DOYON
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Fort Wainwright Heat and Power Study

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Nicholas Janssen, PE, PhD

Utilities Engineer

njanssen@doyonutilities.com

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I. Executive Summary

Current assets for heat and power generation and distribution at Fort Wainwright, Alaska (FWA) are owned and operated by Doyon Utilities, LLC under federal contract. These assets have provided heat, power, and freeze protection for mission-critical utilities for more than 60 years. Though many of the system components have been upgraded, some of these assets are at or near the end of their useful life. As such, there is currently discussion between DU and the US Army about their economic viability and strategic condition. The present study discusses their capabilities, condition, and suitability for the application(s) to which they serve. It is demonstrated that the methods of co-generation that have been employed historically are a good fit for the current demand profiles at Fort Wainwright and that resilience and cost-effectiveness are best realized in the continued investment in current generation and distribution infrastructure.

II. Current Assets for Heat Supply

Fort Wainwright has a Central Heat and Power Plant (abbreviated as CHPP) and a Heat Distribution System (HDS). The CHPP, installed in 1953, is a coal-fired power plant that generates steam and electricity to meet the heating and electricity demands of the post. The CHPP is a combined heat and power plant, abbreviated in the power industry as “CHP.” It is recognized that “CHPP” and “CHP” can be confused, therefore this explanation is given to assist understanding. The coal currently combusted in the plant is subbituminous coal, provided by rail from the Usibelli Coal Mine in Healy, Alaska. The CHPP currently uses a General Electric GE PAC8000 control system that replaced a Westinghouse Distributed Control System (WDPF) that had been in service since 1996.

A. Generation

The CHPP has six identical coal stoker boilers each rated for 480 pounds per square inch gage (psig) and 700°F, delivering 150,000 pounds per hour (lb/h) superheated steam at 435 psig and 650°F. The design boiler efficiency at maximum continuous rating is 81.2%. Flue gas is filtered through baghouses before being exhausted through the stack.

The CHPP has three 6 MW condensing steam turbine generators (STG) and one 4 MW backpressure unit currently being rebuilt and placed into service in February 2020. Condensing turbines operate at 425 psig with controlled extraction to supply steam to the HDS at 80 psig. STG exhaust steam is condensed in the outdoor air-cooled condenser (ACC).

B. Heat Distribution

The heat distribution system (HDS) is an underground steam distribution utility corridor, or “utilidor” system that also includes some direct buried piping. Utilidors are typically an underground concrete tunnel with cast-in-place reinforced concrete floor and walls and pre-cast reinforced concrete top. Utility systems within the utilidors network include steam supply and condensate return piping with condensate pumps, steam traps, pressure reducing valves, and expansion joints. Potable water and wastewater are also routed through the utilidors. The utilidors rely on heat loss from the steam lines to provide freeze protection of all piping systems. The steam system has 24-inch and 16-inch steam mains supplying 80 psig steam at 450°F from the CHPP. Most steam and condensate pipes are installed inside the utilidor. A small portion of the steam system is direct buried. Most of the system was built in the early 1950s, with numerous upgrades and additions over the years. The original steam system had asbestos insulation. When upgrades have been made to the system the old asbestos insulation is abated and replaced by non-asbestos insulation. The HDS consists of approximately 28.6 linear miles of utilidors. Additionally, there are an estimated 5.9 miles of direct-buried steam piping and 6.4 miles of direct-buried condensate piping. It is estimated that the condensate system returns 90% of the steam distributed. FWA also has utility systems of hot water supply/return piping and glycol supply/return piping systems.

C. Condition of CHPP

The Fort Wainwright CHPP employs some of the original equipment that was installed in 1953. FWA utilizes a combination of six Wickes stoker boilers for heat and power generation, which DU inspects on an annual basis. The superheater sections of the boiler were re-tubed in the early 1990s. A condition assessment on Boiler 5 was conducted in 2016, which indicated that the superheater tubes and waterwall tubes were in fair condition. However, the economizer tubes were in poor condition, indicating that a re-tube should be performed. Boiler 4’s economizer was replaced in the last twenty years, though the other boilers have original economizers. It is likely that all the other boilers will require an economizer re-tube. Aside from the tubes, many other parts of the boiler are likely to require replacement in the coming years. Stoker grating is one of the next items that is being looked at for replacement. (The grating in Boiler 5 was replaced in the fall of 2019.)

Throughout the years, maintenance and rehab activities have been conducted on the FWA turbines. Turbine generator 1 (TG-1) is currently being rebuilt and should be in operation as a backpressure turbine by February 2020. Though all turbines are original, modifications and replacements such as shaft replacement, blade replacement, and turbine rewinds have been performed. It is likely that only the outer casings of the turbines are original components, but they do not show any signs of failure. As the turbines continue to age, further maintenance and replacements will be required for effective operation.

Other energy generation equipment has been installed more recently. The air-cooled condenser is a newer piece of equipment and was installed in the mid-2000s. Deaerators, water treatment equipment and other auxiliary equipment have also been replaced.

Finally, the CHPP roof was replaced in 2019, but the building envelope is showing signs of degradation. Additional repairs will be needed if continued service is expected.

Fort Wainwright is one of the oldest operating power plants in the country. Investments can be made to maintain and sustain operations over the next ten years before major equipment replacements are required. If long-term use of the plant is anticipated, condition assessments should be performed on all critical equipment to determine the current condition, find needed repairs and identify remaining useful life.

D. Condition of HDS

The condition of the heat distribution system on FWA is presently under investigation. In 2019, DU contracted Southern Services, LLC to conduct pipe wall loss assessments on approximately 20% of the steam and condensate piping on post. Results generally indicate that HDS steam pipe wall loss is minimal with significant remaining useful life. Condensate pipe, which is normally schedule 80 steel, will require rehabilitation efforts for continued use. DU is exploring trenchless technologies for condensate piping rehab, such as Cured In Place Pipe (CIPP). Appurtenances such as racks, hangers, guides, expansion joints, and anchors have not been evaluated to such an extent but are replaced upon opportunity.

Utilidor maintenance projects are usually rather complicated in scope, as the condition of water, sewer, steam, and condensate piping (and their appurtenances) are all a consideration. It is possible to replace certain sections with direct bury piping, however substantial thought and care should be applied to freeze protection. Nonetheless, it is imperative that utilidors be adequately heated both for the freeze protection of piping within them AND for the freeze protection of shallow-buried pipes that enter and exit them through frozen ground.

III. Summary of Heat and Power Demands

A. Installation Heat Demand

Nearly all facilities on FWA are heated by steam, either directly or by district ethylene glycol loop. The FWA steam load bottoms out at about 100,000 lbs/hr during the summer and peaks out at nearly 350,000 lbs/hr in the winter, with much of the data falling between 120,000 and 250,000 lbs/hr. A 1981 USACE study[1] calculated the rate of utilidor heat loss as a percentage of rate of heat exported to buildings to range between 12% in the winter months and 25% in the summer months (when rate of heat delivered is much lower.) This "loss," however, should be considered an indispensable freeze protection demand that prevents mission-critical utilities from freezing.

B. Utilidor Heat Demand

In most parts of the world, sufficient burial depths place utility piping below the typical frost line in order to prevent freeze-ups. Depth of freezing is highly dependent on surface conditions and soil conductivity, but it is not uncommon for them to reach 10 to 15 ft deep or more in the Fairbanks area. Fort Wainwright's freeze protection strategy is to circulate water to and from heated areas in spray-foamed piping systems. This allows for shallower burial depths (and hence reduced excavation and soil remediation costs) as well as better access to the utility piping. Thus, it is imperative to the entirety of the utility infrastructure at FWA that the utilidor system be given a sufficient source of heat.

C. Electrical Demand

Post electrical demand bottoms out at a 9 MW base load, which occurs during the summer months. Electrical demand peaks during the winter months (due to block heaters, shorter days, electric heaters, etc…) at about 19 MW with about 80% of the demand falling between 11 and 15 MW. Some of this power is purchased from Golden Valley Electric Association (GVEA) when economically or strategically advantageous. Moreover, power is also exported to GVEA when a surplus can be generated.

D. Steam to Power Load Ratios

One of the most important factors in evaluating the suitability of the current and/or any proposed heat and power generation technology is the ratio of steam load (klbs/hr) and power load (MW). These data are plotted and sorted below, in Figure 1. The coincident steam-to-power load ratios show a range of from slightly less than 8 lbs/kWh (pounds per kilowatt-hour) to just over 26 lbs/kWh. The range is highest during the winter months when the demand for heating is highest and the demand for electric power is also highest.

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[1] G.L. Phettenplace, W.Willey, and M.A. Novick, *Losses From the Fort Wainwright Heat Distribution System*, USACE Special Report 81-14, Sep 4, 1981.

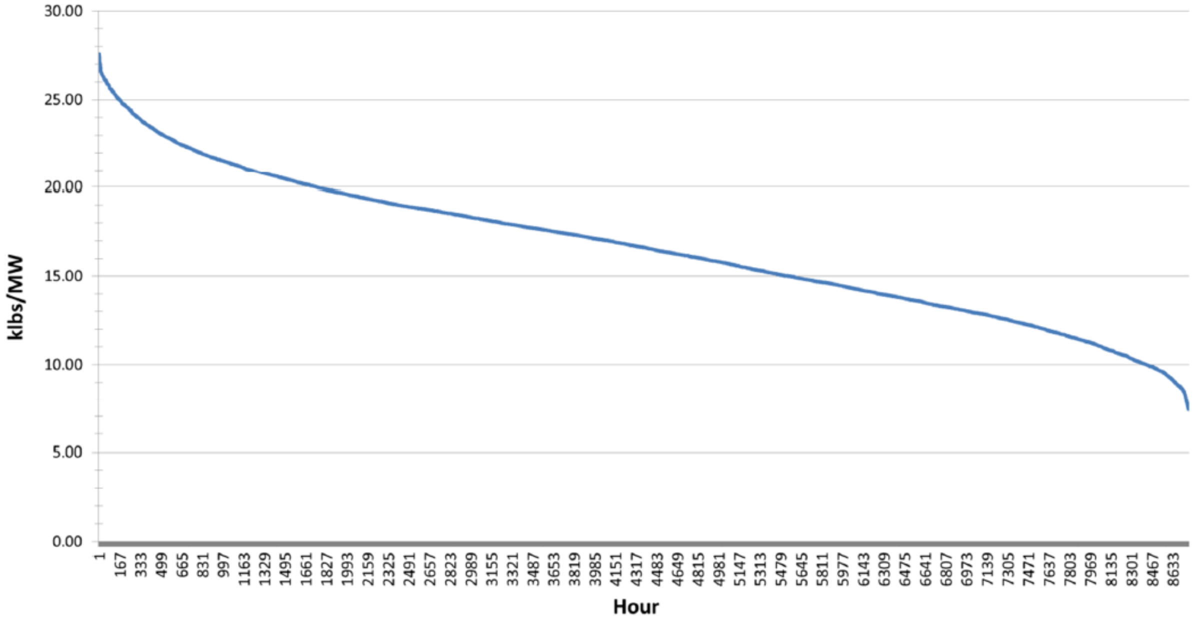

Figure 1 - FWA steam to power load ratios, sorted

The following are general recommendations for CHP technology suitability, given power ratios:

- High steam-to-power load ratio (20+): Use Rankine Cycle technology (conventional boilers and backpressure steam turbine generator (STG) based CHP, such as exists at FWA). These are typically found in frigid climate zones.
- Mid steam-to-power load ratio (7 to 20): Use Brayton Cycle technology (combustion turbine generator (CTG) with heat recovery steam generator (HRSG) based CHP).
- Low steam-to-power load ratio (2 to 7): Use Combined Cycle technology (CTG and with HRSG and backpressure STG based CHP).
- Ultra-low steam-to-power load ratio (<2): Use Combined Cycle (CTG and with HRSG and condensing STG) or Renewable Power Generation technologies – No CHP solution. These are typically found in hot climate zones.

The actual steam-to-power load ratios of the FWA CHPP are more closely aligned with what would be considered mid steam-to-power ratios suggesting a Brayton cycle approach. A Brayton cycle CHP system can operate with an unfired HRSG at 5 lbs steam/kWh requiring no cooling tower and therefore maximizing thermal efficiencies while producing all the electric power demanded. By duct firing the HRSG and adding steam boiler capacity, winter thermal loads could be served.

Although the steam-to-power ratio discussion, above, reviews a new CHP technology that may be a good fit for FWA loads, it should be noted that the current CHPP is a system well-suited to the post it is serving. The implementation of a combined heat and power system has allowed the Army to self-generate heat and power at higher efficiencies. Using extraction steam to heat post has certainly allowed the efficiency of the plant to remain well above a typical Rankine cycle installation.

E. Co-generation

Another term for the process utilized by a CHP is “co-generation.” Co-generation is the use of a heat engine or power station to generate electricity and useful heat at the same time. There are thermodynamic (and hence economic) benefits to co-generation, particularly when there is a demand for a heat resource.

In thermodynamics, not all units of energy are considered “equivalent.” For example, a BTU of *heat* is far less valuable than a BTU of electricity, or *work*. This is because the second law places restrictions on how efficiently one form may be converted to another. It is trivially easy to convert one unit of *work* to one unit of *heat*—just think of friction, or electrical resistance. However, the conversion of *heat* into *work* is far more complicated. There are no known examples of man-made or naturally occurring devices capable of converting one unit of *heat* into one unit of *work*.

Any device that is designed to convert heat into work is referred to as a *heat engine*. Automobile engines, steam turbines, and gas turbines are some common examples. Heat engines all work on a cycle and exchange heat with their surroundings. This heat is a natural byproduct of the process and is unavoidable. Automobile engines reject this heat through a radiator and by exhaust. Power plants often reject this heat to a lower temperature sink, such as a river, pond, or as in the case of the FWA CHPP, a series of air-cooled condensers. This may seem wasteful or inefficient, but it is a natural fact of the physical world. Co-generation facilities can generate useful work for a process while capturing this lower-grade “waste” heat and utilizing it for some economic benefit.

On Fort Wainwright, there is a *substantial* demand for low grade heat. All occupied facilities as well as the utilidor systems must be heated, both for creature comfort and freeze protection. Moreover, there is a substantial *supply* of low-grade waste heat. In fact, there would be enough by-product heat available from the generation of FWA’s electrical demand alone to heat all of post (and the utilidor system) 12 months out of the year. Utilizing extraction steam, as is currently practiced, splits the difference roughly 50/50 between an external supply of heat (that must be paid for) and free waste heat (which is a byproduct of generating electricity).

IV. Discussion

Among the primary goals of the heat and power systems at Fort Wainwright are cost-effectiveness and resilience, which tend to exist in tension. Cost-effectiveness is coupled with efficiency and thermal performance, which has been shown to be above average at the existing FWA CHPP. Resilience is the ability for a system to recover from an adverse or unplanned situation. Continuous improvement efforts conducted by DU have historically been aligned with one or both of these goals, as are planned capital improvement projects.

A. Cost-effectiveness

The FWA CHPP has been in operation for more than 60 years and has required regular maintenance and capital upgrades, as would any plant of its age. As discussed in the previous section, the system is well-suited to its application as a co-generation facility based on electric, thermal, and economic performance. Long-term cost-effectiveness of heat and power generation/distribution will thus be a function of the ability to control up-front capital costs as well as minimize long-term O&M expenses.

A comprehensive engineering study was commissioned by DU in 2017 in order to provide the utility better understanding of the financial and strategic implications of various energy alternatives. The results are summarized and discussed below at a high level.

1) Capital Costs

Though newer technologies and fuel sources exist, such alternatives would require more than an overhaul of the existing infrastructure, with considerable capital investment—principally, a brand-new facility (or facilities). Similarly, any substantial changes to the method of heat distribution or utilidor freeze protection would also necessitate a considerable up-front investment. The most cost-effective capital investment alternative has been shown to be the continued assessment, rehabilitation, and advancement of the existing generation and distribution infrastructure.

2) O&M Expenses

Long-term O&M costs are primarily driven by the price of fuel. Fuel options in the Alaska interior are certainly limited. Figure 2 shows the relative cost and availability of fuel options in Fairbanks. Coal and Ultra Low Sulfur Diesel (ULSD) stand out as the most available and most cost-effective options.

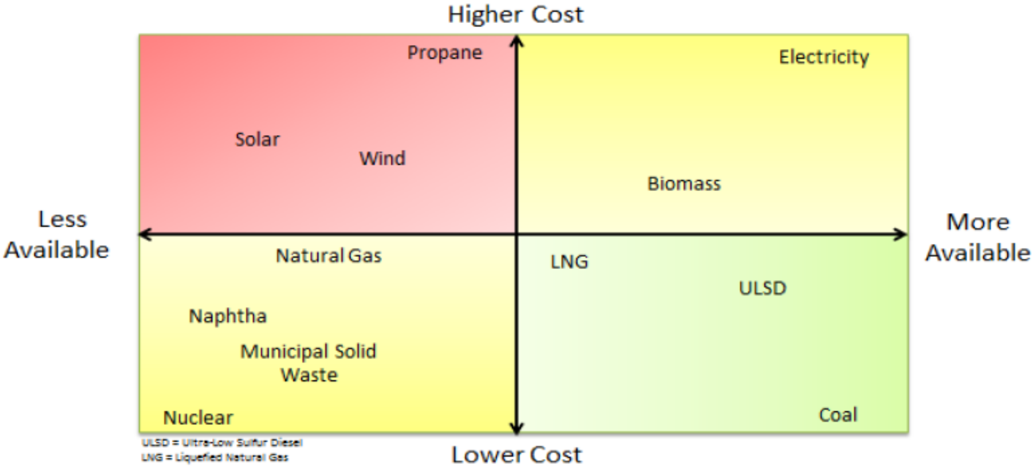

Figure 2 - Fuels evaluation based on current cost and availability

Considering the suitability of the existing system to supply heat and power to post, the value of the existing generation and distribution infrastructure, and the relatively low price of coal as a fuel, continuing to operate the FWA CHPP with necessary investments made stands out as the most prudent way to keep energy costs low for the US Army.

B. Resilience

Along with cost-effectiveness and energy efficiency, resilience (the ability to recover quickly from adverse situations) is a critical objective of the US Army. In the case of heat and power generation, this implies several goals:

1) Utilization of multiple fuel sources, or the ability to store the primary fuel source in the event of a supply chain disruption.

The current system relies upon coal as a fuel source. However, the US Army maintains a 90-day supply of coal behind the CHPP, which safeguards against a disruption in transportation between Healy and

Fairbanks. Other fuel sources are either scarce, unavailable, or much more difficult to store in the necessary quantities.

2) Multiple sets of smaller generation equipment, as opposed to a single point of failure. This includes boilers, turbines, and all critical plant equipment.

   The CHPP utilizes six stoker boilers, of which a minimum of four are necessary at peak demand. Having multiple units allows for critical redundancy, even during the coldest part of the year.

3) Self-reliance, or a lack of dependence on other adjacent sources. (GVEA, or other local utilities.)

   Fort Wainwright is generally self-sufficient but receives needed support from adjacent utilities. (Exception: all wastewater collection runs through a single outfall point to College Utilities.) The electrical grid is backed by Golden Valley, which can sustain Fort Wainwright at current loads. Note that sole reliance upon FWA's connection to the GVEA system does not meet current DoD resilience guidance.

V. Conclusions

Fort Wainwright operates in a sub-arctic environment where many fuel sources are scarce and freezing temperatures create a demand for a reliable, cost-effective source of power and energy. The existing FWA CHPP and utilidor systems are well-suited to this environment and resulting applications. Currently planned upgrades focus on critical plant equipment and building envelope—both of which are driven by past and on-going condition assessments. Continuous improvements in generation efficiency and better utilization of byproduct heat may allow for some reduction in energy costs. Investment in existing generation and distribution infrastructure offers the most cost-effective path forward in achieving the resilience required by the US Army for strategic operations at Fort Wainwright.