Greenhouse Gas Analysis of the Champaign County Forest Preserve District

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Milestone #3

ENVS 492 - Sustainability Capstone Project Based Learning

Greenhouse Gas Analysis of the Champaign County Forest Preserve District

Executive Summary

In order to sustain a healthy environment, it is mandatory to control and limit the release of greenhouse gases, particularly carbon dioxide (CO2). The Champaign County Forest Preserve District (CCFPD) is a local non-profit organization in Champaign County, Illinois that offers public services including conservation, restoration, and recreation, and are motivated to strive for improved sustainability of their own facilities. However, as a public organization, the CCFPD has limited resources and budget, so decreasing environmental impact needs to have minimal cost to the district. By decreasing energy use, the energy bills to the district will decrease, as well as the CO2 emissions associated with energy used.

We created a script in python that will take utility data records kept by the district and generate comparative plots of their energy use and corresponding CO2 emissions over time and space. This script is compatible with any range of years and will be able to be used indefinitely by the district, so that they can continue to evaluate their energy use for many years to come.

Going through several years of data and manually organizing and comparing trends for energy reduction in Excel would take a lot of time that staff working for the district could spend better elsewhere. By using programming to automate parts of the comparison process, time and resources are saved, and the process for continued analysis in future years becomes more streamlined.

With the results of the analysis for 2017, we found that Lake of the Woods was the preserve that used the most energy and had the most associated emissions. Most of the emissions for Lake of the Woods were caused by natural gas used for heating, and the three buildings with the highest emissions at the preserve were the Museum, the Greenhouse, and the Proshop Clubhouse.

As the building with the highest emissions, we examined the Museum of the Grand Prairie for areas of improvement as an example of how the CCFPD can use the script to target and evaluate potential money saving and emissions-reducing projects. With the assistance of U.C. Berkeley's "Home Energy Saver" tool, we estimated that the Museum can save approximately $4700 annually if upgrades were made to the furnace and insulation of the Museum.

Overall, the project was completed on schedule and provided the CCFPD with valuable plots and analysis identifying necessary trends that inform and will continue to inform areas of economic and environmental improvements. Moving forward, these plots will help inform policy and sustainable projects in the future of the CCFPD.

Introduction

Greenhouse gas (GHG) emissions released from the anthropogenic burning of fossil fuels have numerous negative impacts on the surrounding environment. With an increasing global population, the demand on industries will continue to exacerbate already-limited resources while producing more GHG emissions. This includes increasing the number of extreme weather events that will affect agriculture in developing countries and bleaching the world's coral reefs that are home to 25% of known marine species (WWF 2019). In order to sustain a healthy environment, it is mandatory to control and limit the release of GHGs, particularly carbon dioxide (CO2).

The Champaign County Forest Preserve District (CCFPD) is a local non-profit organization in Champaign County, Illinois that offers public services including conservation, restoration, and recreation. Their vision is "To provide excellent places and experiences for current and future generations", which motivates the district to strive for improved sustainability of their own facilities (CCFPD 2019). However, as a public organization, the CCFPD has limited resources and budget, which often need to be focused elsewhere rather than addressing sustainable improvements. This desire to decrease environmental impact while having minimal cost to the district can be accomplished by examining the district's energy use for areas of reduction. By decreasing energy use, the energy bills to the district will decrease, as well as the CO2 emissions associated with energy used.

The CCFPD keeps records of their energy utility bills, which contain district-wide energy-use data for several years. Analyzing this set of data will allow the park district to target improvements to energy efficiency and emissions in a way that can maximize cost savings and environmental impact. Analysis of this data has not occurred yet because the necessary resources to interpret the collected data have not been allocated. Going through several years of data and manually organizing and comparing trends for energy reduction in Excel would take a lot of time that staff working for the district could spend better elsewhere. By using programming to automate parts of the comparison process, time and resources could be saved, but there is not currently someone on staff who has the necessary skill set and bandwidth to devote to this project.

We propose to create a script in python that will take utility data and generate comparative plots of their energy use and corresponding CO2 emissions over time and space. This will allow the CCFPD to guide facility improvement projects and inform future policy decisions. With the results of this analysis for the most current year with complete data, we will also examine the building which we identify as the largest source of emissions within the district for areas of improvement as an example to how they can use the program to target and evaluate potential money saving and emissions-reducing projects. This script will be compatible with any range of years and will be able to be used indefinitely by the district, so that they can continue to evaluate their energy use for many years to come.

Objectives

We received utility invoices of diesel fuel, unleaded fuel, natural gas, propane, and electricity for each preserve within the district from 2013-2018. Using these invoices, our primary objective was to return plots representing GHG emissions and energy use from the district over different temporal and spatial scales. These plots can be used for future analysis to guide future facility and policy decisions.

Meeting this objective required a python script that created the plots, a standardized template holding utility information that the script interfaced with, and a training guide instructing future users how to run the script to produce particular desired plots.

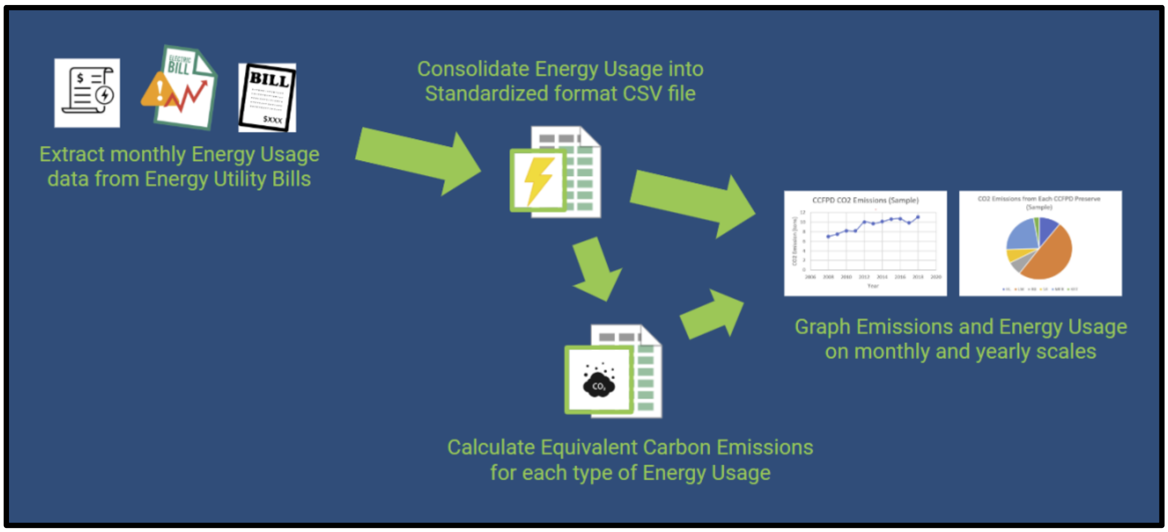

Figure 1: Data analysis process to create emissions and energy use graphs from energy utility bills

Because the CCFPD uses three different utility companies, and each company's utility invoice formats vary across years, automating data extraction from the invoices themselves would've been difficult. We manually entered the information needed into a separate csv file for each year. Column organization and csv naming conventions will not change between years, enabling the user to analyze multiple years of data with the same code. Figure 2 shows a sample of formatted data as well as the columns we chose to include for each datapoint from the utility bills.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	PRESERVE	BUILDING	ENERGY_TYPE	ENERGY_UNIT	ENERGY_PROVIDER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
2	HQ	Headquarters	ELE	KWH	Ameren	104	88	86	92	97	83	27	23	25	16	12	12
3	HQ	Bell Tower HQ	PRP	gal	Progressive	535.2	0	255.6	0	0	0	0	0	0	0	413.1	351.7
4	HQ	Heritage Hall	ELE	KWH	Ameren	3,184.00	2,926.00	2,572.00	2,571.00	2,451.00	2,825.00	2,992	2,768	2,515	2,475	2,493	2,672
5	LW	P1	ELE	KWH	Ameren	549	408	363	506	279	1150	2343	1988	816	1188	64.49	59.15
6	LW	P1	PRP	gal	Progressive	401.6	0	219.3	0	0	0	0	0	0	0	538.2	451.5
7	LW	P2	ELE	KWH	Ameren	939	736	678	717	645	1536	2616	1796	954	1172	975	774
8	LW	Bathhouse	ELE	KWH	Ameren	6	5	5	108	677	587	591	529	562	587	77	0
9	LW	Izaak Walton	ELE	KWH	Ameren	217	159	136	152	125	162	194	201	149	104	220	163
10	LW	Izaak Walton	PRP	gal	Progressive	100.1	0	0	0	0	0	0	0	0	0	97.1	102

Figure 2: Standardized Columns within CCFPD_Yearly_Energy_Usage_2017.csv

In this format, the csv file can accommodate for differences in the data supplied. If the column headings are the same, the number or order of the rows shouldn't matter when performing data analysis in python. This resilience allows our code to be adaptable to additions or subtractions of data (e.g. if a new building was added and demanded electric and propane). In the event that the format of future utility data changes (probable on the utility company's end), the Project Sponsor plans to task a new project team to automate a process that will pull specific data from the utility-provided data and place it into the template that we have created.

Since we have consolidated all the information into a year-specific csv file, it is possible to automate analysis and visualization using python. We wrote a python script that converts the amount of energy used into the corresponding kilowatt hours and carbon emissions, and then calculates and plots the total energy used in kilowatt hours and the total tons of CO2 emitted.

We started our analysis with data from 2017 to figure out the best ways to represent the data visually for one year, and then modified the script to work for the past and future years. Once we had several years of data in a changeable format, we were able to compare energy use and GHG emissions over multiple years for the district, each preserve, building, and type of energy. Figure 1 illustrates the conversion process of the received data from CCFPD into the appropriate charts for best visualization.

Our secondary objective was to analyze the plots so that we could provide a prime example of an improvement that the CCFPD could make in the future. With this specific analysis, we aimed to perform a case study that indicated which improvements can be made to decrease cost and environmental impact as well as showed the CCFPD exactly how these plots could be used to guide future change.

Finally, to properly handoff the successfully running script to the CCFPD, our last objective was to train the Project Sponsor (and other CCFPD employees who will interact with the program) on how the script functions and what parameters must be changed in order to produce desired plots. With this complete knowledge, we will present to the Environmental Committee on the results of this project.

Overall, analysis of these plots has potential to inform greener policy decisions and allow the CCFPD to continue to market themselves as an environmentally responsible establishment, which is expected to increase public interest. With a repeatable and user-friendly program, we hope that the CCFPD will be able to track their emissions information and the progress of their sustainability efforts in the years to come.

Scope

With the overarching goal of using the CCFPD's energy-use data (electric, natural gas, propane, diesel fuel, unleaded fuel) to create visually-informative plots of CO2 emissions, our tasks were focused on coding a concise and user-friendly script in python by converting our data into a standardized format, converting the standardized energy-use data into CO2 emissions, and ultimately calculating and plotting the total tons of CO2 emitted.

This analysis will allow the CCFPD to:

1) Verify the effectiveness of previous sustainability efforts

2) Inform future facility and policy decisions

3) Monitor its impact on the local environment

4) Communicate its environmental impact to the public

Task 1: Initial Set-up for project

To start the project, we needed to collect the data we would analyze from our project sponsor, as well as establish background knowledge of the problem. We learned about CCFPD through reading and visiting Lake of the Woods forest preserve on a tour with Peter Goodspeed. The following subtasks make up task 1:

- Background reading
- Retrieve data sample set
- Site visit with Project Sponsor
- Find emission factors for each type of energy used by CCFPD

Task 2: Convert all CCFPD energy data into a standardized format

The energy data we received from Project Sponsor and Finance Director was from three electric companies (Ameren, Constellation Energy, and Eastern Illini Electric), one gas/diesel company (United Fuel), and one propane company (Progressive Propane). As a result, the datasets were not given in the same format and the format of the data within one company may have changed over the time period in which we are analyzing. In order to standardize all of the given energy data into a csv or data frame, the following subtasks were accomplished:

- Develop a template for a csv file that can be populated by the CCFPD for future years
- Manually pull data from given Excel files and extract them into a csv file

Task 3: Convert energy and fuel use data into kilowatt hours and CO2 emissions

This task was essential for all subsequent tasks and subtasks. Our end goal was to plot tons of CO2 emissions emitted from the CCFPD, as well as the energy used in kWh. Thus, it was mandatory to accurately convert the energy data into equivalent kilowatt hours and metric tons of CO2. Free online tools helped us find conversion factors and complete the conversion. To complete this task, the following subtasks were accomplished:

- Identify each electric, heat, and transportation providers
- Identify production method of each energy source (e.g. coal versus natural gas)
- Using Python, calculate total energy use for: the entire district, each preserve, each building, by type of energy
- Identify conversion factors and online conversion tools
- Using Python, calculate total CO2 emissions for: the entire district, each preserve, each building, by type of energy
- Make the script repeatable for any year

Task 4: Plot CO2 Emissions and Energy Use

In addition to plotting emissions, we plotted energy use from the preserves. Visualizing energy use, in addition to emissions, will give CCFPD a reference to the correlation between emissions and energy use. To complete this task, the following subtasks were accomplished:

- Identify how to best visualize the energy use and emissions (i.e. how many graphs, what types of graphs)
- Identify how to best visualize the emissions (i.e. how many graphs, what types of graphs)
- Using Python, plot the calculated totals for energy use and emissions

Task 5: Applied Analysis of Building with Largest Energy Use and Emissions

While our Project Sponsor initially just asked us to produce plots of the CCFPD's emissions and energy use, we decided to take this project one step further by showing how the plots can be used to minimize economic and environmental impacts from their facilities. We performed a case study on the building with the largest energy use and emissions in the CCFPD. To complete this task, the following subtasks were accomplished:

- Analyze the plots to identify which building uses the most energy and produces the most emissions
- Analyze the plots to identify which energy type is responsible for the most emissions
- Talk with facility/building staff to identify current conditions/upgrades/future plans for that facility's energy type

- Tour the facility to better visualize and comprehend the energy type's setup and function

- Use UC Berkeley's "Home Energy Saver Tool" to run a model that recommends which upgrades would benefit the building's energy/emission/cost needs and goals.

Task 6: Develop Training Materials and Train Project Sponsor

After we had a successfully running script, we aimed to train our project sponsor on how to use the script. We will make sure that their computers have the proper software and they have a user's manual. To complete this task, the following subtasks were accomplished:

- Developing a user's manual for continued utilization
- Installing Jupyter notebook on a CCFPD computer
- Make sure all file paths are correct for proper running
- Train Project Sponsor Peter Goodspeed in how to use script

Task 7: Present findings to the CCFPD Sustainability Committee

Peter Goodspeed wants us to present the results of this project to the CCFPD Sustainability Committee in order to show them what the current state of the District is and to inform them of potential future changes that can be made to further the District's sustainability efforts. We are prepared to present at Headquarters on Lake of the Woods Forest Preserve on December 16, 2019 at 12:30pm. To complete this task, the following subtasks were accomplished:

- Complete the final report and presentation for the course
- Revise the final presentation specifically for the Board
- Rehearse presentation in front of Project Advisors and Project Sponsor

Completing the GHG analysis of the Champaign County Forest Preserve District required several tasks and subtasks that work to standardize given energy data in order to effectively plot carbon dioxide emissions that easily depict the entire district and each preserves impact on the community. With descriptive plots, it is our hope to present our results to the CCFPD Board of Directors who can take this information to improve the CCFPD's operations for a more sustainable future.

Results and Discussion

The following action items have been accomplished:

1. Updated Electric Emission Factor - We recognized that the electricity emission factor could be more pertinent to Illinois. We calculated a new electric emission factor (seen in row 1 of Figure 3) based on the total electric generation and carbon dioxide emissions in Illinois, publicly available data from the U.S. Energy Information Administration. All other emission factors were identified as accurate and pertinent to Illinois. These factors were provided by the U.S. Environmental Protection Agency and the U.S. Energy Information Administration.

Type of Energy	Emission Factor
Electric	$5.63* 10^{-4}$ metric tons CO2/kWh
Gas	.0551 metric tons CO2/gas therm
Propane	$5.761* 10^{-3}$ metric tons CO2/gal propane
Unleaded	$8.887* 10^{-3}$ metric tons CO2/gal
Diesel	$10.18* 10^{-3}$ metric tons CO2/gal

Figure 3: Energy emission factors provided by the EPA and EIA

2. Completed Python Code - We completed the Python script that converts all energy data into equivalent kilowatt hours, converts all energy data into carbon dioxide emissions, and plots the energy and emissions over different spatial and temporal scales. Excerpts from the script can be seen in Figures 4 and 5 below.

   We ensured that the Python script can easily be used to analyze any year by including a single line of code (line 2 in Figure 4) that the analyzer can manually change. For example, if the analyzer wishes to evaluate the year 2015, line 2 is the only code that (s)he must change before rerunning the program and receiving the new plots that correspond to the year 2015.

CELL 2: User Inputs

```
#Path to data, directory contains a folder with all the standardized data
my_directory = r"C:\Users\wacke\Documents\ENVS 492"

# Change the list "years" to match the list of years you want to analyze.
years = [2017,2018]

# Change preserve_name to specify which preserve you want to see plots of in more depth
preserve_name = 'LW'

# Change building_name to specify which building you want to see plots of in more depth
building_name = 'Museum'

# Change textcolor to change the color of text shown on figures
textcolor = "black"

# Change sizeoflabels to change the size of the text on the figures
sizeoflabels = "large"
```

Figure 4: Section of Python script that converts all given energy data into equivalent kilowatt hours

CELL 4: Data Visualization

```
params = {"ytick.color" : textcolor,
          "xtick.color" : textcolor,
          "axes.labelcolor" : textcolor,
          "axes.edgecolor" : textcolor,
          "axes.labelsize" : sizeoflabels}

plt.rcParams.update(params)

prvs = ['LW', 'HL', 'MF','HQ', 'SR']


for year in years:
    leaf = str(year)
    mypath = os.path.join(my_directory, leaf)

    KWHeq = pd.read_csv(mypath+"_energy_and_emissions\CCFPD_KWHeq_" + str(year) + ".csv")
    Emissions = pd.read_csv(mypath+"_energy_and_emissions\CCFPD_Emissions_"+str(year)+".csv")

    # Plot the annual energy and emissions use by preserve
    kwh_title = 'Total CCFPD Energy Use in ' + str(year)
    kwh_x = 'Preserves'
    kwh_y = 'Energy (Equivalent kWh)'
    plot_prsv_energy(KWHeq, prvs, kwh_title, kwh_x, kwh_y, textcolor)
    plt.savefig(mypath+'_energy_and_emissions/'+str(kwh_title)+'.png', bbox_inches = "tight")
```

Figure 5: Section of Python script that plots annual energy use and annual emissions for each preserve

3. Produced CO2 Plots - The most valuable results we achieved were the plots produced from the utility data. With visual representations of temporal and geospatial trends, the CCFPD will be able to focus their sustainability improvement efforts into the areas that can have the most total impact. See below for an analysis on a set of plots produced by this effort.

   For interpretation of the results, the following acronyms are provided:

FOREST PRESERVE	ENERGY TYPE
HQ- Headquarters	DSL- Diesel Fuel
LW- Lake of the Woods	UNLD- Unleaded Fuel
MF- Middle Fork	GAS- Natural Gas
SR- Sangamon River	PRP- Propane
HL- Homer Lake	ELE- Electricity

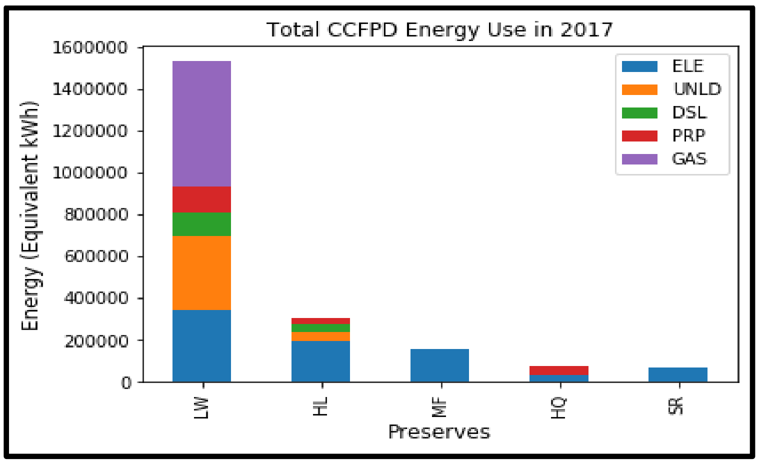

Figure 6

Figure 6 depicts the CCFPD's total energy use in equivalent kilowatt hours (ELE, UNLD, DSL, PRP, GAS)) in 2017 for each preserve (LW, HL, MF, HQ, SR). The following observations were concluded during the analysis of Figure 6:

- *Lake of the Woods Forest Preserve has the highest energy demand in the district.* This high demand is due to the number of facilities/features on site (23 facilities and features are on this preserve while the second highest concentration belongs to Homer Lake Forest Preserve, with 12 facilities and features). LW also uses all of the energy types compared to the smaller preserves (i.e. MF, SR), which only use one of the energy types, electric.

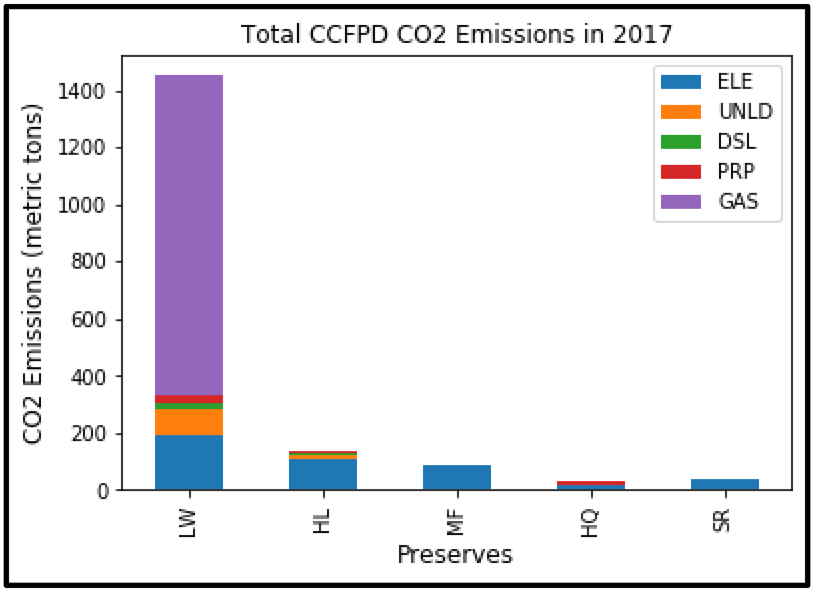

Figure 7

Figure 7 depicts the CCFPD's total emissions from each energy type (ELE, UNLD, DSL, PRP, GAS) in 2017 for each preserve (LW, HL, MF, HQ, SR) in metric tons of carbon dioxide. The following observations were concluded during the analysis of Figure 7:

- *Lake of the Woods Forest Preserve produces the most CO2 emissions in the district.* These high emissions are due to the number of facilities/features on site (23 facilities and features are on this preserve while the second highest concentration belongs to Homer Lake Forest Preserve, with 12 facilities and features). LW also uses all the energy types compared to the smaller preserves (i.e. MF, SR), which only use one of the energy types, electric.
- *Most of the emissions from Lake of the Woods is from natural gas.* Despite Figure 6 showing that natural gas, unleaded fuel, and electricity, all account for a similar amount of Lake of the Woods energy use, natural gas has a larger emissions factor, making it the largest contributor to emissions.
- Throughout the year (of 2017), the CCFPD produces a total of 1,741 metric tons of CO2, equivalent to the emissions produced by 435 Honda Civics or 174 US citizens in one year (Cx Associates, 2012).

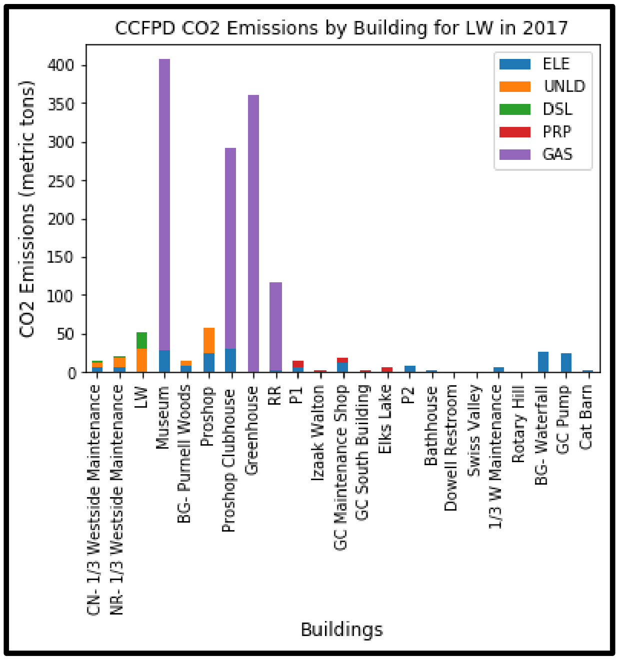

Figure 8

Figure 8 depicts the CCFPD's total emissions from each energy type (ELE, UNLD, DSL, PRP, GAS) in 2017 for each building in Lake of the Woods in metric tons of carbon dioxide. The following observations were concluded during the analysis of Figure 8:

- *The Museum of the Grand Prairie produces the most CO2 emissions in Lake of the Woods Forest Preserve.* Other high emitters include the Greenhouse and the Proshop Clubhouse. This plot was used to further identify where the CCFPD's efforts can be best spent when upgrading features on particular buildings if their goal is to reduce energy use and emissions.

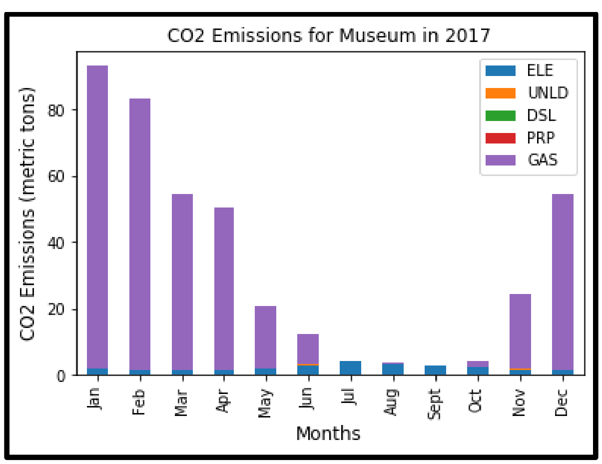

Figure 9

Figure 9 depicts the Museum's total emissions (in metric tons of carbon dioxide) from each energy type (ELE, UNLD, DSL, PRP, GAS) in 2017. The following observations were concluded during the analysis of Figure 9:

- *The museum uses the most natural gas in the winter months for heating*. If heating upgrades were made to the museum, it's possible that the amount of natural gas used and, consequently, emissions produced would noticeably decrease.

4. Created Training for CCFPD - A project objective is to allow continued use of this program so the CCFPD can track their emissions, see the progress of their sustainability efforts, and inform greener policy decisions in the years to come. To meet this objective, it isn't necessary for future users to learn how to code, but rather to learn to understand the code. Most importantly, future users must know what they need to change to get the results they want to analyze. A complete training manual for this Python script has been included in the Appendix.

5. Performed a Case Study - The most beneficial aspect of obtaining these energy use and emissions plots is the ability to use them to identify patterns or trends that indicate potential areas of economic or environmental improvements. We identified that the building that uses the most energy, and consequently produces the most emissions, was the Museum of the Grand Prairie at Lake of the Woods Forest Preserve. Heating with natural gas is the primary reason for the Museum's high energy consumption. With the help of the Project Sponsor and others from the Museum, we discovered the following:

    - The Museum's furnaces were last upgraded in 2010 and 2013 and are due for replacement within the next 5-8 years.
    - The Museum has single-pane windows and can cost-effectively improve insulation by replacing them with double-pane windows.
    - The Museum's current roof has no insulation and can benefit significantly by installing insulation.
    - The "porch area" has R10-R20 insulation and can benefit from upgrading to a higher level.
    - The Museum's walls are insulated with 4" fiberglass batts and can benefit from upgrading to a higher level.

    With the assistance U.C. Berkeley's "Home Energy Saver" tool, we estimate that the Museum can save approximately $4700 annually if upgrades were made to the features listed above.

Upgrade	Estimated Cost	Annual Savings	Payback (yrs)	Annual Avoided Emissions
Energy Star Furnace	$ 8,379.00	$ 1,244.00	7	15,706.00
Roof Insulation	$ 9,793.00	$ 2,883.00	3	38,035.00
Double-Pane Windows	$ 1,296.00	$ 89.00	15	1,185.00
Basement Wall Insulation	$ 6,321.00	$ 551.00	11	6,862.00

Figure 10

Moving Forward

Visualizing and analyzing the CCFPD's emissions and energy use across different temporal and spatial scales satisfies the need for a more comprehensive and accurate use of data. In this project, we were able to identify trends and offer suggestions for reduced emissions and energy use within the district's preserves with a Python script. With more time, we would have liked to 1) perform a more comprehensive analysis by evaluating a larger range of years, 2) automate the process of making a standardized csv of energy data, and 3) code an interactable graphic user interface for the user.

In the United States, 20-46% of annual GHG emissions are absorbed by naturally-vegetated forests and grasslands (CMAP, 2013) . It is important that the CCFPD sustains its own forests and grasslands because they have the potential to offset a portion of the Champaign County emissions. A promising future use of this project will be coupling it with the CCFPD's current effort to map each preserve's acreage and ecosystem makeup. Using this information, it may be possible to identify the approximate amount of carbon dioxide emissions that the entire district uptakes annually. These two efforts can work in tandem to quantify the CCFPD's net carbon emissions. This can indicate if the CCFPD is a carbon source or sink within Champaign County.

We hope that this project will continue to be used and added on to in future years by the CCFPD. With it, they can continue to analyze their past and present emissions and perform case studies, similar to the Museum, if their produced plots indicate areas of improvement.

Project Schedule Update

Week	7	8	9	10	11	12	13	14	15	16	17
Dates	10/7	10/14	10/21	10/28	11/4	11/11	11/18	11/25	12/2	12/9	12/16
Task 1: Initial Set-up											
Retrieve data sample set											
Site visit with Project Sponsor											
Task 2: Convert Energy Data into Standard Format											
Create template combining energy data for each building											
Create script to pull data for each building & preserve											
Task 3: Convert Energy & Fuel Data into CO2 Emissions											
Using Python, calculate total energy use for: the entire district, each preserve, each building, by type of energy											
Identify conversion factors											
Write script to aggregate monthly and annual emissions											
Calculate total CO2 emissions for district, each preserve, each building, and type of energy											
Task 4: Plot Tons of CO2 Emitted and Energy Use											
Identify how to visualize energy and emissions with plots											
Plot energy use and emissions for: the entire district, each preserve, each building, by type of energy											
Task 5: Perform Case Study of the Museum											
Plot Analysis: Identify which building produces most energy and emissions and which energy type is responsible											

Work with facility staff for tour and interview of facility											
Identify potential upgrades with UC Berkeley's Home Energy Saver Tool											
Task 6: Develop Training Materials and Train Project Sponsor											
Develop a user manual for continued utilization											
Train Project Sponsor how to use the script											
Task 7: Present Results to CCFPD Sustainability Committee											
Complete final report and presentation											
Revise final presentation for the Sustainability Committee											
Present to Project Sponsor and Sustainability Committee											

The duration of this project was 10 weeks. Tasks 1 and 2 had to be complete before we began any further tasks. Task 3 had to be complete before Task 4, while Tasks 5 and 6 could be done simultaneously. Tasks 2, 3, and 4 were on the critical path to complete this work. Task 2 was on the critical path because it was necessary for the script to be repeatable for other years. If we extended the duration of this task, the subsequent tasks (which require more time) would've been stressed. Task 3 was on the critical path due to the absolute necessity of its completion. Without converting the energy data into CO2 emissions, the corresponding plots cannot be created. Like Task 3, Task 4 also required a longer duration of time. This was the final task that must be completed because it directly produces the project deliverables.

Organizational Breakdown Structure

Our organization structure is highlighted in Figure 8 below. Charlee Thompson lead written communication efforts (e.g. emailing the project sponsor, managing project deliverables, and setting up meetings), but both project team members contributed to written communication measures. Grace Wackerman lead data analysis efforts (writing the python scripts, proper visualization techniques), but both project team members contributed to data analysis efforts. Peter Goodspeed, the Project Sponsor, was our main point of contact within the CCFPD. John Baker, the CCFPD Finance Director, was the main advisor for questions specific to the raw utility data. Project Advisors, Lance Schideman and Vince Spagnola, were responsible for answering questions specific to project management.

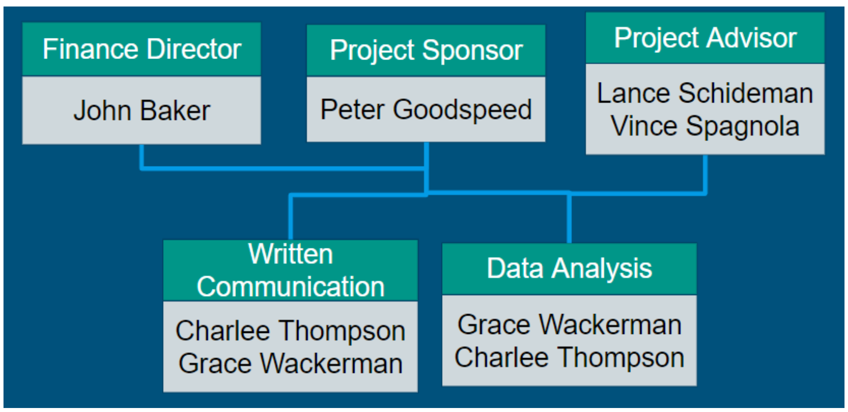

Figure 9: Project Organizational Breakdown Structure

Budget

To complete this project, we did not require monetary resources. We were equipped with the necessary software and hardware. Our primary project resource was time. Weekly, Charlee and Grace spent 2 hours in class on the project, and 1.5 hours meeting outside of class, as well as 2 hours working individually. Over the course of the semester, the total time available to work on this project was approximately 99 person hours.

The most time-consuming elements were Tasks 3 & 4. Together, they took approximately 60 of our person hours, while the remaining tasks took the remaining 39 hours. If we assigned a standard rate for an internship at the CCFPD, $12/hr, our time-budget would be equivalent to $1188 total for the 99 person hours.

Conclusion

Upon completion of this project, we were able to effectively plot the Champaign County Forest Preserve District's energy use and carbon dioxide emissions. Throughout the plotting process, we identified that

Lake of the Woods produces the most emissions, and that natural gas used for heating is the culprit. The Museum of the Grand Prairie was the largest user of natural gas and can make significant improvements to economic and environmental efficiency with heating upgrades, starting with roof insulation. The case study of the Museum was a successful example of how we hope that the CCFPD can use our plotting program. We will hand off our code, training guide, and analysis to the CCFPD for their internal use.

Acknowledgements

We would like to express sincere gratitude to our project sponsor, Peter Goodspeed, for providing guidance, offering suggestions, answering questions, and giving us a tour of Lake of the Woods as our primary contact at the Champaign County Forest Preserve District. We would also like to thank John Baker, who provided us with all CCFPD utility data and answered our questions pertaining to utilities and finance, and Tim Sullivan, who provided us with information related to the Museum's heating system and upgrades.

Creating successful code was possible through review and advice from John Drake in the Department of Computer Science and Avinash Madhavan in the Department of Electrical and Computer Engineering at the University of Illinois at Urbana-Champaign.

Finally, we would like to give special thanks to our project advisors, Dr. Lance Schideman and Vince Spagnola who organized the course and offered valuable feedback and suggestions throughout the duration of this effort.

Group Reflections

Pursuing and completing this project offered us valuable opportunities to learn new technical and non-technical skills while working towards a goal that we both saw as important. What we personally gained from this project was the chance to learn and improve our coding skills in Python. This is a skill that will be relevant to each of us in our future academic and professional careers. Additionally, we gained experience working as a self-lead team, mimicking real-world scenarios that we each will encounter numerous times throughout our professional careers.

Similar to any project, we identified lessons learned from decisions/mistakes that, if avoided, would streamline the project's progress. Before initiating this project, we underestimated the effort and time needed to learn how to accomplish desired tasks in Python. If we were to do this project again, we would likely adjust our schedule so that plotting was a couple of weeks sooner. This adjustment would allow us to meet some of the deliverables we outlined in the "Moving Forward" section: 1) perform a more comprehensive analysis by evaluating a larger range of years, 2) automate the process of making a standardized csv of energy data, and 3) code an interactable graphic user interface for the user.

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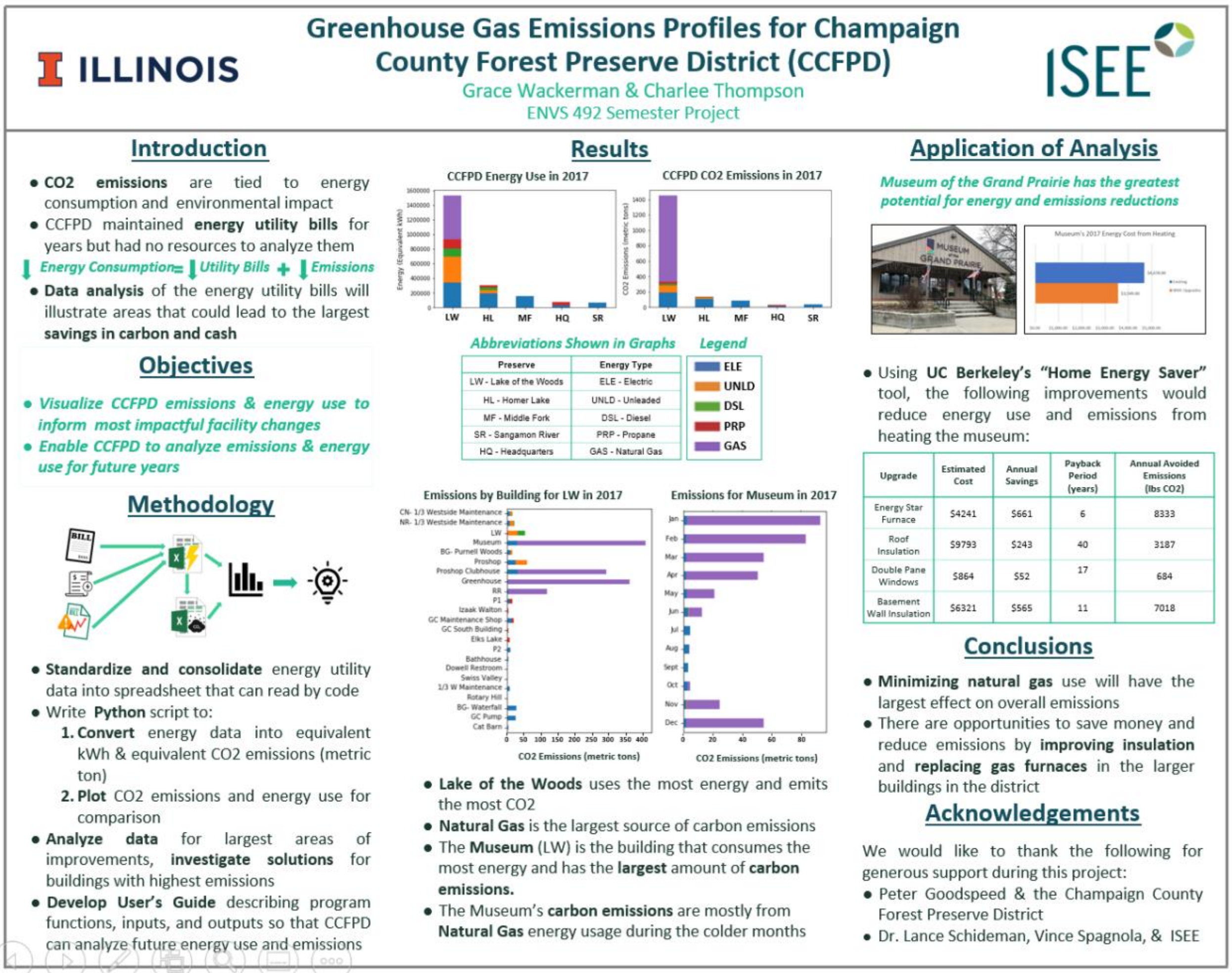
APPENDIX

I. Poster for Expo



II. Training Guide

Greenhouse Gas Analysis of the Champaign County Forest Preserve District

TRAINING GUIDE

Purpose

The Champaign County Forest Preserve District (CCFPD) has emphasized the need for accurate and detailed data for strategic planning. With it, they hope to best guide future internal policy decisions by evaluating the effectiveness of their current and future practices using their utility data.

To help achieve this goal, a python script that calculates and plots metric tons of CO2 emitted on different spatial and temporal scales has been created. With visual representations of seasonal, monthly, and annual trends in emissions across the district, the CCFPD will be able to focus their sustainability improvement efforts into the areas that can have the most total impact.

It isn’t necessary for future users to learn how to code, but rather to learn to understand the code. Most importantly, future users must know which inputs they need to change to get the results they want to analyze. This Training Guide outlines and details the function of the python script.

What does the Code do?

In this notebook, we will calculate greenhouse gas emissions from utility bills for the Champaign County Forest Preserve District (CCFPD). This program will:

1. Load energy data from a standard template
2. Convert energy data in comparable kilowatt hours and metric tons of CO2
3. Plot energy and emissions for each preserve on different spatial and temporal scales

User Inputs

The intent of automatting the tasks of plotting the CCFPD energy and emissions over different spatial and temporal scales is to provide an easier and faster experience plotting and analyzing a large and changing dataset. The following describes and details what the user needs to input to plot a range of years when a new year is analyzed:

CELL 2: User Inputs

```
#Path to data, directory contains a folder with all the standardized data
my_directory = r"C:\Users\wacke\Documents\ENVS 492"

# Change the list "years" to match the list of years you want to analyze.
years = [2017,2018]

# Change preserve_name to specify which preserve you want to see plots of in more depth
preserve_name = 'LW'

# Change building_name to specify which building you want to see plots of in more depth
building_name = 'Museum'

# Change textcolor to change the color of text shown on figures
textcolor = "black"

# Change sizeoflabels to change the size of the text on the figures
sizeoflabels = "large"
```

Figure 1

my_directory

A directory catalogues a specific pathway to a particular folder or file on the User's personal computer. The directory that needs to be set by the user is the folder that would be where all the files will be created. This folder should also contain the folder with the standardized data.

years

The most important user input is the year. Whichever year or range of years the User chooses to analyze can be entered in **years**. Changing the year will allow for the python script to read the corresponding standardized utility spreadsheet, save energy and emissions csv's with the appropriate name, and plot with the appropriate labels.

preserve_name

Changing preserve_name allows for the user to generate plots specifically for that preserve.

building_name

Changing building_name allows for the user to generate plots specifically for that building.

textcolor

Change **textcolor** to change the color of the text on the figures.

sizeoflabels

Change **sizeoflabels** to change the size of the text on the figures.

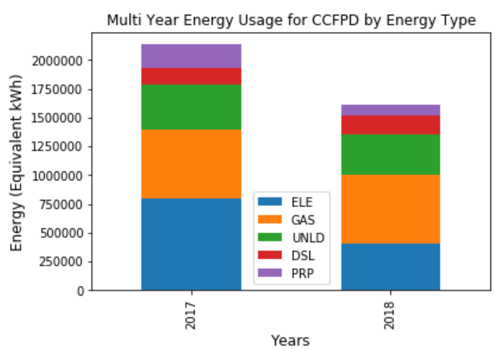
Comments

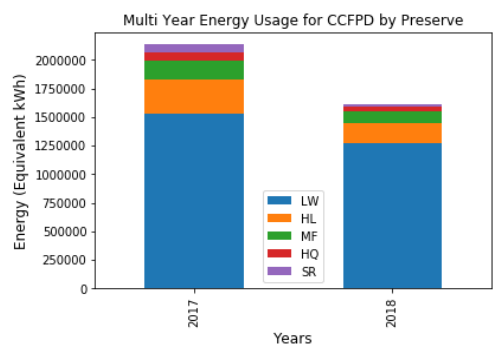
Within each cell, comments (notated as green text beginning with "#") are used to further describe the function of the code below it. Comments can be edited without affecting the function of the cell or entire python script.

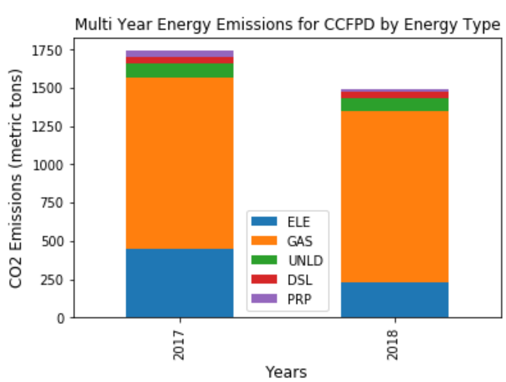
The User is free to edit comments to satisfy their personal understanding of the script.

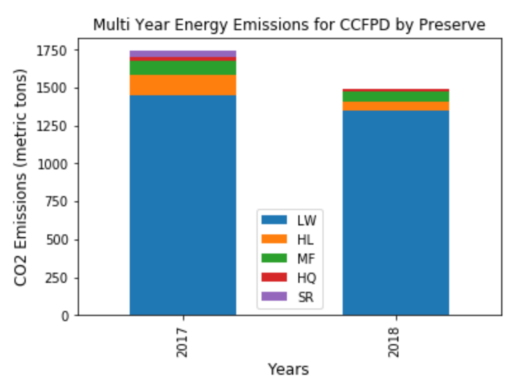
Outputs

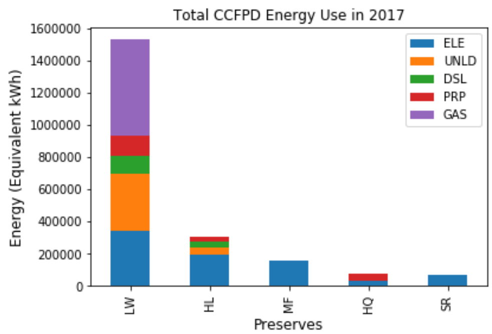
CSV files will be saved containing equivalent kWh information and the equivalent emissions for each year analyzed. The data saved in the files will be visualized in a series of plots. The following plots were created for the range of years of 2017-2018:

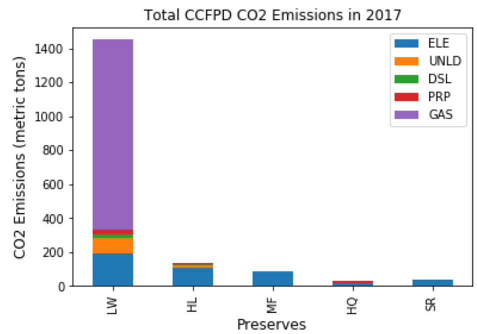


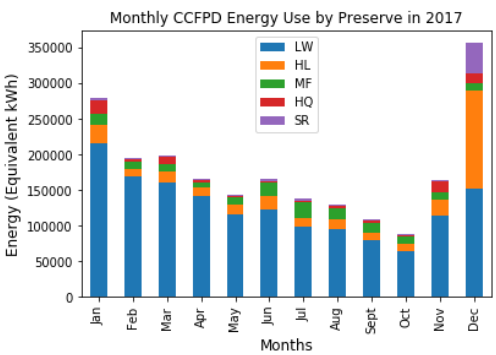


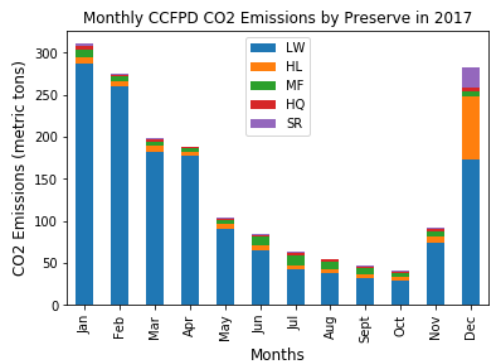


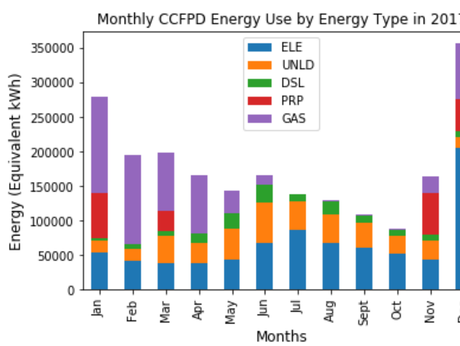


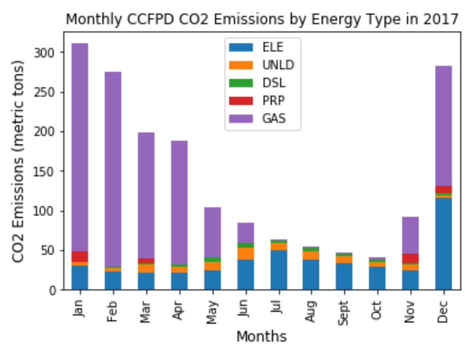

Total CCFPD Energy Use in 2017
Energy (Equivalent kWh)
Preserves
LW
HL
MF
HQ
SR
ELE
UNLD
DSL
PRP
GAS

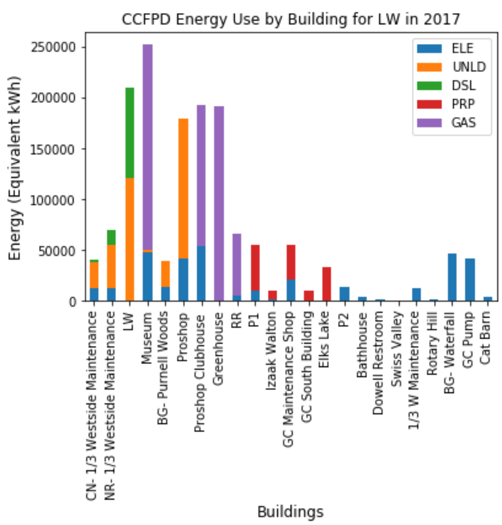

Total CCFPD CO2 Emissions in 2017
CO2 Emissions (metric tons)
Preserves
LW
HL
MF
HQ
SR
ELE
UNLD
DSL
PRP
GAS

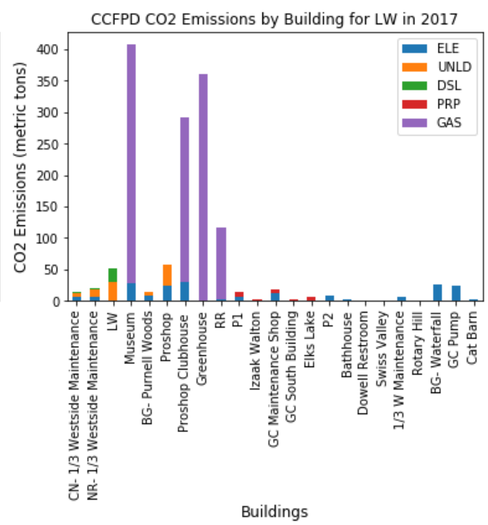

Monthly CCFPD Energy Use by Preserve in 2017
Energy (Equivalent kWh)
Months
LW
HL
MF
HQ
SR

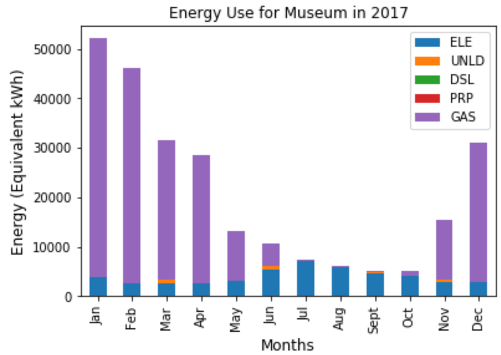

Monthly CCFPD CO2 Emissions by Preserve in 2017
CO2 Emissions (metric tons)
Months
LW
HL
MF
HQ
SR

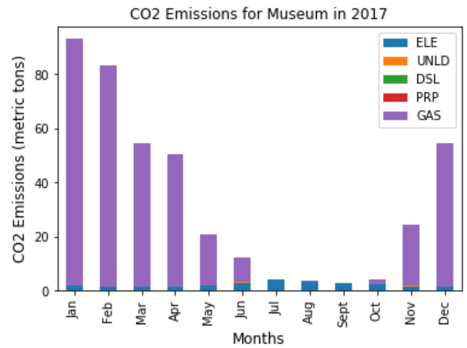

Monthly CCFPD Energy Use by Energy Type in 2017
Energy (Equivalent kWh)
Months
ELE
UNLD
DSL
PRP
GAS

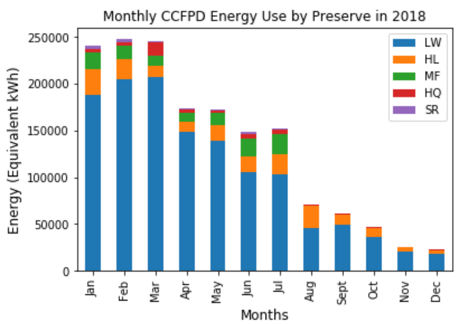

Monthly CCFPD CO2 Emissions by Energy Type in 2017
CO2 Emissions (metric tons)
Months
ELE
UNLD
DSL
PRP
GAS

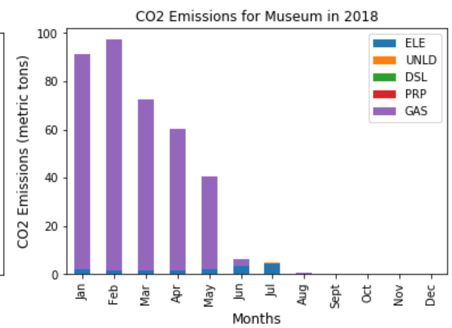

CCFPD Energy Use by Building for LW in 2017
Energy (Equivalent kWh)
Buildings
ELE
UNLD
DSL
PRP
GAS

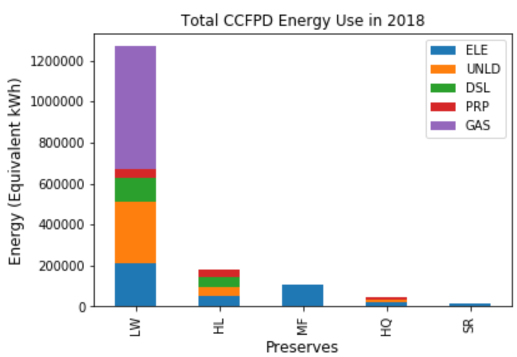

CCFPD CO2 Emissions by Building for LW in 2017
CO2 Emissions (metric tons)
Buildings
ELE
UNLD
DSL
PRP
GAS

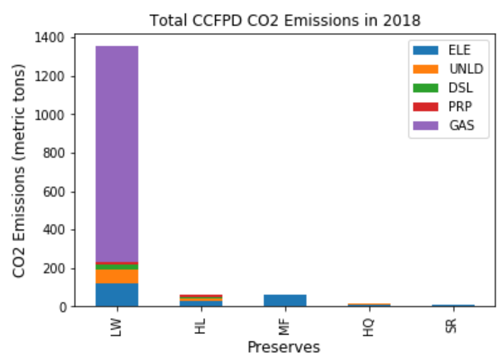

Energy Use for Museum in 2017
Energy (Equivalent kWh)
Months
ELE
UNLD
DSL
PRP
GAS

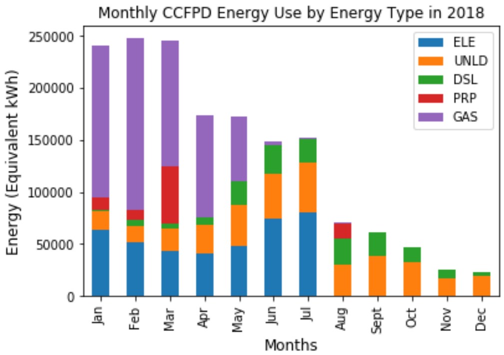

CO2 Emissions for Museum in 2017
CO2 Emissions (metric tons)
Months
ELE
UNLD
DSL
PRP
GAS

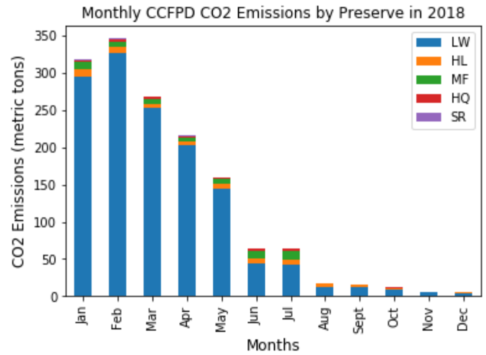

Monthly CCFPD Energy Use by Preserve in 2018
Energy (Equivalent kWh)
Months
LW
HL
MF
HQ
SR

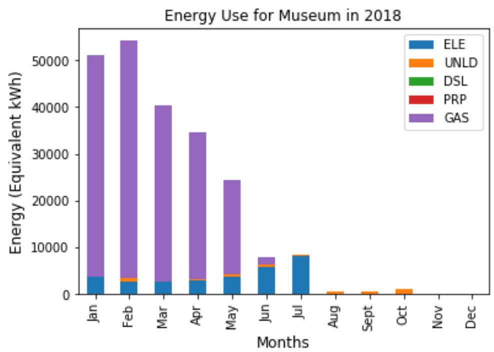

CO2 Emissions for Museum in 2018
CO2 Emissions (metric tons)
Months
ELE
UNLD
DSL
PRP
GAS

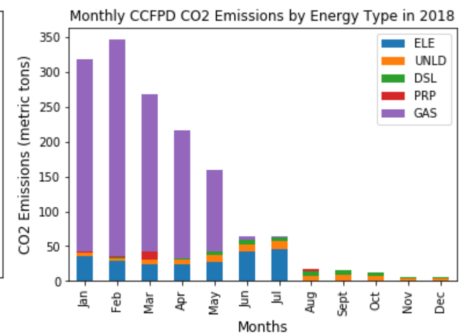

Total CCFPD Energy Use in 2018
Energy (Equivalent kWh)
Preserves
ELE
UNLD
DSL
PRP
GAS


Total CCFPD CO2 Emissions in 2018
CO2 Emissions (metric tons)
Preserves
ELE
UNLD
DSL
PRP
GAS


Monthly CCFPD Energy Use by Energy Type in 2018
Energy (Equivalent kWh)
0
50000
100000
150000
200000
250000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Months
ELE
UNLD
DSL
PRP
GAS


Monthly CCFPD CO2 Emissions by Preserve in 2018
CO2 Emissions (metric tons)
0
50
100
150
200
250
300
350
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Months
LW
HL
MF
HQ
SR

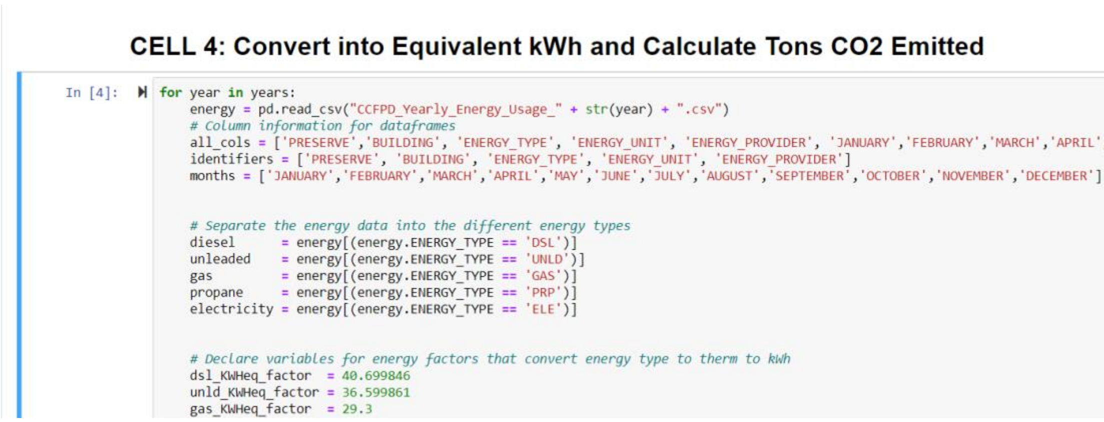

Energy Use for Museum in 2018
Energy (Equivalent kWh)
0
10000
20000
30000
40000
50000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Months
ELE
UNLD
DSL
PRP
GAS


Monthly CCFPD CO2 Emissions by Energy Type in 2018
CO2 Emissions (metric tons)
0
50
100
150
200
250
300
350
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Months
ELE
UNLD
DSL
PRP
GAS

Cells

The python script has been organized so that separate tasks are in different "cells". There are 5 cells, each with a descriptive title of the function that the code within them performs.

For example, the function of **CELL 4** is to calculate the emissions that correspond to the energy data provided in the standardized utility spreadsheet. This is described in **CELL 4**'s title: "CELL 4: Convert into Equivalent kWh and Calculate Tons CO2 Emitted". See Figure 1 below for an excerpt of **CELL 4**.



CELL 4: Convert into Equivalent kWh and Calculate Tons CO2 Emitted

```
In [4]:  for year in years:
             energy = pd.read_csv("CCFPD_Yearly_Energy_Usage_" + str(year) + ".csv")
             # Column information for dataframes
             all_cols = ['PRESERVE','BUILDING', 'ENERGY_TYPE', 'ENERGY_UNIT', 'ENERGY_PROVIDER', 'JANUARY','FEBRUARY','MARCH','APRIL',
             identifiers = ['PRESERVE', 'BUILDING', 'ENERGY_TYPE', 'ENERGY_UNIT', 'ENERGY_PROVIDER']
             months = ['JANUARY','FEBRUARY','MARCH','APRIL','MAY','JUNE','JULY','AUGUST','SEPTEMBER','OCTOBER','NOVEMBER','DECEMBER']


             # Separate the energy data into the different energy types
             diesel      = energy[(energy.ENERGY_TYPE == 'DSL')]
             unleaded    = energy[(energy.ENERGY_TYPE == 'UNLD')]
             gas         = energy[(energy.ENERGY_TYPE == 'GAS')]
             propane     = energy[(energy.ENERGY_TYPE == 'PRP')]
             electricity = energy[(energy.ENERGY_TYPE == 'ELE')]


             # Declare variables for energy factors that convert energy type to therm to kWh
             dsl_KWHeq_factor  = 40.699846
             unld_KWHeq_factor = 36.599861
             gas_KWHeq_factor  = 29.3
```

Figure 2

The following describes and details the function of the 5 cells:

CELL 1: A "library" is a file that contains a set of useful code, such as simple functions, complex functions, or variables. CELL 1 imports all libraries needed at any point in the rest of The python script. Do not change the code in CELL 1.

CELL 2: This Cell is where the user can specify the range of years they want to output graphs for as well as what color and size they want the text on the figures to appear as. **Years** is a list and the user can input any number of years by listing the years wanted in the brackets and separating them with commas. Changing the year will allow for the python script to read the corresponding standardized utility spreadsheet, save energy and emissions csv's with the appropriate name, and plot with the appropriate labels. Changing variables **textcolor** and **sizeoflabels** allows for some choice in design. The user may want to change **textcolor** to "white" if they want the figures to be readable on a dark background.

CELL 4: This cell is essential to plotting any energy data. The given energy data (located in the standardized utility spreadsheet) is in different units (e.g. electricity in kilowatt hours, diesel in gallons, natural gas in gas therms, etc.) and thus must be converted to thesame unit. CELL 4 converts and calculates all of the energy data into the equivalent value in kilowatt hours and creates a new csv with this data. This cell is also essential to plotting any emissions data. CELL 4 calculates the equivalent emissions associated with the given energy data in the standardized utility spreadsheet and creates a new csv with this data.

CELL 5: This cell uses the new csv files that were created in CELL 4 to plot stacked Bar graphs of the total energy use and total emissions from the CCFPD in the specified years. Additionally, CELL 5 prints out the numeric values for the total emission (metric tons CO2) for each month in the year and the entire year itself.

How to Format Utility Bill Data to be Used by the Code

The User will NOT need to rewrite any code if the dataset changes, such as when a building is removed from a preserve or if natural gas is added to an existing building. So long as the standardized utility spreadsheet is created to the Users specifications, the python script will account for any changes between different years analyzed. The User should enter corresponding data into the following columns:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	PRESERVE	BUILDING	ENERGY_TYPE	ENERGY_UNIT	ENERGY_PROVIDER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
2																	
3																	
4																	

Figure 3

To be used with the code, the spreadsheet needs to be saved as a csv with this naming convention:
CCFPD_Yearly_Energy_Usage_2018
The User should substitute the year of the data where '2018' appears in the name.

All the standardized csv files need to be stored in the same place. The folder where they are stored needs to be called:
standardized_energy_data