Electrical and Computer Engineering Program

Spring 2020 ECEN 404: ELECTRICAL DESIGN LAB

Final Report
Carbon Footprint Dashboard in TAMUQ

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On my honor, as an Aggie, I have neither given nor received unauthorized aid on this academic work.

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Abstract

Carbon dioxide in the atmosphere is one of the leading causes of climate change and global warming. Many different sources contribute to the emission of carbon dioxide; however, energy consumption is directly proportional to carbon dioxide emission. Qatar is ranked second for the amount of carbon dioxide emitted per capita [1], which means that the amount of carbon dioxide emitted compared to the population is significantly high. Also, Texas A&M University at Qatar is ranked the second-largest carbon dioxide emitter in Education city. Therefore, from the data collected and provided to us by the building of operation (OBO) and Central facilities (CP1), the energy consumption of the building was found to be extremely high. The building is sectioned into three zones, but if we divided it into two areas, there would be the Research area, in addition to the academic area. Due to the lack of resources, authorization, and information, it was highly challenging to extract the power consumption data that led to the research area. Therefore, our project focuses on the academic area only. We were able to collect and separate each of the components into three categories, lighting, plug loads, and HVAC system. Specifically, each equipment in the building, including lights and HVAC, has a rated power. With the data we currently have, we were able to construct a monitoring system (dashboard), which includes a carbon footprint calculator, presenting the total and current power consumption, in addition to recommending solutions to reduce the power consumption of the building.

Chapter 1

In this chapter , the problem statement will be introduced and the motivation that led to the proposed solution based on the literature review.

A. Literature review

The Intergovernmental Panel on Climate Change (IPCC) published guideline documents in 1996 To manage greenhouse gas emissions. Then in 2001, the Greenhouse Gas Protocol Initiative published the Corporate GHG Protocol standard based on the guidelines provided by (IPCC) [1]. The Greenhouse Gas Protocol (GHG Protocol) is the standard international guidelines used to assess the emissions of greenhouse gases and how to minimize their emissions. The GHG Protocol Corporate Standard divides the company's GHG emissions into three scopes. Scope 1 is direct emissions; this includes the sources that directly emit GHG gases. Scope 2 emissions include indirect emissions from the generation of purchased electricity. Lastly, scope 3 includes emission caused by upstream and downstream activities. In our project, we referred to GHG Protocol Scope 2 Guidance, and in chapter 4, we explained how we used this document in our design[2].

Methods and Available calculators for carbon footprint

Many types of carbon footprint calculators are available online.most of these calculators are not profitable. These calculators aim to give the user estimation of their carbon emission. U.S. Environmental Protection Agency (USEPA), American Forests, and The Conservation Fund are famous examples of carbon footprint calculators. All of these calculators that can be used to track the household carbon emission. The user is required to enter their home energy consumption to provide an estimation for their CO2 emissions annually. The difference lies in the vision of the institution where(USEPA) aims to motivate the user to take action to minimize their emission while American Forests and The Conservation Fund aim to Conserve the environment by motivating the consumer to donate to plant more trees [3].

Process-based life cycle assessment (P-LCA) and input-output based life cycle assessment (IO-LCA) are the two main approaches commonly used to quantify the negative impact human activities and products have on the environment. In this study, the authors merged the two assessments and proposed focused analysis to determine the emission of GHG. The collected data are publicly available under the EIO-LCA database along with other data gathered from the U.S. Bureau of Economic Analysis and U.S. Environmental Protection Agency (EPA). Based on the data, GHG emission can be computed by multiplying the data with their crossing emission factors. The analysis was performed on both residential buildings and commercial buildings. The results showed that more than 45 % of the GHG emissions are caused by electricity consumption for both residential and commercial buildings. Results show that an energy efficiency plan would significantly contribute to the reduction of carbon emissions [4]. Lastly,In this study, the authors propose a comprehensive approach that can be used in the analysis of carbon emission. Four indicators were introduced: Carbon Intensity, Dependency, Exposure, and Risk. For each indicator, an equation was constructed and tested in different scenarios. His method can help to allocate the sources that cause the most emission to apply energy efficiency policies on that source. This approach was applied only to scope 1 &2, excluding 3.

B .Motivation

Over the last decades, global temperatures increased due to the burning of fossil fuels and the release of greenhouse gases[5]. Greenhouse gases absorb long-wave infrared radiation that is radiated from earth surfaces and release some back to outer space[2]. Infrared radiation is invisible to the eye but can be detected through heat sensors, or the sensation of warmth on the skin[6]. The increase of greenhouse gases, carbon dioxide, in particular, led to trapping heat instead of releasing it back to outer space, which also led to the increase of climate temperatures. “The term carbon footprint refers to the total greenhouse gas emissions associated with a particular policy, individual, event, development or product [7].In our case, the carbon footprint can be used to measure the amount of carbon dioxide released due to the energy consumption of a building. The reason why this is significant is that historically Carbon dioxide in the atmosphere was estimated to be just below 300ppm(parts per million), whereas, as the industrial sector started to rise, the Carbon dioxide levels increased up to 400ppm today and rising[8]. Today, with the increase of population, economic growth, and building operations carbon dioxide emission is significantly increasing[5]. Since the relationship between energy consumption and carbon dioxide emission is directly proportional. Large buildings such as Texas A&M University at Qatar consume more energy taking into account offices, laboratories, air conditioning, and more.

C. Problem statement

Texas A&M University at Qatar (TAMUQ) building will be the case study for this project. As mentioned previously, TAMUQ is a large building that provides different services such as air conditioning, laboratories, and more. This means that the building requires a sufficient amount of power which is a major issue. This issue is not only environmental, however, economic, social, and the frontal image of TAMUQ. Since the building needs more power means more energy, more carbon dioxide will be emitted in the atmosphere which accounts for the environmental issue. In addition, the more power the building requires, the more money is spent. TAMUQ must then compensate by increasing their tuition fees as an example. Finally, global warming has played a huge role this year of 2019, where businesses world-wide are trying to decrease the percentage of harm they are causing the environment. In the long run, TAMUQ’s frontal image must be satisfied to support the environment by contributing to decreasing the levels of carbon dioxide emission and sustaining energy.

D. Proposed solution

Our proposed design is divided into two main parts that complete each other: the first is to build a carbon footprint dashboard and the second part is proposing solutions based on literature review to reduce the carbon footprint in TAMUQ. For the first part, we started by data collection and used this data to create an excel spreadsheet to study the three main components in the building which are plug loads,lighting, and HVAC. the necessary calculations and assumptions were made in the excel sheet and then this sheet was used in the programming part by using python as a program tool to construct the dashboard. Many libraries were used to code the program and present at the end three charts in the dashboard and a tips box. The proposed solutions are chosen depending on the amount of electricity saving we could reach to help reduce the carbon footprint in TAMUQ by a good percentage.

Chapter 2

In this chapter, our design is compared to similar designs in the same field and how our design is better in achieving the goal. The performance criteria of our design is mentioned depending on the direct relation of each to the project.

A.Benchmarking

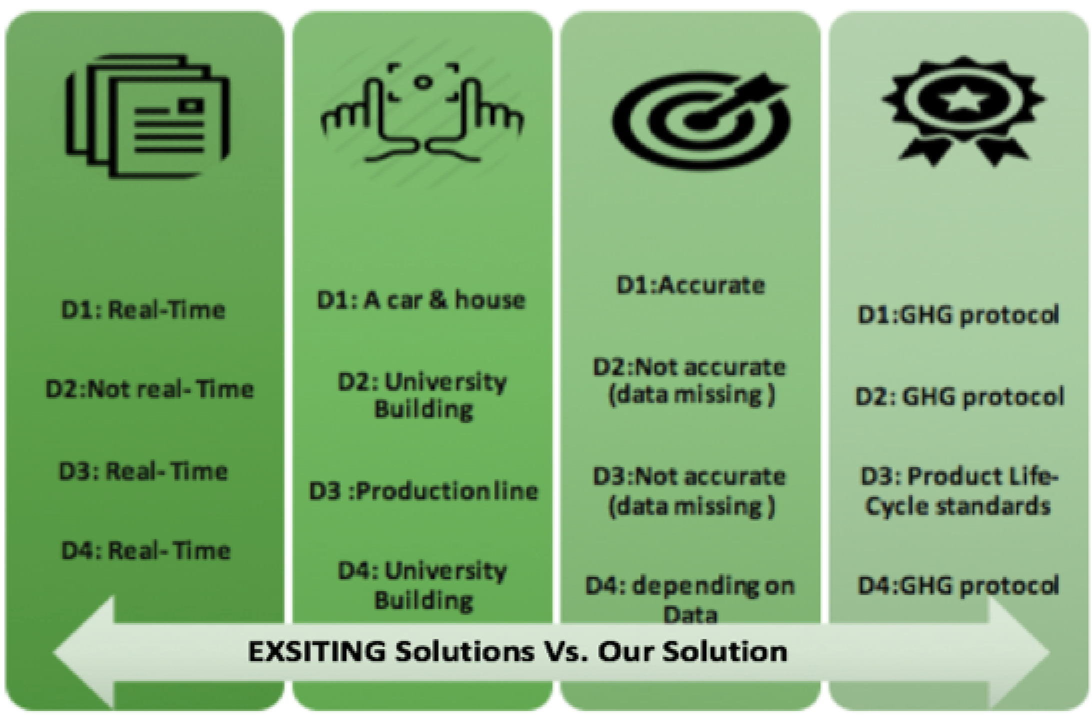

Figure 1: *Comparison of the designs based on the chosen criteria for Benchmarking*

D1: IoT Design: A Carbon Footprint Monitoring System[9]
D2: Qatar University Campus Carbon Calculator[10]
D3: Real-Time Carbon Emissions Monitoring Tool for Prefabricated Construction: An IoT-Based System Framework[11]
D4: Our project monitoring the carbon footprint in TAMUQ

There are different designs that involve monitoring the carbon Footprint through different components and using different tools. However, it is important to verify how each design works. Also, efficiency and accuracy are crucial. Above, in figure 1, we have covered different aspects from different designs that were implemented by other engineers globally. The most significant parts will be discussed below.

Based on our initial design we wanted to have the project using real-time data so we compared it to a project with similar features but our final project was not real-time because of the lack of data and we did not have authorization to use smart meters as planned and mentioned in the proposal.

Type of Data

As stated above, our project "TAMUQ carbon footprint dashboard" is implemented where the information gathered will be not real-time data . Also the IoT-Based System Monitoring Tool for the construction phase gives a real-time measurement for the carbon emissions for all the activities displayed in an on-line BIM platform. Whereas the project done in Qatar University had the similar goal as our goal which is measuring the carbon footprint on campus. They were able to make the necessary assumption and get results depending on the inputs they had. But they used U.S conversion factors so the results were not accurate, but for our design we are planning on using Qatar's conversion factors to get accurate results. In addition, we are planning to create a monitoring system to be able to figure the highest energy consumption component and improve that. As for the project done in Qatar University, they were only satisfied with their findings of the carbon footprint values and stopped there, but for future they are planning to find solutions to reduce carbon footprint.

Efficiency

For the case study of the AirVantage Carbon Footprint Monitoring system, it is highly efficient, where the application is being used and controlled by a smartphone. Our design of a carbon footprint dashboard is very similar to that design since we are also designing a dashboard , however, not using the same platform. Also, when building their carbon footprint calculator, they have used the conversion factors based on a different country which decreased the accuracy and efficiency of their design. The IoT-Based System Monitoring Tool for the construction phase had good efficiency since the sensors were collecting real-time carbon-related data and saving them in the databases. The equations that govern the system separate the activities and display real-time cumulative amounts.

Accuracy

As mentioned previously, QU did not use Qatar's conversion factors. This is important since this also affects the accuracy of the design. As for our project, Qatar's conversion factor will be used for our design. Also, for the TAMUQ building, each component that requires electricity will be examined. This means that everything that consumes energy will be measured but for missing data it will affect the accuracy. This can be related to the AirVantage Carbon Footprint Monitoring system since only the household and Car were measured in real-time, however, the scope was less. The accuracy for the IoT-Based System Monitoring Tool for the construction phase was not high since they lacked some data required for the calculations.not only that some parameters were not taken into consideration so this lowers the accuracy of the system.

Emissions

The amount of Carbon dioxide emitted due to the energy consumption of all three cases, QU, AirVantage Carbon Footprint Monitoring system, and IoT-Based System Monitoring Tool for the construction phase was reduced. The same aspect will be implemented in our design. The aspect of controlling and reducing the energy consumption of the components. The outcome is designed to reduce the carbon dioxide emission. Also, IoT-Based System Monitoring Tool for the construction phase was to find an approximation for the amount emitted in order to know the optimum decisions that reduces the emissions with a certain percentage.

B. Performance criteria

In this section we focused on introducing the criteria that best matches our design goal and that is directly or indirectly related to our aim. The criteria are:

Public health

Public health is one of the main aspects that our design targets. We plan to reduce the carbon footprint in TAMUQ by reducing power consumption. Qatar mainly depends on burning natural gas to produce and supply electricity. One of the consequences of burning natural gas is that the more we burn, the more carbon dioxide is emitted. This means the more power we consume at TAMUQ, the more carbon dioxide is emitted. Increased levels of carbon dioxide reduces the quality of the air, which causes headaches, restlessness. Not only that high level of CO_2 generally over 2000 ppm causes difficulty breathing, increased heart rate, and infectious disease transmission. Therefore, having a monitoring system can help in reducing the amount of CO_2 associated with energy consumption and improve the quality of the air[12].

Safety

The safety aspect is not relative to our project since our project is not interfering with the safety protocols and procedures in the university building, even if it was implemented in another building. However, our project is directly related to the safety of the environment and it's explained in detail in the environment section.

Welfare

In this case, the welfare of the people in Qatar can be directly and indirectly related to our project. As may be mentioned in other parts of this paper, people living their daily lives without the thought of how consuming energy can harm the environment, therefore, their health is the biggest issue. Reducing some of the factors may save a large portion of income, for those who have to pay for electricity and water. As for the country and government, also reducing major factors will for sure save more money. This money can aid people, such as unemployment pays, health insurance, and more.

Global factor

Our project is targeted to measure the carbon footprint in Texas A&M at Qatar building. This leads to help locate the major components that consume a great amount of energy, therefore, try to decrease their consumption. However, this is not only a Qatar or TAMUQ problem. This is a global issue. The global factors that are affected due to the amount of carbon footprint emission are the global environment and global economics. Due to the amount of carbon footprint globally, temperatures are rising tremendously resulting in many different issues such as climate change, global warming, sea levels rising, and more. Environmental problems also affect economics. Many businesses need to have specific weather and land. For example, in Qatar, it is hard to grow crops due to the weather changes and due to the chemicals emitted including carbon dioxide. Finally, awareness is key since the environment is affected highly.

Cultural & social

Our project is related to the culture and social life since part carbon footprint is emitted by the contribution of people. Because of the lack of awareness in the social and cultural life we suffer here in Qatar from high carbon footprint emission worldwide. People have a major impact since they consume energy everyday therefore emit carbon dioxide, and the misuse of energy might lead to major impacts that will affect their life in the long run. Culture and social life are important factors that affect the results of our project. Because we need the collaboration of people to reach our goal in the project and therefore reduce carbon footprint. Awareness is the element we are using for our project successfulness. Since raising awareness about carbon footprint and efficient energy consumption usage would make people aware of the problem and taking actions to help reduce carbon footprint.

Environmental

Our project is directly related to the environment, since it focuses on GHG emissions. Energy consumption is directly proportional to carbon dioxide emissions and these emissions affect the environment badly by increasing climate change and global warming. The reason why this is significant is that historically Carbon dioxide in the atmosphere was estimated to be just below 300ppm(parts per million), whereas, as the industrial sector started to rise, the Carbon dioxide levels increased up to 400ppm today and rising. Today, with the increase of population, economic growth, and building operations carbon dioxide emission is significantly increasing. Since the relationship between energy consumption and carbon dioxide emission is directly proportional. Large buildings such as Texas A&M University at Qatar consume more energy taking into account offices, laboratories, air conditioning, and more. Thus providing a monitoring system and proposing a solution to reduce carbon footprint would help the first TAMUQ building to lower its energy consumption and be an eco friendly building. This will motivate other buildings in Qatar Foundation to do the same and thus reaching our goal of reducing carbon footprint and having a clean and healthy environment by using energy in an efficient way.

Economics

Our project is directly related to the economy since by achieving our goal of reducing carbon footprint we will be able to reduce the costs of paying bills. In addition to reducing the cost of burning fuels to produce electricity to the buildings. Also using energy in an efficient way will help to save energy and therefore helps to raise the economy. Indirectly related it is known as well that companies prefer to approach eco friendly countries for business so that would help Qatar to have more investments and therefore improve its economy.

Chapter 3

In this chapter, the functional modeling flow chart will be explained with detailed functionality mentioned using the block diagram of our design.

A.Block diagram

The block diagram below explains the functionality of the prototype. We created a graphical user interface that has a number of widgets. Widgets are the elements presented in the dashboard. The programming language used here is python and specifically object oriented programming. First we created a class that will have all the objects. The first step is to extract all the input data from the CSV file, then create a function for each element in the dashboard. So we have a function for the bar graph, gauge chart, pie chart text boxes, and the scrolled text. In each function we specified which part of the CSV data used and all the features for the widgets using tkinter GUI with the embedded modules such as Matplotlib. Lastly, to keep the dashboard open we used mainloop.

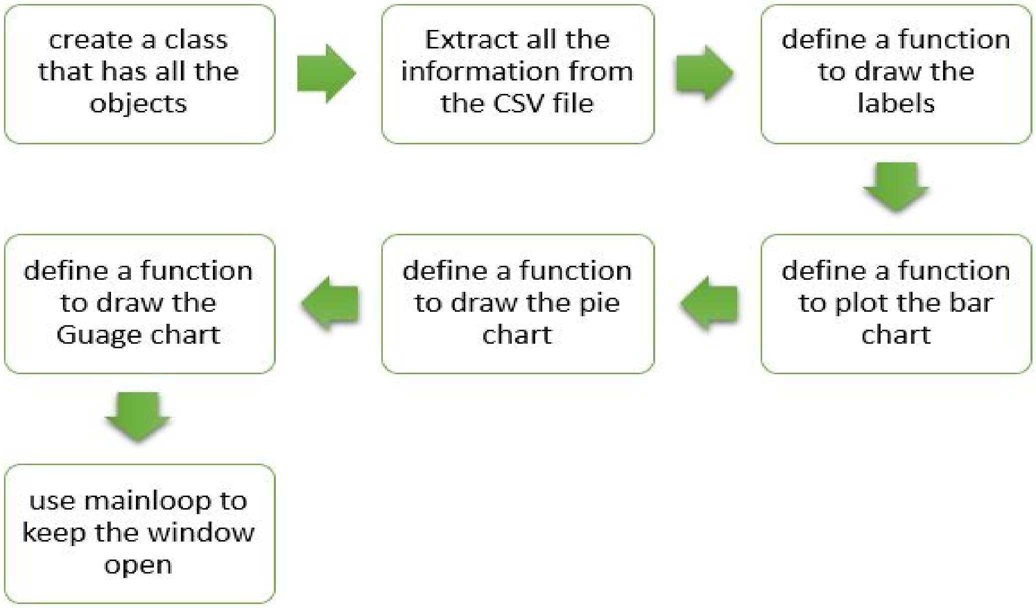

Figure 2 : *Block diagram of the program code*

Chapter 4

In this chapter, the final detailed system design is mentioned in detail, including the technical standards used for the project and the constraint and how we tackled them.

A. Final detailed system design

The final system design is the carbon footprint dashboard which has three main charts to display the power consumption and carbon footprint based on the entered data (figure 5). But our proposed design is divided into two main parts that complete each other. The first part is building a carbon footprint calculator and the aim of this calculator is to measure and keep track of the carbon footprint in TAMUQ, the second part is to propose solutions to reduce the carbon footprint.
In order to reach this goal, the plan for the project was set, which includes first the area of study where we chose to be in TAMUQ building and following the GHG protocol guideline we chose scope 2 which is electricity since this is our main focus. We decided to study three main components in the building which are HVAC, lighting ,plug loads. We collected data from the building of operation and IT in TAMUQ regarding these components and made some assumptions for the missing data that we needed. We

added all the data in an excel sheet(figure3). The spreadsheet shows the power consumption and carbon footprint for each component with their subcategories as well. This helped us to gain information about how much each component consumes from the total power of the building and we obtained the following results(figure4). The chart (figure4) shows the distribution of power consumption in TAMUQ where HVAC consumes 60%,lighting 9%, and 31% plug loads. These values gave us a clear idea about how the power is distributed.

Calculations

For the calculations done in the excel sheet, we gathered the information about the total number of each equipment and the model number and we started researching about the power consumption for each one. Since the equipment used are many and are not limited to few so we found the average power consumption for each of the equipment depending on its model. We got the operating hours from the IT desk in TAMUQ and the missing ones were assumed depending on the usage in the university. Having both the operating hours and power consumption in Watts we are able to calculate the power consumption in Kwh using equation 1:

$$Kwh = \frac{Watts * time(hrs)}{1000}$$

After finding the power consumption in Kwh per unit we multiply it by the total number of equipment to find the total power consumption in Kwh by using equation2:

$$total\ power\ consumption\ (Kwh) = power\ consumption\ per\ unit\ (Kwh) * total\ number\ of\ equipment$$

After finding the total power consumption we are able to find the carbon footprint in KgCo2e by using qatar conversion factor which is

Qatar conversion factor =0.596345388

We can find the total carbon footprint in KgCo2e using equation 3:

$$total\ carbon\ footprint(kgco2e) = total\ power\ consumption(kwh) * conversion\ factor$$

Category	subcategory	model number	total number	power consumption per unit W	Operating hours	power consumption in Kwh	total power consumption in Kwh	Carbon footprint in kgCo2e
Plug loads	Computers	DELL	1452	150 W	9 hr	1.35	1960	1170.12
	AV equipment	EXTRON	539	200 W	8 hr	1.6	862.4	514.85
	Serves	DELL	90	135 W	24 hr	3.24	291.6	174.085
	printers	HP	300	350 W	8 hr	2.8	840	501.48
	Peripherals	DELL	1025	100W	9 hr	0.9	922.5	550.73
	others	APPLE,Vornado Heater, DELL and others	819	80W	12 hr	0.96	786.24	469.38
lighting	CFL light	GE Lighting Long Last	250	42 W	24 hr	1.008	252	150.444
	fluorescent light	GE Lighting T5 Long Last	550	80 W	24 hr	1.92	1056	630.43
	LED	Philips	500	58 W	12 hr	0.696	348	207.756
HVAC	AHU		75	7457 W	24 hr	178.96	13422.6	7999.8696
	heaters	york	488	5530 W	24 hr	132.63	64723.68	38575.31
	pumps							

	total power consumption	total carbon footprint	Total power consumption per day in Kwh	total carbon footprint per day
Plug Loads	5662.74	3380.65	18413.05	10992.5908
lighting	1656	988.632		
HVAC	11094.31	6623.3		

	Monthly Energy consumption KWh						
Meter #	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20
198344	163241	186219	170534	171,710	190990	191060	175470
198345	112312	110338	128634	127,640	133780	127800	78230
198347	130000	130000	130000	130000	130000	130000	130000
198348	189256	139513	131202	124,996	62498	63020	90370
Electrical Total consumption	594809	566070	560370	554346	517268	511880	474070
Solar Inverter production	25231	17653	21161	18224	19333	17124	17321
HVAC cooling energy consumption	2109684	1549792	1614108	1,644,776	NA	NA	NA
electrical Total consumption per day in Kwh	19826.9	18869	18679	18478.2	17242.2	17062.6	15802.3
HVAC cooling energy consumption per day	70322.8	51659.73	53803.6	54825.86	NA	NA	NA

Figure 3 : Excel spreadsheet for plug loads,HVAC,lighting in TAMUQ

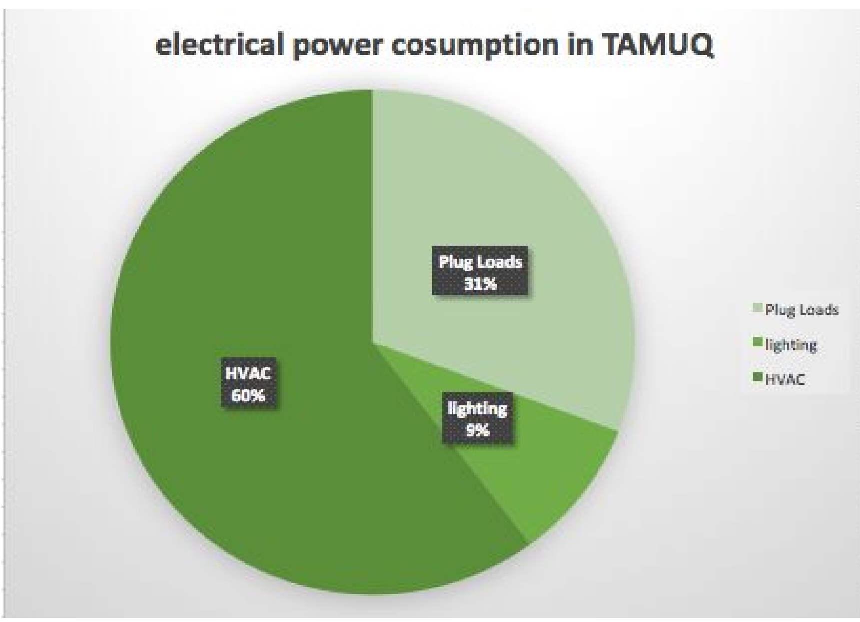

Figure 4: chart showing the electrical power consumption in TAMUQ

In our analysis we started by understanding how electricity is distributed in the building, starting from the main supply which is Khahramaa, it feeds six main panels in the building. Two of these panels are for the research area and the other four are for the academic. In our project we are focusing on the academic area so we are considering these four panels.

To build our calculator we used the spreadsheet that has all data, and we used python to program the calculator. The system will work depending on the input given, for example if the input was lighting the system will generate the power consumption and carbon footprint for this component for the previous year's and the coming one. Since the data of the system is managed to be generated in a specific boundary by having a specific minimum and a specific maximum.

The developed dashboard will show three visulas, three are charts and one tips box. The bar chart will show the total power consumption,carbon footprint and the amount of power that can be saved if we performed our recommended solutions, and this graph will show the values of the previous years that were added in the excel sheet. For the second chart which is the pie chart, it will show the three component's power consumption and their percentage of power consumption in TAMUQ specifically. The third chart which is the gauge chart,will show the total power consumption in a specific range to see if the current value is high or low and this gives an excellent visualization tool for all people to understand and raise awareness about the importance of reducing carbon footprint in the TAMUQ community. Finally, we added a tips box to reduce carbon footprint and added motivational advice to raise awareness in the TAMUQ community.

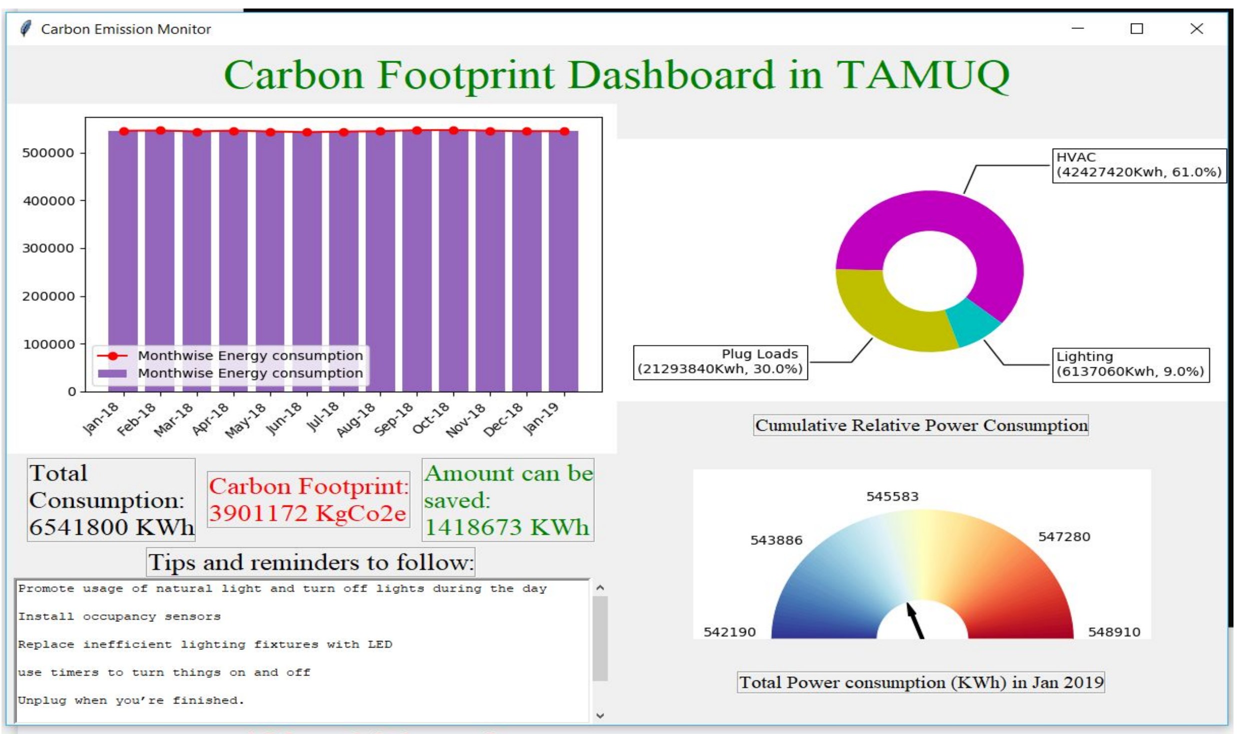

Figure 5: Developed Dashboard to show the power consumption and carbon footprint in TAMUQ

B.Technical standards

For the technical standards we only used the GHG protocol scope 2. The GHG Protocol classifies a company's emissions into three 'scopes'. In our case we only focused on scope 2 which is the purchased energy. We used this document as guidance on how to calculate the equivalent carbon footprint associated with the TAMUQ building[2]. We were able to identify all the inputs which are plug loads, HVAC and lighting and the subcategories that are available in TAMUQ. Then, how to do all the conversions and calculations in order to do analysis and modify the data to predict how much can be saved.

Constraints

The main constraint in our study was the lack of smart meters in the university; this means we don't have real time data. The existing meters in the main panels record cumulative data so it was hard to extract the daily or monthly consumption in TAMUQ. Also we didn't get the approval to install smart meters nor clamps meters. We overcome these constraints by collecting the data from building operations , central facilities in the education city and creating a data inventory. Afterward we created an excel sheet with the set of input data in a csv format to use it in the program. A sample of the generated data is shown in the figure 6 The data set contains HVAC, plug load, lighting and their monthly consumption from 2008 to 2019. The values of the monthly consumption are generated randomly with a specified range taken from data inventory. We had made some assumptions for some of the missing data so this might affect the accuracy for the dashboard.

Equipment	Month	Consumption
HVAC	6/1/2008	331860
HVAC	7/1/2008	331890
HVAC	8/1/2008	332880
HVAC	9/1/2008	330330
HVAC	########	332010
HVAC	########	332970
HVAC	########	331830
HVAC	1/1/2009	332850
HVAC	2/1/2009	332190
HVAC	3/1/2009	332970
HVAC	4/1/2009	332550
HVAC	5/1/2009	330240
HVAC	6/1/2009	332730
HVAC	7/1/2009	330000
HVAC	8/1/2009	331170
HVAC	9/1/2009	331620
HVAC	########	330960
HVAC	########	331080
HVAC	########	332460
HVAC	1/1/2010	331530
HVAC	2/1/2010	330510
HVAC	3/1/2010	331800
HVAC	4/1/2010	330210
HVAC	5/1/2010	330930
HVAC	6/1/2010	330300
HVAC	7/1/2010	331860
HVAC	8/1/2010	331500
HVAC	9/1/2010	330780

Figure 6:sample input data using CSV excel file

C. The link between our project and ECEN courses

ECEN214 is a basic electrical engineering course that helped us in our project. Since our project revolves around power consumption it was important to know the basics of an electrical system including voltage, current, power, energy and wire connections. In addition, there were several approaches when it came to collecting data. For example, one approach included switching of a certain element or equipment to see how the others affect the total power consumption. That approach was introduced in ECEN 214. Moreover, ECEN 210 was also very important to achieve the final monitoring system (dashboard). Although the language we have used was python, however ECEN 210 gave us the programming skills that we needed which helped us achieve the final dashboard. For example, constructing the barchart and pie chart. Also, some ECEN electives such as ECEN 438, a power electronics course, benefited us with the terminologies and understanding them, such as rated power and more.

Chapter 5

In this chapter the simulation results and visual prototyping of the design is mentioned including a detailed explanation of the program code.

A. Simulation results, visual prototyping and analysis for designed circuits

The developed carbon footprint dashboard (figure 5) is the final designed dashboard for our project. We can present the power consumption and carbon footprint clearly using it and raise awareness for people in the TAMUQ community to be aware and enlighten them about the importance of this subject. Following the carbon footprint dashboard there are proposed solutions which are the second part to help reduce the carbon footprint in the building, we created a literature review for each component and studied how it can be improved. For the lighting, in TAMUQ we are using three different types of lighting, and each is different from the other. Focusing on CFL lights (Fluorescent lights) and LED lights, the total power consumption for lighting is approximated to be 1656 Kwh and when converted to carbon footprint it is found to be 988.632 KgCo2e. So we researched about better components that would help us reduce this amount of power consumption. The replacement of CFL with LED GE 39283, and Fluorescent with LED Osram would make a difference in the power consumption [13]. These components are a better substitute to the current ones since by using them the total power consumption, shown in *figure 7*, is approximated to be 947.4 Kwh and the carbon footprint is 565.59KgCo2e, therefore we are saving 708.6Kwh which is equivalent to 43%.

	total power consumption in Kwh	Carbon footprint in kgCo2e
Lighitng	1656	988.632
lighting Modified	947.4	565.5978
saved power consumption in kwh	708.6	423.042
saved power consumption in %	43%	43%

Figure 7 : *showing the power consumption and carbon footprint of lighting before and after the modification*

The HVAC system consumes the largest amount of the power consumption in the building. Shown in (*Figure 4)*, HVAC consumes 60% of the total power consumption. Therefore through research, we found the following recommended solutions:

1) *Building Recommissioning*

Where recommissioning is a process for investigating, analyzing, and optimizing the performance, and implementing improvement measures to ensure continued proper performance[14]. This means that regular schedules must be set to review the equipment to ensure they are at optimal operating capacity, and fixing any issues that arise[14]. For example, monitoring the HVAC system to measure system efficiency, in addition to system inefficiencies such as leaks[14]. This process is proven through research that it can lead to 10-15% of annual energy costs[14]. Which means that the energy consumption goes down.

2) *Modifying thermostat*

Through research, we have found that the thermostat (temperature) affects the energy consumption of the HVAC significantly. Depending on how much the temperature is increased, it is important that the occupants are satisfied with the temperature of the room. As shown in *figure 8*, if the temperature is set to be at 18 degrees celsius and we increase it to 20 degrees celsius, then we would save up to 12% of energy[15]. For simplicity, if we recommend surveying the occupants' temperature preferences in the Texas A&M building, then this will present an average temperature that would be increased based on the survey.

	total power consumption	total carbon footprint
Plug Loads	5662.74	3380.65
lighting	1656	988.632
HVAC	11094.31	6623.3
changing the temperature from 18 to 21		
HVAC	9762.99	5828.5

Figure 8: table showing the total power consumption and carbon footprint for HVAC before and after modification

Plug loads are one of the inputs for our system and this includes Computers,AV equipment ,Servers ,Printers ,peripheral such as PC monitors and laptops,Others . Plug loads are the second highest power consumer, their consumption is between 25-30% of the total power consumption[16]. Reducing the power consumption for the plug loads is a challenging goal to achieve because first we need to educate and encourage both the tenant owners and the occupant to apply energy efficiency measures and techniques. In our case we need to educate the building operation for the campus, faculty, staff and students on the importance of conserving the energy. And what is even more challenging is to sustain the continuous effort for optimizing energy usage. There are numerous solutions that are proven to reduce the power consumed by plug loads by 45%[16]. These solutions can be categorized to behavioral and technical solutions. Three main technical approaches to minimize the energy consumed by the plug loads; The first approach is the technical solutions which include integrating circuit controls, installing meters and sub-meters to monitor the power consumption, using Advanced power strips (APS). The second approach is raising awareness among occupants[16].

Standby mode is the mode that users usually put when they are not using their appliances. A fraction of the power consumed for the plug loads is due to the standby mode since some of the appliances are parasitic load i which means they still draw current in the standby mode. The only solution for the parasitic load is to turn off the plug load[16]. There are many types of Advanced power strips (APS) that can be used to control the power drawn from equipment. These types are master-controlled, timer, activity monitor, remote switch, and masterless. Different types are used for different purposes.these APS can be used in offices, conference rooms , printers rooms and computer labs. These APS can be schedule-based control, or load-sensing which makes it effective in reaching reduction goals[16].

Metering the main panels is an important step to zoom into the load profile and manage the power consumption. However Submetering is an excellent approach that can provide high resolution data and highlight the areas where energy efficiency measures can be applied and reflect on the overall performance. Another metering option is using a data logger. Data loggers are simply electronic devices that record data over time, it can be connected to individual devices or in the sub-distribution boards[16].

The second solution is changing the behaviour and the attributes of the occupants toward energy conservation. This can be done by engaging the occupant; their participation is crucial because with their support and contribution, energy reduction measures will be achieved. There are several methods to engage the occupants; the first method is raising awareness Campaigns, this can include workshops, newsletters ,emails and regular meetings. There are many organizations such as Department of Energy’s (DOE’s) Better Buildings Alliance (BBA) and Regional Energy Efficiency Organizations (REEOs) that developed e-learning platforms to educate building tenants and occupants. These platforms aim to provide guidance and engage occupant in applying policies to reduce plug load energy[16]. Second method is to motivate the occupant by doing competitions and awards for those who contribute to the greater reduction of energy. The third method is Data Transparency, using dashboards occupants can be aware of their consumption and raises the sense of responsibility among them[16].

The type of the equipment also makes a difference, tenant owners should consider equipment recommended by ENERGY STAR which is a U.S. Environmental Protection Agency voluntary program. This program aims to promote energy efficiency and sustainability by providing information for efficient products and equipment[17].

Finally, Installing DC microgrids is also another promising solution to optimize the energy usage for the plug loads. Since most of the working hours are during the daytime and most of the office equipment such as personal laptop, office computers ,phone chargers etc uses DC power. We can generate on-site green electricity through photovoltaic and use high efficiency DC to DC converters and during the night time shift back to using the purchased energy[17].

B. Program code

Tinker, numpy, and pandas are the three main libraries used. With the help of numpy we were able to do all the mathematical computation. tinker was used to plot all graphs and specify their features. Lastly, pandas was used to extract the file that has all the input data. The libraries used support real time data which mean if the system is connected to a real time meter the data shown in the dashboard will also be real time. Also the Comma Separated Values (CSV) file is useful because it is used for exchanging data between different applications.

Figure 9 shows part of the program code for bar graph text boxes, and the scrolled text. The bar chart presents the monthly consumption of electricity in KWh. the months and number of bars has to be specified in the program code. Below the bar chart there are three text boxes; the first one shows the total power consumption for the specified month and the box beside it shows the equivalent carbon footprint.the last box shows the amount can be saved by following all the reduction strategies which ranges from 20-25% of the total power consumption., the scrolled text is dedicated for tips and reminders for modification that can help in reducing the power.

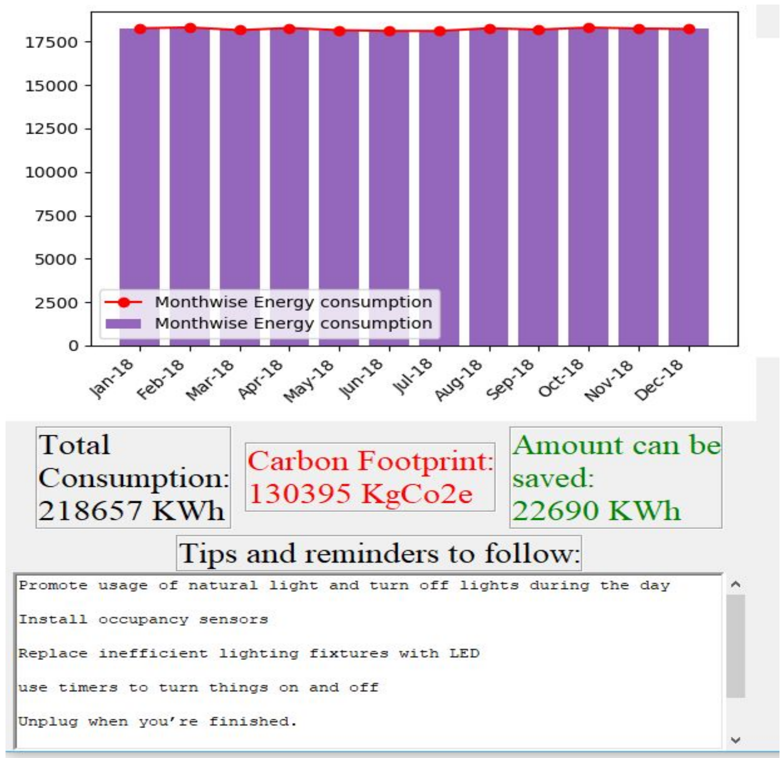

Figure 9 (a) : bar graph text boxes, and the scrolled text.

```
        ax1.legend()
        # This line rotates the x-axis labels by 45 degrees.
        ax1.set_xticklabels(df_chart['mmmYY'].tail(bars), rotation=45, horizontalalignment='right')
        # To pack the layout of the graph. This line will avoid any part of the plot overlapped to each other if smaller window size is used.
        fig.tight_layout()
        # Careate a canvas with parent of chartFrame and add the figure object on the canvas
        self.canvas = FigureCanvasTkAgg(fig, master=self.chartFrame)
        # packe the canvas for the window
        self.canvas.get_tk_widget().pack()
        # finally print the plot on the window
        self.canvas.draw()
```

Figure 9(b) :part of the program code for bar graph.

```
    def drawLabels(self, args):
        # These are self explainatory labels syntax including their font style, size, colors, borders etc
        # padx means the padding distance in pixels on x-axis, pady is the padding on y-axis
        year_to_show = 2018
        ttk.Label(self.labelsFrame, wraplength=200, borderwidth=2, relief="groove", text = "Total Consumption:\n"+str(int(self.df_new[self.df_new['year']==year_to_show]['Consumption']))+" KWh",
                  font = ("Times New Roman", 20)).pack(side=LEFT, pady = 5)
        ttk.Label(self.labelsFrame, wraplength=200, borderwidth=2, relief="groove", foreground ="red", text = "Carbon Footprint:\n"+str(int(self.df_new[self.df_new['year']==year_to_show]['CO2']))+" KgCo2e",
                  font = ("Times New Roman", 20)).pack(side=LEFT, padx = 10, pady = 5)
        ttk.Label(self.labelsFrame, wraplength=200, borderwidth=2, relief="groove",foreground ="green", text = "Amount can be saved:\n"+str(int(self.df_new[self.df_new['year']==year_to_show]['savings']))+" KWh",
                  font = ("Times New Roman", 20)).pack(side=LEFT, pady = 5)
```

Figure 9(c) :part of the program code for text boxes.

```
        self.canvas.draw()

    def drawTextArea(self, args):
        # creates a label
        ttk.Label(self.textFrame, borderwidth=2, relief="groove", text = "Tips and reminders to follow:",
                  font = ("Times New Roman", 20)).pack()
        # Opens file in read only mode. All the tips and info will be stored there
        f = open("tips.txt", "r")
        # creates a text area where the text from the file will be displayed.
        displayText = ScrolledText(self.textFrame, height=10, width=70, borderwidth = 3)
        # Text from the file is inserted in the text area
        displayText.insert(INSERT, f.read())
        # pack the widget to display it on the window
        displayText.pack()
        # uncomment line below if you want the text area to be read only
        #displayText.configure(state='disabled')
```

Figure 9(d) :part of the program code for scrolled text.

Pie chart

As for the pie chart presented in figure 10(a), it will call each of the inputs of lighting, HVAC, plug loads. The program will then seperate each of the inputs and present their power consumption, also calculate the percentage of power consumption for each as presented in figure 10(b) and 10(c). Moreover, if the inputs of power consumption start from the year of 2009, and we choose to present the power consumption of the year 2010, then the pie chart will show the power consumption of 2010 in addition to 2009. The pie chart will also show the increase or decrease of the percentages.

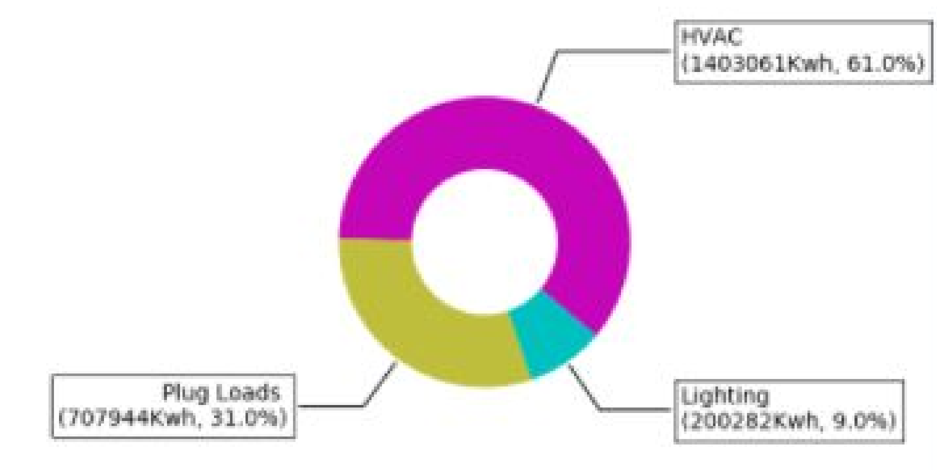

Figure 10(a): Pie chart

```
def drawPie(self, *args):
    # creates a figure object and add subplot
    self.fig1, ax = plt.subplots(figsize=(6, 3), subplot_kw=dict(aspect="equal"))
    # Group the actual data equipment wise and sum the consumption for each equipment and copy the result into a temp dataframe
```

Figure 10(b): Creating the pie chart

```
    # this loop will append the labels into list with percentage values and actual consumption
    for x in data:
        temp = round((x/dataSum)*100)
        newList[i] = equipment[i]+' \n('+str(x)+'Kwh, '+str(temp)+'%)'
        i=i+1
```

Figure 10(c): Loop that inputs the power consumption and calculate the percentage

Gauge chart

The last chart is the gauge chart and the aim of it is to point the power consumption of any month in a specific range. So first we define the minimum and maximum from the consumption excel sheet that we created. The highest total power consumption is considered as maximum and the lowest total power consumption is considered as minimum and this is mentioned in the code below in figure 8.a. We labeled three values between the minimum and maximum that are listed as 75%,50%,and 25% of the maximum value and a screenshot of the code is mentioned below figure 8.b. Thus we are able to point the power consumption of a specific month according to the minimum and maximum as shown in figure 11.

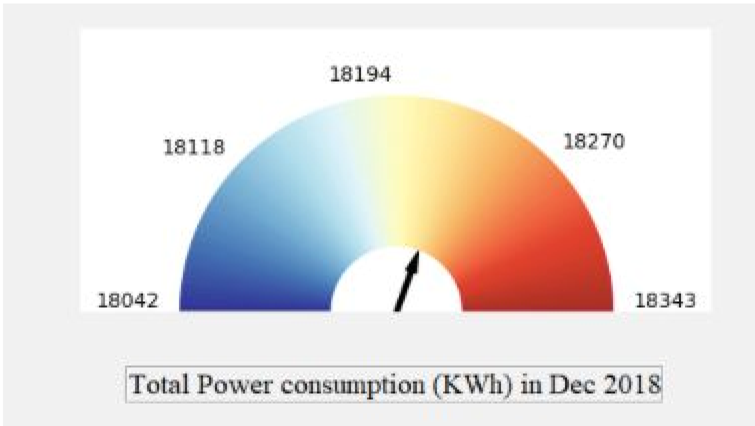

Figure 11(a): showing the gauge chart of the total power consumption in Kwh for December 2018

Figure 11 (b): showing the definition of the gauge function and minimum and maximum

```
labels = [' ']*len(dial_colors)*2
labels[1] = mx # maximum value to dispaly here
labels[25] = int(values_list[75])  #75% of the max value
labels[50] = int(values_list[50])  # 50% of the max value
labels[75] = int(values_list[25])  # 25% of the max value
labels[98] = mn  # diplay the min value on the left most side
```

Figure 11.(c): showing the labels according to the percentage taken from the maximum value

B.Functional prototyping

There were two versions for the dashboard, in the first version that is shown in figure 12. it had only two plots and combo boxes. In the combo boxes The user had to choose the year, month and the input to plot the power consumption and the equivalent carbon footprint in a line graph. It was not the best approach since it didn't have many elements that present data. Even though it was basic but it was beneficial since it helped us explore the language syntax and the libraries that we used on creating the final version. The final version has many elements that summarizes the power consumption and the equivalent carbon footprint. To make each element unique we made each element show different information to make the dashboard comprehensive.

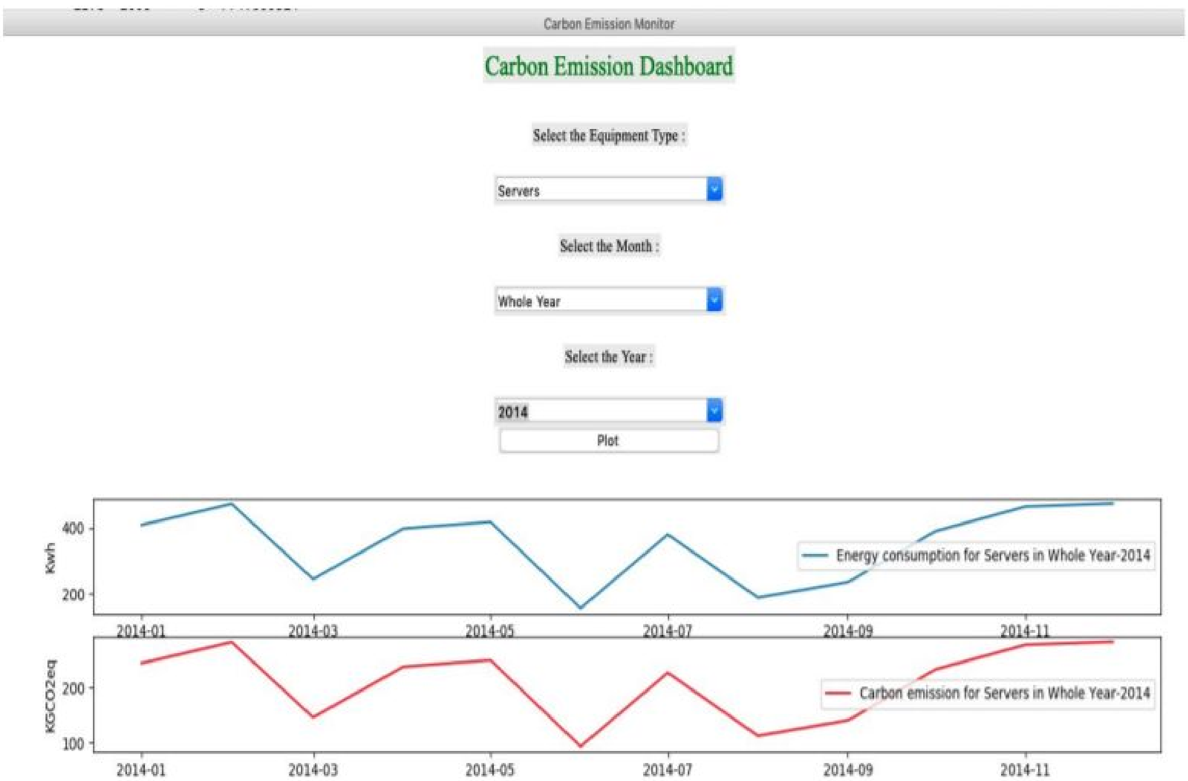

Figure 12: the first version of the dashboard

Testing and Troubleshooting

For our project testing and troubleshooting revolves around two main obstacles which are the data and the programming part. For Troubleshooting We had to create a data inventory since we lack smart meters. But we had to make sure the values are realistic, reasonable and compatible with the data provided by TAMUQ building of operation and central facilities (CP1) . This was done through collecting the data manually for each component separately then adding up all the component consumption and comparing it with the data provided. For the programming we initially used random values to work on creating the functions. Then we replaced the random values with the generated ones. As for testing, we used the Command Prompt to execute the program code. The Command Prompt's commands and the generated dashboard is shown in figure 13. To make sure the program works we made changes in the input data and it was reflected on the dashboard which means the system works.

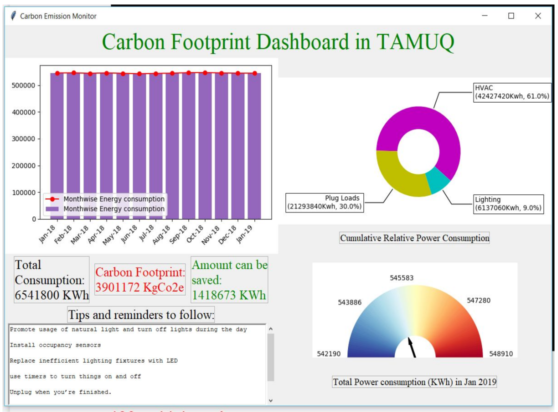

Figure 13: testing the program code

Experimental results

The project is divided into two parts, the goal of the first part was to create a dashboard to monitor the power consumption in TAMUQ. We had created a prototype for the dashboard. Comparing the previous prototype with the final version we can clearly see that the current dashboard is a better version since it conveys more information than the previous one because it summarizes TAMUQ power consumption in a few charts. The second part was coming up with solutions that would lower the power consumption in TAMUQ. We gathered information about the inputs and how much can be saved for each input. Some of the solutions for the plug loads and lighting were technical which required installing additional equipment and changing some of the existing equipment to improve the efficiency without interfering or disturbing the work quality in TAMUQ. The other solutions are behavior-based energy efficiency solutions requiring creating a set of guidelines ,policies educating occupants can follow so they can Incorporate the best practices to minimize their consumption .

Chapter 6

In this chapter, we mentioned the conclusion of our project and discussed it to verify the results and at last mentioned the future recommendation for our project.

A.Conclusion

In conclusion, what led us to work on this project is the high percentage of carbon dioxide in the atmosphere, which is leading to climate and global warming. In addition, Qatar is ranked second highest globally for the amount of carbon dioxide emission world wide. Therefore, choosing the Texas A&M at Qatar building to study, we received data from central facilities (CP1) and from the building of operation (OBO) that proved the high rates of power consumption throughout the years. This data was collected monthly by CP1 and not real-time data. It was difficult to place smart meters to the panels, so the data was collected manually and separated into three categories of lighting, HVAC, and plug loads. Finally, with some data missing, we researched and came up with proposed solutions to reduce the power consumption of the building, since the power consumption is directly proportional to the carbon emitted. In addition, a monitoring system (dashboard) is constructed to monitor the power consumption and carbon footprint of the building.

B.Discussion

The first attempt for the dashboard is a simple dashboard which we needed to develop more. The main obstacle in our project is not having real time data. So we had to create an inventory survey and gather the information manually and request information from building operations(OBO) and central facilities 1(CP1) in Education City. Although still some of the data is missing, we were able to estimate the power consumption on a monthly basis. Then we used the estimated value to generate random values on a csv file. This approach is useful in our case however it will lower the accuracy of the information shown in the dashboard. The final version of the dashboard includes figures of the total power consumption over the years for all components, which includes all the inputs of plug loads, HVAC, and lighting. The barchart presents the data of the total power consumption of a full year. Whereas, the pie chart presents the distribution of the power in terms of the inputs (HVAC, lighting, plug loads). For example HVAC has a percent of 60% and this X KWh consumption and this will be useful when doing analysis for the data. In addition, the gauge chart indicates whether the current power consumption is high or low based on the maximum and the minimum values specified in the csv file. If the current power consumption is high, this means that it would be close to the maximum value, therefore the indicator arrow would point to red color. But if the power consumption is low, this means that it would be closer to the minimum value, therefore the inductor arrow would point to the green color. Finally, for tips and reminders, an added section where it could be used to raise awareness about energy efficiency.

C.Verification

The data collected and provided are approximated to be almost equal. Which means that the collected data is consistent with the data read by the panels. In addition, through testing, the data presented on the monitoring system was very close to the data calculated and collected. This verifies that even though some data is still missing, the values presented were approximately equal.

D.Future recommendations improvements and optimizations

In order to reach the best result in terms of energy efficiency and sustainability in our project we need to focus on having a customized energy efficiency plan for TAMUQ. Which means that we should include all the proposed solutions that best match our building by taking into consideration its infrastructure. Also by taking the advice of central facilities and building of operation regarding the proposed solutions. In the future, it would be best to have real-time data. The accuracy will increase and it would be easier to monitor the power consumption of the building.

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Appendices

Program code

```python

import pandas as pd   # Library for data analytics
import numpy as np  # Library to handle dataframes
from datetime import datetime as dt
import calendar
import matplotlib.pyplot as plt      # Library to create charts
from matplotlib.figure import Figure # # Library to create charts
from matplotlib import cm, gridspec  # Library to create charts
from matplotlib.backends.backend_tkagg import FigureCanvasTkAgg # Library to create charts
import tkinter as tk     # Library to create GUI
from tkinter import ttk # Library to create GUI
from tkinter import * # Library to create GUI
import math    # Library for mathematical computations
from PIL import Image, ImageTk  # Image handeling Library
from mpl_toolkits.axes_grid1 import make_axes_locatable  # Library to manipulate images
from tkinter.scrolledtext import ScrolledText   # GUI Library for text box

# This is the class file to do everthing in the dhashboard
class plotCo2:
    # Constructor function. It will be called when the class object is created
    def __init__(self,  window):
        #firstTime = 0
        self.window = window    # windows object is the main GUI object where all the widgets need to be added
        self.df  = pd.read_csv('random_data2.csv')            # Read the data file and store it in a dataframe object
        self.df['Month'] = pd.to_datetime(self.df['Month']) # convert the Month column from string object to DateTime object
        self.df['year'] = self.df['Month'].dt.year    # extract the year value from date object
        self.df['month'] = self.df['Month'].dt.month  # extract the month value from date object
        self.df['monthName'] = self.df['Month'].dt.strftime('%b') # Extract month name from month number (change %B for full month name)
        self.df['CO2'] = self.df['Consumption']*0.596345388     # CO2 emission calculation from consumption. This will create a new column in the dataframe
        self.df['savings_%'] = np.random.randint(20, 25, self.df.shape[0])  # Raandom savings. Between 20% to 25%. This will create a new column in the dataframe
        self.df['efficient_energy'] = self.df['Consumption']-(self.df['Consumption']*self.df['savings_%']/100) # This will create a new column in the dataframe calculating the efficient_energy with savings between 5%-10%
        self.df['savings'] = self.df['Consumption']*self.df['savings_%']/100 # This will create a new column in the dataframe, showing actual saving
        self.df_new = self.df.groupby(['year'], as_index=False).sum()       # This will create a new dataframe object. This groups/sums the consumption, Co2 and saving year wise
        #print(self.df_new)
        # This will create a new dataframe object. This groups/sums the consumption, Co2 and saving year wise
        self.df_monthwise = self.df.groupby(['month', 'monthName','year'], as_index=False).sum()
        self.df_monthwise['year']=self.df_monthwise['year'].apply(str)   # convert int column to string column
        self.df_monthwise['mmmYY'] = self.df_monthwise['monthName']+'-'+self.df_monthwise['year'].str.slice(start=-2)  # create new column with mm-yy format (e.g. Jan-19)
        self.df_monthwise.sort_values(['year', 'month'], inplace=True)  # sort the whole dataframe with year and month
        self.df_monthwise.reset_index(drop=True, inplace=True)

```

```python

        #print(self.df_monthwise.tail(20))
        #print(pd.__version__)
        monthList = self.df['month'].unique().tolist()  # create uniques list of month names available in the dataframe
        #monthList.sort()
        yearList = self.df['year'].unique().tolist() # create uniques list of years available in the dataframe
        yearList.sort()   # sort year list

        #ndArray object needs to be converted into list object so that it can be added into combobox
        # unique list of equipment available in the dataframe
        self.equipmentList = self.df['Equipment'].unique().tolist()
        #print(type(equipmentList))
        #print(equipmentList)

        # label text for title
        ttk.Label(window, text = "Carbon Footprint Dashboard in TAMUQ",
                  foreground ="green",
                 font = ("Times New Roman", 35)).pack(side=TOP, pady=5,padx=10)
        # Follwing lines create multiple frames for each widget to be added to the main window
        # The main window is divided into two frames/parts: left and right
        self.leftFrame = Frame(self.window)
        self.leftFrame.pack(side=LEFT)      # pack function adds the widget to the parent place holder which is main window in this case
        self.rightFrame = Frame(self.window)
        self.rightFrame.pack(side=LEFT)

        self.chartFrame = Frame(self.leftFrame)  # This is place holder for bar chart
        self.chartFrame.pack()
        self.labelsFrame = Frame(self.leftFrame)  # Place holder for labels related to consumption, co2, savings
        self.labelsFrame.pack()
        self.textFrame = Frame(self.leftFrame) # Place holder for text box
        self.textFrame.pack()

        #self.guageFrame = Frame(self.rightFrame)
        #self.guageFrame.pack()

        self.plotBarChart(self)    # function to draw bar chart
        self.drawLabels(self)   # function to draw labels
        self.drawTextArea(self) # function to create text box for tips
        self.drawPie(self)      # function to draw pie chart
        self.drawGuage(self)    # function to draw guage chart
```

```python
        self.drawGuage(self)    # function to draw guage chart

    def drawLabels(self, args):
        # These are self explainatory labels syntax including their font style, size, colors, borders etc
        # padx means the padding distance in pixels on x-axis, pady is the padding on y-axis
        year_to_show = 2018
        ttk.Label(self.labelsFrame, wraplength=200, borderwidth=2, relief="groove", text = "Total Consumption:\n"+str(int(self.df_new[self.df_new['year']==year_to_show]['Consumption']))+" KWh",
                font = ("Times New Roman", 20)).pack(side=LEFT, pady = 5)
        ttk.Label(self.labelsFrame, wraplength=200, borderwidth=2, relief="groove", foreground ="red", text = "Carbon Footprint:\n"+str(int(self.df_new[self.df_new['year']==year_to_show]['CO2']))+" KgCo2e",
                font = ("Times New Roman", 20)).pack(side=LEFT, padx = 10, pady = 5)
        ttk.Label(self.labelsFrame, wraplength=200, borderwidth=2, relief="groove",foreground ="green", text = "Amount can be saved:\n"+str(int(self.df_new[self.df_new['year']==year_to_show]['savings']))+" KWh",
                font = ("Times New Roman", 20)).pack(side=LEFT, pady = 5)

    def plotBarChart(self, args):
        year_to_plot = '2018'  # Enter the year from where you want to view the bar chart. MUST Keep this value in single quotes
        bars = 15 # Number of months to show in the bar chart starting from the first month of the year in the above line

        # Get the index value of the year enetered above. This will return an array of indexes if there are more than one records available for this year
        y_index = self.df_monthwise[self.df_monthwise['year']==year_to_plot].index.values
        df_chart = self.df_monthwise.iloc[y_index[0]:y_index[0]+bars]  # Copies the data rows from the year and number ofrecords to show into another dataframe
        # create the figure object with specified size.
        fig = Figure(figsize=(6,4))
        # add a subplot into the figure object.
        ax1 = fig.add_subplot()
        # This line plots the bar chart on the figure, with specified label and bar color
        ax1.bar(df_chart['mmmYY'].tail(bars), df_chart['Consumption'].tail(bars), label='Monthwise Energy consumption', color='tab:purple')
        # This line plots the line chart with label, color and line style. Marker o will be marke on the line
        ax1.plot(df_chart['mmmYY'].tail(bars), df_chart['Consumption'].tail(bars), label='Monthwise Energy consumption', color='r', linestyle='-', marker='o')
        # Enabled the legend to show. Without this line the legend of the plot will disappear
        ax1.legend()
        # This line rotates the x-axis labels by 45 degrees.
        ax1.set_xticklabels(df_chart['mmmYY'].tail(bars), rotation=45, horizontalalignment='right')
        # To pack the layout of the graph. This line will avoid any part of the plot overlapped to each other if smaller window size is used.
        fig.tight_layout()
        # Careate a canvas with parent of chartFrame and add the figure object on the canvas
        self.canvas = FigureCanvasTkAgg(fig, master=self.chartFrame)
        # packe the canvas for the window
        self.canvas.get_tk_widget().pack()
        # finally print the plot on the window
        self.canvas.draw()
```

```python
        self.canvas.draw()

    def drawTextArea(self, args):
        # creates a label
        ttk.Label(self.textFrame, borderwidth=2, relief="groove", text = "Tips and reminders to follow:",
                font = ("Times New Roman", 20)).pack()
        # Opens file in read only mode. All the tips and info will be stored there
        f = open("tips.txt", "r")
        # creates a text area where the text from the file will be displayed.
        displayText = ScrolledText(self.textFrame, height=10, width=70, borderwidth = 3)
        # Text from the file is inserted in the text area
        displayText.insert(INSERT, f.read())
        # pack the widget to display it on the window
        displayText.pack()
        # uncomment line below if you want the text area to be read only
        #displayText.configure(state='disabled')

    def drawPie(self, *args):
        # creates a figure object and add subplot
        self.fig1, ax = plt.subplots(figsize=(6, 3), subplot_kw=dict(aspect="equal"))
        # Group the actual data equipment wise and sum the consumption for each equipment and copy the result into a temp dataframe
        df_ = self.df.groupby(['Equipment'], as_index=False).sum()
        # Select only 3 equipment and copy in another dataframe
        df_2 = df_[((df_['Equipment']=='Plug Loads') | (df_['Equipment']=='Lighting') | (df_['Equipment']=='HVAC'))]
        # sort the result with respect to consumption
        df_2.sort_values('Consumption', ascending=False, inplace=True)
        # copy the consumption array to an array object
        data = df_2['Consumption']
        # sum the whole consumption. This is necessary to get the percentage of each equipment consumption
        dataSum = data.sum()
        # select the unique list of equipment
        equipment = df_2['Equipment'].unique().tolist()
        i=0
        # create an empty list with data array size. This list will be used to display the labels
        newList = [None]*len(data)
        # this loop will append the labels into list with percentage values and actual consumption
        for x in data:
            temp = round((x/dataSum)*100)
            newList[i] = equipment[i]+' \n('+str(x)+'Kwh, '+str(temp)+'%)'
            i=i+1
```

```python
        for x in data:
            temp = round((x/dataSum)*100)
            newList[i] = equipment[i]+' \n('+str(x)+'Kwh, '+str(temp)+'%)'
            i=i+1

        #add colors, m=megenta, c=cyan, y=yellow
        colors = ['m','y','c']
        # create pie chart
        wedges, texts = ax.pie(data, wedgeprops=dict(width=0.5), startangle=-40, colors=colors)
        # Box style for lable display
        bbox_props = dict(boxstyle="square,pad=0.3", fc="w", ec="k", lw=0.72)
        kw = dict(arrowprops=dict(arrowstyle="-"),
                  bbox=bbox_props, zorder=0, va="center")
        i=0
        # This loop will print the labels on the pie chart with 360 degree rotation
        for i, p in enumerate(wedges):
            ang = (p.theta2 - p.theta1)/2. + p.theta1
            y = np.sin(np.deg2rad(ang))
            x = np.cos(np.deg2rad(ang))
            horizontalalignment = {-1: "right", 1: "left"}[int(np.sign(x))]
            connectionstyle = "angle,angleA=0,angleB={}".format(ang)
            kw["arrowprops"].update({"connectionstyle": connectionstyle})
            ax.annotate(newList[i], xy=(x, y), xytext=(1.35*np.sign(x), 1.4*y),
                        horizontalalignment=horizontalalignment, **kw)

        # Careate a canvas with parent of rightFrame on the right side and add the figure object on the canvas
        self.canvas2 = FigureCanvasTkAgg(self.fig1, master=self.rightFrame)
        # pack the canvas
        self.canvas2.get_tk_widget().pack(pady=10)
        # display on the window
        self.canvas2.draw()
        #plt.show()

        ttk.Label(self.rightFrame, borderwidth=2, relief="groove", text = "Cumulative Relative Power Consumption",
                font = ("Times New Roman", 15)).pack(pady=5)

    def drawGuage(self, args):
        # select the minimum and maximum consumption
        mn = self.df_monthwise['Consumption'].min()  # Minimum value of the month wise consumption
        mx = self.df_monthwise['Consumption'].max()  # Maximum value of the month wise consumption
        values_list = np.linspace(mn,mx,100)           # generates 100 points between min and max
        # set your color array and name of figure here:
        dial_colors = np.linspace(0,1,100) # using linspace, create 100 point array each will be of different color. Refer dial function. this will be passed to dial function
```

```python

    def drawGuage(self, args):
        # select the minimum and maximum consumption
        mn = self.df_monthwise['Consumption'].min()  # Minimum value of the month wise consumption
        mx = self.df_monthwise['Consumption'].max()  # Maximum value of the month wise consumption
        values_list = np.linspace(mn,mx,100)           # generates 100 points between min and max
        # set your color array and name of figure here:
        dial_colors = np.linspace(0,1,100) # using linspace, create 100 point array each will be of different color. Refer dial function. this will be passed to dial function

        figname = 'testDial'
        # specify which index you want your arrow to point to. Here we show the arrow poiting at the last month of the consumption
        lastMonth = self.df_monthwise['Consumption'][self.df_monthwise.shape[0]-1]   # Lat month total consumption
        relatedValue = min(values_list, key=lambda x:abs(x-lastMonth))    # Find the related value in the list of values which is equal to the last month value
        #print(relatedValue, lastMonth, np.argwhere(values_list==relatedValue))
        arrow_index = np.argwhere(values_list==relatedValue)  #point where the arrow should be pointing at
        # create labels at desired locations
        # note that the pie plot plots from right to left
        labels = [' ']*len(dial_colors)*2
        labels[1] = mx # maximum value to dispaly here
        labels[25] = int(values_list[75])  #75% of the max value
        labels[50] = int(values_list[50])  # 50% of the max value
        labels[75] = int(values_list[25])  # 25% of the max value
        labels[98] = mn  # diplay the min value on the left most side

        # create figure object and specify figure name
        fig, ax = plt.subplots()

        # make dial plot and save figure
        self.dial(dial_colors, arrow_index, labels, ax)
        ax.set_aspect('equal')
        # as the dial function creates a pi plot, so we need to cut that plot into half to make a guage chart. In order to do that, we will save the Figure
        # on the disk and then load it again to trim in into half
        plt.savefig(figname + '.png', bbox_inches='tight')

        # open figure and crop bottom half
        im = Image.open(figname + '.png')
        # get the height, width of the image
        width, height = im.size

```

```python

        # make dial plot and save figure
        self.dial(dial_colors, arrow_index, labels, ax)
        ax.set_aspect('equal')
        # as the dial function creates a pi plot, so we need to cut that plot into half to make a guage chart. In order to do that, we will save the Figure
        # on the disk and then load it again to trim in into half
        plt.savefig(figname + '.png', bbox_inches='tight')

        # open figure and crop bottom half
        im = Image.open(figname + '.png')
        # get the height, width of the image
        width, height = im.size

        # crop bottom half of figure
        # function takes top corner and bottom corner coordinates
        # of image to keep, (0,0) in python images is the top left corner and save the figure again
        im = im.crop((0, 0, width, int(height/2.0))).save(figname + '.png')
        # Load image for displaying
        i = Image.open(figname + '.png')
        width, height = i.size
        # create a PhotoImage object and add image i into it
        ph = ImageTk.PhotoImage(i)
        # add an image label
        label = Label(self.rightFrame, image=ph)
        # padding at y-axis
        label.pack(pady=30)
        # keep the label reference for displaying. This is very important
        label.image=ph
        # draw the image label on the right frame
        ttk.Label(self.rightFrame, borderwidth=2, relief="groove", text = "Total Power consumption (KWh) in "+str(self.df_monthwise['monthName'][self.df_monthwise.shape[0]-1])+' '+str(self.df_monthwise['year'][self.df_monthwise.shape[0]-1]),
                font = ("Times New Roman", 15)).pack(pady=5)
    # function plotting a colored dial
    def dial(self, color_array, arrow_index, labels, ax):
        # Create bins to plot (equally sized)
        size_of_groups=np.ones(len(color_array)*2)

        # Create a pieplot, half white, half colored by your color array
        white_half = np.ones(len(color_array))*.5
        color_half = color_array
        color_pallet = np.concatenate([color_half, white_half])
        # This creates a color map of 100 color shades between Red and Blue with Yellow in between.
        cs=cm.RdYlBu(color_pallet)
        # Draw the piechart of the colors first which wil be then be cropped to guage chart.
        pie_wedge_collection = ax.pie(size_of_groups, colors=cs, labels=labels)
        # setting the colors of each wedge of the pie to 100 colors of array from Red to Blue shades with Yellow in between
        i=0
        for pie_wedge in pie_wedge_collection[0]:
            pie_wedge.set_edgecolor(cm.RdYlBu(color_pallet[i]))
            i=i+1
```

```python
        # Create a pieplot, half white, half colored by your color array
        white_half = np.ones(len(color_array))*.5
        color_half = color_array
        color_pallet = np.concatenate([color_half, white_half])
        # This creates a color map of 100 color shades between Red and Blue with Yellow in between.
        cs=cm.RdYlBu(color_pallet)
        # Draw the piechart of the colors first which wil be then be cropped to guage chart.
        pie_wedge_collection = ax.pie(size_of_groups, colors=cs, labels=labels)
        # setting the colors of each wedge of the pie to 100 colors of array from Red to Blue shades with Yellow in between
        i=0
        for pie_wedge in pie_wedge_collection[0]:
            pie_wedge.set_edgecolor(cm.RdYlBu(color_pallet[i]))
            i=i+1

        # create a white circle to make the pie chart a dial
        my_circle=plt.Circle( (0,0), 0.3, color='white')
        ax.add_artist(my_circle)

        # create the arrow, pointing at specified index
        arrow_angle = (arrow_index/float(len(color_array)))*3.14159
        arrow_x = 0.2*math.cos(arrow_angle)
        arrow_y = 0.2*math.sin(arrow_angle)
        ax.arrow(0,0,-arrow_x,arrow_y, width=.02, head_width=.05,
            head_length=.1, fc='k', ec='k')

# This is starting point of the program.
# Creating tkinter main GUI window
window = tk.Tk()
window.title('Carbon Emission Monitor')
#window.geometry('800x600')
# calling the main class
start = plotCo2(window)
# mandatory function for GUI window to keep the window open
window.mainloop()

```

Sample input data

random_data2 - Notepad

File Edit Format View Help

```
Equipment,Month,Consumption
HVAC,6/1/2008,331860
HVAC,7/1/2008,331890
HVAC,8/1/2008,332880
HVAC,9/1/2008,330330
HVAC,10/1/2008,332010
HVAC,11/1/2008,332970
HVAC,12/1/2008,331830
HVAC,1/1/2009,332850
HVAC,2/1/2009,332190
HVAC,3/1/2009,332970
HVAC,4/1/2009,332550
HVAC,5/1/2009,330240
HVAC,6/1/2009,332730
HVAC,7/1/2009,330000
HVAC,8/1/2009,331170
HVAC,9/1/2009,331620
HVAC,10/1/2009,330960
HVAC,11/1/2009,331080
HVAC,12/1/2009,332460
HVAC,1/1/2010,331530
HVAC,2/1/2010,330510
HVAC,3/1/2010,331800
HVAC,4/1/2010,330210
HVAC,5/1/2010,330930
HVAC,6/1/2010,330300
HVAC,7/1/2010,331860
HVAC,8/1/2010,331500
HVAC,9/1/2010,330780
HVAC,10/1/2010,331350
HVAC,11/1/2010,331050
HVAC,12/1/2010,332430
HVAC,1/1/2011,330390
HVAC,2/1/2011,331230
HVAC,3/1/2011,330150
```

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```
Plug Loads,4/1/2014,165510
Plug Loads,5/1/2014,165330
Plug Loads,6/1/2014,165720
Plug Loads,7/1/2014,166050
Plug Loads,8/1/2014,165480
Plug Loads,9/1/2014,167460
Plug Loads,10/1/2014,167280
Plug Loads,11/1/2014,165360
Plug Loads,12/1/2014,165270
Plug Loads,1/1/2015,167100
Plug Loads,2/1/2015,165210
Plug Loads,3/1/2015,165900
Plug Loads,4/1/2015,166830
Plug Loads,5/1/2015,166260
Plug Loads,6/1/2015,166500
Plug Loads,7/1/2015,166920
Plug Loads,8/1/2015,167340
Plug Loads,9/1/2015,165900
Plug Loads,10/1/2015,165480
Plug Loads,11/1/2015,167850
Plug Loads,12/1/2015,165570
Plug Loads,1/1/2016,167910
Plug Loads,2/1/2016,166440
Plug Loads,3/1/2016,167850
Plug Loads,4/1/2016,167280
Plug Loads,5/1/2016,166290
Plug Loads,6/1/2016,166650
Plug Loads,7/1/2016,166650
Plug Loads,8/1/2016,165180
Plug Loads,9/1/2016,165690
Plug Loads,10/1/2016,165060
Plug Loads,11/1/2016,167160
Plug Loads,12/1/2016,167370
Plug Loads,1/1/2017,166770
Plug Loads,2/1/2017,167430
```

random_data2 - Notepad

File Edit Format View Help

```
Lighting,12/1/2011,48030
Lighting,1/1/2012,49110
Lighting,2/1/2012,47100
Lighting,3/1/2012,47370
Lighting,4/1/2012,48090
Lighting,5/1/2012,47160
Lighting,6/1/2012,49320
Lighting,7/1/2012,49260
Lighting,8/1/2012,48150
Lighting,9/1/2012,47010
Lighting,10/1/2012,47070
Lighting,11/1/2012,48330
Lighting,12/1/2012,49050
Lighting,1/1/2013,47490
Lighting,2/1/2013,46950
Lighting,3/1/2013,48120
Lighting,4/1/2013,48480
Lighting,5/1/2013,46650
Lighting,6/1/2013,47340
Lighting,7/1/2013,47700
Lighting,8/1/2013,46800
Lighting,9/1/2013,48060
Lighting,10/1/2013,47700
Lighting,11/1/2013,47340
Lighting,12/1/2013,47430
Lighting,1/1/2014,46590
Lighting,2/1/2014,49050
Lighting,3/1/2014,47970
Lighting,4/1/2014,47040
Lighting,5/1/2014,49320
Lighting,6/1/2014,46560
Lighting,7/1/2014,48600
Lighting,8/1/2014,49140
Lighting,9/1/2014,47340
Lighting,10/1/2014,47880
```