Energy Efficiency, Water Efficiency, and Renewable Energy Site Assessment

San Juan National Forest – Dolores Ranger District, Colorado

Kosol Kiatreungwattana and Alicen Kandt

Produced under direction of the U.S. Forest Service by the National Renewable Energy Laboratory (NREL).

**NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC**

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Strategic Partnership Project Report
NREL/TP-7A40-70561
January 2018

Contract No. DE-AC36-08GO28308

Energy Efficiency, Water Efficiency, and Renewable Energy Site Assessment

San Juan National Forest – Dolores Ranger District, Colorado

Kosol Kiatreungwattana and Alicen Kandt

Suggested Citation

Kiatreungwattana, Kosol, and Alicen Kandt. 2018. *Energy Efficiency, Water Efficiency, and Renewable Energy Site Assessment: San Juan National Forest - Dolores Ranger District, Colorado*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-70561. <https://www.nrel.gov/docs/fy18osti/70561.pdf>.

**NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC**

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

Strategic Partnership Project Report
NREL/TP-7A40-70561
January 2018

Contract No. DE-AC36-08GO28308

NOTICE

This manuscript has been authored by employees of the Alliance for Sustainable Energy, LLC (“Alliance”) under Contract No. DE-AC36-08GO28308 with the U.S. Department of Energy (“DOE”).

This report was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

Cover photo by Kosol Kiatreungwattana, NREL

NREL prints on paper that contains recycled content.

Preface

As part of ongoing efforts by the U.S. Forest Service to reduce energy use and incorporate renewable energy technologies into its facilities, the Department of Energy's National Renewable Energy Laboratory performed an energy efficiency, water efficiency, and renewable energy site assessment of the Dolores Public Lands Office, warehouse and bunkhouse in the San Juan National Forest in Colorado. This report documents the findings of this assessment, and provides site-specific information for the implementation of energy and water conservation measures, and renewable energy measures.

Contacts

United States Forest Service

Ryan Halonen
Engineer
San Juan National Forest
Phone: 970-385-1217
rharonen@fs.fed.us

Michele Parker
Operations Specialist
Office of Sustainability & Climate Change
Phone: 907-518-1079
mmparker@fs.fed.us

National Renewable Energy Laboratory

Alicen Kandt^{1,2}
Project Leader, Senior Engineer
Phone: 303-384-7518
Email: alicen.kandt@nrel.gov

Kosol Kiatreungwattana, PE, CEM, LEED AP^{1,2}
Senior Engineer
Phone: 303-384-7918
Email: kosol.kiatreungwattana@nrel.gov

¹ Members of the site assessment team

² Report authors to whom any questions should be directed

Acknowledgments

The National Renewable Energy Laboratory team thanks the United States Forest Service (USFS) for the opportunity to perform this energy efficiency and renewable energy assessment of the Dolores Ranger District Office, warehouse and bunkhouse in the San Juan National Forest in Colorado. In particular, the assessment team is grateful to Ryan Halonen, Bryce Paul, Rene Farias, and Kathryn Garrou for their generous assistance and cooperation throughout the site assessment.

List of Abbreviations and Acronyms

AC	alternating current
AHU	air-handling unit
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAS	building automation system
BF	ballast factor
Btu	British thermal unit
CAV	constant air volume
CFL	compact fluorescent lighting
cfm	cubic feet per minute
CHW	chilled water
CO ₂	carbon dioxide
CO ₂ e	carbon dioxide equivalent
Cx	commissioning
DC	direct current
DCV	demand control ventilation
DDC	direct digital control
DHW	domestic hot water
DOE	U.S. Department of Energy
EA	excess air
EE	energy efficiency
ECM	energy conservation measure
EISA	Energy Independence and Security Act
EO	executive order
EPAct	Energy Policy Act
EPDM	ethylene propylene diene monomer
ESPC	energy savings performance contract
EUI	energy use intensity
FEMP	Federal Energy Management Program
ft ²	square foot
FY	fiscal year
GHG	greenhouse gas emissions
gpf	gallon per flush
gpm	gallon per minute
HID	high-intensity discharge
hp	horsepower
HVAC	heating, ventilation, and air conditioning
ITC	investment tax credit
kBtu	1,000 British thermal units
kW	kilowatt
kWh	kilowatt-hour
LED	light-emitting diode
LEED	Leadership in Energy and Environmental Design
LPD	lighting power density
M&V	measurement and verification

MMBtu	1,000,000 British thermal units
MAU	makeup air unit
MWh	megawatt-hour
NEMA	National Electrical Manufacturers Association
NREL	National Renewable Energy Laboratory
O&M	operation and maintenance
OA	outdoor air
PLC	programmable logic controller
PV	photovoltaic
ppm	parts per million
RE	renewable energy
REM	renewable energy measure
RH	relative humidity
SHW	solar hot water
Ta	ambient temperature
UL	Underwriters Laboratory
USDA	United States Department of Agriculture
USFS	United States Forest Service
VAV	variable air volume
VFD	variable frequency drive
W	watt
WCM	water conservation measure
WE	water efficiency
yr	year

Executive Summary

This report summarizes the results from an energy efficiency, water efficiency, and renewable energy site assessment of the Dolores Ranger District in the San Juan National Forest in Colorado. A team led by the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) conducted the assessment with United States Forest Service (USFS) personnel on August 16-17, 2016, as part of ongoing efforts by USFS to reduce energy and water use and implement renewable energy technologies.

The audit team visited three buildings within the Dolores Ranger District: Dolores Visitor Center and offices (referred to as Administration Office in this report), Warehouse, and Bunkhouse. The staff at the Dolores Ranger District is very proactive and knowledgeable at conserving energy and water and is eager to incorporate renewable energy technologies. Some facilities currently incorporate many best practices to reduce energy use including efficient interior lighting, occupancy sensors in the office areas, regular operations and maintenance, and engaged management. The staff also actively puts effort into energy conservation and is pursuing renewable energy technologies.

For each building, the audit team conducted a site assessment to identify energy conservation measures, water conservation measures, and renewable energy measures. Details of the analysis and calculations can be found in each site section. Not all measures were recommended at this time due to the relatively long payback periods (over 15 years) and these measures were not included in the bundled analysis. Annual electricity use, after the cost effective measures are incorporated, was estimated. Then, a photovoltaic (PV) system was sized with the goal of providing sufficient electricity to make the facility net-zero electric. It should be noted that, for the climate, a 1,612 kWh electricity reduction from energy efficiency can reduce 1kW of PV capacity needed. The Administration Office and Warehouse can reach net-zero electricity after implementing recommended energy efficiency measures and a 32-kW PV system.

The majority of water consumption was for domestic use. The facilities use minimal domestic water for their landscape. The Administration Office has a xeriscape landscape with perennials and shrubs at the front area and around the building. The water conservation measure of low flow restroom fixtures was not cost effective.

Table ES-1 summarizes the quantified energy savings by the financially viable individual energy conservation measures and the renewable energy measures, which again is assumed to be measures with a simple payback of 15 years or less. Water savings from a water conservation measure is presented in Table ES-2.

Table ES-1. Energy and Cost Savings of Energy Conservation Measures

Energy Conservation Measures	Annual Electricity Savings (kWh/yr)	Annual Natural Gas Savings* (Therms/yr)	Annual Cost Savings (\$/yr)	Installed Costs (\$)	Simple Payback Period (yrs)	Percent Electricity Reduction
Programmable thermostat	9,882	2,707	2,468	624	0.3	8.9%
Testing, adjusting, and balancing	11,253	3,488	3,017	24,040	8.0	10.1%
VAV Retrofit	13,467	(52)	1,455	6,240	4.3	12.1%
Indirect-Direct Evaporative Cooler	17,560	(209)	1,825	31,200	17.1	15.8%
Condensing Water heater*	-	278	142	975	6.9	0.0%
Low wattage T8 fluorescent*	8,357	(28)	905	520	0.6	7.4%
T-12 to LED at Warehouse	4,904	n/a	539	3,998	7.4	4.4%
LED Exterior Lighting at Warehouse	3,863	n/a	425	683	1.6	3.5%
Daylighting	9,124	(16)	995	2,184	2.2	8.2%
Energy Star refrigerators	1,924	n/a	212	1,560	7.4	1.7%
Windows sealing	105	410	221	1,956	8.9	0.1%
Combined ECMs (under 15 years payback)	62,879	6,787	10,378	42,779	4.1	56.5%
32 kW Solar PV system	51,624	n/a	5,885	\$96,000	16.3	46.4%
Combined EE and PV	114,503	6,787	16,263	\$138,779	8.5	103%

* incremental cost was considered; replace units at the end of life

Table ES-2. Water and Cost Savings of Water Conservation Measures

Water Conservation Measures	Annual Water Savings (gal/yr)	Annual Cost Savings (\$/yr)	Installed Costs (\$)	Simple Payback Period (yrs)
Low-flow Urinals and Toilets	20,570	216	6,240	28.9

Commissioning

The assessment team strongly recommends that recommended measures from this report are commissioned when implemented. Commissioning (Cx) is a quality control process that can be integrated with the installation of new systems. Cx 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 Cx in all of the cost and payback data presented in this report. The assessment team recommends that any hired Cx 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 (IMPVP) 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.

Sustainable Operation Options

All USFS sites are required to pursue sustainability initiatives as outlined in Element 10 of the Climate Change Performance Scorecard. Other sustainable operation options include sustainable purchasing, minimizing waste, recycling programs, composting programs, transportation efficiency programs, and energy awareness campaigns.

Table of Contents

Preface	i
Contacts	ii
Acknowledgments	iii
List of Abbreviations and Acronyms	iv
Executive Summary	vi
Commissioning	vii
Measurement and Verification	vii
Sustainable Operation Options	viii
Table of Contents	ix
List of Tables	x
List of Figures	xi
Background	1
Project Background and Intent	1
EPA Act 2005	1
EISA 2007	2
EO 13693	2
Other Mandates	3
Introduction	4
Site Overview	4
Administration Office and Warehouse	4
Climate Data	13
Incentives	15
Building Energy Modeling	15
Energy Conservation, Water Conservation, and Renewable Energy Measures	17
HVAC Measures	17
Indirect-Direct Evaporative Cooler	20
Lighting Measures	22
Plug Loads Measures	28
Envelope Measures	29
Water Conservation Measures	31
Renewable Energy Measures	31
Bunkhouse	34
Energy Conservation, Water Conservation, and Renewable Energy Measures	36
Appendix A: Renewable Energy Information	37
Photovoltaics	37

List of Tables

Table 1. Administration Office and Warehouse - Annual Electricity, Natural Gas, and Water Use.....	11
Table 2. Durango, Colorado Historic Weather Summary.....	14
Table 3. Administration Office - Energy and Cost Savings from Temperature Setback.....	17
Table 4. Administration Office - Energy and Cost Savings from TAB.....	18
Table 5. Administration Office - Energy and Cost Savings from Replacing VFDs.....	19
Table 6. Administration Office - Energy and Cost Savings from Add-on Indirect-direct Evaporative Cooler	20
Table 7. Administration Office - Energy and Cost Savings from Condensing Water Heater	22
Table 8. Administration Office - Energy and Cost Savings from Low-wattage T8 Fluorescent Lamps	22
Table 9. Warehouse - Energy and Cost Savings from Linear LED Lamps	25
Table 10. Warehouse- Energy and Cost Savings from LED Exterior Lighting	26
Table 11. Administration Office- Energy and Cost Savings from Daylighting.....	28
Table 12. Administration Office - Energy and Cost Savings from Energy Star Refrigerator	29
Table 13. Administration Office - Energy and Cost Savings from Window Seals	30
Table 14. Administration Office - Water and Cost Savings of Low-flow Urinals and Toilets	31
Table 15. Predicted Solar Output from Ground-Mounted PV System	33
Table 16. Bunkhouse - Annual Electricity, and Natural Gas.....	34

List of Figures

Figure 1. Aerial view of Dolores Ranger District Office.....	4
Figure 2. Administration Office, Warehouse and Bunkhouse.....	4
Figure 3. Administration Office – Interior Lights	5
Figure 4. Warehouse – Shop Interior Lights.....	6
Figure 5. Parking Lots Lights	6
Figure 6. Administration Office – Appliances in Breakroom.....	7
Figure 7. Snow Sensor of Snow-melting System	8
Figure 8. Control System of Snow-melting System	8
Figure 9. Administration Office – HVAC units	9
Figure 10. Administration Office – VFD Drive	9
Figure 11. Administration Office – HVAC Controls.....	10
Figure 12. Administration Office and Warehouse - Monthly Electricity Consumption for 2014 to 2016	12
Figure 13. Administration Office and Warehouse - Monthly Natural Gas Consumption for 2014 to 2016	12
Figure 14. Administration Office and Warehouse - Monthly Water Consumption for 2014 to 2016...	13
Figure 15. Administration and Warehouse - eQUEST model representation.....	16
Figure 16. Administration and Warehouse - eQUEST Baseline End-use Energy.....	16
Figure 17. Damper between Plenums	18
Figure 18. Non-working Variable Frequency Drive.....	19
Figure 19. Administration Office - Water Heater.....	21
Figure 20. Linear lamps: Fluorescent versus LED	24
Figure 21. Warehouse – Interior Lighting	25
Figure 22. Warehouse exterior lights.....	26
Figure 23. Potential Daylighting in the Perimeter Areas	27
Figure 24. Administration Office - Refrigerators	28
Figure 25. Administration Office - Window seals.....	30
Figure 26. Available Ground Area for PV System.....	32
Figure 27. Estimated PV production from PVWatts	33
Figure 28. Bunkhouse - Monthly Electricity Consumption for 2014 to 2016	35
Figure 29. Bunkhouse - Monthly Natural Gas Consumption for 2014 to 2016.....	35
Figure A-1. Generation of Electricity from a PV Cell.....	37
Figure A-2. Roof Mounted PV Array Diagram.....	38

Background

The United States Forest Service (USFS), acting in compliance with Executive Order 13693, is pursuing the implementation of energy conservation measures (ECM), water conservation measures (WCM), and renewable energy measures (REM). Along with the pursuit of energy goals within the EO 13693, the USFS is strongly considering pursuing Net Zero Energy (NZE), Leadership in Energy and Environmental Design (LEED), and Green Globes status to showcase their commitment to sustainability and environmental stewardship. The inclusion of the investigated ECMs, WCMs, and REMs would move the Dolores Ranger District closer to obtaining these goals, accruing LEED points and being labelled a high performance and sustainable building (HPSB).

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 efficiency (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 by USFS to identify and assess the feasibility of incorporating sustainable opportunities within the Dolores Ranger District in the San Juan National Forest, including:

- Optimizing the energy performance of the buildings
- Assessing the potential for water efficiency measures and improvements in the overall environmental quality of the building
- Investigating an option of on-site renewable energy technologies to reach net zero energy.

Project Background and Intent

USFS chose to conduct this assessment as a means of identifying energy and water conservation measures and renewable energy 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 as well as aid in striving towards net-zero energy. Conservation measures implemented from performance contractors should be sub-metered 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: EPCA 2005, Energy Independence and Security Act (EISA) (2007), EO 13693 (2015), and other mandates.

EPCA 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.

EISA 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.

EO 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 Therms 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(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.

Other Mandates

- [EPA 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 (CO₂-e) per year must report their emissions by March 31, 2011, for 2010 emissions. Reports submitted annually thereafter.

Introduction

This report summarizes the results from the EE, WE, and RE site assessment of the Dolores Ranger District in Dolores, Colorado. A team led by NREL conducted the assessment on August 16-17, 2016. The energy assessment was conducted on these three facilities: Administration Office, Warehouse, and Bunkhouse.

Site Overview

Administration Office and Warehouse

The Dolores Ranger District is located at 29211 Highway 184, Dolores, Colorado. The Dolores Ranger District is responsible for land and resource management for multiple uses including recreation, wildlife, fish, water, and wilderness. Figure 1 shows the aerial view of the facilities in Google Earth and Figure 2 shows photos of the Administration Office, Warehouse and Bunkhouse.

Figure 1. Aerial view of Dolores Ranger District Office

Source: Google Map

Figure 2. Administration Office, Warehouse and Bunkhouse

Photos by Kosol Kiatreungwattana, NREL

The Administration Office and Warehouse remain open year-round. There are approximately 55 occupants. The operating hours are Monday through Friday from 7:00 a.m. to 5:00 p.m., closed on weekends.

The Administration Office and Warehouse were built in 2005 and have one level above grade. The office and warehouse area are approximately 18,500 sf and 7,900 sf, respectively. The Administration Office and Warehouse were built at the same year. Therefore it is assumed that they have similar building construction. The building construction has a steel framed structure with R-19 fiberglass batt insulation and a stucco wall on top. Some walls are 6.5-inch structural insulated panels. Roof is an asphalt shingle roof with R-38 insulation in the attic. Windows have a clear double-pane glazing with aluminum frame.

Most interior lights in the Administration Office are indirect-direct fixtures with T-8 fluorescent lamps. The interior lighting is controlled by wall switches. Lights in the mail and copy room are controlled by occupancy sensors. There are several LED recessed lights. Figure 3 shows a photo of the interior lights in the Administration Office.

Figure 3. Administration Office – Interior Lights

Photo by Kosol Kiatreungwattana, NREL

Lighting in shop area in the Warehouse is comprised of fixtures with two T-12 fluorescent lamps. Exterior and parking lots lights are LED fixtures. Figure 4 and Figure 5 show a photo of the interior lights in the Warehouse and the parking lots.

Figure 4. Warehouse – Shop Interior Lights
Photo by Kosol Kiatreungwattana, NREL

Figure 5. Parking Lots Lights
Photo by Kosol Kiatreungwattana, NREL

The plug loads in the Administration Office consist of office equipment including laptop computers with docking stations, desktop computers, LCD/LED monitors, multi-function printers, fax machine, secondary printers, visual and audio displays, and LCD/LED televisions. There is a breakroom that contains a water boiler, refrigerator, toaster, and microwave as shown in Figure 6.

Figure 6. Administration Office – Appliances in Breakroom
Photo by Kosol Kiatreungwattana, NREL

The building has an electric- resistant, snow-melting system on the roof on the north side. This system was controlled through snow sensors that detect outside conditions. However, the assessment team found that the systems were turned on in the summer and were not properly controlled. Figure 7 and Figure 8 show the sensors and control panels of the snow-melting systems.

Figure 7. Snow Sensor of Snow-melting System
Photo by Kosol Kiatreungwattana, NREL

Figure 8. Control System of Snow-melting System
Photo by Kosol Kiatreungwattana, NREL

The Administration Office is served by two heating, ventilating and air-conditioning (HVAC) systems. They are constant air volume. One unit was upgraded with a variable frequency drive (VFD) but it was not working. It appeared that moisture had gotten into the HVAC unit and the breaker kept tripping off. Figure 10 shows the HVAC unit with a non-working variable frequency drive. The building automation system is a simple system from Schneider Electric as shown in Figure 11. The cooling and heating setpoints were set at 72°F and 70°F, respectively. There was no temperature setback during unoccupied times.

Figure 9. Administration Office – HVAC units
Photo by Kosol Kiatreungwattana, NREL

Figure 10. Administration Office – VFD Drive
Photo by Kosol Kiatreungwattana, NREL

Figure 11. Administration Office – HVAC Controls
Photo by Kosol Kiatreungwattana, NREL

The electricity provider for the Dolores Ranger District is Empire Electric Association. The natural gas provider is Atmos Energy. The Montezuma Water Company provides water for the site. The average annual utility consumption and costs are summarized in Table 1.

Table 1. Administration Office and Warehouse - Annual Electricity, Natural Gas, and Water Use

Average: 2014 to 2016		
Electricity	Annual Use	111,320
	<i>(kWh/year)</i>	
	Blended Rate	\$0.11
	<i>(\$/kWh)</i>	
Natural Gas	Annual Use	9,000
	<i>(Therm/year)</i>	
	Rate	\$0.51
	<i>(\$/Therm)</i>	
Water	Annual Use	475
	<i>(1,000 gallons/year)</i>	
	Rate	10.4
	<i>(\$/1,000gallon)</i>	
	Annual Cost	\$4,926
	<i>(\$/year)</i>	

The monthly electricity consumption for the Administration Office and Warehouse for 2014 through 2016 is given in Figure 12. Figure 13 shows the monthly natural gas consumption for 2014-2016, and Figure 14 shows the monthly water consumption for that same time period. The majority of water consumption was for restroom and domestic use. The facilities use minimal domestic water for their landscape. The Administration Office has a xeriscape landscape with perennials and shrubs at the front area and around the building.

Figure 12. Administration Office and Warehouse - Monthly Electricity Consumption for 2014 to 2016

Figure 13. Administration Office and Warehouse - Monthly Natural Gas Consumption for 2014 to 2016

Figure 14. Administration Office and Warehouse - Monthly Water Consumption for 2014 to 2016

Climate Data

The Dolores Ranger District is at an elevation of approximately 7,000 feet above sea level and located in the southwestern corner of Colorado. Dolores has moderate temperatures year-round. With a typical summer temperature of around 85°F, Dolores is at its warmest during the month of July. It is coldest in January, when temperatures can reach as low as 10°F. Because of Dolores's altitude, temperature variations between night and day can be quite drastic, sometimes hitting a 34-degree swing during the summer months and 24 degrees during winter. Table 2 gives a historic weather summary for Dolores, Colorado.

Table 2. Durango, Colorado Historic Weather Summary

Average Temperature														Years on Record: 97
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
F	46.3	26.8	30.3	37.2	42.9	53	61.7	67.5	65	58	48.1	37.5	28	
Average High Temperature														Years on Record: 97
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
F	61.7	41.3	43.5	50.9	57	69.2	79.6	84.1	81.4	74.8	64.3	52.6	41.7	
Average Low Temperature														Years on Record: 97
	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
F	30.9	11.7	17.1	23.5	28.9	36.6	43.8	50.8	48.6	41.3	31.9	22.5	14.4	
Average Precipitation														Years on Record: 97
in	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
	18.6	1.6	1.5	1.9	1.6	1.2	0.7	1.4	1.9	1.7	1.8	1.6	1.6	
Average Number of Days With Precipitation														Years on Record: 97
Days	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
	79	7	7	8	6	6	3	8	9	7	6	6	6	
Highest Recorded Temperature														Years on Record: 97
F	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
	99	80	65	77	76	84	95	99	92	88	82	71	60	
Lowest Recorded Temperature														Years on Record: 97
F	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
	-21	-20	-21	-9	5	16	21	38	34	19	4	-4	-19	
Average Length of Day														Years on Record: 30
Hours	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
	12.6	10.4	11.3	12.4	13.7	14.7	15.2	14.9	14	12.8	11.6	10.6	10.1	
Average Number of Days Above 90F/32C														Years on Record: 97
Days	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
	4.9	—	—	—	—	—	1.6	2.8	0.4	—	—	—	—	
Average Number of Days Below 32F/0C														Years on Record: 97
Days	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
	189.9	30	27.6	27.1	20.6	6.8	0.6	—	—	2.7	16.2	27.8	30.4	
Average Snowfall														Years on Record: 97
in	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
	65.2	15.4	13.2	10.6	4.6	0.8	—	—	—	—	1.5	7.2	11.9	
Average Number of Days With Snow														Years on Record: 30
Days	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
	32.7	6.6	6	5.4	2.9	0.4	—	—	—	—	1.1	4.4	5.9	

Source: Weatherbase. Accessed December, 2016: <http://www.weatherbase.com>

Incentives

The USFS does not pay taxes so it cannot take advantage of the 30% investment tax credit (ITC) or Modified Accelerated Cost Recovery System (MACRS).¹ USFS could investigate partnering with a tax paying entity if it is interested in these tax credits. Under an Energy Savings Performance Contract (ESPC), ESPC-ENABLE², Utility Energy Savings Contract (UESC), or Power Purchase Agreement (PPA) a third-party developer (who can capture tax-based incentives) finances, owns, and maintains the EE and/or RE system. The USFS would purchase the energy from the developer rather than owning the systems, and no upfront investment would be required from the USFS.

Building Energy Modeling

Building energy modeling was used to determine the energy use characteristics of the two buildings – the Administration Office and the Warehouse – and to calculate energy and energy cost savings from various ECMs. 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, lighting and plug load 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, internal loads, operating schedules, lighting, plug load, 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.

The existing operating condition of HVAC, lighting, and plug loads systems was modeled including current operating schedules and 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 15. The geometry of the buildings was simplified for modeling purposes to accurately simulate energy transfer through all surfaces in the building.

¹ <http://programs.dsireusa.org/system/program/detail/676>

² The ESPC-ENABLE program offered through FEMP provides small federal facilities with a standardized, streamlined process to install targeted energy conservation measures and solar PV systems in 6 months or less.

Figure 15. Administration and Warehouse - eQUEST model representation

Source: Image generated using eQUEST

The baseline energy model for the Administration and Warehouse buildings was calibrated to within 5% of the annual existing average electricity and natural gas consumption. Figure 16 presents the predicted monthly energy use and end-use energy from calibrated baseline.

Figure 16. Administration and Warehouse - eQUEST Baseline End-use Energy

Source: Figures generated using eQUEST

Energy Conservation, Water Conservation, and Renewable Energy Measures

The following sections contain the HVAC, lighting, plug load, envelope, WCMs, and REMs that were analyzed for the Administration Office. Cost estimates were based on the RS MEANS (2014) and NREL cost database.

HVAC Measures

The following sections contain the HVAC ECMs that were analyzed.

Temperature setbacks

Current Condition: Temperature setpoints of all thermostats in the Administration Office were set at constant at most times. There were no temperature setbacks during unoccupied hours and weekends.

Investigated Action: Implement temperature setbacks during unoccupied hours and weekends. Table 3 provides the calculated energy and cost savings and simple payback for implementing this measure. Calculation assumptions are also given below.

Table 3. Administration Office - Energy and Cost Savings from Temperature Setback

Energy and Cost Savings	
Electricity Savings (kWh/yr)	9,882
Natural Gas Savings (Therms/yr)	2,707
Cost Savings (\$/yr)	\$2,468
Implementation Costs (\$)	\$624
Simple Payback (yrs)	0.3

Assumptions:

- The eQUEST energy model was used to calculate the energy and cost savings from implementing the measure.
- Temperature setpoints were set at 72 °F for cooling and 69 °F for heating
- Implement the temperature setbacks of 82 °F for cooling and 64 °F for heating during off-hours (6 p.m. to 7 am next day) and weekends.
- Labor costs were estimated at 1 hours per thermostat x \$120/hour, which totals \$480.
- A 30% contingency was added to the overall cost.

HVAC Testing, Adjusting, and Balancing

Current Condition: The HVAC was rebalanced in 2014. The air in the plenum is transferred through dampers between areas. Figure 17 shows the damper in the plenum. However, the assessment team observed the breakroom area was severely depressurized. Depressurization in a building is commonly caused by imbalanced ventilation air, return air and exhaust air. Building occupants also reported that they are often uncomfortable (i.e. too hot or cold) in many areas throughout the building. Air circulation in some areas was insufficient.

Figure 17. Damper between Plenums

Investigated Action: To improve occupant comfort, testing, adjusting, and balancing (TAB) should be completed for the building. TAB involves measuring and analyzing the various flows of air, and ensuring that distribution of heating and cooling throughout the building meets the required specifications as intended in the design. Table 4 provides the calculated energy and cost savings and simple payback for this measure. Calculation assumptions are also given below.

Table 4. Administration Office - Energy and Cost Savings from TAB

Energy and Cost Savings	
Electricity Savings (kWh/yr)	11,253
Natural Gas Savings (Therms/yr)	3,488
Cost Savings (\$/yr)	\$3,017
Implementation Costs (\$)	\$24,040
Simple Payback (yrs)	8.0

Assumptions:

- The eQUEST energy model was used to calculate the energy and cost savings from implementing the measure.
- The cost is assumed to be \$1 per square-foot and the building is 18,492 square-feet, for a total cost of \$18,492.
- A 30% contingency was added to the implementation cost.

Constant Air Volume to Variable Air Volume System

Current Condition: Currently, there is a variable air volume (VAV) system at the Administration Office. The assessment team observed that the variable frequency drive (VFD) as shown in Figure 18 was recently installed but not working properly and needed a replacement. The fan never ramped down. Therefore, the system has been operating as a constant air volume (CAV) system.

Figure 18. Non-working Variable Frequency Drive

Investigated Action: Replace the VFD. Table 5 provides the calculated energy and cost savings, and simple payback for replacing the VFD. Calculation assumptions are also given below.

Table 5. Administration Office - Energy and Cost Savings from Replacing VFDs

Energy and Cost Savings	
Electricity Savings (kWh/yr)	13,467
Natural Gas Savings (Therm/yr)	(-52)
Cost Savings (\$/yr)	\$1,455
Implementation Costs (\$)	\$6,240
Simple Payback (years)	4.3

Assumptions:

- The eQUEST energy model was used to calculate the energy and cost savings from implementing the measure.
- The cost of VFDs for the AHUs is \$2,800.
- The labor cost associated with installing the VAV boxes was estimated to be \$500 per zone, totaling \$2,000 for all 4 VAV boxes.
- A 30% contingency was added to the final cost.

Indirect-Direct Evaporative Cooler

Current Condition: Currently, there is a direct expansion (DX) HVAC system at the Administration Office. Alternatively, an indirect-direct evaporative cooler could be used for cooling. Evaporative cooling works well in the Colorado climate. It could save significant cooling energy.

Investigated Action: Retrofit the DX unit with add-on indirect-direct evaporative cooling. Table 6 provides the calculated energy and cost savings, and simple payback for an add-on evaporative cooler. Calculation assumptions are also given below.

Table 6. Administration Office - Energy and Cost Savings from Add-on Indirect-direct Evaporative Cooler

Energy and Cost Savings	
Electricity Savings (kWh/yr)	17,560
Natural Gas Savings (Therm/yr)	(-209)
Cost Savings (\$/yr)	\$1,825
Implementation Costs (\$)	\$31,200
Simple Payback (years)	17.1

Assumptions:

- The eQUEST energy model was used to calculate the energy and cost savings from implementing the measure.
- The installed cost of the indirect-direct evaporative cooler is estimated at \$750 per ton of cooling, which assuming 32 tons of cooling, approximately totals at \$24,000. Please note that this cost was assumed that the retrofit kit is available by the manufacturer.
- A 30% contingency was added to the final cost.

Condensing Water Heater

Consider using a high efficient condensing water heater in place of a standard efficiency water heater at the end of life.

Current Condition: Domestic hot water was provided by a 40-gallon standard efficiency natural gas hot water heater as shown in Figure 19.

Figure 19. Administration Office - Water Heater

Investigated Action: Replace the standard efficiency (80%) natural gas water heater with a high efficient (93%) condensing water heater. Table 7 provides the calculated energy and cost savings and simple payback for this measure. Calculation assumptions are also given below.

Table 7. Administration Office - Energy and Cost Savings from Condensing Water Heater

Energy and Cost Savings	
Electricity Savings (kWh/yr)	n/a
Natural Gas Savings (Therm/yr)	278
Cost Savings (\$/yr)	\$142
Implementation Costs (\$)	\$975
Simple Payback (years)	6.9

Assumptions:

- The eQUEST energy model was used to calculate the energy and cost savings from implementing the measure.
- The existing water heater is recommended to be replaced with the condensing water heater at the end of life. The incremental cost of the condensing water heater is used for this calculation and estimated at \$750.
- A 30% contingency was added to the final cost.

Lighting Measures

The following sections contain the lighting ECMs that were analyzed.

Low Wattage T-8 Fluorescent Lamps

Current Condition: The interior lighting system includes linear fluorescent T-8, 32 Watt, 2-lamp fixtures with electronic ballasts. The estimated runtime of these is approximately 2,600 hours per year, based on the schedule of occupants.

Investigated Action: Retrofit all of the standard T-8 lamps with low wattage T-8 lamps during a regular replacement cycle or as they fail. The low-wattage T-8 lamps should be specified at 28 W with a color temperature of 4,100 Kelvin or matching the existing. When lamps are replaced incrementally, there is no additional labor cost and only a small incremental cost for the purchase of low-wattage lamps. Table 8 provides the calculated energy and cost savings and simple payback for this measure. Calculation assumptions are also given below.

Table 8. Administration Office - Energy and Cost Savings from Low-wattage T8 Fluorescent Lamps

Energy and Cost Savings	
Electricity Savings (kWh/yr)	8,357
Natural Gas Savings (Therms/yr)	(-28)
Cost Savings (\$/yr)	\$905
Implementation Costs (\$)	\$520
Simple Payback (years)	0.6

Assumptions:

- The eQuest energy model was used to estimate the savings from implementing this measure.
- No additional labor costs were included for incremental replacement.
- Incremental lamp costs were estimated at \$1/lamp for 400 lamps.
- Energy savings take into account interactions with the heating and cooling system
- A 30% contingency was added to the overall cost.

It should be noted that the assessment team investigated the option of using linear light-emitting diode (LED) lamps. The LED retrofit for T8 fluorescent fixture are not cost-effective for this case. In addition, there are also some potential concerns with linear LED such as power, output, electrical, distribution, color, and efficacy. DOE has conducted investigations on linear LED lamps. Figure 20 shows a comparison between linear fluorescent and LED lamps. In the future, as the technology matures, LED retrofits may be appropriate for this application.

LINEAR LAMPS

Fluorescent versus LED

Troffer luminaires typically use either T12 (1.5" diameter) or T8 (1" diameter) linear fluorescent lamps. All fluorescent lamps require a ballast, which can be magnetic or electronic.

Typical 4' T8 fluorescent lamps are nominally rated at 25 to 32 W, although the actual power draw will depend on the electronic ballast driving it, which draws a few additional watts. T12 lamps can consume up to 40 W, plus a few ballast watts.

Typically, 28 W T8 fluorescent lamps are rated to emit about 2,700 lumens, with the final output multiplied by the ballast factor (BF), a characteristic of the ballast that can range from about 0.70 to 1.2. 32 W T8 lamps are nominally rated at around 3,000 lumens.

Including ballast losses, T8 fluorescent lamps typically deliver between 80 and 100 lm/W, with T12 lamps slightly lower. Total luminaire efficacy is typically between 50% and 90% of lamp efficacy.

One of the key characteristics of fluorescent lamps is that they emit light equally in all directions around the major axis of the lamp; that is, they are omnidirectional. Luminaires are designed to redirect the omnidirectional emission, but they do so at different efficiency levels.

For new projects, most high-efficiency linear fluorescent lamps will have a CRI in the 80s and a nominal CCT of 3000 K, 3500 K, 4000 K, or 5000 K, although products are available with a range of attributes.

Fluorescent lamps can be operated in instant-start sockets (shunted), or rapid-start sockets (unshunted), depending on the design of the installed ballast. Unshunted sockets can be wired to be shunted or unshunted.

Traditionally, linear fluorescent lamps have rated lifetimes of around 20,000 to 40,000 hours. However, some new lamps have rated lifetimes in excess of 80,000 hours. Typically, ballasts have an expected lifetime of around 50,000 to 60,000 hours.

General

Linear LED lamps often have a similar form factor to T8 fluorescent lamps, but usually about half of the volume is dedicated to thermal management and/or an integral driver (others have an external drive). Some lamps can operate on an existing ballast, but others require rewiring.

Power

The input power for linear LED lamps can vary substantially. The Series 21 lamps ranged from 11.5 to 28.6 W, including the driver. In some cases, linear LED lamps may draw more power than the fluorescent lamp they are intended to replace.

Output

The Series 21 linear LED lamps emitted between 1,300 and 3,200 lumens, with all but one lamp emitting less than 2,400 lumens. The mean was 1,790 lumens, which is slightly below what is typically necessary to deliver illuminance equivalent to 28 W fluorescent (0.87 BF).

Efficacy

Most of the tested LED lamps were between 80 and 115 lm/W, with one product at 143 lm/W. Thus, few offered substantial energy-efficiency advantages. However, in some luminaires the LED lamps produced higher luminaire efficiencies than the fluorescent benchmark.

Distribution

None of the CALIPER-tested LED lamps were omnidirectional, or even close, with beam angles between 105° and 120° for lamps with a clear lens and between 126° and 160° degrees for lamps with a diffuse lens. Directional emission may increase the efficiency of some luminaires.

Color

The Series 21 LED lamps had CRIs between 68 and 90, and CCTs between 3000 K and 6000 K. Given the variety, it is important to understand what is necessary or desired for a given space.

Electrical

There are at least seven electrical configurations for linear LED lamps, based on the need for shunted sockets, unshunted sockets, or no sockets at all, and the need for an internal or remote driver. This necessitates careful specification, and may limit future interchangeability.

Life

Most of the Series 21 linear LED lamps had a rated lifetime of 50,000 hours, with some as low as 35,000 hours and others as high as 72,000 hours. Few manufacturers noted how this value was derived.

Figure 20. Linear lamps: Fluorescent versus LED

Source: ssl.energy.gov

Replace T-12 to Linear LED Lamps at Warehouse Shop

Current Condition: The warehouse shop lighting system includes linear fluorescent T-12, 40 Watt, 2-lamp with magnetic ballasts. The estimated runtime of these is approximately 2,600 hours per year, based on the schedule of occupants. Figure 21 shows the linear fluorescent T-12 in the warehouse shop.

Figure 21. Warehouse – Interior Lighting

Investigated Action: Retrofit all of the T-12 lamps with linear LED lamps. The linear LED lamps should be with a color temperature of 4,100 Kelvin or matching the existing. Table 8 provides the calculated energy and cost savings and simple payback for this measure. Calculation assumptions are also given below.

It should be noted that the LED retrofit for T8 fluorescent fixture was not recommended on the previous measure. However, the LED retrofit for T12 fluorescent fixture were found to be cost effective for this situation due to the long runtime of the fixtures. The measure should be carefully implemented of the potential concerns with linear LED such as power, output, electrical, distribution, color, and efficacy as stated in Figure 20.

Table 9. Warehouse - Energy and Cost Savings from Linear LED Lamps

Energy and Cost Savings	
Electricity Savings (kWh/yr)	4,904
Natural Gas Savings (Therms/yr)	n/a
Cost Savings (\$/yr)	\$539
Implementation Costs (\$)	\$3,998
Simple Payback (years)	7.4

Assumptions:

- The NREL spreadsheet tool was used to estimate the savings from implementing this measure.
- Fixture retrofit costs were estimated at \$50/fixture for 41 fixtures, which totals \$2,050.

- Labor costs were estimated at 0.5 hour per fixture at \$50/hour, which totals \$1,025.
- A 30% contingency was added to the overall cost.

LED Exterior Lighting at Warehouse

Current Condition: The exterior lighting around the building is 75W halogen bulbs. The runtime is estimated to be 12 hours/day, 7 days/week, for a total of 4,380 hours/year.

Figure 22. Warehouse exterior lights

Investigated Action: Retrofit the halogen lamps with LED lighting. LED outdoor lighting systems can provide similar characteristics to the current lighting system while using significantly less energy, and with much longer lifespans. LED lamps with similar lumen output to a 75W halogen lamp use only 12W. Table 10 provides the calculated energy and cost savings and simple payback for this measure. Calculation assumptions are given below.

Table 10. Warehouse- Energy and Cost Savings from LED Exterior Lighting

Energy and Cost Savings	
Electricity Savings (kWh/yr)	3,863
Natural Gas Savings (Therms/yr)	n/a
Cost Savings (\$/yr)	\$425
Implementation Costs (\$)	\$683
Simple Payback (years)	1.6

Assumptions:

- Engineering calculations were used to estimate the savings from implementing this measure.
- Replace 14 x 75W lamps with 12W LED.
- The runtime was assumed at 4,380 hours per year.
- 12W LED lamp cost was estimated at \$25/lamp × 14 lamps totaling \$350.
- Labor rate was assumed at \$50/hr and labor time per lamp was 15 minutes/fixture, totaling \$175.
- A 30% contingency was added to the overall cost.

Daylighting Controls

Current Condition: The perimeter spaces of the Administration Office do not have daylighting controls. There were windows along the north and south perimeter walls that have good daylighting access.

Figure 23. Potential Daylighting in the Perimeter Areas

Investigated Action: Daylighting control systems dim or shut off lights when there is sufficient natural light available using photocells, dimmable ballasts, and logic controllers. It is very important that any daylighting system is professionally commissioned after installation and that it is properly and regularly maintained thereafter.

The energy and cost savings for installing perimeter on-off daylighting controls are given below along with the calculation assumptions and simple payback. Table 11 provides the calculated energy and cost savings and simple payback for this measure. Calculation assumptions are also given below.

Table 11. Administration Office- Energy and Cost Savings from Daylighting

Energy and Cost Savings	
Electricity Savings (kWh/yr)	9,124
Natural Gas Savings (Therms/yr)	(-16)
Cost Savings (\$/yr)	\$995
Implementation Costs (\$)	\$2,184
Simple Payback (years)	2.2

Assumptions:

- The eQUEST energy model was used to calculate the energy and cost savings for installing perimeter continuous day lighting controls.
- Labor costs are assumed to be \$200 per photocell, which totals \$1,200.
- A total of approximately 6 photocells are needed at an installed cost of \$80 per photocell, which totals \$480.
- A 30% contingency was added to the overall cost.

Plug Loads Measures

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

Energy Star Refrigerator

Current Condition: The two existing refrigerators were approximately 10 years old. Current refrigerators use much less energy than older models.

Figure 24. Administration Office - Refrigerators

Investigated Action: Replace the existing refrigerators with Energy Star refrigerators. Table 12 provides the calculated energy and cost savings and simple payback. Calculation assumptions are also given below.

Table 12. Administration Office - Energy and Cost Savings from Energy Star Refrigerator

Energy and Cost Savings	
Electricity Savings (kWh/yr)	1,924
Natural Gas Savings (Therms/yr)	n/a
Cost Savings (\$/yr)	\$212
Implementation Costs (\$)	\$1,560
Simple Payback (years)	7.4

Assumptions:

- Energy Star Calculator (www.energystar.gov/index.cfm?fuseaction=refrig.calculator) was used to calculate the energy and cost savings from implementing this measure.
- Estimated size of the refrigerator was 16.5-18.9 cubic feet with a top freezer.
- The cost of the refrigerators was estimated at \$1,200 total.
- A 30% contingency was added to the overall cost.

Envelope Measures

In general, envelop improvements can be very expensive to implement. They also give low energy cost savings that results in non-economic viable options. As one of the project goals was to reach net-zero energy, this section was to investigate a potential envelope ECMs and their economic value.

Window sealing

Current Condition: Existing window seals were in fair condition. Figure 25 shows an example of some of the cracks around windows.

Figure 25. Administration Office - Window seals

Investigated Action: Replace the existing window seals, and caulk all joints between the frame and the wall. Table 13 provides the calculated energy and cost savings and simple payback. Calculation assumptions are also given below.

Table 13. Administration Office - Energy and Cost Savings from Window Seals

Energy and Cost Savings	
Electricity Savings (kWh/yr)	105
Natural Gas Savings (Therms/yr)	410
Cost Savings (\$/yr)	\$221
Implementation Costs (\$)	\$1,956
Simple Payback (years)	8.9

Assumptions:

- The eQUEST energy models were used to calculate the energy and cost savings from implementing this measure.
- It was assumed that window seals and caulking reduce infiltration by 50%

- Window seals and caulking cost was assumed at \$10 per window for 43 windows, total of \$430.
- Labor rate was assumed at \$50/hr and labor time per window was 0.5 hour/window, total of \$1,075.
- A 30% contingency was added to the overall cost.

Water Conservation Measures

The following sections contain the water conservation measures that were analyzed.

Low-Flow Urinals and Toilet

Current Condition: The assessment team observed two standard efficiency urinals with a rating of 1 gallon/flush (gpf) and 6 standard efficiency toilets with 1.6 gallons per flush during the site visit.

Investigated Action: Replace the current urinals and toilets with low water consumption urinals (0.2 gallon/flush) and toilets (1.1 gallon/flush). Table 14 provides the calculated water and cost savings and simple payback. Calculation assumptions are also given below.

Table 14. Administration Office - Water and Cost Savings of Low-flow Urinals and Toilets

Water and Cost Savings	
Water Savings (gal/yr)	20,570
Cost Savings (\$/yr)	\$216
Implementation Costs (\$)	\$6,240
Simple Payback (years)	28.9

Assumptions:

- Energy Assessment Calculation Worksheets were used to calculate the water and cost savings from implementing the measure
- There were two urinals and six toilets
- The cost of a low-flow urinal and low-flow toilet was estimated to be \$400 per fixture
- Water rate was at approximately \$10.5 per 1,000 gallons.
- The labor time associated with installing the new urinals and toilets was estimated to be 4 hours per fixture at \$50/hr.
- A 30% contingency was added to the final cost.

Renewable Energy Measures

The following section contains the renewable energy (RE) measures that were analyzed. Solar photovoltaic (PV) systems were the only RE measures analyzed for the Dolores Ranger District Office.

Ground-Mounted Photovoltaic System

Current Condition: There are ample available south-facing, unshaded land areas that could host PV systems. These areas are located to the southwest of the Administration Office, to the south of the warehouse, and to the northwest of the main entrance.

Investigated Action: A ground mounted solar PV system of approximately 32 kW was sized to make the Administration and Warehouse buildings net-zero electricity on an annual basis. Any one of the three ground areas in Figure 26 would be able to accommodate the 32 kW PV capacity. This PV capacity and combined energy efficiency measures (under 15 years payback) would reduce electricity by 100%. Table 15 provides the calculated energy and cost savings and simple payback. Calculation assumptions are also given below.

Figure 26. Available Ground Area for PV System

Source: Google Earth Pro

Table 15. Predicted Solar Output from Ground-Mounted PV System

Estimated Energy and Cost Savings	
Direct Current Nameplate Capacity (kW)	32
Orientation	180° (south)
Tilt	20° fixed
Estimated Electricity Production (kWh/yr)	51,624
Estimated Cost Savings (\$/yr)	\$5,885
Installed Cost	\$96,000
Simple Payback (yr)	16.3 years

Assumptions:

- PVWatts software was used to model the PV. Results are shown in Figure 27.
- The orientation was assumed at 180° which for the area in the middle of the site (west of the entrance) is ideal. The other areas have less ideal of orientation and require a larger PV capacity to get the same electricity production.
- The assumed total installed cost was \$3.0/Watt; no incentives are included.
- System loss of 14% was used.

Figure 27. Estimated PV production from PVWatts

Bunkhouse

The assessment team was not able to access the building during the visit due the fact that the house was locked and the employee with a key could not be reached.

The Bunkhouse was built in 2005 and has one level above grade. The Bunkhouse area is approximately 2,300 sf. The building has a steel framed structure with R-19 fiberglass batt insulation and a stucco wall on top. Some walls are 6.5-inch structural insulated panels. Roof is an asphalt shingle roof with R-38 insulation in the attic. Windows are a clear double-pane glazing with aluminum frame.

There are approximately 10 occupants in the Bunkhouse. The operating hours are 24/7, but the number of employees varies seasonally.

Most interior lights in the Bunkhouse are recessed fixtures with T-8 fluorescent lamps. The interior lighting is controlled by wall switches. The plug loads in the Bunkhouse consist of a toaster, three washers and dryers, four refrigerators, and a microwave.

The electricity provider for the Bunkhouse is Empire Electric Association, the natural gas provider is Atmos Energy, and the Montezuma Water Company provides water for the site. The average annual utility consumption and costs for the Bunkhouse are summarized in Table 16.

Table 16. Bunkhouse - Annual Electricity, and Natural Gas

Average – 2014 to 2016		
Electricity	Annual Use	
	(kWh/year)	9,883
	Blended Rate	
	(\$/kWh)	\$0.17
Natural Gas	Annual Cost	
	(\$/year)	\$1,734
	Annual Use	
	(Therm/year)	989
	Rate	
	(\$/gallon)	\$0.71
	Annual Cost	
	(\$/year)	\$707

The monthly electricity consumption for the Bunkhouse for 2014 through 2016 is given in Figure 28. Figure 29 shows the monthly natural gas consumption.

Figure 28. Bunkhouse - Monthly Electricity Consumption for 2014 to 2016

Figure 29. Bunkhouse - Monthly Natural Gas Consumption for 2014 to 2016

Bunkhouse- Energy Conservation, Water Conservation, and Renewable Energy Measures

The audit team could not access the bunkhouse due to the fact the bunkhouse was locked and the employees who had the key could not be reached. However, the team identified ECMs for HVAC, lighting, plug loads, envelope, and WCMs for the bunk house. No engineering calculations of the energy conservation measures were performed since detailed data on the existing systems could not be collected.

Envelope

- Weather stripping for windows
- Wall, roof insulation and window upgrade

Plug Loads

- Energy Star appliances
- Consolidate and reduce number of refrigerators, washers, and dryers

Lighting

- Replace any incandescent with compact fluorescent or LED lamps

HVAC

- High SEER air conditioning units
- Reduce the water heater from two to one unit.

Renewable Energy

- Solar PV system on the roof

Appendix A: 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 (DC) electricity generated by the array is then converted by an inverter to useable alternating current (AC) that can be consumed by adjoining buildings and facilities or exported to the electricity grid. PV system size varies from small residential (2-10 kilowatts (kW)), commercial (100-500 kW), to large utility scale (10+ megawatts (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 below shows the major components of a grid-tied PV system.

Figure A-2. Roof Mounted PV Array Diagram

Source: NREL