University of Guelph

Greenhouse Gas Emissions Summary

Energy Consumption and GHG Weather Normalization

2002 – 2021

Project No. 22005

Date: July 20, 2022

Revision: 1

EXECUTIVE SUMMARY

An overview of actual and weather normalized energy consumption and related greenhouse gas ("GHG") emissions at the University of Guelph. The University is located at 50 Stone Rd E, in Guelph, Ontario and has approximately 7,021,532 square feet of assignable and non-assignable space. The report encompasses energy consumption and associated GHG emissions as a result of stationary combustion of natural gas ("NG") and grid electricity consumption on campus, as they pertain to the Major, Minor and Student Housing utility accounts. A summary of weather normalized consumption data and climate normalized GHG emissions is also included.

The major emissions sources located at the University come from the stationary combustion of natural gas in five (5) low NO_x wall-fired boilers. Additional de minimis emissions come from the combustion of No. 2 fuel oil in the emergency generators, which will not be discussed due to limited data and invariability with the weather.

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1. GENERAL STATIONARY COMBUSTION

The following accounts are reported annually by the University of Guelph to the Ministry of the Environment ("MOE") as part of the mandatory greenhouse gas reporting:

TABLE 1. MOE REPORTED ACCOUNTS

Campus Account	Fuel Source	Related Emissions
Major Natural Gas	Natural Gas	CO_2, CH_4, N_2O
Minor Natural Gas	Natural Gas	CO_2, CH_4, N_2O
Student Housing Natural Gas (SHS)	Natural Gas	CO_2, CH_4, N_2O
Transit Petroleum[1]	Fuel Oil[2]	CO_2, CH_4, N_2O

Each of these accounts contribute to the overall fossil fuel consumption on campus related to general stationary combustion.

Fossil fuel consumption on campus related to stationary combustion and the related greenhouse gas emissions from 2002 to 2021 can be found in Table 3 below. The numbers have been adjusted to follow current (2021) MOE reporting standards in the greenhouse gas reporting guidelines. (Environment and Climate Change Canada, 2021). As can be seen in Figure 1 below, GHG emissions strongly correlate with natural gas consumption; as natural gas consumption for stationary combustion increases, so too do GHG emissions. As such, normalization of the data will have a similar impact on both natural gas consumption and GHG emissions trends.

At the time of this report, the following years and accounts are missing natural gas consumption data: Minor account 2005 – 2011, 2013 and Student Housing (SHS) 2002 – 2021. Missing data was estimated based on historical utility data where there is consistent data for all utility accounts. The missing account information makes up approximately 6% of the total annual natural gas consumption and has a minimal overall effect on consumption and GHG trends.

For the purpose of this report, actual and estimated natural gas consumption data, and resultant GHG emissions will sometimes be referred to as "reported" data.

[1] Fuel oil supplier – delivers fuel oil to campus
[2] #2 ULS furnace oil, #2 ULS diesel

The following GHG quantification criteria were used to calculate GHG emissions from combustion of natural gas as required by Environment and Climate Change Canada [Table 2]. (Environment and Climate Change Canada, 2021).

TABLE 2. GHG QUANITIFICATION CRITERIA

Natural Gas HHV (MJ/m^3)	38.800
EF - CH_4 (g/m^3)	0.0372
EF - N_2O (g/m^3)	0.0350
GWP CH_4 (2001-2011)	21
GWP N_2O (2001-2011)	310
GWP CH_4 (2012-2021)	25
GWP N_2O (2012-2021)	298

TABLE 3. SUMMARY OF CAMPUS NG CONSUMPTION AND RESULTANT GHG EMISSIONS

Year	Actual Consumption (m^3)	Actual GHG Emissions (tCO_2e)
2002	21,006,231	41,109
2003	22,481,251	43,995
2004	21,870,069	42,799
2005	21,772,143	42,608
2006	20,887,739	40,877
2007	23,131,726	45,268
2008	23,284,933	45,568
2009	23,559,978	46,106
2010	22,075,682	43,202
2011	22,857,548	44,732
2012	19,644,840	38,439
2013	22,378,702	43,789
2014	23,335,462	45,661
2015	22,430,378	43,890
2016	20,588,771	40,286
2017	20,645,023	40,396
2018	21,015,450	41,121
2019	22,093,965	43,231
2020	18,579,357	36,354
2021	20,992,503	41,076

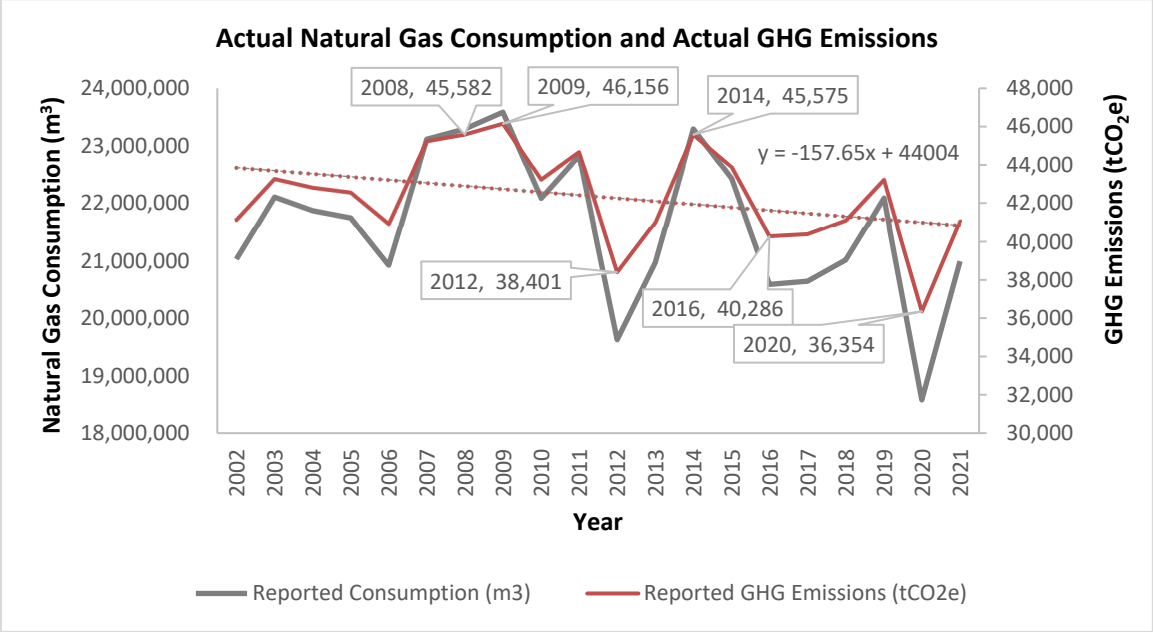

FIGURE 1. CORRELATION BETWEEN NG CONSUMPTION FROM GENERAL STATIONARY COMBUSTION AND GHG EMISSISSIONS

The historical data indicates that natural gas consumption and related greenhouse gas emissions were lowest in 2020 (36,354 tCO_2e), 2012 (38,401 tCO_2e) and 2016 (40,286 tCO_2e) and highest in 2009 (46,156 tCO_2e), 2008 (45,582 tCO_2e) and 2014 (45,575 CO_2e) [Figure 1]. Overall, campus greenhouse gas emissions from natural gas combustion have been declining.

Emissions from the combustion of No. 2 fuel oil is often reported as a “de minimis” emission and is often not considered significant enough to be reported to the MOE. Due to the limited data for historical No. 2 fuel oil consumption, it’s lack of variable loads and its designation as a “de minimis” emission, it has been excluded from this report. No. 2 fuel oil consumption is primarily used for backup emergency generators on campus and has no variable load, therefore it is not expected to show a correlation with the weather.

2. EMISSIONS FROM STATIONARY COMBUSTION AS THEY RELATE TO WEATHER

To better understand greenhouse gas emissions trends for the stationary combustion data reported above, the data was normalized to account for variations in the weather over the last 30 years and to account for climate trends. For the purposes of this report, only energy consumption with variable loads which are affected by changes in the weather were evaluated.

Annual energy consumption totals for natural gas and resulting greenhouse gas emissions, were normalized to the weather based on the total average monthly heating degree days ("HDD") for the last 30 years with reference to HDD in each year from 2002 to 2021. A base temperature of 18°C was used. Below is the overall trend in HDD from 2002 to 2021. It is expected that annual heating loads will follow HDD trends.

2.1. Heating Degree Days

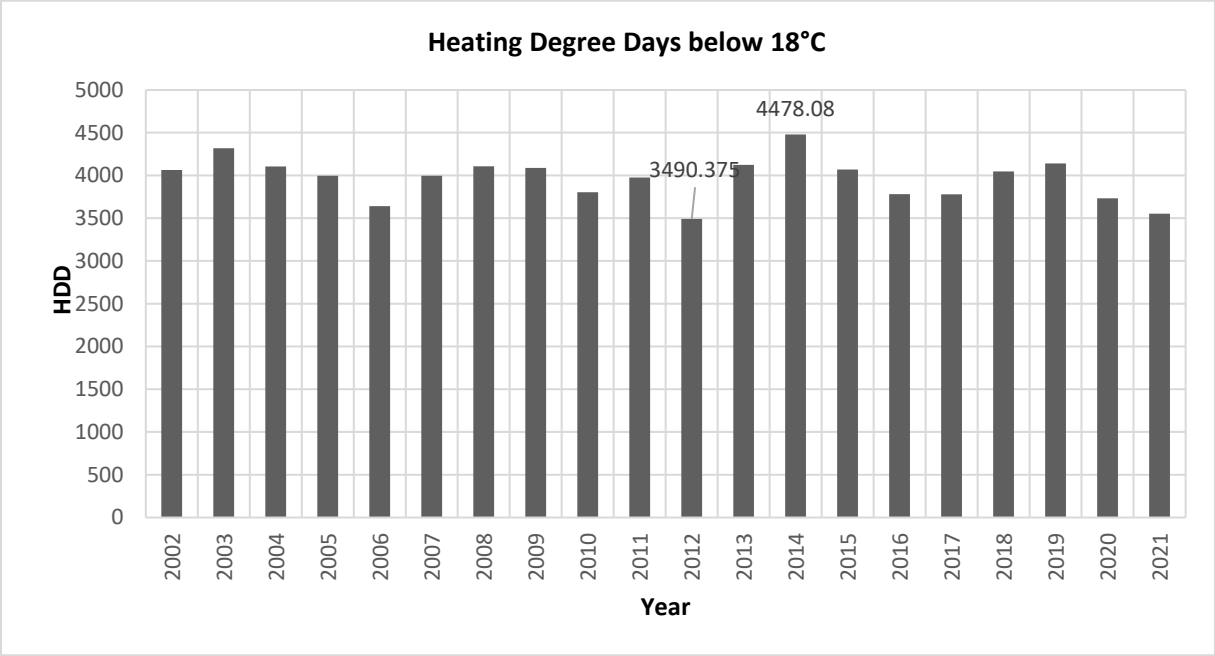

FIGURE 2. HEATING DEGREE DAYS FOR UNIVERSITY OF GUELPH 2002-2021

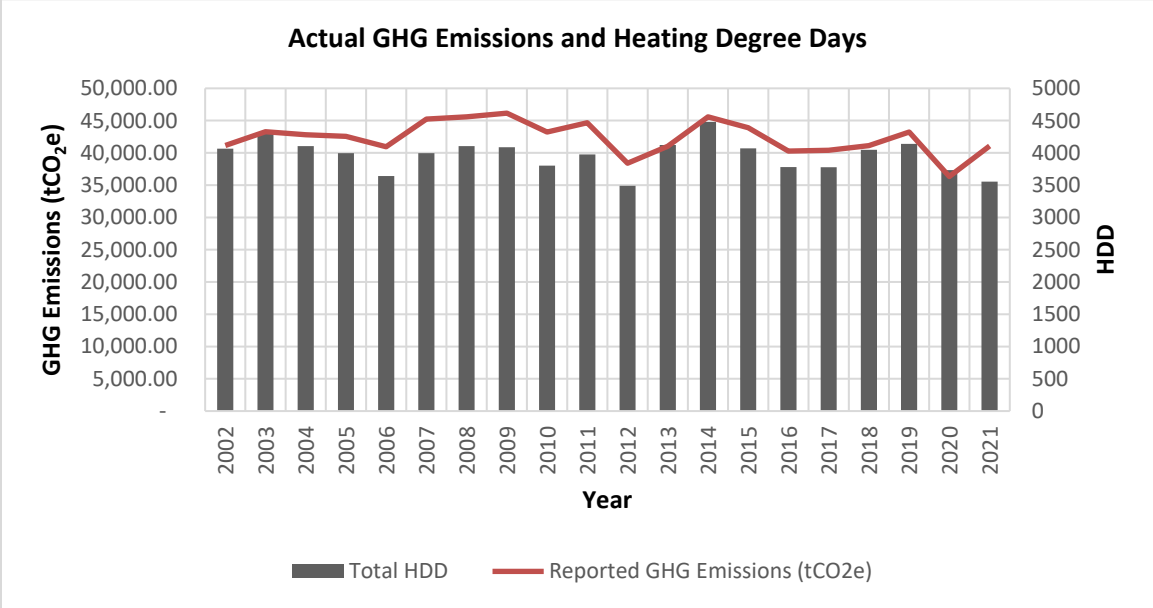

FIGURE 3. COMPARISON OF GHG EMISSIONS AND HDD.

The historical data indicates the lowest number of heating degree days were in 2012 (3,490), 2021 (3,553) and 2006 (3,640) and greatest in 2014 (4,478), 2003 (4,318) and 2019 (4,140). While the data indicates GHG emissions were lowest in 2020 (36,354 tCO_2e), 2012 (38,401 tCO_2e) and 2016 (40,286 tCO_2e) and highest in 2009 (46,156 tCO_2e), 2008 (45,582 tCO_2e) and 2014 (45,575 CO_2e), the correlation between the two datasets; HDD and GHG emissions from stationary combustion of natural gas, is positive with a correlation coefficient of 0.7.

2.2. Natural Gas Consumption and Emissions Normalization

Based on the above HDD trend and the 30 year average monthly HDD in Guelph, Ontario (NASA, 2021) a comparison of actual and normalized data, as well as the percent difference between the two datasets can be found in Table 4 below. The overall annual trend for the normalized greenhouse gas emissions from natural gas combustion on campus is shown in Figure 4.

TABLE 4. ANNUAL ACTUAL AND NORMALIZED NG CONSUMPTION AND RESULTANT GHG EMISSIONS.

Year	Actual Consumption (m^3)	Normalized Consumption (m^3)	Actual GHG Emissions (tCO_2e)	Normalized GHG Emissions (tCO_2e)	Percent Difference (%)
2002	21,006,231	20,799,855	41,109	40,705	1%
2003	22,481,251	21,491,865	43,995	42,059	5%
2004	21,870,069	21,643,629	42,799	42,356	1%
2005	21,772,143	22,446,176	42,608	43,927	-3%
2006	20,887,739	22,044,108	40,877	43,140	-6%

2007	23,131,726	23,173,346	45,268	45,350	0%
2008	23,284,933	22,865,622	45,568	44,747	2%
2009	23,559,978	23,297,609	46,106	45,593	1%
2010	22,075,682	22,781,666	43,202	44,583	-3%
2011	22,857,548	23,298,674	44,732	45,595	-2%
2012	19,644,840	22,097,885	38,439	43,239	-12%
2013	22,378,702	21,946,032	43,789	42,942	2%
2014	23,335,462	21,744,624	45,661	42,548	7%
2015	22,430,378	24,424,980	43,890	47,792	-9%
2016	20,588,771	22,758,872	40,286	44,532	-11%
2017	20,645,023	22,524,992	40,396	44,075	-9%
2018	21,015,450	21,044,393	41,121	41,178	0%
2019	22,093,965	21,968,346	43,231	42,986	1%
2020	18,579,357	19,314,966	36,354	37,794	-4%
2021	20,992,503	22,596,407	41,076	44,215	-8%

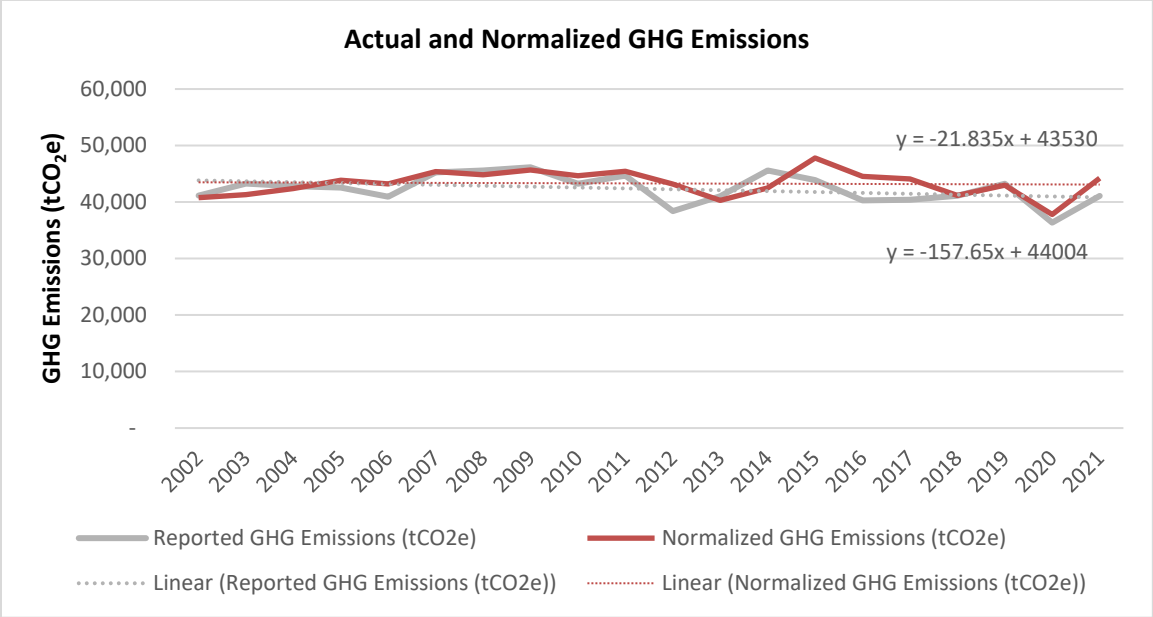

FIGURE 4 COMPARISON OF ACTUAL AND NORMALIZED GHG EMISSIONS 2002-2021

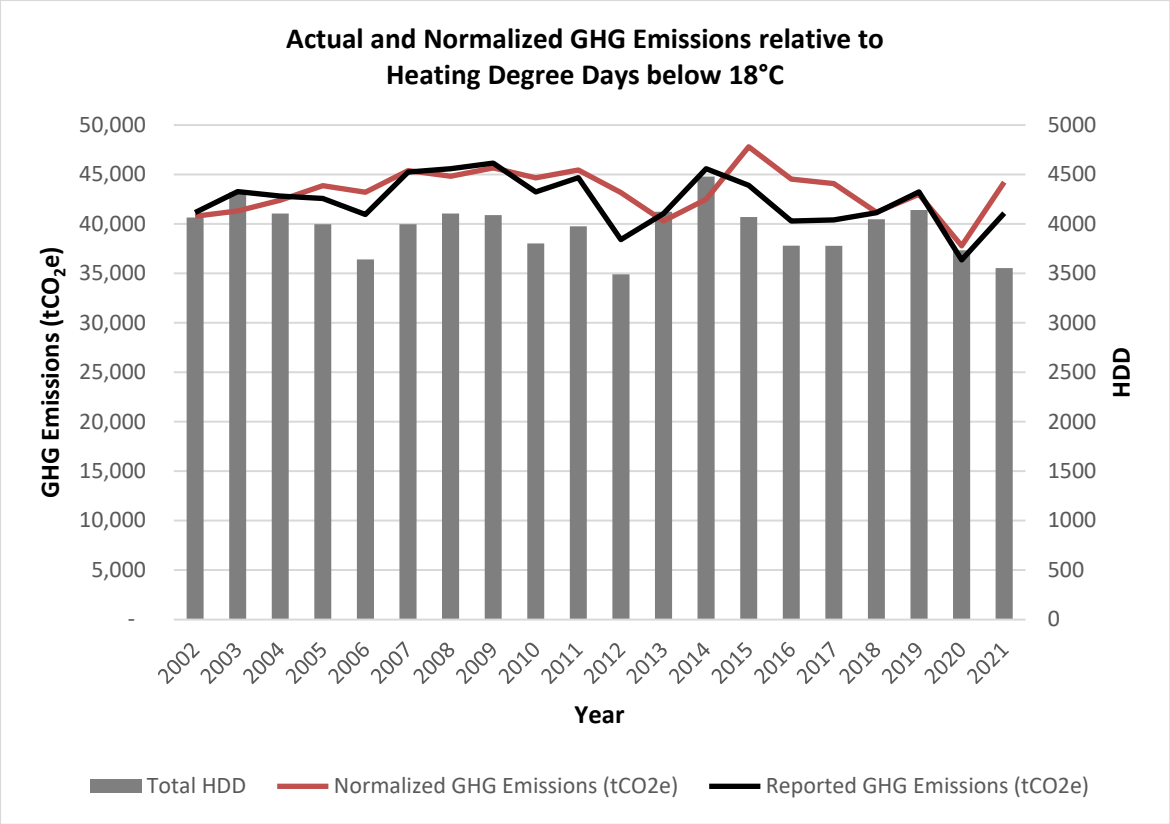

FIGURE 5. ACTUAL AND NORMALIZED GHG EMISSIONS COMPARED TO HDD

Actual natural gas consumption and resultant GHG emissions correlate with total annual HDD [Figure 5]. As would be expected, the normalized data does not correlate with the degree day data as there is greater variance in the data when the degree days differ from the normalized data.

When compared to the normalized data, actual data was significantly lower than the normalized data in 2012 (-12%), 2016 (-11%), 2015 (-9%), 2017 (-9%) and 2021 (-8%). There are several factors that may influence this, such as decrease in thermal load unrelated to the weather or thermal efficiency improvements on campus.

When compared to the normalized data, actual data was higher than the normalized data in 2014 (7%) and 2003 (5%). Similarly, factors that may influence this are increase in thermal load unrelated to weather or thermal inefficiencies.

Overall, actual consumption and emissions data follow the normalized data closely, and are in fact more often below the expected thermal load consumption.

3. ELECTRICITY

The following accounts shown in Table 5 are not required to be reported to the MOE but have been included in this report to provide a more comprehensive look at the University's energy usage and overall greenhouse gas contribution. The table lists the campus hydro accounts reviewed for this report, the sources of electricity, and their related emissions. It should be noted that the electricity consumption data made available at the time of the report is not fully comprehensive due to limited historical data found. Some electricity data used in this analysis was estimated based on trends shown in the annual data that was complete. The estimated electricity consumption data accounts for approximately 4% of the total historical electricity consumption discussed in this report.

TABLE 5. ELECTRICITY ACCOUNTS

Campus Account	Electricity Source	Related Emissions
Major Hydro, Minor Hydro & Student Housing	Hydroelectric	Zero
	Nuclear	CO_2, CH_4, N_2O (indirect)
	Wind	CO_2, CH_4, N_2O (indirect)
	Solar	CO_2, CH_4, N_2O (indirect)
	Natural Gas	CO_2, CH_4, N_2O
	Coal	CO_2, CH_4, N_2O

The electricity supply mix for Ontario, as reported by the Independent Electricity System Operator ("IESO") for the years 2002 to 2021 is shown below in Table 6 and Figure 6. Coal made up approximately 27% of Ontario's grid in 2002, and then gradually declined before being completely phased out by 2015. Nuclear increased from 32% in 2002 to 60% in 2020, while the amount of hydroelectric power remained relatively consistent, at an average of 24%. Wind power was not present in Ontario's grid in 2002, but its capacity gradually increased over time, contributing to 8% of Ontario's electricity supply mix in 2021.

TABLE 6. ONTARIO'S ELECTRICITY SUPPLY MIX 2002 – 2021

	Source of Electricity						
Year	Nuclear	Hydroelectric	Gas	Wind	Solar	Coal	Other
2002[3]	32%	27%	13%	0%	0%	27%	0%
2003	43%	23%	9%	0%	0%	25%	0%
2004	50%	25%	8%	0%	0%	17%	0%
2005	51%	22%	8%	0%	0%	19%	0%

[3] 2002 Electricity supply mix is based on the OEB's generation capacity data for 2002. Source: https://www.oeb.ca/documents/msp/panel_mspreport_imoadministered_071002.pdf

2006	54%	22%	8%	0%	0%	16%	0%
2007	52%	21%	9%	1%	0%	18%	0%
2008	53%	24%	7%	1%	0%	15%	1%
2009	55%	26%	10%	2%	0%	7%	1%
2010	55%	20%	14%	2%	0%	8%	1%
2011	57%	22%	15%	3%	0%	3%	1%
2012	56%	22%	15%	3%	0%	3%	1%
2013	59%	23%	12%	3%	0%	2%	0%
2014	62%	24%	10%	4%	0%	0%	0%
2015	60%	24%	10%	6%	0%	0%	0%
2016	61%	24%	8%	6%	0%	0%	0%
2017	63%	26%	4%	6%	0%	0%	0%
2018	61%	25%	7%	7%	0%	0%	0%
2019	61%	25%	6%	7%	0%	0%	0%
2020	60%	25%	7%	8%	1%	0%	0%
2021	58%	24%	9%	8%	1%	0%	0%

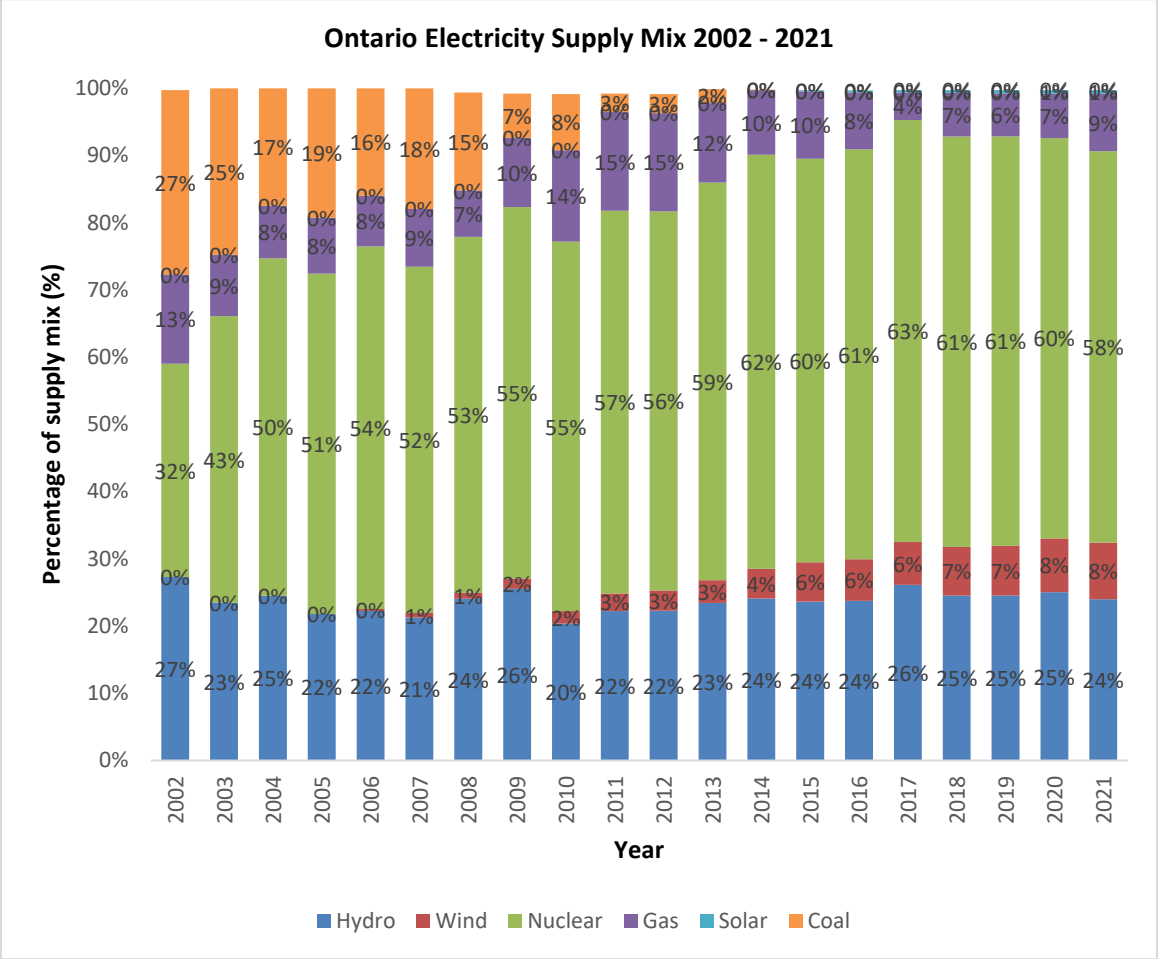

FIGURE 6: ONTARIO'S ELECTRICITY SUPPLY MIX AS REPORTED BY THE IESO AND OEB

The University's annual electricity consumption for the years of 2002 to 2021 is provided below in Table 7 and **Error! Reference source not found.**.

TABLE 7. ANNUAL ELECTRICITY CONSUMPTION

Year	Electricity Consumption (kWh)
2002	104,101,309
2003	102,731,676
2004	105,691,550
2005	103,485,559
2006	107,362,520
2007	115,424,161
2008	115,071,326
2009	111,140,326
2010	110,849,792
2011	109,332,526
2012	113,975,369
2013	113,330,796
2014	108,331,560
2015	105,400,979
2016	104,767,879
2017	99,379,975
2018	102,002,063
2019	102,988,490
2020	90,931,580
2021	95,364,552

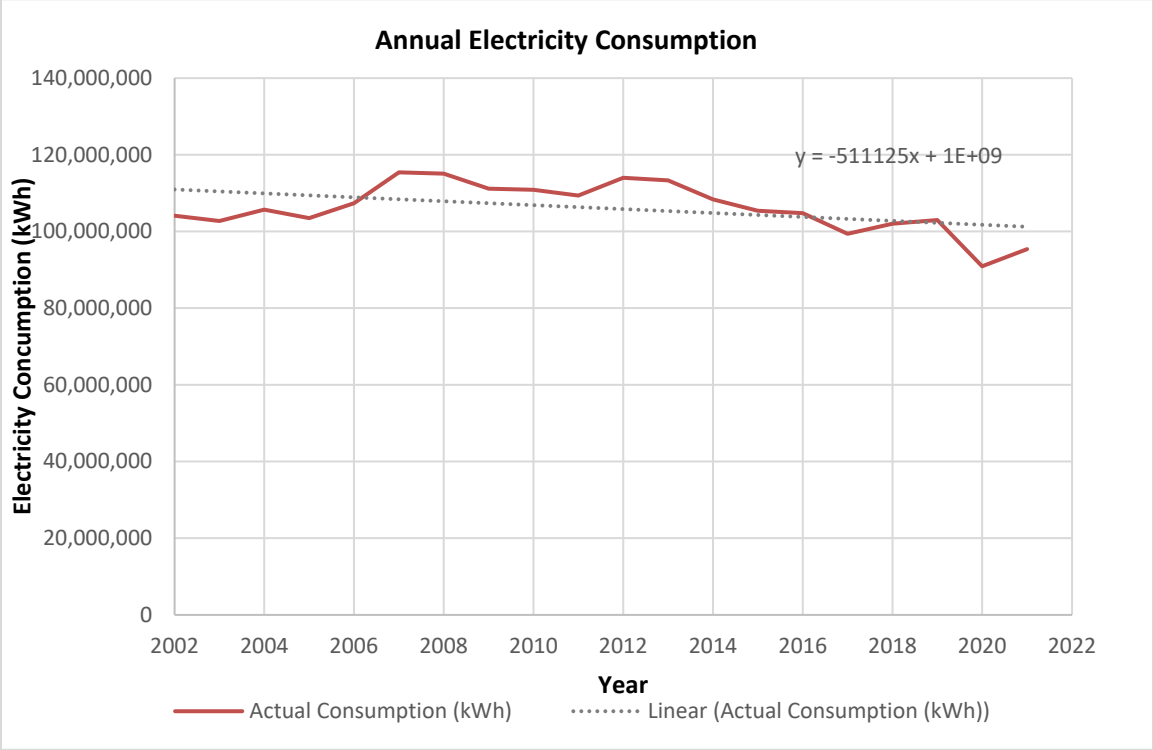

FIGURE 7. ANNUAL ELECTRICITY CONSUMPTION

Based on Ontario's electricity supply mix [Table 6], the University of Guelph's electricity consumption was broken down into the approximate amounts from each of the supply mix sources. This can be seen below in Table 8 and Figure 8. The total consumption from each source was estimated by multiplying the total annual consumption by the supply mix percentage for each source for the corresponding year.

TABLE 8. ELECTRICITY CONSUMPTION PER ELECTRICITY SUPPLY MIX SOURCE

Year	Nuclear (kWh)	Hydro (kWh)	Gas (kWh)	Wind (kWh)	Solar (kWh)	Coal (kWh)	Other (kWh)
2002	33,041,080	28,410,494	13,831,326	0	0	28,527,581	290,828
2003	43,789,551	24,119,007	9,383,475	0	0	25,439,644	0
2004	53,052,473	25,906,143	8,267,918	0	0	18,465,017	0
2005	52,406,148	22,554,545	8,623,797	0	0	19,901,069	0
2006	57,922,505	23,882,739	8,098,170	301,966	0	17,157,140	0
2007	59,461,377	24,548,949	9,922,479	764,398	0	20,726,957	0
2008	60,966,854	27,666,238	7,945,917	1,011,299	0	16,758,661	722,356
2009	61,413,777	28,361,999	11,463,905	1,712,142	0	7,295,212	893,291
2010	60,937,983	22,566,901	15,069,103	2,058,219	0	9,261,985	955,602
2011	62,256,772	24,304,226	16,056,846	2,846,441	0	2,992,412	875,828
2012	64,270,696	25,377,915	16,668,335	3,453,799	0	3,228,551	976,074

2013	67,041,789	26,566,505	13,393,640	3,826,754	0	2,354,926	147,183
2014	66,749,763	26,095,007	10,409,868	4,782,912	12,661	70,337	211,011
2015	63,295,448	24,893,009	10,560,671	6,171,820	171,439	0	308,591
2016	63,898,999	24,876,709	8,849,698	6,480,487	320,540	0	341,445
2017	62,396,574	25,964,137	4,063,353	6,336,076	344,352	0	275,482
2018	62,265,487	25,016,766	6,634,280	7,394,458	414,643	0	276,428
2019	62,736,924	25,261,328	6,592,929	7,633,918	485,795	0	277,597
2020	54,160,456	22,762,196	5,983,558	7,278,968	493,489	0	252,913
2021	55,522,291	22,877,860	8,161,108	8,027,319	501,707	0	274,267

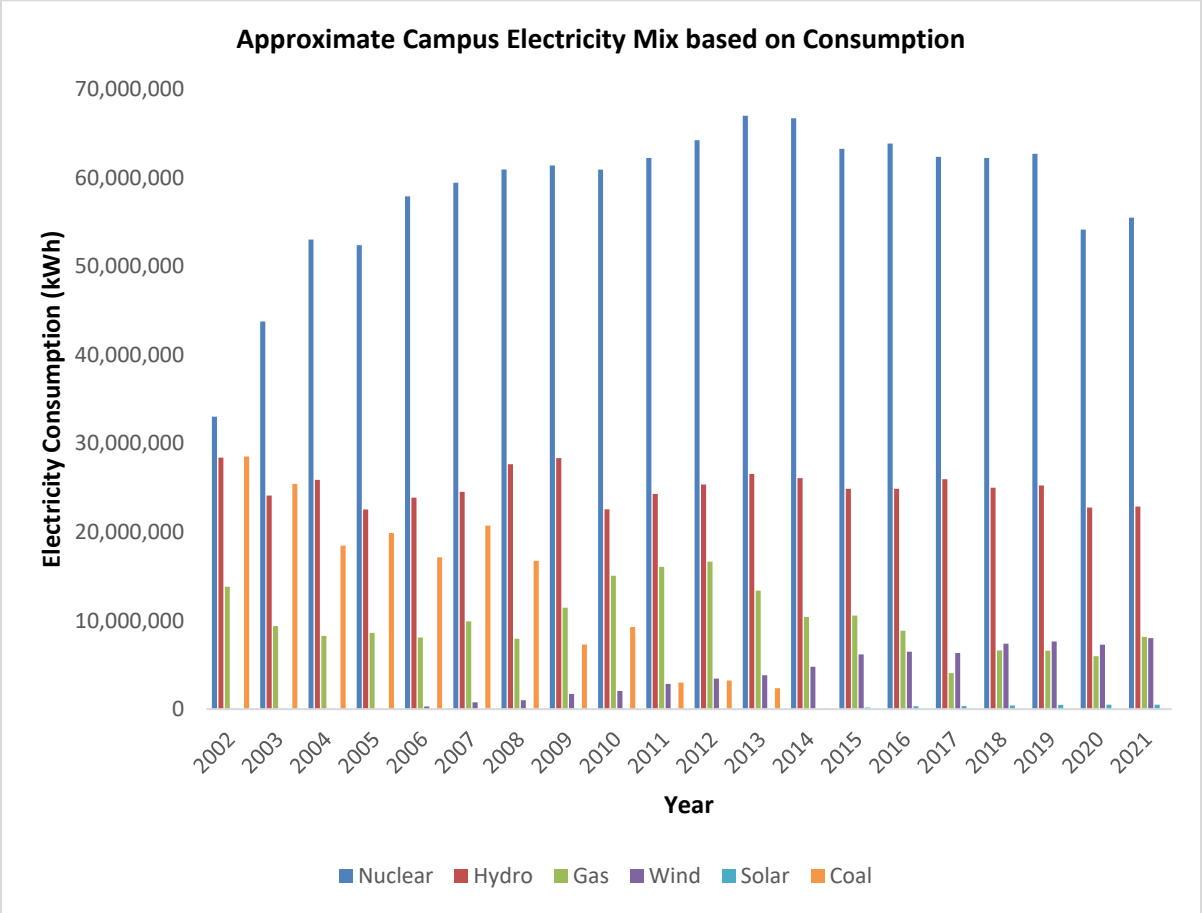

FIGURE 8. ANNUAL CAMPUS ELECTRICITY MIX BASED ON CONSUMPTION AND ONTARIO SUPPLY MIX

The GHG emissions related to electricity consumption were estimated using emissions rates associated with each electricity generation source. The emissions rates used in this analysis were

obtained from an Intrinsik report[4] generated for Ontario Power Generation Inc. ("OPG"), with the exception of the emissions rate for coal, which was obtained from a report from the World Nuclear Association ("WNA") [5] . The emissions rates were multiplied by the associated consumption for each source (Table 8) to determine the approximate GHG emissions from each source. The emissions rates used in this report are shown below in Table 9.

For the purpose of this report, "other" source of electricity was considered negligible as no accurate data could be found to determine the combination of fuel sources that made up the "other" fuel supply in the Ontario electricity mix. As they do not directly emit greenhouse gases during the electricity generation stage, nuclear and renewable resources are regarded as emission-free energy sources by Natural Resources Canada[6]. It should be noted however, that the related standard operating and maintenance activities of these technologies require energy inputs, many of which involve the use of fossil fuels and therefore contribute to the overall greenhouse gas emissions output. This report includes the associated greenhouse gas emissions related to electricity consumption at the University of Guelph.

TABLE 9. EMISSION RATES FOR VARIOUS SOURCES OF ELECTRICITY GENERATION

Source	Emission Rate (gCO_2e/kWh)
Nuclear	0.15
Hydroelectric	0
Gas	525
Wind	0.74
Solar	6.15
Coal	888
Other	0

Based on these reported emission rates, the largest contributor to GHG emissions from the Ontario electricity supply mix is electricity generated from the direct combustion of fossil fuels, in this case coal and natural gas. The total estimated emissions from each electricity generating source are shown below in Table 10.

[4] Intrinsik. (2016). *Greenhouse gas emissions associated with various methods of power generation in Ontario.*
[5] WNA. (2011). *Comparison of Lifecycle Greenhouse Gas Emissions of Various Electricity Generation Sources.*
[6] NRCAN Energy Fact Book 2021-2022. Source: https://www.nrcan.gc.ca/sites/nrcan/files/energy/energy_fact/2021-2022/PDF/2021_Energy-factbook_december23_EN_accessible.pdf

TABLE 10. GHG EMISSIONS FROM ELECTRICITY CONSUMPTION AT THE UNIVERSITY OF GUELPH BASED ON THE ONTARIO ELECTRICITY SUPPLY MIX.

	Source							
Year	Nuclear (tCO_2e)	Hydroelectric (tCO_2e)	Gas (tCO_2e)	Wind (tCO_2e)	Solar (tCO_2e)	Coal (tCO_2e)	Other (tCO_2e)	Total (tCO_2e)
2002	5	0	7,261	0	0	25,332	0	**32,599**
2003	7	0	4,926	0	0	22,590	0	**27,523**
2004	8	0	4,341	0	0	16,397	0	**20,746**
2005	8	0	4,527	0	0	17,672	0	**22,208**
2006	9	0	4,252	0	0	15,236	0	**19,496**
2007	9	0	5,209	1	0	18,406	0	**23,624**
2008	9	0	4,172	1	0	14,882	0	**19,063**
2009	9	0	6,019	1	0	6,478	0	**12,507**
2010	9	0	7,911	2	0	8,225	0	**16,147**
2011	9	0	8,430	2	0	2,657	0	**11,099**
2012	10	0	8,751	3	0	2,867	0	**11,630**
2013	10	0	7,032	3	0	2,091	0	**9,136**
2014	10	0	5,465	4	0	62	0	**5,541**
2015	9	0	5,544	5	1	0	0	**5,559**
2016	10	0	4,646	5	2	0	0	**4,662**
2017	9	0	2,133	5	2	0	0	**2,149**
2018	9	0	3,483	5	3	0	0	**3,500**
2019	9	0	3,461	6	3	0	0	**3,479**
2020	8	0	3,141	5	3	0	0	**3,158**
2021	8	0	4,285	6	3	0	0	**4,302**

The data in Figure 9 below shows that the University's GHG emissions from electricity consumption gradually declined from 2002 to 2021. This was largely due to Ontario's grid moving away from electricity generated by the combustion of coal, and the increase in more renewable and lower emitting sources of electricity. The GHG emissions from electricity usage reduced from 32,500 tCO_2e in 2002 to 4,302 tCO_2e in 2021, a reduction of approximately 87%. 2017 had the lowest annual GHG emissions due to electricity consumption. This can be attributed to 2017 being the year with the lowest contribution of fossil fuel sources in Ontario's electricity supply mix (4%).

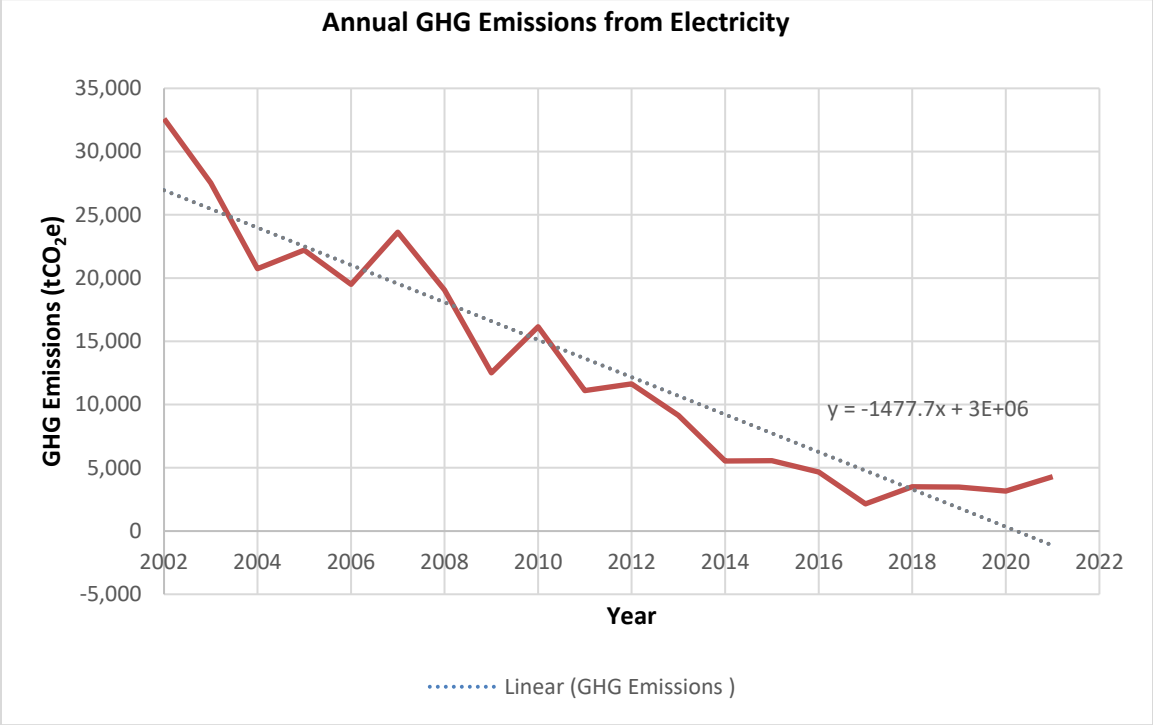

FIGURE 9. ANNUAL GHG EMISSIONS FROM ELECTRICITY CONSUMPTION AT THE UNIVERSITY OF GUELPH FROM 2002 - 2021

4. ELECTRICITY CONSUMPTION AS IT RELATES TO WEATHER

To better understand the greenhouse gas trends for the electricity consumption reported above, the data was normalized to account for variations in the weather over the last 30 years and account for any trends in the climate. For the purposes of this report, only normalized energy consumption with variable loads which are affected by changes in the weather were evaluated.

4.1. Cooling Degree Days

Annual energy consumption totals for electricity, as well as their resulting greenhouse gas emissions, were normalized to the weather based on the total average monthly cooling degree days ("CDD") for the last 30 years with reference to CDD in each year from 2002 to 2021. A base temperature of 18°C was used. Below is the overall trend in CDD from 2002 to 2021, to better understand the anticipated electrical loads for each of those years.

Figure 10 shows the monthly trends of CDD for each year from 2002-2021. In colder months during the winter (December through March), there are typically no CDDs, whereas the warmer months, such as July and August see the highest number of CDDs.

Figure 11 below shows the total annual CDD for each year from 2002 to 2021. The year with the greatest number of cooling degree days was 2005 (520 CDD). The year with the lowest number of heating degree days was 2009 (190 CDD).

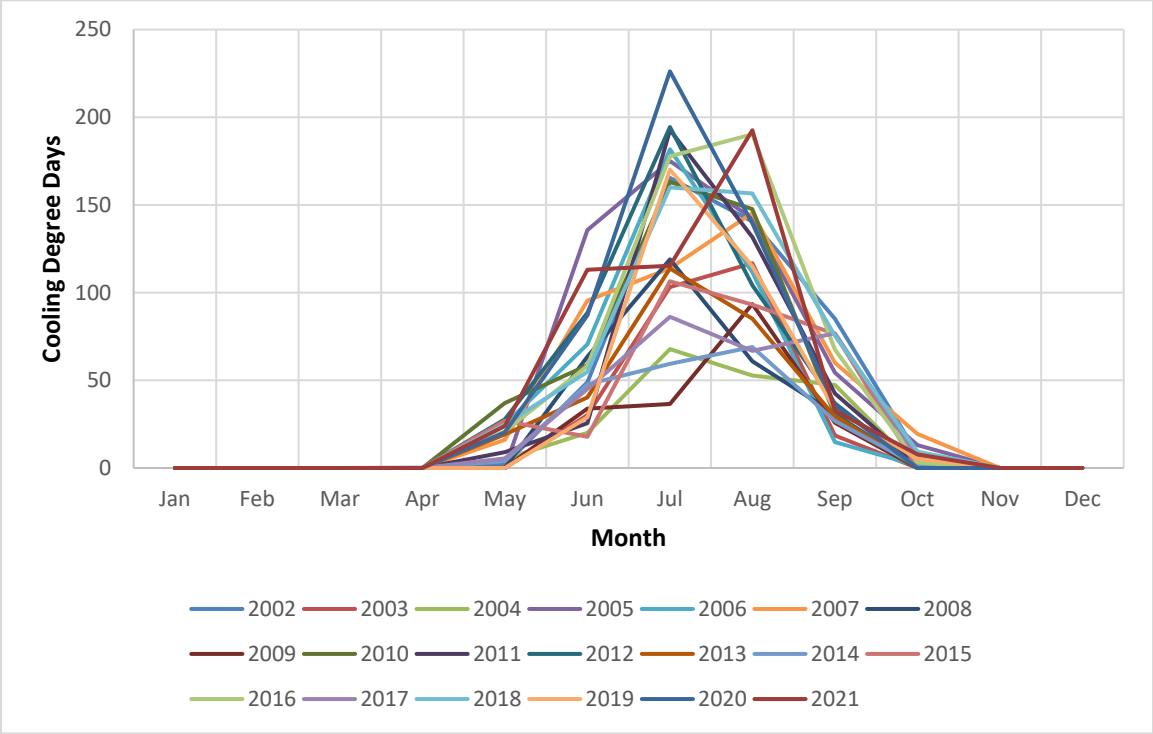

FIGURE 10. MONTHLY COOLING DEGREE DAYS ABOVE 18°C AT THE UNIVERSITY OF GUELPH FOR 2002 – 2021

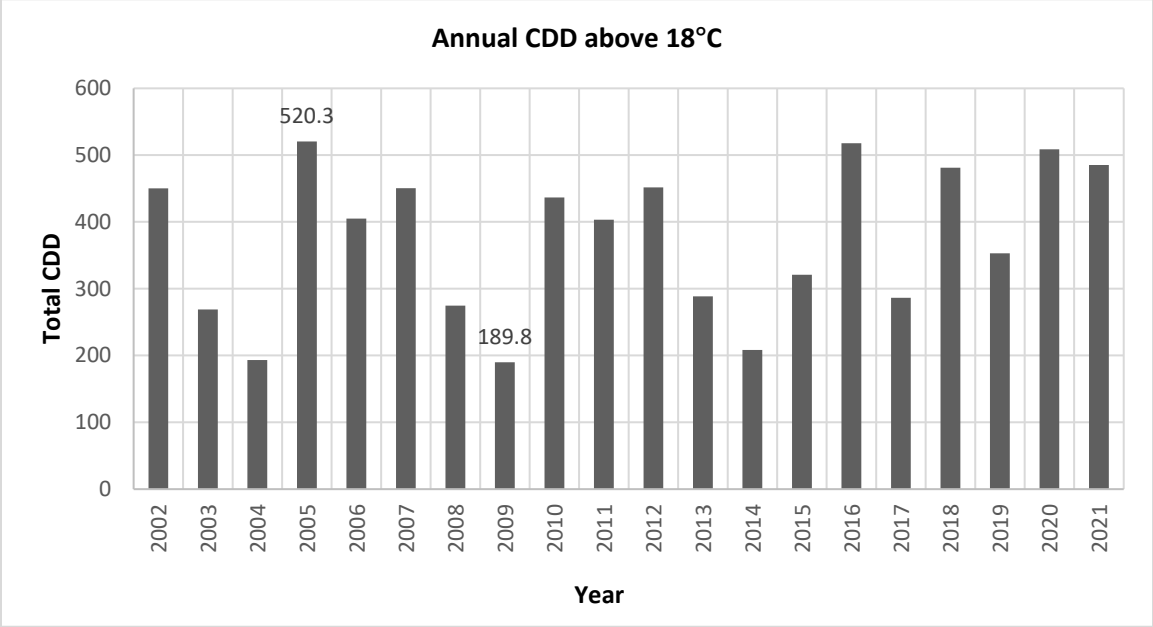

FIGURE 11. TOTAL ANNUAL CDDS FOR THE UNIVERSITY OF GUELPH FOR 2002 – 2021

4.1. Electricity Consumption and Emissions Normalization

Based on the monthly CDDs for each year, and the 30-year average monthly CDDs, normalized variable electricity consumption and resultant GHG emissions were calculated. These are shown in Table 11 below and compared to the actual consumption and GHG emission data.

TABLE 11. ANNUAL ACTUAL AND NORMALIZED ELECTRICITY CONSUMPTION AND RESULTANT GHG EMISSIONS

Year	Actual Consumption (kWh)	Normalized Consumption (kWh)	Actual GHG Emissions (tCO_2e)	Normalized GHG Emissions (tCO_2e)	Percent Difference (%)
2002	104,101,309	102,273,743	32,599	32,027	2%
2003	102,731,676	100,367,516	27,523	26,890	2%
2004	105,691,550	105,275,084	20,746	20,664	0%
2005	103,485,559	95,614,665	22,208	20,518	8%
2006	107,362,520	106,750,540	19,496	19,385	1%
2007	115,424,161	109,484,057	23,624	22,409	5%
2008	115,071,326	120,145,036	19,063	19,904	3%
2009	111,140,326	110,003,003	12,507	12,379	1%
2010	110,849,792	101,479,363	16,147	14,782	8%
2011	109,332,526	106,537,067	11,099	10,815	3%
2012	113,975,369	109,828,283	11,630	11,207	4%
2013	113,330,796	113,107,184	9,136	9,118	0%

2014	108,331,560	107,989,340	5,541	5,524	0%
2015	105,400,979	101,489,398	5,559	5,353	4%
2016	104,767,879	97,656,151	4,662	4,346	7%
2017	99,379,975	96,301,061	2,149	2,083	3%
2018	102,002,063	97,352,272	3,500	3,341	5%
2019	102,988,490	99,163,831	3,479	3,350	4%
2020	90,931,580	79,533,507	3,158	2,762	13%
2021	95,364,552	88,362,868	4,302	3,986	7%

The normalized electricity consumption and resultant GHG emission trends can also be seen in Figure 12 below. There is a gradual decline in GHG emissions over time, while the normalized electricity consumption stays consistent overall. As mentioned previously, the presence of coal combustion as a source of electricity generation before 2015 impacted the GHG emissions from electricity consumption. The GHG emissions from 2002 to 2021 have been greater affected by Ontario's electricity supply mix than by consumption alone. Figure 13 below shows the relationship between GHG emissions and the percentage of Ontario's electricity generated by coal combustion sources. In 2002, the Ontario electricity supply mix generated 27% of its supply from coal as a source, and by 2015 coal had been eliminated from Ontario's electricity supply mix.

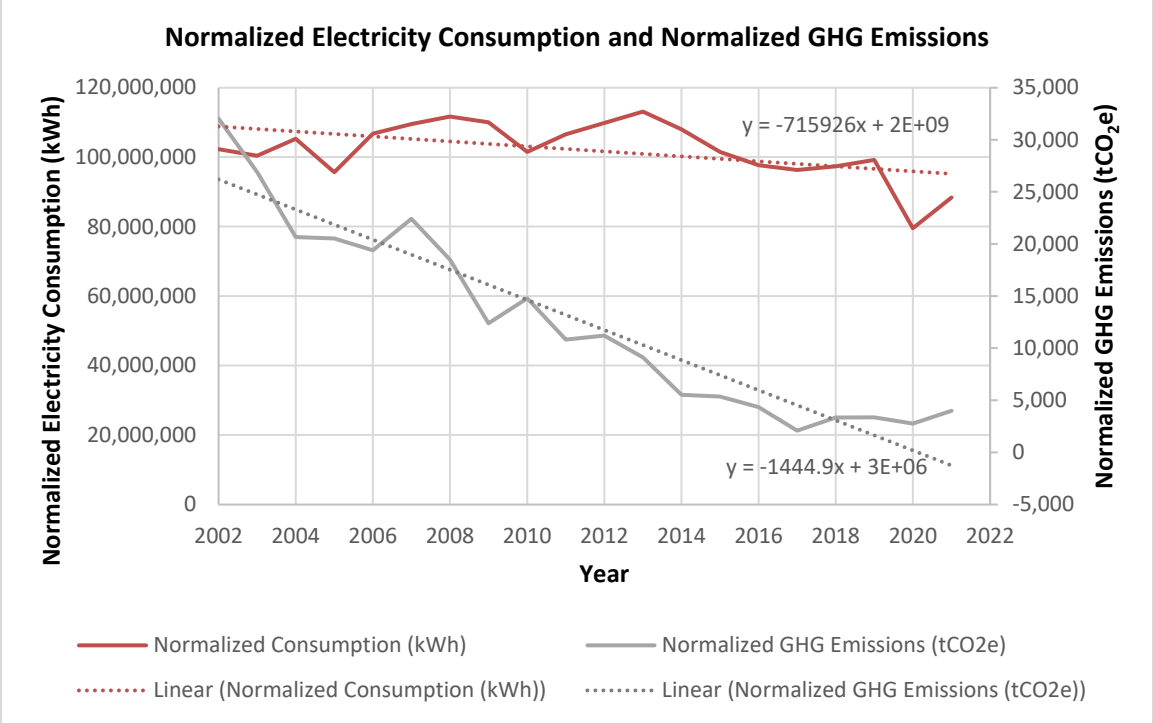

FIGURE 12. ANNUAL NORMALIZED ELECTRICITY CONSUMPTION AND RESULTANT ANNUAL NORMALIZED GHG EMISSIONS

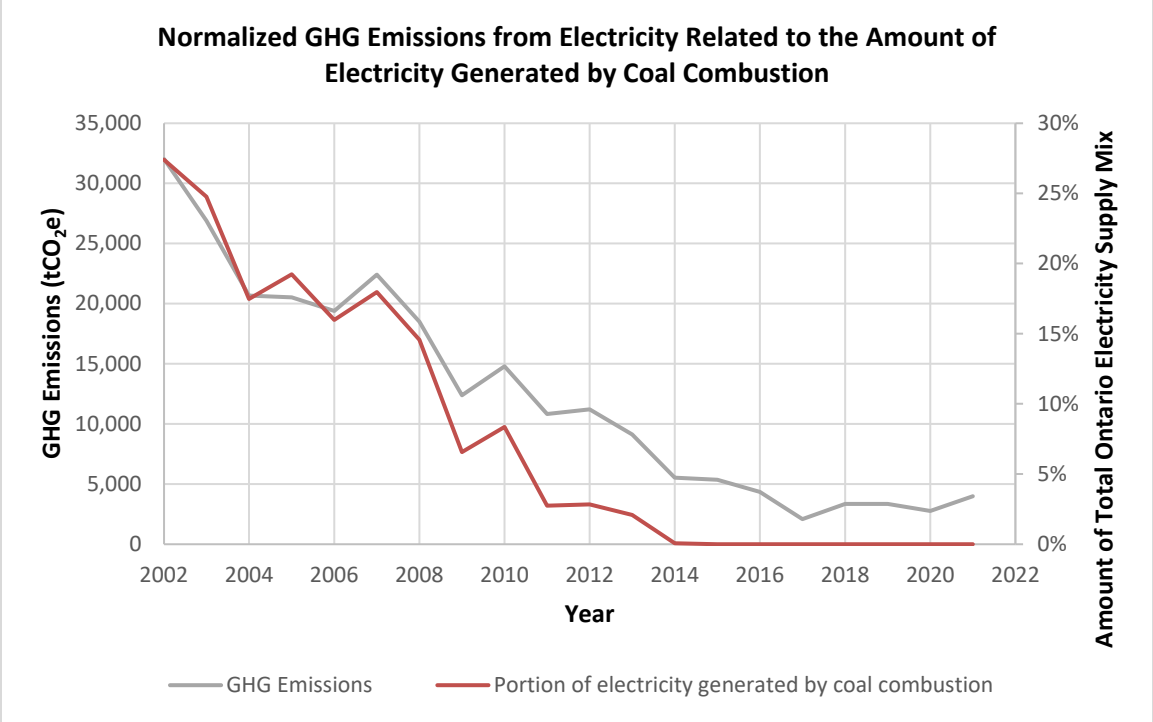

FIGURE 13. ANNUAL NORMALIZED GHG EMISSIONS AND THE PORTION OF ONTARIO'S ELECTRICITY GENERATED BY COAL COMBUSTION

A comparison of actual and normalized annual GHG emissions is shown below in Figure 14. The data from Table 11 above and Figure 14 below, indicate that the actual GHG emissions from electricity follow the trend of the normalized figures quite closely. The actual electricity data is typically higher than the normalized data. 2020 electricity data deviates the most from the normalized data, whereas electricity data in 2004 and 2014 are most closely aligned with the normalized data. Climate change has likely had an impact on this; as the cooling degree days increase, so does the demand for electricity, and therefore also the resultant GHG emissions.

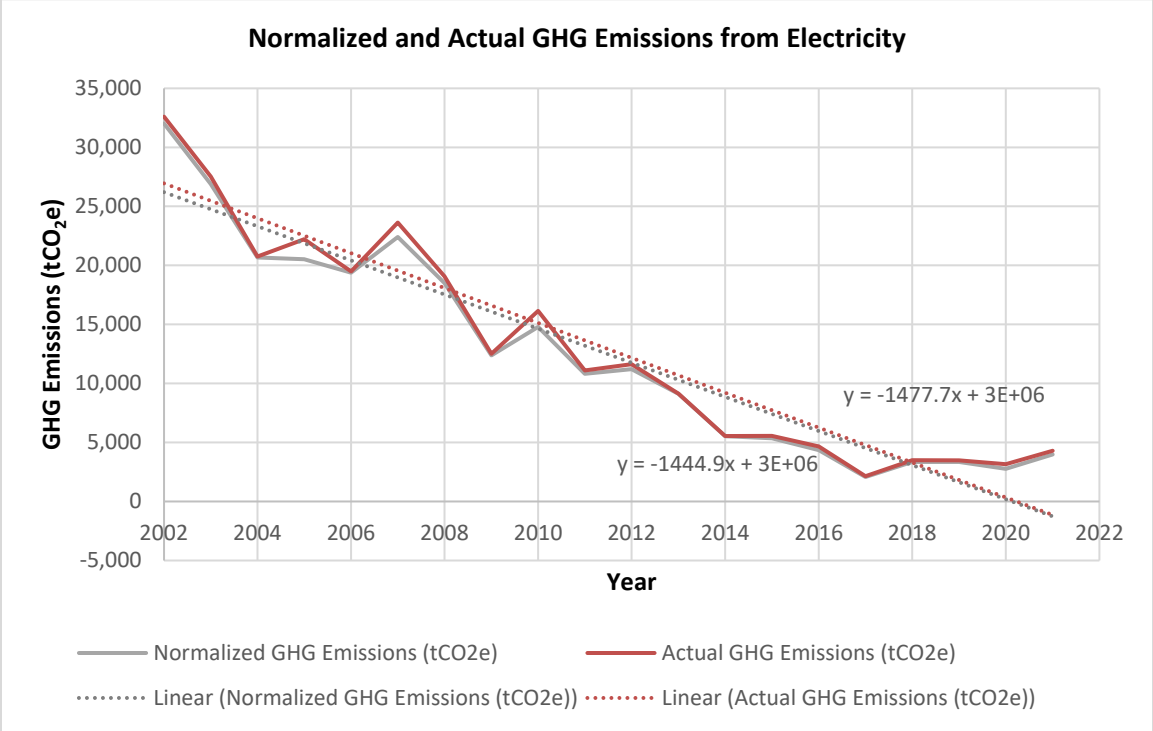

FIGURE 14. GHG EMISSIONS FROM ACTUAL ELECTRICITY CONSUMPTION AND NORMALIZED ELECTRICITY CONSUMPTION

The overall monthly trends of the normalized, total actual, and variable electricity consumption are shown below in Figure 15, Figure 16, and Figure 17, respectively, for the years of 2002 to 2021. The months of February and December typically have the lowest electricity consumption, while the months of June, July, and August typically have the highest electricity consumption.

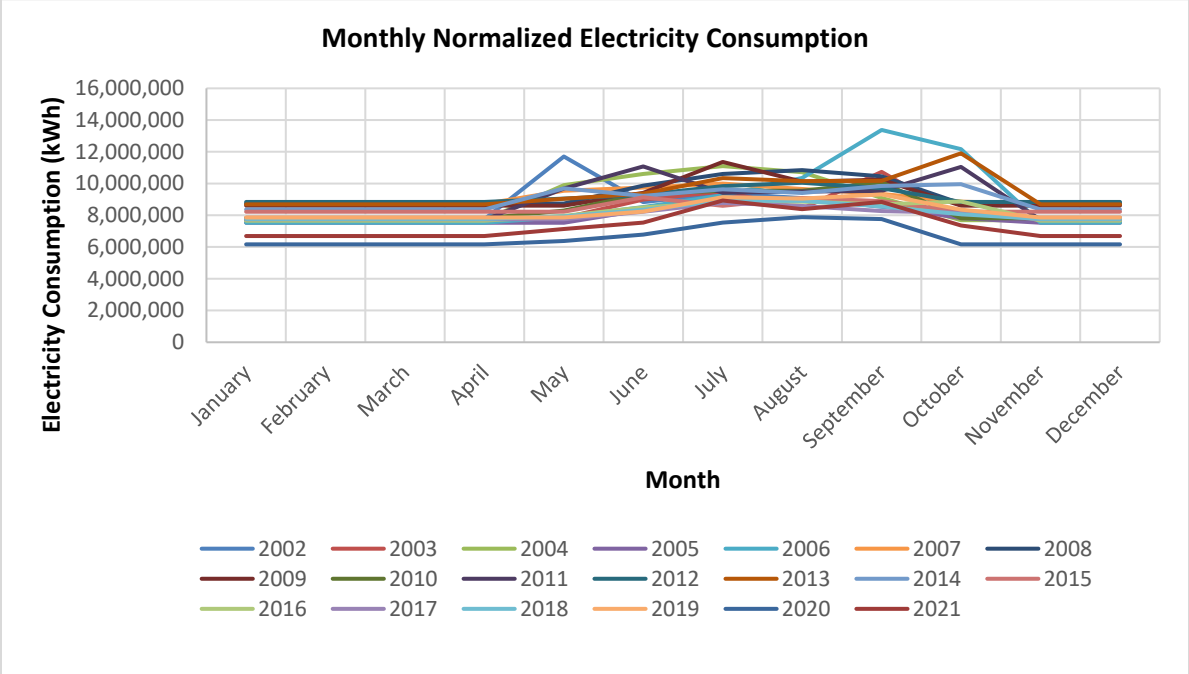

FIGURE 15. ANNUAL NORMALIZED ELECTRICITY CONSUMPTION PER MONTH

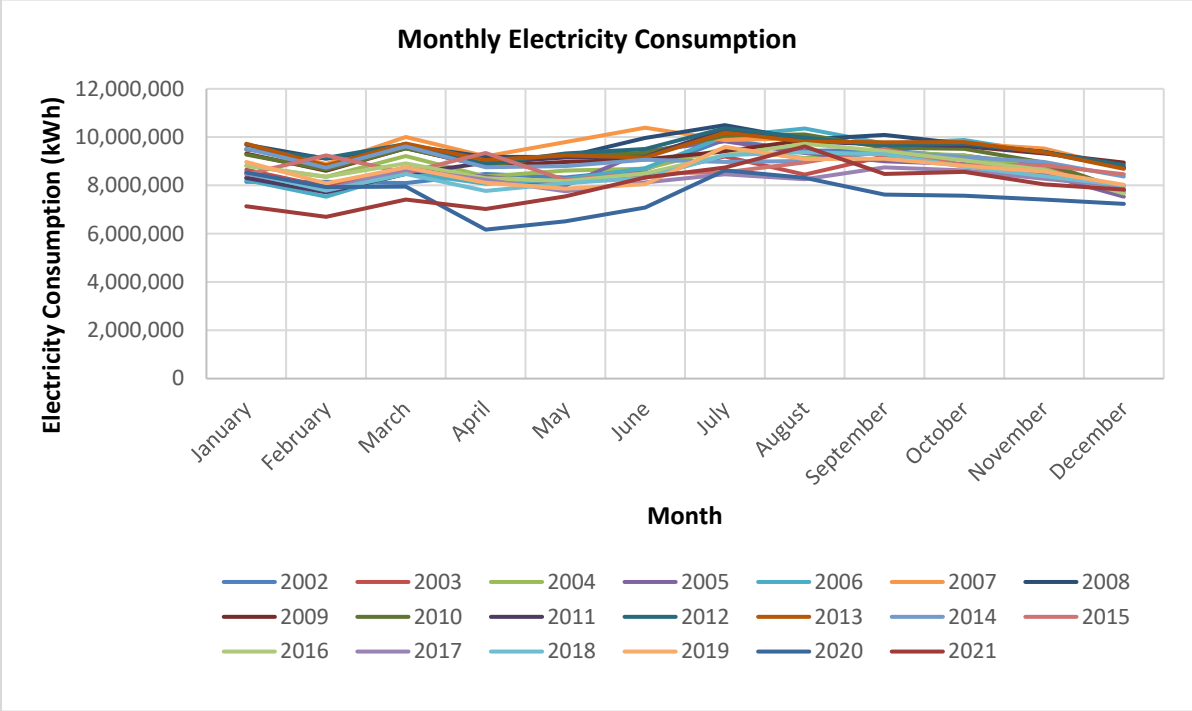

FIGURE 16. ANNUAL ELECTRICITY CONSUMPTION PER MONTH

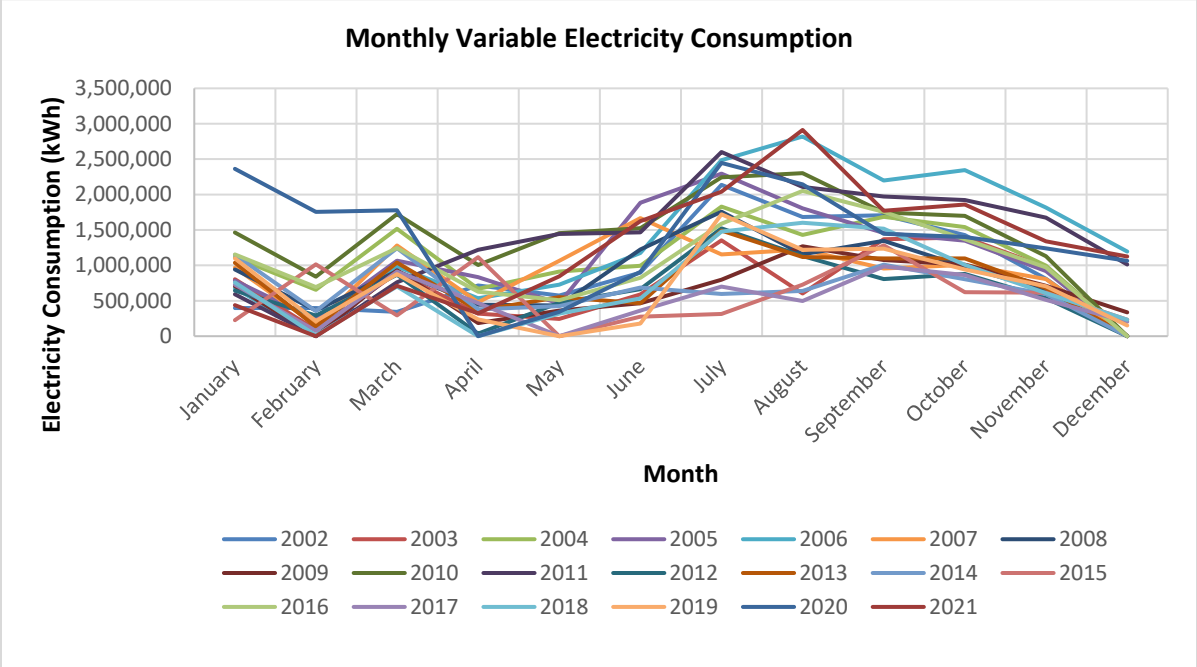

FIGURE 17. ANNUAL VARIABLE ELECTRICITY CONSUMPTION PER MONTH

5. SUMMARY

The trend of the total combined GHG emissions from both stationary natural gas combustion and electricity are shown below in Figure 18 (for both actual and normalized values). This data shows that 2002 had the highest GHG emissions (73,748 tCO_2e), and there was a decline in emissions over time, with minimum GHG emissions occurring in 2020 (39,512 tCO_2e).

Figure 19 below shows a breakdown of the total annual GHG emissions by each source (i.e., natural gas combustion and electricity). The decline in total GHG emissions over time from 2002 to 2021 is largely attributed to the decrease in GHG emissions from electricity generation over this period.

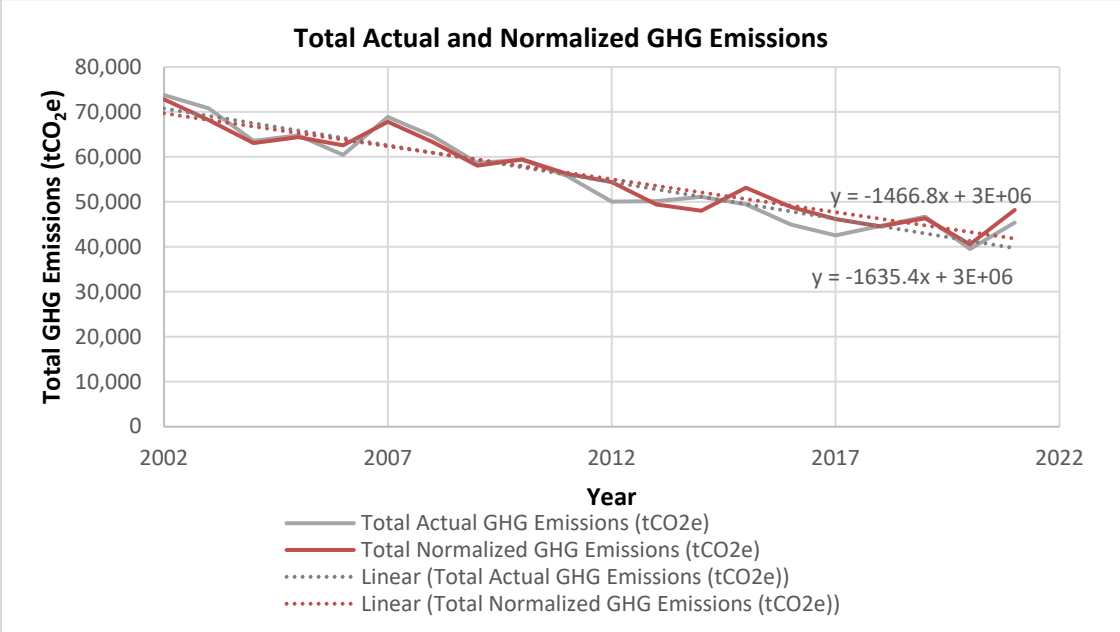

FIGURE 18. TOTAL ANNUAL GHG EMISSIONS FROM STATIONARY COMBUSTION AND ELECTRICITY AT THE UNIVERSITY OF GUELPH FROM 2002 – 2021

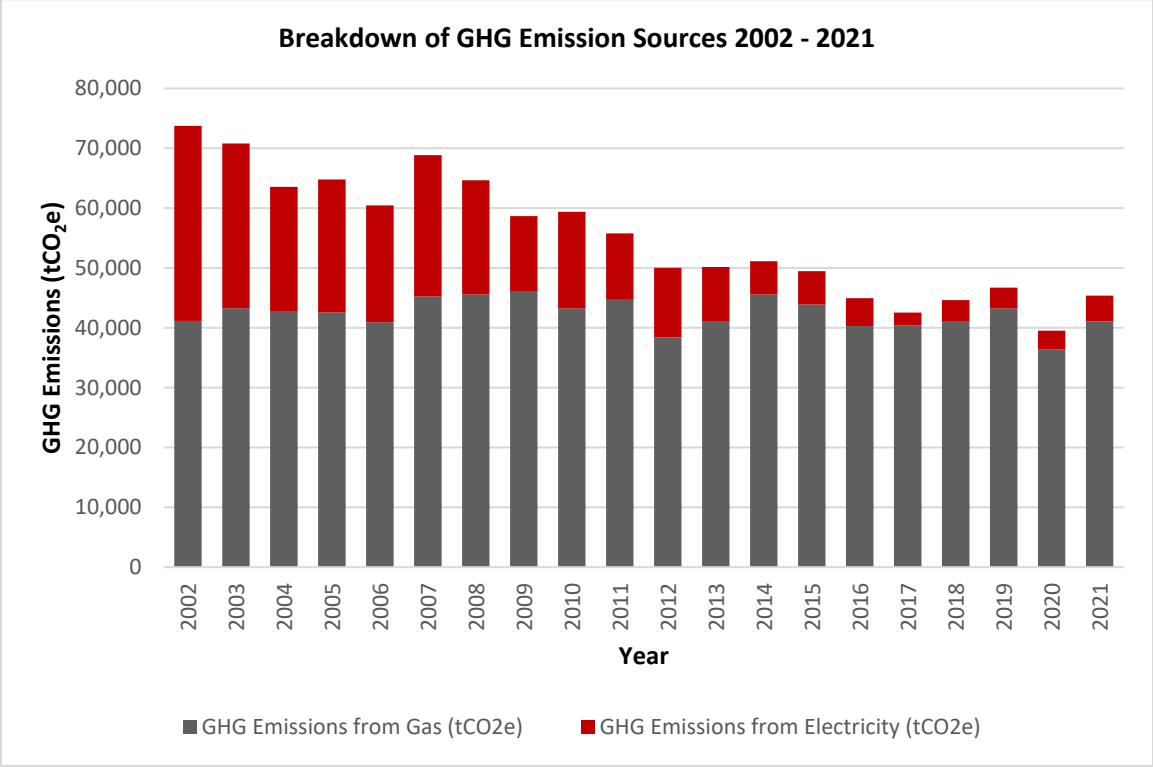

FIGURE 19. BREAKDOWN OF THE TOTAL ANNUAL GHG EMISSIONS BY SOURCE

Overall, the data indicates GHG emissions at the University of Guelph have been declining since 2002. Greenhouse gas emissions from natural gas combustion are decreasing with reduced consumption. Electricity consumption on campus is decreasing as well. Greenhouse gas emissions from electricity consumption, however, are influenced by the Ontario electricity supply mix and follow the overall trend of the supply mix.

The actual consumption and emissions data is closely aligned with the normalized data. Natural gas data is typically lower than the normalized natural gas data, indicating overall efficiencies in the way natural gas is consumed on campus. Electricity data is closely aligned with the normalized data and is more often higher than the normalized electricity data.

Climate change is also a factor that should be accounted for. As heating degree days decrease due to climate change, so too will GHG emissions from natural gas combustion. Similarly, as the cooling degree days increase, so does the demand for electricity and resultant GHG emissions.