ACEP
Alaska Center for Energy and Power

UNIVERSITY OF ALASKA FAIRBANKS

Organic Rankine Cycle technology uses an organic fluid with a boiling point lower than that of water to convert the waste heat from diesel generators into electricity.

Organic Rankine Cycle Technology Briefing

Diesel generators are the main source of electricity in remote Alaska communities. The best systems convert roughly 40% of diesel fuel energy content into electricity, with the remaining energy converted to heat. If not captured by heat recovery devices, this heat is lost into the atmosphere through exhaust and cooling systems. When it is not practical to use engine waste heat for space or domestic water heating, this heat energy can be used to generate additional electricity through organic Rankine cycle (ORC) technology.

An ORC uses an organic fluid with a boiling point lower than that of water to convert the waste heat from the cooling jackets and exhaust stacks of generators into mechanical work and, ultimately, electricity. Exhaust stack gases can be very hot (over 1000°F), while cooling jacket water is lower temperature (as low as 165°F). The ORC is utilized as a waste heat to power (WHP) system to generate electricity that is supplied to the grid.

Current Installations in Alaska

Four different models of ORC generators have been or are being installed in different parts of Alaska, as summarized in the following table:

Organic Rankine Cycle has the potential to lower energy costs by converting waste heat from diesel generators into heat. However, the technology is best suited for communities with at least 1 MW of diesel generation.

ACEP Organic Rankine Cycle Projects

Green Machine Project

Tanana Chiefs Council ORC Project

Fuel Use Variability Study

Pilgrim Hot Springs Project

Learn more on our website at uaf.edu/acep

Location	Manufacturer	Model	Heat Source	Cold Source	Nameplate Capacity (kw)	Number of units	Total Capacity (kW)
Cordova	Pratt & Whitney	PureCycle 280	Cooling Jacket	Air Coil	260 kW	1	260 kW
Kotzebue	Energy Concepts	Ammonia Power Cycle	Exhaust Stack	City Water & Air Cooler	162 kW	1	162 kW
Unalaska	ElectraTherm	Green Machine	Cooling Jacket	Sea Water	50 kW	3	150 kW
Tok	ElectraTherm	Green Machine Block 1	Cooling Jacket	Well Water	50 kW	1	50 kW

Organic Rankine Cycle

Key Performance Metrics

Capacity factors range from 33-52% for existing installations; Kotzebue's ORC installation is still in progress. In Unalaska, the low amounts of waste heat can be attributed to low utilization levels of the system rather than inefficient ORC operation. The Tok system is a prototype model that is not yet commercially available, which may account for the same issue. While operation and maintenance costs vary, each installation has achieved significant annual fuel savings: $70,000 in Unalaska and a projected annual savings of over $300,000 for the Cordova installation.

The ORC unit itself accounts for one-third to one-half of total capital costs, indicating that Alaska projects should expect total capital expenditures to be two to three times the cost of the ORC unit itself. Shipping makes up less than 10% of the cost in all installations.

A 20-year design life is the industry standard for commercial ORC generators, although of the installations in Alaska, only the Unalaska Green Machines have achieved reliable operation beyond a few weeks.

Organic Rankine cycle generators are most efficient with higher-temperature waste heat sources. Choice of working fluid is also a factor in efficiency. All ORC units in Alaska use either R-245fa (pentafluoropropane) or ammonia.

Technology Trends

New ORC systems are being developed to utilize more efficient working fluids better suited to particular waste heat source temperatures. An ORC offers the potential to combine multiple waste heat sources of different qualities or to incorporate solar thermal and biomass heat sources.

Technology Gaps & Barriers to Success

Some systems have been highly reliable and cost-effective, while other installations have not been. An entire ORC project can be expected to run 200–300% of the ORC system cost to cover shipping, infrastructure, and labor. Modifying existing generation for an ORC system can be highly challenging, and in some cases, the ORC system may be best implemented with a ground-up new generator design. The smallest reliable system, which operates in Unalaska, has a 50 kW nameplate capacity. ORC systems of this size require 500 kW of heat, meaning the diesel generator needs to have a 700 kW nameplate at bare minimum. Based on current demonstrated ORC performance, this technology is best suited for communities with waste heat streams of 1 MW or more of diesel generation.

Capturing exhaust heat from diesel generators allows elevated cycle temperatures, but may conflict with tightening emissions restrictions, as heat exchangers can interfere with exhaust composition. It can also be difficult to get performance guarantees from ORC manufacturers. Installations that are more efficient require approved rate adjustments to recover debt and cost; however, rate proceedings are very expensive and time-consuming.

Recommendations

With the state's power cost equalization formula relying on gallons of diesel burned, it can create a disincentive for offsetting diesel consumption. Uncertainty over the effect of exhaust stream heat recovery on emissions and the progression of EPA emissions requirements pertaining to rural diesel generators further discourages investment in ORC projects. The State of Alaska or Alaska Economic Development Council could insist that the EPA provide clarity and accommodations on emissions to create an environment conducive to such investments. Current powerhouses are trying to make engines more efficient with decreased emissions and rates for customers; however, as emissions laws are toughened, utilities are not seeing real returns on their capital investments in these projects. An incentive is recommended, along with a simplification in the rate-making process.

UNIVERSITY OF ALASKA FAIRBANKS · ACEP Alaska Center for Energy and Power · ALASKA ENERGY AUTHORITY

For the full report visit www.uaf.edu/acep

For more information on ORC contact

Alaska Center for Energy and Power at (907) 474-5402;

Alaska Energy Authority — www.akenergyauthority.org

November 10, 2017