AVALON ENERGY MANAGEMENT
A Division of Avalon Mechanical Consultants Ltd.

ENERGY STUDY
ROYAL ROADS UNIVERSITY
VICTORIA, B.C.

June 30, 2009

300-1245 Esquimalt Road
Victoria, B.C.
V9A 3P2
Tel: (250) 384-4128
Fax: (250) 384-4134
bob@avalonmechanical.com

LIST OF TABLES

APPENDICES

Appendices **D** to **M** are provided electronically.

Statement Concerning Liability

1 SUMMARY

Royal Roads University (RRU), in Victoria, BC, has commissioned this study of their Campus to investigate energy use reductions and cost avoidance, and as a step toward their goal of lessening the environmental impact of their buildings.

If

- all the recommended work were to be properly installed and operated, and
- the facility operating schedules remained constant, and
- no new loads were added, and
- energy pricing stayed constant.

then the anticipated energy savings for all the recommended measures would be as shown in Table 1.

Table 1 Total Potential Annual "Savings" Identified

	kWh/yr	GJ/yr	%	$
Electricity	908,688		22%	$53,511
Gas		5982	24%	$86,287
Maintenance				$21,977
Opportunity				($500)
Water				$250
Total				**$161,525**

Water reductions of 162,000 litres per year are assumed from new shower heads.

Notes: 1. Opportunity savings are reduced maintenance requirements for in-house staff (primarily reduced light bulb changes due to longer life of proposed technologies).
2. In-house costs relate to IT staff's involvement with proposed "sleep mode" computer network software management.
3. Actual energy cost reductions (old energy costs minus new costs) will be less if energy rates rise, although actual savings should be greater.

The preliminary budget costs for implementing the recommendations are $1,061,592. These costs include engineering, implementation and project management, but not GST. Construction costs reported herein are estimates and can differ significantly from tendered costs as a result of market conditions, absence of competition, inflation, or unforeseen complications.

The financial performance of the project is summarized as follows:

- the simple payback for the project is anticipated to be 6.6 years. The payback may be reduced further if BC Hydro or Terasen incentives can be secured. NRCan incentives (Eco-Energy and REDI) may also be available.
- the equivalent internal rate of return would be estimated at 12.9%, based on a 15 year life and no escalation in energy rates;
- the net present value for the project is expected to be $753,811, based on a 4.0 % discount rate and 15 year life.

The recommendations contained in this report will result in additional benefits which include the following:

- replacement of equipment near the end of its life with new equipment,
- improved maintenance as a result of information available from the proposed DDC system upgrades,
- provision of improved documentation for facility systems,
- reduce greenhouse gas emissions by 336 tonnes of equivalent CO_2 per year.

Notes:

1. PST is included in the savings, but GST is not.
2. Consumption saving discount for BC Hydro rate 1211 is assumed to be offset by transformer losses, and is not applied to the savings.
3. Opinions of lighting Maintenance savings are included, as the project will
   - replace many old T12 fluorescent lamps and ballasts;
   - replace incandescents with compact fluorescents that last 8 times longer;
   - add controls which reduce lamp/ballast burn hours, and
   - clean luminaires as part of the installation.
4. Opinions of added gas heating due to lighting and other power reductions is accounted for.
5. Opinions of added maintenance of new equipment is accounted for.

1.1 Background of Project

With the support of BC Hydro's *Power Smart Program*, Royal Roads University (RRU) has initiated this investigation. This work compliments the RRU Sustainability Plan, which has firm energy reduction targets, and various energy awareness initiatives.

The purpose of this report is to identify and describe energy saving opportunities related to the RRU Campus buildings; particularly their power, lighting, envelope and HVAC systems.

This energy study consists of the following:

- a review of existing conditions,
- definition of potential improvements,
- estimations of energy cost avoidance resulting from these improvements,
- opinions of probable costs for the recommended bundle of improvements.

For the purposes of this report, buildings are identified by number, as in the following table and in the subsequent site plan:

Table 2 Building Number Designations

Bldg No.		Bldg No.	
1	Castle (1)	2	Greenhouse (2)
3	Bldg 3 Admin House	4	Mews (4) Conference Ctr
5	Bldg 5 House	6	Cedar (6)
7a	Arbutus (7A)	7b	Bldg 7B1, 2, 3
9	Gatehouse (9)	10	Bldg 10 (fourplex)
12	Bldg 12 Faculty House	14	Bldg 14 Office House
16	Bldg 16 House	21	Millward (21)
22	Pool 22 Gym 25	23	Nixon (23)
24	Grant (24)	30	Library (30)
32	Boatshed (32)	34	Rose Garden Cottage (34)
77	Rowing Centre (77)	27	Bldg 27 Commandant's Residence
28	Bldg 28 Vice Commandant's Residence		


North
Sooke Road
← Colwood
Victoria →
9
7A
7B
10
12
University Drive
Mayne Avenue
West Campus Road
Belmont →
College Drive
Serpentine Road
West Campus Road
23
T11
24
Neptune Way
21
College Drive
1
30
University Drive
Library
34
27
28
22
5
2
14
16
College Drive
4
3
6
77
32
University Drive
Esquimalt Lagoon

1.2 Report Summary Table

Table 3 Bundle of Recommended Energy Options

		Electricity Consumption		Electricity Demand		Total Est.		Estim.	Estim	GHG	Estim.		Estim.	Estim.	Simple	Comments
BLDG	OPTION	Estim Savings kWh/yr	Estim Savings $/YR	Estim. Savings kW	Estim. Savings $	Electrical Savings $	Heating Penalty GJ	Fuel GJ Savings	Gas Saving $	tonne CO2 reduced	Other Savings $	Estim. Total Savings	Capital Cost $	Equip Life (YR)	Pay-Back (YR)	
all	Lighting	477,474	$18,998	194	$18,275	$37,273	-307	0	-$4,428	10	$22,316	$55,161	$451,886	7	8.2	
all	Vending Machine Control	18,790	$748	0	$0	$748	-5	0	-$70	0	$0	$678	$2,400	5	3.5	
all	Mechanical Insulation	319	$13	0	$0	$13	0	93	$1,340	5	$0	$1,353	$6,050	10	4.5	
all	Computer Pwr Mgmt	120,978	$4,813	0	$0	$4,813	-62	0	-$897	2	-$500	$3,416	$9,200	2	2.7	
all	Low Flow Shower Heads	0	$0	0	$0	$0	0	15	$223	1	$250	$473	$2,000	5	4.2	estimate 40 heads
all	DDC Recommissioning	17,772	$707	0	$0	$707	0	332	$4,790	17	$0	$5,497	$20,000	2	3.6	
1	Air Sealing	0	$0	0	$0	$0	0	206	$2,974	10	$0	$2,974	$14,000	10	4.7	defunct EFs, sprinks, etc.
1	Architectural Insulation	0	$0	0	$0	$0	0	259	$3,741	13	$0	$3,741	$25,000	10	6.7	attics
1	Expand DDC Control	0	$0	0	$0	$0	0	127	$1,828	6	$0	$1,828	$14,000	2	7.7	night setback
1	New Backup Boiler	0	$0	0	$0	$0	0	680	$9,807	34	$0	$9,807	$70,000	15	7.1	old blr rated 60%
3	Air Sealing	0	$0	0	$0	$0	0	8	$112	0	$0	$112	$500	10	4.4	
			$0		$0				$0	0						
4	Air Sealing	0	$0	0	$0	$0	0	98	$1,415	5	$0	$1,415	$8,500	10	6.0	
4	DDC	41,272	$1,642	0	$0	$1,642	0	120	$1,733	7	$0	$3,375	$37,100	2	11.0	all bsmt ahus + hydronics
4	Outdoor Reset for Boiler	0	$0	0	$0	$0	0	64	$924	3	$0	$924	$5,000	2	5.4	
5	Air Sealing	0	$0	0	$0	$0	0	10	$149	1	$0	$149	$500	10	3.4	
5	Duct Insulation	0	$0	0	$0	$0	0	1	$19	0	$0	$19	$120	10	6.2	duct in crawlspace
5	Heat Pump	-8,854	-$352	-5	-$424	-$777	0	75	$1,083	4	$0	$306	$6,500	10	21.2	new 1200 cfm oil w.add on 3T
6	Air Sealing	20,379	$811	0	$0	$811	0	0	$0	0	$0	$811	$5,750	10	7.1	gen+ 2shop ducts@14x22
6	Jalousie Storms	1,313	$52	0	$0	$52	0	0	$0	0	$0	$52	$500	10	9.6	two 20*76, bsmt south
6	Tank Insulation	450	$18	0	$0	$18	0	0	$0	0	$0	$18	$200	10	11.2	DHWT jacket
7b	Air Sealing	9,963	$396	0	$0	$396	0	0	$0	0	$0	$396	$1,750	10	4.4	
7b	DDC	13,260	$528	6	$566	$1,094	0	0	$0	0	$0	$1,094	$3,000	2	2.7	SE ERPs stats broken

BLDG	OPTION	Electricity Consumption: Estim Savings kWh/yr	Electricity Consumption: Estim Savings $/YR	Electricity Demand: Estim. Savings kW	Electricity Demand: Estim. Savings $	Total Est. Electrical Savings $	Heating Penalty GJ	Estim. Fuel GJ Savings	Estim Gas Saving $	GHG tonne CO2 reduced	Estim. Other Savings $	Estim. Total Savings	Estim. Capital Cost $	Estim. Equip Life (YR)	Simple Pay-Back (YR)	Comments
7b	Reduce demand penalty	0	$0	3	$236	$236	0	0	$0	0	$0	$236	$500	5	2.1	remove oversized resist heat
9	Air Sealing	0	$0	0	$0	$0	0	15	$217	1	$0	$217	$750	10	3.5	attic; bsmt
9	Heat Pump	-10,271	-$409	-5	-$495	-$904	0	99	$1,421	5	$0	$517	$7,000	10	13.5	
10	Air Sealing	0	$0	0	$0	$0	0	49	$710	2	$0	$710	$3,864	10	5.4	fireplaces, etc
10	OA reset on heating water	0	$0	0	$0	$0	0	23	$335	1	$0	$335	$5,000	5	14.9	new 3-way valve & control
12	Heat Pump	-13,724	-$546	-5	-$424	-$971	0	132	$1,901	6	$0	$930	$6,500	10	7.0	
14	Air Sealing	0	$0	0	$0	$0	0	13	$186	1	$0	$186	$750	10	4.0	attic; bsmt
14	Heat Pump	-10,271	-$409	-5	-$424	-$833	0	88	$1,264	4	$0	$431	$6,500	10	15.1	
14	DHW Temp Reduction	1,296	$52	0	$0	$52	-1	0	-$10	0	$0	$42	$100	2	2.4	151 F at tap
16	Air Sealing	2,012	$80	0	$0	$80	0	0	$0	0	$0	$80	$500	10	6.2	
21	Air Sealing	0	$0	0	$0	$0	0	47	$678	2	$0	$678	$3,800	10	5.6	shaft, windows
21	DDC	24,157	$961	0	$0	$961	0	137	$1,974	7	$0	$2,935	$18,200	2	6.2	I/L 3 drier w EFs; pumps & fans
21	VSD	35,654	$1,419	0	$0	$1,419	0	604	$8,706	31	$0	$10,124	$20,400	5	2.0	MUA(x3) in summer
21	Solar Thermal	-495	-$20	0	$0	-$20	0	185	$2,662	9	$0	$2,642	$42,000	15	15.9	huge tanks
22	Air Sealing	0	$0	0	$0	$0	0	45	$649	2	$0	$649	$4,369	10	6.7	chlr rm louvre, gym lvrs etc.
25	Architectural Insulation	0	$0	0	$0	$0	0	39	$558	2	$0	$558	$3,780	10	6.8	pool south
22	Architectural Insulation	0	$0	0	$0	$0	0	336	$4,849	17	$0	$4,849	$29,700	10	6.1	spray gym ceiling + net
25	Time Scheduling	0	$0	0	$0	$0	0	123	$1,777	6	$0	$1,777	$1,000	2	0.6	back-up boiler
25	DDC	5,299	$211	0	$0	$211	0	0	$0	0	$0	$211	$900	2	4.3	DHW pumps (2)
25	Separate DHW for Summer	1,552	$62	0	$0	$62	-1	344	$4,952	17	$0	$5,014	$6,500	10	1.3	12 showers
23	Air Sealing	0	$0	0	$0	$0	0	40	$577	2	$0	$577	$7,000	10	12.1	cap old RT EF, etc
23	Architectural Insulation	0	$0	0	$0	$0	0	39	$558	2	$0	$558	$3,780	10	6.8	1st steam header room wall
23	DDC	18,055	$718	0	$0	$718	0	121	$1,740	6	$0	$2,459	$14,200	2	5.8	New HW boiler CVs

BLDG	OPTION	Electricity Consumption		Electricity Demand		Total Est.		Estim.	Estim	GHG	Estim.		Estim.	Estim.	Simple	Comments
		Estim Savings kWh/yr	Estim Savings $/YR	Estim. Savings kW	Estim. Savings $	Electrical Savings $	Heating Penalty GJ	Fuel GJ Savings	Gas Saving $	tonne CO2 reduced	Other Savings $	Estim. Total Savings	Capital Cost $	Equip Life (YR)	Pay-Back (YR)	
24	Air Sealing	0	$0	0	$0	$0	0	44	$635	2	$0	$635	$3,035	10	4.8	roof holes and 215 windows
24	Fume EF User Switch	1,125	$45	0	$0	$45	0	147	$2,124	7	$0	$2,169	$700	2	0.3	114 fume hood RT fan
24	VSD	20,047	$798	0	$0	$798	0	0	$0	0	$0	$798	$9,000	5	11.3	Faulty ASD AH2 RF
24	Stove Igniters	11,900	$473	0	$0	$473	0	517	$7,455	26	$0	$7,929	$12,500	5	1.6	Kitchen Hoods (2) & MUA
24	DHW Storage Tank(s)	0	$0	0	$0	$0	0	28	$405	1	$0	$405	$2,750	10	6.8	exist once-thru cond blr
30	Air Sealing	0	$0	0	$0	$0	0	45	$649	2	$0	$649	$3,000	10	4.6	
30	Architectural Insulation	0	$0	0	$0	$0	0	27	$386	1	$0	$386	$2,460	10	6.4	above T-bar east wing
30	DDC	106,989	$4,257	0	$0	$4,257	0	197	$2,839	12	$0	$7,096	$41,640	2	5.9	MZ1&2, F2,3,4,5. Pumps, DX
30	Demand Ventil. Control	0	$0	0	$0	$0	0	486	$7,008	24	$0	$7,008	$10,000	5	1.4	MZ1 & 2
30	Turn Off Lag Boiler	0	$0	0	$0	$0	0	155	$2,236	8	$0	$2,236	$1,000	2	0.4	condensing lead
30	Heat Reclaim	-728	-$29	0	$0	-$29	0	72	$1,042	4	$0	$1,013	$6,500	10	6.4	ERV to relieve pos pres
30	Cap AH2 Office Zone	0	$0	0	$0	$0	0	73	$1,058	4	$0	$1,058	$1,250	10	1.2	blows into Blr Rm
30	DHW Temp Reduction	1,573	$63	0	$0	$63	0	0	$0	0	$0	$63	$100	2	1.6	179 F at tap
34	Remove Hall EBB	1,400	$56	1	$47	$103	0	0	$0	0	$0	$103	$100	10	1.0	EBB right below HP Tstat
	Contingency												$96,508			
	GRAND TOTALS	*908,688*	*$36,155*	*184*	*$17,356*	*$53,511*	*-375*	*6,357*	*$86,287*	*336*	*$22,065*	*$161,863*	*$1,061,592*			

The term "**Consumption**" refers to the amount of energy used and metered.
The term **"Demand"** refers to the peak momentary electrical draw on the meter, from which the monthly demand penalty is calculated.

Building 25 is out of sequence in the first column of the table above because it shares a central plant with Building 22.

The details of the options are presented in section 4 of the report. They are generally arranged in order of likely implementation (best ROI) as follows:

- Load reduction options (e.g., wall insulation).
- Distribution upgrade options (e.g., pipe insulation).
- Plant upgrade options (e.g., new heat pumps).

Within the above framework, we generally present the waste-reduction options (e.g., running equipment less) before the efficiency increase options (e.g., replacement of equipment). This ordering facilitates the calculation of savings for the overall bundle of options to be implemented. The bundle has been adjusted so that the savings associated with each line item takes the reductions of the previous items into account; this avoids double counting of savings.

2 CUSTOMER INFORMATION

Royal Roads University
2005 Sooke Road, Victoria, B.C. V9B 5Y2

Contact: Mr. Bob Whitmore, Associate Vice President
Planning & Site Operations
phone: 250 391-2607

Physical & Environmental Resources (PER) staff's contributions were crucial to the completion of the project. Conservation Consultant, Richard Collier also provided valuable assistance.

Table 4 University Overview

Facilities	
Number of metered sites	**Hydro Meters:** One bulk meter. **Gas Meters:** Castle 1, Greenhouse 2, Bldg 3, Mews 4, Bldg 5, Gatehouse 9, Fourplex 10, Bldg 12, Bldg 14, Millward 21, Pool Gym 22, Grant 24, Library 30, Boatshed 32, Bldg 27 and Bldg 28..
Types of facilities	Classroom, office, cafeteria, labs, recreation
Key line of business	Education; 370,502 ft^2 of covered space
Environmental issues	GHG emissions, recycling, water usage
Stakeholders	Students, faculty, staff, management, City, Province
Number of employees & students	**staff**: academic 137; Admin 292; **students:** 240 on campus (daily average) (179 in residence).

The university has an active distance learning program (student FTE in 08/09 was 2096).
Enrolment at the RRU Campus has risen by 18% in the last 2 years.

3 DESCRIPTION OF FACILITY, HARDWARE & SYSTEMS

3.1 University Overview

Royal Roads University (RRU) maintains its campus in Greater Victoria, and houses arts and academic programs. Serving a diverse population of credit, non-credit and international students, it offers a variety of programs, and grants undergraduate and graduate degrees. RRU is the site of the original Dunsmuir family estate and includes numerous heritage buildings, designated under various programs. The campus also includes the buildings built for Royal Roads Military College.

3.2 RRU Building Descriptions

3.2.1 Architectural Systems

There are a plethora of construction types and vintages on the campus. See Appendix “A” for a succinct presentation of the details.

3.2.2 Occupancy Patterns

Peak occupancy occurs in the summer, with other peaks in spring and fall. Teaching areas are normally open Monday to Friday, 8:00 am to 5:00 pm plus night classes, but certain areas have extended hours. Summer occupancy is only marginally less; detailed schedules were used for simulations where available. Administration areas are active 12 months per year (working hours).

3.3 Mechanical Systems

3.3.1 Description of Mechanical Systems

There is a vast array of mechanical system types on campus. The systems can be identified in Appendix “A”. Points that are salient to the recommendations include the following:

- The castle has a very old steam heating system, with virtually no mechanical ventilation.
- The houses generally have gas or oil furnaces, which are generally quite old. There are some boilers and electric baseboards as well.
- The library has 2 multizone AHUs which run continuously and over-pressurize the building during free cooling. The condensing boiler runs hot. Consumption is very high due to extremely poor envelope.
- Controls on campus are generally conventional electric or pneumatic, with small pockets of DDC.
- Most multi-boiler plants flow water thru lag boilers.
- Many fans run continuously.

Operation of many of the mechanical systems is somewhat unpredictable. For example, the major fan systems in Building 4 (Mews) were off for an extended period, and were turned back on in August, 08. The complicated cafeteria exhaust and make-up fan systems have a DDC strategy, but are controlled manually. The new maintenance staff are trying to understand the building HVAC and bring a more systematic approach to its operation.

A summary of Domestic Hot Water systems is contained in Appendix “B”.

3.3.2 Equipment Inventory & Energy

An inventory of the mechanical system was compiled, and is the basis for the energy simulation table in section Energy Analysis 3.6. The power requirement of each item was estimated as follows:

Where only horsepower was known: hp * 0.746 kW/hp * Load Factor. (1.73 for 3 phase only)

Where running amperage was known: $\frac{A*V*1.73*0.95PF}{1000}$

Equipment run times were determined in consultation with RRU Physical and Environmental Resources (PER) Dept.

3.4 Controls System

3.4.1 Description of Controls System

There is a mixture of electric, programmable electronic, pneumatic and DDC controls. All campus DDC control panels are manufactured by Delta Controls.

3.5 Process System

3.5.1 Description of the Process Systems

- Greenhouses (Bldg 2).
- Gym (Bldg 22).
- Science labs and data centre (Bldg 24).
- Trades shops (Bldg 7b).

3.5.2 Equipment Inventory with Energy

A detailed equipment inventory was compiled to produce the energy simulations per building. The inventory for the Grant Bldg 24 is contained in Appendix “C” as an example. A detailed comprehensive inventory has been provided to RRU.

3.6 Energy Analysis

The simulated energy use per building is shown in the following table:

Table 5 Existing Facility Energy Performance Summary

ENERGY	Floor Area (sm)	kWh/yr	MJ/sm.yr
2007 Hydro	34,433	4,106,402	429
2007/08 Gas	24,936	4,520,833	653
	34,433	**8,627,235**	**902**

COST	Power Factor Charge	Total Charge	$/SM
2007 Hydro	0	$198,834	$5.77
2007/08 Gas	NA	$211,575	$6.14
		$410,409	**$11.92**

3.6.1 Reconciliation of Bills & Simulations

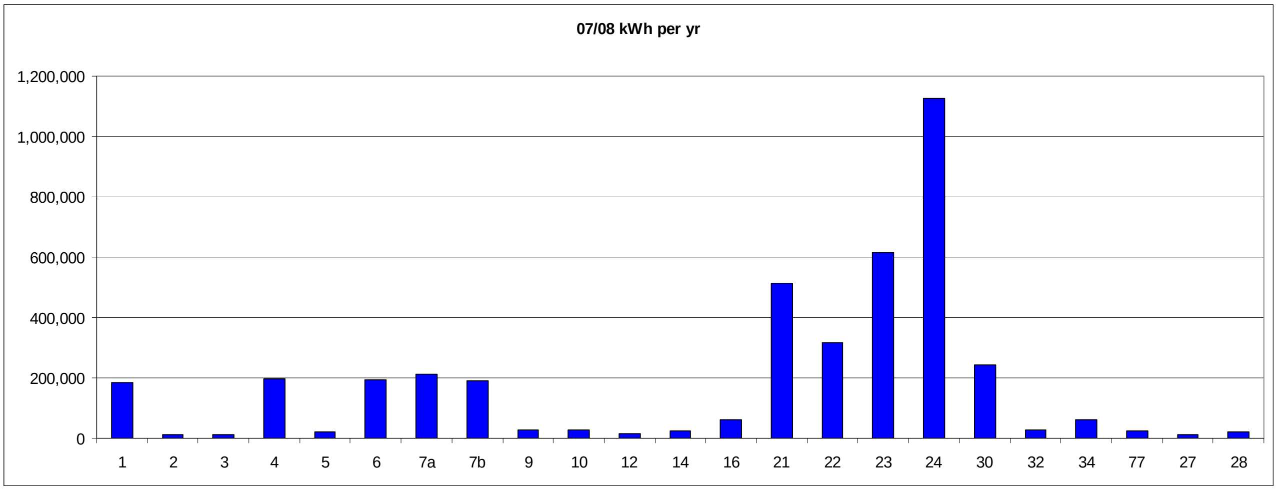
Table 6 Hydro End-Use kWh/yr Breakdown 07/08

Simulations	kWh/yr	
Mechanical	*1,357,965*	33%
Lighting	*1,292,484*	31%
Plug Load	*1,495,549*	36%
Sim. Total	*4,145,999*	100%
Hydro Bills	4,106,402	99.0%

"Mechanical" is predominantly HVAC equipment;
There is one Hydro meter which serves the 24 buildings.

Breakdown of Hydro Consumption:

Graph 1: Simulated kWh/yr of electricity per **building**.



Graph 2: Simulated kWh of electricity used per square foot per **building**.

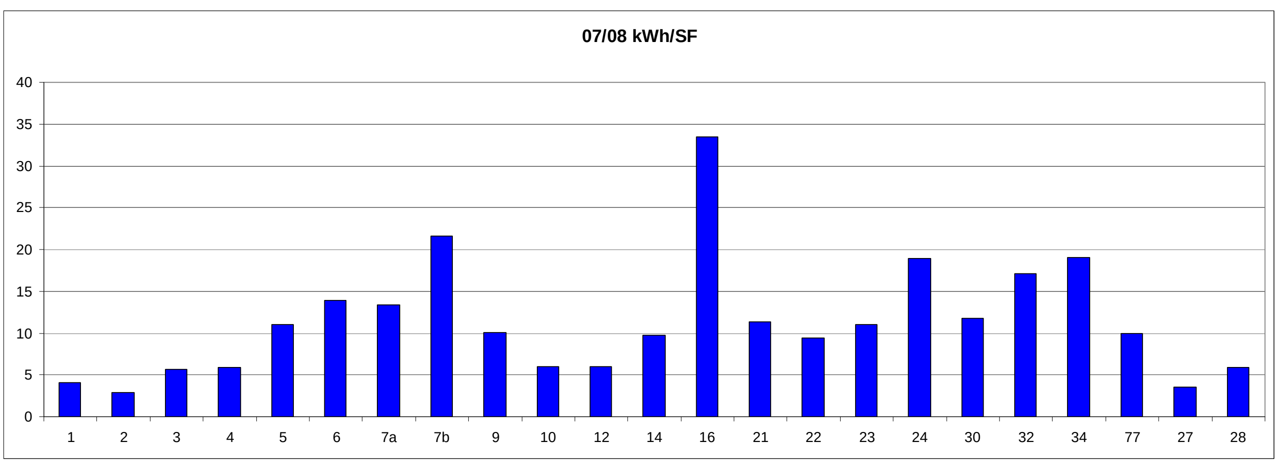
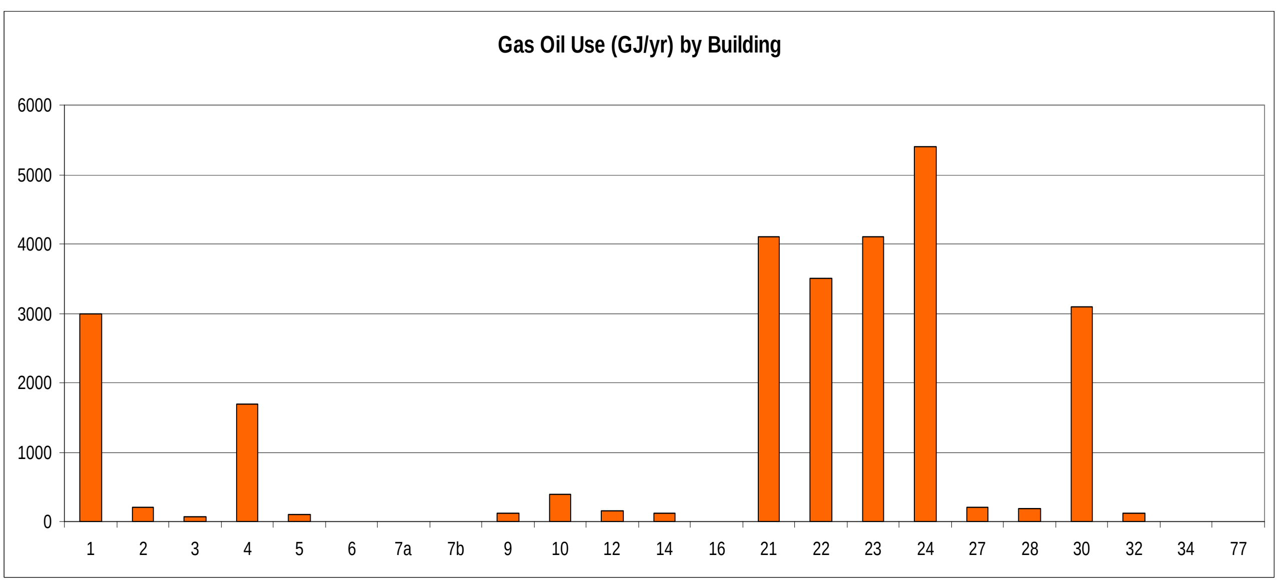


Table 7 List of RRU Gas Meters

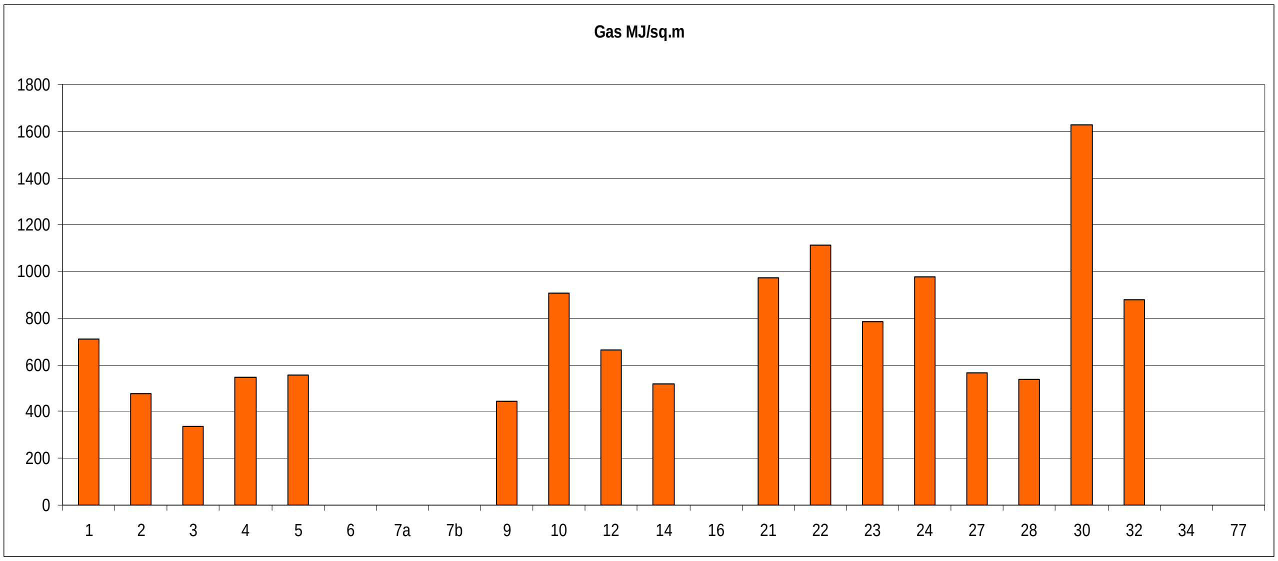
Castle (1)
Greenhouse (2)
Bldg 3
Mews (4) Conference Ctr
Bldg 5
Gatehouse (9)
Bldg 10 (fourplex)
Bldg 12
Bldg 14
Millward (21)
Pool 22 Gym 25
Grant (24)
Library (30)
Boatshed (32)
Bldg 27 Commandant's Residence
Bldg 28 Vice Commandant's Residence

Breakdown of Terasen Gas Consumption

Graph 3: Simulated GJ of fossil fuel used in each **building**



Graph 4: Simulated MJ of fossil fuel used per square meter in each **building**



4 ENERGY CONSERVATION OPPORTUNITIES

Section 4 contains descriptions of the proposed options. **Table 8 Options Listed by Type** provides a summary of data to refer to when reading the relevant report sections.

Table 8 Options Listed by Type

Report Section	BLDG	OPTION	Total Est. Electrical Savings $	Heating Penalty GJ	Estim. Fuel GJ Savings	Estim Gas Saving $	GHG tonne CO2 reduced	Estim. Other Savings $	Estim. Total Savings	Estim. Capital Cost $	Estim. Equip Life (YR)	Simple Pay-Back (YR)	Comments
4.1	1	Air Sealing	$0	0	206	$2,974	10	$0	$2,974	$14,000	10	4.7	defunct EFs, sprinks, etc.
4.1	3	Air Sealing	$0	0	8	$112	0	$0	$112	$500	10	4.4	
4.1	4	Air Sealing	$0	0	98	$1,415	5	$0	$1,415	$8,500	10	6.0	
4.1	5	Air Sealing	$0	0	10	$149	1	$0	$149	$500	10	3.4	
4.1	6	Air Sealing	$811	0	0	$0	0	$0	$811	$5,750	10	7.1	gen+ 2shop ducts@14x22
4.1	9	Air Sealing	$0	0	15	$217	1	$0	$217	$750	10	3.5	attic; bsmt
4.1	10	Air Sealing	$0	0	49	$710	2	$0	$710	$3,864	10	5.4	fireplaces, etc
4.1	14	Air Sealing	$0	0	13	$186	1	$0	$186	$750	10	4.0	attic; bsmt
4.1	16	Air Sealing	$80	0	0	$0	0	$0	$80	$500	10	6.2	
4.1	21	Air Sealing	$0	0	47	$678	2	$0	$678	$3,800	10	5.6	shaft, windows
4.1	22	Air Sealing	$0	0	45	$649	2	$0	$649	$4,369	10	6.7	chlr rm louvre, gym lvrs etc.
4.1	23	Air Sealing	$0	0	40	$577	2	$0	$577	$7,000	10	12.1	cap old RT EF, etc
4.1	24	Air Sealing	$0	0	44	$635	2	$0	$635	$3,035	10	4.8	roof holes and 215 windows
4.1	30	Air Sealing	$0	0	45	$649	2	$0	$649	$3,000	10	4.6	
4.1	7b	Air Sealing	$396	0	0	$0	0	$0	$396	$1,750	10	4.4	
4.2	1	Architectural Insulation	$0	0	259	$3,741	13	$0	$3,741	$25,000	10	6.7	attics
4.2	6	Jalousie Storms	$52	0	0	$0	0	$0	$52	$500	10	9.6	two 20*76, bsmt south
4.2	22	Architectural Insulation	$0	0	336	$4,849	17	$0	$4,849	$29,700	10	6.1	spray gym ceiling + net
4.2	23	Architectural Insulation	$0	0	39	$558	2	$0	$558	$3,780	10	6.8	1st steam header room wall
4.2	25	Architectural Insulation	$0	0	39	$558	2	$0	$558	$3,780	10	6.8	pool south
4.2	30	Architectural Insulation	$0	0	27	$386	1	$0	$386	$2,460	10	6.4	above T-bar east wing
4.3	all	Lighting	$37,273	-307	0	-$4,428	10	$22,316	$55,161	$451,886	7	8.2	
4.4	5	Duct Insulation	$0	0	1	$19	0	$0	$19	$120	10	6.2	duct in crawlspace

Report Section	BLDG	OPTION	Total Est. Electrical Savings $	Heating Penalty GJ	Estim. Fuel GJ Savings	Estim Gas Saving $	GHG tonne CO2 reduced	Estim. Other Savings $	Estim. Total Savings	Estim. Capital Cost $	Estim. Equip Life (YR)	Simple Pay-Back (YR)	Comments
4.4	6	Tank Insulation	$18	0	0	$0	0	$0	$18	$200	10	11.2	DHWT jacket
4.4	all	Mechanical Insulation	$13	0	93	$1,340	5	$0	$1,353	$6,050	10	4.5	
4.5	5	Heat Pump	-$777	0	75	$1,083	4	$0	$306	$6,500	10	21.2	new 1200 cfm oil w.add on 3T
4.5	9	Heat Pump	-$904	0	99	$1,421	5	$0	$517	$7,000	10	13.5	
4.5	12	Heat Pump	-$971	0	132	$1,901	6	$0	$930	$6,500	10	7.0	
4.5	14	Heat Pump	-$833	0	88	$1,264	4	$0	$431	$6,500	10	15.1	
4.6	14	DHW Temp Reduction	$52	-1	0	-$10	0	$0	$42	$100	2	2.4	151 F at tap
4.6	24	DHW Storage Tank(s)	$0	0	28	$405	1	$0	$405	$2,750	10	6.8	exist once-thru cond blr
4.6	25	Separate DHW for Summer	$62	-1	344	$4,952	17	$0	$5,014	$6,500	10	1.3	12 showers
4.6	30	DHW Temp Reduction	$63	0	0	$0	0	$0	$63	$100	2	1.6	179 F at tap
4.6	all	Low Flow Shower Heads	$0	0	15	$223	1	$250	$473	$2,000	5	4.2	estimate 40 heads
4.7	1	Expand DDC Control	$0	0	127	$1,828	6	$0	$1,828	$14,000	2	7.7	night setback
4.7	4	DDC	$1,642	0	120	$1,733	7	$0	$3,375	$37,100	2	11.0	all bsmt ahus + hydronics
4.7	4	Outdoor Reset for Boiler	$0	0	64	$924	3	$0	$924	$5,000	2	5.4	
4.7	10	OA reset on heating water	$0	0	23	$335	1	$0	$335	$5,000	5	14.9	new 3-way valve & control
4.7	21	DDC	$961	0	137	$1,974	7	$0	$2,935	$18,200	2	6.2	I/L 3 drier w EFs; pumps & fans
4.7	23	DDC	$718	0	121	$1,740	6	$0	$2,459	$14,200	2	5.8	New HW boiler CVs
4.7	24	Fume EF User Switch	$45	0	147	$2,124	7	$0	$2,169	$700	2	0.3	114 fume hood RT fan
4.7	24	Stove Igniters	$473	0	517	$7,455	26	$0	$7,929	$12,500	5	1.6	Kitchen Hoods (2) & MUA
4.7	25	Time Scheduling	$0	0	123	$1,777	6	$0	$1,777	$1,000	2	0.6	back-up boiler
4.7	25	DDC	$211	0	0	$0	0	$0	$211	$900	2	4.3	DHW pumps (2)
4.7	30	DDC	$4,257	0	197	$2,839	12	$0	$7,096	$41,640	2	5.9	MZ1&2, F2,3,4,5. Pumps, DX
4.7	30	Turn Off Lag Boiler	$0	0	155	$2,236	8	$0	$2,236	$1,000	2	0.4	condensing lead
4.7	34	Remove Hall EBB	$103	0	0	$0	0	$0	$103	$100	10	1.0	EBB right below HP Tstat
4.7	7b	DDC	$1,094	0	0	$0	0	$0	$1,094	$3,000	2	2.7	SE ERPs stats broken
4.7	7b	Reduce demand penalty	$236	0	0	$0	0	$0	$236	$500	5	2.1	remove oversized resist heat
4.8	21	VSD	$1,419	0	604	$8,706	31	$0	$10,124	$20,400	5	2.0	MUA(x3) in summer
4.8	24	VSD	$798	0	0	$0	0	$0	$798	$9,000	5	11.3	Faulty ASD AH2 RF
4.8	30	Demand Ventil. Control	$0	0	486	$7,008	24	$0	$7,008	$10,000	5	1.4	MZ1 & 2
4.8	30	Cap AH2 Office Zone	$0	0	73	$1,058	4	$0	$1,058	$1,250	10	1.2	blows into Blr Rm

Report Section	BLDG	OPTION	Total Est. Electrical Savings $	Heating Penalty GJ	Estim. Fuel GJ Savings	Estim Gas Saving $	GHG tonne CO2 reduced	Estim. Other Savings $	Estim. Total Savings	Estim. Capital Cost $	Estim. Equip Life (YR)	Simple Pay-Back (YR)	Comments
4.9	all	DDC Recommissioning	$707	0	332	$4,790	17	$0	$5,497	$20,000	2	3.6	
4.11	all	Computer Pwr Mgmt	$4,813	-62	0	-$897	2	-$500	$3,416	$9,200	2	2.7	
4.12	1	New Backup Boiler	$0	0	680	$9,807	34	$0	$9,807	$70,000	15	7.1	old blr rated 60%
4.13	21	Solar Thermal	-$20	0	185	$2,662	9	$0	$2,642	$42,000	15	15.9	huge tanks
4.14	30	Heat Reclaim	-$29	0	72	$1,042	4	$0	$1,013	$6,500	10	6.4	ERV to relieve pos pres
4.15	all	Vending Machine Control	$748	-5	0	-$70	0	$0	$678	$2,400	5	3.5	
		Contingency								$96,508			
		GRAND TOTALS	*$53,511*	*-375*	*6,357*	*$86,287*	*336*	*$22,065*	*$161,863*	*$1,061,592*			

4.1 Air Sealing Throughout

4.1.1 Description

The recommendation involves having a member of the in-house maintenance staff (or a contractor) inspect the selected buildings during windy winter days to identify areas of excessive air infiltration. This should be done with a "smoke pencil" or some other non-toxic identifier. The Federal Building Energy Technology Transfer Program document entitled *Air Sealing Homes for Energy Conservation* (catalogue # M92-6/1984E) is an excellent resource for selecting product types and identifying risks.

The most effective sealing will often be done at the top floor ceiling (around chimneys, light fixtures, plumbing stacks, etc.) or in the basement/ground floor (foundation sills, duct or conduit penetrations, etc.). Special care should be taken in selection of non-toxic sealants, and sealants rated properly where surfaces are subject to high temperatures. V-seal and door sweeps can be applied to doors, and new fin-seal can be applied to windows.

Work in the Castle also includes application of drywall to the tongue-in-groove planks of the 3rd floor closets.

4.1.2 Affected Area(s)

Buildings 1, 3, 4, 5, 6, 7b, 9, 10, 14, 16, 21, 22, 23, and 30.

4.1.3 Opinion of Probable Schedule

1 year

4.1.4 Estimated Service Life

8 to 10 years

4.1.5 Opinion of Probable Annual Energy Savings, Cost and Payback

Refer to **Table 8 Options Listed by Type** on page 18.

4.1.6 Description of Energy Analysis

This estimate is very rough and is based upon educated impressions of the buildings' envelopes, and a high evaluation of the staff's technical abilities and conscientiousness. Paybacks range from 3 to 9 years. Six of the buildings were evaluated in detail by Canam Building Envelope Specialists. An example report is contained in Appendix "D".

4.1.7 RRU Operational Resources Required

Contractor coordination.

4.1.8 Synergy

If some of the other controls recommendations below are implemented, there will be increased savings effectiveness due to envelope improvements. Comfort should increase due to the reduction of drafts.

4.2 Architectural Insulation

4.2.1 Description

The recommended scope involves insulation of the **Castle** as follows:

Attic floors: Tower work would include new internal walls that would create a perimeter walkway and a new interior room (so the perimeter masonry walls could continue to evaporate moisture and so that insulating around services in the floor, such as pot lights, can be minimized. The interior room would have batts between roof joists.

The other attics would have blown-in insulation (floors and angled wall stud cavities). Air and vapour barrier would result from sealing and painting the underside of the ceilings.

There is also a small project recommended for **Bldg 4 (Mews)** that involves installation of small interior storms for the jalousie windows on each side of the back basement (south) door.

Bldg 30 (Library) appears to be constructed primarily of un-insulated concrete and single pane glass. Insulation of exterior walls above the T-bar is recommended. New windows were evaluated, but payback was too long.

4.2.2 Affected Area(s)

See above

4.2.3 Opinion of Probable Schedule

1 year

4.2.4 Estimated Service Life

15 years

4.2.5 Opinion of Estimated Annual Energy Savings, Cost and Payback

Refer to **Table 8 Options Listed by Type** on page 18.

4.2.6 Description of Energy Analysis

See Appendix “E”.

4.2.7 RRU Operational Resources Required

Project management

4.2.8 Synergy

This project would increase comfort for staff and students, and allow for smaller heating equipment when future replacements occur.

4.3 Lighting

4.3.1 Description

Many lighting and lighting control retrofits have been described and paybacks have been estimated by Quantum Lighting. Details are contained in Appendix "F". Future heritage review may result in minor scope modification.

4.3.2 Affected Area(s): The entire campus

4.3.3 Opinion of Probable Schedule: Dependant upon funding and project priorities.

4.3.4 Estimated Service Life: Varying from 2 to 20 years

4.3.5 Opinion of Probable Annual Energy Savings, Cost and Payback

Refer to **Table 8 Options Listed by Type** on page 18. The summary differs from the appendix in that the summary includes the 25 cent/kW demand discount for rate 1211, and includes a penalty for additional heating required as a result of removed lighting wattage.

4.3.6 Description of Energy Analysis: See appendix "F"

4.3.7 RRU Operational Resources Required: Project management

4.3.8 Synergy

This project would reduce over-heating in summer, greatly reduce maintenance, simplify lighting replacements by reducing the great number of different types of lights, improve light quality and increase aesthetics in certain areas.

4.4 Mechanical Insulation

4.4.1 Description

The recommended scope involves insulation of the following:

Building	System
1	Insulate DHW Piping in East & West Attics
3	Insulate DHW Piping
4	Insulate DHW and Boiler Piping
5	Insulate branch duct in crawlspace of north bedroom
6	Blanket for DHW tank in cold space
7a	Insulate DHW Piping
10	Insulate Boiler Piping
21	Insulate Boiler Room Piping
23	Insulate Steam Hotwell and Condensate Piping
27	Insulate Basement Piping
28	Insulate Basement Piping
34	Insulate DHW Piping

Some of these are all small projects which could be done by in-house forces who would:

- Visit each location to verify pipe sizes and lengths, and note existing insulation thicknesses and jacket methods
- Purchase insulation of desired lengths and jacket types. Minimum thickness to be 1”. Match thickness of existing insulation (unless it is less than 1”). Note that smoke and flame ratings of the insulation products shall be suitable for 200°F application.
- Install insulation and finish.

4.4.2 Affected Area(s)

See above

4.4.3 Opinion of Probable Schedule

1 year

4.4.4 Estimated Service Life

15 years

4.4.5 Opinion of Probable Annual Energy Savings, Cost and Payback

Refer to **Table 8 Options Listed by Type** on page 18.

4.4.6 Description of Energy Analysis

See Appendix “G”.

4.4.7 RRU Operational Resources Required

One person week if the installation is done in-house.

4.4.8 Synergy

There are certain boiler rooms which are hot due to parasitic heat losses. These rooms would be more comfortable as a result of this work.

4.5 Heat Pump Conversions

4.5.1 Description

Houses 5, 12 & 14 could have their old oil-fired furnaces replaced by 3 ton heat pumps, and bldg 9 by a 3.5 ton. Non-energy benefits include

- The furnaces are getting old - new furnaces would be provided
- Ongoing maintenance of the oil appliances would be reduced
- The projects would include a service upgrade to 200 A
- GHG emissions would be all but eliminated
- Summer A/C would be an option.

Savings result from replacement of furnace heat (75% seasonal efficiency), with air source heat pump heat (200% efficiency).

4.5.2 Affected Area(s)
See above

4.5.3 Opinion of Probable Schedule
1 year

4.5.4 Estimated Service Life
15 years

4.5.5 Opinion of Probable Annual Energy Savings, Cost and Payback
Refer to **Table 8 Options Listed by Type** on page 18. The reported costs are incremental costs, calculated as follows:

Report Cost = (total cost – cost to replace old furnace)

4.5.6 Description of Energy Analysis
See Appendix "H".

4.5.7 RRU Operational Resources Required
Project management.

4.5.8 Synergy
Replacement of furnaces at the end of their lives; reduced maintenance for oil appliances; expanded electrical service; GHG emission reduction.

4.6 Domestic Hot Water

4.6.1 Description
Low flow shower heads: There are numerous shower heads on campus in the large dorms, the recreation centre and the various residences. There appears to have been no recent purchasing policy, so various types are installed. The recommended scope involves review by the PER staff, and replacement of standard shower heads (>9 LPM), with low flow shower heads (<7 LPM). Clocked filling of a pail of known volume can provide showerhead flow data. The number of 9.5 LPM shower heads are estimated by PER at 40. A reduction to 6.8 LPM (40% of which is assumed to be heated to an average of 124F) results in water, sewer and heat cost savings.

Building-Specific Options:

Bldg	Recommendation
14	DHW Temp Reduction
21	Solar Thermal
24	DHW Storage Tank
25	Separate DHW for Summer

Temperature Reduction: The recommended scope involves lowering the temperature of the stored domestic hot water in building 14.
This is a very small project which could be done by in-house forces, or a contractor. Note that the temperatures cited in Appendix “I” refer to temperatures delivered at the faucet, so tank temperatures could be approximately 5F higher.

Solar Thermal: The recommended scope involves installation of a south-facing solar panel array on the roof of the Millward Building. The work is intended to preheat city water before being heated by the conventional DHW system, as depicted below:

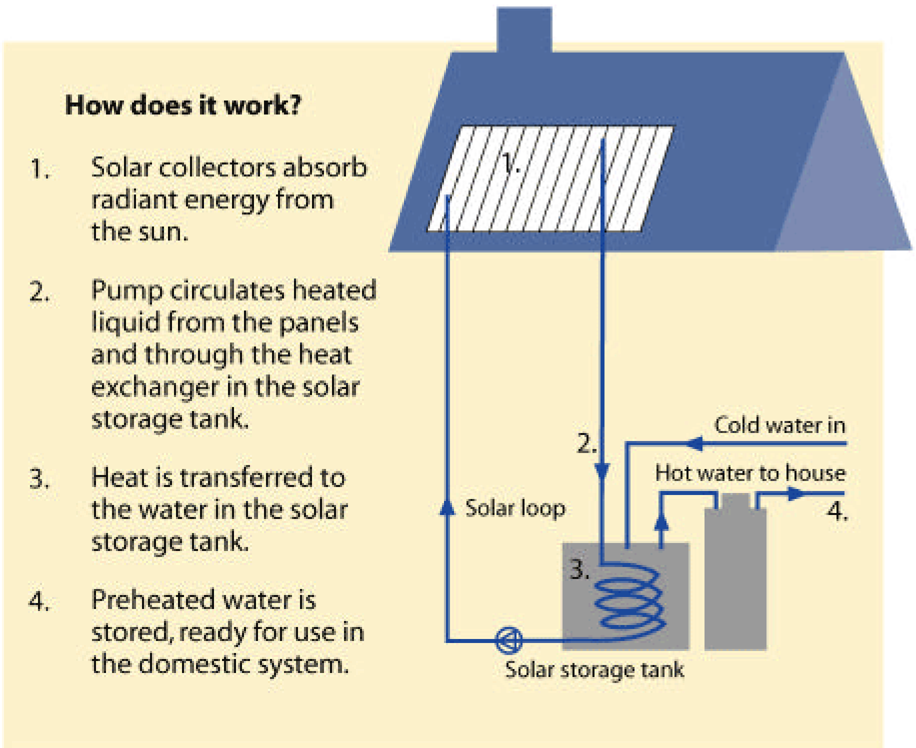


Figure 1. Solar thermal system. Source: Solar BC

A flat plate, glycol collector system is recommended.

The pre-existing conventional domestic hot water (DHW) system in the building consists of three 1200 gallon tanks which are heated by boiler water originating from the Nixon Bldg boilers. The recommendation involves converting one of these large tanks to a solar storage pre-heat tank tied into the cold water line.

Storage Tank: The 1 million Btuh condensing boiler which heats the DHW in the Grant Building is once-through, and according to PER staff, tends to cycle rapidly. The recommendation involves the addition of a 115 gallon storage tank and pump. City water would still go to the inlet of the boiler, but a small storage volume would allow the burner to run at low fire for longer periods. The system would target a 134F set point for boiler discharge, and would turn the pump off when the tank reached 129F.

Summer DHW System: The pool/gym complex contains 12 showers that seem to be the sole load on the over-sized boiler plant during summer. The recommendation involves the installation of a stand-alone gas-fired DHW tank to handle summer DHW. This will allow the large plant (with 6 storage tanks, large pumps, room fan, etc.) to be turned off.

4.6.2 Affected Area(s)

See above

4.6.3 Opinion of Probable Schedule

1 year

4.6.4 Estimated Service Life

2 years for temperature adjustment and 10 years for solar and storage.

4.6.5 Opinion of Probable Annual Energy Savings, Cost and Payback

Refer to **Table 8 Options Listed by Type** on page 18.

4.6.6 Description of Energy Analysis

Low flow shower heads: The number of 9.5 LPM shower heads are estimated by PER at 40. A reduction to 6.8 LPM (40% of which is assumed to be heated to an average of 124F) results in water, sewer and heat cost savings.

Temperature Reduction: Bldg 14. New temperatures vary from 125F to 133F. See Appendix "J". Savings include somewhat cooler water usage (except for showers) and parasitic heat losses. No gym or cafeteria or process heaters are included. There is no bonus/penalty for air conditioning or heating (mechanical rooms do not require heat).

Solar Thermal: Bldg 21. The solar utilisation factor, with the large storage tank, is estimated at 20% of the calculated 923 GJ load.

Storage Tank: Bldg 24. A 15% reduction in the estimated DHW load of 187 GJ is assumed from running the boiler longer at a lower fire.

Summer DHW System: Bldg 25. The summer gas consumption for a little-used gym was 420 GJ ($5700) last summer. Based upon 15 showers per day, plus a significant stand-by loss allowance, the projected consumption is 91 GJ ($1215).

4.6.7 RRU Operational Resources Required

Shower head replacement
Temperature adjustments
Manaul change-over for Gym each spring and fall.

4.6.8 Synergy

Minor effects.

4.7 DDC Controls – Add New Control Points Onto the Existing DDC Network

4.7.1 Description

The recommendation involves connecting into the existing campus I.T. Ethernet to serve new DDC panels in or near the buildings listed below. This would allow time scheduling and other energy strategies for the following systems:

Building	System
1 Castle	Room Temp Sensors (8): allows setback
	Steam Pressure Sensor: allows trending
	Condensate Temp Sensor: alarms trap problems
	Boiler 2 Burner Controls: allows setback
4 Mews	Boiler Plant and 2 AHUs: allows setback & unocc.
7b PER	Replace 4 broken line voltage stats with Mini Panel, and remove excess electric baseboards.
21 Millward	Pump Control (5): allows setback & unocc.
	Drier EF (3): enable only when driers on
	VSDs for Three hallway pressurisation MAUs
23 Nixon	Pump Control (2): allows setback & unocc.
	Boiler Isolation Control Valves (2): close lag boiler
	Condensate Temp Sensor: alarms trap problems
25 Pool	Add DHW pumps 5 & 7 (duplex) onto Delta system
30 Library	Boilers (2): allows setback
	Pumps (4): allows setback & unocc.
	AHUs (2 multizones, ea. 6 zones): allows setback & unocc. In conjunction with capping of AH2 office zone
	CO2 sensor recommendation is in section 4.8
	One 20T D/X system: allows opt start and setback

Each building would have an appropriately sized DDC panel. Groups of building controllers would be networked together. Each group would then be tied into the campus network via an IP connection with an EtherLink panel.

Related projects which are not strictly DDC projects:

Bldg 10 boiler reset option involves a new 3-way mixing valve and an electronic controller (Tekmar or equal) rather than DDC.
Bldg 24 Lab 114 fume hood exhaust switch is recommended to reduce on-time by 21%. Control is not DDC.
Replace faulty VSD for AH2 will provide better conditions, solve building pressure problems, and save energy.
Cafeteria stove igniters would replace pilot lights and allow large EFs to be turned off during unocc hours.
Bldg 25 DHW pump control will have synergy with the recommendation to install a separate gas-fired DHW tank to serve the 12 showers in summer (allowing full shutdown of over-sized boiler plant).
Bldg 34. Removal of large unnecessary electric baseboard from right below t'stat is recommended, but is not a DDC project.

4.7.2 Affected Area(s)

See above

4.7.3 Opinion of Probable Schedule

Depends on funding

4.7.4 Estimated Service Life

5 years until possible software or hardware upgrades.

4.7.5 Opinion of Probable Annual Energy Savings, Cost and Payback

Refer to **Table 8 Options Listed by Type** on page 18. Please note that most electrical heating applications will not result in demand savings, except the zones where 2 or more circuits serve one space, in which case one circuit can be disabled from May to October.

4.7.6 Description of Energy Analysis

See Appendix "K"

4.7.7 RRU Operational Resources Required

Familiarization with the new systems, once installed.

4.7.8 Synergy

The addition of the recommended control points will be of benefit due to:

- Automatic alarms of equipment failure or poor room temperatures to maintenance staff.
- Automatic maintenance reminders based on actual run-times.
- Reduced need to physically inspect equipment (for example, daylight savings time is automatically adjusted, eliminating the need to go to each programmable 'stat or timer).
- Graphics can greatly reduce the amount of time new staff members or

contractors require to understand the systems.

- DDC greatly increases the ease and effectiveness of troubleshooting.
- The ease of expansion for options such as carbon dioxide sensors, occupancy sensors, humidity controls, security, lighting, etc.
- Less equipment run time should result in less maintenance.

4.8 Library Demand Controlled Ventilation

4.8.1 Description

Multi-zone units A-1 & A-2 and return fans F-1 & F-2 are connected to a time clock located in the east boiler room. The units were found to be in “hand” operation (**running 24/7**). During occupied hours, the units will run continuously and could shut off during unoccupied hours. During unoccupied hours a wall mounted night set back thermostat could energize the units if the space temperature drops below set point.

The temperature control of the multi-zone units are by pneumatic controls. A discharge air controller located in the control cabinet modulates the mixed air dampers to maintain the set point. The mixed air damper on both A-1 and A-2 are set to maintain a discharge air temperature of 50°F. There is DX cooling installed in A-2 (none in A-1).
The outdoor air enters through a wall louvre and is ducted to the mixed air section. The hot decks on both units are served by individual hot water heating coils. The cold deck on unit A-1 has a DX cooling coil with a outdoor condensing section and A-2 and there is no cooling located in unit A-2.The zone dampers are served by individual pneumatic room thermostats which modulates the zone dampers to maintain the room set point.

A belt drive return fan located in west mechanical room and another in the east boiler room picks up the return air from the space through ductwork and is either mixed with the outdoor air or discharged into the mechanical or boiler room and relieved to the outdoors through a wall louvre.

Library supply airflows were measured as part of this study:

Table 9 Library Air Balance Test Results

Unit No.	Design Airflow CFM	Full Heat (cfm)	Full Cool (cfm)	Mix (cfm)	Damper Setting
A-1	21,880	15,055	18,120	18,120	100% O/A
F-1	15,000	12,020	12,020	12,020	100% Relief
A-2	8790	7745	11,095	11,095	100% O/A
F-2	5750	2830	2830	2830	100% Relief
A-1		2760	1880	1755	Min. 10% actually 18%
A-2		5495	3575	3575	Min. 10% actually 71%
Relief Air F-1			7730		100% Relief
Relief Air F-2			2830		100% Relief

The OA damper on A-2 requires maintenance, and the A-2 “office” zone branch should be capped and sealed.

A single carbon dioxide ($C0_2$) sensor, configured to measure both supply and outdoor air CO_2 concentrations, is recommended in the supply air ducting of each AHU.

In heating operation, the DDC system would modulate the air handling unit outside air (O/A) dampers towards their closed position as occupants leave the building (and the measured S/A carbon dioxide (CO_2) concentration falls). This would reduce unnecessary outdoor air intake during heating mode, and save heating gas.
The S/A $C0_2$ set point would be selected to satisfy the ventilation loads in the most densely occupied zone under usual conditions. The outdoor air dampers would be DDC controlled to limit the maximum supply CO_2 concentration level of about 200 to 300 ppm above outdoor level (depending on the design occupant density).

This arrangement offers the following benefits over space or return carbon dioxide sensor locations:

- Sensor malfunction can be alarmed when outdoor air readings fall outside normal range;
- Reading error is reduced as drift is largely cancelled out – both concentrations used in the calculation are measured by the same sensor;
- Outdoor air CO_2 concentration is measured rather than assumed. This should increase the accuracy of control;
- Return CO_2 set points are not useful when more than one room or space is served by the system.

ASHRAE Standard, 62.1-2004, recommends that ventilation rates be maintained at a minimum of 0.06 cfm/sq.ft. Damper leakage is expected to provide this level of ventilation.

4.8.2 Affected Area(s)

Systems were selected based on outdoor ventilation rates, occupancy profiles, weekly operating schedules supply air temperature reset schedules and, ultimately, energy savings potential. One would think that there would be a number of good candidates for this strategy in the building, but most the minimum O/A damper settings seem to be quite low, leaving little opportunity for savings. There are zones where the indoor air quality is suspect due to the low damper settings. The ventilation of the building requires further study, but there is an argument for applying S/A CO_2 sensors to most of the AHUs to improve IAQ in the building.

4.8.3 Opinion of Probable Schedule

1 year

4.8.4 Estimated Service Life

5 years

4.8.5 Opinion of Probable Annual Energy Savings, Cost and Payback

Refer to **Table 8 Options Listed by Type** on page 18.

4.8.6 Description of Energy Analysis

The following is a description of the saving calculation methodology for the A-1: Building balance point = 12C (54F), as revealed by the linear regression correlating heating consumption with daily average outdoor temperature. This building has an extremely poor envelope (mostly plate glass and uninsulated concrete). Experience suggests that the OAD may be at minimum for approximately 1593 hours per year (approx 35% of fan run time). Historical weather data indicates that the average outdoor temperature in the morning warmup hours of the 8 coldest months of the year is approximately 43F.
Assuming

- a pre-existing minimum O/A of 40% (adequate for 400 people, infiltration notwithstanding), and
- an average 10% O/A can become the new minimum setting due to CO_2 input (max zone occupancy is reported to 45 people)

the calculated savings are as follows:

CFM = 30% x 15055 CFM = 4517 cfm reduction
Delta T = 73F RAT – 43F OAT = 30F

4517 cfm x 1.08 x 30F x 1593 hr / 3412 kWh/Btu = (351 GJ)assuming 70% efficiency. This represents 11% of the annual heating.

4.8.7 Operational Resources Required

RRU will have to monitor calibration alarms.

4.8.8 Synergy

This recommendation provides a powerful tool when dealing with indoor air quality problems or concerns.

4.9 DDC Re-Commissioning

4.9.1 Description

Our review of the Delta DDC systems (version 3.22) identified many DDC points, sequences, and HVAC components that were not functioning correctly. In some cases, energy was being wasted; in other cases comfort levels were being compromised. This usually leads to higher energy consumption, increased occupant complaints, and premature equipment failure.

Annual schedules were missing in all cases. The following is the list of days where buildings could be in unoccupied mode:

Days	Holiday
1	Labour day
1	Thanksgiving
1	Remembrance Day
8	Xmas (8 days)
1	Good Friday
1	Easter Monday
1	Victoria Day
1	Canada Day
15	*per year*

Weekly schedules were missing in the majority of cases. The practice of extending occupied hours results in fewer complaints to PER about space temperature, but it is generally agreed that the cost of heating the entire campus for a few after-hour workers is unjustified, and not in keeping with the intent of RRU's Energy Project Charter. It is hoped that the university's ***Sustainability Plan*** will garner support for a new conservation ethic where students, faculty and staff will gladly wear sweaters and take other measures to end unnecessary after-hours heating.

Many of the systems are operating in manual mode. The following is recommended:

a. Install more hardware input points for feedback on temperature and CO_2 conditions in the space.
b. Install more hardware output points for better control of equipment. (See section 4.7).
c. Send at least 2 PER maintenance staff to introductory DDC training sessions, and then advanced training.

Joint DDC Re-commissioning by PER, the Energy Consultant and Contractor's DDC Technician is recommended for all energy systems. The following tasks are recommended:

1. Eliminate incorrect sensor scale ranges, and review sensor calibration.

2. Review Outdoor Air minimum positions for ventilation. Also ensure that OA temperature sensors are reporting the correct OA temperature.
3. Test heating and chilled water valves for leakage when closed.
4. Outputs which are in manual mode shall be placed into auto where possible. A monthly report of manual points is recommended.
5. Check for areas which do not have unoccupied set backs. Review all unoccupied Rm Temp trends to verify that setbacks are being achieved.
6. Experiment with temperature and pressure set points. More investigation will be put into lowering heating set points on mornings of warm days (so boiler heat is not injected into the space, and then absorbed by the A/C) – a temperature prediction strategy.
7. Apply for BC Hydro's *Continuous Optimisation Program* so a smart power meters can be installed to record and graph electrical demand and consumption, and so that the DDC systems automatically employ load shedding, by raising summer space temp set points, and lowering winter space temp set points in electrically heated areas.
8. Set up more trend logs and log sheets (e.g., all reheat valves on each AHU) to make it easier to evaluate system performance.
9. Change set point calculation for reheat system SAT and multizone system cold deck SAT to satisfy an average of the hottest 20% of zones, rather than the single hottest zone.
10. Implement the following strategies, where applicable and practical:

Table 10 DDC Recommissioning Strategy Checklist

1) Fan systems	annual and weekly schedule
	optimal start
	supply air temperature reset
	supply air pressure reset
	demand ventilation control
	HCV to 100% during NSB (to shorten run time)
	close OAD during morning warm-up
2) Hot water distribution	optimal start
	pump lock-out on warm day
	supply water temperature reset
	variable flow control
3) Chilled water distrib.	N/A
4) Boiler plant	lock-out on warm day
	sequencing to maximize efficiency
	optimal stop of primary hot water
5) D/X Cooling	lock-out on cold day
6) Miscellaneous	circulation pump control

Additionally, it is recommended that all DDC-controlled lag boilers on campus be held off in the autumn in an effort to determine accurate lockout ambient temperatures per building. Boiler water temperature alarms should be trended to help ascertain correct lag boiler OAT set points. This is recommended because some lag boilers are bypassing water when off (cooling the return water and releasing warm air up the stack, and radiating heat to boiler room), and are enabled quite a lot. This involves a manual maintenance procedure (spring and fall) for valving off lag boilers, and tagging the boiler burner indicating that the valve is closed.

4.9.2 Affected Area(s)

See above

4.9.3 Opinion of Probable Schedule

1 year

4.9.4 Estimated Service Life

5 years, barring possible software or hardware upgrades.

4.9.5 Opinion of Probable Annual Energy Savings, Cost and Payback

Refer to **Table 8 Options Listed by Type** on page 18.

4.9.6 Description of Energy Analysis

See Appendix "L" where savings are estimated at

- 5% of mechanical Hydro for 25% of floor area, and
- 5% gas savings for 25% of floor area .

4.9.7 RRU Operational Resources Required

The installation of more sophisticated sequences will be less effective if the on-site operator is not familiar with them and/or does not support them. It is recommended that the Controls Technician implement, monitor and tune the strategies as seasons and occupancy change, and that he identifies and fixes problems as they occur. The recommendation involves a good deal of this person's time, at least until the controls have been recommissioned and are operating satisfactorily. This recommendation also involves a manual maintenance procedure (spring and fall) for valving off lag boilers (and tagging the boiler burner indicating that the valve is closed).

4.9.8 Synergy

Less equipment run time should result in less maintenance and longer equipment life.

4.10 Formally and Systematically Include Energy Measures into O&M

4.10.1 Description

Although campus maintenance has been strong in many areas, the existing O&M Workorder System could be modified to automatically schedule energy-related tasks at regular intervals. The tasks include the following general procedures:

Table 11 Energy/Water-Related Maintenance Procedures

What	Why
Filter changes	Less resistance for fan motor
Lubrication	Energy not lost to friction
HX, coil and fan wheel cleaning	Improved heat transfer
Duct/pipe leaks	Wasted heat
Duct/pipe, crawl/attic insulation	Wasted heat
Faucet leaks	Wasted heat/water
Toilet running	Wasted water
Rad/grill cleaning	Improved heat transfer
Air venting from hydronics	Improved heat transfer
Lag boiler off in summer (close bypass)	Wasted heat
Boiler combustion, draft, allowable and desired water temp, scheduling	Wasted heat
Pump/fan speeds and balance	Wasted power & heat
Cooler/freezer door gaskets	Wasted power
Lighting controls and cleanliness	Wasted power
Controls settings and operation	Reduced operation
Envelope Air sealing	Wasted heat
Review steam traps	Wasted heat
Load Creep	Why savings are low
Energy awareness (last out turns stuff off)	Wasted power

4.10.2 Affected Area(s)

The entire campus

4.10.3 Opinion of Probable Schedule

Dependant upon funding, manpower and project priorities.

4.10.4 Estimated Service Life

Dependant on persistency of the PRD.

4.10.5 Opinion of Probable Annual Energy Savings, Cost and Payback

Not considered herein.

4.10.6 Description of Energy Analysis

Not considered herein.

4.10.7 RRU Operational Resources Required

Project management

4.10.8 Synergy

This type of measure would have a positive impact on occupant comfort, equipment longevity, noise, aesthetics and other areas.

4.11 Computer Power Management

4.11.1 Description

This option involves the following:

Implementing Faronics Power Save software (or equal) for the computers on campus. This is the crux of the described energy project. The following has been assumed based on information from the College's IT department.

- Approximately 715 computers at the Royal Roads campus,
- 60% left on 24 hrs/day, 7 days/week,

Faronics Power Save software is recommended by BC Hydro Power Smart to reduce energy consumption by switching off workstations based on schedules or user activity.

4.11.2 Affected Area(s)

Administration, offices and labs throughout the RRU Campus.

4.11.3 Opinion of Probable Schedule

12 months

4.11.4 Estimated Service Life

5 years

4.11.5 Opinion of Probable Annual Energy Savings, Cost and Payback

Refer to **Table 8 Options Listed by Type** on page 18. We have allowed $500 per year for in-house staff to support the sleep mode software system, and 1 person-week for in-house staff during implementation.

4.11.6 Description of Energy Analysis

Implement power management software on all workstations currently being left on continuously can save approximately $10/workstation per year.

Table 12 Computer Energy Management Software Savings

	Existing			Proposed			Savings		
Number of PCs	Hours of Use per Year per Computer	Watts per PC	kWh/ yr per PC	Hours of Use per Year per Computer	Watts per PC	kWh/yr per PC	Savings kWh/yr per Station	Savings kWh/yr	Net Savings $/yr
429	8760	50	438	3120	50	156	282	166,380	$3,200
								Cost	$9,200

Assumptions:

(1) 60% of users leave their computers on at night and weekends. Monitors switch off automatically after 15 minutes.

(2) Proposed usage will be 3120 hours per year, or 12 hours/day, 5 days/week.

(3) Net savings: Heating penalty of $897/year, maintenance costs of $500/year.

(4) Energy management software applied to all 715 computers, although savings will only be made in the 60% which are currently being left on.

Important Considerations:

(1) At the Corporate Level – Energy Policies can be deployed top down for computer savings.

(2) Future trends – CPU's will use more power as they become faster.

(3) Determination that more than 60% of users leave their PC's on at night will increase savings.

4.11.7 RRU Operational Resources Required

RRU staff will be deeply involved in the procurement and implementation of this measure. There will be some ongoing system management, and we are allowing $500/yr for in-house IT support time.

4.11.8 Synergy

The savings will be augmented in summer due to reductions in air conditioning, and will improve occupant comfort in areas where cooling capacity is marginal. Winter savings will be offset somewhat in perimeter rooms where additional heat may be required due to less computer heat.

4.12 New Steam Boiler for the Castle

4.12.1 Description

There are 2 low pressure steam boilers which heat a common piping. The larger east boiler is 180% the size of the west boiler. The west boiler has a nameplate efficiency of 61%, which is very low. Previous recommendations regarding envelope air sealing and insulation are expected to reduce the heat load of the building. This lower heat loss would allow the smaller boiler to heat the building for more hours of the year. Replacement of the smaller boiler would be more cost effective than the larger boiler, so the recommendation is as follows:

Replace the 60% efficient boiler with an 85% boiler. Standard of acceptance:

- Cleaver-brooks Model CFH 700-10-15# steam boiler c/w all necessary safety and operating controls; modulating 5:1 turndown; rated 85% efficiency; low NOx (20ppm) operation.
- Condensate/feedwater system: one Cleaver-Brooks Model PBFS-IDP-CR3-3K packaged Duplex (100% pump standby) boiler feedwater system c/w pump and motor assemblies, all necessary operating trim and steam preheat system, and including startup services.
- Blowdown system: one Cleaver-Brooks Model A14B packaged Boiler Blowdown system c/w necessary operating trim, and including startup services.

4.12.2 Affected Area(s)

Hatley Castle

4.12.3 Opinion of Probable Schedule

1 year

4.12.4 Estimated Service Life

25 years

4.12.5 Opinion of Estimated Annual Energy Savings, Cost and Payback

Refer to **Table 8 Options Listed by Type** on page 18.

4.12.6 Description of Energy Analysis

Original consumption of 3000 GJ/yr is expected to be reduced by the preceding recommendations to 2429 GJ/yr.
Savings % = (85-61)/85 = 28%
28% * 2429 = 680 GJ/yr.

4.12.7 RRU Operational Resources Required

Project management

4.12.8 Synergy

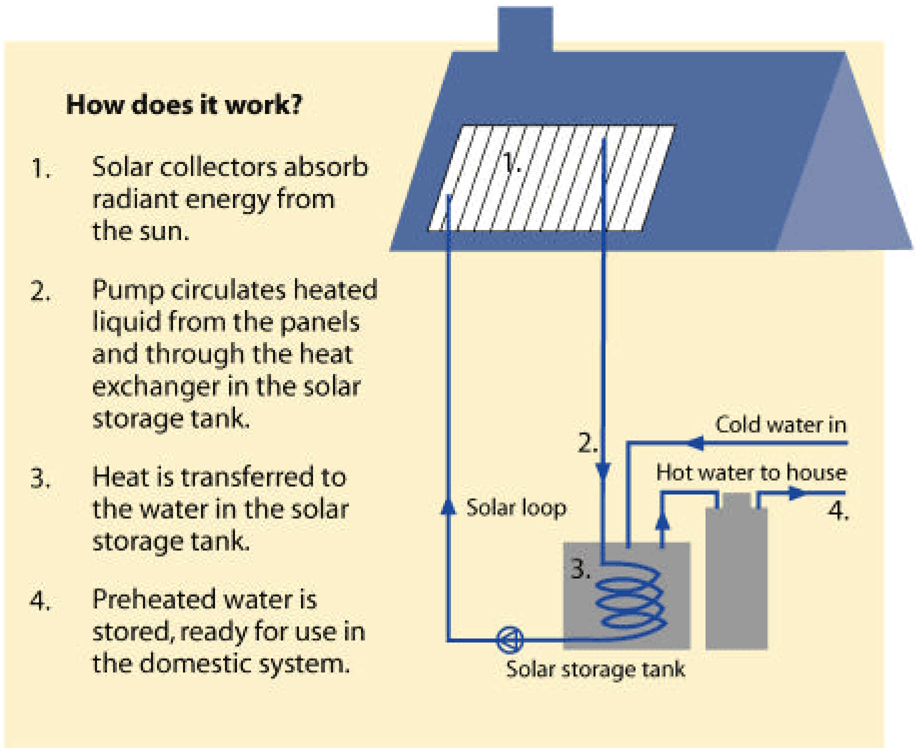
This project would provide a new boiler of high quality.

4.13 Solar Thermal System for Domestic Hot Water – Millward Building

4.13.1 Description

The recommended scope involves installation of a south-facing solar panel array on the roof of the Building 21. The work is intended to preheat city water before being heated by the conventional DHW system, as depicted below:

Figure 2. Solar thermal system. Source: Solar BC



A flat plate, drain-down collector system is recommended.
The pre-existing conventional domestic hot water (DHW) system in the building and consists of three very large storage tanks (1200 gal each), heated by the Grant Building boiler plant via heat exchangers in each tank. The proposed system would use one of the existing tanks as the solar storage tank (see fig.2) tied into the cold water line before it reaches the other DHW tanks.

4.13.2 Affected Area(s)

The Millward Bldg

4.13.3 Opinion of Probable Schedule

1 year

4.13.4 Estimated Service Life

20 years

4.13.5 Opinion of Probable Annual Energy Savings, Cost and Payback

We have estimated the DHW consumption as 923 GJ/yr of Natural Gas. Due to the large storage volume, and the heaver summer use of the building, we project a 20% solar utilisation factor for savings of 185 GJ/yr.
Refer to **Table 8 Options Listed by Type** on page 18.

4.13.6 Description of Energy Analysis

30% solar contribution is assumed for a full system, and 15% for a summer system

4.13.7 RRUOperational Resources Required

Project management

4.13.8 Synergy

We believe that this project could increase awareness of energy and GHG initiatives at the site, and provide inspiration for existing and proposed sustainability programs and efforts.

4.14 Energy Recovery Unit for the Library

4.14.1 Description

The 2 large air handlers in the building (A-1 and A-2) were designed such that the return fans are significantly smaller than the supply fans (69% and 65% respectively). On free cooling economiser mode, out-swinging building doors will not close. In heating mode, overall air flow drops significantly (16% and 30% respectively).

The proposed 1450 CFM system would be a dual fan ERV that could function as exhaust only during summer economiser mode, and could recover heat (and reduce the amount of outdoor air in the AHU's to near zero) during heating mode.

4.14.2 Affected Area(s)

See above

4.14.3 Opinion of Probable Schedule

1 year

4.14.4 Estimated Service Life

15 years

4.14.5 Opinion of Estimated Annual Energy Savings, Cost and Payback

Refer to **Table 8 Options Listed by Type** on page 18.

4.14.6 Description of Energy Analysis

See Appendix "M".

4.14.7 RRU Operational Resources Required

Project management

4.14.8 Synergy

This project would provide more dependable indoor air quality by reducing the need for manual adjustment of dampers.

4.15 Vending Machine Sensors Throughout the Campus

4.15.1 Description

- Investigate the use of VendingMisers® or other external control devices that can help reduce energy use. The VendingMiser has been designed for refrigerated vending machines. Locations that are unoccupied during nights and on holidays present the best opportunities for savings. The inventory is comprised of 6 cold beverage machines.
- A controller plugs into the wall - the vending machine plugs into the controller, and a low voltage wire is run to a wall or ceiling bracket for the PIR occupancy sensor. The controller powers the unit down unless someone walks by, or the controller determines that refrigeration is required for the product.
- The units are available from http://www.optimumenergy.com/management/miser.html
- The leasor should move the machines. It is recommended that all machines on campus be done on one day. The units can be purchased and installed by RRU in-house forces, or a contractor.
- When initiating or renewing a vending machine agreement, require your distributor to supply the most energy-efficient model available.
- Ensure vending machine controls are set at minimum lighting and cooling energy use at night, on weekends or other unoccupied periods if the machine does not carry dairy products, fresh juices or other perishable items.
- Evaluate compressor operations. What is the temperature of the room where the machine is located? A warmer room will require the compressor to activate more frequently. How often is the machine restocked? Opening and closing the machine and restocking with room-temperature items will require the compressor to turn on more frequently as well.

4.15.2 Affected Area(s)

Throughout the campus.

4.15.3 Opinion of Probable Schedule

1 year

4.15.4 Estimated Service Life

5 years

4.15.5 Opinion of Estimated Annual Energy Savings, Cost and Payback

Refer to **Table 8 Options Listed by Type** on page 18.

4.15.6 Description of Energy Analysis

A typical machine is powered at 1.43 kW. The VendingMiser is projected to reduce run hours by 6 hours per day.

4.15.7 RRU Operational Resources Required

Installation and coordination of moving with supplier.

4.15.8 Synergy

Reduced heat output can result in shorter air conditioner run time, but can increase heating loads slightly.

APPENDIX “A”

Existing Building General Summary

Building	Square Metres	Occupancy	Year Built	Construction	Windows	Mechanical	Electrical Characteristics	Lighting
Castle (1)	4,212	75	1908	Stone Masonry	Stone mullion and wood framed double hung single pane	Gas Furnace	400amp 120/208/3P 4 wire	Fluorescent
Greenhouse (2)	418	1 - 5	1914	Cast Iron / Wood Glass	Cyprus framing and single glazed over cast iron structure	Gas fired hot water	200amp 120/240 1P / 3 wire	Fluorescent
Bldg 3	223	2 - 4	1912-1914	Wood	Double glazed	Gas fired hot water	100amp 120/240 1P 3 wire	Incandescent
Mews (4) Conference Ctr	3,120	22 - 450	1912	Day block / stucco and wood frame	Single Pane wood	baseboard htg hot water; HVAC (bsmt)	400amp 120/208/3P	Fluorescent
Bldg 5	179	4	1912-1914	Wood	Double glazed	Oil fired hot air	100A 120/240 1 P 3 wire	Incandescent/C.F.
Cedar (6)	1302.7	25 - 30	1912	Clay tile; stucco and timber	Single Pane metal	Heat Pump	600amp 120/208v 3 P	Fluorescent
Arbutus (7A)	1472.4		1940	Wood	Single Pane wood	RT Heat Pumps & HVAC	800amp 120/208v 3P	Fluorescent
Bldg 7B1, 2, 3	828	15 - 20	1940	Wood on Slab	Aluminum double glazed	Heat Pump	347/600v 400amp	Fluorescent
Gatehouse (9)	260	6	1910	Wood	Double glazed	Oil fire forced air	100amp 120/240v 1P 3 wire	Compact Fluorescent
Bldg 10 (fourplex)	426	7	1910	Wood	Wood frame single glaze	Gas fired hot water	200amp 120/240 1P / 3 wire	Fluorescent
Bldg 12	233	2 - 4	1912-1914	Wood	Aluminum double glazed	Oil fired hot air	100amp 120/240v 1P 3 wire	Fluorescent
Bldg 14	223	2 - 4	1912-1914	Wood	Aluminum double glazed	Oil fired forced air	100amp 120/240v 1P 3 wire	Fluorescent
Bldg 16	167.2	2 - 4	1912-1914	Wood	Aluminum double glazed	Electric baseboard	200amp 120/240 1P / 3 wire	Incandescent
Millward (21)	4207.8	70 - 80	1991	Concrete	New aluminum / double glazing	AHU (x2)	1200amp 120/208v 3 P	Fluorescent
Gym (22)	1417.4	50	1942	Wood	Single glazed original wood	AHU (x3)	225 amp panel 120/208V 3P	High Pressure Sodium (HPS)
Nixon (24A)	5204.5	210 - 230	'44 / reno 1998	Concrete	Single glazed wood	n/a	n/a	Fluorescent
Grant (24)	5,528	550	'42 / reno 2002	Concrete	Yellow cedar wood framed single glazed with oak interior wood framed lam glass units	Condensing boilers	200amp 120/208v 3P 4 wire	Fluorescent
Swimming Pool (25)	1,733	not in use	1956	Concrete block	Original single glazing	AHU (x3)	400amp 120/208/3P	n/a
Library (30)	1907.3	70 - 80	1975	Concrete	Single glazing / silicone sealed	HVAC multi-zone units (x2)	600amp 120/208v 3 P 4 wire	Fluorescent
Boatshed (30)	142	10 - 15	1942	Wood	Single glazing wood frame	Gas Furnace	200amp 120/2008V 1 P 3 wire	Fluorescent
Rose Garden Cottage (34)	300	20	2001	Wood	New aluminum / double glazing	Heat Pump	200amp 120/240v 1P 3 Wire	Fluorescent

Rowing Centre (77)	223	10 - 12	1990	Wood	Double glazed and skylights	Electric Heat	100amp 120/240v 1P 3 wire	H.P.S.
Bldg 27 Commandant's Residence	353	16	1942	Wood	Aluminum double glazed	Gas fire hot water	125amp 120/240v 1P 3 wire	Incandescent
Bldg 28 Vice Commandant's Residence	353	12	1942	Wood	Aluminum double glazed	Gas fire hot water	125amp 120/240v 1P 3 wire	Incandescent

18,754

APPENDIX “B”

Existing DHW Summary

Bldg No.	Building Name	Floor	Room	DHW	DHW Temp at Tap	Tank Type	Tank Dimensions	DHW recirc pump	Length & dia of uninsul'd DHW lines	Useful Heat	HWT Jacket	Comments
1	HatleyCastle	B	basement cage	100g E T	115	4 tanks each with 6x5000 W		Yes	0	0%	No	4 Fairly new tanks -- serves the entire building
2	Greenhouse	1	Service Rm.	40g E T	135	"John Wood" 2 X 3000 W	20" dia X 48"		1/2" x 10'-0"	0%	No	unheated space (could use DHW Jacket)
3	House 3											Couldn't Access
4	Mews Conference Centre	B	boiler room	75g NG T	135	Tank #1 "State" 250,000 BTU/HR		Yes	0	0%	No	new tank -- serves the entire kitchen only
4	Mews Conference Centre	B	boiler room	80g NG T	137	Tank #2 "John Wood" 199,000 BTU/HR		Yes	0	0%	No	new tank -- serves the remainder of the building
5	House 5	2	Unfinished Basement	45g E T	128	"John Wood" 2 X 3000 W			1/2" x 40'-0"	50%	No	Staff Residence (old laundry bldg.)
6	Cedar	B	celler room	40g E T	121	"John Wood" 2 X 3000 W 240/1/60	20" dia X 48"	No	1/2" x 3'-0"	0%	No	Tank located in leaking celler (wet floor) (candidate for a insul Jacket)
7A	Arbutus	Main	Janitors Closet	10g E T	133	"GSW" 1500 W 240/1/60	16" dia X 20"	No	1/2" x 3'-0" 3/4" x 2'-0"	0%	No	New Tank - Mounted on a Platform
7B	Facilities -7B 1,2,3	Main	Mech/Fire room	40g E T	122	"John Wood" 2 X 3000 W 240/1/60	18" dia X 50"	?	0	0%	No	Fairly new tank
9	Gatehouse	2	basement	40g E T	136	"John Wood" 2 X 3000 W	20" dia X 48"		1/2" x 50'-0"	50%	No	Unfinished Basement
10	House 10 (fourplex)	2	2 in Boiler Rm 2 in Meter Rm.	2X 45g E T 2X 40g E T	132 133	"John Wood" 2 X 3000 W (2 tanks identical)	20" dia X 48"	No	3/4" x 4'-0" (inside boiler rm)	0%		Newer Tanks (candidates for DHW Jacket)
12	House 12	2	Unfinished Basement	40g E T	130	"John Wood" 2 X 3000 W	20" dia X 48"	No	1/2" x 35'-0"	50%	No	Residence (currently unoccupied)
14	House 14	2	Unfinished Basement	45g E T	151	Covered Over??	20" dia X 48"	no	1/2" x 50'-0"	0%	Yes	Offices
16	House 16	1	Closet	45g E T	126	"John Wood" 2 X 3000 W	20" dia X 48"	No	1/2" x 12'-0"	50%	no	Staff Residence
21	Millward Building	1	Mech/Fire room	500g HE x 3	128	Storage Tanks 1,2&3 (approx 1000 gal each)	48" dia X 78"	Yes	0	0%	No	3 large DHW holding tanks located in 1st fl of Millward boilers located over in Nixon Bldg. "Weil McLain" NG min. 750,000 BTU/HR to max. 2,049,000 BTU/HR each Note: 2 rooftop ahu's are tied into this DHW system

Bldg No.	Building Name	Floor	Room	DHW	DHW Temp at Tap	Tank Type	Tank Dimensions	DHW recirc pump	Length & dia of uninsul'd DHW lines	Useful Heat	HWT Jacket	Comments
22	Gym		Mens Change	45g E T	130	"John Wood" 2 X 4500 W	20" dia X 50"	No	1/2" x 2'-0"	30%	No	
23	Nixon Building	2	boiler room	75g HE x 3	120	Storage Tanks 1,2&3 (75 gal each)	26" dia X 60"	Yes	0	0%	No	"Raypak" NG boiler adjacent to DHW tanks. Model E962 WTDB-N-2P, 975,000 btu/hr
24	Grant Building	1	boiler room	"Gas Fired Comml Water Heater"	130	No Tank	n/a	Yes	0	0%	No	Aerco KC Gas Fired Commercial Water Heater - Instantanious type DHW heater 1,000,000 BTU/HR serves entire bldg. including cafeteria
25	Pool	B	pool pump and Mech Room	119g HE x 6	124	"A O Smith" Model: TJV-120M	29" dia X 62"	Yes	0	0%	No	Possible heat recovery from shower drain stacks. One of 3 Boilers ?
27	Commandant's Residence	2	boiler room	60g NG	140	Rhem Rudd 60000 BTU/HR	20" dia X 60"	No	1/2" x 14'-0"	0%	No	Semi-finished Basement+M6
28	Vice Commandant's Residence	2	boiler room	60g NG	123	GE 50000 BTU/HR	20" dia X 60"	No	3/4" x 3'-0"	0%	No	Offices plus classes for Greenhouse students
30	Library	Lower	boiler room	30g E T	179	"John Wood" 2 X 3000 W 240/1/60	22" dia X 48"	No	0	0%	No	Older Tank (missing cover plate)
32	Boat Shed	Main	above W/C	10g E T	121	"GSW" 1500 W 240/1/60	16" dia X 20"	No	0	0%	No	New Tank - Mounted above w/c ceiling
34	Rose Garden Shed	B	Closet below Stairs	40g E T	132	"Giant" Model # 152ETE-3FSM 2 X 3000 W	23" dia X 50"	No	3/4" x 4'-0"	0%	No	New Tank - Mounted in closet below stairs
77	Rowing Centre											

APPENDIX "C"

Example Mechanical Inventory

24 such files were produced in the course of this work.

EQUIPMENT INVENTORY FOR: RRU			BUILDING:	Grant 24										May, 09
EQUIPMENT	SERVES	MODEL	LOC	SIZE	USE				SIZE		Age	Flow	PD	COMMENTS
		MAKE	Rm#	HP	hr/dy	d/wk	wk/yr	hr/yr	kW	kWh/yr		cfm/gpm	in./ft	
AHU-1	West Wing	Haakon Pentpak	Rooftop	25.00	14	7	51	4998	17.7	88552	1999	25000	5	ddc 208 asd econo hydr
RF-1	West Wing	Haakon Pentpak	Rooftop	15.00	14	7	51	4998	10.6	53131				
AHU-2	East Wing	Haakon Pentpak	Rooftop	20.00	14	7	51	4998	14.2	70842		18150	5	ddc 208 asd econo hydr
RF-2	East Wing	Haakon Pentpak	Rooftop	7.50	14	7	51	4998	5.3	26566				ASD shot
AHU-3	Kitchen/Caf	Haakon Pentpak	Rooftop	10.00	14	7	51	4998	7.1	35421		8100		ASD shot
RF-3	Kitchen/Caf	Haakon Pentpak	Rooftop	2.00	14	7	51	4998	1.4	7084				
AHU-4	Science Lab	Haakon Pentpak	Rooftop	10.00	14	7	51	4998	7.1	35421		8000	3.75	
SF-101	Mech rm	Greenheck BSQ-160-10	Mech rm	0.33				500	0.2	117				
SF-102	Elec rm	Greenheck BSQ-160-7	Elec rm	0.10				8760	0.1	621				
EF-103	West elect rm	Greenheck CSP-210	Ceiling	0.10				8760	0.1	621				
EF-104	Comm rm west	Greenheck CSP-210	Ceiling	1.00				8760	0.1	876				
EF?	Washroom	Greenheck CSP-210	Ceiling	0.16				8760	0.1	993				
EF-106	East elec rm	Greenheck CSP-210	Ceiling	0.10				8760	0.1	621				
EF-105	Comm rm east	Greenheck CSP-210	Ceiling	0.10				8760	0.1	876				
EF-108	Elev rm	Greenheck CSP-210	Ceiling	0.10				8760	0.1	621				
EF-201A	Kitchen hoods	Greenheck CUBE-300XP-30	Rooftop	3.00				6000	2.1	12757				cooks manual

EQUIPMENT INVENTORY FOR: RRU			BUILDING:	Grant 24											May, 09
EQUIPMENT	SERVES	MODEL	LOC	SIZE	USE				SIZE		Age	Flow	PD	COMMENTS
		MAKE	Rm#	HP	hr/dy	d/wk	wk/yr	hr/yr	kW	kWh/yr		cfm/gpm	in./ft	
EF-201B	Kitchen hoods	Greenheck CUBE-240XP-30	Rooftop	3.00				6000	2.1	12757				cooks manual
EF-202	Dishwasher	Greenheck CUBE-101HP4	Rooftop	0.25	4	7	50	1400	0.2	248				
EF-204	Elec/comm rm west	Greenheck CSP-224	Ceiling	0.10				8760	0.1	621				
EF-205	Loading dock	Greenheck CUBE-121-3	Rooftop	0.33				8760	0.2	2049				
EF-206	East elec rm	Greenheck CSP-210	Ceiling	0.10				8760	0.1	621				
EF-207	Comm rm east	Greenheck CSP-210	Ceiling	0.10				8760	0.1	621				
EF-303	West elect rm	Greenheck CSP-210	Ceiling	0.10				8760	0.1	621				
EF-304	Comm rm west	Greenheck CSP-210	Ceiling	0.10				8760	0.1	621				
EF-305	East elec rm	Greenheck CSP-210	Ceiling	0.10				8760	0.1	621				
EF-306	Comm rm east	Greenheck CSP-210	Ceiling	0.10				8760	0.1	621				
EF-401	East washrm	Greenheck CUBE-200-20	Rooftop	2.00	11	7	52	4004	1.4	5675				
EF-402	West washrm	Greenheck CUBE-161-10	Rooftop	1.00	11	7	52	4004	0.7	2838				
EF-403	Fumehood	Greenheck CUBE-240XP-15	Rooftop	1.50				8760	1.1	9312				
EF-404	Fume hoods	Greenheck CUBE-141-5	Rooftop	1.00				8760	0.7	6208				
EF-405	Biol lab	Greenheck SFB-12-15	Rooftop	1.50				7000	1.1	7441				
EF-406	Fume hoods	Greenheck SFB-12-15	Rooftop	1.50				7000	1.1	7441				
A/C	Computer lab	Canatal 9AD22	Computer lab	7.5				8760	5.3	46562				
AC reheat	Computer lab	Canatal 9AD22	Computer lab					0	12.0	0				
AC humidifier	Computer lab	Canatal 9AD22	Computer lab		8	7	8	448	6.8	3046				
AC compressor	Computer lab	Canatal 9AD22	Computer lab		10	7	50	3500	10.0	35000				
A/C backup	Computer lab	DataAireDAA1332	Computer lab	3				0	2.1	0				backup
AC reheat	Computer lab	DataAireDAA1332	Computer lab					0	15.0	0				backup

EQUIPMENT INVENTORY FOR: RRU			BUILDING:	Grant 24										May, 09
EQUIPMENT	SERVES	MODEL	LOC	SIZE	USE				SIZE		Age	Flow	PD	COMMENTS
		MAKE	Rm#	HP	hr/dy	d/wk	wk/yr	hr/yr	kW	kWh/yr		cfm/gpm	in./ft	
AC humidifier	Computer lab	DataAireDAA1332	Computer lab					0	5.4	0				backup
AC compressor	Computer lab	DataAireDAA1332	Computer lab					0	5.0	0				backup
P-101A	Htg system	Armstrong 2x2x10 4380	Mech rm	5.00	24	7	30	5040	3.5	17859				
P-101B	Htg system	Armstrong 2x2x10 4380	Mech rm	5.00			0	0	3.5	0				lead/lag
P-102	DHW recirc	Armstron Astro 50	Mech rm	0.08				8760	0.1	517				
P-103	Quarter deck	Armstrong H51	Mech rm	0.25	24	7	30	5040	0.2	893				serves HX
P-104	B3 wing	Armstrong 1.5D 4360	Mech rm	0.25				5040	0.2	893				
P-401	AHU-1 coil	Armstrong H51	Rooftop	0.33				5040	0.2	1179				
P-402	AHU-2 coil	Armstrong H51	Rooftop	0.33				5040	0.2	1179				
P-403	AHU-3 coil	Armstrong H51	Rooftop	0.33				5040	0.2	1179				
P-404	AHU-4 coil	Armstrong H51	Rooftop	0.25				5040	0.2	893				
B-101	Htg system	Viessman VSB-46	Mech rm		4	7	30	840	0.9	714	2001			condensing 506mbh to 1.73MMBH
B-102	Htg system	Viessman VSB-46	Mech rm					0	0.9	0				lead/lag auto RW CV
FC-1	Main entry 121	Trane FFCB030	Ceiling	0.05				200	0.0	7				17 MBH
FC-2	Entry 126	Trane FFCB060	Ceiling	0.12				200	0.1	17				36 MBH
FC-3	Entry 115	Trane FFCB060	Ceiling	0.12				200	0.1	17				36 MBH
HC-1	Kitchen/caf	Trane DTTB	Ceiling					0	0.0	0				no power
HC-2	Kitchen/caf	Trane DTTB	Ceiling					0	0.0	0				no power
HC-3	Kitchen/caf	Trane DTTB	Ceiling					0	0.0	0				no power
DHWH-1	DHW	Aerco KC1000GWW	Mech rm					0	0.0	0				70MBH - 1MMBH, over-sized no stor 135F, 93%
EF-1	Lab ovens	Carnes VIBK18	Rooftop	0.75				8760	0.5	4656				could sched w AH4
EF-1	Registration jan rm	Nutone 695PC	Jan rm	0.25				8760	0.2	1552				

EQUIPMENT INVENTORY FOR: RRU			BUILDING:	Grant 24										May, 09
EQUIPMENT	SERVES	MODEL	LOC	SIZE	USE				SIZE		Age	Flow	PD	COMMENTS
		MAKE	Rm#	HP	hr/dy	d/wk	wk/yr	hr/yr	kW	kWh/yr		cfm/gpm	in./ft	
EF-2	Chem storage	Carnes VIBK08	Lab ceiling	0.50				8760	0.4	3104				switch
EF-3	Lab jan rm	Nutone 695PC	Jan rm	0.10				8760	0.1	621				
UH-1	Main lab 105	Trane UHSA 020	Ceiling space		4	5	14	280	0.1	28				105-120v wall stat for fan
UH-2	Main lab 104	Trane UHSA 060	Ceiling space		4	5	14	280	0.1	28				rm 104120v wall stat for fan
UH-3	Main floor lab	Trane UHSA 060	Ceiling space		4	5	14	280	0.1	28				120v wall stat for fan
UH-4	Main floor lab	Trane UHSA 060	Ceiling space		4	5	14	280	0.1	28				120v wall stat for fan
EUH 106	Main floor lab		Ceiling space		4	5	14	280	7.5	2100				in-blt
EUH 107	Main floor lab		Ceiling space		4	5	14	280	3.5	980				in-blt
EUH 104	Main floor lab		Ceiling space		4	5	14	280	15.0	4200				in-blt
EF-1	Fume hood	Cook 135 CPV	Rooftop	1.00				8000	0.7	5670		2014		950 L/s @ 360 Pa
EF-2	Fume hood	Cook 135 CPV	Rooftop	1.00				8000	0.7	5670		2014		950 L/s @ 360 Pa
EF-3	Fume hood	Cook 135 CPV	Rooftop	1.00				2500	0.7	1772		2014		950 L/s @ 422 Pa
EF-4	Fume hood	Cook 135 CPV	Rooftop	1.00				3000	0.7	2126		2014		950 L/s @ 422 Pa
Compressors	controls		Old RT mech rm	0.75				3000	0.5	1595				Old area/.33 backup
Comp Rm AC	IT	Bohn BRL021	Old roof (NW)	1.50	8	7	40	2240	1.1	2381				2*1.5 cond unit
Comp Rm AC	IT	Keeprite KVC1412027A	Old roof (NW)	1.50	8	7	40	2240	1.1	2381				2*1.5 cond unit
SF-1 old	153/154	Mark Hot	Old RT mech rm	2.00	12	5	52	3120	1.4	4422				econo pnew act DDC
P-sf1	SF1 HC	Grundfos	Old RT mech rm					3120	0.1	265				
SF-2 "Senior"	158	Carrier	Old RT mech rm	2.00	2	5	52	520	1.4	737				HP DDC - over-sized
RF-2	158		Old RT mech rm	0.50	2	5	52	520	0.4	184				
HP senior ODU	158	Carrier 38arq008-501	Old roof (NW)		2	5	30	300	7.5	2250				7.5T
SF 3-4? "junior"	159	Carrier	Old RT mech rm	0.50	12	5	52	3120	0.4	1106				HP DDC

EQUIPMENT INVENTORY FOR: RRU — BUILDING: Grant 24 — May, 09

EQUIPMENT	SERVES	MODEL MAKE	LOC Rm#	SIZE HP	USE hr/dy	d/wk	wk/yr	hr/yr	SIZE kW	kWh/yr	Age	Flow cfm/gpm	PD in./ft	COMMENTS
RF junior	159		Old RT mech rm	0.25	12	5	52	3120	0.2	553				
HP junior ODU	159	Carrier 38BQ008530	Old roof (NW)		3	6	40	720	7.5	5400				7.5T
SF-152 micro	152		Old RT mech rm	0.50	12	5	52	3120	0.4	1106				HP DDC
RF-152	152		Old RT mech rm	0.25	12	5	52	3120	0.2	553				
HP micro ODU	152	York E2R4048S256	Old roof (NW)		3	6	40	720	4.0	2880				
SF	59481							mech		561763				

APPENDICES D to J are provided electronically