TEXAS A&M
UNIVERSITY *at* QATAR

Electrical and Computer Engineering Program

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Benchmarking Analysis
Monitoring The Carbon Footprint 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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Acronyms

TAMUQ: Texas A&M at Qatar

CO2: Carbon Dioxide

QU: Qatar University

IoT: The Internet of Things

AirVantage IoT platform: A management interface

GHG: Greenhouse gas

RFID : Radio-frequency identification

BIM platform: Building Information Modeling (BIM)

1 Introduction

1.1 Problem Statement

Human development is compromised due to high levels of carbon dioxide in the atmosphere. Qatar is negatively imaged since it is ranked as the highest carbon dioxide emitter per capita globally[1]. Texas A&M University at Qatar (TAMUQ) building will be the case study for this project. 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 satisfy to support the environment by contributing to decreasing the levels of carbon dioxide emission and sustaining energy.

1.2 Proposed design

TAMUQ is being ranked second in education city for its high energy consumption. This affects the environment in the first place and its image in education city and in Qatar. Our aim in our proposed design is to create a real time monitoring system in the building to measure the carbon footprint. We are aiming to build a carbon footprint calculator to calculate and convert the energy consumption values that we get from the university which is in Kwh to carbon footprint unit which is KgCo2e. Our second goal is to analyze the highest energy consumption component in the building and propose solutions to reduce its high energy consumption. We will study three main areas in the building, which are the academic, and research. The academic section includes classrooms, offices, and students labs. For the research section it includes researchers offices and their labs. Depending on the results we will get we will demonstrate solutions to reduce carbon footprint in TAMUQ building.

2 Existing solutions

2.1 Qatar University Campus Carbon Calculator

A project was done in QU under the name of Campus Carbon Calculator. The aim of the project is to measure the total amount of carbon footprint in a specific building, they used an online calculator that had the U.S. conversion factors. This calculator is available online and a lot of universities and schools use to measure their carbon footprint in the U.S. The spreadsheets used were originally based on the workbooks provided by the Intergovernmental Panel on Climate Change (IPCC) [2]. Their Calculator has adapted this IPCC data for use at institutions like a college or university, but follows virtually the same protocols. In their project they focused on collecting data and inputting them in the calculator. The data they focused on is the building's area, number of offices, number of researcher's offices and total number of students, researchers including full time and part time [2]. They gathered the data and put them as inputs in the calculator and therefore were able to calculate the carbon footprint in the building. They got the value of total electricity in Kwh and using the calculator they obtained it in KgCo2e and they included scope 1 and scope 2 [2]. The calculator they used in QU had the conversion factor of the U.S so the results weren't accurate but they focused on the assumption they made.

2.2 IoT Design: A Carbon Footprint Monitoring System

From New Zealand, Christever del Rosario built a daily Carbon Footprint monitoring system. The system that he built measured both CO2 emissions from his car and indirectly measures the energy consumption from his household[3]. Del Rosario achieved this by a mobile app that he developed using the AirVantage platform. The app monitored both the CO2 emission of his car and certain parameters from his household. That was achieved by using sensor data and connecting it to the app. AirVantage also was used by Del Rosario to remotely control the smart plugs and smart switches in his household, in addition, reduce unnecessary energy consumption[3]. Also, using the same Carbon Footprint monitoring system that he built and by analyzing the historical data that was already stored in AirVantage, Del Rosario identified some simple ways to reduce his carbon footprint[3]. Finally, Del Rosario has more ideas to add to his application and searching for improvements and solutions. Christever del Rosario won first place in Sierra Wireless co-sponsored "In the Air," an Internet of Things (IoT) design challenge organized by Element14[3].

2.3 Real-Time Carbon Emissions Monitoring Tool for Prefabricated Construction: An IoT-Based System Framework

There are three main phases to identify the sources and analyze carbon emissions in a building; the construction phase, operation phase and maintenance phase .The emission in the construction phase for any building is higher than the emissions in the operation and maintenance phases. 30% of total carbon emissions annually comes from the construction phase [4]. According to the authors, no monitoring tool is available to track carbon emissions in the construction phase in the literature review. A real-time monitoring system was developed and has been tested on a real building components production line. The goal of this system is to minimize GHG emissions, especially carbon emissions, in the construction phase. The proposed design uses an IoT-based system along with different sensors, such as RFID sensors, to store the data about the emissions to collect data. Three main activities were considered in this system components manufacturing, transportation, and on-site installation. The results are displayed in an on-line BIM platform to take corrective actions to reduce excessive emissions[4].

3 Benchmarking

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:

1- public health
2-Safety
3-Welfare
4-Global factor
5- Cultural and social
6-Environmental
7-Economics

3.1 Public health

The public health is one of the main aspects that our design target. 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 CO2 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 CO2 associated with energy consumption and improve the quality of the air[5].

3.2 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 its explained in detail in the environment section.

3.3 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.

3.4 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.

3.5 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 affects 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.

3.6 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 the 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 start 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 first TAMUQ building to lower its energy consumption and be eco friendly building. This will motivate other building 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.

3.7 Economics

Our project is directly related to 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 raise its economy.

Critrail considered for each design	Meaning
Cost	The total cost of implementing the design.
Type of data	Type of data feed to the system.
Efficiency	Evaluate the efficiency of the system
Maximum range	The range where the system is applied
Environmentally friendly	Evaluate the system whether it is environmentally friendly or not
Accuracy	Evaluate the accuracy of the system
Protocol	Protocols followed while designing the system
Emission	Applied solution to reduce the emissions

Table 4.1: Criteria for the Benchmarking analysis

4 Benchmarking Table

Critrail considered for each design	QU carbon calculator	AirVantage carbon Footprint Monitoring system	Real-Time Carbon Emissions Monitoring Tool for Prefabricated Construction: An IoT-Based System Framework	TAMUQ carbon calculator
Cost	N/A	N/A	N/A	2739$
Type of data	Not real time	Real time	Real-time	Real time
Efficiency	2	1	2	1
Maximum range	One building	One building + One car	building for production line	One building
Environmentally friendly	1	1	1	1
Accuracy	3	1	2	1
Protocol	GHG protocol	GHG protocol	Product Life-Cycle standards	GHG protocol / ISO 14067protocol
Emission	3	3	3	3

1 : High	**2: Medium**	**3 : Low**

Table 4.2: comparison of the designs based on the chosen criteria for Benchmarking

5 Benchmarking Analysis

There are different designs that involves monitoring the carbon Footprint through different components and using different tools. However, it is important to verify how each design works. Also, the efficiency and accuracy are crucial. Above, in table 4.2, we have covered different aspects from different designs that were implemented by other engineers globally. The most significant parts will be discussed below.

5.1 Type of Data

As stated above, our project “TAMUQ carbon footprint calculator” is planned to be implemented where the information gathered will be observed in real-time. Also the IoT-Based System Monitoring Tool for the construction phase gives a real-time measurements for the carbon emissions for all the activities displayed in a 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.

5.2 Efficiency

For the case study of AirVantage Carbon Footprint Monitoring system, it is highly efficient, where the app is being used and controlled by a smartphone. Our design of a carbon footprint calculator is very similar to that design since we are also designing a monitoring system, however, not using the same platform. Also, QU, 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 save them in the databases. The equations that governs the system separate the activities and display real-time cumulative amount.

5.3 Accuracy

As mentioned previously that 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 in real-time. 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.

5.4 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.

6 Summary

Summarizing, it was observed that some designs were very similar to our design, however, they approached it differently. Our design is to calculate the carbon footprint in Texas A&M building using a carbon footprint calculator and monitor it in real-time. In the case of QU, they have built the calculator to calculate the carbon footprint of one building, however, it was not in real-time, in addition to the conversion factors they used were for a different country. Another case where a carbon footprint monitoring system was built to monitor the energy consumption of a residential building and one car in real-time. This design is the most comparable to our design since the engineer also used an app for his design. Finally, real-time carbon emissions monitoring Tool for Prefabricated Construction. This design is intended to monitor the carbon emission of the construction phase. Also, it was achieved to monitor in real-time using an IoT framework.

We are still working on our proposed design and we might change the monitoring system to a real time monitoring system but this depends on the equipment available. We will also try to reach more experts in the field to help us in our analysis and

interpretation. We will also change the study of the whole building and will focus instead on academic and research part.

7 Conclusion

In conclusion, our project aims to design a real-time monitoring system to measure the carbon footprint in the Texas A&M building. For us to achieve this goal we need to build a carbon footprint calculator to calculate and convert the energy consumption of the building's components to carbon footprint . We have searched for existing solutions to compare and observe their approach to our design. We have found three different existing designs, one is Qatar University carbon footprint calculator, second is the carbon footprint monitoring system, finally is the real-time carbon emissions monitoring tool for prefabricated construction. In a table, we have compared and observed the differences between each design and our design.

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