UBC ACADEMIC DISTRICT ENERGY SYSTEM

THE UNIVERSITY OF BRITISH COLUMBIA
Energy & Water Services

THE UBC POINT GREY CAMPUS IS SITUATED ON THE TRADITIONAL, ANCESTRAL, AND UNCEDED TERRITORY OF THE MUSQUEAM PEOPLE.

System Name

The University of British Columbia's Academic District Energy System

Location

Vancouver, British Columbia, Canada

Owner

The University of British Columbia

Type of ownership

Publicly owned by the Province of British Columbia

Contact

Energy & Water Services

The University of British Columbia
6130 Agronomy Road, 2nd Floor
Vancouver, BC Canada, V6T 1Z3

Phone: 604 822 5301

FAST FACTS

UBC Vancouver campus

17 million square feet
207 spin-off companies
13,237 degrees granted in 2017

Population

56,000 students including more than 16,000 international students from 156 countries
15,700 faculty and staff

UBC District Energy System

10 million square feet, made up of 162 buildings

$70 million in cumulative energy and water savings from supply and demand side projects since 2000

THE UNIVERSITY OF BRITISH COLUMBIA

Energy & Water Services

The University of British Columbia (UBC) is consistently ranked among the 40 best universities in the world and is a global centre for research and teaching. Since 1915, UBC's entrepreneurial spirit has embraced innovation and challenged the status quo. It's this ground-breaking spirit that has driven the transformation of UBC's Academic District Energy System (ADES) into one that is efficient, reliable, resilient, and increasingly sustainable — a district energy system that is a platform for the integration of renewable and waste heat sources for its campus.

From 2011 to 2017 UBC's aging gas-fired steam district energy system was replaced, piece-by-piece, creating a state-of-the-art, low-temperature hot water system. The *ADES Steam to Hot Water Conversion Project* replaced 14 trench km (8.7 trench mi) of 90-year-old steam piping, converting more than 141 buildings off of steam. In 2017, UBC shut the doors of its steam powerhouse replacing the system's primary energy source with the new 45 MWt (154 MMBtu/hr) Campus Energy Centre (CEC) which, together with the distribution, improves energy efficiency by more than 24 per cent.

The ADES is also becoming increasingly more renewable — in 2012, the International District Energy Association (IDEA) Innovation Award winning 6 MWt (20.5 MMBtu/hr) biomass gasification system and a 2 MWe cogeneration unit were added to provide renewable electricity and thermal energy for the campus. Today, 25 per cent of the campus' heating and hot water needs are met by using clean wood waste.

These milestone projects, alongside energy conservation, have helped UBC achieve a 34 per cent reduction in greenhouse gas (GHG) emissions from 2007 levels, against a backdrop of increased student enrolment (16 per cent) and growing building floor space (23 per cent).

UBC continues to provide reliable, cost-effective, and increasingly sustainable utilities to its campus and broader community. For those who work, study, live, and play at UBC, utilities are served to multiple facilities including: 1.6 million square metre (17 million square feet) of core academic/ research and animal care buildings, 12,000 housing beds, an Olympic size swimming pool and other athletic facilities, 330 bed hospital, and the world's largest cyclotron.

Looking ahead to 2020, UBC will be tripling the capacity of its biomass plant, energizing two-thirds of the ADES with renewable fuel sources. This increase in capacity will further diminish UBC's reliance on fossil fuels and lead to the reduction of an additional 13,000 to 15,000 tonnes of carbon dioxide (tCO2) annually.

Wrapped in 800 hectares (2000 acres) of dense forest known as Pacifc Spirit Regional Park, UBC's campus proper is more than 400 hectares (900 acres) containing 838,000 square metres (9,021,000 square feet) of academic building space, and another 760,000 square metres (8,176,000 square feet) of ancillary space such as student housing and athletic facilities.

1.0 An efficient system

UBC ENERGY AND WATER SERVICES

Like any growing city, UBC's Vancouver campus faces an ever-increasing demand for basic services like electricity, heat, natural gas, water, and sewer. To manage the costs of these services, UBC's Energy and Water Services (EWS) manages and operates UBC's utility assets, delivers utility master plans, load forecasts, and associated capital upgrades.

The unit combines the utility and district systems managers, trades, and operators with professional engineers and building management systems specialists. This group focuses on delivering reliable, efficient service, and collaborates to identify new energy and water saving opportunities.

TRANSITIONING TO LOW TEMPERATURE HOT WATER

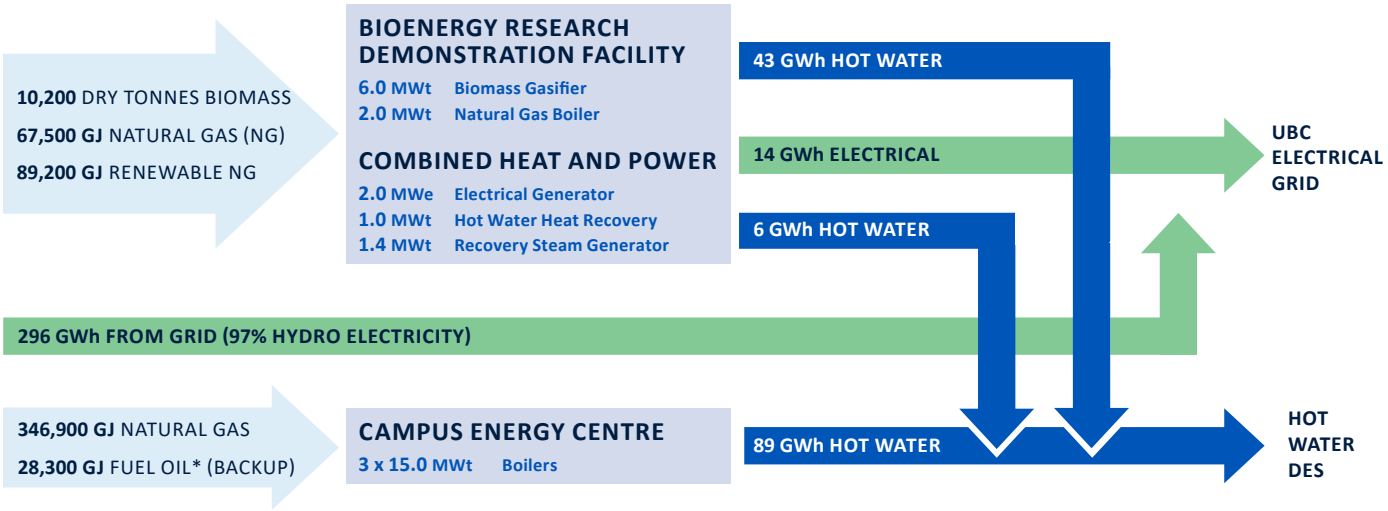
The multi-year transformation of UBC's Academic District Energy System (ADES) halved its natural gas use through major conservation, efficiency, and renewable energy capital projects.

Before the conversion, UBC's steam powerhouse had a peak steam load of 120 MWt (250,000 lb/hr) and was the leading seismic risk for the Vancouver campus. In addition, despite previous investments, the system faced a staggering maintenance liability of $190 million and needed significant capital renewal. The steam powerhouse was also identified as the primary source of campus greenhouse gas emissions — producing more than 50,000 metric tonnes of carbon dioxide annually. It was clear that there was an opportunity for the installation of an efficient, resilient, and cleaner campus heating system — one that could become a platform to accommodate the future integration of renewable and waste heat sources. All signs pointed towards a new low temperature hot water energy system.

The $88 million *ADES Steam to Hot Water Conversion Project* replaced 14 trench km (8.7 trench mi) of 90-year-old steam piping with new insulated piping, converted 115 buildings to the highly efficient hot water district energy system through 102 energy transfer stations, addressed process and legacy steam

UBC Academic District Energy system energy balance

Total system energy efficiency is 75 per cent in Fiscal Year 2018/19



**Fuel oil used due to the Enbridge T-South natural gas line explosion in northern British Columbia. Please refer to Section 3.0*

UBC 2010 CLIMATE ACTION: Greenhouse Gas reduction targets
33% below 2007 levels by 2015
67% below 2007 levels by 2020
100% below 2007 levels by 2050

requirements in 26 buildings, decommissioned its 92 year-old steam powerhouse, and built a 45 MWt (154 MMBtu/hr) natural gas fired Campus Energy Centre to meet all campus energy needs.

The project improved energy efficiency by more than 24 per cent, saved 270 million litres (71 million US gallons) of water, and was instrumental in enabling UBC to achieve its 2015 greenhouse gas emissions reduction target.

Today, UBC's ADES is energized by waste heat recovery from an upgraded biogas-fuelled cogeneration engine and a renewable energy biomass gasification system. For peaking loads the system uses its high-efficiency natural gas-fired hot water boilers. The distribution system is primarily comprised of a low temperature hot water system with approximately 3 per cent distribution loss. A small and shrinking section of steam legacy grid is still in use, providing process steam to two buildings. In 2019, this small section will be shut down permanently and will result in further improvements to the system's overall efficiency.

BASELOADED COGENERATION

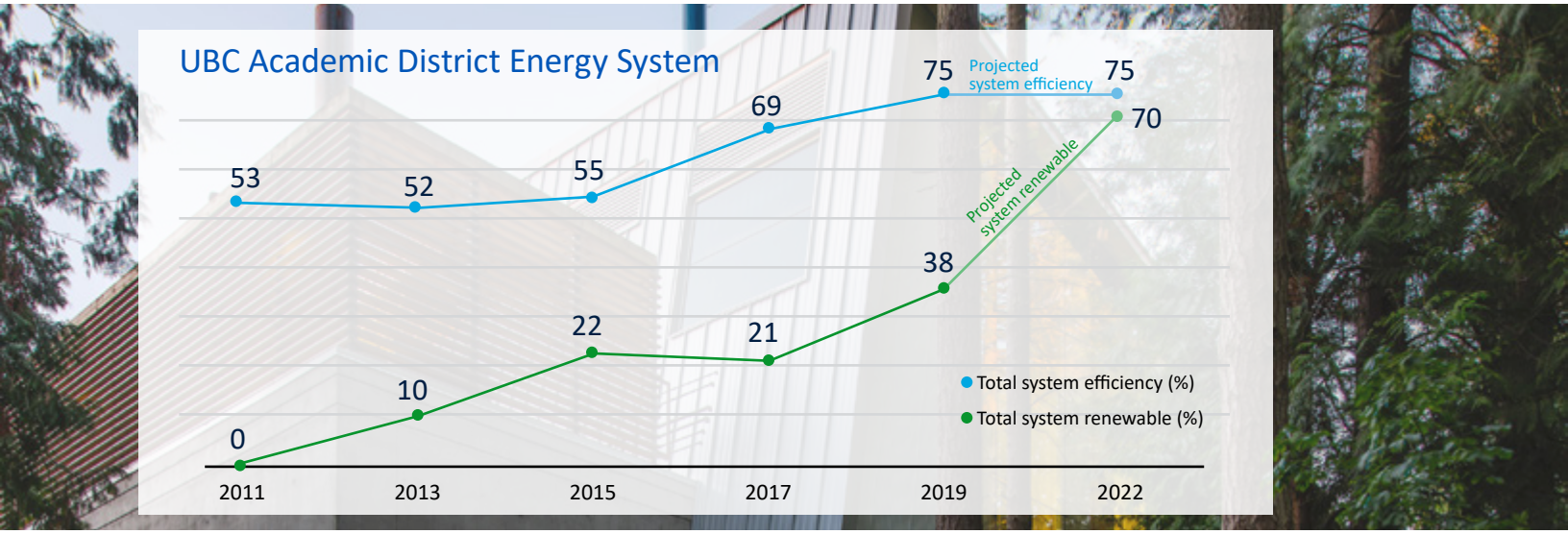
The campus' electrical and thermal systems are baseloaded with the Bioenergy Research and Demonstration Facility's (BRDF) 2 MWe cogeneration engine. Originally operated as North America's first demonstration of a community-scale internal combustion engine based combined heat and power (CHP) system fuelled by biomass, the engine has run since 2014 on a mixture of natural gas and upgraded biogas, providing 5 per cent of UBC's electrical supply. Two forms of heat are recovered from the engine; steam, via a 1.4 MWt (4.8 MMBtu/hr) heat recovery steam generator, and, taking advantage of the new lower temperature hot water ADES, 1 MWt (3.4 MMBtu/hr) of hot water via the addition of a heat exchanger, recovering heat from the engine's cooling systems. The engine's combined heat and power efficiency is 64 per cent.

BASELOADED BIOMASS

The ADES is secondarily baseloaded with the BRDF's 6 MWt (20.5 MMBtu/hr) clean wood waste gasifier and steam boiler. The system daily gasifies two to three truckloads of ground and chipped clean wood, an abundant local and renewable fuel source, which is then combusted to generate more than 25 per cent of the thermal supply on campus. The facility has contributed to a 14 per cent reduction in UBC's greenhouse gases and has averaged an efficiency of 77 per cent over the last five years. The steam from both the cogeneration and biomass systems feeds the hot water ADES via steam to hot water converters with some steam provided directly to the residual process steam legacy grid. The BRDF also has a backup 2 MWt (6.8 MMBtu/hr) natural gas steam boiler.

CAMPUS ENERGY CENTRE

The new 45 MWt (154 MMBtu/hr) natural gas-powered hot water plant, consists of three 15 MWt (51.2 MMBtu/hr) hot water boilers. The plant provides heat for the peaking thermal loads of the campus. It boasts an average efficiency of 86 per cent since beginning operations in 2015, easily exceeding the steam powerhouse it replaced, by more than 10 per cent.



TOTAL SYSTEM EFFICIENCY

Since 2017, the hot water ADES has averaged 81 per cent efficiency, including biomass contributions and distribution losses.

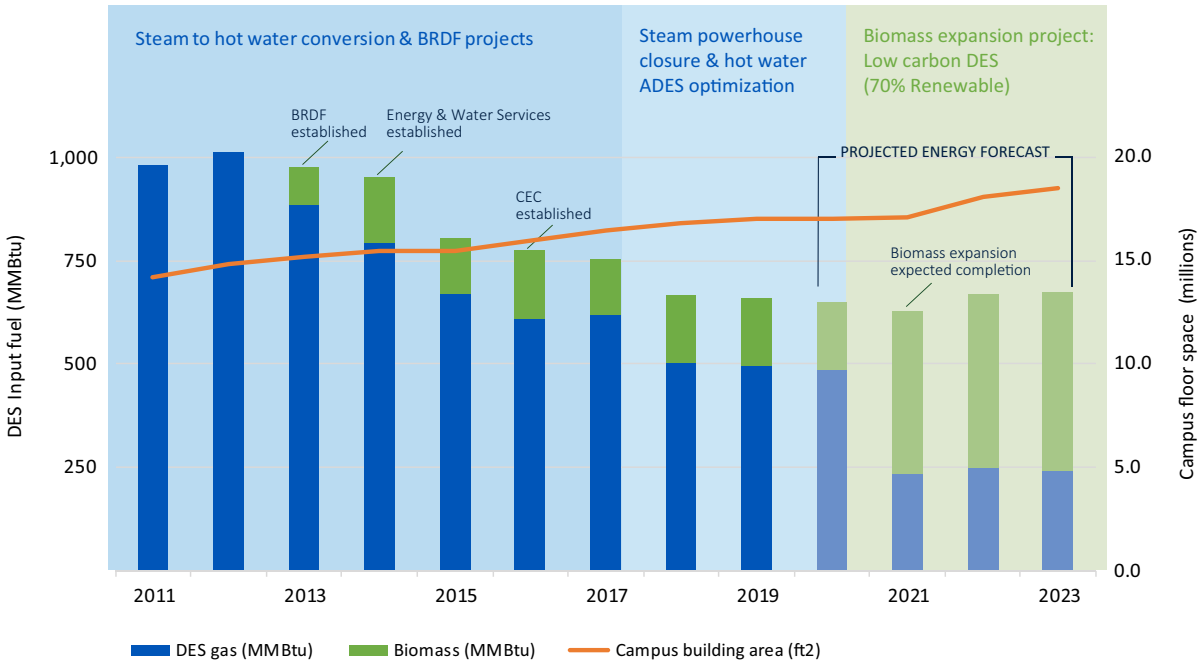
The combined hot water and remaining steam district energy system's total system efficiency was 75 per cent in the 2018/19 fiscal year, up from 53 per cent in 2011/12, as calculated by:

$$\textbf{\textit{Total System Efficiency}} = \frac{\textit{Energy (electrical, hot water, steam) net of distribution losses}}{\textit{Fuel Input (all fuels including biomass, natural gas, renewable natural gas, and fuel oil)}}$$

EFFECT ON A CAMPUS LEVEL

Despite adding 33 per cent more floor space and 46 percent more students, UBC's ADES uses half the amount of fossil fuels as it did 10 years ago, and will be halved again in 2021 when the biomass expansion project is completed. The sum of the supply side improvements, alongside building energy conservation (see Section 5), are apparent in UBC's ADES overall reduction in fuel use as shown in chart.

Historical and forecasted energy use by type



2.0 Proven reliability

UBC enables an environment that supports exceptional learning and research outcomes. Reliable and available utilities are essential to achieve this mission. UBC's district energy and other utility systems are designed and maintained to ensure uninterrupted service for all its customers including highly critical research, animal care, and medical facilities.

REDUNDANT, LOOPED, & UNDERGROUND SYSTEMS

The Vancouver campus district systems are maintained at N+1 redundancy and utility infrastructure have multiple campus entry points.

Hot Water ADES: UBC's hot water district energy system is a looped system, minimizing the impact of a potential breaks or failures. It is designed as a multiple loop system with numerous zones divided by isolation valves allowing for system repair or extension while minimizing heat interruption to customers.

Electrical: UBC has two main overhead high voltage transmission cables supplying the campus, with either transmission line able to carry the full campus load. Once reaching campus, the lines travel underground, preventing the risk of damage due to windstorms. All UBC buildings are supplied by normal feeder cables from UBC's own main substation, and in an emergency, all buildings are equipped to be supplied via a second standby feeder. Within the campus, critical buildings have back-up generators for electrical power. This ensures a high level of system reliability for all campus facilities and services.

Water: The main campus has one normal supply and one emergency supply, while the residential neighbourhood has one supply, with emergency backup provided by the main campus, as required.

Natural Gas utilities: The campus has four lines of natural gas service with a complete internal ringmain distribution system enabling gas services to be maintained at any point of service.

Year	Utility	Availability	Reliability
5 Year Average	Hot Water	99.99%	100%
	Electrical	99.97%	99.99%
2017	Hot Water	99.99%	100%
	Electrical	99.98%	99.99%
2018	Hot Water	100%	100%
	Electrical	99.99%	100%

Availability: *Total hours of forced outage/total hours in period x number of production units*

Reliability: *Total customer hours of unplanned and interrupted service / total annual customer hours (deviation from acceptable operational criteria)*

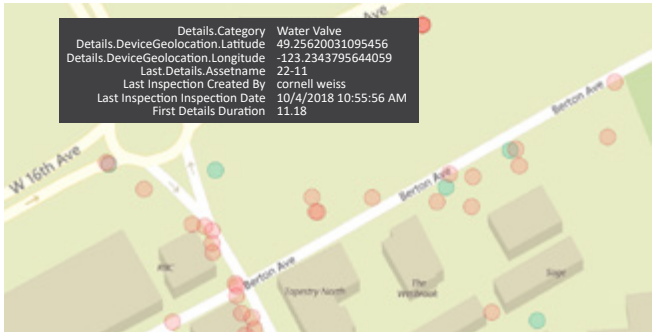
NOTE: *UBC's water, natural gas, sanitary & sewer utilities have been 100 per cent available and reliable over the last 5 years.*

PLANNED PREVENTIVE MAINTENANCE

The ADES and utility infrastructure undergo scheduled routine maintenance, as well as planned inspections, testing; and sampling to ensure optimal reliability.

In 2018, UBC Energy and Water Services modernized how it schedules, tracks, informs, and manages its preventative maintenance program. Deploying the use of BuiltSpace, a cloud-based application, UBC's utility systems'

BuiltSpace, a cloud-based application



Note: *BuiltSpace utilizes any mobile device for maintenance crews to receive and respond to maintenance orders.*

Digital signage located at the front entrance of UBC's Campus Energy Centre

maintenance crews can utilize any mobile device to receive a maintenance order, geo-locate assets, receive asset information and service history, report damage or failure, escalate issues to management, upload pictures of service, and manage any other system-related maintenance.

The application summarizes the work performed to identify areas of further action and optimization. In addition with geo-locating assets, any discrepancies can be marked on the map, uploaded to a geographic information science (GIS) technician who can 'live' update the map for further accuracy.

RENEWED INFRASTRUCTURE

Aging and vulnerable systems and equipment are targeted for replacement prior to failure. The *ADES Steam to Hot Water Conversion Project* addressed a significant portion of deferred maintenance associated with the vulnerable steam system piping, heat exchangers, and valves. To address water service, annually two kilometres (3.2 mi) of aging cast iron piping is replaced with ductile iron piping. Two to three electrical substations are replaced each year, alongside four to five linear kilometres (2.5-3.0 mi) of electrical paper insulated lead or plastic insulated (XLPE) cables. For sanitary and storm water sewer systems, close to 14 km (8.7 mi) of piping is CCTV inspected, flushed, and relined or repaired as necessary, every year. The natural gas system is annually cathodically surveyed.

LEAK DETECTION

The hot water district system is fitted with a leak detection system which is monitored 24/7 by plant operators. The system alarms against both hot water and ground water leaks through a protective insulation jacket. The system enables UBC Energy and Water Services to respond quickly and address leak repair prior to a catastrophic interruption.

SECURE BUT ENGAGED

Utility plant access is tightly controlled and monitored, but the plant has been constructed to provide public facing glass of the production units as well as screenage and signage allowing for community access and education. Visitors to the plant can look at, take a guided tour of, and learn about the equipment providing these essential services.

GIS MAPPING

All of the UBC utility systems are mapped and in GIS to help with response to utility issues, and to assist informing contractors where to dig.

3.0 Resiliency

A major earthquake could occur at any time in British Columbia. Providing electricity, heat, water, and sanitary sewer services are essential to UBC's recovery plans in the event of such an occurrence. Careful planning and preparation to make the ADES and utility infrastructure more resilient and will minimize injury and loss, prevent panic, and facilitate rescue and cleanup efforts.

ADES FUEL RESILIENCY IN RESPONSE TO CRISIS

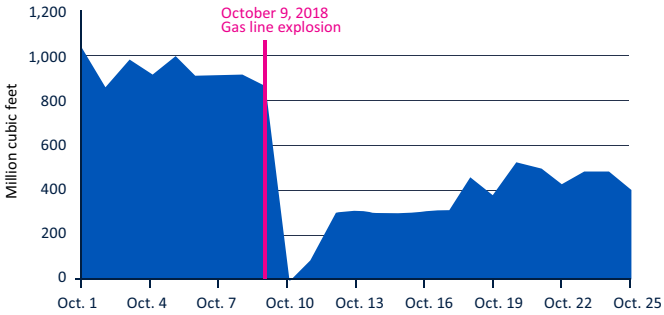
In October 2018, the Enbridge T-South natural gas line exploded in northern British Columbia resulting in 100 per cent loss of supply. This pipeline is the main natural gas supply line to the greater Vancouver region. An acute natural gas shortage occurred, immediately triggering reductions, restrictions, and remarkable price fluctuations lasting through the winter to March 2019.

In response to this natural gas emergency, UBC seamlessly switched to its fuel oil backup at its Campus Energy Centre with no impact to campus service. UBC maintains 290,000 litres of fuel oil (77,000 US gallons) on site ready for this type of situation.

In the past, UBC's ADES had been 100 per cent reliant on natural gas utility providers (with fuel oil backup), but today it has multiple fuel options, redundancies, and backup, including natural gas, fuel oil, renewable natural gas, and biomass. The impact of this natural gas shortage was lessened as 25 per cent of the ADES thermal energy is provided with biomass. Fuel pricing during the crisis was upwards of $50/GJ CAD ($40/MMBtu US) for natural gas and $30/GJ CAD ($24/MMBtu US) for fuel oil compared to $3.25/GJ CAD ($2.6/MMBtu US) for biomass.

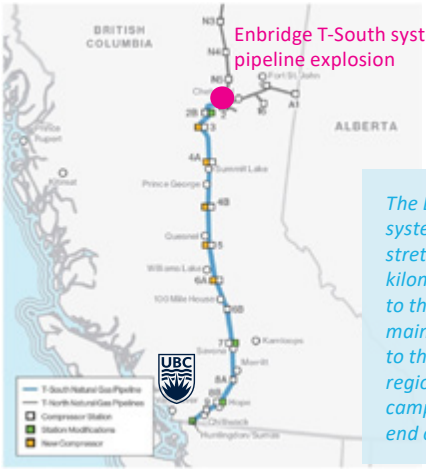
In the event of future incidents, the planned 2021 expansion of the biomass plant (see Section 9.0) will further mitigate impacts of this nature, with biomass supplying 70 per cent of the campus' thermal energy. UBC's ADES continues to strengthen its fuel resiliency with multiple levels of fuel redundancy – biomass with full natural gas backup and fuel oil backing up the natural gas.

Daily natural gas flows into northwest Sumas



Source: Genscape Inc.

The Enbridge T-South system pipeline



The Enbridge T-South system pipeline, which stretches over 1,000 kilometres from Chetwynd to the B.C.-US border is the main natural gas supply to the greater Vancouver region. UBC Vancouver campus is located at the end of the T-South system.

Source: Enbridge Inc.

REDUCING RISK

The number one seismic risk on the UBC Vancouver campus was the steam powerhouse; its decommissioning in 2017 eliminated a significant risk to UBC's infrastructure. The steam powerhouse was replaced by the combination of the BRDF in 2012 and the CEC in 2015, both designed to withstand natural disasters and enable services to be available post-disaster.

UBC's *ADES Steam to Hot Water Conversion Project* demonstrates an innovative approach to infrastructure management, and leverages cyclical maintenance investment to achieve multiple sustainability objectives. The project has eliminated $190 million in deferred maintenance costs, reduced operating costs, improved safety and resiliency, and dramatically reduced energy and water consumption.

N+1 REDUNDANCY

Many of UBC's systems have N+1 redundancy (i.e. backup) features, which offer resilience. For example, during recent wind storms in January 2018, one transmission line was downed twice during a 10-day period due to felled trees. The UBC Vancouver campus did not experience an outage due to a fully redundant second transmission line.

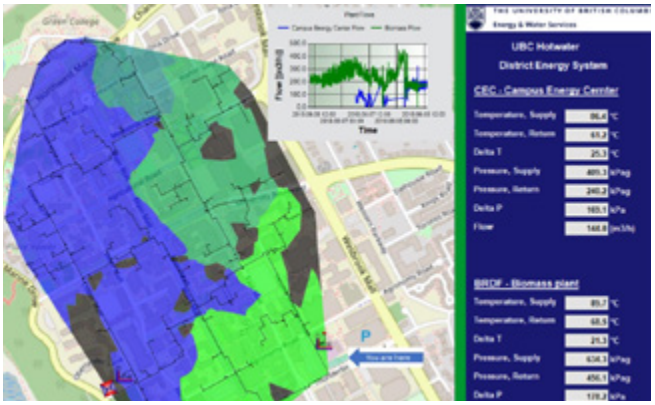
OPTIMIZATION, MODELING, AND SIMULATION

UBC is continually improving its district system's operation. In 2018, the hot water ADES has been modelled in *Termis*, a real-time district energy optimization software, to improve service, minimize losses, plan expansions, and create what-if scenarios to understand areas of vulnerability in the system, to increase resiliency. The ADES model has been connected to real-time plant and building data allowing UBC Energy and Water Services engineers to monitor the system in real-time and address areas of concern.

The UBC electrical distribution system is modelled with ETAP, an electrical power system analysis software. While currently a static model, UBC is upgrading the ETAP model to a real-time model, similar to *Termis*, in 2019.

Potable water, sanitary, and storm water sewer systems are all modelled using Bentley, a static modelling tool.

Termis, a real-time district energy optimization software



4.0 Environmental benefits

UBC's ADES has a long history of reducing its emissions and environmental impact. The steam district's original 1925 coal-fired boilers were converted to fuel-oil in the 1950s and then to natural gas in the 1960s. Fifty years later those steam boilers are now decommissioned, replaced with biomass and high-efficiency natural gas-fired hot water boilers. Each conversion has significantly reduced air pollutants, greenhouse gas emissions, and continued UBC's commitment to mindful environmental stewardship.

GREENHOUSE GAS EMISSION REDUCTIONS

UBC is committed to climate action to avoid and minimize the impacts of climate change, demonstrate its leadership in research, innovation and learning, reduction in operational costs, to create and sustainable solutions for the university. UBC has inventoried its GHG emissions since 2006 and has been carbon neutral since 2010 by paying carbon offsets on its direct and indirect emissions, amounting to more than $1 million annually. In 2007, UBC met the Kyoto Protocol targets (to reduce GHG emissions by six per cent below 1990 levels), despite double-digit increases in floor space and student enrolment. In 2010, the Vancouver campus Climate Action Plan

(CAP) committed UBC to achieve further GHG reduction targets against a 2007 baseline. UBC is committed to reducing GHG emissions by 67 per cent by 2020 and plans to be GHG emission free by 2050.

It is worth noting that UBC's GHG commitments and targets are all based on natural gas as the baseline fossil fuel and with 'green' hydroelectricity.

Within the CAP, in 2016 UBC's Vancouver campus achieved its 2015 GHG emissions reduction target from a 2007 baseline, despite a further 16 per cent increase in building floor space and a 23 per cent increase in student enrolment over the same period.

This success was achieved through three major projects:

- Replacing the steam-based campus ADES with a new hot water-based ADES improving efficiency by 24 per cent.
- Building the BRDF to fuel switch from natural gas to biomass, reducing fossil fuel use by 25 per cent.
- Creating an energy team that optimize building performance and reducing energy usage through the Building Tune-up Program – generating enough savings to offset campus growth.

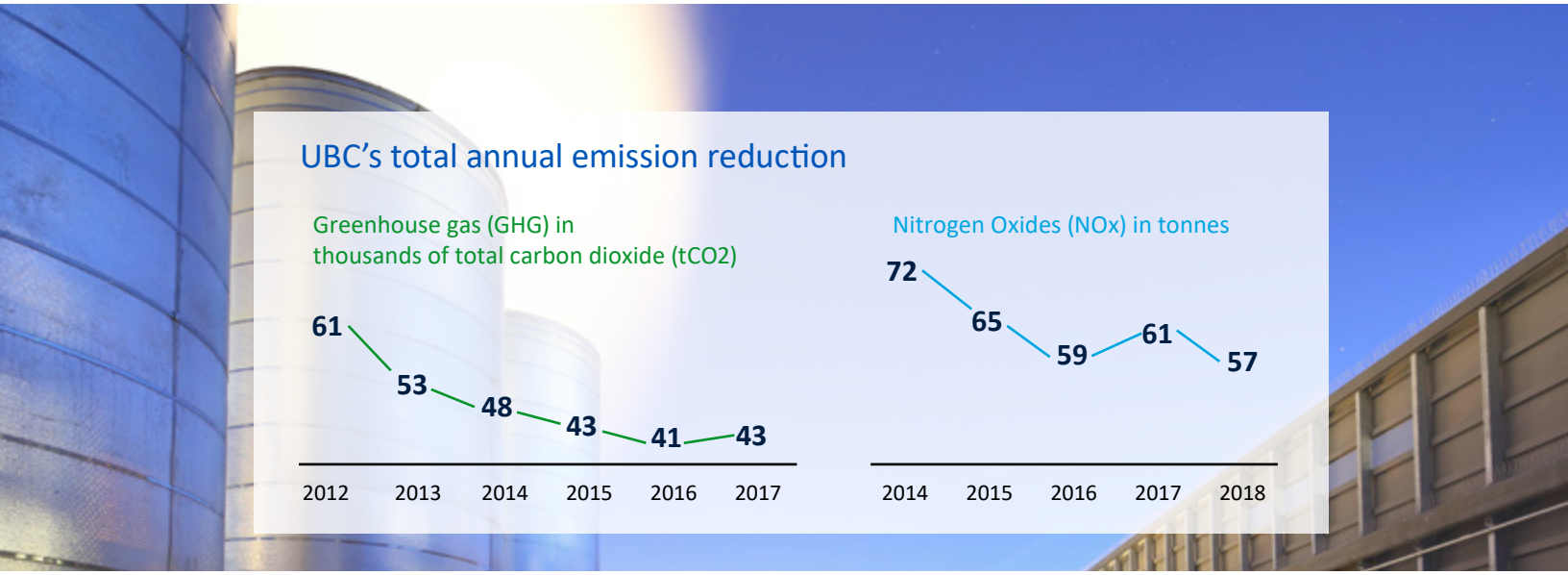
In 2017, the updated Climate Action Plan for 2020 was developed, identifying 24 actions to advance toward the 2020 target. Under the plan the BRDF's biomass capacity will be tripled, driving GHG emissions down and significantly reducing UBC's reliance on fossil fuel (natural gas) (See Section 9.0)

AIR EMISSIONS —NOX AND PARTICULATES

UBC's ADES continues to reduce its air pollutants through use of new technology, monitoring, and operational practices. Both the CEC and BRDF underwent a rigorous air quality dispersion modelling and permitting process prior to project construction.

The BRDF operates under a Metro Vancouver Air Quality Regulatory Permit which requires annual stack testing, continuous emission monitoring, a fuel plan, and maintenance records. The BRDF project met self-imposed emission limits that were stricter than the air quality regulatory permit levels. As part of the air quality tracking, UBC installed an ambient air monitoring station on top of the neighbouring residence building to track NO, NO_2, and particulate matter in real time.

UBC continues to reduce its reliance on natural gas by expanding the use of biomass, reducing the impact of available supply, and having to use fuel oil as backup. As a result, UBC's absolute emissions have been decreasing over time despite campus growth.



5.0 Sustainability

The University of British Columbia continually pushes the boundaries on sustainability.

UBC has a long history of innovation and sustainability. In 1990, UBC signed the Talloires Declaration, pledging to make sustainability the foundation for all campus operations, research, and teaching. They were the first university in Canada to adopt a sustainable development policy and, in 1998, opened a Sustainability Office and hired a dedicated energy manager. Three years later, they launched the EcoTrek program, the largest energy and water retrofit program of its kind at the time, retrofitting 288 buildings resulting in an annual savings of $2.6 million in commodity costs. In 2011, UBC opened its Centre for Interactive Research on Sustainability (CIRS) LEED® Platinum — home to many research projects and programs that continue to push the envelope in sustainable building design and technology. In 2015, UBC achieved their second consecutive AASHE Gold status in the Sustainability Tracking, Assessment and Rating System (STARS). Today, UBC is an active member of the University Climate Change Coalition (UC3). Along with 18 other leading North American universities, UBC acts as an agent for collective climate action by convening climate change forums with community and business leaders from its region.

WATER CONSERVATION

UBC distributes 3.77 billion litres (996 million US gallons) of water annually, two thirds of which is distributed to its campus. UBC campus has achieved a 50 per cent reduction in absolute water use since 2000, deferring the need for capacity increases despite growing by 46 per cent over that period.

- Thanks to the ADES Steam to Hot Water Conversion Project, today's hot water ADES uses 2000 times less water than the steam system it replaced, annually saving 270 million litres (71 million US gallons) of water.

Today's hot water ADES uses 2000 times less water than the steam system it replaced, annually saving 270 million litres (71 million US gallons) of water.

  The newly installed hot water system is a closed loop with leak detection systems to prevent water losses.
- UBC continues to audit existing buildings for water conservation opportunities and implement retrofits which conserve more than 170 million litres of water (45 million US gallons) annually, enough to fill UBC's award-winning new Aquatic Centre 35 times every year.

RENEWABLE ENERGY

Biomass: UBC's BRDF's 6 MWt (20.5 MMBtu/hr) system processes two to three truckloads of ground and chipped clean wood waste. The gasification process uses the material to produce a synthesis gas (syngas), which is combusted to generate more than 25 per cent of the hot water used for heating campus buildings. The BRDF's 2 MWe cogeneration engine uses a mix of biogas and natural gas to generate about five per cent of the campus' electricity requirements, and the waste heat generated is used in the ADES.

Solar: UBC's CIRS building has solar heating collectors that are used to preheat domestic hot water. The building is also energized by use of photovoltaics (PV) with a 25-kilowatt PV cell array. A larger 1000-kilowatt PV to hydrogen fuel project is under development in conjunction with researchers and operations and is to be mounted on top of a parkade adjacent to the CEC and next to UBC's main electrical substation.

ENERGY METERING AND MANAGEMENT PLAN

The goal of UBC's Energy Management Plan (EMP) is to generate enough savings to offset growth and have targeted new annual savings of 4 GWh electrical and 20,000 GJ (18,956 mcf) of natural gas, while maintaining past savings. The EMP identifies conservation and efficiency opportunities while continuously monitoring the thermal energy, electricity, and water usage of large buildings. It also provides benchmarking and data analysis to identify over-consuming buildings or systems, and establishes multi-year targets for energy savings.

BUILDING ENERGY CONSERVATION

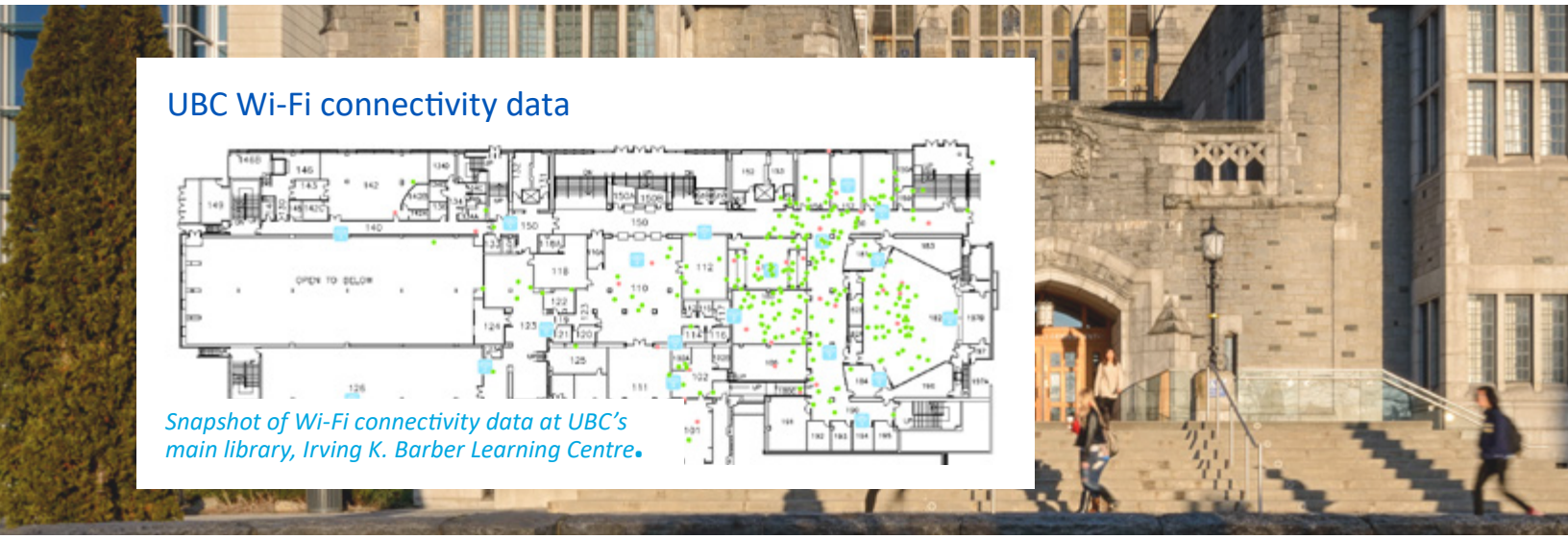
Over the last 19 years, UBC has taken an active role in managing its demand for consumption of energy and water. In 2014, UBC formed its Energy Conservation and Innovation team consisting of energy engineers and building automation systems (BAS) specialists. The BAS team maintains UBC's automated building management system, troubleshoots problematic systems, and manages all of the campus HVAC system programming and scheduling. They collaborate with the energy engineers who identify new energy saving opportunities and implement all programming changes resulting from energy audits.

Due to the continuing successes of UBC's energy management programs, UBC has now accumulated 55 GWh of electricity savings and 557,500 GJ (528,408 mcf) of annual natural gas savings over 2000 levels — totaling more than $70 million in savings and cost avoidance to date. These savings were realized through a combination of utility-scale infrastructure upgrades, energy retrofits on the building scale including heat recovery chiller installations, and a campus-wide LED retrofit campaign, as well as control optimizations across core academic buildings.

BIG DATA

Since 1998, UBC has been tracking energy use, and by 2006, it had a comprehensive metering infrastructure that could calculate energy use intensities for buildings. UBC's energy conservation efforts continue to adapt, employing new technologies and data analysis tools such as initiatives in building analytics that harnesses big data for smarter buildings. Through the use of Skyspark, our building analytics software platform, UBC is leveraging the untapped capabilities of modern building automation and controls systems to automatically detect operational and system inefficiencies sooner. This has prevented energy intensification of old facilities as well as extended the life cycle of operating equipment.

UBC has also tapped into the use of Wi-Fi connectivity data as a proxy for building occupancy; the data is then used as a sensory input to control the supply of HVAC services to classrooms, and other large spaces on campus.



UBC Wi-Fi connectivity data

Snapshot of Wi-Fi connectivity data at UBC's main library, Irving K. Barber Learning Centre.

OTHER

LEED: Both the ADES plant buildings are LEED® Gold. UBC has 27 buildings that are certified to the LEED® gold level and two are certified to platinum level. All new construction is built to a minimum of LEED® Gold standard. UBC's ADES provides multiple LEED® credits to buildings that connect to the system.

Fleet vehicles: UBC Energy and Water Services uses hybrid and electric vehicles as part of UBC's award winning fleet, which has won consecutive platinum ratings from local fleet associations.

Waste: UBC currently diverts 61 per cent of its overall waste through recycling and composting programs with the goal of achieving 80 per cent by 2020.

Sustainability Fund: UBC maintains a $1 million Sustainability Revolving Fund, which provides a minimum of $10,000 for projects that reduce consumption of energy, water, or other resources that support UBC's sustainability objectives and that will result in ongoing cost savings.

UBC's Energy and Water Services has leveraged internal loans of up to $100 million in funding for major renewal capital projects. The significant savings of energy, carbon, water, maintenance, and other operational savings are used to repay the loans.

6.0 Healthy and safe work environment

One of UBC's primary objectives is to ensure a healthy, safe, and thriving work environment for staff and the broader campus community. Those working with utility systems are at higher risk for health and safety issues. UBC's Energy and Water Services (EWS) staff are serious about safety and have developed a campus-wide reputation for having a deeply embedded culture of health and safety. This engagement is reflected in our lost-time incidents statistics.

Lost-time injuries	
2015	0
2016	0
2017	1
2018	1
2019 to date	0

RESPONSE TEAMS

- Confined Space Rescue Team: UBC EWS has a dedicated highly trained confined space rescue team who are equipped with a fully mobilized rescue trailer.
- Spill Response Team: UBC EWS has a dedicated fully mobilized spill response team to respond to major spills with expertise and equipment to safely minimize any impact on the environment.

SAFETY AT ALL LEVELS

Energy and Water Services has a Joint Occupational Health and Safety Committee. The active employee-lead committee helps identify health and safety related issues and make recommendations for improvement, while ensuring compliance with legislative requirements. Building a culture of safety helps EWS continue to improve by learning from incidents across campus and support injury prevention through awareness and training. In addition to meeting monthly, committee members participate in incident investigations, conduct regular workplace inspections, and give oversight to the departments/units:

- Comprehensive health and safety policies and procedures.
- In-depth new employee orientation.

- **Shop safety meetings:** Shop safety meetings provide a venue for employees to meet and discuss health and safety issues. This platform also encourages open communication regarding safety practices. Shop safety meetings generally include a short safety topic and presentation.
- **Crew Talks:** Crew Talks occur prior to the start of a job to provide information and address questions from the crew.
- Safety training (e.g. fall protection, confined space entry, moderate risk asbestos removal, isolation and lockout, bucket truck, manlift/ scissor lift) an annual calendar is created for ongoing staff training.
- Professional development funding and trade specific training.
- Hazard identification, risk assessment, control methods (e.g. job safety reviews, fall protection plans, etc.).
- Respirator fit testing. Biannual hearing testing.
- Worksite safety boards include health and safety messaging (e.g. contact information, health and wellness initiatives, Joint Occupational Health & Safety Committees meeting minutes, incident statistics).

A HEALTHY WORK ENVIRONMENT

- Employees receive free access to a health and wellness centre offering use of fitness equipment, exercise and yoga programs, and massage and physiotherapy services. On and off-campus health, fitness, and family discounts are also provided.
- Travelling health fairs offering heart health screenings, lung and bone health assessments, diabetes awareness, and cardiovascular health assessment program.
- Confidential counselling and health care benefits including health and well-being services, career, life events, and financial counselling services.

7.0 Customer engagement

Engaging customers and the UBC Vancouver campus community has been integral to the success of UBC's ADES during its 10-year transition to hot water. Prior to constructing the BRDF, several stakeholder engagement sessions were hosted to help identify and address public concerns, including: noise, emissions, truck traffic, and beautification. Once the facility was operational a Community Relations and Emissions Committee, made up of a broad cross-section of stakeholders, kept the project accountable and worked as a communication channel to the greater community.

RESPONDING TO AND MANAGING CUSTOMER GROWTH

One of UBC's major initiatives is to expand student housing — adding more than 1,000 beds per year up to 2030. The goal is to house 50 per cent of their 56,000 students on campus. As a result, our student housing customers have grown substantially, by 60 per cent in floorspace, and continue to be the largest and fasting growing customer. In response, UBC Energy and Water Services (EWS) supports and works closely with a newly hired Student Housing and Athletics energy manager. This new position is dedicated to student housing and athletic facilities in efforts to assist our main customer in energy reduction and decarbonisation.

HELPING OUR NEIGHBOURS

UBC utility crews are prepared to respond to priority situations of UBC's resilient assets — so much so, that they have also served the larger community, beyond their boundaries,

TRIUMF Power outage


Residential Water Leak


Neighbourhood fuel leak

by responding to the urgent situations of customers and neighbours. In 2018, that included:

TRIUMF Power Outage: Construction activity within the site of UBC's largest single customer, TRIUMF, caused a major power outage to the entire TRIUMF campus facility. Thanks to UBC EWS staff's response and supply of their emergency stock of cables, TRIUMF's power was restored in less than 30 hours.

Residential Water Leak: UBC EWS was first to respond to a catastrophic failure in one of our neighbouring residential water lines, assisting with isolating the leak and securing the site for the safety of the public.

Neighbourhood Fuel Leak: UBC EWS crews put to use their mobile spill response trailer in response to a diesel fuel leak from a local transit bus on the site of a non-UBC neighbour.

SUPPORTING ACADEMIC CUSTOMERS

Going beyond the standard model, the university academic community joined forces with EWS staff to study and conduct research within our ADES production facilities. The BRDF is a signature Campus as a Living Laboratory project. The concept of the project is to integrate UBC's core academic mandate of research and teaching within the district infrastructure. As a living laboratory, the BRDF provides a platform to use the physical plant and combine opportunities for staff and students to test, study, teach, apply, and share lessons learned while exploring new technology and developing policies.

Research activities, valued at more than $500,000, have been linked to the facility through many UBC departments and researchers. Doctoral and master students take samples of biomass supply and biomass syngas for analysis and research. The BRDF has engaged students, researchers, faculty, and staff on all levels to learn about UBC's ADES and further their studies. It will further provide research opportunities for faculty and students by the provision of a new 2,500 square foot research high head laboratory alongside the upcoming Biomass Expansion Project (see Section 9.0).

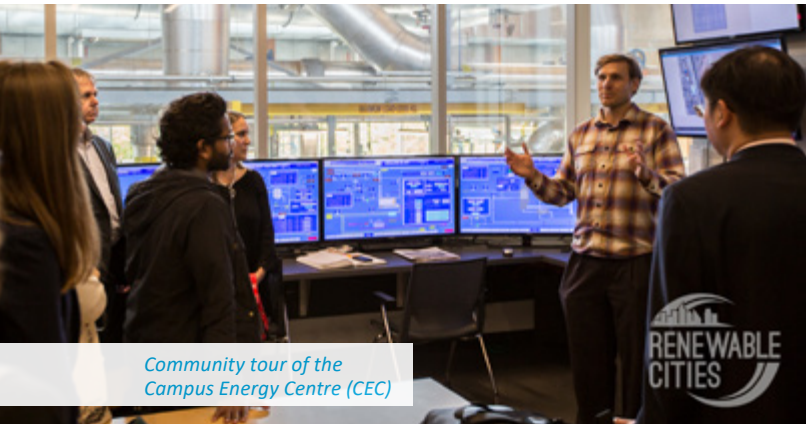
More than 1,000 people are hosted each year at the biomass facility and CEC, to share information on the process and how this unique facility supports campus life. This integration of operations and academics challenges the campus community to work across traditional boundaries and sectors to affect change.

8.0 Community involvement

UBC Energy and Water Services (EWS) engages the broader community, particularly in the promotion of District Energy, by hosting events, tours, and supporting initiatives. UBC is an active member of IDEA, regularly contributing to conference presentations, case studies, and surveys. UBC hosted the IDEA 109th Annual Conference and Trade Show in June 2018 — acting as technical chair, developing and contributing to the proceedings, as well as providing technical tours of its ADES system.

REGIONAL COMMUNITY

- UBC EWS strongly supports the development of new district energy initiatives in the community, namely the privately owned (Corix Utilities) Neighborhood District Energy System in the UBC South Campus residential community.
- UBC EWS is a lead contributing member to the region's District Energy Providers Workshop, a quarterly collaborative workshop of DES Providers in the greater Vancouver region, comprising local utilities and municipally owned service providers to discuss common challenges, share information, and celebrate successes.
- UBC EWS is taking an active role in the Community Energy Association, an independent advisor and collaborator with community energy managers from provincial and local governments on accelerated action on climate and energy.
- UBC EWS provides data and information relating to the ADES as a Regional District energy benchmarking tool.



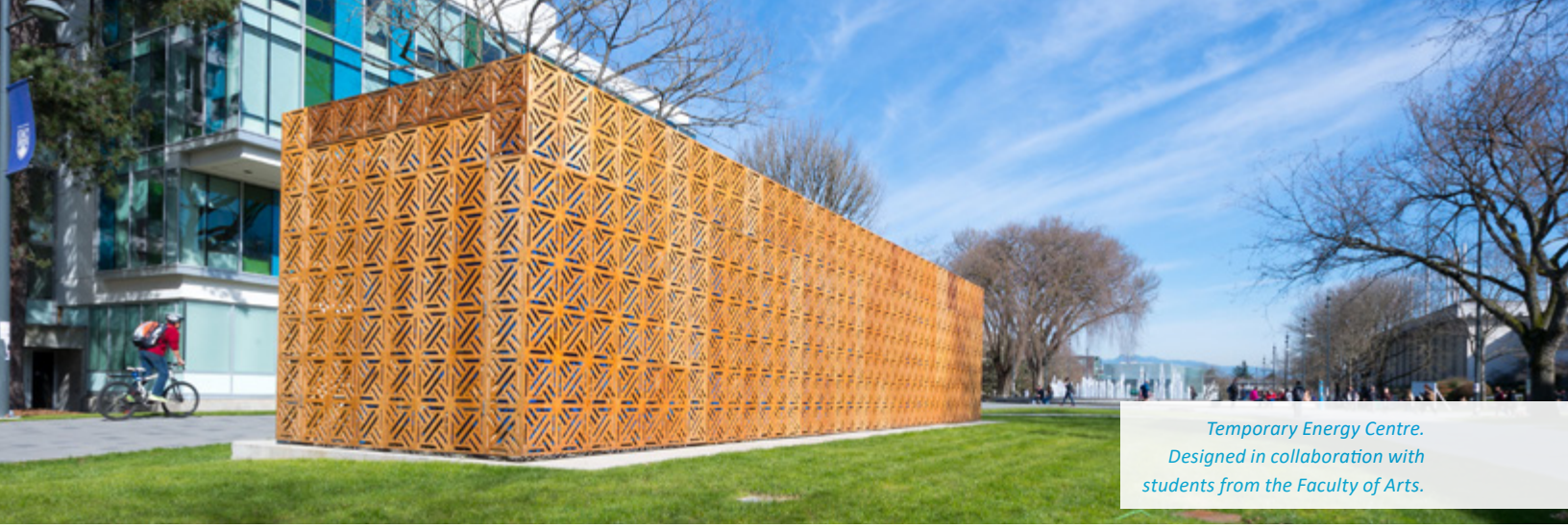
Community tour of the Campus Energy Centre (CEC)

- UBC EWS provides tours of the BRDF and CEC to local and international city officials, professional bodies, companies, conferences, and delegates from around the world, including hosting specialized researchers [*Click here to view: BRDF virtual tour*]

ACADEMIC COMMUNITY — APPLIED LEARNING

- UBC EWS provides learning opportunities for students to perform studies and projects on our district system, including hosting occupational health students to conduct noise assessments of our plants.
- UBC EWS recruited students from the Faculty of Arts to beautify the system's temporary energy centre during the transition from steam to hot water.
- UBC created educational materials about the ADES and BRDF to further promote the use of efficient, reliable, and environmentally sound district energy.

  Click the following links to view:
  The BRDF story
  Carbon Cycle
  Energy Systems
- UBC EWS works closely with faculty and students to provide energy and emission data from the ADES and buildings to allow for real-world study and applications.
- UBC EWS engages its students on the topic of district energy and regularly provides presentations, interviews, videos, and tours about the ADES. [*Click to view: Talk and Tours of Campus Energy Centre*]



Temporary Energy Centre. Designed in collaboration with students from the Faculty of Arts.

VANCOUVER CAMPUS OPERATIONS

- UBC EWS provides its utility data to the greater public online — this information allows the public and campus to access historical and real-time data (electrical, thermal and water) for the UBC Vancouver campus and buildings.
- UBC EWS is strongly supporting the development of UBC's Climate Action Plan, Water Action Plan, and Green Buildings Plan – which lead Universities worldwide in aggressive greenhouse gas, water, and energy reduction targets.
- UBC EWS supports sustainability campaigns such as the National Sweater Day, #RippleEffectUBC, Green Labs initiatives, and others by participating and providing energy analysis, monitoring, and verification of energy savings for the campaigns.
- UBC EWS works in close partnership with UBC's utility providers — BC Hydro, FortisBC, and Metro Vancouver, leveraging high value programs and incentive monies to create regional savings of electricity, natural gas, and water. Some of these initiatives include installing heat recovery chillers, switching fuel from gas to biomass and heat pumps, and launching a program to eliminate '*once through cooling*' in UBC laboratories.

AWARDS AND ASSOCIATIONS

UBC's ADES has been recognized with several awards, giving UBC the opportunity to tell and retell its District Energy stories of GHG reductions, energy efficiency, and resiliency.

The BRDF has received multiple awards and recognitions, including KPMG Infrastructure 100 Award (2012), the Canadian Wood Council Wood Building and Design Award (2013), and the IDEA Innovation Award (2016), to name a few.

The CEC was a winner in its category at the 2018 Canadian Green Building Awards and received the Architectural Institute of British Columbia's Lieutenant Governor General Award of Merit in 2018.

From the Association of Physical Plant Administrators, UBC was honoured with both a Sustainability Award and Effective and Innovative Practices Award for its energy conservation and climate action efforts. From the Association of Energy Engineers, UBC was honoured to receive the International Institutional Energy Management Award (2018).

UBC EWS staff are professional members of the International District Energy Association, Engineers and Geoscientists of BC, Community Energy Association, Association of Energy Engineers, and Association of Physical Plant Administrators.

9.0 Next steps

BIOMASS EXPANSION

This project, expected to be operational in 2020, is for the addition of 12 MWt (41 MMBtu/hr) of new hot water boiler capacity to the existing BRDF to allow the campus hot water heating system to meet projected demand from growth in the coming years. The expanded use of biomass as an energy source will provide heat at a lower cost than natural gas. In addition, the expanded use will help UBC to diversify its fuel mix, allowing more effective management of the fuel cost risk, as well as lowering GHG emissions resulting in reduced carbon tax costs.

This expansion is expected to result in further cost savings of more than $1 million annually for at least 15 years when compared to the business as usual scenario (natural gas-fired boilers). The projected savings would be primarily due to reduced fuel commodity costs, lower carbon tax costs, and offsets by switching from natural gas to a biomass fuel source, thus significantly reducing UBC's reliance on fossil fuels, reducing carbon emissions, and improving fuel resiliency and diversification.

The BRDF expansion will also help UBC achieve its Climate Action Plan 2020 target of 67 per cent GHG emission reduction over 2007 levels. It would also continue to provide research opportunities for faculty and students by the provision of a new 2,500 square foot research high head laboratory contained within the BRDF.

There is no other project on campus that is projected to reduce this volume of GHG emissions — 13,000–15,000 tonnes/year — in such a cost-effective manner.

[*Click here to view the IDEA Conference Proceeding on this project*]

COGENERATION AND RENEWABLE NATURAL GAS PRODUCTION

UBC is in the early study stage of evaluating the development of a 25-30 MWe biogas-fired cogeneration facility. As the campus electrical and thermal demand grows over the next 30 years the need for cogeneration is more apparent, as well as the university's drive for increased resiliency. The sustainability challenge is that for any new cogeneration production the gas fuel source needs to be a biogas as opposed natural gas. Therefore, UBC is looking to develop its own sources of biogas i.e. upgraded landfill gas, bio-digestor gas, or equivalent.

DISTRICT COOLING AND THERMAL ENERGY STORAGE

UBC is in the early study stage of evaluating the development of a district cooling system. As the campus demand for cooling grows and the effects of climate change are perceived, the case for a district cooling system strengthens. There are several nodal opportunities currently under evaluation with an ultimate aim to move to a central system. The existing CEC has been future-proofed to allow for a central chiller plant installation opportunity. In addition to the development of a cooling system will be the ability to integrate thermal energy storage (TES) at the CEC site. Load shifting between heating and cooling systems will be explored as well as regular cooling TES.

Unit Conversions

1 gigajoules (GJ)	947.8171 cubic feet (cf) natural gas
1 megawatt hour (MWh)	3.6 gigajoule (GJ) 3.412 million British Thermal Units (MMBTU)
1 gigawatt hour (GWh)	3600 GJ 3412 MMBTU
1 dry tonne of biomass	18 GJ of energy
1 megawatt thermal (MWt)	3.412 MMBTU/hour
1 kilometre	0.621 miles
1 square meters	10.764 square feet
MWe	megawatt electrical
1 US gallon	3.785 litres

GHG emissions are measured in tonnes of CO_2 equivalent (tCO_2e)

All dollar values are in Canadian currency. 1 CAD = 0.75 USD as of publication date