Electrical and Computer Engineering Program

Spring 2020 ECEN 404: ELECTRICAL DESIGN LAB

Progress Report
Carbon Footprint Calculator in TAMUQ

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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. In addition, 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 difficult to extract the power consumption data that led to the research area. Therefore, our project focuses on the academic area only. Specifically, each equipment in the building, including lights and HVAC, has a rated power. We were able to collect and separate each of the components into three categories, lighting, plug loads, and HVAC system. With the data we currently have, we were able to construct part of a monitoring system (dashboard), which includes a carbon footprint calculator, in addition to recommending solutions to reduce the power consumption of the building. As we divided the components into three categories, the recommended solutions that we came up with were mostly through excessive research. With the delay of data, we were unable to test the system and our recommended solutions through the monitoring system (dashboard). Therefore, presenting the first proposed solution for the lighting category, we have found that there are different types of lights used in the building. Through research, we discovered that different types of lights can be substituted instead for the original lights that are used. This is calculated to save around 43% of power consumption. The second proposed solution regards the HVAC system category. Also through research we found two different proposed solutions. First was building commissioning, which saves up to 10-15% of power consumption[2]. Second was modifying the thermostat, which is one of the main contributors to the power consumption of this category. Through research, the temperature is changed usually based on the preferences of the occupants. Therefore, we proposed a solution of conducting a survey to determine the prefered temperature of the occupants. Increasing the temperature by 1 degree celsius, can save up to 10% of the power consumption[3]. Finally, the plug loads category, which is the most challenging category. Since this category revolves around what is plugged in, and lack of awareness, we cannot monitor the occupants all day. However, we propose that since the building of operation (OBO)

has the upper hand, computers and other resources that are managed by TAMUQ building, it can be controlled to reduce a percentage of the power consumption.

Visual prototyping and Analysis for Designed Circuits

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 the TAMUQ building and following the GHG protocol guideline, we chose scope 2 which is electricity since this is our main focus[4].

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(figure1). 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 which are presented in figure 2. The chart (figure2) 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.

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		
lighting	1656	988.632	18413.05	10992.5908
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 1: Excel spreadsheet for plug loads,HVAC,lighting in TAMUQ

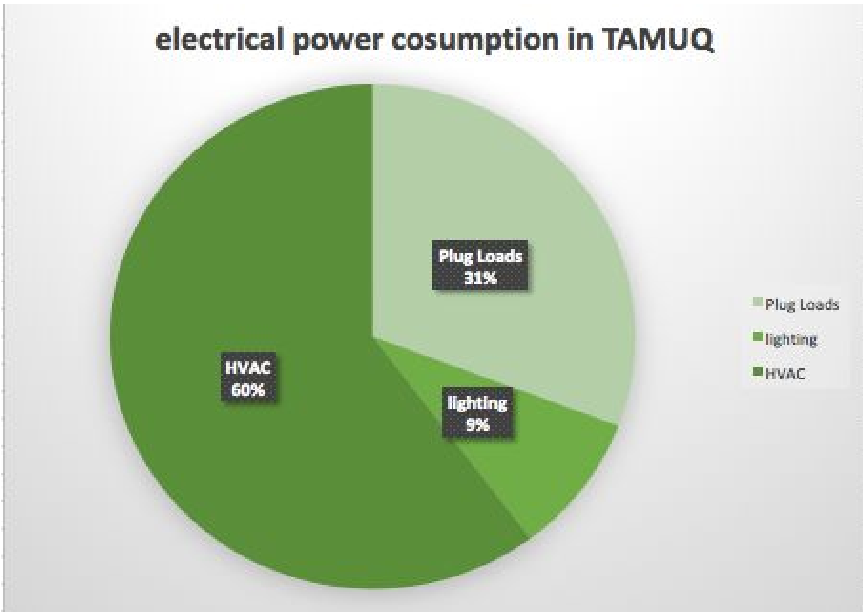

Figure 2: Chart showing the electrical power consumption in TAMUQ

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

To build our calculator we used the spreadsheet that has all data, and we used python language 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 years 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 two graphs, the first is showing the power consumption in Kwh and the second is showing the carbon footprint in kgCo2e with respect to specific months of the year. The inputs for the system would be any component of the three main categories and their subcategories, the user can then choose the month and the user can choose the whole year as well. The dashboard will present the results of this specific componet's power consumption and carbon footprint for the specific chosen time.

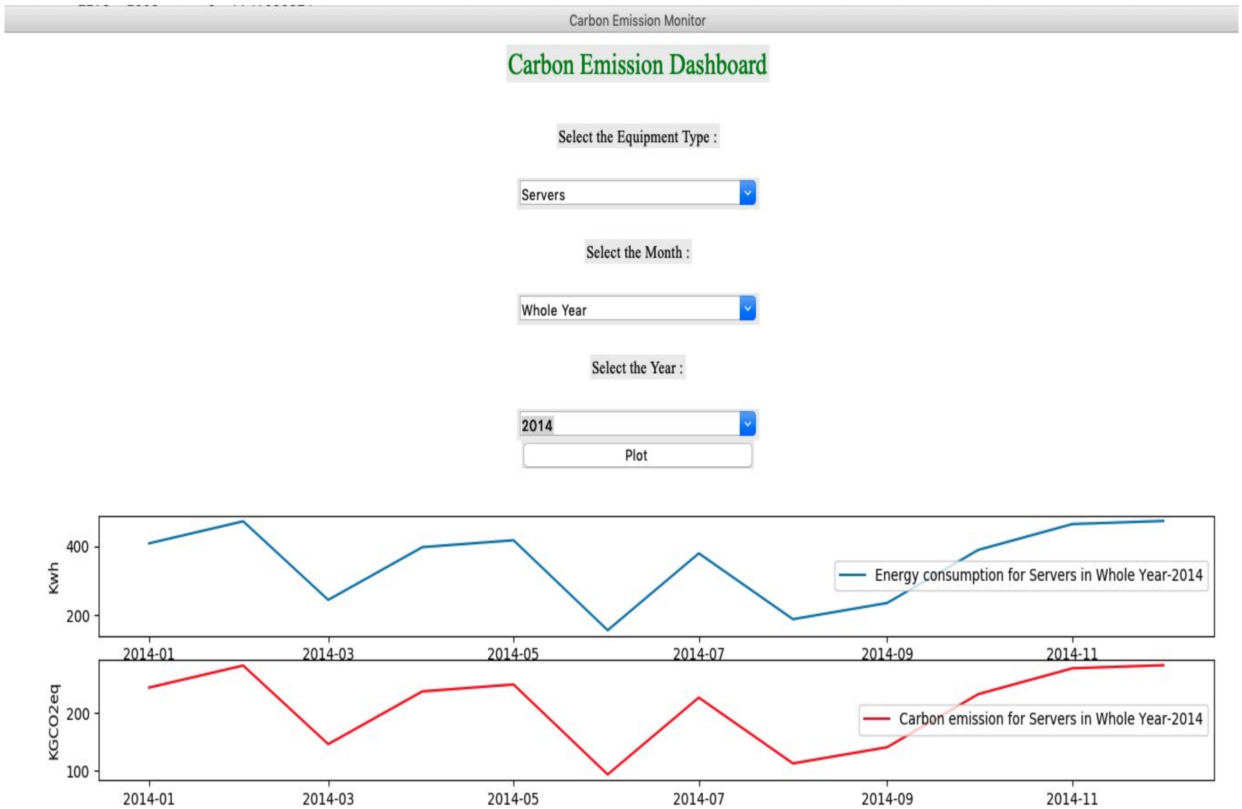

Figure 3: initial Dashboard to show the power consumption and carbon footprint in TAMUQ

Proposed solutions

For the second part which is proposing solutions to 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 [5]. These components are a better substitute to the current ones since by using them the total power consumption, shown in *figure 4*, 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 4 : *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 3*, 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[2]. 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[2]. For example, monitoring the HVAC system to measure system efficiency, in addition to system inefficiencies such as leaks[2]. This process is proven through research that it can lead to 10-15% of annual energy costs[2]. 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 5*, 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[6]. 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 5: 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[7]. 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 44%[7]. 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[7].

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[7]. 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[7].

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[7].

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[7]. 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[7].

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[8] .

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[8].

Code explanation:

Block diagram

The block diagram below explains the functionality of the prototype. First the user has to select the input or component he wants to view. If the user didn't select an equipment , computers are the default option. Secondly, the user has to select the month he is interested in and January is the default option if the user did not choose. Lastly, the user has to select the year he wants to view the and if he didn't choose 2008 is the default answer. Two graphs will be generated, the first graph is the power consumption in Kwh for the specific component at the specified year and month. The second graph is the equivalent carbon footprint in KgCo2e.

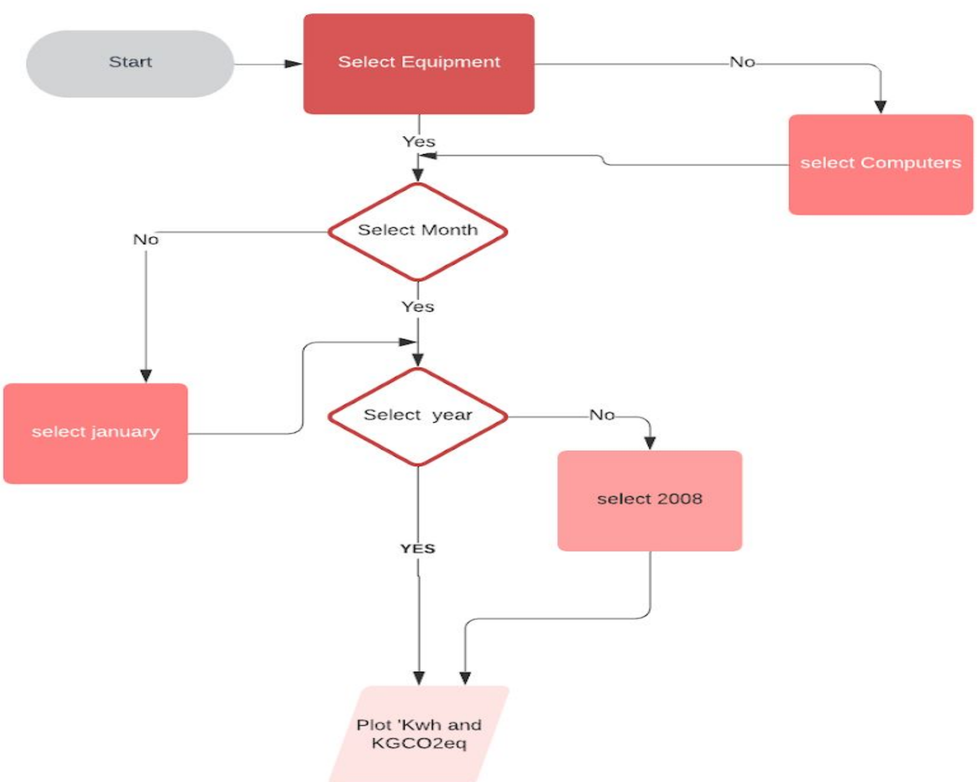

Figure 6: Block diagram of the program code

Program code

The program is written in python and specifically we used object oriented programming. As shown in the prototype below there are two main parts. The first part which is shown in figure -is creating combo boxes that allow the user to choose the desired information from a drop-down list. We created three drop-down lists which are the component, months and the years. The second part is plotting the total power consumption in Kwh and the equivalent carbon footprint in KgCo2e using tkinter GUI with the embedded Matplotlib module.

Figure 7 *:part of the program code for the combo boxes*

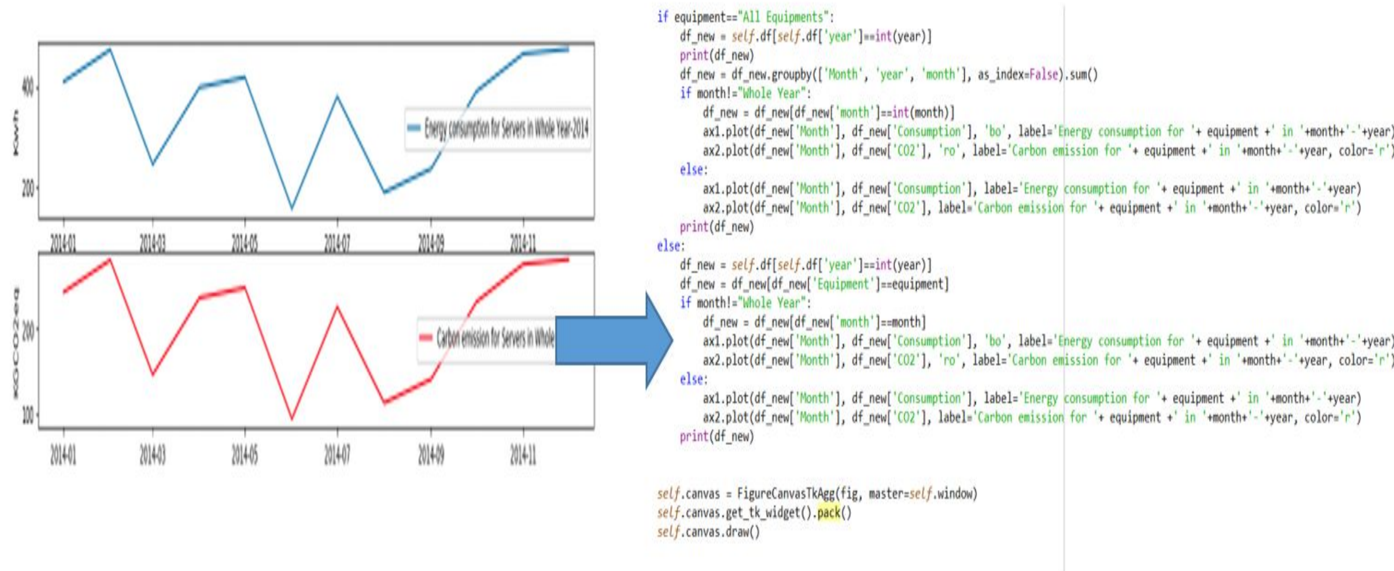

Figure 8: *part of the program code to plot power consumption and carbon footprint.*

Testing and Troubleshooting

For our project testing and troubleshooting revolves around the data we have collected and the data we have received from TAMUQ building of operation and central facilities (CP1). We have collected data manually. That is by adding up the components in each office, classroom, and lecture halls. Where each component has a rated value in KWh. On the other hand, the data sent from the building of operations and CP1 were the total power consumed in the building.

As a test we have divided the components into three parts of plug loads, lights, and HVAC. With the data collected manually, we added all the data to find the total power consumption. We have compared the data with the data provided to us, and it was found that there was a vast difference between the values. Troubleshooting, we found that we had data missing. Since our project depends heavily on data, we were set back from creating and finishing the monitoring system. Recently, we have received most of the data we need that approximates to the total power consumption. Therefore, we used the data we have to construct a monitoring system using python language. However, the final monitoring system is not fully done. In *figure 7* and *8*, we have constructed a sample dashboard with some of the data missing. Using the random function, it was possible to present that data we have in continuous graphs.

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. This is the first attempt for the dashboard and we are currently working on creating more visuals. However, the first attempt was successful because we were able to extract the chosen data by the user from the csv file that contains the data for all the inputs and plot the power consumption and carbon footprint for the specified element in the specified period. 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 . Lastly, we still lack some information about the HVAC system so we will try to come up with general solutions that can be applicable for different types of HVAC systems.

Progress compared to proposed timeline

Table1: Current progress

Current Progress			
	January	February	March
Data Collection			
Carbon Calculator			
Monitoring system			
Project Implementation			
Propose solution			
Testing			

Completion	In progress

Table 2: Proposed Timeline

Proposed Timeline					
	Dec	**Jan**	**Feb**	**Mar**	**Apr**
Data collection					
Carbon calculator					
Monitoring system					
Implementation of the project					
Propose solutions					
Testing					

Complete	**Planned**

As shown in table 1, through January and February, our main focus was data collection. We obtained most of the data needed, however, still there is some data missing. As for the other tasks, we are still working on them. Whereas shown in table 2, our proposed timeline, data collection was planned to be completed by January. The difference between our proposed timeline and current progress is the duration of data collection. Since our project depends heavily on data collection, all tasks will be behind in schedule. However, having most of the data we need, we were able to start building the carbon footprint calculator, monitoring system, and the implementation part of the project.

Conclusion

In conclusion, what led us to work on this project is the high percentage of carbon dioxide in the atmosphere, which leads 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. However, the final dashboard is still not fully done.

Discussion

The first attempt for the dashboard is a simple dashboard which we need 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 , request information from building operations and central facilities 1 in the education city. Still some of the data are missing but we were able to estimate the power consumption on a monthly basis. then 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 will include a figure that Total power consumption over the years for all components, this includes all the inputs, plug loads, HVAC, and lighting. The second figure is a gauge chart that indicates whether the current consumption is high or low. The will be based on the maximum and the minimum value specified in the csv file. If the current consumption is high which means it is near the maximum indicator arrow will point on red color but if the consumption is low which means the current value is near the minimum value the inductor arrow will point on the green color. The third figure is a pie chart that shows 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. Lastly, add a section for tips and reminders to raise awareness about energy efficiency.

Verification

The data collected and provided are approximated to be almost the same. Which means that the collected data is consistent with the data read by the panels. However, the monitoring system showed some issues with presenting the data. As for the recommended solutions, we still did not finish the code therefore, we cannot verify our recommended solutions yet.

Future recommendations, Improvements and optimization

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 and by taking the advice of facilities and building of operation regarding the proposed solutions.

We also want to improve our calculator by adding a minimum and maximum that match the values that we have to have a good comparison in terms of numbers to be able to generate data within specific boundaries.

In addition to improving the calculator in terms of having more visuals and better presentation of results in the dashboard. Also to have different charts that show the power consumption and carbon footprint for the previous and the coming years. Finally, we are still working on adding tips to reduce carbon footprint and motivational advice to raise awareness in the community.

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https://newbuildings.org/sites/default/files/PlugLoadBestPracticesGuide.pdf

Twenty percent of the electricity consumption in California's office buildings can be attributed to plug loads (Moorefield et al. 2011). Through metering, solutions for reducing plug load energy consumption in office buildings have also been evaluated, such as installing advanced power strips, converting to ENERGY STAR®-certified appliances, and/or implementing behavioral campaigns. A combination of savings strategies like this demonstrated a 47% reduction in associated electricity consumption in one office building (Lobato et al. 2011)

https://link.springer.com/article/10.1007/s12053-016-9503-2#Tab2