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ENERGY USE AND COSTS FOR OPERATING SANITATION FACILITIES IN RURAL ALASKA

A survey

October 2011

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ABSTRACT

Electricity and fuel oil are the primary energy sources for operating rural Alaskan water and sewer utility systems. These systems can consume a large percentage of community and individual financial resources. Information on the energy consumption and operating costs of these rural water and sewer utilities is not readily available. In order to better understand the costs of rural sanitation services, the Alaska Native Tribal Health Consortium (ANTHC) Division of Environmental Health and Engineering (DEHE) gathered available information by surveying various system operators and local governments.

This survey gathered information about energy use and costs for water and sewer systems in rural Alaska from the Alaska Rural Utility Collaborative (ARUC), the Alaska Village Electric Cooperative (AVEC), energy audits, and telephone surveys focusing primarily on systems in cold climates that rely on energy-intensive features. The resultant data set represents the role of sanitation systems in rural Alaska's energy situation and the impact of energy costs on the realized public health benefits of sanitary water and sewer systems. Preliminary analysis indicates the following:

- High energy costs and economic conditions in rural communities challenge the sustainability of water and sewer systems.
- A considerable percentage of a community's household income often pays for water and sewer and the largest portion of these costs goes to energy.
- Operational issues, aged infrastructure, deferred maintenance, system expansion without concern for energy use, antiquated technologies, and other conditions contribute to high energy use and costs for delivery of services.
- Energy needs vary notably between communities and system types.
- Many sanitation systems have not been audited or surveyed. Statewide energy audits are needed to build understanding of energy use and local practices.
- By utilizing energy audit findings, each water and sewer system type can realize reductions in energy use. Within the physical constraints of each system, an effective Energy Management System (EMS)¹ should be implemented. Based on fundamental engineering and operation and maintenance principles, an EMS must be unique to each system and produce measurable energy savings and cost controls.
- A set of current best-practices as well as "benchmark" standards for arctic water and sewer utility energy efficiency are needed for the wide array of design professionals and operators who work in rural Alaska.
- Waste-heat recovery efforts are effective at reducing fuel costs in all system types.
- Further study is needed on costs for individual households to maintain service from water mains to houses.

¹ An EMS addresses energy efficiency through plant design and operation. It includes monitoring of plant performance to meet design efficiency goals. EMS embraces energy consumption as a critical measure of both the water plant's and the operator's performance.

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1.0 INTRODUCTION

Rural Alaska, home to 229 Alaska Native tribes, is one of the coldest and most isolated regions in the U.S. As a result, it uses more energy than any other state and residents pay some of the highest costs per BTU² and kWh³.

Water and sewer utilities rely heavily on electricity and heating oil to provide reliable service through the cold winter months; consequently, they represent a significant percentage of each community's fuel consumption and costs. Stored water must be continually heated, usually with oil fired boilers, and circulated with electric pumps to prevent system freeze-up. Individual homeowners with water and sewer services must shoulder costs for heat tracing lines, pump unit operation, and in-home water heaters to receive the crucial health benefits of sanitary water and sewer systems.

The ANTHC vision is that Alaska Natives are the healthiest people in the world. DEHE, along with the State of Alaska's Department of Environmental Conservation, Village Safe Water program, designs and constructs sanitation projects in rural Alaskan communities in order to prevent a wide range of potentially life-threatening health problems. After construction is complete, communities are responsible for the operation and maintenance of these essential facilities. In Arctic Alaska, where the Median Household Income (MHI) is typically below \$30,000 per year, water service costs can easily exceed the EPA guideline of two and a half percent of the MHI (Mumm 2010). See Table 1: Average Annual Water and Sewer System Energy Costs, for data on costs as a portion of the MHI.

As part of an initiative to support communities in gaining the health benefits of sanitation systems despite rising energy costs, DEHE gathered data on current energy use and costs in rural Alaska. Of 188 communities in which DEHE has conducted projects, a representative sampling of 75 communities in the colder, more remote regions were surveyed, including communities served by the DEHE's Alaska Rural Utility Collaborative (ARUC)⁴ or participating in ARUC's billing assistance program. Data were collected on the fuel and electricity used to support the water and sewer utility, and data from all sources confirmed large differences among the surveyed communities. The data were analyzed by comparing effects of several variables. Each community is unique; therefore, clear trends in relationships between each variable and each system type were not present.

² **British thermal unit** is a traditional unit of energy equal to about 1,055 joules. It is approximately the amount of energy needed to heat 1 pound of water (i.e. around 0.1198 US gallons) from 39 to 40 ° F (3.8 to 4.4° C).

³ The **kilowatt hour**, is a unit of energy equal to 1000 watt hours or 3.6 megajoules. For constant power, energy in watt hours is the product of power in watts and time in hours. The kilowatt hour is most commonly known as a billing unit for energy delivered to consumers by electric utilities.

⁴ **ARUC** currently operates and manages 23 remote community water and wastewater systems under contract with the local government owners of these systems and provides billing assistance for 13 additional communities.

Data on energy consumption was broken down by four primary system types, each of which requires different amounts of energy for routine operation and maintenance:

- Circulating arctic water and vacuum sewer
- Circulating arctic water and conventional gravity sewer
- Conventional water distribution and gravity sewer
- Washeteria/watering point with honeybucket sewage disposal

DEHE examined individual systems in each category with costs noticeably higher or lower than average and found that factors affecting high energy use and costs include the system type, elevated cost of fuel due to community isolation, poor maintenance, facility age, operator training, geographical region, population, and size of the system (i.e., length of the water transmission lines).

2.0 SYSTEM TYPES

2.1 Circulating Arctic Water with Vacuum Sewer

Circulating arctic water with vacuum sewer systems use above ground pipes and/or box utilidors to convey water and evacuate sewage. These systems are exposed to cold ambient air temperature extremes and lose much more heat than buried pipes. To prevent freezing of water and sewer mains, heat is added to the water and is circulated from a central facility. These systems also rely on a vacuum sewage conveyance pipe. Figure 1 depicts a typical circulating water and vacuum sewer system and Figure 2 provides a photo of a utilidor.

Although vacuum systems are effective, they require large amounts of energy, particularly when operating in winter mode. Heat must be added to maintain a water temperature of 38 to 40 degrees Fahrenheit. Water must be circulated throughout the community and to individual homes.

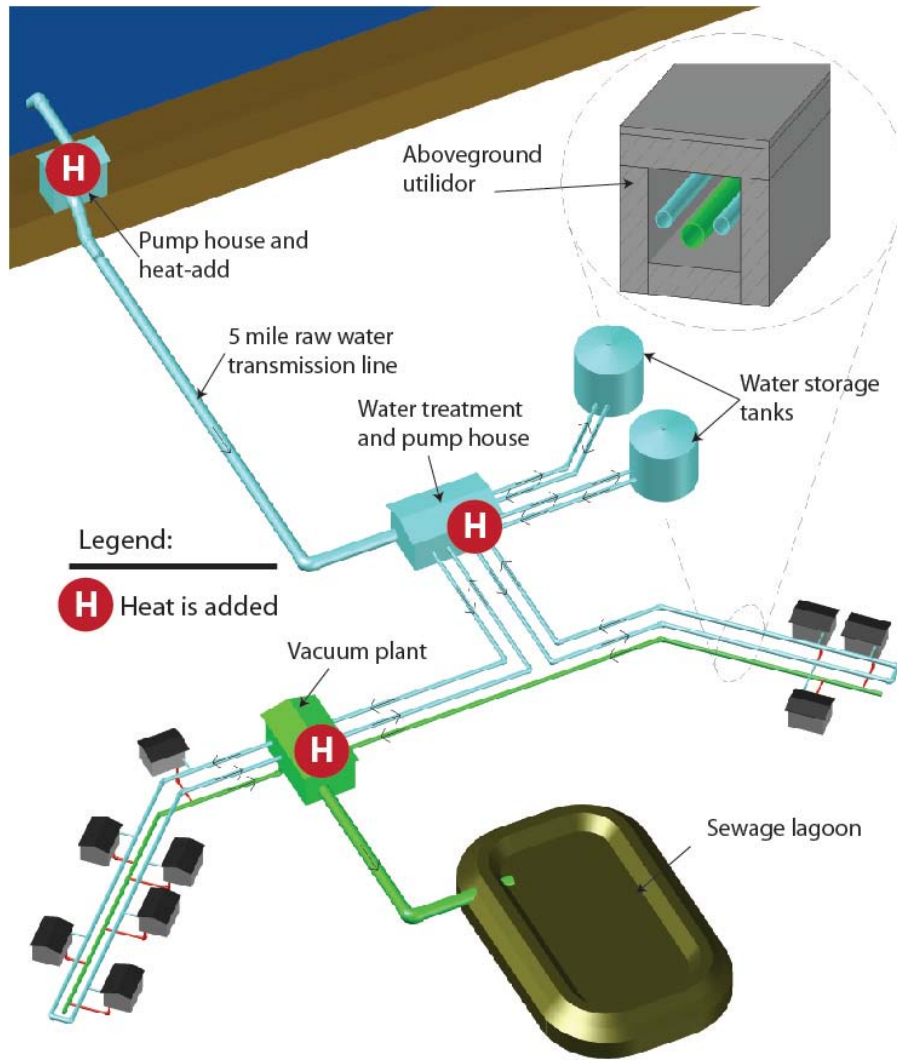


Figure 1: Schematic Diagram of a Typical Water and Vacuum Sewer System with Utilidor



Figure 2: Photo of Existing Circulating Water and Vacuum Sewer Main within Utilidor

2.2 Circulating Arctic Water with Gravity Sewer

A circulating arctic water and gravity sewer system uses direct-buried insulated water and sewer pipe. Heat is added to the water at a central pump house and water mains are circulated to prevent freezing during the winter months using pit orifices⁵, circulation pumps, extended mains, or other strategies.

2.3 Conventional Water and Gravity Sewer System

A conventional water and gravity sewer system uses non-insulated pipe buried below the frost line. Water is pressurized for distribution, but is not circulated and heated. Instead, individual households may have to use electric heat tape for their water service during the colder months of the year. In these cases, the individual residents face a higher cost burden.

2.4 Washeteria with Watering Points

A central washeteria provides the only safe watering point and laundry facility for a community. Residents must obtain water from the watering point, haul sewage from their homes via honeybucket, and visit the washeteria to use showers, washing machines, and dryers. Although washeterias provide key sanitation services that communities would otherwise lack, they provide a much lower public health benefit than fully piped systems. These facilities require large amounts of energy to treat water, heat water for facility use, and operate high-temperature hydronic dryers.

3.0 ENERGY SURVEY METHODS

This survey sought to collect representative fuel and electricity consumption records over the longest period of time possible. Data were typically available for the period between 2009 and 2011. The four primary sources accessed to compile the data for this survey include the ARUC, electrical meter readings, energy audits, and telephone surveys.

3.1 Alaska Rural Utility Collaborative

ANTHC currently manages ARUC, which provides management and operation services for water and sewer systems in 23 communities and billing assistance services in an additional 13 communities. ARUC receives monthly records of fuel use, water production, and electricity consumption for water and sewer facilities in these communities.

3.2 Electrical Meter Readings

The Alaska Village Electric Cooperative (AVEC) provided electrical meter data for 53 communities in rural Alaska, including information for the entire

⁵ A **pit orifice** is a device used to keep water flowing between water mains and service lines.

community and for specific water and sewer facilities. For non-AVEC communities, electrical meter readings and costs were given to ANTHC by the community contact person.

3.3 Energy Audits

To date, energy audits have been completed for five rural Alaskan communities. These energy audits gathered information on a number of community buildings, including water and sewer facilities, through extensive monitoring and onsite observations. The audits' primary objective was to make recommendations for reducing energy use and costs. The audits relied on the collection of accurate energy consumption records, which were used when available. An additional 32 energy audits are currently ongoing.

3.4 Telephone Surveys

Finally, telephone surveys conducted in June and July 2011 gathered information for the remaining communities that did not have data available through the first three methods. A majority of the fuel data for non-ARUC communities was obtained this way. When possible, the city or Tribal office provided electronic records, but more often, the city clerk or water plant/washeteria operator provided an estimate due to the lack of recorded data. Appendix B presents the data obtained from the telephone surveys.

3.5 Research Challenges

The most reliable sources of energy use data were ARUC and AVEC. The energy audits also provided an accurate, albeit partial, overview of the energy situation because of their relatively short timeframe and the limited number of communities that have been audited to date. Outside of these sources, it is difficult to find accurate fuel consumption records for most water and sewer utilities in rural Alaska.

In addition, city and/or tribal entities generally operate multiple facilities and purchase fuel for a variety of buildings and vehicles, as well as individual users. Because these entities do not usually account for individual building energy use, and fuel metering is very rare, tank gauging and delivery records are often the only records available. This reality limits the potential accuracy of an analysis derived from community-reported data and independent verification of these numbers has not been performed.

Nevertheless, the composite picture provided by these four sources makes it clear that water and sewer system energy cost and consumption is an urgent issue in rural Alaska. Further analysis of more accurate information, which is crucial to understanding the energy situation in each community and to providing necessary solutions, will require more extensive energy audits in terms of both locations and time periods. Energy needs vary greatly based on weather extremes, delivery

challenges, cost of fuel, boiler efficiency, operation and maintenance variables, water system operating set points, water use, and many other factors.

4.0 ENERGY SURVEY FINDINGS

Survey data clearly demonstrates the known energy situation in rural Alaska. Table 1 presents average data for each system type, broken down into types of energy and categories of payers.

Parameter	Circ/Vac	Circ/Grav	Washeteria	System Type Conventional
Low total energy \$ per capita	\$180	\$81	\$69	\$30
Average total energy \$ per capita	\$345	\$252	\$310	\$115
High total energy \$ per capita	\$618	\$919	\$786	\$108
Low fuel \$ per capita	\$25	\$25	\$20	\$6
Average fuel \$ per capita	\$115	\$153	\$225	\$37
High fuel \$ per capita	\$247	\$640	\$610	\$98
Low subsidized elect \$ per capita	\$31	\$8	\$3	\$27
Average subsidized elect \$ per capita	\$103	\$46	\$40	\$42
High subsidized elect \$ per capita	\$193	\$195	\$79	\$18
Low total energy \$ per household	\$718	\$354	\$255	\$292
Average total energy \$ per household	\$1494	\$884	\$1148	\$316
High total energy \$ per household	\$2782	\$3860	\$2750	\$87
Low % MHI for energy	2.5%	1.1%	1.0%	0.3%
Average % MHI for energy	4.8%	3.8%	3.5%	1.1%
High % MHI for energy	10.4%	12.0%	7.5%	0.2%
Average community fuel cost	\$72,910	\$51,292	\$86,332	\$4,933
Average community share of elect cost	\$65,535	\$15,536	\$15,463	\$5,672
Average PCE share of elect cost	\$80,259	\$20,641	\$16,928	\$4,827
Low w/s energy cost per community	\$85,799	\$15,069	\$35,914	\$570
Average w/s energy cost per community	\$218,703	\$87,468	\$118,723	\$15,431
High w/s energy cost per community	\$517,527	\$269,510	\$223,187	\$4893

Table 1: Average Annual Water and Sewer System Energy Costs

Figure 3 presents preliminary data gathered from ARUC in 2010 for eight communities' total energy costs devoted to water systems. In each, water systems require a significant percentage of the total energy consumed by the community. In some cases, water systems actually represent up to a third of total community energy costs. The data in Figure 3 provided the impetus for this survey study, which confirmed the preliminary assessment that the energy situation in rural Alaska is serious.

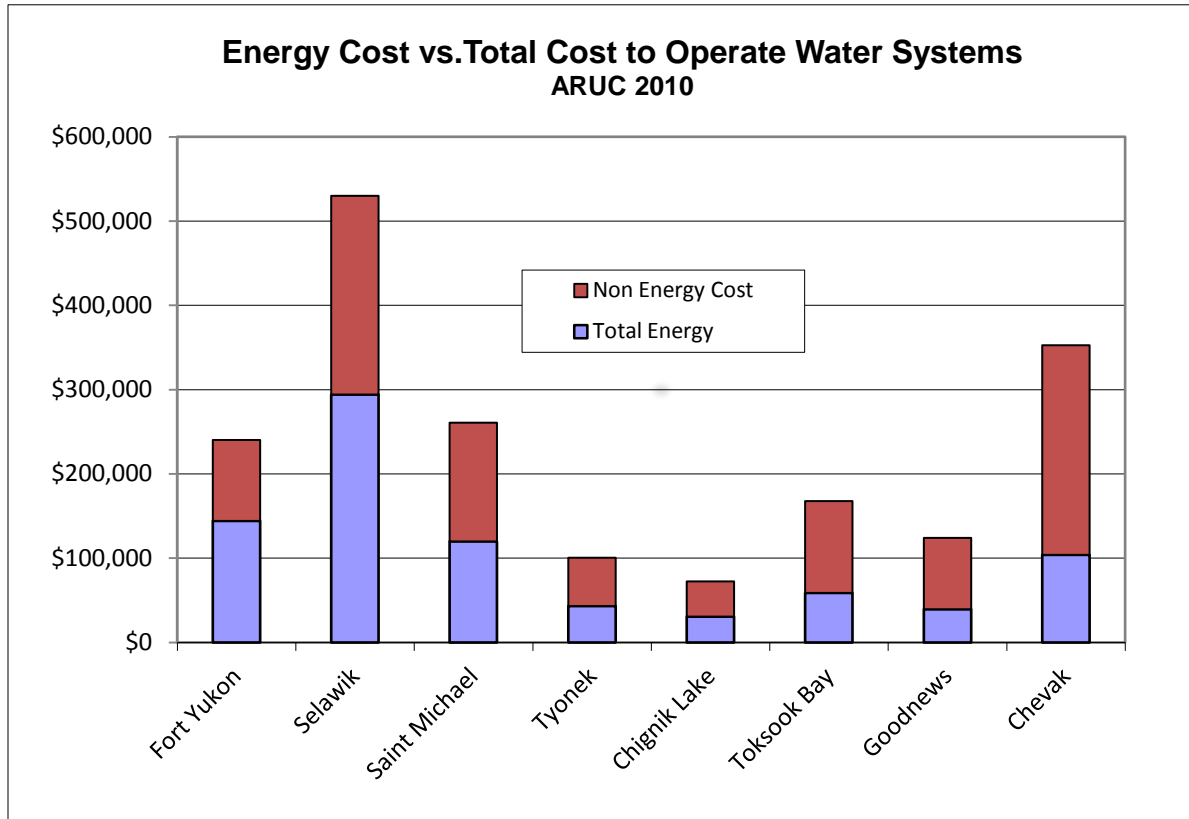


Figure 3: Portion of Community Energy Costs for Water Systems

Figure 4 presents the average annual energy cost to operate each water system type and breaks each down by the community's cost for fuel, the community's cost for electricity, and the Power Cost Equalization (PCE)⁶ subsidy for the electrical cost.

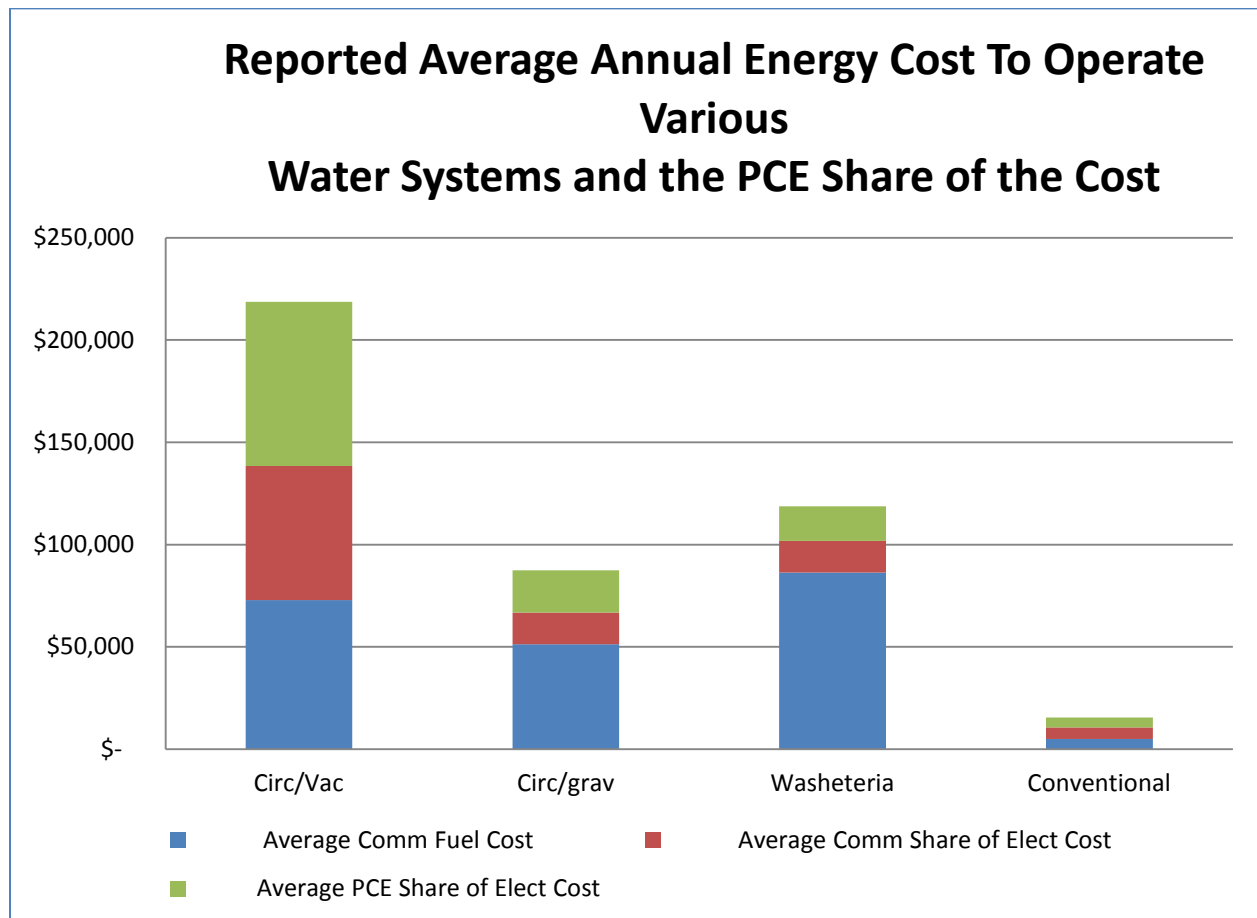


Figure 4: Average Annual Water System Energy Costs with Community Fuel Cost, Community Electrical Cost, and PCE Electrical Cost

⁶ **Power Cost Equalization (PCE)** is a subsidy from the State of Alaska to residential utility customers in rural Alaska. The point of PCE was originally to help "equalize" power costs between rural and urban areas of the state following massive investment in urban power-producing infrastructure without a commensurate investment in rural power generation.

Figure 5 presents the costs to individual households and on a per capita basis for water and sewer systems.

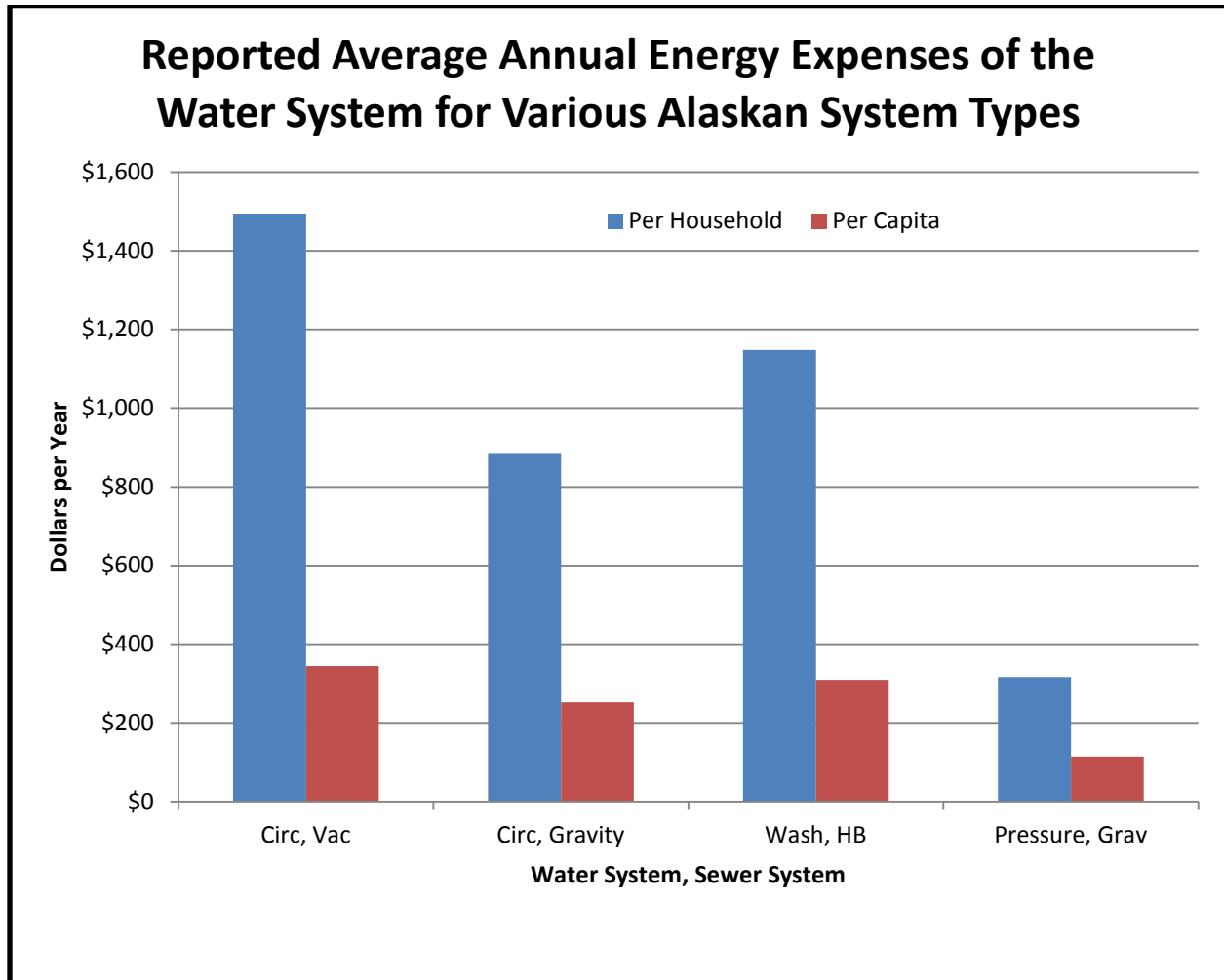


Figure 5: Average Annual Water and Sewer System Energy Costs for Consumers

5.0 OBSERVATIONS

While energy for water and sewer systems is expensive across the State of Alaska, analysis of data from the four system types makes it clear that there are significant differences in energy use and costs between system types and between communities within each system type. Even after normalizing energy costs for the number of service connections or per capita, severe disparities exist between types and communities. As expected, the aboveground circulating water with vacuum sewer systems were the highest energy users on average. Somewhat surprisingly, washeterias with watering points were the second highest energy users per capita, on average.

Overall, costs must be reviewed in the context of levels of service to accurately assess the energy reality in rural Alaska. For example, costs associated with an arctic water and

sewer system, such as in Brevig Mission, cannot be directly compared to the costs of a washeteria as a measure of affordability, because the systems provide different services. For Brevig Mission, the cost reported is for the community to provide water and sewer service to individual homes. Washeteria costs cover water treatment as well as washing machines, dryers, sinks, toilets, showers, and sometimes saunas to customers. A homeowner in Brevig Mission would pay the community utility for monthly water and sewer service and would also pay for household electricity and fuel, operation of domestic hot water heaters, heat tapes, laundry appliances, small circulation pumps, and other needs.

Water consumption patterns vary between system types. For instance, a vacuum sewage system uses significantly less water than a conventional system, primarily due to low water use fixtures and the fact that utilidor leaks are far easier to detect and fix than those in a buried pipe. As a result, general comparisons of affordability must take into account numerous factors beyond items such as costs per kWh.

Additionally, some water and wastewater systems had low fuel oil consumption. These systems also had functioning heat recovery systems. The obvious conclusion is that heat recovery efforts were displacing fuel oil use. The typical waste-heat systems found were capturing heat from the power plant cooling system through a liquid-to-liquid heat exchanger.

6.0 CONCLUSIONS

Given the preliminary data gathered from ARUC, AVEC, energy audits, and telephone surveys, some general conclusions about energy use and costs can be made for community-wide water and sewer service.

- Reduced energy use and costs can be achieved for all systems through improved design and operational features, including operation and maintenance activities focusing on energy conservation.
- Combined circulating arctic water and vacuum sewer systems have significant energy use and costs.
- Waste-heat recovery systems are effective at reducing fuel costs in all systems.
- Large cost savings from heat recovery systems are also possible for washeterias.
- Circulating arctic water and gravity sewer systems are also high in energy use and costs due to energy required to operate them and maintain circulation.
- Buried systems require less energy to prevent freezing than aboveground systems.
- Conventional water and sewer systems, as expected, have the lowest costs for fuel and for energy use. However, communities with these systems would still benefit from energy efficiency improvements.

- Operational improvements as described in energy audits can dramatically reduce energy use. Although tools and techniques are readily available to accomplish this, funding for implementation is usually not readily available.
- Within each system category, a wide range of energy use and costs is observed; this reflects the unique features community systems have due to location, system condition, outdoor air temperatures, fuel and electrical rates, operation and maintenance costs, size, and original design.
- Energy audits provide reliable energy consumption data. Recommendations based on traditional methods for reducing energy can produce substantial savings, and operational parameter changes or the use of new technology can have even greater impacts.
- While this survey provides preliminary data on community costs, further study is needed on individual household costs for items such as electric heat tapes and water pumping, which are necessary to maintain service from water mains to houses. Water wasting to prevent freeze-ups is a recognized problem that significantly increases costs to the community facility. Proposed solutions must recognize that when water circulates between households and facilities, providers and users are interdependent.

7.0 RECOMMENDATIONS

Energy costs are becoming an urgent crisis in rural Alaska. They could ultimately prevent communities from using their water and sewer systems and therefore have a serious impact on the health of residents. As DEHE continues to gather data on Alaska rural energy use and costs, it is imperative that stakeholders begin to concentrate on causes of high energy consumption and potential interventions to reduce it. Fuel oil cost is subject to market forces and somewhat out of the control of the community, but how energy is used is subject to local control and management. Recent energy audit findings identify operational and system improvements that will result in relatively immediate cost savings. Through increased awareness and oversight of energy management and application, communities can greatly reduce energy use and costs. The following are recommendations based on this survey:

- This survey is the start of an important initiative to define the challenges to the sustainability of rural water and sewer systems. A better understanding of energy use and costs will enable rural communities to take advantage of energy conservation technologies and practices. Therefore, DEHE plans to conduct telephone and onsite surveys of households to assess water and sewer costs for in-home services and support communities in taking the next steps towards energy efficiency.
- Detailed energy audits should be conducted starting with the most apparent high energy users in Arctic areas of Alaska. Audit recommendations should be

implemented. Depending on the cost of these improvements, state, federal, or other grant or loan support will likely be needed.

- Fuel use should be strictly monitored and properly accounted for to reduce the unintentional waste that tends to occur. Although fuel costs will continue to escalate over time, with foresight, the impacts of higher energy costs can be mitigated.
- Operational data can be enhanced through remote monitoring and better achieved through energy efficiency awareness.
- Minimizing water system heat loss will reduce the demand for fuel and potentially reduce pumping and heat tape electrical costs.
- A “best practices” guide to achieving optimum energy efficiency for new designs and best-practice solutions for upgrades and operation of aging infrastructure must be developed for those who work with arctic systems.
- A “benchmark” standard for arctic water and sewer utility energy efficiency, shared by all design and operations professionals should be developed, since the current standard is the EPA guideline that the water operational cost should not exceed two and a half percent of the community’s Median Household Income (MHI) for the system to be affordable and sustainable.
- Each water and sewer system type can realize reductions in energy use. Within the physical constraints of each system, an effective EMS should be implemented. An EMS is unique to each system, is based on fundamental engineering and operation and maintenance principles, and produces measurable energy savings and cost controls. The EMS must include a focus on water system operator training for energy efficiency and remote monitoring to ensure proper operation.

APPENDIX A: COMMUNITIES SURVEYED

Akiak	Grayling	Napaskiak	Scammon
Akutan	Holy Cross	Nenana	Selawik
Alakanuk	Hooper Bay	New Stuyahok	Shageluk
Ambler	Huslia	Newhalen	Shaktoolik
Anvik	Igiugig	Newtok	Shishmaref
Atmautluak	Kaltag	Noatak	Shungnak
Brevig Mission	Kasaan	Noorvik	Sleetmute
Buckland	Kiana	Nulato	South Naknek
Chefornak	Kivalina	Nunam Iqua	Stebbins
Chevak	Kobuk	Nunapitchuk	Tanacross
Chignik Lagoon	Kokhanok	Old Harbor	Togiak
Chignik Lake	Kwethluk	Ouzinkie	Toksook Bay
Eek	Larsen Bay	Pitka's Point	Tuluksak
Elim	Lower Kalskag	Quinhagak	Tunututliak
Emmonak	Manokotak	Russian Mission	Tyonek
Gambell	Marshall	Saint Mary's	Wales
Golovin	Mekoryuk	Saint Michael	White Mountain
Goodnews Bay	Mountain Village	Savoonga	

APPENDIX B: WATER AND SEWER SYSTEM ENERGY USE SURVEY DATA

Community	Population	Water	Sewer	Reported avg elec use (kWh)	Total electrical costs	Reported fuel use (gal)	2010 heating fuel price	Total heating fuel cost	Fuel data source	Electrical data source
Akiak	346	Circ	Gravity	74,741	\$ 47,087	2,000	\$5.00	\$10,000	ARUC	ARUC
Akutan	1,003	Individual	Individual	9,916	\$ 3,203	1,163	\$3.95	\$4,592	City	City
Alakanuk	677	Circ	Vac	348,000	\$ 179,916	2,800	\$6.11	\$17,108	AEA	City
Ambler	258	Circ	Gravity	151,546	\$ 81,532	32,400	\$5.10	\$165,240	ARUC	City
Anvik	85	Circ	Gravity	11,351	\$ 7,174	3,817	\$5.15	\$19,657	ARUC	AVEC
Atmautluak	277	Wash	HB	65,961	\$ 46,106	7,500	\$5.53	\$41,475	ARUC	energy Audit
Brevig Mission	388	Circ	Gravity	110,897	\$ 57,999	4,518	\$9.58	\$43,282	ARUC	ARUC
Buckland	416	Haul	Haul	78,240	\$ 50,465	3,860	\$5.50	\$21,227	WTP Op	City
Chefornak	418	Wash	HB	7,658	\$ 3,446	6,000	\$9.49	\$56,940	ARUC	ARUC
Chevak	938	Circ	Vac	208,349	\$ 109,591	21,046	\$6.12	\$128,800	ARUC	AVEC
Chignik Lagoon	78	Pressure	Individual	14,749	\$ 5,899	3,067	\$5.50	\$16,866	ARUC	City
Chignik Lake	73	Pressure	Individual	23,044	\$ 4,332	750	\$4.85	\$3,638	ARUC	City
Eek	296	Wash	HB	39,205	\$ 20,387	2,110	\$6.02	\$12,699	energy Audit	PCE Data
Elim	330	Circ	Gravity	52,960	\$ 28,757	4,568	\$4.50	\$20,558	City	City
Emmonak	762	Circ	Vac	82,621	\$ 41,311	21,000	\$7.60	\$159,600	City	AVEC
Gambell	681	Circ	Gravity	169,392	\$ 86,051	5,858	\$5.56	\$32,570	City	City
Golovin	156	Circ	Gravity	35,621	\$ 20,304	16,314	\$4.79	\$78,144	ARUC	ARUC
Goodnews Bay	243	Pressure	Gravity	72,089	\$ 34,242	2,615	\$4.95	\$12,942	ARUC	AVEC
Grayling	194	Circ	Gravity	55,019	\$ 30,315	20,720	\$6.01	\$124,527	AEA	AVEC
Holy Cross	178	Circ	Gravity	52,263	\$ 29,006	2,995	\$5.90	\$17,668	City	AVEC
Hooper Bay	1,093	Wash	HB	204,731	\$ 105,232	37,180	\$3.13	\$116,373	energy Audit	ARUC
Huslia	275	Circ	Gravity	48,658	\$ 24,815	17,798	\$6.00	\$106,785	City	AVEC
Igiugig	50	Circ	Gravity	15,758	\$ 12,654	486	\$5.22	\$2,537	ARUC	ARUC
Kaltag	190	Circ	Gravity	6,695	\$ 3,608	7,845	\$5.15	\$40,402	City	ARUC
Kasaan	49	Pressure	Gravity	1,416	\$ 302	14,550	\$3.18	\$46,269	City	AVEC
Kiana	363	Circ	Gravity	122,551	\$ 72,795	6,985	\$5.60	\$39,116	ARUC	ARUC
Kivalina	374	Wash	HB	54,425	\$ 30,260	20,441	\$8.06	\$164,754	City	City

Community	Population	Water	Sewer	Reported avg elec use (kWh)	Total electrical costs	Reported fuel use (gal)	2010 heating fuel price	Total heating fuel cost	Fuel data source	Electrical data source
Kobuk	151	Circ	Gravity	97,196	\$ 84,561	13,904	\$3.90	\$54,226	ARUC	AVEC
Kokhanok	170	Pressure	Gravity	17,989	\$ 16,190	3,600	\$4.50	\$16,200	Village	ARUC
Kongiganak	439	Wash	HB	66,000	\$ 36,300	36,899	\$5.61	\$207,003	WTP Op	ARUC
Kotlik	577	Circ	Vac	186,028	\$ 96,176	4,354	\$6.89	\$29,999	ARUC	AVEC
Koyuk	332	Circ	Gravity	79,081	\$ 42,466	16,000	\$5.15	\$82,400	City	Village
Koyukuk	96	Wash	HB	16,104	\$ 7,247	5,551	\$3.97	\$22,036	City	AVEC
Kwethluk	721	Wash	HB	56,344	\$ 29,299	3,000	\$4.85	\$14,550	City	AVEC
Larsen Bay	87	Pressure	Gravity	39,160	\$ 16,056	21,105	\$7.20	\$151,956	City	ARUC
Lower Kalskag	282	Circ	Gravity	68,519	\$ 35,561	3,645	\$5.59	\$20,376	ARUC	TCSA
Manokotak	442	Circ	Gravity	60,606	\$ 33,333	3,294	\$4.55	\$14,990	City	ARUC
Marshall	414	Circ	Gravity	74,082	\$ 34,152	2,417	\$4.27	\$10,321	City	AVEC
Mekoryuk	191	Haul	Haul	28,469	\$ 16,455	1,812	\$5.23	\$9,477	City	Util Co
Mountain Village	813	Circ	Gravity	33,372	\$ 16,886	10,224	\$4.75	\$48,564	ARUC	ARUC
Napaskiak	405	Haul	Haul	37,095	\$ 10,238	9,000	\$5.46	\$49,140	City	City
Nenana	378	Circ	Gravity	205,377	\$ 42,513	11,363	\$4.47	\$50,794	energy Audit	energy Audit
New Stuyahok	510	Circ	Gravity	55,153	\$ 35,188	37,180	\$6.26	\$232,747	WTP Op	energy Audit
Newhalen	190	Circ	Gravity	34,909	\$ 20,875	17,236	\$5.00	\$86,181	ARUC	AVEC
Newtok	354	Wash	HB	1,902	\$ 1,522	4,415	\$6.19	\$27,326	WTP Op	AVEC
Noatak	514	Circ	Gravity	131,974	\$ 105,183	878	\$5.57	\$4,888	Village	City
Noorvik	668	Circ	Vac	215,185	\$ 122,440	13,227	\$6.17	\$81,611	AEA	energy Audit
Nulato	264	Circ	Gravity	142,627	\$ 72,455	9,125	\$4.75	\$43,344	City	AVEC
Nunam Iqua (uses waste heat from PP)	187	Circ	Vac	139,339	\$ 73,850	1,850	\$5.92	\$10,952	WTP Op	ARUC
Nunapitchuk	496	Haul	Haul	3,800	\$ 1,930	635	\$6.15	\$3,905	City	AVEC
Old Harbor	218	Pressure	Gravity	53,337	\$ 28,109	8,282	\$5.19	\$42,985	City	ARUC
Ouzinkie	172	Pressure	Gravity	8,924	\$ 3,213	13,403	\$5.90	\$79,075	City	ARUC
Pitka's Point	109	Wash	HB	40,237	\$ 19,193	9,228	\$7.20	\$66,442	ARUC	ARUC
Quinhagak	669	Circ	Pressure	95,990	\$ 48,475	5,915	\$3.43	\$20,288	ARUC	City
Russian Mission	312	Circ	Gravity	34,914	\$ 17,352	2610	\$3.95	\$10,310	ARUC	ARUC

Community	Population	Water	Sewer	Reported avg elec use (kWh)	Total electrical costs	Reported fuel use (gal)	2010 heating fuel price	Total heating fuel cost	Fuel data source	Electrical data source
Saint Mary's	507	Circ	Gravity	106,319	\$ 50,714	4,593	\$6.18	\$28,385	ARUC	ARUC
Savoonga	671	Circ	Vac	163,987	\$ 70,842	7,637	\$6.50	\$49,641	ARUC	ARUC
Scammon Bay	474	Circ	Gravity	41,655	\$ 22,119	5,610	\$5.79	\$32,482	ARUC	AVEC
Selawik	829	Circ	Vac	734,410	\$ 422,286	15,595	\$5.79	\$90,295	ARUC	Village
Shageluk	83	Wash	HB	22,240	\$ 12,832	6,000	\$5.65	\$33,900	energy Audit	TCSA
Shaktoolik	251	Circ	Gravity	40,092	\$ 21,730	4,494	\$5.62	\$25,256	ARUC	ARUC
Shishmaref	563	Haul	Haul	27,990	\$ 15,758	568	\$3.47	\$1,970	City	City
Shungnak	262	Circ	Gravity	50,855	\$ 32,750	550	\$6.75	\$3,713	WTP Op	Village
Sleetmute	86	Circ	Gravity	29,947	\$ 21,831	5,000	\$4.88	\$24,400	City	PCE Data
South Naknek	79	Pressure	Gravity	6,494	\$ 3,344	20,720	\$5.65	\$117,068	ARUC	AVEC
St. Michael	401	Circ	Vac	225,881	\$ 108,875	11,000	\$8.99	\$98,890	ARUC	AVEC
Stebbins	556	Wash	HB	46,764	\$ 25,206	2,438	\$5.46	\$13,314	City	ARUC
Tanacross	136	Circ	Gravity	42,480	\$ 15,803	2,623	\$5.60	\$14,689	City	AVEC
Togiak	817	Circ	Gravity	8,127	\$ 4,632	12,056	\$5.17	\$62,327	WTP Op	AVEC
Toksook Bay	563	Circ	Gravity	93,975	\$ 46,517	8,213	\$5.50	\$45,169	City	City
Tuluksak	373	Wash	HB	37,237	\$ 22,342	4,150	\$7.98	\$33,117	ARUC	AVEC
Tuntutuliak	408	Haul	Haul	15,487	\$ 10,067	3,817	\$6.92	\$26,413	Village	ARUC
Tyonek	177	Pressure	Gravity	45,360	\$ 4,990	4,525	\$5.00	\$22,625	ARUC	ARUC
Wales	145	Wash	HB	10,785	\$ 6,341	7,265	\$4.03	\$29,278	WTP Op	Util Co
White Mountain	190	Circ	Gravity	44,553	\$ 32,078	4,180	\$5.52	\$23,074	Util Co	City

APPENDIX C: WORKS CITED AND RECOMMENDED READING

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