Energy Management Analysis: The College of Engineering Building

EE 499

Senior Project

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Abstract

The Energy management system has been a rising demand & a need in today's market. Energy management is the understanding & control of energy in a given system. This trend is ever increased by the demand. Previous studies have relied on their own infrastructure & thus unable to be implemented in a broad general application. We used the data of our own College of engineering building in the University of Business & Technology which has Electrical Components, Airconditioning & Sunlight affecting the internal consumption of the building. Our findings have shown by using the building's electrical system case comparison analysis we are able to compare Case I: fully operational electrical system with Case II scheduled operations electrical system, then by using our proposed optimization method we have developed Case III which has saved energy & cost of 96 SR per month. The necessity for further zoning more areas in a given infrastructure have provided better optimization for the energy management system, thus showing a more promising understanding & control of energy.

Acknowledgment

Foremost, we would like to express our sincere gratitude to our project supervisor Dr. Mohammed Algarni for the continuous support, expert advice & encouragement throughout this difficult senior group project. We thank him for his patience, motivation, enthusiasm & immense knowledge, as well as our parents & friends who are always their when we need them the most through this difficult time.

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Chapter 1:

Introduction

Chapter 1: Introduction

1.1 Introduction

Energy efficiency is a commitment to get the maximum impact from energy consumed. Energy efficiency encompasses a range of technologies, behavior, and industries, and it had relevant applications to most sectors of the economy. Energy efficiency continues to change with our evolving energy system, providing an unending source of opportunities. As a result, energy efficiency requires continued commitment, assessment, and development of new strategies. From our continuous research in energy efficiency and data collection methods it is possible to arrange a system to get the most out of energy cost and redundancy. Our research has come to the tipping point of understanding that energy efficiency starts before the construction of a building, but as we know the building is already constructed, so we can start with what is being used in the electrical engineering building which is the premise of our project. As we learned Smart sensors, appliances, human interactions, room utilities, room sizes, etc.…. are all connected to energy efficiency, because each aspect that is enlisted have a direct impact in energy consumption. The project will start with the building and its consumption as we move forward in developing a plan to maximize.

1.2 Background and Significances

How many people know that replacing light bulbs will help creating more efficient electric grid which will lead to the reduction of electricity price for everyone? How many people know that the increased of energy efficiency will prevent asthma attacks, and save billions in healthcare costs? How many know that energy efficiency usage is a huge job creator and it's capable of boosting the local economy development? Based on national political arguments, not enough.

For example, let's take for example when the Department of Energy in the US in 1970s, when they started creating tools, equipment, and appliance energy standards, the energy efficiency has become the country's third largest electricity resource, providing the grid more than nuclear power, where without it they would need at least 313 large power plants to meet the energy needs. Since 2000, the nation's GDP grown by about 30%, all of this to give you an insight of how important is to utilize the energy we have by improving the efficiency to provide more energy with better cost.

Let’s illustrate by simple and scientific approaches of how we can implement energy efficiency to get the bigger picture of the many benefits that we can have. Leaving electronics and appliances turned on during our absence will drain energy for nothing, we can easily sleep mode or sensors to turn it off when we are not present. Replacing the dirty filters when they are clogged so they don’t reduce the airflow, which makes the blower work harder to push air through, this will increase energy consumption. Compromised equipment that is not functioning correctly will be a drain to energy consumption, so there are not benefits to keeping them. What about the cooling and heating system? HVAC new control system will save and reduce energy costs regarding the ac and heating.

There are studies showing positive results of applying energy efficiency, related to the environment, creating jobs, and economy wise. Saving energy will reduce greenhouse gas emissions and benefit the environment. It is a massive job creator and provides boost to local economic development. It saves money, where is the lowest cost energy resource, meaning it is less expensive to save energy through efficiency measures than it is to generate it through any other means. Studies have proved that increased building efficiency leads to additional disposable income that is spent locally, which connects with other existing jobs with a newer job.

1.3 Motivation

After attending this school, there are classes that has its AC units and lights fully ON for no reason at a certain time during the week. As electrical engineers, this wasted energy and unused spaces can be saved and used more efficiently.

1.4 Aim and Objectives

The aim is proposing a plan and a design of taking a full advantage of the EC building to save the most energy possible, and creating the optimum schedule with the least cost. The final goal is to prove the importance of energy efficiency and how it can be applied in all buildings with using less fossil fuels.

1.5 Thesis Outline

This thesis consists of five chapters as follow

Chapter 1:

Chapter 2: contains the Literature will begin by talking about: - Problems - Energy Efficiency

Chapter 3: contains the Solutions (methodology)

Chapter 4: contains the Results

Chapter 5: contains the Discussions (Supports for our conclusions)

Chapter 6: contains the Future Works

Chapter 2:

Literature Review

Chapter 2: Literature Review

2.1 Overview

This chapter will be covering the literature review about the research topic. The recent studies about energy efficiency will be discussed alongside with the applied solutions. Additionally, some available case studies will be reviewed and significant results will be illustrated. This should help to highlight the main factors of building's energy management process which will be used later to assess the energy efficiency at CE.

There are hundreds of thousands of methods for energy efficiency available, but as you will see in the next chapter, we picked these solutions and what can be made by them.

In this overview, we will only talk about energy efficiency, emissions effects and its reduction methods, history of electrical efficiency until now and the advantages of increasing efficiency.

Emissions effects and their reduction methods are ways to reduce emissions and to decrease their effects. Emission effects are critically dangerous to the environment and the people, either financially or medically. It will be explained more in **Error! Reference source not found.**.

"Those who do not learn from history are doomed to repeat it" (George Santayana). From the previous quotation, Learning the history of energy efficiency shall provide a workplan to find the best methods to apply in managing energy at the College of Engineering building (CE) efficiently.

Increasing efficiency is always something desirable for as engineers, either electrical, mechanical, civil, etc

2.2 Emissions Effects and Its Reduction

Energy can neither be created nor destroyed; rather, it transforms from one form to another.

- a scalar quantity
- abstract and cannot always be perceived

- given meaning through calculation
- a central concept in science

Energy can exist in many different forms. All forms of energy are either kinetic or potential. The energy associated with motion is called kinetic energy. The energy associated with position is called potential energy. Potential energy is not "stored energy". Energy can be stored in motion just as well as it can be stored in position (Glenn).

Electricity

What is electricity? A basic definition of electricity is a form of energy that results from the flow of charged particles. Electricity being the flow of moving electrons, it should be known this produces a resultant called electrical current. This current allows objects to work in tangent with each other by flowing through conducting materials connecting them. The path that the electrons flow through is called a circuit. Circuits connect all of our electronic devices allowing us to live the way we do today (*Physics of Electricity*).

Fossil Fuel is a fuel formed by natural processes, such as anaerobic decomposition of buried dead organisms All fossil fuels are burned in air to provide heat. Fossil fuels include coal, natural gas, oil shales and heavy oils. This heat can be used directly to produce steam to drive generators that can supply electricity.

Fossil fuels include coal, petroleum, natural gas, oil shales, bitumens, tar sands, and heavy oils. All contain carbon and were formed as a result of geologic processes acting on the remains of organic matter produced by photosynthesis, a process that began in the Archean Eon (4.0 billion to 2.5 billion years ago). Most carbonaceous material occurring before the Devonian Period (419.2 million to 358.9 million years ago) was derived from algae and bacteria, whereas most carbonaceous material occurring during and after that interval was derived from plants (Kopp).

“Global emissions in 2010 approached 30 gigatons (Gt). Approximately 12 Gt (40%) are emitted from electricity generation sector through the combustion of fossil fuels like coal, oil, and natural gas to generate the heat needed to power steam-driven turbines” (El-Shennawy).

The aim is to reduce emission by: **energy efficiency**, improvements in building are important to reduce gas lacking making buildings safer and builds friendly environment They also help improve reduce the cost of energy, increase fuel capacity and emits the need for additional power capacity. Options include:

• Using appliances and lighting that are highly efficient.

• Using lights applicable with sensors or turning down thermostats.

Energy & Fossil Fuels

From fossil fuels and solar power to Thomas Edison and Nicola Tesla's electric marvels, the world runs on energy. Harness your natural resources and test your knowledge of energy in this quiz.

All fossil fuels can be burned in air or with oxygen derived from air to provide heat. This heat may be employed directly, as in the case of home furnaces, or used to produce steam to drive generators that can supply electricity. In still other cases—for example, gas turbines used in jet aircraft—the heat yielded by burning a fossil fuel serves to increase both the pressure and the temperature of the combustion products to furnish motive power (Kopp).

Energy Efficiency

At its most basic, energy efficiency refers to a method of reducing energy consumption by using less energy to attain the same amount of useful output. For example, an energy-efficient 12-watt LED bulb uses 75-80% less energy than a 60-watt traditional bulb but provides the same level of light (Energy Efficiency).

Energy management is the process of tracking and optimizing energy consumption to conserve usage in a building (Wilson).

There are few steps for the process of energy management:

- Collecting and analyzing continuous data.
- Identify optimizations in equipment schedules, set points and flow rates to improve energy efficiency.
- Calculate return on investment. Units of energy saved can be metered and calculated just like units of energy delivered.

- Execute energy optimization solutions.
- Repeat step two to continue optimizing energy efficiency.

2.3 History of Electrical Efficiency Until Now

A word can have multiple and ambiguous meanings in everyday language but they have precise meanings in science. Efficiency in physics (and often for chemistry) is a comparison of the energy output to the energy input in a given system. It is defined as the percentage ratio of the output energy to the input energy, given by the equation: This equation is commonly used in order to represent energy in the form of heat or power.

"Efficiency" is often confused with "effectiveness", and the two should be recognized as distinct from one another when analyzing energy systems. Energy efficiency measures how much a system is getting out of the fuel or primary energy flow it is using. If the energy system is effective, it is making use of this energy towards the right goal. For example, a car is a very effective form of transportation, since it is able to move people across long distances and to specific places. However, a car may not transport people very efficiently because of how it uses fuel.

The first generation of efficiency programs: “Just Use Less”

The beginning of energy efficiency as we know it was in the 1970s and ‘80s, and was called “conservation.” Responding to the price shocks of the Arab Oil Embargo, Congress established the Department of Energy in 1977 to, among other things, diversify energy resources and promote conservation. The Low Income Weatherization Assistance Program (WAP) was among its first programs. To date, WAP has served over 7.4 million homes, helping the nation’s most vulnerable reduce energy costs while increasing comfort and safety. Another early program – the Residential Conservation Service (RCS) – established by the 1978 National Energy Conservation Act, promoted energy audits and asked consumers to insulate their homes, weather-strip windows, wrap water heaters, turn down thermostats, and turn-off lights.

1.The rebound effect (1860s-1930s)

The rebound effect, defined above as energy savings that are less than proportional to energy efficiency improvements, can take three major forms (Linares and Labandeira 2010): the direct rebound effect, which consists of less-than-proportional savings in the use of the very service that was subject to efficiency improvements; the indirect rebound effect, coming from the income effect created by the savings, leading to an increased consumption of other energy services; and the general-equilibrium rebound effect, resulting from changes in relative prices that stimulate energy-intensive sectors.2 In addition to this typology, an important question is the magnitude of the rebound, which can be very different from one situation to another. It can simply consist of savings slightly smaller than efficiency gains, but it can also produce a somewhat counter-intuitive situation, in which energy consumption actually increases – generally referred to as backfire effect.

2. The energy efficiency gap (1980s-1990s).

The concept of energy efficiency gap developed in the late 1970s and 1980s and reached maturity in the early 1990s. Broadly speaking, the energy efficiency gap refers to the notion that investment in energy efficiency is, by some measure, suboptimal. The problem can equally affect the extensive and intensive margins of investment; that is, produce too few and/or too small investments. The crux of the concept is that the reference taken for optimality differs in engineers' and economists' views, with important consequences for any conclusion as to the magnitude of the gap. As we will see below, the concept creates a new demarcation line between engineers and economists which superimposes on, and to some extent even encompasses, the one associated with the rebound effect.

3. Green nudges (since 2000s)

The energy efficiency gap essentially is a neo-classical economic concept, in the sense that, by drawing a line between market failures and non-market failures, it provides a framework to think of energy efficiency investment in situations where the fundamental assumptions of well-functioning markets – perfect competition, perfect information and well-defined property rights are violated. The framework also has a practical appeal in that it provides clear guidance for policy-making: for any market failure proved significant, there is a policy remedy to implement.

4. A synthetic framework

Our historical journey has revealed demarcation lines between engineers and economists that first emerged in the context of energy efficiency through the rebound effect. In the late 20th century, divergences on the role of market feedbacks were supplemented by contrasted views of decision-making mechanisms. Most recently, the acknowledgement of behavioural barriers has been an opportunity to reconcile the economic and the engineering perspectives over energy efficiency. Both camps consider these barriers as central, legitimizing policy measures for energy improvements. Yet behavioural analysis led to a new fault line – one between nudge advocates and a more sceptical community – about the effectiveness of nudges, which might be strongly driven by pre-existing market failures. Not only does this new fault line not clearly separate out economists and engineers – there are advocates of both positions in both camps – it does not either fit into the conceptual framework that prevailed up to now; indeed, it is seemingly orthogonal to the usual demarcation lines structuring the debate over the energy efficiency gap.

2.4 The Advantages of Increasing Efficiency

Energy auditing its sole purpose is to report all the wasted energy resources.

The building needs to reflect engineering principles and concepts by optimizing all energy resources fed into it. An example: - the amount of energy used might be high in lighting, which increases its intensity thus distributed correctly. Therefore, all aspects of energy being used in the building will need to be inspected, optimized, and analyzed.

Auditing inspects the panels to know what needs to change in cost and waste properly.

Now, what are the pros of investing in using energy efficiency? An energy-efficient building can save money while reducing its carbon footprint. According to the U.S. energy of information administration and the EPA, which is an abbreviation od Environmental protection agency, they both have conducted a thorough search where they have found residential and commercial building account for 39% of energy consumption in the U.S., which tells us there is plenty of room for improvement.

As we have mentioned briefly before, Saudi Arabia's government requires companies to be socially responsible, in the people and the environment, as popular demand has increased in greed of real estate sector and energy-efficient building.

All energy-efficient buildings are its definition are designed to reduce energy use and decrease or distinguish waste and emissions. There are risks and benefits with every investment, such as the fact environmental benefits may come with added economic costs.

We ask the question, is it worth investing in an energy-efficient building? Where are the interests? Green investing to help the environment, or is it purely financial or both? The investing perspective is whether following your environmental principles will hurt or help you financially.

Now we will go through the list of pros-cons.

First, we will cover the cost because a budget is mainly the prime driver of any energy project.

Pro: At the right angle at the right location, an energy-efficient building can realize zero utility bills as long as the sun cooperates correctly. An increase in the first five years after installing solar electric systems, solar water heaters, geothermal heat pumps, small wind turbines, and fuel cell systems placed into service. The percentage increase would be up to 20% in the value of the property. In 10 years to 20 years, it will be up to a max of 30% to 35% increase making it a great resale value in the long run, but before 25 years unless replaced.

Con: As an upfront cost, energy-efficient buildings are at the bottom of the list, although some costs can be saved from the Saudi government's initiative of green buildings investment energy savings and reduced repair bills.

Working or living in an energy-efficient building

Pro: Energy efficient building is built with natural; products that make them healthier because they have fewer dangerous chemicals. This can eliminate all respiratory symptoms like allergies, asthma, etc., saving health costs to residents or workers. The energy-efficient building will require fewer repairs because the high-quality building materials are made more durable.

Con: As for residents, they will have little to no control over temperatures because of the cooling compounds which use natural resources. As we have discussed, it is vital to position the building for maximum use of these natural resources; you might have to build the building on a property in a way you would not prefer, which could mean that blinds or shades would need to be installed.

Natural Resources:

Pro: - Reducing the carbon footprint, energy-efficient buildings depend on sun, wind geothermal energy, which reduces the dependency on conventional sources of energy.

Con: To have the advantages of these natural resources, we must build them in a location that will use the natural resources. Our preferred property may or may not be a good choice because nearby buildings or trees could block the sun, making us vulnerable to changes in neighboring structures that may or maybe not produce unwanted shade. Buildings that intend to use wind or geothermal energy resources have positioning limits.

Return on investment:

Pro: Because of the materials used, energy-efficient buildings have an increased lifespan, which provides a better return on investment.

Con: it can get expensive unless we get accurate figures on construction and long-term usage cost.

Materials:

Pro: Most of the materials used for energy-efficient buildings are from renewable materials for construction, such as recycled metal, concrete, sheep's wool, straw, compressed earth blocks, bamboo, and lumber. Five of all these are recyclable, reusable, and non-toxic, which complements the no respiratory problems.

Con: The building materials can be more expensive.

If we decide to go forward with the construction of the energy-efficient buildings or re-defining a conventional building to an energy-efficient one, it will cost us more as an upfront cost, but we will benefit from a higher value, easier resale, and savings in running costs for the life of the building, as well as reduce the carbon footprint and global warming.

2.5 Summary

This chapter covered recent researches about Energy efficiency and building energy management systems. The discussed solutions are summarized in Table 0-1 below.

Table 0-1: Pros and Cons of Building Energy Management Systems

	Pros	Cons
Cost	After installation there will be zero utility bills. Surplus of 20% to 35% in the span of 25 years	Increased upfront cost, but some saved from Saudi government's initiative of green buildings investment energy savings
Working or living in an energy-efficient building	High quality & healthier materials	No control of cooling components
Natural Resources	Reduction on dependency of conventional sources of energy	Building limitation due to layout
Return on investment	High quality materials offer increased lifespan	Expensive
Materials	Recycled materials	Increased upfront cost

Chapter 3:

Methodology

Chapter 3: Methodology

3.1 Overview

In this project, the aim is to analyze the energy consumption at CE building and improve its efficiency. Therefore, the first step is to explain the building design, number and size of rooms, usability, directions, isolation materials. Then, the load of each room will be measured and total energy consumption will be calculated.

3.2 The methodology for the CE building case study

In this project, the CE building at University of Businesses and Technology in Dahban will be investigated. The building is an educational building that works about 8 hours daily, 300 days a year. Usually, this type of buildings is two times more energy-intensive than other government buildings. The building, as shown in Figure 3-1, consists of xxxx rooms distributed among two floors. It also contains other service rooms such as elevators, toilets, café etc.

Figure 0-1: CE building layout

The project only considers classrooms with the attached services which are located in the second floor. In order to get the calculations for the energy consumption accurately based on all the installed devices that consumed. The devices in the class rooms with the quantities and the energy consumed shows in the Figure 3-2

Equipments in the classes	W/H
PC	200
LED Lights	8.5
AC	555
Screen	7
Motioin Sensor	5
Smoke Detectors	0.4
Speaker	20

Figure 0-2: The devices in the classrooms

After calculating the total load for each classroom, the building will be divided into different zones. The aim of this new layout is to categorized the building sections based on the energy consumption. This will allow to utilize the building based on the exact needs, classes schedule, which shall guarantee minimum energy consumption instead of distribute the schedule randomly which is the current situation.

3.3 Illumination or Sun Radiation

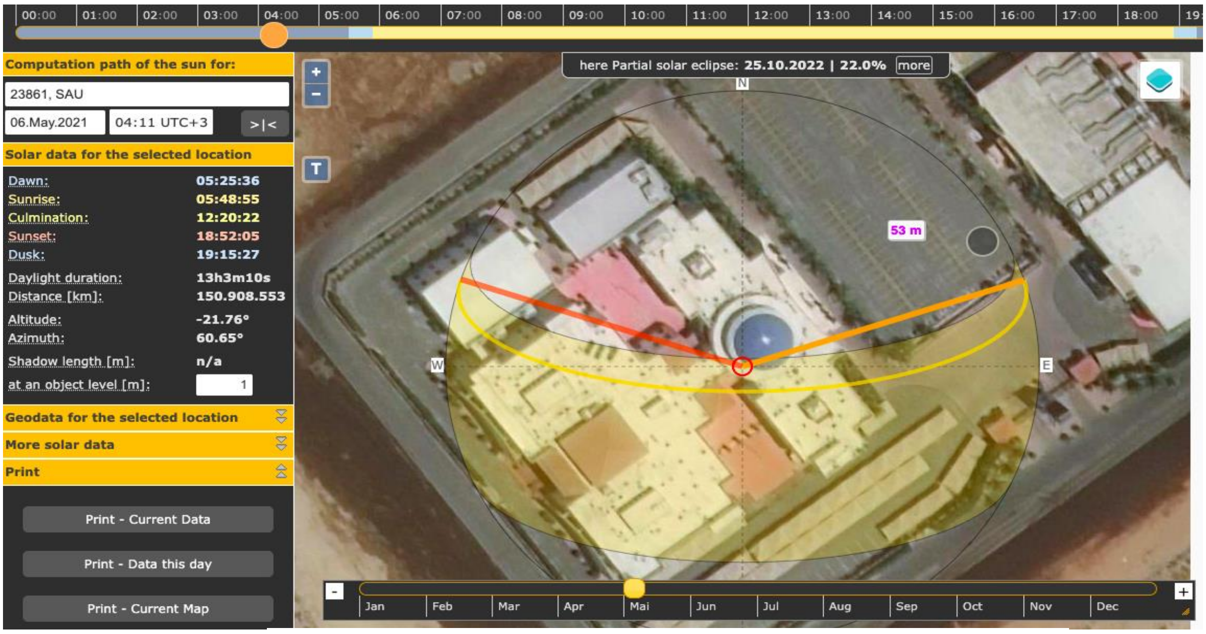

Figure 0-3: Sun Radiation on EC Building

Researching the sun movement over the EC building is an essential step to scientifically study the case of how the sun radiation is affecting the ground and the building to heat up. The significant increase of the outside temperature causes the Central Air Condition to over work by a 30 % during the peak of sunlight.

The methodology in the case study used is illumination. Illumination is a critical factor in the energy consumption of any building, especially in energy auditing. All classrooms facing direct or indirect sun radiation are considered and highlighted as shown in Figure 0-4

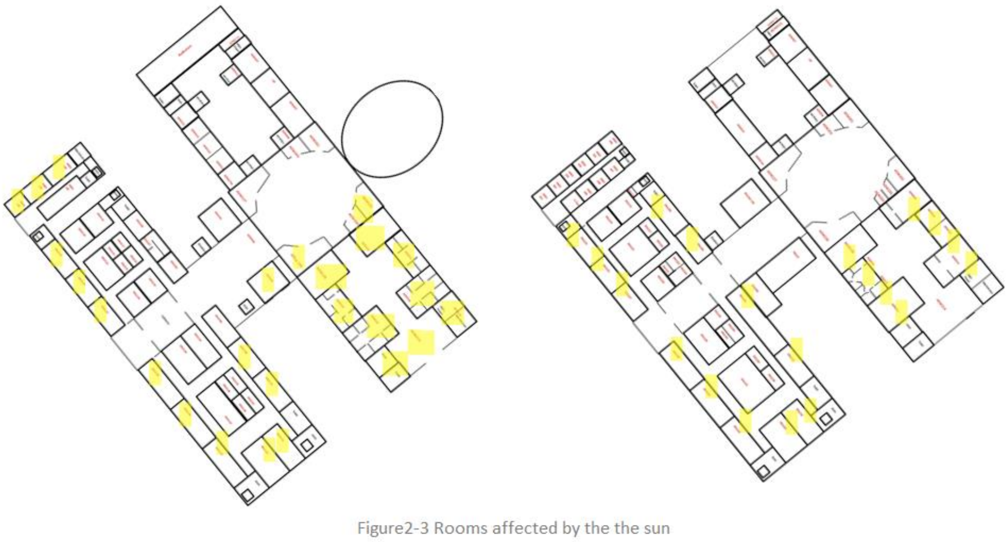

Figure 0-4: Classrooms faces sun radiation are highlighted in yellow

The sun radiation does heat the grounds and the building that leads to an excessive use of the AC to continue keeping the cool temperature constant during the day. The daylight duration is 13 hours where most of the classrooms in the second floor is exposed to the sun radiation. By choosing two different time sets in morning and afternoon, the results of the relationship between the sun lights and the excessive usage of the AC will increase the total energy consumption. Based on the classification of the second floor to multiple zones, the assumption has been made that each zone will have its own Air Central Unit. The first time set will be in the morning where the temperature will be 35 C degree and the second time set will be after noon where the temperature will be 45 C degree. The energy consumption will be increased due to the increased temperature after noon up to 30 %.

- Due to the rise of the temperature, zone green will be affected the most by the sunlight where the AC is going to work excessively up to 30 %.
- Considering the shading effect of the green zone, the AC in zone blue will work considerably extra up to 15 %.
- The furthest building of the sunlight range, the AC in red zone will work more of a 10 %.

3.4 Rooms Capacity

Room capacity is the second factor that is used in the case study. The case study shows the difference between the rooms based on capacity. There are classes with capacity of 26, 30, 36, 40, 60. The aim here is to optimize the utilization of each class according to the number of students per section.

For example, if the enrollment for a course is 16 students. Why is the class assigned in a room capacity 36 students, but this can be changed to a classroom with less capacity, 26 or 30. This help saving energy without affecting the delivery quality. Having a quick comparison between a small size classroom with a large size, such as comparing a classroom with a capacity of 18 and a classroom with a capacity of 60:

Table 0-1 comparison between a small size classroom with a large size

Capacity (no. Student)	Energy Consumption (W/Hr)
18	911.3
60	1738.8

With a random selection to the classrooms, the results will neglect the proper selections of the classrooms, which it should be based on the student capacity in order to reach the efficient consumption.

3.5 CE building zones

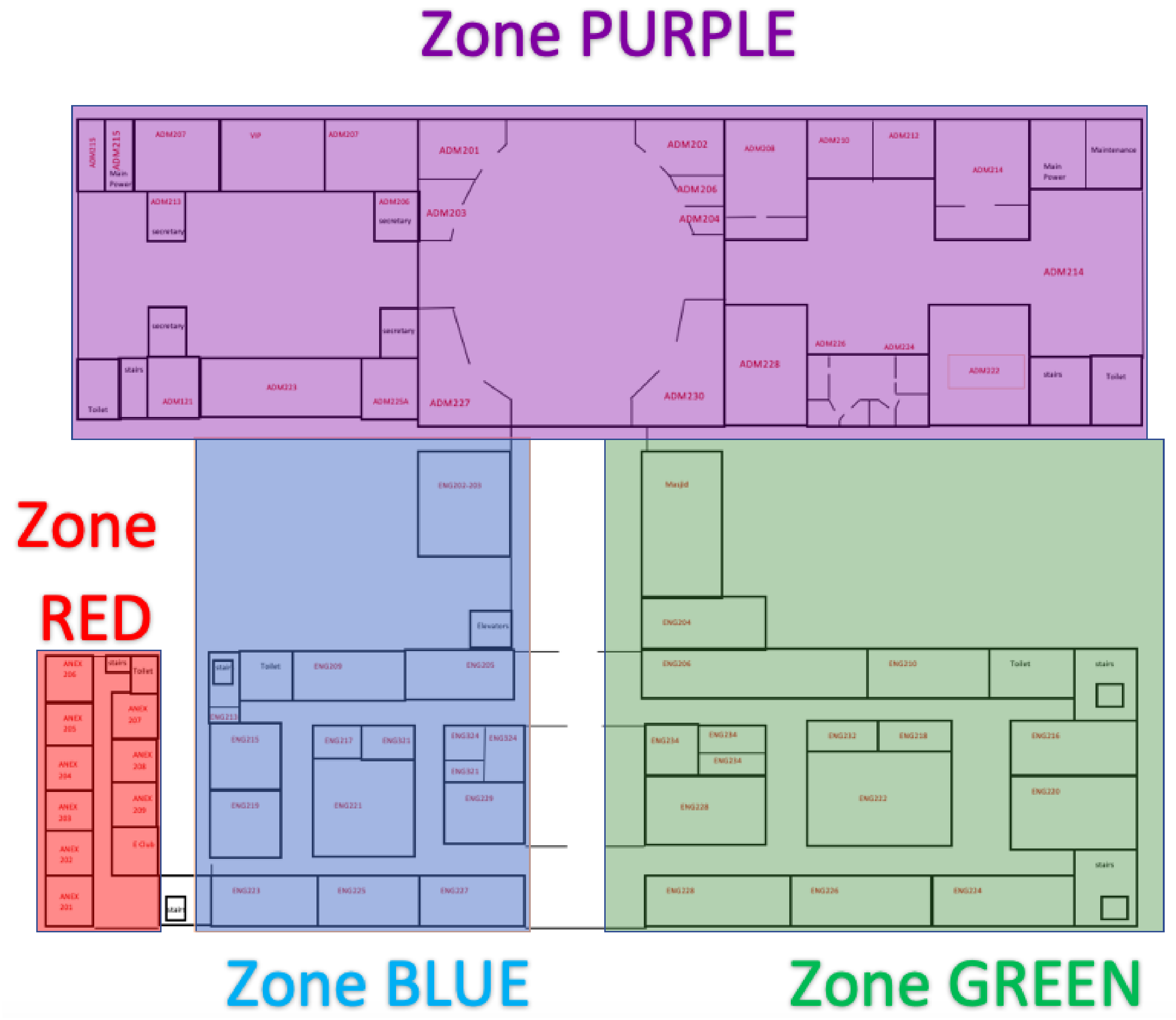

Figure 0-5 Building Zones

Starting by dividing the second floor to zones to be able to monitor, calculate the energy consumption of each zone. The map of the second floor is divided by these three main parts: Staff offices, classrooms, corridors and service rooms Figure 0-4. Due to the lack of information related to the electrical components in the staff offices, the purple zone will be over looked. Classrooms, corridors, and service rooms will be combined and separated to three zones Red, Blue, Green to measure and control energy consumption. The two division is based on the crowed density of each classroom and the sunlight affection. By auditing and monitoring the energy of the second floor, it will be efficient to utilize the available spaces in a specific zone without any other energy waste in the other zones, corridors and service rooms unnecessarily.

Purple zone, due to the lack of information and the access to these faculty offices, the assumption will be built that all of them will be Fully ON whenever the faculty is using the office room.

However, the project is focused entirely on reducing the energy consumption of the students' classrooms, which the purple zone will be neglected.

Green zone contains classrooms that is affected by sunlight:

ENG 206, ENG 210, ENG 216, ENG 220, ENG 224, ENG 226A, ENG 226B, ENG 228

This is almost 67% of the green zone, where it will push the AC to work harder to maintain the cool temperature, and it can be prevented by not using those classrooms during the peak of sun light. An important factor will be considered that is the green zone will be the first zone exposed to the sun light. Following chart shows the total power consumption without any sunlight affection toward the AC. Table 0-2.

Table 0-2:Green Zone

Green zone	Student Capacity	Energy Consumption
Masjid	-	-
ENG 204	30	830.8
ENG 206	60	1405.5
ENG 210	46	1153.8
ENG 216	32	850.8
ENG 220	30	833.8
ENG 222	-	-
ENG 224	35	850.8
ENG 226	30	850.8
ENG 228	30	859.3
ENG 230	30	884.8
ENG 234C	Office	-
ENG 218	Utility	-
ENG 234A	Utility	-
ENG 234B	Utility	-
ENG 132B	Electric room	-
Total Energy consumption	8,520.4 W/hr	

Not to forget the sunlight will force the AC system to work up to 30% extra afternoon since the sun is rising from the east.

Blue zone contains classrooms that is affected by sunlight:

ENG 205, ENG 209, ENG 223, ENG 225, ENG 227

This is almost 50% of the blue zone, where it will push the AC to work harder to maintain the cool temperature, and it can be prevented by not using those classrooms during the peak of sun light. Table 0-3

Table 0-3: Blue Zone

Blue zone	Student capacity	Energy Consumption
ENG202	-	-
ENG205	30	894.8
ENG209	45	1153.8
ENG215	34	850.8
ENG219	30	850.8
ENG221	Teacher Lounge	-
ENG223	30	850.8
ENG225	35	850.8
ENG227	30	850.8
ENG229	36	867.8
ENG324	1	-
ENG213	kitchen	-
ENG217	Utility	-
ENG321A	Utility	-
ENG321B	Utility	-
ENG324B	Utility	-
Total Energy consumption	7,170.4 W/hr	

The blue zone is not exposed to the sun light as much as the green zone, the sunlight will force the AC system to work a 15% extra. The previous chart shows the total Energy consumption without any sunlight affection toward the AC.

Red zone contains classrooms that is affected by sunlight.

This is almost 100 % of the red zone, where it will push the AC to work harder to maintain the cool temperature. Table 0-4

Table 0-4: Red Zone

Red zone	Student capacity	Energy consumption
ANEX 201	18	847.3
ANEX 202	30	847.3
ANEX 203	30	847.3
ANEX 204	33	847.3
ANEX 205	37	838.8
ANEX 206	26	838.8
ANEX 207	31	838.8
ANEX 208	32	847.3
ANEX 209	30	847.3
E-Club	12	855.8
Total Energy consumption	8,456 W/hr	

However, the constructed space made a gap between the blue zone and red zone, this gap is causing an amount of shading towards the red zone where it is receiving the minimum of sunlight causing the AC a 10% extra work.

Corridor Zone

Calculating the Energy consumption in the corridor of second floor. These are the devices on the floor Table 0-5

Table 0-5:Devices in The Corridors

Device	Consumption rate (W/Hr)
AC (ON)	555
LED lights	8.5
Smoke sensor	0.4

The hallways are divided to a right side, left side, middle section.

Table 0-6

Table 0-6: Energy Consumption for Corridors

	Right side	Left side	Middle section
AC(ON)	10	10	6
LED lights	23	21	25
Smoke sensor	10	10	7
Energy Consumption Watt per hr	5,749.5	5,732.5	3,545.3

The total Energy consumption in one hour is 15,027.3 W per hr

3.6 The methodology is used at UBT EC building

There are three cases used to study the Energy consumption of Engineering building at University of Businesses and Technology. The cases focused on the second floor of the Engineering building because of the first floor contained labs and computers lab. The second floor has more classes capacity than the first floor. Three cases are carried to calculate the energy consumption as follow:

Case I:

Fully operation energy used for the class rooms in second floor at Engineering building.

Case II:

Will illustrate the total energy consumption and its cost based on a given schedule.

Case III:

Proposed optimized operation plan will be applied to reduce the energy consumption. The results from former cases will be analyzed to validate the proposed method.

Chapter 4:

Results & Discussion

Chapter 4: Results & Discussion

4.1 Overview

By optimizing the schedule to reach more energy saving, all classrooms were rearranged with consideration reaching the full capacity of the used zone and shutting down the power to the unused zones. At certain days and different times there will be a need to more classrooms, there will be the availability of a second zone to be used. Calculating the total energy consumption of the second floor and the cost of the CE building.

4.2 The total cost and energy

After establishing the foundations based on the given data, the next study will be building three cases based on a given schedule showing the differences of the energy consumption in the building.

case 1: zones fully powered all day

case 2: choosing two time sets 9 am, 3:15 pm. Fall 2018

case 3: Optimized schedule to reduce the consumption

Table 4-1: Energy Vs Cost

	Case 1	Case 2		Case 3	
		9 AM	3 PM	9 AM	3 PM
Energy Consumption (KW/hr)	28.017	22.394	23.824	21.9	20.52
		9 AM	3 PM	9 AM	3 PM
Cost (SR/hr)	5.05	4.03	4.3	4.3	3.69

4.3 Results and facts at the UBT EC building

Case 2 involves a two time sets that defines the classes of (Sun and Tue) and the (Mon and Wed)

At time set 9 AM, the given schedule and its power consumption Figure 4-1

Class at 9:00 AM in ENG Building (Fall 18)							Zone
Class	Time	Day	Room	Capacity	Actual Enroll	Energy Consumption	
ARCH 221 Materials And Construction I	09:00-10:00	S. T	ENG 204	36	16	9115.8	Green
ME 306 Basic Workshop		S. T	ENG 224	30	21	9135.8	Green
CE 434 Foundation Engineering		S. T	ENG 228	30	29	9144.3	Green
COMM 101 Communication Skills		S. T	ENG 216	30	33	9135.8	Green
IE 331 Probability And Engineering Statistics		S. T	ENG 206	60	28	15809.8	Green
CE 333 Geotechnical Engineering		S. T	ENG 227	36	11	9135.8	Blue
IE 341 Work Study		S. T	ENG 225	30	36	9135.8	Blue
CE 212 02 Surveying & Spatial		S. T	ENG 229	36	21	13572.8	Blue
CE 323 Soil Machanics		TH	ENG 227	36	14	9135.8	Blue
EE 412 Semiconductor Devices		S. T	ENG 219	30	28	9135.8	Blue
CE 322 Hydraulics		S. T	ANX 204	26	19	9132.3	Red
CE 353 Hydrology And Water Resources		S. T	ANX 208	26	9	9132.3	Red
IE 201 Introduction To Engineering Design I		M. W	ENG 226	36	10	9135.8	Green
CE 412 Foundation Design		M. W	ENG 216	30	25	9135.8	Green
IE 432 Design Of Industrial Experiments		M. W	ENG 226	36	37	9135.8	Green
MATH 203 Calculus Iii		M. W	ENG 224	30	33	9135.8	Green
MATH 241 Applied Linear Algebra I		M. W	ENG 220	30	33	9118.8	Green
EE 322 Systems Analysis		M. W	ENG 204	36	10	9115.8	Green
PHYS 101 General Physics I		M. W	ENG 210	46	36	13581.3	Green
CE 212 01 Surveying & Spatial		M. W	ENG 227	36	24	9135.8	Blue
IE 423 Computer Aided Manufacturing		M. W	ENG 229	36	3	13572.8	Blue
CHEM 101 General Chemistry I		M. W	ENG 219	30	31	9135.8	Blue
IE 341 Work Study		M. W	ENG 209	45	34	13581.3	Blue
CE 423 Hydrology & Water Resources		M. W	ANX 208	26	5	9132.3	Red
CE 313 Basic Structural Analysis		M. W	ANX 207	34	37	9123.8	Red
Total						252.763	
Average						10.11052	

Figure 4-1: Case 2(9AM)

The graph indicates that the 9 am classes is spread out randomly in the three zones without any efficiency.

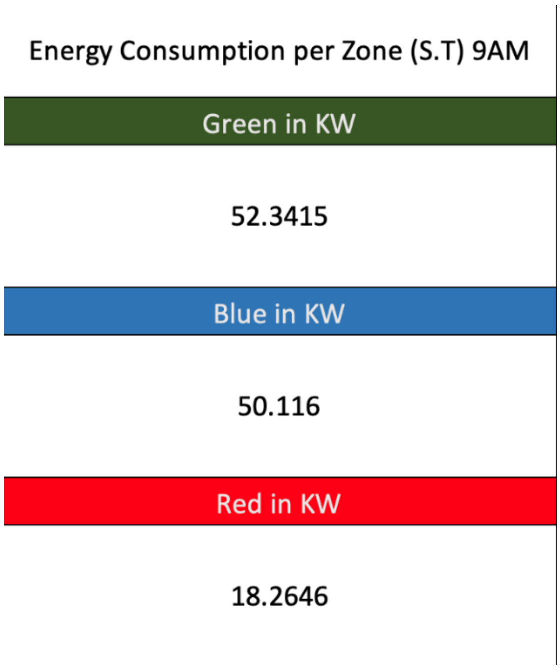

Figure 4-2: Case 2 Energy Consumption (S.T 9AM)

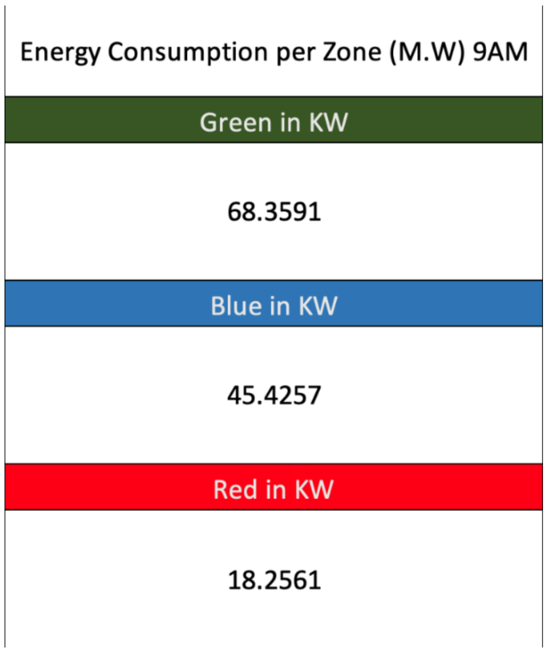

Figure 4-3: Case 2 Energy Consumption (M.W 9AM)

Based on the total energy consumption at 9 AM, Figure 4-2 and Figure 4-3. The total energy consumption is 252.8 KW/hr.

The cost of these classes per hour at their days is $Cost = 252.763 * 0.18 = 45.5\ SR$

At time set 3 PM, the given schedule and its Energy Consumption Figure 4-4

Class at 3:15 AM in ENG Building (Fall 18)						Energy Consumtion	Zone
Class	Time	Day	Room	Capacity	Actual Enroll		
IE 445 Healthcare Managemt	15:15 - 16:15	S. T	ENG 210	46	16	17559.3	Green
IE 451 Production Planning And Control		S. T	ENG 224	30	34	11787.8	Green
IE 490 Special Topics In Industrial		S. T	ENG 210	60	5	17559.3	Green
MATH 101 Calculus I		S. T	ENG 206	60	25	20450.8	Green
MATH 102 Calculus Ii		S. T	ENG 220	30	24	11770.8	Green
MATH 203 Calculus Iii		S. T	ENG 219	30	28	10461.8	Blue
EE 250 Basic Electrical Circuits		S. T	ENG 225	30	6	10461.8	Blue
EE 311 Electronic Dev. &Circ		S. T	ENG 225	30	16	10461.8	Blue
ESP 102 Introduction To Academic Writing		S. T	ENG 215	30	32	10461.8	Blue
MATH 204 Introduction To Differential Equations		S. T	ENG 223	30	33	10461.8	Blue
IE 351 Industrial Management		S. T	ENG 209	45	11	15570.3	Blue
PHYS 101 General Physics I		S. T	ENG 229	36	34	15561.8	Blue
CE 442 Reinforced Concrete Design Ii		S. T	ANX 204	26	32	10016.3	Red
CHEM 102 General Chemistry Ii		S. T	ANX 203	26	37	10016.3	Red
MATH 099 Pre-Calculus		M. W	ENG 228	30	19	11796.3	Green
IE 310 Project Management		M. W	ENG 210	46	33	17559.3	Green
CE 261 Thermodynamics I		M. W	ENG 206	60	8	20450.8	Green
PHYS 102 General Physics Ii		M. W	ENG 226	36	32	11787.8	Green
MATH 099 Pre-Calculus		M. W	ENG 225	30	34	10461.8	Blue
CE 424 Construction Estimating		M. W	ENG 227	36	9	10461.8	Blue
CE 433 Construction Estimating		M. W	ENG 227	36	26	10461.8	Blue
CE 462 Engineering Geology		M. W	ANX 205	34	12	10007.8	Red
Total						285.5891	
Average						12.98132273	

Figure 4-4: Case 2 (3PM)

Figure 4-5 provides the 3 pm classes is almost at peak energy consumption, which it can optimized and the classes of red zone can be moved to another day.

Figure 4-5: Case 2 Energy Consumption (S.T 3PM)

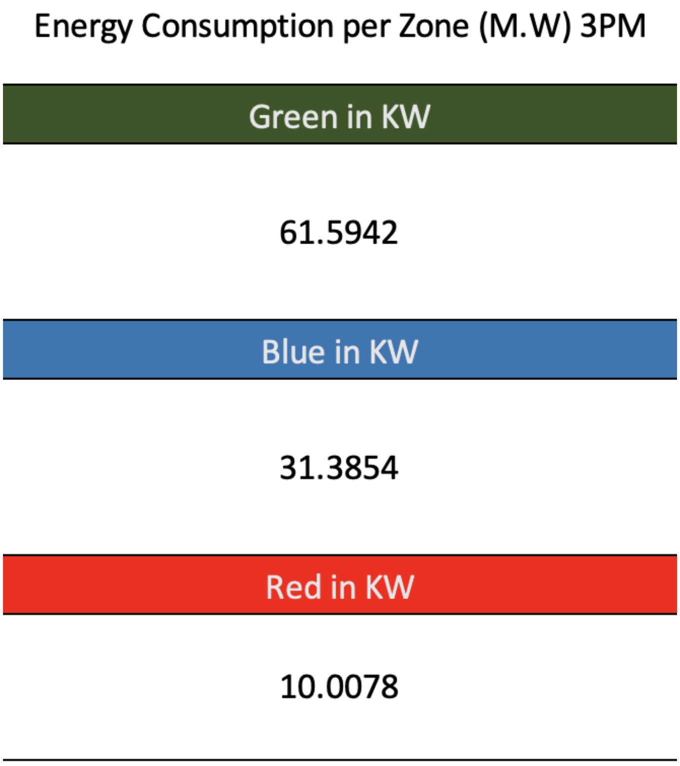

Figure 4-6: Case 2 Energy Consumption (M.W 3PM)

Based on the total energy consumption at 3 PM, Figure 4-5 and Figure 4-6. The total energy consumption is 285.589 KW/hr.

The cost of these classes per hour at their days is $Cost = 285.589 * 0.18 = 51.41\ SR$

In case 3, the classrooms of the given schedule will be rearranged to achieve the extra optimization of the power consumption and to reduce the total cost. The goal is to collect the classes to achieve full capacity for two zones and to shut down the power flow to the third zone in order to save power.

At time set 9 AM, the given schedule and its power consumption Figure 4-7.

Class at 9:00 AM in ENG Building (Fall 18)							Zone
Class	Time	Day	Room	Capacity	Actual Enroll	Energy Consumption	
ARCH 221 Materials And Construction I	09:00-10:00	S. T	ENG 223	30	16	9135.8	Blue
ME 306 Basic Workshop		S. T	ENG 225	35	21	9135.8	Blue
CE 434 Foundation Engineering		S. T	ENG 229	36	29	13572.8	Blue
COMM 101 Communication Skills		S. T	ENG 221	15	33	9135.8	Blue
IE 331 Probability And Engineering Statistics		S. T	ENG 227	30	28	9135.8	Blue
CE 333 Geotechnical Engineering		S. T	ENG 215	34	11	9135.8	Blue
IE 341 Work Study		S. T	ENG 205	30	36	15809.8	Blue
CE 212 02 Surveying & Spatial		S. T	ENG 209	45	21	13581.3	Blue
CE 323 Soil Machanics		TH	ENG 219	30	14	9135.8	Blue
EE 412 Semiconductor Devices		S. T	ANEX 204	33	28	9132.3	Red
CE 322 Hydraulics		S. T	ANEX 202	30	19	9132.3	Red
CE 353 Hydrology And Water Resources		S. T	ANEX 201	18	9	9132.3	Red
IE 201 Introduction To Engineering Design I		M. W	ANEX 202	30	10	9132.3	Red
CE 412 Foundation Design		M. W	ANEX 206	26	25	9123.8	Red
IE 432 Design Of Industrial Experiments		M. W	ANEX 205	37	37	9123.8	Red
MATH 203 Calculus Iii		M. W	ANEX 208	31	33	9132.3	Red
MATH 241 Applied Linear Algebra I		M. W	ANEX 204	33	33	9132.3	Red
EE 322 Systems Analysis		M. W	ANEX 201	18	10	9132.3	Red
CE 423 Hydrology & Water Resources		M. W	ANEX 209	32	5	9132.3	Red
CE 212 01 Surveying & Spatial		M. W	ANEX 203	30	24	9132.3	Red
IE 423 Computer Aided Manufacturing		M. W	ENG 221	15	3	9135.8	Blue
CHEM 101 General Chemistry I		M. W	ENG 223	30	31	9135.8	Blue
IE 341 Work Study		M. W	ENG 225	30	34	9135.8	Blue
PHYS 101 General Physics I		M. W	ENG 229	36	36	13572.8	Blue
CE 313 Basic Structural Analysis		M. W	ENG 209	45	37	1153.8	Blue
Total						240351	

Figure 4-7: Case 3 (9 AM)

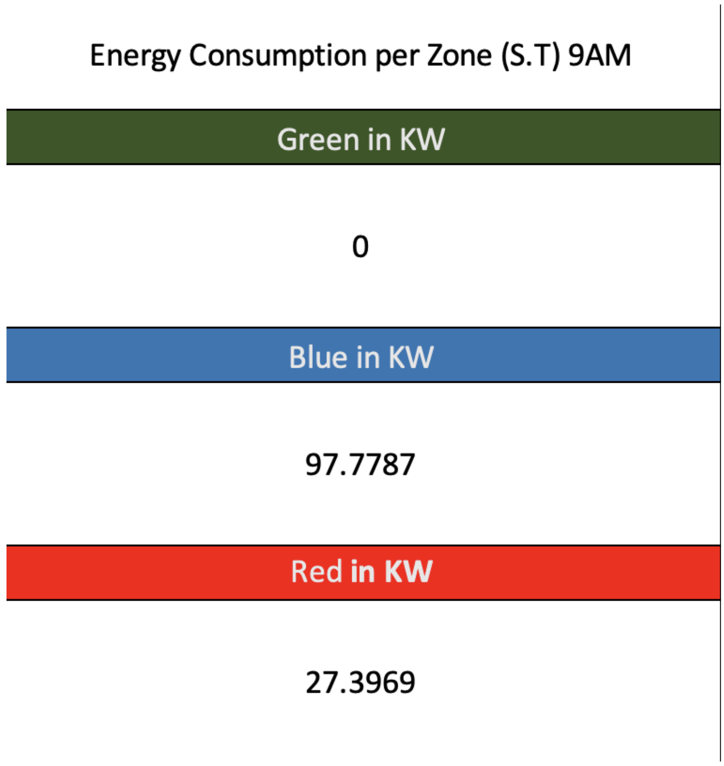

Figure 4-8: Case 3 Energy Consumption (S.T 9AM)

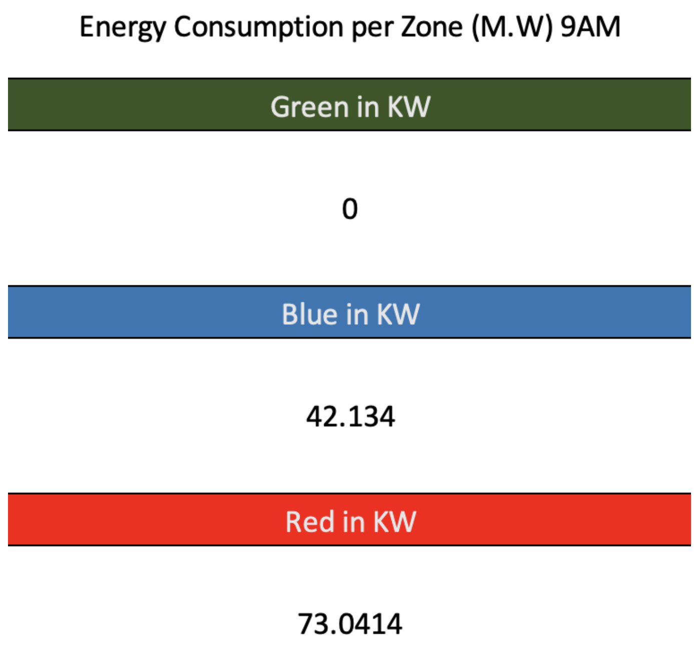

Figure 4-9: Case 3 Energy Consumption (M.W 9AM)

Based on the total energy consumption at 9 AM, Figure 4-8 and Figure 4-9. The total energy consumption is 240.4 KW/hr.

The cost of these classes per hour at their days is $Cost = 240.4 * 0.18 = 43.3\ SR$

At time set 3 PM, the given schedule and its power consumption:

Class at 3:15 PM in ENG Building (Fall 18)						Energy Consumtion	Zone
Class	Time	Day	Room	Capacity	Actual Enroll		
IE 445 Healthcare Managemt	15:15 - 16:15	S. T	ANEX 209	32	16	10016.3	Red
CE 442 Reinforced Concrete Design Ii		S. T	ANEX 204	33	32	10016.3	Red
IE 490 Special Topics In Industrial		S. T	ANEX 202	30	5	10016.3	Red
IE 351 Industrial Management		S. T	ANEX 201	18	11	10016.3	Red
MATH 102 Calculus Ii		S. T	ANEX 206	26	24	10007.8	Red
MATH 204 Introduction To Differential Equations		S. T	ENG 223	30	33	10461.8	Blue
IE 451 Production Planning And Control		S. T	ENG 225	35	34	10461.8	Blue
PHYS 101 General Physics I		S. T	ENG 229	36	34	15561.8	Blue
EE 250 Basic Electrical Circuits		S. T	ENG 221	15	6	10461.8	Blue
EE 311 Electronic Dev. &Circ		S. T	ENG 227	30	16	10461.8	Blue
ESP 102 Introduction To Academic Writing		S. T	ENG 215	34	32	10461.8	Blue
MATH 101 Calculus I		S. T	ENG 205	30	25	18130.3	Blue
CHEM 102 General Chemistry Ii		S. T	ENG 209	45	37	15570.3	Blue
MATH 203 Calculus Iii		S. T	ENG 219	30	28	10461.8	Blue
MATH 099 Pre-Calculus		M. W	ANEX 202	30	19	10016.3	Red
IE 310 Project Management		M. W	ANEX 204	33	33	10016.3	Red
CE 261 Thermodynamics I		M. W	ANEX 206	26	8	10007.8	Red
PHYS 102 General Physics Ii		M. W	ANEX 208	31	32	10016.3	Red
MATH 099 Pre-Calculus		M. W	ANEX 205	37	34	10007.8	Red
CE 424 Construction Estimating		M. W	ANEX 201	18	9	10016.3	Red
CE 433 Construction Estimating		M. W	ANEX 209	32	26	10016.3	Red
CE 462 Engineering Geology		M. W	ANEX 203	30	12	10016.3	Red
Total						242.2196	

Figure 4-10: Case 3 (3 PM)

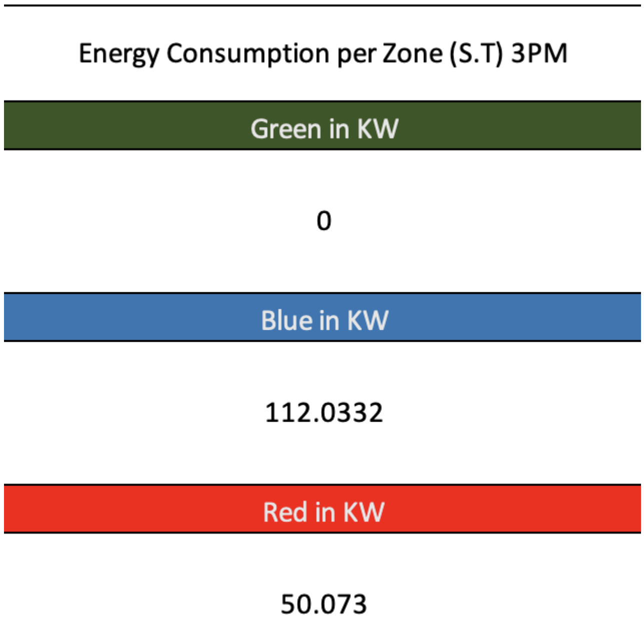

Figure 4-11: Case 3 Energy Consumption (S.T 3 PM)

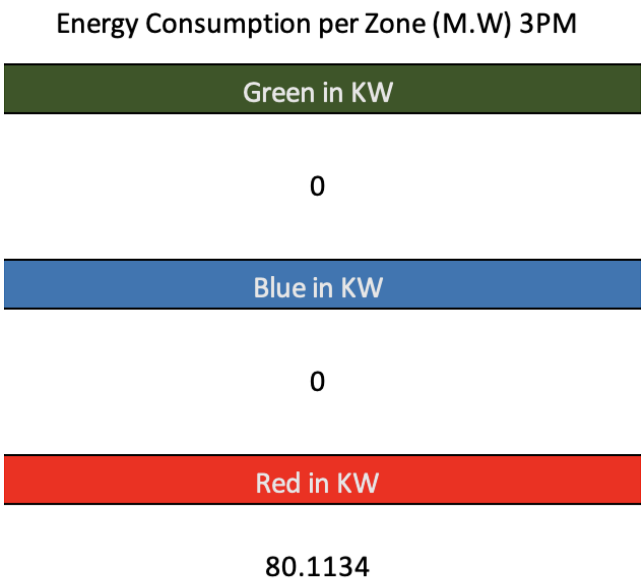

Figure 4-12: Case 3 Energy Consumption (M. W 3 PM)

Based on the total energy consumption at 3 PM, Figure 4-11and Figure 4-12. The total energy consumption is 242.219 KW/hr.

The cost of these classes per hour at their days is $Cost = 242.219 * 0.18 = 43.6\ SR$

The research has shown how much of affection the sunlight to the total energy consumption, based on the excessive load that will be on the AC. By optimizing the spaces, there will be an efficient distribution towards the classrooms where each section has its right size of a class. This process will lead to grouping the random classrooms in case 2 to a more efficient utilization where there is no waste for energy like in case 3. Overall Comparison between all cases at two time sets Figure 4-13 and Figure 4-14.

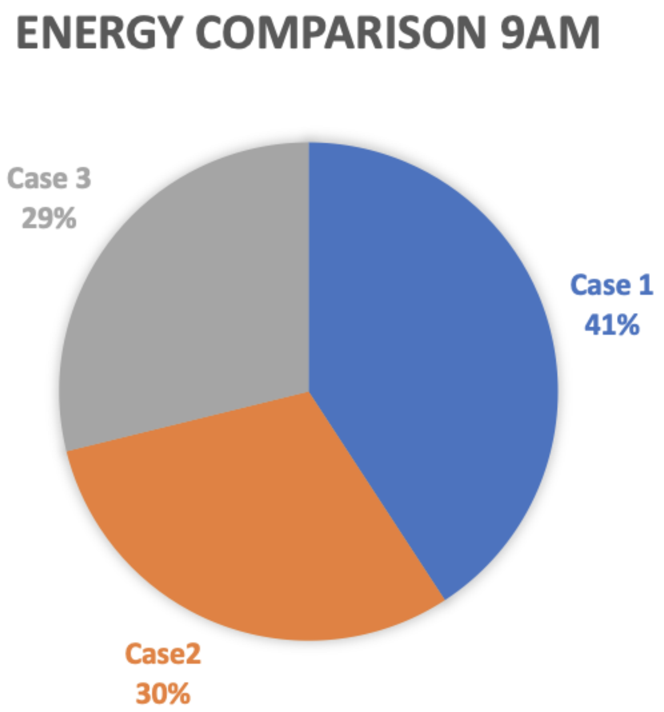

Figure 4-13: Overall Comparison 9AM

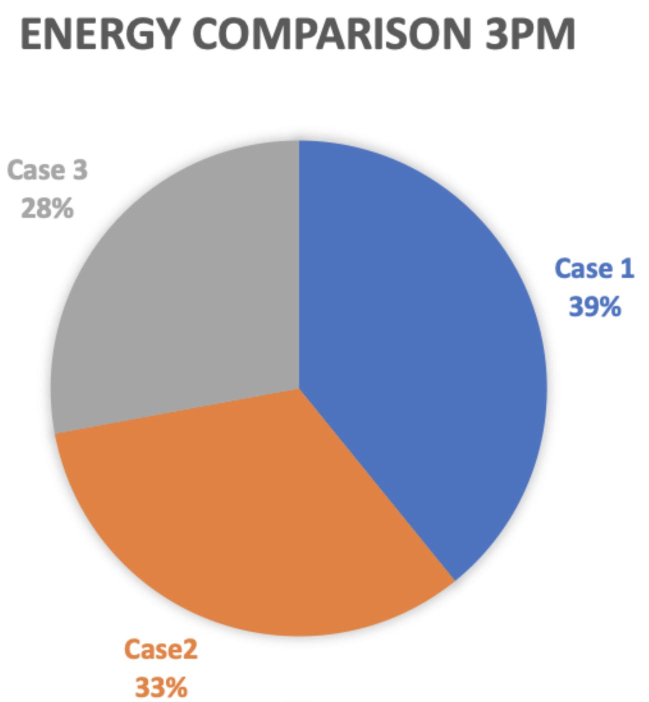

Figure 4-14: Overall Comparison (3PM)

By utilizing the available spaces of the second floor, case 3 focused on using the least power consumed zone, zone red, and if needed, using the blue zone, where all the classrooms will be on the west side of the building. As a result, the green zone will not be used and therefore reaching the target of maximizing the energy saving efficiently Figure 4-15. By locking an entire green zone, the saving from the corridors will be 5.75 KW/hr and that will save a total cost of 1.03 SR/hr. Figure 4-16

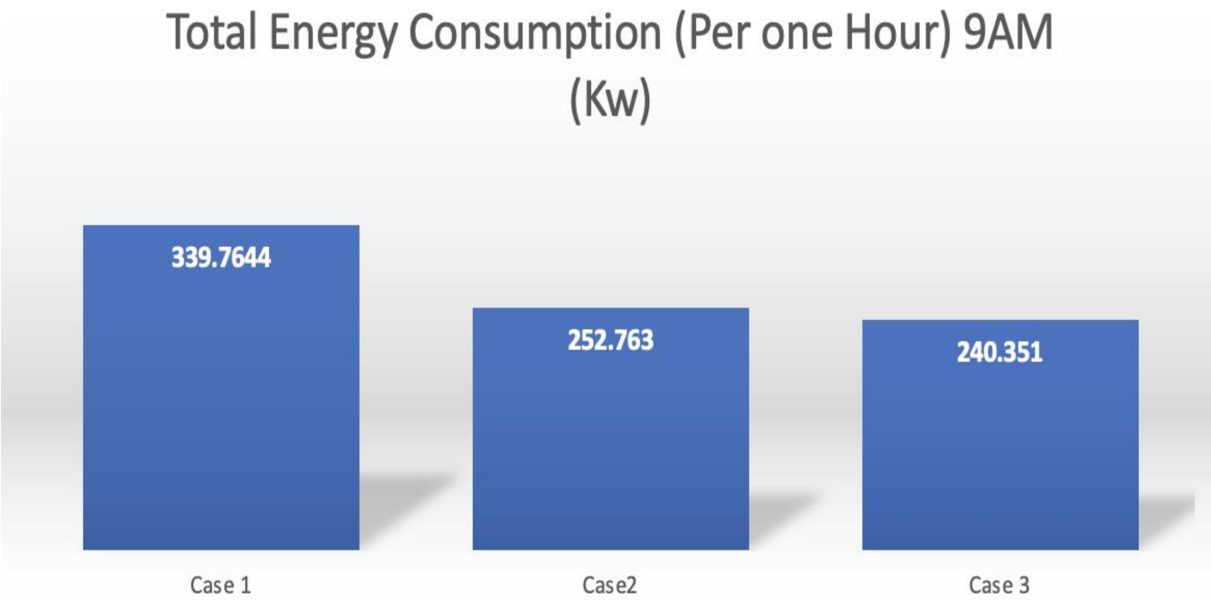

Figure 4-15: Total Energy 9 AM

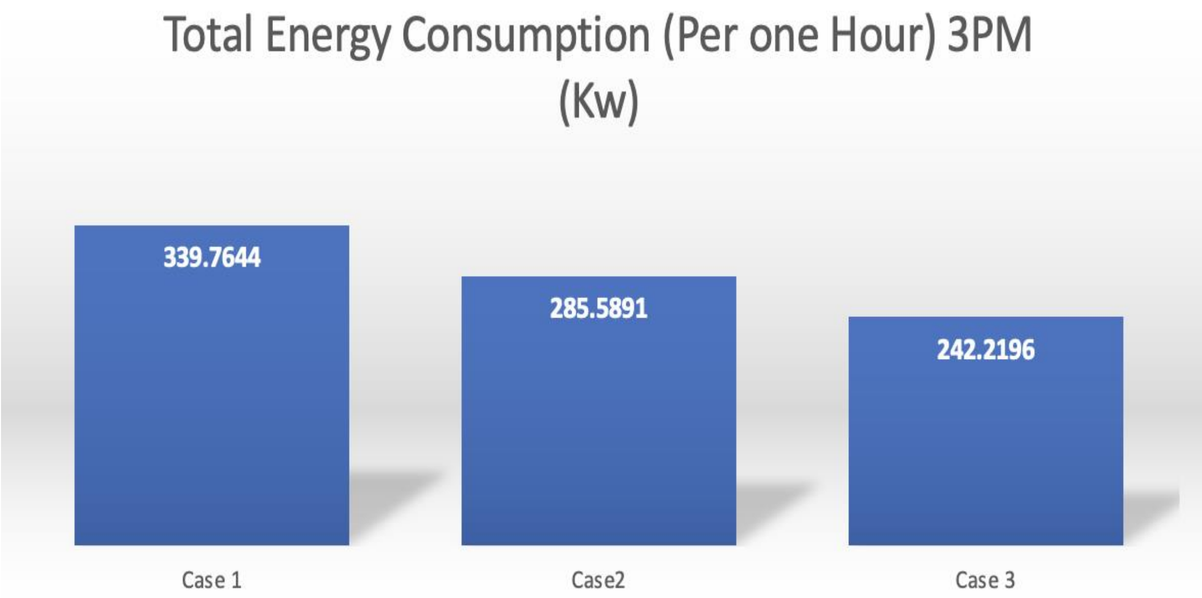

Figure 4-16: Total Energy 3 PM

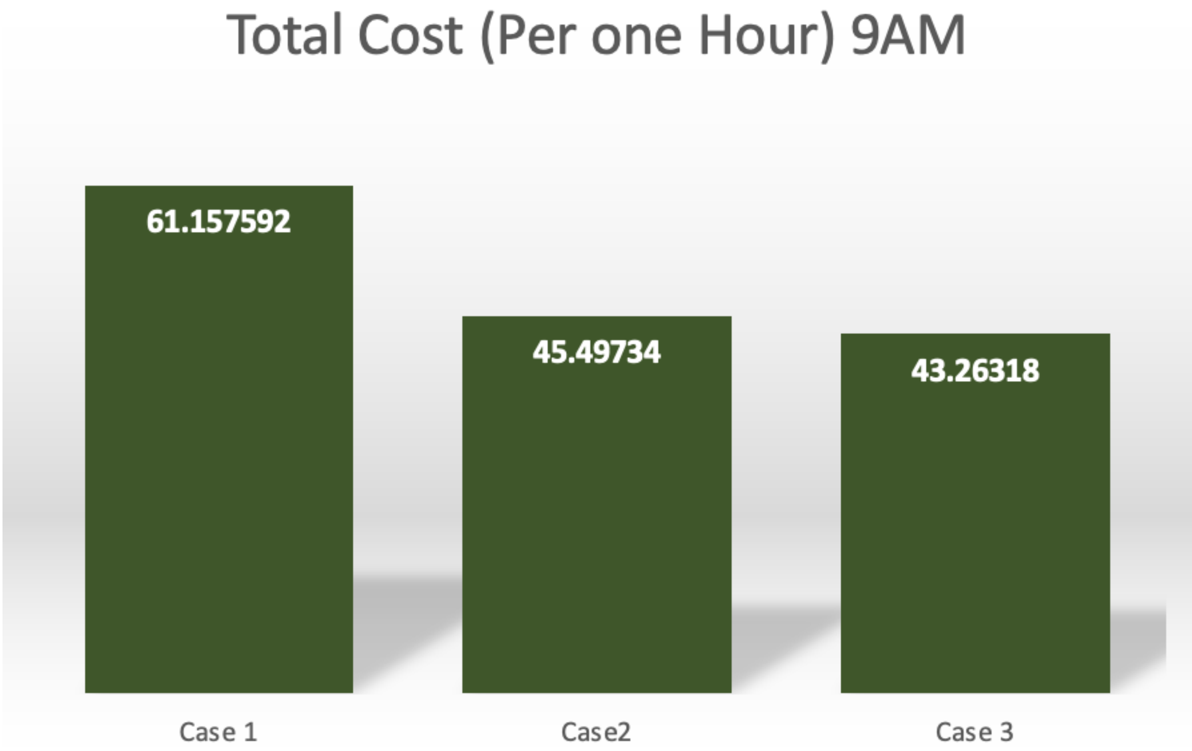

Figure 4-16: Total Cost

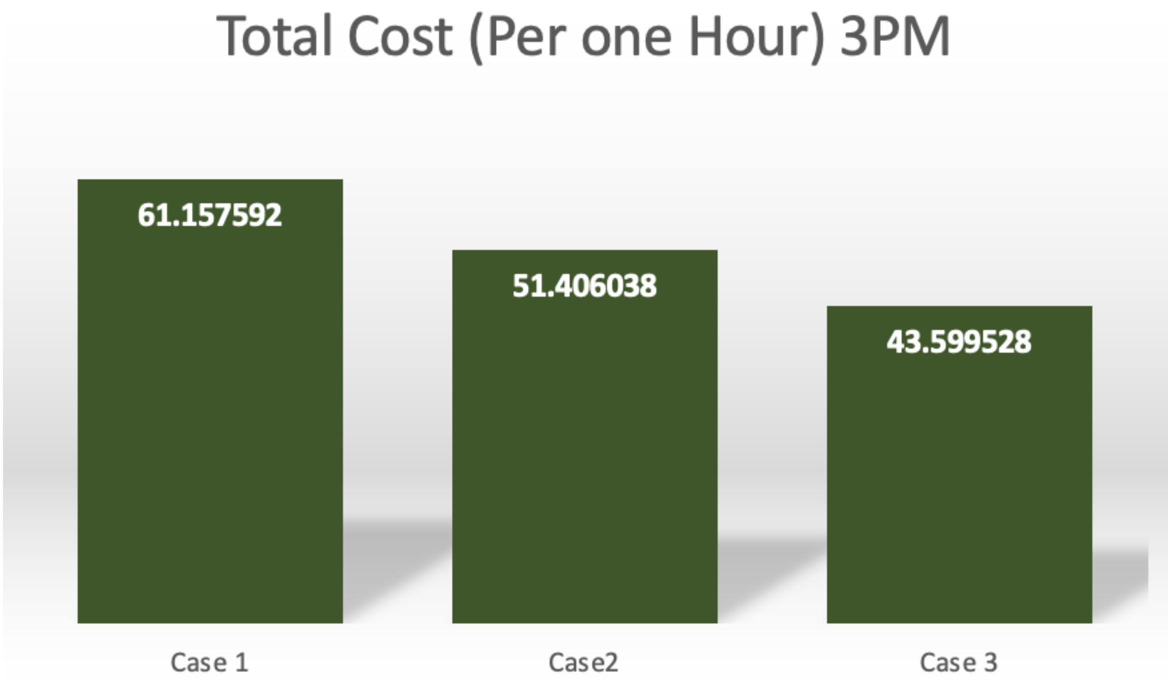

Figure 4-: Total Cost

4.4 The percentage of energy

Percentage per each case that includes the energy providing the corridors which will show the saved energy percentage. The energy that is saved in case 3 will be 134KW for two hours (9AM and 3PM) which will save us 24 SR per week.

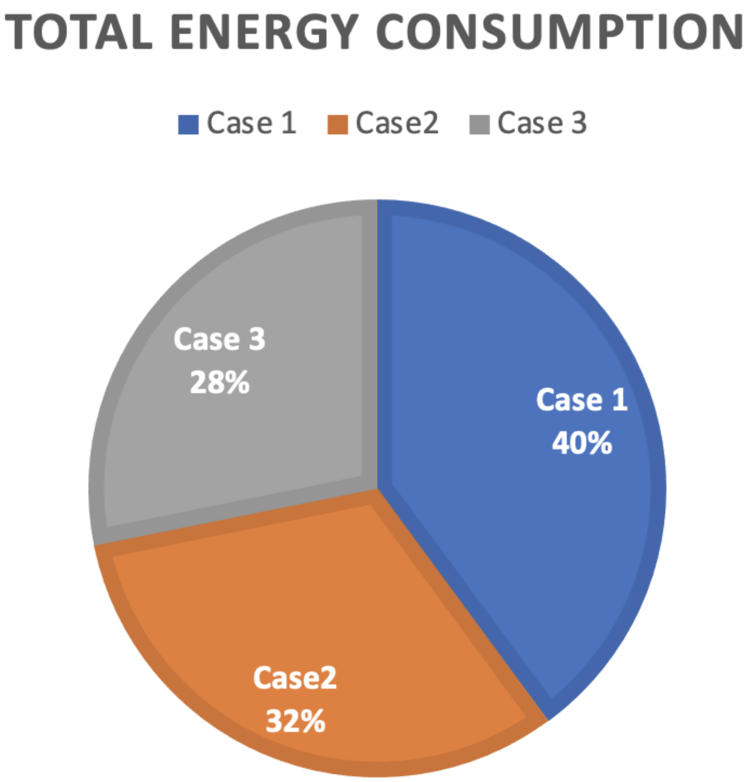

Figure 4-17: Percentage Energy Comparison Results

Table 4-2: Total Energy Comparison Results

Case Number	Total Energy Consumption (Kw) Per Week
Case 1	1419.1656
Case2	1136.8122
Case 3	1002.0492

The 4 % saved weekly is 134 KW is saving a total cost of **24 SR.** The saving is only for two hours in a week. What if applying the management for the whole day? The saving will be worth doing the management.

Table 4-3: Cost per Week and Semester

	Total Cost (Per week)	Total Cost (Per semeter)
Case 1	255.449808	4087.196928
Case2	204.626196	3274.019136
Case 3	180.368856	2885.901696

The saved cost per semster is 389 SR.

4.5 Transfer 9 AM schedule to 3 PM.

The idea to transfer 9 AM schedule to 3 PM, is to measure the effect of sun radiation to the consumed energy. Based on the total energy consumption at 9 AM schedule transferred to 3 PM, shown in Figure 4-18. The difference in energy consumption is 1417.6 KW per semester. The additional cost of these classes per semester if 9 AM transferred to 3 PM, shown in Figure 4-19 is:

$$Cost = 1417.6 * 0.18 = 255.1\ SR$$

One of the solutions that can be provided is to make the classes time at 9 AM. The solution will save amount of energy for long term.

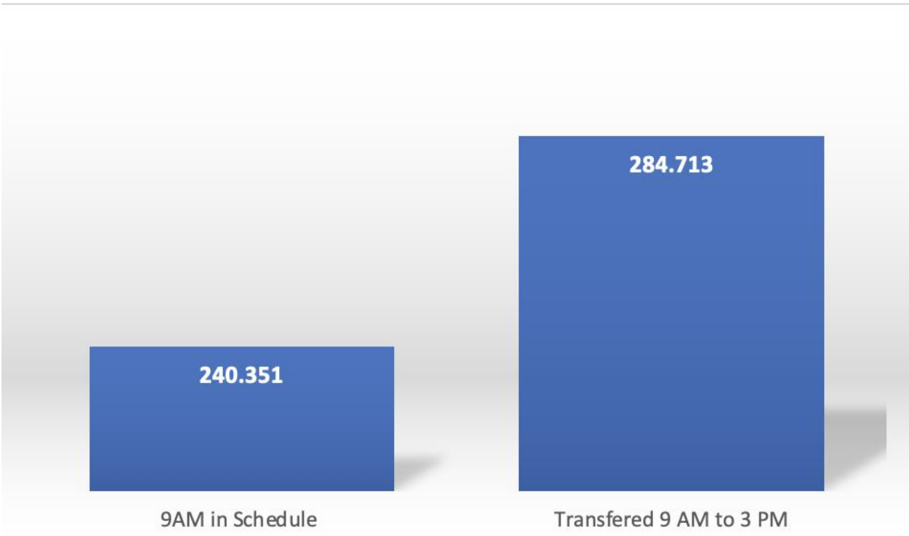

Figure 4-18 Consumption for 9 AM schedule transferred to 3 PM

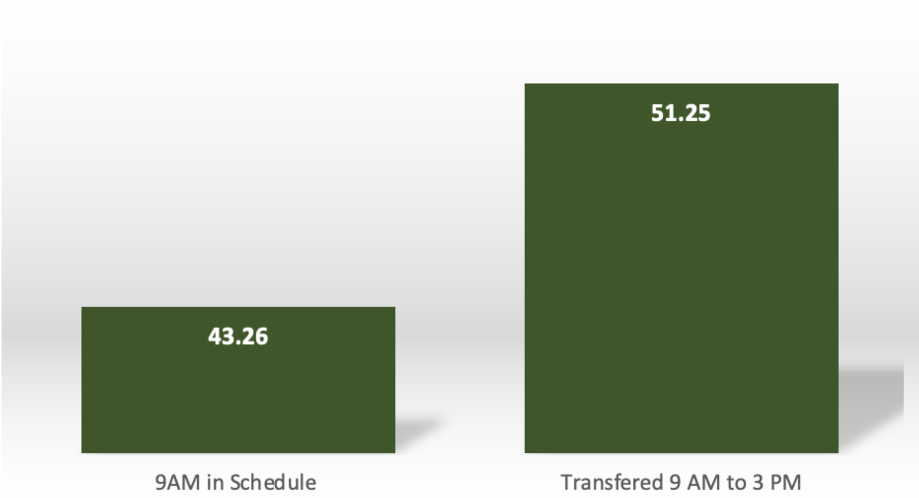

Figure 4-19 Cost for 9 AM schedule transferred to 3 PM

Chapter 5: Conclusions and Future Work

Chapter 5: Conclusions and Future Work

5.1 Conclusions

Collecting the data of the electrical components of the CE building & data measurements of the sunlight radiation directly affecting some of the zones which we have mentioned in earlier chapters, we analyzed the data by finding correlations & causations that have been affecting the cost & energy consumption.

Calculating the total energy consumption of the second floor & the cost of the CE building we have used the method of zoning the building's layout to use for our Cases. Using the proposed optimization Case III, we have effectively shut down a zone & re-scheduled the other zones to be used more effective & utilized for saving cost & energy. Calculating the total energy consumption of the second floor and the cost of the CE building.

We have achieved great stride in through our analyzes of the Cases. As what has been said in each given section, we can conclude that the proposed optimization Case III will cause a great cost & energy reduction long-term. The total consumption of energy percentage as shown in chapter 4 figure 4-17 is effectively showing us cost & energy savings of 4% or 96 SR/month which is the difference of the scheduled Case II & the proposed optimized Case III.

5.2 Future Work

- Shading is a simple & cheap method that can be applied to the Eastern side of the building to retain the temperature within the building & remove the affect of the sunlight radiation from increasing the internal heat, which would cause the air conditioners to use less energy to keep up with the cooling.

- Taking the initiative of using solar panels can be a wise decision for the long run, both in affectively decreasing carbon footprint by using renewable energy.

- Installing motion and heat sensor in all classrooms in the building, which would be connected to a control system powered by a machine learning algorithm to collect even more accurate & precise data to help initialize a better zoning layout solution we might haven't thought of before.

- Taking advantage of splitting the second-floor classrooms to more than 3 zones depending on the optimization result we get from the machine learning algorithm through the control system.

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