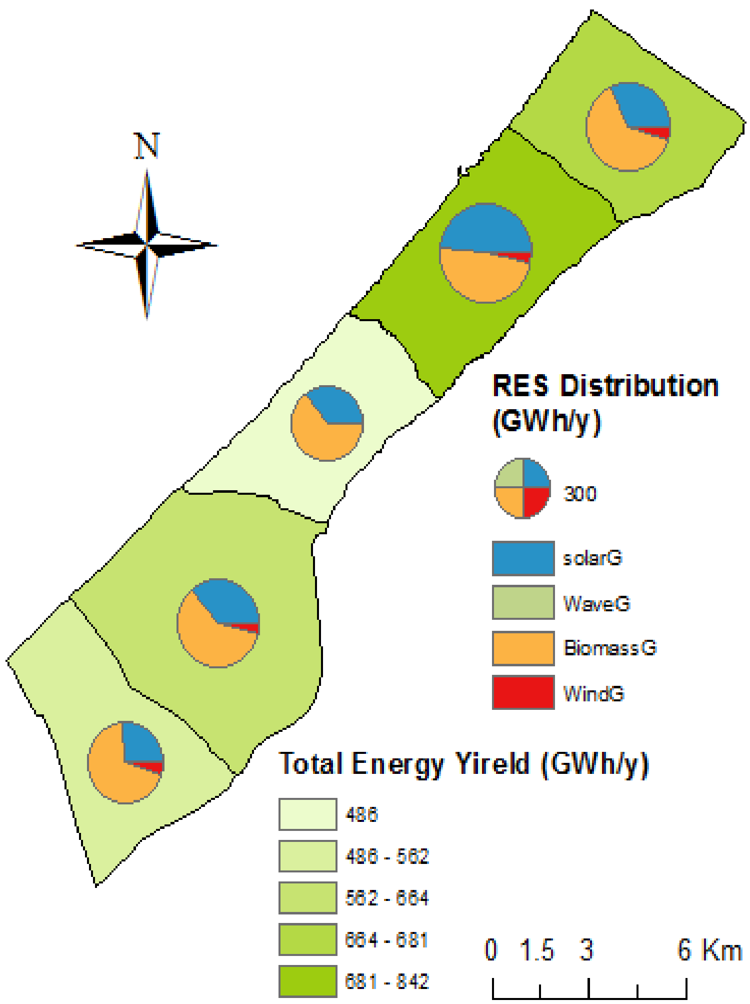
Friends of the Earth Palestine

A Just Recovery Renewable Energy Plan for Gaza: Opportunities and Challenges



Source: AlNajjar et.al., 2020

2021

Acronyms

DNI	Direct Normal Irradiation
GDP	Gross Domestic Product
GHI	Global Horizontal Irradiation
GTI	Global Tilted Irradiation (GTI)
GWh	Giga What per hour
GEDCO	Gaza Electric Company
MWh	Mega what per hour
KWh	Kilo What per hour
PCBS	Palestinian Central Bureau of Statistics
PENRA	Palestinian Energy and Natural Resources Authority
m2	Meter square

Table of Contents

List of Figures

1. Introduction

The Gaza Strip is a narrow strip stretching along the southeast corner of the Mediterranean. It is about 41 km long, the narrowest width is 6 km and the widest is 12 km wide, with a total area of 365 km^2. It lies on Longitude 34°26′ east and Latitude 31° 10′ north of the equator. According to the last census of the Palestinian Central Bureau of Statistics, 2018, the population of Gaza Strip was estimated at 2.09 million. The average population density is 4986 people per square kilometres, while in the camps, the density can rise to as high as 100,000 people per square kilometres.

The Gaza Strip is categorized as tropical region with a relatively hot summer and mild winter with daily average temperature and relative humidity vary in the ranges of 13.3 °C to25.4 °C and 67% to 75%, respectively.

Energy problem in Gaza is among many other problems that affect social and economic conditions of the Palestinian People. The fact that most of the energy is imported with relatively higher prices places more economic burdens on the poor and marginal people.

Furthermore, the fact that the electricity used in Gaza Strip is totally controlled by Israel either directly or indirectly places additional complexity and increase the energy insecurity in Gaza. Gaza power generation plant was securing nearly 100 megawatts of electricity. The produced quantity has considerably decreased due to the repeated bombarding of the electric power station by Israel while the produced portion is being dependent on Israeli controls of fuel supply to Gaza as well. The fuel quantities allowed to enter Gaza are sufficient to produce nearly 65 megawatt of electricity which is equivalent to only 12% of the electricity demand in Gaza.

The current study will try to highlight the main social, natural, political and economic challenges and obstacle that facing securing household electricity needs in Gaza from pure renewable energy sources.

2. Objectives

The main objective of this study is to examine the possibility of household electricity coverage from pure renewable energy sources in Gaza.

3. Methodology

The methodology used in developing the study can be summarized as follows:

1. Reviewing existing published material on renewable energy and electricity consumption and generation.

2. Reviewing the National strategies, laws and policies, Solar atlas related to renewable energy and electricity in Gaza.

3. Meeting with relevant stakeholders, mainly Palestinian Energy Authority and discuss the main issues and needs as well as gaps.

4. Calculating electricity demand based on the household electricity average monthly use and considering the population number and growth rate as reported by Palestinian Central Bureau of Statistics (PCBS) and average household size.

5. Considering two scenarios for projecting demand. The first is do nothing scenario which is based on the assumption that household electricity use is constant and losses remain at its current level of nearly 25% over the coming decade, while the second scenario is the improved scenario which assumes that efficiency is improved and 5% saving in household electricity use is achieved following the PENRA's energy efficiency plan 2020-2026.

6. Studying the main obstacles and constraints that may affect the realization of project objective, e.g., space needed for solar energy panels versus available space, economic, political, etc.

7. Identify the other potential renewable energy sources including wind energy, bio mass and wave.

4. Electricity Supply and Demand

4.1. Electricity Supply and Use

Current Gaza's electricity supply comes from two sources (after the stop of supply from Egypt): the first being Israel's electricity company, which supplies 120 mw of electricity to the Gaza Strip through ten lines; the second being the Gaza Power Plant, the transformers and fuel tanks of which have been bombed multiple times by Israel since 2006 and of which the capacity has been reduced from 140 mw to 70 mw, as shown in figure 1.

According to the Gaza Electricity Distribution Corporation (GEDCO), the ban on the entry of fuel used to operate the power plant has caused a decline in the amount of electricity produced by the plant, which has a current capacity of no more than 45 MW. As a result, the aggregate amount of electricity available in the Gaza Strip from all sources is about 116 mw[1], while the average demand ranges between 425 mw during the morning hours and increases during the day and evening to exceed 540 MW. GEDCO estimated that the gap between supply and demand of electricity is about 75%, prompting the company to supply only four hours of electricity at a time followed by 16 hours of power cut.

[1] http://www.mezan.org/en/post/23999

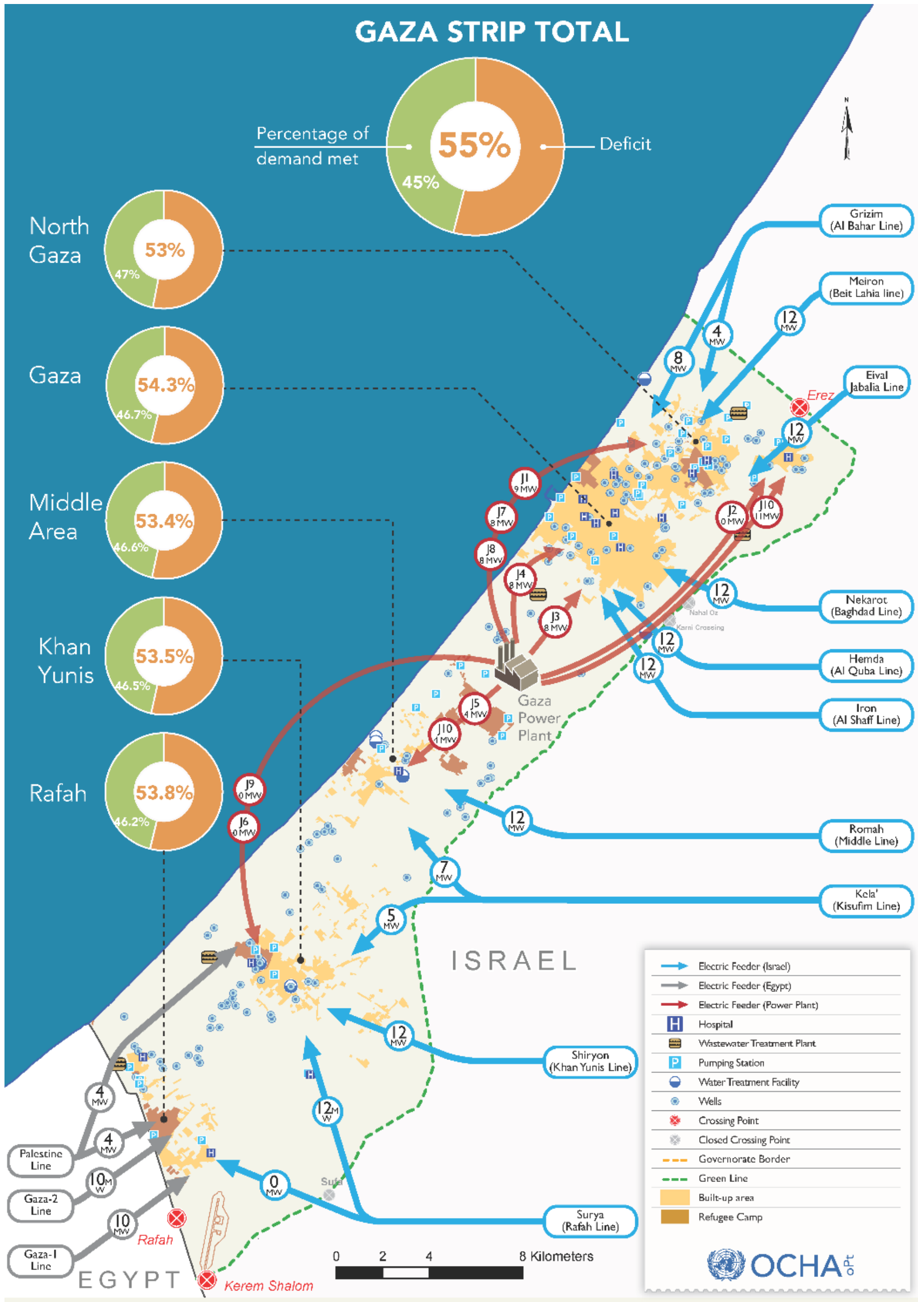


Figure 1: Main Electricity Supply Sources to Gaza

This power cut and shortage has severely affected the availability of essential services, particularly health, water and sanitation services, and undermined Gaza's fragile economy, particularly the manufacturing and agriculture sectors as reported by OCHA, 2021[2] .

[2] https://www.ochaopt.org › page › gaza-strip-electricity

It is worth noting however, that the information reported by GEDCO, shows a downward trend in the electricity demand from the company from 2017 to 2021 as shown in figure 2.

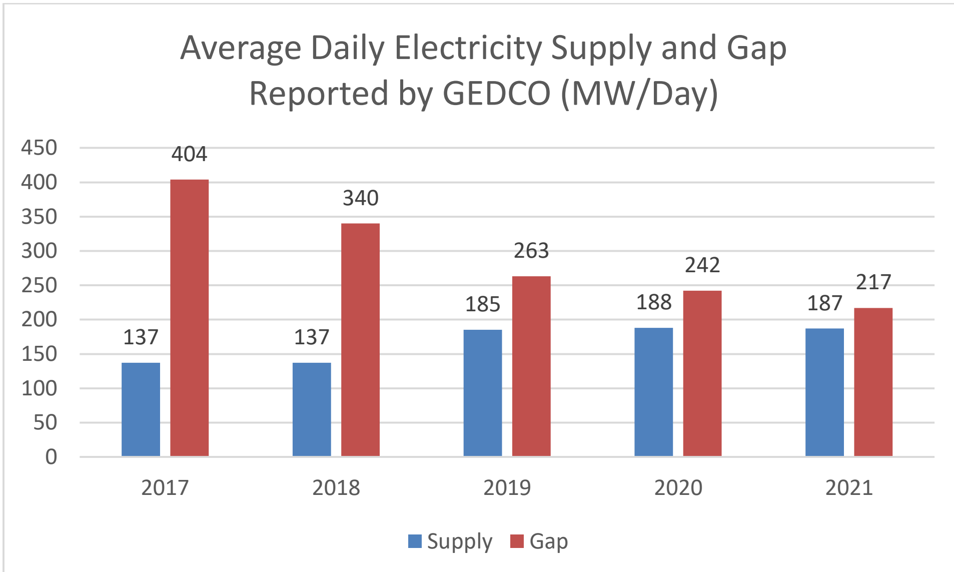


Figure 2: Electricity daily supply and gap from GEDCO

As can be seen from Figure 2, gap between the electricity supply from GEDCO has declined by nearly 187 MW/day between 2017 and 2021 without increase in supply managed by GEDCO. This might suggest that the small-scale decentralized electricity generation run by private sector is likely the main cause for this decline but it is not likely that the demand has decreased below the levels reported by GEDCO earlier e.g., 540 MW/day.

Nonetheless, someone can also assume that demand has fallen due to the deteriorated economic conditions resulted from the prolonged blockade which affected people's ability to pay for the service especially because the cost of electricity is high. A recent study by ICRC 2021, has shown that nearly 500,000 people in Gaza can't afford paying for electricity from private suppliers and thus not having electricity.

According to PCBS, the monthly average household electricity consumption (based on consumption during January 2015) was 265 KWh in Gaza.

In the meantime, there is big variation in electric supply across Gaza governorates with the largest supply registered in Gaza City according to 2013 statistics as reported by Juaidi et.al (2016) as shown in Figure 3.

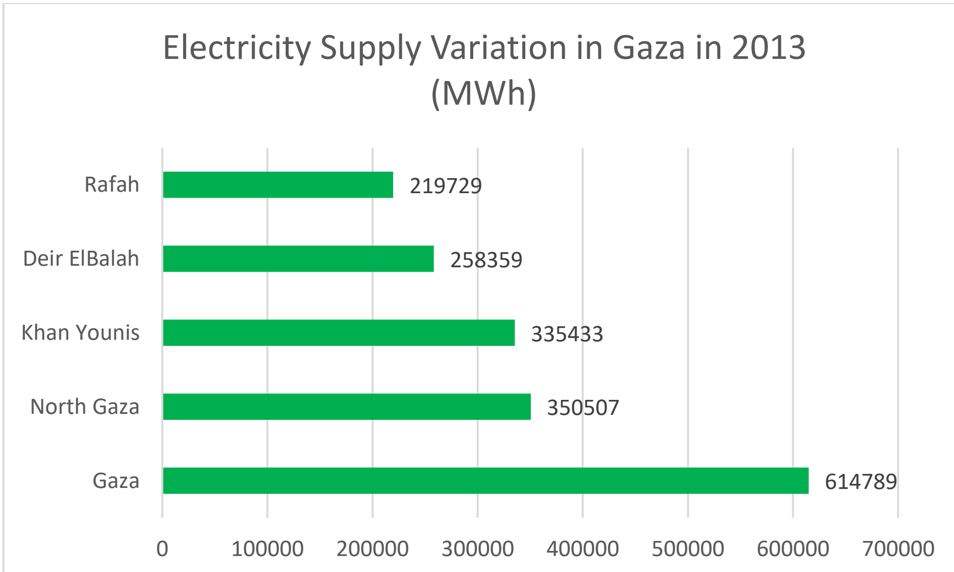


Figure 3: Amount of Electricity Supply by Governorate

This huge variation is largely due to population number from one part and also the commercial and light industrial activity presence on the other part. As population grows and development needs increase, it is also expected that the need will increase as well. The next section will address the demand for electricity in Gaza.

4.2. Electricity Demand

In 2008 the average electricity consumption was about 282.2 megawatt while currently it has reached a peak demand of 540 megawatts as reported by GEDCO and is expected to increase to about 701 megawatts in 2025 as reported by Palestinian Energy Authority. The peak demand usually occurs during winter when people use electricity for indoor heating. Peak demand is of a particular significance especially when there is a lack of fuel for use in indoor heating instead of electricity. Summer involves another peak demand period manifested in the need for air conditioning leading to additional electricity consumption. However, the summer peak is lower than the winter peak, because fewer households have access to air conditioning equipment than those with access to the relatively affordable electric indoor heaters. According to the Palestinian Energy Authority, it is expected that peak demand on electricity will double toward the year 2025 as shown in Figure 4.

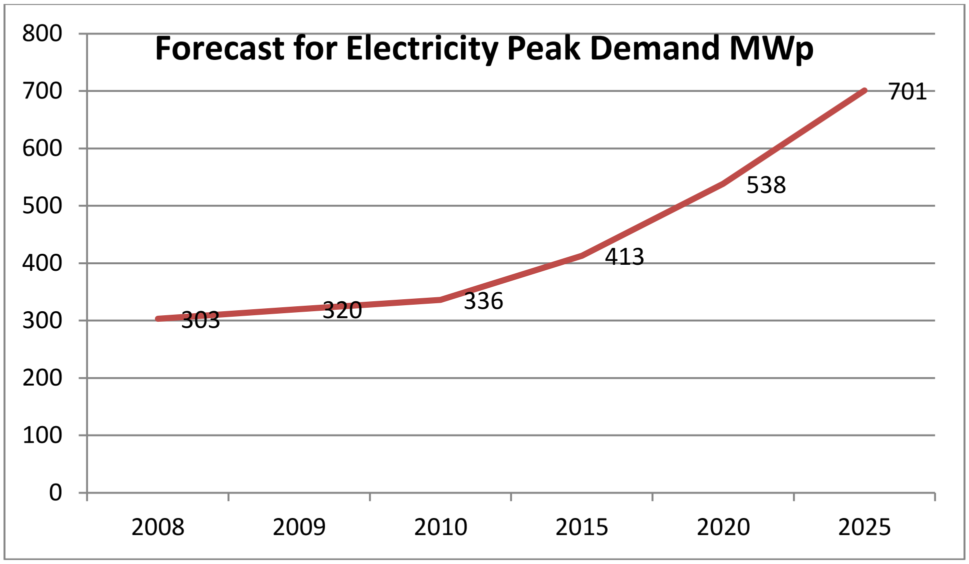


Figure 4: Electricity Peak Demand toward 2025

In addition, demand for electricity will increase in the coming decade due to population growth, urban expansion and development of commercial and industrial activities. Urbanization in Gaza has increased enormously during the past three decades. It increased from 3% in 1972 to 47% of total area in 2013 as shown in figure 5 and will reach 58.83% (212.3 km2) by 2023 as reported by Abuelaish et.al (2016).

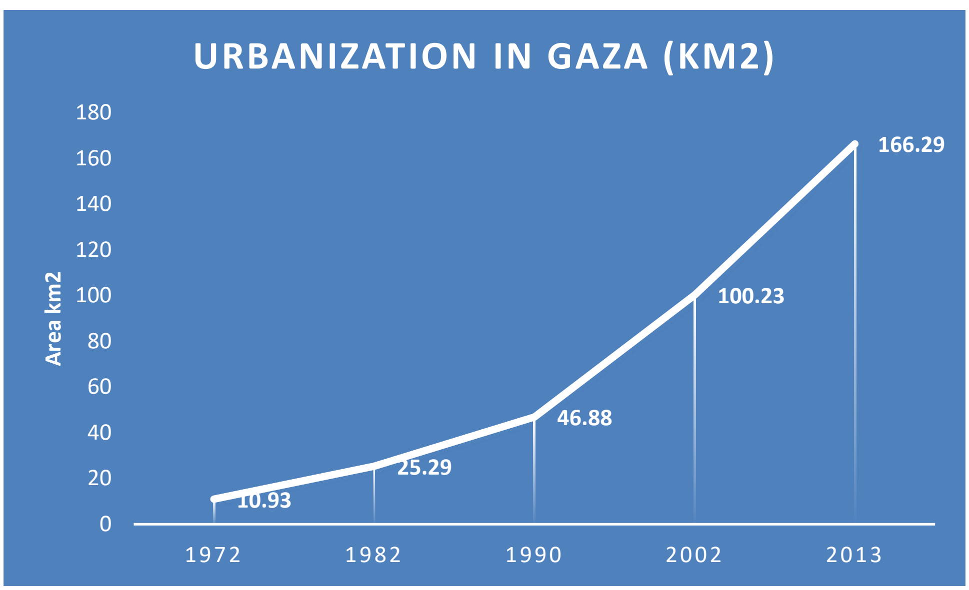


Figure 5: Rapid Urbanization in Gaza

However, for the purpose of this report, the main factors that will be considered for calculating electricity demand under each scenario can be summarized as follows:

1. Current Situation

The main assumptions under this scenario are as follows:

1. Household monthly demand is constant over the coming decade and stays at the average monthly household use of 265 KW.
2. Electricity conveyance system has the capacity to supply the quantity needed and losses is nearly 25% as stands now.
3. Electricity Supply is on the basis of 24 hours supply.
4. Number of households, number of population and growth rate is at 2.9% as reported by PCBS 2017 and average family size - household size is 5.5 persons.
5. GDP will be around its current average value of 450$/capita

Based on the above assumptions, total monthly household electricity demand will increase by 34% over the coming decade up to 2030. The highest increase will be in Gaza of 41.7GW/ month while the lowest will be in Rafah of 16 GW/month as shown in Figure 6.

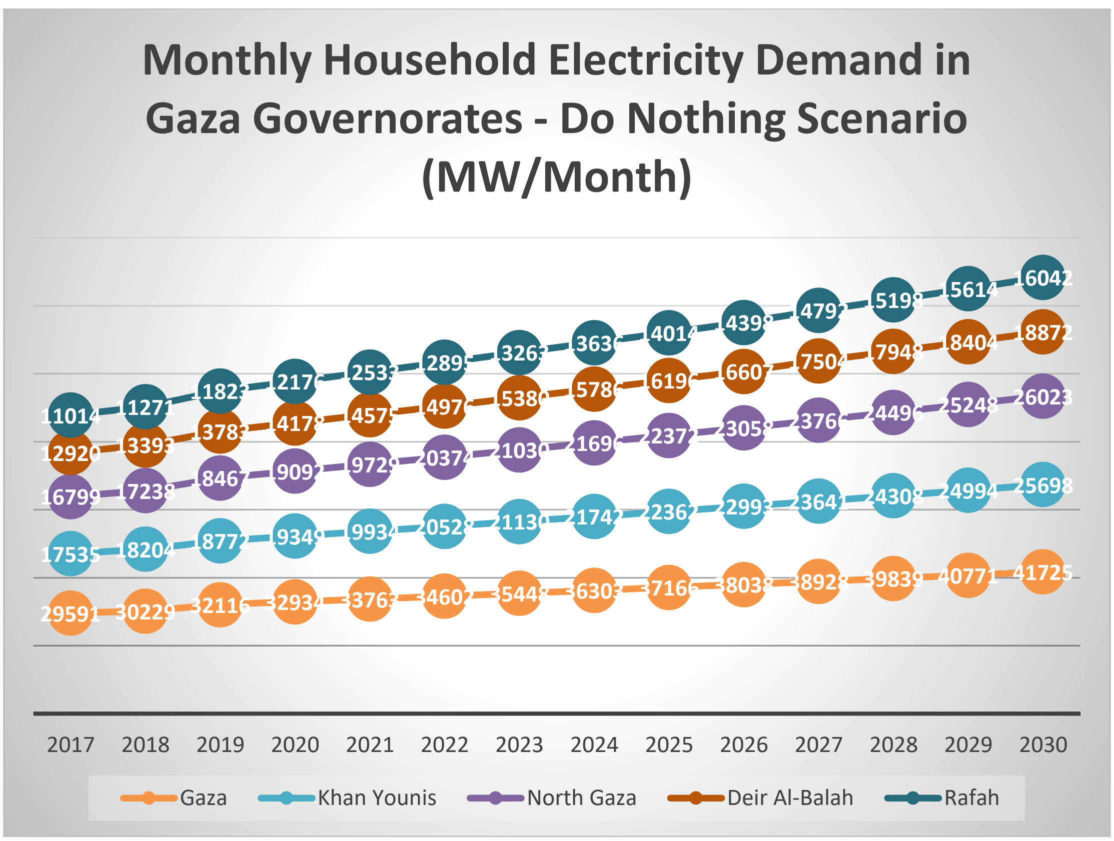


Figure 6: Household Electricity Demand Do Nothing Scenario MWh/month

When looked at the overall demand for the entire Gaza Strip, it was noticed that electricity demand will grow from its current level of 778 GW/Year to 1040 GW/ Year as shown in Figure 7.

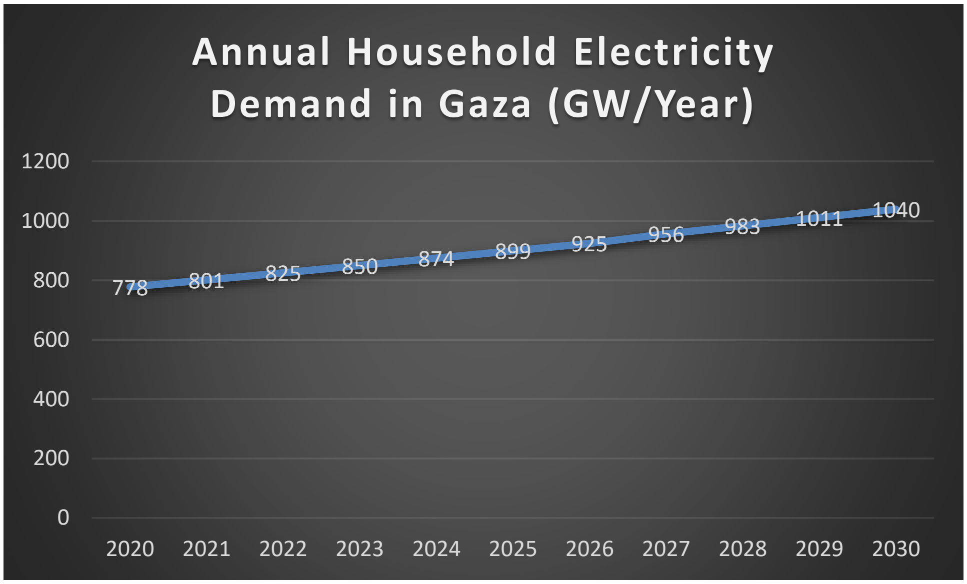


Figure 7: Annual Household Electricity Demand Do Nothing Scenario GWh/Year

Nonetheless, in order to be able to meet this demand at the assumed monthly levels, electricity supply must be increased by 25% to account for system losses. This means that the monthly total electricity supply will vary from 972 GWh/month to 1300 GWh/ Month in 2030 as shown in Figure 8.

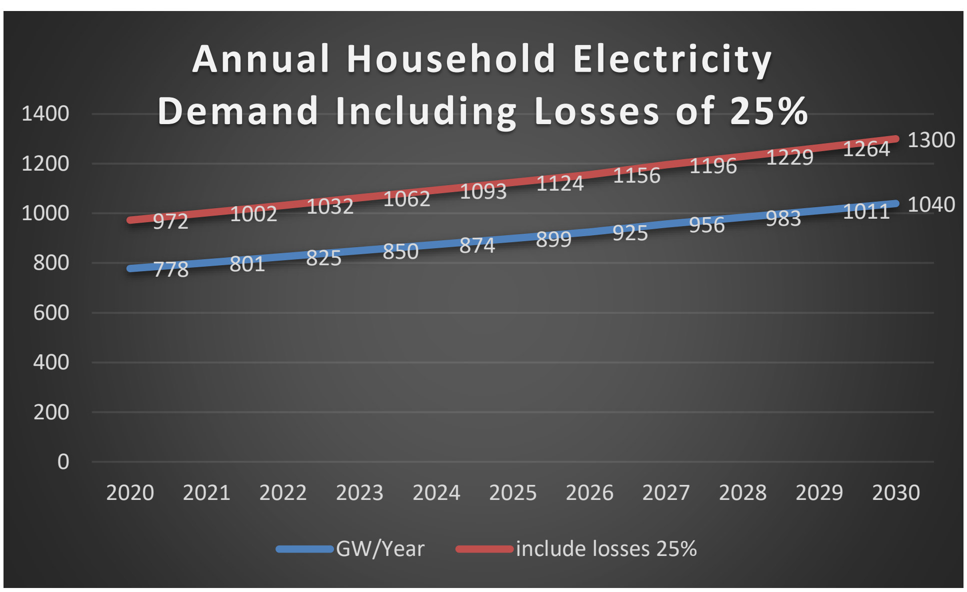


Figure 8: Annual Household Electricity Demand Do Nothing Scenario including Losses of 25% (GWh/Year)

2. Conservation Scenario

The main assumptions under this scenario can be summarized as follows:

1. Electricity demand will be based on improved average household electricity conservation of 5% lower than current monthly consumption rate of 265 KWh.
2. Demand will grow with population growth (hence the number of households) but more conservation measures are considered in line with the energy efficiency action plan proposed by the Palestinian Energy Authority for the period 2020 - 2030. In this scenario it is assumed that electricity savings will be 5%.
3. Electricity conveyance system has the capacity to supply the quantity needed while efficiency is increased and losses reduced by 10%.
4. Population growth is the same as current scenario, 2.9% and average family size is 5.5 persons.
5. GDP will be around its current average value of 450$/ Capita

It is projected that total monthly household electricity demand will increase by 34% over the coming decade up to 2030. The highest increase will be in Gaza of 39.6 GW/ month while the lowest will be in Rafah of 15.2 GW/month as shown in Figure 9.

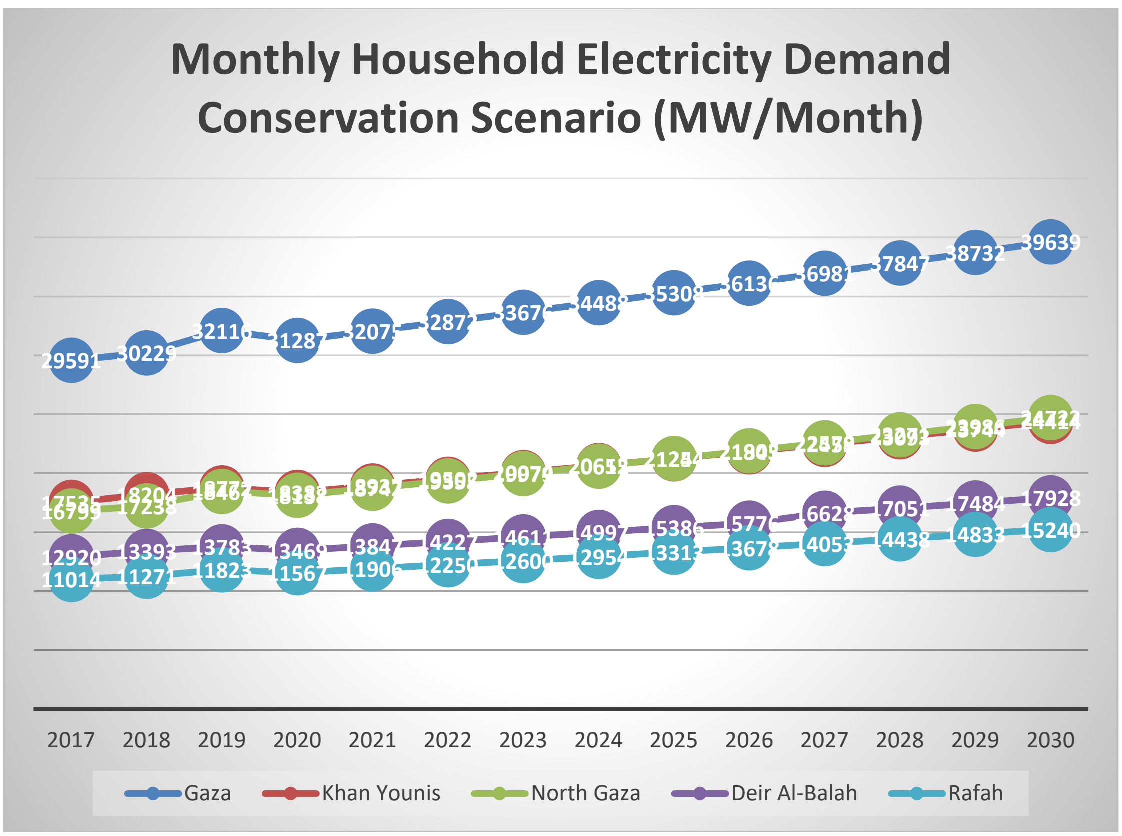


Figure 9: Monthly Household Electricity Demand in Gaza Governorates Conservation Scenario (MW/Month)

In addition, annual household demand will reach 988 GWh in 2030 as shown in Figure10.

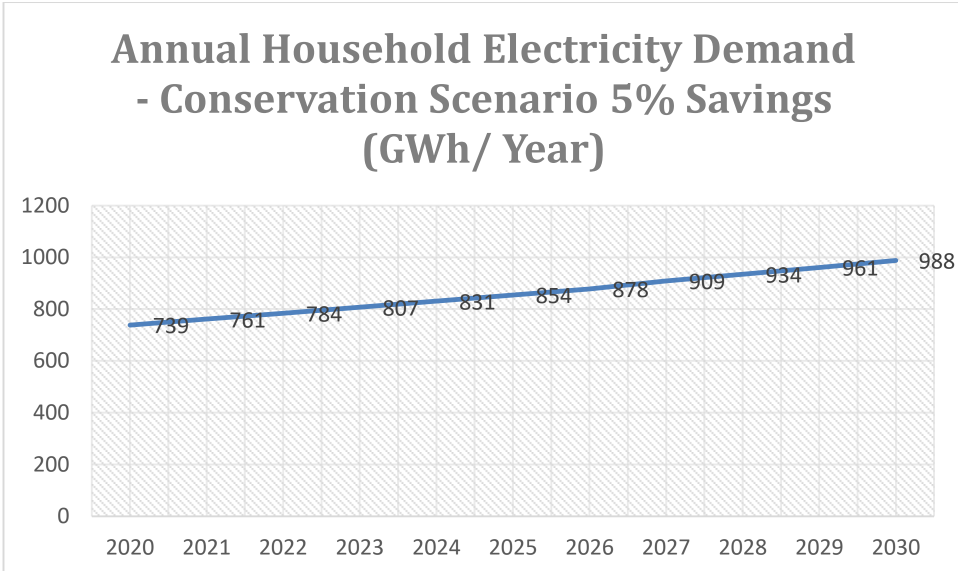


Figure 10: Annual Household Electricity Demand CS GWh/Year

Nonetheless, in order to be able to meet this demand at the assumed monthly levels, electricity supply must be increased by 25% to account for system losses. This means that the monthly total electricity supply will vary from 849 GWh/month to 1136 GWh/ Month in 2030 as shown in Figure 11.

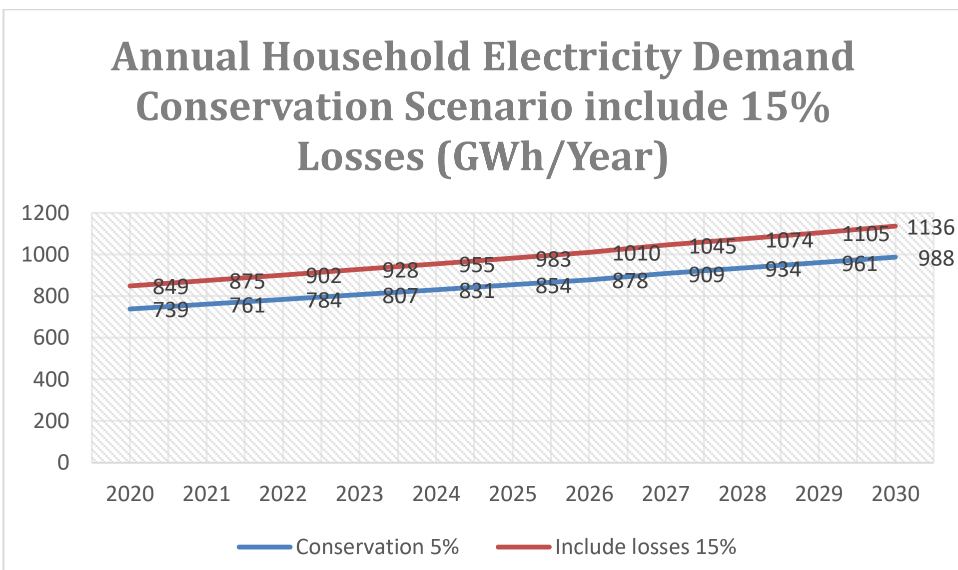


Figure 11: Annual Household Electricity Demand CS including losses GWh/Yr

When comparing the two scenarios it was realized that total electricity saved over the coming decade will be 1566 GWh as shown in Figure 12.

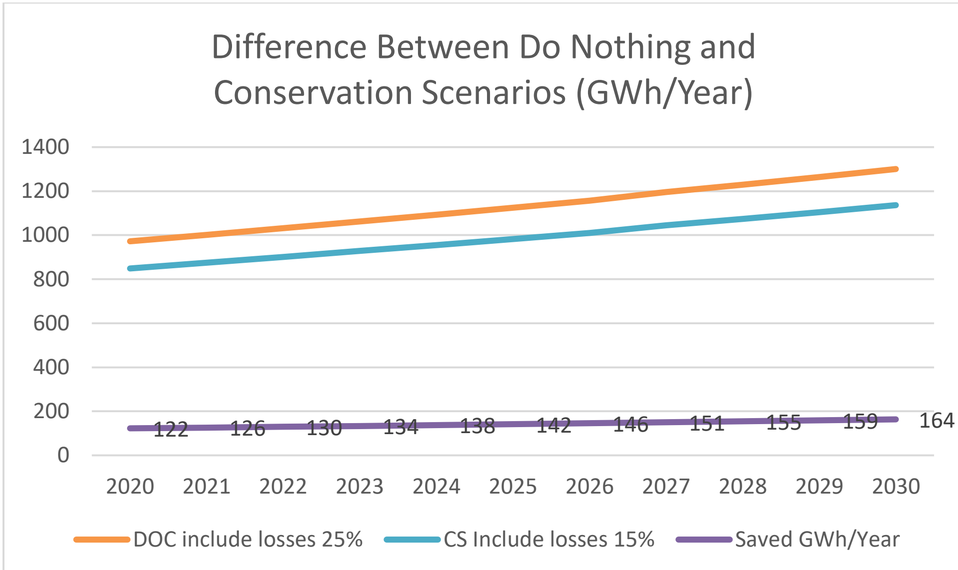


Figure 12: Comparison between Do Nothing and Conservation Scenarios - GWh/Yr

It is clear that conservation scenario, if considered, will create more positive impact on environment and will reduce CO2 emission by 1.16 million Ton over the coming decade as shown in Figure 13.

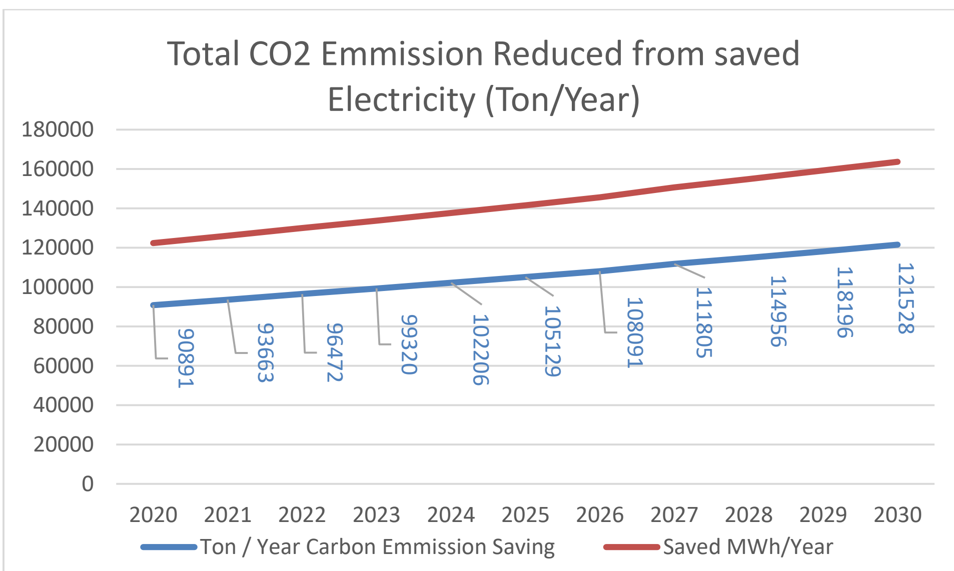


Figure 13: Reduced CO2 Emissions (Ton/Year)

In the light of projected growth in demand for household electricity, the heavy reliance on external sources (especially Israel) for the supply of electricity, the high costs of electricity and environmental impacts associated with using traditional energy sources to generate electricity, and given the long blockade imposed on Gaza with severe restrictions on the import of fossil fuel needed to generate own electricity from Gaza Power Plant, it is imperative to consider all possible alternative sources that can supply adequate and sustainable energy, taking into account cost-effectiveness and people affordability as well as environmental concern mainly climate change and reduction of CO2 emission. Renewable energy alternatives are of special interest in Palestine and highly encouraged by Palestinian Energy Authority through the Solar Initiative, the Energy Action Plan and other initiatives to help meet the growing electricity demand and increase Palestinian energy security. The following sections will address the potential renewable energy sources in Gaza.

5. Renewable Energy Sources in Gaza

5.1. Wind Energy

Wind speed measurements are not fully available for all Gaza Strip. However, data on wind speed can be obtained from meteo-climate diagrams based on climate simulation models. Such data can give an indication of the potential suitability of any given location for wind energy generation. Yet, surface measurements for wind speed and availability throughout the year is needed prior to any decisions for considering such locations as viable for wind energy production. The long term average wind speed at 10 m height above surface as reported by PENRA 2016, can be shown in Figure 14.

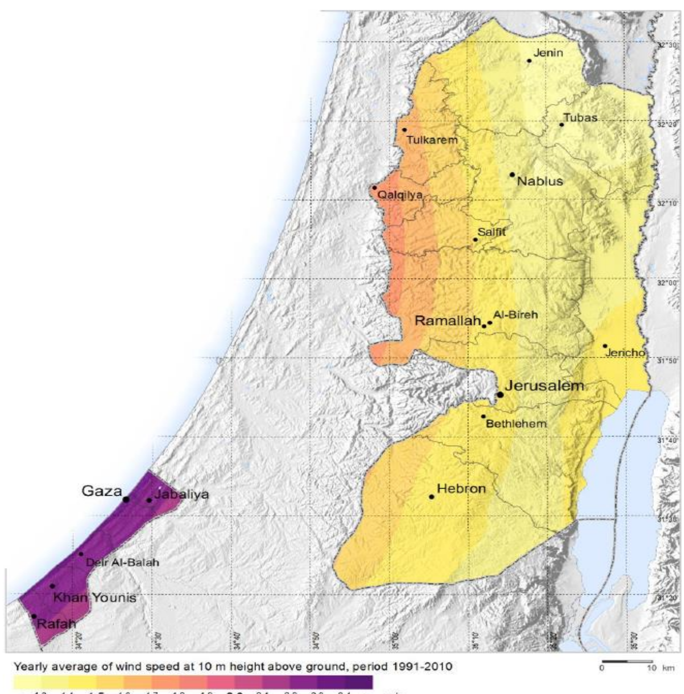


Figure 14: Average Wind Speed at 10 m above ground surface

It can be noticed from figure 14 that wind speed at 10 m height above ground surface in Palestine (both West Bank and Gaza) is generally low and vary from 1.2 m/s to >2.5 m/s. In the meantime, wind speed recorded in Gaza at 40 m height above ground surface proved to be better. It was found that maximum wind speed occurs in February and reaches 7 m/s while it is minimum in August and reaches around 3.7 m/s with yearly average wind speed of nearly 4.7 m/s at Gaza coastline as reported by PENRA, 2016.

Therefore, the current wind speed levels may not be considered as economically feasible options since they fall below the required wind speed level of 12 m/s.

The energy outputs from wind turbines vary in accordance with wind speed. The nominal energy output of wind turbines is achieved at 12 m/s wind speed and decrease with decreasing wind speed as shown in Table 1.

Table 1: Wind energy loss with decreasing wind speeds

Wind speed	Nominal energy output of wind generator (%)	Actual energy output of the same wind generator (%)	Energy loss (%)
12m/s	100%	100%	0
8m/s	100%	44.4%	55.6%
6m/s	100%	25%	75%
4m/s	100%	11.1%	88.9%
3m/s (minimum required wins speed)	100%	6.2%	93.8%
2 m/s	100%	0	100%

Source PENRA (2016)

In conclusion, wind generation in Gaza can be possible at the coastline even though it may not be fully economically feasible given that the actual output will not exceed 40% of the turbines in the best cases. But this needs a long-term record for wind speed on the ground before moving to this decision.

5.2. Bio energy

Agricultural residues, animal manure, food processing wastes and organic municipal waste constitute the largest portion of biomass sources in Gaza. According to Prof. Abdel Majeed Nassar- reported by Heinrich Boll 2019, total solid waste production in Gaza in 2020 reached 2,230 tons per day of which 65% is organic, 11% is plastic and 12% is paper. The produced waste is either sent to already overloaded landfills or randomly dumped in the shrinking spaces in Gaza causing huge environmental and health hazard problems. Despite the fact that converting biomass into clean energy is simple and economical technology and is ideal in the case of Gaza, especially with the limited space required to install, there is no any mean exist yet to utilize this biomass resources for generating energy through digesters, which indeed is considered a lost opportunity in Gaza.

Al Najjar, et. al., 2020, reported that there are different sources of biomass resources such as Municipal solid waste, sewage sludge, agricultural residue and animal manure, especially poultry farms. The quantity of biomass generated from these sources as shown in Figure 15.

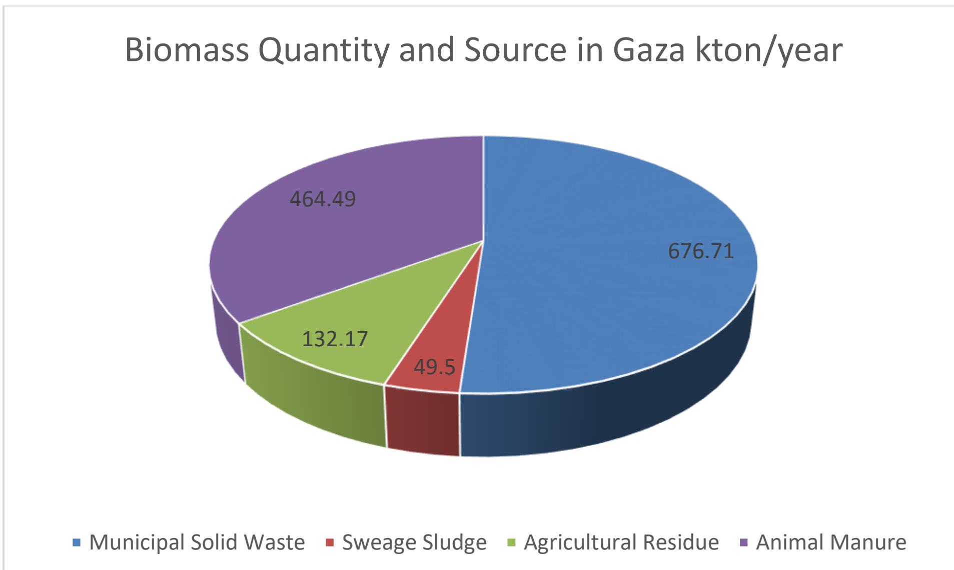


Figure 15: Biomass sources and quantity in Gaza kton/year

Al Najjar et.al., also concluded that the most significant source of biomass that has the highest potential energy generation is the animal manure followed by the agricultural residue and municipal solid waste where the quantity of potential thermal energy that can be generated from these three sources is nearly 1910.7 GWh/year as shown in Figure 16.

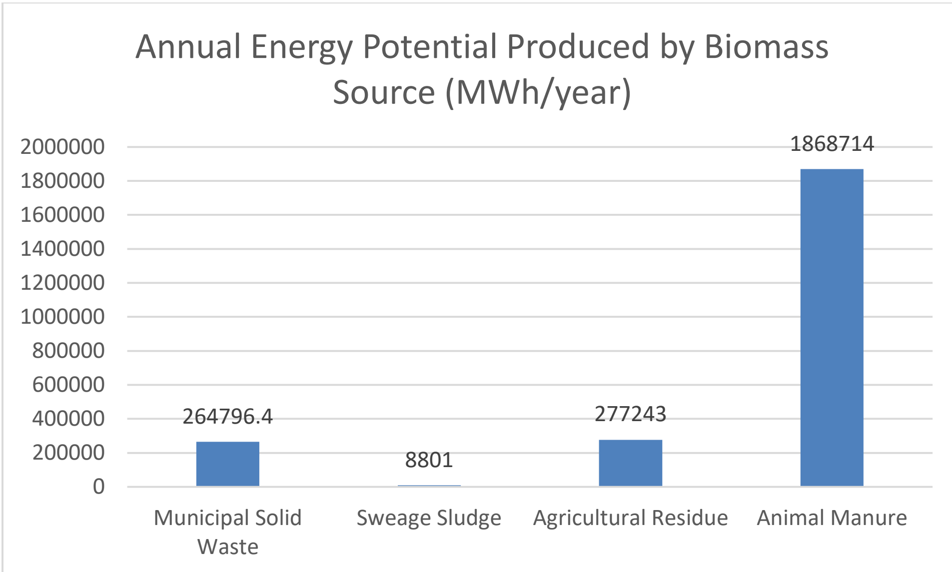


Figure 16: Biomass sources and quantity of energy produced MWh/year

Based on these figures reported by Al Najjar et.al. 2020, the produced equivalent electricity from the thermal energy produced from biomass sources is nearly 671.8 GWh/year which is sufficient to meet 60% of the household annual electricity need in Gaza (1136 GWh/year) as calculated in this research.

Potential energy generation from the various biomass sources in the different governorates of Gaza has also been developed by Al Najjar et.al., as shown in Figure 17.

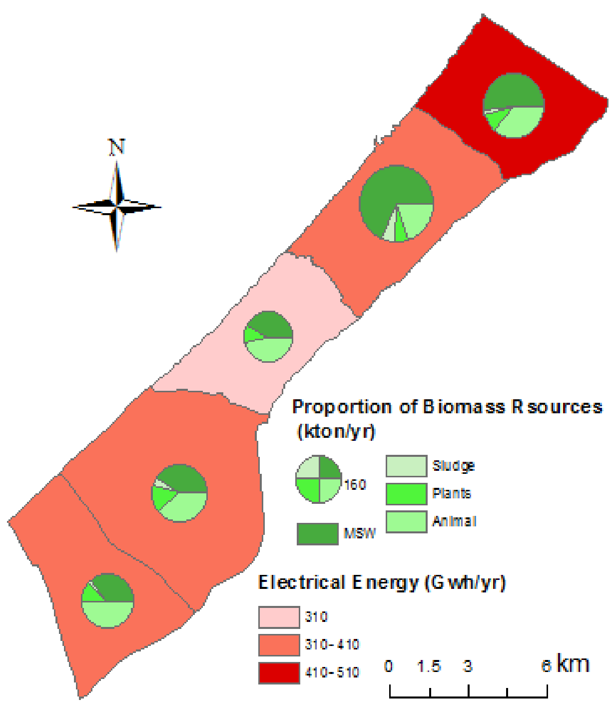


Figure 17: Biomass sources and quantity of electricity produced in Gaza GWh/year

5.3. Wave Energy

Utilizing wave energy in Gaza is still premature and requires detailed information on the wave velocity and duration. It also requires the identification of the best location to place the equipment for generating energy from the waves.

Research conducted by Eco Clinic Gaza (2020) has reported some information about wave direction and velocity and they showed that average velocity recorded in January 2018 is nearly 0.007574 m/s to the Northern Direction as shown in Figure 18.

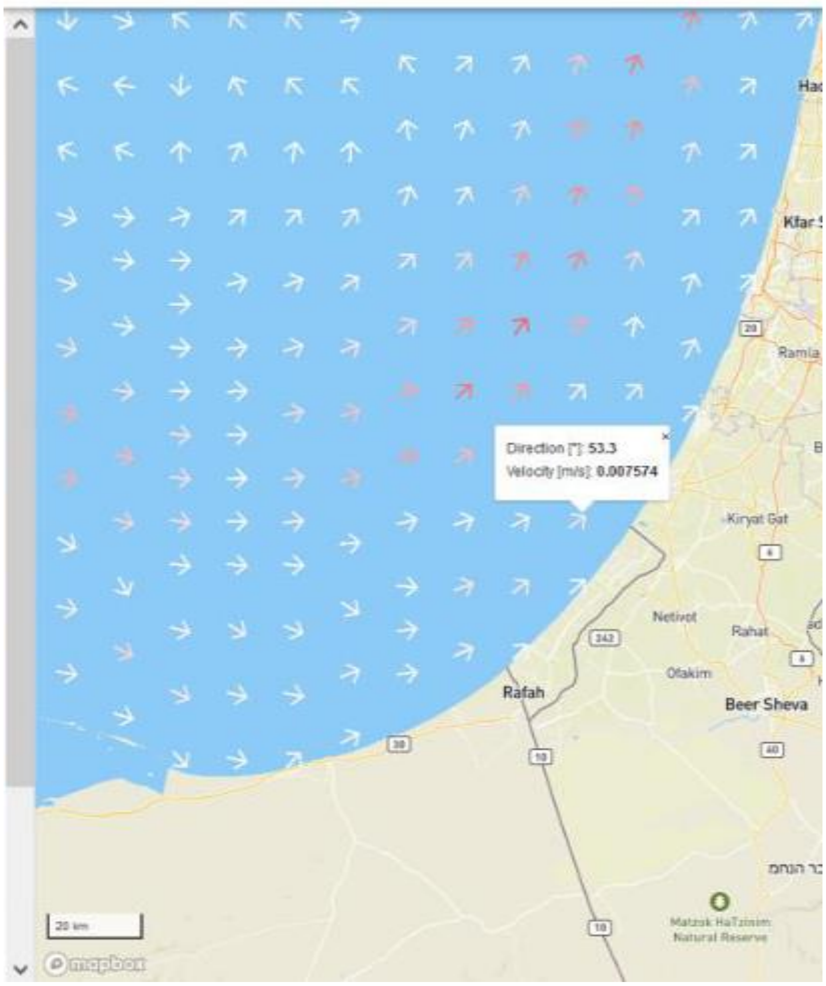


Figure 18: Wave velocity and direction

In addition, the Islamic University in Gaza has monitored potential energy from wave in some places in Gaza coast. In addition, another study conducted by Al Najjar et.al., 2020 reported that two wave parameters, including wave height and wave cycle time, are very important for the estimation of wave energy in the sea. They found that wave duration varies between 3.2 s and 3.6 s and the wave height varies between 0.561 m and 0.67 m in different seasons in the northern Mediterranean coastal area of the GS. They concluded that in the light of wave height and duration, the average wave power extractable from the Mediterranean shoreline is between 1.2 kW/m and 2 kW/m. The average annual wave power density is determined by dividing the total annual available energy (AAE) density in MWh/year by the number of hours in a year as shown in Figure 19 along the coast. AAE densities are generally between 11.3 and 17.52 MWh/m along the coast.

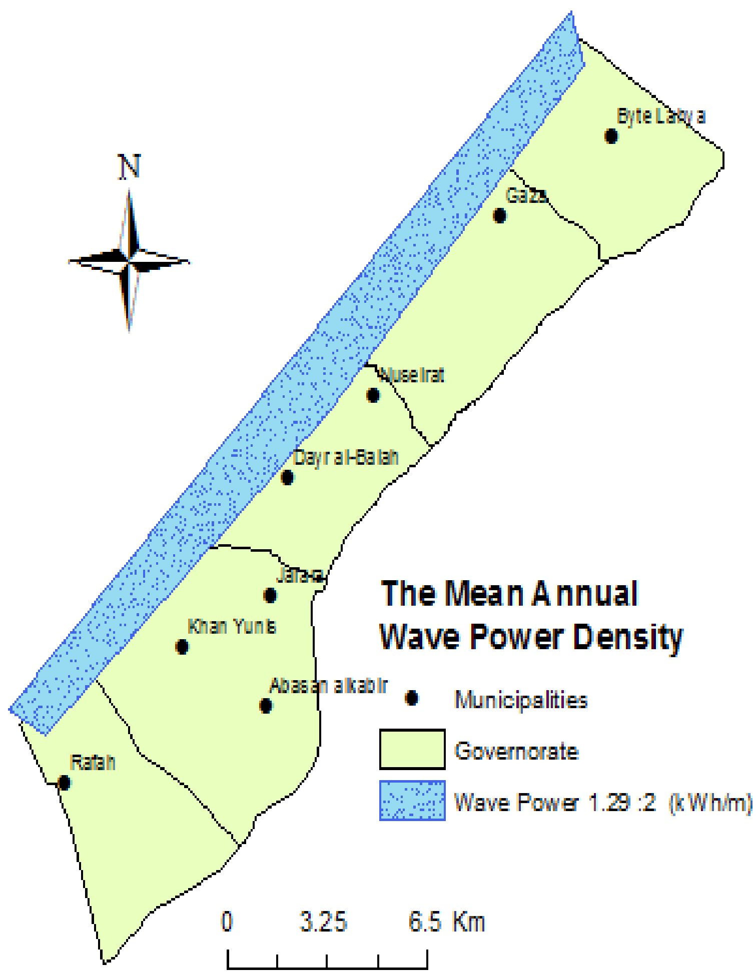
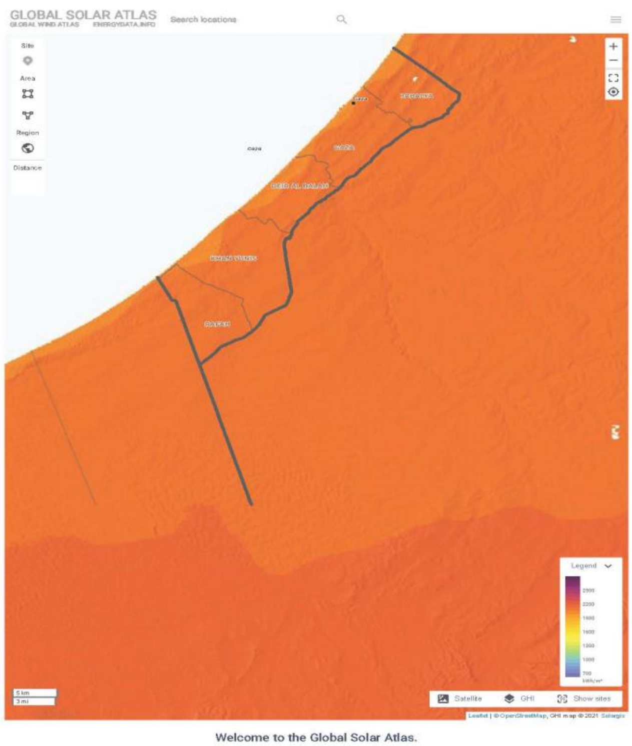
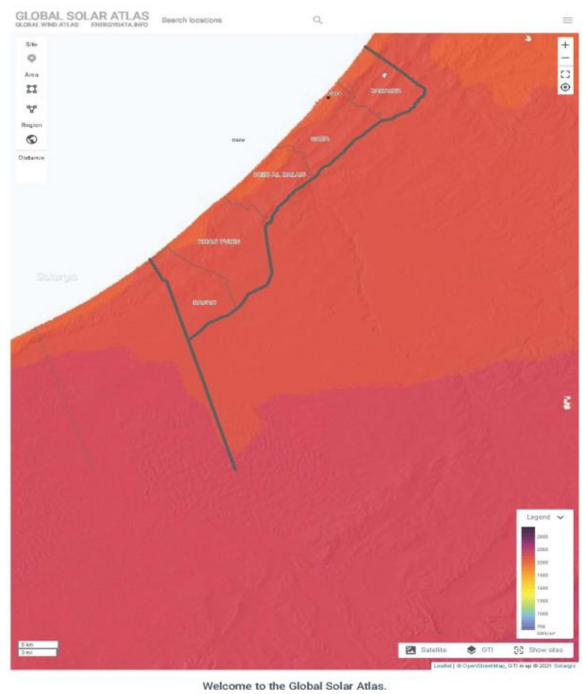


Figure 19: Wave total annual power density (kWh/m)

5.4. Solar Energy

Solar irradiation in Gaza is considered one of the highest irradiations within Palestine. Data available from Global Solar Atlas shows that the average Global Horizontal Irradiation (GHI) vary from 2092 KWh/m2 in South Eastern part of Rafah to nearly 2024 KWh/m2 in the North-western Part of Gaza Strip, while Global Tilted Irradiation (GTI) vary from 2333 kwh/m2/year South eastern part of Rafah to 2300 KWh/m2 in Beit Lahiya and Direct Normal Irradiation (DNI) varies from 2287 kWh/m2/ year in Rafah to 2230KWh/m2 in Beit Lahiya as shown in Figure 15.





Source: Global Solar Atlas

(a) (b)

Figure 20: Average Global Horizontal Irradiation - a (GHI) and Global Tilted Irradiation – b (GTI) in Gaza

This satellite-based data gives an important indication related to the potential development of solar energy generation in Gaza. However, before commencing any plans, it is important to monitor and obtain metrological data on the ground. The last is very essential for assessment, engineering design and hence for investment costs. The other important aspect related to solar energy generation is the type of solar technology used. In case of investing in solar concentrators (CPV and CSP) Direct Normal Irradiation (DNI) is the relevant solar parameter. If investing in PV systems, Global Tilted Irradiation (GTI), i.e. sum of direct and diffuse solar radiation falling at the surface area, is the relevant and most important solar parameter for potential evaluation.

Since the most common investments in solar energy are PV power systems, Global Tilted Irradiation (GTI) is therefore the most important parameter to be considered. As mentioned earlier, GTI is highest in Rafah area and therefore, monthly PV output in Rafah vary from 17330 KWh in July – August to 11600 KWh in December with total annual average of 179.4 MWh as shown in Figure 16.

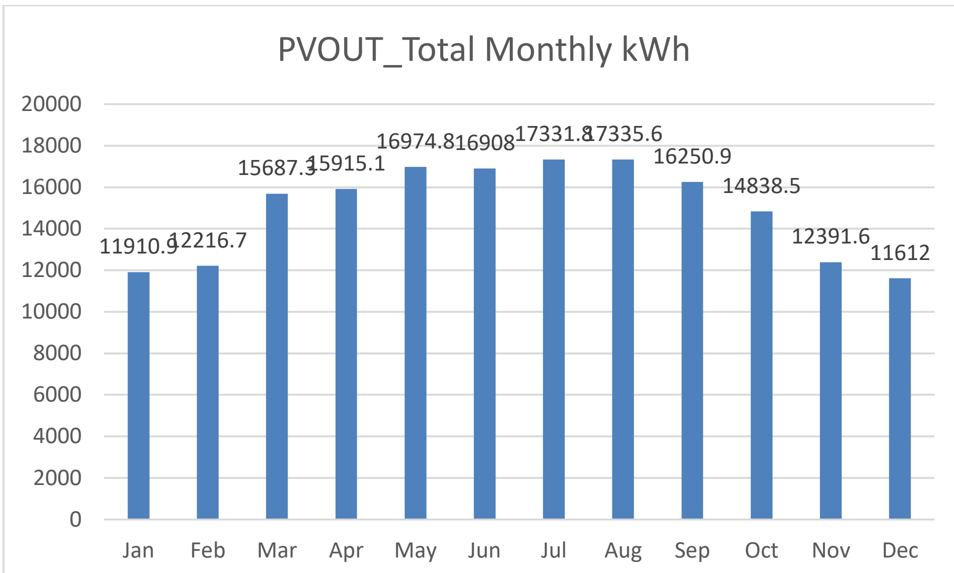


Figure 21: Monthly PV Output in Rafah KWh

In the meantime, the specific PV electricity output per year from a typical open-space PV system with a nominal peak power of 1 kWp system, i.e. the values are in kWh/kWp for each governorate in Gaza is shown in Figure 17.

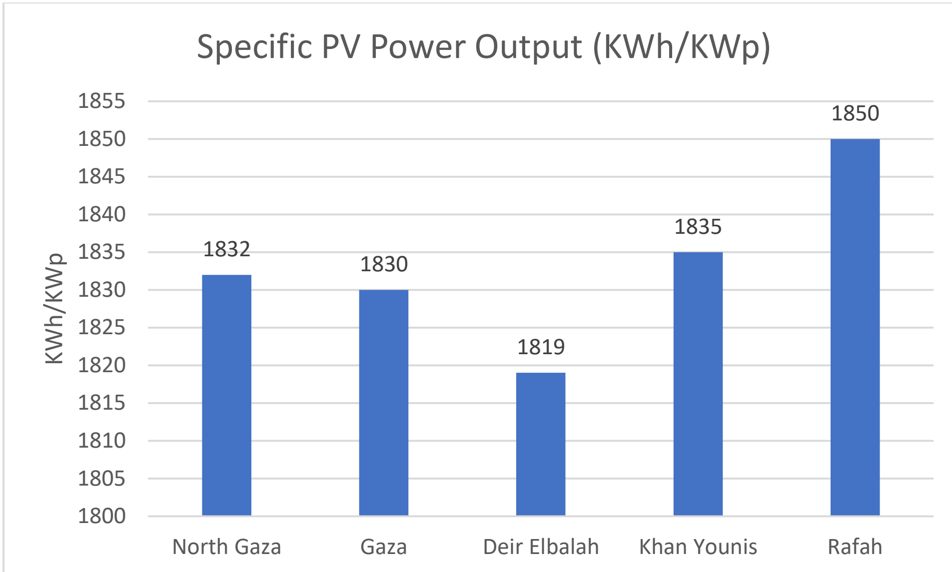


Figure 22: Annual PV electricity output from an open-space fixed PV system with a nominal peak power of 1 kW [kWh/kWp]

It is good to mention that calculating PV output for 1 kWp of installed power makes it possible to scale the estimate of PV power production plant of any size. However, the power production strongly depends on geographical location of the power plant. Potential electrical production and the performance ratio of PV power plants is also influenced by different climatic conditions.

From the point of view of natural geographic conditions, PV installations can be advised to be optimally located on slightly inclined terrain oriented to the South, in territory with low natural pollution sources (e.g. sand, bare land), that can be available in the eastern side of Gaza strip.

An optimal location of PV systems can be advised in area that are not too much windy in order to avoid the negative effect by increasing dirt on surface of PV modules which reduces efficiency and increases Operation and maintenance cost.

Based on the above information, it is clear that there is good potential for solar energy generation in all governorates of Gaza. However, there are several challenges facing the realization of medium-large scale solar energy generation including the following:

1. The Political situation and risk
2. Economical situation and possible investment under such unstable environment
3. Space availability for the construction of solar energy plants.

However, given the dare electricity situation in Gaza and the potential of solar energy availability, it is imperative to take some risks to generate part of total energy required to meet the household electricity demand. In this respect, two possible scenarios can be proposed as follows:

1. Utilizing the open space which is still available in eastern part of Gaza or what is known as seam zone to install solar energy PV plants.
2. Utilizing the roof tops of buildings to generate solar energy.
3. There is a third scenario, considering a floating platform where PV panels can be mounted. However, such scenario has several challenges and will not be considered in this research.

The following sections will shed lights on the potentiality of generating solar energy under the first two scenarios.

Scenario 1: Generating Solar Energy by Using Open Space in Eastern Gaza

It is well known that Gaza is one of the most densely populated areas in the world where population density reaches more than 40000 inhabitants/ km2 according UN Habitat 2014. Moreover, the urbanization is increasing rapidly as mentioned earlier and will reach 59% toward the year 2023. The land use map in Gaza shows that the only empty land or arable land is that the access restricted area in the eastern part of Gaza which forms 12% of the total area of Gaza strip as reported by UN Habitat 2014 and shown in Figure 23.

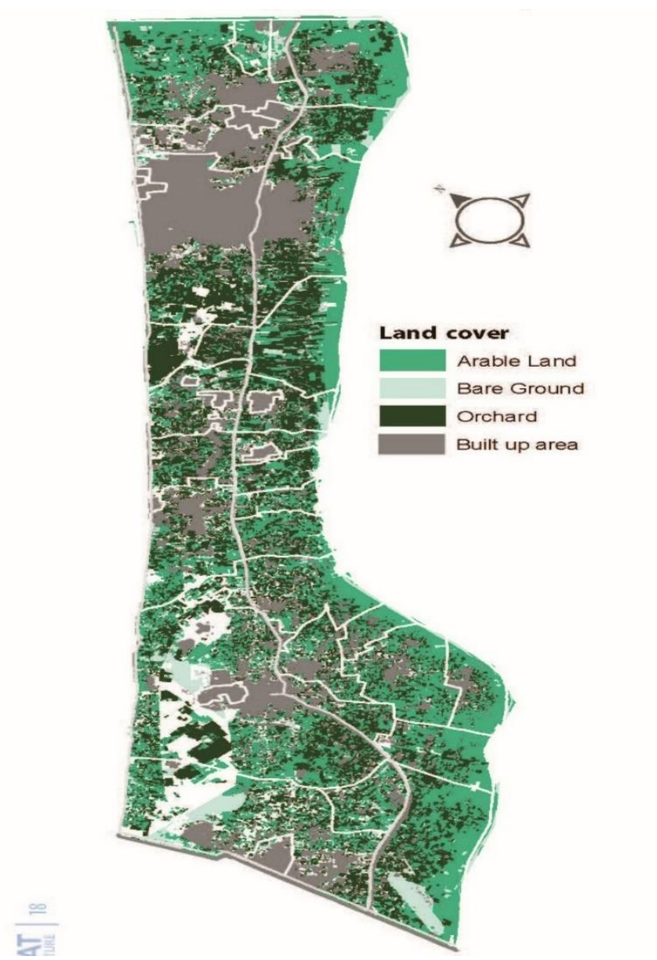


Figure 23: Land Use Map of Gaza

Considering this scenario for solar energy generation would entail political settlements or international partnership as proposed by the Office of the Quartet[3] in their proposed renewable energy work stream which aims to develop at least one solar PV plant in the Gaza buffer zone by establishing political alignment, supporting suitable commercial agreements by working with key partners and completing the necessary technical evaluations. The intent of this project in Gaza, is to act as a model for developing further solar PV sites in the buffer zone, making use of land that is currently unused or underutilized.

If we assume that the political constraint is dealt with, the potential renewable energy generation from the buffer zone will ultimately be viable and total annual Global Tilted Irradiation is around 2228 kwh/m2. In the mean-time, total photovoltaic output from each installed 1 KWp system is around 1.77 MWh / year or the output from a plant of 1000 KWp will be around 1.83 GWh/ year as extracted from Global Solar Atlas.

Knowing that household electricity demand in Gaza is nearly 1136 GWh/year toward 2030, means that a total of 630 plant of 1000KWp is needed or 315 plant of 2000 KWp or any size of plant given the land availability in specific locations in the buffer Zone in Gaza to generate 1150 GWh/year. Given that land requirement for the plant of 1000KWp is 10,000 m2 (10 Dunums) of shadow free area, means that generating the needed electricity requires 6300 dunums of shadow free open space.

Despite the large number of relatively medium size solar energy plants foreseen under this scenario, which makes their management a bit more difficult. However, it is likely that it may create opportunity for private sector involvement in renewable energy production and open more job opportunities in Gaza and reduce the risk of loosing all the investments in case of any political crisis.

Scenario 2: Utilizing the rooftops of buildings in Gaza to produce solar energy

Given the current political context and risk involved in Gaza, it may be difficult to consider scenario 1 for generating needed energy. This would leave no choice but to consider the smaller scale PV systems by using the roof tops of buildings. This option has also been recommended by World Bank[4] where they indicated that extreme land constraints in the Gaza strip limit the available solar potential to 160 MW of rooftop solar. However, even this limited solar capacity could play a vital role in increasing energy security and acting as an electricity safety net.

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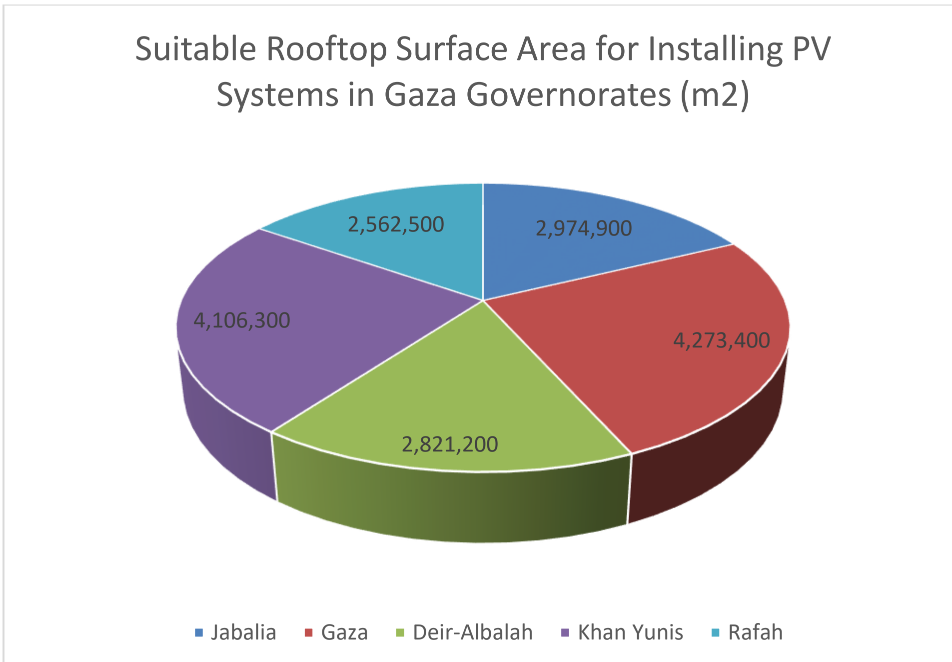
[3] http://www.quartetoffice.org/page.php?id=5e1e7ay6168186Y5e1e7a

[4] https://documents1.worldbank.org/curated/en/351061505722970487/pdf/Replacement-MNA-SecuringEnergyWestBankGaza-web.pdf

Moreover, Nassar et.al, 2018, has studied this option in details. They concluded that a PV system of up to 555 MWp can be installed on the rooftop of Gaza Strip's buildings as an urgent step to meet current unmet demand and upscale it with time to be energy self-dependent. The first step will cost about 800 million $US and the expected price of electricity will range between ($US 0.07–0.11) per kWh, which is four times less than the present price ($US 0.29–0.46) per kWh. They also concluded that there are nearly 16.74 million m2 of suitable rooftop surface area for installing the PV systems in various governorates as shown in figure 24.



Source: Data compiled from Nassar and ALSadi, 2018

Figure 24: Suitable Rooftop surface area for PV installation in Gaza (m2)

Based on the available suitable surface area, Nassar and Alsadi, 2018, concluded that it is possible to generate 110 GWh/year by utilizing part of the available buildings surface area in each city to meet the current electricity demand load of 552 GWh/year.

The current study will consider the rooftops of existing buildings and housing units to calculate the potential solar energy generation in each governorate in Gaza on the assumption that total number of buildings, including those under construction identified by PCBS 2017 census are the base for this calculation and that at least 25% of buildings can provide 100 m2 space each for installing fixed PV system of 10 KWp on each building. Figure 25, shows the number of buildings in the different Gaza Governorates.

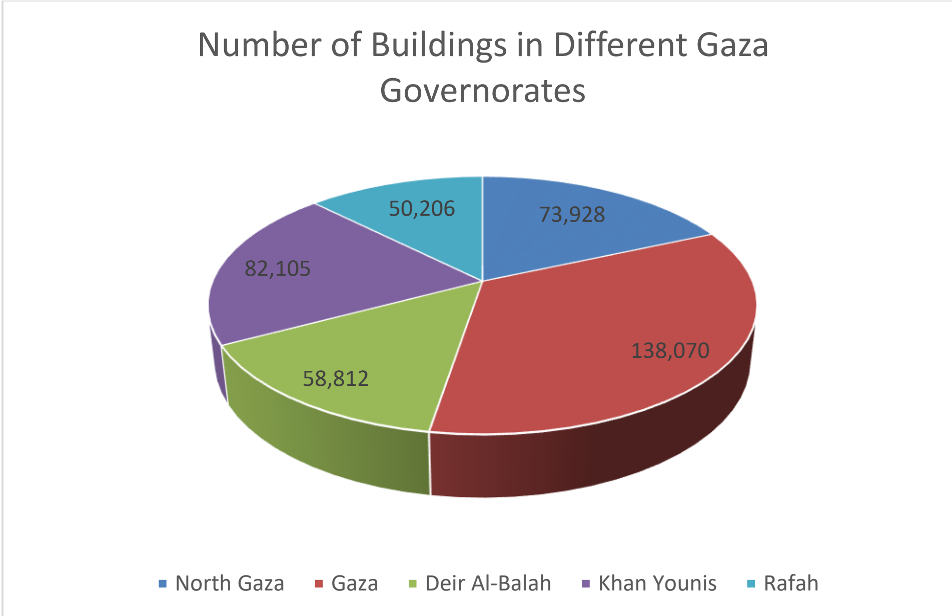


Figure 25: Number of Buildings in different Gaza Governorates as defined by PCBS 2017

Based on the above assumptions, total solar energy that can be generated is around 1765 GWh/year which is more than sufficient to meet the household electricity demand of 1136 GWh/year toward 2030 as defined in this report. The produced annual solar energy in each governorate under this scenario is shown in Figure 26.

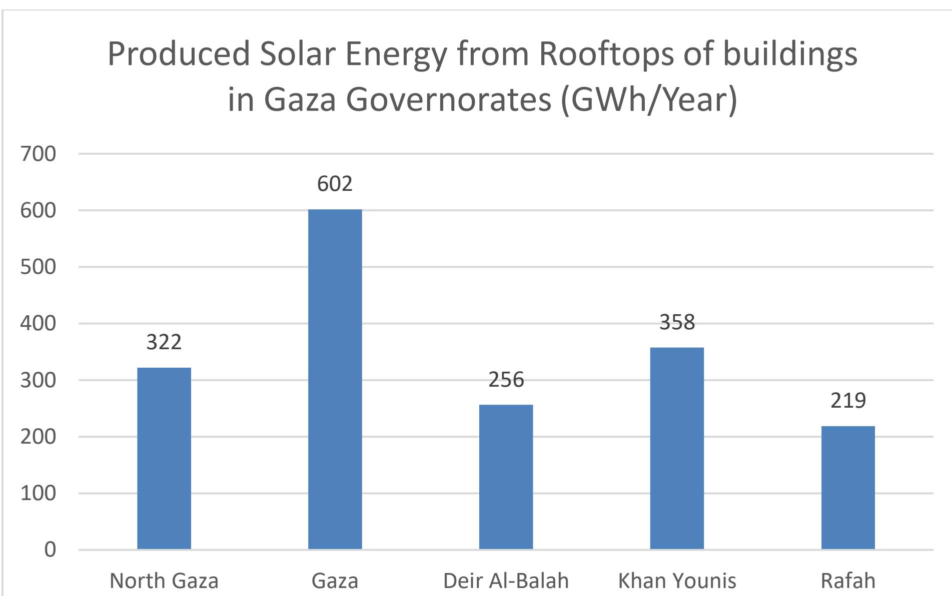


Figure 26: Produced Solar Energy from Rooftops of Buildings in Gaza Governorates

It can be concluded that both scenarios can produce the needed electricity demand in Gaza. However, scenario 1 has more challenge and politically is more sensitive than scenario 2 while investment cost is slightly less than scenario 2 it cost nearly 620 Million US$ while scenario 2 cost 642 Million US$ as shown in Figure 27.

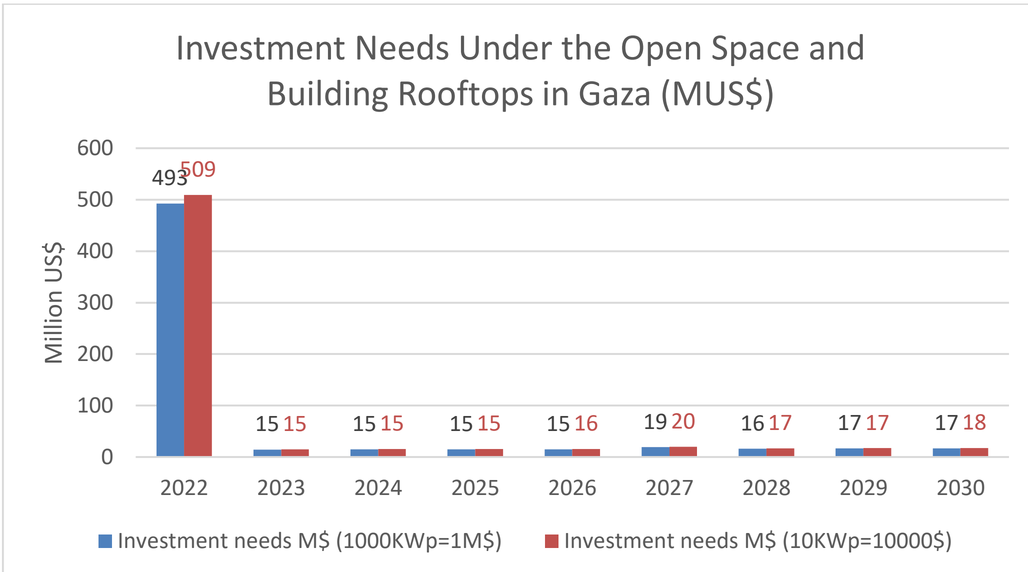


Figure 27: Comparing Investment cost under open space and Building rooftops scenarios

6. Conclusions and Recommendations

- It was concluded that the current electricity supply level covers 25% only of the needs in Gaza Strip. The supply in Gaza is by rotation among various areas for duration of 4 - 6 hours.
- Electric consumption is higher in the areas with higher population which indicates that the main electricity consumption goes to the household use.
- Demand for electricity will grow as population grows and will reach 1136 GWh/year toward 2030 under conservation scenario.
- The conservation scenario is calculating electricity demand is preferable to the Do-Nothing scenario in a sense that it will reduce the CO_2 emission by 1.16 Million Ton over the planning period until 2030.
- Bio energy is a good potential renewable energy in Gaza. Total electricity equivalent that can be produced from different bio mass resources is 671.8 GWh/year which is equivalent to 60% of the electricity household needs. It is also noticed that animal manure is considered the most important biomass resources folloed by agricultural residue and then municipal solid waste.
- It was concluded that wind energy is a potential. However, the wind speed according to the information available falls below the optimum required level of 12 m/second. It is concluded that turbines will be 40% efficient under the current wind speed in Gaza.
- Solar radiation is best in the southern part of Gaza, in Rafah and Khan Younis with GTI is nearly 2350 kwh/m2.
- It is clear that investing in renewable energy projects is economically and environmentally feasible, yet, to encourage the development and investment in this sector an incentive policy needs to be clearly developed to address this issue.
- It is recommended to utilize empty spaces in the eastern part of Gaza for generating electricity from solar energy in order to meet the growing demand. The total potential energy that can be generated under this option is 1153 GWh/year and requires 6300 dunums of shadow free space to install 630 PV plants of 1000 KWp.
- It is also recommended to utilize the roofs of buildings to generate electricity from solar energy. Under this option it is possible to generate the electricity needed to cover household demand by utilizing the rooftops of 50939 building to provide 5093900 m2 of shadow free surface area for installing 50939 PV plant of 10KWp each.
- Investment needs under the open space option is nearly 621 million US$ toward 2030 while it is 642 Million US$ in the case of using building rooftops.

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