AMERICAN UNIVERSITY OF BEIRUT

INTRODUCING MICRO-GRIDS IN LEBANON: OPPORTUNITIES AND CHALLENGES- THE CASE STUDY OF RASHAYYA

by
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AN ABSTRACT OF THE THESIS OF

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Title: Introducing micro-grids in Lebanon: opportunities and challenges- the case study of Rashayya

Lebanon suffers from a huge electricity deficit for a long time because the demand is super passing the supply in addition to a huge economical deficit due to the mismanagement of this sector. Many experts say that the solution might be in implementing microgrids that motivate the usage of renewable energy distributed generators especially with the price reduction in the PV cells and the wind turbine due to the increase in production and technological advancement. The literature review has shown that the microgrids have many benefits in both the developed and developing countries and have shown its good performance and it was able to reach its target based on some case studies even though some barriers were found to be existing.

Rashayya ‘s area seems to be the perfect place for the government to implement those projects due to many geological, economical and technical issues. A study done for Rashayya’s area was very beneficial in specifying the barriers that might face such projects and what might motivate it to achieve its established targets and to propose some policies and recommendations that might help in moving this sector forward and overcome the barriers. Moreover, modeling of a PV farm in Rashayya using Homer software has shown that the PV farm will be financially feasible with a payback period of seven years. The Lebanese government incorporation with the local municipalities needs to work more on implementing such projects mainly with the current electricity crisis that were are facing right now.

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CHAPTER I

INTRODUCTION

According to The World Economic Forum's 'Global Energy Architecture Performance Index' (which combines 18 indicators that reflects how accessible, secure, and diversified is a country's energy architecture and how this architecture impacts development, economic growth, and the environment), Lebanon is placed the third from the bottom out of the 127 countries.

Lebanon depends entirely on imports to fulfill the needs of the private and the public sectors. The heavy fuel used for electric generation and the high sulfur gas oil are imported by the government while the Diesel Jet A1, Gasolines (95/98), Bitumen, and LPG are imported by the private sector. In 2015, the government imported on the behalf of EDL (Power plants) a total amount of 1,500,000 MT of fuel while the private sector imported 1,900,000 MT of Gasoline, 1,450,000 MT of Diesel, 523,000 MT of Gasoil, 200,000 MT of LPG and 240,000 MT of Jet A1 (Chammas, 2015).

Lebanon suffers from a huge deficit in the electricity sector. Some regions in Lebanon get less than 12 hours of electricity per day, and this problem has amplified significantly after the Syrian' crisis that resulted in over one million refugees settling in Lebanon (Westall, 2015). To solve this problem, Lebanese citizens used small diesel generators that produce around 30% of the total electric energy consumed. Electricity bills are considered to be a heavy burden on the Lebanese people as the private electricity generation is costing them nearly double the usual public institution electricity bill (Fardoun, 2012).

The public institution electricity of Lebanon (EDL-Electricite du Liban) was found by decree No. 16878 on July 10, 1964, under the control of the Ministry of Energy and Water (MEW). It mandated the responsibilities of generation, transmission, and distribution of electricity in Lebanon. EDL monopolizes the electric sector by controlling more than 90% of the electric energy sector in Lebanon (Fardoun, 2012).

Currently, electric generation in Lebanon originates from two main sources: thermal and hydraulic (World Bank, 2009). EDL operates 6 thermal power plants with a total capacity of 2038MW. The hydraulic power plants are Litani, Safa, and Kadisha that are considered to be public companies with some authorities and two other companies: Ibrahim, AL- Bared that are considered to be property companies of EDL with a total capacity of 273.6MW (Fardoun, 2012).

The electricity segment in Lebanon suffers from a big discrepancy in its generation capacity to cover up the demand (Fardoun, 2012). Although two floating production plants were connected, the power deficit is still at a high range which is equal to 5524GWhr as shown in the figure below (Bouri, 2016).

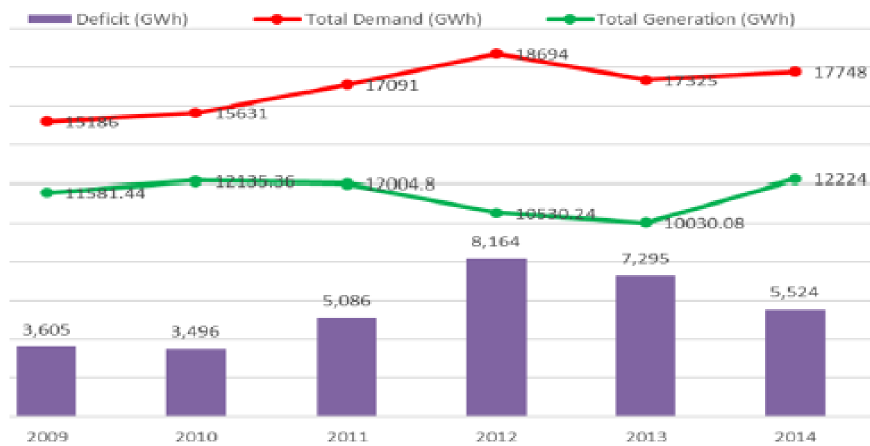


Figure 1. Demand, generation, and the deficit of electrical energy including the power ships (Bourj, 2016)

This deficit is considered to be the consequence of numerous causes, and the major ones are listed below:

1- There are a limitation and clear aging of two out of four major thermal plants that existed before the civil war (Zouk and Jieh). This limitation led to an increase in the daily cost of maintenance, a dramatic amplification in technical problems, and a severe decrease in plant efficiencies.

2- Even though four of the generation plants were designed to perform on natural gas, they are fueled by expensive gas oil (diesel) that causes high generation costs. This is because natural gas is not yet broadly available.

3- Absence of periodic preventive maintenance.

4- In most cases, low-quality fuel is used in electricity generation plants.

5- Plants' establishment criteria are far below normal international acceptable standards.

6- Load factors (i.e. ratio of actual output to potential output) are low, and this will lead to a gap in the overall generation capacity.
7- There are significant shortfalls in thermal efficiency which raise the production cost.
8- The lack of proper and clear administrative orders to request fuel shipment on time. Moreover, oil installations (Zahrani and Tripoli) were forced to provide EDL with the stock market prices and to transfer fuel in tanks leading to additional losses (Fardoun, 2012).

In addition to this deficit, the sector has another problem which is the high cost of subsidies for electricity in Lebanon. The average cost of production of 1 kWh is 17 to 23 US dollar cents (depending on international oil prices), while the average tariff rates are around 9.5 cents and thus leading to huge financial deprivation in the electric sector that reached 2.026 USD billion in 2013 (Bouri, 2016) and 1.8 USD billion in 2018 (OUAZZANI, 2019). These losses certainly make EDL less enthused to produce more electricity since more electricity means more losses.

Many Lebanese experts think that microgrids might be a solution for the Lebanese electricity sector problems. Microgrids are defined Pranadi as: "the microgrids system is a small power supply system that consists of loads and distributed energy resources (DER), such as renewable energy (RE) sources, co-generation, combined heat and power (CHP) generation, fuel cell and energy storage systems." Microgrids can work in a corporation with gird or switch to the isolated mode when needed. (LANTERO, 2014) This type of grids will motivate the usage of renewable energy that is experiencing a booming phase with the efforts to move from the traditional fossil fuel power generation which is considered to be the main source of energy used to run our cars, heat our homes, and produce the power required by our factories. Coal, oil, and natural gases are considered to be finite resources, their supply is limited and their consumption rates surpass their formation rate. Moreover, to produce energy from fossil fuel, it needs to be burned. The combustion of those fuels is accompanied by the generation of greenhouse gases that affect global warming. In the past two centuries, the average earth temperature had risen and if this continues, the sea level will rise to result in floods, droughts, heatwaves, and other extreme weather conditions that may occur more often (NREL, 2001).

Net metering can be used by microgrids to increase the benefit of using renewable energy sources and to make it financially attractive. Net metering allows the distribution of renewable generators to export their excess electricity to the main utility grid and the utility will in return bill the customers for their “net" energy use (SEIA, 2017). Virtual net metering (VNM) is a type of net metering that addresses the multi-owned distributed energy resources (DER) and it is defined by the California Public Utilities Commission as “a tariff arrangement that enables a multi-meter property owner to allocate the property's solar system's energy credits to tenants. The VNM tariffs were first piloted under the CSI Multi-family Affordable Solar Housing Program (MASH) as a means of providing equal and direct benefits of the solar system to low-income tenants in an affordable housing complex.”

A. Study Objective and Significance

This dissertation aims at focusing on the microgrids and the possibility of using microgrids in helping to resolve the energy problem in Lebanon and more specifically in the area of Rashayya. The thesis is trying to answer the following questions:

1- What are the challenges and opportunities that can drive the microgrids or prevents its advancement in the area?
2- Who are the main players in this field and how can they affect such projects?
3- Is it feasible to use microgrids in Rashayya mainly using solar power?

This research will add value to the literature since it will be the first paper that studies the possibility of applying microgrid projects in Rashayya and addresses the economic benefits that may results from the installation of (a) microgrid(s). It also covers the implementation of microgrids projects in rural areas in general. Moreover, this thesis will treat extensively the barriers that prevent the advancement of this sector in Lebanon.

The research starts with chapter one which is a literature review that includes the worldwide situation of microgrids and virtual net metering. chapter two which is a literature review will treat the challenges and drivers of the microgrids from studies that include developing and developed countries. Finally, a literature review for the virtual net metering will be conducted to evaluate their barriers and drivers.

Also, this research studies in chapter 3 the drivers and challenges of microgrids in Rashayya's area besides studying an already existing microgrid in Kfarmeshkeh one of Rashayya's villages. The final chapter will be a conclusion in addition to some recommendations that might help to motivate this sector.

B. Research Methodology

The chapters that follow will present an overview of the electric and power sectors situation in Lebanon, the policymaking and governing laws. A literature review of the microgrids and the VNM will also be conducted. Moreover, it includes a case study of an already existing solar farm in Kfarmeshkeh. Besides, a simulation of a PV farm in Rashayya will be conducted to identify its economic feasibility. The data in this study are obtained from online resources in addition to two direct interviews. Finally, an analysis of the obtained results will be conducted and followed by some recommendations addressing the local authorities and the Lebanese policymakers.

CHAPTER II

LITERATURE REVIEW

Microgrids are spreading more and more and going out from pilot demonstration sites and lab benches into commercial projects, this is highly encouraged by falling cost, track records technological improvement, and the recognition of their benefits. In general, microgrids are used to manage the addition distributed clean energy resources, improve the relatability of the electric grid, reduce GHG emission due to the combustion of fossil fuel, and to generate electricity in areas not served by centralized electrical infrastructure (Hirscha, et al., 2018). As an example, for a study done in Nepal, the study has compared households that benefit from microgrids in comparison to those that don't. The studies show that the households that benefit from electricity circulating in the microgrids will have a higher income (by around 2600 NPR which is approximately equal to 22$), higher literacy rates by 2%, increase in women involvement in decision-related to household finance, children education, and health than the nearby houses that do not have access to electricity. Finally, the availability of electricity from microgrids creates employment, increased business activities, and improved livelihood in general (Basnet, et al., 2015). On the other hand, the benefits of microgrids in the developed countries are very different. A case study of a microgrid in the USA shows that the main benefits of microgrids are in increase the resiliency (the ability to bounce back from a problem quickly) and reliability (the fraction of time an acceptable level of service is available) of "critical facilities" such as transportation, drinking water, and waste treatment, communications, food, health care, and emergency response infrastructure. In the EU, the main driver for implementing microgrids was an environmental one because microgrids motivate the usage of the environmental energy sources and this is to avoid a global average temperature rise exceeding 2°C over pre-industrial levels, which is considered to be the safe limit or the admissible level that does not affect human life on Earth (Hirscha, et al., 2018). On the challenges side, the experiment of the Chhattisgarh Renewable Energy Development Agency located in India has shown that microgrids have the following barriers: limited electricity service levels because some citizens utilize a huge amount of electric energy which fails if the system demand did not much the supplied better. The second barrier was the payment collection since many microgrid consumers did not pay their payment even with the existence of a non-payment penalty but they are often not exercised. Another barrier was the extension of the central grid allowing the residence to subscribe to relatively unlimited power and this motivates them to switch towards the central grid especially when the microgrid offers electricity only for lightning. Finally, the lack of security is also considered a major barrier because in the rural area in India rebel groups are active and this poses security issues for Center for Rural Educational and Development Action CREDA as well as third-party service provider personnel. (Schnitzer, et al., 2014) Challenges also differs between the developing and developed countries. A study was done by Aalborg University in Denmark and that treats different case studies of microgrids in developed countries including Germany, USA, Netherlands, Japan, and Denmark shows that the barriers are more technical and regulatory like Dual-mode Operation, Power & Frequency Control, Protection & Safety, Bi-directional flow of power & ability to trade locally, Interconnection Rules, and the high cost.

The main drivers and challenges of microgrids are reviewed below and are divided into social, technical, financial, environmental and policy barriers.

A. Microgrids barriers and challenges.

1. Social Barriers

The first barrier that might face the microgrid projects is the lack of community engagement. The fact that the microgrid is designed to serve a community makes the involvement of the stakeholders a very important issue. The usage of land or even the donation of renewable energy to function the lighting system and the water pumping system without engagement from the community can lead to problems that affect microgrids projects. Another social barrier is a lack of education. Many remote societies have little knowledge about energy conservation and energy efficiency and this leads to higher electric load that might fail the grid. Moreover, the lack of knowledge about renewable energy maintenance especially the PV cells that are considered as LOW maintenance power source leads to the misconduct that those power sources don't need maintenance and this is a major reason why the PV microgrid systems fail and abandoned a few years after installation. Finally, we have the insecurity barrier that leads to the theft of energy generation equipment which can affect both the decentralized and centralized systems (Akinyele, et al., 2018).

2. Technical barriers

Because microgrids are complex and include many components challenges related to each of its components can easily arise. Those challenges can start with problems with the efficiency and durability of actual storage and generation units to the effective functionality of control and communication software. The second barrier is the ability of the grid to switch from grid-connected to the isolated mode and to have enough generation to provide reliable power. The switch to island mode will result in a black outage which allows a short period of an outage before re-energizing the system in island mode. Re-synchronizing the two grids is also a major technical barrier. The resynchronizing needs to carefully choose the moment of reconnecting the two grids need further frequency and/or voltage controls in the islanded microgrid (Soshinskayaa, et al., 2014).

3.Financial barriers

The microgrids have also some financial barriers. A major barrier is the use of the storage system which is considered to be very expensive until today (MariyaSoshinskaya, et al., 2014).

Another main barrier is the lack of financial support offered by the government. Many communities -especially within developing countries- are very motivated to implement microgrids but the lack of financial capabilities prevents them from doing so. Moreover, many microgrids (mainly in developing countries) are implemented by politicians who aim to gain votes. This will create an ownerships struggle and this raises a question of who takes the financial accountability of managing the maintenance and operation activities. Finally, the replacement of the microgrid part is usually costly and may lead to the microgrid failure (Akinyele, et al., 2018).

4. Environmental barriers

The lack of a well-planned environmental impact assessment (EIA) can be a major barrier for microgrids. Some EIA evaluates the solar PV impact on the environment without taking into consideration the disposal of the batteries or the storage system. Furthermore, many EIA does not take into account the emission that generates from the manufacturing of renewable energy generators or even their disposal (Akinyele, et al., 2018).

5. Policy barriers

The absence of a good policy framework that encourages microgrids is considered to be a major drawback. Many countries do not have a policy that regulates motivator policies for microgrids such as net metering/net billing, feed-in tariffs (FiTs), tax credits/incentives, feed-in premiums (FiPs), and some countries has regulation but they are badly designed/ implemented and this prevents the advancement of this field. Moreover, some countries lack the political will or the political stability needed to implement those projects. The policies that encourage the participation of the private sector is also absent in some developing countries. (Akinyele, et al., 2018) Finally, some developing countries like Indonesia do not have a clear quality control policy, and these results in choosing cheap components by the local government that are afraid to be accused by corruption, and therefore and due to the bad quality of the component the system generally fails (Derks, et al., 2019).

B. Microgrids drivers and opportunities.

1. Social Drivers:

The microgrids are becoming more and more popular in delivering energy for critical facilities like a police station, fire departments, wastewater, and water treatment plant in addition to the hospitals. Those microgrids aim to secure the electricity circulation after a disaster or storm that might cut out the energy delivered from the main grid which might result in security and health threat.by this way the area become an island of power where community members can get clean water, charge cell phones and gas up cars (Wood, 2018).

2. Technical Drivers:

The microgrids' main advantage is ensuring the circulation of electric current when the main grid is experiencing an outage by switching to island mode. The microgrid’s generators, and possibly batteries, then serve the microgrid’s customers until power is restored on the central grid. In addition to reliability, microgrids ensure power resilience. power resilience is a term that means the ability to avoid power outages or return it as quickly as possible. Microgrids restore the power after a very small interval of time which leaves occupants barely aware a disturbance occurred. Furthermore, microgrids can strengthen the nearby grid. The microgrids can help and serve as an electric source on peak time and help to reduce the electric deficit in the main grid. Another technical driver is the short length of the microgrids. Microgrids extend only to the location of loads it serves, unlike main grids which might extend for several miles and which result in higher energy loss. The microgrids also can help to defeat cyber-attacks. The main grids are generally less resistant to the cyberattacks than the microgrids. Microgrids can switch between the generator and it can have a higher level of security (Wood, 2018).

3.Environmental Drivers:

Many businesses and communities establish clean energy targets to conserve energy and decrease the environmental impact of their power generation. Microgrids can motivate the usage of many clean energy sources including solar, wind, hydro, and fuel cells. the microgrids are designed to integrate those sources into the energy mix intelligently and can achieve specific sustainability goals, like the usage of lowest carbon resources to the maximum possible degree (Wood, 2018).

4. Financial Drivers:

Microgrids can reduce the cost of energy and give revenue for customers who use renewable energy generators (i.e solar, wind) in their homes. The reduced cost can be achieved by the good management of the energy supply while the revenue can come from selling the excess electricity to the microgrid. Microgrids operators can get revenues due to imposing charges on their maintenance and operation services. The microgrids also have the option of selling green energy certificates because of the usage of green energy to generate electricity. Besides, they avoid production loss during a power outage, they keep jobs within the community, and they attract skilled workers to a region (Wood, 2018).

C. Virtual Net Metering.

Net metering is an accountability mechanism that help consumers who own renewable energy sources to reduce their electricity bills. This mechanism is used generally to motivate the renewable energy sector. The net meter is responsible for metering in both directions, i.e., the export and the input side and by calculating the difference we will get the total consumed power. Basic net metering, however, has its challenges and barriers which includes the impossibility of producing solar power for the residence that share the same rooftops without clear rooftop ownership, similarly, large commercial establishments and institutions may have a different load on different locations and this leads to not benefit from the net metering with its full capacity. Moreover, sometimes the small scale generation source will seem not feasible from an economical point of view while if a shared project was implemented it will be economically feasible to install net metering. Because of the previously mentioned barriers, and to overcome them a new concept was developed which is the virtual net metering.

Virtual net metering is a concept that is used to allocate credits to linked accounts and to help overcome the main barriers of the original net metering strategy. This system allows the selling of energy produced by a joint renewable power source whether it is an on-site or off-site source. Virtual net metering is applied in the USA, Brazil, Australia, Greece, Canada, and other countries. Virtual net metering defrays the high capital cost of the Renewable distributed generators on multiple customers and a bigger scale will have better economic feasibility. In other a larger scale will mean cheaper unit electricity. Consumers can take advantage of making the generation more affordable. Furthermore, VNM overcomes the ownership barrier by allowing the production of a facility on an unrelated property. Investors can implement any distributing generator facility anywhere in the geographic limit of the virtual net metering program and still receive bill credits. Another driver is it allows the owner that doesn't have high generation ability in their utility to produce that power in another region with higher potential. VNM also makes the distributed generating of power more equitable by reducing the capital cost and allow groups to participate, and this helps in the integration of low- and middle-income families that had no access before. Finally, the widespread usage of virtual net metering technics will help in creating jobs and create opportunities for developers that didn't exist before. (Huecker, 2013) Even with all the mentioned benefits VNM still have some challenges. The first is the lack of experience with VNM projects. VNM is a relatively new program and it appears to have a general lack of knowledge among renewable installers. The lack of knowledge also prevents the militant's owners from benefiting from the VNM and even some of the owners did not even the existing if such a system. Finally, the VNM might require an interconnection upgrade which might be costly on the consumers (SFEnivronement, 2013).

D. Renewable energy.

Microgrids, in general, include a renewable energy source of energy which generally comes with a storage system. The drop-in renewable energy prices motivate the implementation of microgrid projects (see Figure 4). The PVs capacity has largely increased during the past decade (see Figure 2). This was mainly due to the subsidies offered by the governments and the reduction in the production cost of those cells. The European Union was leading the market (mainly Germany and Italy) until 2015 when the rate of investment in Asia super passed the European rate and this was mainly due to the investment in China and Japan (ECA, 2018).

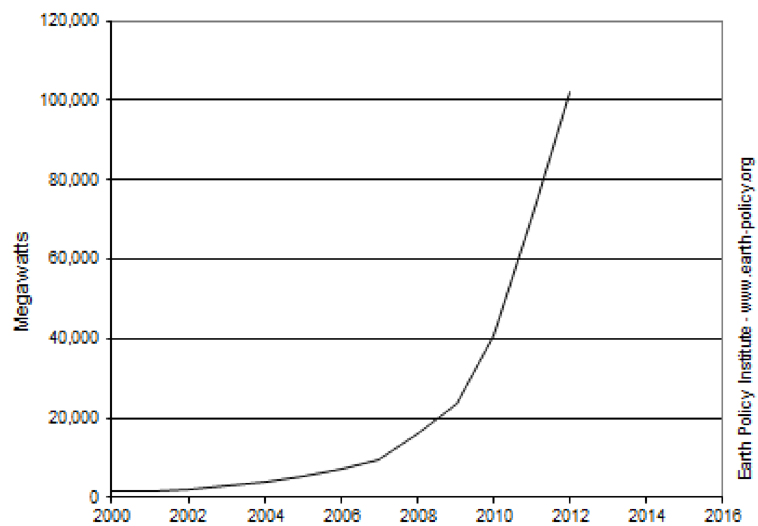


Figure 2. The growth of the solar energy produced worldwide (Solar Electricity Cost, 2018)

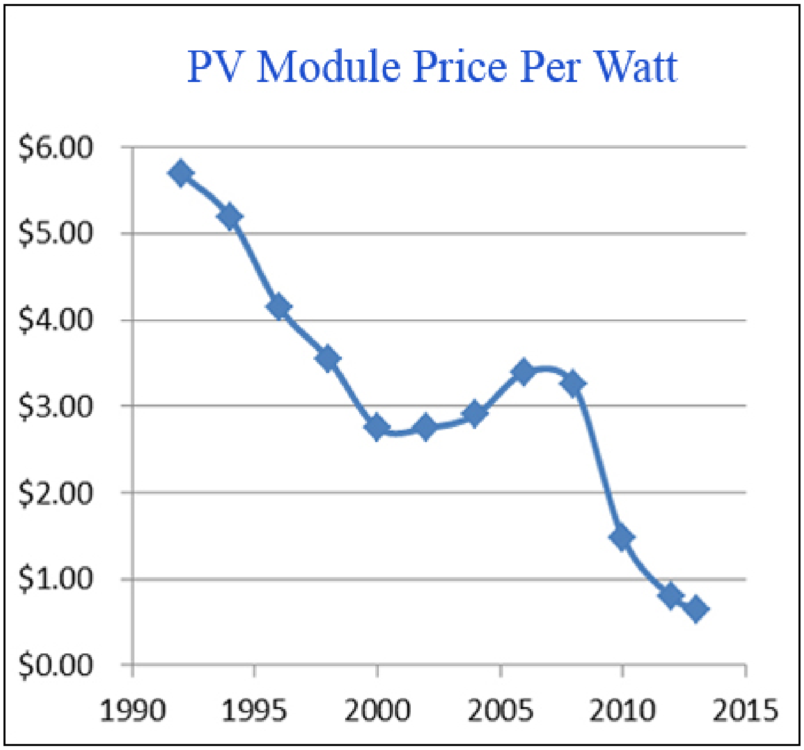


Figure 3. PV Module Price Per Watt (Kitco, 2017)

Wind turbines projects are characterized by the high capital cost and the long time needed to design and install such projects. This is in addition to the time required to get the license needed by the local authorities to start those kinds of projects which may take several years. The EU mainly lead the market until 2014 when the investment in this field from India and China has super passed the European investment. Like PV technology, wind turbine projects are becoming more and more feasible due to the subsidies and huge mass production (ECA, 2018) (see Figure 7).

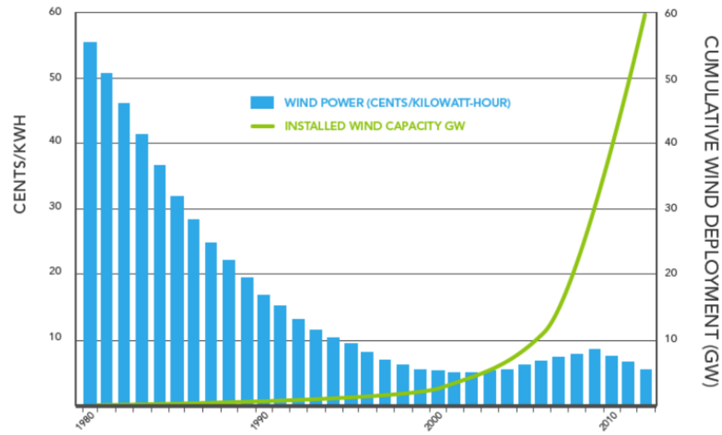


Figure 4. Wind energy cost/kWh, and the installed Capacity in GW between 1990 and 2012 (Kitco, 2017)

China is leading the RE market with more than 695 GW of installed capacity followed by the united states with approximately 245 GW then Brazil with 135 GW. Other countries leading this sector are presented in the graph below.

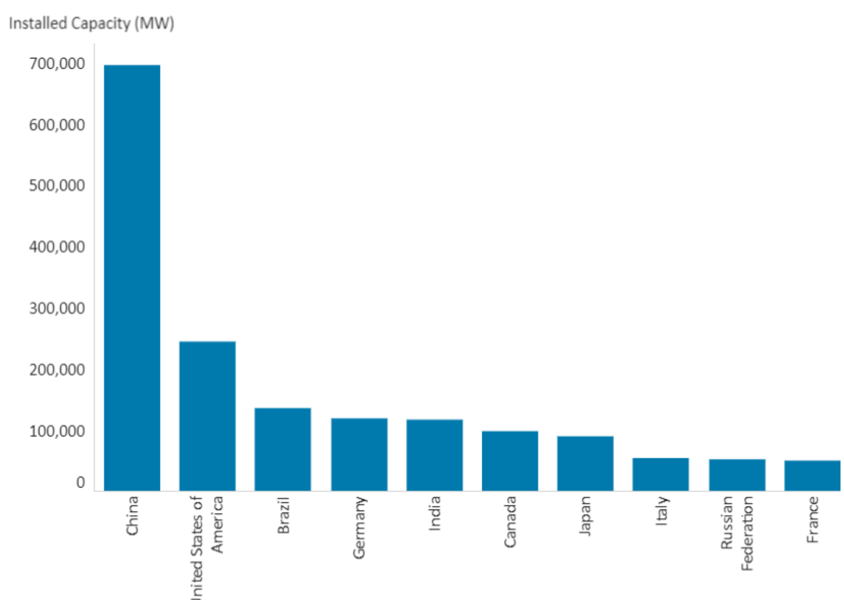


Figure 5. A histogram of the installed renewable energy capacity (IRENA, 2018)

E. Kabrikha microgrid case study

An initiative led by the European union (EU) funded UNDP-CEDRO-4 project was implemented in Kabrikha by installing a microgrid that includes a 250 kWp solar PV capacity synchronized to two existing generators of 450 and 325 KVA. The microgrid in Kabrikha will offer the electricity for the houses in the village when the grid power is off (through injecting solar power in the municipality diesel grid network) and will be connected to the main grid when utility (EDL) electricity is on. The design of the microgrid is shown in the Figure 9.

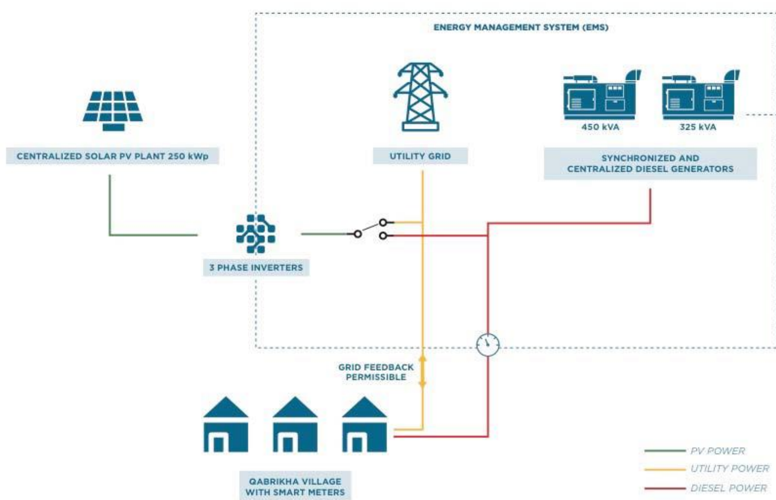


Figure 6. Kabrikha micro-grid design

This program introduces virtual net metering in Lebanon by applying the net metering scheme that falls under the EDL Decision 318-32/2011 to the community where the output of the net metering will be distributed as per an ownership subscription agreement for households or institutions. Approximately 100 households are signed up to the Kabrikha net metering scheme. However, to date, the utility (EDL) has yet to test the VNM model at Kabrikha. With the latest explosion in Beirut in August 4th, 2020, this testing will be delayed as EDL's building has been severely damaged.

Assessment on Kabrikha indicate that the savings are approximately $15,865 per year (based on oil price 60$/barrel) on reduced EDL electricity bills, and $20,850 for reduced diesel genset operations, for a total of $36,700 saving. The cost of the 250 kWp solar plant is estimated to be around 200000$ (based on an estimation 800$/kW). However, the addition of between 20% to 50% of the original price is needed to account for the additional network requirement (e.g. to connect the solar system to the diesel and the utility grid), and data collection and communication hardware that will be used by to apply virtual net metering. The expected payback period is ranging between 6.2 years and 10.2 years, and it is expected to reduce the to reduce each of the subscribed householder's bills by 220$ annually.

CHAPTER III

MICROGRIDS IN RASHAYYA'S AREA

A. Renewable Energy Drivers in Rashayya

Microgrids are considered very suitable to be implemented in Rashayya's region for several financial, technical, and environmental reasons indicated below;

1- The high solar potential in Rashayya's area. This potential is one of the highest all over Lebanon and it achieves 5.2 kWh/kWp each day for an yearly average yield of 1900 kWh/kWp as shown in the Figure 10 below.

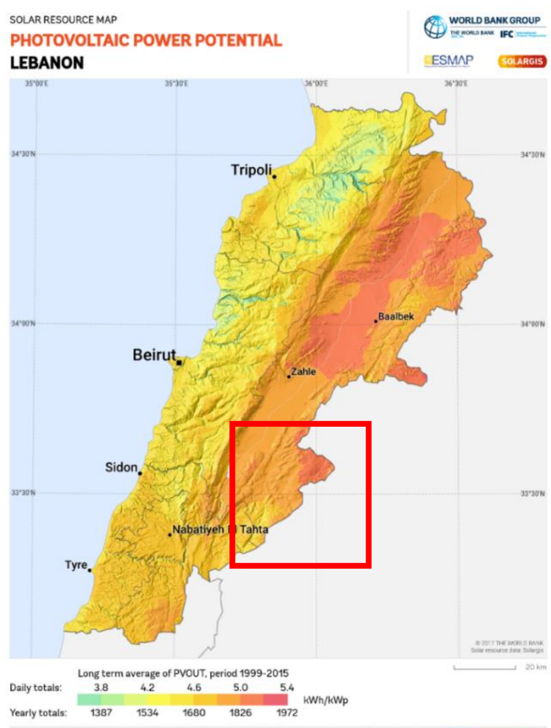


Figure 7. Photovoltaic Power Potential (The World Bank, 2017)

2- The wind energy potential: Rashayya's region is ranked second (after Akkar's region) regarding its potential to produce electricity from wind energy as shown in Figure 11. Even though Rashayya has high potential energy but in the rest of this study, we will only consider the integration of solar PV systems (the assessment of wind power is outside the scope of this thesis although it would be interesting for future research to combine solar and wind energy for Rashaya's microgrid concept).

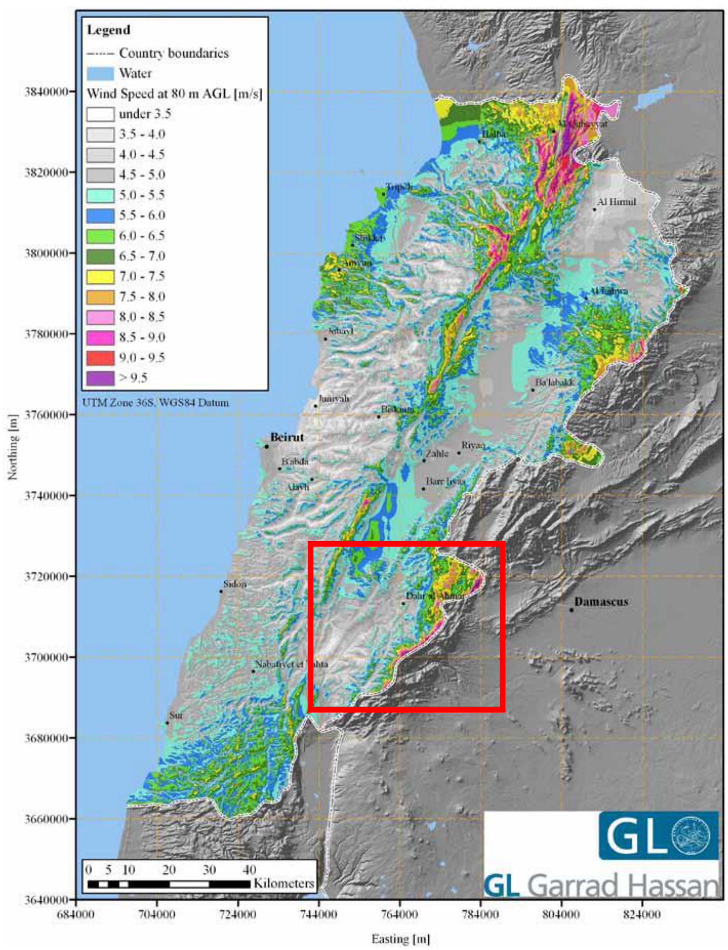


Figure 8. Central estimate wind map of the Republic of Lebanon at 80 m above ground

3- The low cost of land: The cost of $1m^2$ in Rashayya's area is approximately $5. Those areas are nearly empty and do not acquire any major activities (no agricultural nor industrial).

4- The infrastructure of the area will help also to implement such projects. The existence of many roads (Figure 12) and the electric grid will help and enhance the opportunity of implementing such projects in that area. This will lower the cost of such a project in terms of capital investment.

Figure 9. Lebanese road map

5- The presence of Syrian refugees in the area is another big driver for such projects. The United Nations programs and some European countries are contributing to develop and support the host communities. Many projects were already established and installed in this area such as solid waste treatment plants, agricultural aiding projects, reforestation projects, artificial lakes, diesel generators, and many other projects that aim to enhance the living standards and prevent immigrations. Assisting in setting up a microgrid is getting increased attention from the donor community in Lebanon.

6- In addition to the previous drivers, we also have the credibility of the local municipalities and municipality federations. The municipalities in Rashayya's area have a good reputation and good relations with the European countries and the United States. As mentioned above many projects were implemented in collaboration with the European countries including Germany, Netherland, Denmark, Italy, and many others.

7- Securing electricity for the critical departments. Rashaya has two hospitals, 1 police department, 1 firefighter department, 1 red cross emergency center, and a blood donation center. Those departments have their backup units represented by the backup generators but many of them are facing problems with the diesel generators mainly with the repair and maintenance operation which is resulting sometimes in a power outage and this is can be partially solved through a microgrid concept.

8- Microgrids also will enhance the economic situation in Rashayya. Rashayya is famous for its stove industry and it contains plastic and food processing manufactures. Those manufacturers need electricity to function and the microgrid can help in reducing the electricity problem of the grid.

9- Microgrids will motivate the implementation of renewable energy distributed generator and this will reduce GHG emission due to the usage of diesel power generators that are used to fill the gap in electricity shortage.

10- The LCOE for renewable energy sources is considered to be much lower than the LCOE from the energy produced from the Lebanese power grid or from the diesel generators. The LCOE of the different power stations owned by the government are shown in the figure below, the diesel generators LCOE is considered to be 25 cents/kWh, while the LCOE of solar and wind energy is considered to be less than 10 cents/kWh (EBRD, 2019).

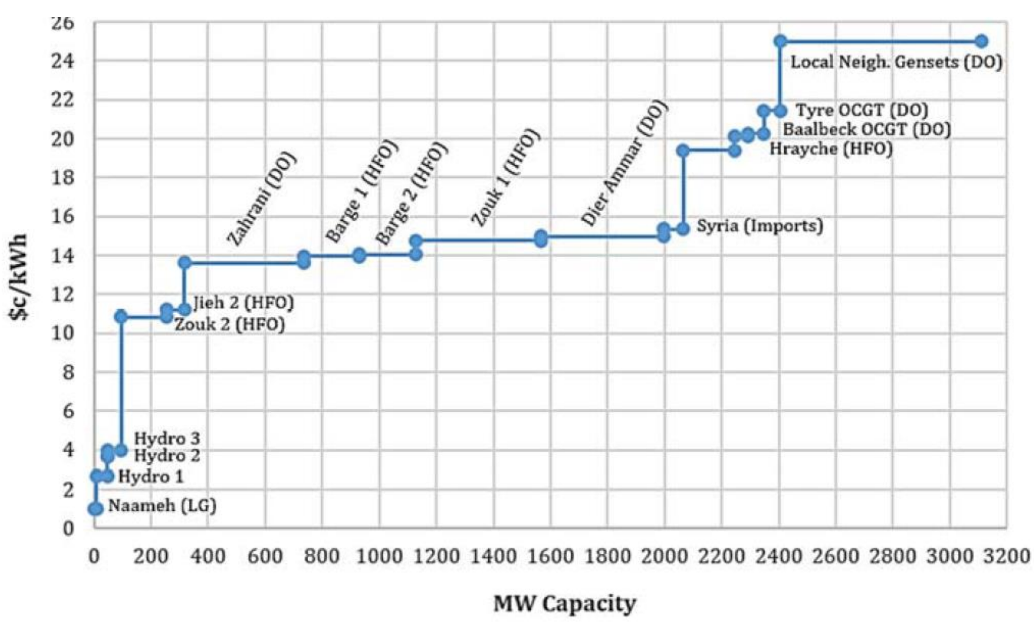


Figure 10. Generation costs of Lebanese power plants (including local genets) (EBRD, 2019)

11- Creating job opportunities; In fact, with every 10MW of distributed PV, there is the provision of 113 full-time employment opportunities (EBRD, 2019), including jobs from the installation, operation, and maintenance of the microgrids.

12- The availability of electricity at affordable prices will also enhance the educational sector. The educational sector nowadays is highly dependent on electricity and the opportunities that it offers especially the internet taking into consideration the dependency on online learning after the spreading of coronavirus.

13- Microgrids will allow the usage of a virtual net metering system. This system will help in reducing the financial barrier by including the consumer in the funding process of the microgrid. The consumer will benefit from the net metering system and reduce their bills while the municipality will benefit from obtaining the needed funds or a part of it from the local habitants.

14- The Paris Agreement, in its Article 9, states that: “Developed country Parties shall provide financial resources to assist developing country Parties concerning both mitigation and adaptation in continuation of their existing obligations under the Convention.” (PARIS AGREEMENT, 2015). This agreement will help in obtaining financial support for renewable energy sources that are a main part of the microgrids.

Screening these reasons helps to establish a theoretical vision of implementing microgrid. Following that, the example of implementing microgrid in Kfameshkeh will represent a real comparative example of implementing microgrid in Rashayya.

B. Renewable Energy Barriers in Rashayya

An interview was conducted with the president of Jabal al-sheik Municipality Federation Sheikh Saleh Abou Mansour, who is trying to implement microgrids that use renewable energy generators in the area and was a contributor to the only renewable energy project established in one of the Federation villages, (Kfarmeshkeh). President Saleh summarized the barriers that faced the establishment of such projects by the following reasons:

1- The first barrier mentioned was the huge capital cost of the PV farms or the wind turbines in addition to the cost of the infrastructure of the microgrid, and this problem increased with the Lebanese economic crisis that prevented the government from paying the municipalities their shares of revenues from the telecommunication sector. This decreased the municipality's revenues and prevented them from implementing infrastructural projects to save money for more important duties and to ensure that the employees will get their salaries and wages.

2- The second barrier is the corruption in the central government and many municipalities. Corruption is the main reason for which many European countries are not motivated to invest in Lebanon. Even if the proposal came to a happy ending, it would be after a long time and this of course is preventing the advancement in this field. Sheikh Salah stated that the federal system or at least the decentralized system is a must to develop and push future renewable energy projects.

3- Another barrier was the general knowledge of the citizens. The citizen's knowledge about renewable energy, microgrids, and VNM projects is still not mature and they do not have wide knowledge about the importance of such projects and their economic and environmental benefits, so citizens are not motivated to implement such projects or even vote for the candidates who are proposing their implementation.

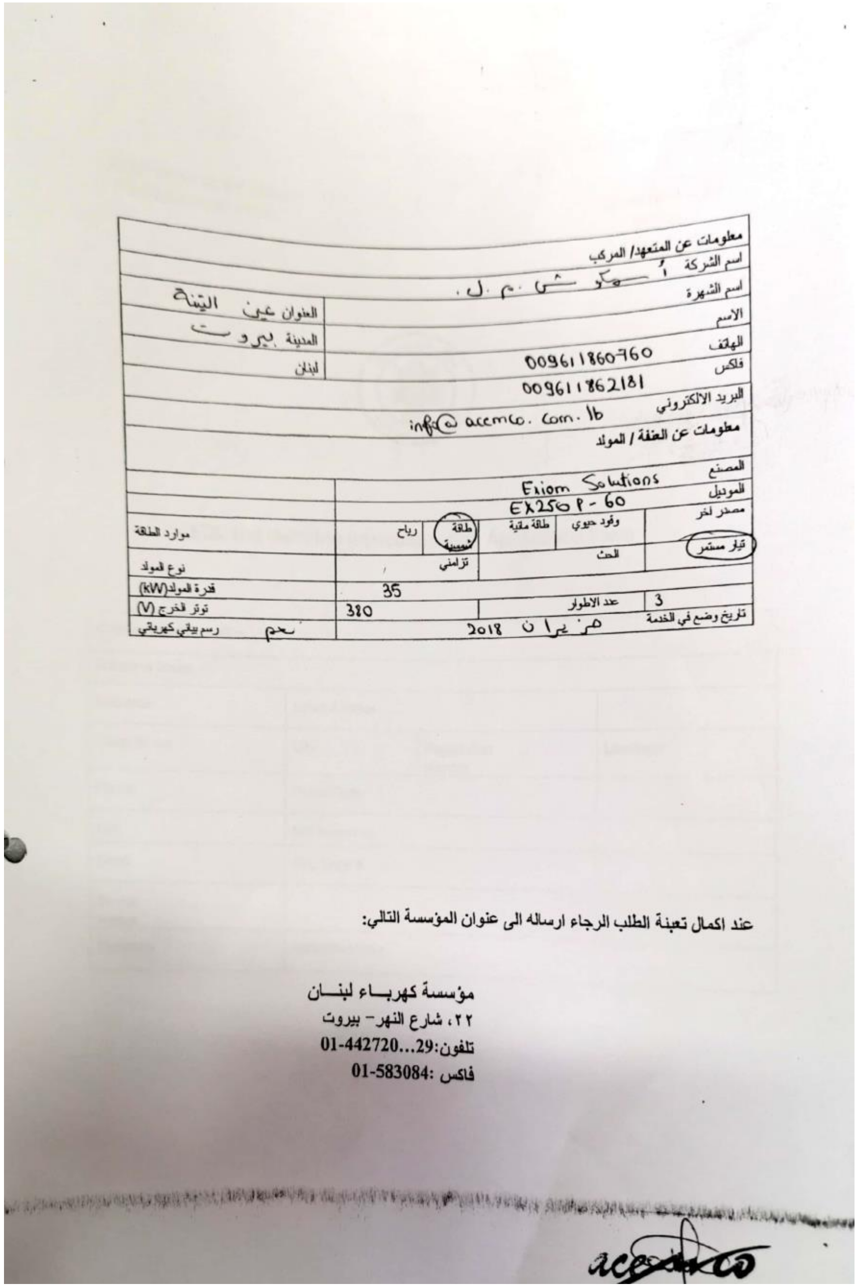
4- The fourth barrier in the opinion of Sheikh Saleh was the financial laws for municipalities. The municipalities cannot use the revenues from the power plants directly. Revenues should be placed in an account in the central bank, and then if needed, the municipality should send a petition to get the fund and this may take weeks or even months. This is a major barrier for many municipalities since they cannot wait for weeks to fix or resolve a critical problem.

5- The fifth barrier is the need for a backup system which is considered costly. On average there are 65 days without solar radiation in addition to the night hours when we cannot rely on the PV cells to generate electricity, and of course, we cannot rely on the wind turbine for the full 24 hours. The storage system does not seem a good solution for the reliability because of its huge cost and it is a relatively short lifetime which ranges between 5-8 years. So microgrids will require the backup diesel generators. Using the backup generator will increase the cost of operation and maintenance mainly the fuel and of course will increase GHG emissions.

6- The sixth barrier is the Lebanese bureaucracy in the Lebanese system. One real example is a small village in Rashayya’s area called Kfarmeshkeh which has implemented microgrid incorporation with Caritas and the USA. The project includes 220 solar panels and a generator that aims to provide the village with the needed electricity during a grid outage.

Figure 11. The solar power plant in Kfarmeshkeh (Caritas, 2019)

In fact, for applying the project, it passed by many stages. The studies start by 2014 and the net metering was not installed until late 2019. This long time is considered a huge drawback for the Lebanese system and it is preventing the advancement of the renewable energy field in the country. The net meter was installed after one year from asking for permission from the Ministry of Energy and Water (the net meter was installed in June 2019 after 1 year from taking permission in 2018) and this means that the municipality has lost 1 year of net metering.



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معلومات عن العنفة / المولد

المصنع Exiom Solutions

الموديل EX250P - 60

موارد الطاقة	رياح	طاقة شمسية	طاقة مائية	وقود حيوي	مصدر اخر
نوع المولد		تزامني		الحث	تيار مستمر
قدرة المولد(kW)	35				
توتر الخرج (V)	380			عدد الاطوار	3
رسم بياني كهربائي	نعم		حزيران 2018		تاريخ وضع في الخدمة

عند اكمال تعبئة الطلب الرجاء ارساله الى عنوان المؤسسة التالي:

مؤسسة كهربـاء لبنـان

٢٢، شارع النهر– بيروت

تلفون:01-442720...29

فاكس :01-583084

accmco

Figure 2. The form of taking permission for installing the net meter

7- The final barrier is the legal one. The laws regulating the electric sector are creating a monopoly in the sector. The main law that regulates the electric sector in Lebanon is Law number 462 this law was issued in September 2002 and it aims to unbundle the electric activities (i.e. distribution, generation, and transmission) in addition to the establishment of the national regulatory electric Authority (NERA). The law mentioned that the distribution and transmission activities should be managed by a joint-stock company first owned by the Lebanese government and which their boards are assigned from the council of minister. When the joint becomes privatized within 2 years the shares of the public sector should be sold taking into consideration that it does not exceed 40% of the total shares, and then the COM will instruct to sell the total shares to the private sector within a specified period. The Law mentioned that this should be done after the establishment of NERA which has independency on the administrative, technical and financial levels(.the Republic of Lebanon, 2002) Unfortunately, this law was never applied due to political struggles on the names of the NERA board member which prevents its establishment. Then a new Law was established in 2006 which was Law number 775 and which permits the ministry of power and water to grant licenses for private companies to generate electricity for one year and this is applicable until the establishment of NERA. But the consequences of the June war between Israel and Lebanon in 2006 prevented the implementation of this law (The dynamics of energy policy in Lebanon when research, politics, and policy fail to intersect., 2013). Similarly, another law was established in 2014 under the name Law 288 and it gives the right for the ministry of water and power to give license for electric generation for 2 years until the establishment of NERA but this law also failed and it was not able to motivate any investor to enter this field. Then the law number 54 that was extended by law number 288 gives the right for the ministry of power and water and the ministry of finance to both the send IPP proposals to the Council of Ministers who can license IPPs until the establishment of the NERA. Only one project which is a wind project was signed under this law of a total capacity exceeding 200MW. Those laws are considered major barriers for the microgrids projects. Considering these barriers, a developed analysis of implementing a microgrid in Rashayya must be conducted next.

C. Economical and Technical Study for the Implementation of a Microgrid in Rashayya's area

PV farm economic analysis:

1. The energy supplied by the grid and the private generators.

The utility grid of the Rashaya region was found to consumer approximately 21 GWh per year and 20.56 GWh per year from diesel generators. The data was collected directly from Rashayya's feeder that comes out from the central distribution utility in Jeb Janine for year 2019 and the data for the diesel generator were obtained from the Jabal Al Sheik Municipality Federation that was trying to move all distributed generators towards a single place because it increases the efficiency.

2. Load Profile.

The graphs below represent the average load profile for 1 day. This graph was obtained using the data available in the municipality of Rashayya. This data was used before in a study concerning the establishment of a single power plant instead of the distributed generators all over the village.

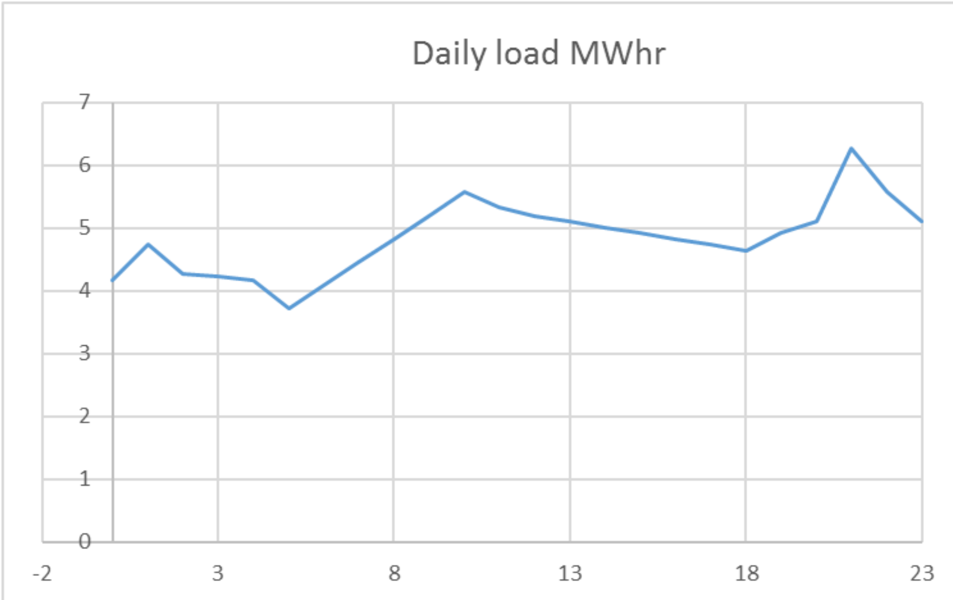

Figure 3. Rashayya Load Profile

The solar global horizontal irradiance has an annual average of 5.32/KWh/m^2. Figure 17 below shows also the daily radiation and the clearness index generated by the Homer Software.

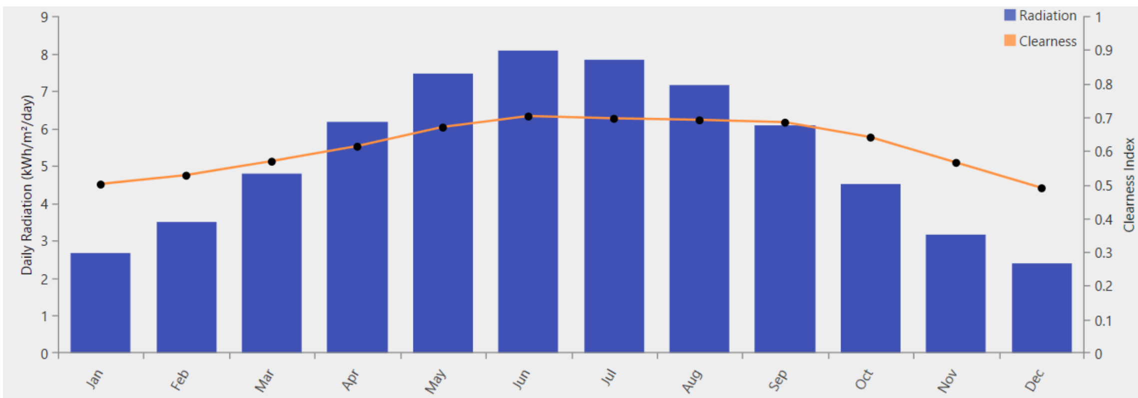

Figure 4. Daily radiation and clearance index in Rashayya's Area generated by HOMER

Upgrading of the existing system: The plan is to build a solar power plant and to transfer all of the existing generators into a single power plant and the two sources will be connected through a microgrid to the houses and the main grid.

3. System Modeling

Priority of Operation:

The supply of electricity as mentioned above comes from three sources the electric generators, the grid, and the solar panels. The priority will be for the solar PV system if the energy produced exceeds the demand the excess will be dropped into the grid. When the PV system cannot meet the load demand, the balance will be supplied by the grid whenever it is available and from the diesel generators at all other times. (Chedid & Ghajar, 2019)
The PV cell used will have the following characteristics:

Table 1: Solar panel Characteristics

Characteristic	Value
Power (W)	300
Capital Cost ($/kW)	700
Efficiency (%)	18
NOCT (°C)	45
Temperature Effect on Power (%/°C)	-0.39

The output of this cell is of 300W in the ideal case but at the project condition, the output will change with the temperature at the project site.

The calculation of the output of the solar system is indicated below:

First, we need to get the ambient temperature and this is available from the Homer resources (Figure 18).

Figure 5. Average daily temperature in Rashayya's Area generated by HOMER

Then the temperature of the cell is calculated as:

$$T_{cell} = T_{amb} + \frac{NOCT - 20°\text{C}}{0.8} \times 1 = 38.5°\text{C}$$

Then under the project condition the power produced will become:

$$P_{dc,PTC} = 300 \times [1 - 0.0039 \times (38.5° - 25°)] = 284.2W$$

Assuming that the combined dirt and mismatch losses amount to 10% and the inverter efficiency is 95%, then the power output would be equal to 243W or approximately 240W. the solar panels should supply the same value that the diesel generators produce.

The energy supplied by the generator in the year 2019 is equal to 20.56 GWh:

$$P_{ac,PTC} = \frac{Energy\ (kWh/year)}{(4.8\, h/day\, @1\ SUN) \times 365} = \frac{20.56 \times 10^6}{4.8 \times 365} = 11.735\ MW$$

The equivalent DC power under STC is:

$$P_{dc,STC} = \frac{P_{ac,PTC}}{0.8} = \frac{11.73}{0.8} = 14.65MW$$

The total area needed for the plant is:

$$A = \frac{P_{dc,STC}}{1(kW/m^2) \times efficiency} = \frac{14650\ kW}{1(kW/m^2) \times 18\%} = 81834\ m^2$$

EDL Grid:

The EDL grid is not reliable at all. The grid has cycles of 6-4-4-4-6 in which the grid is switching between on and off. Figure 19 below is generated using the HOMER software where the y-axis represents the hours of the day while the x-axis represents the days of the year. The black color signifies the electricity outage while the green color represents the normal functioning of the grid.

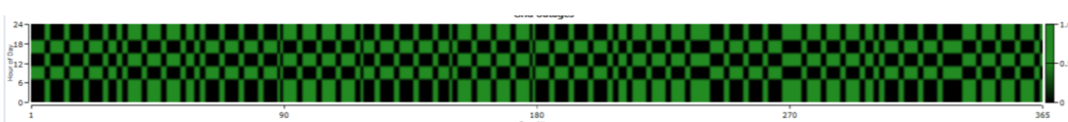

Figure 6. Grid outage and normal functioning generated by HOMER

During outages, the generators managed by the municipality technician turn on to fill the needs of Rashayya's citizens. According to the municipality the generators run at an average cost of 0.23$/kWh this cost is highly affected by the diesel cost which is unstable and it includes the cost of oil and maintenance.

4. Simulations Results:

The system simulation was done with an estimated lifetime period equals to 25 years. This period is considered logical since the PV effective lifetime is considered to be 25 years. The model was simulated at a discount rate equals to 8% and an inflation rate equals 2%. After the simulation, the cheapest system was found to be the hybrid Grid-Generators with the PVs farm in comparison to the already existing system which is represented by the combination of the grid with 18 generators. The system is formed of PVs with a total capacity of 1565 kW priced at $700/kW which results in a total capital cost of 1,100,000$ while the diesel generators were purchased at 60000$ (for the 18 generators with capacity 450KW). The grid is considered to have infinite capacity and modeled at 9999999 kW. The LCOE of the new system is equal to 0.168$ while it was 0.225 in the already applied system. The emission reduces by 19670135kg/year and the fuel consumption reduces by around 7565436L per year.

Table 2: Payback period generated by HOMER

Metric	Value
Net Present Cost ($)	17.2M
Internal Rate of Return (%)	18.2
Simple Payback period (yr)	5.45
Discounted Payback period (yr)	6.76

CHAPTER IV

CONCLUSION AND RECOMMENDATION

A. Conclusion and Result Analysis

The electric sector in Lebanon suffers and it was a major reason for the debt in Lebanon. The Lebanese government is subsidizing the electric sector with more than 2 billion each year. Lebanese citizens also suffer from the power outage that can reach up to 12 hours in some Lebanese areas even after the usage of 2 barrages to help in reducing this gap. Moreover, Lebanon depends heavily on fossil fuel in producing the electricity and this leads to energy insecurity taking into consideration that Lebanon is a pure consumer of fossil fuel and it did not have any proven oil or gas resources yet.

Microgrids which are becoming more and more popular worldwide (in developing and developed countries) is proposed by many experts to be a solution for the above mentioned electric problems. The microgrid can provide relatively reliable electric current and can help in reducing the deficit by using renewable energy power sources which can feed the grid with the excess power. Moreover, the microgrid will increase energy security and help in energy diversification.

According to the data collected in this research Rashayya is considered to be a perfect location to implement renewable energy using microgrids project in Lebanon which are motivated by the Electricity Plan for many reasons including The High Photovoltaic Potential in Rashayya's area, the high wind energy potential, The low cost of land, and the credibility of the local municipalities and municipality federation. The simulation of a microgrid that delivers the electricity to Rashayya's villages shows that it will be financially feasible. Implementing the VNM program will help in reducing the capital cost on the municipalities and it will allow the consumer in Rashayya to benefit from the net metering system and this will offer more reliable electricity at a lower price.

The barriers for implementing such project in Rashayya's area was found to be the huge capital cost of the microgrids infrastructure and the PV farms, the corruption in the central government and many municipalities, the general knowledge of the citizens, the financial laws for municipalities, the reliability of the renewable energy resources, the current laws and regulation that regulates the electric sector, the Lebanese bureaucracy, and the absence of the local expertise.

Fighting those barriers is a must to enhance the electric sector and driver microgrids projects forward. Fighting corruption can use the strategy proposed by Mohinder Gulati and M.Y. Rao this plan is divided into 4 main categories: Governance Variables, Institutional and Policy Variables, Process Variables, and Utility Management Variables. This strategy suggests including employee incentives which may be Protection to honest staff, and Penalty for collusion with the consumer, Improve Utility business processes and use modern technology which increases transparency in the application of procedures, and finally Political commitment which includes No interference in favor of influential offenders. Institutional mechanisms for accountability may include regulatory and legal issues like establishing norms and standards, Ensuring regular audits, Support of judicial system, and independent monitoring. Finally, this strategy increases public participation by making the information accessible to the public. (Gulati, et al., 2006)

The financial law for municipalities should be reformed. But because the policymaking process in Lebanon takes time a solution that was adopted by the municipality of Rashayya can be a temporary solution. The municipality of Rashayya is forming an NGO that is formed from some local experts' in the energy, economic, financial, and legal fields in addition to "AL-MAkhateer" to run the financial resources that are generated from the production of the diesel generator microgrid and this will solve the financial problem for municipalities and increase the transparency by making the data and information available for public.

Another basic step to overcoming the above-mentioned barriers would be changing the law and regulations that regulate the electric sector and preventing the advancement of microgrids projects. Jordan has been ranked 3rd regarding renewable energy production and Lebanon can benefit a lot from this experience especially that Lebanon and Jordan share any similar similarities regarding the energy sector including the availability of fossil fuel resources and the geographical location. One major reason for this achievement was the unbundling of the three-sector transmission, distribution, and generation and their privation as shown in the figure. The Energy and Minerals Regulatory Commission (EMRC) is an entity with administrative and financial independence established by the law No. 17 in 2014 by which three entities were merged to form EMRC. EMRC provides licenses for power providers and distributors in addition to setting the electricity tariffs. (RES4MED, 2019)

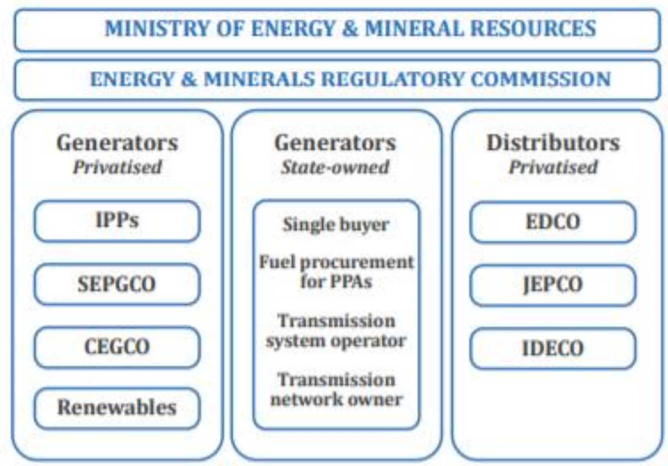

Figure 17: Electricity Sector System in Jordan (RES4MED, 2019)

NERA also should be established and the Law number 462 which is going to allow the entrance of the private sector into the field of generating electricity and this will increase the competitiveness and the diversification of electricity resources and this results in better and more reliable service, and with lower cost.

Moreover, the Lebanese government should try to reduce bureaucracy. The experience of Kfarmeshkeh with net metering was not a good one and this was mainly due to the bureaucracy. The government can use anti bureaucracy policies that twill surely motivate microgrids this might include: focusing on the need to reduce procurement costs, avoiding the need for repeated form-filling, increasing the efficiency of the procurement of framework contracts, increasing the commercial skills of the Senior Civil Service to improve decision-making, improving decision-making by selecting and managing consultants effectively, ensuring that training and guidance emphasize the importance of focusing on outcomes rather than processes. (Boateng, et al., 2003)

The general knowledge and the availability of skilled workers are also a major barrier in making microgrids popular and increase their implementation rate. Kabrikha village was an example of how general knowledge can affect microgrids. 100 houses have agreed to participate in the V-24 program that uses microgrid technology with net metering. General knowledge can be enhanced through conferences, media coverage, educational system, and another way. Also, to enhancing general knowledge of this sector some workshop can be done like the one that was established in Qaroun village that treats microgrid and solar system installation, in addition, the two institutes located in Rashayya are highly motivated to adopt a program that treats microgrid, renewable energy systems, and net metering. (You Rise, 2019)

B. Recommendation

Many recommendations should be taken into consideration following the literature review:

1- Enhance the Net metering system. The net metering system that exists today does not motivate investment in the renewable energy sector. The net metering should allow the carrying of the excess of energy for next year, or maybe the government should consider moving into the Feed-in-Tariffs and virtual net metering system strategies in this way the investor will be more motivated to invest in this sector and to increase the production capacity for microgrids.

2- A corporation with other countries and to benefit from their experience. For example, the Jordanian ministry of energy and mineral resources to get benefit from its experience in the field of renewable energy and microgrids.

3- the municipalities are highly motivated to fight corruption to build trust with the donors and get the needed funds. Moreover, fighting corruption will allow us to have a lower Levelized cost of electricity and motivate investors to invest in this field.

4- The formation of the National Electricity Regulatory Authority (NERA) as soon as possible to isolate the energy sector from any political influence which will surely help in motivating the filed in Lebanon. The political parties should put their benefit away and try to push this sector forward for the benefit of the Lebanese citizens. This will help in getting a license for microgrids and make it legal which will motivate investors to invest in this field. Also, the update the electricity generation laws in such a way to motivate the private sector to enter the market, to give better regulation to the sector. The laws should motivate the BOT and PPA projects which attracts investment from the private sector and overcome a major barrier which is the huge capital cost of such projects.

5- Reducing the bureaucracy in getting a license and installing net meters. The bureaucracy was one major challenge regarding the implementation of the microgrid that is formed from a diesel generator and a PV farm in Kfarmeshkeh and it prevents the benefit from net metering for 3 years. Bureaucracy is a major barrier for private investment and it prevents the advancement of the sector and the implementation of those projects in Rashayya.

6- The municipalities of Rashayya have to contact European countries to get funds for implementing such projects. The major barrier for implement renewable energy projects in Rashayya is a financial one. The municipalities can overcome those barriers by contacting European countries that are interested in renewable energy projects and are motivated by the Kyoto Protocol and the CDM in addition to their will to implement projects that will help in improving the life of Syrian refugees which might prevent their immigration towards their countries.

7- Enhancing the general knowledge about renewable energy and establishing a workshop to train skilled workers. This step can be incorporation with NGOs that have huge experience with offering such a workshop. Those workshops will prepare the foundation for implementing renewable energy projects and will motivate the private investors to invest mainly due to the availability of the skilled workers that will help in reducing the cost of installing the renewable energy project.

8- Introducing virtual net metering concepts to the residence and policymakers. This technique will largely influence the microgrid's projects and help in overcoming their major barrier which considered to be the financial one.

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