Factor Four at BCIT – An Authentic Living Lab Experiment

Prepared by Alex Hebert

Prepared for: BCIT LTC, as part of the LTF grant program

Summer 2018

Table of content

Introduction

Eight years ago, the BCIT School of Construction and the Environment (SoCE) started a living lab experiment with a focus on sustainability and energy conservation. It is called: the Factor Four initiative. What does it mean? What has been done in eight years? Was the work successful and what were the lessons learned? This report is an attempt to answer all these questions and hopefully, document the work done in a way that can serve BCIT faculty in their important journey to making BCIT students job-ready at graduation.

In 1972, the Club of Rome – a global think tank concerned with the future of humanity and the planet – published a book titled *The Limits to Growth*. Through computer modeling, The Limits to Growth demonstrated that unchecked economic and population growth in a global system of limited resources is unsustainable. As a possible solution to the challenges identified in *The Limits to Growth*, Ernst von Weizäcker of the Wuppertal Institute (Germany) and Amory and Hunter Lovins of the Rocky Mountain Institute (USA) published a report – **Factor Four**: Doubling Wealth, Halving Resource Use – to the Club of Rome in 1995. Factor Four develops the concept of resource productivity. Factor Four, in a nutshell, means that resource productivity can—and should—grow fourfold.

The concept of transforming BCIT's campuses into living laboratories of sustainability (**Living Lab** approach) was adopted by the Institute in 2007 through an initial agreement between Administrative Services and the SoCE, which was later adopted by Information Technology Services. At a high level, living labs use the campus as a vehicle to engage students, faculty and staff in solving real-world challenges. BCIT's buildings are no different than real world buildings. Asking students to help reduce energy and greenhouse gas emissions by 75% (i.e.: by a factor of four) in a sample of BCIT buildings is what this living lab is about.

This report presents how tackling campus renewal using the Living Labs approach can yield significant benefits to BCIT`s community as a whole, including students and staff. The report provides a progress update on the Factor Four initiative, examples of completed projects, an overview of teaching resources created for faculty, lessons learned and more.

The concept of Living Labs

Living labs at BCIT is defined as a collaborative approach to hands-on learning that uses the campus as a vehicle to engage students, faculty and staff in solving real-world challenges.

The following is an extract from BCIT's website:

What are Living Labs? Living Labs:

- *Foster skills development through access to campus infrastructure and information*
- *Demonstrate leading edge technologies and equipment, and present opportunities to conceptualize, design and implement solutions that advance the state of practice*
- *Use participatory research and learning*

The following overarching principles help guide the development of BCIT campuses as Living Labs of sustainability:

- *Make infrastructure and building systems visible and data pertaining to their operation accessible to the BCIT community for educational and applied research purposes.*
- *Adopt a problem-based learning pedagogy to engage faculty and students directly in helping to solve challenges pertaining to the campus' operations and development.*
- *Showcase best practices both in the built and natural environment as well as in the operations and educational delivery activities of the Institute so that all students at BCIT are exposed to sustainability in action - regardless of what program they take.*

BCIT's SoCE Factor Four Initiative is designed and deployed under these living lab principles. The next sections provide specific examples of real life projects that allowed BCIT`s students to contribute to BCIT`s Burnaby campus renewable, BCIT's journey towards sustainability and to making them job-ready at graduation. Part of the intent of this paper is to demonstrate how living labs initiatives can be true win/win for students and universities.

Factor Four – A successful living lab experiment on BCIT`s Burnaby campus

BCIT's SoCE is leading the Factor Four Initiative in the buildings it occupies (7 building covering 320,000 ft2 of floor area) at the north end of the Burnaby campus. The purpose is to explore whether a 75% reduction (fourfold) in energy and materials use can be achieved without compromising service levels. The primary objective is to provide students with real-life learning opportunities. A reduced ecological footprint, lower operating costs, and campus renewal using unconventional financing are co-benefits. As discussed earlier, Factor Four follows BCIT's living labs principles.

BCIT's Factor Four initiative has targeted three sectors for action. Each sector has established Factor Four goals and is tracking progress toward meeting those goals. The sectors are:

- **Energy**
- Materials
- Restoration

This report is covering the **Energy** sector only.

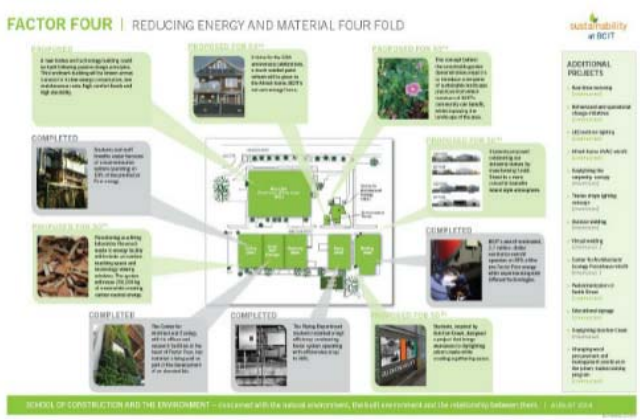
Watch this 2-minute video produced by BCIT School of Business students to better understand what Factor Four is about. There is probably no one better suited to explain the initiative in a simple and succinct message than talented BCIT students.

https://youtu.be/5Em75vlHDdM

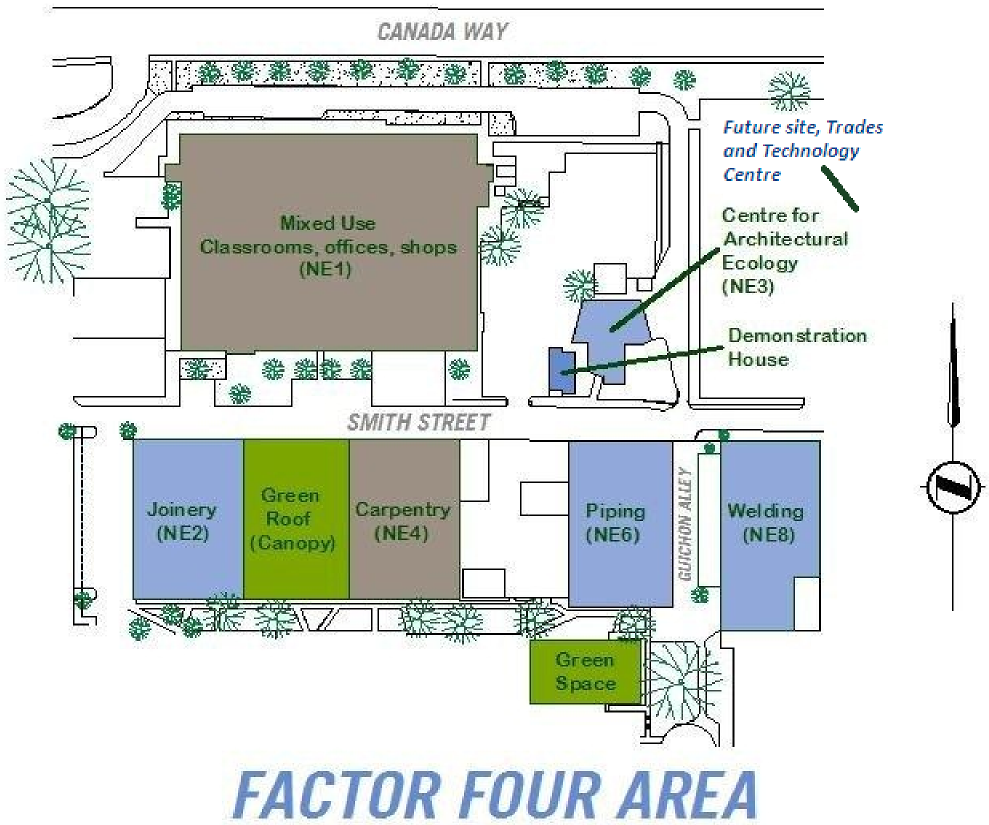
Education first

All Factor Projects described in the following sections have a connection to students. Sometimes students came up with the original idea, sometimes they completed a feasibility study. In some other cases they were involved in the design or the construction. For all projects, real data (energy, professional reports, lessons learned, etc.) was made available to current and future students so they can learn from our successes and mistakes while being in a BCIT classroom.

Factor Four Energy Progress Update



BCIT's Factor Four Area is composed of seven buildings as shown in the Burnaby campus map below.

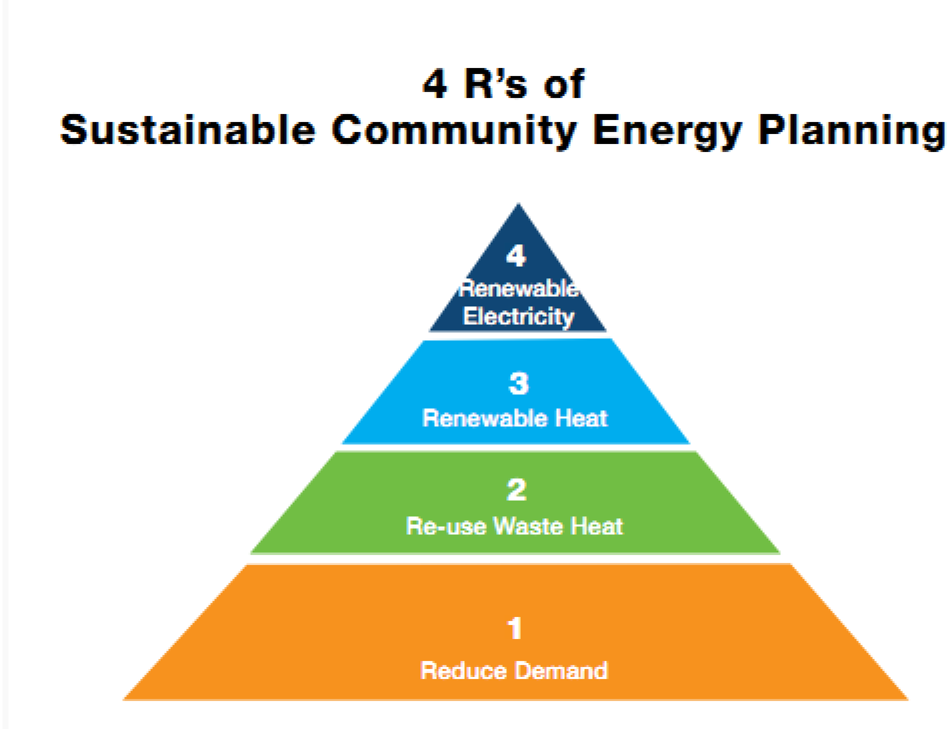


Two types of energy – electricity and natural gas – are consumed in these buildings to provide services to the building occupants: predominantly lighting, space heating, space cooling, ventilation, and educational programs. A 75% reduction in energy throughput would be required to meet the fourfold improvement in resource (energy) productivity targeted by Factor Four. This 75% reduction represents 30,000 GJ per year in reduced energy throughput (compared to the 2008-2009 fiscal year throughput of 40,000 GJ combined electricity and natural gas). To provide an order of magnitude, producing the equivalent of the 30,000 GJ per year using solar panels located in BCIT`s parking lot 7 (OASIS research project) would require approximately 30 to 60 additional OASIS projects.

Energy Planning Framework

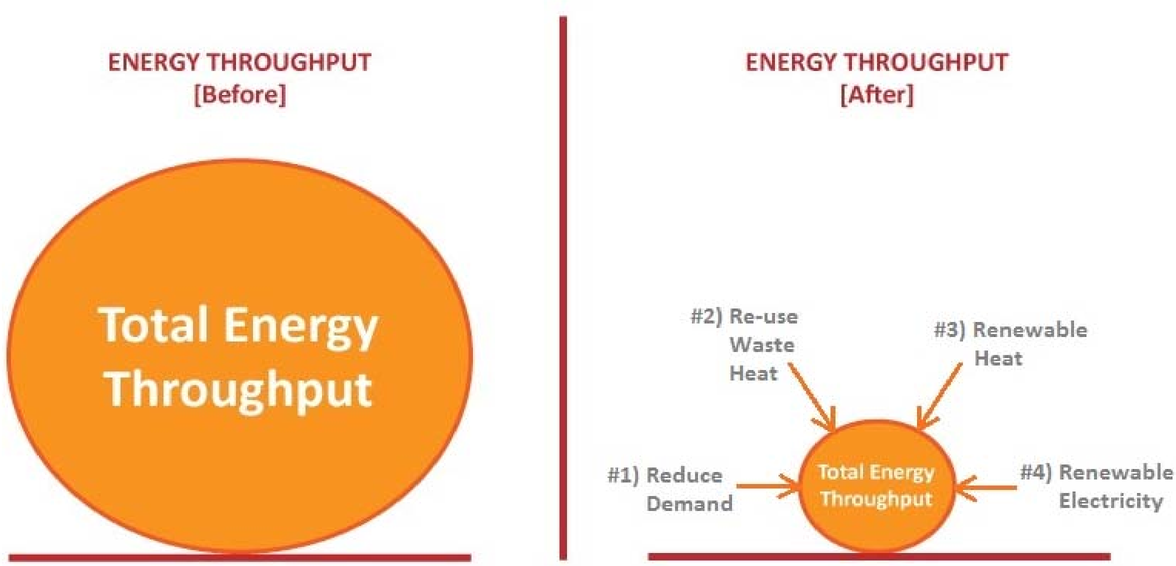
As we teach at BCIT in planning courses, every great idea needs a strategy and a plan to guide activities toward reaching destination – Factor Four is no different. BCIT's Factor Four Energy team adopted a systematic approach to develop its energy management strategy and subsequently its Strategic Energy Management Plan that charts the course to reduce energy throughput in the Factor Four Area by 75% or 30,000 GJ/year.

"The 4Rs of Sustainable Community Energy Planning" guided development of BCIT's over-arching energy management strategy. The method was developed by Community Energy Association and provides a process for local governments to build communities that, from an energy perspective, are more sustainable. The approach is depicted and described below.



Source: Community Energy & Emissions Planning – A Guide For B.C. Local Governments, September 2008

This approach in taught in BCIT's Sustainable Energy Management Certificate and BCIT's Community Energy Management certificate. The Factor Four team translated the 4Rs to fit local reality at the north end of the Burnaby campus. The "4Rs" framework for the Factor Four energy reduction plan used language presented below:



Progress update

This section presents a partial progress report. It focuses on the energy component of Factor Four and summarizes:

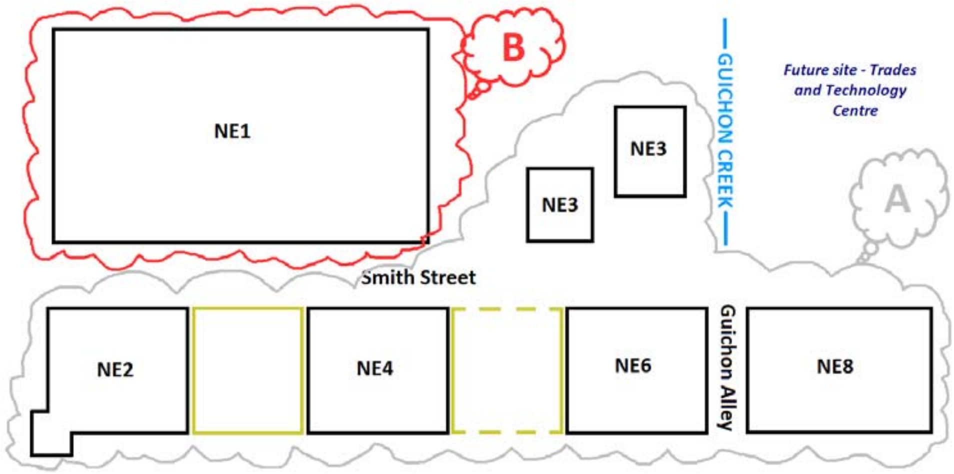
- Progress made to date (a list of projects implemented, and associated energy and GHG reductions);
- Progress made to date looking at various “Living Labs Factor Four statistics”.

Furthermore, this section focuses on 6 buildings (NE2 to NE8) and excludes NE1.

Why exclude NE1? Various energy studies (four in total) have been completed on NE1 by the Factor Four team. With the Facilities and Campus Development decision to limit investment in NE1 and plans for its eventual demolition, the Factor Four team made the following recommendation (as documented in its energy plan – May 2015 version):

> *To build the NE1’s replacement building with an energy intensity of 70 kWh/m^2 or less, which will reduce the energy intensity of the new building by 75% with respect to the actual energy intensity of NE1. To achieve this energy intensity is doable as it is the requirement of the proven Passivhaus Standard for commercial buildings.*

Hence the energy section of the Factor Four initiatives has been divided in two phases, A and B as represented in the figure below. Phase A is about implementing projects in the existing buildings that will reduce the energy through put by 75% and phase B is about building a new building that consumes 75% or less energy than the existing NE1. Having a new construction case study in Factor Four area is a perfect complement to all the other renovation projects. The recent (2018) decision of locating the new Trades and Technology Centre within the boundaries of Factor Four creates extraordinary possibilities. The Factor Four story can now be written with replacing NE1 with TTC, as long as TTC is designed and build with a 70 kWh/m^2 per year performance target. When both phases are implemented the Factor Four area will achieve its energy target. SoCE will be delivering its Trades and Technology programs at the North end of the Burnaby campus on 25% of its old footprint, making it a world reference in sustainability in the built environment.



If A = $75\%^{+}$ reduction and B = $75\%^{+}$ reduction, then A + B = $75\%^{+}$

Energy Projects Overview

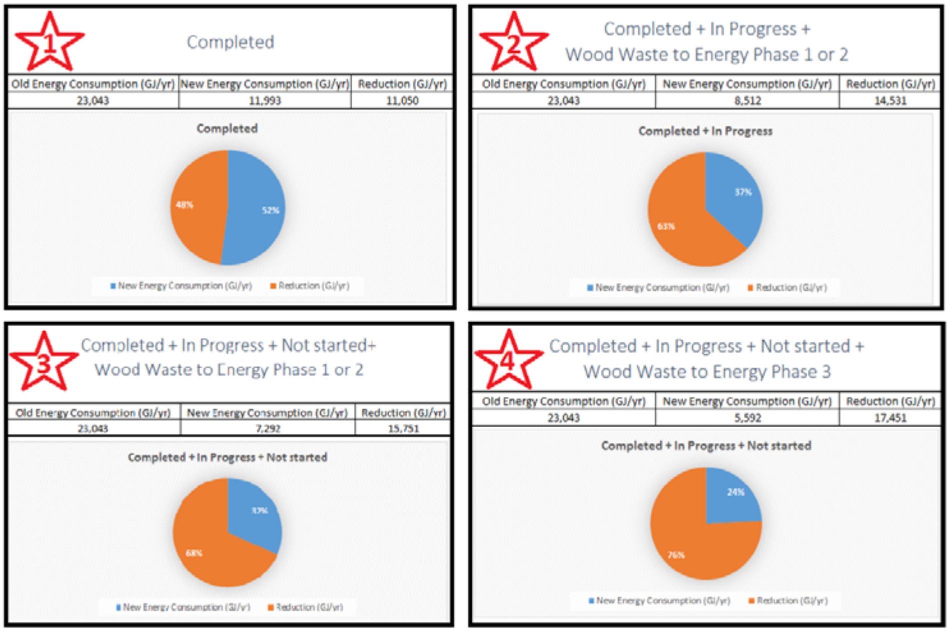
The following projects are all listed in the Factor Four Energy Reduction plan:

<table>
<tr><th>Completed to date</th><th>In-Progress*</th><th>Not Started*</th></tr>
<tr><td>Dust Extraction in NE2/4</td><td rowspan="3">AFRESH – REFRESH</td><td rowspan="2">Outdoor Welding in NE6</td></tr>
<tr><td>High Efficiency Boilers in NE6</td></tr>
<tr><td>Welding Ventilation in NE8</td><td rowspan="2">Light Savers – Phase 2 of 2 [Lighting Redesign]</td></tr>
<tr><td>Light Savers – Phase 1 of 2</td><td rowspan="3">Heat Doctors – Phase 2 of 2</td></tr>
<tr><td>Heat Doctors – Phase 1 of 2</td><td rowspan="2">Wood-Waste-to-Energy - Phase 2 of 2</td></tr>
<tr><td>LED outdoor Lighting</td></tr>
<tr><td>Windows Upgrade in NE3</td><td rowspan="2">Wood-Waste-to-Energy Phase 1 of 2</td><td rowspan="2">Heat Recovery in NE8</td></tr>
<tr><td>Solar PVs in AFRESH</td></tr>
</table>

* Definitions:

- In-Progress: funding has been allocated, work has begun;
- Not Started: funding not allocated yet, work has not begun.

Energy data based on projects listed in section 3**

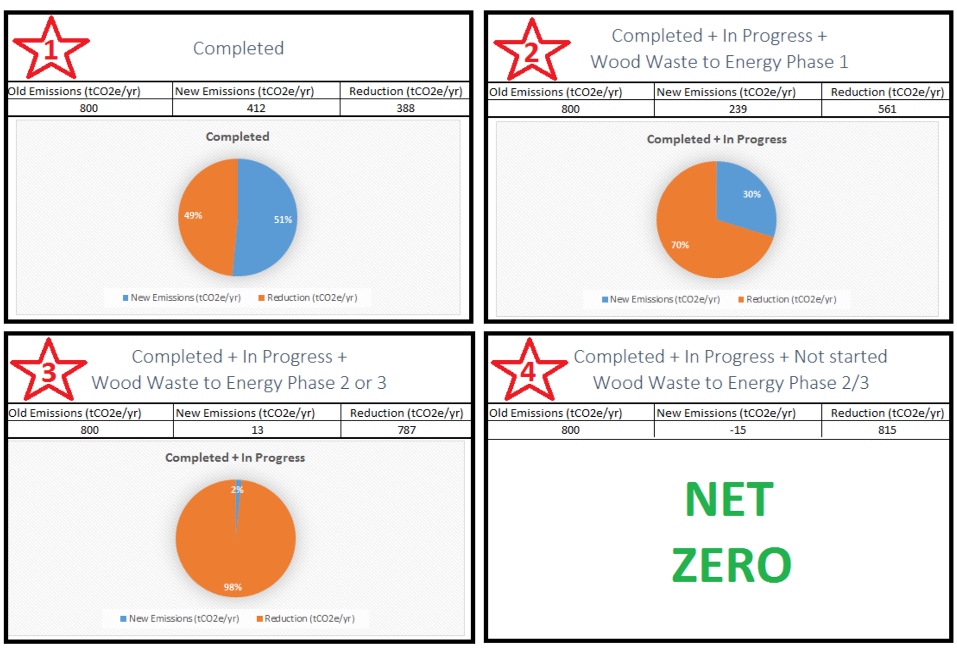


** Wood-Waste-to-Energy (WWTE) phase 1: When boiler operates on BCIT clean wood only; WWTE phase 2: When boiler operates at capacity with BCIT clean wood, and a top-up with clean imported wood from Burnaby (but energy throughput only based on BCIT wood); WWTE phase 3: When boiler operates at capacity, with all wood waste from BCIT and a top-up from imported wood (but energy throughput only based on BCIT wood).

<u>Verified at the meter</u>

The completed reduction % shown above is calculated at the project level (with individual M&V). Data at the building energy sub-meters level show an actual reduction of 53%.

GHG data based on projects listed in section 3***



*** Wood-Waste-to-Energy (WWTE) phase 1: When boiler operates on BCIT clean wood only; WWTE phase 2: When boiler operates at capacity with BCIT clean wood, and a top-up with clean imported wood from Burnaby (but energy throughput only based on BCIT wood, GHG on all wood); WWTE phase 3: When boiler operates at capacity, with all wood waste from BCIT and a top-up from imported wood (but energy throughput only based on BCIT wood, GHG on all wood).

Other Living Labs Statistics

Factor Four is about creating value for students and Faculty. And it is creating such value, as shown by the various figures presented below:

- More than 20 projects implemented across all 7 buildings;
- More than17 case studies and 60 stories published;
- More than 250 students directly involved in projects;
- More than 30 real life drawings (architectural, mechanical, structural and electrical) provided to students for in-class exercises and academic projects;
- More than 10 real life engineering reports shared with students for in-class review;
- 19 new energy meters installed with web accessible live data;
- 10 educational videos produced, including videos on rooftops and in mechanical rooms;
- Hundreds of building automation system points trended and shared with students for analysis;
- More than 50,000 views of the Factor Four website;
- More than 800 participants in Factor Four guided tours;
- More than $4M invested in the name of education and the planet;

Once all projects are implemented, SoCE will have reduced the building operating budget by approximately $300k per year (incl. biomass and street lighting; with energy, carbon and maintenance savings).

A selection of Living Lab projects completed as part of Factor Four

This section presents a selection of examples of living lab projects completed as part of the Factor Four initiative energy component and how they were documented to create case studies useful to BCIT students.

Wood-waste-to-energy

Background

Thirteen buildings on BCIT's Burnaby campus have their space heating and domestic hot water heating needs met by a "district energy" system. Water is heated in natural gas-fired boilers in a central heating plant located in building SE08. The hot water is then piped underground in insulated pipes to the individual buildings. Heat transfer equipment in each building transfers heat from the district energy system into the buildings' space heating and domestic hot water heating equipment. District energy systems can generally provide these heating services more energy-efficiently than by using dedicated heating equipment in each building.

Problem and/ or Opportunity

Because NE01 is the only building in the Factor Four Area that is connected to the district energy system, expanding district energy service to the Area was identified as potential means by which energy throughput could be reduced. The Factor Four team commissioned a district energy study (as part of the "On-Site Renewable Heat Situation Analysis") in 2011 that identified an opportunity to not only expand district energy to the Factor Four Area but to do so using a renewable, carbon-neutral energy source.

BCIT's carpentry and joinery programs together generate approximately 250,000 kg per year of wood waste in the form of cut-offs and sawdust. The Institute pays approximately $20,000 to $25,000 per year for off-site disposal of this "waste" stream. The opportunity lies in the fact that this is actually not a "waste" stream but in fact a source of renewable heat. BCIT's wood waste-to-energy facility will burn this wood to heat water that can then be used in a district energy system. The heat generated by the wood waste will offset natural gas currently consumed to heat the buildings. Because natural gas is a fossil fuel, burning it emits greenhouse gases (GHGs) into the atmosphere that have been linked to climate change. In contrast, wood is considered a "biofuel" and burning it is considered "carbon neutral" – i.e. zero GHGs! The wood waste-to-energy system will therefore have the financial benefits of saving natural gas costs, carbon emissions offset payments, and disposal costs. Built following Living Lab design criteria, the new facility will also be a benefit to BCIT's student as they learn about these advanced renewable energy technologies. The educational boiler house will be equipped with large windows, covered outdoor lectures areas and various displays, all designed with the intent of maximizing the student experience.

Solution

The wood waste-to-energy facility comprises a wood fuel preparation and storage system and a 775 square foot (72 m2) educational building that houses a biomass boiler, a state-of-the-art air emissions filtering system and an advanced combustion and emissions monitoring system. The small building is attached to the southwest corner of Building NE02. The various figures and photos below provide an explanation of how the system will work.

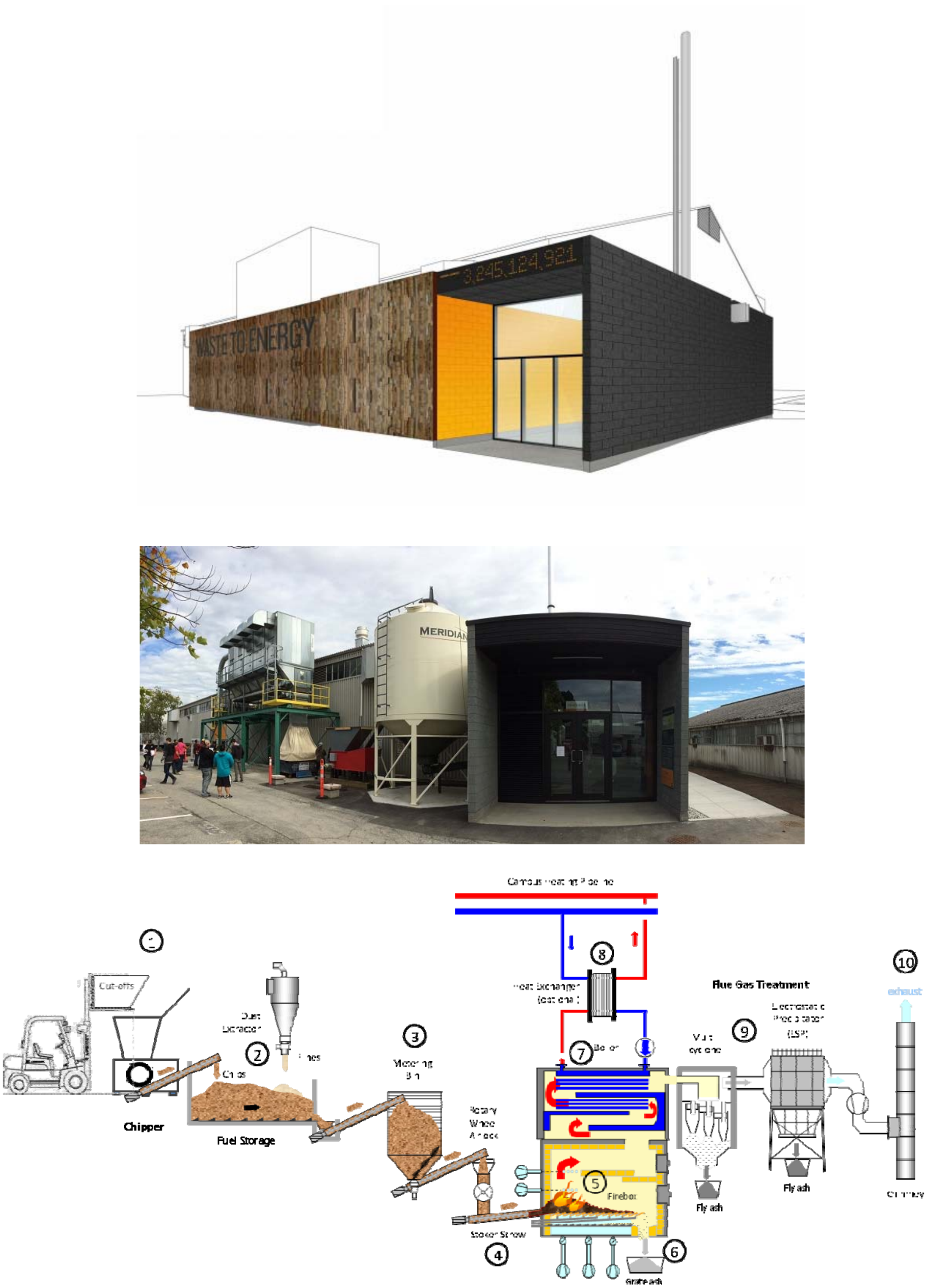


Figure 1: Wood Waste-to-Energy System – An example similar to the BCIT system

Description for Figure 1

1. **Chipping**: Wood cut-offs from various collection points are delivered by a fork lift and tipped into the hopper of the chipper. The unit grinds the cut-offs into pieces of no more than 50 mm (2") size. Oversized pieces are removed by an internal screen and reground. An incline auger conveys the chips into the fuel storage bin.
2. **Fuel storage**: The silo stores approximately 43 m^3 of fuel (wood chips), which is equivalent to approximately 8 days of maximum wood waste production. The technology selected is a standard agricultural silo with smooth walls.
3. **Fuel metering**: The metering bin has been removed from scope. Metering will most likely be done by adding load cells to the legs of the silo.
4. **Stoking the fuel**: Fuel is stoked into the firebox by an auger. To avoid backfires, fuel needs to pass a rotary safety wheel, a lock that prevents embers or hot gases entering the upstream fuel supply chain.
5. **Combustion**: Fuel stoked into the firebox is combusted on a grate in an electronically controlled fashion. Primary combustion ('gasification') takes place on the flat moving grate. Wood gases escaping from the fuel pile are oxidized in the secondary zone of the combustion chamber located above the grate. Both primary and secondary air supplies are automatically controlled via the flame temperature and oxygen content in the flue gas. The automated system controller adjusts the pace of the grates to ensure complete combustion as the fire bed travels along.
6. **Ash removal**: Ash is removed from the firebox by a set of screws. Outside the firebox a screw conveys the ash to an ash dumpster. The ash bin will need to be emptied on a regular basis.
7. **Heat production**: Flue gases are drawn from the firebox into the secondary combustion chamber and subsequently into the hot water heater by a frequency-controlled fan. The boiler is equipped with radiant and convection zones that transfer the heat to the water surrounding the fire tubes. A built-in pneumatic cleaning system removes soot that has settled on the flame tubes, thereby extending the period between cleaning.
8. **Heat Transfer**: Hot water generated in the boiler is pumped to a heat exchanger. The secondary side of the heat exchanger is connected via insulated underground pipes with the campus heating system. The arm of the heating network connecting the NE01 will be used to feed the heat generated into the campus heating network.
9. **Flue gas cleaning**: The stainless steel mesh filter is designed with small pores or pathways that allow gas to pass but stops particulates. The particulates removed from the flue gas are collected on the outside of the filter and add to the filtering properties of the mesh system, but also increase the pressure drop across the filter. This dust cake needs to be periodically removed, usually by a soot blower. The filter allows this facility to operate well under the Metro Vancouver emission limit of 18 mg/m^3 of particulate matter.
10. **Exhaust discharge**: Cleaned flue gases are emitted to the atmosphere via an insulated chimney.

Energy Savings and GHG Emissions Reductions

Each year, the wood waste-to-energy system will save approximately 4,800 GJ in natural gas consumption (4,000 GJ of energy stored in our fuel, processed in a 85% efficient system, displacing a natural gas combusted in a 70% efficient system) and will reduce CO2 equivalent emissions by 240 tonnes. At $9.5 and including the cost of natural gas, carbon tax, and carbon offsets, BCIT will save approximately $45,000 per year. GHG emissions associated with trucking the wood waste for disposal will also be avoided.

PROJECT PARTNERS

- BC Bioenergy Network
- BC Ministry of Advanced Education through the Carbon Neutral Capital Program
- Stuart Olson
- BC Ministry of Environment
- BC Hydro
- Canfor
- BCIT's Steel Trades
- BCIT's Carpentry

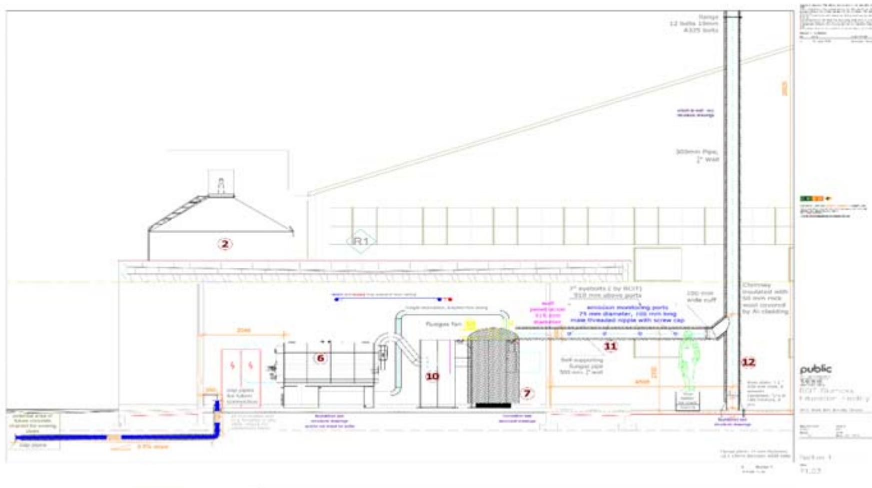
PROJECT FAST FACTS

- Approximately 4,800 GJ of natural gas displaced
- More than 240 tonnes of CO2eq avoided
- One waste hauling truck removed from campus each week
- 250,000 kg of wood waste with a new purpose
- More than 10 school programs involved in the project

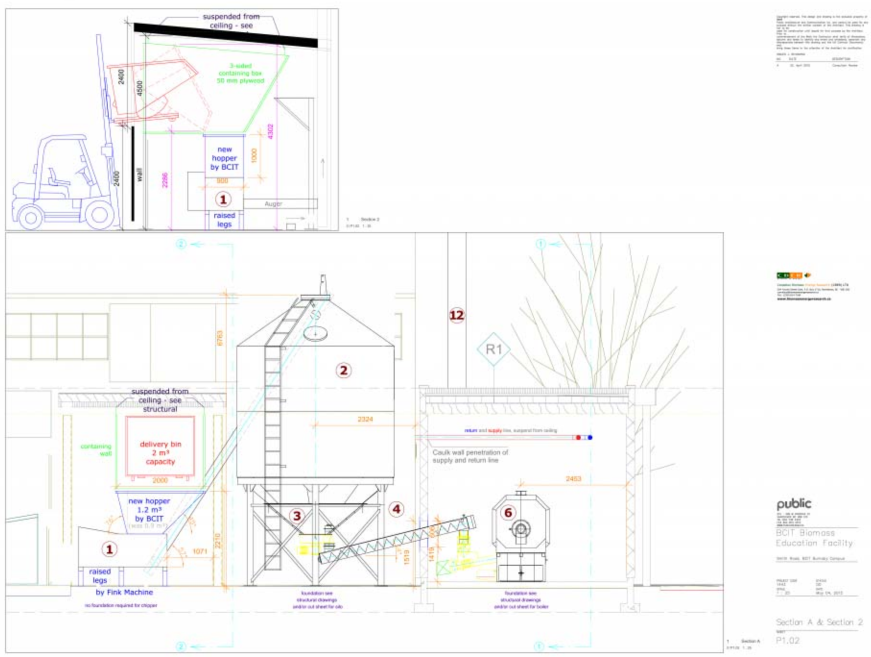
What's included project folder

The design for the project was completed with education in mind. The educational boiler house is equipped with large windows, covered outdoor lectures areas and various displays to make it easy for classes to visit the site.

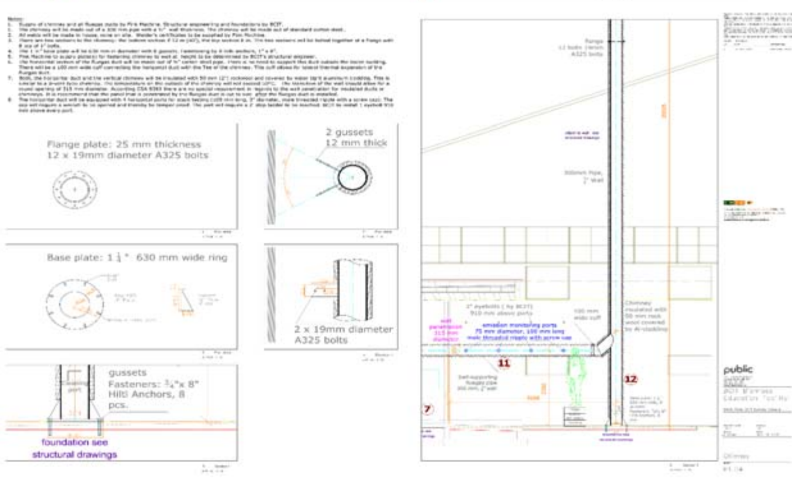
In additions, engineering and architectural drawings of the project can be downloaded from the website so students can be exposed to real-life technical documents. This is also true for several feasibility study and other documents of interest.



public
BCIT Biomass Education Facility



suspended from ceiling - see
3-sided containing box 50 mm plywood
new hopper by BCIT
raised legs
Auger
wall
suspended from ceiling - see structural
containing wall
delivery bin 2 m³ capacity
new hopper 1.2 m³ by BCIT
by Fink Machine
Caulk wall penetration of supply and return line
public
BCIT Biomass Education Facility
Section A & Section 2
P1.02



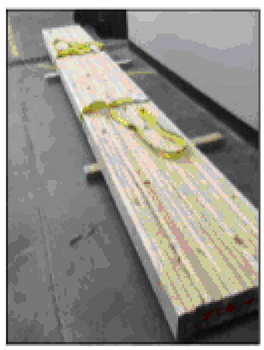
Flange plate: 25 mm thickness 12 x 19mm diameter A325 bolts
2 gussets 12 mm thick
Base plate: 1 ¼" 630 mm wide ring
2 x 19mm diameter A325 bolts
gussets Fasteners: ¾"x 8" Hilti Anchors, 8 pcs.
foundation see structural drawings
public

Highlight – what's special

Approximately $1M of unconventional external funds received in order to build the facility.

Students from 10 different programs participated in the project. A summary of student involvement is presented below:

- Steel hopper for the chipper fabricated by Metal Fabrication trades students
- Roof structure for the facility was prefabricated by Carpentry trades students
- Chipper enclosure steel structure fabrication by Metal Fabrication trades students
- Chipper enclosure erection by Iron Working trades students
- Air Quality Dispersion Model (legal requirement, Metro Vancouver, value of $10,000 if completed by private sector) completed by a Environmental Engineering student (as a capstone project)
- Environmental Engineering students completed a literature review exercise
- An exchange student (School of Energy - Germany) completed a sound map of the area to establish a pre-system noise baseline
- An exchange student (School of Construction – Austria) completed a technology review
- An Energy Management student completed a fuel study including waste audit and sample chemical analysis



Roof element pre-fabricated by a team of BCIT Carpentry students

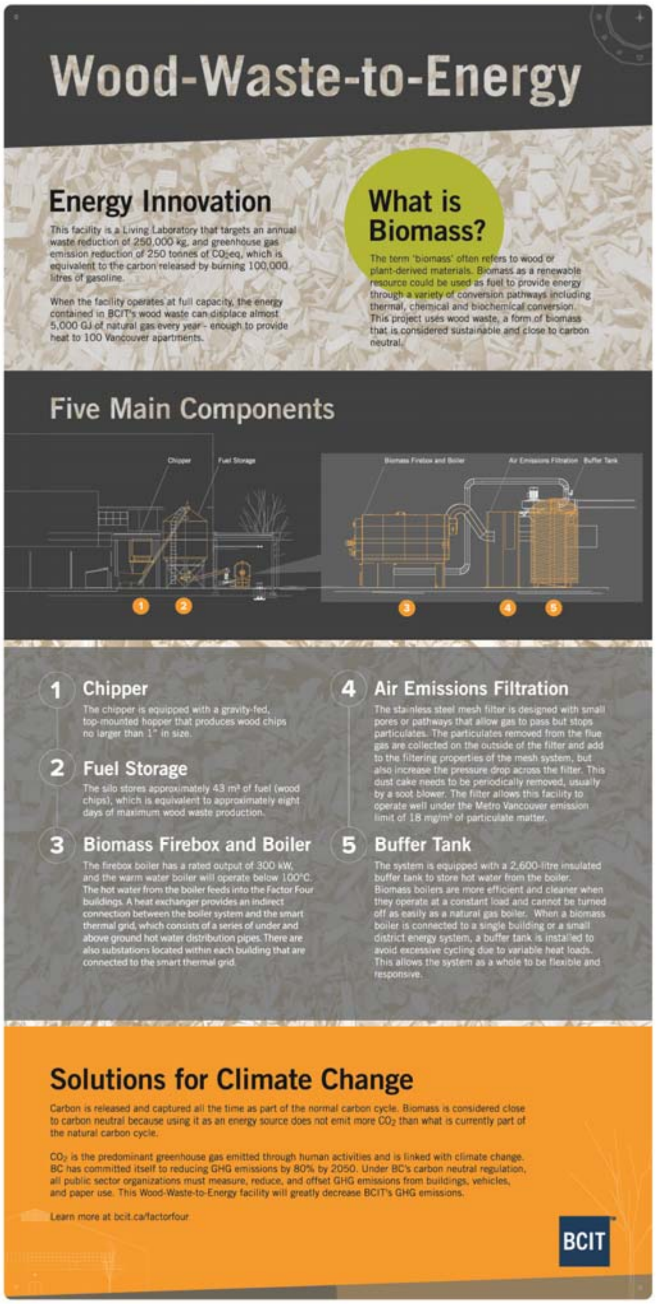
Finally, large educational signage (up to 4 feet by 8 feet – as shown in image below) was installed on site to guide students and visitors in their learning experience:

W.O.#:	55427	Designer:	DIGDUG	Product 1
Size:	40"W x 80"H	Quantity:	1 single sided	
Colours:	CMYK	Lamination:	lustre	
Material:	Digitally printed matte calendered vinyl	Finishing:	.5" rounded corners	
Substrate:	3mm alupanel			

FASTSIGNS. More than fast. More than signs.

Sign cost includes two proof changes. Additional proof changes will incur a design charge.

At FASTSIGNS Vancouver, we take pride in precision, but the final examination for accuracy is your responsibility. Before giving approval, please examine all proofs carefully for the accuracy of information presented, as well as quantity, sizes, spelling, punctuation, graphics, colours and general layout.



flat orange colour
to match pantone below

Building Direct Digital Controls made accessible to BCIT students

Overview

Once again, BCIT demonstrates its focus on making its campus into a living lab for students and instructors. Faculty can now request access to enteliWEB which is a powerful web-based tool used by BCIT Facilities Services to monitor the campus DDC system to maintain a comfortable, efficient and sustainable learning environment. This feature provides instructors an alternative to PowerPoint presentations and allows students to use real data (perhaps of their own classroom) in their projects, connecting the knowledge they've learned in the classroom to real-world examples.

Created as a collaboration between BCIT's Building Science program, BCIT's Facilities Services, and the Factor Four Team, this web-based feature can be accessed from any computer and used to enhance the learning experience at BCIT.

What's included

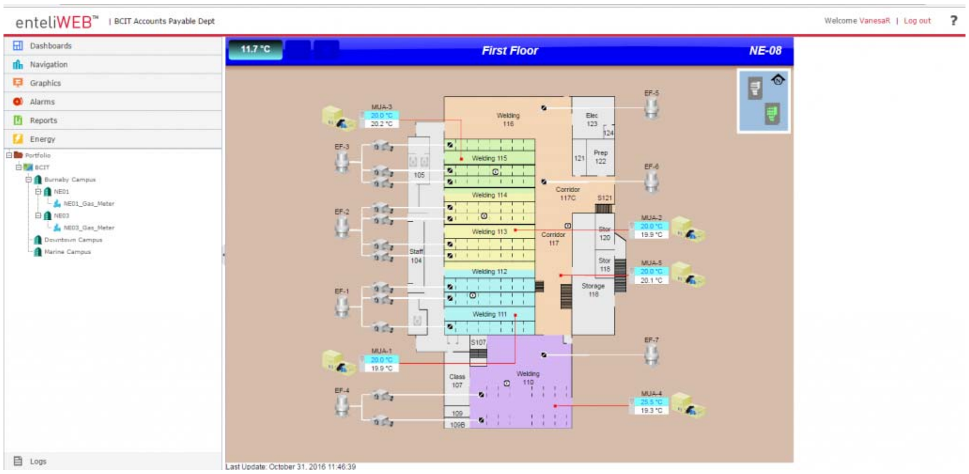
Two distinct features are available for the students:

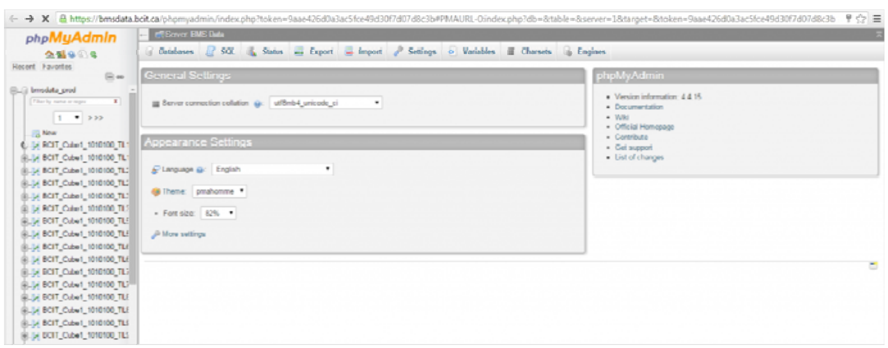
- A read-only access to the DDC system graphics and logic pages;
- Access to a database with all input/output (I/O) points of the existing DDC system located in the Factor Four buildings (trend logs).

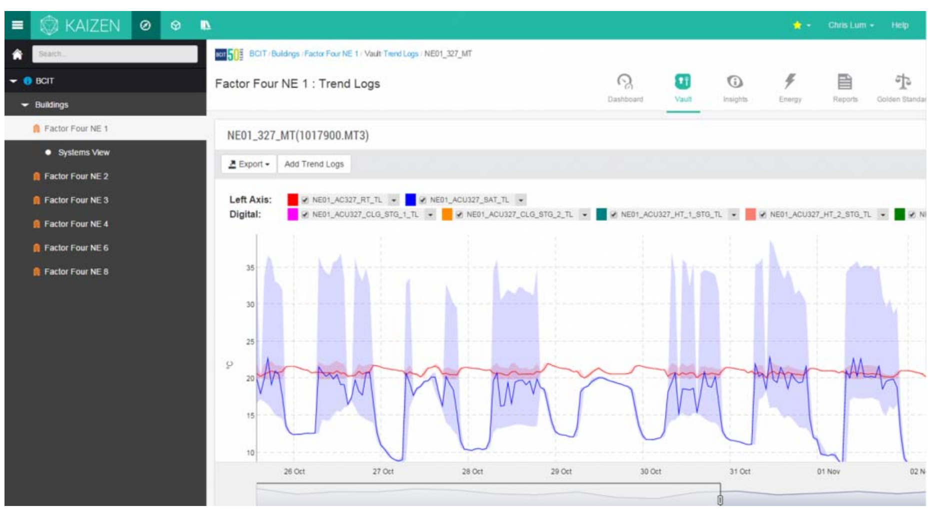
About DDC:
Direct Digital Control (DDC) is the automated control of a condition by a computer. BCIT's DDC is a network of sensors, operable devices and controllers that together provide the heating, ventilation and air conditioning for all buildings on campus. Also referred to as BMS, or Building Management System, the DDC is comprised of:

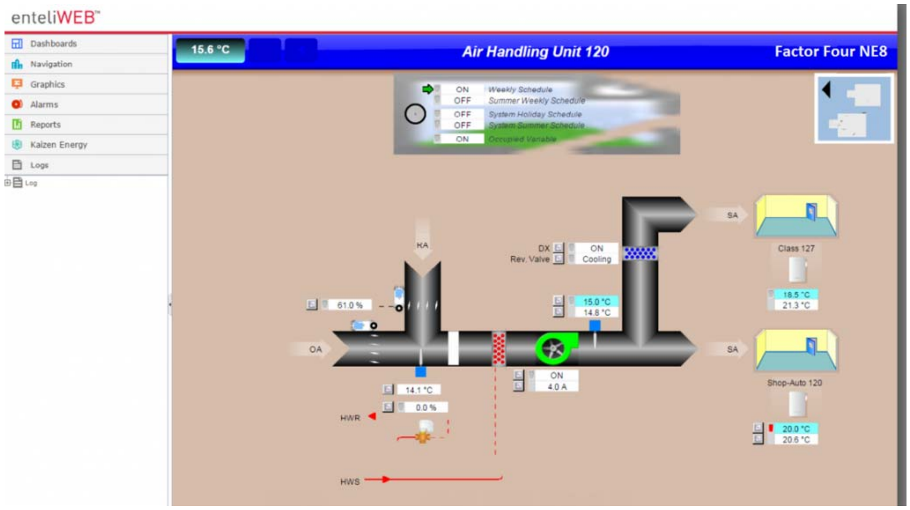
- Sensors –indicate temperature, pressure, etc. and on/off status
- HVAC devices – valves, dampers, fans, pumps, etc. that regulate indoor comfort
- Controllers – programmable mini-computers, to monitor input signals and control HVAC devices
- Interface – software that allows operators to monitor and adjust DDC: enteliWEB
- Database – storage of operational data over time: Copper Cube
- Connectivity – communication protocols, wiring, internet

The BCIT learning experience is definitely enhanced by the enteliWEB which is one brand of interface software on the market. BCIT has engaged ESC Automation, a division of Delta Controls, to install and customize enteliWEB for our needs. EnteliWEB combines visual dashboards with easy-to-use facility management tools, such as real-time data, alarms and trend log data. It can also produce powerful reports to monitor energy consumption and help lower costs. A registered user (Faculty member) can access this web-based application through any computer browser.





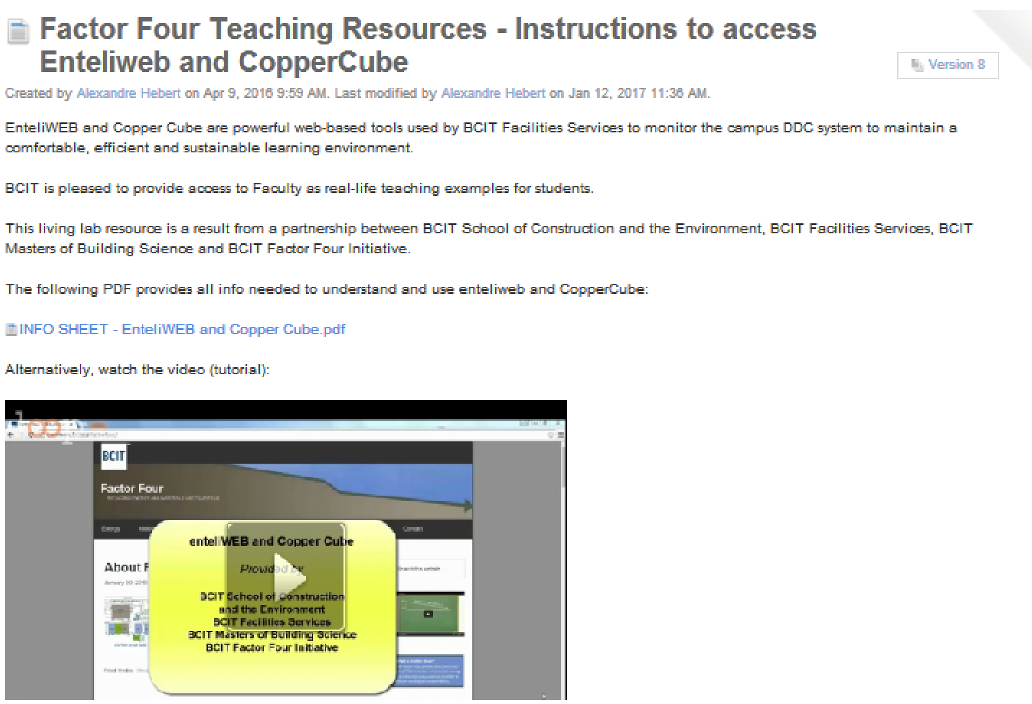




Highlight – what's special

This project provides a very unique living lab experience. Two examples of such non-conventional learning are presented below:

- A password protected (using BCIT intranet / the Loop) video tutorial was created to help instructor learn how to use the system.



Factor Four Teaching Resources - Instructions to access Enteliweb and CopperCube

Version 8

Created by Alexandre Hebert on Apr 9, 2016 9:59 AM. Last modified by Alexandre Hebert on Jan 12, 2017 11:36 AM.

EnteliWEB and Copper Cube are powerful web-based tools used by BCIT Facilities Services to monitor the campus DDC system to maintain a comfortable, efficient and sustainable learning environment.

BCIT is pleased to provide access to Faculty as real-life teaching examples for students.

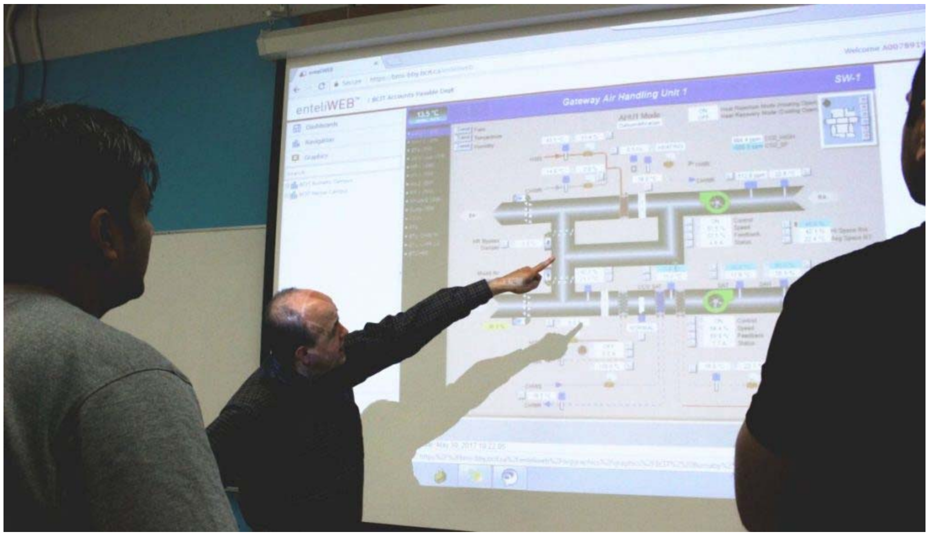
This living lab resource is a result from a partnership between BCIT School of Construction and the Environment, BCIT Facilities Services, BCIT Masters of Building Science and BCIT Factor Four Initiative.

The following PDF provides all info needed to understand and use enteliweb and CopperCube:

INFO SHEET - EnteliWEB and Copper Cube.pdf

Alternatively, watch the video (tutorial):

- Rodrigo Mora, instructor, Master in Building Science (SoCE) was up for the challenge and created a case study using his dedicated classroom in NE1. Using the read-only access to enteliWEB, Rodrigo works with his students in an indoor air quality course on understanding what makes a room (the classroom they are in) comfortable (e.g.: room temperature, humidity levels, CO_2 levels, etc.), reading the live data from the sensors in the building and troubleshooting the problems by investigating the HVAC system.



Rodrigo Mora and students troubleshoot NE1's HVAC system using EnteliWEB

Below are presented quotes from project participants:

"Students have the ability to develop a greater practical understanding of the underlying operation of real buildings," says Abbas Rangwala, a Building Science Masters student who has been involved in using the building automation system. "With the access to near real-time data, students can then work with the Facilities Department at BCIT, moving the focus more towards preventive maintenance rather than reactive maintenance, thereby further optimizing the operation of the numerous mechanical systems."

"Our students are building operators and engineers who want to learn more about building systems and how building analytics can be applied. An example of what they would be looking for is a period of time where the air handling unit is both heating and cooling. This is an undesirable condition but happens pretty commonly," says Craig Somers, an instructor in the BCEM program. "I use demo data regularly but it's more interesting to do our analytics with real data and real sites," he adds.

"While Facilities Services' overarching mandate is always to support the core business of BCIT, living lab initiatives that provide us with opportunities to collaborate directly with that business make our work here unique and exciting," says Peter Morgana, Manager, Facilities Services. "We've invested almost $200,000 over the past two years to upgrade all the building automation control hardware and network infrastructure on the Burnaby campus to the most current technology. (We still have a few pneumatically controlled buildings in the museum to remind us of a much lower-tech era!) These upgrades have transitioned us to powerful web-hosted, user-friendly interfaces, tools and dashboards, creating opportunities for innovation limited only by imagination. Access to the system for our staff, students, and faculty is now as simple and secure as logging onto any other website. I've never worked anywhere where I had the help of the world's brightest minds looking over my shoulder!"

Alex Hebert, BCIT's Energy Manager, recalls his mechanical engineering education at a traditional university and how he graduated without being exposed to real building mechanical systems. "I envy *our students. Imagine being enrolled in an indoor air quality course and having the instructor ask you to comment on your perception of the air-quality in the classroom you are sitting in. Too hot, too cold, too stuffy? No problem, let's have a look at the air handling unit serving this classroom and see what we can improve. And then you go, diving directly into the live DDC system and troubleshooting the sequence of operation. Building operating systems are very complex and this is an example of smart education for a complex world."*

LED outdoor lighting retrofit

Overview

Effective outdoor lighting is essential to ensuring safety and security on all BCIT campuses. Nearly 800 lighting fixtures illuminate Burnaby campus streets, pathways, and parking lots. These lights are controlled by a mix of timers and photocells. On average, they operate 12 hours per day, 365 days per year and consume approximately 616,000 kWh in electricity.

Problem and/or Opportunity

Almost all Burnaby campus outdoor lighting was high intensity discharge (HID) technology. Light-emitting diode (LED) technology has made great strides in recent years and can provide better lighting levels and quality of light using a fraction of the electricity required by HID lighting. Outdoor LED lighting provides an excellent opportunity to reduce electricity consumption. Additionally, they have a longer use life and require less maintenance and replacement costs.

Solution

In 2011, BCIT began a pilot test to evaluate LED lighting for illuminating streets, parking lots, and pathways. The pilot was successful, resulting in a plan to retrofit all HID outdoor lights on the Burnaby campus with LEDs.

The Factor Four area benefited from this campus-wide project. The existing HID lights used HPS technology and had standard ballasts. As a result of the project, 63 lights in the area were replaced. 4 HID cubed-top street lights (250W), 15 wall-mounted HID lights (70W), 25 exterior wall packs (150W), 1 square head HID parking light (100W), and 18 parking lot HID lights (250W) were replaced with LED lights with wattages of 86W, 13W, 40W, 133W, and 127W respectively. Each luminaire contained one lamp. Our electricians reported that all retrofits were easily made. Since replacement, LED lightings have been effective in providing outdoor lighting to the Factor Four area.

Technologies Implemented

- Outdoor LED street lighting:
  - General Electric LED 127 Watts Cobra Head for all street lights (replacing 250 Watts HID) – 4100 °K
  - General Electric LED 126 to 152 Watts (various models) Square Head lights for all parking lights (replacing 250 Watts HID) – 4100 °K
- Outdoor LED wall-mounted lighting:
  - Cooper LED 40 Watts Wall Pack (replacing 150 Watts HID) – 4100 °K
  - Premium Lighting LED 13 Watts Wall Pack (replacing 70 Watts HID) – 4100 °K

Energy Savings and GHG Emissions Reductions

- The LED lighting system reduce the Factor Four electricity demand by approximately 9 kW and electricity consumption by approximately 40,000 kWh per year compared to the old HID lighting. Annual cost savings are approximately $4,000. Once implemented across the entire Burnaby Campus, the project will save an estimated 352,000 kWh per year in electricity.

Additional Benefits and Features

- On average, an HID lamp will operate for approximately 15,000 to 20,000 hours before burning out. In contrast, the new LED lights are expected, on average, to last for approximately 50,000 to 60,000 hours. The longer LED life expectancy means that approximately 3 lamp changes per lighting fixture can be avoided using LEDs. So in addition to exceptional energy savings, the new LED lighting will require significantly less time and money for maintenance staff to replace burnt out lamps.

Project Fast Facts

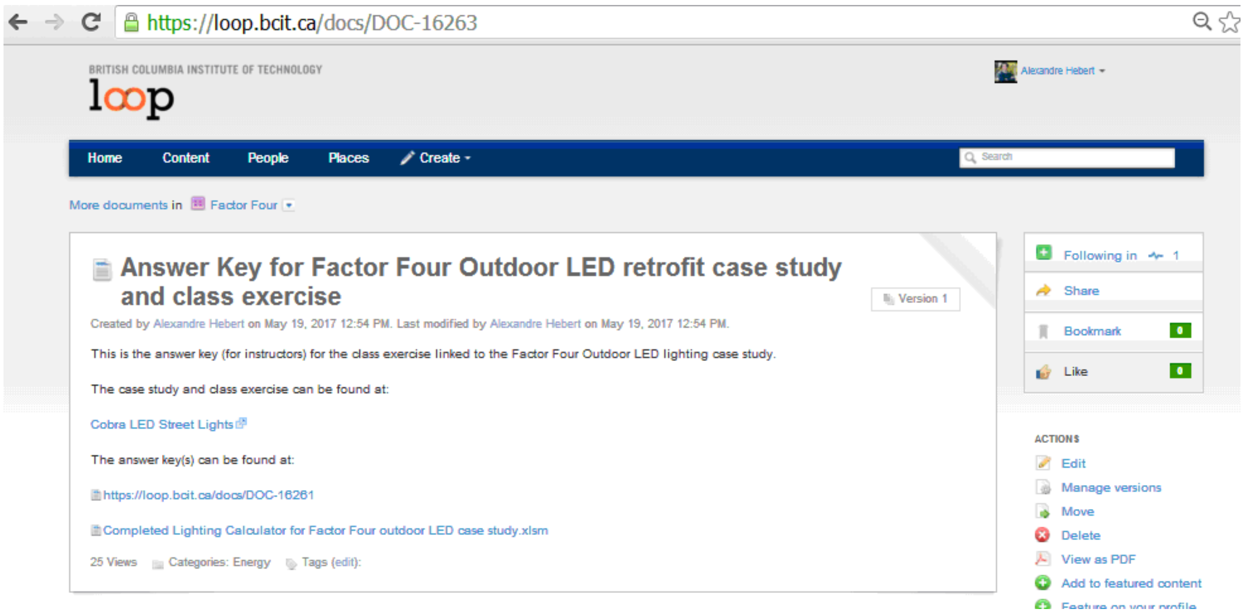
- Approximately 39,857 kWh of electricity conserved per year
- $4,000 saved on energy usage
- Colour temperature: 4100 °K
- At least 50,000 hours of lifespan (at L70 rating)

What's included

A full list of LED equipment installed on Smith street, including lighting specifications and quantities, A discussion about the health impact of blue lights An in class exercise to calculate energy savings from a led retrofit using a BC Hydro-developed methodology.

Highlight – what's special

Easy to use, password protected answer key was developed for the instructors:



NE8 ventilation

Background

NE08 is home to the students and faculty of the Welding Program at BCIT. Welders contribute to a vast variety of BC's industries including the production of structural steel for high-rise buildings and bridges, shipbuilding, mining, pipelines, and more. Metal welding and cutting produce air contaminants that are potentially harmful to students and faculty. Ventilation systems that remove these contaminants must therefore be put in place to ensure that the welding shop remains comfortable and safe for its occupants.

The old NE08 welding shop ventilation system was installed in 1983 and was due for replacement. It comprised five zones designed to remove air and welding vapours from work stations (welding booths, cutting tables, grinding machines, etc.). Each of the five zones was equipped with multiple exhaust fans and make-up air units that replaced the extracted air with outside air to prevent the building from operating under negative pressure. Staff turned the system on in the morning (at 7:00 AM Monday through Friday and at 8:00 AM Saturday). Staff turned the ventilation system off at the end of the instructional day (at 10:00 PM Monday through Friday and at 4:00 PM on Saturday). Once on, the ventilation fans ran at constant extraction volume and maximum capacity (approximately 66,000 cubic feet per minute) regardless of whether one welding booth was in operation or all 112 booths (80 booths for arc welding and 32 booths for oxy-acetylene welding) were in operation. The make-up air units needed to supply outside air to replace the extracted air. During colder months, this make-up air had to be heated by natural gas burners located in the make-up air units.

Problem and/or Opportunity

Analysis of historic energy consumption data showed that NE08 had the highest energy consumption per square metre of floor space of any building in the Factor Four Area. NE08 therefore became the subject of two high-level energy audits in 2010: one by BCIT SEMAC students and the other by a consultant engaged by BCIT under the Fortis BC Energy Assessment Program. Both studies identified the inability of the existing ventilation system to adapt to varying ventilation requirements as a significant source of energy wastage – electricity to run the ventilation and make-up air fans and natural gas to heat the make-up air – and, as such, an outstanding energy savings opportunity. Based on these two studies, the SoCE released funds for a detailed study of the ventilation system.

Solution

A new “intelligent”, “demand-controlled” ventilation system has now been installed in NE08. The system is “intelligent” in that it is able to detect how many work stations are in use at any given time then adjust ventilation and make-up air fan speeds to provide just the right amount of ventilation and make-up air to the building. This strategy – known as “demand-controlled” ventilation – minimises the amount of electricity required to operate the ventilation and make-up air fans as well as the amount of natural gas required to heat the make-up air during colder months. Here’s how it works:

1. Each welding booth is equipped with a fume hood connected to the main air extraction system ducting. Each fume hood continually extracts approximately 200 cubic feet per minute (cfm) from inside the booth. This constant volume extraction and equivalent make-up air provide base ventilation to meet building code requirements regardless of how many work stations are actually in use. The fume hood extraction also serves as “back-up” in case the students do not properly locate the telescopic arms while welding (see below).

2. Each work station is also equipped with a telescopic arm that is also connected to the main air extraction system ducting. While the work station is not in use, a damper in the work station ducting remains closed so that no air extraction is applied to the telescopic arm in the idle work station.

3. Work stations are equipped with one of three control technologies that signal the system to begin extraction:

i. Control Technology 1 – As a student switches welding equipment, a current transformer (commonly called a CT) signals the controller that extraction at the telescopic arm is required. This technology is being tested in all arc-welding booths except 16 that are using technology 2 (see below). The advantage of this technology is that fumes are only extracted when created, maximizing energy savings. The disadvantage is that it does not offer a “buffer” and a fear is that during the first fraction of a second, the fumes are not captured by the telescopic arm (and rather gets capture by the hood extraction).

ii. Control Technology 2 – As a student enters the welding booth, a motion sensor located inside the booth signals the controller that extraction at the telescopic arm is required. This technology is being tested in 16 arc welding booths. The advantage with this technology is that it offers a guaranty that when a student will create fumes, the ventilation system will already be On. The disadvantage is the fan could be extracting air (warm air in the winter) for fairly long period of time before any fumes are created, as the student needs to do a lot of preparation work in the booth before striking an arc.

iii. Control Technology 3 – As a student enters a grinding booth, they have to step on a pressure sensitive mat that is connected to the control box. The disadvantage of this solution lies in the unknowns regarding maintenance (how difficult it will be to clean the mats, and how likely is it they will get damaged because of hot material falling on the floor).

iv. Control Technology 4 – A fourth technology that has not been implemented as part of this project is an arc sensor. As a student switches welding equipment on, an arc sensor located on the equipment sends a signal to the ventilation system controller telling it that this station is no longer idle and now needs extraction at the telescopic arm. This technology has similar pros and cons to the CTs option.

Testing different technologies is one more way BCIT is embracing the living lab concept.

4. Once occupancy is detected, the ventilation system controller opens the damper in the extraction system ducting at that work station to apply extraction to the telescopic arm in that work station.

5. The ventilation system controller then sends signals to the variable frequency drives on the extraction fan and the make-up air fan telling them both to speed up enough to supply additional extraction and make-up air to the system to accommodate the extra operating work station. For every work station that comes online, the system adds approximately 500 cfm of extraction and make-up air capacity.

6. While the work station is in operation, air contaminants are removed through the fume hood and the telescopic arm to maintain air quality.

7. As students switch equipment off (in the case of the arc sensor controls) or leave the booth (in the case of the occupancy sensor controls), the ventilation system controller closes the damper at the telescopic arm and instructs the extraction fan and make-up air fan to slow down in response to the lower extraction demand.

The project was completed in the fall of 2013.

Watch this educational video for an overview of the project by lead project engineer Richard Corra (Rocky Point Engineering):

https://youtu.be/2E5HCFijvoA

Energy Savings and GHG Emissions Reductions

Total energy conservation (measured, normalized savings after a few months of operations) :

- 6,500 GJ/yr of natural
- 800,000 kWh/year of electricity
- 9,500 GJ/yr or 2,550,000 eKwh/yr of total energy conservation per year
- 150 kW reduction in electricity demand
- At 2014 energy rates: $150,000 per year (including demand charges)

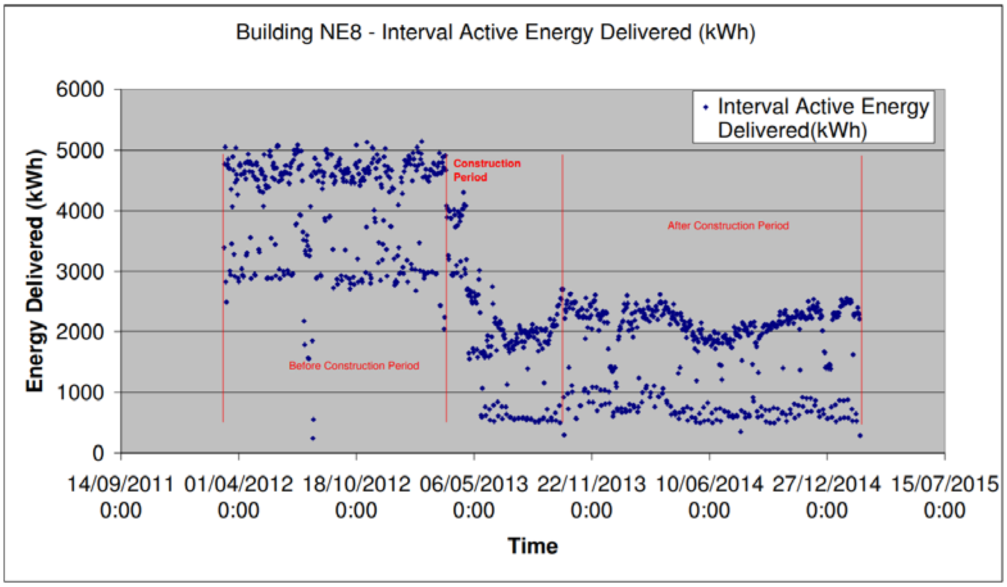
Project Fast Facts:

- $515,000 incremental cost
- $172,000 of utility incentive
- $150,000 saved in 2014
- 350 tonnes of CO2e reduced
- This project is equivalent to not burning more than 150,000 litres of gasoline every year

What's included

- Old System Air Balancing Report
- Data Logger NE8 Welding Machines – Utilization rate
- Raw data before and after renovation
- NE8 Measurement and Verification (M&V) – Partial (using BCIT-own, building-level meter)
- NE8 Measurement and Verification (M&V) – Full version by third party (using utility-own, sub-station level revenue meter – i.e.: metering multiple buildings)

- "In-class" exercise inspired by this Factor Four project



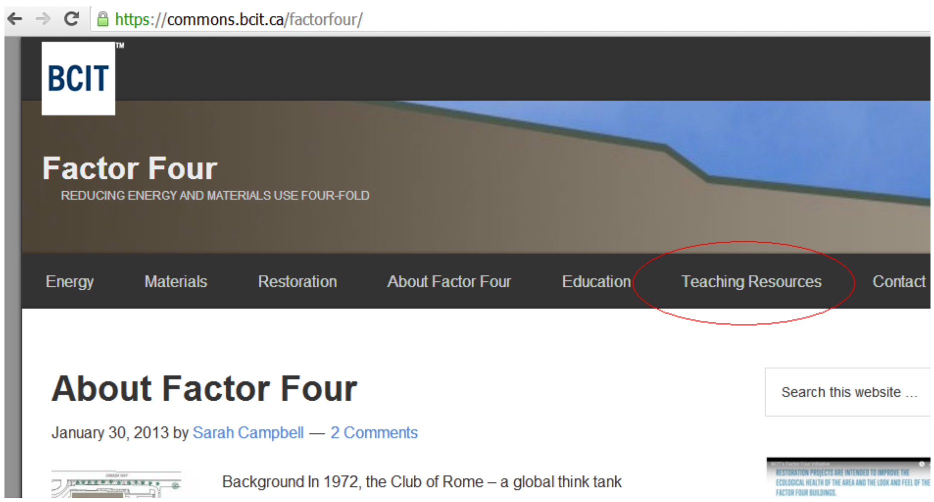
Before and after data

Highlight – what's special

- The new system improves ventilation effectiveness and air quality for students and faculty.
- The upgrade reduces noise levels in the welding shop, making NE8 a better place to work in, making it more suitable for education.
- As part of the new ventilation system design, space for heating coils was included in the design of the make-up air units. The heating coils, once installed, will make it possible to heat NE08 using carbon-neutral hot water from the Factor Four wood waste-to-energy facility once it is operational.
- The feasibility study for a facility upgrade was fully funded and developed by the School of Construction and the Environment. When the ministry asked for shovel-ready projects, BCIT was ready with a solid study that gave BCIT a surprise $2.7M of unexpected funding to renew its infrastructure.
- This project is the largest of all Factor Project yielding $150,000 per year of savings.

Factor Four made easy for Instructors

Factor Four is about student education. All projects are designed and implemented with students learning in mind. This is why a webpage was created for students and instructors interested in bringing Factor Four in the classroom.



The teaching resource page's URL is:

https://commons.bcit.ca/factorfour/teaching-resources/

The Factor Four educational toolbox includes:

- Building Info Pages;
- Live Energy Data for all Factor Four buildings;
- Remote Access to Building Automation System and associated trend logs;
- Case Studies;
- Video Series;
- Self-Guided Tour;
- Answer Keys

The following sections summarize what instructors will find for each of the above bullet points.

Factor Four Building Info Pages

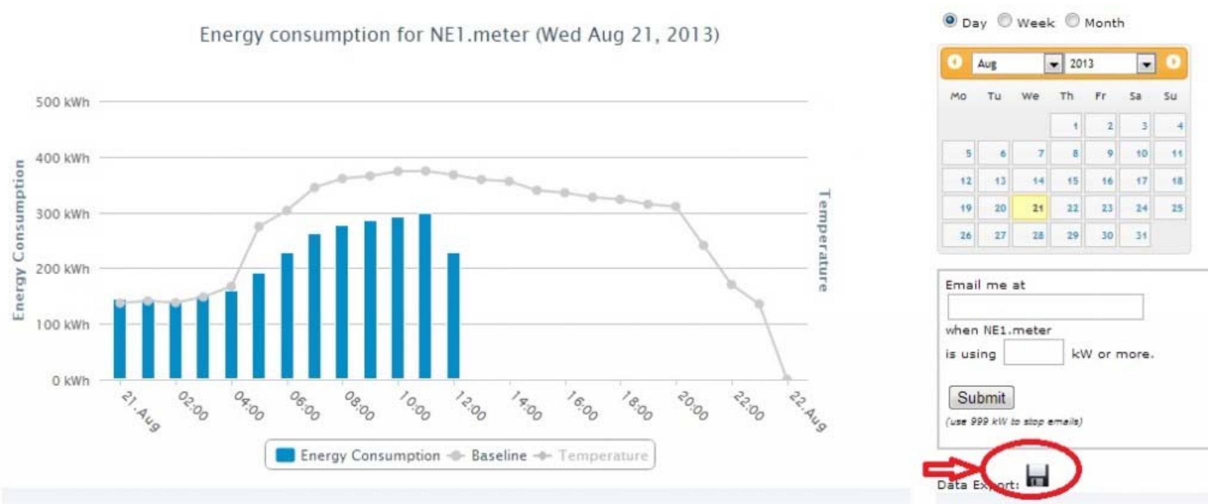
There are 7 buildings within the Factor Four area. Each building has a page on this website. The following is documented on each building page:

- General description of the building (including construction type)
- Fast facts (e.g.: floor area, age, etc.)
- A project folder
    - Floor plan

- o Aerial photo
- o Other photos
- o Condition survey and equipment inventory
- o Mechanical drawings
- o Single line diagrams
- o Link to real-time energy data

Factor Four Live Energy Data

All seven Factor Four buildings are individually monitored in real-time for electricity, natural gas and when applicable, hot water. Note: all data can be exported to Microsoft Excel (CSV file) by clicking on the floppy disk icon as shown in the figure below.



The Factor Four EMS was developed and is provided by BCIT SMART research group.

Factor Four Remote Access to Building Automation System (BAS) and Archived Data

This feature gives access to Faculty and Students to BAS data in “real time and near real-time” so that they can learn the dynamics of building operation, and understand the factors that affect building performance.

Two distinct features are now available:

- A read-only access to the DDC system graphics and logic pages;
- Access to a database with all input/output (I/O) points of the existing DDC system located in the Factor Four building (trend logs).

Instructors are able to give demonstrations in class or via Blackboard Collaborate. Students will have real data to analyze as part of class assignments or research projects.

Factor Four Case Studies

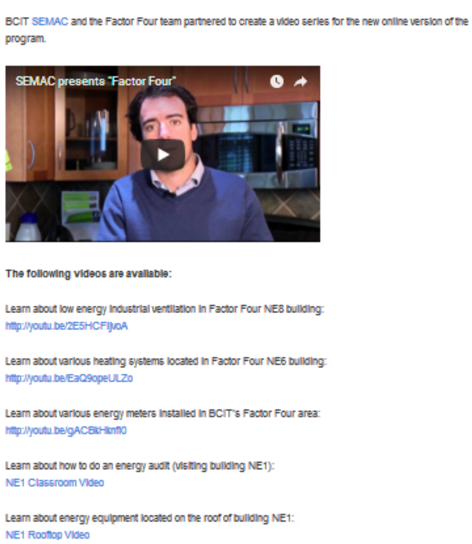
Many Factor Four projects have been documented so they can be used in-class as case studies for students.

Each case study provides the following information:

- Background on the project
- Problem and/or Opportunity
- Solution selected
- Technologies Implemented
- Energy Savings and GHG Emissions Reductions
- Additional Benefits and Features of the project
- Project Partners
- Project Fast Facts
- Project Folder
  - Photos (when available)
  - Documents & Reports (when available)
  - Drawings, Schematics, & Specifications (when available)
  - Calculations (when available)
  - Videos (when available)
  - Instructor Resources (when available), including exercises, presentations and recorded tutorials

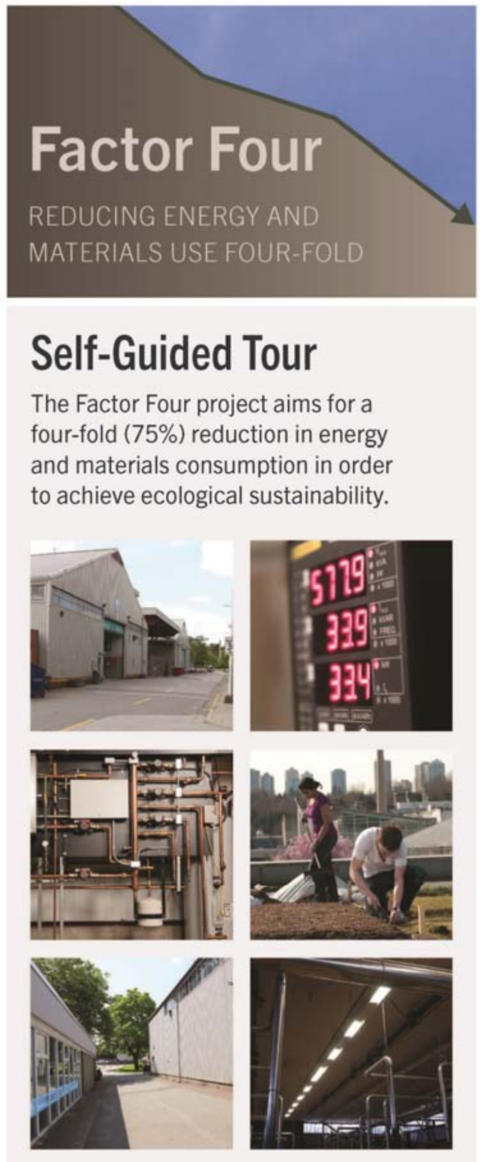
Video Series

The BCIT Centre for Energy Systems Application (CESA), the BCIT Sustainable Energy Management Advanced Certificate (SEMAC) and the Factor Four team has partnered to create a series of educational videos in the Factor Four area. The videos provide “virtual tours” of mechanical rooms, electrical vaults and rooftops.



Self-Guided Tour

A self-guided tour brochure and map was developed for anyone on the Burnaby campus interested in walking the Factor Four area to witness first hand the numerous projects implemented.



The map can be downloaded as a pdf and the 17 tour stops all have an on-site educational sign to help instructors guide the discussion with their students.

Answer Keys

Some Case Studies include class exercise(s) for instructors to use. To make it easier for busy instructors to insert new material in their existing course(s), a password protected answer key was developed for each Factor Four in-class exercises.

Lessons Learned and Conclusion

Many lessons were learned in the last eight years of working on Factor Four's Living Labs. This section provides five lessons learned that might help others with their Living Labs of Sustainability journey.

Lesson 1 – Nothing gets done without a TIM:

"Working towards sustainable solutions requires involving professionals and stakeholders from all sectors of society into research and teaching. This often presents a challenge to scholars at universities, as they lack capacity and time needed for negotiating different agendas, languages, competencies, and cultures among faculty, students, and stakeholders. Management approaches and quality criteria have been developed to cope with this challenge, including concepts of boundary organizations, transdisciplinary research, transition management, and interface management. However, few of these concepts present comprehensive proposals how to facilitate research with stakeholder participation while creating educational opportunities along the lifecycle of a project."

A report was created by Katja Brundiers *, Arnim Wiek and Braden Kay; School of Sustainability, Arizona State University, PO Box, 875402, Tempe, AZ 85287-5402, USA.

"The report recommends the position of a transacademic interface manager (TIM) supporting participatory sustainability research and education efforts.. The article provides practical guidance to universities on how to organize these critical endeavors more effectively and to offer students an additional career perspective."

From: https://pdfs.semanticscholar.org/8c13/6a3ede81c6eaaf6723d962e8f17d5d82152c.pdf

The need for a TIM (as outlined by the academic researchers interested in how to make Living Labs a success) is lesson learned number one for the Factor Four Energy initiative. Without a dedicated person with a clear job description, nothing gets done.

Lesson 2 - Plan for urgency and quick/highly visual wins

Kotter's 8-Step Change Model is about implementing change successfully. Kotter is professor at Harvard Business School and world-renowned change expert. He introduced his eight-step change process in his 1995 book, "Leading Change."

The first of the eight steps is called: “Creating a Sense of Urgency”. Although tackling carbon emissions in the name of climate change appears to be somewhat urgent, it anecdotally does not drive change. Health and Safety concerns do. Two of the largest Factor Four projects were approved after WCB (Workers Compensation Board) air quality complaints had been filled.

Understanding that the drivers for an energy conservation project can be other than saving the planet and/or saving money is essential.

Another important step of the Kotter change model is about creating quick wins. Nothing motivates more than success according to Kotter. You need to plan for highly visible quick wins that your staff and students can see.

The challenge with energy efficiency and conservation is that it is mostly invisible. In the case of Factor Four, the first visible project by design was project number 10, the wood-waste-to-energy facility. Its construction only started in year five of the ten year plan. The first nine projects, although having a significant impact on energy use, were all somewhat invisible (by being located on a roof, inside a locked mechanical room, etc.). The welding ventilation project is mostly located on the roof, the heat doctor initiative is mostly computer based, etc.

Trying to implement the Kotter’s Change Model with the financial constraints dictating when the first visible project would be constructed, a visibility/quick wins plan was required. In the case of Factor Four for every invisible project a visible educational sign was created and installed on site. A self guided tour with narration for the guide was released. Guided tours of the hard to see projects were provided to almost one thousand people. Successes were communicated through different channels again and again.

Finally, the restoration pillar of the Factor Four initiative is an essential element of the quick win / visibility aspect of the journey. In addition to directly reducing energy use, the Factor Four initiative is looking to make holistic changes to create a sense of place and pride for our staff and students. The Restoration initiatives (https://commons.bcit.ca/factorfour/restoration/) are a complement to the work in areas of energy and materials conservation. The restoration projects made changes that psychologically prepared students and faculty for sustainable change. These quick-win projects will drew on the skill and knowledge of the faculty, staff and students in the SOCE, which offers a wide range of programs including: Ecological Restoration, Joinery, Carpentry, Piping, Interior Design, Metal Fabrication and Architectural Science, to only name a few.

Examples of Restoration visible wins include:

- Guichon Alley:
  - Art exhibit (“Our past, our future”)
  - Naming
  - Benches and planters
  - Living walls
- Smith Street renewal:
  - Additional side-0walk

- Planters
- Lamp post banners
- Overhead door replacement
- Public art and more

Lesson number two: plan for urgency, quick wins and visibility.

Lesson 3 – Dense and BHAG makes story telling easier

BHAG: Big Hairy Audacious Goals

Targeting 30,000 GJ per year diluted across all five BCIT campuses would most likely not represent much excitement. Targeting 7 buildings on one single street (as opposed to 60 buildings spread across 4 different municipalities) made story telling easier by achieving extremely ambitious (BHAG) reductions of 50% greenhouse gas emissions, soon 75 to 90%.

Story telling is an important contributor to success. In a home-made experiment, Jennifer Aaker, a marketing professor at Stanford's Graduate School of Business, had each of her students give a 1-minute pitch. Only one in 10 students used a story. The others stuck to facts and figures. The professor then asked students to write down what they remembered. Approximately 5 percent of students remembered a statistic while 63 percent remembered the story.

According to Professor Aaker, "Research shows our brains are not hard-wired to understand logic or retain facts for very long. Our brains are wired to understand and retain stories. A story is a journey that moves the listener, and when the listener goes on that journey they feel different and the result is persuasion and sometimes action."

Story telling is not easy but is necessary. Planning to make story telling possible (e.g.: working on one single street with density of results as opposed to across 5 campuses, 4 municipalities and 60 buildings) is an example of such planning.

Lesson 4 - Unconventional capital exist and shovel ready helps

A shovel ready project is a project for which enough design and costs estimate exist so that last minute funding opportunities can be captured. An example of such shovel ready project is the welding ventilation retrofit. SoCE had prepared a primary design and business case. All info required was readily available when BCIT campus development quickly needed projects to submit to the Ministry for funding. Info that would normally required 6 months to a year of work was complied in less than 2 weeks, resulting in an unexpected $2.7M of funding to renew one of BCIT's most critical facility.

Unconventional capital is money obtained to upgrade facilities from channels other than conventional ministry facilities capital funding. The wood-waste-to-energy project brought in approximately one million dollar of such unconventional funds to build a world class renewable energy facility at almost no cost to BCIT. Examples of such funding include:

- Approximately $350,000 from a carbon reduction government program
- Approximately $200,000 from an industry association
- Approximately $300,000 from utilities
- Approximately $150,000 (cash and discounts) from private sectors

Lesson five: last minute funding opportunities and unconventional funds exist. Be ready.

Lesson 5 - Change is possible and reduction doable, but it is not easy

The initiative has achieved a 50% greenhouse gas emissions reduction to date and is well on the way to be at 75% to 90% by 2020 (10 years after project started).

Each successful project used existing off the shelve technology. Reducing energy consumption and green house gas emissions is therefore doable.

But change is hard as demonstrated by the following stories:

- Dust extraction retrofit in NE2

  Despite having a document showing the existence of a proven energy efficient replacement technology, BCIT facilities department went ahead with the design of a replacement solution that would use more energy than the old system. The SoCE team managed to interrupt the procurement process after the project had been tendered to an old technology provider. This was the first Factor Four project and such confrontation lead to a rough start. The system that got installed successfully installed uses year-after-year 90% less electricity than the old system.

- Welding ventilation retrofit in NE8

  After the announcement of the $2,7M of government funding in August 2013, BCIT's Project Services department tried to divert the funding to other maintenance projects including a roof repairs. The intervention of BCIT President was required to keep the project on track.

- Wood-waste-to-energy near NE2

  Despite having approximately 1 millions dollars of external funding allocated to the project, BCIT VP office recommended returning funding to industry partners. Once again, an intervention from the SoCE Dean was required to save the project.

- Light Savers in NE4 and NE6

  After the success of the Light Savers project in building NE2, a work request was submitted to BCIT Facilities department to implement the equivalent changes in 2 additional buildings. The work request was closed and documented as completed. It is only months later that it was observed that the work had never been done, the work request being wrongly documented as completed. A new work request was issued only to lead to the same unsuccessful ending.

Lesson learned number five: change is doable but hard. Perseverance is required.

Conclusion

Perseverance and a plan to guide decisions in difficult times can lead to significant success and progress. It is somewhat prudent to affirm that the Factor Four initiative has had a positive impact on BCIT's students, faculty, infrastructure and brand.

It started with an idea and through good planning, skilled teams, and a strong political acumen, the Factor Four initiative has demonstrated the value of living labs as a mean to progress towards environmental sustainability.