Final Report – Vacuum Sanitation Energy Efficiency Retrofits

Cover Sheet

DOE Award No. DE-IE0000031

Type of Award: Energy Efficiency Retrofits for Rural Alaskan Vacuum Sewer Systems

Applicant/Grantee: Alaska Native Tribal Health Consortium

Project Title: Vacuum Sanitation Energy Efficiency Retrofits Project

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Project Location: Alakanuk, Alaska; Kotlik, Alaska; Noorvik, Alaska

Project Period: Start: 8/1/2016
End: 1/31/2019

Fuel Use Targeted in project:

Reduction in electrical power and heating fuel consumption through efficiency upgrades to vacuum sewer system in targeted rural Alaskan communities.

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Executive Summary

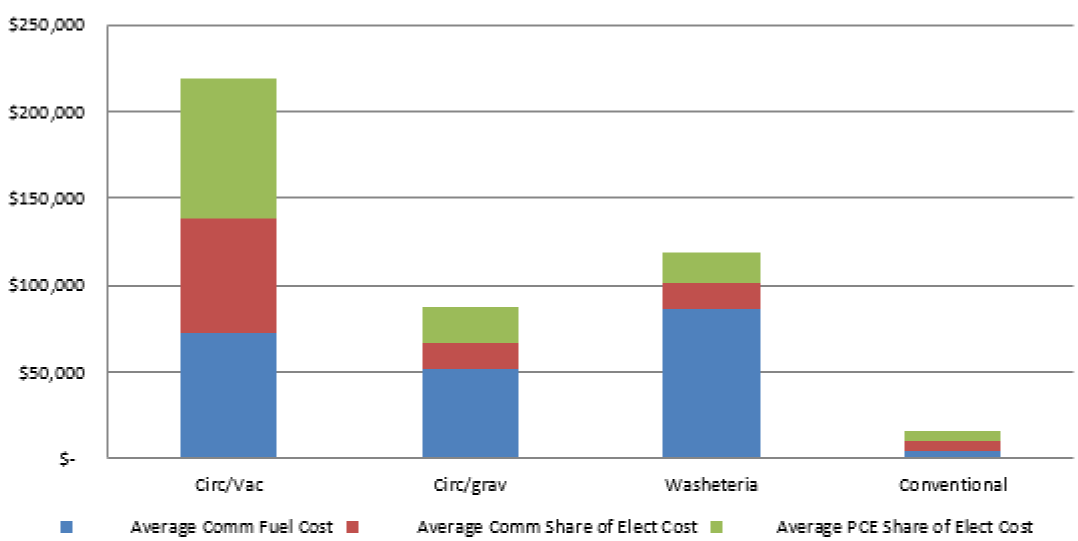
The Alaska Native Tribal Health Consortium (ANTHC) is a non-profit Tribal health organization designed to meet the unique health needs of Alaska Native and American Indian people living in Alaska. In partnership with communities and health organizations across the state, ANTHC provides health services to over 175,000 Alaska Native and American Indian people.

Part of ANTHC's mission includes ensuring that Native Alaskan communities have access to clean and safe water and sewer services. ANTHC works with communities to provide safe drinking water and healthy wastewater services that directly supports the health of Alaska Native people.

To ensure water and sewer facilities operate sustainably, ANTHC Alaska Rural Utility Collaborative (ARUC) and Tribal Utility Support (TUS) programs provide operations and maintenance services on rural sanitation facilities. A key component of many water and sanitation systems in rural Alaskan villages is the vacuum sewer system, which is typically installed in places where the topography is primarily flat and the elevation differential is not enough for a gravity powered sewer system to function without freezing during the winter.

The vacuum sewer system is also the most costly and energy intensive form of sewer system, due to many factors including: large horsepower vacuum pumps needed for operation, potential for frequent vacuum leaks which increase the pump's run-times, man-power needed to maintain pipe grade throughout the system, and the amount of heat needed to be added to the above ground pipes to keep them from freezing.

Figure 1: Annual Energy Cost to Operate Various Water and Sewer Systems



The Vacuum Sanitation Energy Efficiency Retrofits Project implemented strategies to reduce the operating costs for vacuum sewer systems located in the remote Alaskan communities of Alakanuk, Kotlik, and Noorvik. A variety of deep energy efficiency retrofits were installed to reduce the amount of diesel fuel and electricity required to operate these systems which use large amounts of energy to pump, heat, and collect sewage from the community.

Key Objectives:

The Vacuum Sanitation Energy Efficiency Retrofits Project implemented energy efficiency measures at water treatment plants located in the following Alaskan communities: Alakanuk, Kotlik, and Noorvik. In addition to energy efficiency retrofits, ANTHC staff trained local water plant operators to ensure a thorough maintenance routine was incorporated into the operator's duties.

Scope:

This project included installing new pumps, variable frequency drives and controls, vacuum valves and seals, and other minor energy efficiency retrofits. These improvements allowed the vacuum system to perform more efficiently and reduced the amount of energy required to operate the systems. Other retrofits included minor weatherization such as weather stripping, window repair, and reducing excessive air transfer, installing light-emitting diode (LED) lighting at each facility, optimizing existing heating systems, and modifying pumping rates and practices in the water treatment systems. Local operators were also trained on how best to incorporate best practices into their retrofitted systems.

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Project Overview

Part of the U.S. Department of Energy, Office of Indian Energy's mission is to fund and implement a variety of programmatic activities that assist American Indian Tribes and Alaska Native villages with energy cost reductions. To advance this mission, the Office of Indian Energy provided $457,622 in grant funding (and $217,499 in matching funds provided by the State of Alaska) to ANTHC to implement energy efficiency strategies at water treatment plants located in the Alaskan communities of Alakanuk, Kotlik, and Noorvik. Energy efficiency improvements were installed to reduce the consumption of diesel fuel and electricity. The retrofits focused on improvements to the very energy-intensive practice of operating a vacuum sewer system in rural Alaska, which uses large amounts of pumping energy and heating energy to collect sewage from the community and prevent it from freezing.

Previously, these three water treatment plants (WTP), which also serve to collect sewage, used a cumulative 31,688 gallons of diesel fuel per year for heating and 458,568 kWh of electricity. The cost of electricity alone was $68,549. After implementing efficiency measures, electric consumption was reduced by a total of 79,857 kWh, the diesel equivalent of 2,033 gallons. This represents a 21% reduction in total electrical use. In 2018 all three WTPs used 378,711 kWh of electricity.

Had these efficiency measures not been implemented the cost associated with operating the electrical systems would have been 24% higher, costing $88,013. This assumes that the only factors in the increasing cost is inflation and electrical rate increases from 2013 to 2018; it does not consider the degradation over time due to routine wear on the system.

The data available for the heating system upgrades did not allow for definitive results about the savings associated with these efficiency upgrades.

Project Objectives

This project worked within the sanitation systems in the communities of Alakanuk, Kotlik, and Noorvik to reduce energy costs, improve safety, and increase sustainability of critical public infrastructure through deep energy retrofits. The retrofits were conducted based on the findings of previous energy audits conducted for each community's water and sewer plant.

Primary objectives of this project included:

1. The first and foremost objective was to reduce energy costs in the sanitation systems in the communities of Alakanuk, Kotlik, and Noorvik. Reductions were targeted to be an estimated $201,771 annually. Vacuum sewer systems are the most expensive types of community sanitation systems to operate in Alaska. Reducing these costs will improve sustainability of this crucial public health infrastructure and offer opportunities to reduce the extremely high water and sewer service fees charged to impoverished communities.

2. In addition to the cost, reducing the actual energy consumption in the sanitation system in the communities of Noorvik, Kotlik, and Alakanuk also reduced the amount of diesel fuel that needed to be stored in each community and the amount of electrical demand on the local power grid. Reductions were targeted to be 48.1 % annually.

3. Replacing rotary vane style vacuum sewer pumps with oil-less vacuum pumps reduced fire danger significantly and lowered the energy consumption of the system. Fires from vacuum

pumps in Kotlik and similar communities have put millions of dollars of critical infrastructure at risk.

4. The final, and most impactful objective, was to improve local training and technical capacity through on-site training.

The most important improvements to the energy consumption of the facilities was to install newer vacuum pumping technology. Vacuum sewer service in these communities is used because the active layer of permafrost and the flat topography of the community impose limitations on burying pipes in the ground and make that practice exceedingly difficult, in some cases near impossible. All pipes are above ground and in order to induce the flow of sewage, a pair of central vacuum pumps are used to move sewage from homes to a central collection point. This system uses an incredible amount of electricity. ANTHC utilized innovations in pumping and controls technology to upgrade the sewage collection system and drastically reduced electricity consumption.

This effort included the installation of new pumps, new variable frequency drive controls, and vacuum valves and seals. The effect of these improvements allows the vacuum system to perform more efficiently. Other retrofits included minor weatherization such as weather stripping, window repair, and reducing excessive air transfer and ventilation. Installation of light-emitting diode (LED) lighting at each facility, improvements to the fuel oil boiler heating system, minor modifications in pumping rates, and training in best practices in the water treatment system were also a key component to the retrofits in each system.

All of the recommended changes came with a heavy emphasis on increasing local technical capacity, utilizing local labor for installation of equipment, and increasing local ownership and enthusiasm. For energy efficiency measures to yield lasting results, changes to the operating parameters of the sanitation system must be accompanied by training and local understanding and ownership. ANTHC has too often seen tribes receive energy efficiency assistance from entities that install new equipment without properly educating and training local staff to properly operate and maintenance required to keep the equipment efficiently running. ANTHC has developed an energy efficiency program that utilizes experienced Utility Support Engineers and Utility Support Specialists that are vested to ensure the community has the right equipment; coordinates the local operations staff; and provide extensive personalized training. This has proven to improve community operations of the equipment and system to maximize energy savings.

Activities Performed

To achieve these objectives, the follows tasks were completed before December 31, 2017:

1. **Task 1: Energy Efficiency Project Preparation**
    1.1. **Develop Energy Efficiency Retrofits and Training Plan**: Energy efficiency measures were identified using the recommendations from energy audits completed by ANTHC energy auditors. Training and retrofit plans identified specific improvements from each energy audit and the required training needs for local operators.
    1.2. **Develop Material Take Off:** A Material Take Off (MTO) was created for each community that identified required materials for each project. In total, $238,335 was spent on materials, fuel, and contracted costs. $102,281 was spent for Alakanuk, $47,088 for Kotlik, and $88,633 for Noorvik. Major equipment costs totaled $109,075 including five Mink Aqua Vacuum Pumps.

These costs assume a 2% inflation factor between date of purchase and application. A transformer upgrade was originally budgeted, but during the course of the project this was deemed unnecessary. Instead, controllers were installed to handle the new vacuum pumps and ensure their successful operation.

1.3. **Order and Consolidate Materials:** ANTHC's purchasing department acquired the appropriate materials, which were then prepared and shipped to each community.

2. Task 2: Implement Retrofits and Provide Training

2.1. **Ship Materials:** Materials were shipped in a single shipment via barge when possible, or one air freight shipment as necessary. All materials were shipped following all Hazmat guidelines and federal and state shipping regulations. Materials were received by each community's water plant operator(s) and stored in the water plant until ANTHC Utility Support Engineers and Utility Support Specialists scheduled installation.

2.2. **Install Energy Efficiency Equipment and Provide Training:** Led by Utility Support Engineers and Utility Support Specialists, retrofits were implemented in coordination with the local water plant operator(s) and laborers, as well as any needed specialists such as plumbers and electricians. Training was provided to ensure proper efficient and sustainable operations. This took an average of two weeks per community in the field.

2.3. **Identify and Address Additional Needs:** Any changes to the original scope of work were identified during the first implementation trip. Based on that trip, additional retrofits and/or training areas were identified, including required materials. Typical supplemental retrofits consisted of (but were not limited to): replacing fan belts in the heating system, replacing fuses in breaker panels, supplying minor spare parts (such as fuses), etc…

2.4. **Acquire and Consolidate materials:** Additional materials for each community were purchased after the initial site visit and consolidated for a final training and retrofits implementation trip.

2.5. **Ship Additional Materials to Community:** This task included the final shipment(s) of materials to the communities for final retrofit implementation.

2.6. **Secondary Installation of Energy Efficiency Equipment and Training Task Details:** A final training and retrofit installation trip occurred for each community at this time, for about one week on average. Utility Support Engineers and Specialists coordinated and led this trip to provide any remaining efficiency training and equipment installation not performed on the first trip.

3. Task 3: Verify results and evaluate effectiveness of retrofits and training

ANTHC worked with the communities to acquire energy usage records and any performance records/issues with new equipment over this period. The projected energy savings were compared against the actual energy savings to determine performance. Data will be further maintained by ANTHC in its energy retrofit tracking databases, and provided upon request to the Department of Energy (DOE) for future verification of project results.

3.1. **Energy data calculations:**

3.1.1. **Electrical Energy** data was collected from billing and analyzed comparing 2013 values with 2018 values. The data from 2013 was adjusted to account for inflation so that all applicable dollar values are represented in 2018 values.

3.1.2. **Heating Energy** data was collected from billing records. However there was not enough consistency in the record keeping to draw a firm conclusions beyond anecdotal evidence. High level investigations indicate savings, but to reiterate, the nature of the data available made quantifiable and conclusive results infeasible.

Milestones

Four deliverables were tracked for each community as a method of tracking milestone progress.

- Milestone 1: Development of Training Plan
- Milestone 2: Development of Material Take Off
- Milestone 3: Production of Trip Report, to include analysis and comparison of work completed and remaining work needed to be done.
- Milestone 4: Production of Second Trip Report, to include analysis and comparison of work completed and remaining work needed to be done.

The Training Plan and Material Take Off lists from Milestone 1 and 2 respectively were completed in spring of 2016. Milestones 3 and 4 were completed during the summers of 2016 and 2017, with the last field work being completed in late 2017. The prolonged implementation window was due to various scheduling constraints within ANTHC's Utility Support team and stakeholder availability as well as the realities of conducting a construction project in rural Alaska. Various travel logistics in rural Alaska was a contributing factor in impacting the implementation schedule.

Conclusions and Recommendations

Approximately one year after all energy efficiency measures were implemented, data was collected on the energy use of each community's water and sewer plant. The following conclusions were reached using baseline data from calendar year 2013, compared against data from 2018. For this report, all dollar values from 2013 calculated with inflation accounted for to bring the values to 2018 dollar values.

Aggregate Community Findings	2013	2018	% Change	Without Energy Efficiency	% Variance
Electric use	458,568 kWh	378,711 kWh	-17%	458,568 kWh	21%
Electric cost	$68,549.30	$70,962.83	4%	$88,013.20	24%
Average electric rate	$0.16	$0.19	20%	$0.19	0%

The aggregate electrical data from Alakanuk, Kotlik, and Noorvik is shown above. While the total electrical consumption was reduced by 17%, there was still an overall operational cost increase of 4%. This increase is due largely to the increased energy rates. The cost of energy throughout Alaska, particularly in rural communities[1] [2], is a large burden on the operation of modern water and sewer systems.

[1] Electricity in Alaska: A Growing and Changing Picture – Institute of Social and Economic Research, University of Alaska Anchorage https://iseralaska.org/static/legacy_publication_links/2014_04-RS-ElectricityInAlaska.pdf

[2] Energy Information Administration – Alaska Analysis https://www.eia.gov/state/analysis.php?sid=AK

However, without the energy efficiency measures implemented in this project, and assuming the electrical demand for operating the three water and sewer systems would have remained largely the same, the increased electrical rates (plus inflation) would have caused a 24% increase in operational costs of $24,046. This assumes that no further degradation of the water and sewer system would take place over the five year time frame.

In terms of thermal demands for operating these water and sewer systems, no solid conclusions could be drawn from the heating fuel data available. Given a larger time scale, and more accurate data recording, anecdotal information from the trip reports composed by the Utility Support Engineers could be verified. Some discussion around heating fuel reductions is present, but there is minimal supporting data. The trip reports illustrate the need for additional training and education increasing the longevity and efficiency of the heating systems.

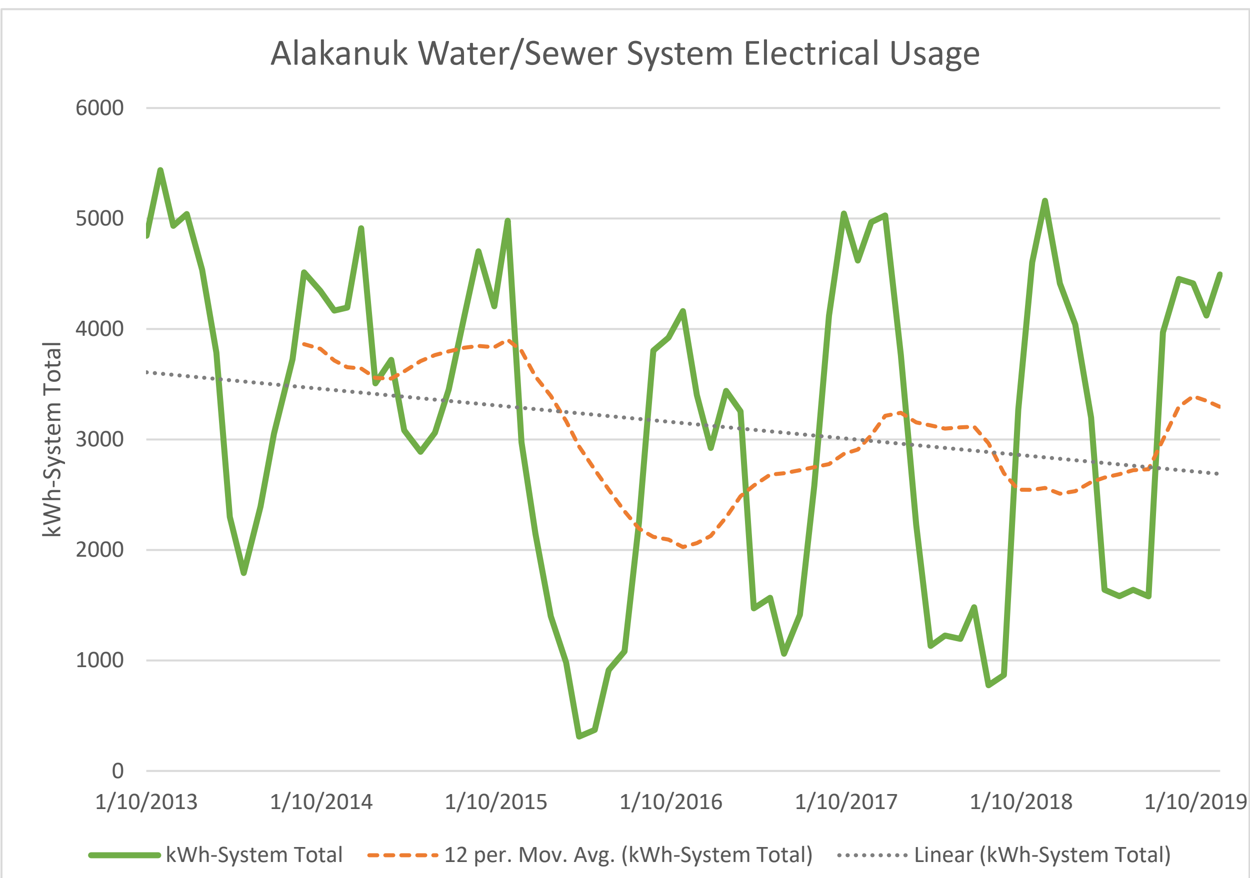
Each community's electrical data for the operation of the water and sewer plant over the five year period from 2013 to 2018 is discussed below. Each community experienced a drop in the amount of electricity used, however that number varies depending on the community.

Alakanuk

Out of the three communities that were included in this project, Alakanuk experienced the lowest energy consumption reduction, but the highest proportional cost reduction. This can be attributed to the Alakanuk also having the highest cost of electricity. Therefore each kWh that is not used has a much larger impact on operational costs.

Alakanuk Findings	2013	2018	% change	Without Energy Efficiency	% Variance
Electric use	46,354 kWh	39,549 kWh	-15%	46,354 kWh	17%
Electric cost	$7,797.34	$7,671.55	-2%	$9,209.08	20%
Average electric rate	$0.17	$0.20	17%	$0.20	0%

Furthermore, the final trip reports from Utility Support Engineers that were deployed to the community indicate that the local workforce would benefit from additional training and education. One of the key challenges of operating modern infrastructure in rural Alaska is ensuring that the local workforce is invested in the successful and efficient operation of their systems.



Shown here is the Alakanuk vacuum pumps being upgraded in October 2017. Clockwise from the top left: original installation; partially upgraded installation; upgrades completely installed.

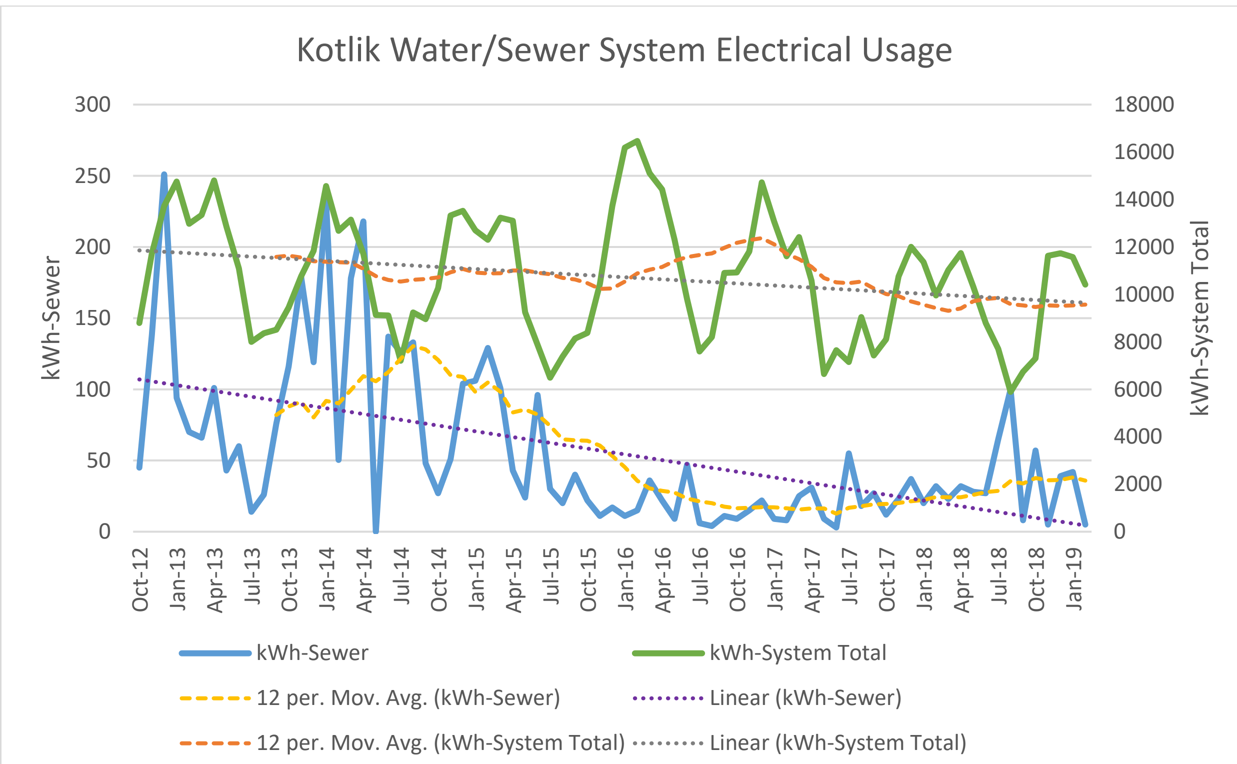
Bottom left is the completed Noorvik vacuum pump installation. Bottom right is the Kotlik installation in progress.

Kotlik

Throughout the life of this project, Kotlik experienced a reduction in total electrical energy use of 17% and reduced operating cost by 1% over 2013 levels. However, when the increased electrical rates are accounted for, and assuming the vacuum sewer system would not have experienced additional degradation, the system cost 20% less to operate than it would have if no energy efficiency upgrades were implemented.

Kotlik Findings	2013	2018	% change	Without Energy Efficiency	% Variance
Electric use	13,6765 kWh	11,4196 kWh	-17%	13,6765 kWh	20%
Electric cost	$21,750.35	$21,477.73	-1%	$25,866.25	20%
Average electric rate	$0.16	$0.19	18%	$0.19	0%

It is also worth noting that Kotlik has some of the most extensive records, which in itself indicates a high level of local ownership in the system. The training and education that was conducted alongside the implementation of the energy efficiency upgrades is easily visible in the data patterns reflected by the drastic and persistent reduction in electrical energy used to operate the vacuum sewer system as shown in the chart below.

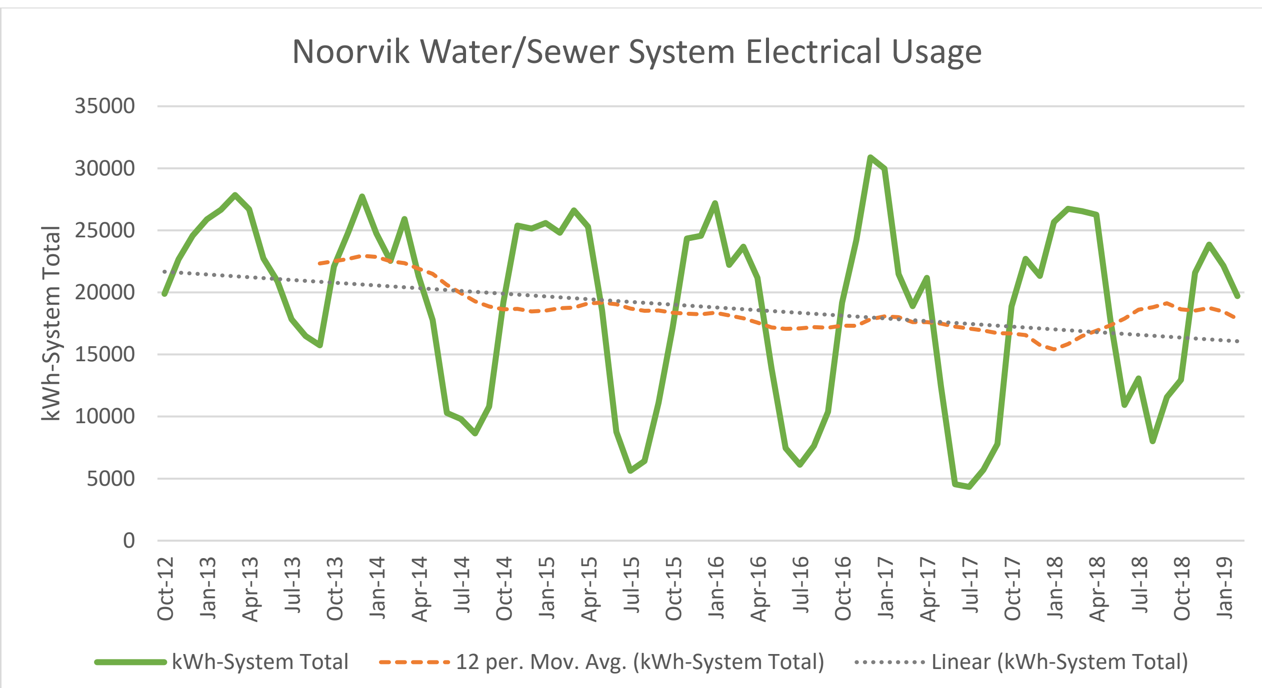


Noorvik

Noorvik experienced an overall increase of operational costs of 7%. This is due largely to the prodigious increase in the cost of electricity in the community, 34%. When this increase in the cost of energy is considered, the result of conducting these energy efficiency upgrades becomes more apparent. Assuming the system continued to use approximately the same amount of energy as it did in 2013, and assuming no further degradation of the system occurred over the five year time span being analyzed, the total cost of operating the system would have risen by 24%.

With that in mind, over a twenty year life of the system, the cost of operating it would have nearly doubled (a 96% operational cost increase). Instead, a 7% increase over five years multiplied out over a twenty year lifespan would drastically lower the expenses to a much more tenable 28% operational increase.

Noorvik Findings	**2013**	**2018**	**% change**	**Without Energy Efficiency**	**% Variance**
Electric use	275449	224966	-18%	275449	22%
Electric cost	$39,001.61	$41,813.55	7%	$51,782.72	24%
Average electric rate	$0.14	$0.19	34%	$0.19	0%



Lessons Learned

Many of the challenges associated with this project are challenges that are common to nearly all rural Alaska construction projects face; i.e. weather, limited transportation, limited barge freight window, etc. At present, the most effective tool to mitigate these challenges is the application of best practices in project management and collaborating with closely with all stakeholders

A major improvement to the sustainability of the project is funding for further training. Without sustained training, reminders, or assistance to build and reinforce the initial training provided, operators typically retreat to less effective operational norms. This results in equipment falling into disrepair, and eventual premature failure, thus leading to the projected energy savings being lost. The most critical component of any utility system is the operator. To that end, ANTHC's Utility Support Engineers and Utility Support Specialists are committed to training and working with the operators in villages all across Alaska to ensure that these systems, the people who use them, and the people who benefit from them are invested in the system's successful operation. Thus ensuring the equipment and overall system is maintained properly, and operated sustainably.

Based on reports from Utility Support Engineers that were deployed to the field, maintaining the seals on the vacuum systems is also a critical component of these systems. For example, in Kotlik the local operator(s) was thoroughly trained on the importance of maintaining a good seal on the vacuum seal which contributed to the sustained electrical cost reductions.

In rural Alaska, water and sewer connections enter the home above grade in arctic boxes; an insulated covering that prevents exterior weather from penetrating the building envelope where the water and sewer system connections enter/leave the building. One of the major weak points in any rural Alaskan sewer system, vacuum or otherwise, is the connection point. In future projects, it is recommended that tasks be included to assess and repair faults and deficiencies in these connections prior to failure. However, on individual residences this may prove to be a complex task; coordination with individual homeowners must be closely monitored to ensure the construction/implementation of upgrades to arctic box connection points has a minimum impact on the daily life of the resident(s) therein.

Pictured: Arctic box separating from structure