CARLETON UNIVERSITY **ENERGY MASTER PLAN**

2018-2021

Sustainability
CARLETON UNIVERSITY

Carleton
UNIVERSITY

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OUR JOURNEY

The Carleton University 2018-2021 Energy Master Plan builds on the work and progress the campus has realized as a result of initiatives implemented in its inaugural Energy Master Plan launched in early 2014.

Carleton has had a long-standing commitment to sustainable operations, including recycling, and energy efficient design that date back to the early 1990s. In 2009, the university conducted a pilot project with Green Globes to develop an environmental assessment tool for university campuses. As a result, the Canal Building became a living laboratory with cutting-edge sustainable design features. Engineering students have had the opportunity to use the building for their research to assess green building operation standards.

Over the course of the last three years, Carleton has made tremendous progress in reducing energy and water consumption across campus, incorporating energy efficient designs for new construction, retrofitting existing buildings to decrease energy consumption and creating initiatives to engage our faculty, staff and students in sustainability best practices and research opportunities, as well as implementing green practices in our buildings, including residences.

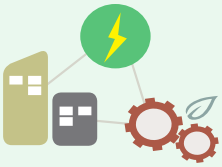
When the university started on this journey, the idea was to implement a three-pronged, campus-wide approach that addresses the facility's condition, energy utilization and improving sustainability ratings. To assist us in this work, Carleton engaged the services of Honeywell which provided its expertise in creating a multi-year, detailed roadmap to improving the efficiency and functionality of all buildings. Comprehensive audits/assessments were conducted to help us establish a list of buildings to be included in the first phase of renewal; the audits identified the buildings which would benefit the most from the renewal efforts.

2.6 Million

2.6 Million kWh
Electricity Reduction

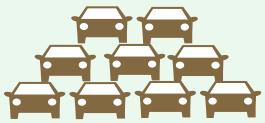
2,004

2,004 Metric tons of CO_2 saved



5

5 building energy retrofits completed



429 Annual Greenhouse Gas emissions from 429 cars

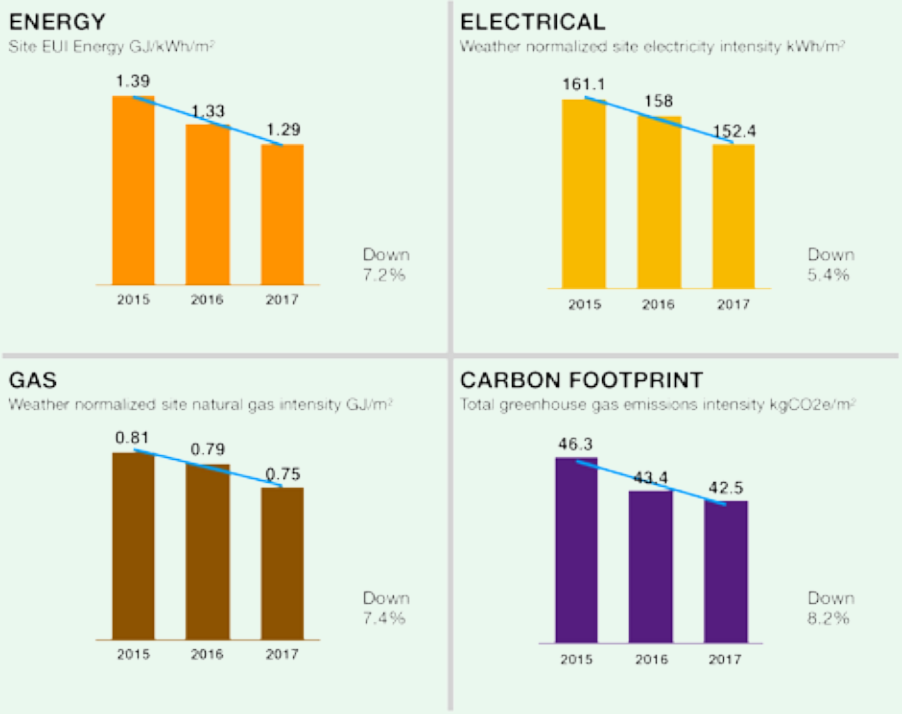
In each building, renewal included: lighting upgrades, new plumbing fixtures to improve water consumption, building envelope improvements and upgrades to the building's heating and cooling systems. The analysis of consumption confirmed marked improvement to making the buildings more efficient.

Overall, the analysis of initiatives carried out over the last three years shows the university has realized continuous improvement in reducing its energy, water, waste and carbon footprint 2015-2017 (inclusive).

25,000 m3

Water reduction

1 Co-generation plant



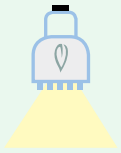
These savings have provided the university with a baseline by which to further develop goals and initiatives for the 2018-2021 Energy Master Plan that also takes into account future campus growth, and the university's priorities as outlined in the Strategic Integrated Plan (SIP), and the Campus Master Plan. The new Energy Master Plan also supports the Carleton University Sustainability Strategic Plan that embeds environmental sustainability in university operations. This Plan is being updated in 2018.

Other achievements (2014 to 2017) include:

- Implementation of the Green Globes rating system, achieving a minimum rating of 3 out of 5 (9 buildings are now certified): New Health Sciences Building has 4 Green Globes rating
- $1-million Green Revolving Fund established: 13 projects funded and over 75 submissions since 2013
- Eco Reps staff and student program established
- Electric Vehicle charging station program established and is expanding
- Development of campus bike share program
- Implementation of Energy Display Screens, showing live energy data
- Improved waste reduction offerings (compostable/single stream collection)
- Research Opportunities for students created in partnership with the Faculty of Engineering (Smart building technology research project expanded to five buildings)
- Carleton Sustainable Energy Research Centre established
- New master's degree in Energy Engineering and Sustainable Energy Master's Policy
- Global Water Institute established and Carleton Jarislowsky Chair in Water and Global Health announced

4.2 Million

4.2 Million lb of steam saved



652,000 kWh LED
replacement energy savings

13 Projects funded through the Green Revolving Fund

9 Green Globe rated buildings on campus.

25%

25% ESAT rating improvement in Athletics

Silver AASHE stars rating

We have learned that "sustainability" and "renewal" are comprehensive terms that reflect work that often intersects and overlaps in our project planning and that of other departments, including Dining Services. Taking this into account, our renewal initiatives are now developed with a holistic approach that includes energy, water, building operations functionality and work environment improvements. We have also integrated a collaborative approach with stakeholders so we are better aware of departmental priorities in advance to ensure our work has the best possible impact on building occupants and users.

In order to measure our progress, Carleton has adopted two tools that help us continuously improve – the STARS (Sustainability Tracking and Assessment Rating System) certification program and Green Globes building assessment. To date, Carleton has achieved Silver Level in the STARS certification program and we have committed to bringing existing buildings up to a minimum three Green Globes rating. The new Health Sciences Building has been rated at four Green Globes and 8 other buildings on campus have at least a 3 out of 5 green globe rating or better.

Green Globe Buildings

- Canal Building – 5 Green Globes
- Frontenac Residence – 3 Green Globes
- Herzberg Laboratory Addition – 4 Green Globes
- Lennox-Addington – 3 Green Globes
- MacOdrum Library – 3 Green Globes
- Residence Commons Addition – 4 Green Globes
- River Building – 4 Green Globes
- Russell-Grenville – 4 Green Globes
- Health Science – 4 Green Globes

We know we are on the right path because Carleton has received national and international recognition for initiatives to make the campus greener in terms of our buildings, our dining services, transportation and our efforts to engage students, faculty and staff. Some of these include:

- Carleton is ranked 33rd globally and 2nd in Canada by UI Green Metric, World University Rankings
- Named one of Sierra Magazine's "Coolest Schools" in 2017
- Fairtrade Campus Certified in 2017
- Zero waste status achieved in University Centre Food Court
- Richcraft Hall winner of the Unique Venues, Best Earth Friendly Venue
- Recipient of the Effective and Innovation Practices Award from the Association of Physical Plant Administrators (APPA)
- Bronze level bicycle friendly business award, Share the Road Cycling coalition

These are just a sample of our achievements and the future looks bright. We have measured our progress from the past to build this new Energy Master Plan for the next three years.

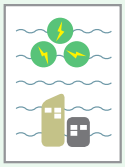
I would like to take this opportunity to thank the Facilities Management and Planning team and Honeywell for the research and work that went into developing the 2018-2021 Energy Master Plan.

I am pleased to present the 2018-2021 Energy Master Plan.

Darryl K. Boyce
Assistant Vice-President (Facilities Management and Planning)

17%

17% projected energy savings from phase 2 of energy retrofits



7

7 building energy retrofits planned

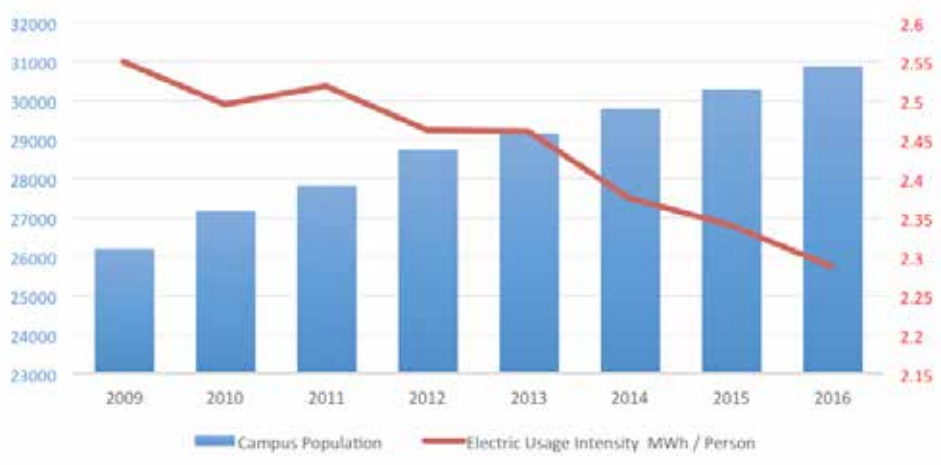
OUR ACCOMPLISHMENTS

UTILITIES VS. CAMPUS GROWTH

The foundation of the first Energy Master Plan was to implement strategies to ensure that everything we do includes measures to save water, energy and reduce the university's carbon footprint. The challenge was to do this while the campus population, as well as its built environment, was growing. Despite this reality, we were successful in making progress and produced reductions in each area.

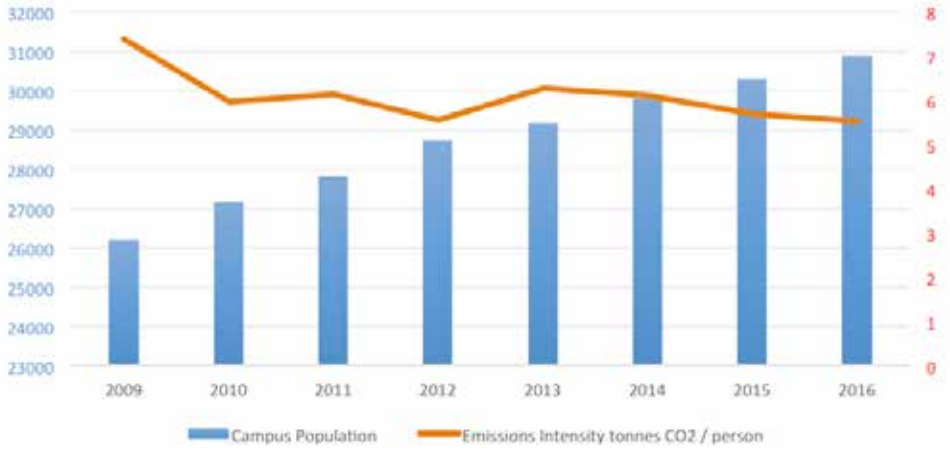
While Figures 1.1, 1.2, and 1.3 take into consideration a longer time frame (2009-2016) than the original Energy Master Plan, it also includes the total annual energy and water consumption for the entire campus population. These figures also include total student enrolment data.

Figure 1.1 - Campus Population Growth vs. Energy Usage Intensity



This highlights that overall campus population has increased since 2009 by 18%, while over the same time frame energy consumption per person has decreased by 11%, from 2.55 MWh/person to 2.29 MWh/person.

Figure 1.2 - Campus Population Growth vs. CO2 Emissions Intensity



The graph above demonstrates the decrease in CO_2 emissions per person of 20% from 2009 to 2016, while the overall campus population growth was 18% for the same time frame.

In Phase 1 of Carleton's building renewal program, five buildings were identified as benefitting most from upgrades to lighting, water measures and electricity. The results of the building renewals are shown below.

1.3 Annual Utility Consumption Savings

Buildings	Electricity (kWh)	Steam (lb)	Natural Gas (m3)	Water (m3)
Robertson	526,503	598,219	-	3,948
Loeb	436,928	388,938	-	9,739
Athletics	335,287	1,755,013	19,076	6,404
Mackenzie	839,430	1,183,680	-	1,464
Minto	555,060	364,538	-	3,692
Totals:	**2,693,208**	**4,290,388**	**19,076**	**25,247**

Overall, the electrical savings shown in table 1.3 is the equivalent of the **annual electricity usage of 300 Canadian homes**[1] and the green house gases savings would be equivalent to **taking 435 cars off the road for every year**.[2]

In addition to these initiatives, the university invested $1.6 million to replace all exterior lighting to brighter, more efficient LED lights. Included in this project was replacement of the lighting in the tunnel system. This initiative will be concluded in 2018 and will save an estimated $115,000 annually.

An example of an operational efficiency project is our steam trap survey inspection program. The last inspection identified faulty steam traps that were leaking steam resulting in an estimated annual loss of $54,000. Including the cost of the inspection and required repair, the payback period of this project was 55 days.

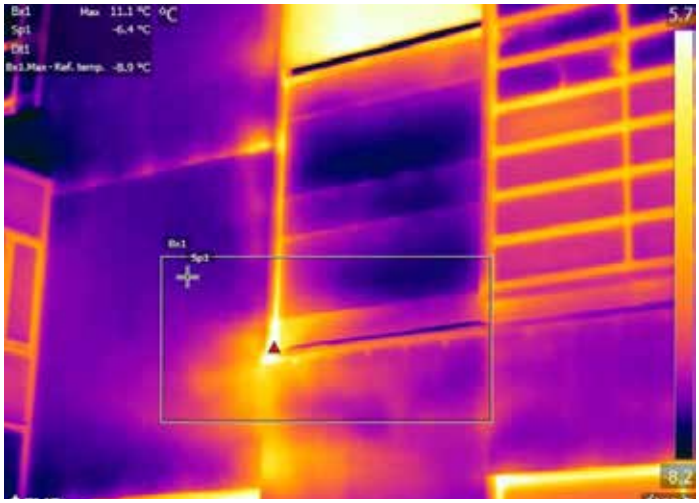
Carleton is using the CopperTree analytics tool that allows the university to optimize the use of data from buildings to improve efficiency. As well, the university also began implementing the ASHRAE BEQ (Building Energy Quotient) that provides a building audit and steps that can be taken to improve its energy rating.

We are also incorporating innovative technologies into our energy analysis, including campus-wide energy metering and the use of infrared thermographic inspections to identify problem areas on building exteriors.

1 Based on Statictics Canada 2015 energy consumption of 92.5 GJ per household

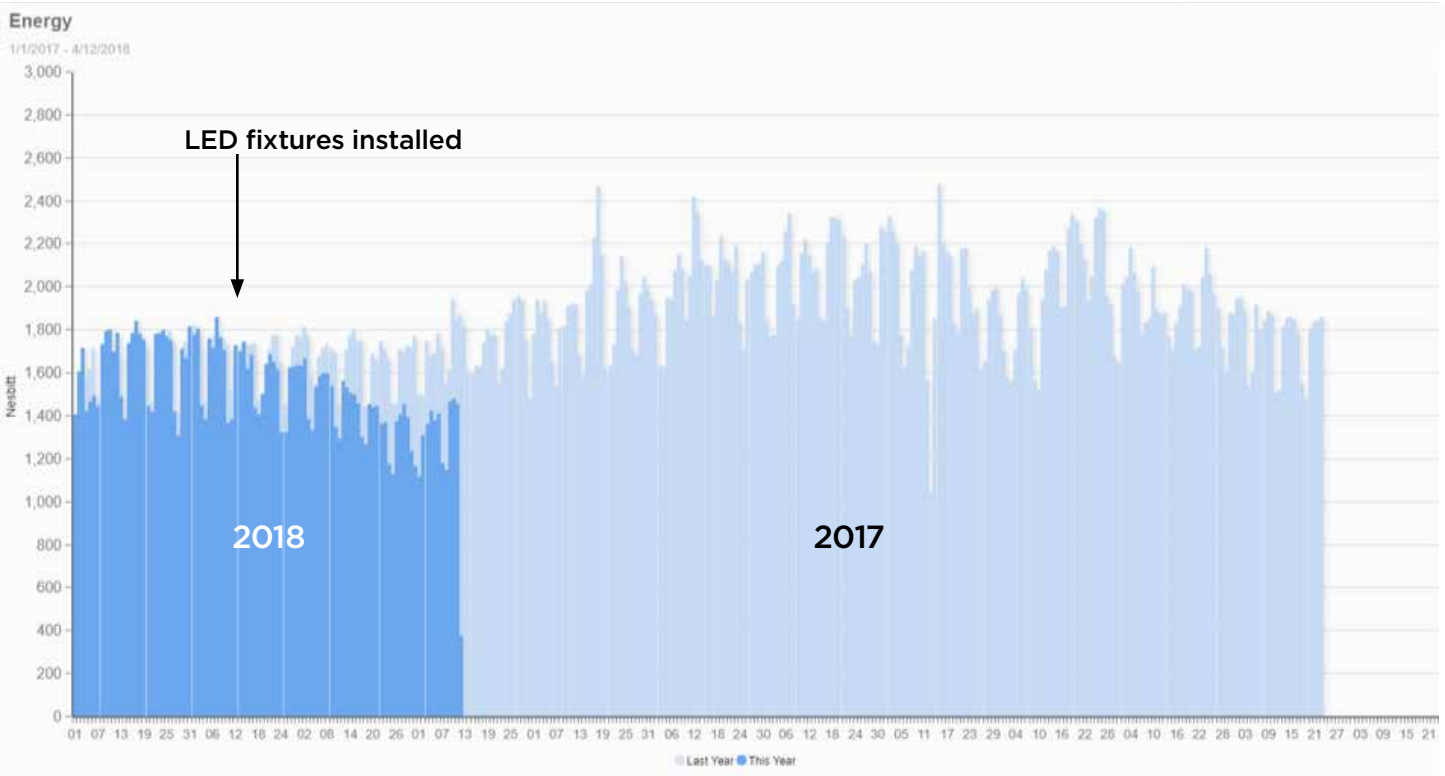
2 Based on US EPA average of 4.6 metric tons of carbon dioxide per year

The thermographic image below is an example which indicates an area where warm air is escaping the building. This allows for a more targeted approach to repairs and upgrades to the building envelope.



The energy metering allows for continuous hourly tracking of a building's energy usage. For example, as part of the energy retrofit work at the Nesbitt Building, all the interior lighting fixtures were replaced. The immediate impact on the energy consumption of the building can be tracked as shown below:

1.4 Data Summary



MOVING FORWARD

The 2018-20121 Energy Master Plan provides a road map for Carleton University's energy and carbon reduction initiatives over the next three years.

This Energy Master Plan is intended to support the Campus Master Plan by providing a detailed analysis of the campus' historical energy and water use, as well as future utility requirements to satisfy the campus' physical development outlined in the Campus Master Plan. This Energy Master Plan also identifies energy and water conservation opportunities in existing buildings to further reduce future energy requirements.

Once the current Campus Master Plan (last updated in 2016) is implemented, the total campus building floor area will grow by 88%, compared to the 2016 base year. The new campus' annual electricity, fuel and water consumption is expected to increase 66%, 61% and 45% respectively, from 2016 base year levels.

As a result of a comprehensive review of utility data, projected campus growth (student and buildings) and in keeping with Carleton University's commitment to achieve overall energy reduction of 2% annually, the following key priorities have been identified for the 2018-2021 Energy Master Plan:

2% Annual energy reduction commitment

1. New Co-generation Energy Plant

This project includes the installation of a 4.6 megawatt natural gas fired turbine which will provide approximately 40% of the campus electrical consumption. The waste heat generated by the turbine will be captured by a heat recovery boiler which will provide steam to the campus and, for most of the year, will replace the university's existing steam boiler system. This will increase the efficiency of steam production for the campus by 7-9% on a higher heating value basis.

During summer months when the campus steam load is reduced, excess steam will be supplied to a new 1,000 tonne absorption chiller which will be tied into the existing chiller plant in the Steacie Building to provide cooling for the surrounding buildings. This new absorption chiller will be the primary source of cooling which will further reduce the campus electrical consumption by allowing the existing electrical chillers to be used as a secondary source.

As well, additional instrumentation will be added to the co-generation plant which will feed live data to a lab within the Faculty of Engineering and Design to offer students new research opportunities.

2. Implement Phase 2 of the Energy Renewal Plan

In Phase 2 of the building renewal program, the university will continue to build on the successes of Phase 1. The data and analysis contained in this report is intended as benchmark for future planning.

Energy conservation efforts offer an opportunity for the university to mitigate future energy requirements and reduce or delay future capital expenditures for building infrastructure renewal and services. Based on the preliminary assessment of the selected facilities, about 17% and 3% reduction of energy and water respectively, is possible.

An in-depth analysis of water and energy consumption influenced which buildings were identified for renewal in the 2018-2021 Energy Master Plan.

3. **Develop an ongoing program to increase operational efficiency**

   Significant energy savings can be realized through the operational optimization of our existing systems and equipment. This optimization will include the commissioning of new/renovation building projects, ongoing preventative maintenance program and operation adjustments to reduce energy consumption.

4. **Completion of LED lighting replacement (all exterior lights and tunnel lighting)**

   All exterior light fixtures, including parking lots, roadways, pathways and tunnels, were replaced with more energy efficient LEDs. This project will provide an annual savings of 652,000 kWh. With funding with the Green Revolving Fund, a $1-million initiative to engage our campus community to bring forward ideas that will make our campus more sustainable, tunnel lighting was also upgraded. The overall LED lighting project will save the equivalent CO_2 emissions from 53 homes energy for one year and annual cost savings of an estimated $115,000.

5. **Update and operationalize the Sustainability Strategic Plan: In Progress**

   The updated Sustainability Strategic Plan will provide a road map for Carleton and outline concrete steps to reduce the university's environmental impact. With an eye towards the future, the plan will provide guidance and focus for the many sustainability initiatives already happening on campus, as well as those still in the planning stages. The new plan includes actions to enhance sustainable travel, will link to our work to manage energy use and other resources, will provide actions towards sustainable procurement and wider engagement on our campus.

6. **Increase research opportunities**

   Building on Phase 1, this next Energy Master Plan incorporates opportunities on all fronts to provide Carleton students with research opportunities. The new Co-generation plant will be outfitted with a live data feed to the Faculty of Engineering and Design and ongoing research will be conducted within the Canal Building, as a few examples. Over the next three years, engaging our students and offering them the chance to conduct research linked to sustainability will continue to be part of our action planning.

7. Introduce Green Engagement Fund (expansion of existing $1-million Green Revolving Fund)

The Green Revolving Fund was created to build upon our culture of sustainability and to allow us to better embrace innovation and thinking outside of normal boundaries. The Green Revolving Fund is a $1-million investment in sustainability-related projects across campus, which are suggested by our wider community, including staff, faculty and students. The extension of this program to include an Engagement Fund will allow for smaller projects and ideas, which don't necessarily have a payback but would benefit the campus, to be implemented. The main criteria for projects will be to undertake initiatives and ideas with positive environmental impacts to engage the community to embrace carbon reduction actions.

8. Exploring partnerships with the private sector to act as a demonstration host for emerging technologies

Carleton University will continue to seek out partnerships in this field. We are known for our ability to form collaborations between our cutting-edge researchers and the private sector. The Energy Master Plan allows for these activies to continue and flourish.

9. Expand access to energy data, including expansion of energy display screens at key campus locations

Carleton has a number of existing energy display screens on campus which allows for real time energy data to be presented. The focus has been on residence buildings and our student population living on campus, where during focused engagement weeks we have seen reduction of up to 10% on baseline electricity performance due to increased awareness. The expansion of this program will allow for additional screens across campus which will link to energy and water data, waste and recycling information, events and ideas for carbon reduction.

10. Ensure that Energy Master Plan takes into account plans for the future growth of the campus as outlined in the Campus Master Plan

The Campus Master Plan outlines a long-term vision for the development of the campus. This road map for the future will be consulted throughout the implementation of the Energy Master Plan to ensure that planning reflects future growth and development across the campus.

Future energy requirements to support campus expansion were considered (refer to Section 4). These requirements were calculated based on the assumption that all new buildings will be designed and operated to achieve a minimum rating of 3 Green Globes as defined by the Green Building Initiative.

The analysis that supports the 2018-2021 Energy Master Plan is included in Sections 3 and 4 of this document.

BUILDINGS RENEWAL PLAN – PHASE 2

The seven facilities listed in the table below have been identified for Phase 2 building energy conservation projects. These have the potential to create approximately $581,000 in annual utility savings. In early 2018, work began in the Nesbitt Building.

Phase 2.1 Opportunities

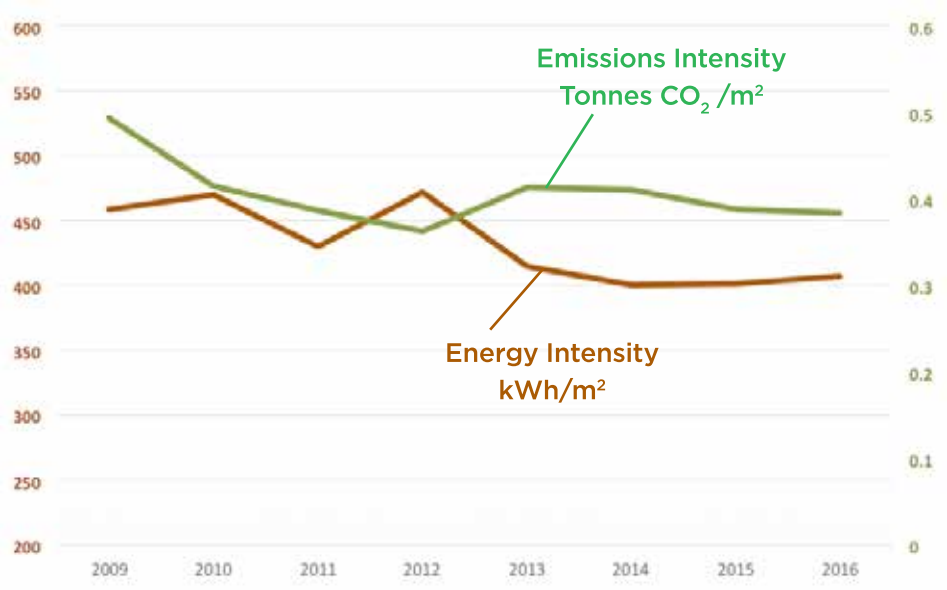
Building	Electicity kWh	Steam Lbs	Water m3	Total Savings	Percentage Reduction	GHG Reduction eCO2 t/yr
University Centre	656,070	1,390,183	10,315	164,365	23%	119
Nesbitt Building	156,823	2,558,018	880	68,927	31%	176
St. Patrick's	218,092	107,322	2,035	50,489	8%	19
Tory Building	381,367	475,897	5,871	92,599	13%	50
Dunton Tower	490,125	786,695	186	119,542	24%	76
Southam Hall	385,195	1,559,834	2,357	85,131	30%	74
Maintenance Building	60,705	456,000	0	16,825	6%	32

UTILITY ANALYSIS

The Utility Analysis contained in this section is a detailed examination of the data that supports the goals identified in the 2018-2021 Energy Master Plan.

Utility data that has been compiled, reviewed and analyzed includes campus utility bills for the period between January 2009 and December 2016. In addition, sub-metered utility data for individual campus buildings was also reviewed and analyzed for the 2009 to 2016 calendar years. The results of this analysis are presented in this report. The energy performance trends identified in the analysis are summarized below and demonstrate the impact resulting from the university's commitment to reduce the energy and greenhouse gas footprint, while facing a continuously developing campus and increased population growth.

Figure 3.1 – Carleton University Campus Energy Performance Indices



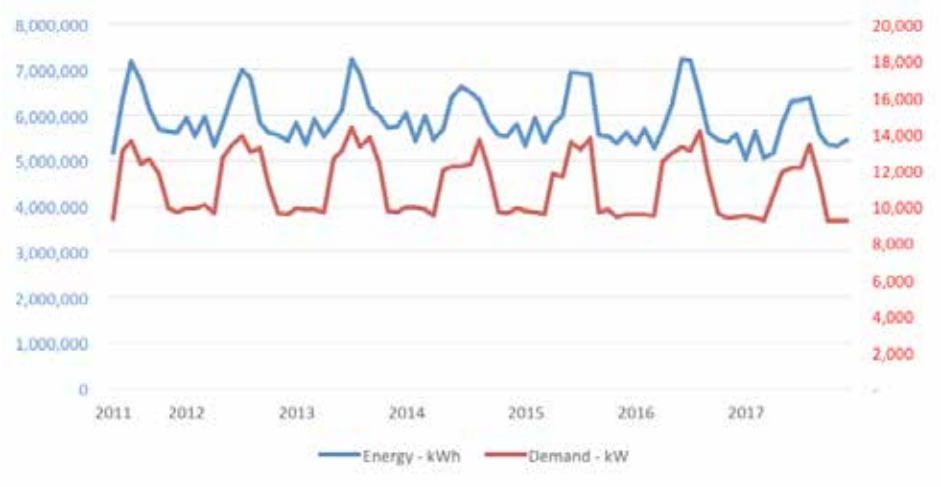
UTILITY ANALYSIS

ELECTRICITY

An electric meter measures three feeds of electricity consumption for the entire university campus, which is further sub-metered at the building level.

The historic trend of campus energy and peak demand in Figure 3.2 shows a large base load: energy = 5,200,000 kWh/month and peak monthly demand = 11,000 kW and a characteristic summer cooling component.

Figure 3.2 – Campus Electrical Consumption and Peak Demand



NATURAL GAS

Several meters measure natural gas consumption on campus. For the purpose of this report, campus gas consumption has been divided into 2 categories:

1. **Central Heating Plant (CHP) gas – natural gas consumed in the CHP.**
   The CHP supplies steam to the majority of the buildings on campus. This is the largest gas account in terms of volume. The historic trend of CHP gas used on campus is shown in Figure 3.3 and indicates a base load of about 200,000 m3 and a characteristic winter heating component.

2. **Other gas – natural gas consumed in the individual buildings**
   The historic trend of other gas use on campus is shown in Figure 3.4 for the years 2009-2016 and indicates a base load of about 17,000 m3 and a characteristic winter heating component. Partial consumption data was available for 2012; hence the trend displays an abnormal consumption profile.

Figure 3.3 - Campus CHP Natural Gas Consumption

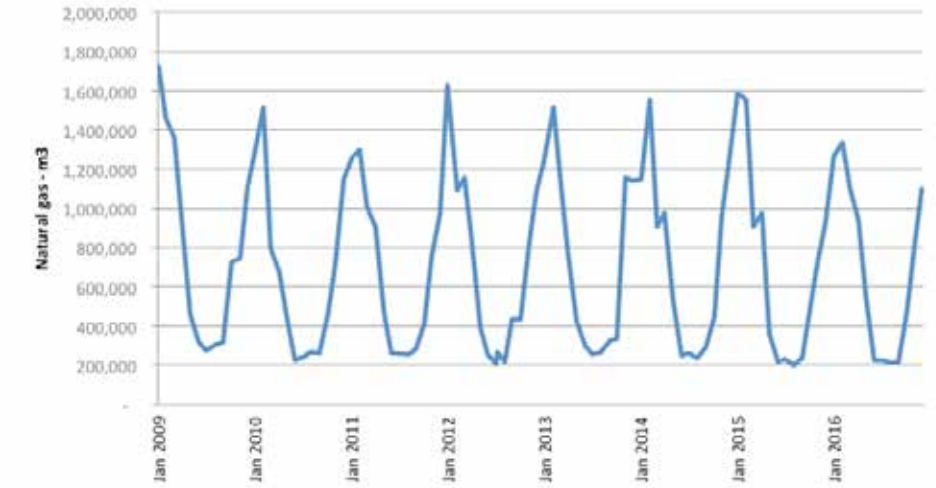
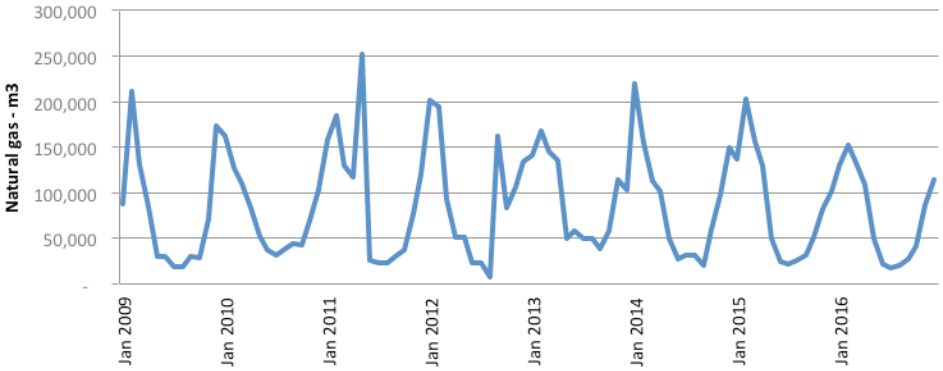


Figure 3.4 - Other Natural Gas Consumption



WATER

Three meters measure total water consumption on campus. For the purpose of this report, the data has been consolidated to reflect the entire campus' use. The historic trend of campus water use shown in Figure 3.5 indicates a relatively constant consumption of approximately 35,000 m^3/month up to May 2010 and again from March to December 2016. In the period between these dates, the campus water consumption pattern was skewed by a series of meter reading errors. A metering issue regarding water consumption was identified and resolved in 2015, which resulted in ongoing consumption misreadings throughout 2014 and 2015 and possibly prior. This has been resolved with Carleton's operations team and the City of Ottawa.

Figure 3.5 - Campus Water Consumption

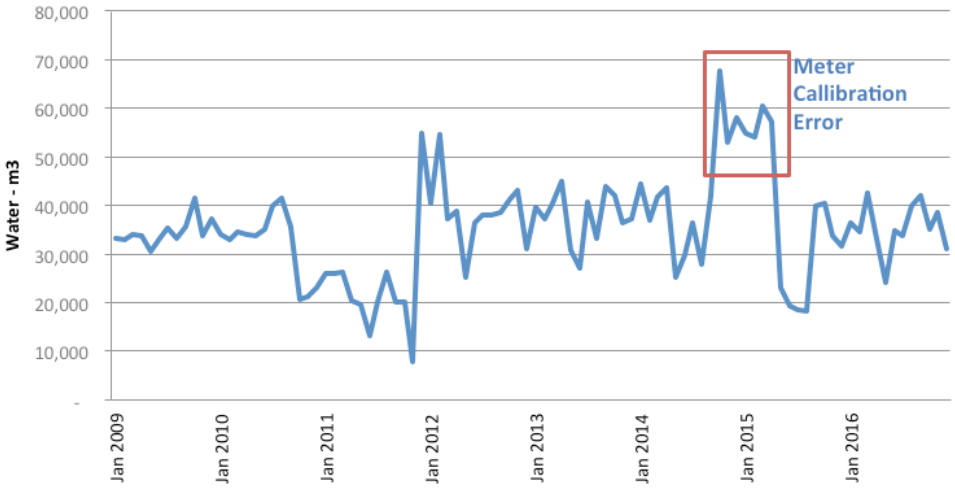


Figure 3.6 - Utility Energy Breakout

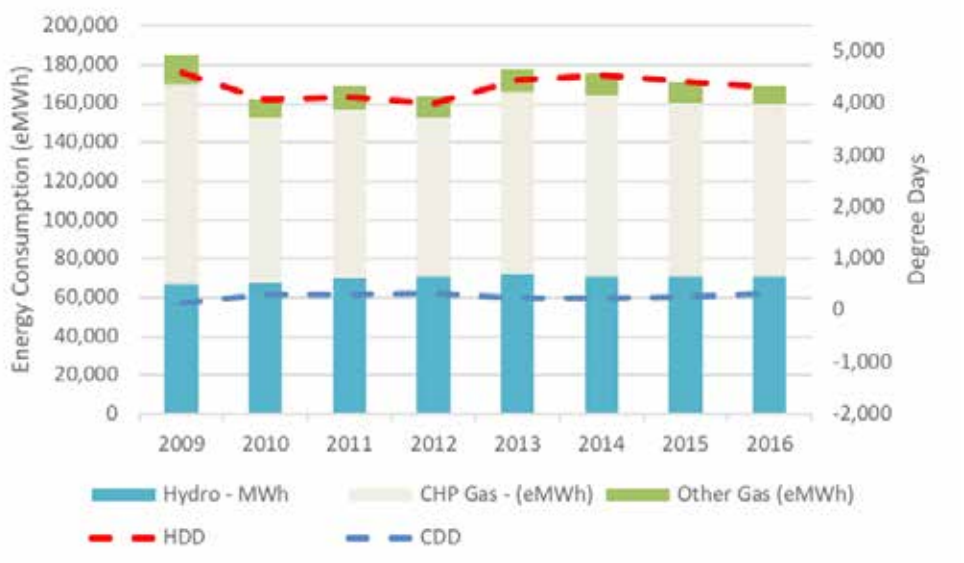


Table 3.7 – Utilities vs. Campus Growth

Year	2009	2010	2011	2012	2013	2014	2015	2016
Energy Indices								
EUI (ekWh/ft²)	42.6	38.5	35.7	43.8	37.3	36.8	35.9	35.5
EUI[1] (ekWh/ft²)	42.6	43.7	40.0	43.8	38.6	37.3	37.4	37.9
EUI (ekWh/ Person)	6.9	6.2	6.2	7.1	6.2	6.0	5.8	5.6
HDD	4,605	4,063	4,112	4,004	4,447	4,546	4,428	4,320
CDD	146	308	301	345	247	229	252	340
Water Indices								
WUI (10 x m³/m²)	10.6	9.9	6.4	10.5	10.2	11.4	10.2	9.6
WUI (m³/person)	15.9	14.7	10.3	16.6	15.8	17.4	15.1	14.1
Utilities								
Hydro - MWh	66,766	67,773	70,090	70,744	71,787	70,798	70,922	70,636
Hydro - kW (peak)	12,535	12,867	13,596	13,854	14,313	13,656	13,748	14,141
CHP Gas (100xm³)	96,601	79,891	81,177	77,035	88,346	87,874	84,240	83,864
CHP Oil (l)	0	0	325,977	6,792	517,663	924,708	0	231,560
Gas (100xm³)	9,091	8,997	11,716	10,251	11,066	10,488	10,083	8,958
Water (10xm³)	41,433	38,599	27,970	46,198	45,320	50,598	45,094	42,580
Building Data								
Total bldg. area (m²)	391,492	391,492	440,097	440,097	442,985	442,985	442,985	442,95
Student Population								
Students	24,295	25,262	25,893	26,773	27,212	27,824	28,289	28,845
Faculty	833	849	861	875	859	869	878	893
Staff	1,057	1,052	1,073	1,083	1,090	1,103	1,128	1,137

1 EUI shown is weather Normalized to 2009 base energy consumption for annual performance comparison

For the period between 2009 and 2016, the total building floor area increased from 391,492 m^2 to 442,985 m^2 and full- and part-time student enrolment increased from 24,295 to 28,845. In this comparison, the weather sensitive factors affecting electricity and gas consumption patterns are somewhat muted except for the sharp drop in CHP gas consumption from 2009 to 2010 due to a warm winter in 2010. This is shown in Figure 3.6. The upward trend in energy and water consumption was expected due to the internal load growth, increase in student enrolment and the addition of new campus buildings.

ENERGY AND WATER SUB-METERING

The majority of buildings on campus are equipped with the following types of sub-meters:

Electricity – measures individual building energy consumption in kWh

Steam – measures individual building steam or medium temperature hot water (MTHW) consumption in klbs (of steam)

Natural gas – measures individual building gas consumption in m^3 (these are Enbridge gas meters, see Utility Map Tables 3.10, 3.11 and 3.12)

Water – measures individual building water consumption in m^3

Chilled water – measures individual building cooling energy consumption in kBtu (1000 Btu).

Sub-metered energy and water use data for individual buildings between 2009 and 2016 are summarized in Tables 3.10, 3.11 and 3.12 respectively. The deviations in energy and water use between the actual utility bills and the sub-meter data are noted below:

Electric sub-meters

Total billed electricity consumption on campus was 10% and 11% higher in 2009 and 2012 respectively, compared to the total individual building electrical sub-meter readings for these years. In 2016, an issue with the phasing of the electrical sub-meter serving the Residence Commons building was discovered and corrected. The resulting effect improved the sub-meter discrepancy from the main utility account to 5%.

The following non-metered electrical loads may account for the remaining deviations:

- Campus street and parking area lights
- Tunnel lights
- Sports field lights
- Grounds Building
- Bronson Sub-station
- Accuracy of building electric sub-meters:
  - Depends on the meter class and typically ranges between +/- 0.5% accuracy for Class .5 meters to +/- 0.2% accuracy for Class .2 meters (as per ANSI C12.2 Standard)

Steam/MTHW sub-meters (CHP gas)

Individual building sub-meters measure thermal energy consumption expressed in klbs (1000 pounds) of steam. Conversion of natural gas input to CHP steam output was necessary to facilitate a comparison. For the purpose of this analysis, the following assumptions and conversion factors have been used:

- CHP seasonal plant efficiency = 70%
- Steam consumed within CHP = 15% of total steam output
- 1 m^3 of natural gas = 0.03584 MMBtu
- 1 klbs of steam = 1 MMBtu

Total steam/MTHW use in individual buildings had a high correlation with the total billed natural gas consumption at the CHP. However, a growing disparity is developing with - 0.1%, 2.5% & 9.2% deviations in 2009, 2012 and 2016, respectively.

Other Gas

Campus total billed “other gas” consumption was 18.4%, 6.8% and 33% lower in 2009, 2012, and 2016 respectively, as compared to the total individual building gas sub-meter readings for these years. These deviations may be due to billing estimates and subsequent corrections by Enbridge.

Water

Campus total billed water consumption was 7.2%, 3.9%, and 9.5% lower in 2009, 2012, and 2016 respectively, as compared to the total individual building water sub-meter readings for these years. These deviations may be attributed to water sub-meter inaccuracies.

Chilled water

Some of the university buildings, which do not have their own cooling plants, are equipped with the chilled water meters. These meters measure the supplied cooling energy by electric chillers located in the nearby buildings. The consumption of electricity and steam is captured by the electricity and steam sub-meters of the chiller plant host.

Figure 3.8 – Weather Normalized Annual Energy Index by Building

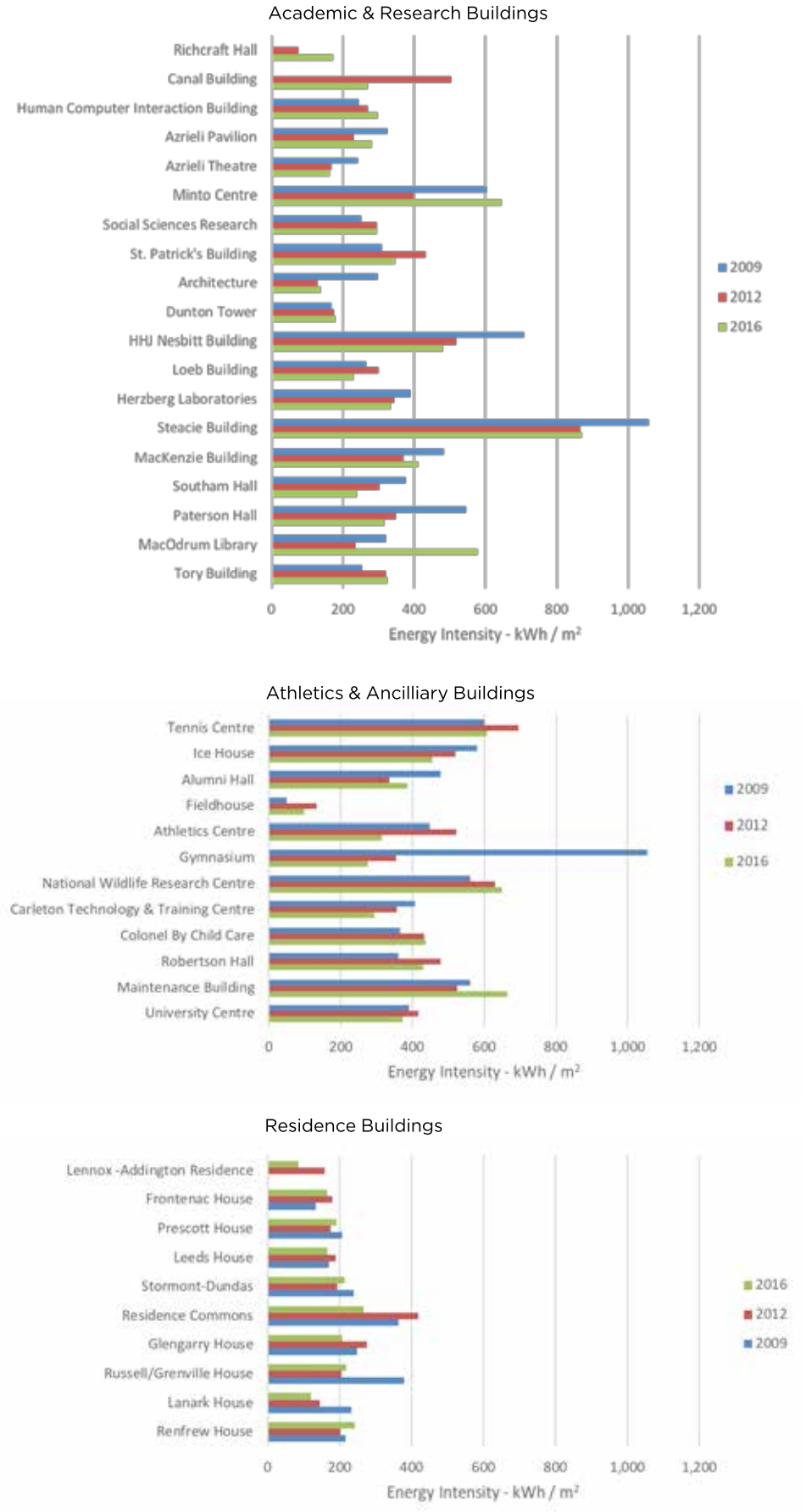


Figure 3.9 –Annual Water Use Index by Building

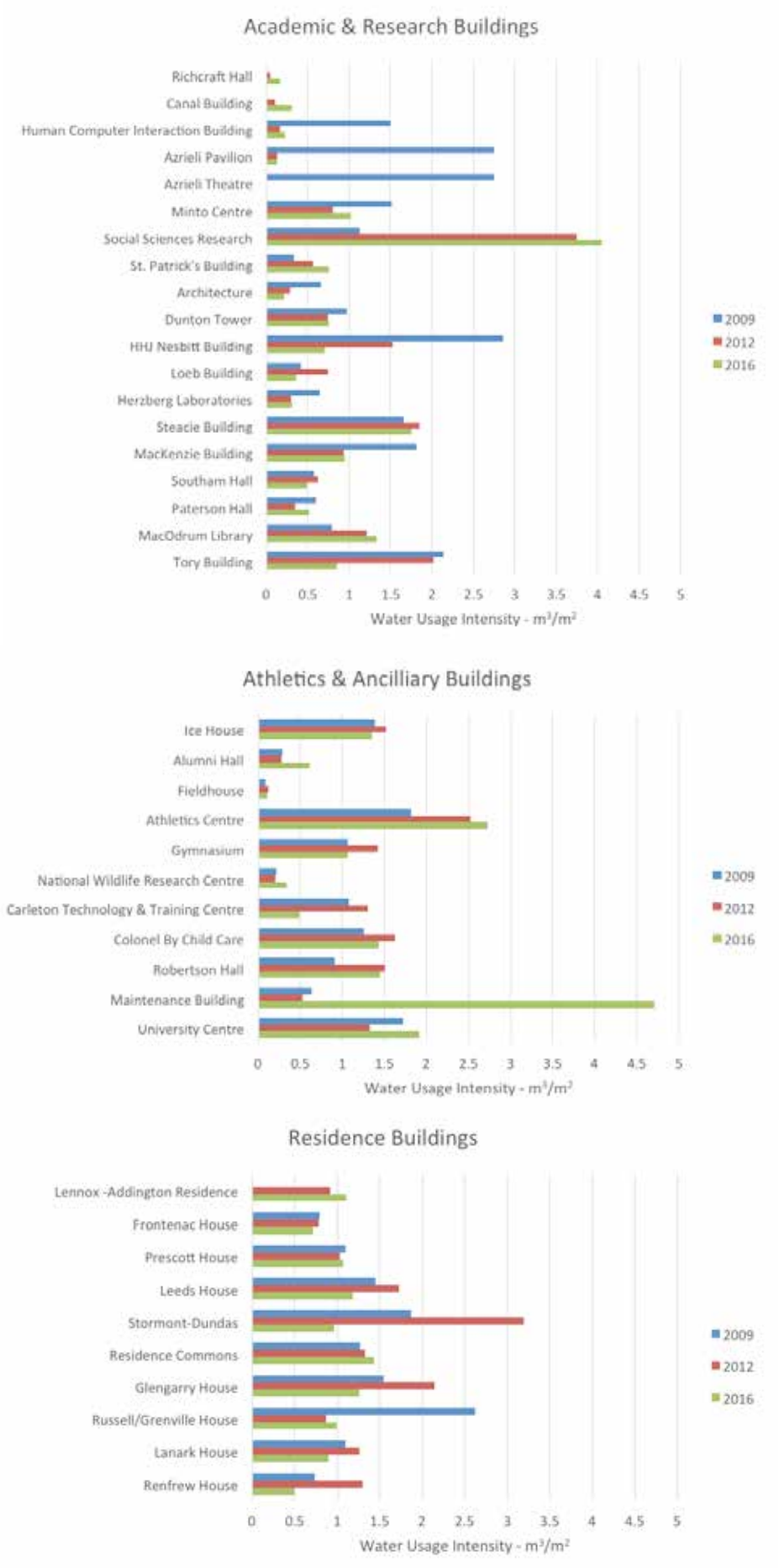


Table 3.10 – 2009 Building Energy and Water Use – Sub-meters

Bldg.	Building Name	EXISTING USAGE			
Code		Electricity	Steam - MTHW	Natural Gas	Water
#		kWh	MMBtu	m3	m^3
1	Tory Building	2,141,450	3,069	20,803	27,414
2	MacOdrum Library	4,085,033	6,785	0	15,085
3	Paterson Hall	1,047,456	10,257	0	4,478
4	Southam Hall	1,468,491	6,875	0	5,324
5	Renfrew House	247,716	2,774	0	3,596
6	Lanark House	213,032	3,042	0	5,235
7	University Centre	3,321,228	8,073	71,175	28,406
8	Gymnasium	578,196	0	210,392	2,776
9	Physical Rec Centre	1,803,356	11,103	13,655	21,107
10	Mackenzie Building	4,520,439	13,307	66	31,763
11	Maintenance Building	1,117,560	3,881	3,019	2,580
12	Steacie Building	3,317,104	24,546	384	16,443
13	Herzberg Laboratories	3,133,139	8,136	0	9,121
14	Russell/Grenville House	562,955	9,606	0	23,347
15	Loeb Building	3,229,891	8,722	10,383	9,205
16	HHJ Nesbitt Biology	1,079,573	11,578	0	18,100
17	Robertson Hall	1,887,744	4,216	0	7,831
18	Glengarry House	1,495,861	7,041	0	22,232
19	Residence Commons	1,856,258	12,262	75,757	21,856
21	Dunton Tower	1,643,380	4,276	0	16,707
22	Architecture	776,703	5,915	5,830	5,645
23	St. Patrick's Building	1,077,700	1,994	48,057	2,400
24	Social Sciences Research	145,563	0	18,250	1,500
25	Life Sciences Research	1,184,022	5,761	0	5,000
26	Stormont-Dundas	1,123,563	5,214	0	20,479
27	Minto Centre	3,601,736	8,913	0	15,538
28	Colonel By Child Care	75,147	0	11,240	657
29	Carleton Technology	1,481,882	3,777	0	6,814
30	Leeds House	1,272,607	0	135,063	22,742
31	Azrieli Theatre	520,943	1,108	0	9,670
32	Azrieli Pavilion	1,036,309	1,557	0	12,673
33	National Wildlife Research Centre	2,226,052	3,079	0	1,168
34	Prescott House	1,243,890	4,324	7,757	13,773
35	Fieldhouse	90,875	0	13,011	384
36	Alumni Hall	1,115,376	1,892	0	1,009
37/38	Human Computer Int. & Visual	1,588,677	2,090	0	13,542
39	Ice House	2,312,785	0	296,135	12,910
40	Tennis Centre	258,325	0	168,951	1,500
41	Frontenac House	718,098	1,122	4,345	6,464
	2009 Total	**60,600,115**	**206,295**	**1,114,273**	**446,474**
Actual consumption from 2009 bills		**66,765,583**	**206,000**	**909,062**	**414,331**
% deviation Actual vs. Submetered		**10.2%**	**-0.1%**	**-18.4%**	**-7.2%**

Table 3.11 – 2012 Building Energy and Water Use – Sub-meters

Bldg.	Building Name	EXISTING USAGE			
Code		Electricity	Steam - MTHW	Natural Gas	Water
#		kWh	MMBtu	m3	m^3
1	Tory Building	2,753,123	3,613	28,757	25,854
2	MacOdrum Library	2,750,652	5,846	0	22,943
3	Paterson Hall	672,855	6,528	0	2,567
4	Southam Hall	1,275,616	5,162	0	5,817
5	Renfrew House	255,607	2,524	0	6,344
6	Lanark House	208,350	1,649	0	6,021
7	University Centre	3,281,840	6,208	168,723	21,846
8	Gymnasium	251,157	0	64,993	3,712
9	Physical Rec Centre	1,572,976	8,380	14,797	29,258
10	Mackenzie Building	3,762,182	9,221	39	16,437
11	Maintenance Building	1,925,540	526	5,031	2,126
12	Steacie Building	2,989,160	19,148	259	18,389
13	Herzberg Laboratories	2,910,217	6,708	0	4,259
14	Russell/Grenville House	537,152	4,390	0	7,744
15	Loeb Building	3,720,466	9,749	8,237	16,524
16	HHJ Nesbitt Biology	732,153	8,683	0	9,640
17	Robertson Hall	2,927,808	4,153	0	13,056
18	Glengarry House	1,609,802	8,032	0	30,821
19	Residence Commons	1,372,519	16,383	99,337	22,751
21	Dunton Tower	1,882,556	3,804	0	12,834
22	Architecture	565,793	1,617	6,695	2,453
23	St. Patrick's Building	1,607,684	2,517	66,099	3,963
24	Social Sciences Research	141,927	0	24,273	10,658
25	Life Sciences Research	1,169,991	4,602	0	14,438
26	Stormont-Dundas	960,943	3,941	0	35,091
27	Minto Centre	3,646,516	1,543	0	8,229
28	Colonel By Child Care	72,710	0	14,964	855
29	Carleton Technology	1,323,426	3,231	0	8,308
30	Leeds House	1,283,503	0	162,773	27,167
31	Azrieli Theatre	419,737	584	0	10
32	Azrieli Pavilion	900,469	559	0	587
33	National Wildlife Research Centre	2,492,752	3,497	0	1,120
34	Prescott House	1,208,162	3,024	8,339	12,865
35	Fieldhouse	268,833	0	30,635	540
36	Alumni Hall	811,009	1,229	0	961
37/38	Human Computer Int. & Visual	1,825,421	2,124	0	1,528
39	Ice House	2,810,525	0	194,978	14,098
40	Tennis Centre	299,166	0	195,162	0
41	Frontenac House	667,700	2,633	1,765	6,407
42	Canal Building	1,779,784	9,367	0	1,020
43	River Building	776,977	1,668	0	851
44	New Residence	969,300	5,099	4,139	14,527
	2012 Total	**63,394,055**	**177,941**	**1,099,995**	**444,621**
Actual consumption from 2012 bills		**70,744,261**	**182,217**	**1,025,132**	**461,981**
% deviation Actual vs. Submetered		**11.6%**	**2.4%**	**-6.8%**	**3.9%**

Table 3.12 – 2016 Building Energy and Water Use – Sub-meters

Bldg.	Building Name	EXISTING USAGE			
Code		Electricity	Steam - MTHW	Natural Gas	Water
#		kWh	MMBtu	m3	m^3
1	Tory Building	2,708,000	4,194	18,998	10,891
2	MacOdrum Library	4,585,880	27,958	0	25,224
3	Paterson Hall	702,413	5,735	0	3,862
4	Southam Hall	994,168	3,226	0	4,532
5	Renfrew House	205,371	3,174	0	2,440
6	Lanark House	187,011	1,257	0	4,284
7	University Centre	3,028,813	7,239	69,996	31,486
8	Gymnasium	129,995	0	45,526	2,784
9	Physical Rec Centre	1,381,818	6,709	12,609	31,741
10	Mackenzie Building	3,659,449	11,614	9	16,514
11	Maintenance Building	2,963,200	2,250	11,931	19,171
12	Steacie Building	3,094,436	19,330	126	17,497
13	Herzberg Laboratories	2,576,406	6,279	0	4,365
14	Russell/Grenville House	554,755	4,803	0	8,871
15	Loeb Building	2,918,057	4,506	6,119	7,883
16	HHJ Nesbitt Biology	642,869	7,886	0	4,489
17	Robertson Hall	2,699,771	2,719	0	12,533
18	Glengarry House	1,578,087	4,627	0	18,133
19	Residence Commons	2,683,642	8,403	74,464	24,588
21	Dunton Tower	1,693,173	4,142	0	13,070
22	Architecture	516,245	1,888	5,656	1,879
23	St. Patrick's Building	1,353,865	2,158	17,965	5,273
24	Social Sciences Research	123,120	0	24,367	5,400
25	Life Sciences Research	1,170,536	5,437	0	4,426
26	Stormont-Dundas	928,827	4,767	0	10,586
27	Minto Centre	3,494,735	10,145	0	10,464
28	Colonel By Child Care	79,656	0	15,136	754
29	Carleton Technology	1,179,263	1,868	0	3,107
30	Leeds House	1,222,649	0	127,696	18,529
31	Azrieli Theatre	427,460	521	0	3
32	Azrieli Pavilion	834,382	1,341	0	597
33	National Wildlife Research Centre	2,714,832	3,834	0	1,868
34	Prescott House	1,165,871	3,929	3,424	13,437
35	Fieldhouse	297,031	0	15,800	458
36	Alumni Hall	1,410,461	1,416	11,332	2,138
37/38	Human Computer Int. & Visual	2,038,696	2,914	0	2,077
39	Ice House	3,246,544	0	136,579	12,579
40	Tennis Centre	313,602	0	166,835	0
41	Frontenac House	692,286	2,311	1,615	5,843
42	Canal Building	1,954,273	2,169	0	2,806
43	Richcraft Hall	2,884,868	7,220	0	2,920
44	Lennox Building	1,050,300	7,099	4,048	17,505
	HS Building	712,260	1,800	0	1,800
	OCTranspo	18,720	0	0	0
	Parking	556,518	0	0	0
	2016 Total	**69,374,311**	**196,867**	**770,231**	**388,807**
Actual consumption from 2016 bills		**70,636.276**	**178,839**	**1,025,132**	**425,796**
% deviation Actual vs. Submetered		**0.1%**	**-9.2%**	**33.1%**	**9.5%**

UTILITY DATA MANAGEMENT

Over the years, the university has made great progress monitoring, collecting and managing energy and water data for the entire campus and individual campus buildings. Since 2014, virtually all campus buildings are equipped with energy (electricity, steam, natural gas) and water sub-meters.

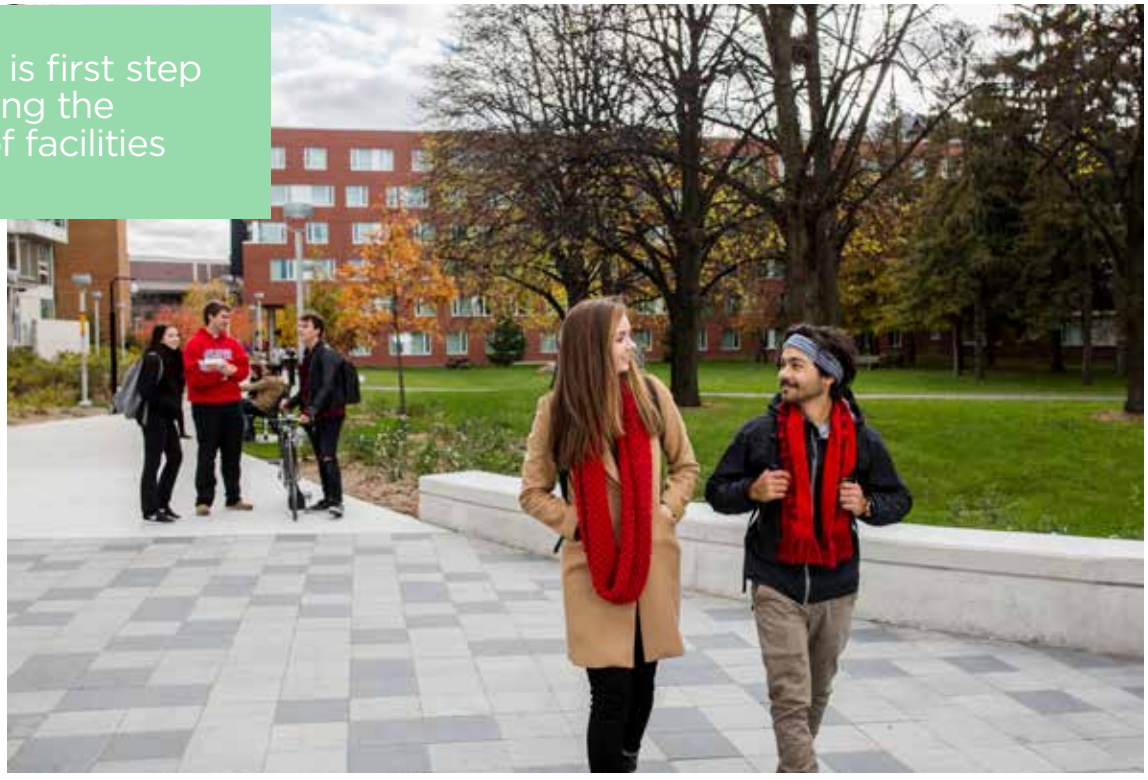
The data captured from both building sub-meters (electricity, steam, water) and individual building gas bills for each budget year is logged, managed and archived in spreadsheets for both “Ancillary” and “Non-Ancillary” facilities. The university has used this data to forecast energy budgets and facilitate utility cost-recovery from various tenants and/or departments. This data was also used for the building energy and water use summaries shown in Tables 3.10, 3.11 and 3.12.

Capturing building operating data is the first step toward improving the management of the university’s campus facilities. Analysis of this data and follow-up actions are foundational in driving operational excellence.

RECENT SUCCESS AND POTENTIAL OPPORTUNITIES

Carleton has successfully undertaken full building retrofits in the ongoing effort to reduce the overall energy consumption and greenhouse gas emissions. These retrofit projects leverage energy savings and provide the opportunity to complete additional renewal services in the effort to improve the built environment for faculty, students and staff as the campus continues to evolve.

Capturing data is first step toward improving the management of facilities



Specifically, in 2016 Carleton University completed major energy conservation projects at eight of its buildings. These projects will reduce the electrical consumption by over 930,000 kWh. The completed projects consisted of lighting upgrades replacing fluorescent fixtures with LED, the installation of variable speed drives on fans, the implementation of computer sleep-mode software.

Figure 3.13 Carleton Energy Full Building Retrofit Success and Potential

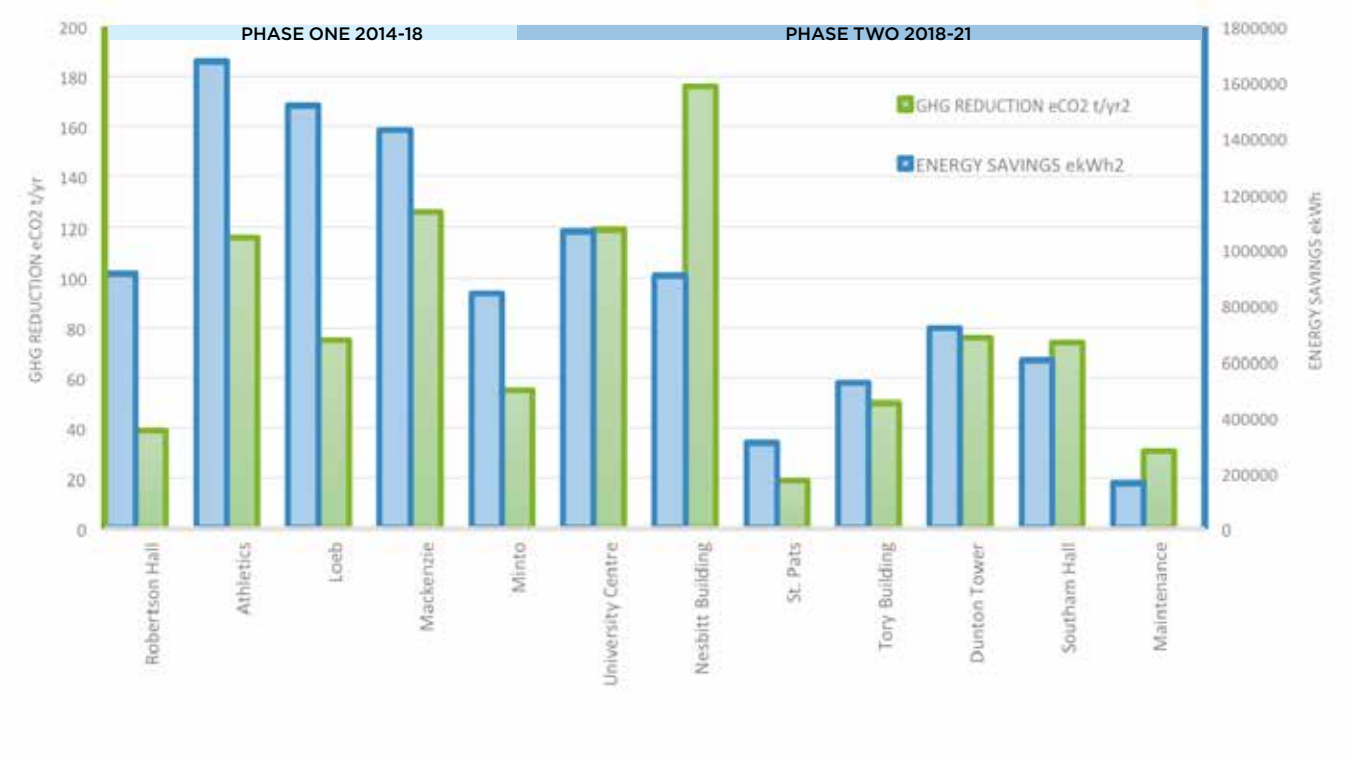


Photo: Doublespace Photography

CAMPUS MASTER PLAN AND FUTURE ENERGY REQUIREMENTS

OVERVIEW

This Energy Master Plan is intended to support the Campus Master Plan by providing a detailed analysis of campus historical energy and water use, as well as fanalyzing future utility requirements to satisfy physical development. The Energy Master Plan also identifies energy and water conservation opportunities in existing buildings to further reduce future energy requirements.

CAMPUS MASTER PLAN

The Campus Master Plan describes the future physical development of the campus. It addresses the location and size of the buildings and general use. This document, which is reviewed and updated every five years, does not provide a timeline for the campus development since it is understood that the progress of the planned development has many dependencies, including the availability of funding.

- Figure 4.1 shows the existing building stock and future development oulined in the Campus Master Plan.
- Figure 4.2 shows the campus key map with the new building statistics.

The current plan calls for construction of new buildings with a total floor area of 430,972 m^2. Under this plan, 42,921 m^2 of the existing building stock will be demolished and the net campus growth will be from 442,220 m^2 to 830,271 m^2

Figure 4.1 – Carleton University Campus Master Site Plan

Figure 4.2 – Key Map for New Buildings Statistics

CAMPUS ENERGY BENCHMARKS

For the purpose of this analysis, the principles of energy benchmarking to predict future energy and water requirements for new facilities developed under the 2016 Campus Master Plan have been used.

Table 4.3 provides a summary of energy and water use benchmarks for the existing campus building stock organized by building type and based on 2016 data.

Average, maximum and minimum performance benchmarks were used to calculate energy and water use for the following building types:

- Academic
- Research
- Athletics
- Ancillary
- Residences

Table 4.3 - Energy Performance Benchmarks - Existing Building Stock

Building Name	Building Type	Area/ft^2
MacOdrum Library	Academic	204,177
Mackenzie Building	Academic	188,095
Loeb Building	Academic	238,375
Nesbitt Building	Academic	68,030
Dunton Tower	Academic	184,876
Architecture	Academic	92,723
St. Patrick's Building	Academic	75,490
Minto Centre	Academic	110,624
Azrieli Theatre	Academic	37,783
Azrieli Pavilion	Academic	49,516
Human Computer Int. & Visual	Academic	97,309
Paterson Hall	Academic	79,989
Southam Hall	Academic	99,526
Canal Building	Academic	96,609
Richcraft Hall	Academic	181,593
Tory Building	Academic / Admin	138,110
	Academic Total	
Steacie Building	Research	107,104
Herzberg Laboratories	Research	152,562
Social Sciences Research	Research	14,370
Life Sciences Research	Research	25,296
	Research Total	
Gymnasium	Athletics	28,159
Physical Rec Centre	Athletics	125,199
Fieldhouse	Athletics	47,998
Alumni Hall	Athletics	37,503
Ice House	Athletics	99,914
Tennis House	Athletics	36,006
	Athletics Total	
University Centre	Ancillary / Academic / Admin	177,183
Robertson Hall	Administrative	93,208
Maintenance Building	Ancillary	43,832
Carleton Technology	Ancillary	68,515
Residence Commons	Ancillary	185,323
Colonel By Child Care	Ancillary	5,662
National Wildlife Research Centre	Ancillary / Academic	60,000
	Ancillary Total	
Renfrew House	Residence	52,680
Lanark House	Residence	51,469
Russell / Grenville House	Residence	95,953
Glengarry House	Residence	154,715
Stormont-Dundas	Residence	118,192
Leeds House	Residence	169,139
Prescott House	Residence	135,005
Frontenac House	Residence	87,998
Lennox and Addington	Residence	170,000
	Residence Total	

Table 4.3 - Energy Performance Benchmarks - Existing Building Stock – cont'd

EXISTING USAGE										
Electricity				Steam -MTHW		Natural Gas		Total BEPI	Water	
kWh	kW	kWh/ft^2	Wft^2	MMBtu	ek Wh/ft^2	m^3	EkWh/ft^2	EkWh/ft^2	m^3	l/ft^2
4,585,880	1,002	22.46	4.91	27,958	8.39	0	0.00	**30.85**	25,224	124
3,659,449	800	19.46	4.25	11,614	14.37	9	0.00	**33.83**	16,514	88
2,918,057	638	12.24	2.68	4,506	11.99	6,119	0.36	**24.59**	7,883	33
642,869	140	9.45	2.07	7,886	37.41	0	0.00	**46.86**	4,489	66
1,693,173	370	9.16	2.00	4,142	6.03	0	0.00	**15.19**	13,070	71
516,245	113	5.57	1.22	1,888	5.11	5,656	0.76	**11.44**	1,879	20
1,353,865	296	17.93	3.92	2,158	9.77	17,965	9.19	**36.90**	5,273	70
3,494,735	764	31.59	6.90	10,145	4.09	0	0.00	**35.68**	10,464	95
427,460	93	11.31	2.47	521	4.53	0	0.00	**15.84**	3	0
834,382	182	16.85	3.68	1,341	3.31	0	0.00	**20.16**	597	12
2,038,696	446	20.95	4.58	2,914	6.40	0	0.00	**27.35**	2,077	21
702,413	154	8.78	1.92	5,735	23.92	0	0.00	**32.70**	3,862	48
994,168	217	9.99	2.18	3,226	15.20	0	0.00	**25.19**	4,532	46
1,954,273	427	20.23	4.42	2,169	28.42	0	0.00	**48.64**	2,806	29
2,884,868	630	15.89	3.47	7,220	2.69	0	0.00	**18.58**	2,920	16
2,708,000	592	19.61	4.28	4,194	7.67	18,998	2.19	**29.46**	10,891	79
	Average	**15.72**	**3.43**		**11.83**		**0.78**	**28.33**		**51**
	Maximum	**31.59**	**6.90**		**37.41**		**9.19**	**48.64**		**124**
	Minimum	**5.57**	**1.22**		**2.69**		**0.00**	**11.44**		**0**
3,094,436	676	28.89	6.31	19,330	52.40	126	0.003	**81.32**	17,497	163
2,576,406	563	16.89	3.69	6,279	12.89	0	0.00	**29.77**	4,365	29
123,120	27	8.57	1.87	0	0.00	24,367	17.74	**26.30**	5,400	376
1,170,536	256	46.27	10.11	5,437	53.32	0	0.00	**99.59**	4,426	175
	Average	**25.16**	**5.50**		**29.65**		**4.44**	**59.25**		**186**
	Maximum	**46.27**	**10.11**		**53.32**		**17.74**	**99.59**		**376**
	Minimum	**8.57**	**1.87**		**0.00**		**0.00**	**26.30**		**29**
129,995	28	4.62	1.01	0	0.00	45,526	24.23	**28.85**	2,784	99
1,381,818	302	11.04	2.41	6,709	19.62	12,609	1.24	**31.90**	31,741	254
297,031	65	6.19	1.35	0	0.00	15,800	6.70	**12.89**	458	10
1,410,461	308	37.61	8.22	1,416	9.61	11,332	0.00	**47.22**	2,138	57
3,246,544	709	32.49	7.10	0	0.00	136,579	20.49	**52.98**	12,579	126
313,602	69	8.71	1.90	0	0.00	166,835	56.91	**65.62**	0	0
	Average	**16.78**	**3.67**		**4.87**		**18.26**	**39.91**		**91**
	Maximum	**37.61**	**8.22**		**19.62**		**56.91**	**65.62**		**254**
	Minimum	**4.62**	**1.01**		**0.00**		**0.00**	**12.89**		**0**
3,028,813	662	17.09	3.74	7,239	10.27	69,996	10.00	**37.76**	31,486	178
2,699,771	590	28.97	6.33	2,719	13.06	0	0.00	**42.02**	12,533	134
2,963,200	648	67.60	14.77	2,250	3.51	11,931	1.21	**73.32**	19,171	437
1,179,263	258	17.21	3.76	1,868	13.82	0	0.00	**31.03**	3,107	45
2,683,642	586	14.48	3.16	8,403	25.91	74,464	5.63	**46.02**	24,588	133
79,656	17	14.07	3.07	0	0.00	15,136	27.75	**41.82**	754	133
2,714,832	593	45.25	9.89	3,834	17.08	0	0.00	**62.33**	1,868	31
	Average	**29.24**	**6.39**		**11.95**		**6.37**	**47.56**		**156**
	Maximum	**67.60**	**14.77**		**25.91**		**27.75**	**72.32**		**437**
	Minimum	**14.07**	**3.07**		**0.00**		**0.00**	**31.03**		**31**
205,371	45	3.90	0.85	3,174	14.04	0	0.00	**17.94**	2,440	46
187,011	41	3.63	0.79	1,257	9.39	0	0.00	**13.02**	4,248	83
554,755	121	5.78	1.26	4,803	13.41	0	0.00	**19.19**	8,871	92
1,578,087	345	10.20	2.23	4,627	15.22	0	0.00	**25.42**	18,133	117
928,827	203	7.86	1.72	4,767	9.77	0	0.00	**17.63**	10,586	90
1,222,649	267	7.23	1.58	0	0.00	127,696	10.10	**17.33**	18,529	110
1,165,871	255	8.64	1.89	3,929	6.57	3,424	0.65	**15.85**	13,437	100
692,286	151	7.87	1.72	2,311	8.77	1,615	0.21	**16.85**	5,843	66
1,050,300	230	6.18	1.35	7,099	8.79	4,048	0.26	**15.23**	17,505	103
	Average	**6.81**	**1.49**		**9.55**		**1.25**	**17.61**		**90**
	Maximum	**10.20**	**2.23**		**15.22**		**10.10**	**25.42**		**117**
	Minimum	**3.63**	**0.79**		**0.00**		**0.00**	**13.02**		**46**

FUTURE ENERGY AND WATER REQUIREMENTS

A number of existing campus buildings will be demolished to make way for new construction. Table 4.4 provides a summary of buildings planned for demolition, as well as 2016 energy and water consumption data. We expect that utilities removed will free up capacity on the existing campus energy and water infrastructure systems.

Average energy and water consumption benchmarks for each building type were used as a starting point for predicting the future energy and water requirements for the new buildings. Given the university's ongoing commitment to energy efficiency and environmental responsibility, this analysis assumes that all new buildings will be constructed to meet the most current construction standards, using high performance building materials, sustainable energy sources and high efficiency building technologies and equipment. The future energy use projections are based on the assumption that all new buildings will be designed and operated to achieve a minimum rating of 3 Green Globes as defined by the Green Building Initiative.

Table 4.4 – Buildings Planned for Removal under 2016 Campus Master Plan

Building Name	Area (ft^2)	Electricity		CHP Gas	Other Gas	Total Gas	Water
		kW	MWh	MMBtu	MMBtu	MMBtu	m^3
Social Sciences Research Bldg.	14,370	27	123	0	873	873	5,400
Paterson Hall	79,989	154	702	5,735	0	5,735	3,862
Life Sciences Research Bldg.	25,296	27	123	0	873	873	5,400
Daycare	5,662	17	80	0	542	542	754
Tennis Bubble	36,006	69	314	0	5,979	5,979	0
Parking Garage	256,857	358	557	0	0	0	0
Maintenance	43,370	648	2,963	2,250	428	2,678	19,171
Total to be removed	**461,550**	**1,299**	**4,862**	**7,986**	**8,696**	**16,682**	**34,587**

Table 4.5 shows the estimated energy and water reduction factors which have been used for this analysis. These factors are preliminary and may be adjusted in the future with advancements in high performance building materials and energy efficient equipment and building technologies.

Table 4.5 – Energy and Water Reduction Factors

Energy and Water Reduction Factors			
Building type	Electricity	Thermal	Water
Academic	30%	40%	50%
Research	30%	40%	50%
Athletics	30%	40%	50%
Ancillary	30%	40%	50%
Residences	30%	40%	50%
Parking	50%		

Table 4.6 is a summary of the estimated annual energy and water consumption for the new buildings based on improved construction standards and energy performance.

Table 4.6 – Projected Energy and Water Consumption in New Buildings

Building type	Area (ft^2)	Electricity		Fuel	Water
		Peak kW	MWh	MMBtu	m^3
Academic	674,798	1,622	7,424	24,890	17,230
Research	1,170,552	4,504	20,612	116,703	108,672
Athletics	169,154	434	1,986	11,444	7,680
Ancillary	857,130	3,834	17,543	45,921	66,848
Residences	620,981	647	2,960	19,608	27,848
Parking	1,106,281	771	1,198		
Total	**4,598,896**	**11,813**	**51,723**	**218,566**	**228,279**

Table 4.7 is a summary of the estimated annual energy and water consumption for the new and expanded Carleton University campus.

Table 4.7 – Projected Energy and Water Consumption for New Campus

	Area (ft^2)	Electricity		Fuel	Water
		Peak kW	MWh	MMBtu	m^3
Existing buildings	4,768,256	14,141	70,636	332,673	425,796
Removed buildings	-461,550	-1,299	-4,862	-16,682	-34,587
New buildings	4,598,896	11,813	51,723	218,566	228,279
Projected campus total	**8,905,602**	**24,654**	**117,498**	**534,558**	**619,488**

EXISTING ENERGY AND WATER SYSTEMS INFRASTRUCTURE

The sheer magnitude of planned campus development will impact the existing energy and water systems infrastructure. A detailed analysis and condition assessment of the existing energy and water services is beyond the scope of this study. However, there is information that is useful to consider which is outlined below.

WATER SERVICE SYSTEM

Two 8-inch water lines from City of Ottawa in the meter chamber on Colonel By Drive are tied to the 16-inch water main serving the existing campus. Campus water consumption is expected to increase over 60% when the Campus Master Plan development is complete. It's expected that upgrades to the water distribution infrastructure will be required to serve the new facilities, with the new feed line serving the new residential and research campuses at the north end of the campus.

ENERGY CONSERVATION

OVERVIEW

Carleton conducted facility walk-through surveys to assess and identify energy and water conservation opportunities in the selected buildings.

ENERGY CONSERVATION OPPORTUNITIES

Based on analysis, we have identified six facilities as strong candidates for future ASHRAE Level 2 and/or Level 3 assessments and potential energy conservation projects. (in terms of magnitude).

Based on our preliminary assessment of the selected facilities, approximately 17% and 3% reduction of energy and water use respectively, is possible. Future assessments will further refine the savings and firm up the project costs to support the university's decision-making process.

- University Centre
- St. Patricks' Building
- HHJ Nesbitt
- Southam Hall
- Tory Building
- Dunton Tower

Table 5.1 provides a preliminary list of identified Energy Conservation Measures (ECMs) opportunities in the selected facilities.

Table 5.1 Preliminary list of identified Energy Conservation Measures (ECM)

	Carleton University	TB - Tory Building	ML - MacOdrum Library	PA - Paterson Hall	SA - Southam Hall	ME - Mackenzie Building	MB - Maintenance Building	SC - Steacie Building	HP - Herzberg Laboratories	LA - Loeb Building	NB - H.H.J. Nesbitt Biology Building	RO - Robertson Hall	DT - Dunton Tower
ECM	**Description**	1	2	3	4	10	11	12	13	15	16	17	21
L	**Lighting Measures**												
L-01	Retrofit/Replace interior fluorescent fixtures to LED	x	x	x	x		x	x		x	x	x	x
L-02	Retrofit/Replace interior fluorescent high-bay fixtures to LED			x	x								
L-02	stairwell lighting control (all bldgs)	x	x	x	x	x	x	x	x	x	x	x	x
E	**Electrical System Measures**												
E-01	Install Vending Miser controllers on drink vending machines			x	x								
C	**Control System Measures**												
C-01	Install new DDC control system			x				x					x
C-02	Expand existing DDC control system	x		x			x	x			x		x
C-03	Integrate control systems using global head end	x	x	x			x	x			x		x
C-04	Re-commission and optimize controls for energy efficiency	x	x	x	x		x	x			x		x
C-05	Re-calibrate and tune control systems	x		x	x		x	x		x	x	x	x
C-06	Optimize fan system operation	x		x	x		x	x		x	x	x	x
C-07	Optimize unoccupied setback	x		x	x		x	x		x	x	x	x
C-08	Reset supply air temperature	x		x	x		x	x		x	x	x	x
C-09	Sequence heating, cooling and humidification	x		x	x		x	x			x		x
M	**Mechanical System Measures**												
M-01	Upgrade air handling systems	x	x	x	x		x	x			x		x
M-02	Install zone dampers and VSD's to match airflow with occupancy			x	x								x
M-03	lab space venturi valves								x		x		
M-04	Install variable exhaust system for kitchen cooking exhaust hood												
M-05	Install low leakage fresh air dampers			x	x				x				
M-06	Convert constant volume systems to variable air volume (VAV)			x	x				x				
M-07	Replace electric motors with high efficiency motors			x							x		x
M-08	Convert 100% fresh air system to mixed air												
M-09	Install outdoor air free cooling on AHU's												
M-10	Install AHU heat recovery (glycol/air to air/refrigerant/heat wheel)		x								x		
M-11	Monitor indoor air quality for demand controlled ventilation (CO2)			x	x				x				
M-12	Monitor CO2 levels to control room ventilation			x	x								
B	**Building Envelope Measures**												
B-01	Retrofit building envelope (caulking, seals & sweeps)			x	x			x	x	x		x	
W	**Water Measures**												
W-01	Install low flow plumbing fixtures												
W-02	Replace washing machines with front loading												

Table 5.1 Preliminary list of identified Energy Conservation Measures (ECM) – cont'd

	Carleton University	AA - Architecture Building	SP - St. Patrick's Building	SR - Social Sciences Research Building	LS - Life Sciences Research Building	MC - Minto Centre	AT - Azrieli Theatre	AP - Azrieli Pavilion	HC/VS - Human Computer Interaction Bldg / Visualization & Simulation Building	CB - Canal Building	RB - River (Richcraft) Building	HS - Health Sciences	Renfrew
ECM	**Description**	22	23	24	25	27	31	32	37	42	43	100	5
L	**Lighting Measures**												
L-01	Retrofit/Replace interior fluorescent fixtures to LED	x	x	x			x	x		x	x		x
L-02	Retrofit/Replace interior fluorescent high-bay fixtures to LED	x					x						
L-02	stairwell lighting control (all bldgs)	x	x	x	x	x	x	x	x	x	x	x	x
E	**Electrical System Measures**												
E-01	Install Vending Miser controllers on drink vending machines						x	x					x
C	**Control System Measures**												
C-01	Install new DDC control system	x		x									x
C-02	Expand existing DDC control system	x	x	x									x
C-03	Integrate control systems using global head end	x	x	x			x	x					x
C-04	Re-commission and optimize controls for energy efficiency	x	x	x			x	x		x	x		x
C-05	Re-calibrate and tune control systems	x	x	x			x	x		x	x		x
C-06	Optimize fan system operation	x	x	x			x	x		x	x		x
C-07	Optimize unoccupied setback	x	x	x			x	x		x	x		x
C-08	Reset supply air temperature	x	x	x			x	x		x	x		x
C-09	Sequence heating, cooling and humidification	x	x	x			x	x		x	x		x
M	**Mechanical System Measures**												
M-01	Upgrade air handling systems	x	x										x
M-02	Install zone dampers and VSD's to match airflow with occupancy		x				x						x
M-03	lab space venturi valves												
M-04	Install variable exhaust system for kitchen cooking exhaust hood												
M-05	Install low leakage fresh air dampers	x					x	x					x
M-06	Convert constant volume systems to variable air volume (VAV)			x			x						x
M-07	Replace electric motors with high efficiency motors	x						x					x
M-08	Convert 100% fresh air system to mixed air												
M-09	Install outdoor air free cooling on AHU's			x			x						
M-10	Install AHU heat recovery (glycol/air to air/refrigerant/heat wheel)												
M-11	Monitor indoor air quality for demand controlled ventilation (CO2)	x		x			x	x					x
M-12	Monitor CO2 levels to control room ventilation	x		x			x	x					x
B	**Building Envelope Measures**												
B-01	Retrofit building envelope (caulking, seals & sweeps)	x		x			x	x	x				x
W	**Water Measures**												
W-01	Install low flow plumbing fixtures	x		x			x	x	x				x
W-02	Replace washing machines with front loading	x		x									

Table 5.1 Preliminary list of identified Energy Conservation Measures (ECM) – cont'd

	Carleton University	Lanark	Russel-Grenville	Glengarry	Stormont-Dundass	Leeds	Prescot	Frontenac	Lennox	Gymnasium	Athletics	FH - Fieldhouse	AH - Alumni Hall and Sports Centre
ECM	**Description**	6	14	18	26	30	34	41	44	8	9	35	36
L	**Lighting Measures**												
L-01	Retrofit/Replace interior fluorescent fixtures to LED	x	x			x	x	x	x	x		x	
L-02	Retrofit/Replace interior fluorescent high-bay fixtures to LED											x	
L-02	stairwell lighting control (all bldgs)	x	x	x	x	x	x	x	x	x	x	x	x
E	**Electrical System Measures**												
E-01	Install Vending Miser controllers on drink vending machines	x	x	x	x	x	x	x	x	x			
C	**Control System Measures**												
C-01	Install new DDC control system	x	x	x	x	x	x			x			
C-02	Expand existing DDC control system	x	x	x	x	x	x	x		x			
C-03	Integrate control systems using global head end	x	x	x	x	x	x	x		x			
C-04	Re-commission and optimize controls for energy efficiency	x	x	x	x	x	x	x	x	x		x	
C-05	Re-calibrate and tune control systems	x	x	x	x	x	x	x	x	x		x	
C-06	Optimize fan system operation	x	x	x	x	x	x	x	x	x		x	
C-07	Optimize unoccupied setback	x	x	x	x	x	x	x	x	x		x	
C-08	Reset supply air temperature	x	x	x	x	x	x	x	x	x		x	
C-09	Sequence heating, cooling and humidification	x	x	x	x	x	x	x	x	x		x	
M	**Mechanical System Measures**												
M-01	Upgrade air handling systems	x	x	x	x								
M-02	Install zone dampers and VSD's to match airflow with occupancy	x	x		x	x							
M-03	lab space venturi valves												
M-04	Install variable exhaust system for kitchen cooking exhaust hood												
M-05	Install low leakage fresh air dampers	x	x	x	x	x	x	x		x		x	
M-06	Convert constant volume systems to variable air volume (VAV)	x	x										
M-07	Replace electric motors with high efficiency motors	x	x		x	x		x				x	
M-08	Convert 100% fresh air system to mixed air		x										
M-09	Install outdoor air free cooling on AHU's		x	x		x				x		x	
M-10	Install AHU heat recovery (glycol/air to air/refrigerant/heat wheel)												
M-11	Monitor indoor air quality for demand controlled ventilation (CO2)	x	x	x	x	x	x	x		x		x	
M-12	Monitor CO2 levels to control room ventilation	x	x	x	x	x	x	x		x		x	
B	**Building Envelope Measures**												
B-01	Retrofit building envelope (caulking, seals & sweeps)			x	x	x	x	x	x			x	
W	**Water Measures**												
W-01	Install low flow plumbing fixtures					x	x	x				x	
W-02	Replace washing machines with front loading					x							

ENERGY MASTER PLAN

TOGETHER WE ARE BUILDING A SUSTAINABLE CAMPUS

ENERGY RETROFIT SAVINGS

2.6 Million

2.6 Million kWh Annual Electricity Reduction

2,004

2,004 Metric tons of CO^2 saved

429

saving the equivalent annual greenhouse gas emissions from **429 cars**

4.2 Million

4.2 Million lb of steam saved

25,000 m³

Water reduction

BUILDING RENEWAL

17%

17% projected energy savings from phase 2 of energy retrofits

5

5 building energy retrofits completed

7

7 building energy retrofits planned

ENERGY PROGRAMS

1 Co-generation plant

13 Projects funded through the Green Revolving Fund

13

9

9 Green Globe rated buildings on campus.

88%

88% projected campus floor area growth

652,000 kWh LED replacement energy savings

25%

25% ESAT rating improvement in Athletics

stars

Silver AASHE stars rating

DO YOU WANT TO LEARN MORE ABOUT THE ENERGY PROJECTS AND INITIATIVES FEATURED IN THIS PLAN OR ABOUT CARLETON UNIVERSITY'S OTHER SUSTAINABILITY PROGRAMS?

VISIT **CARLETON.CA/SUSTAINABILITY** OR CONTACT US DIRECTLY FOR MORE DETAILS.

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