2019-2024
Energy Conservation & Demand Management (CDM) Plan: Project Report

University of Toronto Mississauga

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Introduction

Facilities Management and Planning at UTM ('the client') is interested in developing a Conservation and Demand Management (CDM) Plan in order to find opportunities for operational cost savings through improved resource efficiency and reduced demand, as well as to understand and plan its contribution to mitigating global climate change. The authors will undertake this work as part of the requirements for their course, SM1090H - Capstone Course: Sustainable Enterprise.

Conservation & Demand Management Regulation

Ontario Regulation 397/11: Energy Conservation and Demand Management Plans under the *Green Energy Act, 2009* entered into force on August 23, 2011, and required all public agencies to report on their annual energy consumption and greenhouse gas (GHG) emissions and to submit an Energy Conservation and Demand Management Plan to the Province of Ontario every five years at maximum beginning in 2013 and 2014 respectively.

According to the regulation, submitted energy conservation and demand management plans were to be composed of two parts. The first of these would include a summary of the annual energy consumption and greenhouse gas emissions from the agency's operations. The second would then include descriptions of measures - past, present, or proposed - intended to "[conserve] and otherwise [reduce] the amount of energy consumed and…[manage] demand for energy, including a forecast of the expected results" (O.Reg 397/11). Agencies were also required to publicly disclose these plans as well as their greenhouse gas emissions. The authors were thus approached by the client to prepare UTM's 2019 submission under the regulation.

As of January 1, 2019, the *Green Energy Act, 2009* was repealed, and along with it Ontario Regulation 397/11. However, O. Reg. 507/18: Broader Public Sector: Energy Reporting and Conservation and Demand Management Plans was created under the *Electricity Act, 1998* (Government of Ontario, 2018) to coincide with the repeal of the *Green Energy Act, 2009*, and came into force on January 1, 2019. This regulation maintains the requirements for Energy Conservation and Demand Management Plans and greenhouse gas emissions reporting. Therefore, UTM continues to be required to submit a CDM plan under this regulation.

University Profile

The University of Toronto Mississauga (UTM) was established in 1967 and is "situated on 225 acres of protected greenbelt along the Credit River" (University of Toronto, n.d.). The second largest of the University of Toronto's three campuses by enrolment, UTM played host to approximately 14,186 undergraduate and 699 graduate students in the 2017-2018 academic year. UTM is a division of the University of Toronto, and is thus accountable to institutional commitments made by the University of Toronto.

According to the mission statement of UofT, the university commits itself to “being an internationally significant research university, with undergraduate, graduate and professional programs of excellent quality” (University of Toronto, n.d). Its motto is *velut arbor ævo*, or “as a tree through the ages.”

Project Scope & Objectives

The client is committed to exceeding mandatory requirements by setting targets for emissions reductions that align with Canada’s international policy commitments under the Paris Agreement. In other words, the client has tasked with authors with the creation of a comprehensive Energy and Water Conservation and Demand Management Plan that includes science-based greenhouse gas emissions reduction targets. The objectives of this project are to:

- To understand the broader strategic case supporting the success of CDM Plan;
- To perform a greenhouse gas emissions inventory of UTM’s current and historical scope 1 and 2 emissions;
- To set science-based targets for future emissions reductions based on limiting global warming to below 2°C, as stated in the Paris Agreement, as well as other goals related to UTM’s aspirations for CDM; and
- To develop a roadmap for achieving those goals.

Conservation & Demand Management Best Practices

Energy Management Standards and Guidance

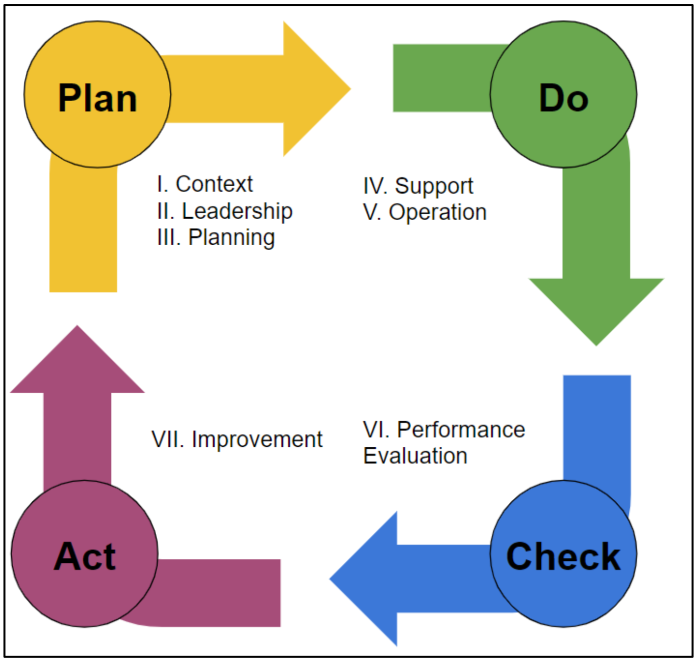
In November 2013, the Ontario Ministry of Energy published "A Guide to Preparing Conservation and Demand Management Plans," providing guidance to public agencies on how to fulfill the requirements of O. Reg. 397/11. As O. Reg. 507/18 is nearly identical in its wording to the former O. Reg. 397/11, this guidance can be additionally applied to CDM plans created after January 1, 2019.

In the guide, three broad categories of conservation and demand management measures are outlined: technical measures, organizational measures, and behavioural measures. The first of these often refers to capital purchases of new technology or equipment, or to maintenance or retrofitting of existing equipment; for example, installation of LED lighting, or re-commissioning of an old building. Organizational measures may refer to development of policy or organizational programs for energy management; for example, hiring of a full-time embedded energy manager. Lastly, behavioural measures focus on driving behaviour change among operators or occupants; for example, a marketing campaign focused on encouraging energy management. Although according to the guide the potential cost and energy savings from technical and organizational measures should be assessed based on case studies or developed through modeling, behavioural measures as a rule of thumb result in 5-10% savings in energy. It is important to consider these three categories of measures in this plan.

The guide also provides strategies for identifying measures: namely, it describes energy audits as important tools for identifying measures. Energy audits were not performed as part of this project, as the authors deferred to the client as experts in the campus facilities and systems, however further savings opportunities could be identified through more regular audits of facility types.

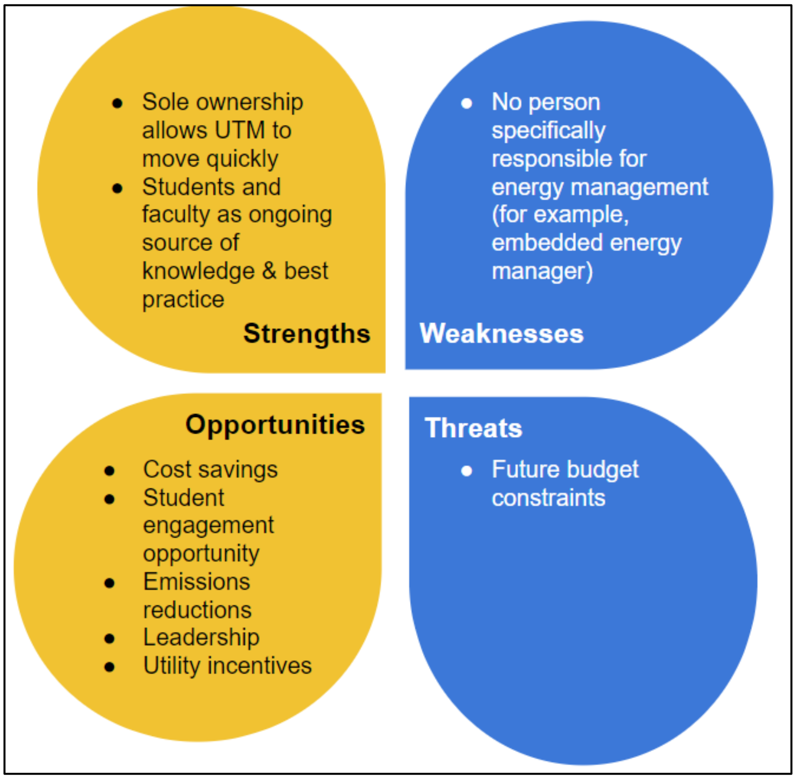
The International Organization for Standardization (ISO) has developed an internationally-recognized standard for energy management systems, ISO 50001:2018(E), which can provide some important lessons for a CDM plan at UTM. ISO 50001 has seven broad sections: (i) Context, (ii) Leadership, (iii) Planning, (iv) Support, (v) Operation, (vi) Performance Evaluation, and (vii) Improvement. Each section of this standard plays an important role in energy management. In general, ISO 50001 follows the broad steps of the Plan, Do, Check, Act framework for continual improvement of processes, as displayed in Figure 1.

Figure 1. Plan-Do-Check-Act Framework & ISO 50001:2018 sections



First, *Context* refers to the internal and external conditions that influence and/or are relevant to the improvement of an organization's energy performance. Internal factors, which are summarized in the figure below, include the strengths and weaknesses of UTM in relationship to the success of an energy management system, as well as the opportunity and threats of implementing an energy management system. There as also a number of external political, economic, social, technological, legal, and environmental factors relevant to implementing CDM at UTM. For example, legal requirements outlined above mandate the creation of a CDM plan, and the current provincial government has indicated the importance of efficiency in public operations - this can likely be extended to the efficient use of resources, which in turn can yield cost savings in the long term.

Figure 2. SWOT Analysis Overview



Social and environmental factors also indicate the importance of CDM - as awareness and concern about climate change grows, UTM's ability to show leadership in CDM can help to positively contribute to global climate change mitigation efforts, and have positive reputational benefits for the university. Additionally, as UTM's identity is largely embedded with its local environment, inaction on this significant environmental issue could inversely have negative reputational benefits, and the potential for lost revenue from an inability to attract students to environmentally-focused programs, such as the MScSM program. However, UTM may be limited in its ability to enact CDM changes if there is little buy-in from students, staff, and faculty. Additionally, provincial changes to funding arrangements for post-secondary institutions may limit capital spending, which in turn may limit any technical or organizational planned or proposed measures.

Leadership refers to a formal commitment at the level of top management to continuous improvement of its energy performance. As described below, UTM has a strong commitment to energy management and emissions reductions through a number of internal policies and public commitments. This CDM plan additionally serves as another policy tool, as provincial requirements dictate that the plan must be signed off on by a member of the senior leadership. However, this section also directs the creation of an energy management team to support continuous improvement and ongoing effectiveness of the energy management system, which is not something that UTM has implemented to date.

Planning involves developing objectives and targets, as well as actions to achieve those targets and to address identified risks and opportunities. It should also involve reviewing current energy performance, establishing a system for collecting energy data, and establishing a baseline and monitoring schedule.

Support then requires the organization to ensure it is organized to successfully implement its plans - for example, by making sure staff are aware of the energy management system, trained to ensure that they understand how to properly perform any work that affects the organization's energy performance, that a clear and direct communication system is established for both internal and external communication regarding the energy management system, and that there is adequate resources and proper documentation. Importantly, ISO 50001 requires that organizations establish a process where anyone "doing work under the organization's control can make comments or suggest improvements to the [energy management system]" (ISO, p.13, 2018). As UTM's Facilities Management and Planning department is largely centralized, and facilities in its portfolio fall under a wide range of building uses (for example, residential, research, *et cetera*), a system that allows staff, students, and faculty to suggest changes may be beneficial.

Operation and *Performance Evaluation* refer to the "Do" and "Check" parts of the cycle, where organizations perform the actions intended to improve performance and subsequently evaluate their performance. *Improvement* thus is intended to take the results of the performance evaluation and to use them as inputs, once again, to develop new actions.

Peer Universities Research

To make an informed decision about proposing energy-saving measures, research on existing measures by other universities has been conducted. The researchers investigated the best energy-saving practices that have been successfully implemented in the universities with similar energy consumption to UTM based on 2016 submissions to the Ontario government under O. Reg. 397/11. These universities include the Ontario College of Art and Design University (OCAD), University of Ottawa, University of Ontario Institute of Technology, Nipissing University, Trent University, Lakehead University, Laurentian University, Ryerson University, University of Toronto at Scarborough, and Wilfrid Laurier University. UTSG was analysed both as the top energy consumer among Ontario universities and as UTM's counterpart in downtown Toronto.

To investigate the best practices of energy saving amongst these universities, the researchers reviewed initial costs of the initiatives, annual savings and estimated reductions in energy use or GHG emissions. Common trends in approaching energy reduction were noticeable, especially in 'low-hanging fruit' initiatives. Although not all universities reported on all three measures, combining information from the sample universities was sufficient to understand the range of costs and savings of the initiatives undertaken.

Below are the major categories of the best practices amongst the sample universities. The range of implementation costs and expected savings were assigned into the following groups: low (<$10,000), medium ($10,000-$100,000), high ($100,000 - $1M) and very high (>$1M).

1. **Determining energy-saving opportunities**

This involves reviewing energy consumption data by building, which allows identifying facilities where a potential for energy saving exists, and developing corresponding goals to achieve the potential savings. To find opportunities of energy savings in all facilities wherever possible, both high- and low-energy facilities need to be reviewed for potential energy-saving measures. Additional energy audits may be necessary, if recent data on energy consumption is not available.

Cost: zero (reviewing existing data) - medium (energy audits).
Savings range: medium - high (depending on the range of initiatives).

2. **Lighting retrofits**

Across the sample universities, many have replaced older, less-efficient lights with high-efficiency LED and T5 light bulbs across campuses. This 'low-hanging fruit' measure is easy to implement in multiple locations and may result in medium-range savings above 100,000 kWh/year for campus-wide projects (e.g. Trent University, 2014; Laurentian University, 2014; UOIT, 2014). Other initiatives included de-lamping (removing some light bulbs to reduce excessive lighting) and daylight harvesting through large window area and rooftop windows.

Cost: medium.
Savings range: medium.

3. **HVAC upgrades**

There is a range of opportunities to save energy through ventilation upgrades, such as installing demand-driven ventilation units, retrofitting HVAC units and filters with more efficient ones, equipping offices, walkways and classrooms with occupancy sensors, and using variable frequency drives. These are expensive, having ranged from $285,000 to $575,000 for the installation of occupancy sensor and automation systems respectively at University of Toronto, St. George campus (UTSG) (University of Toronto: St. George Campus, 2014). However, these measures result in large financial savings and reduced energy consumption - by up to 1 Million kWh/year at UTSG, for example.

Cost: high.
Savings range: high.

4. **Facilities use optimization**

Optimising facilities use includes developing preventative maintenance policies, conducting building audits to identify further saving opportunities, and performing regular efficiency upgrades and retrofits. These can provide significant savings: for example, the University of Ottawa annually saves $1M and 5M kWh after energy retrofits in their laboratories (University of Ottawa, n.d.).

Cost: high.
Savings range: high - very high.

5. **Construction standards**

High efficiency of newly constructed buildings and increasing efficiency of existing buildings are very worthwhile investments, since the savings would last for the lifetime of the buildings. This category involves developing efficiency standards and policies (such as LEED) for newly constructed buildings, as well as insulating building envelopes, making vegetated roofs, and fitting heat-reflective windows in existing buildings. These measures, although costly compared to other measures, result in the most significant energy savings in long term.

Cost: high - very high
Savings range: high - very high

6. **Measurement & monitoring**

Energy monitoring in individual buildings and smaller units becomes possible with using energy meters and sub-meters, sometimes in combination with an automated energy tracking software. Depending on the scale of the initiative involving energy meters, the cost and the resulting savings may range from low to high. For example, UTSG have conducted a comprehensive energy saving program at 15 buildings aiming to identify energy efficiency improvements (University of Toronto: St. George Campus, 2014). Although the cost of the program was close to $1M, it resulted in the energy savings of 2.8M kWh/year.

Cost: low – high
Savings range: low - high

7. **Behaviour change measures**

These measures aim to engage students and faculty in energy conservation, approached through educational campaigns, staff trainings, team games, 'energy weeks' and other educational and entertainment events. Alternatively, university management may use signs promoting energy-saving behaviour in places with high energy use.

Cost: low (signs) - medium (public events)
Savings range: low - medium

2019-2024 CDM Plan

Leadership

UofT has a number of policies expressly committed to environmental protection and environmental sustainability. In March 1994, the Environmental Protection Policy was first approved; the policy commits the university to meet or exceed compliance with environmental regulations, to “operate so as to minimize negative impacts on the environment,” to “respect biodiversity,” and to “adopt practices that reflect the conservation and wise use of natural resources” (University of Toronto, 2010). CDM can reasonably be considered an application of the last of these commitments.

“Grow Smart, Grow Green” is the key principle of campus development, expressed in the UTM Campus Master Plan, stating the UTM Environment Priorities through 2030 as to “Continue to update UTM’s energy inventory annually”. The plan emphasizes the balance between the growth of campus and environmental responsibility. The UofT Infrastructure Plan states a related goal to minimize environmental impact of continued campus expansion and upgrades to existing buildings and landscapes (University of Toronto Campus and Facilities Planning, 2011).

In November 2009, UofT was signatory to a pledge from the Council of Ontario Universities, stating the university community’s recognition of global challenges arising from climate change and environmental degradation, and committing to working together towards a greener world. (COU, 2009).

In 2017, UofT President Professor Meric Gertler established the Presidential Advisory Committee on the Environment, Climate Change and Sustainability, which is mandated to find ways for the university to “advance…[its] contribution to meeting the challenge of climate change and sustainability” (Gertler, 2017). University operations and innovation were two particular areas of focus in this regard. UofT is also a member of the University Climate Change Coalition, or UC3, which is a coalition of 18 leading North American universities formed in February 2018 with the stated mission of “leveraging their [coalition members] institutional strengths as leading research institutions to foster a robust exchange of best practices and lessons learned in pursuit of accelerating local climate solutions that reduce greenhouse emissions and build community resilience” (Second Nature, 2018). A CDM plan is a good way to share initiatives at UTM and demonstrate action towards the commitments of UC3.

Lastly, the client has indicated a strong commitment on the part of UTM to contribute to mitigating the effects of climate change, as UTM has seen its effects firsthand: for example, a 2018 extreme rainfall event caused flooding in the Davis building by overwhelming the drainage system, and such extreme weather events will likely occur with greater frequency as a result of climate change. Long-term benefits of CDM include contributing to climate change mitigation efforts, however UTM cannot alone halt climate change. Showing leadership in CDM and sharing best practices should thus be a significant part of this plan.

Aside from meeting regulatory requirements, releasing a CDM plan provides an opportunity to gain recognition as a sustainably developing and an environmentally-friendly campus, as well as opportunities for long-term operational cost savings through more efficient use of resources and reduced demand.

Resource Consumption & GHG Emissions

UTM-Wide Resource Consumption

In 2014, UTM published its 2014-2019 Conservation and Demand Management Plan. Recognizing the growth of the UTM campus in both student enrolment and building area since 2001, the plan committed to a target of zero increase in energy intensity, or energy use per gross square metre of built space, by 2019. To achieve this goal, a number of strategies were employed, including replacement of the cooling tower, reconstruction of the North Building, replacement of a boiler unit at the Central Utilities Plant, as well as energy metering and creation of a real-time energy dashboard.

Complete energy data through 2018 shows that UTM has thus far exceeded its goal of zero increase in energy intensity. In 2014, UTM's energy intensity was 26.76 m3 of natural gas per campus Gross Square Metres (GSM) and 219.61 kWh of electricity per campus GSM, based on a campus GSM of 185,484 m2. By 2018, UTM's energy intensity had decreased to 25.43 m3 of natural gas and 204.58 kWh of electricity per GSM. This decrease becomes more pronounced if we consider intensity as a measure of consumption per student: in 2018, UTM consumed approximately 352.10 m3 of natural gas and 2,832.54 kWh of electricity per student, or versus 376.07 m3 and 3,085.87 kWh per student in 2014.

Although this is the case, it should however be noted that energy intensity did show a sharp increase from 2017 to 2018 for natural gas, despite an overall downward trend from 2014 through 2017. Electricity showed a slight increase from 2017 to 2018.

In this CDM plan, an energy intensity target is abandoned for a more stringent absolute emissions target. This is to better align with UofT's commitment under UC3, and recognizes UTM's contribution to global climate change.

Campus-wide data is available for energy consumption from natural gas, gasoline, diesel, propane, and electricity from 2005 through 2018, and is shown in Table 1 below. Water consumption data was also gathered, however is incomplete. Gasoline, diesel, propane, and water were not considered in the 2014-2019 CDM plan.

In general, natural gas and electricity consumption have shown gradual increases since 2005, largely attributable to campus growth. Diesel consumption increased sharply in 2013 and 2014, however sharply decreased thereafter. Gasoline consumption alternatively has seen steady decreases since 2005.

As propane is purchased in bulk quantities and water analysis is incomplete, we cannot perform any useful analysis.

Table 1. Detailed Resource Consumption Data[1]

Year	Water Consumption (m3)	Natural Gas Consumption (m3)	Gasoline Consumption (L)	Diesel Consumption (L)	Propane Consumption (L)	Electricity Consumption (kWh)
2005	-	4,508,303.00	14,342.50	7,055.10	0.00	31,065,741.00
2006	-	3,362,536.00	12,869.30	6,594.10	0.00	34,053,569.00
2007	-	3,989,349.00	13,504.00	6,945.90	0.00	36,422,533.00
2008	-	4,201,312.00	10,717.35	6,212.50	0.00	35,561,804.00
2009	-	4,221,793.00	7,808.50	4,764.50	0.00	34,696,203.00
2010	-	4,611,021.00	10,947.50	7,480.83	0.00	36,069,059.00
2011	239,695.00	4,166,099.00	12,438.50	10,359.70	0.00	36,233,178.00
2012	254,713.00	4,303,014.00	11,733.00	10,710.20	0.00	35,824,431.00
2013	232,382.00	4,423,444.00	12,493.50	15,095.40	0.00	39,426,178.00
2014	194,973.00	4,964,129.00	12,379.50	15,520.10	1,641.00	40,733,544.00
2015	223,339.00	4,472,503.00	8,803.50	8,523.30	0.00	39,998,816.00
2016	-	3,977,344.00	7,591.00	4,342.50	1,298.20	40,048,352.00
2017	-	4,185,389.00	5,819.50	5,060.82	0.00	38,493,422.00
2018	234,066.00	4,994,850.00	6,169.00	5,098.20	0.00	40,182,358.00

Building-Level Consumption

Building-level resource consumption data from 2011 through 2015 was made available to the authors. Although there is some variance between this data and the campus-wide data that was provided, the building-level consumption is useful in that it provides a general understanding of the share of overall consumption occupied by each building, seasonal variability in resource consumption by building, and in year-over-year (YOY) trends for consumption in each building. In our analysis however, assets that have been demolished in 2011 or later, such as the old North Building or the microturbine in the Central Utilities Plant, were excluded.

For each resource - water, natural gas, and electricity - we identified the top 10 users in 2015 for both total consumption and consumption intensity (i.e. per m2 of net assigned area).

Water. 28 separate users of water were identified in the data. Of these, the top 5 facilities accounted for approximately 57% of water use. As is evidenced by the net score ranking below, residences should be a key area of focus for CDM efforts related to water.

[1] Graphical representations of resource consumption data can be found in the appendix.

Table 2. Water Net Score Ranking

Rank	Facility	Net Score Ranking ($Rank_{consumption}$ + $Rank_{intensity}$)
1	Central Utilities Plant	3
2	Roy Ivor Hall Residence	7
3	Oscar Peterson Hall	10
4	McLuhan Court Residence	14
Tied-5	William G. Davis Building	16
Tied-5	Recreation Athletics & Wellness (RAWC)	16
Tied-7	Hazel McCallion Academic Learning Centre (HM-ALC)	18
Tied-7	MaGrath Valley Residence	18
Tied-9	Erindale Hall Residence	20
Tied-9	Leacock Lane Residence	19

Electricity. 24 facilities were identified in the data. Of these, the top 7 consuming facilities account for over 75% of annual electricity consumption on campus. The Central Utilities Plant ranked highest in both consumption and intensity.

Table 3. Electricity Net Score Ranking

Rank	Facility	Net Score Ranking ($Rank_{consumption}$ + $Rank_{intensity}$)
1	William G. Davis Building	3
2	Hazel McCallion Academic Learning Centre (HM-ALC)	8
Tied-3	Kaneff Centre for Mgmt & Social Sciences + Innovation Complex	9
Tied-3	Central Utilities Plant	9
5	Recreation Athletics & Wellness (RAWC)	15
6	Schreiberwood Residence	16
7	Instructional Centre	18
8	McLuhan Court Residence	20
Tied-9	Oscar Peterson Hall	21
Tied-9	Grounds Building	21

Natural Gas. For natural gas, 14 facilities were identified in the data. The Central Utilities plant ranked highest in both intensity and consumption - the intensity calculations here included the surface area of the Innovation Complex, Instructional Centre, the Terrence Donnelly Health Sciences Complex, and approximately 95% of the William G. Davis Building, as these buildings are supplied with centralized heating and cooling from the Central Utilities Plant. Once again, residences are present in these rankings, and although the Alumni House represents only a small fraction of total natural gas use, it ranks extremely high in intensity.

Table 4. Natural Gas Net Score Ranking

Rank	Facility	Net Score Ranking ($Rank_{consumption}$ + $Rank_{intensity}$)
1	Central Utilities Plant	2
2	Oscar Peterson Hall	7
3	Recreation Athletics & Wellness (RAWC)	8
4	Student Centre	9
Tied-5	Roy Ivor Hall Residence	13
Tied 5	Communication Culture & Technology (CCT)	13
Tied-7	Early Learning Child Care Centre	16
Tied-7	Erindale Studio Theatre	16
9	Alumni House	18

Building Level Data: Seasonal Resource Consumption, YOY fluctuations. In our analysis, we also looked at the YOY consumption during the winter (i.e. December through February) and summer (i.e. June through August) months. In general, it is our expectation that seasonal consumption should be generally similar each year, with minor fluctuations to account for YOY differences in temperature averages, precipitation, *et cetera*. A significant observation was made regarding the variability of water consumption - in general, water consumption in both winter and summer (and, indeed, in general across the sample years) fluctuated dramatically for virtually every building included in the sample, whereas for electricity and gas most buildings' consumption displayed generally linear patterns across the sample years. This perhaps highlights that existing water systems on campus may (a) not be functioning as they should, or (b) that there continue to remain challenges with water measurement and metering.

GHG Emissions

Methodology. Based on this consumption data, a GHG inventory was performed to analyze UTM's contribution to global climate change. To calculate the emissions from each fuel source, we first calculated the quantities of CO2, CH4, and N2O produced in each year by each fuel source. This was accomplished using the following formula, which is established in the 2017 *Guideline for Quantification, Reporting and Verification of Greenhouse Gas Emissions* from the Province of Ontario (Ontario Ministry of the Environment and Climate Change, 2017):

$$\boldsymbol{CO_2 \ or \ CH_4 \ or \ N_2O \ = Fuel \times EF \times 0.001}$$

Where

$\boldsymbol{CO_2 \ or \ CH_4 \ or \ N_2O}$ = Annual emissions in kilograms of either CO2 or CH4 or N2O, resulting from the combustion of the specified fuel source;

$\boldsymbol{Fuel} =$ Quantity of fuel combusted in the calendar year. The quantity can be expressed in any units, so long as these are consistent with the denominator of the *EF* units; and

$\boldsymbol{EF} =$ the fuel-specific emissions factor for the given GHG. Emissions factors differ by fuel source and, further, by GHG, and are generally provided in grams of the given GHG per unit of fuel. If the emissions factor is provided in kilograms of the given GHG per unit of fuel, the above equation should be adapted as $\boldsymbol{CO_2\ or\ CH_4\ or\ N_2O\ =\ Fuel\ \times\ EF}$ to remove the unit conversion.

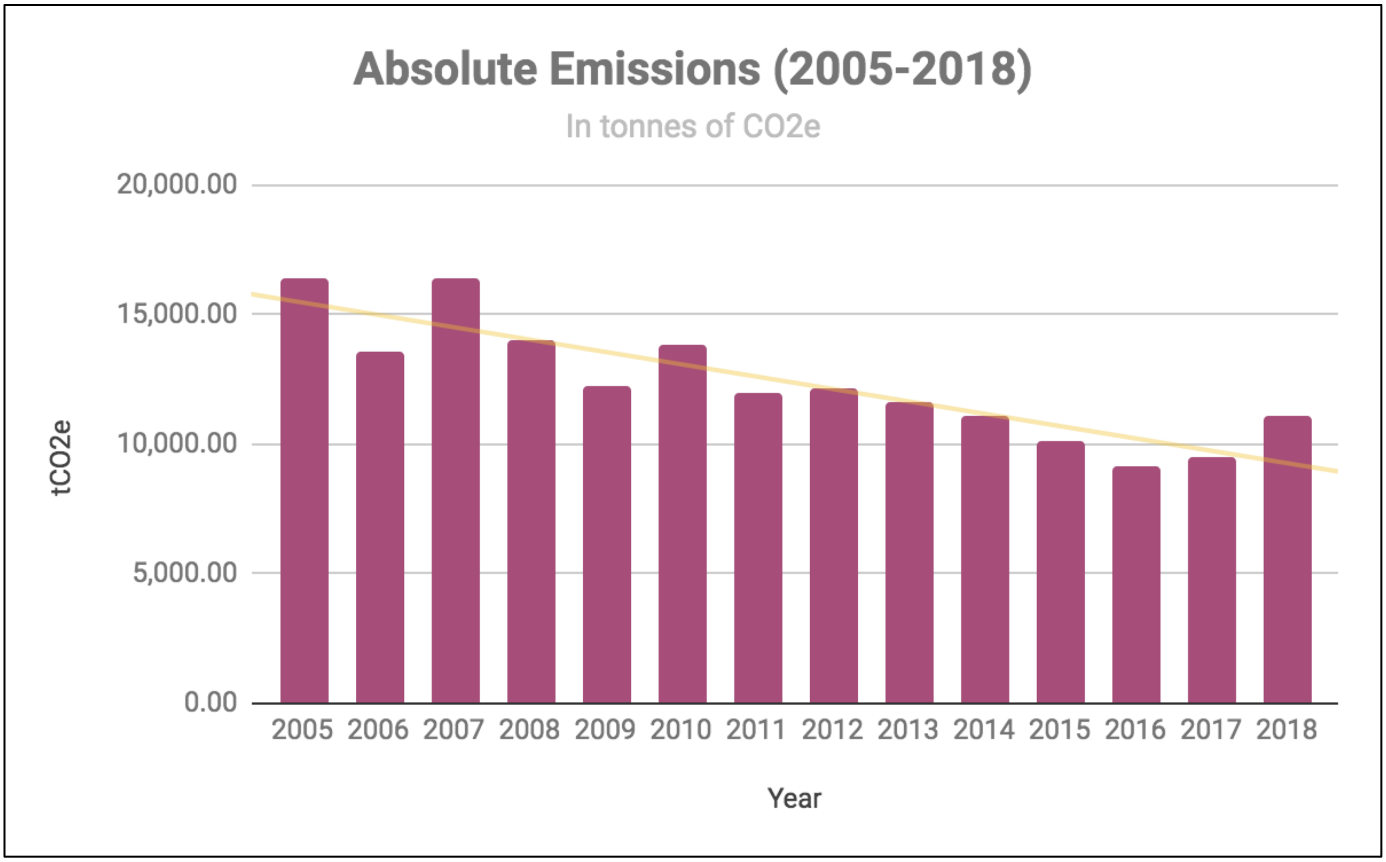
After performing the above calculations for each of CO2, CH4, and N2O, we then multiply the annual emissions of each GHG by its respective global warming potential to convert from kilograms of CH4 and N2O into kilograms of CO2 equivalent (CO2e). The CO2e values for all GHG types are then added together to obtain the total annual emissions for the fuel source in kilograms of CO2e. Total annual emissions from all fuel sources can then be added together to obtain the total annual emissions for the campus in kilograms of CO2e.

In performing our analysis, emissions factors for each fuel source were obtained from the 2018 National Inventory Report. Emissions factors for electricity listed in the 2018 National Inventory Report were however only listed to 2016, and therefore 2016 emissions levels were assumed to 2018. Lastly, in order to reflect the current state of science, 100-year global warming potential values from the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report were used in our calculations. These are slightly different from those in the Fourth Assessment Report, which were used in previous calculations and submissions to the Ontario Government, and thus we have recalculated the emissions for UTM from 2005 using these values.

Absolute Emissions (2005-2018). Since 2005, UTM's absolute emissions have been decreasing. In 2018, the total combined emissions at UTM from natural gas, gasoline, diesel, propane, and electricity was approximately 11,118 tCO2e; this represents a reduction in GHG emissions against 2005 levels of 32.12%. However, using 2014 as a baseline, emissions in 2018 were nearly identical, representing a negligible <0.0001% decrease.

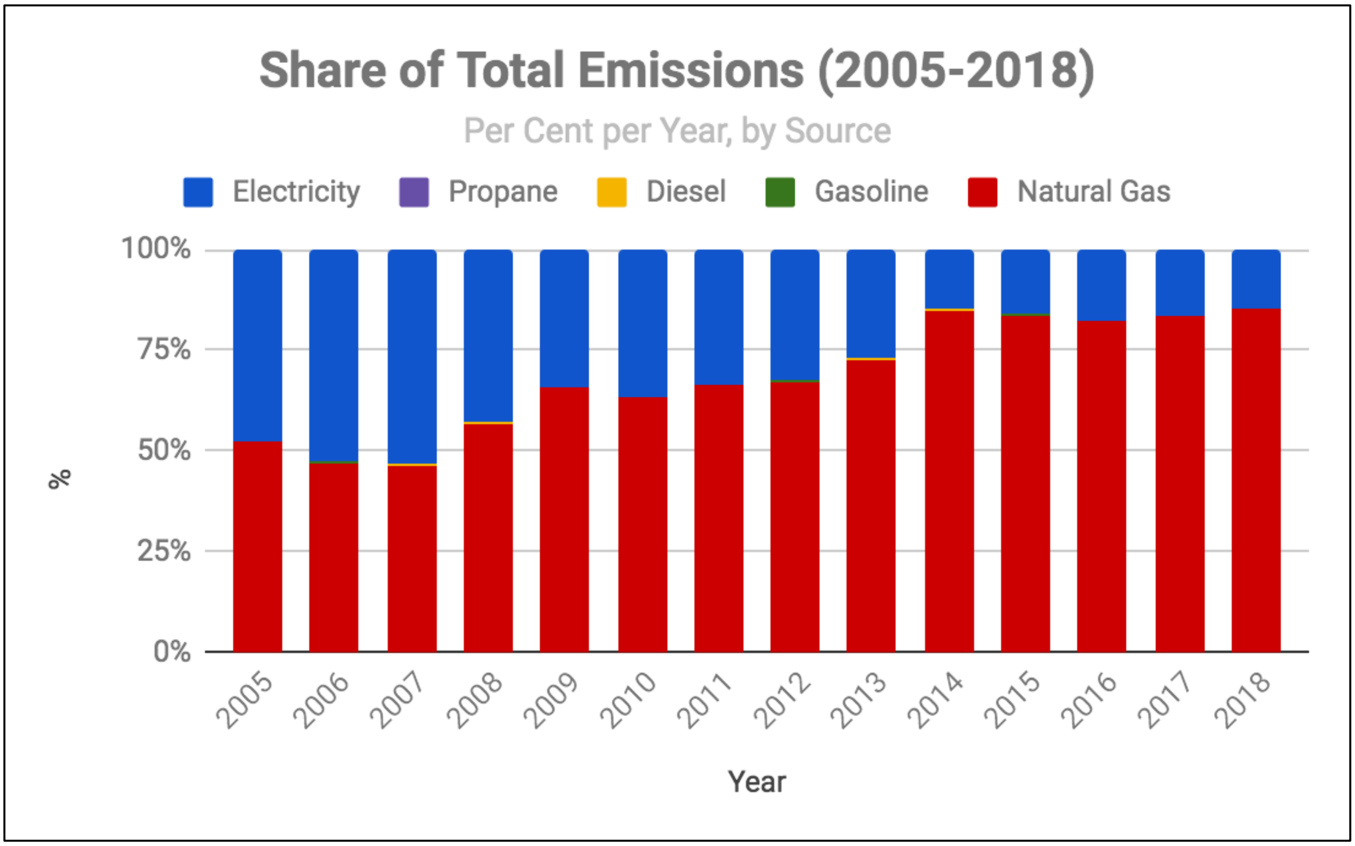
Additionally, emissions intensity in 2018 was reduced by 57.14% compared to 2005. Again however, there was a similarly negligible difference in 2018 emissions intensity as compared to 2014.

Figure 3. UTM Absolute Emissions (Scope 1 + 2), 2005-2018



Each fuel source however does not occupy an equal share of these emissions, and each fuel source's share has changed over time. Whereas in 2005 electricity and natural gas occupied almost equal shares of absolute emissions, natural gas makes up greater than 75% of absolute emissions at UTM in 2018. Annually, gasoline, propane, and diesel collectively represent less than 1% of absolute emissions.

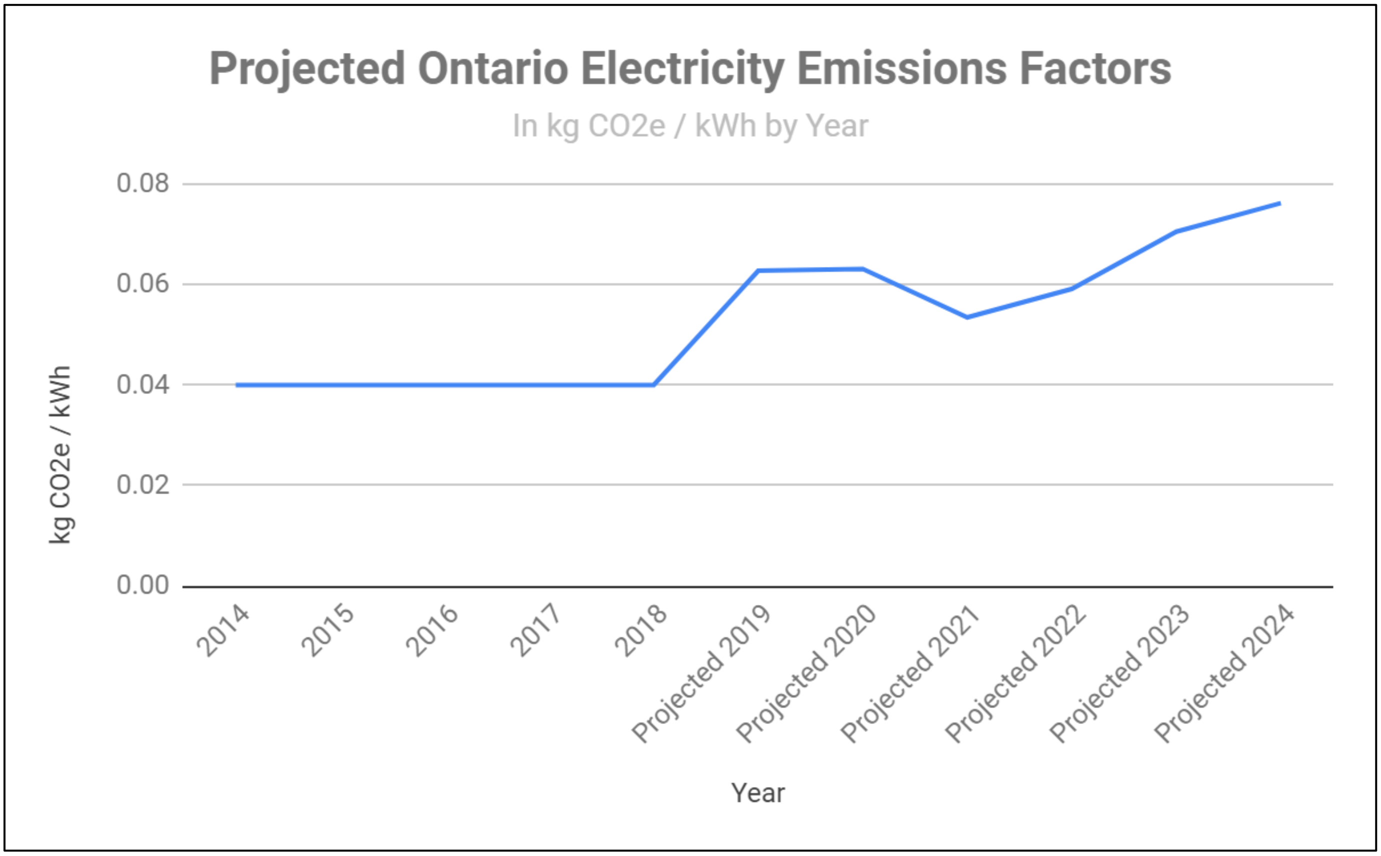
Figure 4. Share of Total Emissions by Source, 2005-2018



The reduction in share of emissions from electricity can largely be attributed to reductions in the emissions factors for electricity in Ontario. Since 2001, the Ontario government has worked to cease coal-fired electricity production, with the final coal-fired generation station, Thunder Bay, closing officially in 2014. This action coupled with increased generation from nuclear and renewable sources like wind, solar, and hydro contributed to these emissions factor reductions.

The dynamic nature of electricity emissions factors is important to recognize, since evidence suggests that emissions factors from electricity in Ontario may soon be increasing. In 2016, the Ontario government started a 10-year project conducting repairs and capacity-building upgrades at the Darlington nuclear generating facility, and is expecting the highest reduction of power output in 2021-2024 while shutting down two units simultaneously (Ontario Power Generation, n.d.). Based on a report prepared by consulting company Intrinsik on behalf of the government of Ontario, it is possible to estimate emissions factors for electricity in Ontario to 2050.Using the best-case scenario from this report (and, therefore, a more conservative estimate of the potential impacts to Ontario's electricity emissions factors), we estimated emissions factors for electricity to our target year of 2024 and used 2018 consumption to estimate the impact of the Ontario government's plans on UTM's total emissions. It was found that, if in 2024 our consumption mirrors 2018, UTM can expect a 13% increase at minimum in its absolute emissions relative to the 2014 baseline. This reinforces the significance of this CDM plan.

Figure 5. Projected Ontario Electricity Emissions Factors to 2024



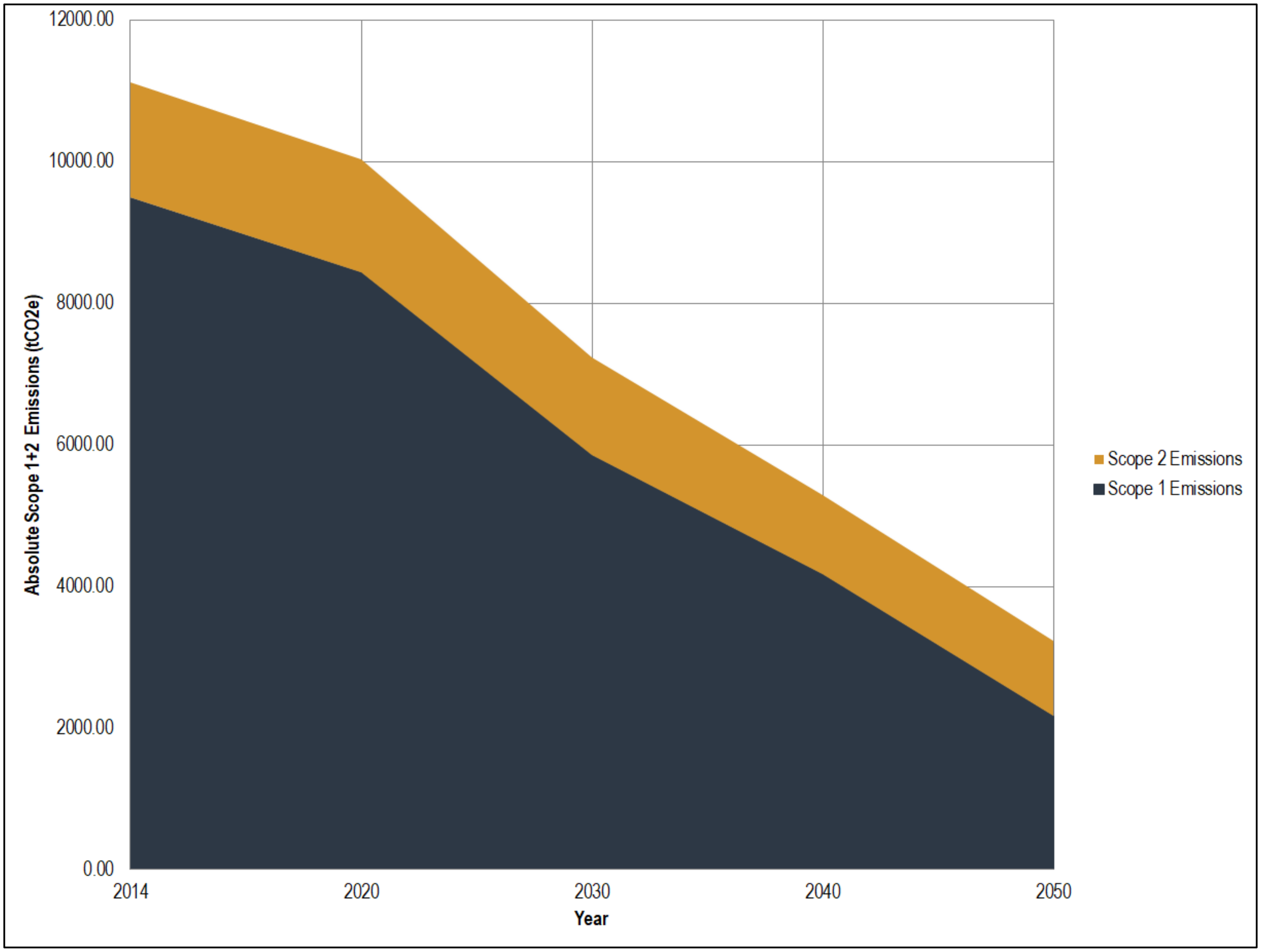
Goals and Objectives

Our client has a stated goal of setting and meeting a science-based target for emissions reductions to the target year of 2024. Science-based targets refer to targets that are developed through the use of climate scenario models, and which demonstrate an alignment with limiting global warming and climate change to a given level (normally 2DS or less). This can be performed using a number of methods, however the most common approach by organizations has been to adopt a sectoral approach (Giesekam, Tingley, & Cotton, 2018). The most widely-used tool to develop such targets is the Sectoral Decarbonization Approach (SDA) Tool from Science Based Targets, which is a global collaboration between CDP (formerly the Carbon Disclosure Project), the World Wildlife Fund (WWF), the United Nations Global Compact Network, and the World Resources Institute (WRI) (Science Based Targets, n.d.).

The SDA Tool, which takes a sector-based approach and is based on limiting global warming to 2DS or below, was thus used to develop a science-based target for emissions reductions at UTM. 2014 was used as the baseline year, and a campus GSM in 2024 of 213,031 m2 was assumed, based on the recent reconstruction of the North Building and the planned construction of two new buildings, a science building and a modular building.

Based on these assumptions, UTM's 2024 emissions target is 8,972.05 tCO2e - this represents an approximately 19% reduction in total emissions compared to 2014. The greatest reduction in emissions is required for UTM's Scope 1 emission, reducing 22% from 9,497.97 tCO2e in 2014 to 7,443.44.

Figure 6. UTM Scope 1 + Scope 2 Absolute Emissions Target to 2050



We can work backwards from these emissions targets to set targets for reducing energy consumption. Assuming the 2014 emissions factor of 0.04 kgCO2e/kWh for electricity, this target represents electricity consumption in 2024 of approximately 38.22-million kWh - in other words, reducing UTM's electricity consumption relative to 2014 levels by 2,518,294 kWh, or 6.2%. However, if we instead assume the 2024 projected emissions factor of 0.08 kgCO2e/kWh, this emissions target would represent only 19.12-million kWh of electricity used in 2024: this means UTM would have to reduce its electricity consumption in 2024 by 21,625,919 kWh, or 53.1%, relative to 2014 levels. This highlights the potential impact that the closing of the Darlington nuclear facility may have on UofT's ability to meet its existing commitments. For scope 1 emissions, meeting this 2024 target represents approximately 3.91-million m3 of natural gas consumed in 2025, and thus requires a minimum reduction of natural gas consumption by 1,052,555.78 m3 relative to 2014. Represented as an intensity target, this CDM plan commits to reducing UTM's carbon intensity to 43.91 kgCO2e / m2, or by 27% in 2024 relative to 2014.

Measures

Planned

There are a number of projects that are currently planned and approved which will contribute to these goals. One of these is the campus-wide real-time energy dashboard, a planned action from the 2014-2019 CDM plan that was recently completed. Other building-specific projects are listed below, and include a combination of technical and operational measures.

Table 5. 2014-2019 CDM Plan Measures Summary

Building(s)	Name	Project cost ($)	Completion Date	Savings		
				Electricity (kWh/yr)	Gas (mmBTU/yr)	Emissions (tCO2e/yr)
Alumni House	Heating & DHW boilers retrofit	220,000	Apr-19	Unknown	Unknown	Unknown
CCT	VFD replacement	450,000	Apr-19	474,930	0	18.9972
	Parking solar thermal	6,000,000	Apr-21	0	961	54
CUP	Chiller retrofit & optimization	4,000,000	Apr-21	417,891	0	35
Davis	LED lighting retrofit	372,519	Mar-19	2,301,180	0	92.0472
	Windows upgrade	1,600,000	Apr-21	Unknown	Unknown	Unknown
	HVAC retrofit	3,000,000	Apr-19	2470	247997	150.876251
	DHW Instantaneous HX	100,000	Apr-21	0	89	5
Erindale Hall	Chiller, heating, & DHW boilers retrofit	750,000	Apr-21	47,389	1,392	81
Kaneff	RTU replacement phase 1	750,000	Apr-19	1,003,853	0	40.15412
	RTU replacement phase 2	1,000,000	Apr-19	34540	286	17.95332

Oscar Peterson Hall	Heating & DHW boilers retrofit	850,000	Apr-21	0	1,305	72
RAWC	HVAC retrofit & solar pool heating	4,500,000	Apr-19	227000	2194	134.5982623
Student Centre	RTU and DHW replacement	500,000	Apr-21	0	554	31

Proposed

As with examples from peer universities, the range of implementation costs and expected savings were assigned into the following groups: low (<$10,000), medium ($10,000-$100,000), high ($100,000 - $1M) and very high (>$1M).

1. Establish an Energy Management Team

Based on ISO 50001, UTM should seek to establish an Energy Management Team consisting of champions who currently play significant roles related to energy management. This team may include engineers, procurement officers, caretakers, and other staff who work in and on facilities and who play direct roles in implementing the recommendations of this CDM plan, however this may also include students, faculty, and staff, who act as primary building occupants and may play significant roles in disseminating information and influencing their peers. In addition, these individuals would bring forth any concerns related to energy management - for example, reducing temperature in a facility (ex: building, pool) may save energy, however may affect occupant comfort, and therefore these individuals would be able to bring that perspective. This also presents an opportunity, once again, to engage students. It may be possible to integrate the Energy Management Team with an existing “Green Team.”

Cost estimate: Low
Savings estimate: unknown; however, has been shown to contribute to long term success and continuous improvement for energy management
Lifespan: Ongoing

2. Develop a communications channel for staff, students, and faculty

A communications channel that allows for bottom-up communication, besides resulting in cost savings, can also contribute to greater employee and student satisfaction. As part of its internal energy management system, Metrolinx established an internal, online communications platform for staff called “Ideas@Work,” which allows for any staff member to suggest an idea that they believe would benefit the company (Transportation Association of Canada, 2015). Other staff can then vote on these ideas, and if ideas reach a threshold of votes, they then are fast-tracked to top management for implementation. A similar system may be implemented at UTM.

Cost estimate: Low
Savings estimate: 5-10% reduction in energy consumption at residences and on campus.
Lifespan: 3 months-1 year

3. Advertise energy-saving behaviours at UTM residences and on campus.

Building level analysis identified two key gaps in current planned measures at UTM. The first of this is a lack of behavioural energy-saving measures. The second is that although several student residences placed in the top ten for facilities when looking at resource consumption, intensity, and a combined score for the two, measures from the 2014-2019 and that are currently planned have largely not been focused on student residences. This is significant, since students represent a significant proportion of daily building occupants, however also because engaging students may provide an opportunity to support other strategic goals of the university.

This behavioural measure would aim to encourage both on- and off-campus students to use energy efficiently and to reduce unnecessary energy use wherever possible. Some ways of delivering information to the residents are:

- Signs and posters at locations where specific energy-saving actions are desirable (e.g. turning off cooking appliances when leaving a kitchen).
- Social events themed around energy efficiency (e.g. energy week, contests, quizzes)
- Promotion of energy-efficient behaviour through conversations between the residence team and student residents in common areas.

It is commonly assumed that typical behavioural measures, if successful, may provide 5-10% reduction in energy consumption. Additionally, in order to have continuous benefits of behavioural measures, the initiatives need to be repeated each academic year for new students, and approximately quarterly as follow-ups.

Cost estimate: medium
Savings estimate: 5-10% reduction in energy consumption at residences and on campus.
Lifespan: 3 months-1 year

4. Conduct staff training about efficient use of energy.

Previous CDM plan did not mention any behavioural measures for engaging staff in energy saving. To do this, an employee engagement team can be formed to make a series of presentations and events for employees in each department about energy efficiency skills in workplace. This can be accompanied by handing out brochures and doing ‘practice days’ where employees can focus on implementing the above skills in their office environments. Semi-annually or quarterly follow-ups, in the form of presentations, practice days and progress evaluations, are necessary to renew employee engagement with the new behaviours and to determine any improvements to the engagement program (methodology from the Natural Resources Canada, 2018).

Cost estimate: medium
Savings estimate: 5-10% reduction in campus-wide energy consumption.
Lifespan: 3 months-1 year

5. **Install low-flow taps with water aerators in the Kaneff Centre and Davis building.**

Traditional taps use large amounts of water, which leads to increased water waste. Low-flow taps will help conserving water and reducing some costs for heating the water. Once complete, the savings will last for the lifetime of the taps, approximately 10 years.

Cost estimate: low
Savings estimate: low
Lifespan: 10 years

6. **Use cogeneration at the Central Utilities Plant (CUP) to provide both electricity and useful heat to the campus buildings.**

Cogeneration, also known as combined heat and power (CHP), is a useful measure to provide the otherwise wasted heat to the nearby buildings. Implementation requires contacting a technical team either amongst campus engineers (if available), or from an external provider. Once completed, the cogeneration system will be in operation for the entire lifetime of the CUP, assuming regular and timely maintenance.

It should be noted that this measure may have a significant impact on our GHG emissions, although it is likely to help make UTM's existing centralized heating and cooling system more efficient and help generate revenue. We recommend this measure in conjunction with measure 8, installing carbon capture technologies.

Cost estimate: high
Savings estimate: high
Lifespan: CUP lifetime

7. **Install Carbon capture technology and heat capture and reuse technologies at the Central Utilities Plant (CUP).**

Carbon capture technology allows removing Carbon compounds from the CUP emissions, while heat capture and reuse increases efficiency of the CUP operation through providing waste heat to nearby buildings and facilities.

An example of such a system in action can be found in the City of Markham. Markham District Energy Inc. (MDEI), a wholly-owned subsidiary of the City of Markham, is a district energy utility that provides combined heat and power to commercial facilities located in key growth centres within the City of Markham. In 2018, MDEI announced a partnership with Pond Technologies (TSX-V: POND), a publicly-traded company located in Markham, ON, to implement its proprietary Matrix System (Markham District Energy Inc., 2018; Pond Technologies, 2018). Pond Technologies was a semi-finalist in 2016 for the Carbon X-Prize, and its scalable system uses CO_2 industrial smokestack emissions to grow algae, which can then be repurposed into a variety of products, such as nutraceuticals, animal feed, or "almost any hydrocarbon-based product" (Pond Technologies, n.d.). Pond has a number of pilot projects funded or underway, including with Stelco Inc. (Pond Technologies, 2019) and Saint Mary's Cement (St. Marys Cement, 2017), and has strategic partnerships with MDEI and SNC-Lavellin.

Regular technical maintenance (once in several years) will be required after installation.

Cost estimate: high
Savings estimate: high
Lifespan: several years

8. Insulate the utility tunnel to Davis Building.

This initiative will prevent heat losses between the CUP and Davis Building, resulting in energy savings and GHG emissions reductions. The insulation would result in energy savings for the lifetime of the insulation materials, assuming timely maintenance and replacement.

Cost estimate: low-medium
Savings estimate: medium
Lifespan: lifetime of insulating materials

Renewable Energy

There are two renewable sources of energy at UTM - solar and geothermal. Two solar arrays have been installed on the south faces of Davis and Instructional buildings and have total energy capacities of 5.4kW and 21kW respectively. The geothermal system, located under the soccer field besides the Instructional building, consists of 117 boreholes, each 168 m deep. The system provides complete heating and cooling to the Instructional Building (IB).

Additional solar PV panels may be installed on rooftops of the campus buildings. The total rooftop area of the UTM campus buildings has been estimated from Google Maps satellite view and amounts to 37,000 m^2 (see Table 6 below for details). Generally, approximations are used to determine a potential energy output (0.117 kW/m^2) of installing solar panels that cover this area, as well as the cost of installation ($1.8/Watt). Therefore, the maximum potential energy output of a rooftop PV system is 4300kW, and the cost of installation of such system is $7.8Million.

Table 6. Estimated rooftop areas of UTM campus buildings.

Building name	Rooftop area (est.), m^2
SU (Chatime)	2,000
Innovation Complex (Kaneff Centre)	800
Davis Building	7,800
Health Sciences Complex	1,000
MIST	2,000
Hazel McCallion Centre (Library)	2,000
Instructional Building	2,800
North Building	3,300

Building name	Rooftop area (est.), m^2
Deerfield Hall	2,400
Erindale Theatre	220
Erindale Hall Residences	800
Colman Commons	1,600
Other residences	10,000
Principal's road (shed)	450
TOTAL (approx.)	**37,000**

Plan Implementation

Prioritizing the measures.

The table below shows the measures ranked by their importance for energy saving and the ease of implementation, sorted by the total ranks (the sums of the two criteria). The ranks range from 1 (most important and easiest to implement) to 9 (least important and most difficult to implement). The highest importance was assigned to those measures expected to result in the highest energy saving, while the highest ease of implementation was assigned to the least labour-intensive measures. The lowest total ranks show the highest-priority measures.

Table 7. Measures Priority Ranking

Measure name	Importance (1 = Greatest, 9 = Least)	Ease of implementation (1 = Greatest, 9 = Least)	Total rank
Establish communication channel	1	2	3
Establish Energy Management Team	3	1	4
Advertise energy-saving behaviours	7	3	10
Conduct staff training	6	4	10
Use cogeneration at CUP	2	8	10
Insulate the utility tunnel to Davis Building	4	6	10
Install on-demand water heaters	5	7	12
Install low-flow taps	9	5	14
Install Carbon and heat capture at CUP	8	9	17

Monitoring and Evaluation

The following table lists the metrics to be reported by UTM in year 2024 (at the end of the 5-year period of the CDM plan). These metrics can also be evaluated annually to track progress towards the final goals.

Table 8. Reporting & Metrics

Measure name	Results / metrics reported
Advertise energy-saving behaviours	- Electricity savings (kWh/year) - Level of awareness and acceptance rate of new behaviours
Staff training	- Electricity savings (kWh/year) - Level of awareness and acceptance rate of new behaviours
Install low-flow taps in Kaneff and Davis buildings	- Number of taps installed - Water savings (m3/year)
Install on-demand water heaters	- Percentage of old heaters replaced - Electricity savings (kWh/year) - GHG emissions reductions (tCO2e/year)
Insulate the utility tunnel to Davis Building	- Electricity savings (kWh/year)
Cogeneration at CUP	- Electricity savings (kWh/year) - GHG emissions reductions (tCO2e/year) - Replacement of any heating equipment
Install Carbon and heat capture at CUP	- GHG emissions reductions (tCO2e/year) - Replacement of any heating equipment

Final remarks

After approval of current CDM plan by senior management at UTM, the CDM plan will be made publicly available through the University website, intranet site, and registrar office (in print format).

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Appendix

Figure 7. Electricity Intensity, 2014-2018

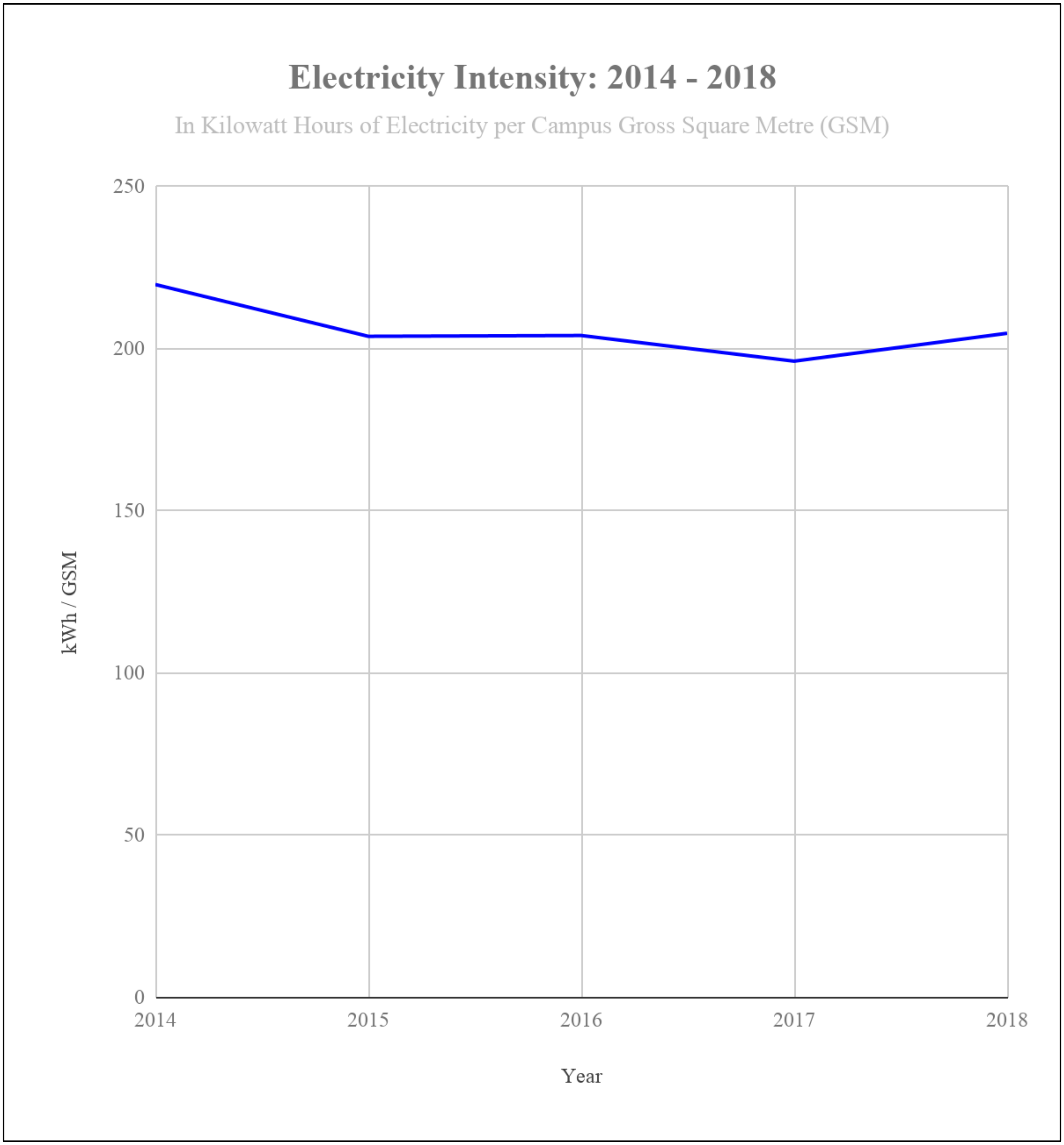

Figure 8. Natural Gas Intensity, 2014-2018

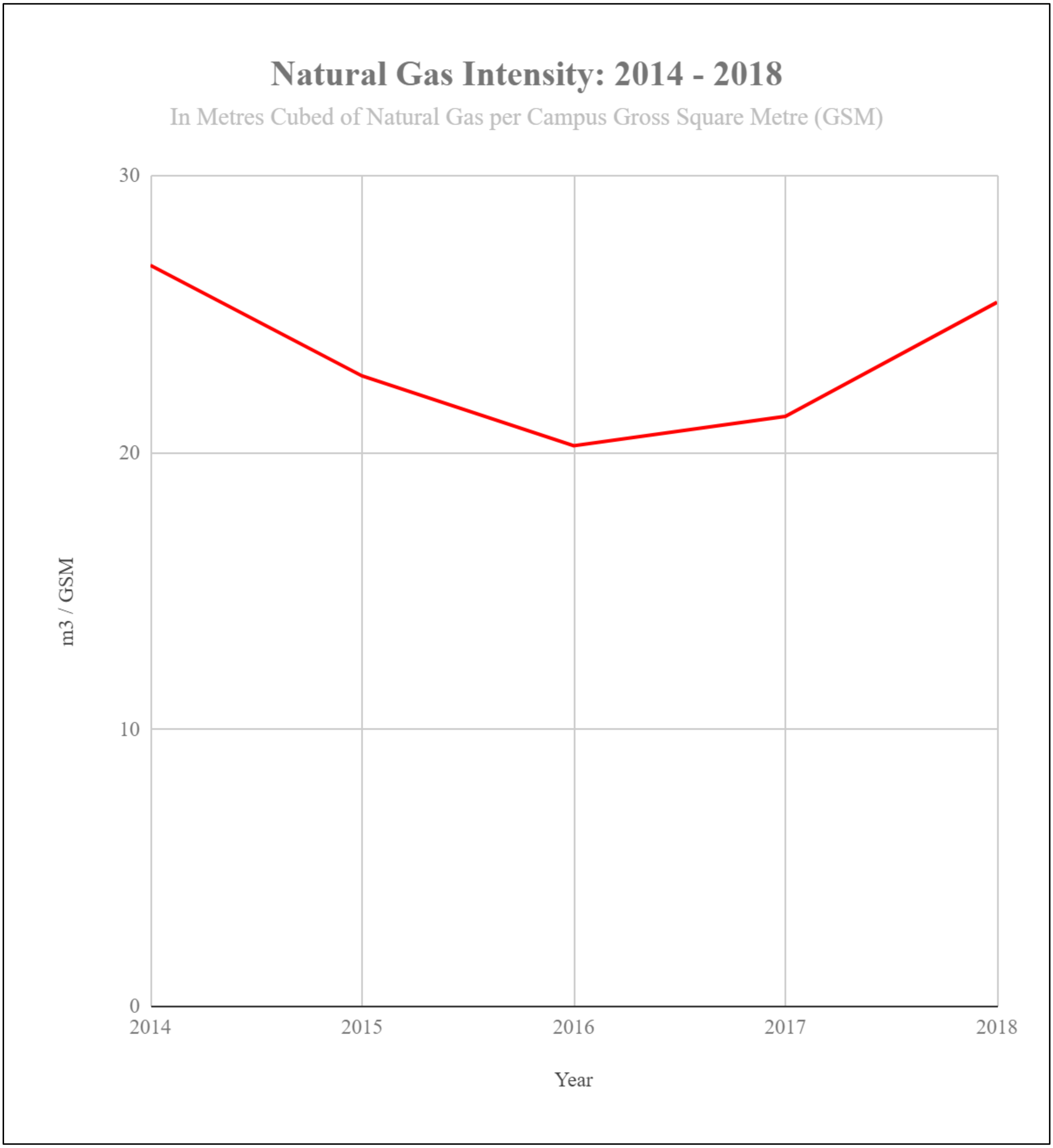

Figure 9. Natural Gas Consumption, 2005-2018

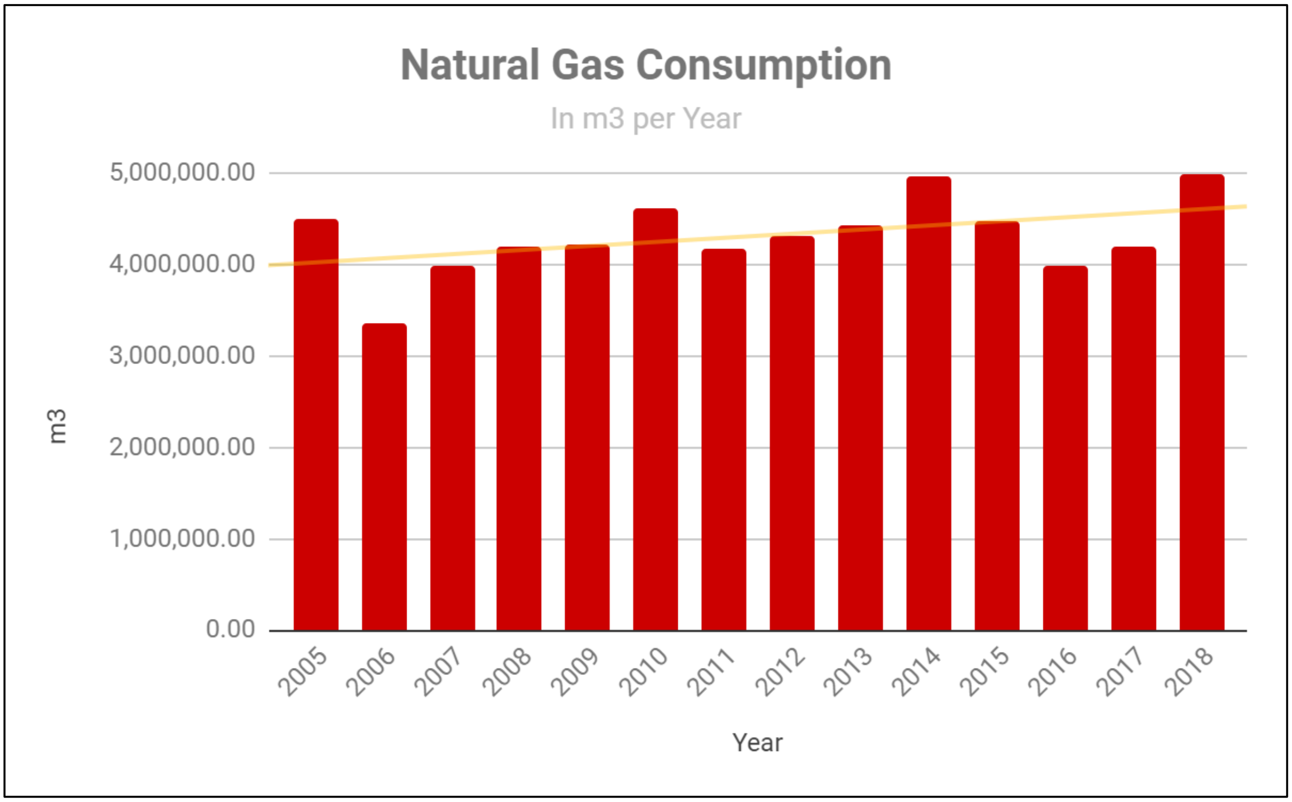

Figure 10. Electricity Consumption, 2005-2018

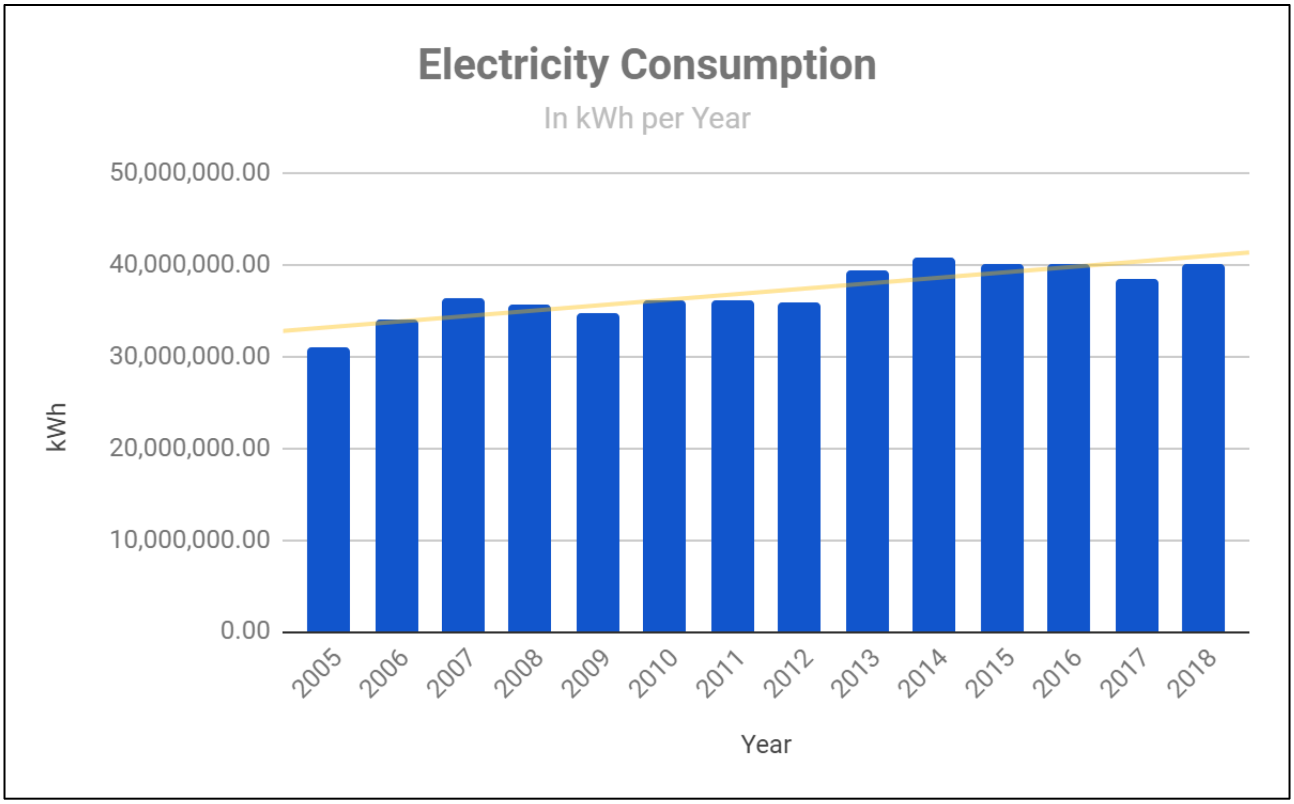

Figure 11. YOY Hydro Use By Facility, 2011-2015

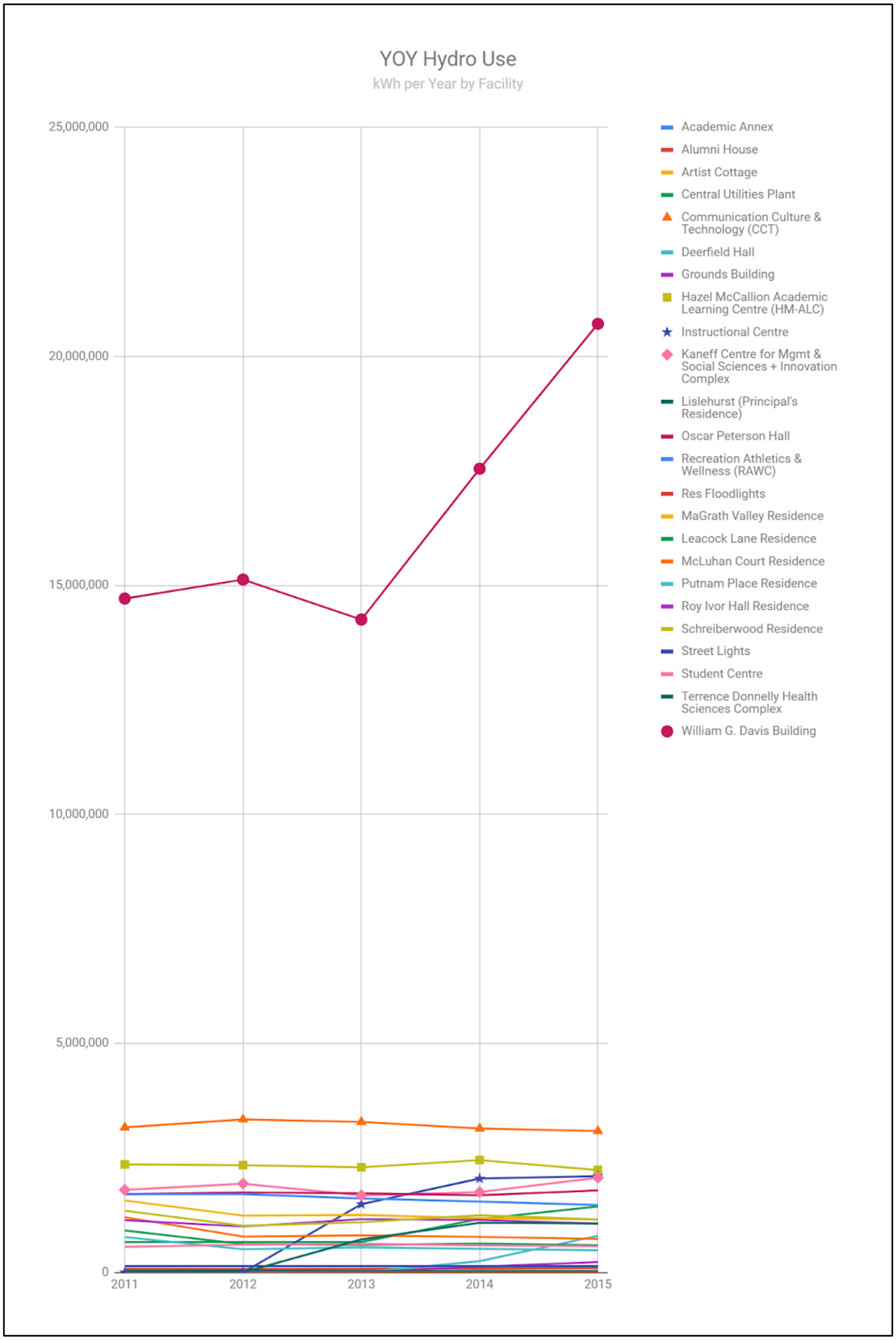

Figure 12. YOY Water Use By Facility, 2011-2015

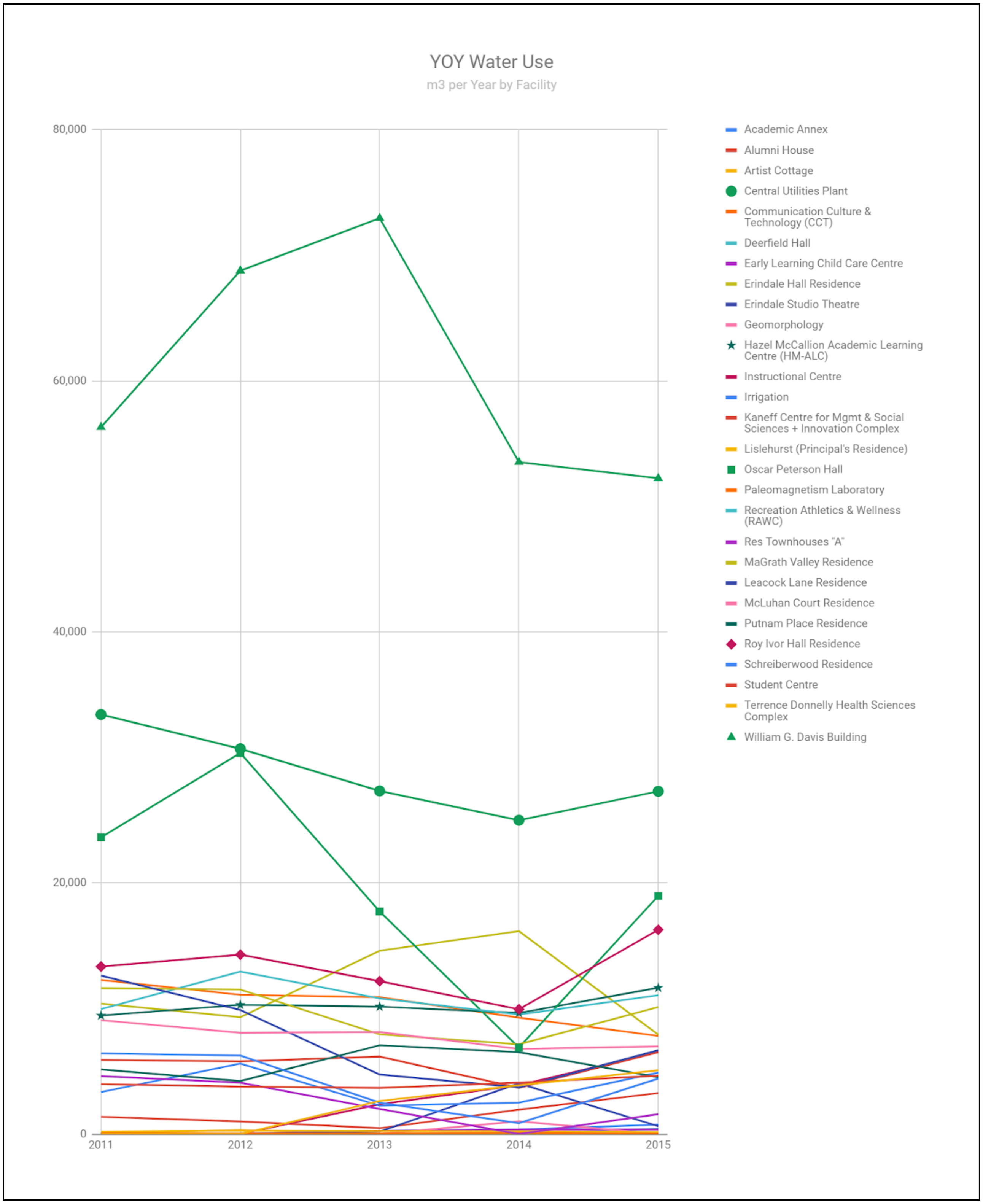

Figure 13. YOY Gas Use By Facility, 2011-2015

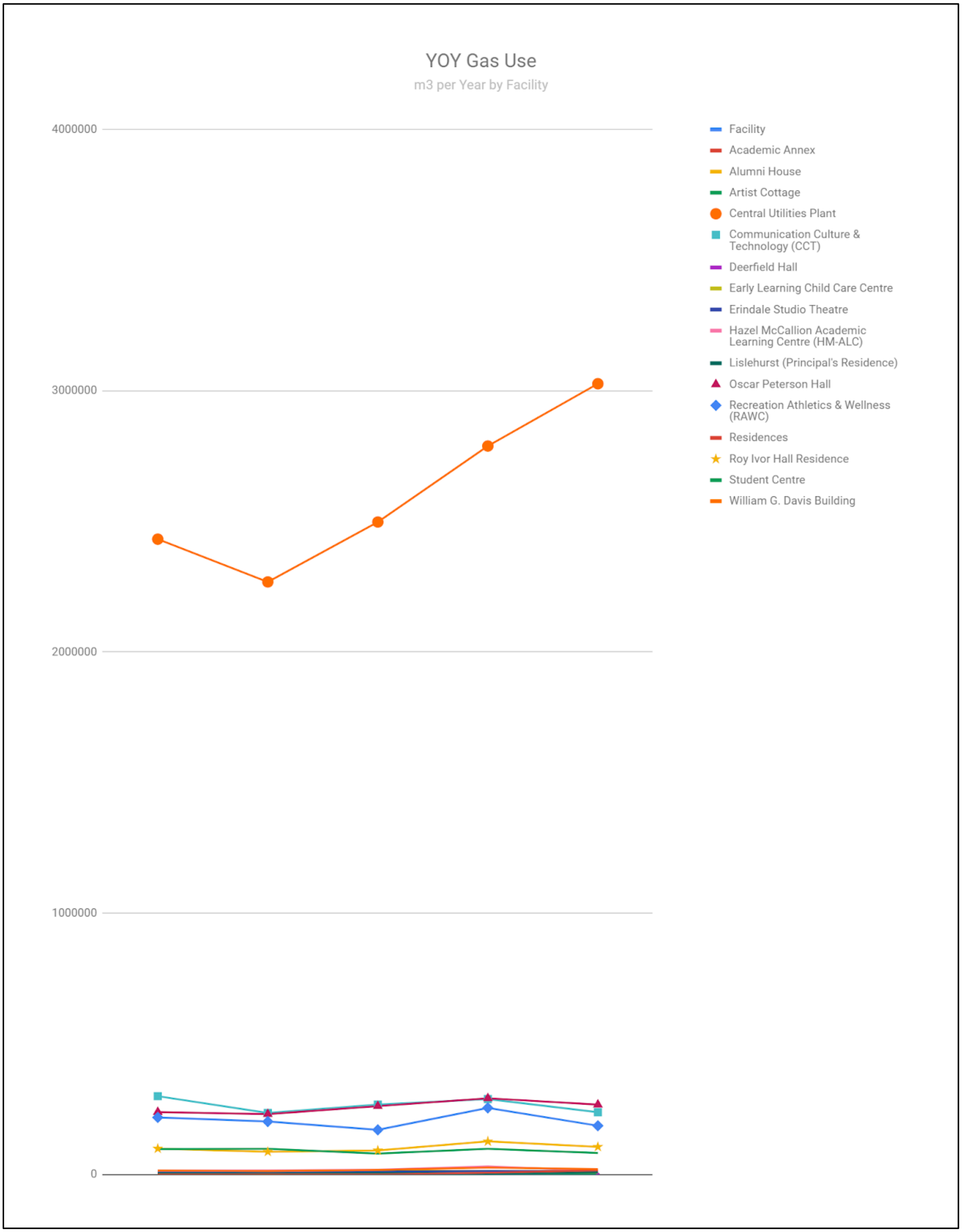

Table 9. Ontario Electricity Emissions Factors

Year	g CO_2e per kWh	Source
2005	250	Canada's 2016 NIR, part 3 pg 69 - Table A13-7, consumption intensity.
2006	210	Canada's 2010 NIR, part 3 pg 42 - Table A13-7, consumption intensity.
2007	240	Canada's 2011 NIR, part 3 pg 72 - Table A13-7, consumption intensity.
2008	170	Canada's 2012 NIR, part 3 pg 75 - Table A13-7, consumption intensity.
2009	120	Canada's 2013 NIR, part 3 pg 78 - Table A11-7, consumption intensity.
2010	140	Canada's 2015 NIR, part 3 pg 99 - Table A13-7, consumption intensity.
2011	110	Canada's 2016 NIR, part 3 pg 69 - Table A13-7, consumption intensity.
2012	110	
2013	80	
2014	40	
2015	40	
2016	40	
2017	40	Assumed from 2016
2018	40	
2019	60	Calculated from https://www.opg.com/darlington-refurbishment/Documents/IntrinsikReport_GHG_OntarioPower.pdf pg 25-26 - Table 4-2 & Table 4-3
2020	60	
2021	50	
2022	60	
2023	70	
2024	80	

Table 10. Fuel Emissions Factors

Fuel	Greenhouse Gas (g GHG / Unit)			Source
	CO2	*CH4*	*N2O*	
Natural Gas	1888	.037	.035	Canada's 2016 NIR, part 2 pg 210-211 - Table A6-1 & Table A6-2
Gasoline	2307	.1	.02	Canada's 2016 NIR, part 2 pg 212 - Table A6-4; Values for "Motor Gasoline"
Diesel	2681	.133	.4	Canada's 2016 NIR, part 2 pg 212 - Table A6-4; Values for "Diesel - Refineries and Others";
Propane	1515	.027	.108	Canada's 2016 NIR, part 2 pg 211 - Table A6-3; Values for “Residential”

Table 11. IPCC Global Warming Potentials (GWPs)

GHG	Formula	100-Year GWP	
		4th Assessment Report	5th Assessment Report
Carbon Dioxide	CO2	1	1
Methane	CH4	25	28
Nitrous Oxide	N2O	298	265

Table 12. YOY Total Emissions & Emissions Intensity Summary

Year	Campus GSM (m2)	Intensity (tCO2e / GSM)	Total Emissions		Scope 1 Emissions		Scope 2 Emissions
2005	113,475.63	0.14	**16,377.49**	=	8611.05	+	7,766.44
2006	126,954.00	0.11	**13,582.58**	=	6431.34	+	7,151.25
2007	157,149.00	0.10	**16,365.08**	=	7623.67	+	8,741.41
2008	157,285.00	0.09	**14,063.05**	=	8017.55	+	6,045.51
2009	157,285.00	0.08	**12,209.19**	=	8045.65	+	4,163.54
2010	158,078.00	0.09	**13,849.04**	=	8799.37	+	5,049.67
2011	178,226.00	0.07	**11,951.91**	=	7966.26	+	3,985.65
2012	178,782.91	0.07	**12,166.20**	=	8225.51	+	3,940.69
2013	178,782.91	0.07	**11,622.22**	=	8468.12	+	3,154.09
2014	185,484.00	0.06	**11,127.31**	=	9497.97	+	1,629.34
2015	196,417.43	0.05	**10,134.32**	=	8534.37	+	1,599.95
2016	196,417.43	0.05	**9,183.87**	=	7581.93	+	1,601.93
2017	196,417.00	0.05	**9,512.50**	=	7972.766054	+	1,539.74
2018	196,417.00	0.06	**11,117.58**	=	9510.288219	+	1,607.29

Figure 14. Emissions Intensity, 2005-2018

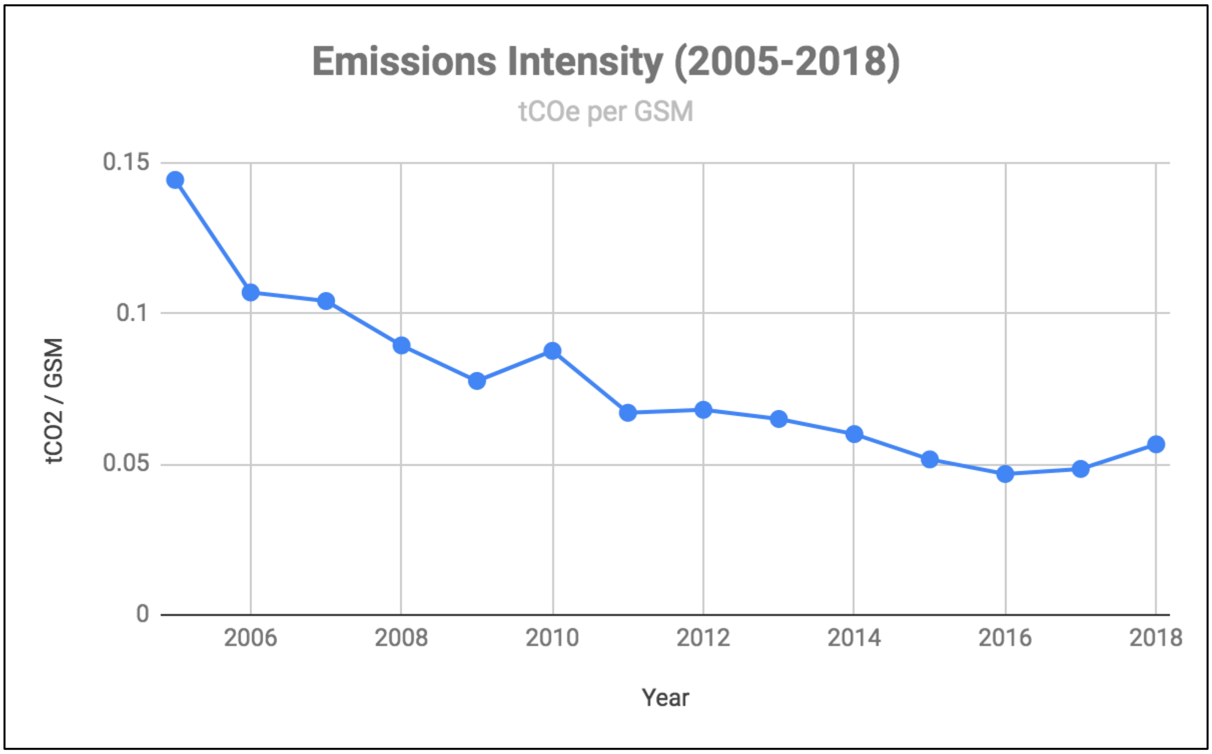

Table 13. Water Consumption Ranking *(Rank$_{consumption}$)*

Rank	Facility	2015 Consumption (L)	% of Total Consumption	Cumulative %
1	William G. Davis Building	52242	23.39%	23.39%
2	Central Utilities Plant	27299	12.22%	35.61%
3	Oscar Peterson Hall	18970	8.49%	44.11%
4	Roy Ivor Hall Residence	16271	7.29%	51.39%
5	Hazel McCallion Academic Learning Centre (HM-ALC)	11652	5.22%	56.61%
6	Recreation Athletics & Wellness (RAWC)	11056	4.95%	61.56%
7	MaGrath Valley Residence	10115	4.53%	66.09%
8	Erindale Hall Residence	7,917	3.54%	69.63%
9	Communication Culture & Technology (CCT)	7,815	3.50%	73.13%
10	McLuhan Court Residence	6,980	3.13%	76.26%

Table 14. Water Intensity Ranking (Rank$_{intensity}$)

Rank	Facility	2015 Consumption Intensity (L/m2)
1	Central Utilities Plant	9.29
2	Alumni House	6.05
3	Roy Ivor Hall Residence	3.03
4	McLuhan Court Residence	2.2
5	Putnam Place Residence	1.96
6	Early Child Care Centre	1.91
7	Oscar Peterson Hall	1.88
8	Student Centre	1.72
9	Leacock Lane Residence	1.69
10	Recreation Athletics & Wellness (RAWC)	1.67

Table 15. Electricity Consumption Ranking ($Rank_{consumption}$)

Rank	Facility	2015 Consumption	% of Total Consumption	Cumulative %
1	William G. Davis Building	20,711,063	46.91%	46.91%
2	Communication Culture & Technology (CCT)	3,086,201	6.99%	53.90%
3	Hazel McCallion Academic Learning Centre (HM-ALC)	2,234,102	5.06%	58.96%
4	Instructional Centre	2,100,651	4.76%	63.72%
5	Kaneff Centre for Mgmt & Social Sciences + Innovation Complex	2,066,060	4.68%	68.39%
6	Oscar Peterson Hall	1,788,398	4.05%	72.45%
7	Recreation Athletics & Wellness (RAWC)	1,471,703	3.33%	75.78%
8	Central Utilities Plant	1,438,169	3.26%	79.04%
9	Schreiberwood Residence	1,155,782	2.62%	81.65%
10	MaGrath Valley Residence	1,153,159	2.61%	84.27%

Table 16. Electricity Intensity Ranking ($Rank_{intensity}$)

Rank	Facility	2015 Consumption Intensity
1	Central Utilities Plant	489.4
2	William G. Davis Building	435.53
3	Grounds Building	314.94
4	Kaneff Centre for Mgmt & Social Sciences + Innovation Complex	249.98
5	Hazel McCallion Academic Learning Centre (HM-ALC)	260.86
6	McLuhan Court Residence	229.63
7	Schreiberwood Residence	225.88
8	Recreation Athletics & Wellness (RAWC)	222.29
9	Student Centre	209.68
10	Putnam Place Residence	208.71

Table 17. Natural Gas Consumption Ranking ($Rank_{consumption}$)

Rank	Facility	2015 Consumption	% of Total Consumption	Cumulative %
1	Central Utilities Plant	3026707	70.59%	70.59%
2	Oscar Peterson Hall	267313	6.23%	76.83%
3	Communication Culture & Technology (CCT)	238243	5.56%	82.38%
4	Recreation Athletics & Wellness (RAWC)	186396	4.35%	86.73%
5	Roy Ivor Hall Residence	105681	2.46%	89.19%
6	Student Centre	82375	1.92%	91.12%
7	William G. Davis Building	20352	0.47%	91.59%
8	Residences	15985	0.37%	91.96%
9	Hazel McCallion Academic Learning Centre (HM-ALC)	14591	0.34%	92.30%
10	Erindale Studio Theatre	12511	0.29%	92.60%

Table 18. Natural Gas Intensity Ranking ($Rank_{intensity}$)

Rank	Facility	2015 Consumption Intensity
1	Central Utilities Plant	42.89
2	Early Learning Child Care Centre	40.27894737
3	Student Centre	30.3816563
4	Recreation Athletics & Wellness (RAWC)	28.15411385
5	Oscar Peterson Hall	26.44113498
6	Erindale Studio Theatre	23.64804839
7	Alumni House	22.68762527
8	Roy Ivor Hall Residence	19.69386101
9	Academic Annex	15.14837103
10	Communication Culture & Technology (CCT)	10.46748526