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INSTITUTE OF GRADUATE STUDIES

SİMULATİON OF A HYBRİD RENEWABLE ENERGY SYSTEM İN BEIRUT, LEBANON

MASTER'S THESIS

Ahmad Mahmoud Omais

Department of Mechanical Engineering
Mechanical Engineering Faculty Program

SEPTEMBER, 2022

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ONAY FORMU

Evrak Tarih ve Sayısı: 25.08.2022-14070

T.C.
İSTANBUL AYDIN ÜNİVERSİTESİ
LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ MÜDÜRLÜĞÜ

11/08/2022

YÜKSEK LİSANS TEZ SINAV TUTANAĞI

Makine Mühendisliği Anabilim Dalı, Makine Mühendisliği İngilizce Tezli Yüksek Lisans Programı Y2013.081011 numaralı öğrencisi **Ahmad OMAİS**'in *İstanbul Aydın Üniversitesi Lisansüstü Eğitim-Öğretim ve Sınav Yönetmeliği'nin 9. (1) maddesine* göre hazırlayarak Enstitümüze teslim ettiği **"Simulation of a Hybrid Renewable Energy Systems in Beirut Port, Lebanon"** adlı tezi, Yönetim Kurulumuzun 04.08.2022 tarihli ve 2022/16 sayılı toplantısında seçilen ve **11.08.2022 tarihli ZOOM toplantı odasında** biz jüri üyeleri huzurunda, ilgili yönetmelik gereğince 75 dakika süre ile aday tarafından savunulmuş ve sonuçta adayın tezi hakkında **oybirliği ile kabul** kararı verilmiştir.

Danışman
Prof. Dr. Zafer ASLAN

İşbu tutanak, tez danışmanı tarafından jüri üyelerinin tez değerlendirme sonuçları dikkate alınarak jüri üyeleri adına onaylanmıştır.

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Tezde kullanılan yöntem (birkaçını birden işaretleyebilirsiniz)

■ Kuramsal ☐ Sayısal ■ Deneysel ☐ Diğer:..............................

Tez içeriği, Proje konusu ile uyuşuyor mu ? ■ Evet ☐ Hayır

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1.Tezde kullanılan yöntem uygun mu?	☐	■	☐	☐	☐
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Tez hakkında verdiğiniz kararın gerekçelerini yazınız. (Gerekirse ek sayfa kullanınız.)

Öğrencinin konusu jüri üyeleri tarafından aşağıdaki gibi değiştirilmiştir:
"Simulation of a Hybrid Renewable Energy Systems in Beirut Port, Lebanon"

Tez kabulü konusundaki görüşünüz

■ Değişikliğe gerek yoktur ☐ Şekil yönünden bazı değişiklikleri yapılması gerekir
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DECLARATION

I hereby declare with the respect that the study "Simulation of a Hybrid Renewable Energy System in Beirut, Lebanon"which I submitted as a Master thesis, is written without any assistance in violation of scientific ethics and traditions in all the processes from the project phase to the conclusion of the thesis and that the works I have benefited are from those shown in the References. (26/06/2022)

Ahmad Omais

FOREWORD

Under efforts taken in this project, it would be an honor to state that it is not have been possible without the kind support and help of many individuals and organizations to complete this project. I would like to extend my sincere thanks to all of them.

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My thanks and appreciations also go to my colleague in developing the project who have willingly helped me out with their abilities.

Septermber, 2022 Ahmad OMAIS

SİMULATİON OF A HYBRİD RENEWABLE ENERGY SYSTEM İN BEİRUT, LEBANON

ABSTRACT

Recently, there has been an increase in demand for energy, which has affected the demand in the different sectors. Most of the developing and developed economies rely on fossil fuels, which has impacted the productivity of the organization. The purpose of conducting this study is on determining the efficacy of the development of an energy production system producing energy from different sources such as solar, wind, and waves in Beirut port, Lebanon. This can be essential in improving the efficacy of the operations and increasing the supply of energy in Beirut port. It provides the key measures that should be followed in improving the efficiency of energy use, which may be integral in realizing the credibility of the ports' operations. As the focus is on solar, wind, and wave energy, it leads to provide the Beirut port management with the opportunity of using different energy sources in addressing the increasing demand for energy.

Keywords: Beirut Port, Energy, Electricity, Wind, Solar, Wave, Renewable, Excess watts.

BEYRUT, LÜBNAN İÇİN HİBRİT YENİLENEBİLİR ENERJİ SİSTEMİ SİMÜLASYONU

ÖZET

Son zamanlarda, farklı sektörlerdeki talebi etkileyen enerji talebinde bir artış yaşanmıştır. Gelişmekte olan ve gelişmiş ekonomilerin çoğu, kuruluşun üretkenliğini etkileyen fosil yakıtlara güveniyor. Bu çalışmanın yapılmasındaki amaç, Lübnan'ın Beyrut limanında güneş, rüzgar ve dalga gibi farklı kaynaklardan enerji üreten bir enerji üretim sisteminin geliştirilmesinin etkinliğinin belirlenmesidir. Bu, operasyonların etkinliğinin iyileştirilmesi ve Beyrut limanındaki enerji arzının arttırılması için gerekli olabilir. Liman operasyonlarının güvenilirliğini gerçekleştirmenin ayrılmaz bir parçası olabilecek enerji kullanımının verimliliğini artırmak için izlenmesi gereken temel önlemleri sağlar. Odak noktasının güneş, rüzgar ve dalga enerjisi olması, Beyrut liman yönetimine artan enerji talebini karşılamada farklı enerji kaynaklarını kullanma fırsatı sunmasına yol açmaktadır.

Anahtar Kelimeler: Beyrut Limanı, Enerji, Elektrik, Rüzgar, Güneş, Dalga, Yenilenebilir, Fazla Watt.

TABLE OF CONTENTS

ABBREVIATIONS

DEG	**:** Dielectric elastomer generator.
DSP	**:** Distribution Service Provider.
EDL	**:** Electricity's du Liban
EPBD	**:** Energy Performance Building Directive.
LCOE	**:** Levelised cost of electricity
NZEB	**:** Nearly zero energy building.
NZEB	**:** Near zero-energy building.
SDGS	**:** Sustainable development goals.
UNDP	**:** United Nations Development Programme.
PV	**:** Photovoltaic.

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I. INTRODUCTION

According to the United Nations Development Programme (UNDP), the developing and developed economies require energy in meeting the sustainable development goals (SDGs) such as poverty reduction and employment opportunities within the economy. The assertion of the UNDP is crucial and it comes at the tome where the efforts of different countries is on meeting the SDGs goals and ensuring that there is sustainability of the operations. Most of the economies have emphasized on the significance of access to energy as a way of improving the livelihood of the individuals. The concern has been on implementing policies encouraging access to water, education, and agricultural productivity, which are the critical factors in reducing poverty index within the population. However, it is important to assess the benefits of energy based on the environmental pollution that can be caused with such initiatives. Over time, concern has been on using fossil fuels as a source of energy, and this notion needs to be changed and be accommodative to the changing consumer needs in the industry. Climate change has left humanity to confront the decline in forests, change in weather patterns, and rise in sea levels. As such, most of the countries have prioritized on the significance of renewable energy as the basis for addressing the energy demand.

A. Background

The modern society is largely dependent on energy, which they are used in different forms such as cooling, heating, and lighting. In most of the countries, the energy is generated from the traditional sources such as hydropower, nuclear energy, and even fossil fuels. From the report by BP Statistical Review of World Energy (2021), Covid-19 pandemic had a negative effect on the energy markets as the primary consumption of energy decreased by 4.5% in 2020, which was one of the largest reductions since 1945. BP Statistical Review of World Energy indicated that oil consumption declined due to the restriction in movement associated with Covid-19 pandemic. Although there was a reduction in the consumption of oil energy, renewable energy increased by 9.7% as the population focused on using solar and wind energy as way of powering their activities.

From the published Electricity Information 2019, it indicates that 2019 saw an increase in world gross electricity production by 1.3% compared to 2018. The electricity generated using combustible fuels was higher during this period accounting for 57.1% (International Energy Agency, 2021). It shows that the global economy is highly dependent on the combustible fuels, and this can be challenging in the future considering that the modern society is aligned to providing renewable energy. According to Julian, Bassil & Dellagi (2020), most of the electricity supplied is provided in more centralized plant locations, which are often located far from the end users of such electricity power. As such, there is a loss of about 10% of the electricity before reaching the consumers. This loss, capped with the demand for energy and diversification of energy production sources, it raises questions on significance of development of an energy production system producing energy from different sources such as solar, winds, and waves.

B. Motivation

In Lebanon, the weather and climatic conditions change throughout the year, and this is one of the main motivations for the development of energy production system at the Beirut port encompassing of solar, winds and waves. As indicated in figure 1, solar energy can be used during the months of May through to October as the weather is warm in some months and hot in August – mainly during the summer. However, solar energy cannot be used as a source of energy between January and April where there is precipitation.

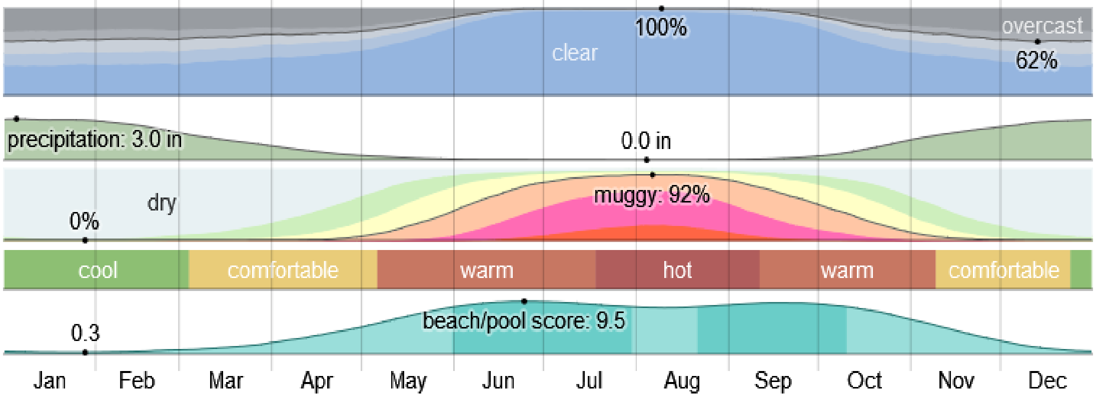


Figure 1: Climate in Beirut, Lebanon

Source: Weather Spark (2021)

As indicated in figure 2 below, the average wind vector in Beirut influences the decision of developing a wind source of energy. The wind experienced in different localities within Beirut is characterized by mild seasonal variations, and depending on the latitude of the region, wind speeds vary. Figure 2 provides average information on the speed of the wind indicating that it averages over 8.0 miles per hour in the months where it is windier – often between December 11 and April 16. February is Beirut's windiest month with hourly wind speed reaching an average of 9.3 miles per hour. From this, it is indicative that using wind energy source can be reliable in February, which can assure the Beirut population on the consistent energy production.

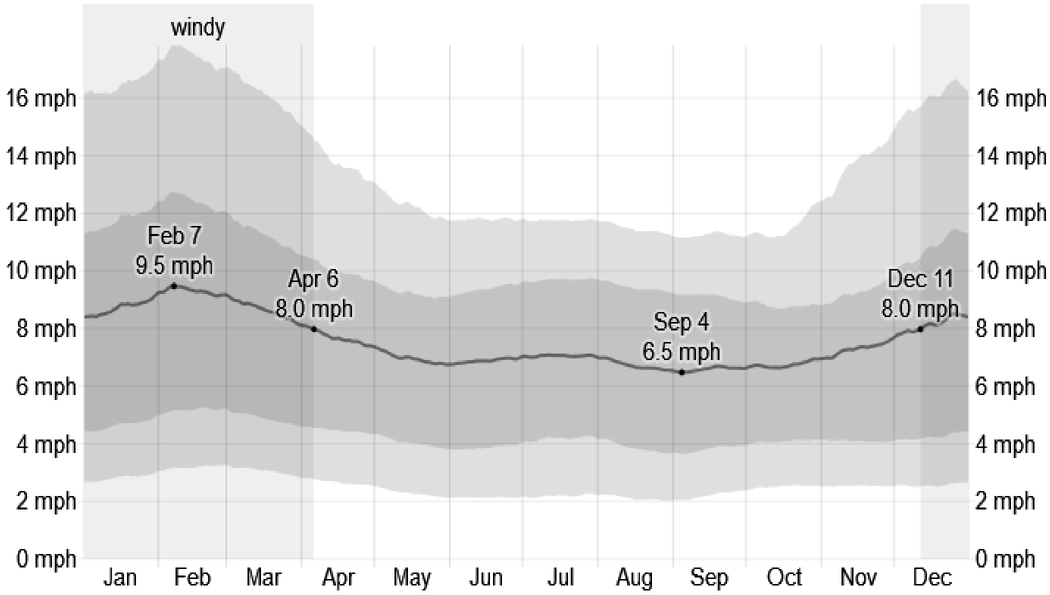


Figure 2: Wind Speed in Beirut, Lebanon

Source: Weather Spark (2021)

Waves are critical in the generation of energy, which can be used in lighting and operations in Beirut port. As provided in previous study by Aoun, Harajli & Queffeulou (2013), there is data variability on the reliability of wave in producing electricity. It indicated that the three buoys in Lebanon failed to provide consistent data – which are South, North, and Center buoys in Lebanon. Only Beirut buoy showed consistent data (Aoun, Harajli & Queffeulou, 2013). As such, with this information, it provides a guideline in the development of the energy production system from waves, which can supplement the energy generated from the other sources during the year.

C. Aim and Objectives

This thesis is dedicated to determining the efficacy of the development of an energy production system producing energy from different sources such as solar, winds, and waves in Beirut port, Lebanon. Specific objectives include:

- To explore the efficacy of developing solar energy in Beirut Port, Lebanon.
- To assess the improvements needed to the energy production system especially on the wind energy.
- To determine the feasibility of the Beirut buoy in providing wave energy to the Beirut Port.

D. Overview of methodology

The focus of this study is on achieving a better understanding of the different energy sources and the feasibility of developing such power stations in Beirut port. A qualitative review of the information provided and performance analysis of the different energy sources is provided. This shall largely depend on the information provided by the Lebanon's meteorological department and the weather information in conducting analysis on the significance of developing such energy sources.

E. Structure of Thesis

The thesis is structured by dividing into five different sections. The first part of the thesis provides the introduction, which presents the background of the current study, the motivation for conducting this study, and objectives. Secondly, the literature review is conducted in which the gap of the study is provided. This provides the basis for undertaking the current study. The third chapter discusses the research methodology, including the steps followed in conducting this study. The fourth chapter provides the findings of the study. The fifth chapter is on the discussion and conclusion of the thesis work.

II. LITERATURE REVIEW

F. Overview of Lebanon energy production

Like most of the developing economies, Lebanon is experiencing energy problems as the production capacity is less than its consumption levels. As such, this has led to air pollution and environmental degradation with the economy utilizing some of the energy sources that not environmentally friendly. The Electricit´e du Liban (EDL) has been involved in the development of the electricity production measures that can meet the consumption needs of the population. The Lebanese government is currently facing over consumption of the electricity that has been caused by increased shortage of the supply of electricity, especially with the growth in population. According to Shihadeh et al. (2018), Lebanon's power generation problem has been linked to four key challenges related to generation of power, distribution and transmission of such electricity.

First issue is on the generation capacity provided by EDL. There has been an increase in demand for the electricity over the past decade with the living population increasing to approximately 6,825,000 persons in 2020 compared to 4,953,000 in 2010. Such an increase in population has meant that the power consumption level also increased giving strain to the EDL generation capacity. There has been a construction of different EDL infrastructure following the war (between 1975 and 1990) with the aim being on improving production capabilities (Blazejczak, Braun & Edler, 2014). Reconstruction of the power sector was considered to be an efficient way of sustaining the power demand and consumption in Lebanon. Although there has been an increase in the household consumption, the increase in the economic activities has meant that the demand for the power and electricity in Lebanon has significantly increased. There has been insufficient installation and this has aggravated reduction in the quantity of electricity supplied. EDL has implemented solutions to rehabilitate different power plants in improving the production capacity for the Lebanese population. Also, privatization of the energy has meant that there has been an increase in the supply of the electricity, which has improved the consumption level in the industry.

Also, Lebanon has been suffering technical losses linked to the distribution and transmission grids. This largely impacted the quantity of the electricity supplied to the individuals. There has also been an issue with illegal connections, which prevents EDL from accurately estimating the quantity consumed and supplied to the individuals (Shihadeh et al., 2018). There has been an agreement in the electricity sector to be reformed, which has meant that there has been implementation of policies in the economy towards increasing the efficiency of the operations. There are numerous reform plans that have not been fully implemented, which has been a major issue in improving the quantity of electricity distributed to the consumers. Energy sector requires immediate support from the other key stakeholders in addressing the issue (Shihadeh et al., 2018). With the Distribution Service Provider (DSP) framework, its improvement can have an impact on the loss reduction especially where there is power grid distribution, and installing smart meters in improving the quantity of electricity produced in Lebanon.

G. Reduction in Energy consumption

In 2010, there was the introduction of the ‘near zero-energy building’ (NZEB), a concept that was developed by Energy Performance Building Directive (EPBD). The intention has always been on reducing the carbon emission and the household consumption of energy, which has meant that it has focused on shifting its design paradigms to developing energy efficient buildings. The concept behind NZEB is on achieving maximum efficiency in the consumption of energy, which is an essential aspect in realizing 2030 challenge of conservation of the energy and providing support to the individuals in providing clean and renewable energy. With the constant development in the economy, the interest of the different countries is on sustainable energy use and increasing the use of the energy towards maximizing the effectiveness in the energy consumption and conservation. The home appliances developed are environmental friendly making the energy consumption level across Lebanon. As such, conservation of energy while considering the economic needs of the population is critical for the country. Having this place can improve the economic growth and sustainability of the region.

Blazejczak, Braun & Edler (2014) study proposed strategies that can influence the sustainable construction of buildings as a way of conserving the energy. First, there should be significant reduction in energy demanded in the economy through the implementation of energy conservation measures and avoiding waste. Also, using sustainable energy sources is effective for the improvement of the environmental needs rather than focusing on fossil fuels. Concern has been placed on the implementation of the effective measures that reduces the use of fossil fuel as this is an avenue for improving the energy conservation. Salem et al (2019) was concerned on the implementation of these buildings highlighting on the risk of overheating. There is a likelihood that the buildings can experience overheating, which can affect the consumption level of such energy. As such, it raised concerns on the significance of using a wide range of energy sources rather than focusing extensively on energy performances building. Developing economies are concerned with increasing productivity, which means that there is extensive use of energy in the production process.

H. Solar energy

Solar energy is considered to be an effective and favorable method of renewable energy sources in regions where the climatic conditions are favorable. Interestingly, there are several techniques that are used in increasing efficiency of the solar panels, with some being considered as cooling techniques such as the active cooling and passive cooling. They rely on the natural convention or conduction enabling it to extract heat from the sun. In further exploring on the cooling effect, Wei, Nan & Guiping (2017) assessed the efficiency of the solar energy in the demand for the energy required in the country. Wei, Nan & Guiping (2017) study assessed the irradiance of the solar energy in ascertaining its efficiency in the industry. With the fact that the solar panels tend to harness limited quantity of solar energy from irradiation, it indicates that small amount of the solar energy can be produced from large quantity of sun irradiation. Wei, Nan & Guiping (2017) provides this equation in calculating solar panel's efficiency:

$$\eta = \frac{Pout}{Pin} = \frac{Vm.Im}{I.S} \quad \text{Equation (1)}$$

- Vm = maximum voltage (V),
- η = efficiency,
- I = intensity of radiation (W/m^2),
- Im = maximum current (A),
- S = solar panel area (m^2)

The efficiency in the solar panel is effective when implementing measures that are integral in realizing success in the dynamic industry. From the experiment conducted in Wei, Nan & Guiping (2017), it is evident that determining the efficiency and irradiation of the solar panel is essential when formulating measures to improve the quantity of the energy required in the economy. The findings of Wei, Nan & Guiping (2017) are provided in the figure below:

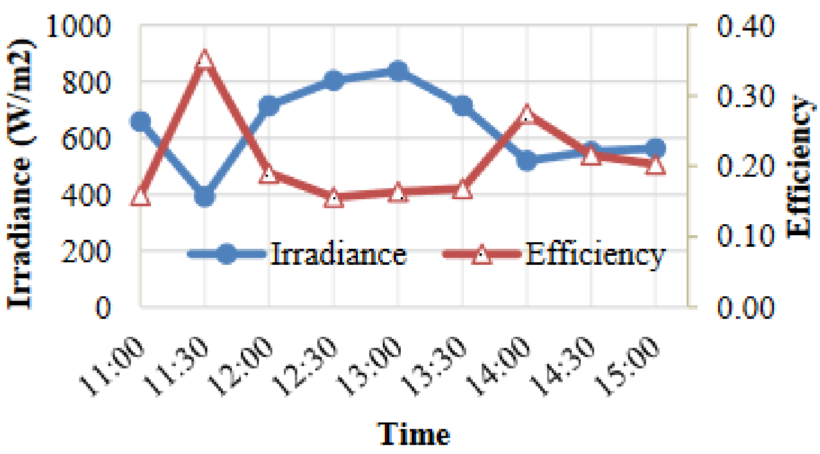


Figure 3: Irradiance vs Efficiency

Source: Wei, Nan & Guiping (2017)

I. Wind energy

According to Pryor, Barthelmie & Shepherd (2020) study, the use of wind energy has significantly increased over the past years due to the focus on renewable energy. New measures are put in place in ensuring that different countries conform to the environmental regulations and the 2030 climate challenge. Numerous countries have developed wind turbines in an attempt to increase the energy production and distribute them across the different sectors. As indicated in Dolatabadi, Mohammadi-Ivatloo, Abapour et al. (2017), the stochastic nature of the speed of wind means that there is fluctuation in the energy generation with some of the regions reportedly having issues with wind energy generation. The use of the wind turbine can only be effective in specific regions where there is sustainable and suitable wind. However, despite all these challenges, different government institutions have strategized on implementing wind turbines in maximizing energy production and meeting the increased consumption levels. Sahu (2018) study proposes the need for the development of policies guiding the implementation of wind energy as was evident in China.

According to Kumar & Gaddada (2015), using the Weibull distribution can be an effective method of estimating the power production and efficiency of the wind turbines. There is a need to determine wind velocity and ascertain the appropriate mechanism to be initiated in providing quality and reliable results on wind information. In most cases, it can be difficult to measures a standardized value of the wind velocity due to the changes in the wind speed and direction. As noted in Khare, Nema & Baredar (2016), having a maximum and minimum wind velocity for any given period can be critical when estimating the energy to be produced by the wind. As such, it offers an insight into the nature of wind velocity to be used and the effective measures that can integrate the different aspects of wind energy in improving the experiences of the individuals in conducting wind turbine analysis.

J. Wave energy

Most of the countries have not utilized wave energy due to its complicated nature and uncertainty in the way it is implemented. As the wave is a random oscillation, direct absorption of such energy can be difficult and requires sophisticated equipment to be used in transmitting energy. According to Rusu & Onea (2018), using waves in producing energy can be advantageous to the country in numerous ways. First, it provides high energy density compared to the other sources of energy. As indicated in Rusu & Onea (2018), the solar energy intensity is often given at 0.1 – 0.3

kW/m^2 while the wave energy intensity is 2 – 3 kW/m^2 which has indicative of improved efficiency of the energy use in such regions. There is limited impact on the environment as the life cycle emissions for such devices tend to be generally low improving the sustainability nature and environmental conservation for the country. Other benefits include little energy loss and natural seasonal variability making it better when the demand for electricity is high during temperate climatic conditions.

Rusu & Onea (2018) study indicates that the location of the wave energy generated devices can be critical in determining the cost implications of the operations. For those devices located in the shoreline, it makes it easy to maintain and understand the changing intensity of the waves during the production of energy. This is essential in improving the efficiency of the operations while maintaining improved wave energy distribution. For the offshore devices, they are located in deep water despite being along the ocean or sea. Their energy distribution is minimal, which has an impact on the overall productivity level. As such, understanding the variability in the waves and improving the efficacy of the operations is essential in increasing its success in the energy production process.

K. Cost and requirements

Costs:

As of 2019, the average cost of constructing solar energy is given at $1,796 per KW, which has seen a decrease by 2.8% from the reported value in 2018. Such a decline in the cost of constructing a solar energy distribution system can be attributed to the decline in the cost of crystalline silicon. Having this in place has meant that there is improvement in the development of key solar technologies for the generation of energy, which impacts the overall productivity level in the long-run. As such, it is necessary to consider the emerging trends in the industry and improve the cost implications of the solar panels offered in the industry.

In favorable weather condition, the levelized cost of electricity (LCOE) for the wind energy is around $7.9c per KWH. Depending on the region that the wind turbines are located, the cost can vary, and this can influence the productivity level and the investment needs of different firms. The location of the wind turbines tends to influence the potential of the different firms, with the levelized cost impacting the overall productivity of the company. As such, it is always necessary to observe the level of the wind energy include the speed and strength in determining the correct position that such initiatives can be implemented.

The cost of wave energy is based on the pelamis device that is used to convert the waves into the energy. Depending on the proximity of the port to the supplier the cost can vary. As it is imported from the United States, Wacop (2021) indicates that the cost of the device is between US$3 and 4 million. Other capital cost required in setting up the wave energy production system include moorings (cost is between US$ 0.3 and 0.4 million), installation (cost is between US$ 1.2 and 1.6 million), and shipping (cost is between US$ 0.18 and 0.24 million). All these are essential in realizing effectiveness of the wave energy development system.

Materials/instruments

According to the National Renewable Energy Laboratory (2015), the materials to be used in making wind turbines include:

- Steel – taking 71 – 79% of the turbine mass
- Fiberglass, plastic, and resin – taking 11 to 16% of the turbine mass
- Cast iron - 5 to 17% of the turbine mass
- Copper
- Aluminum

In the case of solar energy, the main materials required are the solar panels (about 50) and the energy convertor to change the heat to energy. For the wave energy, Uihlein (2016) indicating that it requires wave profile devices, oscillating water columns, and water capture devices. A detailed illustration is given in figure 4 below.

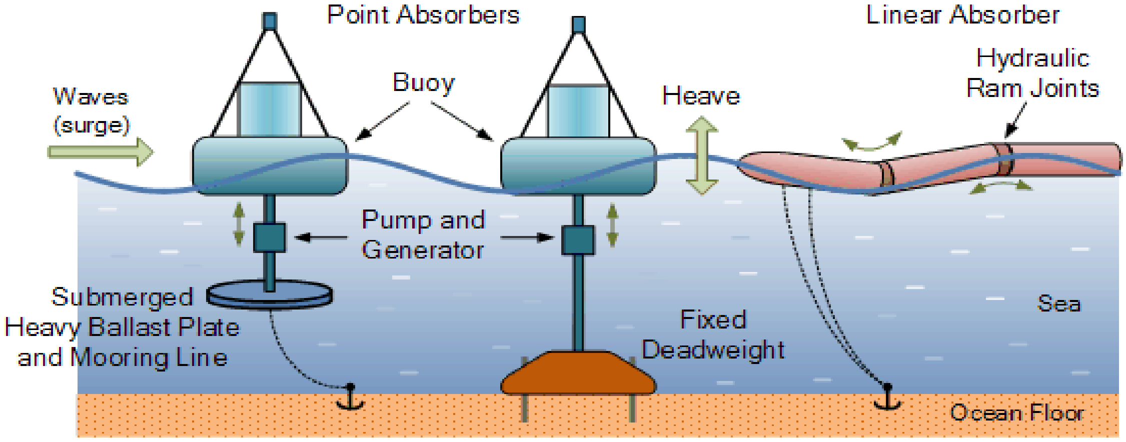


Figure 4: Wave energy production materials

Source: Uihlein (2016)

<u>Examples:</u>

Kurnool Ultra Mega Solar Park, India

Figure 5: Kurnool Ultra Mega Solar Park, India

Source: Evans (2020)

The Gansu Wind Farm in China

Figure 6: Gansu Wind Farm, China

Source: Wartsila (2020)

The Mutriku wave energy plant, Spain

Figure 7: The Mutriku wave energy plant, Spain

Source: Power Technology (2021)

III. METHODOLOGY

In this research, the focus can be on qualitative approach in which field study may be implemented. The researcher shall be relying on ethnography in collecting data and determining the effective measures that can generate efficacy in the implementation of energy production system in Beirut port, which includes wind, solar, and wave energy production systems. A case review of the activities of Beirut port and the challenges experienced in distribution of energy in the port can be undertaken. This may form the basis for implementing strategic measures that can be critical in realizing success of the energy turbines to be implemented in the region.

Figure 8: Beirut Port

Source: http://www.portdebeyrouth.com/index.php/en/

As illustrated in the figure above, the port provides an effective platform in which the development of the solar, wind, and wave energy production systems can be undertaken. For the solar energy, the plant can be located around 500 meters from the coastal area. The location of the solar photovoltaic (PV) clusters is essential in minimizing the possibility of shading. The focus is on maximizing the output in the Beirut port and solar pathfinder may be used in determining the correct location for the plant. Other factors to be considered in selecting the site for solar panels are the sun hours and tilt angle for the solar panels as illustrated in the figure below.

Figure 9: Solar Panels

Source: Khare, Nema & Baredar (2016)

There can be consensus on the energy to be generated from the solar panels, which leads to be based on calculating the baseload of the project using the Wholesale solar calculator. The energy consumed by each system developed can be determined by this calculator, which can be the basis of ascertaining the system voltage and the power output generated from the solar. Also, panel sizing, battery system, and inverter could be used in the solar panels with the focus being on maximizing their use.

For the wind power generation turbines, there location is essential in determining the appropriate mechanism in which the wind energy is produced. The wind turbines shall be located on a higher altitude in the Beirut port, preferably 1 or 2 km from the port. As the wind turbines relies on the speed and strength of the wind, its location can be effective in determining the output generated from the wind. This can be essential in improving the quantity of the wind energy to be produced.

Figure 10: Wind turbine

Source: National Renewable Energy Laboratory (2015)

The design of the wave energy production system is based on the counter spinning aspect that draws the water and increases the possibility of high energy output generated from the waves. The figure below illustrates the way the system could be implemented in generating high level of energy.

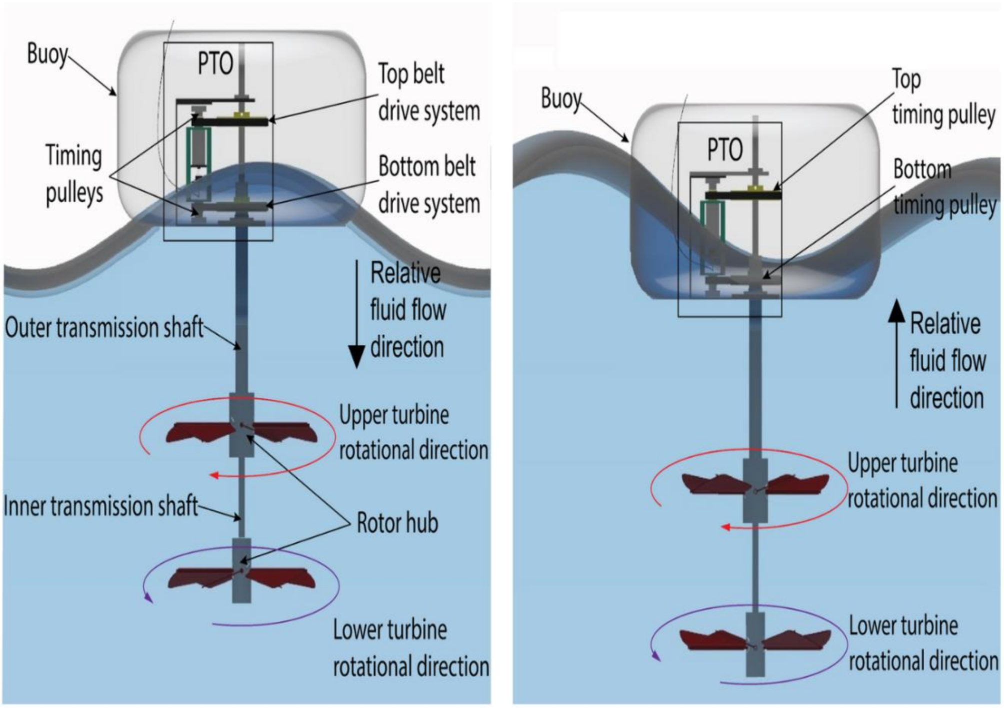


Figure 11: Wave Energy sample design

Source: Uihlein (2016)

When the turbines are in synch with the wave's movement, the energy generated can be maximized, and this may be done through combining counter-rotating dual turbine wheels, and the prototype developed. As such, it is easier to maximize the performances without any technical issues and improve the production capacity of the energy from the ocean waves.

The project takes place in the damaged Beirut port at the coordinates *33.90643830316843N*, *35.518744162796544E*. The position was undergone studies for the parameters that is needed for the project to be successful under all circumstances to satisfy the needs for solar, wave and wind systems. It should take about one to three months to be fully functional depending on the government's and Beirut's port management to clean the supposed area in Beirut and recover some of the main electrical parts in the port.

The project is only designed and simulated not built, the project needs the permission of the government and Beirut's port management to be established, it will take the area of 100 m^2 from the south section of the port.

IV. MODELING AND SIMULATIONS

The project was performed by many industrial platforms to be applicable as a real-time development to solve electricity shortage in Beirut port and to support the main grid of Lebanon in case of excess power. These platforms are popular among industrial companies, and are used to simulate and create a design for the system. This system uses renewable sources provided by ecological system as sun, wind and water to avail the welfares of these free resources, to produce energy starting from the law of energy conservation. Solar panels utilize sun rays to convert it into electricity, while wind turbines use high speed wind in open areas to alter from mechanical energy to electrical energy, while hydro-power when used in open sea zones endures a high input of force from natural waves that carriers water and transform it into electrical energy.

L. The design of the project

After the explosion of Beirut port in the 4th of august 2020 at 5:58 pm, electricity malfunctions occurred more often in the whole of Beirut district, to cover the economical loses due to the incident and to reduce dark hours in the port, this project is set to sail.

Renewable energy is far the cheapest most efficient sources of electricity; the project is divided to three main branches. First we have the solar energy which is obtained by storing particles of sun rays and wind stimulates mechanical turbines to perform a rotary motion supported by wave energy which is colliding on the steel plate. All these act as one to satisfy the needs of lights in Beirut port. Different times of the year causes us to have variables in the system depending on the time of the year where daylight hours, wave length, and wind speed fluctuates.

1. Wave Energy

The transmission of energy from surface ocean waves and using it in beneficial mechanical operations such as electricity production, water desalination, or pumping water to water reserves is known as wave energy. It is one sort of renewable energy. It is not to be confused with tidal energy.

The original wave energy system contains a movable boat shaped made of polycarbonate plastic which endure salt water, heavy weights and UV rays, never forgetting it's light weight that is essential for the task. The boat is fixed with a metal bar that is linked with a rail gear surrounded by a tube, this rail is matched with a gear that captivates upward and downward movement, which is also directly associated with the 2000W turbine then connected with wires to the invertor directly. All items mentioned are made of stainless steel to prevent corrosion and rusting, also for having many variants in its shape with being heavy duty and a high strength material.

Starting with the wave movement coming from any direction towards the plastic boat regardless of its situation, can amplify the rail height which in turn may increase the sensitivity on the main gear. Take for knowledge the boat is the pendulum, this system functions as the pendulum clock, in which it generates energy while going to the extremities, not when staying in the equilibrium, thus when the pendulum is at one of the extremities it's considered as potential energy, nonetheless when moving in any direction it is then going to be transformed into kinetic energy, where it can produce all the power needed for the system. These movements spirit stimulate the rail to rotate the main gear.

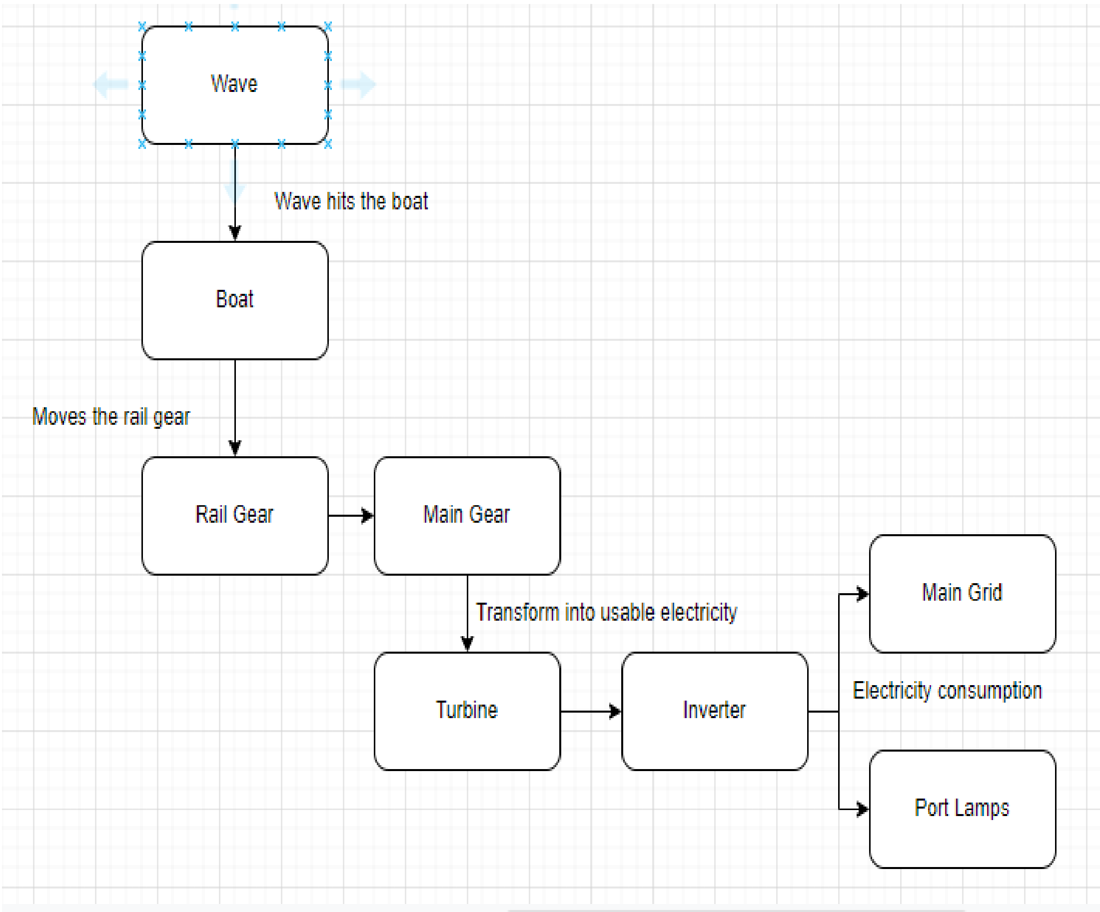


Figure 12: Flow Chart Showing Wave System

Table 1 shows errors and failures in the system. Many precautions were performed to create an anti-failure system, covering all the types of materials and gear safety lubrications. We found out that the system could be exposed to a perpendicular force against the movement of the boat. So to prevent system failure, the rail and the main gears has a swirl tooth profile, they don't change anything in terms of the main direction but it helps to protect from unusual movements.

Table 1: Errors and Failures in Wave Energy System

Errors/Failures	Description	Solution
Corrosion	Highly exposed for salt water, oxygen and sun rays	We coated metals with stainless steel manufactured goods
Breaking	The system is exposed to get hit by solid wastes and heavy waves	We used polycarbonate plastic for the boat
Perpendicular force	Perpendicular force to the movement of the boat	the rail and the main gears has a swirl tooth profile to prevent system breaking
Dried joints	Gear meshes can release lubrications	We created a seal for each joint to prevent lubrication loss

The output of the system is deduced from wave power equation, this equation is,

$$\text{P(wave)} = \frac{(\text{p}\times\text{g\^{}2})\ \times (\text{T} \times \text{H\^{}2})}{64\times\pi} \qquad \text{Equation (2)}$$

Source: https://openstax.org/books/university-physics-volume-1/pages/16-4-energy-and-power-of-a-wave

- P(wave) = Power (Watt)
- g = Gravity (m/s^2)
- T = Wave Period (sec)
- H = Wave height (m)
- p= Water density (g/cm^3)

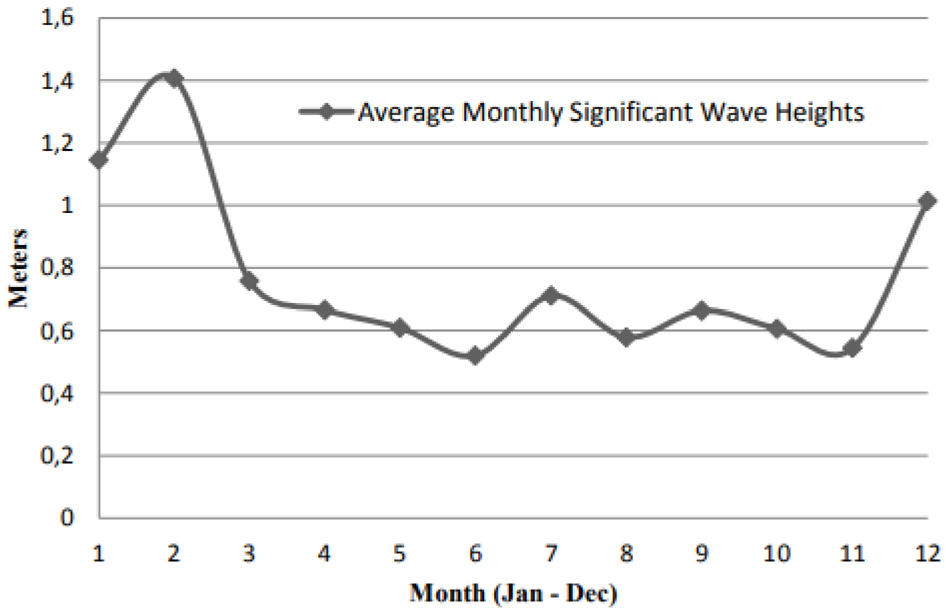


Figure 13: Wave Heights Diagram

Table 2: Average Wave Periods (Monthly)

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Period (Sec)	6.5	6.2	5	5.2	6	6.1	4.3	3.2	4.8	5.3	6.1	7.0

Table 2 shows the average of wave periods in each month of the year. After many studies and research, we obtained wave periods for each month which are used for wave power equation.

Table 3: Data Analysis of Wave Height

Mean	5.529
Standard Error	0.327
Median	6
Mode	6.1
Standard Deviation	1.087
Sample Variance	1.182
Kurtosis	0.790
Skewness	-0.971
Range	3.77
Minimum	3.2
Maximum	6.97
Sum	60.826
Count	11
Confidence Level(95.0%)	0.730

Table 3 shows a various data collection based on average wave periods.

The polycarbonate boat costs around twenty dollars (20$) according to the plastic world prices, the process of molding a single boat costs around (2$), Stainless steel costs 4.38$ per kg in Europe and we need around twelve kilograms for the system, which is around 52.56$. The 2000W Turbine costs 470$ of brand Ista-Breeze of Turkish manufacturing, Corrosion resistant.

2. Solar Energy

A photovoltaic panel is an interlocking set of photovoltaic cells, also known as solar cells that allow the production of electricity when exposed to light. Groups of photovoltaic panels are used for the purpose of producing electricity at the domestic level as well as industrial and heating swimming pools in cold countries.

Lebanon has a Mediterranean weather and time, it has four equal seasons and more day light than night, so solar panels that in habitats Lebanon are more efficient than other countries and can supply more value to the system, after many researches and studies we obtained the average daylight in each month of the year from the lowest of 9.9 to 14.4 hours per day. These studies advanced the research to a beyond level of producing energy and filling gaps of energy around the summer time.

Table 4: Average Hours of Daylight per Month

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Hours of Daylight	10.2	11.0	12.0	13.1	13.9	14.4	14.1	13.4	12.3	11.3	10.4	9.9

Table 5: Data Analysis of Daylight Hours

Mean	12.166
Standard Error	0.463
Median	12.15
Standard Deviation	1.606
Sample Variance	2.582
Kurtosis	-1.565
Skewness	-0.019
Range	4.5
Minimum	9.9
Maximum	14.4
Sum	146
Count	12
Confidence Level(95.0%)	1.021

The system uses two Panasonic mono-crystalline solar panels with an efficiency of approximately 19.7% located in an open area that faces the south at 45° and is directly connected to an inverter to transform it into suitable electricity ready for usage. The purpose that it is facing the south at 45° is that it can collect energy across the day and perform better in our situation.

The 45° is the standard use for implementing and placing solar panels where it gives higher efficiency and better performance according to Oliver Martin the director of operations in Absolute Solar LTD.

The cost of these 250W of model VBH N 330 SAD solar panels per unit is 232.5$, and a total of 465$ per system. Which is technically and financially suitable for the tasks to be done.

The output of solar power has an equation of

$$P(\text{solar}) = W \times h \times e \quad \text{Equation (3)}$$

Source: https://www.saurenergy.com/

- P (solar) = Power (Watt)
- W = Solar panel watts
- h = day light hours
- e = efficiency

3. Wind Energy

Wind energy is energy extracted from the kinetic energy of the wind by using wind turbines to produce electrical energy, and it is considered a type of electromechanical energy.

Climate in Lebanon is mainly humid and has much density due to the location and the nature of Lebanon in water which is known as “Castle of Water” among Arabian countries. Also wind has better velocity comparing to other areas near it, and that goes to the nature of the Lebanese land containing mountains and small distances to the coast. Land-sea-air interactions play an important role on wind velocity variation.

Table 6: Average Wind Speed per Month

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind Speed (m/s)	4.33	3.84	3.44	3.12	3.08	3.12	2.99	2.95	3.03	3.06	3.26	3.6

Table 7: Data Analysis of Wind Speed

Mean	3.328
Standard Error	0.121
Median	3.129
Mode	3.129
Standard Deviation	0.421
Sample Variance	0.177
Kurtosis	1.767
Skewness	1.504
Range	1.386
Minimum	2.95
Maximum	4.336
Sum	39.945
Count	12
Confidence Level(95.0%)	0.267

Temperature changes between air masses cause pressure variances, which result in wind. Winter provides increased temperature gradients, especially when cold fronts sweep in from the polar regions, resulting in higher-than-normal wind speeds.

The system uses one onshore Ista-Breeze aluminum wind turbine with an efficiency of approximately 40%. The system contains a single wind turbine that is facing south-west placed behind the solar panels also connected directly to the inverter. This placement decision is placed upon utilizing the northern wind which popular in

Lebanon for its speed and its consistency nevertheless the wind coming from the west shore; also it is directly connected to an inverter to transform it into suitable electricity ready for usage.

The cost of a single wind turbine is 1200$ including the operational and installation costs. This is technically and financially suitable for the tasks to be done.

The output of wind power has an equation of:

$$P\ (wind) = \frac{\xi\ \rho\ \pi\ d^2 V^3}{8} \quad \text{Equation (4)}$$

Source: https://www.e-education.psu.edu/

- P (wind) = Power (Watt)
- d = Radius (meter)
- v = Wind Speed (m/s)
- ρ = Air Density (Kg/m^3)
- ξ = Efficiency

4. Additional Costs

There are many additional costs shared with all systems such as wires, inverter and an electrical control tablet, the 80Kw multiuse inverter cost 4129$, 800 meters of wires which costs 1$ per meter, and the control is 250$. The whole system needs batteries to keep lamps running at night so we need 8 power-wall Tesla batteries which cost more than a conventional battery but has higher specs and 10-year warranty which can give a total of 81 KW storage to satisfy the system needs at all times of the year which costs 4000$ per battery. Financial analysis can't be implemented in the project due to the absence of building the project, though all the necessary details are given in the costs section in each project. The lifetime of this project can be around for 50 years with proper supervision. Stated by the manufacturers manual.

M. Programs used in the system

To reach the goals and avoid vague pathways and reach precise results we used industrial programs that are entrusted in several global companies like SolidWorks and LabVIEW.

1. SolidWorks

SolidWorks is software for 3D mechanical design by Dassault Systèmes SolidWorks Corp. This program was created in France, which runs on Microsoft Windows. SolidWorks presently employs over two million engineers and designers in over 165,000 firms across the world.

SolidWorks has the following benefits:

- Complex Product Design & Development: One of the key reasons for the platform's popularity is its ability to design and construct the most complicated assemblies. Create entire multi-CAD digital designs, as well as readily discover and fix flaws. It simplifies the creation of systems with thousands of components.
- Save Development Time: Using this program, you can develop designs and mockups faster. When compared to other solutions, it can save up to 30% of the time. Because of its reduced operations and very efficient interactivity, this is achievable.
- Integrated and Automated Design Validation: Another important element is integrated and automated design validation. When you build a design, you may monitor it to ensure that it meets compliance standards. This implies you may produce designs that meet your objectives without deviating during the design process.
- Reduce Delivery Cycle Time: After completing your training, you should be able to work on projects and cut delivery cycle times by up to 35%. It helps to simplify the process by transferring the same data and knowledge base from the concept to the finished result.

- Visual Analytics: Visual reporting and analytics are supported by the platform. This allows you to collect critical data and view the outcomes in 3D design. This speeds up the design process even further.

Source: https://all3dp.com

We created a fully functional prototype of the system using SolidWorks which enhanced my outcomes of the system and employed the researches in a more effective way and helped us understand the environment and the nature of the system without being in real contact. We designed a system that contains two solar panels, one wind turbine with the own wave mechanism.

Figure 14 and 15 represent the system drawn on SolidWorks.

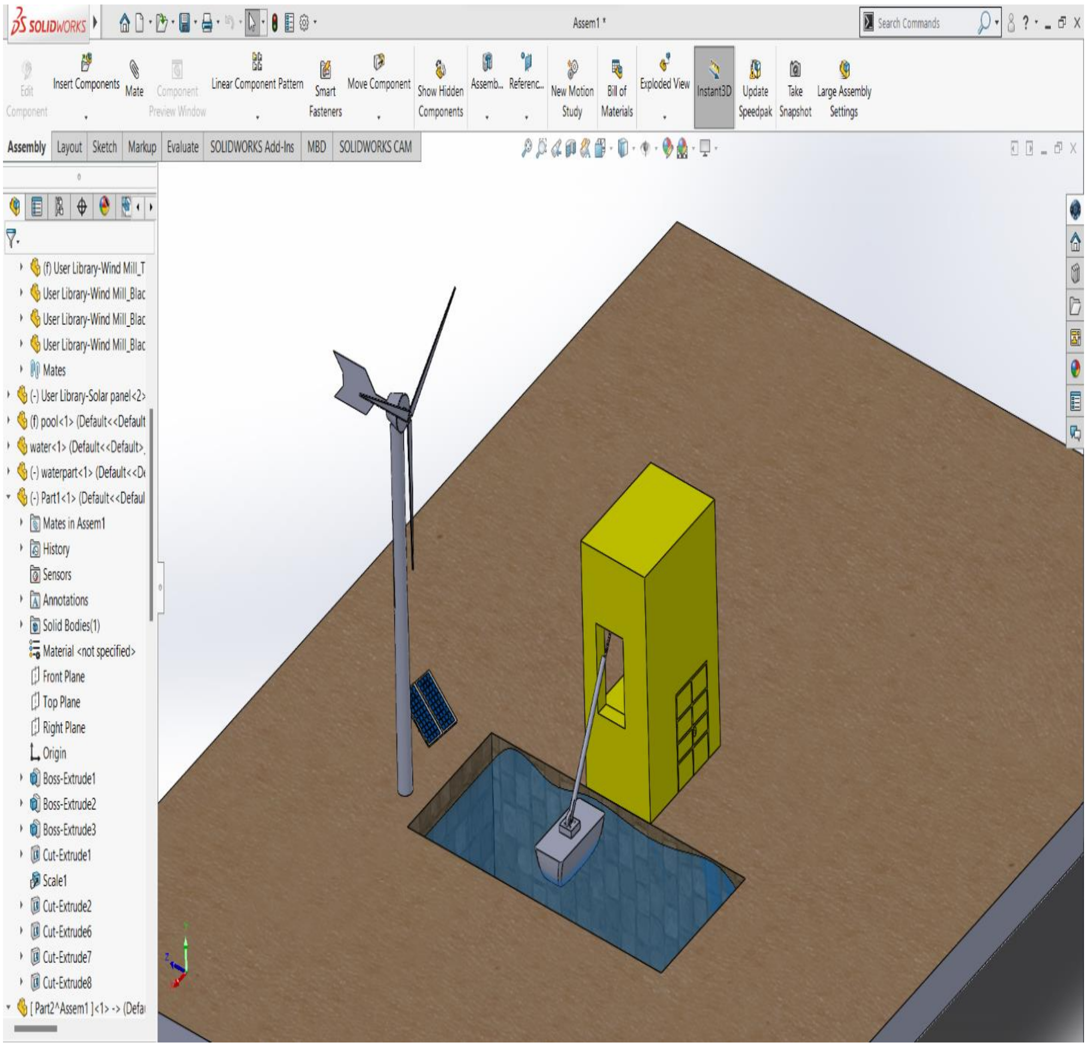


Figure 14: System Representation on SolidWorks

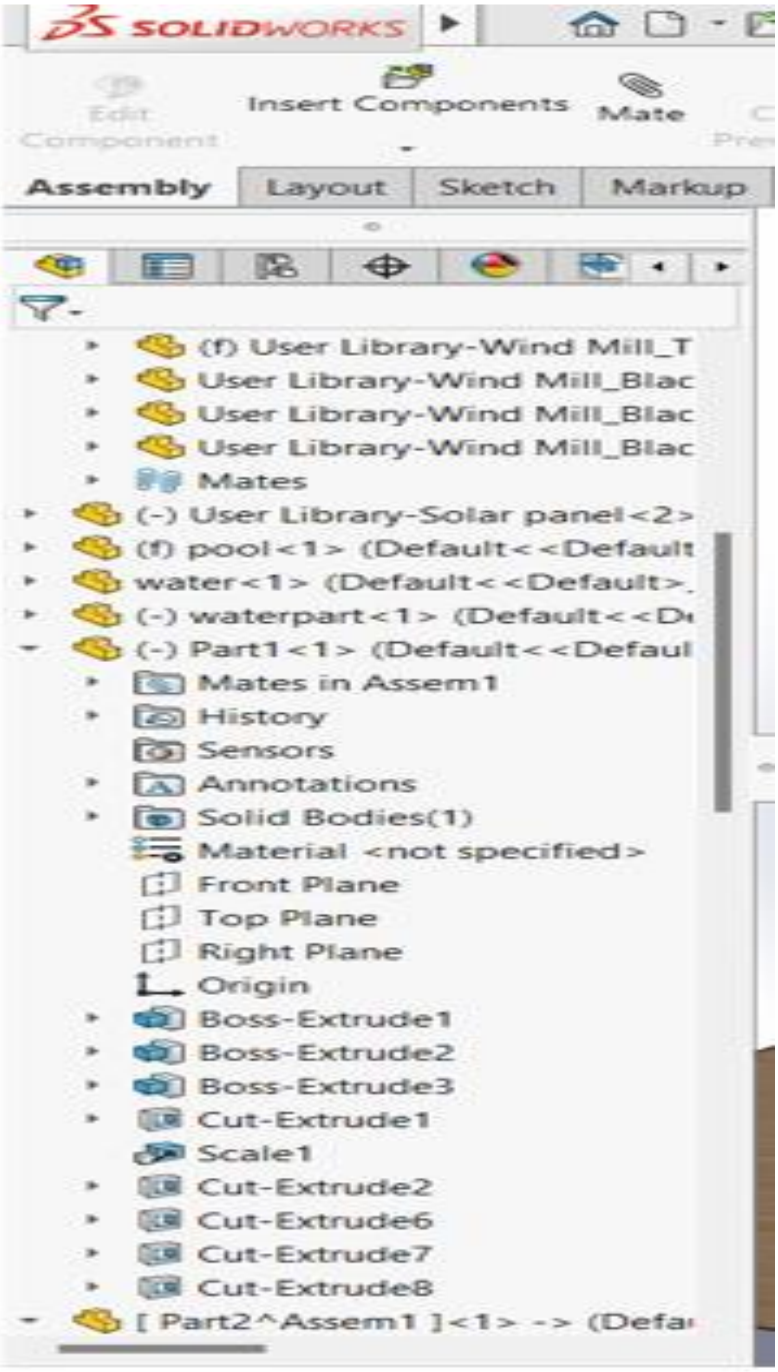


Figure 15: Representation of SolidWorks Part Names

2. LabVIEW

LabVIEW is a popular engineering program developed by the American electronics manufacturer National Instruments. It is compatible with all operating systems and is used for data collecting, control tool, automation system testing, signal analysis and processing, industrial control, and embedded system design.

- LabVIEW makes some things more efficient, which can minimize training or development time and expense. LabVIEW shines in the following areas:
- Developer effectiveness – Because it is graphical and a high-level language, developers may be incredibly efficient (with the correct training). A significant range of application-specific toolkits, such as sound and vibration analysis, electrical power analysis, and digital filter design, further save development time.
- Hardware support — In addition to NI hardware, LabVIEW supports a wide range of alternative buses and protocols, including serial, Modbus, TCP, OPC, and many others.

LabVIEW was used as a data implementer where it takes data from the user and gives results of the work where several variables can be included such as air density and efficiency, nevertheless working on the equations we choose and giving a real interface with the system.

This figure represents the interface of the system.

Excel is used to optimize graphs and tables from the data that we've collected from LabVIEW, for more precision in calculation, and to save time.

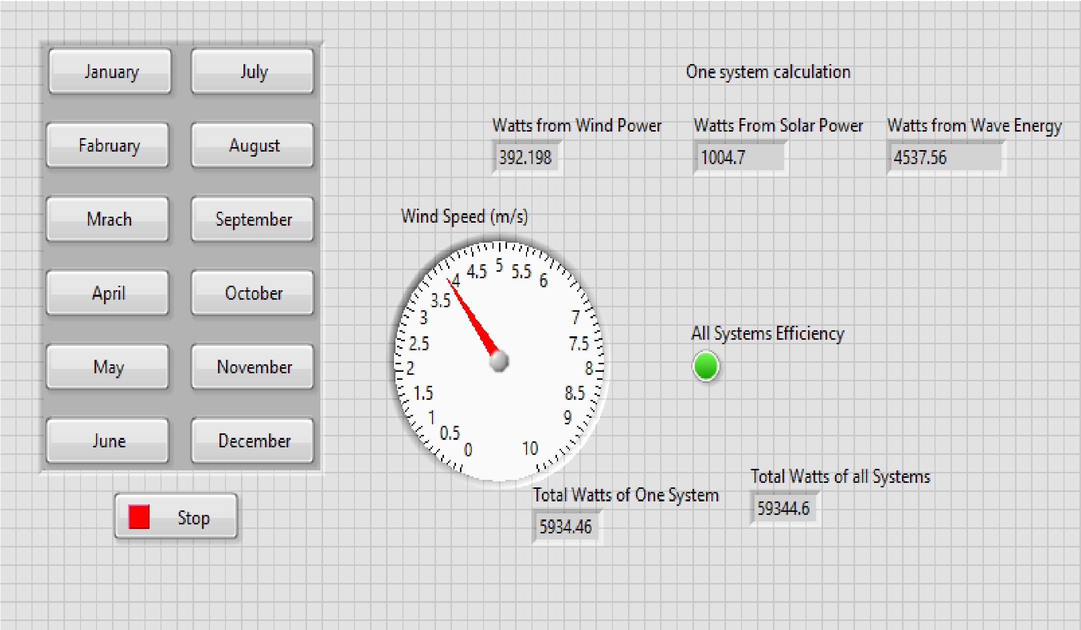


Figure 16: LabView Labeling Interface of the System

Figures 17,18 represents the coding and the usage of data collected to see if the system fails in any month, and the flow chart of the whole system.

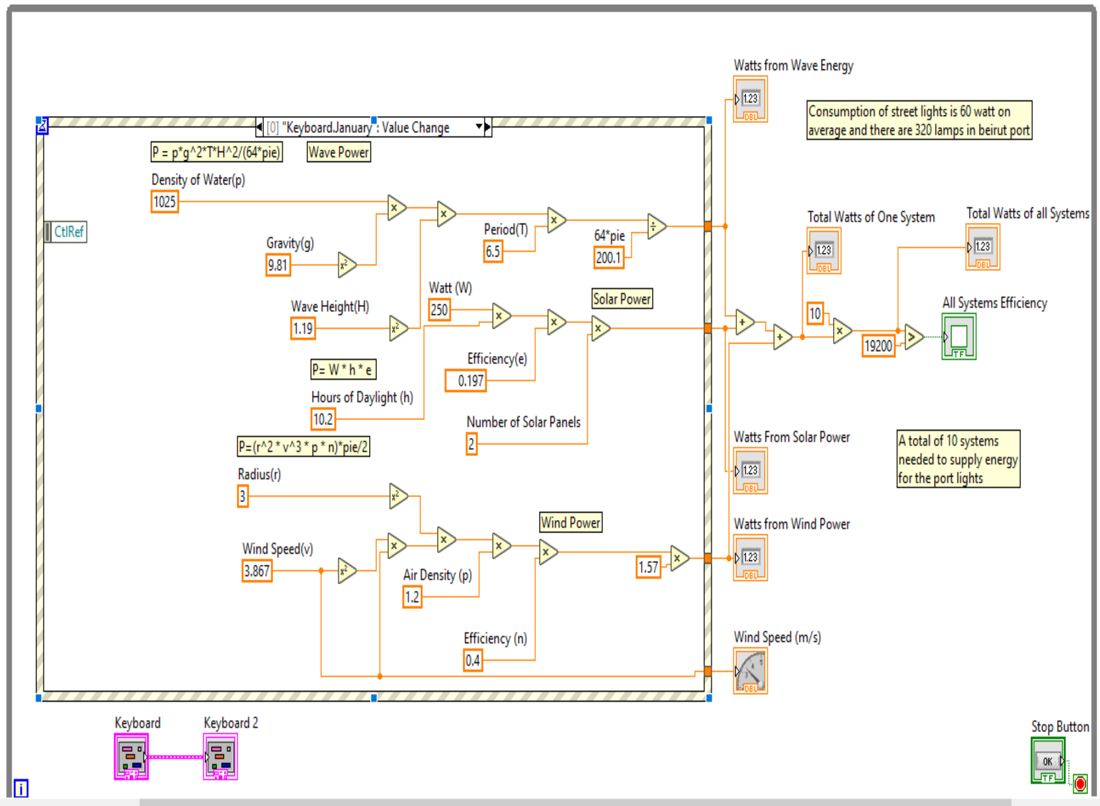


Figure 17: Block Programing

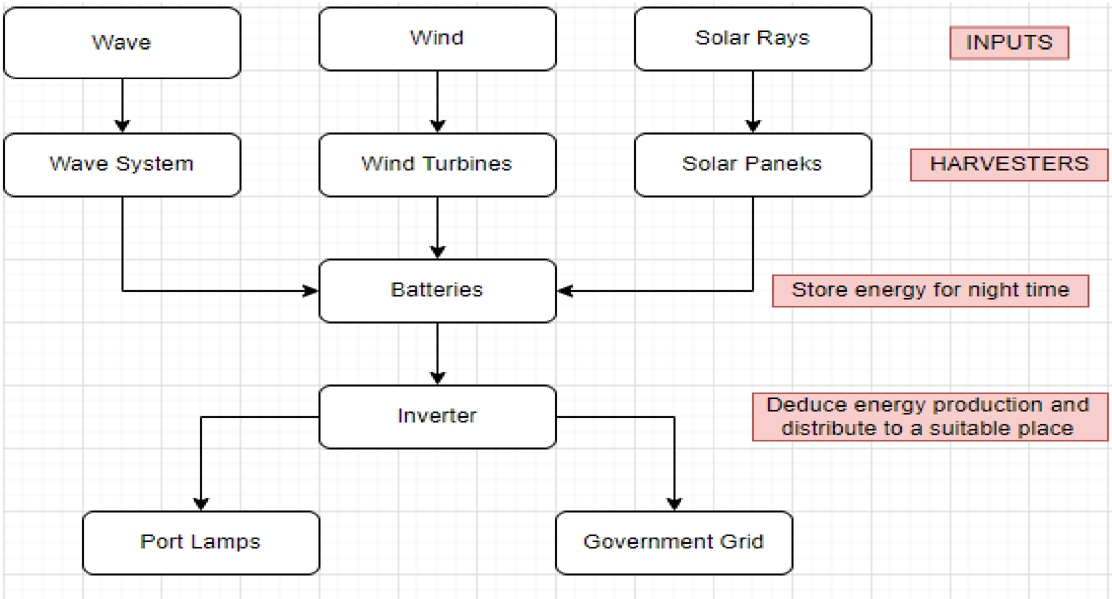


Figure 18: Triple Flow Chart

V. RESULTS AND DISCUSSION

After many researches and studies undergone for the nature of Lebanon we come to the realization of its importance on the renewable energy section in the world due the geographical position and the prosperities it has as a country, so placing renewable energy systems may be more productive than the surrounding countries since Lebanon has open spaces and supplemented with a good amount of water and the four season time frame. The system came to success upon tapping ten units that are similar; each unit contains two solar panels, a wind turbine and a wave system. Two goals were satisfied with the work upon the completion of the tests we have done, these goals simplify into making a working design of the original wave energy system and sustaining the needs of Beirut's port of lighting electricity consumption. To light the *320 60W* LED lamps that were implemented in Beirut's port by the municipality, we needed *10* units that at their lowest can produce enough power to suffice the consumption and contribute to the main grid of the Lebanese electricity department under a suitable payoff from the government to in turn cover the maintenance needed for each unit over the year which could ensure the likelihood of the structure's service life to its fullest.

Safety measures should be considered during installing and maintenance of the system which is bounded to electrocution or shock from electrified wires, arc faults that ignite flames, Explosions are caused by an arc flash, first aid kits should always be in the site, with fire extinguishers, tool and equipment testing.

The system contributes power to the port through connecting everything to the batteries stored there, and then to the inverter to be suitable for being used for the lamps and main grid.

Table 8: Theoretical Power Assessment

	Watts from wind power	Watts from solar power	Watts from wave power	Total Watts from one system	Total Watts from 10 systems	Excess Watts
January	392.198	1004.7	4537.56	5934.46	59344.6	40144.6
February	484.761	1083.5	5990.49	7558.75	75587.5	56387.5
March	384.041	1182	1499.6	3065.64	30656.4	11456.4
April	276.095	1300.2	1256.07	2832.37	28373.7	9173.7
May	207.978	1379	1064.8	2651.78	26517.8	7317.8
June	202.054	1418.4	1011.58	2632.04	26320.4	7120.4
July	207.978	1388.85	1028.05	2624.78	26248.7	7048.7
August	183.125	1310.05	567.894	2061.07	20610.7	1410.7
September	174.12	1221.55	909.577	2295.25	22952.5	3752.5
October	188.674	1113.05	940.574	2242.3	22423	3223
November	234.983	1024.4	1046.76	2306.15	23061.5	3861.5
December	335.26	975.15	3435.96	4746.37	47463.7	28263.7

Number of Lamps=	**320**	**Legend:**
Watts per Lamp	**60**	**Red= Highest watts**
Total Watts Consumption	**19200**	**Blue= Lowest Watts**
		Yellow= Other Information

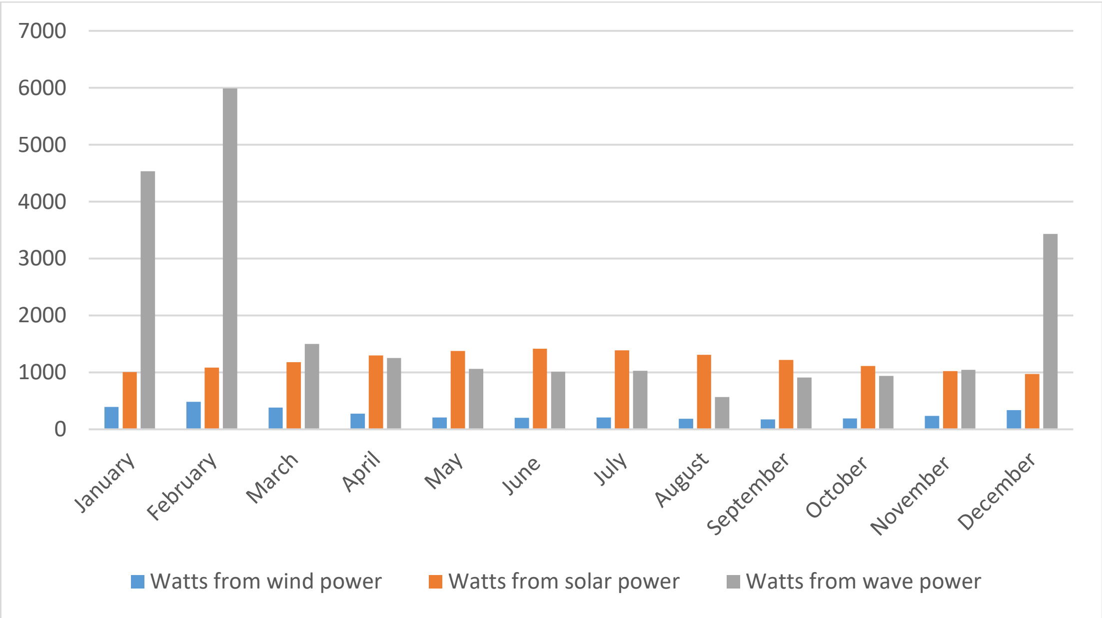
Table 9: Monthly Payoffs

Month	Excess Watts	Governmental Watt cost ($)	Project Watt Cost to the Government($)	Payoffs of the Excess Watts ($)
January	40144.6	0.006	0.003	120.433
February	56387.5	0.006	0.003	169.162
March	11456.4	0.006	0.003	34.369
April	9173.7	0.006	0.003	27.521
May	7317.8	0.006	0.003	21.953
June	7120.4	0.006	0.003	21.361
July	7048.7	0.006	0.003	21.146
August	1410.7	0.006	0.003	4.232
September	3752.5	0.006	0.003	11.257
October	3223	0.006	0.003	9.669
November	3861.5	0.006	0.003	11.584
December	28263.7	0.006	0.003	84.791
Annual	179160,500	0,072	0,036	537478,000

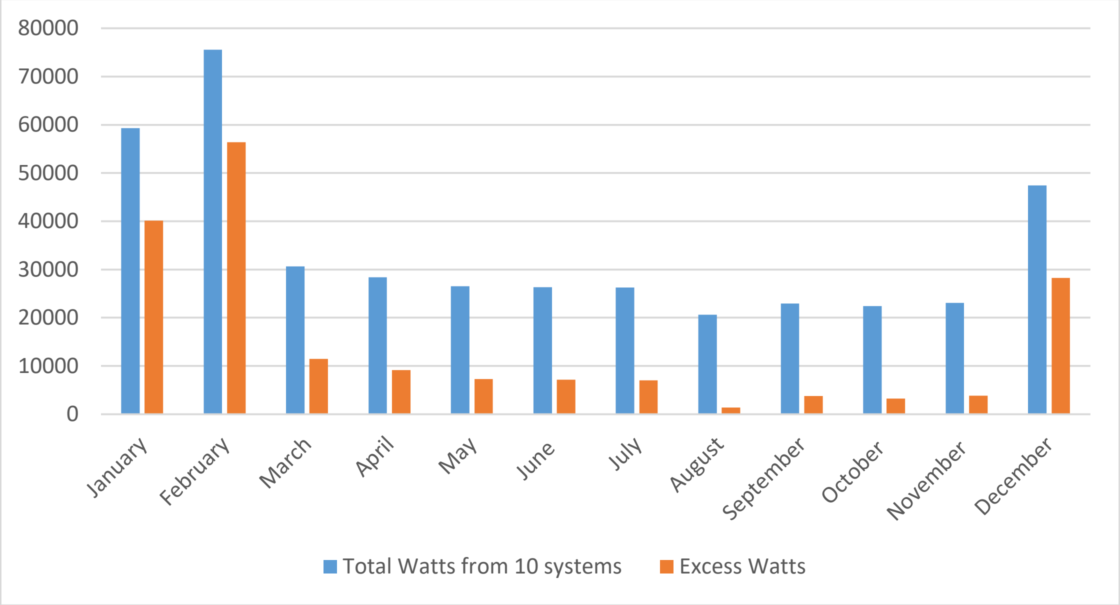
Tables 8,9 show the power flow each month over the year and specifies how much power apiece of the whole system contributes to our total gain. The excess amounts of overspills at each month are sold to the government. These money advantages are all invested in covering maintenance and bonuses for the workers, nevertheless the lowest month in terms of power coverage of the drain in the project is capable of covering the needs and sparing extra Watts to be sold. Although the payoffs from the government are low, but are able to cover wages and maintenance all around the year.

Maintenance is all around grease and man power, each month we need one worker for one day per month to lubricate and clean all ten units which roughly converts to twenty dollars per month, on the other hand put system make *537.4815 $* per year. All the excess money can be saved in case of an unusual problem.

Graph 1 shows the power generation per system for each month. Wave and wind power potentials are higher in winter. Potential of solar power is normally higher in summer months than other seasons.



Graph 1. Monthly Power Curve



Graph 2. Total Energy Generated by Three Systems and Excess Watts

Graph 2 shows monthly variations of total and excess power in Watts. In general, they are maximum in February and minimum in August.

Table 10: Data Analysis for the energy produced

Mean	14930.041
Standard Error	5019.516
Median	7219.1
Standard Deviation	17388.116
Sample Variance	302346604.8
Kurtosis	1.973
Skewness	1.684
Range	54976.8
Minimum	1410.7
Maximum	56387.5
Sum	179160.5
Count	12
Confidence Level(95.0%)	11047.882

Table 11 : Data Analysis for total generated energy from the all systems

Mean	34130.041
Standard Error	5019.516
Median	26419.1
Standard Deviation	17388.116
Sample Variance	302346604.8
Kurtosis	1.973
Skewness	1.684
Range	54976.8
Minimum	20610.7
Maximum	75587.5
Sum	409560.5
Count	12
Confidence Level(95.0%)	11047.882

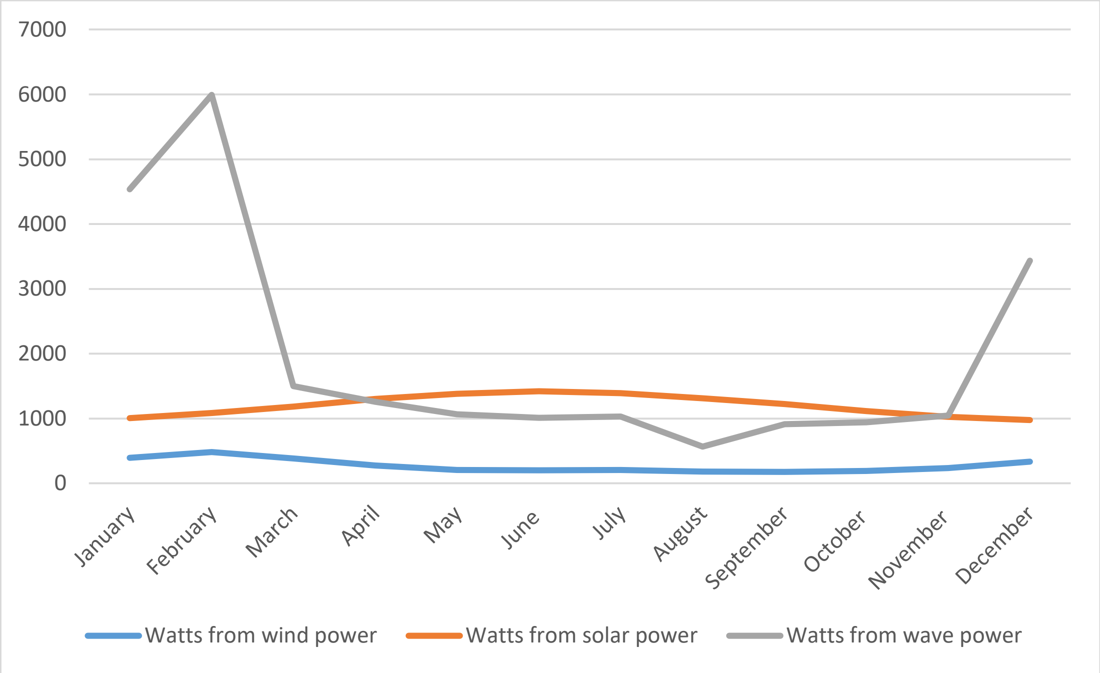
Table 10 and 11 show the data analysis for the results of the energy produced.

N. Analysis

After a quick analysis of the comparison tables based on simulations performed on LabVIEW, we determined the lowest and highest months in power values which are August and February respectively, due to the nature of Lebanon a wide variety of influences occur around the year depending on the season they are currently in. So, a huge gap in value is found between the extremity months but is indeed sufficient for the power usage we want.

According to table 8 and 9 the highest month in value returns a total of *75587.5* Watts, this month has the peak wind speed, with a significant increase in daylight, also has the best outcome from the wave system over the year which contributes highly for the project and the return profits in the year, while august is at the bottom between all months at a rate of *20610.7* Watts, although it has one of the highest rates of energy produced from solar panels because of daylight hours, but the sea is mostly calm and no major waves working the system. August doesn't return much profit for the project nevertheless it keeps the lights on without any troubles.

Graph 3: Power Generation vs. Months



Based on graph 3 calculations and observations, solar and wind power are approximately constant in this system over the year. Where solar power values vary between *975.15* and *1418.4* Watts per month as on average, also wind energy between *174.12* and *484.761* Watts. The reason behind having these low values in these two systems refers to pumping numbers up and keeping a higher minimum value as whole complete system, across the worst months which is august where these two parts play as a regulator function for the main purpose which is wave energy system. The constant consumption that we have each month in the project is what makes it more flexible with choices, so meeting these standards is the only goal in terms of production rate, the consumption is *19200* Watts per month across all the port where we have a production of *20610.7* Watts as a minimum that spare us with *1410.7* Watts that can either be sold or kept for any unusual increase in consumption. Otherwise there are months that contribute highly and spare much more electricity to be sold to the government such as February with *75587.5* Watts that give an excess power with around *56387.5* Watts that also could be sold to the government.

Nevertheless, power produced from wave energy varies harshly through the year where it decreases from *5990.49* to *567.894* Watts and that is dependent on the Lebanese nature and the four seasons split. The low power is then covered by the other systems as mentioned before to at last creating a perfect system that can withstand any difficulties in any time of the year. November to February are the months where the wave systems bloom and produces the most energy but in March it decreases rapidly, while the rest have low sea movement and low production rate.

O. Other Systems Comparison

The system we created bounded by having higher efficiencies and lower costs than other systems, the production rate is seemingly lower due to cost boundaries and fewer components used compared to other projects. These repercussions lead us to have only higher production rate with higher cost systems to compare with.

A European study harnessed the ocean energy and came up with a system that produces electricity, through the following process, the dielectric elastomer generator (DEG) is made of flexible rubber membranes and sits on top of a vertical cylinder with a water level that rises and falls with the motion of the waves. Water entering the cylinder pushes trapped air up, causing the membrane to expand. The water level drops in wave troughs, causing the membrane to compress. Because the rubber membrane contains dielectric material, a voltage is generated both when it expands and compresses. This process generates electricity. This electricity would be carried to shore via underwater cables for commercial use.

Table 12 shows a comparison between the system and a European system.

Table 12: Comparison between Systems

	Average Production Rate(Watts)	Cost($)	Production Rate per Cost (Watts/$)
Beirut Port Project	1940.943	544.56	3.564
European Project	500000	151513	3.3

According to Table 12 the system efficiency per cost is higher than other systems which yields more power when expanding with more units, this result is due to the component selection and the nature of Lebanon as a whole.

VI. CONCLUSION

The project done in Beirut port decreased the costs built up on the port management to help focusing on other damaged parts of the in the port after the explosion, also made an increase in the money flow. The money advancements from it could allow to either invest in the Lebanese economy or increase the number of units implanted, where every year the project returns can cover a wave system to be implemented in project, moreover this system can be upgraded in many fields to be able to satisfy the whole city of Beirut in electricity under good commitment and supervision of the project. Wind direction studies will be implemented in near future to maximize the production of energy. This project covered goals with minimal costs and was successful upon all the fields chosen from durability to power coverage.

After the project undergoes several procedures it will be introduced to the government as a research proposal to be viewed and assessed by the administration specialists in the country and be given green light to start.

The whole electricity will be sent into the inverter to be used in the whole port but instead the system will automatically drain the batteries when the port is satisfied and, be connected to the nearest electrical station near the port and be distributed accordingly to areas near it.

We plan and try to continue to install this hybrid system for solving real world problems co-operation and collaboration with local authorities.

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APPENDICES

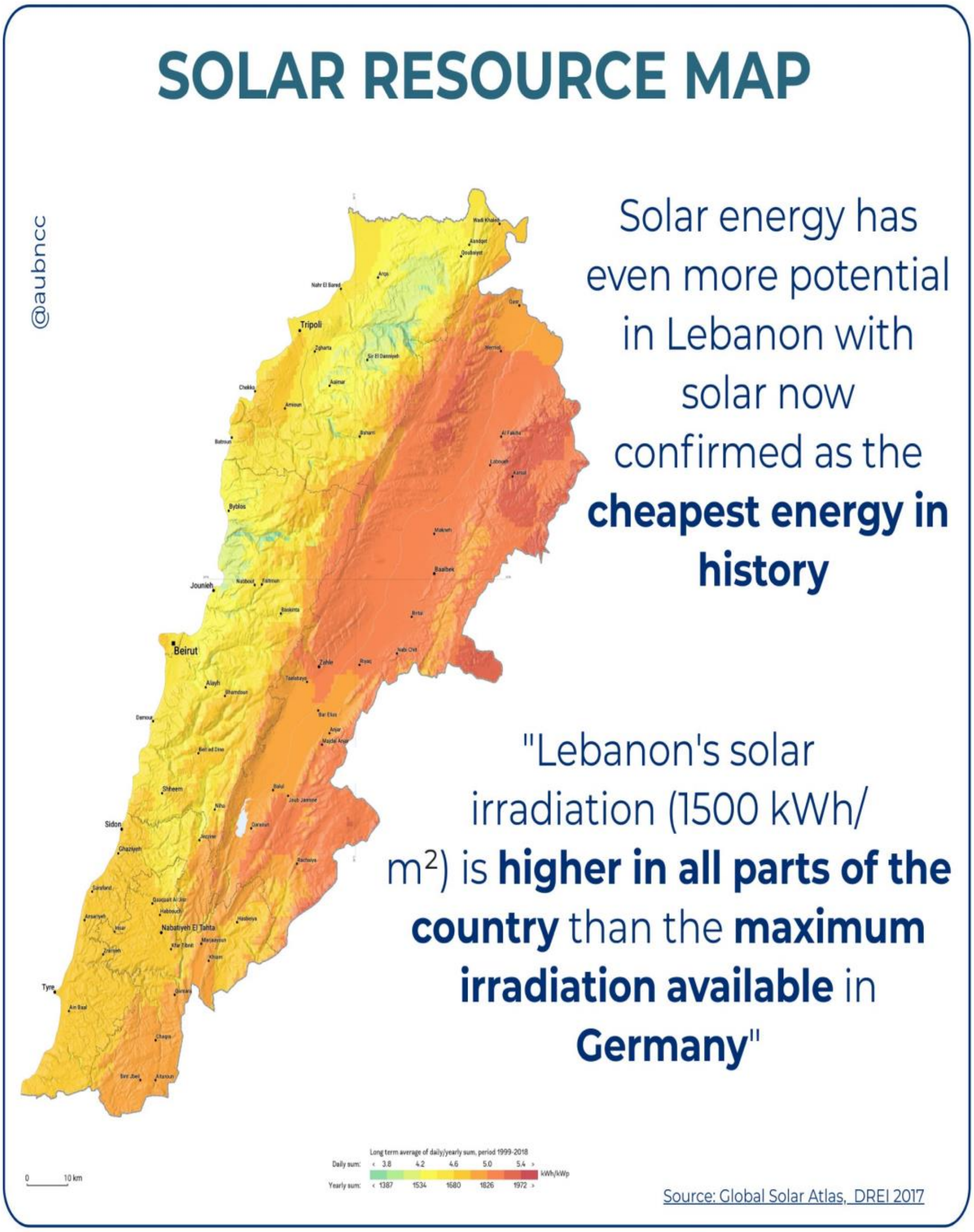
APPENDIX A: Solar energy potential map in the territory of Lebanon (Global Solar Atlas, n.d.).

APPENDIX B: Electricity consumption and production in lebanon.(Electricity consumption and production in lebanon From 1990-2011).

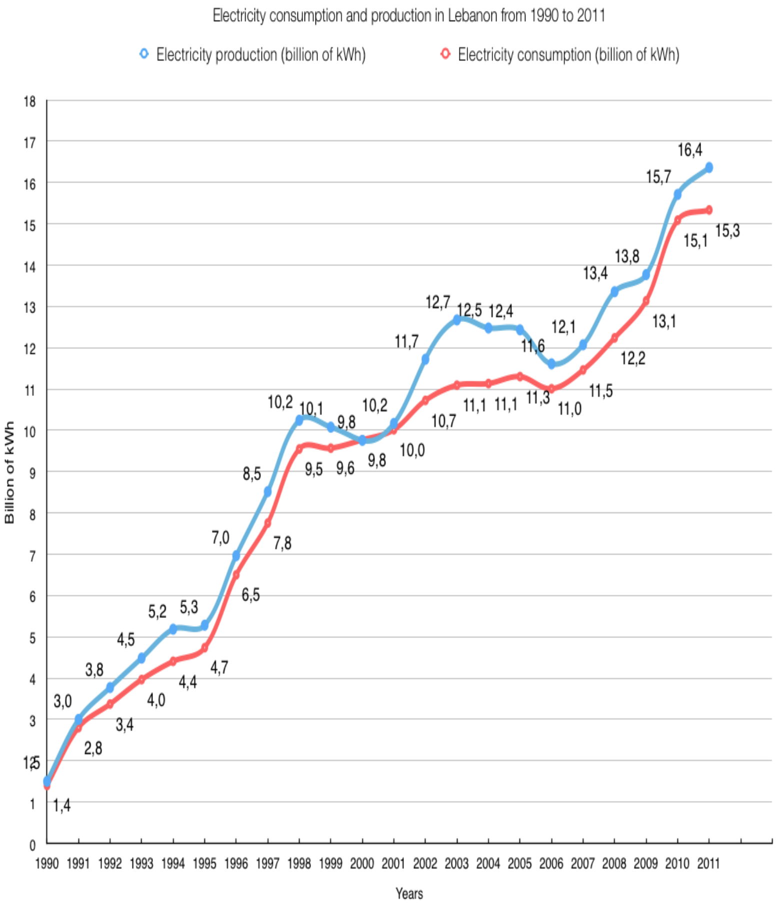
APPENDIX C: Marine renewable energy in the Mediterranean sea and Perspectives(Energies 2020).

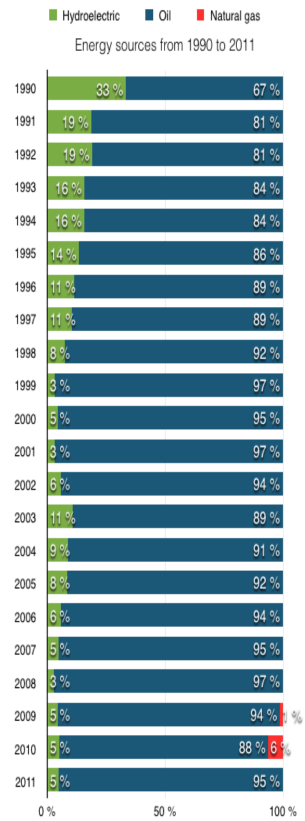
APPENDIX D: Wind speed map of Lebanon (Global Wind Atlas, n.d.)

APPENDIX A


SOLAR RESOURCE MAP
@aubncc
Solar energy has even more potential in Lebanon with solar now confirmed as the **cheapest energy in history**
"Lebanon's solar irradiation (1500 kWh/m²) is **higher in all parts of the country** than the **maximum irradiation available** in **Germany**"
Tripoli
Beirut
Sidon
Tyre
Source: Global Solar Atlas, DREI 2017

APPENDIX B



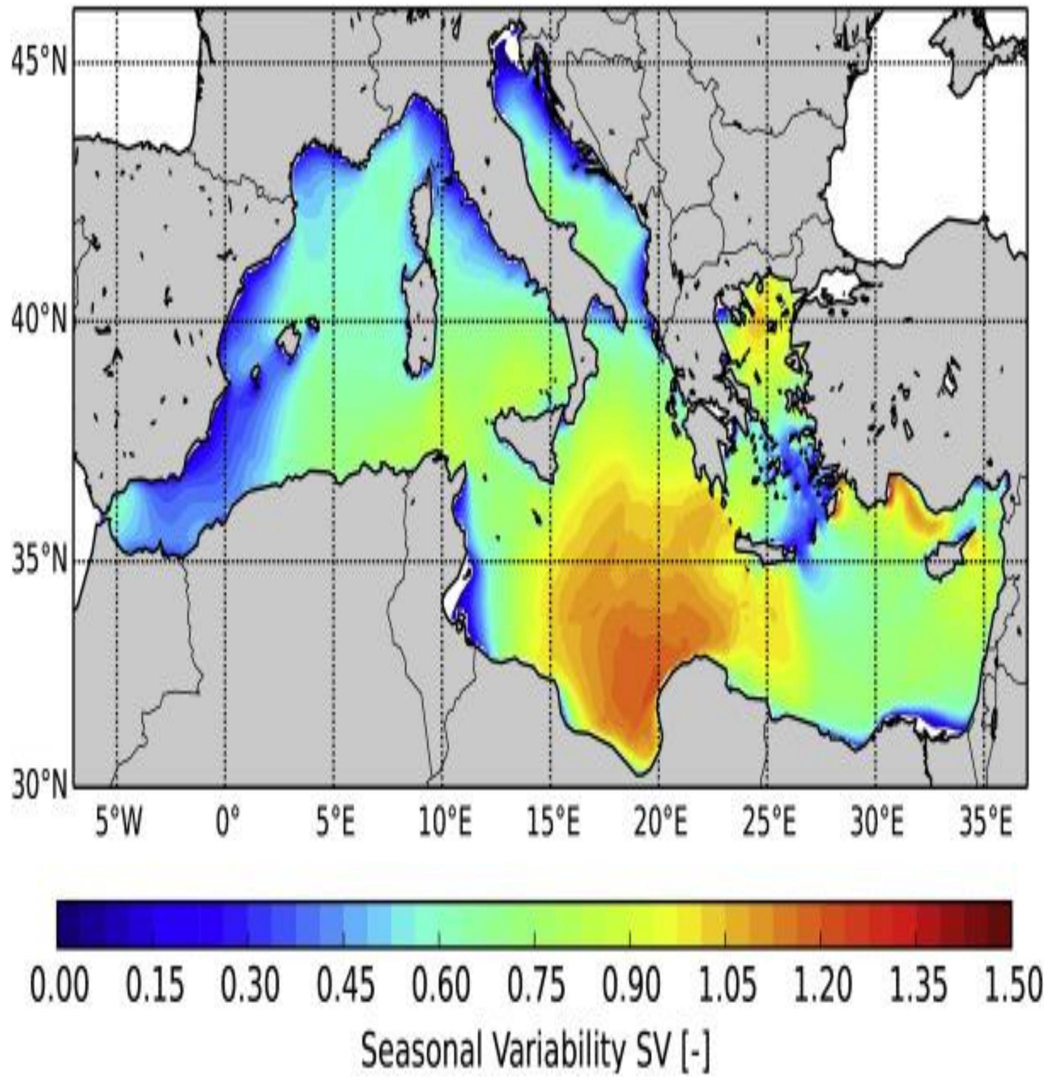


Electric power consumption (kWh) measures the production of power plants and combined heat and power plants less transmission, distribution, and transformation losses and own use by heat and power plants.

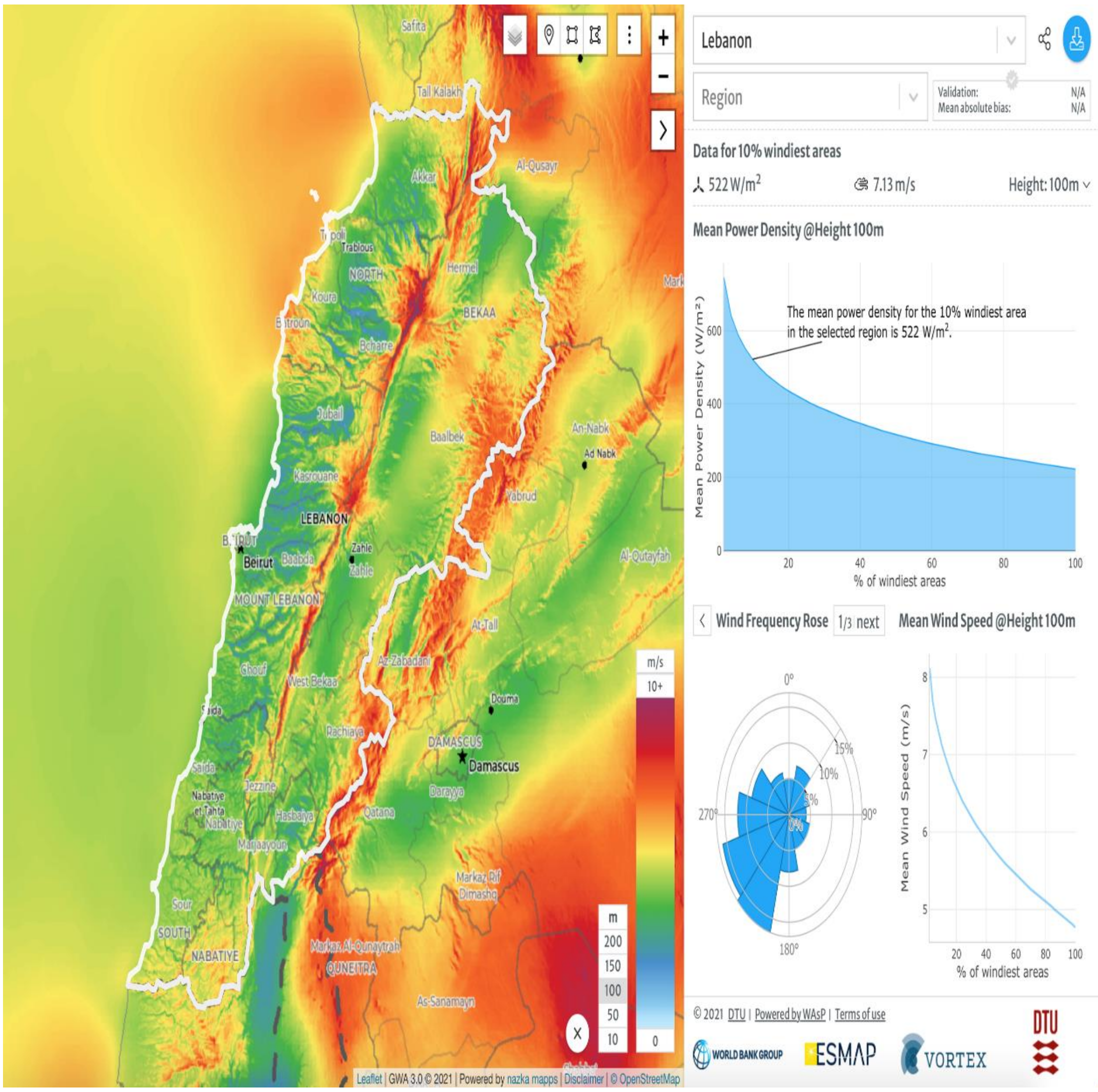
Electricity production is measured at the terminals of all alternator sets in a station. In addition to hydropower, coal, oil, gas, and nuclear power generation, it covers generation by geothermal, solar, wind, and tide and wave energy as well as that from combustible renewables and waste. Production includes the output of electric plants designed to produce electricity only, as well as that of combined heat and power plants.

Data from World Bank

APPENDIX C


45°N
40°N
35°N
30°N
5°W
0°
5°E
10°E
15°E
20°E
25°E
30°E
35°E
0.00 0.15 0.30 0.45 0.60 0.75 0.90 1.05 1.20 1.35 1.50
Seasonal Variability SV [-]

APPENDIX D



Lebanon
Region
Validation: N/A
Mean absolute bias: N/A
Data for 10% windiest areas
522 W/m²
7.13 m/s
Height: 100m
Mean Power Density @Height 100m
The mean power density for the 10% windiest area in the selected region is 522 W/m².
Mean Power Density (W/m²)
% of windiest areas
Wind Frequency Rose
1/3 next
Mean Wind Speed @Height 100m
Mean Wind Speed (m/s)
% of windiest areas
© 2021 DTU | Powered by WAsP | Terms of use
Tripoli
NORTH
BEKAA
Baalbek
LEBANON
Beirut
MOUNT LEBANON
Zahle
DAMASCUS
Damascus
SOUTH
NABATIYE
Leaflet | GWA 3.0 © 2021 | Powered by nazka mapps | Disclaimer | © OpenStreetMap

RESUME

EDUCATION:

- Master in Mechanical Engineering at Istanbul Aydin University. 2020-2022
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SKILLS AND INTEREST:

- Programming Language: Java
- Design and Simulation Technologies: AutoCAD, Solid Works, and Vibration Matlab.
- Ansys solar Program, Hap carrier heating and cooling System program.
- Microsoft Office (Excel, Word, PowerPoint.)
- Networking and Java programming
- Areas of Interest: Strength of material, Material science, C.F.D., Design and Optimization.
- Fire Fighting Experience and general ideas in Codes
- Areas of Interest: Strength of material, Material science, C.F.D., Design and Optimization

TECHNICAL EXPERIENCE:

- Designing pool filters and floor heating.
- Designing and calculating filter values for pools.
- Deal with floor heating preparation.
- Worked for 2 years with UNWFP at Qaaraoun, Lebanon (AFDC association)

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