
NEMA	National Electrical Manufacturers Association
NREL	National Renewable Energy Laboratory
NZE	net zero energy
O&M	operation and maintenance
PV	photovoltaic
ppm	parts per million

RE	renewable energy
REM	renewable energy measure
SHW	solar hot water
USFS	U.S. Forest Service
VAV	variable air volume
W	Watt
WCM	water conservation measure

Executive Summary

This report summarizes results from the energy efficiency, water efficiency, and renewable energy site assessment of the Mendenhall Glacier Visitor Center (MGVC) and site in Juneau, Alaska. The assessment is an American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Level 2 audit and meets Energy Independence and Security Act requirements. A team led by the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) conducted the assessment with U.S. Forest Service (USFS) personnel August 19–20, 2015, as part of ongoing efforts by USFS to reduce energy and water use.

Staff at the site also participates in USFS's Net Zero Fellow program to identify potential net zero energy (NZE) sites in its building stock, and this assessment was also in support of that program.

During the site visit, the team identified a total of 18 possible energy conservation measures (ECM), four water conservation measures (WCM), and six renewable energy measures (REM) with simple paybacks ranging from 0.8 years to 32 years.

The following measures are not recommended at this time due to the relatively long payback periods:

- Constant air volume (CAV) to variable air volume (VAV)
- ENERGY STAR® refrigerators
- Low flow faucets
- All REMs, except REM 5.1 - Install 30.1 killowatt (kW) of hydropower generation on Steep Creek.

The GSHP is not included in the bundled analysis because you cannot combine the boiler measures with the GSHP system. This is not to say the GSHP is not recommended; it is just not included in the bundled analysis.

All recommended measures bundled together:

- Installed cost = $348,446
- Annual cost savings = $42,532/year (yr)
- Simple payback = 8.19 years
- Annual carbon dioxide equivalent (CO_2e) savings = 14.18 metric tons/yr.

Individual Measures

Tables ES-1 through ES-5 summarize the quantified energy savings by the financially viable individual energy and water conservation measures and the renewable energy measures prioritized in order of shortest simple payback to the longest. The tables provide an annotated list of measures, estimated economics, and the CO_2e emissions savings.

Table ES-1. Heating, Ventilation, and Air Conditioning Energy Conservation Measures Summary

ECM#	Energy Conservation Measures	Annual Electricity Savings (kWh/yr)	Annual Thermal Savings (MMBtu/yr)	Annual Cost Savings ($)	Installed Costs ($)	Simple Payback Period (yrs)	Annual CO_2e Savings (metric tons/yr)
1.1	Replace Standard V-Belts with Cogged V-Belts	2,348	0	$291	$416	1.43	0.03
1.2	Hot Water Condensing Boiler	0	72	$1,627	$3,203	1.97	5.18
1.3	Snowmelt System	54,000	0	$9,683	$39,094	4.04	0.68
1.4	Incrementally Install Premium Efficient Motors	3,757	0	$466	$2,054	4.41	0.05
1.5	Install Demand Control Ventilation in Auditorium	2,322	26	$868	$3,900	4.49	1.88
1.6	Install Boiler Stack Economizers	0	26	$598	$2,709	4.53	1.91
1.7	Install Building Automation System	9,866	30	$1,892	$8,580	4.54	2.25
1.8	Lake Loop GSHP	(39,573)	473	$5,802	$117,000	20.17	33.62
1.9	CAV to VAV	52,865	88	$8,540	$218,387	25.57	6.99
HVAC	**Totals[a,b,c]**	**72,293**	**154**	**15,425**	**$59,956**	**3.89**	**11.98**

Note: kWh = kilowatt-hour; MMBtu = one million British thermal units; HVAC = heating, ventilation, and air conditioning.

[a] Total savings do not take into account interactive effects of combining measures.

[b] Does not include CAV to VAV due to the long payback period.

[c] Does not include GSHP system because boiler measure cannot be combined with this measure.

Table ES-2. Lighting Energy Conservation Measures Summary

ECM#	Energy Conservation Measures	Annual Electricity Savings (kWh/yr)	Annual Thermal Savings (MMBtu/yr)	Annual Cost Savings ($)	Installed Costs ($)	Simple Payback Period (yrs)	Annual CO_2e Savings (metric tons/yr)
2.1	Replace the Halogen Flood Lamps with light-emitting diode (LED) Lamps	14,044	(5)	$1,566	$1,269	0.81	(0.20)
2.2	Replace the 65W BR30 with Low Wattage LED Lamps	65,387	(23)	$5,894	$6,921	1.17	(0.91)
2.3	Replace the Standard T-12 Lamps with Low Wattage LED Lamps	2,722	(1)	$570	$5,419	9.50	(0.04)
2.4	Replace the Standard T-8 Lamps and Ballasts with Low Wattage LED Lamps	2,228	(1)	$359	$3,993	11.11	(0.03)
2.5	Replace the Compact Fluorescent Lighting Lamps with Low Wattage LED Lamps	734	(0)	$104	$1,165	11.18	(0.01)

ECM#	Energy Conservation Measures	Annual Electricity Savings (kWh/yr)	Annual Thermal Savings (MMBtu/yr)	Annual Cost Savings ($)	Installed Costs ($)	Simple Payback Period (yrs)	Annual CO_2e Savings (metric tons/yr)
2.6	Install Lighting Sensors in Bathrooms, Break Rooms, and Private Offices	4,298	(2)	$299	$3,359	11.23	(0.06)
2.7	Replace the 175W Exterior Lighting with LED Replacements	6,845	0	$730	$8,780	12.03	0.09
Lighting	**Totals**	**96,257**	**(32)**	**$9,524**	**$30,905**	**3.56**	**(1.16)**

Table ES-3. Plug Loads Energy Conservation Measures Summary

ECM#	Energy and Water Conservation Measures	Annual Electricity Savings (kWh/yr)	Annual Thermal Savings (MMBtu/yr)	Annual Cost Savings ($)	Installed Costs ($)	Simple Payback Period (yrs)	Annual CO_2e Savings (metric tons/yr)
3.1	Remove Excess Printers and Utilize Network Printers	448	(0)	$90	$93	1.03	(0.01)
3.2	Replace Refrigerator with ENERGY STAR Refrigerator	119	(0)	$8	$269	32.46	(0.00)
Plugs	**Totals[a]**	**448**	**(0)**	**$90**	**$93**	**1.03**	**(0.01)**

[a] Total savings does not include refrigerator replacement.

Table ES-4. Water Conservation Measures Summary

ECM#	Energy and Water Conservation Measures	Annual Water Savings (gal/yr)	Annual Thermal Savings (MMBtu/yr)	Annual Cost Savings ($)	Installed Costs ($)	Simple Payback Period (yrs)	Annual CO_2e Savings (metric tons/yr)
4.1	Install Low-Flow Urinals	62,500	0	$744	$1,174	1.67	0.00
4.2	Install Low-Flow Toilets	125,000	0	$1,488	$8,219	5.53	0.00
4.3	Install Low-Flow Showerheads	1,071	1	$17	$99	5.98	0.04
4.4	Install Low-Flow Faucets	13,125	5	$198	$4,193	21.20	0.39
Water	**Totals**	**201,696**	**6**	**$2,446**	**$13,685**	**5.60**	**0.43**

Table ES-5. Renewable Energy Measures Summary

RE#	Renewable Energy Opportunities	Annual Electricity Savings (kWh/yr)	Annual Thermal Savings (MMBtu/yr)	Annual Cost Savings ($)	Installed Costs ($)	Simple Payback Period (yrs)	Annual CO_2e Savings (metric tons/yr)
5.1	Install 30.1 kW Hydropower Generation on Steep Creek	170,067	0	$16,089	$248,000	15.41	3.33
5.2	Install 30.1 kW Hydropower Generation on Steep Creek and 40 kW of Solar Photovoltaic Generation on the MGVC Rooftop	190,617	0	$17,437	$368,000	21.10	3.73

RE#	Renewable Energy Opportunities	Annual Electricity Savings (kWh/yr)	Annual Thermal Savings (MMBtu/yr)	Annual Cost Savings ($)	Installed Costs ($)	Simple Payback Period (yrs)	Annual CO_2e Savings (metric tons/yr)
5.3	Install 30.1 kW Hydropower Generation on Steep Creek and 100 kWh of Lithium Ion Battery Storage	170,067	0	$13,224	$354,000	26.77	3.33
5.4	Install 30.1 kW Hydropower Generation on Steep Creek, 40 kW of Solar Photovoltaic Generation and 100 kWh of Lithium Ion Battery Storage	190,617	0	$14,572	$474,000	32.53	3.73
5.5	Install 40 kW of Solar Photovoltaic Generation on the MGVC Rooftop	32,009	0	$2,770	$120,000	N/A	0.40
5.6	Install 40 kW of Solar Photovoltaic Generation on the MGVC rooftop and 100 kWh of Lithium Ion Battery Storage	32,009	0	-$95	$226,000	N/A	0.40

Commissioning

The assessment team strongly recommends that any recommended measures from this report are commissioned when implemented. Commissioning is a quality control process that can be integrated with the installation of new systems. Commissioning ensures optimal equipment and energy efficiency performance. When energy efficiency measures are not commissioned by an expert experienced in the recommended systems (and advanced control strategies), the anticipated energy savings may not be achieved.

For this reason, the assessment team has included funding for commissioning in all of the cost and payback data presented in this report. The assessment team recommends that any hired commissioning agent be responsible for reviewing retrofit design documents, completing and signing installation checklists, and witnessing startup and functional testing, at a minimum.

Measurement and Verification

It is also recommended that a measurement and verification (M&V) plan be implemented in conjunction with any major retrofit effort. The M&V plan should follow International Performance and Measurement Verification Protocol and provide ongoing energy use information to building operators. This information will serve as a diagnostic tool to ensure the durability of energy savings. The M&V plan should not simply provide a one-year check on the retrofit's impact, but provide continuous feedback on energy consumption by end use.

A cost for M&V is not provided in this report, but it is anticipated that the effort would add less than 0.5 years to the payback period of the bundled implementation effort.

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1 Background

The U.S. Forest Service (USFS), acting in compliance with Executive Order (EO) 13693, is pursuing the implementation of energy conservation measures (ECM), water conservation measures (WCM), and renewable energy measures (REM). Further, the evaluations of three sites—the Mendenhall Glacier Visitor Center (MGVC) in Juneau, AK, the Tiller Ranger District in Roseberg, Oregon, and the Seneca Rocks Discovery Center in Seneca Rocks, West Virginia—are evaluating site energy and water consumption and renewable energy technologies.

Along with the pursuit of energy goals within the EO 13693, the USFS is strongly considering pursuing Net Zero Energy (NZE) and Leadership in Energy and Environmental Design (LEED) status at these sites to showcase their commitment to sustainability and environmental stewardship. The inclusion of the investigated ECMs, WCMs, and REMs would move the MGVC closer to obtaining these goals, accruing LEED points and being labelled a high performance and sustainable building. These audits were conducted in support of USFS's Net Zero Network program.

The U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) is solely dedicated to advancing energy efficiency (EE) and renewable energy (RE) technologies and applications. Since its inception, NREL has supported both the federal and the private sectors in implementing EE, water energy (WE), and RE systems and strategies to lower energy use, and to meet remaining energy needs with resources having minimal environmental impact. NREL assistance was requested to identify and assess the feasibility of incorporating sustainable opportunities within the MGVC, including:

- Optimizing the energy performance of the building
- Assessing the potential for water efficiency measures and improvements in the overall environmental quality of the building interior
- Using on-site RE technologies.

1.1 Project Background and Intent

USFS chose to conduct this assessment as a means to identify energy and WCMs and RE options. The no-cost/low-cost operational modifications that NREL has identified should be the first items to be implemented. The cost savings associated with these measures can then be redirected to implement the more capital intensive projects, which will result in further energy and water savings.

Conservation measures implemented from performance contractors should be submetered and evaluated based on measured savings. Through active participation by the site to implement the projects, USFS will be closer to meeting and exceeding the goals set forth in the applicable legislation. Applicable legislation includes, but is not limited to, Energy Policy Act of 2005 (EPAct 2005), Energy Independence and Security Act (EISA) (2007), EO 13693 (2015), and other mandates.

1.1.1 Energy Policy Act of 2005

[§103] federal buildings must be metered by October 1, 2012, with data provided at least daily and electricity consumption measured hourly (requires an implementation plan and personnel responsible).

[§104] federal agencies shall incorporate energy efficiency criteria consistent with ENERGY STAR and Federal Energy Management Program (FEMP)-designated products for all procurements involving energy-consuming products and services.

[§203] renewable energy is not less than:

2.5% of total consumption during fiscal year (FY) 2006

3% of total consumption during FY 2007-2009

5% of total consumption during FY 2010-2012

7.5% of total consumption during FY 2013 and thereafter.

Note: Accounting of renewable energy can be doubled if on federal or Indian land and used at a federal facility.

1.1.2 Energy Independence and Security Act 2007

[§431] reduce building energy intensity 3% annually through 2015, or 30% total reduction by 2015, relative to a 2003 baseline.

[§432] energy and water evaluations must be completed every four years for covered facilities. Facility energy managers are also responsible for commissioning equipment and establishing operation and maintenance (O&M) plans for measuring, verifying, and reporting energy and water savings.

[§434] ensure major replacements of installed equipment, renovation, or expansion of existing space employ the most energy-efficient designs, systems, equipment, and controls if life cycle cost-effective.

[§434(b)] by October 16, 2016, each agency shall provide for equivalent metering of natural gas and steam.

[§523] 30% of hot water demand in new federal buildings and major renovations must be met with solar hot water if life cycle cost-effective.

[§524] encourages agencies to minimize standby energy use in purchases of energy-using equipment.

[§525] requires procurement to focus on ENERGY STAR and FEMP-designated products.

[§527] each federal agency must issue an annual report that describes the status of initiatives to improve energy efficiency, reduce energy costs, and reduce greenhouse gas (GHG) emissions.

1.1.3 Executive Order 13693

[§3(a)(i)] reducing agency building energy intensity measured in British thermal units per gross square foot by 2.5 percent annually through the end of fiscal year 2025, relative to the baseline of the agency's building energy use in fiscal year 2015.

[§3(b)(v)] ensure that at a minimum, not less than 25 percent of the total amount of building electric energy and thermal energy shall be clean energy, accounted for by renewable electric energy and alternative energy by fiscal year 2025.

[§3(f)(i)] reducing agency potable water consumption intensity measured in gallons per gross square foot by 36 percent by fiscal year 2025 through reductions of 2 percent annually through fiscal year 2025 relative to a baseline of the agency's water consumption in fiscal year 2007.

[§3(g)(ii)(C)] if the agency operates a fleet of at least 20 motor vehicles, improve agency fleet and vehicle efficiency and management by taking actions that reduce fleet-wide per-mile greenhouse gas emissions from agency fleet vehicles, relative to a baseline of emissions in fiscal year 2014, to achieve reductions not less than 30 percent by the end of fiscal year 2025.

[§3(h)(i)] ensuring, beginning in fiscal year 2020 and thereafter, that all new construction of Federal buildings greater than 5,000 gross square feet that enters the planning process is designed to achieve energy net-zero and, where feasible, water or waste net-zero by fiscal year 2030.

[§3(h)(iii)] identifying, as part of the planning requirements of section 14 of this order, a percentage of the agency's existing buildings above 5,000 gross square feet intended to be energy, waste, or water net-zero buildings by fiscal year 2025 and implementing actions that will allow those buildings to meet that target.

[§3(j)(ii)] advance waste prevention and pollution prevention by diverting at least 50 percent of non-hazardous solid waste, including food and compostable material and pursuing opportunities for net-zero waste or additional diversion opportunities.

1.1.4 Other Mandates

[EPAct 1992 §152] install in federal buildings owned by the United States all energy and water conservation measures with payback periods of less than 10 years.

[EPA Mandatory Greenhouse Gas Reporting Rule] facilities and suppliers of fossil fuels or industrial GHGs that emit more than 25,000 metric tons of carbon dioxide equivalent (CO_2e) per year must report their emissions by March 31, 2011, for 2010 emissions. Reports submitted annually thereafter.

2 Mendenhall Glacier Visitor Center

2.1 Introduction

This report summarizes the results from the EE, WE, and RE site assessment of the MGVC and associated site facilities (e.g., public restrooms, pavilion, parking lots, and walkways) in Juneau, Alaska. The assessment is an American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Level 2 audit and meets Energy Independence and Security Act (EISA) requirements. A team led by NREL conducted the assessment on August 19–20, 2015. During the site visit, the team identified a total of 18 possible building ECMs, four WCMs, and six REMs.

2.2 Site Overview

The MGVC and site facilities are located in the Tongass National Forest at 6000 Glacier Spur Rd. in Juneau, Alaska. The site visitor center and facilities are located on Mendenhall Lake at the base of the Mendenhall Glacier, one of the most popular national forest tourist attractions in the United States. The MGVC is the main facility with more than 10,000 square feet (ft^2) devoted to gallery and educational exhibits, a theatre, an observational deck, a small gift shop and bookstore, and office space for full-time and temporary employees.

The entire site includes exterior men's and women's restrooms, an information kiosk, covered shelters, and storage. The site hosts more than 450,000 visors every year of which 260,000 enter and utilize the galleries and amenities in the MGVC.

The majority of visits occur in tandem with the cruise ship industry which peaks in Juneau between May and September. Tour operated buses bring guests directly to the site entrance. There is high variability in the occupancy of the MGVC due to uncontrolled tourism circumstances. Summertime guests vary from 1,000 to 5,000 per day. In the winter months, the MGVC hosts fewer than 4,000 visitors from October to the end of April.

The MGVC was originally built in 1961, primarily as an observation deck with a small café, restrooms, and an apartment for the caretaker. In 1996, the two-story MGVC was expanded to 11,738 ft^2 in order to include elevator access to the building. In addition to an elevator tunnel entrance, a theatre, exhibit spaces, and office spaces were constructed. The caretaker's apartment and the café were converted into offices/breakroom and a gift shop/bookstore, respectively. The building is concrete and wood framed with two stories above ground and an elevator tunnel entrance below. The roof is built-up with membrane roofing and rigid foam insulation.

The MGVC meets historic building eligibility status and as such, any changes to the exterior of the building could incur extra costs or hurdles. Figure 1 is an aerial view of the MGVC and the surrounding facilities taken with Google Earth. Figure 2 is a photo of the MGVC from the north.

Figure 1. Mendenhall Glacier Visitor Center and Surrounding Facilities (aerial view)

Source: Google Earth

Figure 2. Mendenhall Glacier Visitor Center

Photo by David LoVullo, NREL

2.3 Climate Data

The MGVC is located at the base of the Mendenhall Glacier in just north of Juneau, Alaska. The site is at an elevation of approximately 90 feet above sea level and latitude and longitude of 58.25° N, 134.32° W, respectively. The climate in Juneau, Alaska is a subarctic maritime climate. The winters are long and moist with temperatures just below freezing and moderate snowfall from November to March. The spring, summer, and fall have cool temperatures with frequent rains in the summer and fall. On average, precipitation falls 211 days a year. Table 1 gives historic weather summary for Juneau, Alaska.

Table 1. Juneau, Alaska Historic Weather Summary

Source: Weatherbase. Accessed September 14, 2015: http://www.weatherbase.com.

Average Temperature													
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	42.1	28.3	30.1	33.8	40.8	48.6	54.6	56.9	55.9	50	42.4	33.4	29.9
Average High Temperature													
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	48.1	32.8	35.2	39.6	48.4	56.6	62.2	63.9	62.7	55.7	47	37.8	34.1
Average Low Temperature													
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	36.2	23.7	25	28	33.3	40.6	46.9	50	49	44.4	37.8	29.1	25.6
Average Precipitation													
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
in.	62.3	5.4	4.1	3.8	2.9	3.4	3.2	4.6	5.7	8.6	8.6	6	5.8
Average Number of Days With Precipitation													
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Days	229.8	20.6	16.6	18.9	17	16.3	15.8	17.7	19.1	22.4	23.9	20.9	20.6
Highest Recorded Temperature													
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	90	57	57	61	74	82	86	90	84	73	61	56	54
Lowest Recorded Temperature													
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	-22	-22	-22	-15	6	25	31	36	27	23	11	-5	-21
Average Snowfall													
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
in.	86.7	27.7	16.8	11.6	1.1	---	---	---	---	---	0.8	13.1	15.6
Average Number of Rainy Days													
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Days	221	18	17	18	17	17	15	17	18	20	24	20	21
Average Number of Days With Snow													
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Days	43.1	10.6	7.9	6.8	1.3	---	---	---	---	---	0.6	5.9	10
Average Relative Humidity													
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
%	82.7	84.8	84.1	77.5	76.5	73.5	76.5	83.1	84.6	89.1	88.7	86.7	86.1
Average Morning Relative Humidity													
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
%	87	82	83	85	88	88	87	88	91	93	90	86	85
Average Evening Relative Humidity													
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
%	73	79	74	69	63	62	64	70	73	78	80	81	83
Average Dew Point													
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
F	36.7	24.8	25.3	27.2	33	39.9	46.5	50.4	50.5	46.2	39	29.6	26.6
Average Wind Speed													
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
mph	7.5	7.2	7.3	7.9	7.8	7.5	7	6.8	6.9	7.8	8.5	7.6	7.8

2.4 Utility Data

The electricity provider at the MGVC site is Alaska Electric Light and Power (AEL&P). Baseload generation under normal operating conditions for AEL&P is 100% hydroelectric power, provided from several hydropower plants in the area. Fuel oil is purchased and stored on-site for use in the MGVC's hot water boilers. Water and sewer are provided by the City of Juneau.

The average annual utility consumption and costs for years 2011 through 2014 is summarized in Table 2. The blended rate of electricity has gone up slightly in the past four years, though the rate of consumption has remained relatively level. Fuel oil consumption and cost have come down in recent years. Prior to 2014, water was only metered at the lower restrooms; in 2014 a water meter was installed in the visitor's center.

Table 2. Annual Electricity, Fuel Oil, and Water Use at the Mendenhall Glacier Visitor Center

		2011	2012	2013	2014	Average 2011-14
Electricity	**Annual Use** *(kilowatt-hour (kWh))*	287,105	266,595	273,401	264,288	272,847
	Blended Rate *($/kWh)*	$0.112	$0.122	$0.137	$0.124	$0.124
	Annual Cost *($)*	$32,163	$32,601	$37,326	$32,723	$33,703
	Percent of Total Cost *(%)*	53.92%	65.47%	73.20%	62.82%	63.85%
Fuel Oil	**Annual Use** *(gallons)*	3,834	3,375	2,428	3,438	3,269
	Rate *($/gallon)*	$5.90	$3.58	$3.34	$2.89	$3.93
	Annual Cost *($)*	$22,609	$12,093	$8,106	$9,922	$13,182
	Percent of Total Cost *(%)*	37.90%	24.28%	15.90%	19.05%	24.28%
Water	**Annual Use** *(gallons)*	397,000	415,000	456,000	791,000	514,750
	Rate *($/gallon)*	$0.0123	$0.0123	$0.0122	$0.0119	$0.0122
	Annual Cost *($)*	$4,876	$5,102	$5,562	$9,444	$6,246
	Percent of Total Cost *(%)*	8.18%	10.25%	10.91%	18.13%	11.76%
Total	**Annual Cost** *($)*	$59,648	$49,797	$50,993	$52,089	$53,132

The total electricity cost for the MGVC site makes up 63.8% of the total annual utility costs, with a portion coming from the consumption charge and portion from the demand charge.

Fuel oil use makes up 24.3% of the total annual utility cost. Figure 3 shows the average utility cost breakdown at the MGVC site from 2011 to 2014.

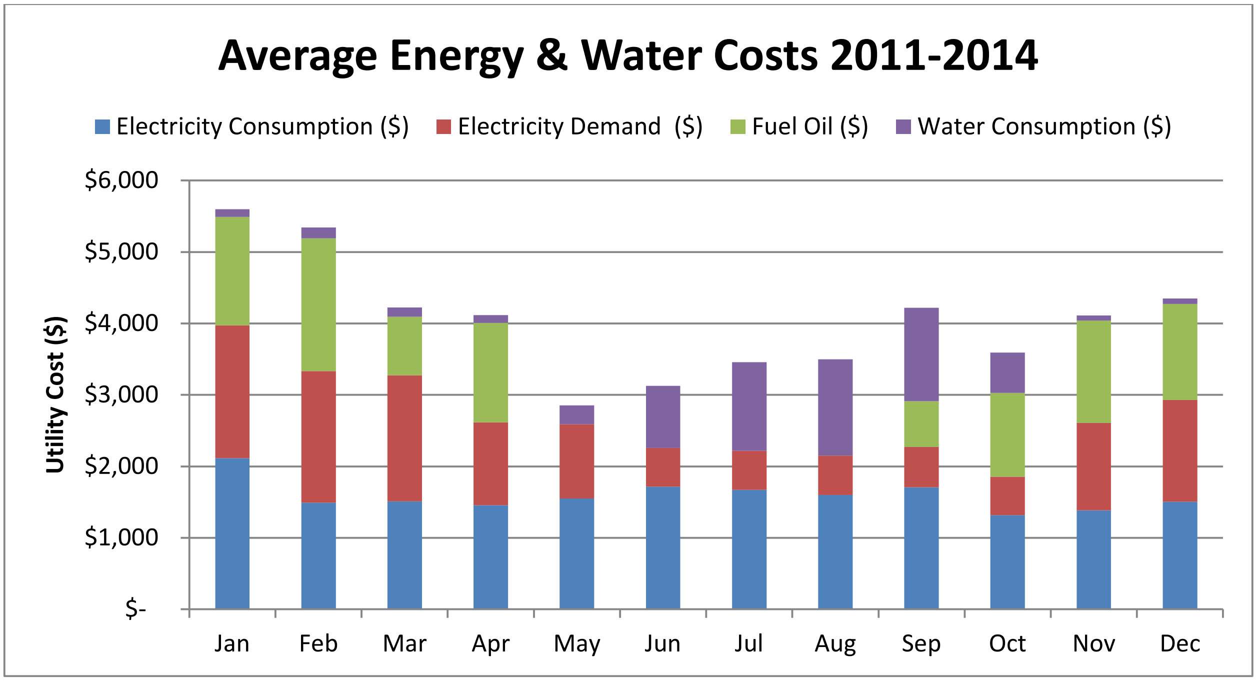

Figure 3. Mendenhall Glacier Visitor Center Site Average Utility Cost Breakdown for 2011 to 2014

The monthly electricity consumption and demand for the MGVC site for 2011 through 2014 are given in Figures 4 and 5. As shown, the electricity consumption is higher in summer and tourist season and taper off in the winter. The electricity demand shows much higher impacts in the winter time; this is likely due to the electric heating snow-melt pads used to thaw icy walkways in the winter. The demand costs in the winter are a significant portion of the utility bills and the site needs to focus on reducing the peak demand.

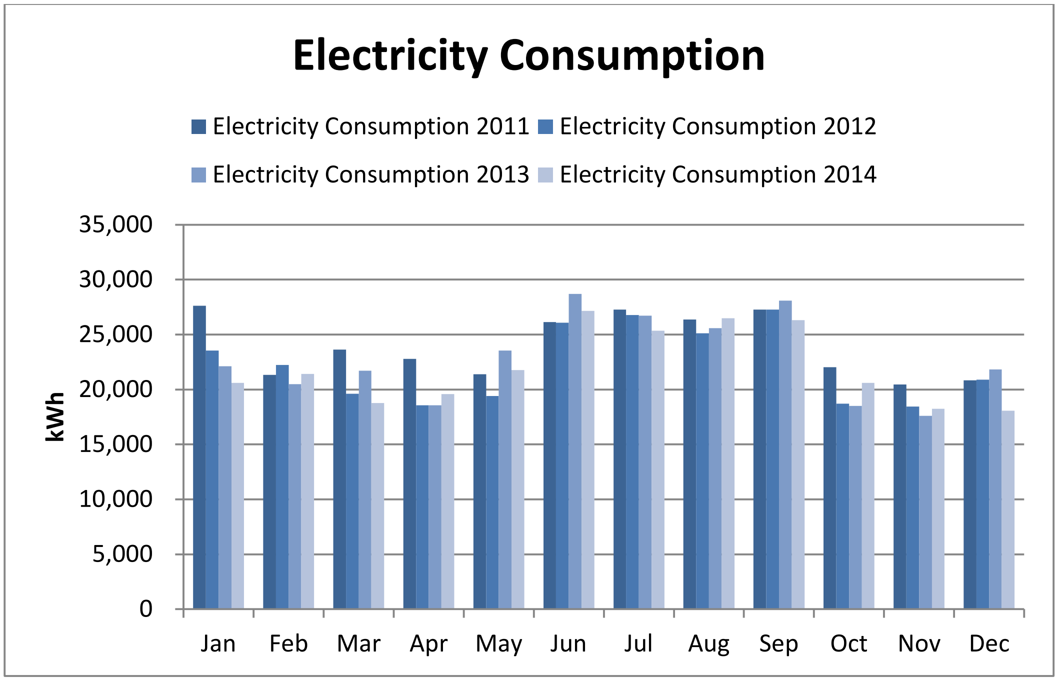

Figure 4. Mendenhall Glacier Visitor Center Site Monthly Electricity Consumption for 2011 to 2014

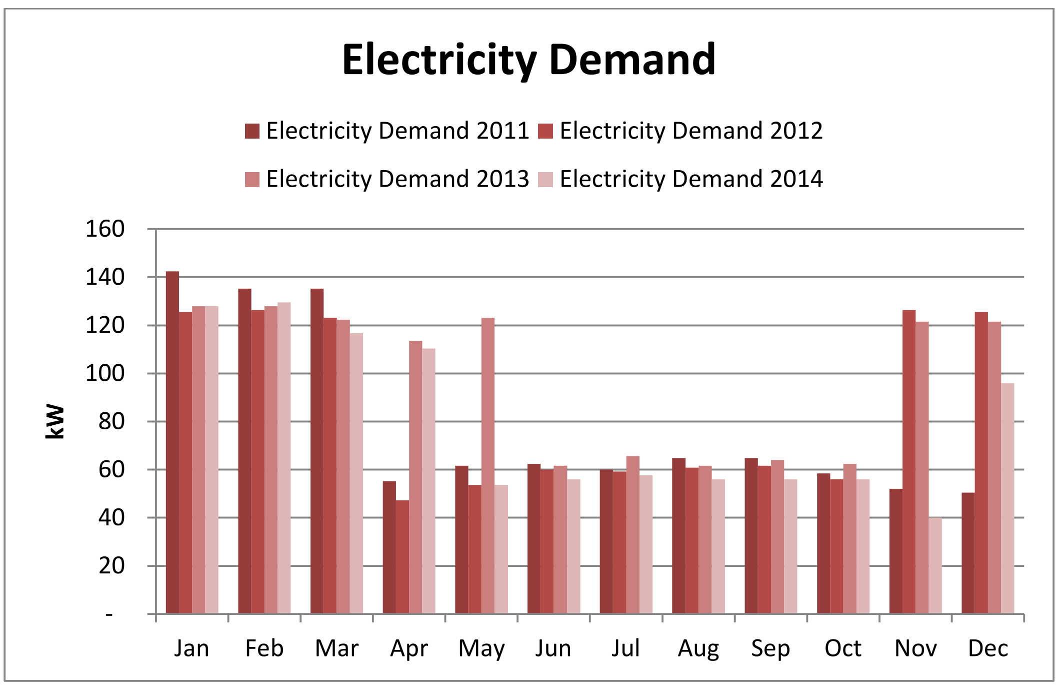

Figure 5. Mendenhall Glacier Visitor Center Site Monthly Electricity Demand for 2011 to 2014

The monthly fuel oil purchases for the MGVC site for 2011 to 2014 are given in Figure 6. As shown, the fuel oil use is highest in the winter months when the site is using and buying more fuel oil. The fuel oil usage for heating is non-zero in the summer months; this is not reflected in Figure 6. This is likely due to its limited use and the unnecessary purchasing of fuel oil during those months.

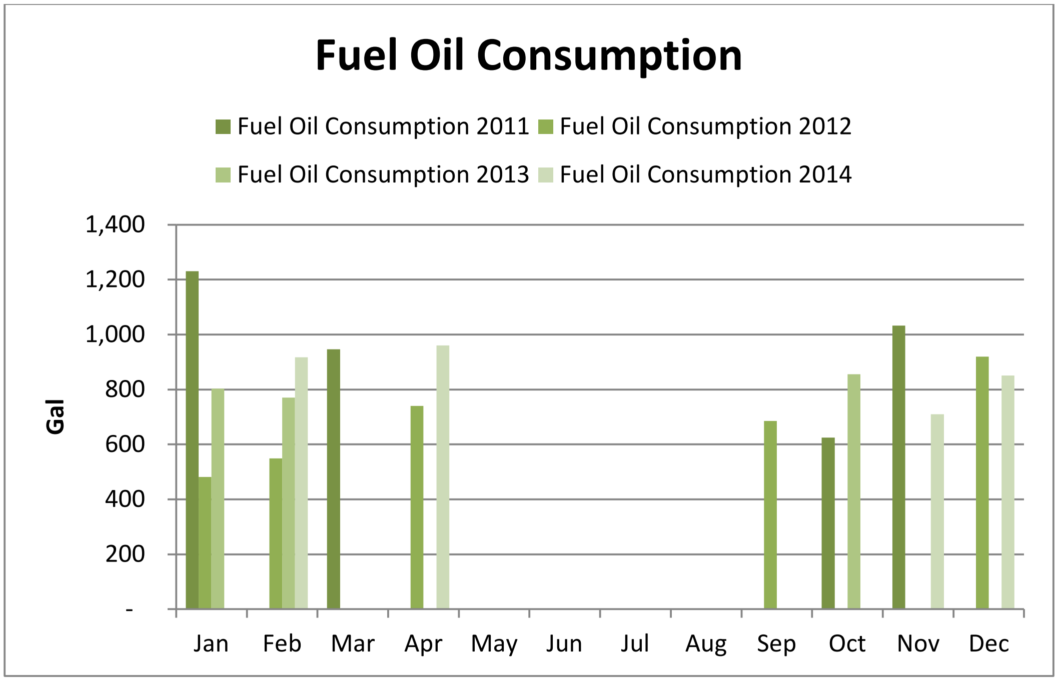

Figure 6. Mendenhall Glacier Visitor Center Monthly Fuel Oil Purchases for 2011 to 2014

Figure 7 shows the monthly water consumption at the MGVC. Water usage at the MGVC is primarily due to guests utilizing the restroom facilities. Wait times for restrooms were described as overly long for female guests in the summertime. The large increase in water consumption in 2014 is due to an additional water meter installed in the MGVC.

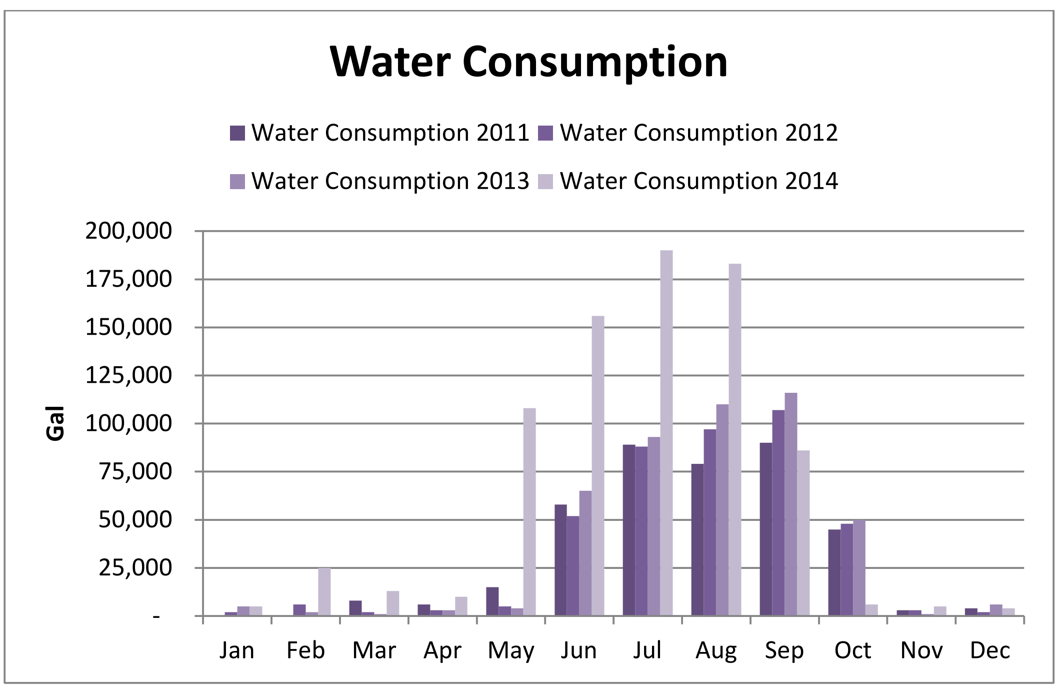

Figure 7. Mendenhall Glacier Visitor Center Site Monthly Water Consumption for 2011 to 2014

2.5 Building and Site Facilities

The description of the MGVC building and site facilities includes occupancy, envelope, heating, ventilation, and air conditioning (HVAC), cooling plant, heating plant, domestic hot water, building automation, lighting, plug loads, and a list of current best practices at the site.

2.5.1 Occupancy

The Mendenhall Glacier site has two distinct seasons: summer from May 1 to September 31 and winter from October 1 to April 30. These seasons coincide with the summer arrival of large cruise ships into Juneau. Throughout the summer, travelers from the cruise ships arrive sporadically to Mendenhall Glacier. Between 1,000 and 5,000 visitors arrive on a typical summer day; the total summer season brings more than 250,000 people through the MGVC and more than 450,000 visitors to the glacier site. The MGVC operating hours are between 8:00 am and 7:30 pm, seven days a week. There are five full-time employees and 20 additional seasonal employees on staff during the summer.

Winter months are quieter at the Mendenhall Glacier. Visitors to the Mendenhall Glacier during the entire winter season are approximately 7,000, with 4,000 people entering the MGVC. The hours of operation are reduced to Friday through Sunday from 10:00 am to 4:00 pm. The site continues to employ five full-time employees during regular business hours.

2.5.2 Heating, Ventilation, and Air Conditioning

The MGVC has three air-handling units (AHU) that serve the building. AHU 1 and AHU 2 are located in the mechanical room and serve the lower office and break room spaces and the upper observatory, gallery and bookstore. AHU 3 serves the auditorium and is located in the plenum space above a rear auditorium room. All AHUs have standard efficiency motors, constant speed fans, and standard v-belts. Filters were on regular maintenance schedule, though at the time of the audit the filters were six months old. No carbon dioxide (CO_2) sensors were installed. The AHUs have temperature based economizers that economize to 65°F. During the winter, evening gatherings in the auditorium often cause uncomfortably hot temperatures and require doors be opened to allow natural ventilation to cool the space. On peak days during the summer the auditorium will over pressurize, making it unable to close doors.

The exterior men’s and women’s restrooms are heated with eight radiant ceiling panels rated at 625 Watts (W) each. A supplemental radiant floor heating system is utilized in the winter and draws a total of 4,400 W. Manual thermostats control these heating units. An exhaust fan runs at all times throughout the summer for ventilation. A 3,000 W electric heater is situated in the restroom maintenance closet to prevent the pipes surrounding the hot water heater from freezing.

The information kiosk is heated with a 3,000 W electric heater that is manually controlled. This structure is only used in the summer months. The underground storage is heated with a 3,000 W wall-mounted, electric heater with a manual thermostat.

2.5.3 Cooling Plant

There are two packaged air conditioning units (ACU); one unit serves the projector room above the auditorium and the other unit serves the elevator machine room. The ACU that serves the projector room is a MovinCool CM12 10,500 Btu/h ceiling-mount spot ACU. This unit was installed to regulate the temperature due to a projector and computer system heat load. There is also a split ACU that serves the elevator machine room that is estimated to be less than one ton in size.

2.5.4 Heating Plant

The MGVC is heated with Weil-McLain Model 578 oil-fired boilers. Two boilers are on-site, one used as a primary and one as a backup, which are rotated into use every six months. The fuel oil used is No. 1 heating oil. The boilers gross output is 453,000 Btu/h.

Baseboard style radiators are found in the observatory, galleries, lower offices, bookstore, and theatre. A heat exchanger with 50% propylene glycol is used to supplement the heating system when required. The glycol loop provides heat to the three AHUs in order to preheat outside air. The glycol loop also provides heating for snowmelt to the outside steps in the winter. This plumbing runs on the outside of the building with closed cell pipe insulation. The hot water and glycol is provided to the zones by nine separate hot water pumps. Two pumps are 3 horsepower while the remaining seven are 1 horsepower. All have standard efficiency motors.

Electric heating mats are used to deice the walkway leading up to the MGVC in the winter time. The 32 mats are buried beneath the concrete walkway from the lower bathroom to the tunnel elevator entrance. It's likely there's no layer of insulation on the bottom-side of the mats. They consume 60 W/ft^2 totaling 96, kW and cause high demand charges in the winter.

A cove hydronic system is no longer operational along the observatory benches near the large northern facing glazing. This system has not been utilized for several years due to frequent malfunction and pipe bursts due to abnormally cold weather conditions.

2.5.5 Domestic Hot Water

Domestic hot water in the MGVC is provided by an 80-gallon AO Smith electric hot water heater with a rating of 9,000 W. The exterior restrooms are supplied hot water from a 50-gallon AO Smith electric hot water heater rated at 4,500 W.

2.5.6 Building Automation System

The MGVC has an older 3-1/2" disk operating system (DOS) as its building automation system (BAS). The BAS controls the three AHUs' start and stop time based on user-input occupancy hours. In addition, they control outside air dampers open and close, space temperature setbacks, boiler hot water supply valve setpoints, and baseboard heating systems. Manual overrides at local thermostats allow staff to alter temperatures based on need. Occupied hour temperatures are 72° F and 58° F during unoccupied hours.

2.5.7 Lighting

The lighting system is controlled by a central lighting program that controls on and off times for all of the spaces. The second floor gallery spaces and exhibits in the MGVC contain an assortment of technologies including halogens, compact fluorescent lamps (CFL), and recently added light-emitting diode (LED) fixtures. Swapping out less efficient bulbs is being done on as as-needed basis. No occupancy sensors, daylighting sensors, or dimming capabilities were observed. The lighting on the first floor is primarily fluorescent T-12, T-8, and CFL bulbs. Many of these fixtures featured bi-level lighting capabilities not utilized by the control system or by occupants.

The exterior bathroom, walkway, kiosk, and bus shelter are lit with T-8, T-12, CFLs and some linear LED bulbs. Exterior parking consisted of 11 high pressure sodium (HPS) lights. Exit lamps have all been changed to LEDs. A detailed lighting schedule is found in the Appendix.

2.5.8 Plug Loads

The plug loads in the MGVC consists of office equipment, laptop computers with docking stations, LCD monitors, a new office multi-function printer, fax machine, secondary printer, visual and audio displays, a projector, and several LCD televisions. The breakroom contains a standard coffee machine, electric tea kettle, refrigerator, microwave, electric range, and oven.

2.5.9 Building Envelope

The exterior of the MGVC is concrete and 2x6 wood framing with R-19 batt insulation. The roof has 6-inch rigid insulation providing the roof with R-30 insulation. Foundation slabs and walls have 2 inches of insulation and a vapor barrier. Windows were replaced in the late 1990s with fixed, double pane clear glass.

2.5.10 Current Best Practices and Observations

Numerous ECMs, WCMs, and best practices have been implemented as part of various renovation projects. The following is a list of current EE projects and practices that were identified:

- General
  - Knowledgeable, proactive, and enthusiastic facilities staff
- HVAC
  - Air-side economizer in the summer months
  - Appropriate space temperature setpoints
- Lighting
  - Appropriate lighting levels
  - Culture of turning lights off (good occupant awareness)
  - Incremental replacement with LEDs
  - LED exit signs

- Plug Loads
    - Advanced metering
    - Majority of computers are laptops
    - New high efficiency multi-function printer
    - Minimal extraneous plug loads
- Water
    - Advanced water meter
    - Majority of faucets were low-flow
    - Water bottle filling stations promoted and utilized.

2.6 Building Energy Modeling

Building energy modeling was used to determine the energy use characteristics of the building, and to calculate energy and energy cost savings from various ECMs analyzed for the project. eQUEST was selected as the building simulation software tool to perform the energy modeling of this site.

eQUEST is a commercially available interface for the DOE-2 hourly building energy simulation program originally developed by DOE. The program is capable of evaluating energy and energy cost savings that can be achieved by applying ECMs, such as improved envelope components, passive heating and cooling strategies, lighting system improvements, and HVAC system improvements. The software is commonly used to analyze new construction buildings and building retrofits.

eQUEST requires a detailed description of the building envelope (for thermal and optical properties), internal loads, operating schedules, lighting, and HVAC system requirements, and utility rate schedules. The major benefits of eQUEST include the ease of defining building geometry, space characteristics, schedules, HVAC systems, and running parametric analyses to study design and retrofit options. Another major benefit of eQUEST is the relatively short simulation run times.

An eQUEST energy model of the MGVC was created. The existing operating conditions of HVAC and lighting systems were modeled, including current operating schedules and, as much as possible, equipment operational characteristics determined from discussion with the facilities team.

A graphical representation of the building energy model developed in eQUEST is shown in Figure 8. The geometry of the buildings was simplified for modeling purposes to accurately simulate energy transfer through all surfaces in the building.

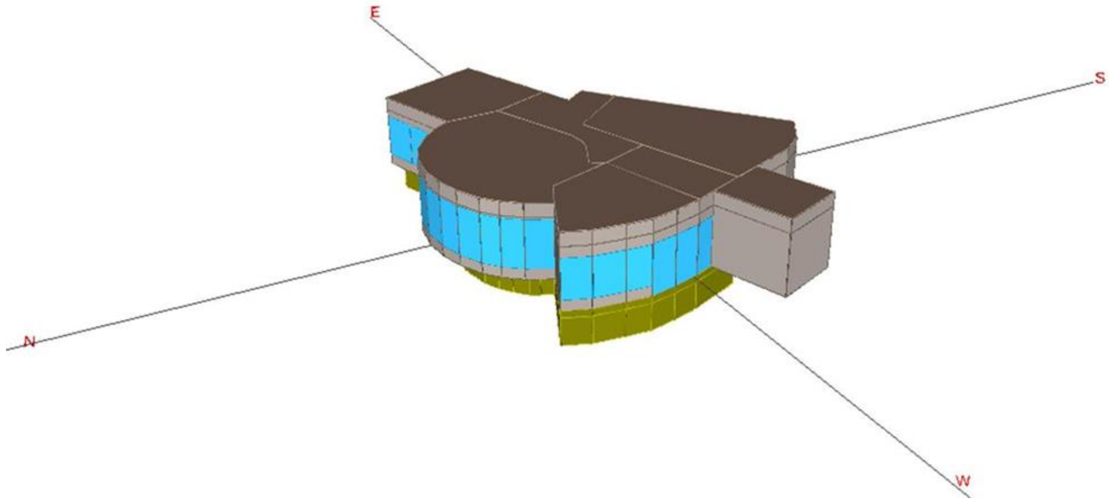

Figure 8. Mendenhall Glacier Visitor Center eQUEST model representation

Source: Image generated using eQUEST

The NREL team used the data gathered during the assessment to develop the eQUEST model. The general facility characteristics that were modeled are provided in Table 3.

Table 3. Mendenhall Glacier Visitor Center eQUEST Summary Information

Mendenhall Glacier Visitors Center—Juneau, Alaska		
Project	Weather Data	Juneau, Alaska
	Building Types	Visitors Center
	Total Number of Buildings Modeled	1
	Building Areas	11,000 ft^2
	Above-Grade Floors	1
	Below-Grade Floors	1
Building Footprint	Building Orientation	Plan North
	Zoning Pattern	AHU zoning
	Perimeter Zone Depth	20-30 ft
	Floor to Floor Height	12 to 22 ft
	Floor to Ceiling Height	8 to 16 ft
	Roof Pitch	0^o
Roof	Construction	Steel frame
	Roof	Built-up roof with ethylene propylene diene monomer membrane
Walls	Construction	Steel framed with mass walls
	Finish	Concrete

Mendenhall Glacier Visitors Center—Juneau, Alaska		
Ground Floor	Over Basement	8” concrete
Below-Grade Walls	Construction	8” concrete
Infiltration	Perimeter	0.038 (cfm*/ft^2)
Ceilings	Interior Finish	Drywall and lay-in acoustic tile
Vertical Walls	Wall Type	Framed
Floors	Interior Finish	Carpet
	Construction	Concrete
Exterior Doors	Door Type	Glass
Exterior Windows	Window Type	Double pane with aluminum frames
Power Density	Lighting	1.8 to 2.0 W/ft^2
	Plug Loads	0.2 to 0.3 W/ft^2
HVAC Systems	System Type	Constant Air Volume (CAV) system
	System Cooling Source	No cooling
	Heating System	Hot water coils
Fan Schedules	Operation Schedule	On 24/7
Heating Primary Equipment	Heating Type	2 x 0.522 MMBtu** No. 1 fuel oil boilers
	Hot Water (HW) Pumping	Constant-speed pumping

*Cubic feet per minute.
**O ne million British thermal units.

The baseline energy model for the MGVC was calibrated to within approximately 2% of the annual energy use from the existing electricity and within 2% of the No. 1 fuel oil use utility data for the past three years. Figure 9 presents the eQUEST output for the calibrated baseline energy model for the MGVC.

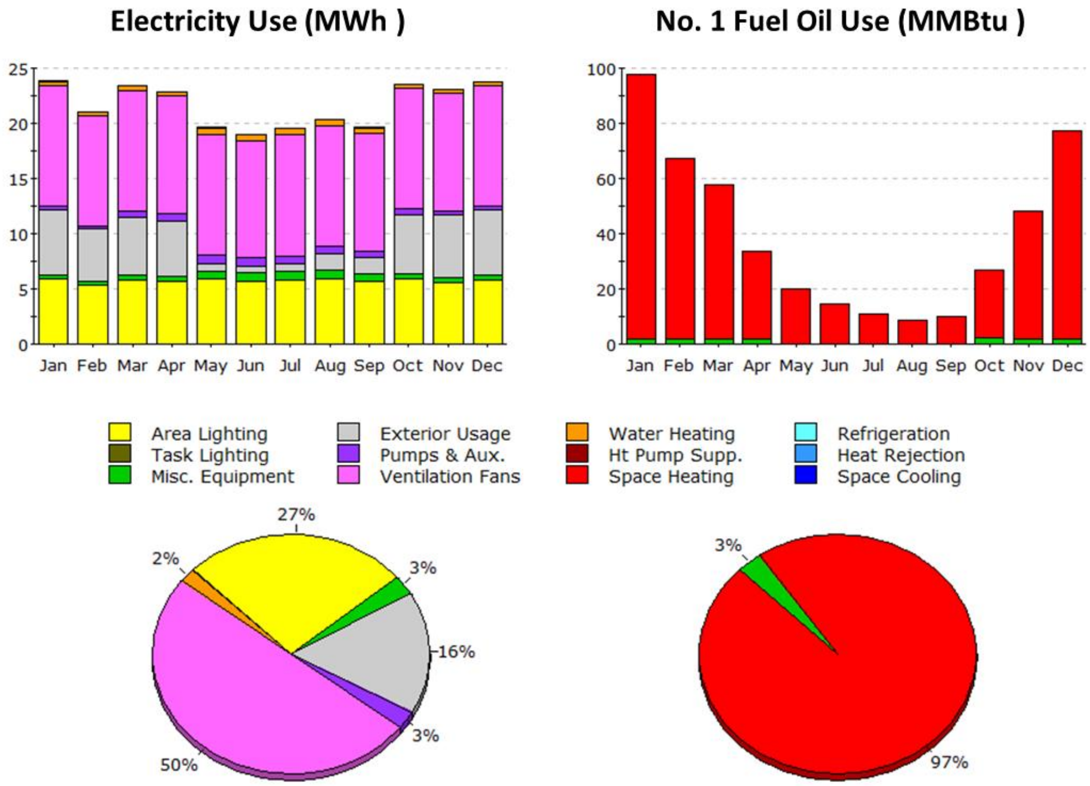

Figure 9. Mendenhall Glacier Visitor Center eQUEST Calibrated Baseline Results for Annual Energy Use

Source: Figures generated using eQUEST

2.7 Renewable Energy Modeling

Renewable energy modelling was used to determine the cost-optimum RE mix with the ultimate goal of creating a net-zero site and facility. HOMER Pro microgrid software was selected as the RE simulation software tool for the RE modeling of the MGVC site.

HOMER is a commercially available microgrid simulation program originally developed at NREL and now run by a Colorado-based company. HOMER simulates the operation of multiple energy generation systems on an hourly basis for an entire year. The software takes into account the variations in demand, load, grid cost of energy, cost of fuel, cost of installation, and operating cost among many other inputs. HOMER examines all possible microgrid system configurations chosen for simulation and allows users to select the optimum system based on any number of variable outputs. HOMER allows sensitivity inputs to help users identify which uncontrollable variables have the largest impact on system configurations. This allows for users to identify significant trends such as at what installation price and utility energy price is a specific system financially viable.

HOMER is an industry leading microgrid simulation tool and is commonly used to find optimal energy solutions for sites or buildings seeking net-zero status. Detailed descriptions of the site energy demands, location, energy costs and distributed generation options are all factored into the simulation outputs. The advantages of HOMER include clearly defined distributed systems to consider, cost sensitivities inputs, variable demand inputs, and detailed output data to determine an optimal solution for a site.

A HOMER microgrid model of the MGVC was created. A graphical representation of the microgrid options considered is shown in Figure 10.

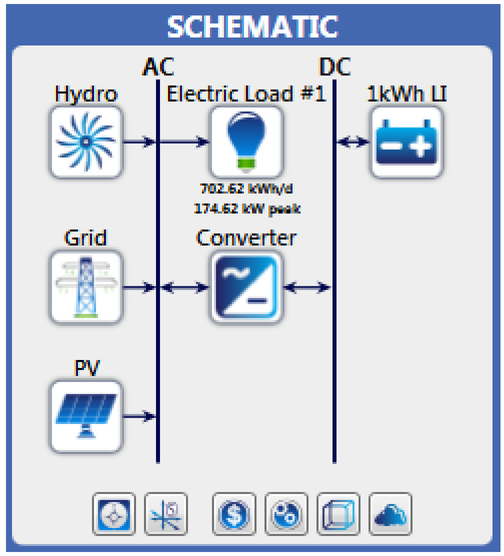

Figure 10. Mendenhall Glacier Visitor Center Site HOMER Microgrid Optimization Schematic

Source: Figures generated using HOMER

The existing load demands, utility rate structure, and location were included in the base model. Renewable energy options modeled included micro-scale hydropower generation, solar photovoltaic (PV) generation, and lithium ion battery storage. The costs associated with grid purchases, installation costs, and grid sellback rates were all varied to search for the optimal solution for MGVC at this time and for future consideration. Estimates for installation costs for the hydro, PV, and batteries were all taken from recent literature.[1,2] The general load, economics, resources, and generation costs are listed in Table 4.

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[1]IRENA, Hydropower Renewable Energy Technologies: Cost Analysis Series; Volume 1: Power Sector Issue 3/5, IRENA. June 2012.
[2] Black and Veatch, Cost Report Cost and Performance Data for Power Generation Technologies; Black and Veatch. February 2012.

Table 4. Mendenhall Glacier Visitor Center HOMER Input Summary Information

Mendenhall Glacier Visitors Center—Juneau, Alaska		
Project Location	Location	Glacier Spur Rd, Juneau, AK 99801, USA
	Latitude	58 degrees 24.93 minutes North
	Longitude	134 degrees 32.69 minutes West
	Time zone	America/Juneau
Load	Data source	Synthetic
	Daily noise	10%
	Hourly noise	20%
	Scaled annual average	702.620 kWh/d
	Scaled peak load	174.6178 kW
	Load factor	0.1677
Generic Micro Hydro	Capital	$248,000.00
	Replacement	$0.00
	O&M	$4,960.00
	Lifetime	50 yr
	Pipe head loss	15%
	Available Head	7.00 m
	Design flow rate	600.00 L/s
	Minimum flow ratio	50%
	Maximum flow ratio	150%
	Efficiency	75%
	Nominal capacity	30.90 kW
Hydro Resource	Annual average	1,467.89 L/s
PV: Generic flat plate PV	Capital	$3,000 per kW
	Replacement	$3000 per kW
	O&M	$30 per kW
	Sizes to consider	0, 40
	Lifetime	25 yr
	Derating factor	75%
	Tracking system	No Tracking
	Slope	45.000 deg
	Azimuth	0.000 deg
	Ground reflectance	20.00%
Solar Resource	Scaled annual average	2.31 kWh/m2/d
Battery: Generic 1kWh Li-Ion	Capital	$700 per kW
	Replacement	$700 per kW
	O&M	$10 per kW
	Quantities to consider	0, 100
	Voltage	6 V
	Nominal capacity	167 Ah
	Lifetime throughput	[3000] kWh
Converter	Capital	$300 per kW
	Replacement	$300 per kW
	O&M	$0.00
	Sizes to consider	0, 120

Mendenhall Glacier Visitors Center—Juneau, Alaska		
	Lifetime	15 yr
	Inverter can parallel with alternating current generator	Yes
Economics	Grid power price	0.124 $/kWh
	Annual real interest rate	6%
	Project lifetime	25 yr

The resource for the micro-scale hydropower data was acquired from the USGS Surface-Water Historical Observations.[3] Three Juneau, Alaska water sources were used as a template for modeling Steep Creek's seasonal flow rates: Salmon Creek, Lemon Creek, and the Mendenhall River. Figure 11 shows the calculated flow rates in Steep Creek used in the HOMER model, these values must be tested and confirmed with local authorities.

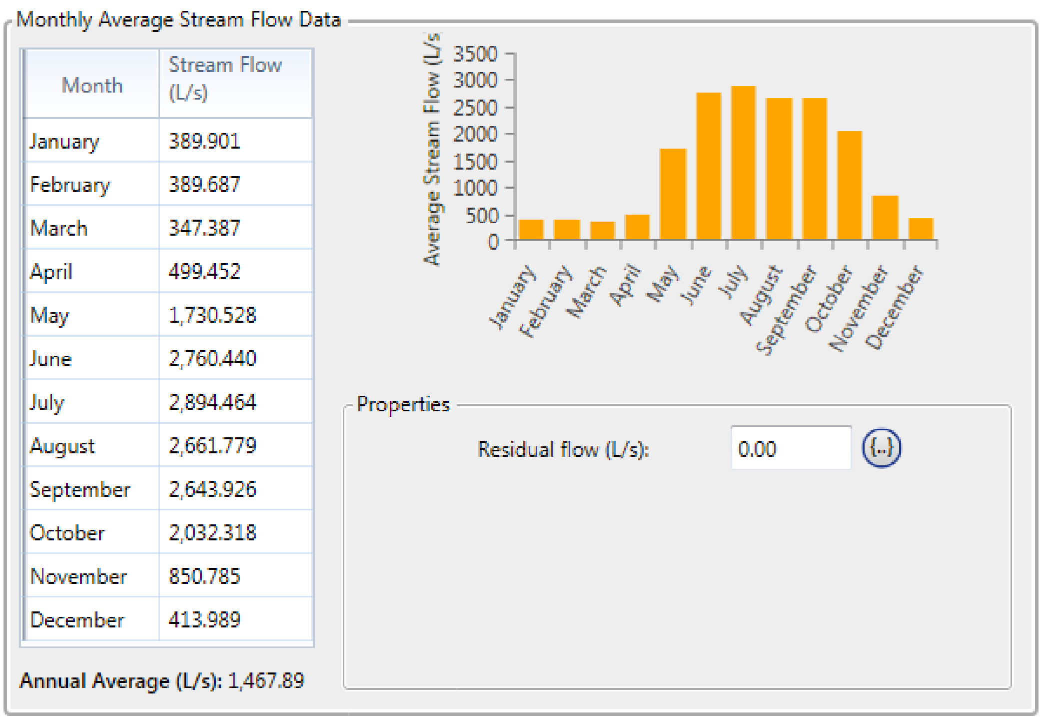

Figure 11. Monthly Average Stream Flow Data Assumed for Steep Creek, Juneau, Alaska

Source: Figures generated using HOMER

[3] http://waterdata.usgs.gov/nwis/sw

2.8 Energy Conservation, Water Conservation, and Renewable Energy Measures

The following sections contain the HVAC, lighting, plug loads, envelope, WCMs, and REMs that were analyzed. The emissions factors used are:

- 0.0000126 metric tons/kWh for electricity (which is relatively low because of the hydropower that makes up a majority of the electricity generation in Juneau).
- 0.0722 metric tons/MMBtu for No.1 fuel oil.

2.8.1 Heating, Ventilation, and Air Conditioning Measures

The following sections contain the HVAC ECMs that were analyzed.

2.8.1.1 Replace Standard V-Belts with Cogged V-Belts

Current Condition: The assessment team observed standard v-belts on all the HVAC fan drives of 4 air-handling units that each have supply and return fans. These motors are asynchronous induction motors. The motors are currently operated for an estimated runtime of 8,760 h/yr.

Investigated Action: Replace all the standard v-belts with cogged v-belts. Cogged v-belts have slots that run perpendicular to the belt's length, which reduce the bending resistance of the belt.

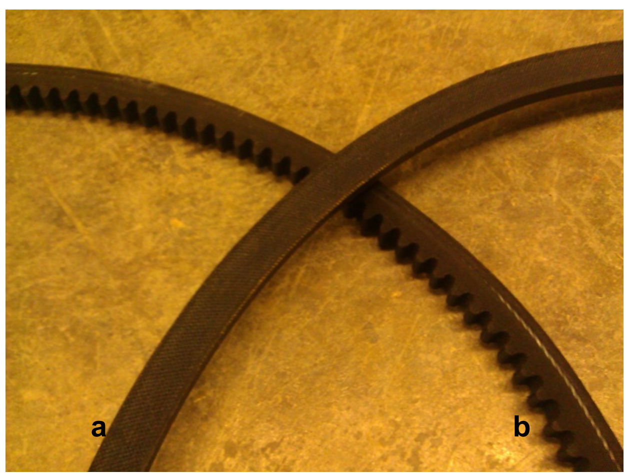

Figure 12. Standard V-Belt (a) and Cogged V-Belt (b)

Photo by Caleb Rockenbaugh, NREL

Cogged v-belts can be used with the same pulleys as equivalent rated v-belts. They run cooler, last longer, and have an efficiency that is on the order of 2% to 3% higher than standard v-belts. The belts associated with the largest motors and the motors that are run closest to full load should be given priority when making replacements.

Table 5 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings for installing cogged v-belts. Calculation assumptions are also given.

Table 5. Energy and Cost Savings Summary for Replacing V-Belts

Energy and Cost Savings	
Electricity Savings (kWh/yr)	2,348
Heating Energy Savings (MMBtu/yr)	0
Cost Savings ($/yr)	$291
Implementation Costs ($)	$416
Simple Payback (yrs)	1.43
CO_2e Savings (metric tons/yr)	0.03

Assumptions:

- Energy savings were calculated using the eQUEST energy model.
- Savings were calculated using a 3% efficiency improvement from the cogged v-belt.
- Labor costs were estimated at $50/h × 0.5 h/motor for 8 motors (4 supply fans and 4 return fans).
- Belt costs were estimated at $15/belt.
- A 30% contingency was added to the implementation cost.

2.8.1.2 Hot Water Condensing Boiler

Current Condition: The MGVC is served by two hot water boilers that operate on No. 1 fuel oil. The boilers have a rated capacity of 0.521 MMBtu/h and 80% efficiency. The boilers are nearing the end of their useful life.

Investigated Action: When the boilers are ready to be replaced, specify condensing boilers with an efficiency of 93% and with a low-fire setting. It is important to note that because the boilers need to be replaced anyway, only the incremental cost of a higher efficiency boiler is considered.

The installation of a lake-source heat pump is also investigated. If this option is pursued condensing boilers will not have to be installed (i.e., the site would install either condensing boilers or a lake-source heat pump system; not both). Table 6 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings for implementing this measure. Calculation assumptions are also given.

Table 6. Energy and Cost Savings from Hot Water Condensing Boiler

Energy and Cost Savings	
Electricity Savings (kWh/yr)	0
Heating Energy Savings (MMBtu/yr)	72
Cost Savings ($/yr)	$1,627
Implementation Costs ($)	$3,203
Simple Payback (yrs)	1.97
CO_2e Savings (metric tons/yr)	5.18

Assumptions:

- The eQUEST energy model was used to calculate the energy and cost savings from implementing the measure.
- The existing steam boilers are 80% efficient.
- The existing steam boilers would be replaced with 2 × 0.521 one million British Thermal Units (MMBtu) per hour hot water condensing boilers that are 93% efficient.
- The boilers are replaced at the end of life and therefore only incremental costs are considered.
- The cost premium for condensing boilers is 11%.[4]
- A standard dual fuel boiler costs $11,200 each[5] and therefore the total cost premium for two condensing boilers is $2,464.
- A 30% contingency was added to the implementation cost.

2.8.1.3 Snowmelt System

Current Condition: There is an electric sidewalk snowmelt system that consists of 30 electric heating mats that are each 4 ft. by 20 ft. The power density of the electric snowmelt system is 50 W/ft^2 and there is a single switch that controls all of the mats, which equals 120 kW of peak electric power. There is no insulation under the electric heating mats and the asphalt is damaged and nearing the end of its useful life. There is also a hydronic snowmelt system for the stairway. The hydronic snowmelt system is not being considered in this analysis.

Investigated Action: At the time the asphalt for the sidewalks needs to be replaced, remove and replace the existing electric snowmelt system and make improvements that include:

- Adding R-10 rigid board insulation below the electric heating mats
- Installing new high-efficiency snowmelt mats rated at 35 W/ft^2
- Installing multiple switches to the snowmelt system so that the mats can be staged on/off in order to reduce peak kW charges
- Installing controls so that the snowmelt system is staged in order to reduce peak kW while still providing adequate snow melting capabilities.

The site expressed interested in carbon fiber snowmelt systems. These systems are currently at the experimental phase and they are being tested in conjunction with concrete surfaces that already require carbon fiber reinforcement. The added cost of concrete and carbon fiber and the current experimental nature of this product make it not feasible to be considered at this time. Table 7 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings for replacing and making improvements to the existing electric snowmelt mats. Calculation assumptions are also given.

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[4] www.gsa.gov/portal/content/163495.
[5] RSMeans Facility Construction Cost Data 2013.

Table 7. Energy and Cost Savings from an Improved Electric Snowmelt System

Energy and Cost Savings	
Electricity Savings (kWh/yr)	54,000
Heating Energy Savings (MMBtu/yr)	0
Cost Savings ($/yr)	$9,683
Implementation Costs ($)	$39,094
Simple Payback (yrs)	4.04
CO_2e Savings (metric tons/yr)	0.68

Assumptions:

- The asphalt is assumed to be replaced at the end of its useful life and so the cost associated with the asphalt is assumed to be zero.
- The total area served by the electric snowmelt system is assumed to be 2,400 ft^2.
- The installed cost of the electric snowmelt mats is $10/$ft^2$, which totals $24,000.
- The wattage of the new snowmelt system is assumed to be reduced from 50 W/ft^2 to 35 W/ft^2.
- The installed cost of adding R-10 rigid board insulation is $1.28/$ft^2$, which totals $3,072.
- The cost of adding controls to stage the electric heating mats is assumed to be $3,000.
- Half of the mats are assumed to be stage on for 30 minute intervals.
- The peak electrical savings is 78 kW during months that the snowmelt system is used, which saves $5,633/yr in peak kW charges.
- The electrical energy savings going to lower wattage mats with board insulations is estimated to be $54,000 kilowatt-hour (kWh)/year, which is based on 1,500 hrs/year of operation.
- The electrical cost savings is based on a $0.075/kWh energy charge.
- A 30% contingency was added to the final cost.

2.8.1.4 Incrementally Install Premium Efficient Motors

Current Condition: The assessment team observed standard efficiency motors driving the HVAC fans/pumps. These motors are asynchronous induction motors and efficiency ratings are below the National Electrical Manufacturers Association (NEMA) Premium efficiency rating. The motors are currently operated for an estimated run time of 8,760 hours annually.

The Copper Development Association recently introduced a line of ultra-efficient motors into the U.S. market, which exceed NEMA Premium standards. These motors utilize a die-cast copper rotor, which reduces the energy requirements of the motor and allows the motor to run cooler. The motor also features an improved heat-dissipation system and new low-friction bearings, both of which help extend the life of the motor. The motor also has a smaller weight and size compared to the standard NEMA Premium efficiency motors. The motors are showing efficiency improvements on the order of 3% to 10% more efficient than current NEMA Premium standards.

Investigated Action: It is not feasible to replace all of the motors currently in operation at this time because of the costs associated with replacing a functioning motor. However, it is recommended that motors be replaced with premium efficiency motors at the end of their useful life. Therefore, only a slight incremental cost is incurred from the price of the motor and labor costs are equivalent to what would have already been required.

Incrementally replace all of the standard efficiency, three-phase, asynchronous induction motors feeding HVAC fans/pumps. Specify NEMA premium efficiency motors with similar enclosure type, speed, mounting, and electrical input. All of the motors are relatively small and it is not worth the cost premium to install ultra-efficient motors. Table 8 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings from installing premium efficiency motors. Calculation assumptions are also given.

Table 8. Energy and Cost Savings Summary for Installing Premium Efficiency Motors

Energy and Cost Savings	
Electricity Savings (kWh/yr)	3,757
Heating Energy Savings (MMBtu/yr)	0
Cost Savings ($/yr)	$466
Implementation Costs ($)	$2,054
Simple Payback (yrs)	4.41
CO_2e Savings (metric tons/yr)	0.05

Assumptions:

- Energy savings were calculated using the eQUEST energy model.
- Labor costs were not included because the motors are being installed incrementally.
- Motor costs were estimated using the MotorMaster database.
- A 30% contingency was added to the implementation cost.

2.8.1.5 Install Demand Control Ventilation in Auditorium

Current Condition: The MGVC does not have a demand-control ventilation (DCV) system with CO_2 sensors in the return-air ductwork. Currently, the outside air is introduced and conditioned at a fixed rate based on the maximum design occupancy in order to satisfy the ASHRAE Standard 62.1, which recommends 15 cubic feet per minute (cfm) to 20 cfm per person, depending on the space type.

Building occupancy in the auditorium fluctuates and is often less than the maximum design occupancy and is effectively being over-ventilated and, as a result, consuming more energy than necessary. This is particularly true of spaces where the occupancy levels vary such as in auditoriums, conference rooms, and training rooms. The building CO_2 level is closely related to the occupancy levels. The typical outside CO_2 level is relatively low concentration, around 400 parts per million (ppm) to 500 ppm, and is used to dilute the higher indoor CO_2 levels.

Investigated Action: Install a DCV system in the auditorium using CO_2 sensors in the return-air ductwork to measure and control the amount of outside air that is used to ventilate the building. This will allow the building to satisfy ASHRAE 62.1 ventilation standards without over-ventilating the building. Therefore, outside air regulation will be based on the actual occupancy rather than the maximum design occupancy. This will reduce the energy demand of the fans and heating/cooling coils used to transport and condition the air throughout the building. Table 9 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings for converting the CAV system to a variable air volume (VAV) system. Calculation assumptions are also given.

Table 9. Energy and Cost Savings from Installing Demand-Control Ventilation in the Auditorium

Energy and Cost Savings	
Electricity Savings (kWh/yr)	2,322
Heating Energy Savings (MMBtu/yr)	26
Cost Savings ($/yr)	$868
Implementation Costs ($)	$3,900
Simple Payback (yrs)	4.49
CO_2e Savings (metric tons/yr)	1.88

Assumptions:

- The eQUEST energy model was used to estimate the savings from installing CO_2 sensors in the return-air ducts for DCV.
- Equipment costs were estimated assuming one CO_2 sensor would be installed in the return-air ducts of the auditorium AHU at a cost of $1,000 per sensor, which totals $1,000.
- Labor costs were estimated at 20 hours per sensor x $50/hr, which totals $1,000.
- Operations and maintenance costs were estimated assuming a technician would spend 20 hours a year maintaining set points at a labor rate of $50/hr, which totals $1,000/yr.
- A 30% contingency was added to the overall cost.

2.8.1.6 Install Boiler Stack Economizers

Current Condition: The MGVC is served by two hot water boilers that operate on No. 1 fuel oil. The boilers have a rated capacity of 0.521 MMBtu/h and 80% efficiency. Neither boiler has a stack economizer on the flue gas exhaust.

Investigated Action: It is recommended that the two boilers have stack economizers installed in order to utilize the hot flue gas exhaust from the boilers to preheat the inlet water to the boilers. The installation of a stack economizer is estimated to have a 30°F temperature rise effect on the inlet water. Table 10 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings for installing boiler stack economizers. Calculation assumptions are also given.

Table 10. Energy and Cost Savings from Installing Boiler Stack Economizers

Energy and Cost Savings	
Electricity Savings (kWh/yr)	0
Heating Energy Savings (MMBtu/yr)	26
Cost Savings ($/yr)	$598
Implementation Costs ($)	$2,709
Simple Payback (yrs)	4.53
CO_2e Savings (metric tons/yr)	1.91

Assumptions:

- The eQUEST energy model was used to calculate the energy and cost savings for installing stack economizers on the boilers.
- The effective boiler efficiency increased by 5%.
- The stack economizers provide a 30°F temperature rise to the inlet water.
- The installed cost of the stack economizers is $2,000/MMBtu/h of boiler capacity, which totals $2,084.
- A 30% contingency was added to the final cost.
- This ECM assumes that new condensing boilers are not being installed.

2.8.1.7 Install Building Automation System

Current Condition: Currently the MGVC has an antiquated BAS that controls the HVAC systems. The BAS does a poor job at scheduling the HVAC equipment and there are no trending capabilities with the system. Figure 13 shows the current BAS.

Figure 13. Current Computer that Operates the Mendenhall Glacier Visitor Center Building Automation System

Investigated Action: Replace the antiquated MGVC BAS with an up-to-date BAS with strong scheduling and trending capabilities. Table 11 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings for installing a BAS. Calculation assumptions are also given.

Table 11. Energy and Cost Savings from Installing a Building Automation System

Energy and Cost Savings	
Electricity Savings (kWh/yr)	9,866
Heating Energy Savings (MMBtu/yr)	30
Cost Savings ($/yr)	$1,892
Implementation Costs ($)	$8,580
Simple Payback (yrs)	4.53
CO_2e Savings (metric tons/yr)	2.25

Assumptions:

- The eQUEST energy model was used to calculate the energy and cost savings replacing the BAS.
- The installed cost is assumed to be $0.5/ft^2 of floor area,[6] which totals $5,500.
- The cost to optimize the BAS system was assumed to be $0.10/ft^2 of floor area,[7] which total $1,100.
- A 30% contingency was added to the implementation cost.

2.8.1.8 Lake Loop Heat Pump System

Current Conditions: The MGVC is currently served by a CAV system with No. 1 fuel oil boilers and no cooling. The site is looking for potential ways to move to an all-electric site and net-zero energy options.

Ground source heat pumps (GSHPs) are heat pumps that use the relatively constant temperature of the earth as a heat source (in heating) or sink (in cooling). These heat pumps produce the hot and cold water that is used to heat/cool a building, and they can also be used to produce some of the hot water needed for occupant use.

Ground temperatures at depths of 20 to 30 feet stay relatively consistent throughout the year. Because of this, heat pumps have a much higher coefficient of performance (COP) than air heat exchange units, such as a standard split DX air conditioner. COP is measured as the amount of thermal energy produced per unit of input energy. Most GSHPs are able to attain COPs of 3.0 to 6.0, whereas average air-source heat pumps have a COP of 1.75 to 2.5. This higher efficiency can lead to large reductions in energy use over the lifetime of a building.

[6] http://www.automatedbuildings.com/news/apr07/articles/esource/070322105430kamm.htm
[7] http://www.automatedbuildings.com/news/apr07/articles/esource/070322105430kamm.htm

There are essentially four types of GSHPs: Closed-loop vertical, closed-loop horizontal, closed-loop pond/lake, and open-loop. The most common type is the closed-loop system in which a closed-loop of water/antifreeze is pumped through a series of pipes/wells in the ground (absorbing/rejecting heat through the pipe walls into the earth) and is then used in the heat exchanger.

This type of system avoids the environmental issues of water usage and water contamination that are present in open-loop systems. The type of system chosen depends upon the soil and rock type at the installation, the land available and/or if a water well can be drilled economically or is already on site. For the MGVC, it is assumed that the systems will be a closed-loop pond/lake system that uses the "Kettle Ponds" as the heat sink or heat source depending on the season.

GSHPs can serve almost any building with both heating and cooling in a wide range of building sizes, from 100 ft^2 to 1 million ft^2. Large buildings may require multiple GSHPs. The same loop may serve multiple smaller buildings. GSHPs are most cost-effective when replacing old equipment, when used in extreme climates (with cold winters, hot summers, or large daily temperature swings), and when electricity is less than three times as expensive per Btu as heating fuels. They tend not to be cost effective in buildings without both heating and cooling requirements, buildings without ductwork, newer buildings (less than four years old), buildings in mild climates, buildings with air source heat pumps, or buildings on central energy plants.

A high level analysis was done to determine the feasibility of using GSHPs at the MGVC. The analysis was carried out by using eQUEST energy modeling software to determine the potential energy and cost savings from installing a closed-loop lake GSHP and estimates were made for installation cost. The heat sink for the GSHP system would be the "Kettle Ponds" located in close proximity to the building.

After calibrating the energy model of the site, a closed-loop pond/lake GSHP system was modeled with the same building characteristics and schedules as the baseline building.

Investigated Action: Install a closed-loop lake system that would use water from the "Kettle Pond" for heat exchange. Table 12 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings for installing a lake loop heat pump system. Calculation assumptions and major energy modeling assumptions are also given.

Table 12. Energy and Cost Savings from Installing Closed-Loop Pond/Lake Heat Pump System

Energy and Cost Savings	
Electricity Savings (kWh/yr)	(39,573)
Heating Energy Savings (MMBtu/yr)	473
Cost Savings ($/yr)	$5,803
Implementation Costs ($)	$117,000
Simple Payback (yrs)	20.17
CO_2e Savings (metric tons/yr)	33.62

Assumptions:

- The eQUEST energy model was used to model the closed-loop pond/lake system, which would use the water from the "Kettle Ponds" as a heat sink/source.
- Max entering water temperature to the lake during cooling season is 95°F.
- Min entering water temperature to the lake during heating season is 35°F.
- The installed cost was assumed to be $6,000/ton, which includes installing the associated piping to the "Kettle Ponds" and installing the zonal heat pumps within the building.
- The estimated total size of the GSHP system is 15 tons, which totals $90,000 for the system.
- The annual energy cost savings is $5,803/yr, which is based on an increased annual electricity use of 39,573 kWh/yr and the elimination of No. 1 fuel oil use.
- A 30% contingency was added to the implementation cost.

2.8.1.9 Convert Constant Air Volume to Variable Air Volume System

Current Condition: Currently, there are four CAV air handlers at the MGVC. In a CAV system, variations in the thermal requirements of the building are satisfied by varying the temperature of a constant volume of air delivered to the building. Alternatively, a VAV system can adjust the flow rate of conditioned air to the space, saving significant fan energy as well as cooling energy.

Investigated Action: The CAV systems in the MGVC should be retrofitted to a VAV system. This will require converting each CAV box to VAV, and variable frequency drives need be installed on the supply and return fans. Each VAV box should be specified with an electronic damper actuator and an electronic temperature and relative humidity (temp/RH) sensor that are controlled through the direct digital control (DDC) system.

Building occupants should not be given the ability to modify the temp/RH set-points. VAV box damper position should be connected to the DDC system. Table 13 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings for converting the CAV system to a VAV system. Calculation assumptions are also given.

Table 13. Energy and Cost Savings from Converting the Constant Air Volume System to a Variable Air Volume System

Energy and Cost Savings	
Electricity Savings (kWh/yr)	52,865
Heating Energy Savings (MMBtu/yr)	88
Cost Savings ($/yr)	$8,540
Implementation Costs ($)	$218,387
Simple Payback (yrs)	25.57
CO_2e Savings (metric tons/yr)	6.99

Assumptions:

- The eQUEST energy model was used to calculate the energy and cost savings from implementing the measure.
- The total area served by the current CAV system is estimated to be 11,000 ft^2.
- There are a total of four CAV AHUs that serve the MGVC.
- The cost to demolish the old CAV AHUs and install VAV AHUs is assumed to be $21,675 per AHU, for a total of $86,700.
- It was assumed that each VAV box could cover 500 ft^2, resulting in an estimated 22 VAV boxes.
- The cost of each VAV box was estimated to be $695 per box, totaling $15,290 for all 22 VAV boxes.
- The labor cost associated with installing the VAV boxes was estimated to be $2,000 per box, totaling $44,000 for all 22 VAV boxes.
- The cost of the controls points at each VAV box were estimated to be $1,000 per point, totaling $22,000.
- A 30% contingency was added to the final cost.

2.8.1.10 Lighting Measures

The following sections contain the lighting ECMs that were analyzed.

Replace the Halogen Lamps with Low Wattage LED Lamps

Current Condition: Halogen lamps rated at 300 W per lamp are found in flood lamps and surface mounted fixtures in the second floor exhibition space and observatory. Halogen lamps of this type are inefficient and generate heat.

Investigated Action: Replace halogen lamps with the equivalent LED lamps. These retrofits are minimal in labor costs per fixture and lower energy consumption. Table 14 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings; calculation assumptions are also given.

Table 14. Energy and Cost Savings from Replacing Halogen Lamps with LED Lamps

Energy and Cost Savings	
Electricity Savings (kWh/yr)	14,044
Heating Energy Savings (MMBtu/yr)	(5)
Cost Savings ($/yr)	$1,566
Implementation Costs ($)	$1,269
Simple Payback (yrs)	0.81
CO_2e Savings (metric tons/yr)	(0.20)

Assumptions:

- Energy Assessment Calculation Worksheets were used to calculate the energy and cost savings from implementing the measure.
- The total number of Halogen fixtures was estimated to be 16 with 1 lamps per fixture.
- The energy rating of the BR30 fixtures was estimated to be 300 W per lamp.
- The energy rating of the LED fixtures was estimated to be 32 W per lamp.
- The cost of each LED lamp was estimated to be $42 per lamp.
- The labor time associated with installing the LED lamps was estimated to be 20 minutes per lamp.
- A 30% contingency was added to the final cost.

2.8.1.11 Replace the BR30 Lamps with Low Wattage LED Lamps

Current Condition: Halogen BR30s rated at 65 W per lamps are found in abundance throughout the second floor gallery and exhibit spaces. These lamps are simple screw in type. A portion of these lights have already been replaced with LED lamps.

Investigated Action: All of the remaining unchanged BR30 lamps should be replaced with LED lamps. The recommended color temperature of 5000 K should be consistent throughout the exhibit and gallery spaces. These retrofits are minimal in labor costs per fixture and lower energy consumption. Table 15 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings; calculation assumptions are also given.

Table 15. Energy and Cost Savings from Replacing BR30 Lamps with LED Lamps

Energy and Cost Savings	
Electricity Savings (kWh/yr)	65,387
Heating Energy Savings (MMBtu/yr)	(23)
Cost Savings ($/yr)	$5,894
Implementation Costs ($)	$6,921
Simple Payback (yrs)	1.17
CO_2e Savings (metric tons/yr)	(0.91)

Assumptions:

- Energy Assessment Calculation Worksheets were used to calculate the energy and cost savings from implementing the measure.
- The total number of BR30 fixtures was estimated to be 121 with 1 lamp per fixture.
- The energy rating of the BR30 fixtures was estimated to be 65 W per lamp.
- The energy rating of the LED fixtures was estimated to be 10 W per lamp.
- The cost of each LED lamp was estimated to be $25 per lamp.
- The labor time associated with installing the LED lamps was estimated to be 20 minutes per lamp.
- A 30% contingency was added to the final cost.

2.8.1.12 Replace the Standard T-12 Lamps with Low Wattage LED Lamps

Current Condition: Standard T-12 Lamps are found throughout the first floor maintenance room, control room, storage areas, and second floor glacier display. T-12 lamps are no longer manufactured so T-12 lamps will become unavailable in the near future.

Investigated Action: Linear LED lamps should be installed in all T-12 lamp fixtures. These retrofits are minimal in labor costs per fixture and lower energy consumption. Table 16 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings; calculation assumptions are also given.

Table 16. Energy and Cost Savings from Replacing T-12 Lamps with Linear LED Lamps

Energy and Cost Savings	
Electricity Savings (kWh/yr)	2,722
Heating Energy Savings (MMBtu/yr)	(1)
Cost Savings ($/yr)	$570
Implementation Costs ($)	$5,419
Simple Payback (yrs)	9.50
CO_2e Savings (metric tons/yr)	(0.04)

Assumptions:

- Energy Assessment Calculation Worksheets were used to calculate the energy and cost savings from implementing the measure.
- The total number of T-12 fixtures was estimated to be 57 with 2 lamps per fixture.
- The energy rating of the T-12 fixtures was estimated to be 34 W per lamp.
- The energy rating of the LED fixtures was estimated to be 22 W per lamp.
- The cost of each LED lamp was estimated to be $22 per lamp.
- The labor time associated with installing the LED lamps was estimated to be 30 minutes per lamp.
- A 30% contingency was added to the final cost.

2.8.1.13 Replace the Standard T-8 Lamps and Ballasts with Low Wattage LED Lamps

Current Condition: Standard T-8 lamps are found throughout the first floor offices, break room, lower restrooms, and exterior restrooms. The first floor offices are on bi-level switches, thought they are not utilized.

Investigated Action: Linear LED lamps should be installed in all T-8 lamp fixtures. These retrofits are minimal in labor costs per fixture and lower energy consumption. Bi-level lighting would still be a functional option in relevant spaces. Table 17 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings; calculation assumptions are also given.

Table 17. Energy and Cost Savings from Replacing T-8 Lamps with Linear LED Lamps

Energy and Cost Savings	
Electricity Savings (kWh/yr)	2,228
Heating Energy Savings (MMBtu/yr)	(1)
Cost Savings ($/yr)	$359
Implementation Costs ($)	$3,993
Simple Payback (yrs)	11.11
CO_2e Savings (metric tons/yr)	(0.03)

Assumptions:

- Energy Assessment Calculation Worksheets were used to calculate the energy and cost savings from implementing the measure.
- The total number of T-8 fixtures was estimated to be 42 with 2 lamps per fixture.
- The energy rating of the T-8 fixtures was estimated to be 32 W per lamp.
- The energy rating of the LED fixtures was estimated to be 22 W per lamp.
- The cost of each LED lamp was estimated to be $22 per lamp.
- The labor time associated with installing the LED lamps was estimated to be 30 minutes per lamp.
- A 30% contingency was added to the final cost.

2.8.1.14 Replace the Compact Fluorescent Lamps with Low Wattage LED Lamps

Current Condition: Wall sconces throughout the first floor and second floor corridors contain CFLs.

Investigated Action: LEDs should be installed in all fixtures with CFLs. These retrofits are minimal in labor costs per fixture and lower energy consumption. Table 18 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings; calculation assumptions are also given.

Table 18. Energy and Cost Savings from Replacing CFLs with LEDs

Energy and Cost Savings	
Electricity Savings (kWh/yr)	734
Heating Energy Savings (MMBtu/yr)	(0)
Cost Savings ($/yr)	$104
Implementation Costs ($)	$1,165
Simple Payback (yrs)	11.18
CO_2e Savings (metric tons/yr)	(0.01)

Assumptions:

- Energy Assessment Calculation Worksheets were used to calculate the energy and cost savings from implementing the measure.
- The total number of CFL fixtures was estimated to be 32 with 1 lamp per fixture.
- The energy rating of the CFL fixtures was estimated to be 12 W per lamp.
- The energy rating of the LED fixtures was estimated to be 5 W per lamp.
- The cost of each LED lamp was estimated to be $9 per lamp.
- The labor time associated with installing the LED lamps was estimated to be 20 minutes per lamp.
- A 30% contingency was added to the final cost.

2.8.1.15 Install Lighting Sensors in Bathrooms, Break Room, and Private Offices

Current Condition: The lighting system is currently controlled with a schedule-based operating system that turns on and off all lighting systems in the mornings and evenings. The office spaces, break rooms, and private offices have manual bi-level controls to go along with the lighting control system. It was unclear if the manual switches or bi-level controls were being utilized

Investigated Action: Occupancy sensors installed at the wall switch turn lights on and off based on simple motion, heat, or sound sensing. This hardware is fairly straightforward to install by an electrician and lowers lighting levels on an as-needed basis. Occupancy sensors are common practice in many buildings and do not have large impacts on user experiences. Table 19 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings; calculation assumptions are also given.

Table 19. Energy and Cost Savings from Installing Lighting Sensors

Energy and Cost Savings	
Electricity Savings (kWh/yr)	4,298
Heating Energy Savings (MMBtu/yr)	(2)
Cost Savings ($/yr)	$299
Implementation Costs ($)	$3,359
Simple Payback (yrs)	11.23
CO_2e Savings (metric tons/yr)	(0.06)

Assumptions:

- Energy Assessment Calculation Worksheets were used to calculate the energy and cost savings from implementing the measure.
- The total number of light fixtures impacted was estimated to be 180 with 2 lamps per fixture.
- The average energy rating of all the fixtures was estimated to be 30 W per lamp
- The number of sensors required was estimated to total 16.
- The cost of each occupancy sensor was estimated to be $45 per sensor.
- The labor time associated with installing the lighting sensors was estimated to be 2 hours per sensor.
- A 30% contingency was added to the final cost.

2.8.1.16 Replace the Exterior Parking Lights with Low Wattage LED Replacements

Current Condition: The current parking structure contains eleven HPS lights. These lights are on a daylight sensor to turn them on and off automatically.

Investigated Action: Modern parking light fixtures now come equipped with high efficiency LED lights. Options are also available for solar powered lamps which run completely off a small solar PV panel and battery. Juneau's shortened daylight hours in the winter make solar powered lamps difficult to justify financially. Replacing exterior HPS lamps with new LED parking lamp fixtures is not recommended at this time due to poor economics. Table 20 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings; calculation assumptions are also given.

Table 20. Energy and Cost Savings from Replacing High Pressure Sodium Parking Lights with LED Parking Lights

Energy and Cost Savings	
Electricity Savings (kWh/yr)	6,845
Heating Energy Savings (MMBtu/yr)	0
Cost Savings ($/yr)	$730
Implementation Costs ($)	$8,780
Simple Payback (yrs)	12.03
CO_2e Savings (metric tons/yr)	0.09

Assumptions:

- Energy Assessment Calculation Worksheets were used to calculate the energy and cost savings from implementing the measure.
- The total number of exterior lights fixtures was estimated to be 11 with 1 lamp per fixture.
- The energy rating of the HPS lamps was estimated to be 175 W per lamp.
- The energy rating of the LED lamps was estimated to be 23 W per lamp.
- The cost of each LED fixture was estimated to be $500 per fixture.
- The labor time associated with installing the LED parking fixtures lamps was estimated to be 120 minutes per fixture.
- A 30% contingency was added to the final cost.

2.8.2 Plug Load Measures

The following sections contain the plug load ECMs that were analyzed.

2.8.2.1 Remove Excess Printer and Utilize Network Printer

Current Condition: There are currently two printers in the office, one new ENERGY STAR® rated network printer and one older model printer. The older printer is used for the seasonal employees on an as needed basis. At this time seasonal employees are restricted from use of the networked printer due to their lack of access behind the USFS firewall.

Investigated Action: Remove the older model printer dedicated solely to the seasonal workers. Printers consume energy at all times when plugged into an outlet. The seasonal employees would have to be granted access to print using the networked printer. This will save on the active, suspended, and standby energy consumed by the secondary printer and should have minimal effect on typical normal activities. Table 21 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings; calculation assumptions are also given.

Table 21. Energy and Cost Savings from Removing Excess Printer and Utilizing a Network Printer

Energy and Cost Savings	
Electricity Savings (kWh/yr)	448
Heating Energy Savings (MMBtu/yr)	(0)
Cost Savings ($/yr)	$90
Implementation Costs ($)	$93
Simple Payback (yrs)	1.03
CO_2e Savings (metric tons/yr)	(0.01)

Assumptions:

- Energy Assessment Calculation Worksheets were used to calculate the energy and cost savings from implementing the measure.
- The total number of computers removed from the secondary printer was estimated to be 5.
- The energy rating of the secondary printer's active, suspended, and stand-by modes was estimated to be 80, 30, and 5 W, respectively.
- The percent of the day the secondary printer was in stand-by was estimated to be 95%.
- The labor time associated with adding the new network printer to all seasonal employees' computers was estimated to be 25 minutes per computer.
- A 30% contingency was added to the final cost.

2.8.2.2 Replace Refrigerator with ENERGY STAR Refrigerator

Current Condition: The refrigerator currently located in the break room is an older model with a top-mount freezer without through-the-door ice dispenser. This refrigerator was currently in working condition and is utilized by the staff.

Investigated Action: Replace the current refrigerator unit with an ENERGY STAR rated refrigerator with the same size capacity. Table 22 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings; calculation assumptions are also given.

Table 22. Energy and Cost Savings from Replacing the Existing Refrigerator with an ENERGY STAR Refrigerator

Energy and Cost Savings	
Electricity Savings (kWh/yr)	119
Heating Energy Savings (MMBtu/yr)	(0)
Cost Savings ($/yr)	$8
Implementation Costs ($)	$269
Simple Payback (yrs)	32.46
CO_2e Savings (metric tons/yr)	0.00

At this time, the high-cost of replacing a functioning refrigerator with a new ENERGY STAR rated unit is not cost effective. This ECM should be considered when the currently functioning refrigerator fails or is due for replacement.

Assumptions:

- Energy Assessment Calculation Worksheets were used to calculate the energy and cost savings from implementing the measure.
- The total number of refrigerators due to be replaced were estimated to be 1.
- The volume of the fresh, freezer and total adjusted volume was estimated to be 20, 6, and 26 ft^2.
- The cost of the ENERGY STAR replacement refrigerator was estimated to be $1,500.
- The labor time associated with adding the new refrigerator was estimated to be 1 hour.
- A 30% contingency was added to the final cost.

2.8.3 Water Conservation Measures

The following sections contain the WCMs that were analyzed.

2.8.3.1 Install Waterless Urinals in all Male Restrooms

Current Condition: The current MGVC male restroom facilities contain urinals rated at the federal standard of 1.0 gallons per flush (gpf). There are two urinals in the second floor male restroom. The first floor male restroom urinals were recently replaced from 1.0 gpf urinals to waterless urinals. The reception received from staff and guest regarding this change is positive.

Investigated Action: Replace current urinals in the MGVC second floor restroom with waterless urinals rated at 0.0 gpf. Waterless urinals eliminate water use and reduce sewer costs. Table 23 provides the calculated water and cost savings, simple payback, and CO_2e emissions savings; calculation assumptions are also given.

Table 23. Water and Cost Savings from Replacing the Existing Urinals with Waterless Urinals

Water and Cost Savings	
Water Savings (gal/yr)	62,500
Heating Energy Savings (MMBtu/yr)	0
Cost Savings ($/yr)	$704
Implementation Costs ($)	$1,170
Simple Payback (yrs)	1.67
CO_2e Savings (metric tons/yr)	0.00

Assumptions:

- Energy Assessment Calculation Worksheets were used to calculate the water and cost savings from implementing the measure.
- The total number of urinals due to be replaced was estimated to be 2.
- The current flush rating of the urinals was estimated to be 1.0 gpf.

- The daily user count of the MGVC restrooms was estimated to be 125 males who used the urinals two times per day.
- The annual water consumption due to urinals was estimated to be 62,500 gallons/yr.
- The proposed toilet rating of the waterless urinals was estimated to be 0.0 gpf.
- The cost of the waterless urinals was estimated to be $400 per fixture.
- The operation and maintenance (O&M) cost was estimated to be $40/yr.
- The labor time associated with installing the waterless urinals was estimated to be 1 hour per fixture.
- A 30% contingency was added to the final cost.

2.8.3.2 Install Low-Flow Toilets in all Restrooms

Current Condition: The current restroom facilities contain toilets rated at the federal standard of 1.6 gpf. There are a total of 14 toilets at the facility. The restroom facilities have an incredibly high volume of traffic in the summer time with guests reaching up to 5,000 people per day.

Investigated Action: Replace the current toilets at the facility with low-flush toilets rated at 1.1 gpf. More efficient flushing toilets save water and sewer costs. Table 24 provides the calculated water and cost savings, simple payback, and CO_2e emissions savings; calculation assumptions are also given.

Table 24. Water and Cost Savings from Replacing the Existing Toilets with Low-Flow Toilets

Water and Cost Savings	
Water Savings (gal/yr)	125,000
Heating Energy Savings (MMBtu/yr)	0
Cost Savings ($/yr)	$1,488
Implementation Costs ($)	$8,219
Simple Payback (yrs)	5.53
CO_2e Savings (metric tons/yr)	0.00

Assumptions:

- Energy Assessment Calculation Worksheets were used to calculate the water and cost savings from implementing the measure.
- The total number of toilets due to be replaced was estimated to be 14.
- The current flush rating of the toilets was estimated to be 1.6 gpf.
- The daily user count of the restrooms was estimated to be 250 males and 250 females, where males used the toilets one time per day and females used the toilets three times per day.
- The annual water consumption due to toilets was estimated to be 400,000 gallons/yr.
- The proposed toilet rating of the low-flow toilets was estimated to be 1.1 gpf.
- The cost of the low-flow toilets was estimated to be $400 per fixture.
- The labor time associated with installing the new toilets was estimated to be 1 hour per fixture.
- A 30% contingency was added to the final cost.

2.8.3.3 Install Low-Flow Showerheads in the Office Shower

Current Condition: The current MGVC break room restroom contains one shower with a rating of 3.5 gallons per minute (gpm). This shower was used sparingly by the staff as a place to rinse off gear and occasionally bathe.

Investigated Action: Replace the current showerhead in the MGVC break room restroom and install a low-flow showerhead rated at 2.5 gpm. More efficient showerheads save water and sewer costs. Table 25 provides the calculated water and cost savings, simple payback, and CO_2e emissions savings; calculation assumptions are also given.

Table 25. Water and Cost Savings from Replacing the Existing Showerhead with a Low-Flow Showerhead

Water and Cost Savings	
Water Savings (gal/yr)	1,071
Heating Energy Savings (MMBtu/yr)	1
Cost Savings ($/yr)	$16
Implementation Costs ($)	$99
Simple Payback (yrs)	5.98
CO_2e Savings (metric tons/yr)	0.04

Assumptions:

- Energy Assessment Calculation Worksheets were used to calculate the water and cost savings from implementing the measure.
- The total number of showerheads due to be replaced was estimated to be 1.
- The current flow rating of the showerhead was estimated to be 3.5 gpm.
- The average use per week for the shower head was estimated to be 20 minutes total.
- The annual water consumption due to the showerhead was estimated to be 3,750 gallons/yr.
- The proposed flow rating of the low-flow showerhead was estimated to be 2.5 gpm.
- The cost of the low-flow showerhead was estimated to be $50 per fixture.
- The labor time associated with installing the low-flow showerhead was estimated to be 30 minutes.
- A 30% contingency was added to the final cost.

2.8.3.4 Install Low-Flow Faucets

Current Condition: The current MGVC restrooms utilize faucets with flow rates listed at 0.5 gpm. There were a total of eight faucets found at the MGVC. This flow rate meets federal water standards for faucets.

Investigated Action: Replace the current faucets found in the MGVC restrooms with low-flow faucets rated at 0.35 gpm. More efficient faucets can save water and sewer costs. Table 26 provides the calculated water and cost savings, simple payback, and CO_2e emissions savings; calculation assumptions are also given.

Table 26. Water and Cost Savings from Replacing the Existing Faucets with Low-Flow Faucets

Water and Cost Savings	
Water Savings (gal/yr)	13,125
Heating Energy Savings (MMBtu/yr)	5
Cost Savings ($/yr)	$198
Implementation Costs ($)	$4,193
Simple Payback (yrs)	21.20
CO_2e Savings (metric tons/yr)	0.39

The high cost of an entire faucet unit makes this WCM less desirable financially. However, low-flow faucet aerators could be installed to replace the current 0.5 gpm aerators at much less cost.

Assumptions:

- Energy Assessment Calculation Worksheets were used to calculate the water and cost savings from implementing the measure.
- The total number of faucet due to be replaced was estimated to be 8.
- The current flow rating of the faucets was estimated to be 0.5 gpm.
- The daily user count was estimated to be 300 males and 300 females, where males wash their hands three times per day and females wash their hands four times per day.
- The annual water consumption due to the showerhead was estimated to be 43,750 gallons/yr.
- The proposed flow rating of the low-flow faucet was estimated to be 0.35 gpm.
- The cost of the low-flow showerhead was estimated to be $300 per fixture.
- The labor time associated with installing the low-flow showerhead was estimated to be 120 minutes.
- A 30% contingency was added to the final cost.

2.8.4 Renewable Energy Measures

The following sections contain the RE measures that were analyzed. The measures below are all considered under the assumption that excess electricity produced will not be sold back to the grid under any circumstances. Oftentimes agreements with utilities allow for some sellback of electricity at a negotiated price, generally around the retail price of electricity or half of the consumption rate. However, conversations with MGVC reveal that the utility in question—AEL&P—is not considering buying back excess electricity. The state of Alaska does not have any net-metering policies in place to require the local utility to purchase electricity. If a sellback rate is successfully negotiated, the economics of RE resources could change to make them even more desirable.

The RE sources examined were determined by local renewable resource availability and interest from the client. One of the goals of this assessment was to identify the most cost effective and reliable method for MGVC to qualify as a NZE building or site. A NZE site generates at least as much energy on site as it consumes. The first step to for any potential NZE site should always be pursuing lowest cost ECMs to lower consumption

2.8.4.1 Install 30.1 kW Hydropower Generation on Steep Creek

Current Condition: The MGVC is participating in the USFS's Net Zero Fellows Program with the goal to create sites which produce as much energy on site as they consume. There is zero energy production currently at the MGVC site; however there is an abundant resource in the form of surface water and hydropower potential.

Nugget Creek used to supply local mines with 3 MW of power in the early 1900s. This hydropower generator is no longer in use but the holding reservoir and penstock are still in place and could be reconstructed for new generation. Steep Creek, which runs on the south side of the MGVC, is another potential resource for hydropower. This creek has environmental and wildlife issues that must be considered to minimize impact. Spawning salmon and feeding bears frequent the lower portion of Steep Creek in the summertime and are one of the main attractions of the Mendenhall Glacier. The upper portion of Steep Creek located above the Steep Creek Falls could be utilized for micro-hydropower generation.

Investigated Action: Construct a 30.1 kW micro-hydropower generation on upper Steep Creek. The hydro was sized such that MGVC would qualify as a net zero site. The hydro would generate 265,000 kWh of electricity per year if run at full operating capacity. The sites annual consumption is 256,000 kWh. The 9,000 kWh of electricity from the hydro greater than the site consumption would qualify MGVC as a net zero site. Table 27 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings.

Table 27. Energy and Cost Savings from Installing 30.1 kW Hydropower Generation on Steep Creek

Energy and Cost Savings	
Electricity Savings (kWh/yr)	170,067
Heating Energy Savings (MMBtu/yr)	0
Cost Savings ($/yr)	$16,089
Implementation Costs ($)	$248,000
Simple Payback (yrs)	15.41
CO_2e Savings (metric tons/yr)	3.33
Cost of Energy ($)	$0.0993

The cost of energy for MGVC would be reduced from a blended rate of $0.124/kWh to $0.099/kWh. This analysis assumes an already high installation cost of $8,000 per kW of power. Additional costs may be incurred with any environmental screening and obstacles. An environmental assessment will be required to ensure impacts to spawning salmon and other wildlife in the area will be minimal. A hydropower resource assessment should also be conducted to confirm the available water flow and head available above the Steep Creek Falls. Calculation assumptions are also given

Assumptions:

- HOMER Pro Energy was used to calculate the energy and cost savings from implementing the measure.
- Grid power price is $0.124/kWh with no sellback price.
- Total alternating current (AC) primary load is 256,456 kWh/yr.
- Total available head for the micro-hydro system is 7 m.
- Design flow rate for the micro-hydro system is 600 L/s.
- Minimum and maximum flow ratio for the micro-hydro system is 50% and 150%.
- Lifetime of the micro-hydro system is 50 years.
- Efficiency of the micro-hydro system is 75% with 15% pipe head loss.
- Capital cost of the micro-hydro system is $248,000 ($8,000/kW).
- O&M cost of the micro-hydro system is $5,000/yr (2% of capital cost).

2.8.4.2 Install 30.1 kW Hydropower Generation on Steep Creek and 40 kW of Solar Photovoltaic Generation on the MGVC Rooftop

Current Condition: The MGVC is participating in the USFS's Net Zero Fellows Program with the goal to create sites which produce as much energy on site as they consume. Potential renewable resources include Steep Creek for hydropower and solar PV generation on the MGVC rooftop. A solar assessment was performed on the rooftop during the site visit to determine the feasibility of generating electricity from solar energy at MGVC. It was determined that a 40 kW array could be installed within the rooftop boundaries of the MGVC. There are currently no net-metering policies at this time in Alaska.

Investigated Action: Install a 30.1 kW micro-hydro system and a 40 kW PV roof-mounted PV array on the MGVC. At the assumed costs for the systems—$8,000 per kW of hydro and $3,000 per kW of PV—the combined system would be able to reduce MGVC's cost of energy to a blended rate of $0.118/kWh. The system would produce a total of 297,000 kWh of electricity which results in a surplus of 41,000 kWh. Table 28 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings.

Table 28. Energy and Cost Savings from Installing 30.1 kW Micro-Hydro on Steep Creek with 40 kW of Solar Photovoltaic on the Mendenhall Glacier Visitor Center Roof

Energy and Cost Savings	
Electricity Savings (kWh/yr)	190,617
Heating Energy Savings (MMBtu/yr)	0
Cost Savings ($/yr)	$17,437
Implementation Costs ($)	$368,000
Simple Payback (yrs)	21.10
CO_2e Savings (metric tons/yr)	3.73
Cost of Energy ($)	$0.1180

The cost effectiveness of the combined hydro and PV system is mostly due to the hydro. The current cost and efficiency of PV located in Alaska does not have parity with the utility. The net-metering policy and zero sellback rate make it difficult for PV to compete. A sensitivity analysis was conducted to determine at was install cost and sellback would a combined hydro-PV system be ideal. An optimal system type graph shown in Figure 14 shows the sellback rate for excess electricity plotted on the x-axis and PV capital cost is plotted on the y-axis. The PV capital cost must be nearly equal to $1 per Watt (W) in order for a hydro and PV system to be the optimal system type. Calculation assumptions are also given.

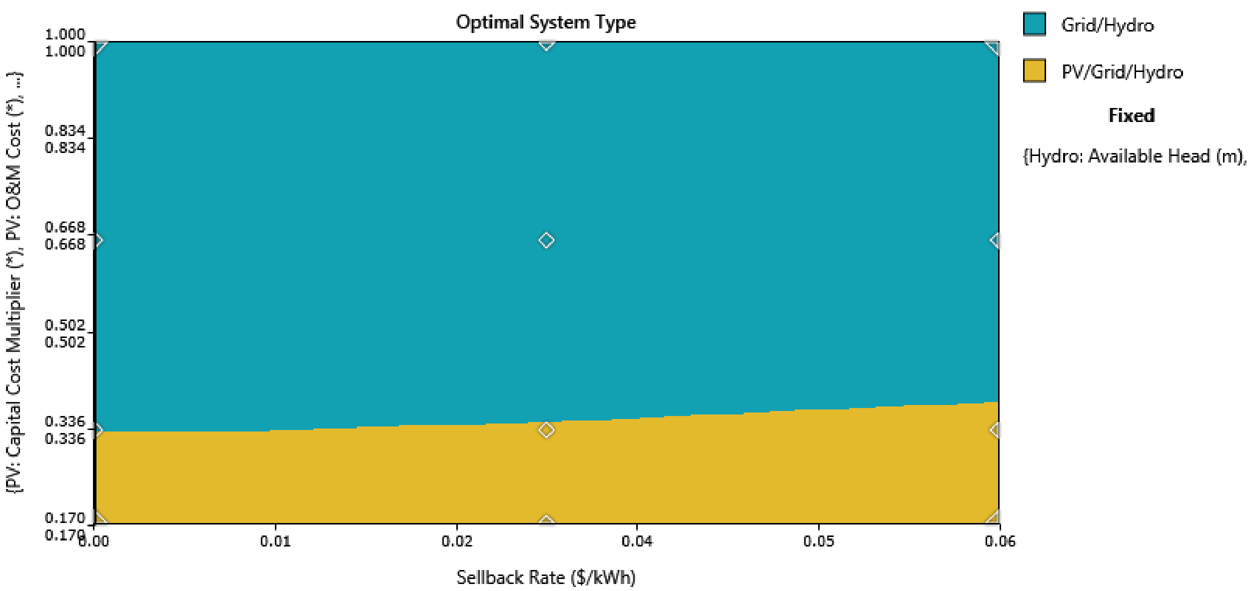

Figure 14. Optimal System Plot of the PV Capital Cost vs. the Sellback Rate (The PV multiplier cost of 1.000 is equal to $3 per Watt)

Source: Optimal System Graph generated by HOMER

Assumptions:

- HOMER Pro Energy was used to calculate the energy and cost savings from implementing the measure.
- Grid power price is $0.124/kWh with no sellback price.
- Total AC primary load is 256,456 kWh/yr.
- Total available head for the micro-hydro system is 7 m.
- Design flow rate for the micro-hydro system is 600 L/s.
- Minimum and maximum flow ratio for the micro-hydro system is 50% and 150%
- Lifetime of the micro-hydro system is 50 years.
- Efficiency of the micro-hydro system is 75% with 15% pipe head loss.
- Capital cost of the micro-hydro system is $248,000 ($5,000/kW).
- O&M cost of the micro-hydro system is $5,000/yr (2% of capital cost).
- Efficiency of the PV is 13%.
- Derating factor of the PV is 75%.
- Lifetime of the PV is 25 years.
- Panel slope of the PV array is 45 degrees.

- Capital cost of the PV is $120,000 ($3/W).
- O&M cost of the PV is $1,200/yr ($30/kW).

2.8.4.3 Install 30.1 kW Hydropower Generation on Steep Creek and 100 kWh of Lithium Ion Battery Storage

Current Condition: The MGVC is participating in the USFS's Net Zero Fellows Program with the goal to create sites which produce as much energy on site as they consume. The upper portion of Steep Creek located above the Steep Creek Falls could be utilized for micro-hydropower generation. A lithium ion battery storage solution was simulated in addition to the hydro.

Investigated Action: Install a 30.1 kW micro-hydro system and a 100 kWh lithium ion battery array at the MGVC. The addition of a battery bank with a hydro resource was unable to reduce the cost of energy from the assumed blended rate of $0.124/kWh. The high costs of battery were cost prohibitive to utilize over the grid connection in the analysis. Table 29 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings.

Table 29. Energy and Cost Savings from Installing 30.1 kW Hydropower Generation on Steep Creek with 100 kWh of Lithium Ion Battery Storage

Energy and Cost Savings	
Electricity Savings (kWh/yr)	170,067
Heating Energy Savings (MMBtu/yr)	0
Cost Savings ($/yr)	$13,224
Implementation Costs ($)	$354,000
Simple Payback (yrs)	26.77
CO_2e Savings (metric tons/yr)	3.33
Cost of Energy ($)	$0.1308

At this time, the high installation costs of batteries are cost prohibitive to use over a grid-tied system. Grid connected systems have the benefit of nearly perfect reliability when the renewable resource cannot meet demand. Figure 15 shows a line graph where the x-axis is the capital cost of the battery installation and the y-axis is the optimal quantity of batteries to install. Battery capital cost is $700 per 1 kWh lithium ion battery such that an installation of a 100 kWh battery bank would cost $70,000. This graph shows that a battery bank would be financially viable at one sixth of their current cost, or $119 per 1 kWh lithium ion battery. Calculation assumptions are also given.

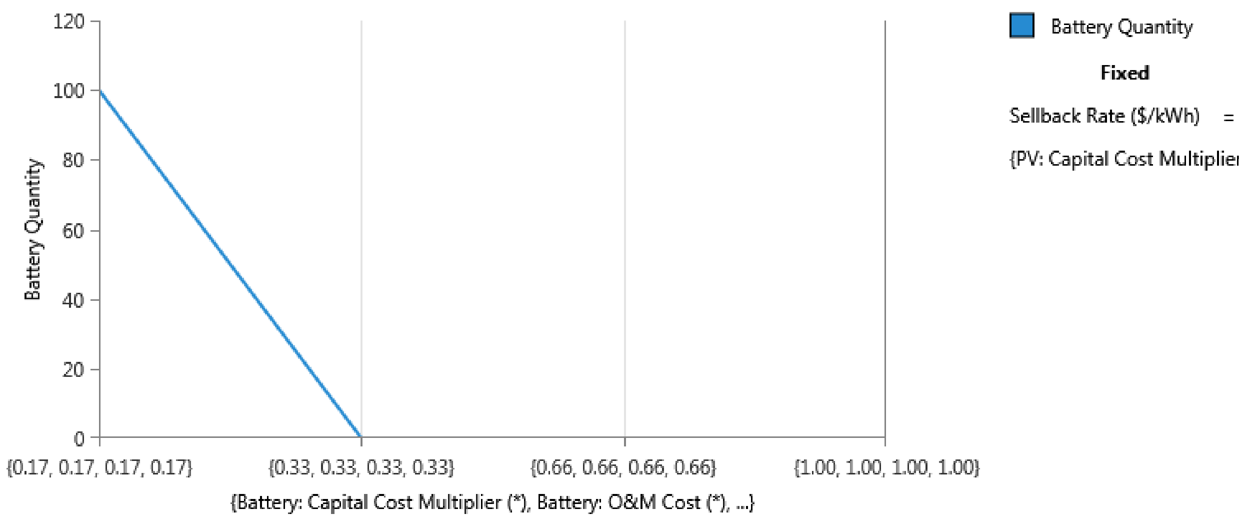

Figure 15. Line Graph of Lithium Ion Battery Quantity vs. the Capital Cost of Batteries (The multiplier cost of 1.00 is equal to $700 per battery)

Source: Line graph generated by HOMER

Assumptions:

- HOMER Pro Energy was used to calculate the energy and cost savings from implementing the measure.
- Grid power price is $0.124/kWh with no sellback price.
- Total AC primary load is 256,456 kWh/yr.
- Total available head for the micro-hydro system is 7 m.
- Design flow rate for the micro-hydro system is 600 L/s.
- Minimum and maximum flow ratio for the micro-hydro system is 50% and 150%.
- Lifetime of the micro-hydro system is 50 years.
- Efficiency of the micro-hydro system is 75% with 15% pipe head loss.
- Capital cost of the micro-hydro system is $248,000 ($5,000/kW).
- O&M cost of the micro-hydro system is $5,000/yr (2% of capital cost).
- A single 1 kWh battery has a nominal voltage of 6 V.
- A single 1 kWh battery has a nominal capacity 166.667 ampere-hours (Ah).
- The batteries have a round trip efficiency of 90%.
- Lifetime throughput of the batteries is 3,000 kWh.
- Capital cost for the batteries is $70,000 ($700/1 kWh battery).
- O&M cost for the batteries is $1,000 ($10/yr/1 kWh battery).

2.8.4.4 Install 30.1 kW Hydropower Generation on Steep Creek, 40 kW of Solar Photovoltaic Generation on the MGVC Rooftop and 100 kWh of Lithium Ion Battery Storage

Current Condition: The MGVC is participating in the USFS's Net Zero Fellows Program with the goal to create sites which produce as much energy on site as they consume. Potential renewable resources include Steep Creek for hydropower and solar PV generation on the MGVC rooftop. The addition of lithium ion battery storage was simulated to see the affects storage has on electricity costs.

Investigated Action: Install a 30.1 kW micro-hydro system, 40 kW PV roof-mounted PV array, and battery storage at the MGVC. This combined system would be unable to lower the cost of energy below the current blended rate of $0.124/kWh. The high installation costs of the PV and battery bank make this configuration financially unattractive. Table 30 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings.

Table 30. Energy and Cost Savings from Installing 30.1 kW Hydropower Generation on Steep Creek with 100 kWh of Lithium Ion Battery Storage

Energy and Cost Savings	
Electricity Savings (kWh/yr)	190,617
Heating Energy Savings (MMBtu/yr)	0
Cost Savings ($/yr)	$14,572
Implementation Costs ($)	$474,000
Simple Payback (yrs)	32.53
CO_2e Savings (metric tons/yr)	3.73
Cost of Energy ($)	$0.1485

A sensitivity analysis was conducted to determine at which capital costs each system configuration would be optimized. Figure 16 shows the optimal system type when all three technologies are compared in all possible configurations. The x-axis shows the battery cost where 1.000 is equal to $700 per 1 kWh battery and the y-axis shows the PV cost where 1.000 equals $3/W of installed capacity. The hydro resource is utilized in every possible scenario. All three of the technologies are utilized only when the PV and battery capital costs are drastically reduced. This is seen in the bottom-left corner where the PV capital cost must be less than $1/W and the battery capital cost must be less than $230 per battery. The battery is utilized in all scenarios where its cost is less than $230 per battery and the PV system is utilized in all scenarios where its cost is less than $1/W. At the current assumed pricing of all three technologies, the most optimal system type includes only the grid and hydro. Calculation assumptions are also given.

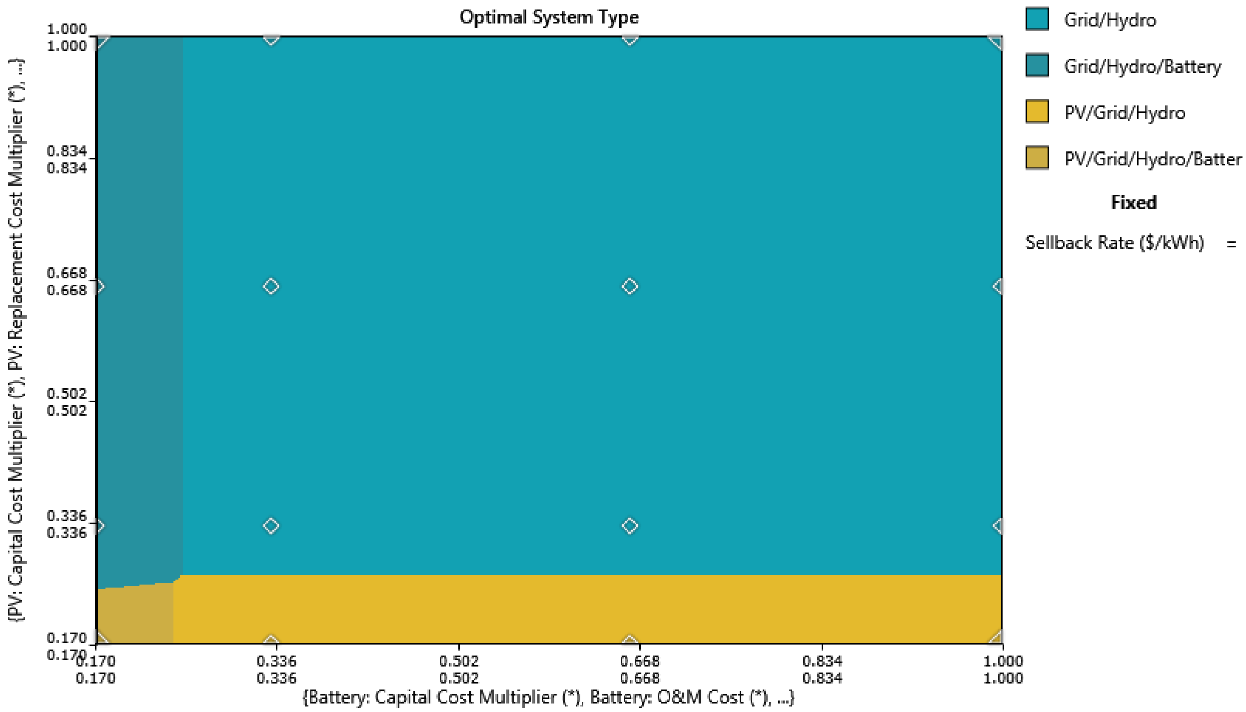

Figure 16. Optimal System Plot of the PV Capital Cost vs. Battery Capital Cost (The PV multiplier cost of 1.000 is equal to $3 per Watt and battery multiplier is equal to $700 per battery)

Source: Optimal System Type generated by HOMER

Assumptions:

- HOMER Pro Energy was used to calculate the energy and cost savings from implementing the measure.
- Grid power price is $0.124/kWh with no sellback price.
- Total AC primary load is 256,456 kWh/yr.
- Total available head for the micro-hydro system is 7 m.
- Design flow rate for the micro-hydro system is 600 L/s.
- Minimum and maximum flow ratio for the micro-hydro system is 50% and 150%.
- Lifetime of the micro-hydro system is 50 years.
- Efficiency of the micro-hydro system is 75% with 15% pipe head loss.
- Capital cost of the micro-hydro system is $248,000 ($5,000/kW).
- O&M cost of the micro-hydro system is $5,000/yr (2% of capital cost).
- Efficiency of the PV is 13%.
- Derating factor of the PV is 75%.
- Lifetime of the PV is 25 years.
- Panel slope of the PV array is 45 degrees.
- Capital cost of the PV is $120,000 ($3/W).
- O&M cost of the PV is $1,200/yr ($30/kW).
- A single 1 kWh battery has a nominal voltage of 6 V.
- A single 1 kWh battery has a nominal capacity 166.667 Ah.

- The batteries have a round trip efficiency of 90%.
- Lifetime throughput of the batteries is 3,000 kWh.
- Capital cost for the batteries is $70,000 ($700 per 1 kWh battery).
- O&M cost for the batteries is $1,000 ($10/yr/1 kWh battery).

2.8.4.5 Install a 40 kW Solar Photovoltaic Generator on the MGVC Rooftop

Current Condition: A solar assessment was performed on the rooftop during the site visit to determine the feasibility of generating electricity from solar energy at MGVC. It was determined that a 40 kW array could be installed within the rooftop boundaries of the MGVC. There are currently no net-metering policies at this time in Alaska.

Investigated Action: Install a 40 kW PV roof-mounted PV array on the MGVC. Installation of this system would increase to the blended cost of energy of the MGVC to $0.149/kWh. Table 31 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings.

Table 31. Energy and Cost Savings from Installing 40 kW Solar Photovoltaic Generation on the Mendenhall Glacier Visitor Center Rooftop

Energy and Cost Savings	
Electricity Savings (kWh/yr)	32,009
Heating Energy Savings (MMBtu/yr)	0
Cost Savings ($/yr)	$2,770
Implementation Costs ($)	$120,000
Simple Payback (yrs)	N/A
CO_2e Savings (metric tons/yr)	0.40
Cost of Energy ($)	$0.1493

Analysis of adding 40 kW of solar PV showed that the solar resource is not great enough to justify the cost of a PV array. The 40 kW PV array was priced at $120,000 or $3/W. Figure 17 shows a line graph where the x-axis is the capital cost of the PV installation and the y-axis is the optimal installed PV capacity. This graph shows that at one third of the PV estimated cost (or $1/W) up to 10 kW of PV would be financially viable. If the PV capital cost lowers to one sixth (or $0.50/W) then more than 80 kW of PV would be financially viable. Calculation assumptions are also given.

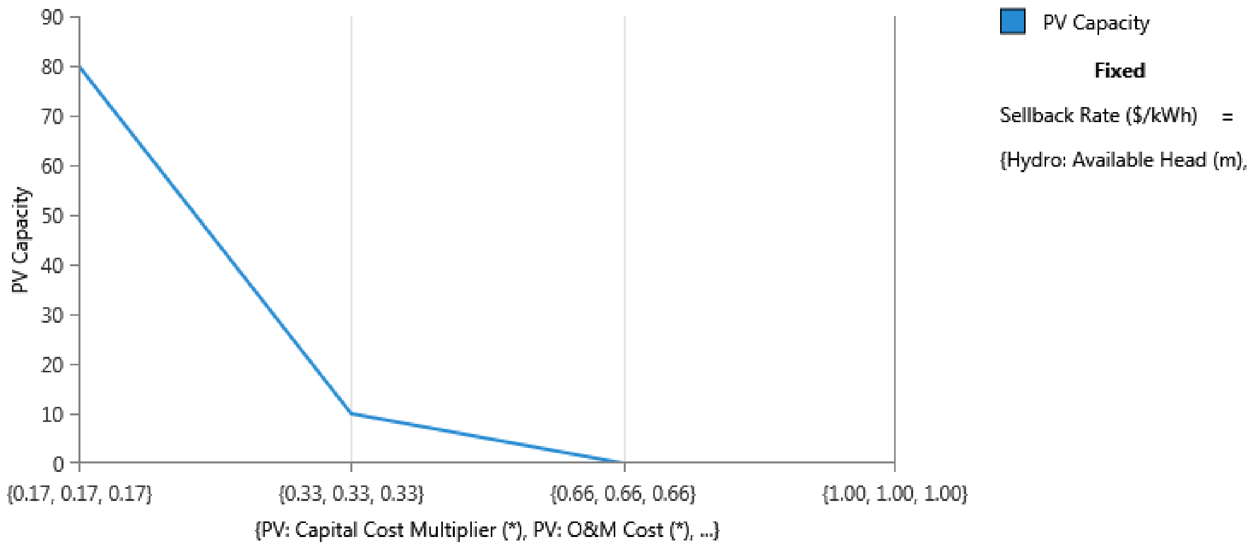

Figure 17. Line Graph of PV Capacity vs. the Capital Cost of PV (The multiplier cost of 1.00 is equal to $3 per Watt)

Source: Line Graph generated by HOMER

Assumptions:

- HOMER Pro Energy was used to calculate the energy and cost savings from implementing the measure.
- Grid power price is $0.124/kWh with no sellback price.
- Total AC primary load is 256,456 kWh/yr.
- Efficiency of the PV is 13%.
- Derating factor of the PV is 75%.
- Lifetime of the PV is 25 years.
- Panel slope of the PV array is 45 degrees.
- Capital cost of the PV is $120,000 ($3/W).
- O&M cost of the PV is $1,200/yr ($30/kW).

2.8.4.6 Install a 40 kW Solar Photovoltaic Generator on the MGVC Rooftop and 100 kWh of Lithium Ion Battery Storage

Current Condition: The MGVC is participating in the USFS's Net Zero Fellows Program with the goal to create sites which produce as much energy on site as they consume. . It was determined that a 40 kW array could be installed within the rooftop boundaries of the MGVC. There are currently no net-metering policies at this time in Alaska. The addition of lithium ion battery storage was simulated to see the affects storage has on electricity costs.

Investigated Action: Install a 40 kW PV roof-mounted PV array and 100 kWh lithium ion battery bank at the MGVC. Table 32 provides the calculated energy and cost savings, simple payback, and CO_2e emissions savings.

Table 32. Energy and Cost Savings from Installing 40 kW Solar Photovoltaic Generation on the Mendenhall Glacier Visitor Center Rooftop

Energy and Cost Savings	
Electricity Savings (kWh/yr)	32,009
Heating Energy Savings (MMBtu/yr)	0
Cost Savings ($/yr)	-$95
Implementation Costs ($)	$226,000
Simple Payback (yrs)	N/A
CO_2e Savings (metric tons/yr)	0.40
Cost of Energy ($)	$0.1925

Analysis of adding a 40 kW of solar PV and 100 kWh of battery storage showed that at this time the solar resources and high battery cost make this an unjustifiable measure. Costs of both technologies would have to be dramatically reduced to make these technologies financially viable. Calculation assumptions are also given.

Assumptions:

- HOMER Pro Energy was used to calculate the energy and cost savings from implementing the measure.
- Grid power price is $0.124/kWh with no sellback price.
- Total AC primary load is 256,456 kWh/yr.
- Efficiency of the PV is 13%.
- Derating factor of the PV is 75%.
- Lifetime of the PV is 25 years.
- Panel slope of the PV array is 45 degrees.
- Capital cost of the PV is $120,000 ($3/W).
- O&M cost of the PV is $1,200/yr ($30/kW).
- A single 1 kWh battery has a nominal voltage of 6 V.
- A single 1 kWh battery has a nominal capacity 166.667 Ah.
- The batteries have a round trip efficiency of 90%.
- Lifetime throughput of the batteries is 3,000 kWh.
- Capital cost for the batteries is $70,000 ($700/1 kWh battery).
- O&M cost for the batteries is $1,000 ($10/yr/1 kWh battery).

3 Conclusions

The staff at the MGVC are very proactive and knowledgeable at conserving energy and water and eager to incorporate RE technologies. The staff currently incorporate many best practices to reduce energy use including appropriate space temperature setpoints, appropriate light levels, turning lights off when not in use, replacing lighting with LED bulbs, installing advanced electrical metering, and having minimal extraneous plug loads. The staff are currently reducing water use and waste generation by installing low-flow faucets and water bottle filling stations and monitoring consumption with advanced water metering. They are also actively pursuing RE technologies in order to participate in the USFS Net-Zero Network program.

The MGVC was built in 1961 and has undergone renovations over time with the last major renovation occurring in 1996. Various upgrades to the building could be made to make the building more sustainable. A total of 18 possible building ECMs, four WCMs, and six REMs were analyzed. A table of the major findings is given in Table 33. Not all measures are recommended at this time due to the relatively long payback periods and these measures are not included in the bundled analysis. A list of the measure not included in the bundled analysis include:

- CAV to VAV
- ENERGY STAR refrigerators
- Low flow faucets
- All REMs except REM 5.1 – Install 30.1 kW of hydropower generation on Steep Creek.

The GSHP is not included in the bundled analysis because you cannot combine the boiler measures with the GSHP system. This is not to say the GSHP is not recommended; it is just not included in the bundled analysis.

Table 33. Summary Table

Measure Type	Number of Measures Investigated	Bundled Installed Cost ($)	Bundled Annual Cost Savings ($/yr)	Bundled Simple Payback (yrs)	Bundled Annual CO_2e Savings (metric tons/yr)
Energy Conservation Measures	18	$339,065	$42,532	8.19	14.18
Water Conservation Measures	4				
Renewable Energy Measures	6				

The audit team found that HVAC measures which could be installed without major renovations or construction included replacing standard V-belts with cogged v-belts and a new BAS with simple programmable thermostats. Incremental replacement of boilers and motors should include condensing boilers, premium efficiency motors, demand control ventilation and stack economizers. Lighting measures to install include immediate replacement of existing lighting with LED equivalent light bulbs and installation of lighting sensors. Toilets and urinals should continue to be replaced with low-flow fixtures where possible. An environmental impact and resource assessment of Steep Creek should be conducted in order to pursue a 30.1 kW micro-hydro installation.

Appendix: Renewable Energy Information

Photovoltaics

Solar PV technology converts energy from solar radiation directly into electricity. Solar PV cells are the electricity-generating component of a solar energy system. When sunlight (photons) strikes a PV cell, an electric current is produced by stimulating electrons (negative charges) in a layer in the cell designed to give up electrons easily. The existing electric field in the solar cell pulls these electrons to another layer. By connecting the cell to an external load, this current (movement of charges) can then be used to power the load, e.g., light bulb.

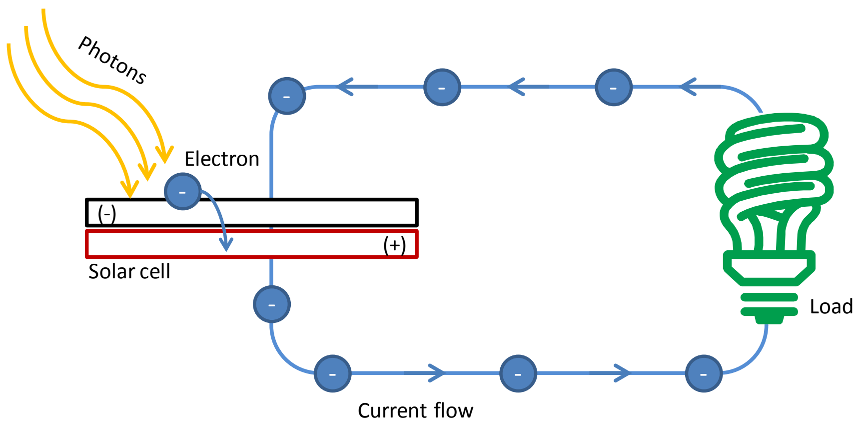

Figure A-1. Generation of Electricity from a PV Cell

Illustration by Jim Leyshon, NREL

PV cells are assembled into a PV panel or module. PV modules are then connected to create an array. The modules are connected in series and then in parallel as needed to reach the specific voltage and current requirements for the array. The direct current electricity generated by the array is then converted by an inverter to useable AC that can be consumed by adjoining buildings and facilities or exported to the electricity grid. PV system size varies from small residential (2kW to 10 kW), commercial (100 kW to 500 kW), to large utility scale (10+ MW). Central distribution plants are also currently being built in the 100 MW+ scale. Electricity from utility-scale systems is commonly sold back to the electricity grid.

A typical PV system is made up of several key components including PV modules, inverters, and balance-of-system components. Figure A-2 shows the major components of a grid-tied PV system.

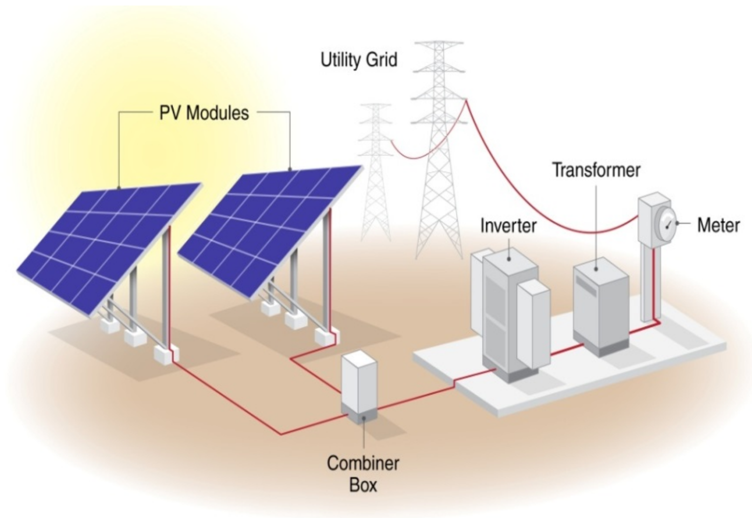

Figure A-2. Ground Mounted PV Array Diagram

Illustration by Jim Leyshon, NREL

Micro-hydro Power

A hydropower system uses the energy in flowing water to convert mechanical energy into electricity. Micro-hydropower systems are small-scale hydropower generators sized between 5 kW to 100 kW of electricity output. There are several methods of harnessing the energy in moving water to produce energy. Most micro-hydro applications utilize run-of-the-river systems; these systems do not require large storage reservoirs. In a run-of-the-river system, a portion of the river is diverted to a channel, pipeline, or penstock, which delivers the water to a turbine to generate electricity. Micro-hydro applications are best suited to smaller communities, small enterprises or single families.

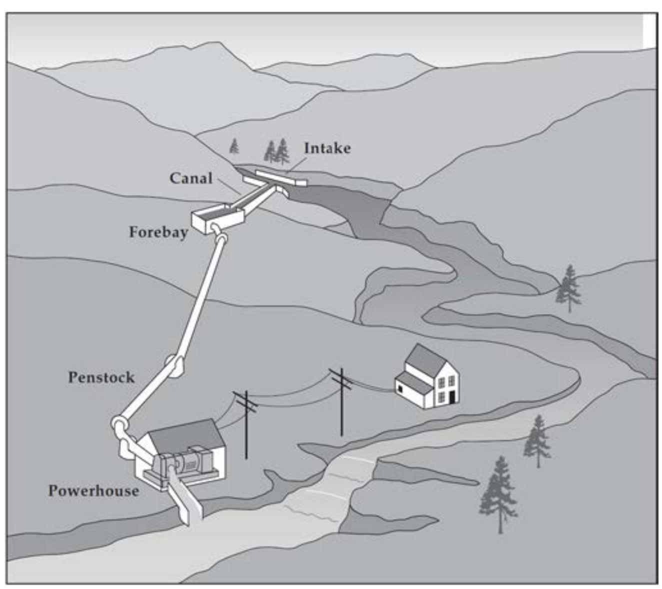

Figure A-3. Illustration of a Micro-hydropower System with Penstock

Source: NREL (http://www.nrel.gov/docs/fy01osti/29065.pdf)

Wind Turbine

Large-scale wind turbines are commonly classified as any wind turbine larger than 100 kW and small-scale wind turbines are classified as less than 100 kW. The wind resource at a site has the largest impact on whether or not a wind project will be feasible. Installing a temporary anemometer and collecting at least a year's worth of wind speed data is highly recommended for large-scale turbines to determine the feasibility of wind. Figure A-1 shows the wind resource in the United States at a hub height of 30 meters. Urban settings are not ideal for wind turbines, as the surrounding buildings would shelter turbines from the wind and cause turbulence. The wind resource at the MGVC is moderate and the visual impact of installing wind turbines at the site would detract from visitor experience and therefore wind turbines are not being considered.

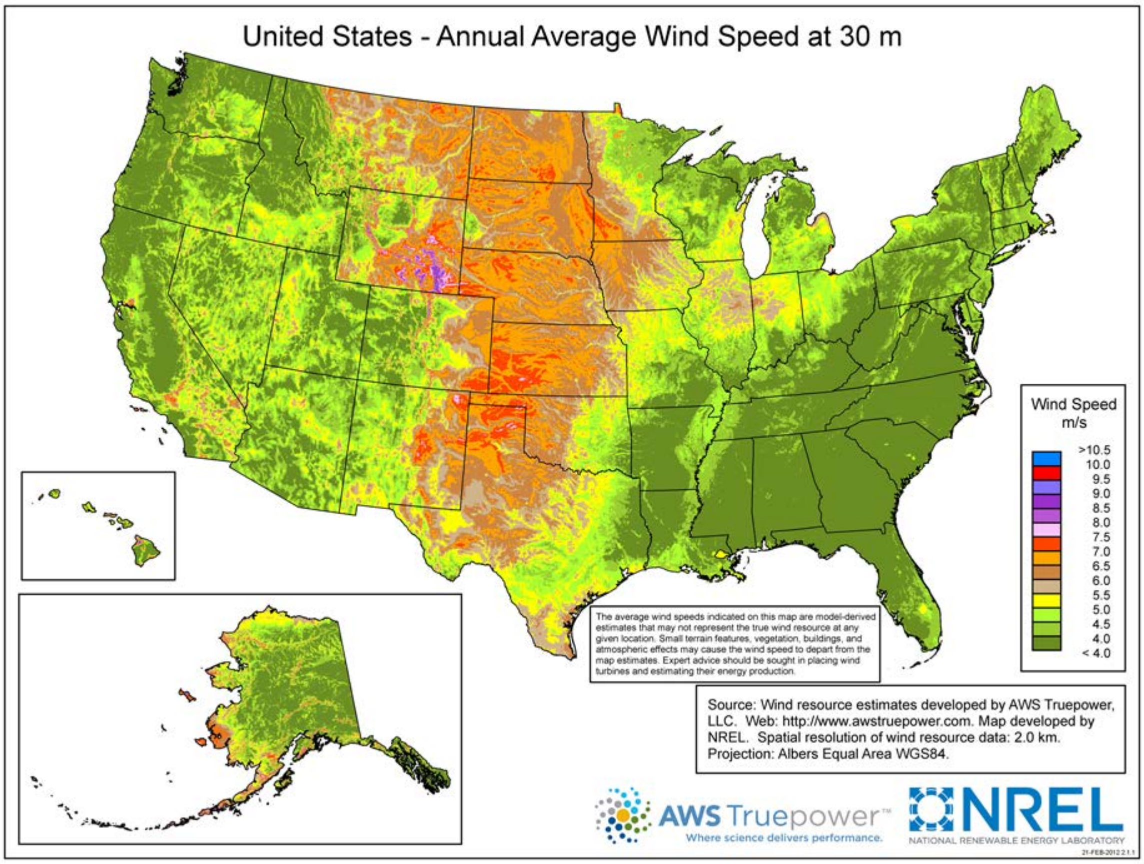

Figure A-4. United States Wind Resource Map at a Height of 30 Meters

Source: NREL (http://www.nrel.gov/gis/images/30m_US_Wind.jpg)

Biomass

Biomass is a RE technology that uses biological material to produce heat and/or electricity. Wood is the largest source of biomass energy but other sources, such as woody plants, grasses, algae, food crops, and landfill gas, are all common sources of biomass. Biomass requires frequent transport of fuel sources to a site, and this can be an issue at sites with high security. There is not a steady source of biomass in the area and therefore biomass is not being considered at the site.

Solar Ventilation Preheat

Solar vent preheat is a RE technology that preheats the incoming ventilation air during the heating season. Figure A-2 shows an example of solar vent preheat panels installed on a building at the NREL campus. The solar vent preheat system is made up of dark perforated panels installed on façades with good solar exposure. The solar vent preheat panels are installed with an air space between the panels and the wall, and this air is heated when the conditions permit. A relatively small horsepower fan circulates the preheated air to the ventilation system during the heating season, which offsets the need to heat the ventilation air with traditional heat sources. The solar vent preheat panels are bypassed during the cooling season. Solar vent preheat is relatively difficult to implement on existing buildings and it also changes the aesthetics of a building. There is also a relatively low solar resource in Juneau, Alaska, and for these reasons, solar vent preheat is not being considered.

Figure A-5. Example of Solar Vent Preheat

Photo by Pat Corkery, NREL 17424

Solar Hot Water System

Figure A-3 shows a typical configuration for a solar hot water (SHW) system. A SHW system was not considered for the MGVC because the building has a relatively small hot water load, the relatively low solar resource, and the nature of the water heating system in the building did not offer a convenient location in which to tie in a SHW systems.

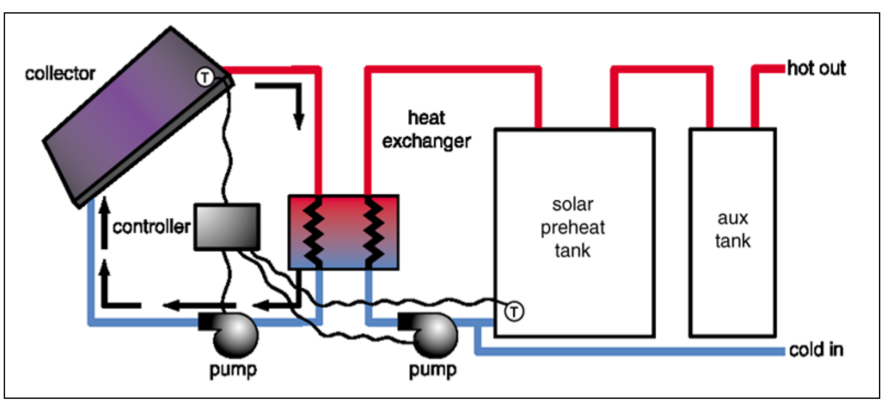

Figure A-6. Typical Solar Hot Water System Configuration

Illustration by Jim Leyshon, NREL