BUILDING REPORT

PROJECT NUMBER: **3018-041 (R.101938)**

FACILITY NAME: **AAFC – OTTAWA**

BUILDING: **BUILDING 20**

1. BUILDING DESCRIPTION

Ottawa's Building 20, the K.W. Neatby Building, is one of the main buildings at the Ottawa site. It is mainly a centralized laboratory with connected offices, growth room spaces, a small cafeteria and a gym room. It is a four-story building with 24,270 m² of surface area (including a penthouse mechanical room).

The building is dated and worn out. There are major investments in architectural and preventive maintenance that should be considered when transitioning to net zero emissions. Based on a complete Building Condition Report (BCR) by Alcaide Webster architects completed in April 2018, as well as our own observations, AAFC must consider HVAC retrofit requirements before any energy efficiency and GHG measures are applied to Building 20.

The following paragraphs present major HVAC components. It is not an exhaustive description, but merely an overview to understand the building's GHG-emitting elements. The sum of required retrofit investments is presented separately from the measures considered in the present study unless they have a direct impact on the GHG reduction measures. Note that major architectural and structural retrofit investments were not considered in the current study because they are normally pushed forward under different objectives (normalization or a change in vocations, etc.).

1.1 Heating

Building 20's heating is achieved by a high-pressure natural gas steam production plant consisting of two 500 BHP steam boilers (16,735 MBtu/h) installed in the building's south wing basement in 2012, as well as one natural gas-fired high temperature water boiler of 750 MBtu/h used on the reheat water loop for the laboratories. High-pressure steam is converted to a low-pressure feed to ensure enough capacity to all south wing perimeter cast-iron radiators and the north-east wing pipe heat fins. The steam also feeds three heat exchangers; one for the boiler room make-up air unit, one for a preheat glycol loop and the other for the laboratory reheat water loop in the north and east wings. Note that the building has two (2) clean steam electrical generators of 20 kW (2.5 BHP) each.

Based on the BCR and from a maintenance investment perspective, AAFC should consider the following costs for heating equipment.

Maintenance actions	Work to be considered	Estimated cost (including soft costs)
Retrofit of steam heating radiators in the north and east wings	Install low-temperature water radiators. Replace supply and return piping. Install new pumps. Consider demolition and refinishing. Design and testing costs.	$ 1,750,000
Retrofit hot water terminal reheat units in the north and east wings	Install low-temperature water terminal reheat units (approximately 100 units). Replace supply and return piping. Install new pumps. Consider demolition and refinishing. Design and testing costs.	$ 2,100,000
Replace condensate lift stations (north and east wings)	Replace dated equipment.	$ 75,000
Replace preheating heat exchanger 3 in the Penthouse glycol loop	Replace dated equipment. Replace pumps and associated accessories.	$ 260,000

1.2 Cooling

Space cooling is provided by two 420 TR modulating centrifugal York chillers. The chillers use R-123 refrigerant which has to be phased out in 2020. The chillers are linked to two (2) 420 TR BAC cooling towers. The building also has two modular scroll chillers of 70 TR each to ensure process heat rejection produced by the growth rooms. The chillers are linked to two (2) 70 TR Evapco cooling towers installed on the north wing's roof. Also, the building has a myriad of ceiling DX expansion cooling units, room window units and wall units. Operators estimate up to 100 window units are individually installed for the summer season.

Based on the BCR and from a maintenance investment perspective, AAFC should consider the following costs for cooling equipment.

Maintenance actions	Work to be considered	Estimated cost (including soft costs)
Replace the York 430 TR chiller in the north wing	Replace chillers to consider R-123 phase out in 2020. Install new pumps. Consider demolition and refinishing. Design and testing costs.	$ 2,500,000
Replace condenser pumps on the York chillers	Replace dated equipment.	$ 75,000
Regroup DX cooling units to centralize needs and production	Replace dated equipment; equivalent to 75 TR of cooling	$ 185,000

1.3 Ventilation

Building 20's ventilation quality and capacity are not equal for the whole building. There are five (5) main make-up air units (MAU 1-5) with VFD's in the north and east wing penthouse mechanical rooms. These units serve the lab sectors and compensate for the exhaust of 88 fume hoods. A small percentage of air-handling ensures the ventilation requirements for the remaining spaces. The south wing is not entirely ventilated and lacks fresh air admittance (very little air ratio is considered for that wing).

As for exhaust systems, 88 fume hoods are to be considered for the lab areas and they are associated with two general modulating exhaust fans to maintain a pressure differential between the labs and the adjacent environment. Duct material varies from galvanized steel to plastic and systems are mostly dated (1992). Some of the lab fume hoods were renovated, but the majority are original. Each fume hood has its fan and from what was observed, they can operate under low and high speed (this information was retrieved from testing documentation obtained from the facility); still, it seems that the present operation (and occupant usage) is on a constant volume. The north and east wings have a roof-mounted exhaust washroom fan. On the other hand, the south wing has a dispersed exhaust system serving restrictive areas. The wing has centralized exhaust fans for only one sector. Some of the washrooms have a wall-mounted exhaust fan (propeller fans).

The following table presents the main ventilation units, complete with a description of each AHU. The CFM considered were estimated or retrieved from the name plate (no balancing report was found).

ID	Type	Description	CFM	% Fresh air
AHU-1	100 % make-up air unit	Make-up air unit for laboratory Mechanical penthouse	25,000	100 %
AHU-2	100 % make-up air unit	Make-up air unit for laboratory Mechanical penthouse	25,000	100 %
AHU-3	100 % make-up air unit	Make-up air unit for laboratory Mechanical penthouse	25,000	100 %
AHU-4	100 % make-up air unit	Make-up air unit for laboratory Mechanical penthouse	25,000	100 %
AHU-5	100 % make-up air unit	Make-up air unit for laboratory Mechanical penthouse	25,000	100 %
AHU-7	Air-handling unit	Fitness room air handling unit - ventilation system with recovery unit	11,000	10 %
AHU-6	Air make-up unit	B69 air-handling unit - ventilation system glycol water heating	11,000	100 %
AHU-8	Air-handling unit	All building basement air-handling unit South wing	8,000	20 %
AHU-9	Air-handling unit	2nd floor South wing Air-handling unit	3,500	20 %
AHU-RT	Air-handling unit	4th floor South wing air-handling unit electric heating	(4 units) 2,000 each	10 %
Kitchen hood	Air-handling unit	Kitchen exhaust hood	1,800 CFM	

Based on the BCR and in a maintenance investment perspective, AAFC should consider the following costs for ventilation equipment.

Maintenance actions	Work to be considered	Estimated cost (including soft cost)
Add ventilation to south wing	Based on the 2005 study to improve air quality, 2 rooftop air-handling units of 15,000 CFM each need to be installed (with heat recovery option). Air distribution is to be considered throughout the wing. Consider demolition and refinishing. Design and testing costs.	$ 4,780,000
Install general and washroom exhaust systems in south wing.	Install new required equipment.	$ 150,000
Replace fume hood ducts and fans	Replace dated ducts in the building regardless if a new hood or new control system is installed.	$ 1,250,000

1.4 Domestic hot water

Domestic hot water for the south wing is produced by two (2) electrical water heaters (6 kW and 13.5 kW capacities), while the domestic hot water for the north and east wings is produced by three gas-fired water heaters (146.4 kW each).

1.5 Electrical services

Electrical services other than HVAC equipment are lighting and processes. Processes are either computers, office equipment, lab-processing equipment, growth room compressors or freezers. As for lighting, it is estimated that 2,200 fixtures of 2 to 4 lamps, each consisting of T8 fluorescent (32 watts) lamps, are present.

1.6 Control and automation

Controls throughout the building were converted to DDC, except for terminal and room control (valves, dampers, etc.) where pneumatic converters are maintained.

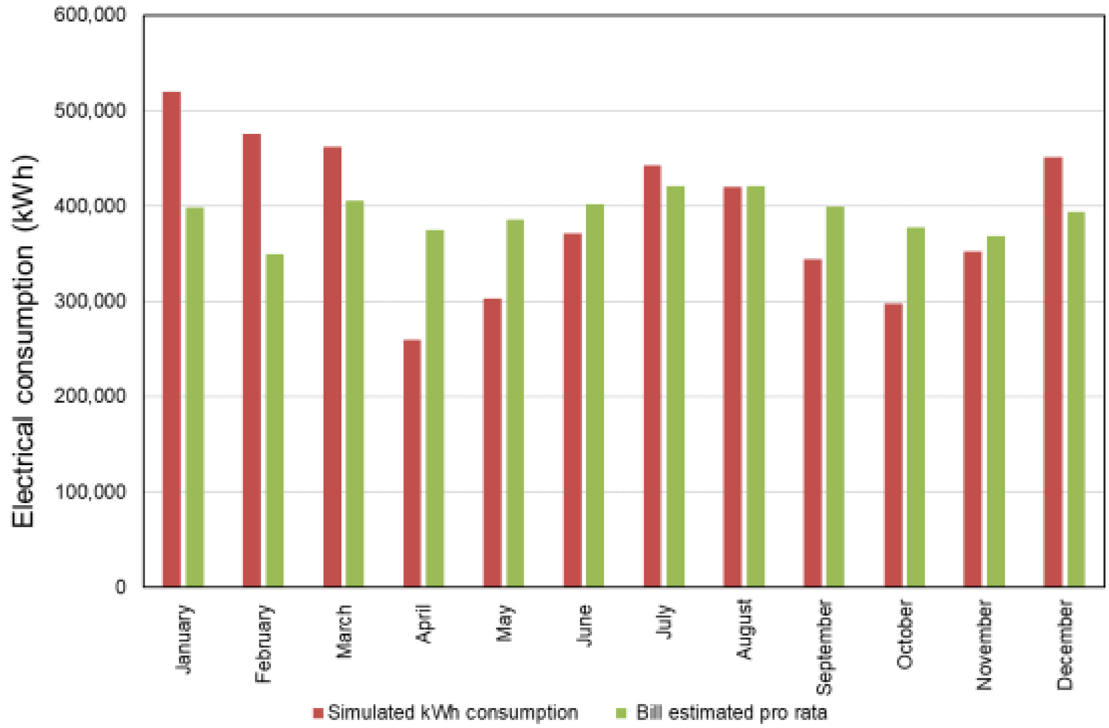
2. ENERGY PROFILE

The energy consumption profile is established through a comparison between metered energy consumption bills and system energy calculations. For the present study, a bin data method was used to establish all consumption that depends on ambient temperature. A definition of the bin data method is as follows:

> *The temperature range method is used to evaluate the energy consumption of different systems when its operation depends on outside temperature. The temperatures are grouped into intervals or ranges, and thereafter, the frequency in hours of this range of temperatures is established from the climatic data collected over several years (usually a 20 year average or an average of the last four years). Thus, using a calculation program and for a given operation schedule, the number for a typical year for each range of temperatures is estimated and then recorded. Finally, a simulation for the consumption of each equipment is calculated according to the operating conditions and the technical specifications of each system.*
>
> *The calculated profile is then compared to a standard energy bill (metered or recorded by the operation staff). Therefore, the assumptions considered to establish the energy consumption for the various systems (ventilation systems for heating, perimeter heating networks, cooling networks, consumption of electricity, and domestic hot water) are validated.*

As for other non-temperature dependent energy consumers, the energy consumption is based on operation schedules and a combination of capacity and diversity factors. It is to be noted that, in establishing a base profile, it is preferable to have a metered consumption (bills or other recorded data) to enable a precise comparison. For Building 20, only natural gas consumption is metered; therefore, it becomes the base point of the comparison. The objective remains to come as close as possible to the metered bill value. For the present scenario, the difference is less than 1 %. The building overview and profile graphs are presented in the table and figures below.

	Fossil fuel consumption			**Electricity**	
	Envelope heating	**Ventilation – Air heating and humidification**	**Domestic hot water production**	**Ventilation- Air handling (Cooling, ventilation, pumps)**	**Laboratory, process, and lighting**
Energy	637,395 m3	507,020 m3	16,820 m3	3,371,191 kWh	1,356,772 kWh
Emissions (tCO_2e)	1,210	962	32	121	49
Proportion (%)	51 %	41 %	1 %	5 %	2 %


600,000
500,000
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300,000
200,000
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0
Electrical consumption (kWh)
January
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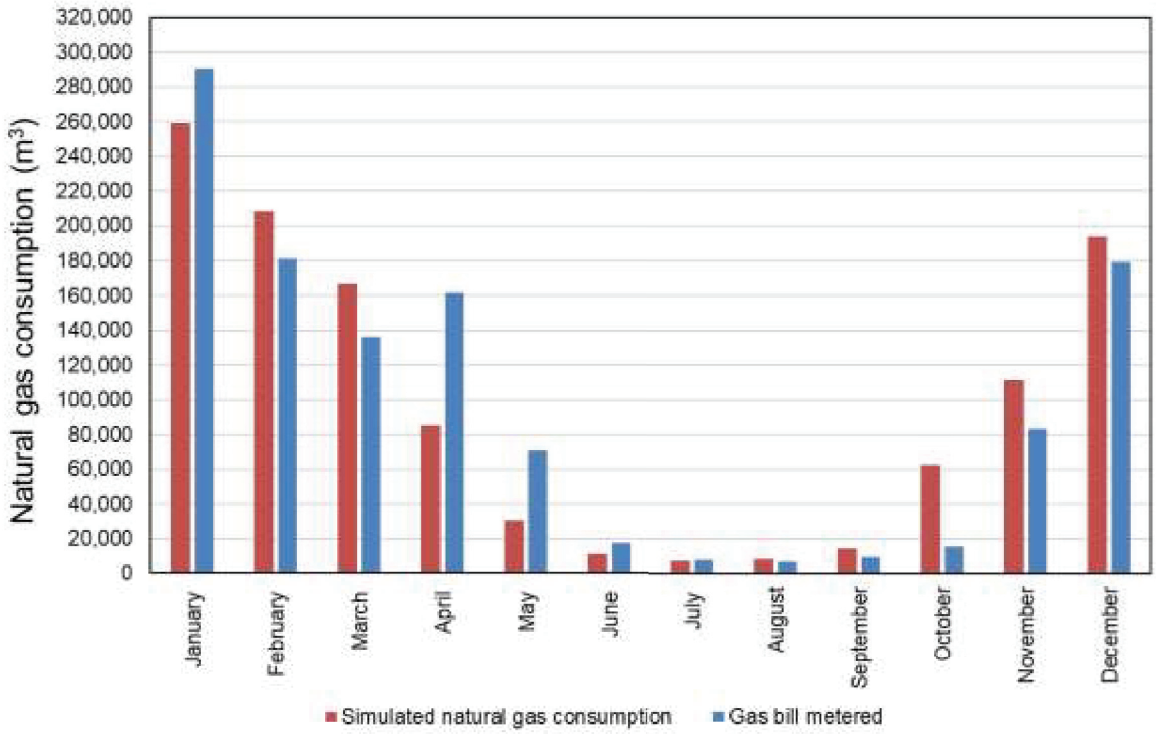
October
November
December
Simulated kWh consumption
Bill estimated pro rata



3. MEASURE IMPLEMENTATION STRATEGY

The main implementation strategy for Building 20 follows the same lines as the general approach mentioned in the previous sections of the Plan. The first focus will be to reduce energy consumption related to natural gas usage by implementing heat recovery strategies and modernizing controls to make system operation close to user needs and reduce losses due to inefficient operation. Finally, measures for implementing energy-efficient and carbon-neutral technologies are introduced to further decrease the building's carbon footprint.

Recommissioning is applied to different AHU systems mainly through room temperature control (AHU-6 to AHU-9). As addressed in the first part of this document, the south wing is very deficient in air quality. For the purpose of the study, we consider that the current operation of the system consumes more energy to compensate for the deficiency. If addressed through maintenance investments, the south wing ventilation systems would operate more efficiently. Thus, investments for new units were not considered and energy reduction is assumed to be the same in the future. This measure will not require major replacements or renovations and will be focused on optimizing the function of current systems. Please refer to Building 20's MES-001 description sheet for more information.

Building 20's energy consumption, in its present state, mostly involves producing steam to preheat and heat a large volume of fresh air required to compensate for fume hood exhausts in the north and east wing laboratories. Logically, the first measure would be to optimize the functionality of the systems. In order to establish parameters for the calculations, assumptions were made based on information obtained during the site surveys and ensuing discussions with operators. It was observed that VFD ratios on fresh air supply were at 65 to 75 % on average and the fume hoods are assumed to be at constant volume. Still, they can operate at two stages and the general exhaust modulates in order to maintain negative pressure in the laboratories.

	Estimated fresh air supplied		**Estimated fume hood airflow**		**General exhaust**	**Differential to maintain a negative pressure in labs**		**Fresh air supply reduction**
Schedule	Actual	Proposed	Actual	Proposed	Modulate to maintain pressure	Actual	Proposed	
	CFM	*CFM*	*CFM*	*CFM*	*CFM*	*CFM*	*CFM*	%
7 :00-17 :00	81,250	60,572	57,797	34,678	14,000	-9,453	-11,893	25 %
7 :00-17 :00	66,625	41,065	43,348	23,119	14,000	-9,277	-3,946	38 %

Considering the state of the actual system, the control retrofit measure would require installing new hoods and new exhaust fans, as well as new variable air volume supply valves. Only the modifications required for efficient operation were considered. Please refer to Building 20's MES-002 description sheet for more information.

Once the quantity of admitted air is optimized, heat would be recovered from the growth rooms' water tower loop through a heat pump. This measure is considered unavoidable since the growth rooms reject heat year-round and this heat is currently lost to the atmosphere. This heat can be recovered to obtain "free" heat energy year-round, without the need for new production equipment. Steam would remain as a backup for peak demand periods. This measure will require the renewal of the make-up units' preheating sections. Please refer to Building 20's MES-006 description sheet for more information.

The effect of grid decarbonisation is introduced after MES-006 (growth room recovery) since it is estimated to be the cut-off between conventional recovery measures and new alternative energy production measures. It will therefore better represent the GHG emissions savings that occur after necessary energy efficiency and recovery measures have been applied, while simultaneously accurately representing the GHG reductions incurred by the alternative energy measures that follow. Please refer to Building 20's MES-007 description sheet for more information.

Following this, high-efficiency heat pumps are recommended to offer baseload heating and cooling when ambient temperatures permit it (higher than -10 °C). All of Building 20's envelope heating and reheat is covered by either steam or the high-temperature water loop. To have the ability to heat through air-source heat pumps, AAFC Ottawa must consider the conversion of all reheat/cooling terminal units, radiators (pipe and fins) and plumbing. The measure requires a very high investment, but considering the age of the current equipment, a replacement should be considered. Please refer to Building 20's MES-010 description sheet for more information.

Once all these technologies have been implemented in Building 20, it is considered that the maximum effort was made to reduce, recover and generate clean energy before resorting to traditional electrical conversion methods. Aerothermal technology and heat recovery measures will cover part of the demand, so electrical boilers will be installed to assist during peak periods and offer redundancy to the system.

In the case of Building 20, the 500 BHP gas-fired boilers are new; therefore, the conversion to electrical equipment for the remaining needs seems drastic. Meanwhile, the conversion to electricity for the remaining heating needs is a requirement to achieve zero emissions in this building. AAFC would therefore only consider using gas for peak needs and would, in this case, buy renewable natural gas fuel at an average cost of $37,000 per year.

3.1 Rejected Measures

As the study progressed, some measures were evaluated and rejected for various applicability reasons. The following paragraphs summarize the process leading to the rejection of certain measures in Building 20.

Regrouping fume hoods, rebuilding complete exhaust systems and manifolding to collect rejected heat was not retained for Building 20 since it was an over-expensive investment when heating from the growth rooms (MES-006) is enough for that purpose.

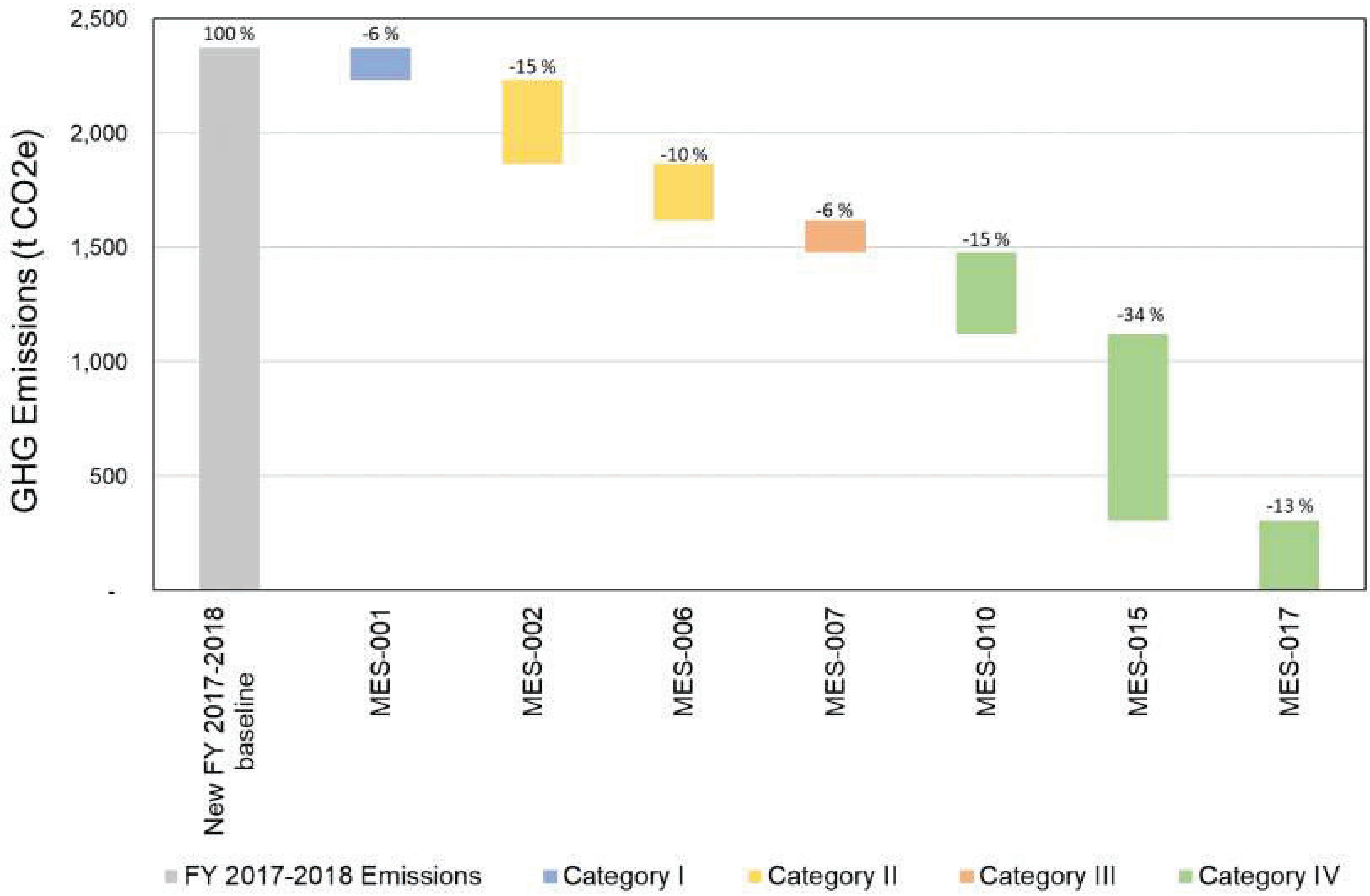
Aerothermal energy was preferred to geothermal for its lower investment cost. Considering the location of Building 20, an equivalent system would have required 50 boreholes, which amounts to an extra investment of $750,000 in direct costs to cover only 390 heating hours when the ambient temperature is less than -10 °C. Both are similar technologies as they provide heating and cooling through a heat pump. Geothermal energy has a higher efficiency due to the constant source/sink temperature, but this increased efficiency came at an investment cost that is too high for the potential upside in Building 20.

Finally, solar wall heating was not implemented since growth room recovery already covers a significant portion of the fresh air heating demands, and other technologies also cover the heating demands in an efficient fashion, thus reducing the added value of solar thermal collectors. Photovoltaic electricity production also was not considered due to its high initial cost and the relatively low electricity cost in Ontario (no acceptable return on investment possible in Ontario locations).

The table below summarizes the measures that are applied or not applied to Ottawa facility's Building 20.

Measure ID	Measure name	Applicable	Not Applicable
MES-001	Recommissioning and operation sequence strategies	X	
MES-002	Laboratory Fume hood replacement and in-depth ventilation review	X	
MES-003	Fume-hood manifold and exhaust system implementation		X
MES-004	Lighting control and conversion		X
MES-005	Heat recovery on fume hoods		X
MES-006	Heat recovery on growth rooms	X	
MES-007	Grid decarbonisation	X	
MES-008	Asset Disinvestment - Work Place Densification		X
MES-009	Greenhouse upgrades and optimization		X
MES-010	Aerothermal energy	X	
MES-011	Geothermal energy		X
MES-012	Non-emitting district energy partnership		X
MES-013	Solar wall		X
MES-014	Biomass boiler conversion		X
MES-015	Electric boiler conversion	X	
MES-016	Photovoltaic electricity production		X
MES-017	Green fuels	X	

The following figure presents the emission reductions waterfall diagram for the main building.



EMISSIONS REDUCTION MEASURES

MEASURE ID:	**MES-001 – RECOMMISSIONING AND OPERATION SEQUENCE STRATEGIES**
PROJECT NUMBER:	**3018-041 (R.101938)**
FACILITY NAME:	**AAFC - OTTAWA**
BUILDING:	**Building 20**

1. GENERAL DESCRIPTION OF MEASURE

Recommissioning consists of reviewing, testing and adjusting building systems according to the actual operations in existing buildings. Throughout this process, HVAC systems are reviewed and adjusted to satisfy present users' demands and building functionality, optimize energy efficiency strategies and respect current code requirements. A recommissioning measure on a building consists of a full building operation review and optimization of its operations automation strategy, as well as air and water balancing and testing. Typical actions resulting from this process are setbacks in room temperature and ventilation ratios according to occupancy, as well as fine-tuning of heating and cooling temperature control setpoints.

2. APPLICABILITY OF MEASURE

A recommissioning process is an applicable measure for Ottawa's Building 20. The building was built in 1950, mainly as a laboratory and offices, and it underwent several changes since occupation. Major operational changes have taken place through the years. The first step in a recommissioning measure would be to proceed with a complete recommissioning study. The objective is to identify all discrepancies between sequencing strategy and actual use. This would result mostly in reduced heating, cooling, electrical power and electrical energy consumption from the ventilation systems though adjustments in the schedule and temperature set points, among others. This considers the effect of recommissioning applied to different AHU units (AHU-6 to AHU-9), as well as the water and steam envelop heating. It is applied mainly through the optimisation of room temperature control and air changes requirement.

In depth renovation is the subject of MES-002 and addresses the ventilation in the laboratories; therefore, it was considered that corrections related to the laboratory sections are included in MES-002 and were not included in MES-001.

Recommissioning does not usually require major replacements or renovations and will be focused on optimizing the function of current systems.

3. ASSUMPTIONS

3.1 Assumption #1: Ventilation systems and steam radiators (envelop heating) will operate following different schedules according to day and night set points. Table 1 below presents an estimated airflow (no TABS documentation is available). Each value is estimated differently based on information available (for example, operator information, nameplate, airflow calculation based on reverse engineering).

3.2 Assumption #2: Adjusting the current South wing (bringing to actual norms and ventilation requirements) ventilation deficiencies was not considered in the calculations. Simulations were made based on actual equipment and operations.

Table 1 - Ventilation Systems General Characteristics

ID	Type	Description	CFM	% Fresh air
AHU-7	Air-handling unit	Fitness room air-handling unit - ventilation system with recovery unit	11,000	10 %
AHU-6	Air make-up unit	B69 air-handling unit - ventilation system glycol water heating	11,000	100 %
AHU-8	Air-handling unit	All building basement air-handling unit - South wing	8,000	20 %
AHU-9	Air-handling unit	2nd floor South wing air-handling unit	3,500	20 %
AHU-RT	Air-handling unit	4th floor South wing air-handling unit - electric heating	2,000 (4x)	10 %
Kitchen hood	Air-handling unit	Kitchen exhaust hood	1,800	0 %

4. PLANNED WORK

Recommissioning scope of work is as follows:

4.1 Recommissioning study to determine present building requirements and sequence operation corrections.

4.2 Review of major control and operation points in accordance with operation strategy (room control, loop control, pump control, etc.).

4.3 Steam and water distribution sequence and temperature adjustment (sequence adjustment considering needs and new requirements).

4.4 Basic electrical work (tune motor and valve controls).

4.5 Implement new room control equipment and strategy for thermostats, valves, air and water control set points, as well as new energy efficiency strategies.

4.6 Yearly maintenance and operation costs of $5,000 must be added to ensure proper function of the new equipment mentioned in the planned work above. These costs will be subtracted from energy savings to accurately represent yearly cost savings for the measure.

The table below presents the UNIFORMAT cost estimate for the specific measure.

Section	Description	Material	Labour	Total
D 3010	<u>*Energy supply*</u> *Investigation of room controls, valves, thermostats, follow-up*	[redacted]		
D 3040	<u>*CVAC Distribution Systems, Ventilation*</u> *Investigation of ventilation units, implementation of corrective measures, follow-up*			
D 3040	<u>*CVAC Distribution Systems, Piping*</u> *Investigation of heating and cooling systems, implementation of corrective measures, follow-up*			
D 3060	<u>*Controls and Instrumentation*</u> *100 pts - Investigation, implementation of corrective measures, follow-up*			
D 5010	<u>*Electrical Services and Distribution*</u>			
	Subtotal mechanical			
	Subtotal electrical			
	Subtotal			
	Design contingencies (25 %)			
	Subtotal			
	Contractor's general conditions (12 %)			
	Subtotal			
	Engineering & PWGSC fees (20 %)			
	Total			

5. <u>IMPACTS ON ENERGY CONSUMPTION AND GHG EMISSIONS</u>

The table below presents the energy and emissions savings that result from the proposed measure.

MES-001	Savings
Annual fossil fuel savings	2 823 GJ
Annual electricity savings	306 GJ
Total annual energy savings	3 128 GJ
<u>Total annual GHG savings</u>	**<u>143 tons</u>**