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Conversion of Ready-mix Concrete Energy to Solar PV

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RIT

Graduate Capstone

CONVERSION OF READY-MIX CONCRETE ENERGY TO SOLAR PV

by

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Graduate Capstone Approval

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This work is dedicated to the people of Africa.

Abstract

The purpose of this project is to study a case of a ready-mix concrete company to evaluate the feasibility of converting the electrical consumption to solar PV. The documentation of this project goes along with the proceeding of the work. Some data in the first and second chapters will be validated and corrected in the validation section. This work aims to encourage the adoption of solar technology in heavy industry. The work looked at various options to convert the energy consumption to solar PV. Taking into consideration the managerial and technical sides.

Contents

Part II: TO-BE

Part I: As-Is

This part contains an introduction of the case, the problem and the approach. The first chapter will present you the company selection, and then it will prepare you with a short background about the concrete plant.

The second chapter describes the problem and the analysis. It contains the collection of data through the information from this data until the validation of the collected data.

The last chapter in this part will present the options based on the previous analysis. It contains the approach towards the solution.

Part I: AS-IS

CHAPTER 1: INTRODUCTION

Energy has been crucial to surviving since the creation of human. We started using energy for heat through burning coal. Then we discovered more abilities of the heat, like shaping clay or moving trains. It's the mean to transportation and to building homes. Since then, we still mainly use energy for the same reasons, transportation and construction.

Construction industry is a heavy energy consumer. And the more it consumes energy, the more it digests money through the cost. There are many ways to think about reducing the cost assigned to energy. One way is through using a better technology with lower energy consumption. Another way is to manage energy usage by changes in the process. Our project here is trying to give recommendations in both aspects -technology and management- after studying the energy consumption nature of a company case.

1.1 Company selection and initial communication

The company selected to be the case of the study is located in the Emirate of Fujairah, United Arab Emirates. Specifically, in the industrial area in Al Hayl (Also written as "Al Hail") where most of the production and maintenance facilities are located. The proposed research project has been firstly welcomed by H.H. Abdullah Mohammed Al-Antali, General Manager of Fujairah National Group. He then moved the communication to one of their group of companies in return to recommendations that can add a value to the company. He -thankfully- connected us with Al Moutasim Billah, production manager at SijiMix and Motaz Atta Allah Mohammed, maintenance manager at SijiMix.

My meeting in December 2018 with Al Moutasim was welcoming in which he expressed his company's interest to collaborate with academic projects that benefits the industry in general. After that, I received a call from the assigned engineer from SijiMix who will guide me through the process of collecting data and communicate with SijiMix departments. The team leader representing SijiMix is engineer Mohammed Abdulrahim. Teamed with him, we went to couple of tours about the company to understand the work environment and experience the environment.

Reaching this stage, a proposal has been discussed and submitted to my academic supervisor Dr. Slim Saidi, associate professor of industrial engineering and the chair of the mechanical/industrial engineering department Dr. Ghalib Kahwaji, professor of mechanical engineering. After their acceptance and guidance, we started collecting the data with the help of Abdulrahim who was more than open to support. We agreed on the workplan and started working from January 2019.

1.2 Background

Before we dig deep into the project, we will give general description about construction industry. In the next paragraphs, we will talk about its relation to the environment, the development and we will look at the concert plant.

1.2.1 Construction and Environment

Environmentally, construction resources are mostly non-renewable like steel, wood, metals and concrete. It causes harmful activities to the environment for example deforestation. It uses a lot of energy, difficult to change due to many reasons (ex: resources, economics, politics, culture) and most of the buildings has not been designed for sustainable reasons thus it's meant to live for long time. Construction is a big contributor to CO_2 emissions due to material used. Not to mention, the transportation related to the process of performing its activities. In a study to asses the association of the CO_2 emissions to the energy consumed during construction in urban space [1], "it was found that the building materials with the highest

CO_2 emissions per kilogram were steel and reinforced concrete used in the structural parts, as well as glass and tiles for the envelops, followed by wood and cement, with the least being ready-mixed concrete, red bricks and sand". We should not confuse the ready-mix concert low CO_2 emission –in the study- as a material to a ready-mix concrete (RMC) plant CO_2 emission. For a plant, ready-mixed concrete is an output. In this project, we are taking a case of a ready-mixed concrete producer.

On the other side, when it comes to waste management, construction materials are not separated or pre-used. Thus, producing a lot of waste. Like historical places, old constructed buildings are often used in industries like tourism.

1.2.2 Development in Construction

A part of the continues revolutions in technology in all industries, construction is developing as well. We previously described construction as a heavy industry in all measures thus, it's difficult to change. But it has proven its ability to take a part in the new digitalized world thanks to research and development R&D. A life example of that is the 3D printed buildings. The Office Of The Future in Dubai sustainable city is the first 3D printed office that's shows the effect of technology in construction.

Efforts has been directed towards better construction. Showing increasing awareness on the topic. Talking about waste for example, Dubai sustainable city has used construction waste in the city architecture.

1.2.3 Concrete Plant

A concrete or a batching plant is a mixing equipment. And concrete" is a mixture of paste and aggregates" [2] used in buildings, roads, dams and pipes. It's widely used in construction. The RMC is the product of the plant. After it's been mixed, RMC should be used within less than 2 hours, says SijiMix engineers. In some projects, the engineers are able to build a temporary concrete plant in site. In others, the project engineer will receive supplies from a nearby RMC company like the one in our case.

Fujairah since years until today is under a big construction project. Covering most of the old roads and building new ones. Many of the big projects in the emirate has been supplied through SijiMix. Projects like Grand Mosque, United steel, Qidfa power plant, Main Oil Terminal and other.

1.3 The company

SijiMix is a RMC company based in Fujairah, UAE. The company have two other branches however our project will study the headquarter only. The manufacturing is happening in 2 batching plants at the headquarter plus a recycling plant. These production plants are coupled with an ice plant and a chiller. Then we have water supply tanks consuming electricity through pumps and a water treatment plant.

The production can reach up to 24 hours in a day based on the customers' requirements, a SijiMix engineer mentioned during a visit to his office. The office activities are happening during 8:00 to 17:00 with exception to the operation office which related to the production needs. Our purpose is to identify the electricity consumption areas and activities to find areas to reduce the consumption from the main grid using different tools or options like renewable energy or others. Currently, the company's electricity is supplied by FEWA except the recycling plant C which works by generator.

The company have a mission to make "continues improvement of" their "product through safe, sustainable and innovative manufacturing practices". And this is where our project lies for the company.

The ready-mix concrete company have the 2015 version of ISO 9001 for Quality Management System, ISO 14001 for Environmental Management System and ISO 45001 for Occupational Health & Safety.

1.3.1 Buildings Map

The map in (Figure 1) shows the location of the buildings in the company. The critical buildings to production line are the plants A, B, ice plant, chiller, Quality Control Lab (QCL) and the operations room. The control room of production is in the plants A and B area. Plant C is a recycling plant that used occasionally. The buildings critical to production are circled in yellow. (Table 1) categories the buildings on the map (Figure 1) based on production criticality:

Table 1: Buildings based on production criticality.

No.	**Critical to Production**	**Supportive to Production**	**Administration and Other**
1	Operation Room	Workshops	Offices
2	Plants A and B	Safety	Masjid
3	Ice plant	Security	Drivers Room
4	Chiller	Chemical plant	Other
5	Operations Room	QC check point	
6	Quality Control Lab (QCL)	Recycling plant (Plant C)	
7		Stores	
8		Maintenance Lab and office	

1.3.2 Questions

At this stage, we have collected information to understand the nature of the industry and the work environment of the company. Our focus is at the electricity usage thus, we will collect data based on how much electricity is consumed, by what devices, for what purpose, at what time. This information will help as answering why the electricity is consumed. Then our work ground is the question “what could be changed to reduce electricity consumption, therefore electricity bill?”. We also know where the company is located so we can use the geographical data when needed.

Another decision at this stage is to not include changing the devices or machines that are critical to production like the batching plants.

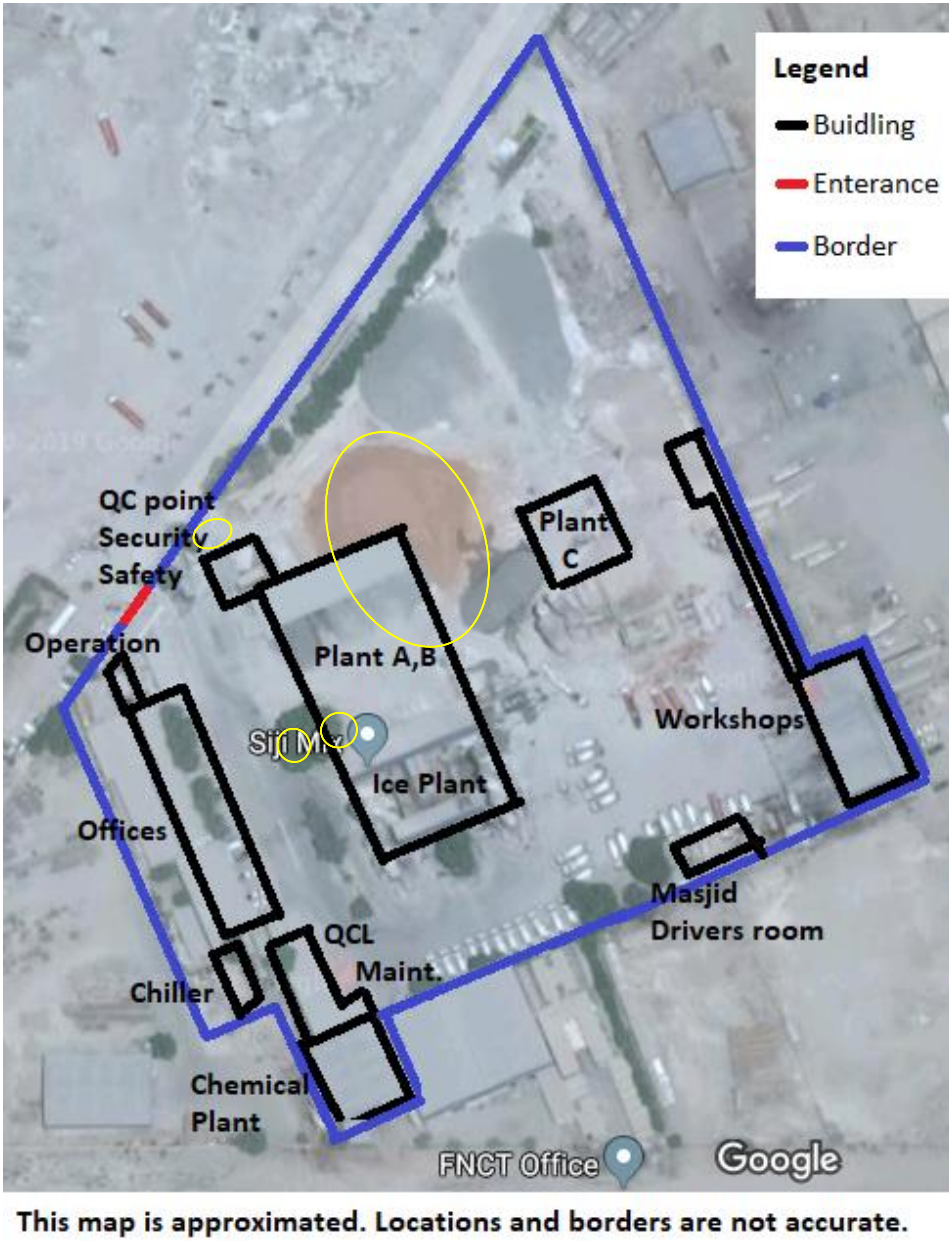

Figure 1: SijiMix buildings map.

Summary and Results of Chapter 1:

1. Our purpose is to identify the electricity consumption areas and activities to find areas to reduce the consumption from the main grid using different tools or options like renewable energy or others.
2. Our focus is at the electricity usage thus, we will collect data based on how much electricity is consumed, by what devices, for what purpose, at what time.
3. This information will help as answering why the electricity is consumed. Then our work ground is the question “what could be changed to reduce electricity consumption, therefore electricity bill?”.
4. A decision taken at this stage is to not include changing the devices or machines that are critical to production like the batching plants.

CHAPTER 2: PROBLEM AND ANALYSIS

2.1 Observations & Data collection

2.1.1 Observations

One of the environmental observations in Al Hayl industrial area -where the company is located- is the mountains surrounding the area. The environment gets dusty from time to time and the dust is not controlled. At the moment of our visits, nearby mountains were crushed contributing to dusty area. The area gets windy sometimes.

Visiting the company frequently, I started to specifically observe the electricity consumption related devices and activities at the company. Generally, the heavy electricity consumption goes to production plant, ice plant and chiller. Other consumption is by the workshops, outdoor lighting, chemical plant and the labs. Smaller consumption by offices and supportive buildings (for example documents store).

2.1.2 Data collection

We have to start with the data that tells us how much electricity is consumed. This data could be received from the company as will as tracked through FEWA open data. Then, we need to identify the consumption by listing all devices as accurate as possible with the help of the company representative. The walkthrough has to be accompanied with interview to the SijiMix engineers each at his area of proficiency.

The interviews will clarify the nature of the consumption and the duration. After that we will be able to tell why the electricity is consumed this way and what could be changed to reduce it. During the visit, we need to track the supply process from customer request until the shipping. We may collect documents from the company if available.

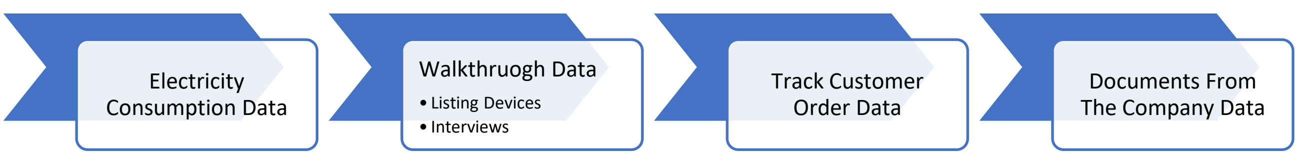

Figure 2: Data collection process.

2.2 Need analysis

The electricity consumption data are collected from FEWA bills. The company have provided the data for 2017 and 2018. For the 2019 data, we have followed the bills on FEWA application. The data for September until December is forecasted to complete a set of 3 years data using moving average forecasting method. This method gives equal weights to the last observations. We will use the data of the same months in the previous years. For example, to forecast for September 2019 we will use the data of September 2018 and 2017.

$$Forecasted\ Consumption\ F_t = \frac{Actual\ Consumption\ A_{t-1} + Actual\ Consumption\ A_{t-2}}{2}$$

Equation 1: Moving Average simple method formula.

The result is shown in table 2:

Table 2: Forecasting energy consumption for the remaining 4 months of 2019.			
No.	**Actual 2017**	**Actual 2018**	**Forecasted 2019**
September	598,000.00	485,000.00	541,500.00
October	328,000.00	339,000.00	333,500.00
November	566,000.00	525,000.00	545,500.00
December	285,000.00	293,000.00	289,000.00

Then, these forecasted values given in KWH are used in the electricity analysis.

2.2.1 Electricity consumption analysis

2.2.1.1 Energy trend

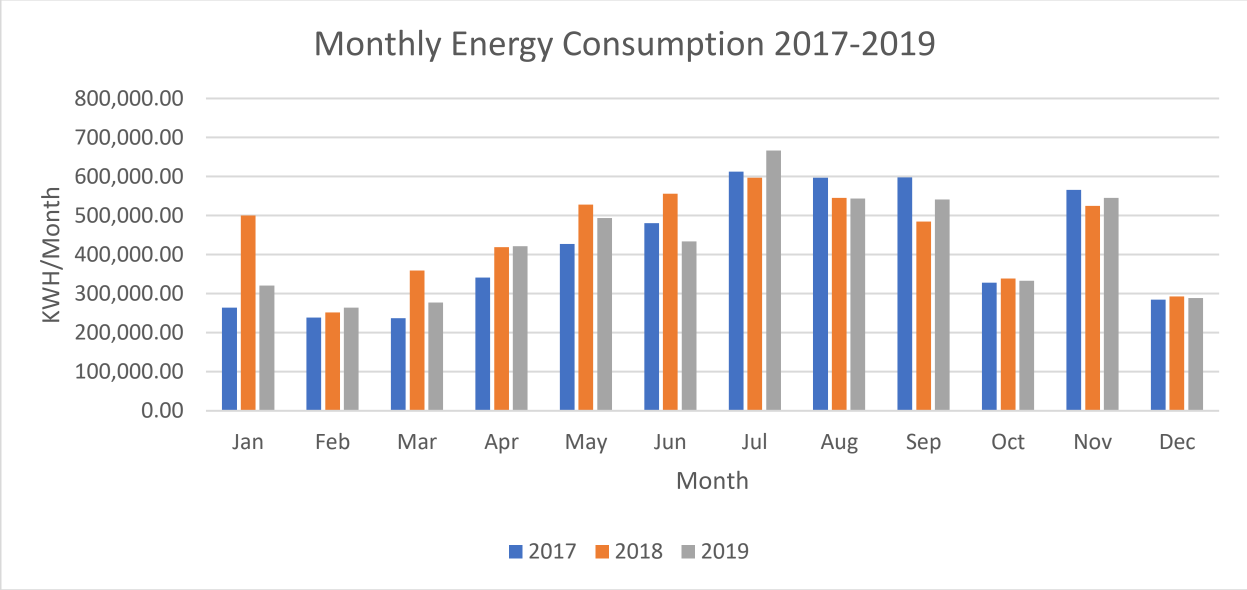

Figure 3: Monthly energy consumption.

(Figure 3) shows the energy consumption with seasonal effect. The consumption is clearly higher in summer season and lower in the cold season. The month of November only is not following the trend for the years 2017 and 2018. The 2019 consumption was forecasted. In January 2018 we also have a peak consumption. The lowest actual consumption among all was in February 2017 and the highest actual consumption is on July 2019. The company's electricity consumption is affected by changes in the weather temperature. However, having a minimum consumption could be shared with an amount of consumption that is not affected by weather. We need to know if there is amount of the electricity not affected by season and how much is that value. For this, we will plot the electricity consumption against the monthly cooling degree days.

2.2.1.2 Cooling Degree days

The cooling degree days CDD is way to measure the amount of energy needed to cool a building. When we plot it versus the consumed energy, we will be able to find the weather dependent and independent values. We have found the CDD from (degreedays.net/) for a nearest recorded values to the location of the company. The values are in appendix 1. The company is located approximately at (56.28E, 25.08N). Using these values we picked a location at degreedays.net/ which is Fujairah, AE (56.32E,25.11N). The CDD are found until August 2019. Values from September to December 2019 are forecasted using moving average method. Values are rounded up when needed.

From (figure 4) we can find the linear equations of each year. Variable "a" describes the efficiency of the building. The lower the value of "a" the more efficient the building. Variable "b" represents the weather independent part of the building like lighting and office equipment. R^2 is the coefficient of determination that tells how close the data to the regression.

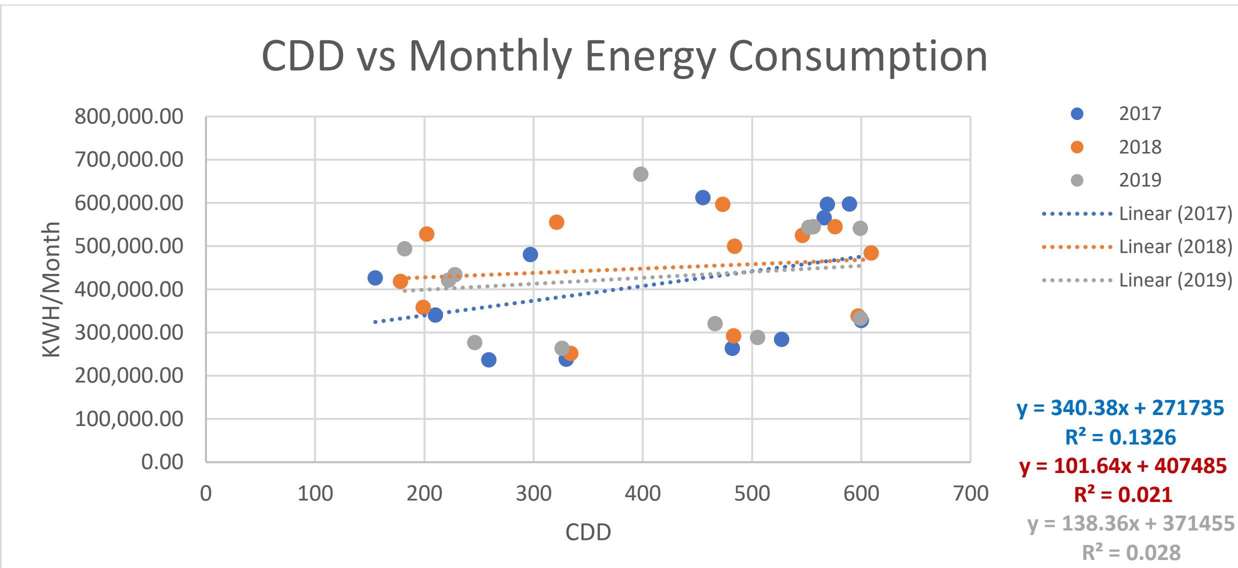

Figure 4: Monthly CDD for Fujairah, AE (56.32E,25.11N) VS the electricity consumption of SijiMix.

Table 3:The values form the linear equations in (Figure 5).					
No.	**Year**	**a**	**b**	**R^2**	**Percentage**
1	**2017**	340.38	271,735	0.1326	13.3%
2	**2018**	101.64	407,485	0.021	2.1%
3	**2019**	138.36	371,455	0.028	2.8%

Looking at the values of "a", the company's energy efficiency increased from 2017 to 2018 and then decreased again in 2019 to a lower level of 2017. Which can predict an improvement in the energy usage. The weather independent part of the energy "b" highly increased from 2017 to 2018, then decreased from 2018 to 2019. Independent activities could be a certain project happened in 2018. Reflecting this finding in (figure 4), this project was most probably happened on January and November of 2018. It may be expanding the building. Because the independent consumption did not get back to 2017 but increased in 2019.

The value of R^2 shows that in year 2017, 13% of the variation in the electricity consumption was due to CDD. The R^2 value is lower in the next 2 years. The linear equation is very weak in explaining the relations between the consumption and the CDD. There is an additional energy consumption added to the company which decreases the share of weather dependent part of the company.

Form (table 3), we also know that the weather independent "b" values are representing devices and activities that are weather independent. We need to categories and define these electricity consumers.

2.2.1.3 12 months rolling sum

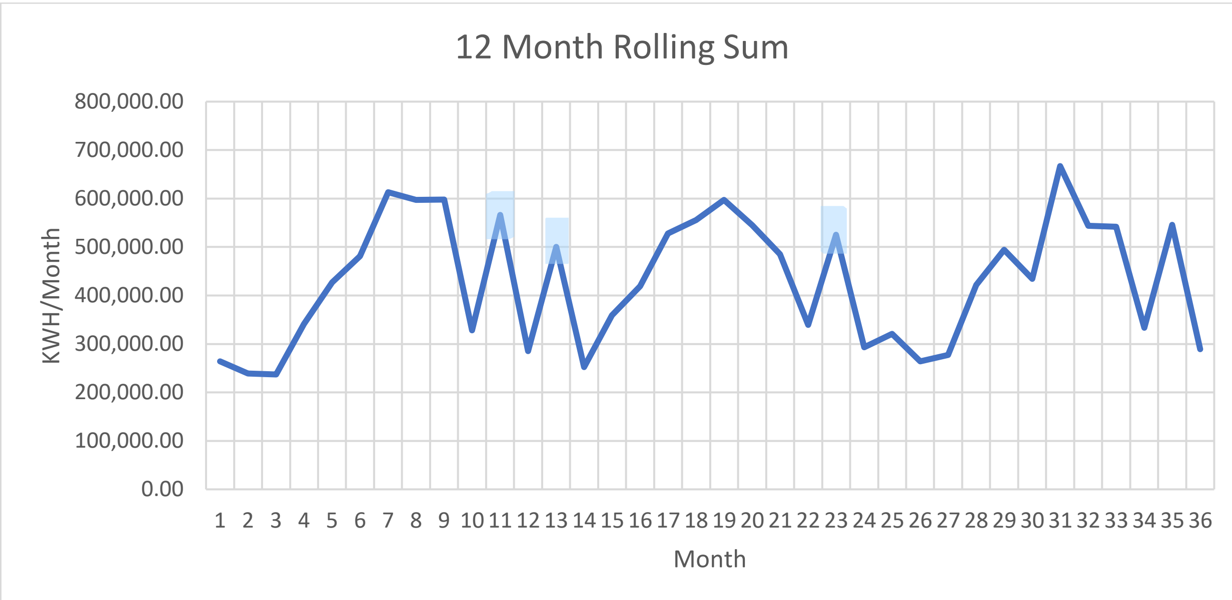

Figure 5: 12 month rolling sum.

The 12 month rolling sum helps determining the energy trend without the effect of the seasons. In (figure 5), there is an obvious outlier in months number 11, 13 and 23. The values after 32 are forecasted so we will not count them. To determine the normal expected range for these values we will take the average between the last and next value. For example, for month 11 we will add the value of month 10 to the month 12 and dived by 2 (see equation 1). The results are shown in the (table 4). Values are rounded up when needed. We also included the forecasted months to see the normal expected trend.

Table 4: The expected range of the outliers.					
No.	Month	Actual value	Value rang	Average	Actual value status
1	11	566,000	328,000-285,000	306,500	Out of range
2	13	500,227	285,000-252,000	268,500	Out of range
3	23	525,000	339,000-293,000	316,000	Out of range
	Month	Forecasted value	Value rang	Average	
4	34	333,500	541,500-545,500	543,000	
5	35	545,500	333,500-289,000	311,250	

We found that for these three months, all the consumption is higher than the expected. The smoothed trend is shown in (figure 6). The trend is clear -periodic- which can help us in the recommendations.

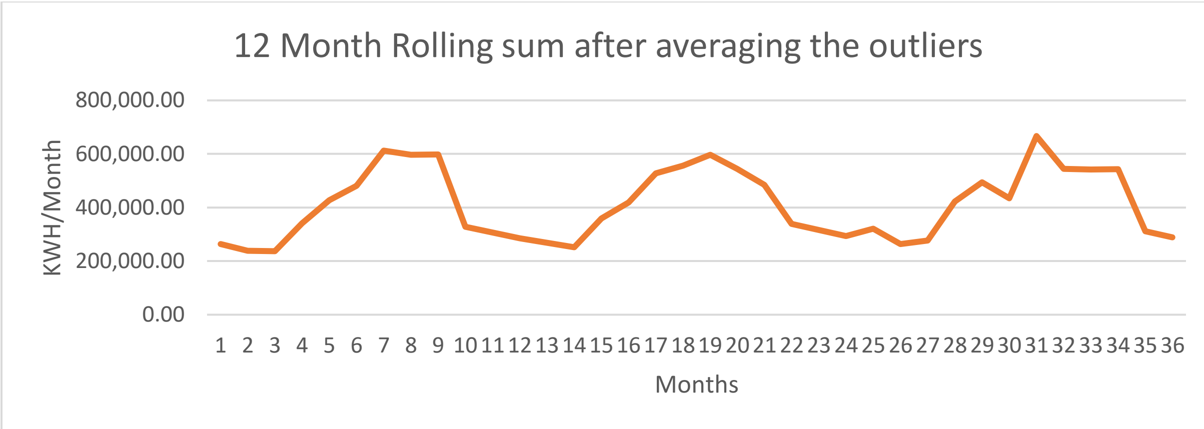

Figure 6: 12 month rolling sum after plotting the outliers in the expected range.

2.2.2 Walkthrough information

2.2.2.1 Building description

- Location: Fujairah, UAE (See figure 1).
- Gross Floor Area (GFA): Main Building: 35,037 m^2 (value approximated using google maps).
- There are 3 electricity meters. (AC meter- Light Power meter -UPS meter).
- Eelectricity purchased from the grid which accounts for the total of the energy consumed in the building.
- 9 buildings connected to the grid and 1 runs on generator: (see figure 1)
    1. Offices
    2. Chiller
    3. QCL Maintenance
    4. Chemical Plant
    5. Masjid & Drivers Room
    6. Workshops
    7. QC, Security and Safety
    8. Operation
    9. Plants A,B & Ice Plant
    10. Plant C (generator)
- Electricity cost: 0.40 AED/kWh. (Value from FEWA bill)
- Electricity emission factor: 0.4333 kg CO2eq/kWh.

Sample Photos

The photos show different types of lights, like florescent and LED. Deferent air conditioners which are window and split. This points out to a previous attempt to increase the efficiency of the devices. Some phots are represented in (figure 7).

Window AC

Split AC

Incandescent light

LED light

Figure 7: Load used at the company.

2.2.2.2 Devices categories and building occupancy

Categorization of devices

During the walkthrough visit, we have counted the devices used in the building and approximated the working hours of each building. We started by listing the devices. We have categorized them according to the next (table 5). We have added the weather dependence factor to help us study this relation later. HVAC devices like big fans used in stores could be weather independent because the stores in the company are closed area which needs ventilation regardless of the temperature.

Table 5: Categories of devices.

No.	Category	Examples	Weather dependence
1	HVAC	Air conditioner, fridge, fan	Mostly Dependent
2	Lighting	Tube light, emergency light, LED	Independent
3	Office devices	Printer, laptop, telephone	Independent
4	Special Devices and Machines	Weighing machine, density meter	Independent
5	Other	Sensors, kitchen devices like boiler	Independent

Building occupancy by time

We have collected data about the time where different buildings are occupied by employees. We represented the data in (figure 8). From the figure, we know that safety office is the longest occupied building during a year. Then, the control room of the patching plant. This room controls the batching plants A and B. After that comes the maintenance office and the operation room with the same time occupancy. The least are the Mosque and Drivers room.

Legend for Figure 8	
Che.	Chemical
PM	Production Manager
Maint.	Maintenance
M&D.	Mosque and Drivers
B.P.	Batching Plant
Oper.	Operator

In general, the administrative buildings have similar occupancy time and the buildings related to operation have similar and higher occupancy time. However, reducing the energy used in the longest occupied buildings will not necessarily have the greatest effect on the energy consumption because the energy depends on the amount of KW consumed by the building as well as the time.

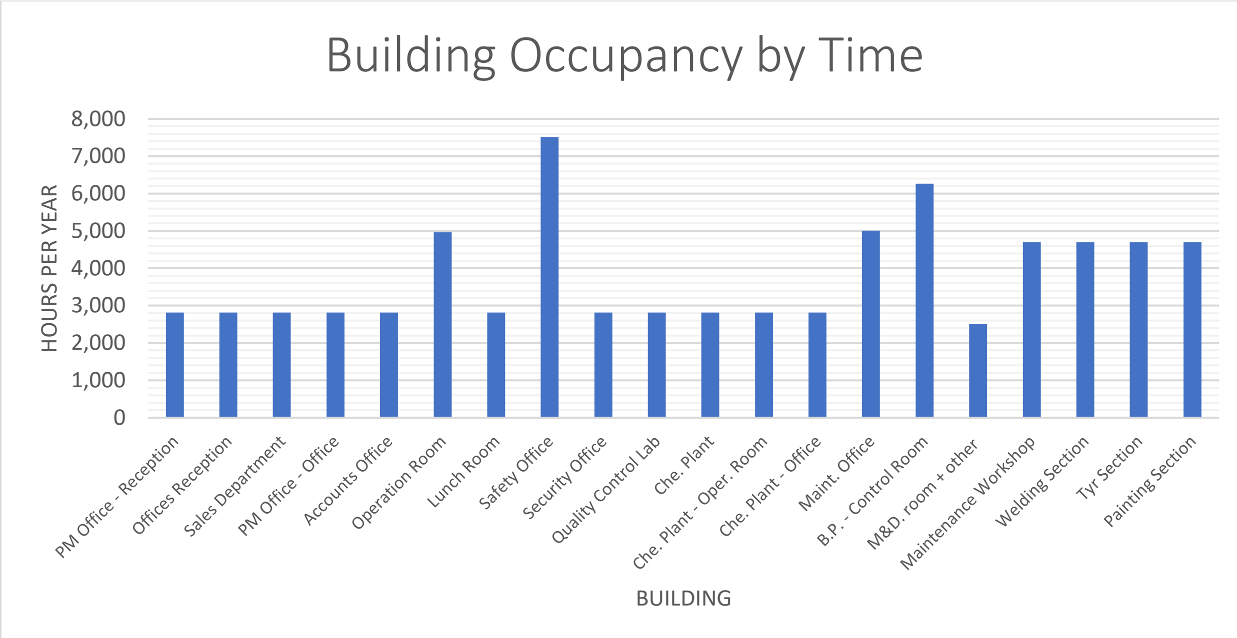

Figure 9: The occupancy of the building by hour per year.

From the categories in table 5, we will be working in the Lighting category and the HVAC category. The other categories include devices that are of very small electrical load or related to safety and security.

2.2.3 Track customer order

The flow of the production process starting from the customer order until the delivery on-site is as shown in (figure 9).

Figure 8: Production Process at SijiMix.

Customer	Request ∨			Inform customer				
Sales	Request received >	customer < NO	Inform customer < NO|YES >	^ PM Approve >				
Accounts		CCD ∨						
QCL		PM < NO|YES >						
Operation					Allocate Manage >	Manage >>>	Manage >>>	Close
Production						Produce >>>	Produce >>>	
Transportation							Transport >>>	Last on site
Time Slots	1	2	3	4	5	6	7	8
Electricity Consumed	Low	Low	Low	Low	Low	High	High >>>	Low

QCL: Quality Control Lab.
CCD: Critical Control Department.
PM: Production Manager.
Note: Trusted customers can contact the operation directly.
All activities are monitored using a software by the production manager.

The flow of the production process includes 2 parts: Production line and Supportive to production. Then we listed the Administrative activities and then the Information needed to start production:

Production line activities by department entail:

- Customer: Represent the need and initiate the request.
- Sales: Handles the request and informs both, the accounts and the QCL.
- Accounts: Informs the Critical Control Department.
- Quality Control Lab: Prepares the formula.
- Operation: Allocates the resources and manages the delivery to site.
- Production: Produces based on the QCL formula and the time and amount specified by operation.
- Transportation: Provide the needed transportation means including emergency needs. Note that quality is checked at the mixer before leaving the company at the quality check point.

Supportive to production activities by department entail:

- Purchase and Supply: Insures the availability of raw material.
- Chemical Plant: Provides the needed chemicals.
- Maintenance Workshops: Mainly, keeps the transportation in a good working condition.
- Quality Check Point: Final check at the produced mix. Checks the output at the transit mixer vehicle.

Administrative activities by department entail:

- Safety: Manages health safety and environmental safety.
- Security: Check the attendance and secure the main entrance.
- Marketing: We are not including the marketing in this study.

Operation information to start production:

The operation needs the following data to start the production:

- Identify plant location to produce based on the location of the supply.
- Customer name and contact.
- Specify time gap between production.
- Site time (delivery).
- Order date.
- Material needed (by code).
- Quantity.
- Cash or credit.

2.2.4 Information from the Documents

From the documents of the company, we know that the company has 3 main transformers until November 2018. In that month, the readings were as following:

Table 6: Data on November 30th, 2018.

No.	Transformer	Total Reading in KWh	Consumption KWh	comments
1	Transformer I	5,694,704.00	157,076.00	SijiMix, LV meter
2	Transformer II	93,470.00	105,669.92	Decortech, LV meter
3	Transformer III	5,111,943.00	182,169.5	Labor Camp Block A, LV meter
Total		**10,900,117.00**	**4,915.42**	**Total AED 179,585.43**

Then, we reflected the data in table 6 in a FEWA bill. See table 7:

Table 7: FEWA bill covering November 2nd, 2018 to December 1st, 2018.			
No.		**KWh**	**Total AED**
1	FEWA bill (without VAT and service charge)	525,000.00	210,000.00

There is a difference in the values for the same month equal to 80,084.58 KWh and 30,414.57 AED. By dividing FEWA bill value by 25 working days in November 2018 we get 21,000 KWh per day and 8,400 AED. So, we expect an activity or event between November 30th and December 1st that caused a high electricity consumption of approximately (80,084.58 KWh and 30,414.57 AED). We got many documents about the readings on November 2018 from the company. We expect there is a monitoring happened specially for that month.

Load distribution

We may use the load distribution data to approximate the maximum load for the devices to use it to calculate the contribution of different devices in the consumption of the electricity. (Table 8) shows the consumption. The full table attached in Appendix 2. From this document, we know that the initial design of the electricity in the buildings of the company was to supply 127.56 KW. If we multiply this by yearly working hours per month of the admirative buildings (216 hours)* we get 27,127.56 KWH consumed each month buy administrative buildings.

Table 8: Load distribution schedule data.		
No.	**Unit**	**Watts per unit**
1	External Fan	100.00
2	Emergency	100.00
3	13A Switched Socket Outlet (S.S.O.)	200.00
4	13A Double Socket Outlet (D.S.O.)	400.00
5	Water Heater	1,500.00
6	S. A/C	3,750.00
7	Pump	1,460.00
8	Lighting	100.00
9	Lighting	250.00
10	Emergency	100.00
11	External Fan	100.00
12	15A Socket Outlet (S.O.)	1,500.00

If the total consumption is 525,000 KWh in November 2018, then about 497,872.44 KWh is consumed by batching plants A & B, ice plant and chiller. We need to validate this finding by confirming the consumption by these plants. We need also to confirm the bill from FEWA includes the following:

- Administrative Buildings. (SijiMix, Decortech, Laboure camp)
- Batching plants A and B.
- Other if any.

The difference between November 2017 and November 2018 electricity consumption is 9,500 KWH. That mean, not only the labor camp electricity consumption is the reason to this increase in electricity consumption because in November 2018 the KWH was 182,169.5 (see table 6).

Calculating the energy consumption per device

We need to give values for the watts needed to approximate consumption by each device in (table 9). These values will then be used to approximate the contribution of the loads in the company.

*This value is calculated based on 54 working hours per week.

Then we will use the data we collected about the time of occupancy (figure 8) to find the contribution of different categories in energy consumption. The watts will be multiplied by working hours in which that unit is located. Results are shown in (table 9). Detailed table is in Appendix 3.

Table 9: Load approximated watts.				
No.	**Unit**	**Watts**	**Category**	**Total in KWH**
1	Big lights	200,00	Lighting	69,488.04
2	All other lights including LED	15.00		
3	Air conditioner	3,000.00	HVAC	606,980.83
4	All fridge’s	800.00		
5	Fans	40.00		
Total				676,468.87

2.3 Validation of data

2.3.1 Information to be validated

1. What happened in 2018?
2. When did the company build the labor camp?
3. What happened on November 2017 and 2018 which caused an unusual high energy consumption?
4. What caused a high consumption in January 2018?
5. Why did the energy efficiency increase from 2017 to 2018? Then decreased slightly in 2019?
6. Did the company make any project(s) internally or by external parties to increase the energy efficiency? Details…
7. How much is the contribution of lighting to the energy consumption in the company?
8. How much is the contribution of HVAC to the energy consumption in the company?

2.3.2 Meeting with the company’s experts

On November 14th, 2019, we have met with the production manager and the maintenance manager. After the discussion we have the following expectations to what happened on the months with outlier consumption.

1. On November 2017, the company had a big project to a customer to supply a tower which increased the consumption.
2. On the end of June 2018 until December 2018, the company had a big project to supply a new road.
3. The electricity consumption data provided previously includes other sister companies (SijiMix, DecorTech, Electromechanical) and the labor camp.
4. The labor camp has been built between 2012-2013. Out of the study period.

5. There is a decrease in the consumption by Ice-plant up to 70% (approximated by the production manager) between November 15th to April 15th. The Ice-plant is used to lower the temperature of the aggregate.
6. The heater and air conditioner usage in the labor camp maybe the reason of the increase in total consumption.
7. Labor camp is approximately 120 rooms with 4 labors per room.
8. The labor camp was working in generator until between 2012 and 2013. Then it became connected to the main grid.
9. There is an increase of about 30% from September to December 2018.

Based on the discussion, the company agreed to provide us with the following:

- The daily production data (m^3) from 2017-2019 of Plants A and B.
- The daily electricity consumption data (KWH) from 2017 – 2019.

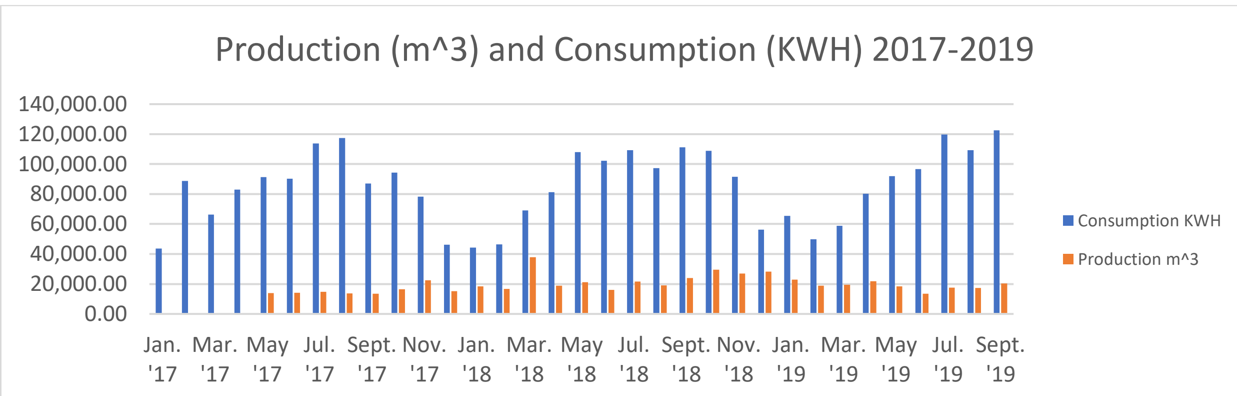

Figure 10: Production (m^3) and consumption (KwH) for the period from May 2017 until September 2019.

Figure 10 shows the production and electricity consumption of the company for the period under study. In this graph, the production is not varying with the consumption of energy. Which means, the periodic behavior of the energy consumption is not influenced by the production.

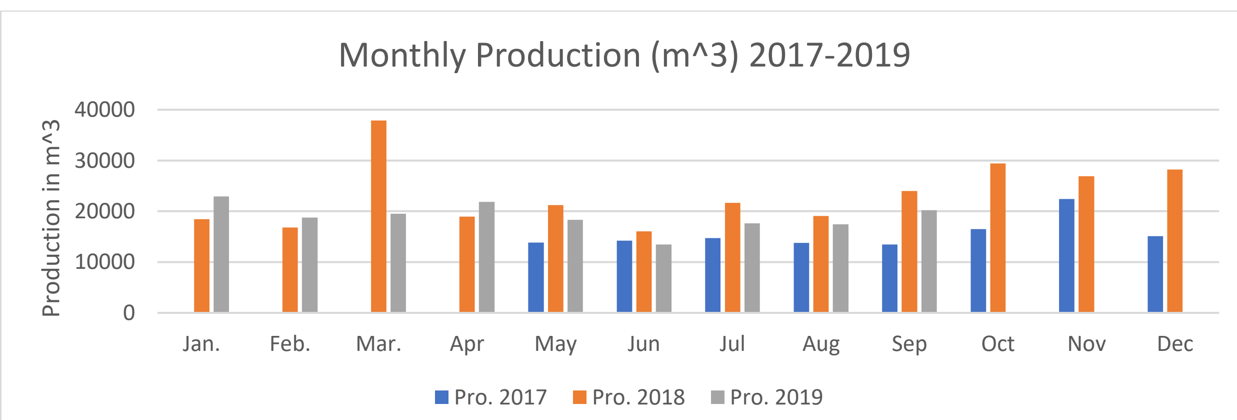

Figure 11: Monthly production by the company from May 2017 until September 2019.

The production was in its maximum on March 2018. And is highly increased on September 2018 until December 2018. Otherwise, the production is normal as shown in this graph. The production in 2018 from May through December was higher than the same period in the previous years. This confirms the company's information during the meeting. See section 2.3.2 point number 2. This increase was due to a big project.

In year 2017, there was an increase in November which was mentioned by the company as a result of a big project. See section 2.3.2 point number 1.

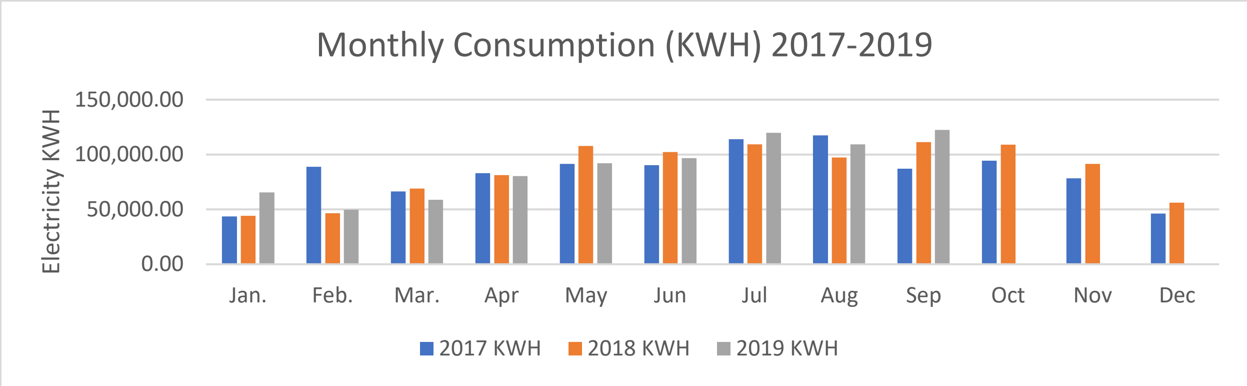

Figure 12: Monthly electricity consumption by the company from January 2017 until September 2019.

Go to section 2.2.1.1 to read about the energy trend. The graph shows the effect of the season in the consumption of energy. It's higher in summer months and lower in winter. There was a high increase in February 2017. And a current increase in September 2019 surpasses the maximum of all year's monthly consumption.

Between October to February, the consumption is decreased. These are the winter months in UAE. According to the company's experts, the ice-plant consumption of energy is 30% decreased from September to December. See section 2.3.2 point number 9.

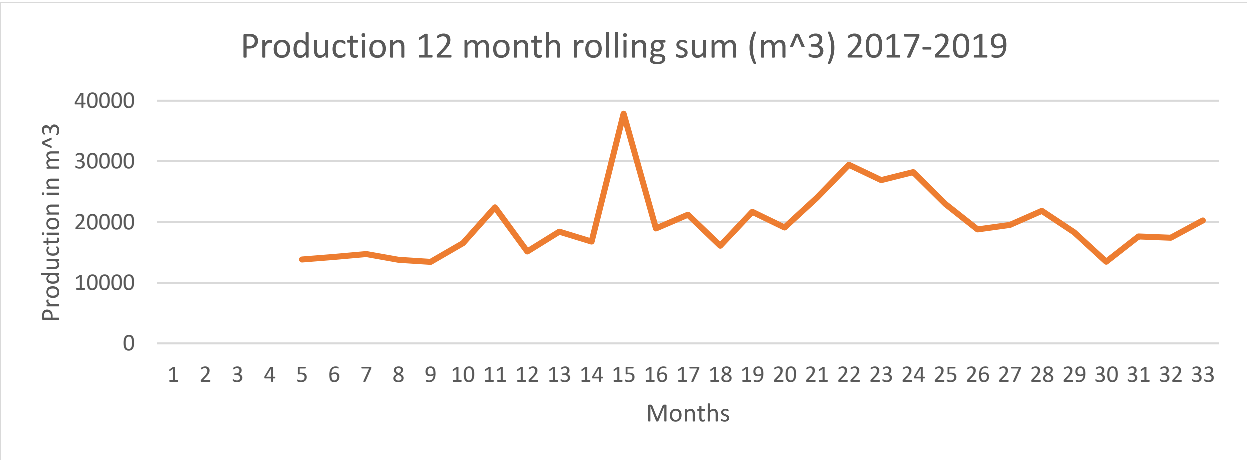

Figure 13: 12-month rolling sum for the company's production (m^3) for 28 months.

Figure 12 is to show the trend without the effect of the season. The production is approximately ranging between 13,400 m^3 to 29,400 m^3. With outlier value at month 15 with value of about 37,870 m^3. The general trend is increasing in 2/3rd of the region then decreasing slightly in the last 1/3rd.

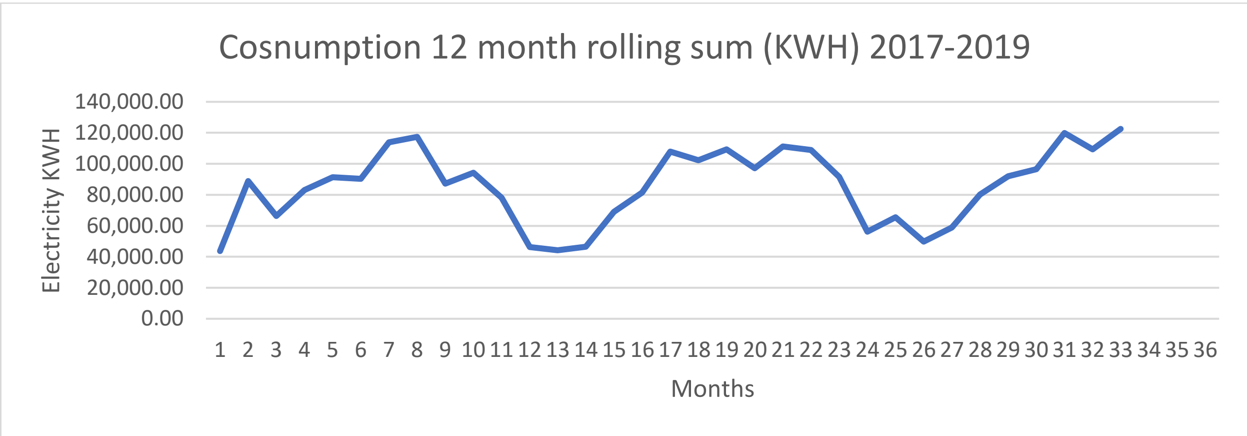

Figure 14: 12-month rolling sum for the electricity consumption by the company for 33 months.

For the consumption shown in figure 14, there is a clear periodic trend. The range is between 40,000 KwH and 120,000 KwH. The last period starting from month 24 is shifted up at the bottom (month 26) and top (month 33) which means an increase in the total consumption in the last period. This shift of the bottom is 5,570 KwH and the shift of the top is 5,060 KwH. There is a consumption source added after month 24 or 25 that caused this shift up.

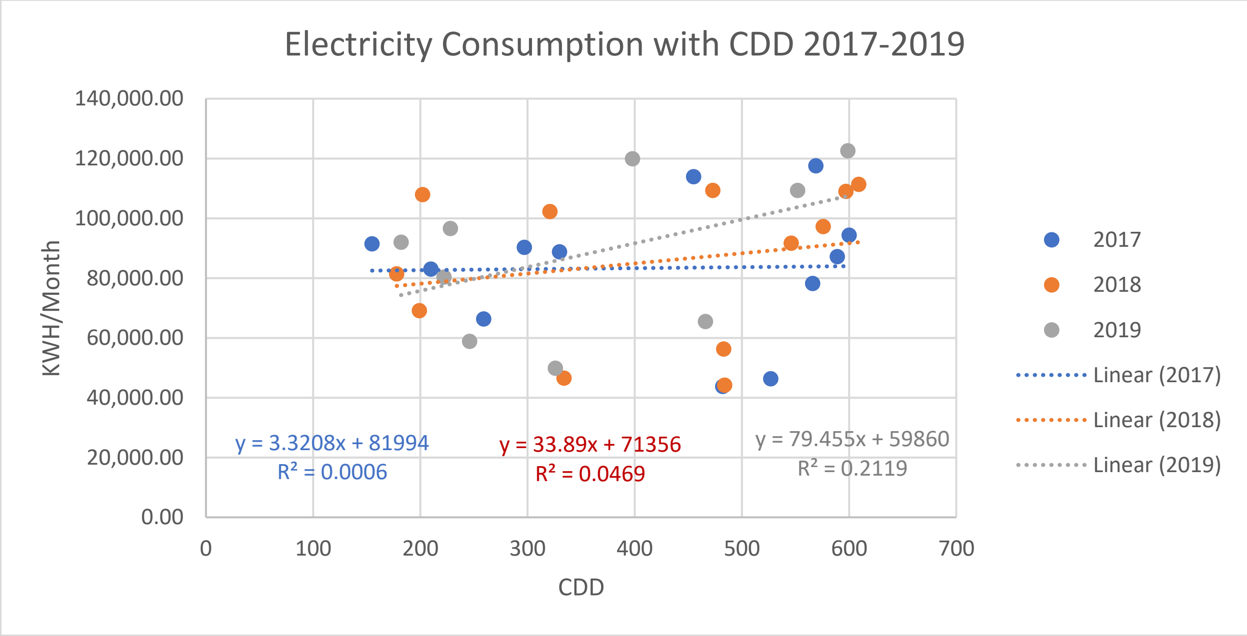

Figure 15: Cooling degree days CDD vs electricity consumption by the company for months January 2017 until September 2019. Fujairah, UAE.

Table 10:The values form the linear equations in (Figure 15).					
No.	**Year**	**a (KWH) weather dependent**	**b (KWH) weather independent**	**R^2**	**Percentage**
1	**2017**	3.3208	81,994	0.0006	0.06%
2	**2018**	33.89	71,356	0.0469	4.69%
3	**2019**	79.455	59,860	0.2119	21.19%

Go to section 2.2.1.2 for more clarification. Looking at “a”, The efficiency decreased as years goes on from 2017 to 2019. The value “b” will tell how much electricity consumption is weather independent. The weather independent share of total electricity consumption decreased as years goes on. At this point, we can’t specify if it is a good or a bad situation.

The value of R^2 is getting better in explaining the linear equation. We can trust the linear equation of 2019. But our data for 2019 are from January to September which is not a complete year. Also, in February 2017, we had an outlier value (See figure 12).

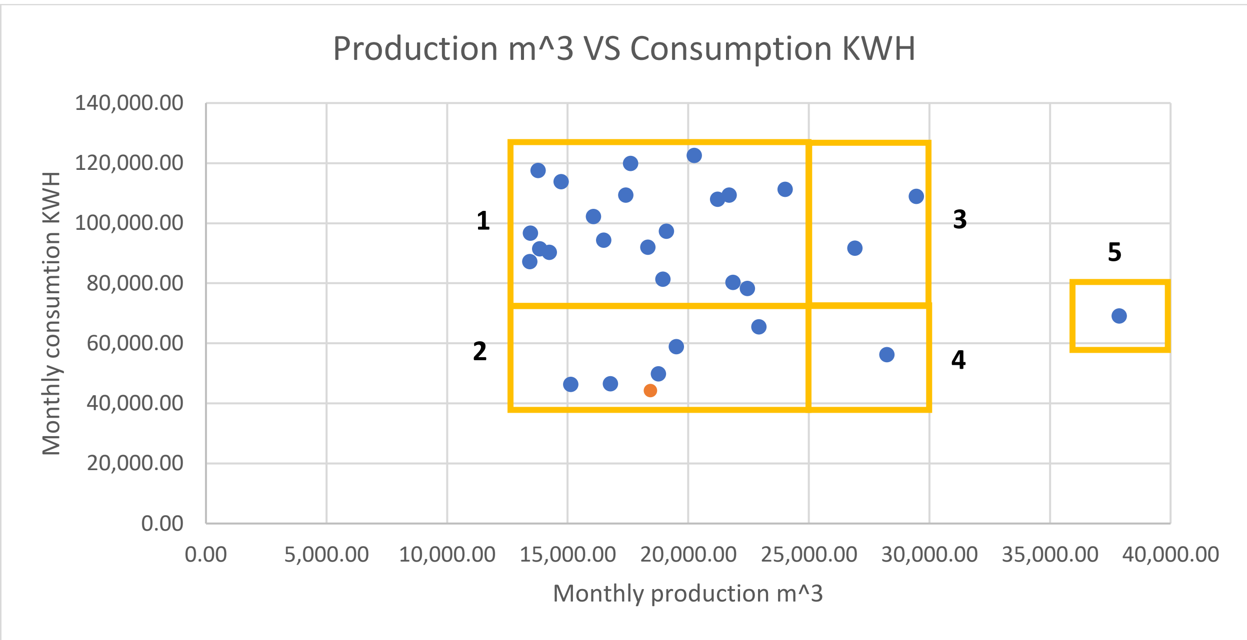

Figure 16: Production m^3 versus consumption in KWH for the months between May 2017 until September 2019.

In figure 16, we will look at the best performance of the electricity consumption. Squares 1 and 2 are showing similar output with the different electricity consumption. Thus, square 2 is better than square 1. Square 3 is even better than 1 and 2, as we have more output for similar consumption in square 1. Same goes for square 4. And the best of all is square 5 with very high output compared to low consumption.

Square 5 value lies on March 2018. A winter month. Then square 4 lies on December 2018. Square 3 lies on October and November 2018.

2.3.3 HVAC and Lighting contribution to electricity consumption calculations

The calculation of the consumption in this part is the base of our calculation later in the project. For this reason, we will use different methods to estimate the HVAC and lighting consumption.

We will first calculate the HVAC and Lighting contribution to the consumption of the energy through the data collected in table 9. By taking the case of November 2018, the consumption will be approximately like the following:

Total Consumption KWH (FEWA bill) = 525,000.00

HVAC Consumption KWH (Calculated) = 607,000.00

Lighting Consumption KWH (Calculated) = 69,500.00

Reminder KWH (Calculated) = -151,500.00

This means, our calculations for the Lighting and HVAC can't be true. We shall not use this result to confirm the amount of the HVAC and lighting electricity consumption in the company. This confirms the data in table 9 are not reliable.

The other method is to find the electricity required to produce 1 m^3 of RMC. To calculate this value, we will take the minimum consumption assuming that it will represent the production + other energy consumption. This value is equal to 44,200.00 KWH (month number 13, Jan. 2018 at production = 18,432.50 m^3). See the red dot in figure 16. If the electricity consumption is linear with the production, then 1 m^3 will require approximately $\frac{18{,}432.50 \text{ m3}}{44{,}200.00 \text{ KWH}} = 2.3980\ KWH$. Based on this, to produce 20,243 m^3 of RMC we require 48,542.714 KWH. The highest electricity consumption is 122,530 KWH with 20,243 m^3.

Therefore,

$$KWH_{\ Total,Highest} - KWH_{\ Production,Highest} = KWH_{HVAC} + KWH_{Chiller} + KWH_{Ice\ Plant} + KWH_{Other}$$

$$122{,}530.00\ KWH - 48{,}542.714 \text{ KWH} = 73{,}987.286 \text{ KWH}$$

Third method is by assuming the lowest electricity consumption represents Production + Other and the highest represents the additional HVAC consumption + Other. So, $122{,}530.00\ KWH - 44{,}200.00 \text{ KWH} = 78{,}330.00$ KWH.

Now, let's study the month of November 2018 where we received a detailed data about the electricity consumption. In table 6, a value of 157,076 KWH is consumed by SijiMix, LV meter (equivalent to 35.3 % of FEWA bill reading). From figure 12, SijiMix alone consumed 91,600.00 KWH in November 2018. So, our limit for the technical side of the solution is 78,330.00 KWH.

The result is we will make the project to serve a value of 73,987.286 KWH or less. Because this value contains HVAC and other devices. We are not able to separate the values because we can't define the operating hours of the chiller and the ice-plant although we know the energy KW of both.

We assume 30% for chiller and 30% for ice-plant (numbers based on factsheet by climatechange.gov.au) [4]. Then, the covered power is 40% of 73,987.286 KWH = 29,594.9144 KWH per month.

Summary and Results of Chapter 2:

1. The environment gets dusty from time to time and the dust is not controlled.
2. Generally, the heavy electricity consumption goes to production plant, ice plant and chiller.
3. In this work, the data for September 2019 until December 2019 are forecasted to complete a set of 3 years data using moving average forecasting method.
4. The month of November only is not following the trend for the years 2017 and 2018.
5. In January 2018 we also have a peak consumption. The lowest actual consumption among all was in February 2017 and the highest actual consumption is on July 2019.
6. Based on (figure 3), the company's electricity consumption is affected by changes in the weather temperature.
7. Electricity consumption could be shared with an amount of consumption that is not affected by weather.
8. We expected an activity or event between November 30th and December 1st that caused a high electricity consumption of approximately (80,084.58 KWh and 30,414.57 AED).
9. Based on the company's initial electrical design, and an amount up to 27,127.56 KWH can be consumed every month by administrative buildings.
10. Thus, if the total consumption is 525,000 KWh in November 2018, then about 497,872.44 KWh is consumed by batching plants A & B, and chiller.
11. We need to validate this finding by confirming the electricity consumption by these plants.
12. We need also to confirm the bill from FEWA includes the following:
    a. Administrative Buildings. (SijiMix, Decortech, Laboure camp)
    b. Batching plants A and B.
    c. Other if any.
13. Not only the labor camp electricity consumption is the reason to this increase in electricity consumption between 2017 and 2018.

<u>After validation summary and results:</u>

14. The periodic behavior of the energy consumption is not influenced by the production.
15. The production in 2018 from May through December was higher than the same period in the previous years. This confirms the company's information that the increase was due to a big project.
16. In year 2017, there was an increase in November which was mentioned by the company as a result of a big project.
17. There was a high increase in February 2017. And a current increase in September 2019 surpasses the maximum of all year's monthly consumption.
18. According to the company's experts, the ice-plant consumption of energy is 30% decreased from September to December.
19. The production is approximately ranging between 13,400 m^3 to 29,400 m^3.
20. There is an outlier value at month 15 with value of about 37,870 m^3.
21. The general trend is increasing in 2/3rd of the region then decreasing slightly in the last 1/3rd.
22. For the electricity consumption shown in figure 14, there is a clear periodic trend.
23. The range of the electricity consumption is between 40,000 KwH and 120,000 KwH.

24. The last period starting from month 24 is shifted up at the bottom (at month 26) and top (at month 33) which means an increase in the total consumption in the last period. Figure 14.
25. This shift of the bottom is 5,570 KwH and the shift of the top is 5,060 KwH.
26. There is a consumption source added after month 24 or 25 that caused this shift up.
27. The weather independent share of total electricity consumption decreased as years goes on from 2017 to 2019.
28. The best performance of the electricity consumption by the company happened on March 2018, December 2018, November 2018 and October 2018 respectively. All are winter months.
29. The project is to cover 29,594.9144 KWH per month.

CHAPTER 3: APPROACH

3.1 Options and Insights

At this chapter, we should look at the available options based on the previous information in CH1 and CH2. A part of working in this section, we have visited big exhibitions related to energy in UAE like TheBig5, WETEX, WGES, GITEX and other. It provided an opportunity of discussion with professionals in the market. The following will present our options.

As stated in the question section 1.3.2, our main objective of the project is answering the question: "what could be changed to reduce electricity consumption, therefore electricity bill?" Adding to that a secondary objective of the solution is for the company to be greener.

We look for implementing the scenario of the best performed month in terms of electricity consumption. That mean, to be closer to winter consumption. For this option, we will need to work in two directions:

The non-human side:

Option 1: Related to production (Ice plant). This option is aiming to map the plants related activities and consumption to study the reduction. This option is not advised as it is critical to production.

Option 2: Related to offices devices like HVAC and Lighting systems. This option is to replace the devices by more efficient ones.

Option 3: Is related to the building performance. For example, using more insulation from outside environment.

And the human side related activities:

Option 4: Time of usage like avoiding the peak hours of energy usage.

Option 5: Way of usage that is creating waste. We may use automated control systems for lighting and HVAC to eliminate waste.

Option 6: Cover parts of the consumption using renewable energy. This option should consider the dust challenge due to the production activities by the company.

Option 7: Buy a new plant that will consume less energy. This will result a huge changing in the company's production. No advised.

We have finally collected these options based on multiple reading to online articles, annual visits and discussions with professionals in congresses and exhibitions in UAE. Based on that we decided to do the following:

Recommend implementing options 2, 3, 4 and 5. And our work will be on option 6 targeting the main and secondary objectives of the project.

3.2 Work plan of this project

The workplan has been built in a way to cover all possible sources of the solution. In every step we will look at a side of the project and find out if it will be related to answering our project question. To avoid going into forever research and analysis, we may skip some steps on the workplan. As far as we see a clear approach to the desired solution within the time frame. So, the plan in figure 17 is the initial road map.

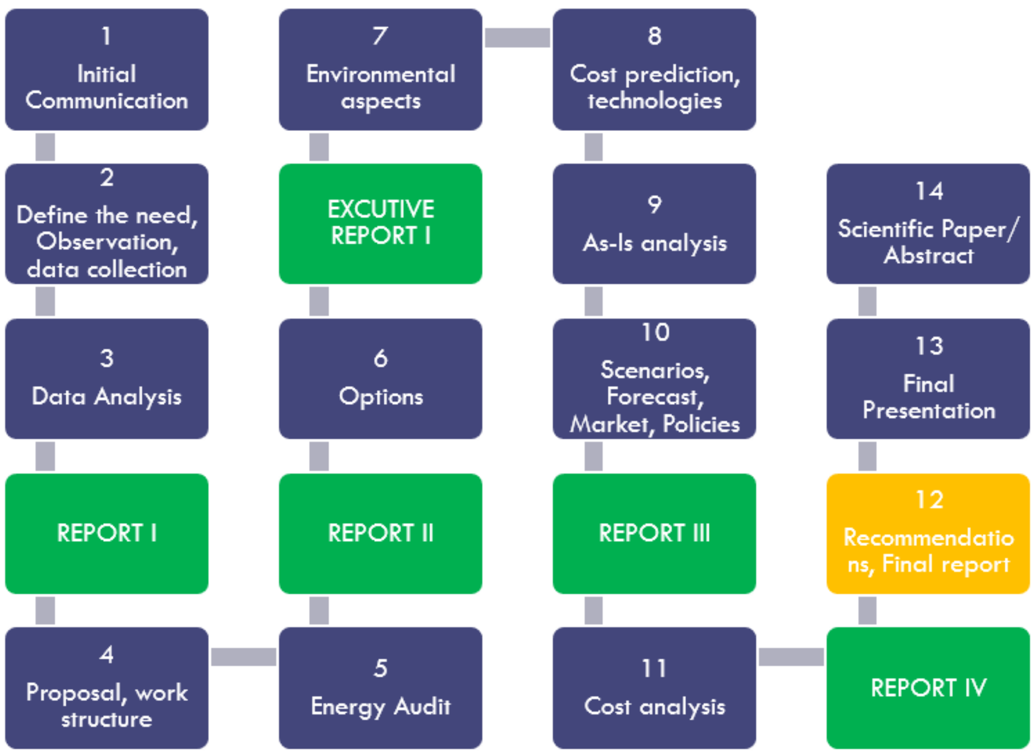

Figure 17: Suggested workplan to reach the solution.

The reports mentioned in figure 17 are not attached in this document.

Summary:

Based on this plan, the next part will build in the points from 8 until the end of the project. We have defined some options in this chapter as well as the roadmap towards the solution.

Part II: To-Be

Part I constructed the analysis and proposals required to reach the executive phase. In this part, chapter 4 is to describe the system based on our choice in chapter 3. Then, financial calculations are presented in chapter 5. Chapter 6 concludes the project and presents the recommendations. Key learnings and next steps are documented in this chapter as well.

Part II: TO-BE

In this part, we are going to work in option 6 (see chapter 3 section1). This part has been updated based on validation of the method by professional engineer. Mentioned in the acknowledgment.

CHAPTER 4: SYSTEMS DESIGN

PV system is commonly configured to be connected in one of three ways: Stand-Alone system which requires a battery. Also, referred to as Off-Grid. This system can work in remote areas as well. Second configuration is Grid-Connected system that can work with the grid. This system could be designed to supply full load or part of the load. Finally, the Hybrid system combines 2 or more renewable energies.

4.1 Technical Specifications

The scope of the work is to design a grid-connected PV system for the company in Fujairah with the following (See figure 18):

- Location: 25.4111° N, 56.2482° E.
- Total annual electricity consumption by SijiMIX (Figure 12) equal to 1,028,598.88 KWH (average to 3 years). Equivalent to 85,716.5733 KWH per month.
- Load to be covered based on calculated electricity consumption by HVAC + Other in SijiMIX is 29,594.9144 KWH per month. (from section 2.3.3)
- Storage: Storage + back-up grid connection.
- Sunshine in UAE: 12 hours.
- Peak sun-hour/day: 5.84 See reference [5].

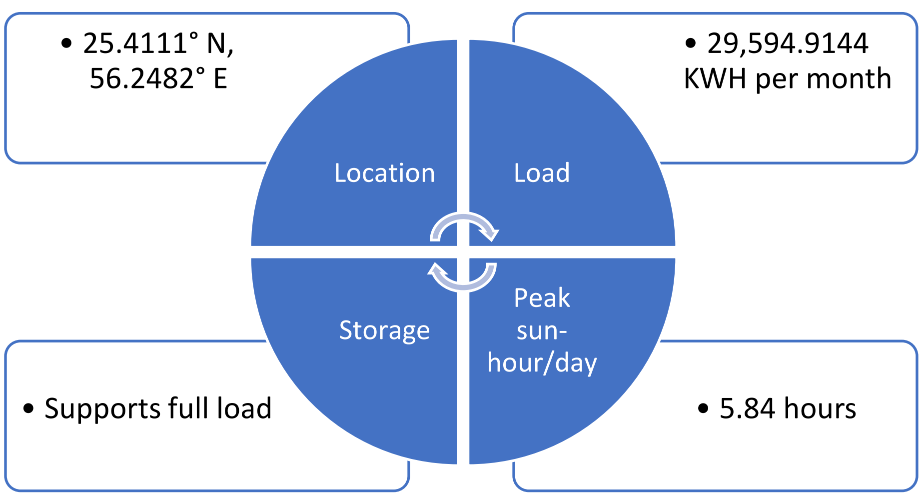

Figure 18: Required System.

Considerations:

The temperature variation can affect the operation and the efficiency of the PV module. Increasing the temperature of the cell will reduce the output voltage by fraction of a percentage.

The system can be wired in series or parallel depends of design specifications.

The system to be designed for this company will be a Grid-Connected configuration with back-up batteries. PV type used is Monocrystalline. An inverter will be used to provide AC output from the DC input coming from the PV array. The controller will function to protect the system from the input variation coming from PV.

4.1.1 Assumptions

These assumptions are based on the visits to the company and discussion with the employees.

- **Wind intensity:** Most of Fujairah's wind ranges between 200 W/m^2 to around 450 W/m^2.
- **Dust:** There is a dust accumulating every day because of the industrial activities by the company and the neighboring companies.
- **Animal Interference:** Animals like birds can affect the array by their natural waste. This factor depends on the exact location of the residence. Some buildings experience a group of birds and some are not.
- **Vandalism:** Fujairah and UAE in general have low crime rate and rigorous law enforcement [3]. There is very low expectation for destruction acts.
- **Distance from power conditioning equipment:** The system is to be installed on the rooftop of the office buildings. However, we expect that more area can be found in the company. For that, we will make the design regardless of the available area. Then we can control the number of PV panels based on the available area.
- **Accessibility for maintenance:** The system should include maintenance cost. This cost is not calculated in our case.

4.2 Analysis

This section is to analyze the electricity demand to design the solar system.

Determine the load: From section 4.1, the total load demand is 29,594.9144 KWH per month. Taking the average per day, the total load is 986.497 KWh for a 30 days month. Annual average sunshine hours are 12 per days but we will consider the peak sunshine which is 5.84 hours. The rated power is 986.497 KWh/5.84 peak hours per day will give 168.92 KWh of rated power. In case the load has been used for 8 hours per day. The load is 21.115 KW if used for one hour. Note that, numbers here are rounded up.

Table 11: Load determination.

No.	**Load**	**Value**
1	Monthly	29,594.9144 KWH
2	Per day (demand)	986.497 KWH
3	Rated Power (demand during peak-hours)	168.92 KW
4	**Per hour (8 hours working day)**	21.12 kW

Design the battery: The battery for our design is a backup. It's to be designed for 5 days of independence. The battery operates at 48V. The total Ah required = rated power / nominal voltage = 47 kWh / 48V = 979 Ah.

Storage capacity

Depth of discharge DOD = 80%.

Amp hour = 1000 Ah

Temperature multiplier = 1.00

Li-ion Battery capacity = [(total energy demand)/(DOD*Nominal voltage)]*days of autonomy =

= [(21.12 kw) / (0.8*48)] * 3 = 1,650 Ah (Lead-Acid Battery 2,640 Ah)

Number of batteries = Total Ah_{day} / Battery Ah = 1,650 / 1000 = 2 batteries (Lead-Acid Battery 3 batteries)

Number of modules:

$Amp_{peak,module}$ = 9.26 A (By manufacturer)

Amp_{array}= (Total Ah_{day} + 20%) / (day length) = (1,650 + 20%) / (12) = 138 A (Lead-Acid Battery 220 A)

Parallel connection

$Modules_{Parallel}$ = Amp_{array} / $Amp_{peak,module}$ = 138 / 9.26 = 15 modules (Lead-Acid Battery 24 module)

Series connection

$Modules_{Series}$= two modules of 38.9 V (By manufacturer) in series to supply 48 V of the battery.

Total

$Modules_{Paralle}$ * $Modules_{Series}$ = 15 * 2 = 30 modules (Lead-Acid Battery 48 modules)

Charge Controller

The selection of the controller is based on the maximum solar input (Amp) by the system. We choose a 150+ Amp controller with 48V.

Inverter

The inverter selection based on the DC inputs from the battery (48V, 5.9 kW). We can select an inverter with 48V and 125 KW.

4.3 Final Design

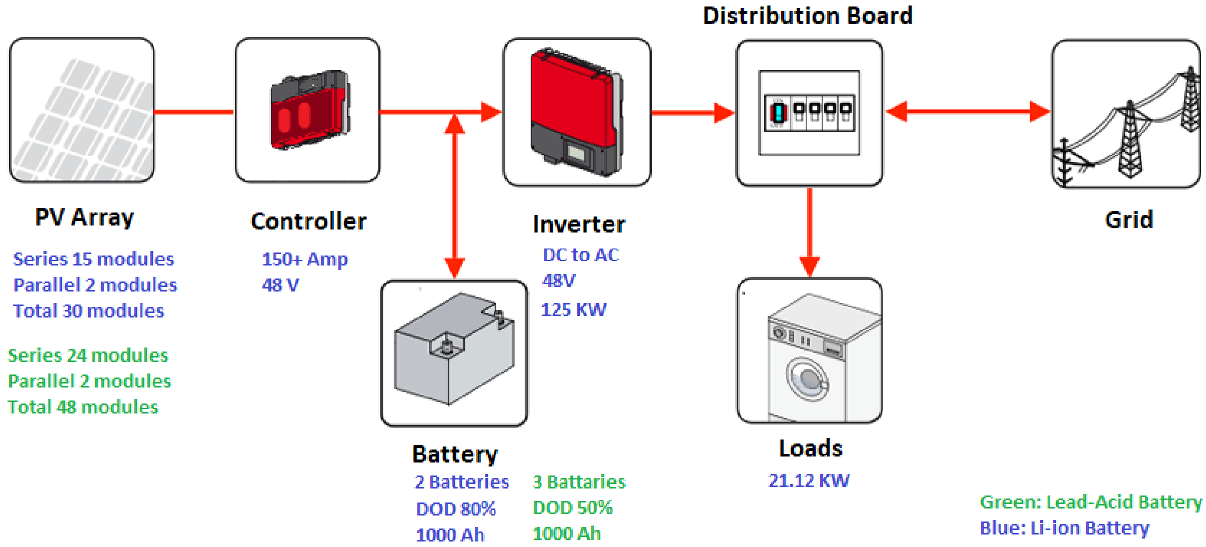

Figure 19: Final system design for Li-ion and Lead-Acid battery. The values here are following the same calculations in section 4.2 with DOD=50%.

4.4 Mechanical parameters

This section is defining some mechanical parameters to be considered in design and installation of the system.

4.4.1 Tilt angle is the angle in which the Solar array can generate the optimum energy. It found from the geographical latitude of the location with +15 degrees in winter and -15 degrees in summer. The maximum energy can be generated when the tilt angle is perpendicular to the solar radiation.

- Tilt angle for Fujairah = geographical latitude = 25.41° N.

4.4.2 Shading can affect the intensity of solar rays reaching the surface of the solar cell, therefore the electricity production.

- Backup design is considered to serve 3 days with shades.

4.4.3 Tracking system can be single axis with one angle of freedom, dual axis with two degrees of freedom or a fixed system with no tracking freedom. Note that the tracking system adds to the cost and energy consumption but also increase the conversion efficiency. For example, it can increase the summer efficiency by up to 30% and winter by 15%.

- The proposed system is a fixed system.

4.5 Validation of the design

Validation of a design can be through simulation or communication with professionals in the field. For practical reasons, we have selected the second option. Because, in simulation many factors are assumed, approximated or theoretical.

To validate this design, we have communicated with Renewable Energy Engineer experienced in solar (mentioned in the acknowledgment). We have discussed the terms and the method. For example, the calculation of power based on sunshine and peak sun-hours. Also, the type of batteries and the cost. In the coming paragraphs, a summary of the discussion is presented.

Sunshine hours vs peak sun-hour

Sunshine hour is anytime we receive sunlight during the day. In UAE, sunshine hours are 12 hours typically between 6:30 to 18:30. Peak sun-hour is when the received sunlight is measured with a specific minimum value. The peak sun-hour is when the light is at the highest value.

Days of autonomy

Based in [5], days of autonomy in UAE are typically 1 day of storage. In our calculations, we have assumed 3 days of autonomy because the specific weather of the area. The area is dusty and mountainous. Which sometimes experience clouds more than other areas in the same city. For this, we chose 3 days of autonomy to avoid the risk.

Type of batteries

The battery we selected at the beginning was Li-ion which was good and highly efficient but expensive as the engineer commented. So, we will change to Lead-Acid battery. The Depth of Discharge will decrease to 50%.

System configuration

Our system is grid-connected but the grid is a back-up incase any failure due to any reason. The design is to support full-load.

Installation cost & Return of investment graph

The cost of the system has been updated based on market estimation from discussion with professionals in notable solar exhibitions in UAE. The following chapter contains detailed financial calculations. We also decided that presenting the return of investment as a graph is better.

Summary:

In this chapter, we designed a grid-connected solar system to cover 29,594.9144 KWH per month. The connection to the grid is a back-up. Mechanical considerations are mentioned as will. Next, we should calculate the financial benefits of the system.

CHAPTER 5: FINANCIAL CALCULATIONS

5.1 Cost estimation

The total cost of PV system is approximated according to current market prices. The following Table 12 list the prices used in our calculations. First, we will calculate the cost of the system to cover the 29,594.9144 KWH. Then, we will calculate the current cost of the same power (29,594.9144 KWH). Then we will compare to find how much time needed to return the investment.

5.1.1 System and installation cost:

Table 12: cost estimation for Lead-Acid battery.			
Unit	Number of units	Unite Price (AED)	Cumulative price (AED)
PV modules	48	800	38,400
Inverter	1	1,500	2,500
Controller	1	2,000	2,000
Battery	3	1,000	3,000
Total System Cost			45,900
Installation Cost (estimated)			7,000

5.1.2 Construction

To determine the construction cost by the developer, we will assume 20% of profit over the system cost. Adding to that the installation cost. Then we can estimate the construction cost.

$$Cost_{Construction} = (Cost_{Mounting, combining, wiring} + Cost_{system} + Cost_{installation}) * (120\%)$$

$$Cost_{Construction} = (10{,}000 + 45{,}900 + 7{,}000) * (1.2) = 75{,}480\ AED$$

5.1.3 Cumulative Cost and Return of Investment

The current cost of electricity consumption by the company for the covered load is 13,672.89 AED per year (See table 13). The cost of the solar system is *75,480 AED* . That mean the system will return investment in 0.46 years (about 6 months) based on the system reduction on the bill. Adding to that, the company should consider cleaning cost and maintenance cost. The PV module lifetime is 25 years and the batteries are about 3 years.

Table 13: Calculation of the current cost based on FEWA Electricity bill.			
No.	Item	calculation	Cost
1	Electricity consumption	29,594.9144 KWH *0.4 AED	11,838 AED
2	Service cost	11,838 KwH/ 10	13,021.8 AED
3	VAT @5%	(13,021.8 AED) *105%	13,672.89 AED
4	Total		13,672.89 AED

Figure 20, shows the Net Present Value of the system. Since our calculations shows that the system will return investment in less than a year, we did not account for the annual discount rate.

Figure 20: Return of investment.

Summary:

To design a system to cover (29,594.9144 KWH) equivalent to 13,672.89 AED, we need to invest 75,480.00 AED which will return investment in half a year. Adding to that, maintenance cost should be specified. And the cost of replacing PV will occur every 25-30 years. And the cost of replacing batteries will occur every 3-4 years.

CHAPTER 6: CONCLUSIONS AND FUTURE WORK

6.1 Conclusion and Results

This work demonstrated the details of converting RMC company energy consumption to solar PV. The project started by short introduction to the concrete industry. Then, it provided details of the company under study. The description of the company in the introduction highlighted the nature of the location. With the pain of electricity cost to the company in mind, we prepared questions to solve.

In chapter 2, we started the data collection process based on questions in the previous chapter. After that, we went through analysis of the case from different perspectives. Starting by analyzing electricity consumption. Analyzing the walkthrough information, we have tracked the customer order process from beginning to the end. We also analyzed data from documents provided by the company. This chapter ended with validation of the data through discussion with the company's experts. After that we updated the findings.

After this step, we looked into the options available in chapter 3. This short chapter is based on different discussion with professionals we met in different energy and solar exhibition in UAE as well as discussion with different faculty members of Rochester Institute technology, Dubai. Then we selected some options to work on them.

In chapter 4, we started the design of the technical system. The chapter contains the technical specifications and assumptions taken in the design stage. The specifications -based on the electricity demand- has been analyzed then executed into a final design. Next, we validated the design through communication and discussion with a professional renewable energy engineer.

Chapter 5, contained the financial calculations of adopting the system. First, we estimated the cost of the system and the service of installation based on current market values. Then, we ended with a value of the return of the investment which shows how much the company can save by selecting the solar option.

Based on this work, the result is the RMC company has an average electricity consumption of 85,716.5733 KWH per month. Based on our analysis, an amount of 29,594.9144 KWH is consumed by activities that are not critical to production. This amount is equivalent to 13,672.89 AED. The proposed design requires investment of 75,480.00 AED which will return investment in approximately half a year.

6.2 Environmental Impact

The design should allow the company to save in the monthly electricity bill as well as reducing the carbon footprint. During our first meetings with the company, the management showed interest in reducing the carbon footprint, hence, our project helps the company to achieve this vision.

FEWA CO_2 measures the carbon emission on Kg CO_2e and categorized it into 3 levels. Level 1, up to 700 Kg CO_2e. Level 2 up to 1,300 Kg CO_2e and level 3 is above 1,300 Kg CO_2e. The Kg CO_2e factor based on KW consumed is found equal to 0.58 Kg CO_2e/KWH. This calculation based on consumption of 321,000 KWH which emitted 188,459.10 Kg CO_2e on January 2019.

Based on that, by covering 29,594.9144 KWH through the solar system we reduce 17,165.05 Kg CO_2e. If the system started in January (compared to January 2019) it can reduce about 9% of the carbon footprint in the month. And about 205,980.6 Kg CO_2e in a year. In other words, the designed solar system will reduce more than 1 month of the carbon footprint.

6.3 Recommendations

The solar industry is growing fast and also the prices of energy per unit cost is reducing. Adding to that, many advanced solar technologies are hitting the market. We recommend a good search before selecting the best solar technology and the provider.

We recommend the solar system regular maintenance and monitoring to be done by the company engineers. As most of the systems are customers friendly. By this, we reduce the cost of maintenance. We also recommend looking for better batteries and not systemically replace with the same type. Development is always expected when replacing of batteries (about every 3 years). Keeping in mind that Li-ion is better (DoD 80%) but expensive and Lead-Acid is cheaper but has lower DoD (50%).

For quality enhancement, we recommend the company to perform regular energy quality assessment using Lean-Six-Sigma framework. There are many successful cases of companies and organization who performed this framework for continues improvement.

Last, the company's willingness to benefit from academia can contribute to its knowledge and development. We recommend the continuity of benefiting from academia by establishing a related program in the company.

6.4 Next step

- Submit the proposal to the company.
- After discussion, the company could decide on the implementation plan of the project.
- The implementation plan should consider points 2,3 and 4 in section 3.1 before implementing the technical design to maximize the benefits towards reducing electricity consumption.

6.5 key learnings

1. Management solutions should come before technical solution.

The human factor is key to the success or failure of any company project. Because they are the users who input to the system. The technical is to take an input then process it. So, its logical to start from the human input.

In our project, my approach was technical, then after discussion with the supervisor and through working and searching I have seen how the management can affect the change. For example, keeping air-conditioner working when it's not needed which is waste. Adding to that, the waste usage during peak-hours where the electricity rate is higher. The internal system cannot change the human-related share of waste. We either add controls to limit the human-factor or change the human behavior. Here comes the management side.

2. Technical solutions are interfered with many practical considerations.

In the case of renewable energy, the first calculations could lead to false excitement but when we take many other factors, the equation may change. An example is the saved amount of the electricity bill before considering the installation and construction cost, the maintenance, cleaning, risk and other. The project was a good training to learn how to calculate these costs.

3. There are many ways to get different information from the same data, hence, different decisions.

Since this project has been started, many data were collected. We have tested the data using tools normally used in energy management decisions. Tools like graphical and statistical representation of data. Through this project, I also learnt an easy way to get to the required results compared to how hard it was at the beginning of the project.

To sum up, this 1-year project prepared me with the tools and mindset to specify the needed data and information to solve such challenges. At the beginning of the project, the focus was challenging although the purpose looked clear. I'm glad that this project was this long.

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Sentences can't be enough to present my deep gratitude towards whoever made this work successful. I wish them all the best.

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Appendix 1

Cooling Degree Days of Fujairah

Description:	**Celsius-based cooling degree days with a base temperature of 15.5 C**	
Source:	**www.degreedays.net**	
Accuracy:	**Estimates were made to account for missing data: the "% Estimated" column shows how much each figure was affected (0% is best, 100% is worst)**	
Station:	**Fujairah, AE (56.32E,25.11N)**	
Station ID:	**OMFJ**	
Month starting	**CDD**	**% Estimated**
10/1/2016	482	0.06
11/1/2016	330	0.07
12/1/2016	259	0
1/1/2017	210	0.1
2/1/2017	155	0
3/1/2017	297	0
4/1/2017	455	0.03
5/1/2017	569	0.03
6/1/2017	589	0.03
7/1/2017	600	0
8/1/2017	566	0
9/1/2017	527	0.1
10/1/2017	484	0.03
11/1/2017	334	0.03
12/1/2017	199	0
1/1/2018	178	0.2
2/1/2018	202	0
3/1/2018	321	0.06
4/1/2018	473	0.1
5/1/2018	576	0.06
6/1/2018	609	0.1
7/1/2018	597	0.03
8/1/2018	546	0
9/1/2018	483	0.07
10/1/2018	466	0
11/1/2018	326	0
12/1/2018	246	0
1/1/2019	222	0
2/1/2019	182	0.07

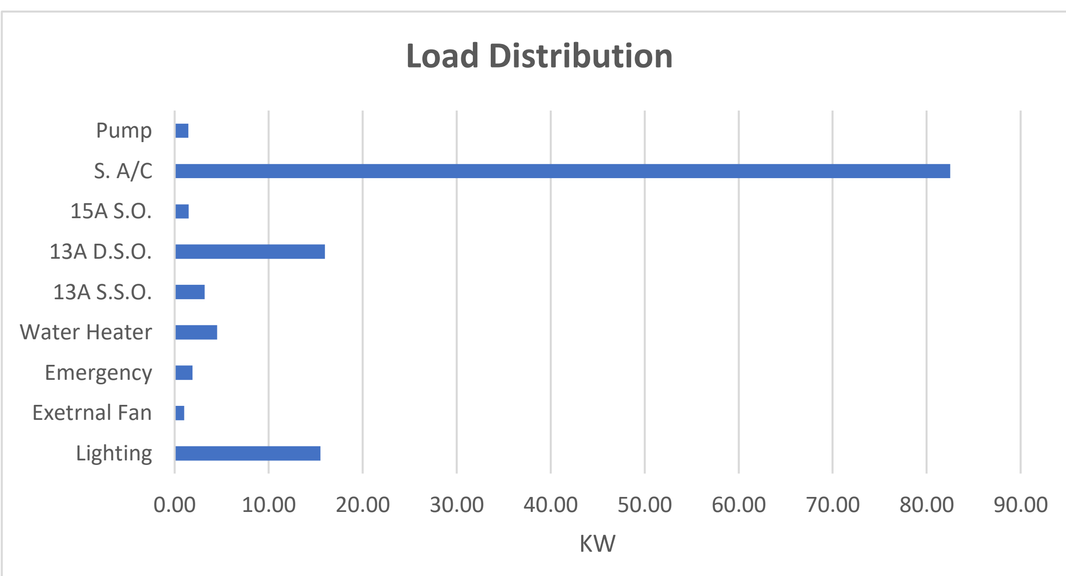
3/1/2019	228	0.1
4/1/2019	398	0
5/1/2019	552	0
6/1/2019	610	0.2
7/1/2019	566	0.1
8/1/2019	550	0.03
9/1/2019	519	0

Appendix 2

Schedule of Load Distribution

Data from Load Distribution					
Item	**Number**	**Watts**	**Total Watts**	**Meter**	**Total (KW)**
Ligting	61.00	100.00	6,100.00	LP-2	19.20
External Fan	3.00	100.00	300.00	LP-2	
External Fan	2.00	100.00	200.00	LP-2	
Emergency	10.00	100.00	1,000.00	LP-2	
13A S.S.O.	7.00	200.00	1,400.00	LP-2	
13A D.S.O.	18.00	400.00	7,200.00	LP-2	
Water Heater	2.00	1,500.00	3,000.00	LP-2	
S. A/C	22.00	3,750.00	82,500.00	AC	83.96
Pump	1.00	1,460.00	1,460.00	AC	
Lighting	79.00	100.00	7,900.00	LP-1	24.40
Lighting	6.00	250.00	1,500.00	LP-1	
Emergency	9.00	100.00	900.00	LP-1	
External Fan	5.00	100.00	500.00	LP-1	
13A S.S.O.	9.00	200.00	1,800.00	LP-1	
13A D.S.O.	22.00	400.00	8,800.00	LP-1	
15A S.O.	1.00	1,500.00	1,500.00	LP-1	
Water Heater	1.00	1,500.00	1,500.00	LP-1	
Total Watts			**127,560.00**		

KW per Item	
Item	**Total KW**
Lighting	15.50
Exetrnal Fan	1.00
Emergency	1.90
Water Heater	4.50
13A S.S.O.	3.20
13A D.S.O.	16.00
15A S.O.	1.50
S. A/C	82.50
Pump	1.46
Total KW	**127.56**



Appendix 3

Detailed calculations of HVAC and Lighting Electricity consumption

Item	Units	Per Items	Category	Location	Working Hours/yr	Watt	Total Kwh/yr
Air Conditioner	1	1	HVAC	Production Manager Office - Reception	1,408.50	3,750.00	5,281.88
Air Conditioner	3	1	HVAC	Offices Reception	1,408.50	3,750.00	15,845.63
Air Conditioner	3	1	HVAC	Sales Department	1,408.50	3,750.00	15,845.63
Air Conditioner	1	1	HVAC	Production Manager Office - Office	1,408.50	3,750.00	5,281.88
Air conditioner	3	1	HVAC	Accounts Office	2,817.00	3,750.00	31,691.25
Air Conditioner	1	1	HVAC	Operation Room	4,965.00	3,750.00	18,618.75
Fridge	2	1	HVAC	Lunch Room	2,817.00	1,500.00	8,451.00
Water fridge	1	1	HVAC	Lunch Room	2,817.00	800.00	2,253.60
Air conditioner	2	1	HVAC	Safety Office	7,512.00	3,750.00	56,340.00
Air conditioner	1	1	HVAC	Security Office	2,817.00	3,750.00	10,563.75
Fan	1	1	HVAC	Security Office	2,817.00	60.00	169.02
Air conditioner	5	1	HVAC	Quality Control Lab	2,817.00	3,750.00	52,818.75
Fridge	2	1	HVAC	Quality Control Lab	2,817.00	1,500.00	8,451.00
Washroom Fan	1	1	HVAC	Quality Control Lab	2,817.00	60.00	169.02
Air Conditioner	1	1	HVAC	Chemical Plant	2,817.00	3,750.00	10,563.75
Air Conditioner	1	1	HVAC	Chemical Plant - Operator Room	2,817.00	3,750.00	10,563.75
Air Conditioner	1	1	HVAC	Chemical Plant - Office	2,817.00	3,750.00	10,563.75
Water Fridge	1	1	HVAC	Chemical Plant - Office	2,817.00	800.00	2,253.60
Small Fridge	1	1	HVAC	Chemical Plant - Office	2,817.00	1,500.00	4,225.50
Air conditioner	2	1	HVAC	Maintenance Office	5,007.00	3,750.00	37,552.50
Fridge	1	1	HVAC	Maintenance Office	5,007.00	1,500.00	7,510.50

Fan	1	1	HVAC	Maintenance Office	5,007.00	60.00	300.42
Air Conditioner	3	1	HVAC	Batching Plant – Control Room	6,260.00	3,750.00	70,425.00
Water Fridge	1	1	HVAC	Batching Plant – Control Room	6,260.00	800.00	5,008.00
Air Conditioner I	2	1	HVAC	Mosque and Drivers Room + other	2,504.00	3,750.00	18,780.00
Air Conditioner II	2	1	HVAC	Mosque and Drivers Room + other	2,504.00	3,750.00	18,780.00
Fan	3	1	HVAC	Mosque and Drivers Room + other	2,504.00	60.00	450.72
Air conditioner	1	1	HVAC	Plant C	0.00	3,750.00	0.00
Air conditioner	7	1	HVAC	Maintenance Workshop	4,695.00	3,750.00	123,243.75
Fridge	1	1	HVAC	Maintenance Workshop	4,695.00	1,500.00	7,042.50
Water Fridge	3	1	HVAC	Maintenance Workshop	4,695.00	1,500.00	21,127.50
Big fan (light connected)	2	1	HVAC	Maintenance Workshop	4,695.00	200.00	1,878.00
Fan	1	1	HVAC	Welding Section	4,695.00	60.00	281.70
Fridge Water	1	1	HVAC	Tyr Section	4,695.00	1,500.00	7,042.50
Air conditioner	1	1	HVAC	Painting Section	4,695.00	3,750.00	17,606.25
Small lights	14	1	Lighting	Production Manager Office - Reception	2,817.00	40.00	1,577.52
Big lights	4	1	Lighting	Production Manager Office - Reception	2,817.00	200.00	2,253.60
Small lights	4	1	Lighting	Offices Reception	2,817.00	40.00	450.72
Big lights	12	14	Lighting	Offices Reception	2,817.00	200.00	6,760.80
Small lights	60	1	Lighting	Sales Department	2,817.00	40.00	6,760.80
Small lights	18	1	Lighting	Production Manager Office - Office	2,817.00	40.00	2,028.24
Big lights	12	1	Lighting	Production Manager Office - Office	2,817.00	200.00	6,760.80
Lights	12	4	Lighting	Accounts Office	2,817.00	40.00	1,352.16
LED lights	6	4	Lighting	Operation Room	4,965.00	40.00	1,191.60
Lighting LED tube	4	16	Lighting	Safety Office	7,512.00	40.00	1,201.92
Light long tube	2	1	Lighting	Security Office	2,817.00	40.00	225.36
Lighting small tube	9	16	Lighting	Quality Control Lab	2,817.00	40.00	1,014.12
Light	1	1	Lighting	Quality Control Lab	2,817.00	40.00	112.68
Big Light	9	1	Lighting	Chemical Plant	2,817.00	200.00	5,070.60

Light - Other	1	1	Lighting	Chemical Plant	2,817.00	40.00	112.68
Light Tube	4	4	Lighting	Chemical Plant	2,817.00	40.00	450.72
Light	4	6	Lighting	Chemical Plant - Office	2,817.00	40.00	450.72
Lighting	4	6	Lighting	Maintenance Office	5,007.00	40.00	801.12
Lighting	6	4	Lighting	Batching Plant – Control Room	6,260.00	40.00	1,502.40
Light	8	1	Lighting	Mosque and Drivers Room + other	2,504.00	40.00	801.28
Light	8	4	Lighting	Mosque and Drivers Room + other	2,504.00	40.00	801.28
Light	2	1	Lighting	Mosque and Drivers Room + other	2,504.00	40.00	200.32
Light long tube	1	1	Lighting	Plant C	0.00	40.00	0.00
Big Light - outdoor	2	1	Lighting	Plant C	0.00	200.00	0.00
Light	29	24	Lighting	Maintenance Workshop	4,695.00	40.00	5,446.20
Big LED light	13	1	Lighting	Maintenance Workshop	4,695.00	200.00	12,207.00
Long tube light	16	1	Lighting	Maintenance Workshop	4,695.00	40.00	3,004.80
Big light	2	1	Lighting	Welding Section	4,695.00	200.00	1,878.00
Long tube lights	5	1	Lighting	Tyr Section	4,695.00	40.00	939.00
Big lights	2	1	Lighting	Tyr Section	4,695.00	200.00	1,878.00
Big light	2	1	Lighting	Painting Section	4,695.00	200.00	1,878.00
Long tube light	2	1	Lighting	Painting Section	4,695.00	40.00	375.60
						1,960.00	**676,468.87**

Appendix 4

Abbreviations

Abbreviations	
RMC	Ready-Mix Concrete
QC	Quality Control
WETEX	Water, Energy, Technology and Environment Exhibition
GITEX	Gulf Information Technology Exhibition
WGES	The World Green Economy Summit
FEWA	Federal Electricity & Water Authority
DoD	Depth of discharge