Comprehensive Energy Audit
For

Manokotak Main Water Treatment Plant

Prepared For
City of Manokotak

March 5, 2018

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PREFACE

This energy audit was conducted using funds provided by the Denali Commission. Coordination with the City of Manokotak has been undertaken to provide maximum accuracy in identifying facilities to audit and coordinating potential follow up retrofit activities.

The Rural Energy Initiative at the Alaska Native Tribal Health Consortium (ANTHC) prepared this document for the City of Manokotak, Alaska. The author of this report is Kevin Ulrich, Assistant Engineering Project Manager and Certified Energy Manager (CEM).

The purpose of this report is to provide a comprehensive document of the findings and analysis that resulted from an energy audit conducted in January of 2018 by the Rural Energy Initiative of ANTHC. This report analyzes historical energy use and identifies costs and savings of recommended energy conservation measures. Discussions of site-specific concerns, non-recommended measures, and an energy conservation action plan are also included in this report.

ACKNOWLEDGMENTS

The ANTHC Rural Energy Initiative gratefully acknowledges the assistance of Water Treatment Plant Lead Operator Rueben Andrew; Water Treatment Plant Operators Howard Ayojiak and Ray Alecnanalook; City Maintenance Garrick Bartman; City Administrator Nancy George, and City Mayor Melvin Andrew.

1. EXECUTIVE SUMMARY

This report was prepared for the City of Manokotak. The scope of the audit focused on Manokotak Main Water Treatment Plant. The scope of this report is a comprehensive energy study, which included an analysis of building shell, interior and exterior lighting systems, heating systems, and electric loads.

Based on electricity and fuel oil prices in effect at the time of the audit, the total predicted energy costs for the Manokotak Main Water Treatment Plant is approximately $22,736 per year. Electricity represents the largest portion with an annual cost of approximately $20,284. This includes $11,433 paid by the City and $8,851 paid for by the State of Alaska Power Cost Equalization (PCE) program. Fuel oil represents the remaining energy use with an annual cost of approximately $2,452.

The State of Alaska PCE program provides a subsidy to rural communities across the state to lower electricity costs and make energy affordable in rural Alaska. In Manokotak, the cost of electricity without PCE is approximately $0.55/kWh and the cost with PCE is approximately $0.31/kWh.

Table 1.1 lists the total usage of electricity and #1 heating oil in the Manokotak Main Water Treatment Plant before and after the proposed retrofits.

Table 1.1: Predicted Annual Fuel Use for the Manokotak Main Water Treatment Plant

Predicted Annual Fuel Use		
Fuel Use	**Existing Building**	**With Proposed Retrofits**
Electricity	36,880 kWh	21,756 kWh
#1 Oil	613 gallons	324 gallons

Benchmark figures facilitate comparing energy use between different buildings. Table 1.2 lists several benchmarks for the audited building.

Table 1.2: Building Benchmarks for the Manokotak Main Water Treatment Plant

Building Benchmarks			
Description	**EUI (kBtu/Sq.Ft.)**	**EUI/HDD (Btu/Sq.Ft./HDD)**	**ECI ($/Sq.Ft.)**
Existing Building	382.8	35.35	$42.08
With Proposed Retrofits	216.7	20.01	$24.55
EUI: Energy Use Intensity - The annual site energy consumption divided by the structure's conditioned area. EUI/HDD: Energy Use Intensity per Heating Degree Day. ECI: Energy Cost Index - The total annual cost of energy divided by the square footage of the conditioned space in the building.			

Table 1.3 below summarizes the energy efficiency measures analyzed for the Manokotak Main Water Treatment Plant. Listed are the estimates of the annual savings, installed costs, and two different financial measures of investment return.

Table 1.3: Summary of Recommended Energy Efficiency Measures

PRIORITY LIST – ENERGY EFFICIENCY MEASURES							
Rank	Feature	Improvement Description	Annual Energy Savings	Installed Cost	Savings to Investment Ratio, SIR[1]	Simple Payback (Years)[2]	CO_2 Savings
1	Well 2 Heat Tape	Implement controls to shut off heat tape when well pump is in operation.	$4,539	$500	106.63	0.1	22,281.2
2	Well 1 Heat Tape	Implement controls to shut off heat tape when well pump is in operation.	$2,118	$1,500	16.59	0.7	10,398.0
3	Lighting: Water Treatment Plant Interior Lights	Replace new energy efficient, direct-wire LED lighting.	$138 + $30 Maint. Savings	$300	4.69	1.8	672.1
4	Setback Thermostat: Water Treatment Plant	Install new programmable thermostats and program an unoccupied setback to 50.0 deg F.	$238	$1,500	1.99	6.3	1,206.4
5	Lighting: Water Treatment Plant Exterior Lighting	Replace new energy efficient, direct-wire LED lighting.	$66	$500	1.55	7.6	323.8
6	Lighting: Lift Station Interior Lights	Replace new energy efficient, direct-wire LED lighting.	$27	$150	1.51	5.6	131.6
7	Lighting: Water Treatment Plant Generator Room Lights	Replace new energy efficient, direct-wire LED lighting.	$1 + $10 Maint. Savings	$100	0.95	9.0	5.7
8	Lighting: Water Treatment Plant Storage Room Lights	Replace new energy efficient, direct-wire LED lighting.	$1 + $10 Maint. Savings	$100	0.95	8.9	5.8

PRIORITY LIST – ENERGY EFFICIENCY MEASURES							
Rank	**Feature**	**Improvement Description**	**Annual Energy Savings**	**Installed Cost**	**Savings to Investment Ratio, SIR[1]**	**Simple Payback (Years)[2]**	**CO_2 Savings**
9	Heating, Ventilation, and Domestic Hot Water	Replace existing water circulation heat-add heat exchanger with new flat-plate version. Replace boiler circulation pumps with smart modulating pumps. Repair or replace broken temperature sensor for automatic flow valve. Insulate heating loop pipes. Clean and tune boilers regularly. Consider new boilers. Reduce use of electric heater in generator room and use hydronic heat to heat the battery instead.	$2,318	$69,000	0.53	29.8	11,768.7
10	Windows: Water Treatment Plant (2)	Replace existing windows with triple pane window.	$17	$1,325	0.22	75.7	91.3
11	Air Tightening	Weatherize around doors and windows.	$9	$1,000	0.08	108.1	48.3
TOTAL			**$9,473 + $50 Maint. Savings**	**$76,975**	**1.57**	**8.1**	**46,932.8**

Table Notes:

[1] Savings to Investment Ratio (SIR) is a life-cycle cost measure calculated by dividing the total savings over the life of a project (expressed in today's dollars) by its investment costs. The SIR is an indication of the profitability of a measure; the higher the SIR, the more profitable the project. An SIR greater than 1.0 indicates a cost-effective project (i.e. more savings than cost). Remember that this profitability is based on the position of that Energy Efficiency Measure (EEM) in the overall list and assumes that the measures above it are implemented first.

[2] Simple Payback (SP) is a measure of the length of time required for the savings from an EEM to payback the investment cost, not counting interest on the investment and any future changes in energy prices. It is calculated by dividing the investment cost by the expected first-year savings of the EEM.

With all of these energy efficiency measures in place, the annual utility cost can be reduced by $9,473 per year, or 41.7% of the buildings' total energy costs. These measures are estimated to cost $76,975, for an overall simple payback period of 8.1 years.

Table 1.4 below is a breakdown of the annual energy cost across various energy end use types, such as Space Heating. The first row in the table shows the breakdown for the building as it is now. The second row shows the expected breakdown of energy cost for the building assuming all of the retrofits in this report are implemented. Finally, the last row shows the annual energy savings that will be achieved from the retrofits.

Table 1.4: Detailed Breakdown of Energy Costs in the Building

Annual Energy Cost Estimate					
Description	**Space Heating**	**Lighting**	**Other Electrical**	**Water Circulation Heat**	**Total Cost**
Existing Building	$2,474	$606	$17,687	$1,968	**$22,736**
With Proposed Retrofits	$1,065	$346	$11,031	$821	**$13,263**
Savings	$1,409	$260	$6,657	$1,147	**$9,473**

2. AUDIT AND ANALYSIS BACKGROUND

2.1 Program Description

This audit included services to identify, develop, and evaluate energy efficiency measures at the Manokotak Main Water Treatment Plant. The scope of this project included evaluating building shell, lighting and other electrical systems, heating and ventilation equipment, motors and pumps. Measures were analyzed based on life-cycle-cost techniques, which include the initial cost of the equipment, life of the equipment, annual energy cost, annual maintenance cost, and a discount rate of 3.0% per year in excess of general inflation.

2.2 Audit Description

Preliminary audit information was gathered in preparation for the site survey. The site survey provides critical information in deciphering where energy is used and what opportunities exist within a building. The entire site was surveyed to inventory the following to gain an understanding of how each building operates:

- Building envelope (roof, windows, etc.)
- Heating and ventilation equipment
- Lighting systems and controls
- Building-specific equipment

The building site visit was performed to survey all major building components and systems. The site visit included detailed inspection of energy consuming components. Summary of building occupancy schedules, operating and maintenance practices, and energy management programs provided by the building manager were collected along with the system and components to determine a more accurate impact on energy consumption.

Details collected from Manokotak Main Water Treatment Plant enable a model of the building's energy usage to be developed, highlighting the building's total energy consumption, energy consumption by specific building component, and equivalent energy cost. The analysis involves distinguishing the different fuels used on site, and analyzing their consumption in different activity areas of the building.

Manokotak Main Water Treatment Plant is made up of the following activity areas:

1) Water Treatment Plant: 364 square feet
2) Generator Room: 88 square feet
3) Storage Room: 88 square feet

In addition, the methodology involves taking into account a wide range of factors specific to the building. These factors are used in the construction of the model of energy used. The factors include:

- Occupancy hours
- Local climate conditions
- Prices paid for energy

2.3. Method of Analysis

Data collected was processed using AkWarm© Energy Use Software to estimate energy savings for each of the proposed energy efficiency measures (EEMs). The recommendations focus on the building envelope; heating and ventilation; lighting, electric load, and other electrical improvements; and motor and pump systems that will reduce annual energy consumption.

EEMs are evaluated based on building use and processes, local climate conditions, building construction type, function, operational schedule, existing conditions, and foreseen future plans. Energy savings are calculated based on industry standard methods and engineering estimations.

Our analysis provides a number of tools for assessing the cost effectiveness of various improvement options. These tools utilize **Life-Cycle Costing**, which is defined in this context as a method of cost analysis that estimates the total cost of a project over the period of time that includes both the construction cost and ongoing maintenance and operating costs.

Savings to Investment Ratio (SIR) = **Savings** divided by **Investment**

Savings includes the total discounted dollar savings considered over the life of the improvement. When these savings are added up, changes in future fuel prices as projected by the Department of Energy are included. Future savings are discounted to the present to account for the time-value of money (i.e. money's ability to earn interest over time). The **Investment** in the SIR calculation includes the labor and materials required to install the measure. An SIR value of at least 1.0 indicates that the project is cost-effective—total savings exceed the investment costs.

Simple payback is a cost analysis method whereby the investment cost of a project is divided by the first year's savings of the project to give the number of years required to recover the cost of the investment. This may be compared to the expected time before replacement of the system or component will be required. For example, if a boiler costs $12,000 and results in a savings of $1,000 in the first year, the payback time is 12 years. If the boiler has an expected life to replacement of 10 years, it would not be financially viable to make the investment since the payback period of 12 years is greater than the project life.

The Simple Payback calculation does not consider likely increases in future annual savings due to energy price increases. As an offsetting simplification, simple payback does not consider the need to earn interest on the investment (i.e. it does not consider the time-value of money). Because of these simplifications, the SIR figure is considered to be a better financial investment indicator than the Simple Payback measure.

Measures are implemented in order of cost-effectiveness. The program first calculates individual SIRs, and ranks all measures by SIR, higher SIRs at the top of the list. An individual measure must have an individual SIR>=1 to make the cut. Next the building is modified and re-simulated with the highest ranked measure included. Now all remaining measures are re-evaluated and ranked, and the next most cost-effective measure is implemented. AkWarm goes through this iterative process until all appropriate measures have been evaluated and installed.

It is important to note that the savings for each recommendation is calculated based on implementing the most cost effective measure first, and then cycling through the list to find the next most cost effective measure. Implementation of more than one EEM often affects the savings of other EEMs. The savings may in some cases be relatively higher if an individual EEM is implemented in lieu of multiple recommended EEMs. For example implementing a reduced operating schedule for inefficient lighting will result in relatively high savings. Implementing a reduced operating schedule for newly installed efficient lighting will result in lower relative savings, because the efficient lighting system uses less energy during each hour of operation. If multiple EEM's are recommended to be implemented, AkWarm calculates the combined savings appropriately.

Cost savings are calculated based on estimated initial costs for each measure. Installation costs include labor and equipment to estimate the full up-front investment required to implement a change. Costs are derived from Means Cost Data, industry publications, and local contractors and equipment suppliers.

2.4 Limitations of Study

All results are dependent on the quality of input data provided, and can only act as an approximation. In some instances, several methods may achieve the identified savings. This report is not intended as a final design document. The design professional or other persons following the recommendations shall accept responsibility and liability for the results.

3. MANOKOTAK MAIN WATER TREATMENT PLANT

3.1. Building Description

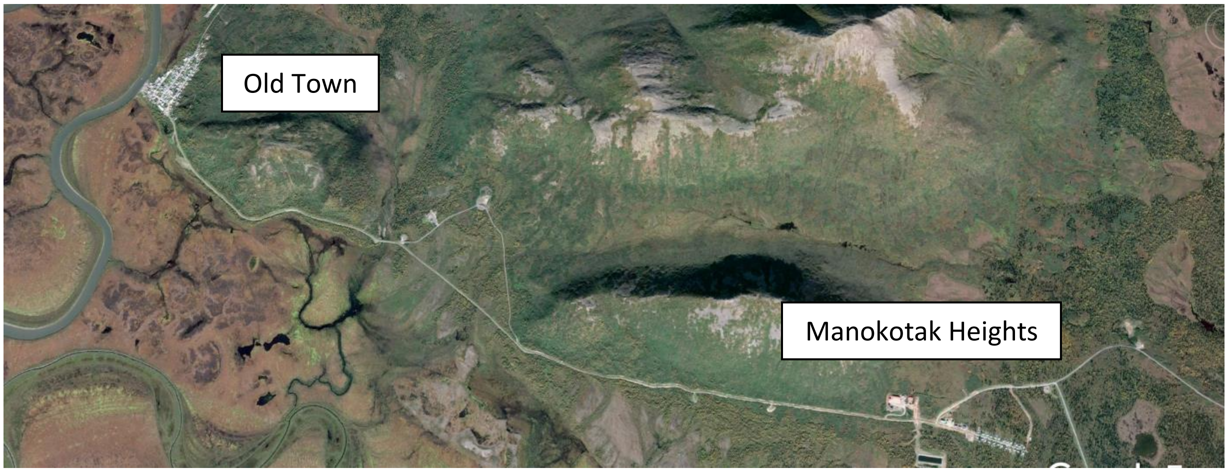

Figure 1: Aerial View of the Community of Manokotak

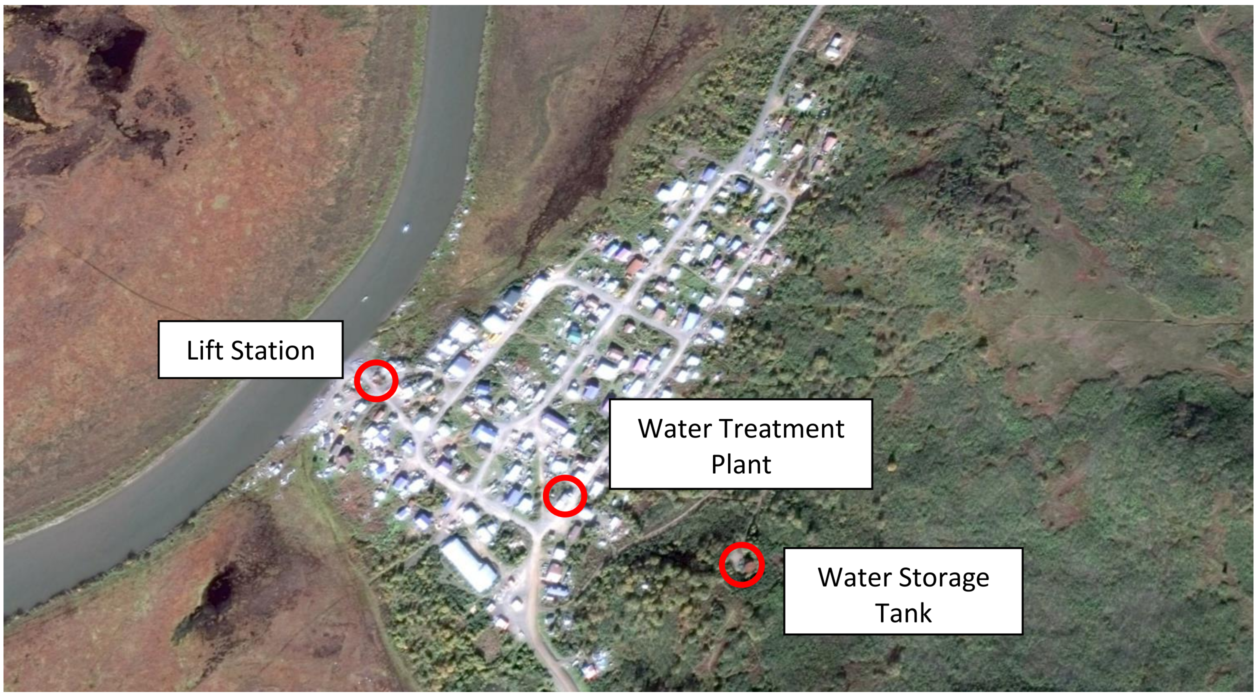

Figure 2: Aerial View of the old town of Manokotak

The 540 square foot Manokotak Main Water Treatment Plant was constructed in the 1970's to house the water intake, treatment, and distribution system for the community of Manokotak. The building is occupied approximately 4 hours per day for five days per week. The chemical injection system that was included during the original construction has since been removed due to changes in water quality.

There is also a water storage tank on the hillside near the community and a lift station on the shoreline of the Igushik River, which runs adjacent to the community. These were also assessed during the site visit and included in this report. The lift station was not heated due to faulty electrical heating, and freezing conditions were present in the building. The water storage tank had leaks in the piping that caused water damage to the pipe insulation.

The Manokotak Water Treatment Plant consists of two individual buildings with a common heating system. The water treatment plant main building is 364 square feet and houses all water intake and distribution components. The adjacent building consists of an 88 square foot storage room and an 88 square foot generator room. The generator room contains the backup generator for the water treatment plant. The main building and the adjacent building are approximately 10 feet. The heating system piping between the two buildings is above ground in an insulated jacket.

Raw water is pumped into the facility from two wells that are both located near the water plant building. One well is approximately 30 feet from the facility and the second well is approximately 50 feet from the facility. After the water is pumped into the facility it is then transported to a gallon water storage tank that is on the hillside near the community. The water storage tank can hold approximately 150,000 gallons of water for community use. The pressure from the water storage tank on the mountain side allows for water distribution to occur often without using the two circulation pumps installed in the water treatment plant. Those pumps will operate when the pressure from the water storage tank is not high enough to produce all the required flow for proper water distribution. The water flows from the tank back to the water treatment plant, where it is heated before being circulated through a single distribution loop in the community.

Description of Building Shell

All exterior walls of the water treatment plant buildings are 2x6 wood-framed construction with 5.5 inches of fiberglass batt insulation.

The roofs of both buildings are 2x6 wood-framed construction with 24 inch truss spacing and 5.5 inches of fiberglass batt insulation. The main building has an attic space with a ceiling height of 8 feet. The adjacent building has a cathedral ceiling with a peak height of approximately 10 feet tall.

Both buildings have elevated foundations with a small crawlspace beneath the floor. There is fiberglass insulation beneath the floors of each building.

The main building has two broken and boarded windows and one double-pane, wood-framed window that is approximately 44” x 45”. There are no windows in the adjacent building.

The main building entrance is a single wood door with metal skin. The storage room entrance is a single wood door with metal skin. The generator entrance is a set of double doors that are both wood doors with metal skin.

Description of Heating Plants

The heating plants used in the building are:

Boiler 1

Nameplate Information:	Weil McLain
Fuel Type:	#1 Oil
Input Rating:	292,000 BTU/hr
Steady State Efficiency:	75 %
Idle Loss:	1.5 %
Heat Distribution Type:	Glycol
Boiler Operation:	Oct - May
Notes:	Rarely cleaned. It was cleaned on site. Boiler 1 has problems with fuel nozzle tuning.

Boiler 2

Nameplate Information:	Weil Mclain
Fuel Type:	#1 Oil
Input Rating:	292,000 BTU/hr
Steady State Efficiency:	75 %
Idle Loss:	1.5 %
Heat Distribution Type:	Glycol
Boiler Operation:	Oct - May
Notes:	Rarely cleaned. Boiler was cleaned on site.

Figure 3: Boilers in the Main Water Treatment Plant

WTP Electric Heater

Fuel Type:	Electricity
Input Rating:	4000 Watts
Steady State Efficiency:	100 %
Heat Distribution Type:	Air
Notes:	Broken

Figure 4: Water Treatment Plant Electric Heater

Storage Electric Heater

Fuel Type:	Electricity
Input Rating:	4000 Watts
Steady State Efficiency:	100 %
Heat Distribution Type:	Air

Figure 5: Storage Room Electric Heater

Generator Electric Heater

Fuel Type:	Electricity
Input Rating:	4000 Watts
Steady State Efficiency:	100 %
Heat Distribution Type:	Air

Figure 6: Generator Room Electric Heater

Space Heating Distribution Systems

There are three unit heaters that are heated by the boilers that provide space heat to all spaces of the water treatment plant. One unit heater is present in the water treatment plant room, one in the generator room, and one in the storage room. All three unit heaters are rated for 40,000 BTU's. There is also a 4000 Watt electric space heater in each of the three spaces. The generator room electric heater was in use during the site visit but the others were not functioning according to the operator.

Figure 7: Storage Room Unit Heater

Figure 8: Generator Room Unit Heater

Figure 9: Water Treatment Plant Unit Heater

Description of Building Ventilation System

There is no mechanical ventilation system in the facility. There is ventilation for the generator room in the event that the generator must be used. There is also ventilation for the boilers, but no mechanical systems for the ventilation process.

Lighting

Lighting in the water treatment plant consumes approximately 1,103 kWh annually and constitutes approximately 3% of the building's current electrical consumption.

Table 3.1: Breakdown of Lighting by Location and Bulb Type

Location	Bulb Type	Fixtures	Bulbs per Fixture	Annual Usage (kWh)
Water Treatment Plant	Fluorescent T8 4ft. 25 Watt	6	4	554
Generator Room	Fluorescent T8 4ft. 25 Watt	2	2	24
Storage Room	Fluorescent T8 4ft. 25 Watt	2	2	24
Exterior	High Pressure Sodium 50 Watts	2	1	435
Lift Station	Incandescent A Lamp 60 Watts	6	1	66
			Total Energy Consumption	1,103

Major Equipment

Table 3.2 contains the details on each of the major electricity consuming mechanical components found in the water treatment plant. Major equipment consumes approximately 32,160 kWh annually constituting about 87% of the building's current electrical consumption.

Table 3.2: Major Equipment List

Major Equipment	Purpose	Rating	Operating Schedule	Annual Energy Consumption (kWh)
Well Pump 1	Pumps water from the well into the water plant storage tanks.	0.75 HP	~ 50% of the time all year	2,455
Well Pump 2	Pumps water from the well into the water plant storage tanks.	0.75 HP	Continuous	4,909
Well 1 Heat Tape	Provides freeze protection for the water intake line from the well to the water plant.	2,160 Watts	~50% of the time in winter season	5,502
Well 2 Heat Tape	Provides freeze protection for the water intake line from the well to the water plant.	3,600 Watts	Continuously during the winter season	9,169
Water Circulation Pumps	Pumps water from the water storage tank through the water distribution loops to the water services	1.5 HP	~ 35% of the time all year	3,375
Lift Station Pump	Pumps sewage collected in the lift station to the sewage lagoon outside of town.	5 HP	~ 22% of the time	6,750
Total Energy Consumption				32,160

The heating circulation system received upgrades less than one week before the site visit, including new glycol circulation pumps and a new heat-add heat exchanger. Because this work took place so close to the site visit, the effects of these upgrades have been included in the recommendations table to showcase the energy savings impact. The new equipment can be seen in Figures 11 and 13.

Figure 10: Old Glycol Circulation Pumps

Figure 11: New Glycol Circulation Pumps

Figure 12: Water Circulation Pumps

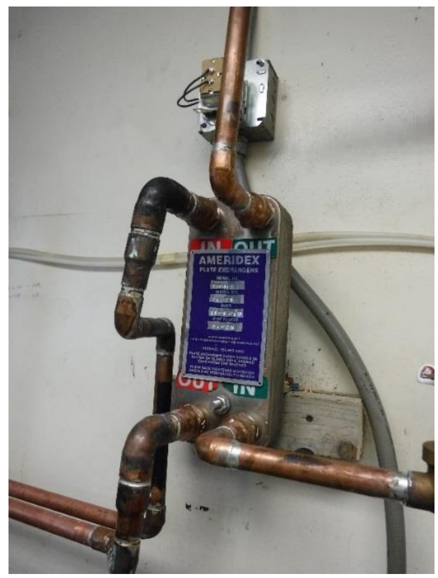

Figure 13: New Water Circulation Heat-Add Heat Exchanger

3.2 Predicted Energy Use

3.2.1 Energy Usage / Tariffs

The electric usage profile charts (below) represents the predicted electrical usage for the building. If actual electricity usage records were available, the model used to predict usage was calibrated to approximately match actual usage. The electric utility measures consumption in kilowatt-hours (kWh) and maximum demand in kilowatts (kW). One kWh usage is equivalent to 1,000 watts running for one hour. One KW of electric demand is equivalent to 1,000 watts running at a particular moment. The basic usage charges are shown as generation service and delivery charges along with several non-utility generation charges.

The fuel oil usage profile shows the fuel oil usage for the building. Fuel oil consumption is measured in gallons. One gallon of #1 Fuel Oil provides approximately 132,000 BTUs of energy.

The Manokotak Power Company, owned by the Manokotak Native Limited, owns and operates a power plant that provides electricity to all residential, public, and commercial facilities in the community.

The average cost for each type of fuel used in this building is shown below in Table 3.3. This figure includes all surcharges, subsidies, and utility customer charges:

Table 3.3: Energy Cost Rates for Each Fuel Type

Average Energy Cost	
Description	**Average Energy Cost**
Electricity	$ 0.55/kWh
#1 Oil	$ 4.00/gallons

3.2.1.1 Total Energy Use and Cost Breakdown

At current rates, City of Manokotak pays approximately $22,736 annually for electricity and other fuel costs for the Manokotak Main Water Treatment Plant.

Figure 14 below reflects the estimated distribution of costs across the primary end uses of energy based on the AkWarm© computer simulation. Comparing the “Retrofit” bar in the figure to the “Existing” bar shows the potential savings from implementing all of the energy efficiency measures shown in this report.

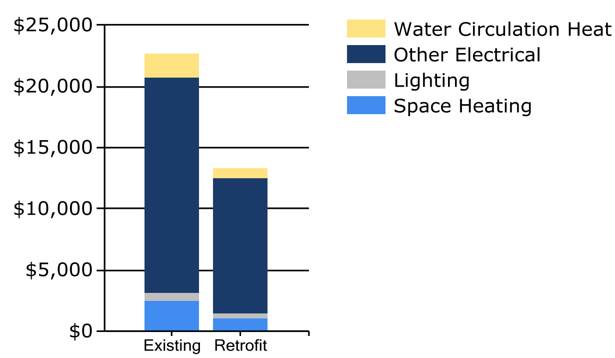

Figure 14: Annual Energy Costs by End Use

Figure 15 below shows how the annual energy cost of the building splits between the different fuels used by the building. The “Existing” bar shows the breakdown for the building as it is now; the “Retrofit” bar shows the predicted costs if all of the energy efficiency measures in this report are implemented.

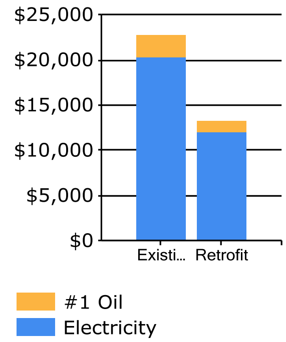

Figure 15: Annual Energy Costs by Fuel Type

Figure 16 below addresses only space heating costs. The figure shows how each heat loss component contributes to those costs; for example, the figure shows how much annual space heating cost is caused by the heat loss through the walls and doors. For each component, the space heating cost for the existing building is shown (blue bar) and the space heating cost assuming all retrofits are implemented (yellow bar) are shown.

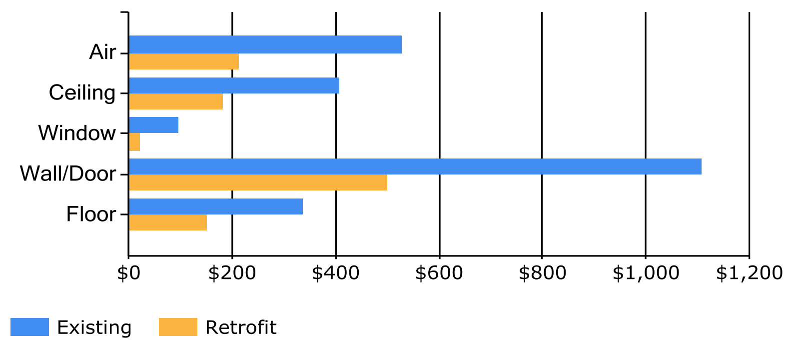

Figure 16: Annual Space Heating Costs

Tables 3.4 and 3.5 below show AkWarm's estimate of the monthly fuel use for each of the fuels used in the building. For each fuel, the fuel use is broken down across the energy end uses.

Table 3.4: Estimated Electrical Consumption by Category

Electrical Consumption (kWh)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Space Heating	629	553	523	369	11	0	0	0	2	383	521	611
Lighting	114	104	114	93	96	55	57	57	93	96	110	114
Other Electrical	3627	3305	3627	3510	1484	1436	1484	1484	1436	3627	3510	3627
Water Circulation Heat	3	2	3	3	0	0	0	0	0	3	3	3

Table 3.5: Estimated Electrical Consumption by Category

Fuel Oil #1 Consumption (Gallons)												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Space Heating	25	21	17	7	2	0	0	0	0	8	19	24
DHW	0	0	0	0	0	0	0	0	0	0	0	0
Water Circulation Heat	69	63	71	74	0	0	0	0	0	76	68	69

3.2.2 Energy Use Index (EUI)

Energy Use Index (EUI) is a measure of a building's annual energy utilization per square foot of building. This calculation is completed by converting all utility usage consumed by a building for one year, to British Thermal Units (Btu) or kBtu, and dividing this number by the building square footage. EUI is a good measure of a building's energy use and is utilized regularly for comparison of energy performance for similar building types. The Oak Ridge National Laboratory (ORNL) Buildings Technology Center under a contract with the U.S. Department of Energy maintains a Benchmarking Building Energy Performance Program. The ORNL website determines how a building's energy use compares with similar facilities throughout the U.S. and in a specific region or state.

Source use differs from site usage when comparing a building's energy consumption with the national average. Site energy use is the energy consumed by the building at the building site only. Source energy use includes the site energy use as well as all of the losses to create and distribute the energy to the building. Source energy represents the total amount of raw fuel that is required to operate the building. It incorporates all transmission, delivery, and production losses, which allows for a complete assessment of energy efficiency in a building. The type of utility purchased has a substantial impact on the source energy use of a building. The Environmental Protection Agency (EPA) has determined that source energy is the most comparable unit for evaluation purposes and overall global impact. Both the site and source EUI ratings for the building are provided to understand and compare the differences in energy use.
The site and source EUIs for this building are calculated as follows. (See Table 3.6 for details):

$$\text{Building Site EUI} = \frac{\text{(Electric Usage in kBtu + Fuel Usage in kBtu)}}{\text{Building Square Footage}}$$

$$\text{Building Source EUI} = \frac{\text{(Electric Usage in kBtu X SS Ratio + Fuel Usage in kBtu X SS Ratio)}}{\text{Building Square Footage}}$$

where "SS Ratio" is the Source Energy to Site Energy ratio for the particular fuel.

Table 3.6: Building EUI Calculations for the Manokotak Main Water Treatment Plant

Energy Type	Building Fuel Use per Year	Site Energy Use per Year, kBTU	Source/Site Ratio	Source Energy Use per Year, kBTU
Electricity	36,880 kWh	125,873	3.340	420,416
#1 Oil	613 gallons	80,909	1.010	81,718
Total		**206,782**		**502,134**
BUILDING AREA		540	Square Feet	
BUILDING SITE EUI		383	kBTU/Ft²/Yr	
BUILDING SOURCE EUI		929	**kBTU/Ft²/Yr**	
* Site - Source Ratio data is provided by the Energy Star Performance Rating Methodology for Incorporating Source Energy Use document issued March 2011.				

Table 3.7: Building Benchmarks for the Manokotak Main Water Treatment Plant

Building Benchmarks			
Description	**EUI (kBtu/Sq.Ft.)**	**EUI/HDD (Btu/Sq.Ft./HDD)**	**ECI ($/Sq.Ft.)**
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With Proposed Retrofits	216.7	20.01	$24.55
EUI: Energy Use Intensity - The annual site energy consumption divided by the structure's conditioned area. EUI/HDD: Energy Use Intensity per Heating Degree Day. ECI: Energy Cost Index - The total annual cost of energy divided by the square footage of the conditioned space in the building.			

3.3 AkWarm© Building Simulation

An accurate model of the building performance can be created by simulating the thermal performance of the walls, roof, windows and floors of the building. The heating systems are modeled as well, accounting for the outside air ventilation required by the building and the heat recovery equipment in place.

The model uses local weather data and is trued up to historical energy use to ensure its accuracy. The model can be used now and in the future to measure the utility bill impact of all types of energy projects, including improving building insulation, modifying glazing, changing air handler schedules, increasing heat recovery, installing high efficiency boilers, using variable air volume air handlers, adjusting outside air ventilation and adding cogeneration systems.

For the purposes of this study, the Manokotak Main Water Treatment Plant was modeled using AkWarm© energy use software to establish a baseline space heating energy usage. Climate data from Manokotak was used for analysis. From this, the model was be calibrated to predict the impact of theoretical energy savings measures. Once annual energy savings from a particular measure were predicted and the initial capital cost was estimated, payback scenarios were approximated.

Limitations of AkWarm© Models

• The model is based on typical mean year weather data for Manokotak. This data represents the average ambient weather profile as observed over approximately 30 years. As such, the gas and electric profiles generated will not likely compare perfectly with actual energy billing information from any single year. This is especially true for years with extreme warm or cold periods, or even years with unexpectedly moderate weather.

• The heating load model is a simple two-zone model consisting of the building's core interior spaces and the building's perimeter spaces. This simplified approach loses accuracy for buildings that have large variations in heating loads across different parts of the building.

The energy balances shown in Section 3.1 were derived from the output generated by the AkWarm© simulations.

4. ENERGY COST SAVING MEASURES

4.1 Summary of Results

The energy saving measures are summarized in Table 4.1. Please refer to the individual measure descriptions later in this report for more detail.

Table 4.1: Summary List of Recommended Energy Efficiency Measures Ranked by Economic Priority

PRIORITY LIST – ENERGY EFFICIENCY MEASURES							
Rank	**Feature**	**Improvement Description**	**Annual Energy Savings**	**Installed Cost**	**Savings to Investment Ratio, SIR[1]**	**Simple Payback (Years)[2]**	**CO_2 Savings**
1	Well 2 Heat Tape	Implement controls to shut off heat tape when well pump is in operation.	$4,539	$500	106.63	0.1	22,281.2
2	Well 1 Heat Tape	Implement controls to shut off heat tape when well pump is in operation.	$2,118	$1,500	16.59	0.7	10,398.0
3	Lighting: Water Treatment Plant Interior Lights	Replace new energy efficient, direct-wire LED lighting.	$138 + $30 Maint. Savings	$300	4.69	1.8	672.1
4	Setback Thermostat: Water Treatment Plant	Install new programmable thermostats and program an unoccupied setback to 50.0 deg F.	$238	$1,500	1.99	6.3	1,206.4
5	Lighting: Water Treatment Plant Exterior Lighting	Replace new energy efficient, direct-wire LED lighting.	$66	$500	1.55	7.6	323.8
6	Lighting: Lift Station Interior Lights	Replace new energy efficient, direct-wire LED lighting.	$27	$150	1.51	5.6	131.6
7	Lighting: Water Treatment Plant Generator Room Lights	Replace new energy efficient, direct-wire LED lighting.	$1 + $10 Maint. Savings	$100	0.95	9.0	5.7

PRIORITY LIST – ENERGY EFFICIENCY MEASURES							
Rank	**Feature**	**Improvement Description**	**Annual Energy Savings**	**Installed Cost**	**Savings to Investment Ratio, SIR[1]**	**Simple Payback (Years)[2]**	**CO_2 Savings**
8	Lighting: Water Treatment Plant Storage Room Lights	Replace new energy efficient, direct-wire LED lighting.	$1 + $10 Maint. Savings	$100	0.95	8.9	5.8
9	Heating, Ventilation, and Domestic Hot Water	Replace existing water circulation heat-add heat exchanger with new flat-plate version. Replace boiler circulation pumps with smart modulating pumps. Repair or replace broken temperature sensor for automatic flow valve. Insulate heating loop pipes. Clean and tune boilers regularly. Consider new boilers. Reduce use of electric heater in generator room and use hydronic heat to heat the battery instead.	$2,318	$69,000	0.53	29.8	11,768.7
10	Windows: Water Treatment Plant (2)	Replace existing windows with triple pane window.	$17	$1,325	0.22	75.7	91.3
11	Air Tightening	Weatherize around doors and windows.	$9	$1,000	0.08	108.1	48.3
TOTAL			**$9,473 + $50 Maint. Savings**	**$76,975**	**1.57**	**8.1**	**46,932.8**

4.2 Interactive Effects of Projects

The savings for a particular measure are calculated assuming all recommended EEMs coming before that measure in the list are implemented. If some EEMs are not implemented, savings for the remaining EEMs will be affected. For example, if ceiling insulation is not added, then savings from a project to replace the heating system will be increased, because the heating system for the building supplies a larger load.

In general, all projects are evaluated sequentially so energy savings associated with one EEM would not also be attributed to another EEM. By modeling the recommended project sequentially, the analysis accounts for interactive affects among the EEMs and does not "double count" savings.

Interior lighting, electric loads, facility equipment, and occupants generate heat within the building. Lighting-efficiency improvements are anticipated to slightly increase heating requirements. Heating penalties were included in the lighting project analysis.

4.3 Building Shell Measures

4.3.1 Window Measures

Rank	Location		Size/Type, Condition		Recommendation	
10	Window: WTP Broken Windows (2)		Glass: No glazing - broken, missing Frame: Wood\Vinyl Spacing Between Layers: Half Inch Gas Fill Type: Air Modeled U-Value: 0.94 Solar Heat Gain Coefficient including Window Coverings: 0.11		Replace existing windows with triple pane window.	
Installation Cost	$1,325		**Estimated Life of Measure (yrs)**	20	**Energy Savings ($/yr)**	$17
Breakeven Cost	$297		**Simple Payback (yrs)**	76	**Energy Savings (MMBTU/yr)**	0.5 MMBTU
			Savings-to-Investment Ratio	0.2		
Auditors Notes: Replacing the windows will improve the total wall insulation and air leakage of the building.						

4.3.2 Air Sealing Measures

Rank	Location		Existing Air Leakage Level (cfm@50/75 Pa)		Recommended Air Leakage Reduction (cfm@50/75 Pa)	
11			Air Tightness estimated as: 675 cfm at 50 Pascals		Weatherize around doors and windows.	
Installation Cost	$1,000		**Estimated Life of Measure (yrs)**	10	**Energy Savings ($/yr)**	$9
Breakeven Cost	$85		**Simple Payback (yrs)**	108	**Energy Savings (MMBTU/yr)**	0.3 MMBTU
			Savings-to-Investment Ratio	0.1		
Auditors Notes: Air tightening comes from replacing windows, sealing around door entrance and main window.						

4.4 Mechanical Equipment Measures

4.4.1 Heating /Domestic Hot Water Measure

Rank	Recommendation				
9	Replace existing water circulation heat-add heat exchanger with new flat-plate version. Replace boiler circulation pumps with smart modulating pumps. Repair or replace broken temperature sensor for automatic flow valve. Insulate heating loop pipes. Clean and tune boilers regularly. Consider new boilers. Reduce use of electric heater in generator room and use hydronic heat to heat the battery instead.				
Installation Cost	$69,000	**Estimated Life of Measure (yrs)**	20	**Energy Savings ($/yr)**	$2,318
Breakeven Cost	$36,806	**Simple Payback (yrs)**	30	**Energy Savings (MMBTU/yr)**	42.4 MMBTU
		Savings-to-Investment Ratio	0.5		

Auditors Notes: The heating circulation system received upgrades less than one week before the site visit, including new glycol circulation pumps and a new heat-add heat exchanger. The glycol circulation pumps were replaced with Grundfos Magna1 variable pumps that vary the pump power and speed based on the instantaneous demand of the system. The heat exchanger was converted to a flat-plate version to increase heat flow and improve the heating distribution efficiency. Because this work took place so close to the site visit, the effects of these upgrades have been included in this recommendation to showcase the energy savings impact. The cost of this retrofit was based on the material and labor costs for the completed upgrade and was estimated at approximately $10,500.

Insulating the heat pipes will reduce excess heating loss and improve heating system efficiency. Estimated cost = $500

The boilers are currently oversized as the maximum heating demand for the entire water treatment plant was estimated to be around 140,000 BTU's, less than half of the current boiler rating of 292,000 BTU's. This recommendation is to replace the boilers with Weil McLain WGO-4 or equivalent models. An additional benefit is that the current boilers are no longer in production and the new boilers will be easier to maintain. Estimated Cost = $55,000

Reduce the use of the electric heat in the generator room and use the hydronic unit heater to provide space heat to keep the generator battery warm. This will take advantage of the cheaper fuel source alternative. The cost is for an electrician to examine the controls and provide any necessary repairs to use the hydronic unit heater. Estimated cost = $4,000

Existing heating system upgrades:	$10,500
Heating system pipe insulation:	$500
Boiler Replacement:	$55,000
Electric Heat Reduction:	$4,000
Total Cost:	**$69,000**

4.4.2 Night Setback Thermostat Measures

Rank	Building Space			Recommendation	
4	Water Treatment Plant			Install new programmable thermostats and program an unoccupied setback to 50.0 deg F.	
Installation Cost	$1,500	**Estimated Life of Measure (yrs)**	15	**Energy Savings ($/yr)**	$238
Breakeven Cost	$2,979	**Simple Payback (yrs)**	6	**Energy Savings (MMBTU/yr)**	4.1 MMBTU
		Savings-to-Investment Ratio	2.0		

Auditors Notes: Implementing an unoccupied temperature setback will reduce the heating consumption while the building is not occupied.

4.5 Electrical & Appliance Measures

4.5.1 Lighting Measures

The goal of this section is to present any lighting energy conservation measures that may also be cost beneficial. It should be noted that replacing current bulbs with more energy-efficient equivalents will have a small effect on the building heating loads. The building heating load will see a small increase, as the more energy efficient bulbs give off less heat.

4.5.1a Lighting Measures – Replace Existing Fixtures/Bulbs

Rank	**Location**	**Existing Condition**		**Recommendation**	
3	Water Treatment Plant Interior Lights	6 FLUOR (4) T8 4' F32T8 25W Energy-Saver Instant StdElectronic		Replace new energy efficient, direct-wire LED lighting.	
Installation Cost	$300	**Estimated Life of Measure (yrs)**	10	**Energy Savings ($/yr)**	$138
Breakeven Cost	$1,406	**Simple Payback (yrs)**	2	**Energy Savings (MMBTU/yr)**	0.6 MMBTU
		Savings-to-Investment Ratio	4.7	**Maintenance Savings ($/yr)**	$30
Auditors Notes: There are six fixtures with four fluorescent T8 4ft. fixtures to be replaced with two LED lamps in each fixture. The LED equivalent lamps are rated for 15 Watts each. 12 replacement lamps are required for this space.					

Rank	**Location**	**Existing Condition**		**Recommendation**	
5	Water Treatment Plant Exterior Lighting	2 HPS 50 Watt StdElectronic		Replace new energy efficient, direct-wire LED lighting.	
Installation Cost	$500	**Estimated Life of Measure (yrs)**	15	**Energy Savings ($/yr)**	$66
Breakeven Cost	$775	**Simple Payback (yrs)**	8	**Energy Savings (MMBTU/yr)**	0.4 MMBTU
		Savings-to-Investment Ratio	1.5		
Auditors Notes: Replace with LED outdoor wall packs, rated for 35 Watts each. There are two units to replace.					

Rank	**Location**	**Existing Condition**		**Recommendation**	
6	Lift Station Interior Lights	6 INCAN A Lamp, Std 60W		Replace new energy efficient, direct-wire LED lighting.	
Installation Cost	$150	**Estimated Life of Measure (yrs)**	10	**Energy Savings ($/yr)**	$27
Breakeven Cost	$226	**Simple Payback (yrs)**	6	**Energy Savings (MMBTU/yr)**	0.2 MMBTU
		Savings-to-Investment Ratio	1.5		
Auditors Notes: Replace with LED A Lamp equivalents, rated for 10-12 Watts each. There are six lamps to replace.					

Rank	**Location**	**Existing Condition**		**Recommendation**	
7	Water Treatment Plant Generator Room Lights	2 FLUOR (2) T8 4' F32T8 25W Energy-Saver Instant StdElectronic		Replace new energy efficient, direct-wire LED lighting.	
Installation Cost	$100	**Estimated Life of Measure (yrs)**	10	**Energy Savings ($/yr)**	$1
Breakeven Cost	$95	**Simple Payback (yrs)**	9	**Energy Savings (MMBTU/yr)**	0.0 MMBTU
		Savings-to-Investment Ratio	1.0	**Maintenance Savings ($/yr)**	$10
Auditors Notes: There are two fixtures with two fluorescent T8 4ft. fixtures to be replaced. The LED equivalent lamps are rated for 15 Watts each. 4 replacement lamps are required for this space.					

Rank	Location	Existing Condition		Recommendation	
8	Water Treatment Plant Storage Room Lights	2 FLUOR (2) T8 4' F32T8 25W Energy-Saver Instant StdElectronic		Replace new energy efficient, direct-wire LED lighting.	
Installation Cost	$100	**Estimated Life of Measure (yrs)**	10	**Energy Savings ($/yr)**	$1
Breakeven Cost	$95	**Simple Payback (yrs)**	9	**Energy Savings (MMBTU/yr)**	0.0 MMBTU
		Savings-to-Investment Ratio	1.0	**Maintenance Savings ($/yr)**	$10
Auditors Notes: There are two fixtures with two fluorescent T8 4ft. fixtures to be replaced. The LED equivalent lamps are rated for 15 Watts each. 4 replacement lamps are required for this space.					

4.5.2 Other Electrical Measures

Rank	Location	Description of Existing		Efficiency Recommendation	
1	Well 2 Heat Tape	Heat Tape		Implement controls to shut off heat tape when well pump is in operation.	
Installation Cost	$1,500	**Estimated Life of Measure (yrs)**	15	**Energy Savings ($/yr)**	$4,539
Breakeven Cost	$53,314	**Simple Payback (yrs)**	0	**Energy Savings (MMBTU/yr)**	28.2 MMBTU
		Savings-to-Investment Ratio	35.5		
Auditors Notes: Implement controls such that heat tape only operates when the well pump is shut off. This includes an additional relay and contact to install to synchronize the operation. Include a manual switch to turn on heat tape in emergency purposes and to turn off heat tape in the summer months.					

Rank	Location	Description of Existing		Efficiency Recommendation	
2	Well 1 Heat Tape	Heat Tape		Implement controls to shut off heat tape when well pump is in operation.	
Installation Cost	$1,500	**Estimated Life of Measure (yrs)**	15	**Energy Savings ($/yr)**	$2,118
Breakeven Cost	$24,880	**Simple Payback (yrs)**	1	**Energy Savings (MMBTU/yr)**	13.1 MMBTU
		Savings-to-Investment Ratio	16.6		
Auditors Notes: Implement controls such that heat tape only operates when the well pump is shut off. This includes an additional relay and contact to install to synchronize the operation. Include a manual switch to turn on heat tape in emergency purposes and to turn off heat tape in the summer months.					

5. ENERGY EFFICIENCY ACTION PLAN

Through inspection of the energy-using equipment on-site and discussions with site facilities personnel, this energy audit has identified several energy-saving measures. The measures will reduce the amount of fuel burned and electricity used at the site. The projects will not degrade the performance of the building and, in some cases, will improve it.

Several types of EEMs can be implemented immediately by building staff, and others will require various amounts of lead time for engineering and equipment acquisition. In some cases, there are logical advantages to implementing EEMs concurrently. For example, if the same electrical contractor is used to install both lighting equipment and motors, implementation of these measures should be scheduled to occur simultaneously.

APPENDICES

Appendix A – Scanned Energy Billing Data

1. Billing Data for the following Fuel Types
   Electricity
   #1 Oil

Month	Water Treatment Plant Electricity	Lift Station Electricity	#1 Fuel Oil
January 2017	3.200	575	105
February 2017	2,825	575	105
March 2017	2,600	600	85
April 2017	2,500	550	80
May 2017	2,203	550	2
June 2017	2,254	1,484	2
July 2017	1,015	600	2
August 2017	1,873	699	2
September 2017	1,650	540	2
October 2017	2,084	519	80
November 2017	3,336	557	95
December 2017	2,785	573	105

The electric records were available for June – December for the total water and sewer electricity costs. The total annual electric usage and the proportional usage of the Manokotak Main Water Treatment Plant, Manokotak Heights Water Plant, and the Lift Station from June – December were used to estimate the approximate electricity distribution for all three buildings for the year.

The total fuel usage for both the Manokotak Main Water Treatment Plant and the Manokotak Heights Water Plant was available. Engineering calculations were used to estimate the total proportional fuel usage for each of the two buildings.

Appendix B – Energy Audit Report – Project Summary

ENERGY AUDIT REPORT – PROJECT SUMMARY	
General Project Information	
PROJECT INFORMATION	**AUDITOR INFORMATION**
Building: Manokotak Main Water Treatment Plant	**Auditor Company:** ANTHC-DEHE
Address: City	**Auditor Name:** Kevin Ulrich
City: Manokotak	**Auditor Address:** 4500 Diplomacy Dr. Anchorage, AK 99508
Client Name: Rueben Andrews	
Client Address:	**Auditor Phone:** (907) 729-3237
	Auditor FAX:
Client Phone: (907) 538-8057	**Auditor Comment:**
Client FAX:	
Design Data	
Building Area: 540 square feet	**Design Space Heating Load:** Design Loss at Space: 11,348 Btu/hour with Distribution Losses: 11,348 Btu/hour Plant Input Rating assuming 82.0% Plant Efficiency and 25% Safety Margin: 17,299 Btu/hour Note: Additional Capacity should be added for DHW and other plant loads, if served.
Typical Occupancy: 0 people	**Design Indoor Temperature:** 56.7 deg F (building average)
Actual City: Manokotak	**Design Outdoor Temperature:** -17.2 deg F
Weather/Fuel City: Manokotak	**Heating Degree Days:** 10,828 deg F-days
Utility Information	
Electric Utility: Manakotak Power Company	**Average Annual Cost/kWh:** $0.55/kWh

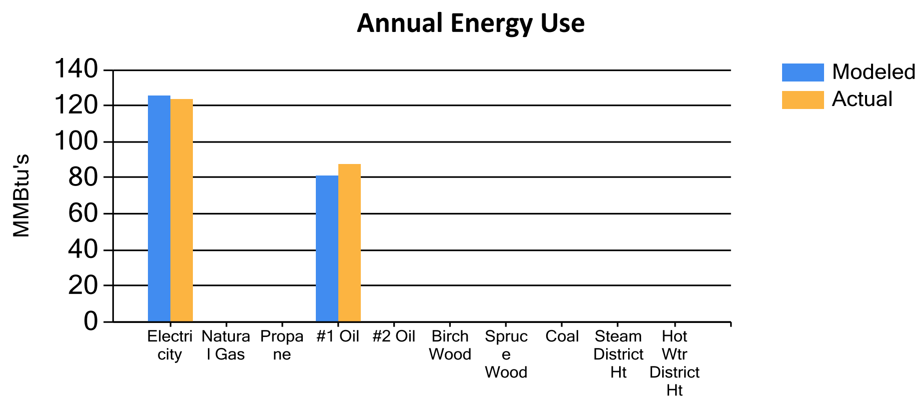
Annual Energy Cost Estimate					
Description	**Space Heating**	**Lighting**	**Other Electrical**	**Water Circulation Heat**	**Total Cost**
Existing Building	$2,474	$606	$17,687	$1,968	**$22,736**
With Proposed Retrofits	$1,065	$346	$11,031	$821	**$13,263**
Savings	$1,409	$260	$6,657	$1,147	**$9,473**

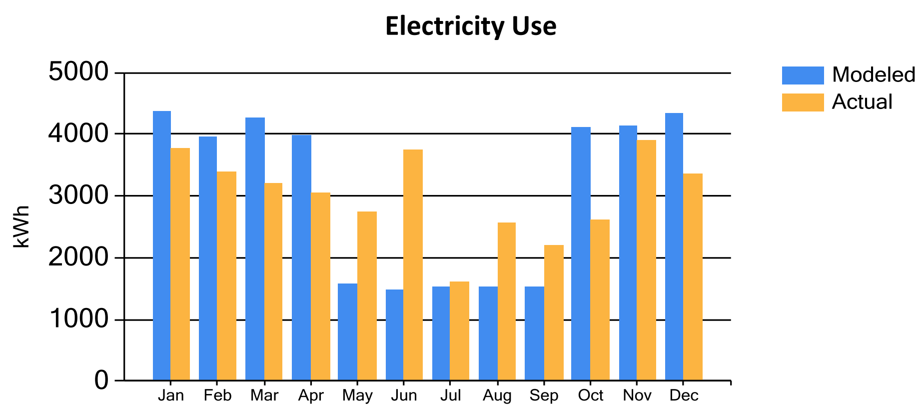
Building Benchmarks			
Description	**EUI (kBtu/Sq.Ft.)**	**EUI/HDD (Btu/Sq.Ft./HDD)**	**ECI ($/Sq.Ft.)**
Existing Building	382.8	35.35	$42.08
With Proposed Retrofits	216.7	20.01	$24.55

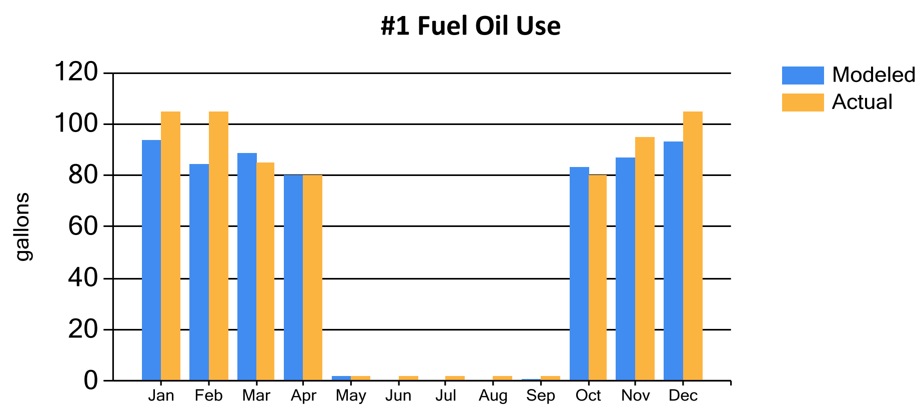
EUI: Energy Use Intensity - The annual site energy consumption divided by the structure's conditioned area.
EUI/HDD: Energy Use Intensity per Heating Degree Day.
ECI: Energy Cost Index - The total annual cost of energy divided by the square footage of the conditioned space in the building.

Appendix C – Actual Fuel Use versus Modeled Fuel Use

The graphs below show the modeled energy usage results of the energy audit process compared to the actual energy usage report data. The model was completed using AkWarm modeling software. The orange bars show actual fuel use, and the blue bars are AkWarm's prediction of fuel use.







Appendix D - Electrical Demands

Estimated Peak Electrical Demand (kW)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Current	9.3	8.8	8.3	7.9	4.5	4.5	4.5	4.5	4.5	7.8	7.7	7.3
As Proposed	5.1	4.7	4.4	4.2	3.5	3.5	3.5	3.5	3.5	4.1	4.0	3.8

AkWarmCalc Ver 2.8.0.0, Energy Lib 9/1/2017