Principia College Greenhouse Gas Inventory (2005-2019)

Center for Sustainability

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2020

"Principia aims to be a community that has zero waste, is sustainable in terms of food and ecology, and is carbon neutral. " ~ *Principia Strategic Plan 2015-2020*

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Executive Summary

Principia College emissions of CO_2, CH_4, and N_2O (see Appendix 1) were analyzed for the decade 2005-2014 by Eckert (2015), and that inventory is herein revised and updated through 2019. The results continue to contribute meaningfully to college-wide audits of sustainability practices and policies, including providing insight into our emissions landscape and suggestions for improvements that can help us reach emission reduction goals.

The analysis is organized in three "scopes", defined as emissions that result directly from sources owned and/or controlled by Principia (Scope 1), emissions that are neither owned nor operated by Principia but whose products are directly linked to on-campus energy consumption (Scope 2), and emissions "attributed" to Principia because, while their sources are neither owned nor operated by the college, we are responsible in some way for them (Scope 3). The most significant Scope 1 emissions are associated with the use of natural gas to heat our buildings. Scope 2 is purchased electricity which, until we transitioned to 100% renewable electricity in 2009, produced a large majority of our greenhouse gas (GHG) emissions. Scope 3 captures a variety of emission sources, the most relevant being employee commuting and student arrival/departure. Making smaller contributions are our CH_4 emissions (mostly related to water use and solid waste disposal) and our N_2O emissions (mostly related to nitrogen fertilizer use). Taken together and standardized as CO_2 equivalents ("eCO_2"), total GHG emissions in 2019 was 3,244 MT eCO_2 or about 4.6 MT per capita, less than one-third the U.S. per capita average.

Our aggregate *use* of energy (electric, natural gas, gas, diesel) during the study period (2005-2019) is statistically flat. Energy-related *emissions*, however, trended upward between 2005 (9,646.5 MT eCO_2) and 2008 (13,814.1 MT eCO_2) due to coal-sourced electricity before plummeting in 2009 with our first purchase of Renewable Energy Credits (REC) to cover 100% of our electricity demand. Emissions then stabilized at a lower level due to annual REC purchases and a slight but statistically significant decline in natural gas use. As a result of our commitment to renewable electric energy, for which we are consistently recognized by the U.S. Environmental Protection Agency as a leader among our peers, GHG emissions declined 76.5% from a peak in 2008 to the most recent calculated levels (2019).

Natural gas is our largest (72.8%) emissions contributor. In addition to maintaining condensing boilers, buildings with the least efficient methods of monitoring and adjusting internal temperature could be targeted for upgrades designed to send heat only where it is needed, and behavioral changes could reduce demand. Building-level energy monitoring could provide a platform for competition and energy awareness, especially in student housing. Consideration could be given to ground source heat pumps for heating and cooling. These systems typically have a Coefficient of Performance of 3 to 5 (vs conventional electric resistance heat of 1 and natural gas of 0.8 - 0.95), are 100% electric, and are less costly to operate. Retro-commissioning of buildings can ensure efficient operations and investment.

Research on carbon sequestration by the Principia Forest suggests that our forested lands currently offset 100% of our emissions; however, because of declining rates of sequestration in the aging forest, that will soon (perhaps by 2026 or 2027) no longer be true (Silcox, 2016). While maintaining our commitment to renewable electric energy, whether through REC purchases and/or on-site generation, efforts must be made to reduce reliance on natural gas and to reduce emissions from fleet and employee-owned vehicles. To the latter, we could incentivize carpooling, maintain a high-efficiency inter-campus fleet, encourage employees to walk/bike to work, and install vehicle charging stations.

INTRODUCTION

Greenhouse gases are gases in the Earth's atmosphere that absorb infrared light and radiate it back down to the Earth's surface (Dessler, 2012). They are a critical part of our atmosphere, as they regulate the temperature of the Earth, preventing extreme warming and extreme cold. The Kyoto Protocol defines the six most influential of these gases as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydro- and perfluorocarbons (HFCs, CFCs), and sulfur hexafluoride (SF_6) (United Nations, 1998) (Appendix 1). It is important to measure the quantities of each of these gases in the atmosphere, as this allows us to describe and understand – as well as predict – the fluctuations in climate that may occur as levels rise and fall, many of which can have negative effects on the environment.

Increases in atmospheric greenhouse gases are causing changes at a global scale, affecting everything from average atmospheric, oceanic, and surface temperatures, to rising sea levels and ocean acidification, to the behavior and survival prospects of plants and animals (Walther et al., 2002; Hsiung and Sunstein, 2007; Nunez et al., 2019). The economic development of human societies (through the burning of fossil fuels for energy) is causing these changes, and so it is our job to reduce and reverse these impacts as best we can.

A Greenhouse Gas Emissions Inventory (hereafter, GHG inventory) is a tool that allows us to determine which greenhouse gases we're emitting, in what quantities, and from what sectors – and how purchasing decisions (especially of energy) and behavior patterns might be affecting these numbers. By focusing mitigation on operational sectors that emit the greatest volume of climate-altering "greenhouse" gases, we can take decisions that result in the greatest emission reductions for the money.

For colleges and universities, the gold standard of GHG Inventory tools was, until recently, the Clean Air-Cool Planet's "Campus Carbon Calculator" (CCC) developed in partnership with the University of New Hampshire's Sustainability Institute (UNH, 2015).

The CCC was embedded in Excel spreadsheets that allowed colleges and universities to complete three main goals: conduct a GHG inventory, project emissions data into the future, and evaluate a portfolio of Carbon Reduction Projects (UNH, 2015). It was created based on standards set by the Greenhouse Gas Protocol Initiative widely used by numerous groups, from corporations to nations, and developed as a "decade-long partnership between the World Resources Institute and the World Business Council for Sustainable Development [which aims] to build a new generation of credible and effective programs for tackling climate change" (WRI/WBCSD, 2008).

The CCC provided the analytical framework for our first inventory (Eckert, 2015). The UNH Sustainability Institute purchased the CCC in 2014 and ultimately replaced it with the Sustainability Indicator Management and Analysis Platform (SIMAP) (UNH, 2020).

Similar to the CCC, SIMAP is a carbon and nitrogen-accounting platform that can track, analyze, and improve campus-wide sustainability (UNH, 2020). The new tool creates a series of tables and graphs that allow the user to see exactly what (and where) emissions are and it helps determine steps to reduce emissions by providing the user with the ability to edit the data and evaluate the potential effect(s) of specific decisions and actions. SIMAP was developed in partnership with University of Virginia and Second Nature (UNH, 2020) and it is the analytical framework used in this report.

METHODS

To assemble and then analyze campus data related to GHG emissions, we used an online tool developed by the University of New Hampshire's Sustainability Institute. The tool, known as the Sustainability Indicator Management and Analysis Platform (SIMAP), was developed over a period of nearly two decades and was preceded by the "gold standard of carbon calculators" known as the Clean Air-Cool Planet "Campus Carbon Calculator" (UNH, 2015).

SIMAP is comprised of three sections, referred to as "Scopes". Scope 1 is defined as, "Direct emissions from sources that are owned and/or controlled by your institution"; Scope 2 is defined as, "Indirect emissions from sources that are neither owned nor operated by your institution but whose products are directly linked to on-campus energy consumption"; and Scope 3 is defined as, "Other emissions attributed to your institution, deemed 'optional' emissions by corporate inventories. This includes emissions from sources that are neither owned nor operated by your institution but are either directly financed or are otherwise linked to the campus via influence or encouragement" (UNH, 2020) (Figure 1).

Scopes 1 and 2 are required for the calculator to run. Scope 3 is optional and can be completed based on the institution's goals and objectives for conducting the inventory. Ultimately, SIMAP allows an institution to create a baseline, benchmark their performance, generate reports, set goals, and analyze progress over time (UNH, 2020).

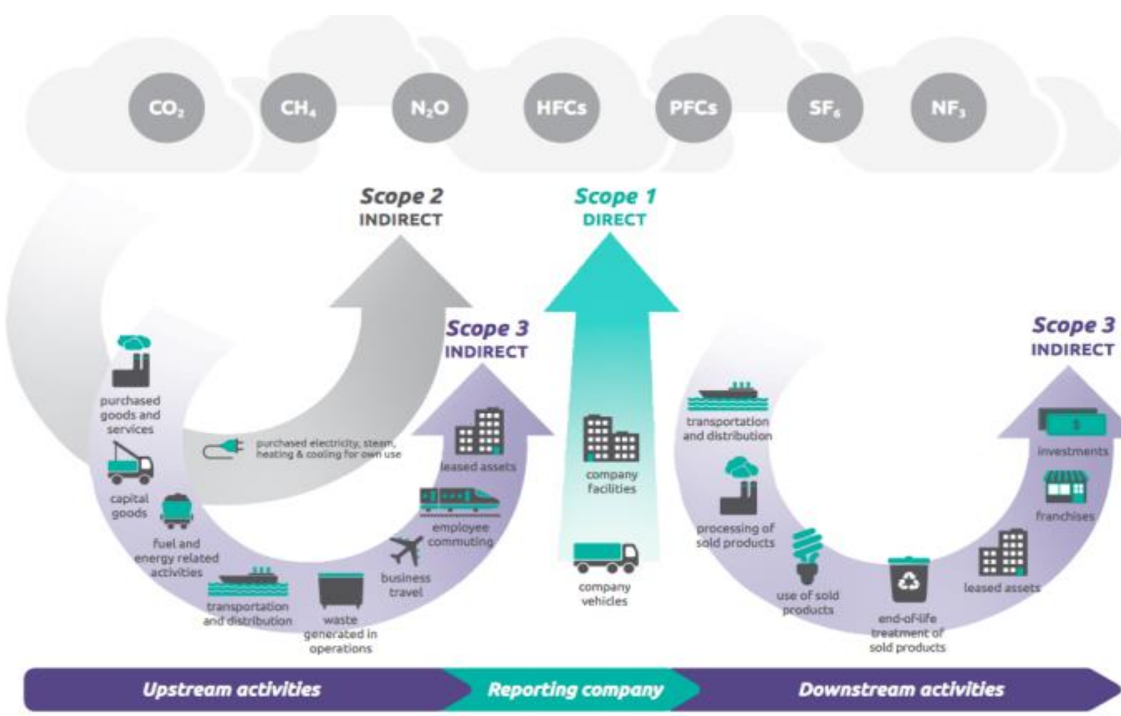

Figure 1. Overview of greenhouse gas protocol scopes and emission across the value chain. Source: [University of New Hampshire Sustainability Institute]

Each scope embraces a suite of information, some of which is relevant to Principia College and some of which is not. As in Eckert (2015), the physical and temporal boundaries of the GHG inventory are associated with the main campus, which includes all academic, administrative, and operations buildings, as well as all student residences, and excludes on- and off-campus housing leased to faculty or staff (emissions from these houses are outside the control of Principia). Data were collected from 2015-2019 and merged with 2005-2014 data reported by Eckert (2015). The dataset allows us to evaluate the effect on our emissions resulting from major campus additions (Crafton Athletic Center, completed in 2007), renovations (Voney Art Studio, completed in 2017; McVay Center for the Performing Arts at Morey, completed in 2019), and upgrades (new West Quad Loop Plant and new energy-efficient boilers in the Central and East Quad Loop Plants, completed in 2012), as well as the decision in 2009 to source our electrical power from 100% renewable resources.

The Greenhouse Gas Protocol Corporate Accounting and Reporting Standard (WRI/WBCSD, 2008) considers material emissions to be 95-100% of an institution's footprint. Sources that sum to <5% of emissions are considered "*de minimus*" and need not be inventoried. Depending on the institution, these might relate to students commuting to class, fertilizer use, methane, off-road diesel, "fugitive" (leaking) coolant emissions from dormitory refrigerators, etc. While "investing time and effort in precise data collection for minute emissions sources is not always the most effective allocation of resources", it's useful to produce high-bound estimates that can be inserted into analysis each year (UNH, 2015). For the sake of completeness, both Eckert (2015) and the present update estimate every emission source so potential "*de minimus*" sources can be accurately identified. In the future, we may elect to continue to inventory these sources – or not.

Data Sources

The majority of information (e.g., total building space, gallons of gasoline and distillate oil, MMBtus of natural gas, refrigerant chemicals [and leak rates] from our chillers, electricity usage) came from the Facilities Department. Facilities staff also provided insight into which emission sources were most relevant to the college – and which were not (e.g., Principia has no on-campus stationary or cogeneration plants fueled by steam coal, incinerated waste, wood chips/pellets, or grass pellets). Facilities staff also provided access to outside contractors for data on fertilizer, water, and propane use (the primary propane user is the house by Schneider's Barn, which is leased to a faculty member). [1]

Operating and energy budgets were provided by the Chief Financial Officer, FTE faculty and staff data by the Chief Operations Officer, student enrollment numbers by the Registrar, faculty and staff commuting habits from a survey Eckert (2015) designed with the Office of Institutional Effectiveness, and information on student travel to and from the college was synthesized from data provided by the Registrar (student home cities enabled an estimation of miles traveled to/from campus) and Campus Security (numbers of student-registered cars on campus, which enabled an estimate of the number of students that drive vs fly to campus).

Landfill information (tonnage collected and whether the landfill recovers or flares CH_4) came from Republic Services. Information on wastewater volume came from American Water, and data were

[1] Throughout the inventory, data were entered on a fiscal year basis (July 1 – June 30)

also collected related to our use of fertilizer (Focal Pointe Outdoor Solutions: lawns; Perfect Play Fields and Links: athletic fields), paper (Mail and Copy Services), and propane (Senger's Gas-Propane Service).

Institutional Data

Having first defined the physical and temporal boundaries of the inventory, the next step was to research and input "Institutional Data" – which included, on an annual basis, the Operating Budget ("all sources of funding the college has financial control of and is plainly considered as the cost to operate the institution"), the Research Budget ("the amount of money received in research grants from external sources", which is not relevant to Principia), and the Energy Budget ("the total spent providing the energy needs for all operations") (UNH, 2015). Next, the "Population" responsible for our emissions had to be defined, including "Full-Time Students"[2] and "Full-Time Equivalent" (FTE) Faculty and Staff (a total of 706 persons). Finally, the Physical Size of the college was determined, which consists of Total Building Space (1,077,376 ft^2) and Total Research Building Space. The latter is not relevant to Principia, as it refers to large universities focused on advanced biomedical, engineering, and other (typically energy-intensive) research activities.

RESULT S

Scope 1

Scope 1 emissions result directly from sources owned and/or controlled by Principia. These are described as "Direct Transportation" (the combustion of fossil fuels in college-owned vehicles), "Other On-Campus Stationary" (the combustion of fossil fuels in college-owned facilities, including boilers and furnaces), "Refrigerants and Chemicals" (e.g., fugitive emissions from refrigeration), and "Agriculture Sources" (e.g., fertilizers releasing N_2O, livestock releasing CH_4). With the exception of Distillate Oil (#1-4), Natural Gas, and LPG (Propane), Principia College has no on-campus stationary or cogeneration combustion sources.

Our gasoline fleet averages 25,000 gallons of fuel per year (range: 20,385 - 26,786 gallons). Refrigerants and Chemicals are minor (estimated at fewer than 10 lb/yr). The college has had multiple fertilizer contractors over the years, some of which are no longer in business, so Eckert (2015) calculated average fertilizer use for 2012-2015 (18,054 lb of synthetic fertilizer, 83.25% N) and repeated that value annually back to 2005 – and now forward to 2019. We have no animal husbandry operations.

Scope 2

Scope 2 emissions are "indirect" in that they result from sources "that are neither owned nor operated by [Principia] but whose products are directly linked to on-campus energy consumption" (UNH, 2015) and therefore we must take ownership of them.

Scope 2 focuses on Purchased Electricity, Steam, and Chilled Water. Only the first of these (Purchased Electricity) is relevant to Principia. Since different fuels are used to produce electricity in different parts of the country, we had to select the appropriate eGRID subregion. Because the North

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[2] The calculations make provision for "Part-Time" and "Summer School" students, but we have no part-time students and summer session students "are not used in any calculations" (UNH, 2015) so we did not determine this number

American Electricity Reliability Corporation[3] (NERC) regions substantially changed between 2002 and 2006, the corresponding eGRID subregions used by SIMAP also changed. Prior to 2006, Principia College fell within the MANS subregion; after 2006, the SRMW subregion (Figure 2).

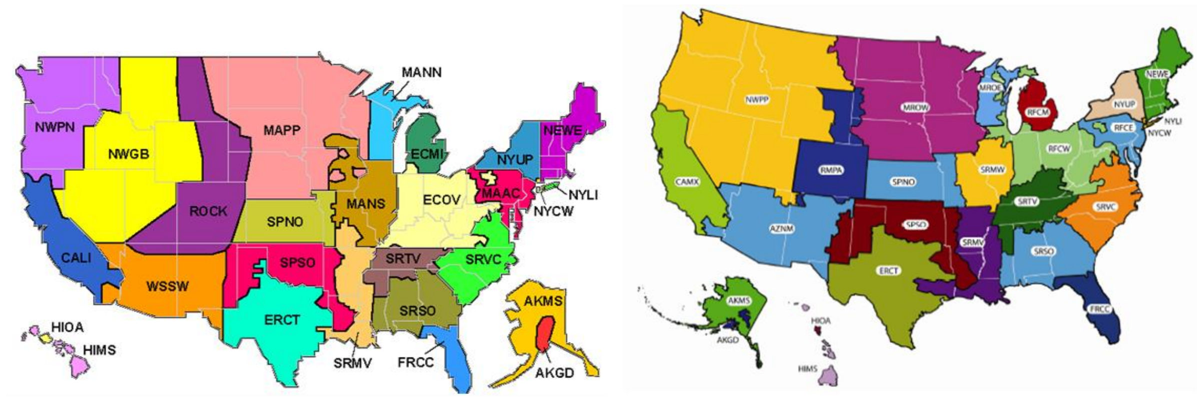

Figure 2. NERC eGRID subregions. Source: CCC Calculator

On average (2004-2019), we use 10,395,385 kWh of electricity (range: 9,506,000 to 11,079,000 kWh) and 92,000 MMBtu of energy (across all sectors) per year (Table 3). Following the transition to renewable power in 2009, energy as a percentage of annual operating budget declined significantly (Figure 3).

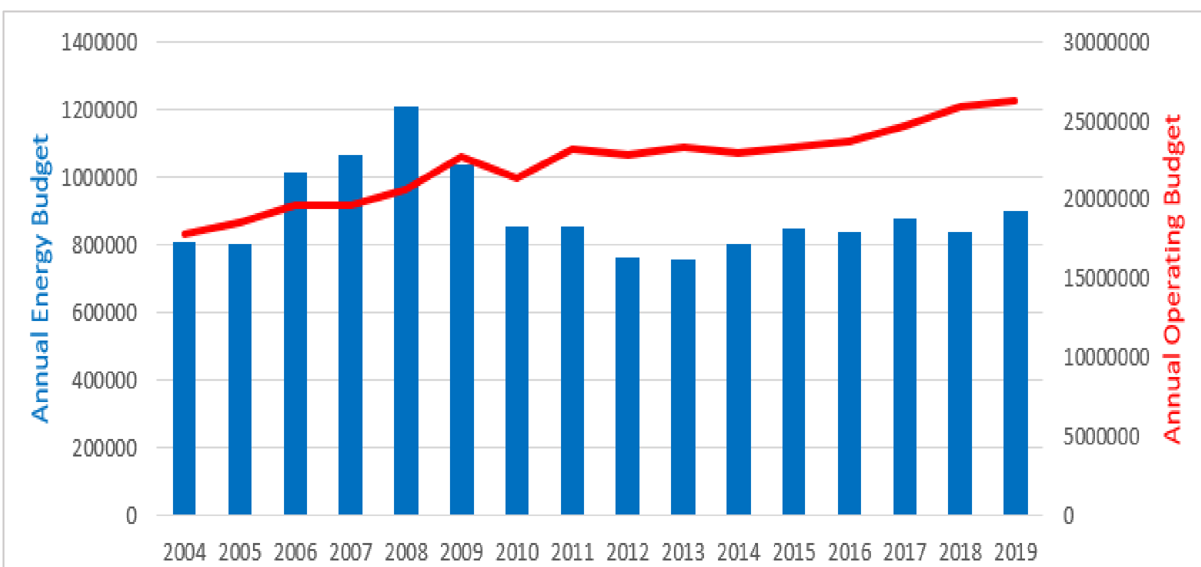

Figure 3. At Principia College, energy spending decoupled from overall spending in 2010, with no significant trend in energy spending between 2010 and 2019. Source: Facilities Department and Chief Financial Officer.

[3] The NERC is a nonprofit international regulatory authority whose mission is "to assure the reliability of the bulk power system in North America." NERC develops and enforces Reliability Standards; monitors the bulk power system; and educates, trains, and certifies industry personnel. NERC is subject to oversight by the Federal Energy Regulatory Commission (NERC, 2015)

Scope 3

Scope 3 emissions are "attributed" to Principia because, while their sources are neither owned nor operated by the college, we are responsible in some way for them. Scope 3 includes so-called "upstream emissions", like purchased goods and services, fuel and transportation, business travel, and commuting … and "downstream emissions", like processing, use or end-of-life treatment of sold products, franchises, and investments (Figure 1). Scope 3 is considered "optional" when conducting a GHG inventory, but we continue to be as complete as we can in our analysis.

Commuting: Based on survey data related to miles traveled by various transportation modes, faculty and staff travel an estimated 1,174,833 automobile miles and 28,570 "carbon-free miles" (walk/ bike to campus) per year. 100% of students "commute" to class using carbon-free modes, which Eckert (2015) estimated at 500 miles/yr. Other choices (e.g., bus, light or commuter rail) are not relevant.

Directly Financed Outsourced Travel and Study Abroad Travel: These were not included because these are not *required* by Principia (e.g., students have the option of studying abroad, but it's not required) and therefore Principia need not take ownership of these emissions.

Student Travel to/from Home: This was estimated from examining the distance between the Principia campus and students' cities of origin, and then estimating the percentage of students who drive (vs fly) based on student on-campus vehicle registrations. Eckert (2015) estimated that students travel an average of 18,359 miles/yr by car and 806,857 miles/yr by air to and from campus.

Solid Waste: We do not incinerate any waste. We send all waste (avg: 188 tons/yr; range: 96 - 315 tons) to the Roxana Landfill, in part through contracted collection services, and we take ownership of the attending emissions. While statistically flat over time, the 2018 peak (Figure 4) may relate to major renovation and construction projects (e.g., Voney Art Studio, completed in 2017; McVay Center for the Performing Arts at Morey, completed in 2019). For the first five years (2005-2009) of our GHG inventory, the landfill recovered a portion of its CH_4 emissions to generate electricity; that is no longer the case.

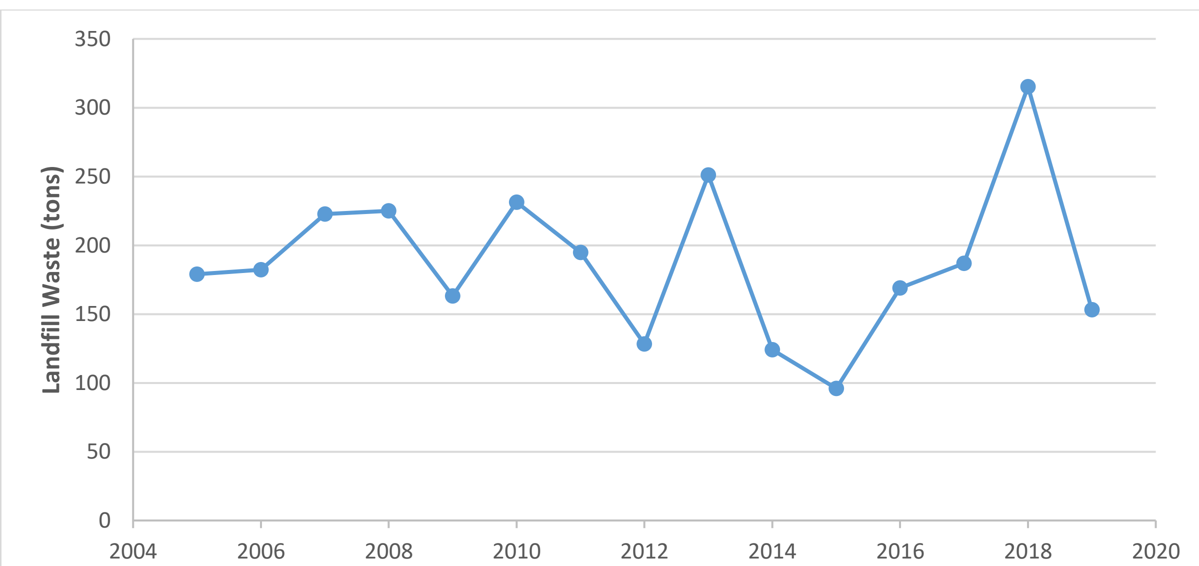

Figure 4. Principia College's landfilled waste, including both college-wide collection and construction waste.

Wastewater: Principia runs an average of 9,534,508 gallons (range: 6,016,411 - 13,737,280) of wastewater through an on-campus septic system and 16,024,786 gallons (range: 15,120,000 - 17,823,000) through an on-campus (aerobic) central water treatment plant every year. Figure 5 displays data for Crafton Athletic Center and the Department of Facilities complex ("Septic") and water use by all other campus buildings ("Aerobic"), plus a "Combined" trend. "Water" represents data from other uses, primarily athletic fields. In aggregate, the college's water use has remained statistically flat ($p=0.844$) between 2005 and 2018; however, "Aerobic" – water use in campus buildings – shows a slight but statistically significant ($p=0.0046$) upward trend despite declining enrollment.

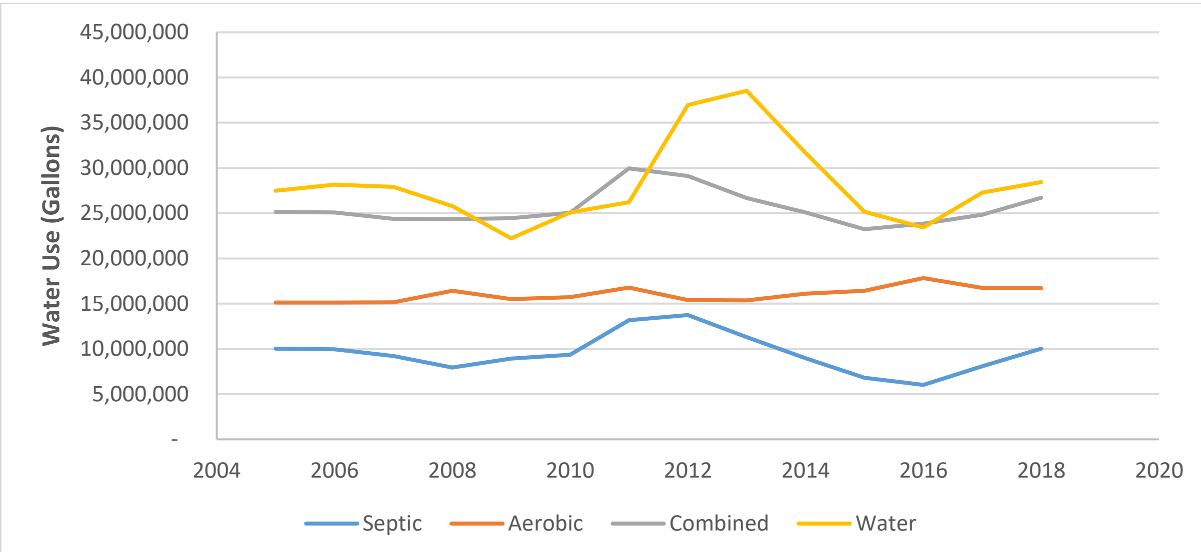

Figure 5. Principia College's volume of wastewater, which contributes to methane (CH_4) emissions (see Figure 9).

Paper: Due to changes in paper vendors and purchasing protocols, we only have reliable data for 2013 and 2014, so Eckert (2015) repeated the purchase volume for the last complete year (2013) back to 2005. In 2014, we used 14,099 lb of 0% recycled uncoated freesheet paper, 2,429 lb of 0% recycled coated freesheet, and 3,180 lb of 30% recycled uncoated freesheet. In 2013, we used 13,120 lb of 0% uncoated freesheet and 2,429 lb 0% recycled coated freesheet. Since 2014, Principia has been committed to purchasing 30% recycled content paper for the networked printers and copiers, with the quantity purchased remaining relatively constant (Ward Patterson, Principia Mail and Copy, in litt. 9 November 2019).

In an attempt to reduce the ecological footprint of our paper use, the college joined the PrintReleaf Exchange in June 2015 and, to date (June 2020), we have offset the equivalent of 9,519,813 total standard pages of paper consumption by reforesting 1,142 standard trees in Madagascar. Madagascar is one of the most threatened ecosystems on the planet, where "more than 80% of the forests are gone, half of them since the late 1950s, [and] 90% of Madagascar's endemic species live or heavily rely on the forest."[4] It is not a perfect solution, but it is an attempt to give back while we chart a course to using less paper overall.

[4] PrintReleaf Madagascar

Finally, Scope 3 includes a category called "Scope 2 T&D Losses", which are defined as the "energy lost while transporting purchased energy" (UNH, 2015). This refers to the fact that electricity companies need to generate more electricity than actually reaches us because some portion is lost during transmission and distribution. So, while we may be using "x" amount of energy, "x + T&D losses" is required and those emissions need to be factored in.

Emissions Calculations

SIMAP calculates our emission levels for CO_2 (Table 1, Figure 6), N_2O (Tables 1, 2, Figure 8), CH_4 (Table 1, Figure 9), and eCO_2 (Table 1, Figures 10, 11). eCO_2 refers to "equivalent CO_2" (non-CO_2 emissions converted to their CO_2 equivalent), which is calculated by determining the gas's global warming potential (GWP) and converting it based on the GWP of CO_2. CO_2, N_2O, and CH_4 are measured in kilograms (kg), and eCO_2 is measured in metric tonnes (MT) of CO_2.

Table 1. Climate-altering emissions (CO_2, CH_4, N_2O, eCO_2) from Principia College during 2005-2019.

Fiscal Year	CO2 (kg)	CH4 (kg)	N2O (kg)	Gross MTCDE	Non-Additional Sequestration (MTCDE)	Biogenic (MTCDE)	Net MTCDE
2005	9,509,248	387	310	9,646.55	0.00	0.00	9646.55
2006	9,992,843	218	374	10,154.89	0.00	0.00	10154.89
2007	12,732,455	237	379	12,896.42	0.00	0.00	12896.42
2008	13,648,271	195	389	13,814.11	0.00	0.00	13814.11
2009	3,653,588	134	218	3,767.01	0.00	0.00	3767.01
2010	3,633,436	134	209	3,744.15	0.00	0.00	3744.15
2011	2,940,636	2,130	162	3,087.18	0.00	0.00	3087.18
2012	2,343,883	1,805	164	2,482.82	0.00	0.00	2482.82
2013	2,950,586	1,804	164	3,089.78	0.00	0.00	3089.78
2014	2,666,987	1,786	166	2,796.41	0.00	0.00	2796.41
2015	3,393,852	1,637	186	3,535.33	0.00	0.00	3535.33
2016	2,535,658	2,315	167	2,703.11	0.00	0.00	2703.11
2017	2,563,161	2,540	168	2,736.50	0.00	0.00	2736.50
2018	3,069,679	2,134	169	3,233.15	0.00	0.00	3233.15
2019	3,089,213	1,977	169	3,244.04	0.00	0.00	3244.04

Table 2. Nitrogen emissions from Principia College during 2005-2019. See also Figure 8.

Fiscal Year	NO2 (kg)	NOx(kg)	Other N (kg)	Gross N (metric tons)	Offsets (metric tons N)	Compost (metric tons N)	Non-Additional Sequestration (metric tons N)	Net N (metric tons N)
2005	310	10,822	3,750	7.24	0.00	0.00	0.00	7.24
2006	374	12,769	3,750	7.87	0.00	0.00	0.00	7.87
2007	379	14,122	3,750	8.29	0.00	0.00	0.00	8.29
2008	389	14,783	3,750	8.50	0.00	0.00	0.00	8.50
2009	218	4,274	3,750	5.19	0.00	0.00	0.00	5.19
2010	209	4,335	3,750	5.20	0.00	0.00	0.00	5.20
2011	162	2,536	3,750	4.62	0.00	0.00	0.00	4.62
2012	164	2,259	3,750	4.54	0.00	0.00	0.00	4.54
2013	164	2,415	3,750	4.59	0.00	0.00	0.00	4.59
2014	166	2,078	3,750	4.49	0.00	0.00	0.00	4.49
2015	186	3,351	3,750	4.89	0.00	-0.23	0.00	4.66
2016	167	2,439	3,750	4.60	0.00	-0.26	0.00	4.34
2017	168	2,436	3,750	4.60	0.00	-0.28	0.00	4.32
2018	169	2,912	3,750	4.74	0.00	-0.24	0.00	4.50
2019	169	2,751	3,750	4.69	0.00	-0.25	0.00	4.44

Table 3. Total energy use by fuel source for Principia College, indicating no significant trend in energy consumption over the period of study (2006-2019) despite a slight but significant ($p=0.012$) decline in natural gas use. See also Figure 12.

Fiscal Year	Electric		Natural Gas		Gas & Diesel	
	kWh	MMBTU	US Therms	MMBTU	Gallons	MMBTU
2005	9,725,068	33,158	505,373	50,525	30,324	9,220
2006	9,505,894	32,410	483,003	48,289	35,619	14,402
2007	10,136,064	34,559	508,265	50,814	28,725	10,868
2008	11,078,636	37,773	517,304	51,718	33,609	10,488
2009	10,798,473	36,818	488,755	48,864	35,855	12,733
2010	10,254,556	34,963	483,330	48,321	31,463	9,854
2011	10,378,915	35,387	493,120	49,300	38,521	16,077
2012	9,981,675	34,033	368,750	36,866	34,785	12,402
2013	9,945,492	33,909	487,690	48,757	29,039	8,955
2014	10,418,379	35,522	429,530	42,943	33,486	12,270
2015	10,251,570	34,953	429,530	42,943	34,365	10,901
2016	10,217,010	34,835	349,810	34,973	30,586	9,931
2017	10,830,120	36,925	350,520	35,044	32,395	10,140
2018	10,872,530	37,070	436,750	43,665	37,384	15,567
2019	10,866,070	37,048	449,460	44,935	32,946	10,849

ANALYSIS

Figure 6 shows Principia College's total carbon dioxide (CO_2) emissions, in kilograms. Up until 2009, our largest source of emitted CO_2 was "purchased electricity". When we switched to purchasing RECs to cover 100% of our electricity consumption in 2009, these emissions plummeted – as did the related Scope 2 T&D Losses – meaning that this single administrative decision reduced our total emissions by about 10,570 MT eCO_2 [5] annually, a 76.5% decline from 2008. Thereafter, our largest emissions arise from "on-campus stationary sources" (mainly natural gas) and are relatively consistent from year to year.

Because our use of natural gas is an order of magnitude higher than our use of Distillate Oil (#1-4) and two orders of magnitude higher than LPG (Propane) – and these are the only "on-campus stationary sources" contributing to our CO_2 emissions – we conclude that the dip in 2012 emissions most likely would have resulted from a reduction in our natural gas usage, which may be attributed to a relatively warm winter in 2012 (according to Midwest Regional Climate Center) (Figure 7). A warmer winter means relatively fewer heating degree days[6], meaning we needed less heat, burned less natural gas, and released fewer climate-altering emissions.

[5] eCO_2, reported in metric tonnes (MT), refers to "equivalent CO_2" (non-CO_2 emissions converted to their CO_2 equivalent), which is calculated by determining the gas's global warming potential (GWP) and converting it based on the GWP of CO_2. See *Emissions Calculations*.
[6] Heating degree days normalize the energy consumption of a heated building and the normalized figures allow us to compare energy consumption figures across years on a like-for-like basis. Source: http://www.energylens.com/articles/degree-days

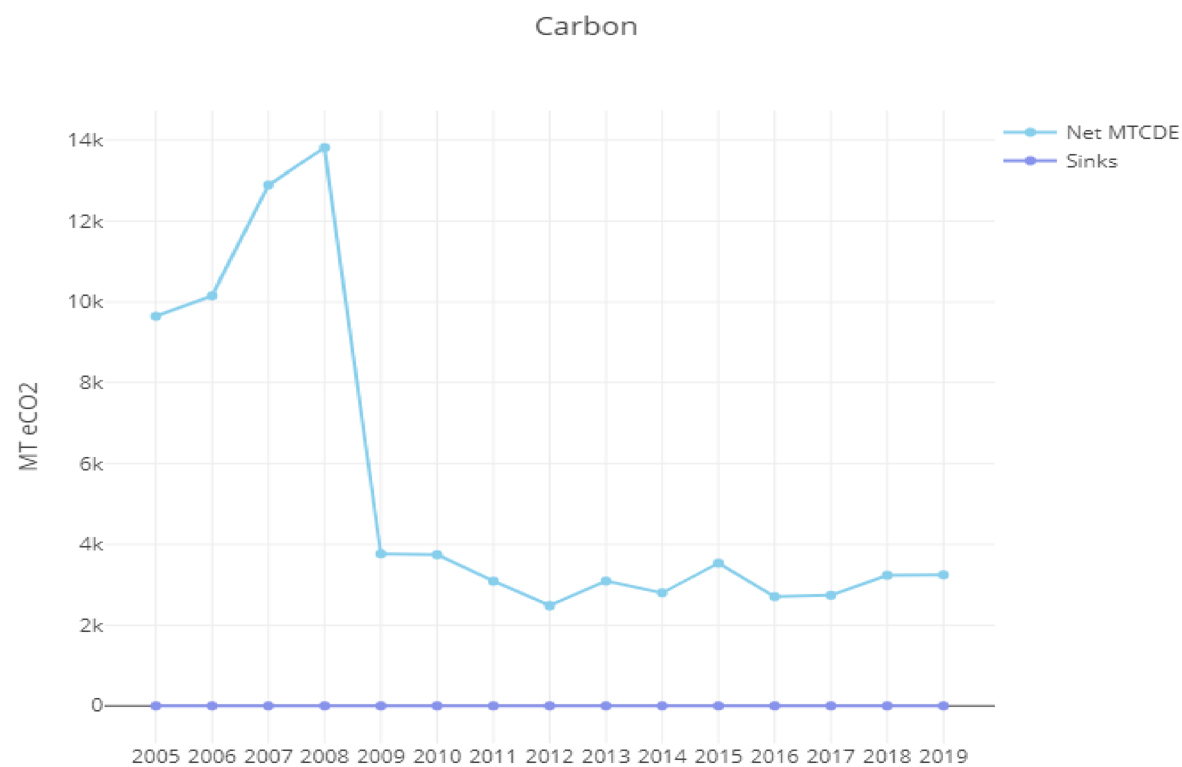

Figure 6. Total carbon dioxide equivalent (eCO_2) emissions estimated for Principia College, 2005-2019, in metric tonnes. MTCDE = Metric Tonnes of Carbon Dioxide Equivalent.

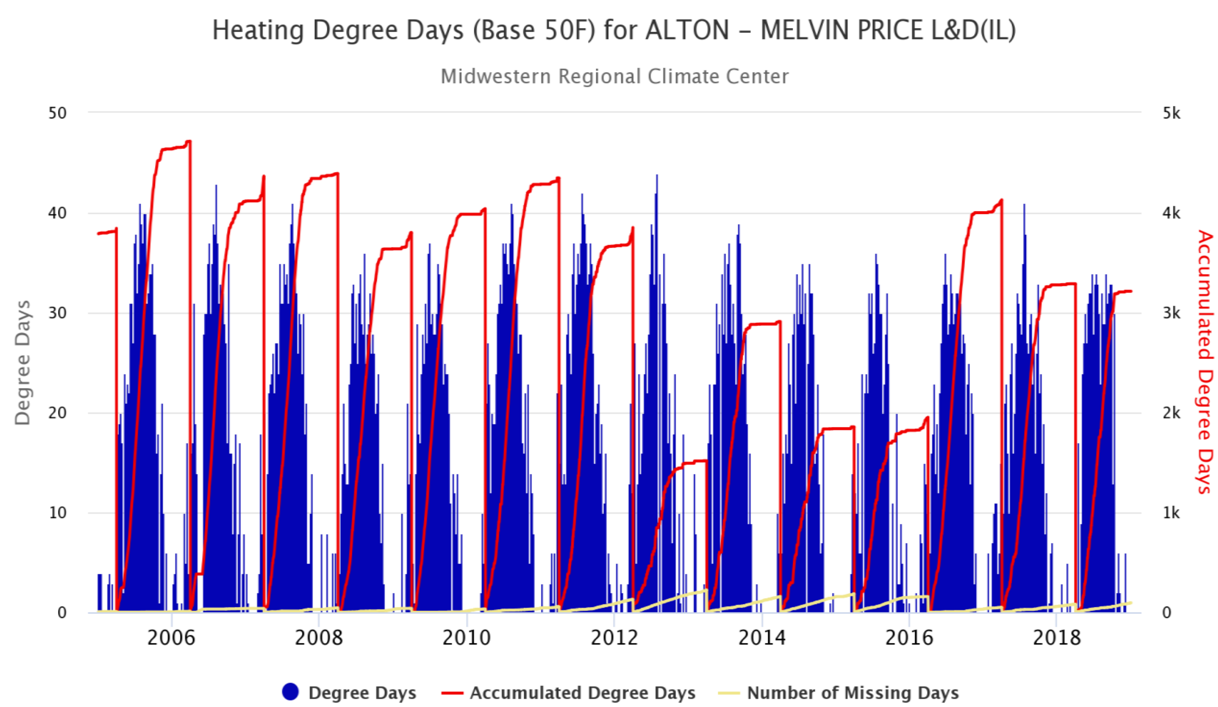

Figure 7. Ambient weather has a direct effect on institutional emissions. A warm 2012 winter and spring lowered our use of natural gas, clearly reducing our emissions from On-Campus Stationary sources (cf. Figures 10, 11).

The largest and most consistent contributor of nitrous oxide (N_2O) emissions (Figure 8) relates to our "agriculture" activities – in our case this represents the use of fertilizer on our grounds and athletic fields (we do not calculate the "agriculture" emissions from college property leased to local farmers). Consistent secondary contributions to N_2O as a greenhouse gas come from our commuting and wastewater. Finally, there is the familiar pattern of emissions associated with purchased electricity (and the attending Scope 2 T&D Losses) falling to zero after the 2009 transition to 100% renewable power (see also Figure 10).

The two major contributors to our methane (CH_4) emissions are from waste water and solid waste disposal. The spike in 2011 (Figure 9) coincides with when the Roxana Landfill stopped capturing its methane and using it for power generation, and instead simply captured it and flared it (Nicholas Bauer, Environmental Manager, Republic Services, pers. comm. *in* Eckert, 2015). As previously noted, the second spike may relate to major renovation and construction projects on campus (e.g., Voney Art Studio, completed in 2017; McVay Center for the Performing Arts at Morey, completed in 2019), which likely resulted in relatively larger volumes of landfilled construction debris.

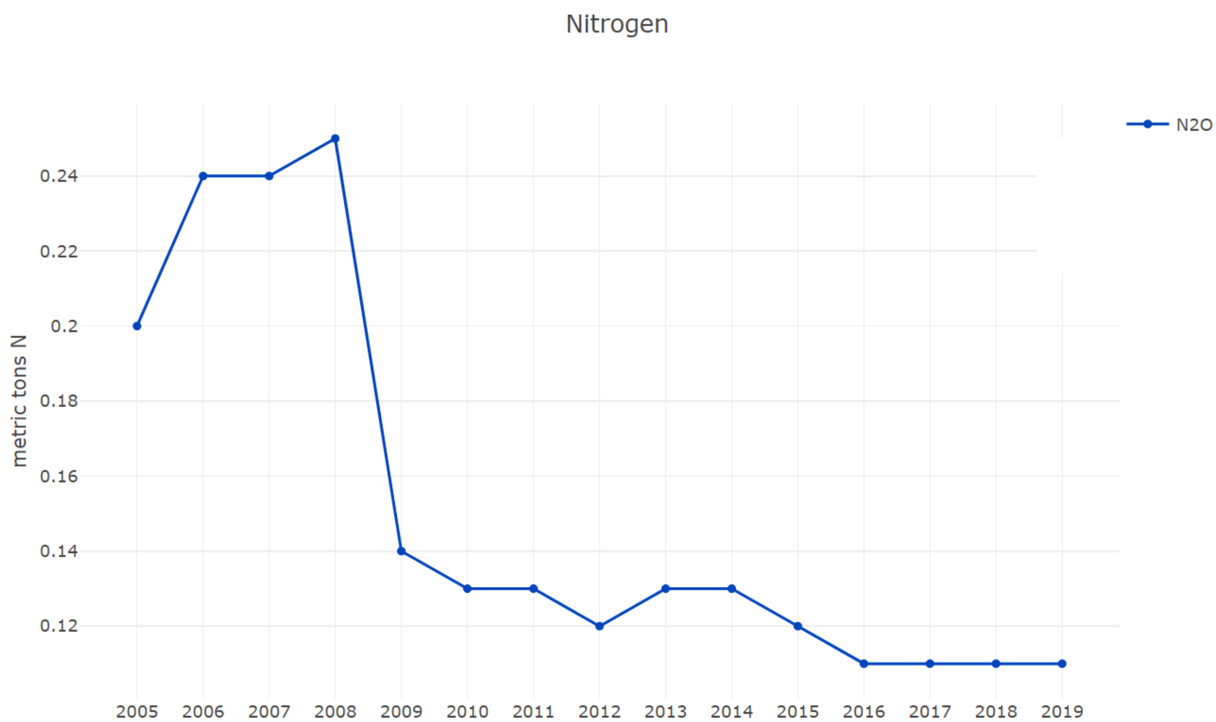

Figure 8. Total nitrous oxide (N_2O) emissions estimated for Principia College, 2005-2019.

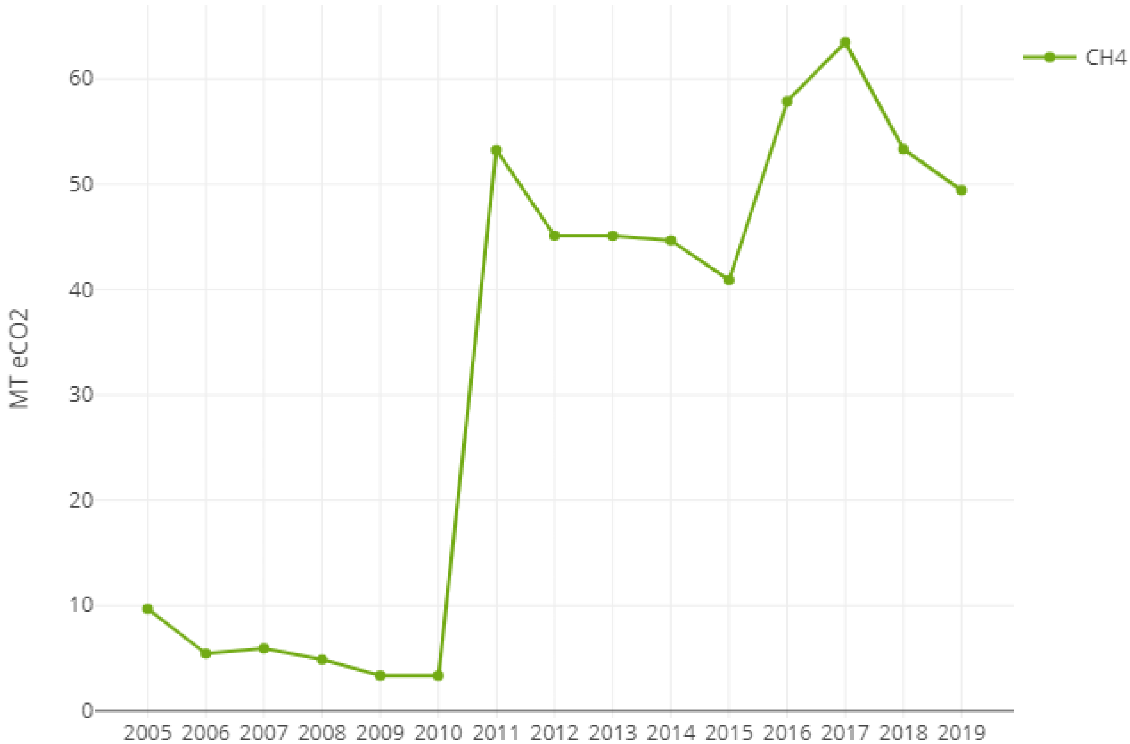

Figure 9. Total methane (CH_4) emissions estimated for Principia College, 2005-2019.

eCO_2 is defined as units of carbon dioxide equivalents, which is a measure of how much each gas contributes to climate change, in relation to carbon dioxide (UNH, 2015).

As we have seen for other emissions, the largest contributor to our eCO_2 emissions was Purchased Electricity (and the attending Scope 2 T&D Losses) until we switched to 100% renewable power in 2009. The next highest values are from On-Campus Stationary Sources and Commuting. The dip in 2012 is due to a decrease in natural gas usage (which we attribute to an unseasonably warm winter, see Figures 6,7), resulting in a transient decrease in overall On-Campus Stationary emissions. Overall, our use of natural gas has declined slightly over the period of study (see also Table 3 and Figure 12). It's difficult to know whether the decline is due to more efficient boilers or declining enrollment, or both.

The data suggest that, going forward, our mitigation actions will need to focus on On-Campus Stationary sources of emissions (dark grey line: Figure 10), which is mainly our use of natural gas, as well as the smaller but consistent emissions sources related to Direct Transportation (campus fleet) and Commuting.

In summary, Scope 1 emissions (bright blue line: Figure 11), arise from sources owned and/or controlled by Principia; e.g., "On-campus Stationary Sources" (mainly our use of natural gas), "Direct Transportation" (e.g., the combustion of fossil fuels in college-owned facilities and vehicles), "Refrigerants and Chemicals" (e.g., fugitive emissions from refrigeration), and "Agriculture Sources" (e.g., fertilizers releasing N_2O). Scope 1 sources should be the primary target of future emissions reduction efforts (see *Discussion & Recommendations*).

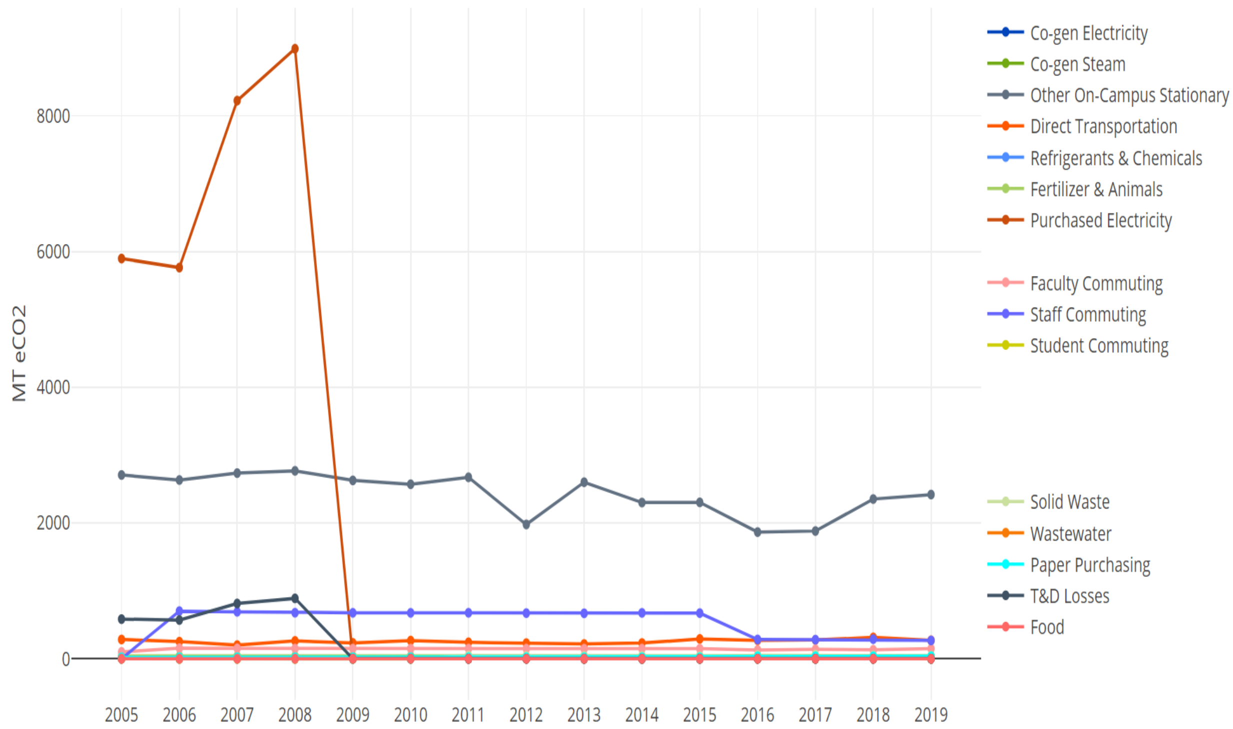

Figure 10. Total carbon dioxide equivalent (eCO_2) emissions estimated by sector for Principia College, 2005-2019. The dip in Staff Commuting reflects an FTE reduction between our first inventory (2005-2014: Eckert, 2015) and this update (2015-2019).

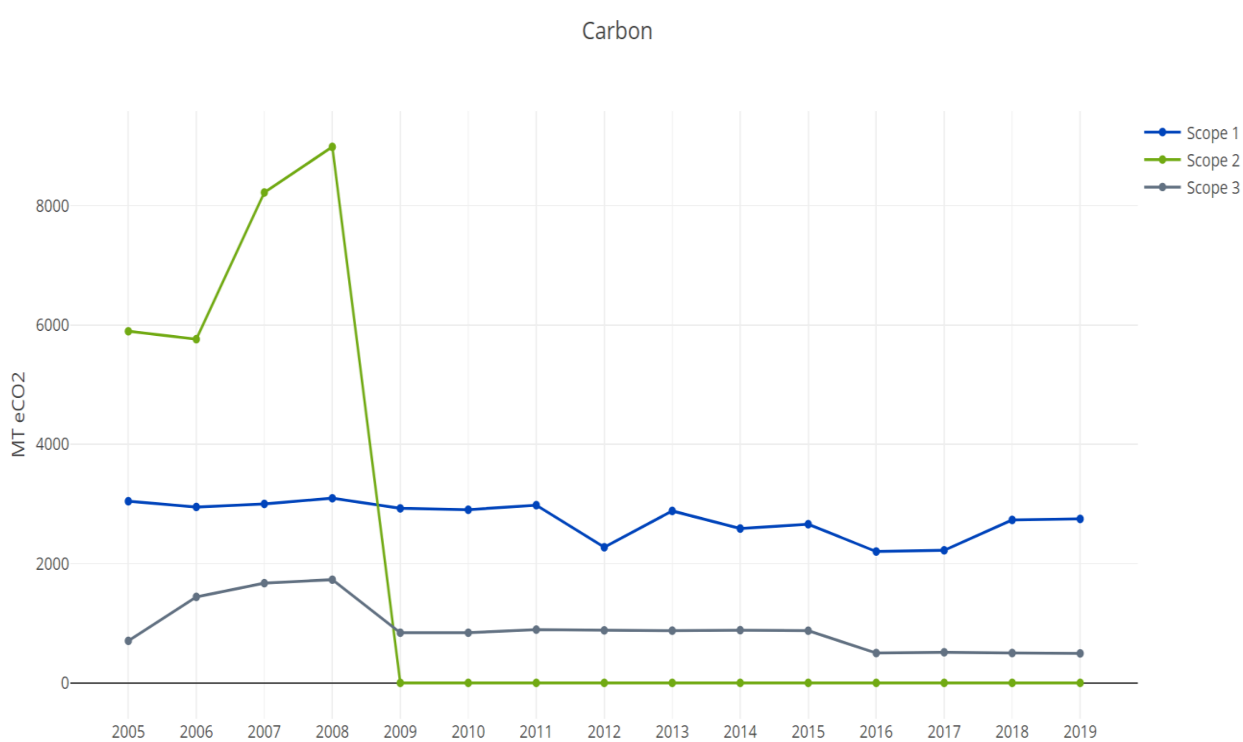

Figure 11. Total carbon dioxide equivalent (eCO_2) emissions estimated by scope for Principia College, 2005-2019.

DISCUSSION & RECOMMENDATIONS

Principia College greenhouse gas (GHG) emissions of carbon and nitrogen were analyzed using the University of New Hampshire's Sustainability Indicator Management and Analysis Platform (SIMAP), developed in partnership with the University of Virginia and Second Nature (UNH, 2020). The analysis extends the work of Eckert (2015) and documents trends in GHG emissions over the 15-year period 2005-2019. Data were entered on a fiscal year basis (July to June), following data entry protocols used by the Facilities Department. The results shed light on progress toward the strategic mandate that the college be carbon neutral, as well as contribute to broader college-wide sustainability performance audits undertaken by the Center for Sustainability using the Sustainability Tracking, Assessment and Rating System™ (STARS) (AASHE, 2013).

The inventory is organized into "scopes", defined as emissions that result directly from sources owned and/or controlled by Principia (Scope 1), emissions that are neither owned nor operated by Principia but whose products are directly linked to on-campus energy consumption (Scope 2), and emissions that are "attributed" to Principia because, while their sources are neither owned nor operated by the college, we are responsible in some way for them (Scope 3).

The most significant Scope 1 emissions were from On-Campus Stationary Sources which include, from highest to lowest, natural gas, distillate oil (#1-4), and LPG (propane). Direct Transportation (gasoline-powered fleet vehicles) and Fertilizer applications also contributed and, less so, our use of Refrigerants and Chemicals. Scope 2 is our Purchased Electricity, which contributes negligible emissions post-2009 (Figure 11). Scope 3 captures a variety of emission sources, the most relevant being Employee Commuting, Student Arrival/ Departure (note: on-campus "commuting" by students is carbon-free, consisting of walking, biking or boarding), Solid Waste (landfill-associated emissions), Wastewater, and, to a smaller degree, Paper Use. See *Emissions Calculations* and *Analysis* for details.

CO_2 emissions occur in every area of our operations and campus life, but the most significant are our on-campus stationary sources, which for us means natural gas (Figure 10). The largest source of our N_2O emissions is our use of nitrogen fertilizers (Figure 8), and most of our methane (CH_4) emissions relate to water use and solid waste disposal (Figure 9). Taken together, and standardized as eCO_2 equivalents, our total emissions in 2019 was 3,244 MT eCO_2 (Table 1), which represents a 76.5% reduction in emissions from our 2008 peak. This significant accomplishment is directly related to a single administrative decision – our commitment to the purchase of renewable power, for which we are consistently recognized by the U.S. Environmental Protection Agency as a leader among our peers.

Are we "carbon neutral"? For the time being, yes. The college's overall energy use has been statistically flat for 15 years (Figure 12) and we generate a laudably low level of GHG emissions – 3,244 MT eCO_2 or about 4.6 MT per capita, less than one-third the U.S. national per capita average. Moreover, the natural metabolism of the 809-hectare Principia Forest is currently offsetting slightly more than 100% of our GHG emissions. However, because of declining rates of sequestration in the aging forest, our best estimates are that that will soon (perhaps by 2026 or 2027) no longer be the case (Silcox, 2016). We can extend the benefits of this vital ecosystem service by actively managing our forest for carbon sequestration; for example, by culling aging, metabolically less active trees and prioritizing the planting of native oaks which research has shown to be "top performing" carbon sequesters (Pierce, 2019). Our native prairies are also a potentially important carbon sink, but their value has not been quantified.

What make sense for Principia if we want to offset emissions that we cannot eliminate? Offsets can be useful in maintaining carbon neutrality because there are emission sources that we do not directly control and cannot eliminate, e.g., students traveling to and from the college. AASHE (2013) makes several recommendations, including carbon storage from on-site composting, purchasing "third-party verified" carbon offsets, and "institution-catalyzed carbon offsets" where the college implements projects in the local community that reduce emissions (e.g., students volunteer to weatherize homes in nearby communities) and there is an agreement that the college "owns" the emissions reductions that result. As previously noted, we could also manage the Principia Forest for carbon sequestration.

Can we establish carbon reduction goals? Yes! By far the largest campus emitter is on-campus stationary sources (Figure 13). The largest part of this is heating, so one way to reduce our overall emissions is to use less heat. The data suggest that an upgrade to condensing boilers in two loop plants was insufficient to result in a meaningful reduction in our Scope 1 emissions, implying that behavioral change (e.g., put on a sweater rather than crank the heat) must also play a role in carbon reduction targets. The old adage "you can't manage what you don't measure" applies here, in that building-level metering could significantly advance our understanding of where and when heat is used, thereby helping to identify where upgrades and/or other changes will have the greatest impact.

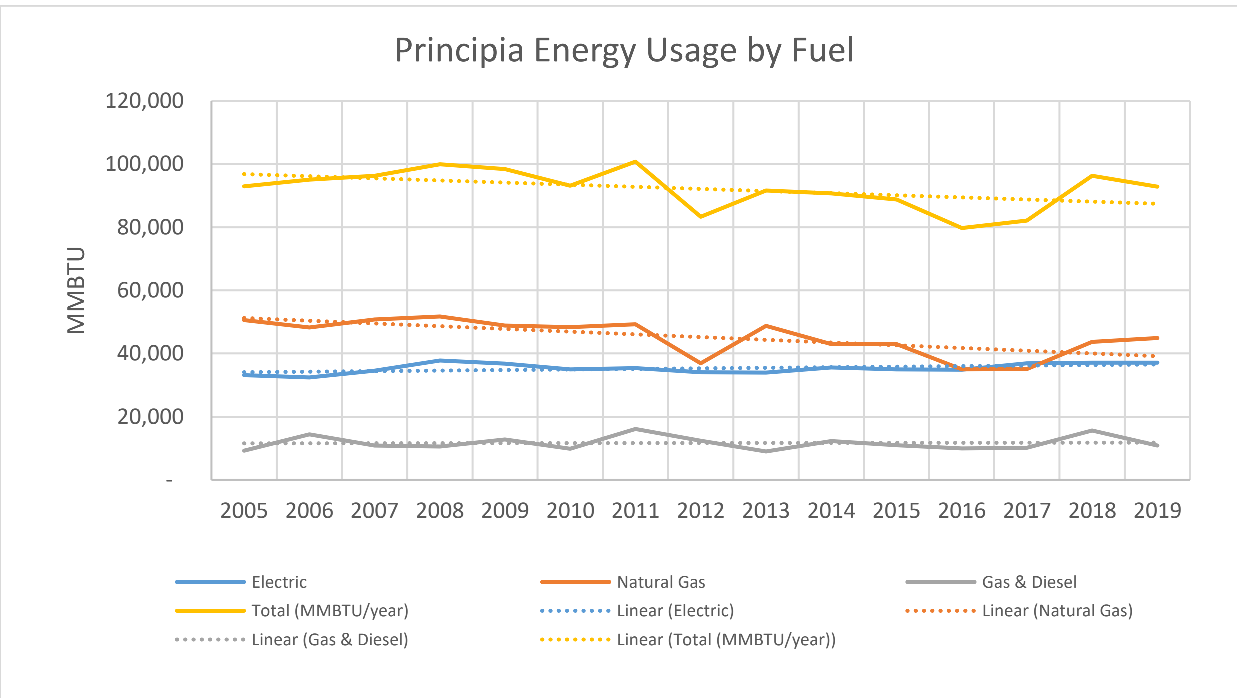

Figure 12. Energy use at Principia College by fuel and cumulatively by year. Cumulatively, our energy consumption has been statistically flat since 2005, despite a slight but statistically significant ($p=0.012$) decline in natural gas use. Data sourced from Table 3.

Second to heating, the next best opportunity to reduce our emissions relates to staff and faculty commuting (Figure 13). One way to approach this is to incentivize carpooling and the use of "greener" transport, whether walking, biking, or driving a more efficient or electric vehicle. Principia could also establish some form of shuttle system. Faculty and staff could park in a group location, and a shuttle could take them to campus and back at the end of the day (Principia already sponsors something similar with hybrid sedans available to carpooling staff who commute between the college and the K-12 School in St. Louis).

Finally, using water more wisely (e.g., installing low-flow shower heads campus-wide), selecting a landfill that captures CH_4 for energy generation rather than flaring it off, reducing our landfill volume, using less paper, and committing to post-consumer recycled content in our copy paper would each contribute to reducing our emissions – often with attending cost savings, as well.[7]

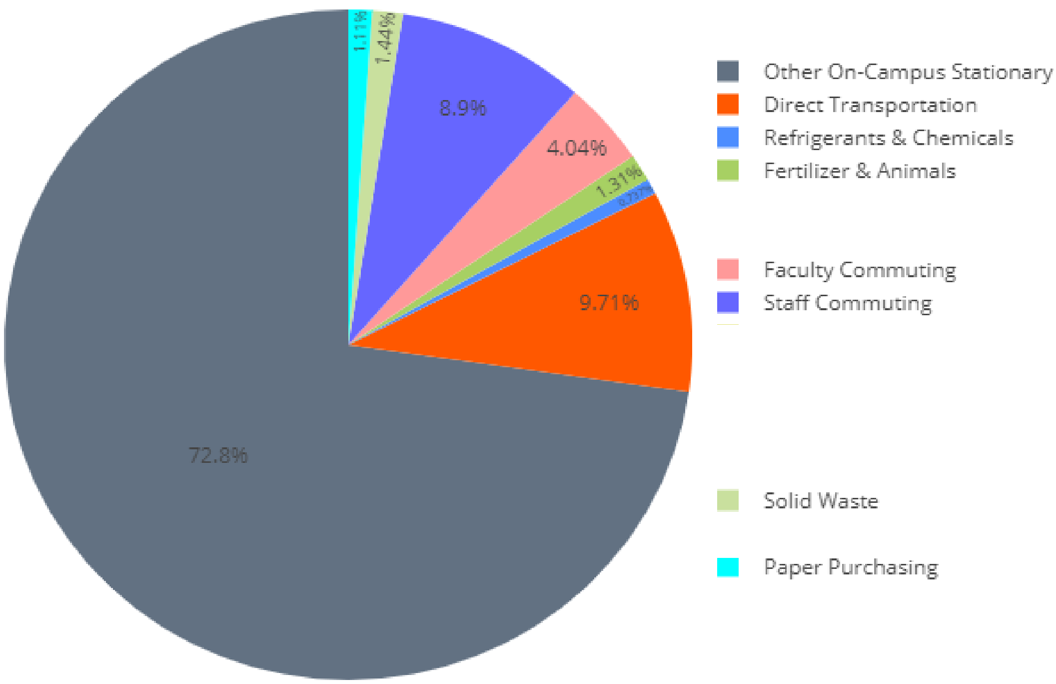

Figure 13. Percentage of Principia College emissions (total = 3,244 MT eCO_2, see Table 1) associated with various sources, 2005-2019. On-Campus Stationary sources contribute 72.8% of total emissions. Commuting and Direct Transportation contribute 22.6%. The remaining components are *de minimus*: Refrigerants and Chemicals (0.7%), Paper Purchasing (1.2%), Fertilizer and Animals (1.3%), and Solid Waste (1.4%).

What would be involved in becoming a "zero carbon" institution? The One Planet Principle "Zero Carbon" recognizes that climate change is due to a human-induced build-up of carbon dioxide (CO_2) in the atmosphere and recommends that we implement energy efficiency in buildings and manufacturing processes and that "all energy be supplied by non-polluting renewable energy generated onsite or offsite."[8] To achieve zero carbon status, we need to eliminate our CO_2 emissions, which is a

[7] *de minimus* sources create <5% of our overall sources, and, once determined, we have the option to not include them in future GHG inventories. Several of our sources fall into this category (Figure 13), but we feel it's important to continue to track them because we should be making an effort to increase efficiency and reduce emissions across all operations.
[8] Source: One Planet Living® Principles: Zero Carbon

higher bar than simply offsetting them to achieve carbon neutrality. One option is to convert from natural gas to electric heating – while at the same time maintaining our commitment to the purchase of 100% renewable power. We reduced our emissions 76.5% from 2008 levels when we purchased 100% renewable power for the first time in 2009 (Figures 10, 11), and we could eliminate 72.8% of what remains by eliminating emissions from natural gas consumption.

There are at least two ways to minimize Principia's reliance on natural gas: switch to a system that utilizes 100% green electricity or convert to 100% biofuel. Both options have strong pros and cons. The most efficient electric system would be to move the campus to a ground source heat pump system. Ground source heat pumps are very efficient and would likely reduce the overall energy needed to heat the campus by 60% - 80%. This technology is readily available and because Principia is on a hydronic loop system, the college is well suited to such an upgrade. Drawbacks include significant cost and the need to replace existing capital equipment prior to end of life.

The other option, switching to a renewable biofuel, would require virtually no upfront capital as the existing equipment could likely run on bio-methane with little or no alteration. The challenge is sourcing enough bio-methane at a price that is not cost prohibitive. The other opportunity related to biofuels is to purchase Renewable Identification Numbers (RINs) for our natural gas consumption – analogous to our purchase of Renewable Energy Credits (RECs) for our electricity consumption (Ross, 2019).

All of these options are feasible, but they all require advance planning and strategic financing, so the most important first step is to create an ***Energy Master Plan*** to guide decision-making processes related to the purchase and consumption of energy over the long term. The Master Plan should establish best practices for building and renovation, including high efficiency standards for heating and cooling systems, and, equally important, we must encourage a campus culture that prioritizes energy efficiency and personal responsibility. Finally, a regular rotation of retro-commissioning of campus buildings can help to ensure efficient operations at a lower cost (ERG, 2020).

If we eliminated the emissions associated with natural gas, the college would emit about 953 MT eCO_2 per year – or about 1.25 MT eCO_2 per person (faculty/staff/student) per year, a mere 8.5% of the average per capita value in the U.S. of 14.6 MT CO_2 per year[9] – and if we made up the difference through various types of offsets and other efficiencies, we could very nearly achieve zero carbon status.

Why does any of this matter? Earth's global surface temperatures in 2019 were the second warmest since modern record keeping began in 1880 (NASA/NOAA, 2020). The causal agent – an increase in atmospheric greenhouse gases – is fundamentally changing the planet. Species are disappearing, storms are stronger, oceans are warmer and more acidic, polar ice caps are melting, ecosystem services are unraveling, and zones favorable to agriculture and forestry are shifting (Melillo et al., 2014; TRS/NAS, 2014; WWF, 2014), not to mention that pollution from burning fossil fuels killed 3.2 million people in 2010 (2.1 million were from Asia, mostly China: Lim et al., 2012). More recently, according to the World Health Organization, "Black carbon, methane, and nitrogen oxides are powerful drivers of global warming, and, along with other air pollutants such as carbon monoxide and ozone, they are responsible for over 7 million deaths each year, about 1 in 8 worldwide" (Ghebreyesus, 2019).

[9] Source: Reported by the Union for Concerned Scientists, based on 2017 data (the latest available) from the IEA Atlas of Energy

Reducing our carbon footprint requires decisions large and small. Some decisions transform us – like transitioning to 100% renewable power – while others, like incentivizing carpooling, reducing paper use, and encouraging students to check the carbon offset box when they fly or to put on a sweater when they're cold, may have smaller results but each decision helps to ensure that we are a community of practice when it comes to sustainability – and not just a passive community waiting for "someone else" to save the planet. Becoming a zero-carbon emissions institution does not require as many changes as you might think. It's not about living without heat or computers or cars, it's about thinking ahead, making smart energy choices, and being aware – and taking ownership – of the consequences of our actions.

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In addition, we remain indebted to those who contributed data and expertise to the baseline inventory (2005-2014) and were acknowledged by Eckert (2015) as follows:

> "No investigation of this size can be undertaken alone, and I'm especially grateful to my Advisor, Dr. Karen Eckert (Professor and Director, Center for Sustainability) for offering this opportunity to me and providing guidance along the way.
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>
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APPENDIX 1

The Kyoto Protocol defines the six most influential climate altering gases as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydro- and perfluorocarbons (HFC, CFC), and sulfur hexafluoride (SF_6) (United Nations, 1998). SIMAP measures three of these – CO_2, CH_4 and N_2O – directly and converts others to their CO_2 equivalent (eCO_2). According to IPCC (2014), "Anthropogenic greenhouse gas emissions since the pre-industrial era have driven large increases in the atmospheric concentrations of CO_2, CH_4 and N_2O. About 40% of these emissions have remained in the atmosphere (880 ± 35 $GtCO_2$); the rest was removed from the atmosphere and stored on land (in plants and soils) and in the ocean (which has absorbed about 30% of the emitted anthropogenic CO_2, causing ocean acidification)."

CO_2 enters the atmosphere through burning fossil fuels (coal, natural gas, oil), solid waste, trees and wood products, and as a result of certain chemical reactions (e.g., manufacture of cement). CH_4 is emitted during the production and transport of coal, natural gas, and oil; it also results from livestock and other agricultural practices and by the decay of organic waste in landfills. N_2O is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste. Measured in gigatons, these emissions are major players in climate change.

What about the fluorinated gases that are also included in the Kyoto Protocol? These are the hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). They have no natural sources and are emitted through industrial processes such as aluminum and semiconductor manufacturing. "Many fluorinated gases have very high global warming potentials relative to other greenhouse gases, so small atmospheric concentrations can have large effects on global temperatures. They can also have long atmospheric lifetimes – in some cases, lasting thousands of years. … Fluorinated gases are removed from the atmosphere only when they are destroyed by sunlight in the far upper atmosphere. In general, fluorinated gases are the most potent and longest lasting type of greenhouse gases emitted by human activities."[10]

PFCs and SF_6 have declined since 1990 ("due to emission reduction efforts in the aluminum production industry [PFCs] and the electricity transmission and distribution industry [SF_6]"[13]), but HFCs, which are used primarily in refrigeration and air conditioning (accounting for 90% of their use: Tejón Carbajal, undated) are rising. SIMAP takes these into account in the category "Refrigerants & Chemicals", converts their emissions to eCO_2, and includes them in our Scope 1 total. For Principia College this category is *de minimus*, comprising 0.7% of our emissions (Figure 13), but globally these chemicals have an important effect on climate.

SF_6 is the most potent greenhouse gas but is not measured by SIMAP because it is not something that a college would likely be generating. It's "mainly used as a gaseous dielectric in gas insulated switchgear power installations" (Dervos and Vassilou, 2000), and is favored as an insulator in gas-insulated switchgear because "it has a much higher dielectric strength than air or dry nitrogen [and] this property makes it possible to significantly reduce the size of electrical gear" (Jakob and Perjanik, undated).

[10] Source: U.S. EPA Overview of Greenhouse Gases