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Development of Carbon Emission Assesment Tool Towards Promoting Sustainability in Cal State LA

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Abstract

The great demand for the burning of fossil fuels has greatly increased greenhouse gases (GHG) concentrations in the atmosphere. An increase in the atmospheric concentrations of greenhouse gases produces a positive climate forcing or warming effect [EPA, Climate Change Indicators]. Therefore, mitigation of GHG concentrations is important to prevent long-term impacts on the environment. On April 4, 2016, California State University, Los Angeles signed the most comprehensive of Second Nature's three Climate Leadership Commitments, the Climate Commitment. Following this commitment, California State University, Los Angeles, set the ambitious goal of operational carbon neutrality by the year 2040. To assist California State University, Los Angeles in moving effectively toward this goal, we developed an energy dashboard that can bring access, awareness, and education to campus about campus carbon footprint and promote energy-efficient behaviors. The developed energy dashboard is an interactive web application that works based on an energy model that is composed of various energy-consuming and GHG producing units such as Heating, Ventilation and Air Conditioning (HVAC), Heated Potable Water (HPW), Electricity, and Campus-Related Commutes. This energy dashboard enables individuals to analyze the campus's energy consumption and carbon footprint. Our research showed that campus-related commute was the first largest contributor to Cal State LA's carbon footprint in 2018 and accounted for 71.5% of carbon emissions. Electricity and heated potable water accounted for 20%, and 8.5% of the total campus carbon emissions, respectively.

Introduction

The Climate of Los Angeles is characterized by very mild, relatively rainy winters and hot summers [Climate and average monthly weather in Los Angeles, n.d.]. As our planet warms and shifts towards higher average temperatures during cold seasons, it can be anticipated that the demand for heating and usage of natural gas will reduce [Aroonruengsawat & Auffhammer, 2011]. However, the increase in extreme high-temperature events would likely lead to an increase usage of air conditioning systems [Aroonruengsawat & Auffhammer, 2011]. Both these scenarios would result in increased usage of electricity demand.

Universities are like small cities that are growing around the world. However, they do not have the grand operational scale and complex regulatory systems as cities do. Therefore, they have the advantage of mitigating greenhouse gasses emissions more easily within their boundaries. Since students, faculties and staff are not aware of the scale of the university's energy consumption or its resulting carbon footprint, they tend to waste energy [Yañez, Sinha, & Vásquez, 2019]. Therefore, to involve these individuals, self-monitoring intelligent dashboards have been created by many universities to support energy conservation [Martini, K. (n.d.)]. Such individuals' knowledge of energy consumption can prompt behavioral choices to reduce energy consumption whenever possible.

Universities around the world have been analyzing their energy use and carbon emissions and developing online energy dashboards to reduce their carbon emissions [de la Cruz-Lovera et al., 2017]. The Association for the Advancement of Sustainability in Higher Education (AASHE) reports that 70 of its member universities and colleges have used some forms of energy dashboards to communicate their energy consumption [AASHE, 2015]. For instance, UC Davis developed an Energy Dashboard in 2016, which analyzed energy data for buildings on the university campus to enable facilities management to improve energy efficiency with knowledge of and input into campus energy operations [Salmon, Morejohn, Pritoni, & Sanguinetti,2016]. Some universities conducted studies for longer periods. For example, the University of Almeria in Spain benchmarked the energy consumption data during a period of seven years alongside cross-sectional building information to establish a linear regression model to forecast future energy use [Chihib, Salmerón-Manzano, & Manzano-Agugliaro, 2020]. The Minnesota State University conducted a study to curb their emissions and control $CO2_e$ emissions by switching to LED lighting and upgrading the Central plant unit [Minnesota state University ESPC case study, 2021]. Their goal was to reduce the annual $CO2_e$ emissions by 4,462 metric tons and save about 400,000 dollars in energy costs over the 18-year contract. In addition, Miami University created a sustainability dashboard to focus on climate adaptation and community capacity building to deal with a changing climate. Their task force created a three-scope Climate Action Plan to mitigate the greenhouse gas emissions on campus. The three scopes are emissions directly produced on campus, emissions from purchased electricity, and emissions from commuting. They generated a Carbon footprint baseline to compare the future reductions and set a Climate Commitment for the University [Miami University, Sustainability Dashboard]. Analyses of this kind can help the university to identify its existing carbon emissions and to better assess the effectiveness of various energy-saving measures. This will result in more economical yet sustainable development on campus [Mohammadalizadehkorde, & Weaver, 2018].

To analyze the energy consumption on our campus, and to show the impact of various energy-saving measures on reducing campus energy consumption and carbon emissions we developed an interactive energy dashboard. The developed energy dashboard can be used to educate our campus community about campus' carbon footprint, to promote energy-efficient behaviors, and to reduce energy consumption on campus. Quantifying GHG contributions and reduction opportunities in various areas could further help to prioritize GHG reduction efforts. Although the university has adopted several low and zero carbon emissions measures such as utilizing solar panels, solar charging stations, and operating a hydrogen production and fueling station, it is still necessary to take further energy-saving measures to reduce the overall carbon emissions. In our analyses, energy consumption was divided into four major categories. We formulated energy consumption in each of these categories to make it possible to analyze the effect of operational variables on energy usage in each category. The analyses presented here are based on the data collected in 2018 and 2019, assuming similar operations in all the examined categories for both years. The sources of energy consumption in this research were broken down to heating, ventilation, air conditioning (HVAC), Electricity, Heated Potable Water or drinking water, and carbon emissions resulting from students, faculty/staff who commute to campus. It should be noted that due to the limited amount of hot water needed, potable water is heated in each building separately on our campus.

The interactive features of the developed energy dashboard would allow the user to assess the effectiveness of various energy-saving measures for reducing campus overall carbon emissions in the analyzed energy units. It should be noted that the practicality of these energy-saving measures would depend on both human, technical, and environmental factors [Agarwal, Weng, & Gupta, 2009]. The dashboard's visual interpretation of the data brings awareness and educates people regarding the carbon dioxide equivalent ($CO2_{e;}$ a standard unit for measuring carbon footprints) emissions from each module classified [Yun, et al. 2014].

Methodology

California State University, Los Angeles, has been in the heart of the city of Los Angeles since 1947 and is located 5 miles away from downtown Los Angeles. It is one of the Universities out of the 23 CSU Universities. It was ranked number one in the United States for the upward mobility of our students in 2017 [About the University, 2021]. In 2019, the university had about a total of 26,000 enrolled students and about 1,700 faculty [Workbook: Enrollment. (n.d.)., 2021]. The campus is approximately 175 acres and consists of more than 48 buildings that include parking spaces for the students, faculty/staff (Figure 1). In 2018 the total energy consumption in electricity was approximately 38,000,000 Kwh, and energy consumption in Heated Potable Water was around 16,000,000 Kwh.

The variables used in the energy formulation in each energy category were divided into three categories: Knobs, which are the variables that the user can adjust; Results, which are the variables that show the effects of changing the knobs; and Constants, which have constant values and are unchanged by alterations to the knobs. Typically, knobs are the input variables in the energy dashboard tool that can be adjusted to increase or reduce the intensity of the measuring object to determine the energy usage on campus (Arvind and Berry, 2015). Constants are the values that cannot be changed but

Figure 1
Campus Map of California State University, Los Angeles

can be seen by the Users for informational purposes. Finally, results are the output based on the input that users have incorporated into the dashboard. For example, a change in temperature (knob) would significantly change HVAC usage (result). This analysis will help us to know the contribution of various energy-consuming categories to energy consumption and carbon emissions on campus. The four main energy-consuming categories that were analyzed in this study are Transportation, Electricity, Heated Potable Water (HPW) and Heating, Ventilation, and Air Conditioning (HVAC).

Transportation

The transportation model analyzes the usage of energy based on the mode of transportation and the total number of gallons of fuel used by students, faculty/ staff commuting to California State University, Los Angeles. In this model, the data were broken down into two categories. Faculty /staff in one category and students in the other category. Further, these two categories were subdivided into drive-alone, rideshare, carpool, and public transportation. The data for students, faculty / staff commute habits to campus were collected through a campus-wide survey. The amount of energy used by commuting is complicated because it requires gathering a large amount of data. To simplify this complicated process and further assess and improve the data collected from the transportation survey, we used the number of daily and semester parking permits purchased in various parking lots on campus. In addition, to obtain information on how many students used public transportation, we used the number of purchased U-passes. U-pass provides unlimited public transportation to students who are enrolled as full-time students at the Cal State University of Los Angeles. The percentage of commuters using various modes of transportation and the total number of miles per commuter were collected from the survey. For this project, we collected the commute habits of students by conducting a campus-wide survey and commute habits of faculty/staff using the results of our campus, the South Coast Air Quality Management District (AQMD) Commuter Survey. The total enrollment of the students in 2019 was about 26,000, and the number of faculty was about 1700. We collected data from 1799 students and all faculty/staff. The results from the students' commuting survey were scaled up to the total number of enrolled students to calculate the total carbon emissions from the students' commute to campus. In the survey, various questions were asked, such as the number of days student/ faculty/staff commute to campus, their zip code, commuter's mode of transportation for each trip during a week, and miles per gallon for the commuter's vehicle, etc. The transportation model multiplies the total number of miles commuted in each commute mode- obtained from the survey by the emission factor for that commute mode (kg of $CO2_e$ per mile). Then the result gets scaled up to the total population.

The Transportation model is defined by five variables. One variable is a Result (total energy used), three variables are Controls (distance, mpg, and unit conversion) and one variable is a Knob (number of trips). Together, these make it possible to model the energy used due to campus-related commutes.

The calculations can be modified in different ways depending on the selected transportation mode. For example, when students or faculty/staff carpool to campus, the resulted energy usage and carbon emissions is divided by the number of people who carpooled together. For public transportation like buses and Metrolink, the energy used can be calculated by a constant number (or factor) given by the U.S. Department of Transportation, which is recorded in Kg $CO2_e$ per mile per passenger. Then, it is multiplied by the total number of miles traveled by students using public transportation. The Kg $CO2_e$ per mile per passenger for the bus, is 0.224, and the Metrolink/Rail is 0.141 kg of $CO2_e$ per passenger in Southern California [Hodges, T, 2009]. We considered all the vehicles as passenger vehicles with 0.411 kg of $CO2_e$ per mile.

Electricity

Energy is frequently used directly in the form of electricity. This can be used in many ways in each building, from lights to computers to mini fridges. Due to the lack of monitoring of individual energy outlets, categorizing the energy usage depends on several approximations and assumptions. Several different variables could affect electricity usage. None of these variables are constants. All the variables are Knobs (number of lights, computers, walkways, personal devices, refrigerators, microwaves and projectors, and miscellaneous categories). One variable is a Result (total energy used). Using these variables together would make it possible to model the energy used as electricity. There is no granular-level data available for the electricity model, as the only data that we have is the metered reading of each building on the campus. But it cannot explain any breakdown of how much electricity was used by lights, microwaves, elevators, and other categories in a building. There was an extensive visual inspection done for three different buildings as a benchmark on campus to determine the number of lights, classrooms, offices, elevators, etc. Based on the class schedules obtained from the university scheduling offices, we did find the hours of operation of each classroom. Further, we made rough assumptions about the usage of other electricity-consuming devices. The buildings that were analyzed to see the energy consumption in different categories are King Hall, Salazar Hall, and Fine Arts. It is noted that this study only focused on electricity consumption in buildings and did not examine the carbon footprint of online instructions.

Heated Potable Water (HPW)

Potable water, or drinking water, is only heated for two circumstances: showers and sinks. Due to the limited amount of hot water needed, potable water is heated on an individual basis instead of at a central unit. On our campus, potable water is heated in each building separately. Each building has a water heater that runs on natural gas. Since we knew how much natural gas was used on campus to heat the water, we used that information to find the mass of water headed on campus. After calculating the mass of the water, we utilized it to calculate the energy used for heating the water as a function of other operational variables. In conclusion, the heated potable water model is defined by eight variables. Four variables are constant (efficiency of natural gas boilers, unit conversion factors, the specific energy of water, and incoming water temperature), two variables are knobs (the amount of water heated and the exiting water temperature), and two variables are results (the amount of energy and natural gas used).

The amount of monthly natural gas used by the entire university in the unit of therms was collected to obtain the energy consumption data for Heated Potable water. Certain assumptions were made to formulate the HPW model. We assumed that the efficiency of all the boilers based on their year and model would be around 82%. The data for the set temperature of the hot water and the temperature that the water goes into the heater were obtained from the facility personnel.

Heating, Ventilation, and Air Conditioning (HVAC)

The HVAC model depends on two factors: hours of operation and horsepower of the equipment in the air handling units. The horsepower of the equipment is the summation of the individual powers of each main piece of equipment in the HVAC system: The Return Fan, the Supply Fan, the Chilled Water (CHW) Pump, and the Compressors. These are the components present in each building. The Central Plant is where the cooling takes place, and its energy consumption is obtained from the meter reading. The hours of operation are based on the external temperature Monday through Saturday. The system is off on Sunday. The HVAC system remains turned off when the external temperature is lower than the thermostat's set temperature. The HVAC system turns on when the external temperature is higher than the thermostat's set temperature. The external temperature is higher during summer, resulting in higher hours of operation.

Similarly, the external temperature is lower during winter, resulting in lower hours of operation. The data for the HVAC model were obtained from three different areas. First, the power data were collected from the horsepower of the individual equipment in the air handling unit in each building. For example, the Return Fan, Supply Fan, CHW Pump, and Compressors each have associated horsepower, which varies in each building. Second, the hours of operation were determined based on the external temperature. Finally, the energy spent in the Central Plant to cool down the water to provide chilled water was determined from the meter reading. Together, these values enabled us to formulate our HVAC model.

The Heating Ventilation and Air Conditioning system (HVAC) energy consumption is not only affected by the operational hours but also by the external temperature. Therefore, HVAC energy usage is much higher in warmer months than in colder months. The HVAC model was formulated based on the equipment in the HVAC system and the number of daily operating hours. The number of hours per day was based on the number of hours that the external temperature was above the thermostat set temperature (i. e. 73 Degrees Fahrenheit), not the number of hours school was in session. Since the HVAC in all universities is set to a specific temperature where there is an automatic turn-on without human interaction, the main factor contributing to this model was the outside temperature.

Result and Discussion

Table I demonstrates the results of our analysis for the transportation model. Our analyses show that 95% of energy consumption/carbon emissions in the campus-related commutes comes from students' commute and 5% from faculty/staff commute. While the data used by the model is self-reported, it can still be seen as highly accurate. The commute data is reported by students and faculty/staff by completing a survey that is sent annually. It should be noted that volume of data obtained each year has increased due to additional surveys submitted by students and staff/faculty which resulted in an accurate analysis. For example, the annual average carbon emissions due to commuting to campus in 2019 were calculated to be approximately 58865 Ton of CO2e for students and 2965 Ton of CO2e for faculty/staff.

This gives an opportunity to show a general concept of how much energy is used by students, as well as shows possibilities for reduction (carpool, bus, etc.).

Figure 2 illustrates the breakdown of electricity usage in one of the analyzed buildings (i. e., King Hall building) as an example of the relative difference in the magnitude of electricity usage in various subcategories of the electricity model. The electrical energy consumed in king hall per month is approximately 172,794 Kwh. The results were compared with the meter reading, and the error was below 5%. The analyses for other buildings are available on our energy dashboard website.

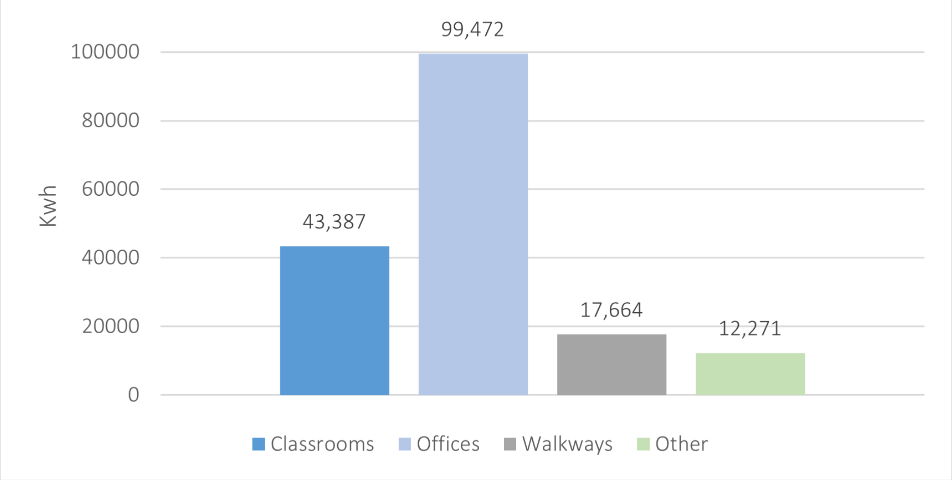
This electricity model is highly accurate but will require the most maintenance to remain so. As of now, the model is based on a current walk through of campus showing the items in use, and the energy used by those items. Due to the rapid growth of technology, many of these items are changed regularly as better items become available (new computers, projector instead of blackboard, etc.). For this model to be maintained accurately, this will need to be updated on a regular basis.

Figure 3 shows the percentage of monthly energy consumed to heat the potable water related to the total annual energy consumed in the HPW category (1.61×107 Kwh) in 2018. The weather temperature in February, March, and April is cooler, resulting in higher demand for the heated water. In addition, school is in session during these months, which means there are more students on campus. As you can see in Figure 4. the energy consumption is higher in February, March, and April. The energy combustion decreases in the hotter months from May to September. However, it was observed that the energy demand increased slowly after September but

Table 1
Annual Average CO2e Emissions Per Commute Mode

Commute Mode	CO$_{2,e}$ Emissions (Ton CO$_{2,e}$)
Drive Alone/Drop Off	53812.85
Rideshare (Uber/Lyft)	2565.82
Carpool	2483.63
Bus	2.27
Metrolink/Rail	0.99

Figure 2
Electricity Consumption for King Hall Building (KWh)



was less in December and January. The lower level of energy combustion in December and January is due to the winter break during that time. As was expected, there is very little energy used by heating potable water, so this accounts for a very small percentage of the campus energy usage overall.

The HVAC results are directly affected by the California's Mediterranean-like climate, where the summers are dry and hot, and winters are humid and freezing temperatures are rare. These weather conditions increase the use of HVAC, and the contribution of the HVAC is more than HPW [("Monthly weather forecast and climate Los Angeles, CA," 2021)]. Most of the university buildings are poorly ventilated with windows which results in no airflow from outside to inside through windows as all of them are closed. The airflow to keep the building cold during summers is through HVAC as there is no other way that the facility is held at that temperature. Based on our analyses the HVAC model accounts for a large percentage of the energy used on campus, which is the result of Los Angeles climate. Our results indicated that the energy used for each building's HVAC was between 20%-50% of

Figure 3

Energy Consumption in the Heated Potable Water Category in 2018 in Kwh

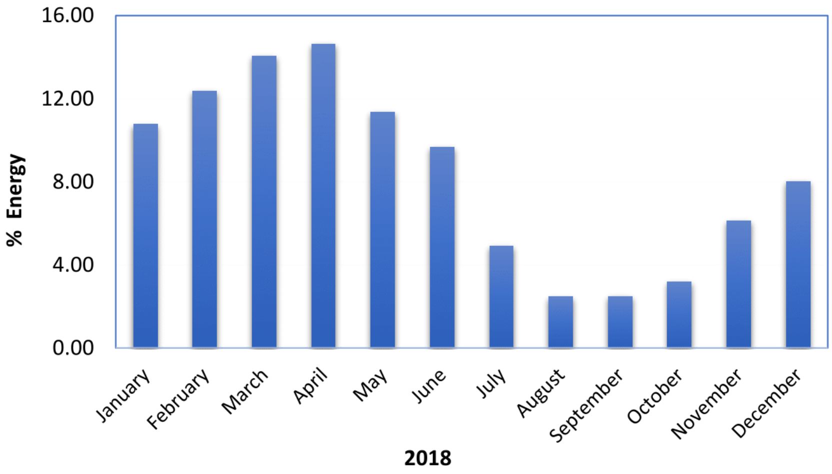
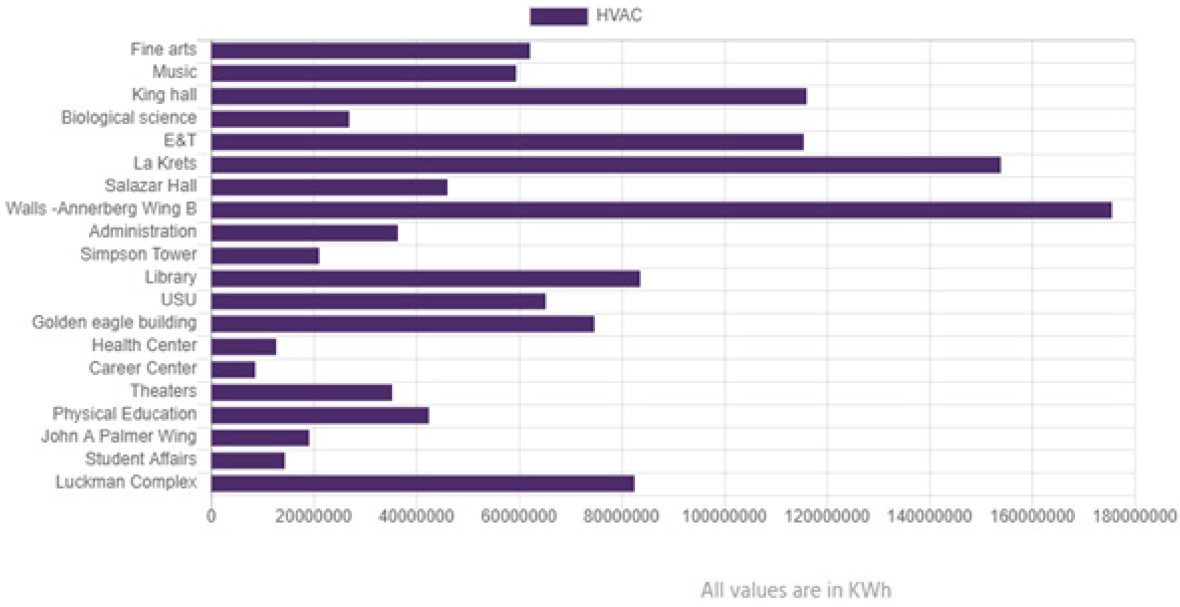


Figure 4

HVAC Annual Average Energy Consumption per Building in 2018



the total energy used per building. Figure 4 shows the HVAC energy consumption per building.

Overall, the HVAC system would represent a great opportunity for energy reduction as its contribution to energy consumption is relatively high and there are various ways to reduce its energy consumption (e.g., adjusting the schedule for course offerings, lowering the HVAC set temperature, etc.).

Finally, the carbon footprint analyses of all the analyzed energy-consuming sectors revealed that campus-related commute, total electricity usage (electricity consumption for lighting and HVAC), and heated potable water account for about 71%, 20%, and 9% of the total campus carbon emissions, respectively. It is noted that uncertainties were not considered in this study. Figure 5 shows the CO_2 emissions equivalent (Gg $CO2_e$) from different Energy-Consuming Categories in 2018. As illustrated in Figure 5 campus related commute is the largest energy consuming activity and contributor to carbon emissions. Generally, commuting-related activities are a major component of many institution's carbon emissions, and our analyses confirms this as well. This result highlights the importance of reducing campus-related carbon emissions by providing hybrid instruction (i.e., a combination of in-class and online learning) and promoting public transportation and carpooling by offering certain incentives.

Conclusion

After analyzing all the four model results for 2018, we concluded that students, faculty/ staff's commute to campus has the most substantial contribution to campus-related carbon emissions. Campus-related carbon emissions can be reduced by taking various measures such as changing lightbulbs with more energy-efficient options, increasing the set temperature in the HVAC system by few degrees, providing online/hybrid instruction and promoting public transportation and carpooling by offering certain incentives. California State University, Los Angeles campus has been working actively in all these areas to reduce its carbon emissions and promote sustainable behaviors. With the use of our interactive energy dashboard, the campus community should be able to better track and compare the energy consumption of different campus-related activities and further assess the impact of taking certain energy-saving and carbon-reducing measures on the reduction of the campus's overall carbon footprint. Also, the campus carbon footprint can be further reduced by utilizing renewable energy and purchasing carbon credits. The campus has already started utilizing renewable energy and low-carbon energy by using solar panels, operating a hydrogen fueling station on campus, and purchasing carbon credits. By taking various energy-saving measures, utilizing more renewable and low-carbon energy, we will reduce our carbon footprint and move toward a more sustainable campus.

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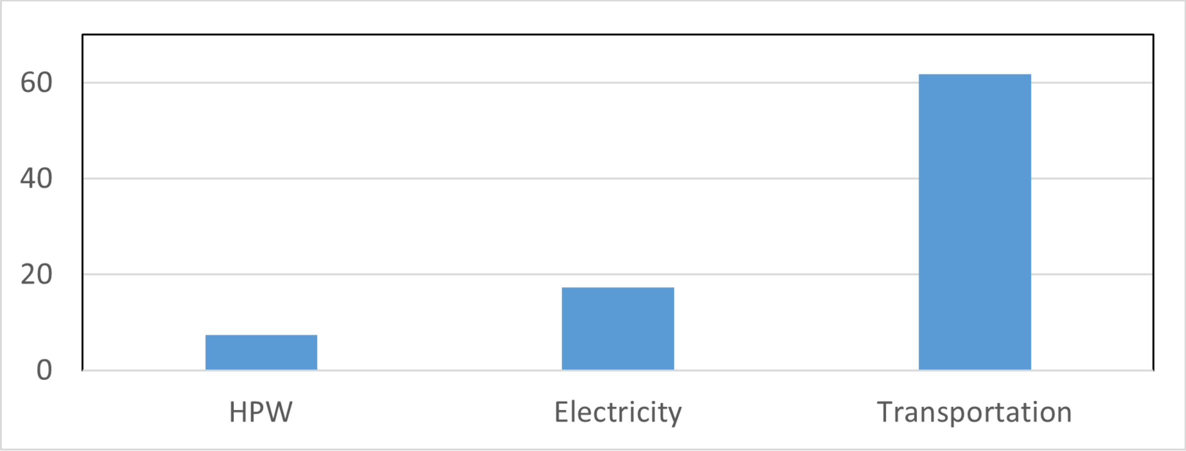
Figure 5

CO2 Emissions (Gg CO2e) from Different Energy-Consuming Categories in 2018



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