The British Columbia Institute of Technology's Dust Extraction Project
Lessons in Planning and Designing for Resource Efficiency

Case Summary

The BCIT Dust Extraction story illustrates how a team of foreword thinking individuals took steps to demonstrate a tangible resource efficiency measure. During the summer of 2010, The British Columbia Institute of Technology (BCIT) replaced a dated Dust Extraction System (DES) in its Joinery and Carpentry shops. The old system consisted of six constant-volume units. These were replaced with two variable[1] frequency drive units (motors) on one solid-state central control panel. The new system is anticipated to use 84% less electricity than an equivalent constant-volume system currently available in the market-place. At the same time, the system will improve human health and safety standards, meeting the Worksafe BC's health and safety requirements, and anticipated lower decibels will reduce noise pollution on campus. In an era of limited capital, the project was particularly successful in "piggy-backing" an energy efficiency measure as part of a specific facility investment project. [2] Life cycle analysis and integrated design are essential elements for wise and efficient facility investment strategies.

A. Background

Policy

BCIT is in the final stages of releasing its new Sustainability policy and Greenhouse Gas and Energy Management policy. These policies support a commitment to help meet provincial goals related to energy consumption and greenhouse gas (GHG) emission reductions. Bill 44 mandates BCIT to be carbon-neutral by 2010, and the provincial Clean Energy Act legislates that the province must become energy self-sufficient by 2016. Conservation initiatives are anticipated to achieve 66 per cent of overall efficiency and a number of behavioral and operational actions are being implemented to reduce energy consumption on campus and help BC meet its conservation target. In September 2010, BCIT's President re-signed the BC Hydro Power Smart commitment.

Site Characteristics

The British Columbia Institute of Technology is home to the largest trades training institution in BC, including woodworking trades such as Joinery and Carpentry. In these programs students practice hands-on woodworking in two,

[1] Variable = equipped with a variable frequency drive that allows speed variation of the motor.

[2] See reference to the 'piggy back' strategy in, Cutting Through the Cost Barrier.

large, warehouse-type shops. These shops are connected by an outdoor canopy where carpentry is often completed.

In order to maintain a healthy working environment for both the students and staff, air quality control measures are put in place. Large volumes of sawdust are created during woodworking and therefore the shops have a ventilation system specifically designed to remove dust (a.k.a.: Dust Extraction System or DES).

The DES is an electrically powered ventilation system mainly comprising of motors, fans, ducting and collection bins. These extraction systems are known for their intensive energy use.

The Joinery shop is 1,877 sq m (20,200 sq ft) and the Carpentry shop is 2,057 sq m (22,150 sq ft). Although the two shops are roughly the same size, the Joinery shop generates far more dust. The Joinery shop alone has approximately 150 work stations. Both shops are run throughout the year and provide a learning space for a cohort of up to 64 students at any given time.

Historical System

The DES system servicing the programs included six dust extraction systems; four in the Joinery shop; two in the Carpentry shop. These were originally installed in 1977, and upgraded in 2003. Each unit has one motor for the fan and one motor for a shaker which shakes filters in the extraction unit to enable the sawdust to fall through. Each of the DES's single speed systems were manually controlled by the users.

In simple terms, a single speed (and constant-volume) system can only be turned on or off. There were 6 on off switches for 6 DES units dedicated to specific zones in the shops. When an instructor or student used one piece of equipment in a shop zone, the dedicated zone unit would operate at full capacity and full speed and volume. There was no ability to optimize volume flow based on the number of stations in use in a given zone. When the system operated at full capacity (i.e. 6 units running together), the total capacity of the system was **130 hp, 97.6 kW**. At 1,000 hrs of operation per year, this represents 97,600 kWh/year.

This DES limited-control system relied on users, to turn off one or many of the 6 units if no equipment was in use in a zone. However, it was often difficult for users to notice a unit running in an empty zone due to the noise of the other units. It is believed that sometimes users would simply forget to turn the un-used unit off.

The old system extracted a greater volume of air through the system in the winter creating the need to provide re-heat for the building. Space re-heating using natural gas added to operational costs and to total GHG emissions (and carbon offsets cost).

B. Project Goals

The project's goal was to execute a dust control management system that met regulatory standards set by Worksafe BC. The replacement of an old DES system provided the opportunity to reduce overall energy consumption, costs and GHG emissions.

C. Project Implementation

Step 1: Initial Planning and Design

A project management team was established in 2009 to undertake a mechanical system review. The team and a contracted engineer met with the user group to lay out a space and utilization plan for each of the workshop areas. Once new configurations were documented, the engineering firm examined different systems which would meet Worksafe BC's standards and BCIT user requirements.

Design Option 1: Bigger is Better

Design option 1, initially proposed consisted of four 'bigger' DESs with an ability to extract more air and therefore, more dust, out of the building. At full capacity, this option draws on a total of **235 hp, 150.7 kW.** This is almost double the capacity of the original system. This option assumes capabilities for dust extraction requirements with all equipment running at the same time. Its bigger 'hp' utilizes a greater amount of electricity.

This system is a mirror image of the historical system. It is a single speed and constant-volume system with a single on off control for each of the 4 units. Based on an identical control strategy, energy modeling (described later in the case) used to calculate energy cost use data assumed identical operating hours to those used in the current system, namely, the total hours of in-class time and representation of how often users did turn off redundant units.

With higher volumes of air exchanged between the indoors and outdoors, an expanded natural gas fueled air re-heat system is required in the winter months. Such a re-heat system would yield a bigger overall environmental impact than the system being replaced, and would add increased operational and capital outlay costs.

Step 2: Re-Design

Design Option 2: Lean is Green

Late in the planning and design phase, the user group took a fresh look at their requirements with the additional perspective of wanting to reduce their energy footprint. As a result, specific requirements changed.

They determined that it was impossible to have the 150+ pieces of equipment running at the same time. In fact, it was uncommon for all 64 students in the classes to each use a machine. In this case engineer modeling conducted assumed a 43% utilization (64/150=0.43). According to DES literature, a DES in an environment such as a woodworking school runs between 30-40 %, and therefore requires only 30-40 % capacity not the 100 % capacity provided for by the 'bigger' units. This assumption led to new specifications and consideration of state-of-the-art variable-speed system.

Right Sizing:. *Greatly oversized equipment operates less efficiently and costs more than properly sized equipment. It is better to plan equipment and space so that future expansion is possible. For example, adequately size mechanical rooms and consider the use of modular equipment.*

The BCIT energy manager and students as well as BCIT staff researched alternative DES solutions and simultaneously conducted building energy audits to inform a base-line. The students and staff discovered the existence of a proven 'intelligent' variable-speed system widely used (some 20,000) in Europe and around the globe. In simple terms[3], 'intelligent' systems include a control panel and sensors at each work station. These sensors or current transformers (CTs) read when a station is in use. The system then opens a gate in the duct unit and sends a signal to the variable frequency drive connected to main fan motor telling it to increase air volume to meet the demand and extracts the dust specific to that station. In this way the system extracts only the amount of air required.

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[3] **Technical Description of the Variable Volume System**

The fan speed is increased or decreased by a control system to maintain a constant pressure in the main pipe system. Each fan speed is controlled by a variable frequency drive with a feedback loop from a pressure sensor located in the pipe system. Seldom used machines are fitted with automatic gates that open when the woodworking machine is in operation and close when the machine is shut down. When the blast gates are opened and main system pressure drops, the system increases the fan speed back to the pressure set point. And when gates are closed and the main system pressure increases, the system decreases the fan speed back to the pressure set point. A main PLC controller determines the correct fan speed through control logic that takes into account the number and identity of machines in operation, the pressure in the main line and the pipe system design.

Total horsepower for this system is **75 hp using a VFD = 16.3kW** based on variable frequency drive (VFD) assumptions[4]. Overall, this solution draws the minimum required cubic foot minutes (CFM)[5]. Therefore it uses less energy and generates less GHG emissions overall.

The instructors discovered a local distributor, and further investigation of the variable speed solution ensued.

Step 3: Tipping the Decision

Life Cycle Analysis

The team under took a cost-benefit analysis which compared installation costs, avoided energy costs and energy consumption reduction. These numbers were run based on a life cycle costing (LCC) principle. [6] The LCC in this case was simple.

The team reviewed the initial capital cost of *Option 1* based on bid information together with anticipated operational costs based on internal calculations. This was compared to the variable speed system – *Option 2.* A decision was easy since *Option 2's* installation and operational costs were cheaper, and had less GHG emissions.

A summary of benefits for *Option 2* includes:

- more efficient performance and resulting energy savings (126,200 kWh/yr), and GHG emission equivalents (approx. 3 tonnes of CO2eq)
- additional GHG Emissions avoidance associated with an avoided natural gas fed re-heat system

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[4] On average: A quarter of the time at 70% speed; Half of the time at 50% speed; A quarter of 25% of the time at 25% speed.

[5] CFM: Cubic Foot Minutes, a measure of the volume of air transported in a minute, or also known as "flow"

[6] Life Cycle Cost Analysis *a measurement of total costs of any given article over its lifespan. It is a financial analysis tool that includes initial cost (e.g.: purchase, construction /installation cost, etc.); operating cost (e.g.: energy cost), other costs (e.g.: maintenance, disposal fee, etc.) and revenues (e.g.: residual value, revenues from being a net energy producer, etc.). Life cycle cost also takes into account time value of money. Source: BCIT* Energy and GHG policy.

Cost Benefit Analysis *or CBA is a relatively simple and widely used technique for deciding whether to make a change. As its name suggests, you simply add up the value of the benefits of a course of action, and subtract the costs associated with it.*

- lower overall installation costs
- material and space savings – 1 unit replaces 4/6 units; 1 waste collection bin replaces 4.
- Lower noise level

Detailed calculations can be found in Appendix A.

Time-line Feasibility

Now ten months into a one year schedule, the project was under pressure to install a new unit in time for the beginning of school. The variable speed solution had to be evaluated for feasibility for completion by August 31st 2010. The installer, the manufacturer and the engineer firm confirmed the feasibility of the new dust collection in operation for NE04 whole building and NE02 North side on or before August 13, 2010.

Mitigating Risks and Guarantees

The variable-system studied is modular and can be easily expanded by adding modular fan units, ductwork systems and accessories. The modular nature of the system allows for **right sizing** rather than over design and this flexibility helps mitigate the risk of going with a 30-40% utilization rate design. BCIT wanted to reduce risk associate with right sizing. The variable-system distributor agreed to a contract that specified they would be responsible for the costs of adding modular units should their capacity estimates prove wrong.

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The business case considered major cost savings achieved if the re-heat is eliminated. The risk is that there may be need for additional radiant heating during any cold spell in winter. However, because the variable speed system provides a lower volume of replacement air to the building, it is still a better option than the existing current system.

The variable speed system introduces new sophisticated control systems and concerns were raised about related potential increased maintenance costs for a more sophisticated system. Some automation is cost effective and some other is not. Some systems are over-engineered and are never cost effective. The decision making team visited installations in two shops as part of its due diligence process. The oldest installation in BC did not have significant maintenance issues at the point in time of the review.

Step 4: Installation and Commissioning

The variable speed system was installed over the summer in time for the Fall term. A one year commissioning phase will be undertaken to fine tune the control interface.

Step 5: Monitoring and Verification (M&V)

M&V is critical step in making the case for LCC, and supporting future decision-making. Ideally M&V is built into the early design phase of a project. In this case, M&V came late in the planning and design process when an alternative solution entered into consideration.

The project selected a *retrofit isolation approach* to conduct its M&V. This approach is used when "end use capacity, demand, or power can be measured during a baseline period and after the retrofit for short-term periods, or continuously over the life of the project." [7] For further details, refer to the Energy Management Handbook referenced below.

The project conducted a base-line review prior to the decommissioning of the old system and when classes were still in use. To make sure the M&V was based on sound analysis, a team including the BCIT Energy Specialist installed motor loggers on each of the motors of the 6 old units that were still in operation at the time.[8]

It is noted that classes in Carpentry and Joinery run 30 to 36 hrs per week. The Dust extraction units, in theory, should not be on for more than 36 hrs per week. It was expected that this number would be lower and verification was conducted using the motor loggers described above. After verification with motor loggers installed for a 4 week duration, it was concluded that equipment was actually running on and off for an average 20 hrs per week. This translates as follows: Running 20 hrs per week, 50 weeks per year = 1,000 hrs per year. This became an important factor in calculations.

Overall, the base-line set trend data against which the new system will be monitored over the course of the first year. Students from the School of

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[7] Energy Management Handbook Seventh Edition, Steve Doty Wayne C. Turner, 2009, *Section 27.4.2.1*)

[8] A motor logger is usually installed on or near a motor and can detect whether a motor is turning or not and log the data for many weeks.

Environment and Construction will be involved in the ongoing monitoring and evaluation process.

D. Project Performance

The following economic, social and environmental impacts have been or are anticipated to be achieved by the project:

Financial

- Energy cost avoidance in the range of $5,000 - $8,000 per year
- BC Hydro incentive of up to $41,000
- Operational savings
- Potential value of a central collection location for wood waste for bio-energy facilities
- Lower bin collection labour; a person used to monitor dust bins every day and used a fork lift to move these. The new system replaces six small bins with one bigger bin. However, labour may be wash taking into consideration labour for the control system.

Environment

- 126,200 kWh/yr in energy savings
- 3 tonnes of CO2eq from electricity
- GHG emissions avoided from space re-heat system
- A modular system means less material and space waste even if one day extra modules were added.

Social

- By the nature of the design, it is anticipated that the noise pollution (decibels) will be lower thus improving the work environment for staff and students
- Teaching demonstration opportunities
- Health and safety – the system will extract more dust from the building
- Broader public awareness
- Early win /demonstration project on the BCIT energy reduction goals and associated campus awareness

E. Scalability Factors

The project serves a number of future scalability possibilities:

Future Integrated Waste to Energy System

Work is being conducted to demonstrate a Factor Four and Factor Ten Economy in the sustainability precinct at the School of Construction and the Environment. A so-called Factor Four economy achieves a reduction of 75 per cent in energy and material used throughput, while a Factor Ten economy achieves 90 per cent.

At the BCIT precinct, a cluster of buildings and infrastructure will be transformed to achieve Factor Four within the next 10 years and Factor Ten within 20. The project presents an ideal opportunity for a small bio-energy installation as a part of an overall sustainability precinct. Wood waste can be use as a source of energy within a district energy system.

Supply Management and Procurement
The project demonstrates the importance of building life cycle costing and energy efficiency targets into procurement decision making for ALL equipment purchases.

Integrated design Management
The project demonstrates the importance of involving all stakeholders in the design process for capital procurement from the beginning. According to a member of the team, "you also need to have the right team and the right culture to overcome risks and unknowns."

Performance vs. Prescriptive Specs: "Public sector organizations tend to be linear in how they think wherein they hire a consultant and assign them the responsibility to come up with a solution. The wave of the future may be to do in-house upfront design, determine performance standards for a number of criteria and then ask suppliers to come up with the most efficient solution. "

Early Win: This project provides a tangible example of steps taken to move from policy to action. With communication of results, the campus can become more aware of the policy and strategies to move from targets to results. If at the end of the year this system does save energy and money, the story can be used to raise further awareness to action.

Sustainability Revolving Fund Launch: "This would have been a nice project to present for green fund." Such a fund would involve seed money being set aside in the annual budget every year and used to fund projects with payback and savings.

Campus as a Living Lab: There are tremendous opportunities for student led action research focused on energy use monitoring, as well as ideas related to bio-mass and the sustainability precinct.

F. Lessons Learned

"The key is whole systems engineering with meticulous attention to detail. Close enough attention often reveals more than just two benefits per technology."[9]

There are three key 'learning' lessons from this project:

Lesson One: **Whole Systems Engineering**: whereby, all aspects of the building or building system are considered in the design phase. Integrated design provides the strategies to achieve a true high performance system that is cost effective over its entire life cycle.

Decision making leading to the selection of the variable speed system considered all aspects of the system design debunking the original assumption that by adding more horsepower the problem would be fixed. By 'right sizing' the system to fit optimum use allowed for a smaller overall modular system and efficiency gains. A broader look also identified savings from an operational perspective whereby the need for re-heat equipment was eliminated.

A future consideration for the trades shop is the installation of a bio-energy plant whereby the wood waste collected in the dust bins could become and energy source for heating. This feature is also under active consideration by the design team.

Lesson Two: Integrated design management: the approach asks all members of the building stakeholder community to look at project objectives from different perspectives. This process pools the knowledge of all the stakeholders.

This project is not a proactive example of integrated design management. The user group played the key role in determining the type of system to be installed however, the original user group consisted only of the facilities team and the end users. It was not until ten months into the project that the energy management team came to the table. However, the experience will likely inform the next design process.

Lesson Three: Change Management Drivers and Barriers: a key driver for change in this case was the user group. This group ultimately controlled which system would be employed. Once a decision was made to prioritize energy efficiency, it changed the business model.

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[9] Natural Capitalism, Tunneling through the Cost Barrier, page 120.

A second key driver was awareness. Consultants hired to find a solution just did not know about the variable speed system. Also, the engineer firm and team were not aware of the existence of such variable speed system.

An initial key barrier was lack of thinking outside the box. When conducting engineering work, it is so much easier to be conservative, and avoid risk. Therefore, the tendency is to build in over-design and consider bigger is better. Risk factors which could cause a different outcome include, having to install a re-heat system and an higher electricity consumption level. In such a case, the system would have cost more and have generated more GHG emissions.

Focus Questions

1. This is a good example of life cycle costing analysis- why or why not.
2. This case should be read in parallel with "Cutting Through the Cost Barriers". What key concepts from that chapter are reflected in this story.

Appendix A
LCC and Cost Benefit Analysis

Operational Energy Savings
A conservative estimate anticipates that the variable speed system will generate 126,200 kWh/yr in energy savings per year as outlined in Table 1.0 below:

Table 1.0 : LCC Analysis

Equipment Tag		Operating	Conditions	Savings
Zones/areas served		Baseline	Proposed	84 %
Peak load	[kW]	n/a	n/a	[kW]
Estimated average load	[kW]	150.7	16.3	134.4 [kW]
Annual hours of operation	[hr/yr]	1,000	1,500	[hr/yr]
Annual consumption	[kWh/yr]	150,700	24,500	126,200 [kWh/yr]

These savings, when calculated with the current BC Hydro's second step rate of $0.0393/kWh is equivalent to approximately $5,000/yr for electricity only. Savings from avoided natural gas and cost of GHG emissions are over and above this.

GHG Savings
Approximately, 3 tonnes of GHG emissions were saved based on electricity use alone. Further GHG savings occurred based on the fact that a natural gas re-heat system was avoided, however specific calculations were not conducted.

Capital Savings
Option 1: Constant-volume System
The capital and installation costs of the baseline design is $749,000 (units only) plus $121,000 of air re-heat units. This represents a total of $870,000.

Option 2: Variable Speed System
The capital and installation costs of the basic market standard is $820,000. This includes $200,000 of control systems.

If comparing options based on the basic unit cost only, Option 1 is cheaper by $71,000. However, when comparing total costs Option 2 is cheaper by, $50,000.

In the end the business case was simple because the variable speed system is cheaper to build.