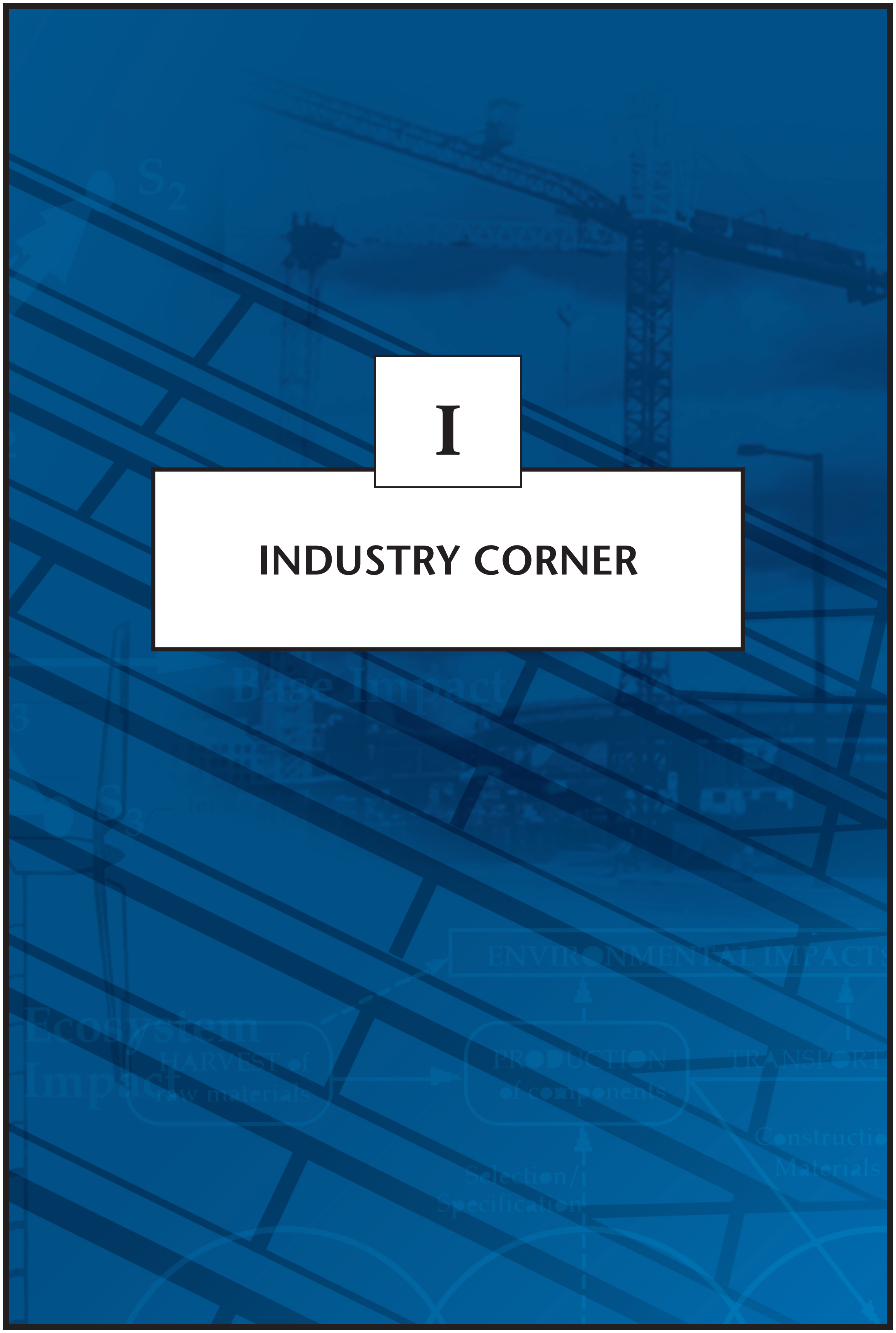

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INDUSTRY CORNER

INTEGRATING OPERATIONS AND RESEARCH TO DEMONSTRATE BIOENERGY HEATING AT THE UNIVERSITY OF NORTHERN BRITISH COLUMBIA

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INTRODUCTION

The University of Northern British Columbia (UNBC) has implemented two bioenergy heating projects to demonstrate renewable energy and carry out research on sustainable resource usage. These projects are of particular interest to remote communities and further the institution's aim to be Canada's Green University™. The wood pellet system is a template for a community building heating system, while the gasification system is sufficient to supply a community scale district energy system. Both projects demonstrate that bioenergy can be implemented at an institutional level, low levels of particulate emissions are achievable, and that integrating campus operations with research provides relevant demonstration of leading-edge technology.

KEYWORDS

bioenergy, renewable energy, district energy, integrated research, college sustainability, carbon neutral

BIOENERGY DEFINED

Bioenergy refers to many forms of plant matter that can be used to provide a net energy output. For two projects at UNBC—a research-intensive university with campuses throughout northern British Columbia—bioenergy refers to heating with biomass sourced as residual wood fibre from local sawmilling operations.

This region includes extensive forestry operations, primarily producing dimensional lumber and softwood pulp. Timber harvested from the forest is trucked to sawmills in the regional centers for milling into dimensional lumber. This is the highest value product from the tree and is sold into the U.S. housing market and also exported to China. Any portion of the log which could not be milled into lumber is then chipped for pulp production. The Northern Bleached Softwood Kraft (NBSK) pulp fibre produced in this region is some of the highest quality fibre in the world, and blended to add strength when used in paper making.

Only "white" wood chips can be used to make pulp, so all of the bark and sawdust is residual fibre. In the past this material was burned to reduce the volume required for waste disposal and the heat was vented to the atmosphere.

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The pulp mills have now installed cogeneration systems that consume the majority of this fibre to produce steam for electricity generation and the pulping process. More recently the region has seen the construction of wood pellet plants which also use this fibre to produce energy pellets for export to European electricity generation markets. The bioenergy systems at UNBC utilize both the residual fibre (typically referred to as hog fuel) and manufactured wood pellets to provide heat to campus buildings.

It is not economical for UNBC to source whole trees directly from the forest to use for space heating. The biomass is a by-product of the sawmilling operations. The higher value products (lumber and pulp) carry the bulk of the harvesting, transportation, and forest stewardship costs.

WHY BIOENERGY?

As Canada's Green University, UNBC evaluates energy infrastructure investments based on benefits beyond simple payback. These projects reduced the need for natural gas to heat the core Prince George campus by over 85%. They were designed to be demonstrations and a model for implementation in remote communities. UNBC provides a location where prospective host sites can observe the equipment in operation, and estimate the operating costs for a system within a similar climate.

Research conducted on these systems includes ash utilization for soil amendment, mass and energy balances, and an examination of the operating costs relative to natural gas. Stakeholder support and enthusiasm is evidenced in the level of student and community interest in the project. Students recently voted UNBC #1 in Canada for Environmental Commitment (Globe 2012).

These projects retain a high proportion of the university's energy dollars in the local community, both through harvesting and sawmilling for fuel, and also through operations and maintenance positions. They link the energy production for the University with the biomass production and forest management of the region. Local energy production such as this is a key element in the pursuit of energy security and local economic development.

Academic impacts to date have included courses on environmental citizenship, project management, environmental engineering, and numerous class tours.

FIGURE 1. Biomass for these projects consists of bark and sawdust produced by the sawmilling and pulp industries in northern BC.

Carbon Neutrality

The *Greenhouse Gas Reduction Targets Act* came into force in the Province of British Columbia in 2008. This legislation requires the public sector in BC to be carbon neutral and commits BC to reducing emissions in line with internationally agreed-to targets: 33% by 2020 and 80% by 2050. It outlines the process for measuring and reporting the carbon emissions of all schools, healthcare facilities, and other government bodies. Each organization is then required to either reduce its emissions to zero or purchase carbon offsets for the emissions that it cannot eliminate. The offsets are to be purchased from the Pacific Carbon Trust, a Crown agency, at a cost of $25/tonne. Within this framework, biomass is considered to be nearly carbon neutral, though the CO_2 emissions are still reported. In 2010, prior to implementing the larger bioenergy project, UNBC purchased $142,000 worth of offsets based on the fuel consumption and electricity use of its buildings and mobile vehicle fleet as well as paper usage.

FIGURE 2. Evaluation of project benefits extends far beyond simple payback. As an education- and research-focused institution, the university's mandate includes the demonstration of systems that are of value to local communities.

LEADER IN RENEWABLE ENERGY

"As Canada's Green University, to be a leader in renewable energy" was identified as a goal in the 2010 University Plan. UNBC bioenergy bridges the gap between research and operations by installing full-scale systems that are required for the operations of the campus, and then making them available so researchers may document the deployment of the technology. The operators are the Facilities Management staff of the university. These shift engineers are the same staff who would operate this type of equipment at any other facility. While the systems aid in UNBC's goals to reduce fossil fuel usage, they do not have clear cost savings drivers. Grid-based energy delivery (hydro electricity and natural gas) is very cost effective for the campus, so it is challenging to justify renewable energy projects for the Prince George campus based on energy cost savings. Operational cost savings alone are insufficient to justify the capital cost in a grid-connected application. On the other side of the spectrum, the research mandate does not justify constructing a full-scale plant on campus. It is not necessary to build and operate renewable energy plants in order to be a leader in renewable energy. There are institutions that are world leaders in aerospace (as an example) yet operate neither an air force nor a space program—the research does not require the university to invest in the physical infrastructure.

It is at the intersection of these two themes—research and operations—that the UNBC bioenergy development has begun to demonstrate leadership in renewable energy. Collecting data on a full-scale system avoids the concerns over how well the resulting models might scale from a pilot facility to a full-sized implementation. The way in which UNBC has integrated the technology into the existing campus infrastructure demonstrates how other organizations might realistically be able to incorporate the showcased bioenergy processes. The projects are designed so that the operating costs are equal to or lower than the operating costs for the heating systems that are being replaced. This provides a financial incentive for the Facilities department to keep them continually operational and providing heat to the campus buildings. In contrast, many research pilot systems cost money for any operating time, and are therefore only given brief running periods in which to collect data.

PELLET SYSTEM

The first UNBC bioenergy system is a wood pellet boiler to heat a single building. The I.K. Barber Enhanced Forestry Laboratory (EFL) consists of a greenhouse, soil preparation spaces, laboratories, and offices. It was originally constructed in 2000, and including an addition in 2004, the total area is 9,967 ft^2. Natural gas boilers provided domestic hot water and space heating via two air handlers, unit heaters, and radiant panels.

The pellet heating system is housed in a steel shipping container adjacent to the building. A grain bin is used as a pellet silo, and is capable of storing 50 tonnes of wood pellets. The Wood Pellet Association of Canada was a partner in the development of the project, and requested a silo of this size in order to demonstrate the delivery of pellets via B-train tractor trailer truck. Annual fuel consumption is estimated to be 150 tonnes. Local industry support is demonstrated through Pacific Bioenergy Corporation donating pellets from their Prince George mill. Trucks can be unloaded by auger or blowline to the top of the silo. An auger at the silo base feeds the pellets to the boiler within the shipping container.

The KOB rotary combustion chamber boiler includes a triple pass heat exchanger to heat the water. A water storage tank within the shipping container provides thermal buffering for periods of low heat demand. Insulated underground pipes carry the hot water into the building where heat exchangers upstream of the existing natural gas boilers transfer the heat into the building's heating system. When the bioenergy system is operating, the water entering the natural gas boilers is already at supply temperature so they do not fire. During periods of

FIGURE 3. Left: Wood pellet heating system for the Enhanced Forestry Laboratory. The fuel silo feeds pellets into the shipping container where a boiler heats water for the building. An emissions filtration system results in particulate emissions that are below natural gas levels. Right: Doug Carter, project manager for the two bioenergy projects, with the wood pellets which are burned in the KOB boiler.

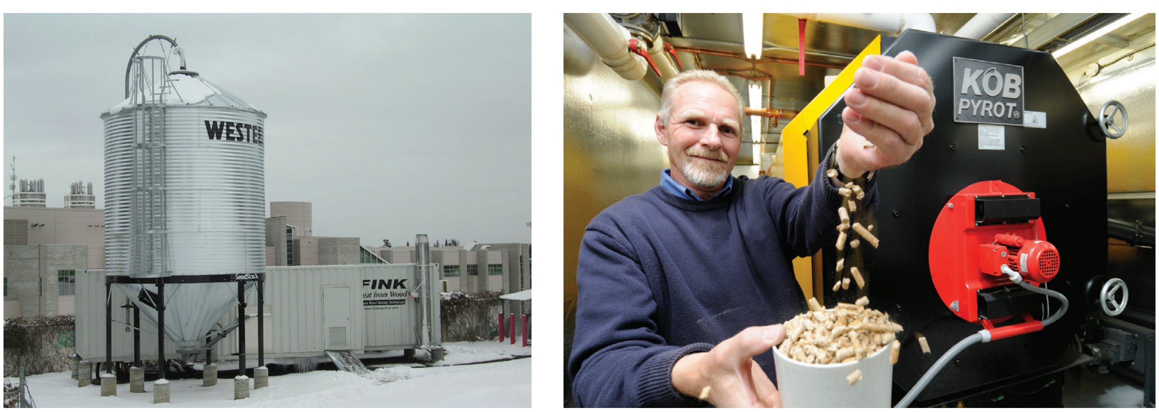


FIGURE 4. View of the UNBC Prince George campus showing several of the core buildings heated by the Bioenergy Plant (top left). A district energy network carries the hot water to over 690,000 ft^2 of building space. The Enhanced Forestry Laboratory is the greenhouse to the right of the Bioenergy Plant.

maintenance, or if the bioenergy system should fail to supply sufficient heat, the gas boilers will start automatically. This provides a redundant heating system—important in any building, but essential for the research greenhouse, where a loss of temperature could jeopardize research productivity.

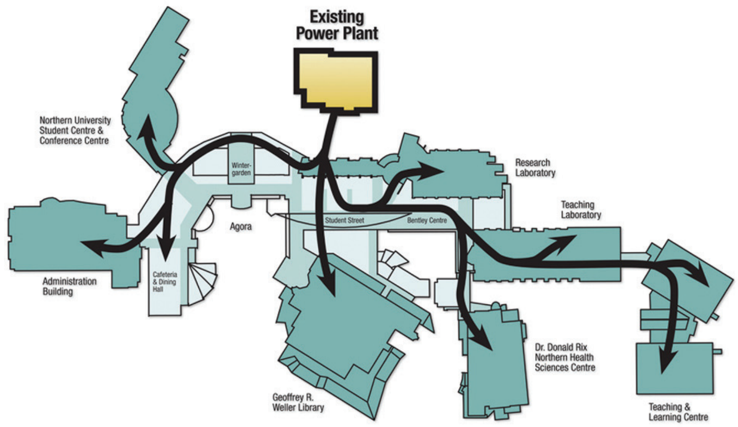
The exhaust gases from the boiler are passed through a filtration system to remove fine particulate matter prior to venting from the stack. Prince George has a sensitive airshed from a combination of geography and significant industrial activity. Most of the city is situated in the valley formed by the confluence of the Fraser and Nechako rivers, which prevents free mixing of air, particularly during temperature inversions and light winds. It was important that this project not increase the particulate loading on the airshed. It serves as a state-of-the-art demonstration for bioenergy systems this size. Natural gas boilers typically emit particulate matter at a rate of 6–10 mg/m^3 of exhaust gas. The stack emissions from the pellet boiler system were measured at 5.6 and 6.7 mg/m^3, demonstrating that it is possible for a biomass heating system to operate as cleanly as natural gas.

Ash from the system is collected in a metal container and disposed of in landfill. Ongoing research at UNBC is investigating productive uses for this by-product, including application to agricultural land as a soil amendment. Lab trials have indicated a significant boost in yield with appropriate application rates.

DISTRICT ENERGY SYSTEM

The Prince George campus was designed as a cogeneration site. The Power Plant would use natural gas to generate electricity and the heat rejected by this generation would be used to heat the campus buildings. Due to a number of factors, the electrical generator was omitted from

FIGURE 5. District Energy system distributes hot water heating to the core campus buildings. This facilitated a cost effective conversion from natural gas to bioenergy heating.



the original construction. Instead, a series of natural gas boilers were installed in the Power Plant to provide the heat to the campus. A network of pipes distributes hot water through all of the core campus buildings, at temperatures of 240°F for supply and 220°F for return. Heat exchangers in each of the buildings transfer heat to secondary glycol loops that distribute the heat to the air handlers and other HVAC equipment within the specific building.

One of the primary advantages to a district energy system is the ease with which different energy sources can be introduced. An input at a single point within the network permits all of the connected buildings to switch energy sources in a single step. There is no need to retrofit heating infrastructure in each of the target buildings because the hot water heating equipment in each building remains the same regardless of what is used to heat the water.

The electrical and natural gas distribution grids are analogous to a district energy system. The transmission wires (or gas pipelines) distribute energy across a large area, and within each home the consumer has appliances to convert that energy to a specific end-use. The electrical utility can bring new electrical generation online without having any effect on the residential consumer because the delivered energy is always in the same form. A district energy system such as the one on the Prince George campus is similar in that the delivered energy is always in the same form—hot water.

Infrastructure upgrade

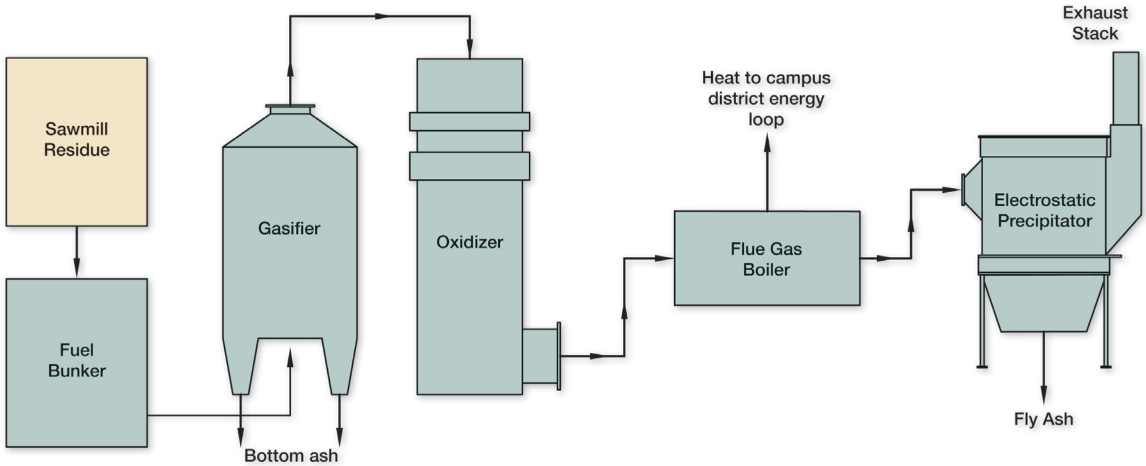
In 2010, the university embarked on an upgrade project to increase the operational efficiency of the district energy network on campus. Piping connections were added to improve the flow dynamics, prepare for future campus growth, and to provide redundancy for maintenance. Energy meters were installed at the heat exchangers for each building so that the operational data could be monitored in real time.

BIOENERGY PLANT—GASIFICATION

Building upon the success of the pellet heating system, a second bioenergy project was conceived. The new system would provide the majority of the heat for the Prince George campus, distributed through the district energy system.

A request for expression of interest seeking bioenergy technology suppliers identified Nexterra Systems Corp. of Vancouver, BC, as the preferred vendor. Nexterra provides a gasification system that converts wood to producer gas (syngas) in a vessel that is separate from

FIGURE 6. Bioenergy Plant gasification system components used to provide 85% of the heat to the Prince George campus. The gasifier converts wood into clean syngas which then combusts in the oxidizer. Hot water from the boiler is distributed to the campus, while the electrostatic precipitator reduces the fine particulate levels in the exhaust to below natural gas levels.



the combustion chamber. This two stage process is designed to achieve very complete conversion of the carbon in the wood, and produces a clean burning gas for either heating or electricity generating needs. The system installed at UNBC burns the gas for heating only.

The fuel supply is hog fuel from a local sawmill, Lakeland Mills, which is the closest mill to the Prince George Campus. The system is expected to consume 6,000 bone dry tonnes of hog fuel annually, which translates to three tractor trailer truckloads daily under full load.[2] The university opted to construct a separate access road for fuel deliveries to the Bioenergy Plant, rather than introduce this additional truck traffic through the campus. Construction coincided with the expansion of the city water main and a new electrical transmission right-of-way. The project was able to reduce costs by coordinating land clearing and excavation with these utility upgrades in a single corridor.

The fuel is deposited in an indoor, heated concrete bunker capable of storing a four-day supply. A hydraulically-powered walking floor feeds the fuel towards an auger and conveyor system which delivers it to the gasifier.

Gasifier

Nexterra produces the fixed-bed updraft gasifier that is at the core of this system. Fuel is fed in from the bottom and forms a conical pile analogous to a volcano as new fuel spills over from the centre. Partial oxidation ensures that the operating temperature is sufficient for gasification; natural gas is only required to pre-heat the system during start-up. Combustion air is introduced at the bottom of the pile to drive the reaction which converts the wood to syngas and non-combustible ash. The amount of oxygen introduced is carefully controlled to avoid temperatures hot enough to fuse the ash into clinker. The feed auger must be able to feed wood pieces up to 3″ in size into the base of the high temperature fuel pile while maintaining an air lock to control the reaction. The dynamics of this material handling challenge are a key

[2]Hog fuel is green wood and bark with a moisture content of 25–60% depending on species and handling. This fuel is sold based on the equivalent dry weight, measured in bone dry tonnes.

element in the system's design and successful operation. Bottom ash is also extracted from the lower portion of the gasifier and conveyed to the ash bin.

FIGURE 7. The interior of the Bioenergy Plant, showing the Nexterra gasifier (back left), oxidizer (centre), boiler (lower right), conveyor (bottom left), and electrostatic precipitator (right).

Oxidizer

The syngas produced in the gasifier is ducted off the top and into the adjacent oxidizer. The gas composition is mainly carbon monoxide, hydrogen, and methane, though it also contains vaporized pyrolysis liquids and hydrocarbons. Additional air is introduced in the oxidizer to achieve complete combustion of the syngas. The oxidizer is lined with refractory brick to withstand the 2000°F operating temperature.

Boiler

The hot flue gases then pass through a flue gas boiler which heats water for the 240°F campus district energy system. A new hot water heating loop was added to the district energy system for the Bioenergy Plant. Water circulates between the Bioenergy boiler and a heat exchanger upstream of the boilers in the original Power Plant. There are two reasons for this separate water loop: the Bioenergy plant is at a higher elevation than the rest of campus so the heat exchanger avoids having to increase the static pressure in the entire district energy loop; and the Bioenergy system can be taken offline without having an impact on the district energy system. The 15 MMBtu/hr boiler is the first pressure vessel in the process; the gasifier and oxidizer operate at atmospheric pressure, or slightly negative to contain the gases.

Electrostatic Precipitator

After the boiler, the flue gases are ducted to the dry electrostatic precipitator (ESP), an emissions filtration system that reduces the particulate matter in the exhaust. The precipitator consists of a series of plates and wires hung within a large steel box. The wires are energized so that the dust particles acquire a charge as the exhaust passes through the precipitator. The charged particles are then attracted to the oppositely charged plates. The dust accumulates, and is periodically shaken off into a hopper at the bottom. This collected fly ash is then transported to the ash bin for disposal.

Commissioning

Commissioning began in November 2010, with substantial completion of the process equipment achieved in March 2011.

The walking floor system in the fuel bunker continues to be refined, as the specified bunker capacity has not yet been achieved. Recent changes to the control strategy appear to permit the advancement of a load of fuel to provide space to deposit a second load, and may have resolved this issue.

A piece of metal made its way into the fuel supply in the spring of 2011 and caused a shutdown of the system when it jammed the gasifier feed auger. This highlighted the need for a fuel-screening system to remove metal and oversize material—something that was not included in the original installation. The gasifier feed auger was repaired and re-installed, but continued to have operational challenges. Nexterra supplied and installed a revised version of the auger.This unit has been operating well since May 2011.

A significant build-up of ash was observed in the boiler during the shutdown to repair the auger. The control parameters were adjusted to reduce the gas velocities through the gasifier and oxidizer and limit the amount of ash carry-over. A sootblower system was also ordered for the boiler, to be installed during the next scheduled maintenance shutdown. The control changes appear to have been effective, as very little ash was found in the boiler when the time came to install the sootblowers.

Performance

The system is able to deliver the nameplate output of 15 MMBtu/hr without any difficulty. It also displayed excellent turn-down performance over the summer months, when it provides the nominal 3 MMBtu/hr required for domestic hot water and minimal space heating.

This system was designed to offset 85% of the natural gas used for heating in the campus district energy system. Year-to-date the Bioenergy Plant has offset an estimated 61% of the natural gas that would have been used for space heating. This is measured from the substantial completion date and includes the prolonged period of downtime while the auger issues were resolved. Measured from when the new auger design was installed, the system has offset an estimated 91% of the natural gas. Both of these numbers include any system downtime for maintenance. The natural gas boilers are still required during maintenance shutdowns and for periods of peak heating demand, which can reach 35 MMBtu/hr for the campus.

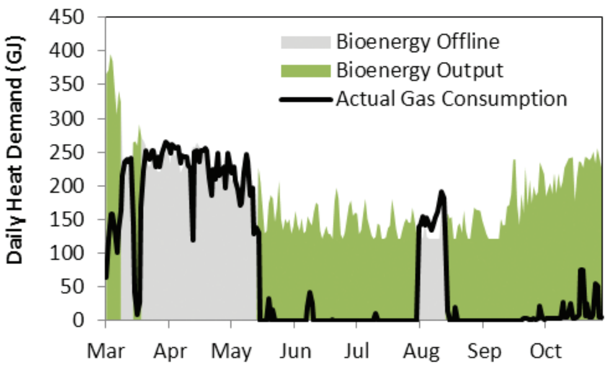
Emissions

The ESP is effective at removing the fine particulate matter from the exhaust stream. Third party testing during the commissioning of the plant identified particulate emissions of 5 mg/m^3, lower than that of the natural gas system it replaces. A Nexterra commissioned study of biomass heating plants across North America to compare the particulate NO_x and SO_x levels concluded that the UNBC installation is one of the cleanest burning biomass plants surveyed.

Operational Impact

The Bioenergy Plant is owned and operated by the university. The Facilities Management shift engineering staff handles all maintenance and daily operations. Two additional shift engineers were hired to assist with the increased workload posed by the bioenergy program. The campus has a shift engineer on site at all times and this makes rounds through the Bioenergy Plant on a regular basis. The system includes an industrial control system (PLC) that runs the process; alarms and process parameters are exported to the campus control network (DDC) for remote review from computers throughout the campus.

FIGURE 8. In the first 8 months of operations, the Bioenergy Plant has offset an estimated 61% of the natural gas that would have otherwise been used for heating. The plant was offline during the commissioning challenges in the spring and the maintenance shutdown in August.



This is an industrial facility, and the operational requirements are somewhat different from those of the balance of the campus. Most of the mechanical spaces at the university are typical of an institutional context—pumps, heat exchangers, and air handlers arranged in a tidy, well-lit room. Such equipment fails in a reasonably predictable manner and has been a part of the operational duties of the Facilities staff since the university opened. In contrast, the Bioenergy Plant includes hydraulic systems, augers and conveyors for hog fuel, refractory brick, ash conveyors, and other industrial equipment. Experience from the forestry operations in this region indicates that such systems (particularly the material-handling components) tend to break down at inopportune times. The skills, knowledge, and experience required to operate and maintain this system represent a growth opportunity for the staff at UNBC and may lead to training programs where the university can help to educate operators for similar systems deployed throughout the region.

The design specifications include two one-week maintenance shutdowns each year. These are primarily scheduled around replacement of the gasifier feed auger, but also include inspection and preventative maintenance of the other equipment. Maintenance work must be strategically planned so that additional downtime is not required, otherwise it will be difficult to achieve the target natural gas reductions.

Public Engagement

More than 1,000 people have toured the Bioenergy Plant in the first year of operation. This includes politicians, UNBC students, prospective developers, industry officials, school children, and community residents. The system uses a fuel resource that is very visible in the community, and the public appreciates the demonstration of an efficient, clean technology. UNBC has hosted two open house events to provide the public with an opportunity to witness the system first-hand.

A research program focused on the impacts and opportunities for biomass extraction is beginning to emerge within the faculty and research mix of the university. Several courses have incorporated tours and case studies based on the bioenergy projects and a number of graduate students are examining aspects of this project in their research.

The City of Prince George is also implementing a biomass district energy system to serve a number of buildings in the downtown core. This project has gone through several design iterations during the time that the UNBC projects were installed. The public perception of the city's project has shifted over this time, likely due to improvements in the project structure. The increased level of public awareness around the low emissions and reliable operation of the UNBC systems may have also contributed.

Financial Considerations

The Bioenergy Plant cost $15.7 million, and was made possible through funding from the Public Sector Energy Conservation Agreement, the Innovative Clean Energy fund (Province of BC), and the Knowledge Infrastructure program (Government of Canada).

The operating budget includes purchased hog fuel, plant utilities, operator salaries, and maintenance expenses. The reduced need for natural gas in the Power Plant boilers provides the funding for this budget. The project also eliminates most of the carbon offsets that the university is required to purchase to achieve carbon neutrality.

Bioenergy projects have higher operating and maintenance costs than equivalent systems using natural gas. As evidenced by Figure 9, only 59% of the operating costs for the facility are for the purchased fuel. The other operating costs are fixed and do not depend on the amount of heat required. It is therefore advantageous to switch as many heating loads as possible onto the district energy system—particularly domestic hot water for the summer months—so that the Bioenergy plant operates at the maximum possible capacity.

BIOENERGY PLANT—BUILDING

The biomass gasification system is housed in a building designed by Hughes Condon Marler Architects. As a public-sector building in British Columbia, it is required to be certified to LEED™ Gold (Province 2011). The 11,000 ft^2 building includes fuel storage, process areas, a control room, and a research laboratory. The classroom-sized research area is housed in the wood-clad mezzanine which overlooks the campus. This was included to provide space for bioenergy research on campus.

The structure takes advantage of the sloped grade on campus. Fuel delivery trucks back in on the upper level to unload into the bunker, while access to the lower level process equipment is provided on the downhill side of the building.

The high fly ash content in the concrete demonstrates one of the potential productive applications of the ash collected in the ESP. Fly ash can be diverted from landfill while offsetting the need for cement, which is itself the product of an emissions-intensive process.

The building makes extensive use of wood, all sourced from British Columbia's extensive forests. The laminated beams and laboratory ceiling of exposed dimensional lumber were specified in the design, but the plywood covering the walls in the process areas was a suggestion by the construction contractor. Prefinished and flame resistant, this plywood presented an installation labour savings over other wall systems, and provides a fitting backdrop for the wood heating equipment.

An estimated 55% percent of the construction waste was diverted from the landfill through re-use and recycling. This posed some challenges due to the distance from Prince George to major recycling markets. The campus is 790 km from Vancouver city centre—very close to the 800 km eligibility limit and a significant distance to transport many of the materials.

FIGURE 9. Preliminary breakdown of the Bioenergy Plant operating costs, based on the first 8 months of operation. The ability to provide an independent report on operating and maintenance costs is a key benefit of the UNBC demonstration site.

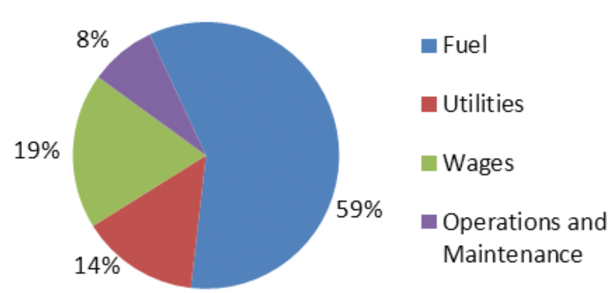


FIGURE 10. The Bioenergy Plant is targeting LEED Gold for New Construction, and features extensive use of wood from British Columbia.

Building heating is a mixture of hot water from the bioenergy process and natural gas. The gas is used in unit heaters for the process areas and as back-up fuel for the air handlers. This satisfied the design requirement to provide a secondary heat source during periods when the biomass system was not running. However, operating experience has shown that the heating loop which normally transfers heat from the Bioenergy Plant to the Power Plant is also capable of transferring heat in reverse. In this way the Power Plant boilers can provide back-up to the Bioenergy Plant as well as to the balance of the district energy system.

The efficient transportation options which already serve the campus enabled a minimal amount of new parking to be installed for this project. The handicapped parking is frequently required when giving public tours and the electric vehicle space has been appreciated by one of the lecturers at the university.

KEY LESSONS LEARNED

It is rare that one would execute the same project twice without changing some aspects of the implementation; these bioenergy projects are no different. For the benefit of those who may consider a similar implementation on a project elsewhere, here are some of the potential change areas that hindsight has identified.

Fuel Supply and Cost

Hog fuel cost represents the bulk of the operating budget and is subject to market fluctuations. An increase in the cost of hog fuel from project planning through to contract execution significantly affected the economic return of the gasification project. The fuel specification from the equipment supplier is quite narrow in what it accepts and may have limited the ability of some local suppliers to bid on the fuel contract. Particularly with biomass projects that use raw wood (not manufactured pellets), it is important to secure a fuel supply that meets equipment specifications at a known cost prior to committing to the project.

The Bioenergy Plant receives wood fuel directly from the sawmill; this hog fuel is notorious for containing materials other than wood chips. The fuel feed system within the plant should include equipment to remove metal, foreign objects, and oversized material from the fuel stream.

Lakeland does not separate sawdust from their bark and other residuals.[3] This fine material can cause problems in the gasification system as the increased surface area allows the sawdust lumps to react faster and then collapse inwards. This disturbs the gasifier pile and can result in carry-over of ash or other particles into downstream vessels.

Efficiency

If hog fuel is free or extremely low cost, the overall efficiency of the system is not a concern: fixed maintenance costs dominate the operating budget. This was the case when hog fuel was a waste that posed a disposal problem, and many biomass-to-energy systems in the forestry industry were constructed under this model. As competition for residual fibre increases the efficiency of the conversion process becomes more important. The gasification system could benefit from increased refractory and insulation to line the oxidizer so that less heat is rejected within the building.

Additional improvements in efficiency will come through combined heat and power, economizers to recover heat given off by the process, and condensing of exhaust gases. Both of the bioenergy systems at UNBC only use medium-temperature heat. For the gasification system, much of the heat given off by the process is not recovered and the high-grade heat that has the potential to produce electricity is converted to medium-temperature water.

Ash Disposal

Biomass-fueled energy systems produce ash as a byproduct. The gasification system produces low-carbon ash in relatively low volumes, yet even this has posed some disposal challenges. Research carried out at UNBC on ash produced by the pellet system has identified uses for this product, particularly as a soil amendment. An ongoing research program is examining the application rates and permitting process required to spread the ash on hay fields.

Facilities Staff Impact

A significant factor in the success of this approach is the willingness of the facilities staff to take on the operation of these systems. This is largely a credit to the commitment of the individuals, and partially a product of the relatively young age of the campus. There hasn't been as much time for the bureaucracy and departmental isolation to develop. However, systems such as these do place additional duties on the facilities staff, and not always in areas that were anticipated. It is readily apparent in the planning phases that the shift engineers will have additional equipment to service and monitor on their rounds. This can be budgeted for and additional staff hired as required. The increased workload for the management and maintenance planning staff is not as readily apparent. These systems require annual maintenance shutdowns where a significant amount of the annual preventative maintenance and inspections will be performed. The duration of these shutdowns should be minimized so that the amount of back-up natural gas heating is minimized. Planning, scheduling, and staffing an industrial-style maintenance shutdown was not something that the university was accustomed to.

Building

The high level of public interest in the project, and the panoramic view from the mezzanine level, has prompted the question of whether a reception space should have been incorporated into the building.

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[3]Sawdust is in demand by pellet producers and is typically separated for sale at a premium.

From an operations perspective, additional catwalks to access the process equipment would eliminate the need to erect scaffolding during each maintenance shutdown. Fortunately the lighting placement was corrected prior to completion of the project, and it should be possible to gain access for lamp replacements without having to remove wall panels. The heating system in the fuel storage area should avoid direct combustion appliances as wood dust can be extremely flammable.

The piping loop between the Power Plant and the Bioenergy Plant is a shallow concrete duct with insulated pipes inside. A full height utility corridor to provide personnel access between the plants would have been preferable. If the cost for this option was too great, direct buried pre-insulated piping would likely provide equal functionality to the concrete duct, with lower cost and maintenance liability.

FUTURE PLANS

The current bioenergy systems provide only heat to the campus; the university intends to add renewable electricity generation on-site.

Aboriginal Affairs and Northern Development Canada has identified approximately 175 northern Canadian communities which are not connected to the electrical grid and therefore depend on local diesel generators for power. The cost to generate this electricity is several times higher than the rate for grid electricity, but the remote locations of such communities make grid connection prohibitively expensive. The emissions associated with transporting and burning diesel, the potential impacts of a fuel spill, and the generator noise are additional factors which are producing increased interest in local, renewable electrical generation options for these communities. The UNBC campus is supplied with low-cost grid electricity, and can use this as a backdrop for developing and demonstrating reliable full-scale renewable energy technologies. In particular, there is interest in technologies that are applicable to remote northern communities and connecting these groups to relevant educational and research programs.

CONCLUSION

The bioenergy heating projects at UNBC are successful demonstrations of leading renewable energy technology. By combining research with the operational needs of the campus it is possible to showcase these systems in a manner that can be adapted to other applications without the hurdle of scaling up a pilot plant. The high degree of community and stakeholder support for these projects indicates what is possible when energy development is attentive to the needs and industrial/economic character of the local community.

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