IDEA2022
Building Connections
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IDEA Innovation Award 2022

Utilizing Organic Rankine Cycle Technology to Improve Campus District Energy System Efficiencies

Prepared By:

DALHOUSIE UNIVERSITY

30 ANNIVERSARY FVB ENERGY INC
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March 24th, 2022

IDEA 2022 Innovation Award Review Submission Panel

idea@districtenergy.org

Reference: **IDEA 2022 Innovation Award Application**
Utilizing Organic Rankine Cycle Technology to Improve Campus DES Efficiencies

To whom it may concern,

Dalhousie University (DAL) in partnership with our District Energy consultant FVB Energy Inc. (FVB) are excited to apply for the IDEA Innovation Award 2022. We have been extremely proud of this project from the day we reviewed the first draft of the feasibility study to the day we prepared this application, and we would like nothing more than to share some of that pride and innovation with the IDEA community and their partners.

Dalhousie is no different than many other Universities and campus energy providers that are struggling to find innovative and economically responsible ways to contribute to Canada's and our own 2050 Net Zero targets. Like many other early 19th Century founded campuses, our existing central steam systems do not always align with our desire to move away from fossil fuels for our production of central heat. This was no more evident than in 2014 when we applied and received our approval for the Nova Scotia Community Feed-In Tariff (COMFIT) program. Our application was based on a biomass powered back pressure steam turbine which was, and still is, the industry accepted standard for biomass/steam based cogeneration. Along with our partners FVB Energy, we decided that status quo was not good enough and we instead pivoted our approach to a biomass powered Organic Rankine Cycle (ORC) Turbine to produce the electricity required under the COMFIT program. The caveat of this approach is the ORC turbine can produce a maximum of 85°C (185F) hot water which meant our entire campus distribution and energy transfer systems would need to be converted to hot water. This required a much greater need for capital funding in parallel with assurances that the efficiency gains and GHG reductions would be realized to make the project economically responsible. Although the ORC technology was well established in Europe for industrial applications, it had never been attempted at a University Campus and, at the time, there was limited suppliers and representatives in Canada for the technology.

We are proud to report that after 2 full years of operation that the innovative approach we took has paid off we are over performing on efficiency gains, revenue and GHG savings. Furthermore, we were able to use the revenue from this project, along with deferred facilities renewal spending, to convert the entire campus to a low temperature hot water system which provides our campus with the vehicle to incorporate more efficiency upgrades and waste energy projects in the future to get to our 2050 net-zero goals. As a result, we are now able to look at data center heat recovery and absorption cooling for the campus utilizing the excess heat we have from the ORC in the summer months.

We thank you for the consideration of our application. If you have any questions about the application or the information presented, then please do not hesitate to reach out to me. We look forward to hearing from you and we are excited to re-connecting with the IDEA community in Toronto this June.

Sincerely,

Peter Coutts, P.ENG
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Department of Facilities Management
Dalhousie University

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IDEA Innovation Award Submission Outline

1. **Project/Program Title**
    - Utilizing Organic Rankine Cycle Technology to Improve Campus DE System Efficiencies

2. **Name and Location of District Energy System or Project**
    - Name: Dalhousie University Biomass Co-generation District Energy System
    - Location: Agriculture Campus – Bible Hill, Nova Scotia

3. **Name of System Owner**
    - Dalhousie University

4. **Name, relationship to the project/program, address, phone number & email of the person submitting the application**
    - Peter Coutts
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5. **Executive Summary – In 700 words or less, summarize the project /program, demonstrating the key aspects of what was done and the overall benefits.**

The 30-year-old biomass boiler and 40 year plus steam system at the Agricultural Campus (AC) provided heating to over 95 per cent of main campus buildings (708,894 square feet) through a district steam/condensate system. In 2014, The University applied for and received a Community Feed-In Tariff (COMFIT) for small scale biomass co-generation created electricity at a rate of $175 per MWh. COMFIT projects in Nova Scotia are required to meet efficiency, air quality standards and biomass fuel specific requirements.

In 2015, the University began a comprehensive renewal project to upgrade the steam distribution system and steam plant. The Project was substantially complete in 2018 and commissioning completed in 2019. Two years of full operation has been achieved.

The project helped to:

- address facilities renewal costs of existing end-of-life equipment and systems;
- support university and community sustainability goals;
- Improve air quality systems;
- purchase local biomass supply that meets our comprehensive biomass values standards;
- incorporate some research, teaching and operations synergies; and
- support local economic development through the construction of the project and ongoing supply.

Through the project, the steam distribution system has been replaced with a district hot water system which is 30% more energy efficient. The old wood biomass steam boiler has been replaced with a biomass fired based thermal oil heater. The thermal oil heat feeds the Organic Rankine Cycle (ORC) which drives a 1 MW turbine generator to create electricity. This efficient organic rankine cycle system is the first installation of its kind at a University campus in North America. Process thermal energy is used for heating the campus. A new air emissions management system was added along with two fuel storage bays. High efficiency pumps have been integrated to circulate hot water. Smart meters and controls were installed to monitor and optimize plant performance and support investigation regarding life cycle emissions and new opportunities.

Key Features:

Conversion of the steam/condensate distribution to hot-water. Overall annual thermal savings of over 11,000 MWht. This included:

- replacing steam and condensate lines from buildings to the plant with hot water lines (2.6 km);
- upgrading 16 building energy transfer stations from steam to hot water;
- converting specialized steam-based equipment such as sterilizers and humidifiers to propane or electric;
- converting an existing steam boiler to hot water, preserving the remaining life of this asset.

Fuel handling. Two new fuel storage bins have been created. Two bins offer flexibility to mix different products. Intended for blending traditional biomass with emerging sources such as willow.

New biomass fuel thermal oil heater. A 5.4 MWth biomass heater (Wellons) has been installed. Fuel is drawn into the thermal oil heater from the fuel handling system. The new thermal oil heater enables a more consistent burn creating less ash and more efficient use of biomass.

Organic Rankine Cycle (ORC) System. The 1 MW Turboden 10 CHP system produces over 8000 MWh annually; roughly 75% of the campus electricity needs. Electricity is exported to the local Nova Scotia Power grid (as per the requirements of any COMFIT agreement).

Electrostatic precipitator (ESP) is specifically designed for cleaning flue gases from wood-fired energy systems. Wellons proprietary ESP has particulate emission guarantee of 35 mg/normal cubic meters @ 8% O2 per COMFIT or below. The treatment time of emissions is 6.7 seconds. The stack height is 44 feet.

Wood Ash Management. In the past, wood ash stayed on the campus farm using campus vehicles to transport the ash in carts during the winter months. With the production of more ash all-year round (estimated at 350 tonnes per year), it is now held in custom designed wood ash bins transported to a local farm for use as fertilizer.

Fuel supply. The University created a biomass value statement that outlines standards for biomass supply. Biomass supply must meet the conditions of COMFIT regulations (COMFIT Directive 002.pdf (novascotia.ca)). The statement and standards provide direction on topics such as fuel type, trucking distance (distance of fuel 175 km or less), and land uses. Each year, the University submits a COMFIT report that outlines where fuel comes from and calculates contributions to silviculture programs through The Registry of Buyers. Presently, there is a three-year contract with two vendors for the supply of sawmill residue only.

6. In 300 words or less, explain how the project/program is innovative and unique.

This efficient ORC system is a first installation of its kind at a University campus in North America. Thermal energy generated from the electricity production is used for heating the campus and the campus has been converted to hot water. The other biomass co-generation options we explored involved producing high pressure steam to supply our district energy system. The ORC option provided an opportunity to produce electricity efficiently without high pressure steam, and to heat the campus with the residual heat.

Other than consuming a small amount of fuel oil to operate a back-up boiler during annual maintenance shutdowns, the Plant utilizes 100% residue (saw dust, bark, & chips) produced from local sawmill operations.

Much of the heat from the power generation process is used to heat the campus, but during the summer there is still some remaining beneficial heat. We are exploring the option of using this in the summer for cooling certain campus buildings. We are also creating a System Energy Flow Dashboard, researching the performance of various biomass products, and supporting more student research on biomass life cycle emissions

The campus ash has been certified as a fertilizer through the Canadian Food and Inspection Agency and is used by local farms as fertilizer.

The plant design also provides operational flexibility. Since the ORC is supplied heat from a Thermal Oil Heater, the plant no longer meets the requirements of a typical steam plant and therefore does not require certification under the Provincial Department of Labor and Advanced Education. This provides Dalhousie the flexibility of hiring operators that do not have a Power Engineering certification.

The Plant Control System is fully integrated with the campus EMCS. Feedback from each building's Energy Transfer Station is used to minimize the DE System's export temperature, increasing the ORC's electrical generation efficiency.

7. With supporting data, demonstrate the improved energy efficiency benefit offered by the project/program, in 250 words or less.

Prior to the project, the University was realizing inefficiencies in the production, distribution and end use of their thermal energy systems. The campus was utilizing steam that was generated by a combination of biomass and oil boilers at 120psi and then distributed at 80psi where it was further reduced at the individual buildings to supply hot water and steam loads.

To utilize an ORC Turbine, the campus had to be converted from steam to hot water. FVB performed a thorough review of the EMCS systems to find which sub-systems were dependent on higher temperatures so they could be targeted and reduced. An aggressive reset schedule was developed for each building to ensure that temperatures would remain low during off-peak periods. Next, we converted all the steam-to-hot water converters into energy efficient hot water transfer stations. This also involved identifying and cataloging all direct steam uses and finding alternative means of supply via hot water or electricity. A new hot water network was established to transport the 85°C water around campus. The capital upgrades have resulted in distribution system efficiency improvement of 30+% with an average annual savings of over 11,000 MWht.

In addition, most of the distribution pumps (77 of them) were replaced with high efficiency pumps with a savings of over 360,000 kWh. The plant has achieved over 50% total energy efficiency and as more heat loads come on and we explore options for summertime cooling, our goal is to achieve a higher efficiency in the 70-80% area.

8. With supporting data and graphics, explain the financial advantages of this project / program in 250 words or less.

Powered by sawmill residue and their ORC Turbine, DAL generates revenue through a provincial community feed-in tariff (COMFIT) power purchase agreement to provide electricity (about 75% of campus electricity use) to the Nova Scotia grid. There is no option to self-generate. The revenue from electricity sales is used to finance the plant renewal project over a 20 year period as well as the conversion of the campus buildings to accept low temperature hot water.

In addition, all the heat generated from the ORC process is captured and used to provide the campuses entire space heating and domestic hot water demands. These demands would otherwise be met by burning biomass (sawmill residue), oil or propane.

A unique benefit related to biomass is that it is not impacted by world geo-political events that regularly impact fossil fuel and natural gas pricing. This has provided fuel cost stability over the past few years while other fuel prices have been quite volatile.

The following table demonstrates some of the key financial success factors for the project:

Key Success Factor	Requirement	Actual Performance (2020-21)	Over Performance (%)
Annual Electricity Revenue ($)	$1,409,930	$1,566,512	11%
Biomass Fuel Costs ($)	$1,200,000	$1,265,449	(5.5%)
Power Generation (KWh)	7,747,000	8,742,600	13%
Biomass Cost /tonne	$60	$56.35	6%

After some considerable commissioning issues and lots of "lessons learned" in the first year of operation, the Plant operation has been very reliable and is exceeding our business case financials. The Plant typically operates 10% above electricity generation expectations. This comes with a small increase in biomass fuel cost (5.5%), but a new fuel contract in 2021 should eliminate the extra fuel cost.

9. **In 250 words or less, please provide any additional information about the project/program (What challenges did you face? What plans do you have for the future? How did your customer base or community react?, etc.)**

As the only biomass cogeneration project in the province under the now closed COMFIT program, the project had a unique set of challenges:

Timing constraints and other requirements related to COMFIT regulations

- Community engagement sessions were held
- Letters of approvals
- Connecting with local Indigenous organizations and government were undertaken
- Deadlines for Power Production constrained the construction schedule / commissioning

Biomass Sourcing

- The University created a biomass value statement that outlines standards for biomass supply. Biomass supply must meet the conditions of COMFIT rules and each year the University submits a COMFIT report that outlines fuel sources and calculates contributions to silviculture programs through The Registry of Buyers.

- The majority of biomass (over 85%) consumed has been sawmill residue from local mills and some smaller amounts of clean wood waste from manufacturing and construction have been used. Other higher priced wood chips from selective forest harvesting for silviculture through local forestry cooperatives have been used and an agreement for willow was negotiated to explore alternative products and their efficacy.

- Despite meeting the COMFIT requirements, the most frequent concern raised by some members of the community is regarding the biomass supply. Going forward, we plan to conduct more research on life cycle emissions and explore social procurement strategies to help ease any concerns from the community.

Overall, the community has been very supportive of the project and we receive regular requests for Plant tours.

We plan to investigate options for utilizing waste heat for cooling, and research funding options for other projects such as permanent air quality monitors and biomass research.

10. Please provide 3 to 5 attachments as images, diagrams or photographs in jpeg format with identifying captions

Figure 1- New Biomass Split Fuel Bin

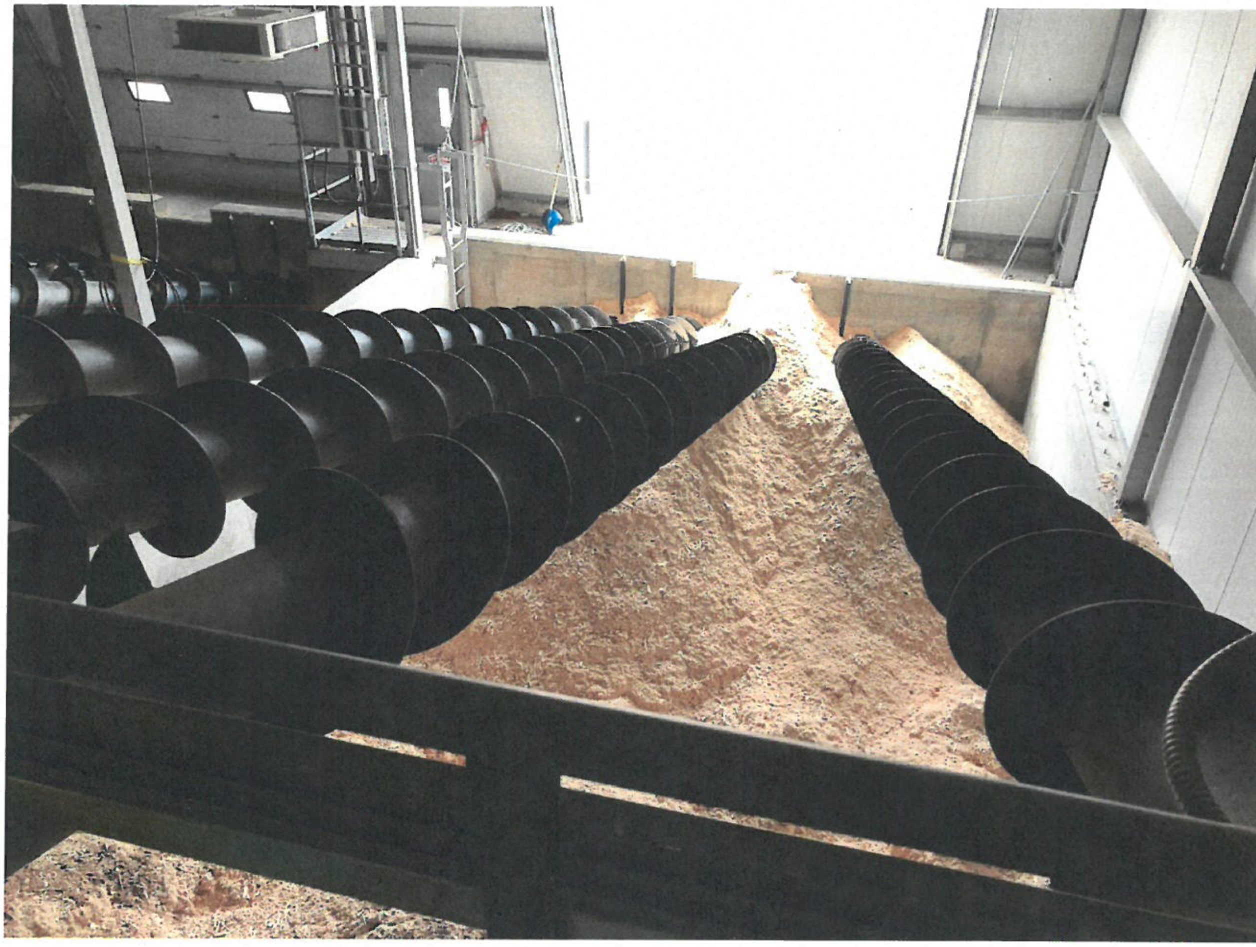

Figure 2- Biomass Fuel Distribution System

Figure 3- Organic Rankine Cycle Turbine

Figure 4- Indigenous Smudging Ceremony for the New System

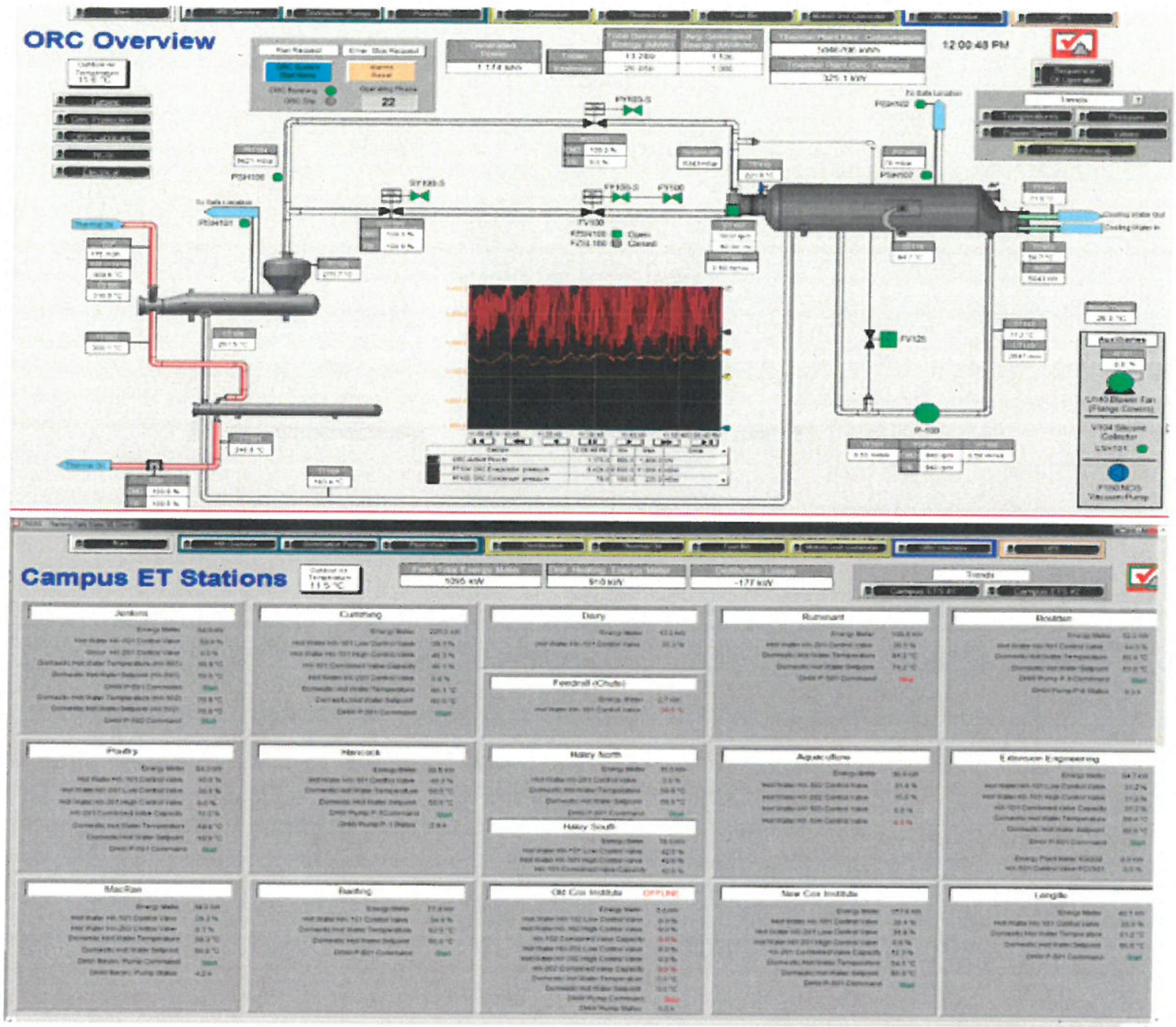

Figure 5- Plant Control System & EMCS Integration