Toronto Metropolitan University

DWB CONSULTANTS

2024 ENERGY CONSERVATION AND DEMAND MANAGEMENT PLAN

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LETTER FROM THE EXECUTIVE DIRECTOR

MARK DETTWEILLER

Executive Director
Campus Development

The 2024-2029 Energy Conservation and Demand Management (ECDM) Plan for Toronto Metropolitan University (TMU) is being published at a pivotal juncture in the university's drive toward creating a more sustainable campus.

In April 2024, TMU published its inaugural Sustainability Action Plan, publicly committing to achieving net zero emissions by 2045 or sooner. The objectives outlined in the Sustainability Action Plan align closely with TMU's 2020-2030 Campus Master Plan, which identifies the creation of a vibrant and sustainable campus as an institutional priority.

TMU's Facilities Management and Development team strives not only to provide an exceptional learning and work environment for our students, faculty, and staff, but also to lead by example and showcase what sustainable, zero-carbon operations can look like in this century and beyond.

Since 2010, TMU's campus area has expanded by more than 20%, adding over 800,000 sq.ft. of floor space. With TMU's School of Medicine set to begin operations in September 2025, further expansion is anticipated. Continuing to reduce the carbon footprint and energy consumption of a rapidly growing institution is not an easy task. However, through extensive collaboration with multidisciplinary internal and external partners, our team is well-suited to meet this challenge.

The 2024-2029 ECDM plan complements TMU's Sustainability Action Plan, and provides updates to TMU's energy and emissions profiles, campus information, and key energy conservation initiatives being implemented to achieve TMU's aspirational goals.

Publishing the renewed ECDM Plan is a small but important step in reaffirming TMU's commitment to sustainability, innovation, and leadership in environmental stewardship, all of which will pave the way for a brighter future for the university and the broader community.

Mark Dettweiler

Executive Director, Campus Development

ACRONYMS

BAS:	Building Automation System
DOAS:	Dedicated Outdoor Air System
ECDM:	Energy Conservation and Demand Management
ekWh:	Equivalent kWh for a Fuel
EUI	Energy Use Intensity (ekWh/m²)
FTE:	Full-Time Equivalent Student
GA:	Global Adjustment
GHG:	Green House Gas
GJ:	Gigajoule
HVAC:	Heating, Ventilation, and Air Conditioning
IESO:	Independent Electricity System Operator
$kgCO_2e$:	Kilogram of Carbon Dioxide equivalent
kJ:	Kilojoule
kW:	Kilowatt
kWh:	Kilowatt-hour
LEED:	Leadership in Energy and Environmental Design
m^2:	Square meters
m^3:	Cubic meters
MWh	Megawatt-hour
PUMA:	Prism Utility Monitoring & Analysis
PV:	Photovoltaic
$TonCO_2e$:	Metric Ton of Carbon Dioxide equivalent
TMU:	Toronto Metropolitan University

See Campus map for buildings acronyms

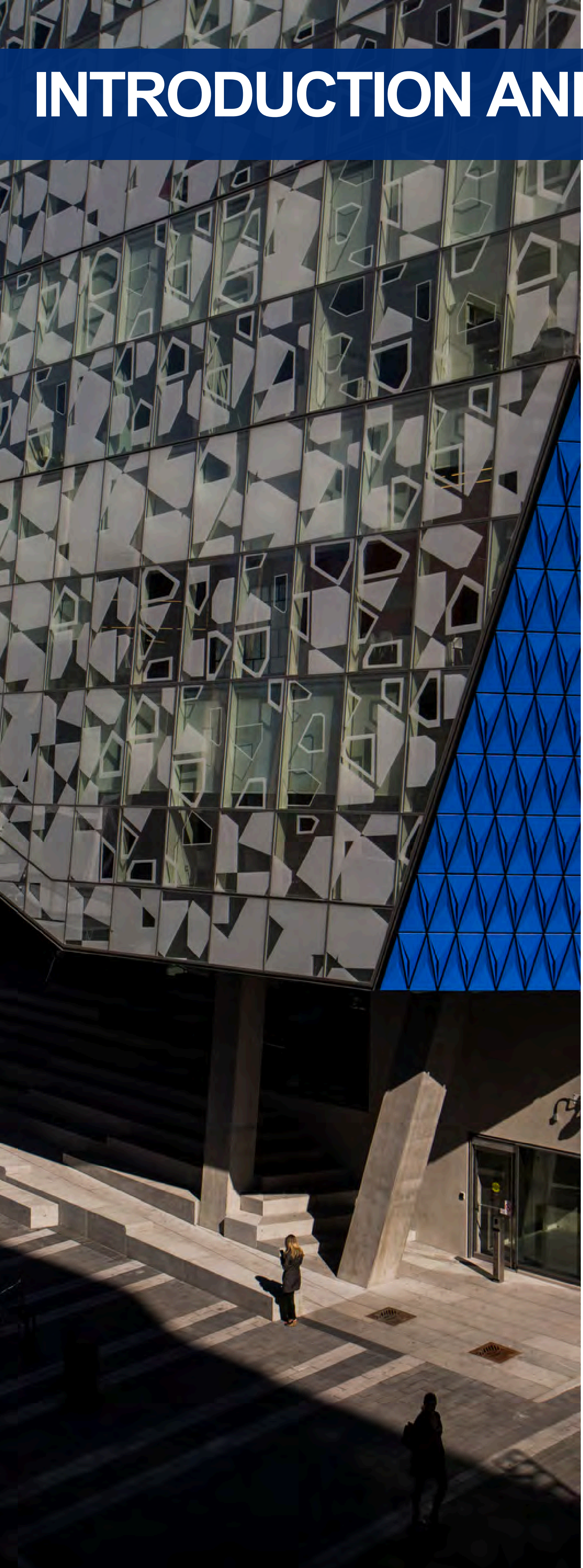
METHODOLOGY

TMU's 2024 ECDM Plan was created in collaboration with DWB Consultants, a firm specializing in building engineering, including energy and sustainability. Energy data presented in this plan comes from different sources, as outlined below.

To calculate the overall energy consumption, utility bills were used. To calculate the energy consumption of each building, data available from TMU's new campus-wide sub-metering system was primarily used. In some cases, partial sub-metered data was used to create a regression model to predict the consumption of a building. When no utilities or sub-metering data were available, BAS trends were used to estimate consumption.

Years are represented in fiscal years (May to April) rather than calendar year, unless stated otherwise. For example, the year 2022 is the year that starts on May 1st 2022 and ends on April 30th 2023. In some cases, when creating the normalized energy benchmarking, the calendar year is used. There may therefore be small variation between the calculated normalized baseline year and the fiscal year energy consumption.

INTRODUCTION AND BACKGROUND



Toronto Metropolitan University (TMU) is located in the heart of downtown Toronto. Operating more than 30 buildings catering to 42,000 students and over 2,700 faculty and staff, TMU has a significant energy, water, and carbon footprint. Rising energy costs, aging infrastructure, and TMU's public commitment to creating a vibrant and sustainable campus highlight the importance of reviewing energy conservation initiatives, setting performance benchmarks, and developing an energy and decarbonization strategy for the future.

The purpose of TMU's 2024 ECDM Plan is threefold, as follows:

- Review energy efficiency and decarbonization progress since publication of the 2019 ECDM Plan.
- Report on TMU's existing energy consumption and GHG emissions profile.
- Benchmark TMU's energy consumption and communicate the university's short and long-term energy conservation and decarbonization strategy.

The ECDM Plan complements TMU's Sustainability Action Plan, which was released in April 2024. Having publicly committed to achieving net zero emissions by 2045, the university aims to build on past energy management successes to reduce and eventually eliminate campus emissions through projects that align well with other key institutional priorities, including upgrading aging campus infrastructure and creating a vibrant, sustainable campus with a strong identity that fosters innovative research.

Ontario Regulation 25/23

Ontario Regulation 25/23, made under the Electricity Act of 1998, directs all public agencies in Ontario to prepare, publicly report, and implement Energy and Conservation Demand Plans (also referred to as 'ECDM Plan') on or before July 1, 2019, and every fifth anniversary thereafter. This is the July 1, 2024 version.

TMU'S DECARBONIZATION GOALS

- **BY 2035, REDUCE SCOPE 1 AND 2 EMISSIONS BY 40% COMPARED TO 2019 BASELINE**

- **BY 2045, ACHIEVE NET ZERO SCOPE 1 AND 2 EMISSIONS**

CAMPUS BUILDING SUMMARY

Building Code	Floor Area (m²)	Building Name	Address	Date of Construction	Building Category
ARC	6,668	Architecture Building	325 Church St.	1981	Academic
BKS	1,303	Bookstore	17 Gould St.	1988	Bookstore
BON	662	Capital Projects & Real State, Security	111 Bond St.	1960	To be determined
CED	3,181	G.Raymond Chang School of Continuing Education	297 Victoria St.	2005	Academic
CIS	842	Creative Innovation Studio	110 Bond St.	Renovated 2020	Academic
COP	638	Co-operative Education	101 Gerrard St.E	1950	Academic
CUI	5,806	Centre for Urban Innovation	44 Gerrard St. E	1941, renovated in 2018	Academic
COP	638	Co-operative Education	101 Gerrard St.E	1950	Academic
DCC	38,008	Daphne Cockwell Health Sciences Complex	288 Church St.	2019	Academic, residential, parking garage
ENG	19,432	George Vari Engineering and Computing Centre	245 Church St.	2004	Academic
EPH/SHE	17,751	Eric Palin Hall/ Sally Horsfall Eaton Centre for Studies in Community Health	87 Gerrard St. E	EPH-1984 SHE- 2002	Academic
GER	2,565	Research and Graduate Studies	111 Gerrard St.E	1950	Academic
HEI	2,475	Heidelberg Centre-School of Graphics Communications Management	125 Bond St.	2002	Academic
ILC	11,675	International Living/Learning Centre	133 Mutual St.	1987	Residence
IMA	9,328	School of Image Arts	122 Bond St.	2012	Academic
JOR	9,063	Jorgenson Hall	380 Victoria St.	1971	Administrative
KHE	11,268	Kerr Hall East	East 340 Church St.	1960	Academic
KHN	9,215	Kerr Hall North	43 Gerrard St.East	1960	Academic
KHS	9,777	Kerr Hall South	50 Gould St.	1960	Academic
KHW	13,498	Kerr Hall West	379 Victoria St.	1960	Academic
LIB	19,468	Library Building	350 Victoria St.	1974	Academic
MAC	20,962	Mattamy Athletic Centre	50 Carlton St.	2012	Athletics
MON	1,964	Monetary Times	341 Church St.	1929	Academic
OAK	1,714	Oakham House	63 Gould St.	1948	Community events
OKF	686	O'Keefe House	137 Bond St.	1880	Being repurposed
PIT	20,537	Pitman Hall	160 Mutual St.	1991	Residence
PKG	11,178	Parking Garage	300 Victoria St.	1991	Parking garage
POD	17,838	Podium	350 Victoria St.	1971	Administrative
PRO	556	112 Bond	112 Bond St.	1860	Administrative
RAC	4,163	Recreation and Athletics Centre	Centre 40 Gould St.	1987	Athletic
RCC	11,022	Rogers Communications Centre	80 Gould St.	1991	Academic
SBB	5,451	South Bond Building	105 Bond St.	2007	Academic
SCC	3,278	Student Campus Centre	55 Gould St.	2005	Community events
SID	3,022	School of Interior Design	302 Church St.	1900	Academic
SLC	12,894	Student Learning Centre	341 Yonge St.	2015	Academic and community events
TRS	17,344	Ted Rogers School of Management	575 Bay St.	2006	Academic
VIC	10,630	Victoria Building	285 Victoria St.	1930	Academic and administrative

TMU CAMPUS PROFILE

Established in 1948 as Ryerson Polytechnic Institute, TMU has undergone considerable growth. Attaining full university status in 1993, TMU has since significantly expanded its offerings and services for students, faculty, and staff. Over the past five years, TMU has expanded by constructing several cutting-edge LEED-certified buildings (Under the LEED New Construction system) such as :

Centre of Urban Innovation

LEED SILVER V3

Daphne Cockwell Complex

LEED GOLD V3

Sheldon and Tracy Levy Student Learning Center

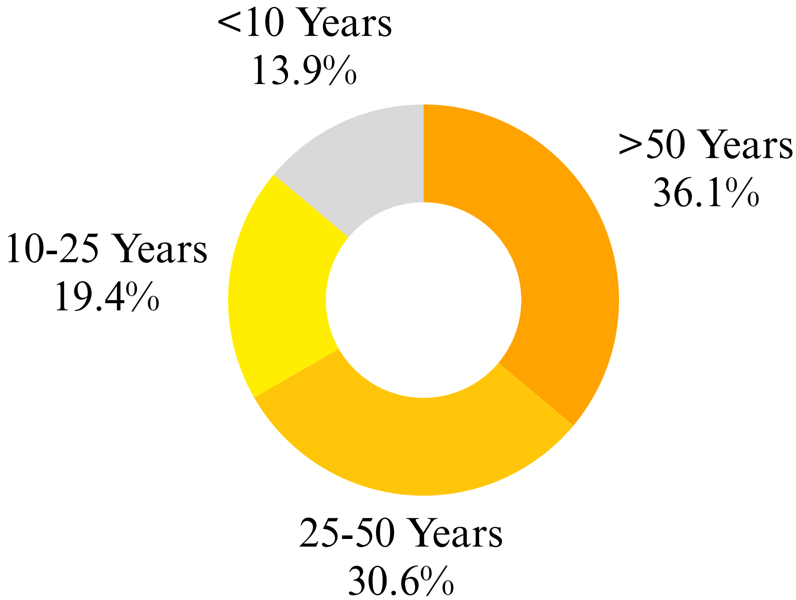
LEED SILVER V3

South Bond Building

LEED GOLD V2

Buildings Categorized by Age

Over 50% of campus buildings are over 30 years old and require infrastructure upgrades. Moreover, being situated in a densely urbanized area, TMU's ability to expand the borders of its campus are limited. TMU's highly urban location presents distinct challenges as well as unique opportunities to explore and implement innovative energy conservation and decarbonization solutions.

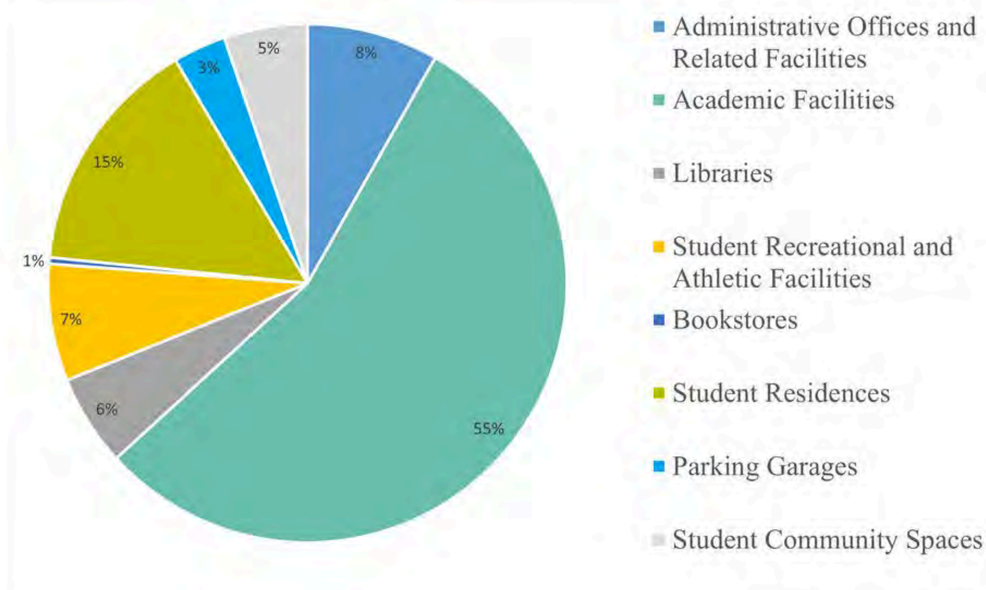


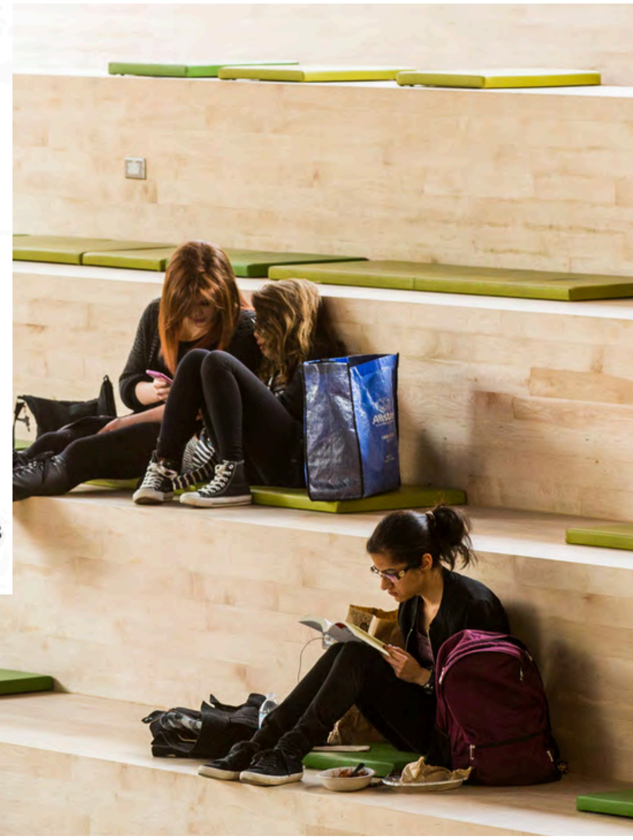
The graph shows the percentage of campus buildings in each age group, based on the number of buildings (as opposed to floor area).

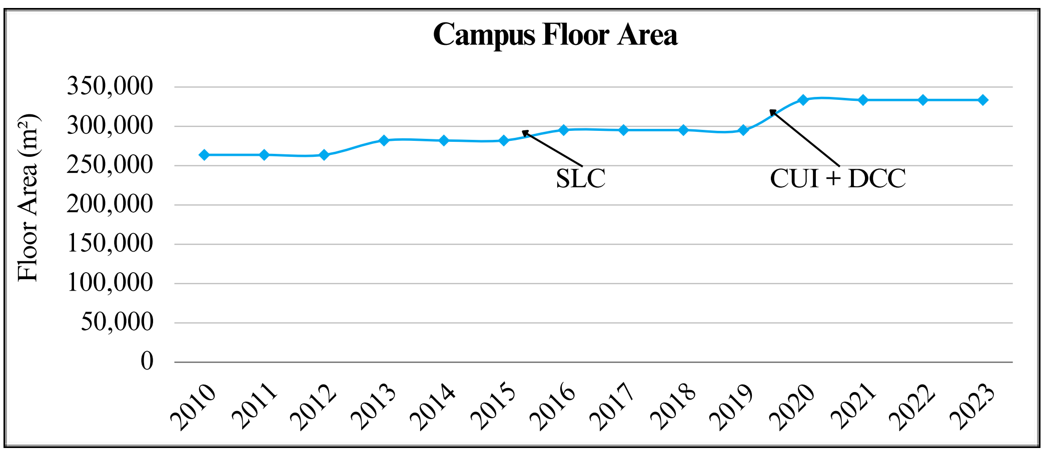
Over 65% of campus buildings are over 25 years old and in need of refurbishment to improve energy performance.

14% of buildings (over 20% of total campus floor area) have been in service for less than 10 years.

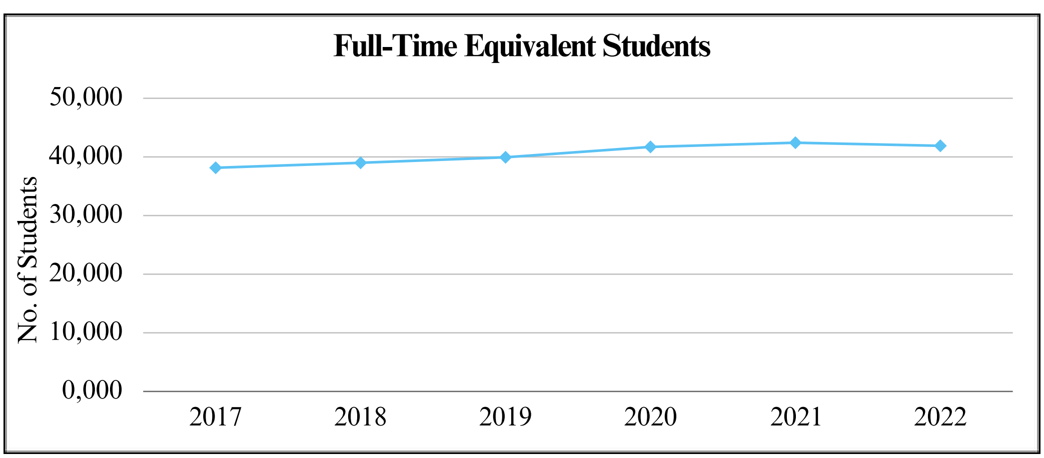
CAMPUS FACILITIES, CATEGORIZED BY PRIMARY BUILDING USE TYPE





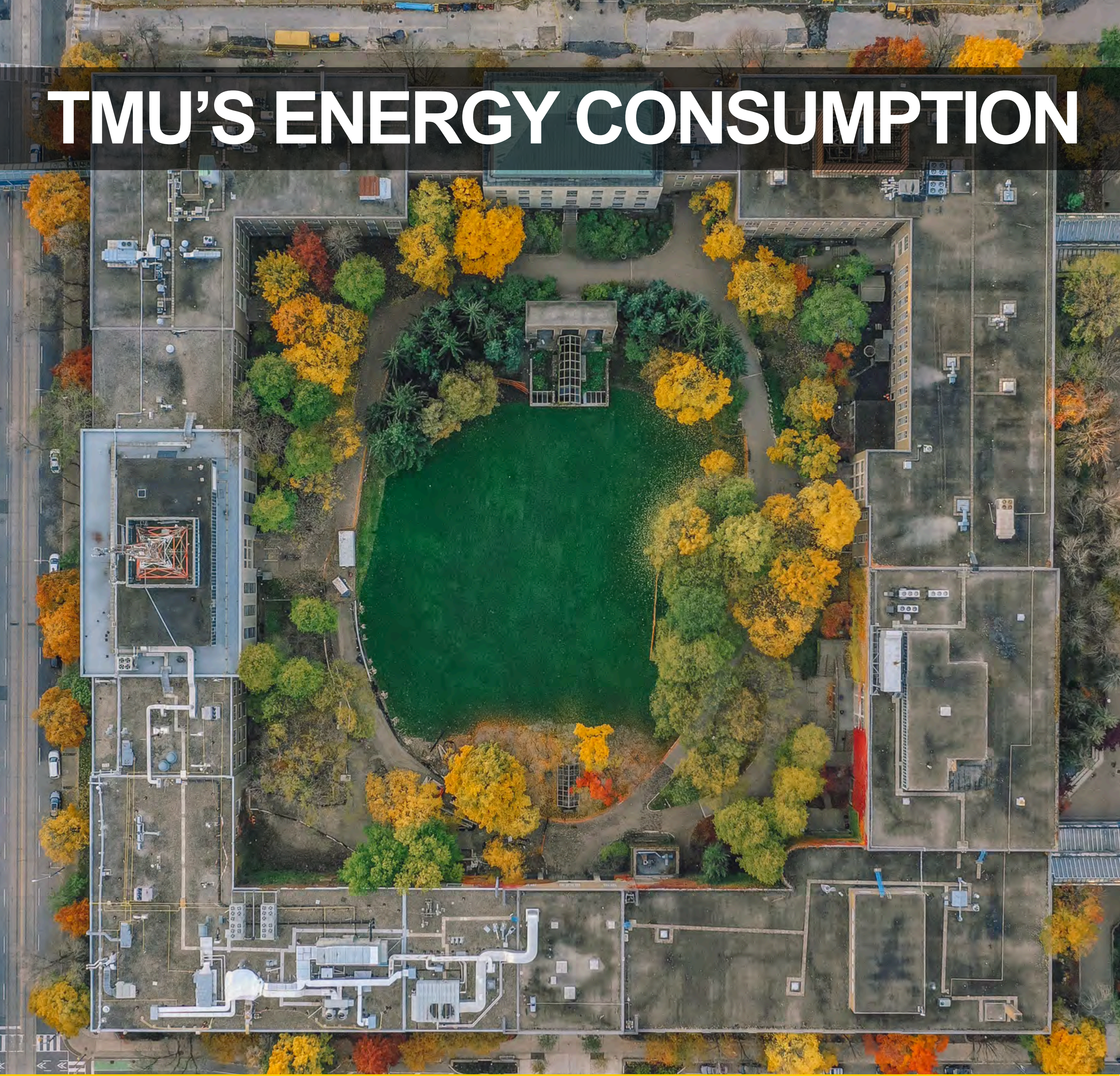


This graph shows the increase in size of the campus since 2010. Addition of the CUI and DCC buildings are primary contributors to the recent increase in campus floor area. Campus floor area has remained mostly constant since the construction of DCC. TMU's School of Medicine, which will come into operation in 2025, will be located in Brampton and be the next major addition to TMU's campus space. As of 2023, the total campus floor area is 333,543 m².



The number of full-time equivalent students (FTEs) continue to increase each year, increasing energy and water use as well as GHG emissions. The new Law School contributed in part to this increase. The new School of Medicine will also increase this metric further.

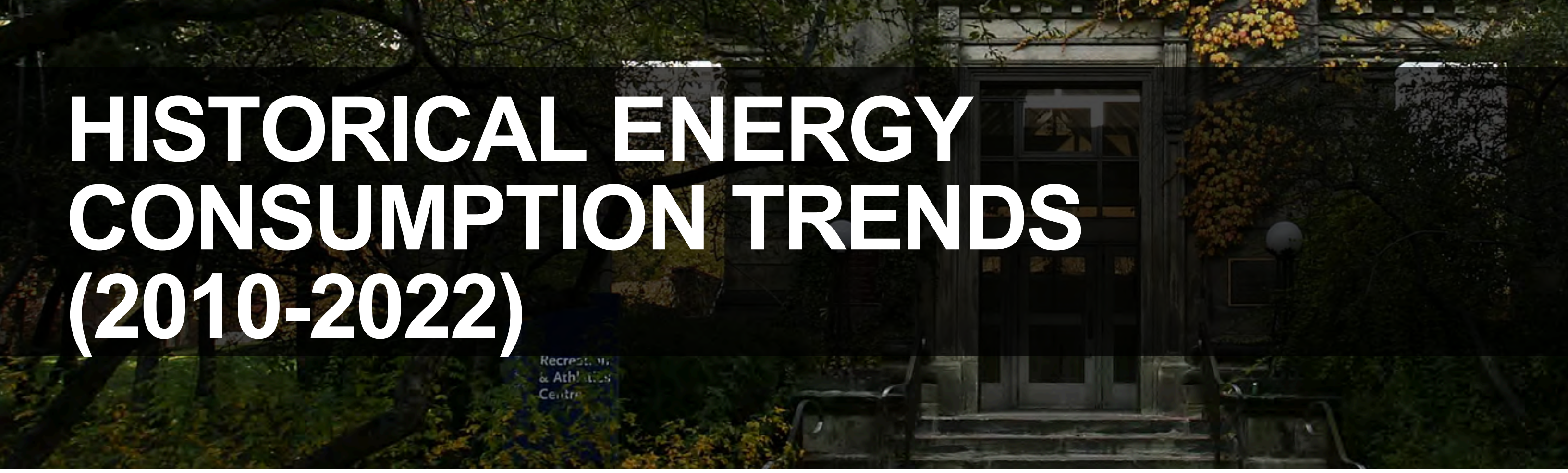
TMU'S ENERGY CONSUMPTION



ENERGY & WATER USE AT A GLANCE*

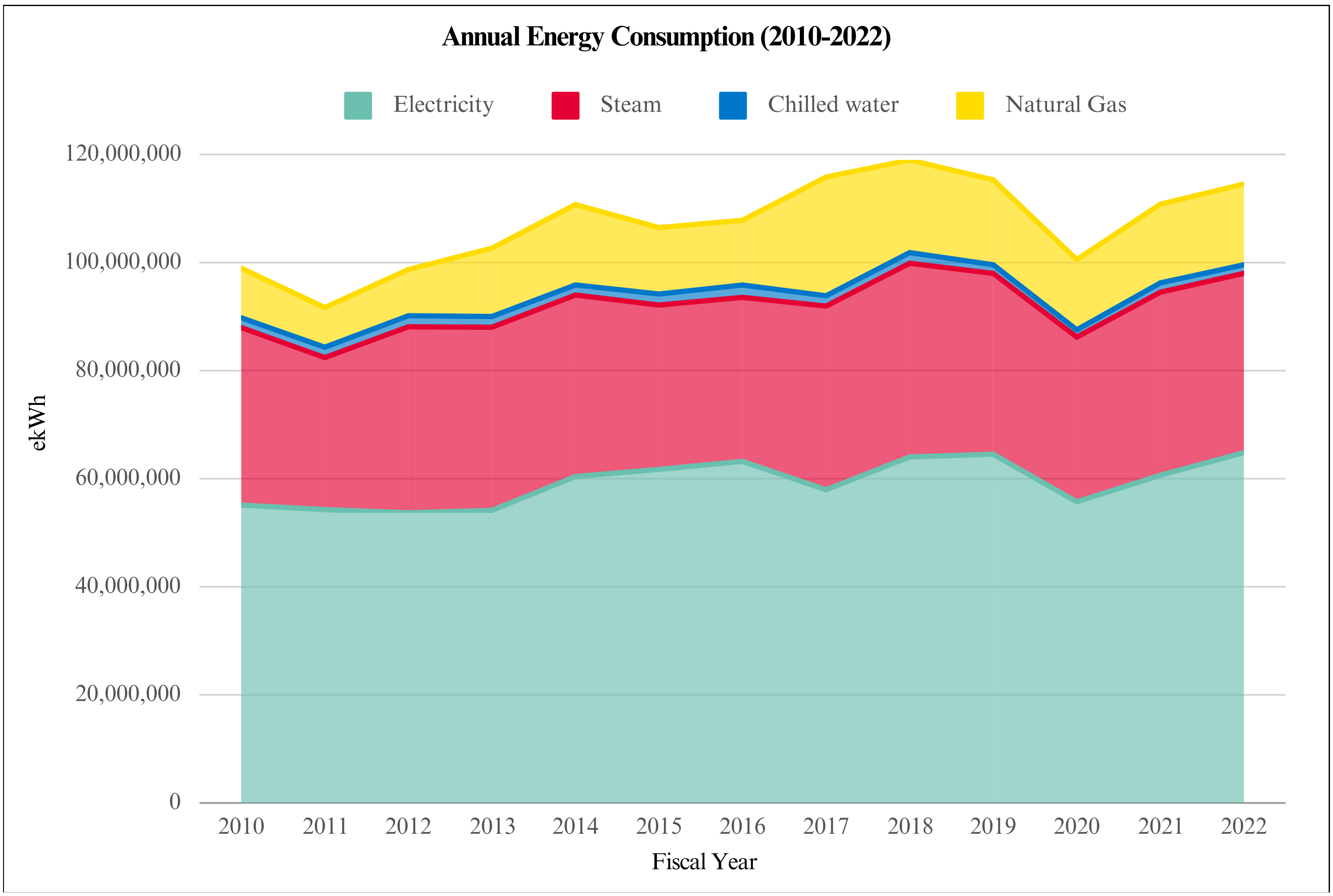
Electricity (kWh)	District Chilled Water (THr)	District Steam (lbs)	Natural Gas (m3)	Domestic Water (m3)
64,831,882	451,479	114,422,390	1,442,383	335,395

*Based on 2022 fiscal year.



HISTORICAL ENERGY CONSUMPTION TRENDS (2010-2022)

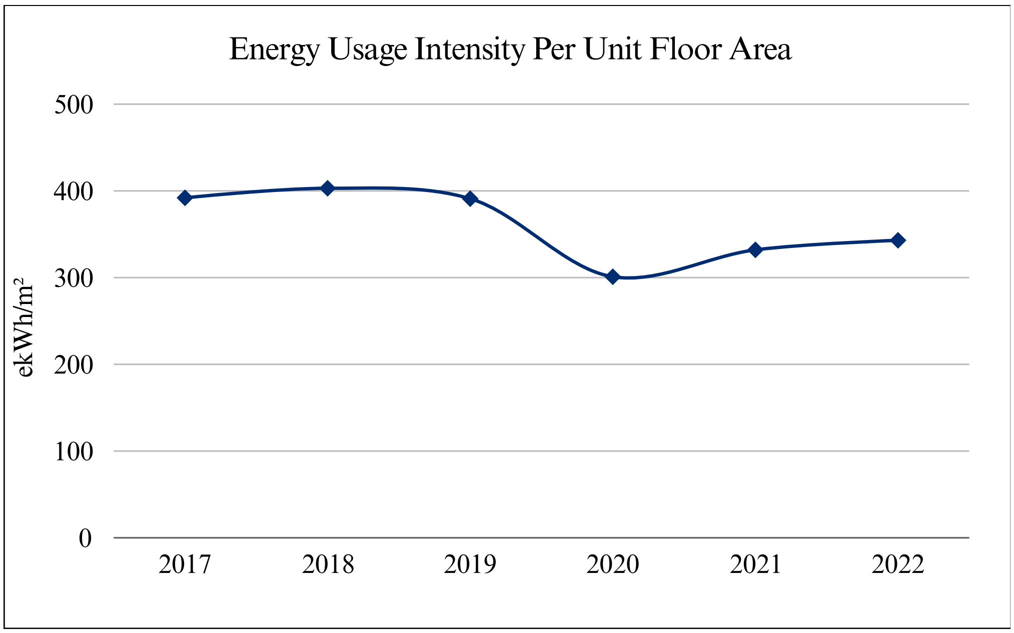
TMU relies on electricity, district steam, natural gas, and district chilled water to meet its energy demands. Many buildings on campus share electrical and steam meters, as indicated in the Appendix B metering layout map. TMU's campus-wide sub-metering initiative allows for the collection of utility consumption data for each building individually.



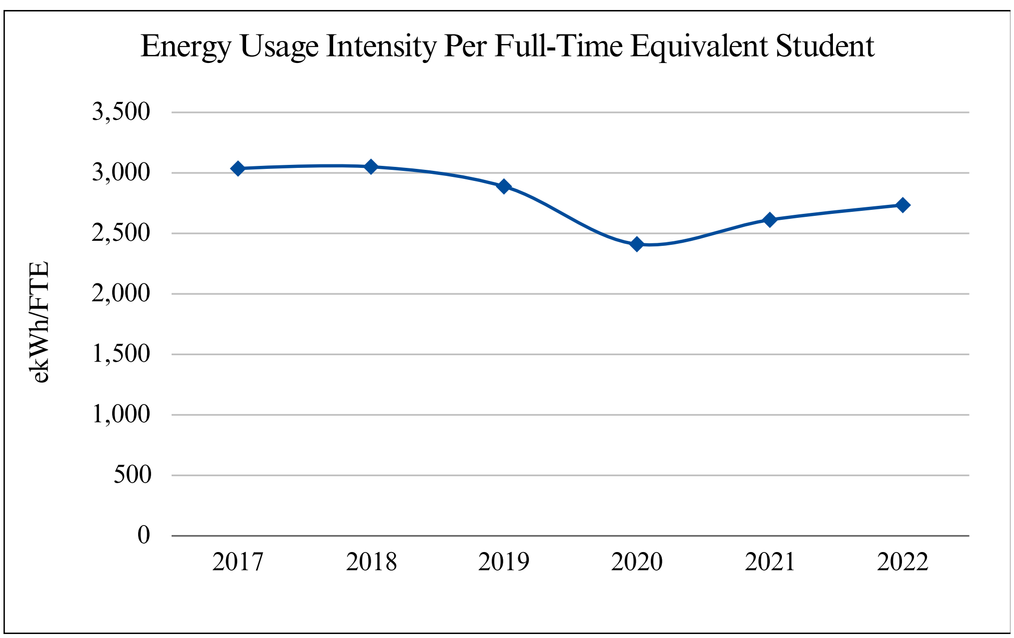
The main element that explains changes in the total energy consumption from the fiscal year 2019 to 2022 is the Covid-19 pandemic, resulting in reduced energy consumption in 2020, 2021, and 2022. While operations at the university have since returned to normal, the change in academic and operational trends, such as the shift toward a hybrid working and learning model, have influenced the energy profile of the university, especially for the electricity associated with cooling, lighting and plug loads. Some energy saving projects were done as well, which have reduced total campus energy consumption compared to the 2018 peak.

HISTORICAL ENERGY CONSUMPTION TRENDS (2010-2023)

In order to benchmark TMU's campus energy consumption, it is useful to assess this metric per campus building floor area and total number of full-time equivalent (FTE) students. Trends for these metrics are shown below.



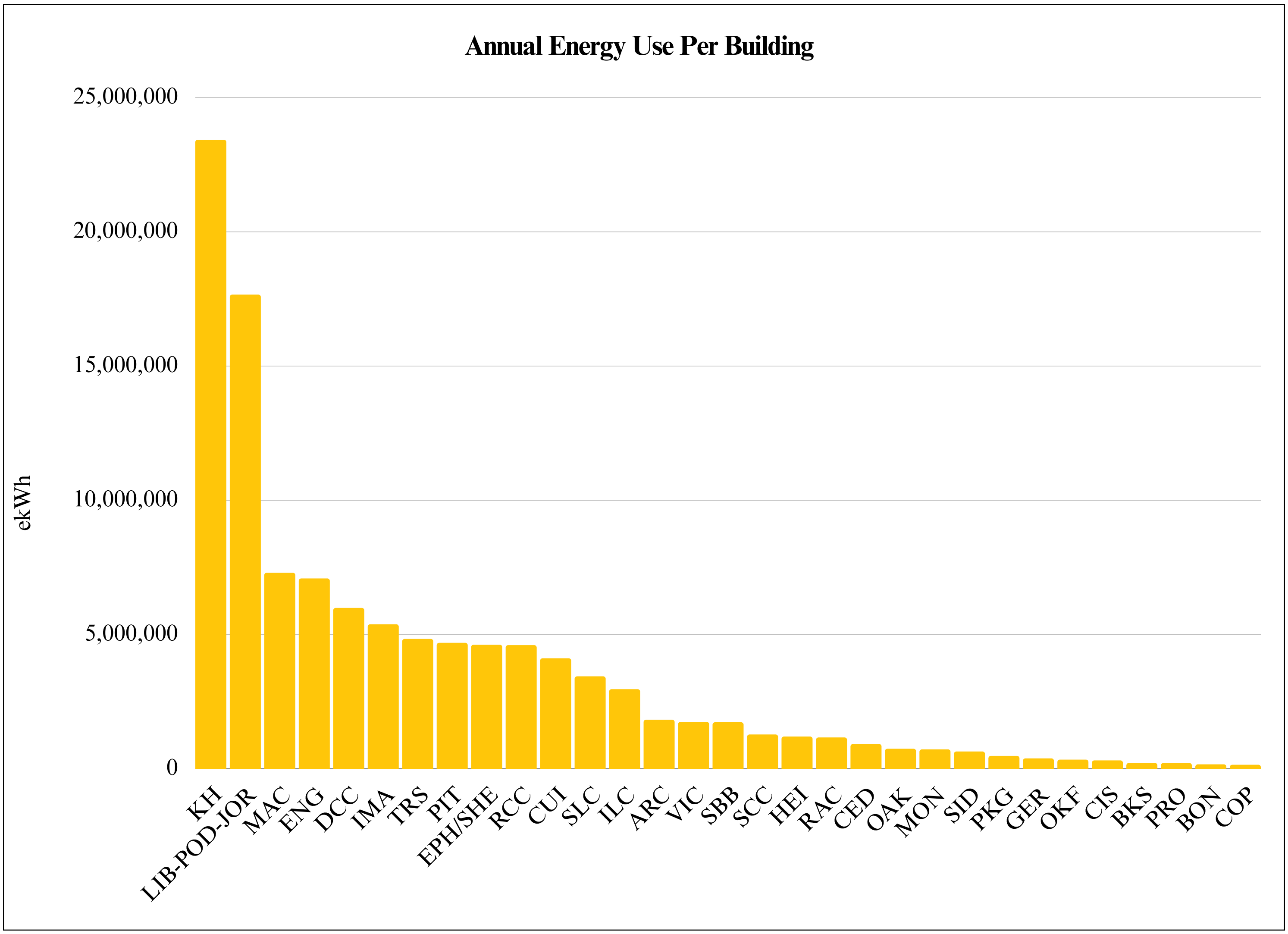
The EUI per unit floor area chars indicates a decrease in the campus EUI since 2018 and 2019. In 2020 and 2021, the main reason for the reduction was the COVID-19 pandemic. Operation of the newly constructed and efficient DCC building also had the effect of reducing the EUI, since it's EUI is lower than the campus average. In 2022, the campus average EUI was 343 ekWh/m², higher then the national median of 289 ekWh/m².



Campus EUI, when assessed based on total FTE students, shows a similar trend to the floor area EUI. This is because an increase in floor area has been accompanied by increased enrolment at TMU. As of 2022, the average Enrollment Intensity was 2,734 ekWh/FTE.

ENERGY CONSUMPTION BY BUILDING

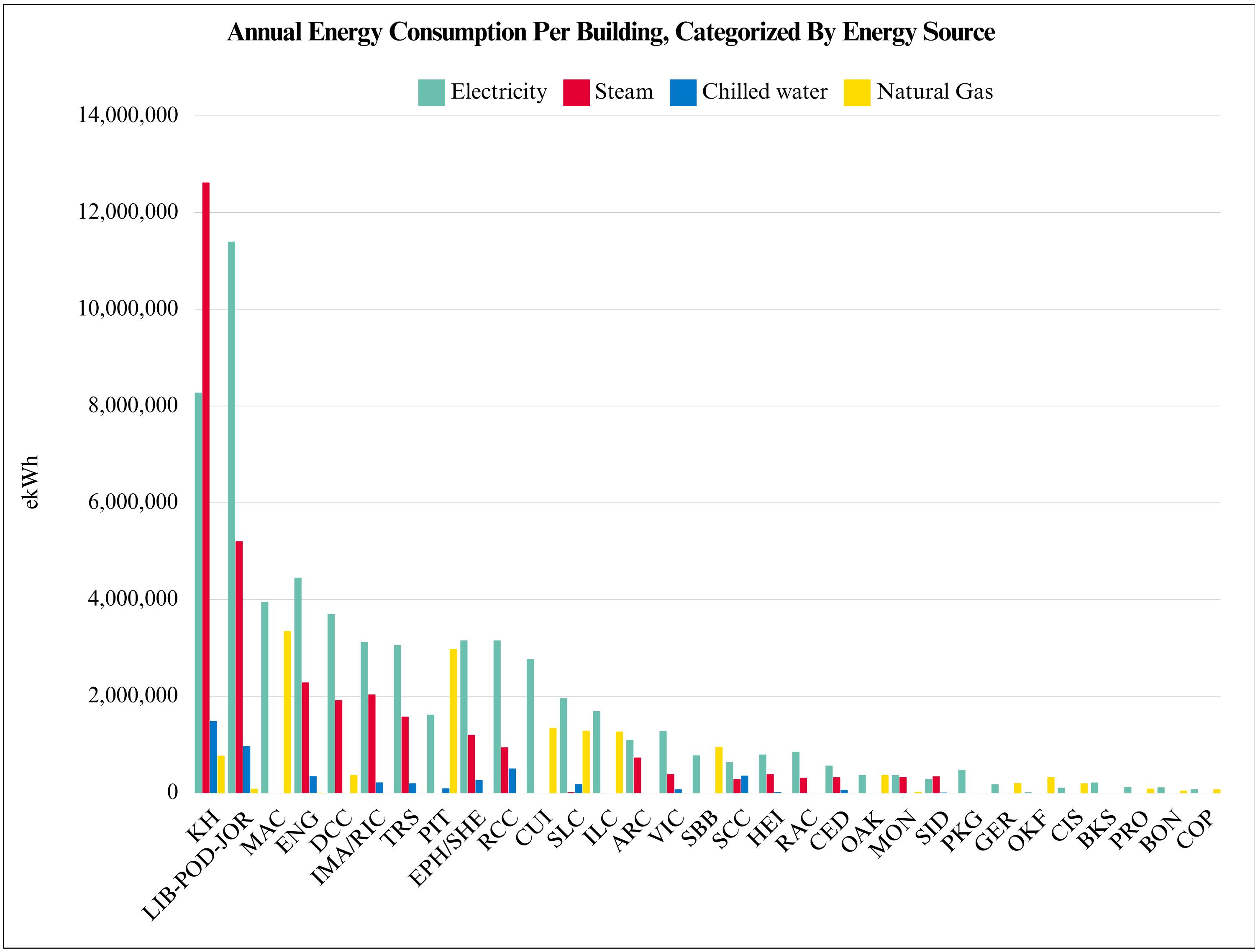
TMU's campus-wide sub-metering system was installed to evaluate the energy consumption of each building individually in order to effectively baseline energy consumption and assess energy conservation potential. While a small portion of this system is currently being commissioned, most of the sub-meters are operational. The table below outlines energy consumption per building. The methodology used to calculate each building is explained further in the next section. A detailed table showing these number is available in Appendix C.



A large component of campus energy consumption is attributed to the KH, LIB, POD and JOR buildings, which are some of the oldest and largest buildings on campus. As per TMU's Campus Master Plan, there are long-term plans to demolish KH in order to build a new and more efficient building. Therefore, while KH has the largest energy footprint, it is not strategic to invest in this building. The LIB-POD-JOR building cluster, however, shows a significant savings opportunity, which have been evaluated through various studies and projects. MAC, ENG, DCC and IMA also have considerable energy consumption, owing largely to the programming scheduled within these buildings.

ENERGY CONSUMPTION BY BUILDING (CONT)

The graph below shows the same information but energy consumption has been segmented into electricity, steam, chilled water and natural gas for each building. Note that the electricity consumption associated with the chilled water is estimated and calculated for each building, using the COP calculated for each plant. The energy used by the plant in KH, LIB and RCC is also removed from their overall consumption to avoid double counting.



While for KH, LIB, POD and JOR the steam consumption is considerable, overall, electricity consumption dominates the campus energy profile. A detailed table showing these numbers is available in Appendix C.

NOTES ON CALCULATIONS

Building Code*	Calculation Notes
OKF	The O'Keefe building has its own dedicated meters, so the year 2023 is represented.
SID	The School of Interior Design electricity comes from the Toronto-Hydro invoices. SID/SCC steam sub-meter is shared, while the SCC meter is not fonctionning. Therefore, the SID and SCC steam consumption split is done based on the building area ratio at the moment.
MON	The Monetary Time Building consumptions comes from the sub-metering entirely. The electricity consumption and natural gas are reliable. The steam meter is less reliable. We used a weather normalized (CWEC) regression model to evaluate the gas and steam consumption to compensate for the missing data.
KH	The Kerr Hall electricity consumption comes from Toronto-Hydro Invoices. The natural gas consumption is the sum of Kerr Hall three meters. Note that RAC natural gas generator is on the same meter as Kerr Hall, but its consumption is not significant. Kerr Hall Chilled Water consumption is the sum of the whole campus, minus each building measured seperately. Therefore, the chilled water consumption is uncertain. The steam consumption for Kerr Hall is also calculated by substracting all the individual building consumption to the sum of the whole campus. So it is quite innaccurate.
RAC	The Recreation and Athletic Centre electricity comes from the LIB building and is sub-metered. The adiabatic cooling tower associated with RAC is located in KH. The steam feed is also metered and located in KH. RAC has no gas use (except for the generator) nor centralized chilled water.
LIB-POD-JOR	LIB-POD-JOR are bindled together since it is challenging to measure the total energy consumption of each building independenty. The LIB-POD-JOR electrical consumption is calculted using the sum of all buildings and substracting RAC and SLC consumption which are known to be accurate. The steam consumption is calculated based on the sum of the LIB, JOR/POD and POD Domestic Hot Water meter. The chilled water consumption is the sum of LIB and POD/JOR meter. The gas consumption is based on the sub-metered data. The LIB Chilled water plant is also sub-metered.
SLC	The Student Learning Centre has its own utility gas meter. The electricity, steam and natural gas sub-meter are used to evaluate the rest of the consumption.
ARC	The Architecture Building electricity comes from the utility invoices. The steam consumption is based on the calculation of the sum of ARC/MON/EPH/SHE, where MON and EPH are substracted. Since MON is not the most reliable meter, ARC calculated steam consumption is also partially innaccurate. We use a weather normalized regression model to calculate ARC steam consumption. ARC does not used chilled water nor natural gas.
EPH/SHE	The EPH-SHE electricity consumption comes from the utility invoices. The steam and chilled water sub-meter are relatively accurate for this building.
PIT	The Pitman Hall share its electrical feed with the adjacent RCC. Both building are sub-metered, as well as RCC chilled water plant. RCC and PIT also share a cooling plant located in RCC that are sub-metered, although the values from the sub-meters is not the most reliable, altough shows reasonable values. PIT natural gas comes from the utilities.
RCC	The Rogers Communication Centre uses a sub-meter to calcule the electricity, steam and chilled water consumption. The RCC cooling plant consumption is sub-metered and redistributed between RCC and PIT.
ENG	The Engineering building use utility invoices for electricity, natural gas and steam. Only the ENG chilled water need to be sub-metered since it comes from the centralized system.
OAK	The Oakham House electriciy comes from the SCC meter and is sub-metered. The natural gas consumption comes from the invoices. OAK does not use centralized steam or chilled water.
HEI	The Heidelberg Centre – School of Graphic Communications Management electriciy comes from the SCC meter and is sub-metered. The steam and chilled water are sub-metered. The HEI electricity consumption is not known for all of 2023, so some calculation were done using 2024 to calculate a whole year of electricity consumption. At the time of our calculation, the HEI chilled water sub-meter was not considered accurate, so the BAS was used to evaluate the consumption, using a regression model and measured cooling output from the cooling coil.
SCC	The Student Campus Centre electricity consumption is calculated based on the sum of SCC/OAK/HEI to which OAK and HEI are substracted. Since HEI has less than one year of consumption, some interpolations are used to evaluate the SCC yearly consumption. SCC chilled water is sub-metered. The SCC steam meter is not fonctionnal. The SID/SCC steam share a meter. The steam consumption is split between the two buildings based on area ratio.
VIC	The Victoria Building electricity consumption is shared with CED and IMA. The VIC electricity consumption is calculed by using the sum of VIC/CED/IMA and subtracting CED and IMA. The steam and chilled water consumption are sub-metered. The steam meter appears to underevaluate the steam consumption, although it is not proven. It appears that low steam flow cannot be read.
CED	The Center for Continuing Education is sub-metered for electricity, steam and chilled water. The meters are reliable.
IMA	The Center for Continuing Education is sub-metered for electricity, steam and chilled water. However, the steam meter is unreliable. The steam consumption was calculated using a weather normalized regression model based on the BAS heating system trends during the winter coldest week. This calculation is relatively innaccurate.

*Buildings not shown in the table have a full year of data available in 2023 from utility invoices. Typically, electricity and gas sub-meters are very reliable. The sub-metered gas consumption is often used in Lieu of the utility monthly consumption, since utility consumption is often estimated, rather than read. Several steam meters also often do not capture low steam load conditions. For LIB, KH and RCC, the power consumption associated with the cooling plants was subtracted from the building consumption. That power is than distributed for each building via their chilled water consumption. We have calculated the average Coefficient of Performance of each plant and use these values to calculate the power consumption.

CAMPUS CHILLER PLANT PERFORMANCE

TMU makes use of three chiller plants, located within the LIB, KH, and RCC buildings. As outlined in the table below, efficiency metrics based on 2023 operational data indicate that all three chiller plants' energy performance can be improved. TMU plans on improving the energy performance of the plants by conducting optimization projects.

Building Code	Cooling Plant Electricity Consumption (kWh)	District Chilled Water Production in THr	Efficiency kW/Ton	Coefficient of Performance (COP)
KH Cooling Plant	854,605	630,189	1.36	2.59
LIB Cooling Plant	3,409,602	3,706,089	0.92	3.82
RCC Cooling Plant	601,557	360,308	1.67	2.11

Note that electricity consumption of the cooling towers are not typically included in the Coefficiency of Performance (COP) calculation, while primary and secondary pumps are. In KH and LIB Cooling plants, ventilation fans are also included in the calculation of the COP since they are monitored on the same meter as the chiller plant. The power draw of these fans are a small fraction of the overall energy demand of the plant.

As campus decarbonization is now a key priority at TMU, improving the energy performance of the chiller plants is key. All 3 chiller plants contribute significantly toward the university's electricity power draw, and increasing their efficiency frees up electrical capacity which in turn allows for more electrification of heating systems.

DISTRICT STEAM

Over 80% of TMU's campus floor area is heated using district steam that is supplied by an external third party, Enwave Energy Corporation. District steam is therefore the primary source of heating for most buildings on campus. The steam is fed into TMU from Enwave at three points, located in KH, TRS, ENG. The KH feed is by far the largest system and supplies most buildings through a TMU-owned steam distribution system. Steam provided by Enwave is at a pressure of 200 PSI, and distributed to TMU's building at a pressure of about 50-60 PSI.

Steam is by far TMU's largest contributor to GHG emissions and contributes significantly to campus operational costs. TMU is currently engaged with various partners to evaluate difference pathways to reduce and eventually phase out steam usage on campus. Steam systems pose the following issues, all of which are drivers to upgrade to a new alternative:

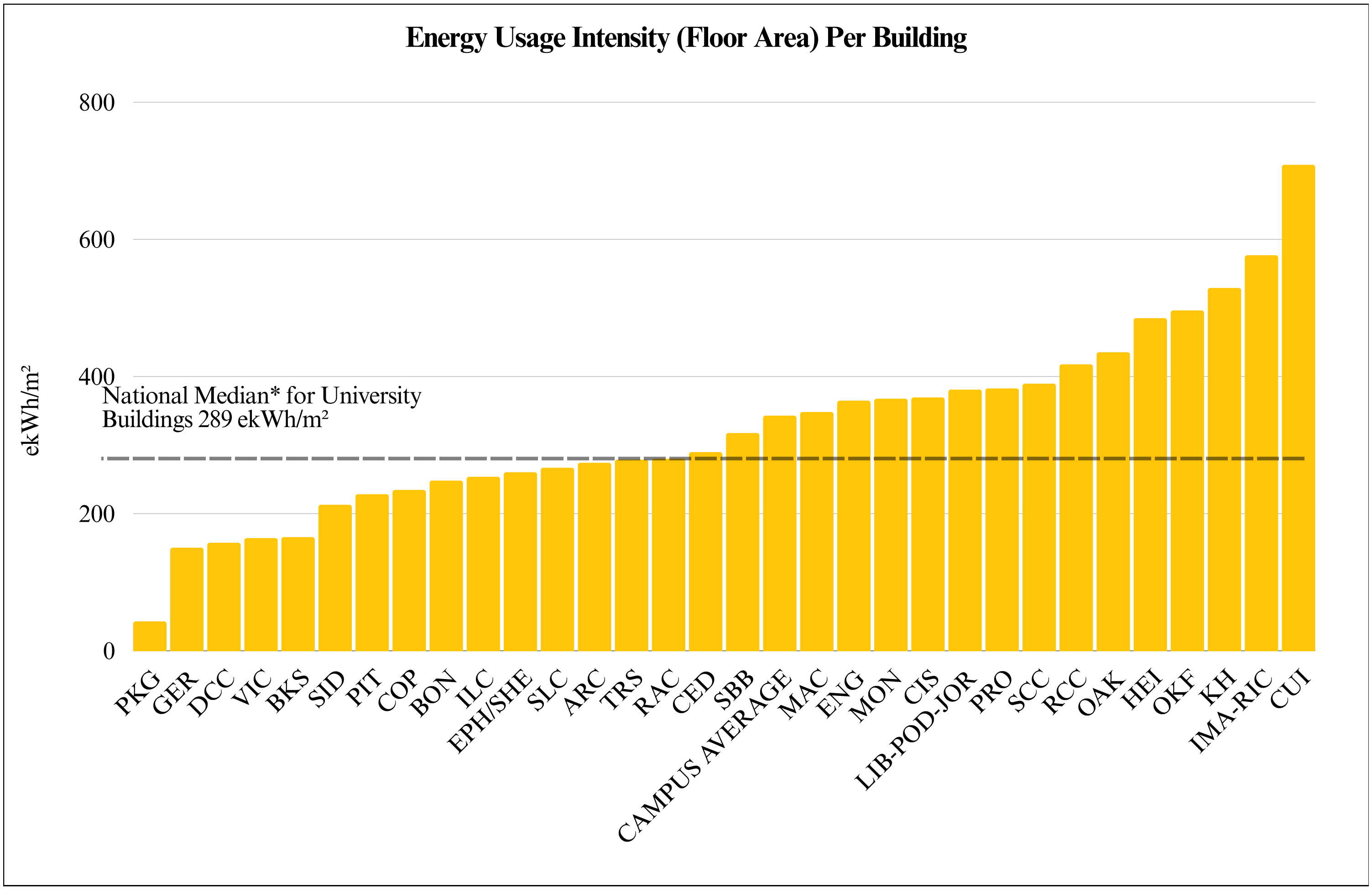
- Steam systems are inefficient when compared to new efficient technology such as air-source heat pumps.
- Steam systems do not allow for optimal heat recovery systems due to their high operating temperatures.
- Steam systems require significant resource allocation for ongoing maintenance.
- Condensate management poses a challenge and is a major source of energy waste.
- Steam has a significantly higher carbon footprint compared to electricity

As previously mentioned, TMU's long-term plan involves the demolition or major refurbishment of the KH building. The KH building is one of the only buildings on campus has relies on steam radiators for heating. All other buildings can be converted to operate with a district hot water loop.

Owing to the presence of KH, TMU recognizes that it is not currently possible to completely eliminate steam use on campus by 2029. Studies are, however, being conducted to assess how best to make other campus buildings shift away from steam. Moving all buildings except for KH away from steam will result in a 50% reduction in TMU's steam use. This equates to an approximate 35% reduction in annual campus GHG emissions.

CAMPUS ENERGY BENCHMARKING

Building-level energy consumption data allows for benchmarking of TMU's campus buildings relative to each other as well as the Energy Star Canadian median for university buildings.



The EUI graph above identifies the most energy intensive campus buildings as IMA, CUI, and KH. These results are expected as KH is an inefficient building, CUI contains several laboratories, and IMA incorporates an image gallery with stringent air conditioning standards. The most energy efficient buildings, on the other hand, can be seen to be the newly constructed DCC building along with older ones such as SID, which underwent an HVAC and building restoration upgrade. It should be noted that PKG is a multi-storey parking garage and does not offer conditioned space, which explains it low EUI. Furthermore, building use differs widely and a fair comparison will require deeper analysis using benchmarks for specific building archetypes.

*Energy Star Portfolio Manager - Canadian Energy Use Intensity by Property Type - Education College/University - Site URL:https://portfoliomanager.energystar.gov/pdf/reference/Canadian%20National%20Median%20Table.pdf

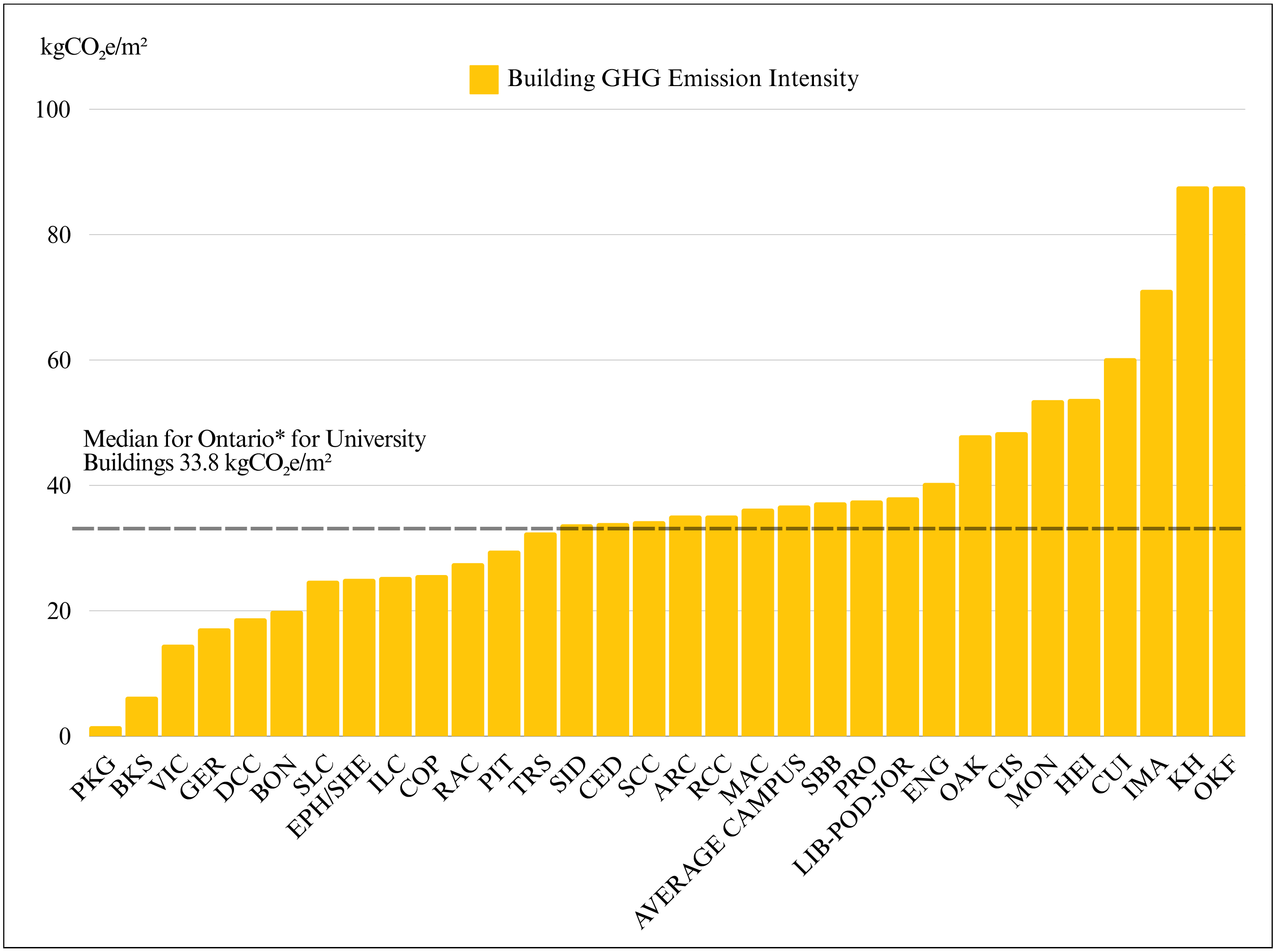
CURRENT STATE OF GHG EMISSIONS

Similar to energy consumption, GHG emissions have been calculated to compare buildings relative to each other. Data from the new campus-wide sub-metering system was used for this purpose. Below is a table showing the result for each building.

Building Code	Electricity $TonCO_2e$	District Steam $TonCO_2e$	District Chilled Water $TonCO_2e$	Natural Gas $TonCO_2e$	Building total $TonCO_2e$
PRO	4.7	0.0	0.0	16.2	**20.9**
OKF	0.5	0.0	0.0	59.6	**60.1**
SID	11.0	90.6	0.3	0.0	**102.0**
MON	14.0	87.0	0.0	4.2	**105.2**
CUI	105.3	0.0	0.0	245.1	**350.4**
COP	2.9	0.0	0.0	13.5	**16.4**
GER	6.9	0.0	0.0	37.2	**44.1**
BON	4.4	0.0	0.0	8.8	**13.2**
KH	314.6	3,325	56.4	140.7	**3,836**
RAC	32.4	82.6	0	0.0	**115.0**
LIB-POD-JOR	342.0	1,371	36.8	15.7	**1,766**
SLC	74.4	3.8	7.0	234.6	**319.8**
ARC	41.6	193.0	0.0	0.0	**234.7**
EPH/SHE	119.9	316.2	10.1	0.0	**446.2**
ILC	64.3	0.0	0.0	231.8	**296.1**
BKS	8.2	0.0	0.0	0.0	**8.2**
PKG	18.2	0.0	0.0	0.0	**18.2**
PIT	61.5	0.0	3.7	543.0	**608.1**
RCC	119.9	248.9	19.2	0.0	**387.9**
ENG	169.1	601.9	13.2	0.8	**785.1**
OAK	14.1	0.0	0.0	68.2	**82.3**
HEI	30.2	102.3	0.7	0.0	**133.2**
SCC	24.1	74.7	13.6	0.0	**112.5**
TRS	116.2	440.3	7.2	0.0	**563.7**
SBB	29.6	0.0	0.0	173.8	**203.4**
VIC	48.6	103.3	2.9	0.0	**154.8**
CED	20.4	85.4	2.3	0.0	**108.1**
IMA	118.8	536.7	8.3	0.0	**663.8**
MAC	150.1	0.0	0.0	610.9	**761.1**
DCC	140.6	505.2	0.0	67.9	**713.8**
CIS	4.2	0.0	0.0	36.6	**40.8**

CAMPUS GHG BENCHMARKING

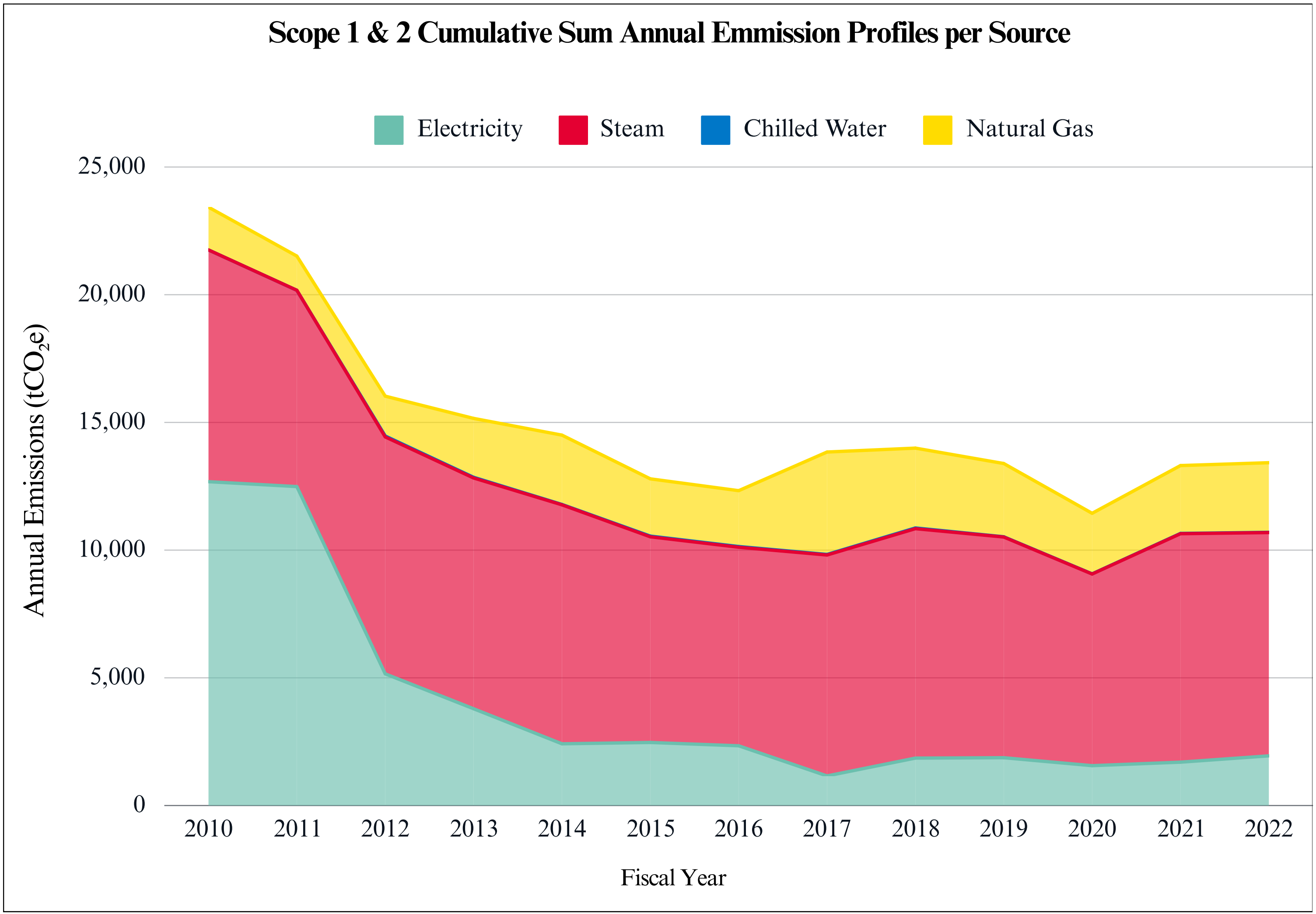
Calculation of GHG emissions per building has allowed for benchmarking of each building against each other as well as the Energy Star Canadian median for university buildings. This is showcased in the graph below.



The most carbon intensive buildings on campus are IMA/RIC, OKF and KH. BKS is heated electrically, and PKG does not have conditioned space, resulting in low intensities. As expected, the EUI graph per building (shown in the previous section) is closely aligned with the GHG emissions intensity graph.

**Energy Star Portfolio Manager - Canadian Regional Median Greenhouse Gas Emissions Intensity - Ontario - Education College/University - Site GHG
URL: https://natural-resources.canada.ca/sites/nrcan/files/energy/pdf/2GHGI_-_English19_0(1).pdf

ANNUAL EMISSIONS PROFILE



TMU's Scope 1 and 2 emissions profile has been influenced by several factors. Emissions attributed to electricity consumption have reduced significantly due to the decarbonization of the Ontario electricity grid. While GHG intensity (tCO_2e/m^2) on campus has improved owing to the construction of efficient buildings such as DCC, absolute have remained constant. GHG emissions were 13,391 tCO_2e/m^2 in 2019 and 13,423 tCO_2e/m^2 in 2022, displaying minimal change. Some of this variation may come from weather, since the absolute emissions are not normalized, but also from the energy reduction associated with staff working from home and from the GHG reduction projects completed.

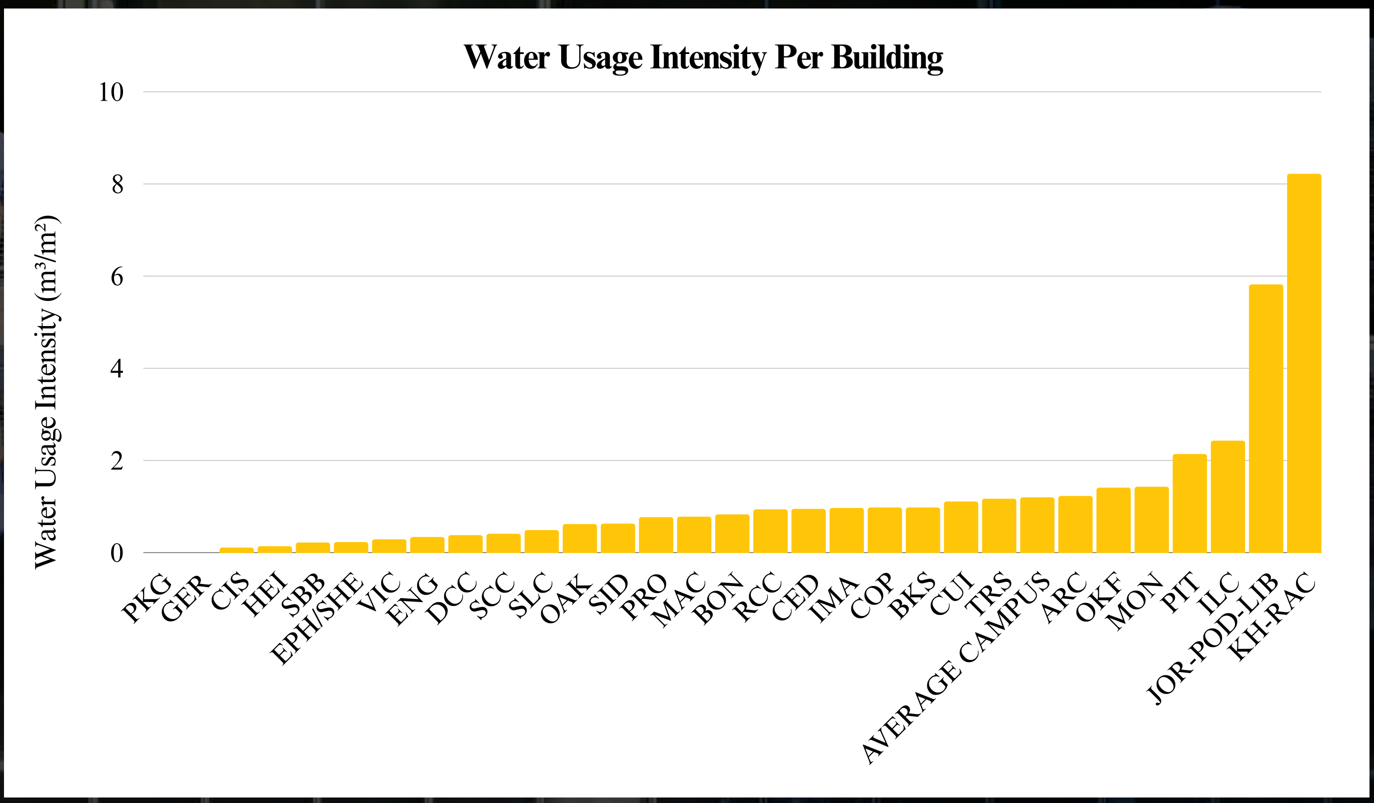
DOMESTIC WATER CONSUMPTION

The water consumption per building is known and shown on the following table. TMU is devoted to using technology and promoting actions that minimize water waste. The university tracks water usage and aims to decrease consumption through environmentally friendly practices. JOR-POD-LIB and KH-RAC are bundled together since they share a common infrastructure. KH has four water meters that are summed to provide total water consumption. In the table below, we observe both the water consumption in meter cube (m^3) as well as the water consumption use intensity in meter cube per meter square of space (m^3/m^2).

Building Code	Domestic Water (m^3)	Water Consumption Intensity (m^3/m^2)
PRO	428	0.77
OKF	965	1.41
SID	1,898	0.63
MON	2,799	1.43
CUI	6,432	1.11
COP	623	0.98
GER	10	0.00
BON	551	0.83
KH	92,592	8.22
RAC		
JOR-POD-LIB	52,713	5.82
SLC	6,343	0.49
ARC	8,210	1.23
EPH/SHE	4,157	0.23
ILC	28,362	2.43
BKS	1,276	0.98
PKG	0	0.00
PIT	43,847	2.14
RCC	10,353	0.94
ENG	6,533	0.34
OAK	1,062	0.62
HEI	357	0.14
SCC	1,354	0.41
TRS	20,320	1.17
SBB	1,216	0.22
VIC	3,057	0.29
CED	3,013	0.95
IMA	9,071	0.97
MAC	16,359	0.78
DCC	14,629	0.38
CIS	93	0.11

DOMESTIC WATER CONSUMPTION (CONT)

The graph below shows the water use intensity for each building, in order to create a basis of comparison for water usage efficiency across various buildings on campus.

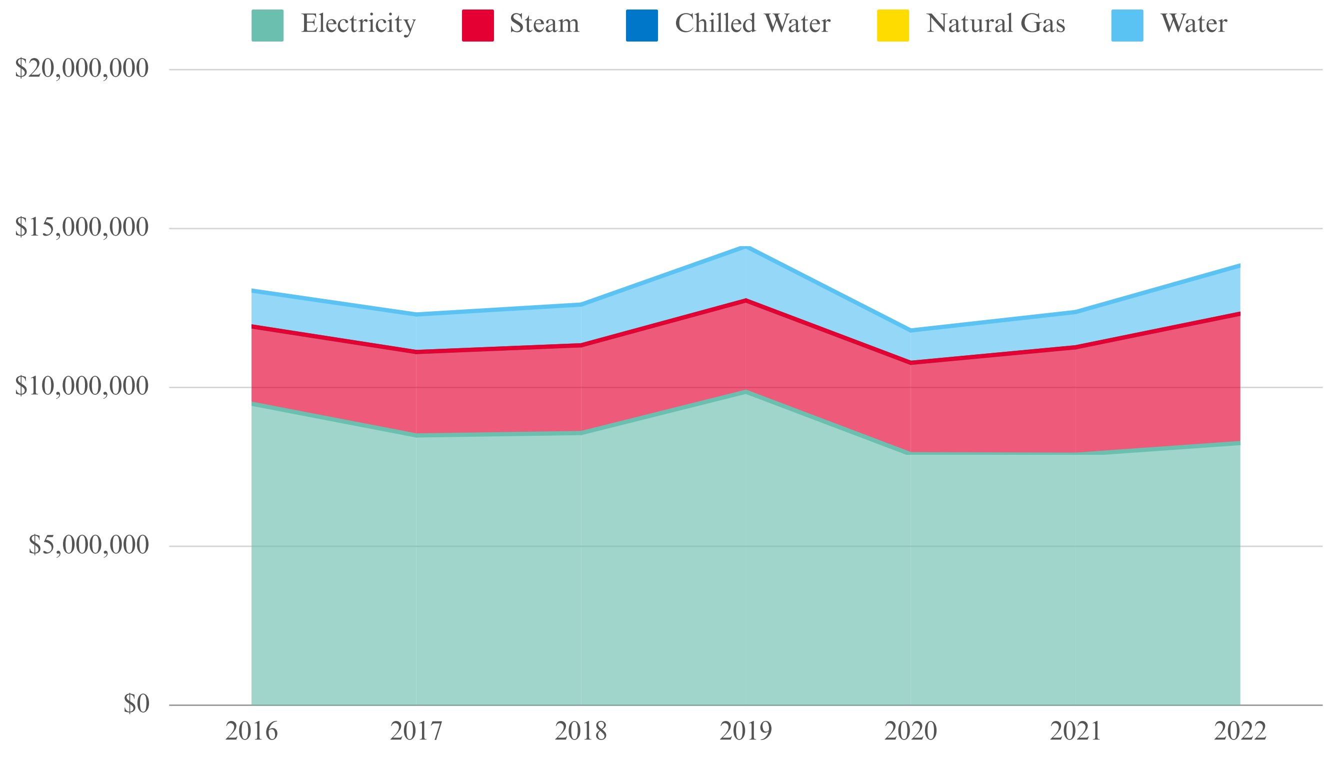


While we expect the residential buildings PIT and ILC to have higher water consumption, some academic buildings also have high usage intensities. One reason for this is the use of evaporative cooling in cooling towers for the chiller plants in in LIB, KH and RC. There are also issues with the steam condensate management that also creates this higher consumption, an issue that TMU is actively working toward resolving in Summer 2024.

TOTAL UTILITIES COST

The cost of energy has been kept below 2019 levels through utility cost optimization strategies such as Class A Global Adjustment optimization and due to the COVID-19 Pandemic. The cost of steam has increased primarily due to the carbon tax and the increase in the cost of natural gas in 2022.

Campus Total Yearly Accumulative Cost of Energy and Water



Total Annual Utilities Cost ($)						
2016	2017	2018	2019	2020	2021	2022
13,503,591	12,988,155	13,191,80	15,011,201	12,321,477	12,971,711	14,587,476

GHG REDUCTION STUDIES

In 2022, TMU procured an ambitious set of decarbonization feasibility studies to identify the GHG reduction potential on the most energy intensive campus buildings. These studies were finished in June 2024 and identified a thorough list of measures (See Appendix D for the complete list proposed). The list of procured studies are as follows:

- LIB,POD, JOR, RAC, and SLC Building Cluster
- ARC, MON, EPH, SHE, PIT. and RCC Building Cluster
- PIT RCC Electrification
- ENG & DCC Heat Recovery Chiller
- POD & JOR Heat Recovery Chiller
- SBB, SID, SCC, HEI, OAK, VIC, IMA AND CED Cluster

The studies analyzed three (3) decarbonization pathways :

Option 1 - Best Life Cycle Cost

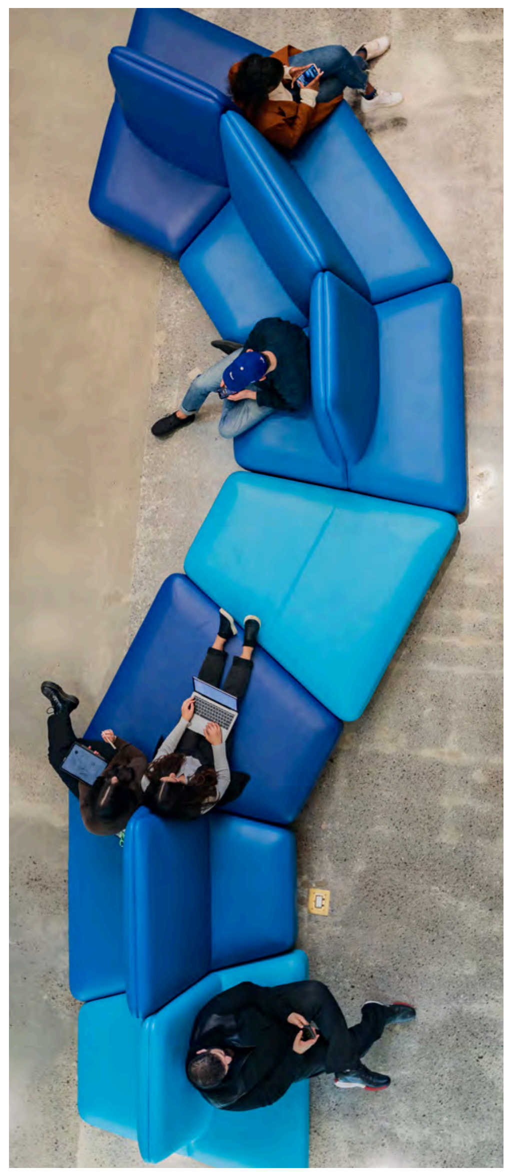
This option looks at the measures that offer the best return on investment. These typically include retro-commissioning measures and low-cost capital improvements. Option 1 provides an overall financially attractive solution to reduce GHG while benefiting from considerable operation cost reduction. However, it doesn't achieve TMU's net zero goals.

Option 2 - Deep GHG Retrofit

This option explores measures that have a deep impact on reducing the GHG on site. This typically includes heat recovery, envelope improvement, electrification, and air source heat pumps. These projects typically contribute to an increase in energy cost, but the future cost of carbon and the Class A rate structure minimizes these cost increases. Option 2 offers a large carbon reduction potential, but at a significantly higher cost.

Option 3 - Maximum Site Carbon

This option combines the savings from both options to provide an overall project that contributes to both GHG reduction and better financial returns. This option has the largest cost, but also provide the largest cost and GHG savings overall. The focus of this cost is on GHG reduction, and financial returns is not given priority.



GHG REDUCTION STUDIES (CONT)

The summary of the three options is presented in the table below. The measure list can be found in the Appendix D.

Project options	Energy Savings %	GHG Savings %	GHG Savings TonCO_2e	Energy Savings ekWh	Annual Cost Savings	Cost Savings CCT2030 Scenario	Cost of Measures	$/Ton$CO_2$e saved
Option 1- Best Life Cycle Cost	6.3%	11.4%	1,534	8,448,571	$639,385	$796,450	$5,662,634	$3,692
Option 2- Deep GHG Retrofit	7.5%	34.8%	4,664	9,991,685	$64,114	$547,125	$22,451,869	$4,814
Option 3- Maximum Site Carbon	10.3%	36.6%	4,912	13,846,643	$424,290	$933,145	$49,144,138	$10,006

Option 1—Best Life Cycle Cost offers a relatively short pay-back period estimated at 9 years with current carbon cost and 7 years when taking future carbon cost into consideration (CCT2030$), while reducing 11.4% of TMU's total campus emissions and 6.3% of total campus energy consumption.

Option 2—Deep GHG Retrofit includes the most cost-effective GHG reduction measures, estimated at 4,664 tCO_2e which represents 34.8% of TMU's total campus GHG emissions. The estimated cost to attain this result is $22,450,000 amounting to a metric of $4,814/t$CO_2$e reduced.

Option 3—Maximum Site Carbon delivers the highest carbon reduction potential with over 4,900 tCO_2e reduced, which amounts to 36.6% of TMU's total campus GHG emissions.

Option 1 shows a good opportunity to save on operational costs while reducing campus emissions considerably. Option 2 is, however, a more attractive solution for TMU to realistically reach its 40% reduction goal by 2035. Additional measures will still be needed, and reducing consumption at other energy intensive buildings like TRS, ILC, MAC and ENG will aid in this effort.

Note: The percentage (%) savings are based on the overall campus consumption. The CCT2030 refers to the cost savings that would be obtained if the energy cost would consider the carbon tax planned for 2030 at $170/t$CO_2$e.

RECENTLY COMPLETED PROJECTS

Campus Wide Sub-Metering project (2019-2023)
You cannot manage what you do not measure. TMU now measures the energy and water consumption of all buildings in 15 minute intervals. This provides valuable information that, for instance, helped create the building benchmarking contained in this ECDM. TMU can now sufficiently measure the savings from its energy, GHG and water conservation efforts. Moreover, the data collected is also shared with researcher who can use the data to educate the future generations on ressources management.

SID HVAC Modernization and building restoration (2023)
The SID building has undergone a series of improvements aimed at improving comfort while reducing GHG emissions. The buildings HVAC and BAS systems were modernized and a new low temperature heating system was installed. The associated savings are estimated at **80,000 ekWh** annually.

RCC building envelope restoration (2021)
The RCC building has undergone a complete building restoration, prolonging its useful life by many years as well as helping reduce air infiltration. The associated savings are estimated at **250,000 ekWh**.

New Kerr Hall Cooling Plant (2019)
A new cooling plant was built in the former steam boiler room in KH. This new cooling plant uses two magnetic bearings chillers, providing cooling to the whole campus, using the most efficient cooling technology available. The plant does, however, require optimization.

RECENTLY COMPLETED PROJECTS (CONT)

VIC Building 7th and 8th Floor Air Handling Unit Replacement (2023)

VIC had aging ventilation systems that required upgrades. TMU replaced the existing ventilation system with a new energy efficient one, equipped with heat recovery and glycol heating systems. The associated savings are estimated at **50,000 ekWh.**

POD Law School Ventilation improvement (2020)

A new space was created on the fourth floor of POD to accommodate TMU's new Faculty of Law. Energy recovery ventilation was installed and all spaces were modernized with LED lighting. The associated savings are estimated at **60,000 ekWh**.

SLC and LIB Cooling plant Retro-Commissioning (2020-2021)

SLC and the LIB Cooling plant had great potential for retro-commissioning. Financing was provided by Natural Resources Canada for this project. Measures implemented include sequence of operation optimization and sensor calibration. The associated savings are estimated at **425,000 ekWh.**

SLC and RCC LED Retrofit (2023-2024)

SLC and RCC'S fluorescent lighting system was replaced with LEDs. In addition to the energy savings, this improves the overall comfort of the occupants, while also reducing maintenance costs owing to the long service life of LED lighting. The associated savings are estimated at **635,000 ekWh.**

EXPECTED PROJECTS IN 2024-2029

LIB-POD-JOR HVAC Modernization

The LIB-POD-JOR HVAC systems are original from the construction and large energy users. The full modernization of these system will provide considerable energy savings with the use of heat recovery, BAS and variable frequency drives. The associated savings are estimated to **600,000 ekWh**.

VIC fourth and fifth floor HVAC modernization

Similar to LIB-POD-JOR, the VIC fourth and fifth floor HVAC systems are in the process of being modernized. The associated savings are estimated to **115,000 ekWh**.

TRS Retro-Commissioning

TRS shows goof potential for BAS and HVAC optimization. This includes reviewing the operation of heat wheels and Enwave deep lake cooling system. The associated savings are estimated at **500,000 ekWh**.

IMA-RIC Gallery optimization and heat recovery chiller

IMA-RIC Gallery is one of the most energy intensive spaces at TMU. Studies have shown that the systems are not operating optimally. Introducing a new sequence of operations that will avoid simultaneous cooling, dehumidification, humidification and heating is key. not operating optimally. Introducing new sequence of operations that will avoid simultaneous cooling, dehumidification, humidification and heating is key. The associated savings are estimated to **2,000,000 ekWh and 400 tCO_2e**.

POD-JOR server room heat recovery chiller

POD-JOR server room is a source of low-carbon heat. Using a HRC to use this heat in the rest of the building during the heating season will reduce steam consumption considerably. The associated savings are estimated at **1,200,000 ekWh and 287 tCO_2e.**

EXPECTED PROJECTS IN 2024-2029 (CONT)

DCC-ENG Heat Recovery Chiller

ENG also has servers that reject heat without being recovered. This heat could be used for DCC since DCC heating system is in ENG. This will help reduce DCC steam use, in addition to avoiding the steam stand-by losses. The associated savings are estimated at **1,500,000 ekWh and 390 tCO_2e.**

LED retrofit for all buildings on campus

TMU plans to replace all fixtures to LED on a 5 years horizon. The associated savings are estimated at **3,000,000 ekWh**.

RCC HVAC modernization and electrification

As suggested in the campus-wide GHG reduction studies, RCC shows an excellent potential for HVAC modernization and electrification, with measures including VFDs, new efficient motors, new pumps and electrical boilers. The associated savings are estimated at **800,000 ekWh**.

ARC HVAC modernization

ARC has aging ventilation system and issues with humidity control. A new HVAC system will contribute to increasing the energy performance of the buildings while improving operations. The associated savings are estimated at **200,000 ekWh**.

EXPECTED PROJECTS IN 2024-2029 (CONT)

Heating System Electrification

The PIT residence has a strong potential for electrification using air source heat pumps in lieu of the existing gas-fired boilers, which are nearing end of life.

Other buildings, including EPH/SHE, MON, LIB, POD, JOR, and SLC offers excellent electrification potential thanks to the Class A rate structure that allows for relatively low cost of off-peak electricity. In this building cluster, the cost of electricity is similar to that of steam, making heating electrification a viable measure.

The associated savings are initially estimated at **2,100,000 ekWh and 3,000 tCO_2e** but these figures require closer study at the individual building-level.

KEY PARTNERSHIPS

Being a higher-educational institute, it is imperative that TMU set an example through its conservation and sustainability initiatives. Both internal and external stakeholders play a key role in campus conservation. External stakeholders at TMU include utility providers and organizations focused on energy, sustainability, and conservation. Examples of such organizations include:

- Canadian Green Building Council (CaGBC)
- Ontario Association of Physical Plant Administrators (OAPPA)
- Natural Resources Canada (NRCan)
- Ontario College and University Sustainability Professional (OCUSP)
- Ministry of Training, Colleges, and Universities (MTCU)
- Green Will Initiative (GWI)

External stakeholders provide TMU with valuable information for advancing conservation efforts. They can also offer funding, alongside utility providers and NRCan, to support these initiatives.

Internal stakeholders consist of operational and academic departments or teams dedicated to conservation and sustainability efforts. Research-oriented internal organizations, such as the Centre for Urban Energy (CUE) and Urban Water TMU (UWTMU), focus on energy and water conservation. These teams operate within the Centre for Urban Innovation (CUI), established in 2018 as a hub for research, incubation, and commercialization, primarily addressing urban infrastructure challenges.

WATER CONSERVATION

Though focusing mainly on energy, TMU also prioritizes water conservation for environmental and cost reasons. Adhering to LEED Silver standards helps, but more can be done, including:

- Upgrade old faucets, toilets, and showerheads in existing buildings with low-flow alternatives.
- Improving the management of steam condensate, to maximize the condensate returned to Enwave steam plant.
- Reduce the cooling tower evaporation by improving the energy efficiency on campus generally.

CAMPUS AS A LIVING LAB

The “Campus as a Living Lab” approach to fostering applied research involves sharing energy and BAS data with researchers to improve energy efficiency on campus and create solutions aimed toward energy conservation and GHG reduction. The DCC, a LEED Gold building, provides data from hundreds of sensors and energy meters to a digital twin that replicates integrates and visualizes building operational data, serving as a valuable tool for ongoing building commissioning.

SCITHUB RENDERING BY WZMH ARCHITECTS

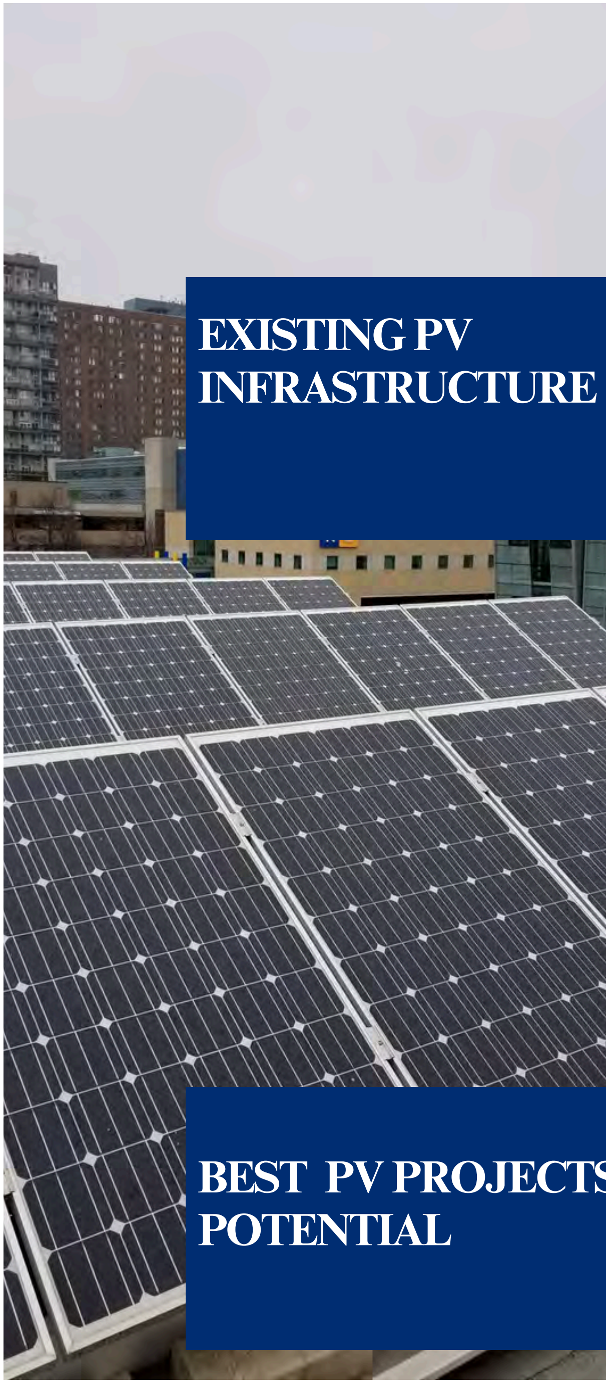
PEAK DEMAND MANAGEMENT

Several campus buildings are enrolled in the IESO's Class A electricity rate program. Participation in this program aids the province of Ontario in reducing or eliminating the need for gas-fired electricity generation during times of peak electricity demand. By participating in this demand management strategy, TMU contributes toward keeping Ontario's electricity grid emissions low.

TMU makes use of external partners to anticipate peak hours, and contributes to the Class A program by reducing electricity consumption and demand associated with participating buildings.

TMU's peak demand strategy is an evolving process, and the university is currently assessing the case for utilizing temporary energy storage solutions during peak events.

RENEWABLE ENERGY ON CAMPUS



TMU currently makes use of a small number of PV panels to generate renewable energy on campus. The PV panels have been installed on the rood of the SCC building and have a capacity of approximately 11kW.

EXISTING PV INFRASTRUCTURE

OAK-SCC Buildings

Capacity :

11 kW

TMU conducted a solar PV production analysis using HelioScope software as part of the GHG reduction studies. Only buildings with sufficient roof surface and minimal shadow from adjacent buildings were considered. These buildings include RCC, IMA-RIC, and KH. While KH was analyzed, it is unlikely to get PV panels as long-term campus plans involve its demolition or significant redevelopment. The generation potential from these sites is highlighted below.

BEST PV PROJECTS POTENTIAL

RCC	226 kW
IMA-RIC	198 kW
KH	410 kW

The studies concluded that the potential for solar electricity generation at TMU's campus is not optimal, primarily due to shadow casted by surrounding towers. If financial incentives are available, however, PV panel installations at RCC and IMA are viable options.

APPENDIX A - CAMPUS MAP

Toronto Metropolitan University Campus Map

Version: October 2022

AOB Atrium on Bay
20 Dundas Street West

ARC Architecture Building — Paul H. Cocker Gallery
325 Church Street

BKS Campus Store
17 Gould Street

BND 114 Bond Street

BON 111 Bond Street

BTS Bell Trinity Square
483 Bay Street

CAR Carlton Cinema
20 Carlton Street

CED The Chang School of Continuing Education (Heaslip House)
297 Victoria Street

CIS Creative Innovation Studio
110 Bond Street

CIV Civil Engineering Storage
106 Mutual Street

COP 101 Gerrard Street East

CPK English Language Institute and International College (College Park)
424 Yonge Street

CUI Centre for Urban Innovation
44 Gerrard Street East

DAL 147 Dalhousie Street

DCC Daphne Cockwell Health Sciences Complex
288 Church Street

DSQ Yonge-Dundas Square
10 Dundas Street East

ENG George Vari Engineering and Computing Centre
245 Church Street

EPH Eric Palin Hall
87 Gerrard Street East

HEI School of Graphic Communications Management (Heidelberg Centre)
125 Bond Street

ILC International Living/Learning Centre
133 Mutual Street and 240 Jarvis Street

IMA School of Image Arts
122 Bond Street

IMC The Image Centre
33 Gould Street

JOR Jorgenson Hall
380 Victoria Street

KHE Kerr Hall East
340 Church Street

KHN Kerr Hall North
31 / 43 Gerrard Street East

KHS Kerr Hall South
40 / 50 / 60 Gould Street

KHW Kerr Hall West
379 Victoria Street

LIB Library Building
350 Victoria Street

MAC Mattamy Athletic Centre
50 Carlton Street

MER Merchandise Building
159 Dalhousie Street

MON Civil Engineering Building (Monetary Times)
341 Church Street

MRS MaRS Building
661 University Avenue

OAK Oakham House
63 Gould Street

OKF O'Keefe House
137 Bond Street

PIT Pitman Hall
160 Mutual Street

PKG Parking Garage
300 Victoria Street

POD Podium
350 Victoria Street

PRO 112 Bond Street

RAC Recreation and Athletics Centre
40 / 50 Gould Street
Accessible entrance: 31 Gerrard Street East

RCC Rogers Communications Centre
80 Gould Street

SBB South Bond Building
105 Bond Street

SCC Student Campus Centre
55 Gould Street

SHE Sally Horsfall Eaton Centre for Studies in Community Health
99 Gerrard Street East

SID School of Interior Design
302 Church Street

SLC Sheldon & Tracy Levy Student Learning Centre
341 Yonge Street

SMH St. Michael's Hospital
209 Victoria Street

TEC Toronto Eaton Centre
220 Yonge Street

TRS Ted Rogers School of Management
55 Dundas Street West

VIC Victoria Building
285 Victoria Street

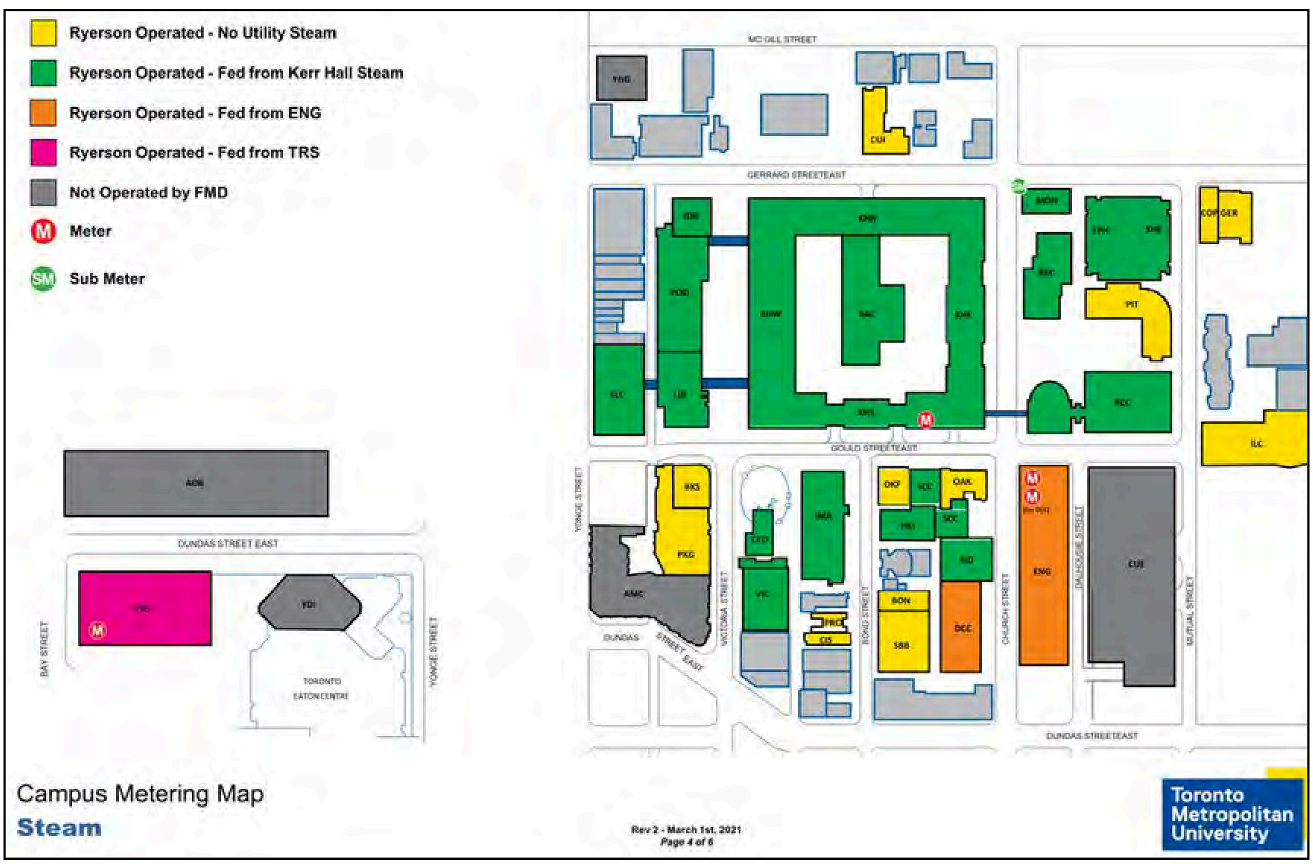
YDI Yonge-Dundas Intersection
1 Dundas St West

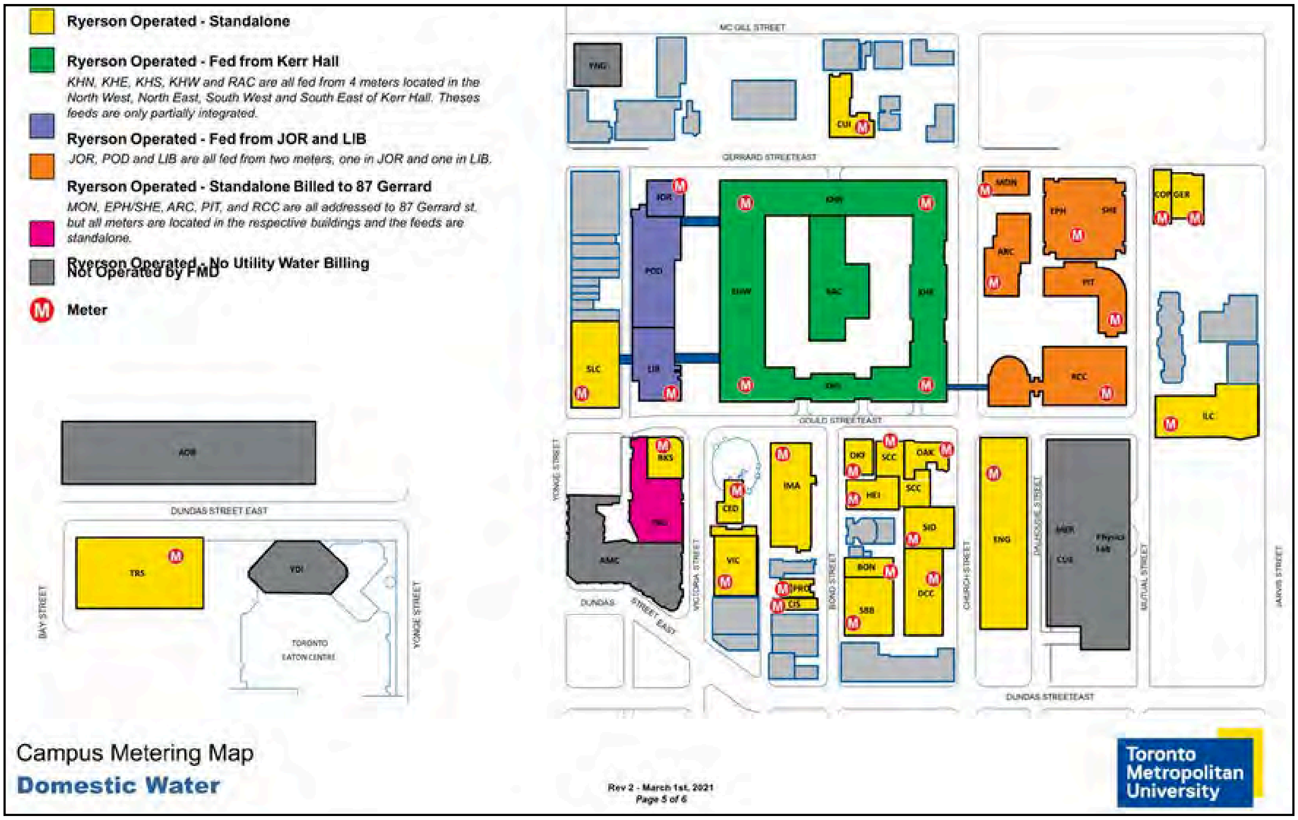
YNG 415 Yonge Street

- ServiceHub
- Security
- Café / Eatery
- The Theatre at The Creative School
- Gallery
- Lake Devo
- Parking
- TTC Subway Stop

Toronto Metropolitan University

APPENDIX B - UTILITIES METERING MAP




Ryerson Operated - Standalone
Ryerson Operated - Fed from Kerr Hall
KHN, KHE, KHS, KHW and RAC are all fed from 4 meters located in the North West, North East, South West and South East of Kerr Hall. Theses feeds are only partially integrated.
Ryerson Operated - Fed from JOR and LIB
JOR, POD and LIB are all fed from two meters, one in JOR and one in LIB.
Ryerson Operated - Standalone Billed to 87 Gerrard
MON, EPH/SHE, ARC, PIT, and RCC are all addressed to 87 Gerrard st, but all meters are located in the respective buildings and the feeds are standalone.
Ryerson Operated - No Utility Water Billing
Not Operated by FMD
Meter
MC GILL STREET
GERRARD STREET EAST
GOULD STREET EAST
DUNDAS STREET EAST
YONGE STREET
VICTORIA STREET
BOND STREET
CHURCH STREET
DALHOUSIE STREET
MUTUAL STREET
JARVIS STREET
BAY STREET
TORONTO EATON CENTRE
AOB
TRS
YDI
CUI
JOR
POD
LIB
SLC
KHN
KHW
KHE
KHS
RAC
MON
EPH
SHE
ARC
PIT
RCC
COP
GER
ILC
BKS
CED
IMA
VIC
AMC
OKF
SCC
OAK
HEI
SID
BON
SBB
DCC
PRO
CIS
ENG
MER
CUE
Physics Lab
Campus Metering Map
Domestic Water
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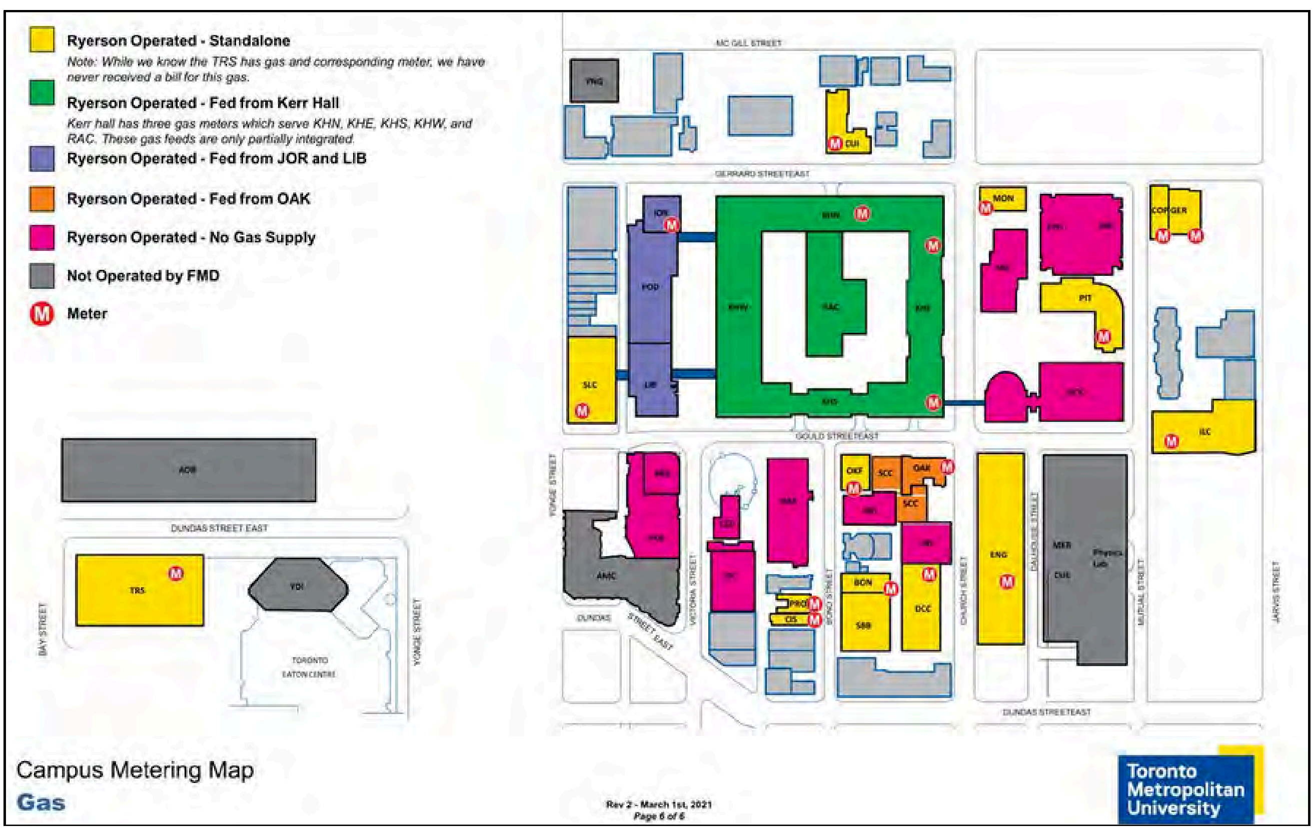
Ryerson Operated - Standalone
Note: While we know the TRS has gas and corresponding meter, we have never received a bill for this gas.
Ryerson Operated - Fed from Kerr Hall
Kerr hall has three gas meters which serve KHN, KHE, KHS, KHW, and RAC. These gas feeds are only partially integrated.
Ryerson Operated - Fed from JOR and LIB
Ryerson Operated - Fed from OAK
Ryerson Operated - No Gas Supply
Not Operated by FMD
Meter
MC GILL STREET
GERRARD STREET EAST
GOULD STREET EAST
DUNDAS STREET EAST
YONGE STREET
VICTORIA STREET
BOND STREET
CHURCH STREET
DALHOUSIE STREET
MUTUAL STREET
JARVIS STREET
BAY STREET
TORONTO EATON CENTRE
AOB
TRS
YDI
CUI
JOR
POD
LIB
SLC
KHN
KHW
KHE
KHS
RAC
MON
PIT
COP
GER
ILC
OKF
SCC
OAK
BON
SBB
DCC
PRO
CIS
ENG
AMC
MER
CUE
Physics Lab
Campus Metering Map
Gas
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APPENDIX C - CURRENT STATE OF ENERGY CONSUMPTION

Ihe next graph shows the actual or estimated energy consumption of each buildings, per source of energy.

Building Code	Electricity (kWh)	District Steam (ekWh)	District Chilled Water (ekWh)	Natural Gas (ekWh)	Building total (ekWh)
PRO	123,762	0	0	88,927	**212,690**
OKF	13,337	0	0	327,025	**340,362**
SID	290,632	344,049	8,807	0	**643,488**
MON	368,515	330,121	0	23,294	**721,930**
CUI	2,771,456	0	0	1,343,869	**4,115,325**
COP	75,633	0	0	74,077	**149,711**
GER	181,886	0	0	203,932	**385,818**
BON	115,868	0	0	48,493	**164,361**
KH	8,277,692	12,621,945	1,483,616	771,708	**23,154,961**
RAC	852,436	313,681	0	0	**1,166,117**
LIB-POD-JOR	11,400,118	5,205,895	969,030	86,182	**17,661,225**
SLC	1,957,869	14,367	183,858	1,286,575	**3,442,669**
ARC	1,095,509	732,692	-	-	**1,828,202**
EPH/SHE	3,156,167	1,200,093	266,046	-	**4,622,306**
ILC	1,692,801	-	-	1,270,831	**2,963,632**
BKS	216,000	-	-	-	**216,000**
PKG	480,002	-	-	-	**480,002**
PIT	1,617,465	-	96,564	2,977,586	**4,691,614**
RCC	3,154,820	944,680	504,993	-	**4,604,493**
ENG	4,450,915	2,284,794	348,363	4,539	**7,088,612**
OAK	372,213	-	-	373,914	**746,127**
HEI	794,585	388,437	17,572	-	**1,200,593**
SCC	635,516	283,690	357,755	-	**1,276,961**
TRS	3,057,340	1,578,337	200,641	-	**4,836,317**
SBB	778,551	-	-	952,940	**1,731,491**
VIC	1,279,773	392,108	75,152	-	**1,747,034**
CED	565,346	324,092	61,110	-	**921,919**
IMA	3,126,163	3,627,367	218,066	-	**3,845,433**
MAC	3,951,218	-	-	3,349,982	**7,301,201**
DCC	3,701,314	1,917,718	-	372,318	**5,991,350**
CIS	110,287	-	-	200,796	**311,084**

APPENDIX D - SUMMARY OF GHG REDUCTION STUDIES

PIT	Operable Windows Management LED Retrofit Booster Pumps Replacement Parking Fans Control
RCC	Lighting Retrofit Lighting Controls Supply Air Temperature Reset VFD on all fans and motor with pressure strategy Air Balancing & Airflow Evaluation and Optimization of Ventilation Demand Control Ventilation for AHU Demand Control Ventilation for Auditorium and Conference Rooms VFD On Cooling Pumps & Differential Pressure Reset General Fan Exhaust Schedule With Ventilation Systems Domestic Hot Water Heat Pump BAS Operating Schedule Improvement RCC Solar Energy Analysis
MON	RTU1 & 2 Supply Temperature Reset Strategy Static Pressure Reset Strategy Demand Control Ventilation Optimization Schedule of System Optimization Exhaust Fan BAS Integration Electrification of the radiator System Electrification of the Glycol Heating Loop
ARC	Lighting Retrofit Electrification of Radiant Heating Optimization and Electrification of Workshop AHU3 ARC Geothermal Energy Analysis
EPH/SHE	Lighting Retrofit for SHE Refurbishment of Heat Wheels Demand Control Ventilation Optimization Rebalancing and Airflow Evaluation Building Exhaust BAS Integration Building Pressure Control Management Improvement of Supply Air Temperature Reset Strategy Supply Air Static Pressure Reset Strategy Electrical Heaters Control on Temperature Sensors BAS Operating Schedule Improvement (Fan Powered Box) Electrification of Heating System Heat Pump
UB	Major Window Upgrade from Single Glazed to Double Glazed Major Window Upgrade from Single Glazed to Triple Glazed LED Retrofit of Remaining Fixtures & Spotlights Lighting Control Exhaust Fans Schedule with Ventilation BAS Schedule Improvement Electrification of heating system Domestic Hot Water Electrification and Heat Pump New Mag Bearing Chillers

APPENDIX D - SUMMARY OF GHG REDUCTION STUDIES (CONT)

SBB	LED Retrofit of Remaining Fixtures & Spotlights Supply Air Static Pressur Reset Strategy Electric Heaters on BAS to control on temperature sensors BAS Operating Schedule Improvement Electrification of Local Steam System Option 2 Air Source Heat Pump Electrification of Heating for RTUs Option 2 Heat Pump Heating for RTUs Cleaning of RTU Condenser Fins
SID	LED Retrofit of Remaining Fixtures & Spotlights Electrification of DHW Electrification of Heating system + Air source heat pump Electrification of Glycol Heating System
SCC	LED Retrofit of Remaining Fixtures & Spotlights Retro-Commissioning of Heat Wheels Retrofit of all VAVs Terminal Units Electric Heaters on BAS to Control Based on Temperature Sensor Electrification of DHW Electrification of Heating system with Air source heat pump Electrification of Glycol Heating System BAS Operating Schedule Improvement
HEI	LED Retrofit of Remaining Fixtures & Spotlights Retro-Commissioning of Heat Wheels Building Pressure Control Management Retrofit of all VAVs Terminal Units Supply Air Static Pressure Reset Strategy Radiant Floor Retro-Commissioning Electrification of Heating system with Air source heat pump Electrification of Glycol Heating System BAS Operating Schedule Improvement
OAK	Window Upgrade LED Retrofit of Remaining Fixtures & Spotlights Replacement of RTUs with Heat Pump and Electrical Heat Replacement of Tempered Loop Pumps and right Size and VFDs Demand Control Ventilation for Kitchen Hoods BAS Operating Schedule Improvement
VIC	LED Retrofit of Remaining Fixtures & Spotlights Lighting Control General Fan Exhaust Schedule with Ventilation Systems 7th & 8th floor electrification of heating with Baseboard Central Heating Electrification BAS Operating Schedule Improvement
IMA	LED Retrofit of Remaining Fixtures & Spotlights Installation of VFDs on Older AHUs with New Motors and Refurbishment IMA Gallery Ventilation Systems Retro Commissioning Heat Recovery Chiller from Gallery System for Preheat and Reheat VAV Minimum Flow Optimization DHW Electrification General Fan Exhaust Schedule With Ventilation Systems IMA Solar Heating & Reheat Systems Electrification BAS Operation Schedule Improvement

APPENDIX D - SUMMARY OF GHG REDUCTION STUDIES (CONT)

CED	LED Retrofit of Remaining Fixtures & Spotlights Building Pressure Control Management , Supply Air Temperature & Pressure Reset Strategy Demand Control Ventilation Retrofit of All VAVs Terminal Units Booster Pump Upgrade Electrification of Heating System Electrification of Glycol Heating System BAS Schedule Improvement with Exhaust Fan
POD	Major Window Upgrade from Single Glaze to Double Glazed Major Window Upgrade from Single Glaze to triple Glazed LED Retrofit of Remaining Fixtures & Spotlights Lighting Control Exhaust Fans Schedule with Ventilation BAS Schedule Optimization Heat Recovery of Kitchen Refrigerator and Freezer Demand Control Ventilation for Kitchen Hoods Central Heating Electrification Electrification of the kitchen steam equipment Domestic Hot Water Electrification and Heat Pump
JOR	Major Window Upgrade from Single Glazed to Double Glazed Major Window Upgrade from Single Glazed to Triple Glazed LED Retrofit of Remaining Fixtures & Spotlights Lighting Control Exhaust Fans Schedule with Ventilation BAS Schedule Improvement
SLC	LED Retrofit of Remaining Fixtures Steam Systems Removal BAS Schedule Improvement Chilled Water Temperature Loop Reset Air Source Heat Pumps
RAC	LED Retrofit of Remaining Fixtures Lighting Control New More Efficient Heat Pumps with ECM Motors and Variable Flow Compressor Electrification of Heating (in Kerr Hall) BAS Schedule Improvement