An-Najah University Journal for Research – A
Natural Sciences

Powering Agricultural Pumps by Solar Photovoltaic System – Case Study from Palestine

Mohammed Ramadan[1] , Ihab H. Alsurakji[2,*], Qusai Al-Khalil[3] & Mohannad Tobah [2,4]

Received 25th Sep. 2023, Accepted 20th Dec., 2023, Published: 1st Aug, 2024, https://doi.org/10.35552/anujr.a.38.2.2187

Abstract: This study investigates how Palestine's dependency on imported electricity might be reduced by utilizing renewable energy (RE). There is tremendous potential for utilizing solar energy (SE) in the area given the profusion of sunshine hours. This study's main objective is to use SE to drive agricultural pumps that draw groundwater out of the ground and deliver it to various irrigation systems. For a number of compelling reasons, SE must be used in agricultural initiatives in Palestine. As a result, the adoption of solar photovoltaic (PV) systems to power pumps and wells located within the Tulkarm District is being examined and compared in this study. wo pumps feeding the same well and rated at 250 and 150 horsepower each have been specifically chosen for this use. Following that, this study gives thorough design requirements, together with the technical and budgetary characteristics of the necessary solar PV system. The planned system consists of 517 PV panels that are carefully placed over a 1300 m^2 area to successfully provide 50% of the energy needs of the pumps. The device additionally has a good payback period of 2.5 years.

Keywords: Renewable Energy, Solar Energy, Palestine, Agriculture, Energy Independence, Photovoltaic.

Introduction

Energy is one of the most important sectors in any country. Stable energy supply is pivotal to sustainable and economic development, human well-being, and environmental protection. Energy supply disruption is an internationally recognized issue that affects different countries due to various reasons. It is essential when examining the energy supply issue in Palestine, to account for the abnormal circumstances. Palestinian cities in the West Bank and Gaza suffer from lack of electricity and other energy sources, it is stated that Palestine imports nearly all its power from the neighboring countries [1]-[5]. Along the same line, Israel plays a major role in controlling the amount of energy reaching the Palestinian cities, since 100% of the fossil fuels and 89% of electricity is imported from Israel [1]-[3]. In other words, Palestine is an energy-dependent state, with high vulnerability due to the ongoing conflict and military occupation.

However, one of the solutions suggested to limit the Palestinian dependency on other countries in the energy sector is Renewable Energy (RE), which can cover the gap between supply and demand of energy in the Palestinian society [3]. Moreover, utilizing RE is the initial step to energy sources diversification in a country with poor natural resources, which is a vital aspect of energy independence. Worthy of noting, Juaidi et al., [2] provided seminal research on the importance of utilizing different RE sources in Palestine.

As much needed, Solar Energy (SE) is an abundant source in Palestine due to the high average sunshine hours per year – amounting up to 3000 hours annually. This advantage shall be used to fill the gap as previously mentioned. Nevertheless, the prices of electricity and fossil fuels are amongst the highest in the region [1], [3], [4], which further stresses the importance of utilizing RE sources. Furthermore, a stable energy supply is crucial to the agriculture sector. Furthermore, a stable energy supply is crucial to the agriculture sector. Increasing the share of RE in Palestine's energy mix is critical to achieve sustainability and contribute to energy independence. Although the energy consumption for agriculture only amounts to 1% of the total electricity consumption of the country [5] and 6% of the total energy consumption [6], a stable energy supply is crucial to the sector. This is because the irrigation systems are often located in remote, rural, and off-grid areas. In addition, the water prices in Tulkarm for irrigation are relatively high [7] and the used pumps constitute the highest capital cost of irrigation systems.

Literature Review

There is a strong consensus amongst scholars that implementing RE in Palestine is the most viable solution to overcome the current situation and change the status quo of the energy sector to the better [2], [8]-[14]. However, large-scale implementation of RE projects is challenged by the current political and economic situation of the area. For instance, Hamed and Peric 2020 [9] documented the role of RE in alleviating energy poverty in Palestine, as well as the current barriers and challenges facing this solution, like lack of autonomy on most of the land in the West Bank and the siege on Gaza Strip. Moreover, Ismail H. et al., [1] discussed the obstacles facing the

1 Department of International Relations and European Studies, Faculty of Social Studies, Masaryk University, Brno, Czech Republic.
E-mail: 504128@muni.cz.
2 Department of Mechanical Engineering, Faculty of Engineering, An-Najah National University, Nablus, Palestine.
*Corresponding author: isurakji@najah.edu
3 Department of Traffic Engineering and Safety, Ministry of Transportation, Tulkarm, Palestine.
E-mail: QusaiAlkhalil@gmail.com
4 E-mail: mohannad.tobah@gmail.com

Palestinian energy independence attempts, as well as the future of RE in Palestine along with suggestions to utilize different types of RE. Similarly, Naim A.N. 2010 [6] discussed the electricity import dependence of Palestine on Israel. This dependency cycle constitutes a strong political leverage to the Israeli side, causing serious challenges to any economic or sustainability plans in Palestine. Nevertheless, the dependency on Israel to meet Palestine's energy needs is concerning when considering the rapid population growth and industrialization in Palestine [15].

Nonetheless, utilizing SE to power agricultural appliances has been widely discussed in literature. For instance, Loxsom and Durongkaveroj 1994 [16] have suggested methods to estimate the performance of PV systems powering water pumps. Their research can be considered a pioneer in the field of using RE to power water pumps. However, Chandel et al., [17] overviewed historical methods of pumping water and the role of RE in increasing the feasibility of the process. Moreover, the article discussed in detail the descriptions of water pumps to be powered by SE and provided several design criteria for different situations as well as the feasibility and limitations of the systems. Similarly, Odeh I. et al., [18] compared diesel and PV systems to power water pumps over the operational period of 3 years and concluded the urge to convert to RE for it is a cheaper and environmentally friendly option. Likewise, Ghoneim A. 2006 [19] presented the results of performance and optimization of PV systems for water pumps in Kuwait area. The discussed system uses a computer simulation program to measure the proposed system's performance. Lastly, the economic feasibility of the system was evaluated using the life cycle cost method [19].

Furthermore, there is consensus that implementing RE systems to power agricultural appliances has positive impact on the sector. For example, Eker B. 2005 [20] highly recommended using simple PV array system to power agricultural pumps and suggested using batteries or storage tower tanks to overcome the fluctuating power production of RE systems. Similarly, Yaseen B. 2009 [21] concluded the cruciality of implementing RE systems in Palestine to challenge the energy supply dependency, with specific recommendation to use RE to power rural areas. Moreover, in his seminal work in the field, Khatib T. 2010 [22] described the potential of SE according to the geographical characteristics of Palestine and discussed pros and cons of implementing SE systems. In addition, the paper presented classification of water pumping systems according to the type of used pump and configuration of the system. Overall, the article shows the basics of designing a water pumping system powered by PV, with recommendations and considerations to account for to increase the reliability and efficiency of the system. Another crucial article investigated the role of implementing adjustable solar panels in increasing power generation, with specifications of the optimal tilt angle to be used (29 degree) [23], which is taken as the tilt angle for the current design.

Case Study: Tulkarm District

Tulkarm District is located in northern West Bank. Two reasons justify the decision to take Tulkarm as the case study. For several years now, Tulkarm city has experienced a shortage in electricity supply. The incoming supply does not match the demand, especially during summertime. This, however, causes fluctuating electricity supply with repetitive, and often long, blackouts. Consequently, it led the municipality to implement large diesel generators around the city as a backup supply in peak hours [24]. Secondly, Tulkarm is an agricultural district. Agriculture represents a critical source of income to most villages in the district; therefore, the number of water pumps is comparatively higher than other areas in the West Bank – 54 operating water wells [25]. Fig. 1 illustrates the locations of water wells in Tulkarm District.

Consequently, to design the optimal PV solution, comparative analysis of 15 wells has been carried out. The decision-making factors took into account the well's pump type, pump power, operational power costs, and annual average hours of operation. Three methods for data collection were adopted: (1) interview with the Ministry of Agriculture Office in Tulkarm City; (2) site-visits and interviews with local farmers and pumps owners; and (3) interview engineers from the Palestinian Hydrologists Association – who have long worked in the field of rehabilitating underground water pumping systems [24], [25]. Accordingly, Table 1 and Fig. 2 represent acquired data and comparison between the study sample of 15 wells.

Consequently, five wells are considered of high priority to implement PV solution. However, well no. 7 is selected for this case study due to space availability to utilize PV panels and for its special condition of having two pumps running with high operational cost. In an ideal scenario, well no. 2 would be selected, but the limitation is unavailability of space.

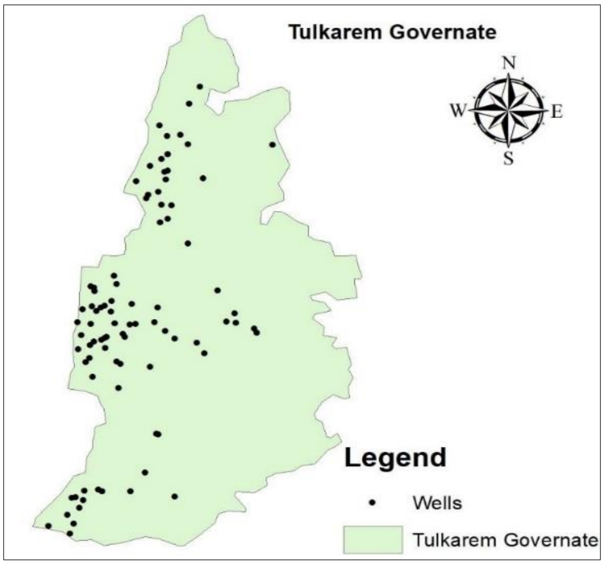

Figure (1): Wells Locations in Tulkarm District (26).

Table (1): Wells data in Tulkarm District.

No.	Owner	Well Code	Town	Pump Power (hp)	Operational cost (NIS/hr)	Annual Ave. working hours (hr/year)	Notes
1	As'ad Rabi	15-19/35	Attil	100	28	2925	--
2	Ra'fat Qubbaj	15-19/6	Nur-Shams	180	80	150	Diesel Generator
3	Fakhouri	15-18/9	Irtah	60	20	300	--
4	A Qasem	15-19/29	Dir El-Ghusson	125	50	4500	Second highest working hours
5	M. Omar	15-18/7	Far'oun	75	30	300	--
6	Ba'ba	15-19/33	Tulkarm	75	25	675	--
7	M. Mikkawi	15-19/22	Illar	100	65	3120	Two pumps
8	M. Khader	15-18/12	Kafr Jammal	100	35	450	--
9	Hasan Issa	15-18/10	Irtah	100	35	900	--
10	Qader Quzmar	15-19/20	Tulkarm	80	24	3150	Third highest working hours
11	J. Awartani	16-19/11	Anabta	100	18	760	SE system implemented
12	M. Halim	15-18/6	Far'oun	150	30-35	5400	Highest working hours
13	M. Abdul-Karim	15-18/20	Jbara	140	35-40	2760	SE system implemented
14	M. Suffarini	15-19/39	Dhennaba	125	35	1950	--
15	Saleh Yasin	15-19/32	Attil	120	35	2200	--

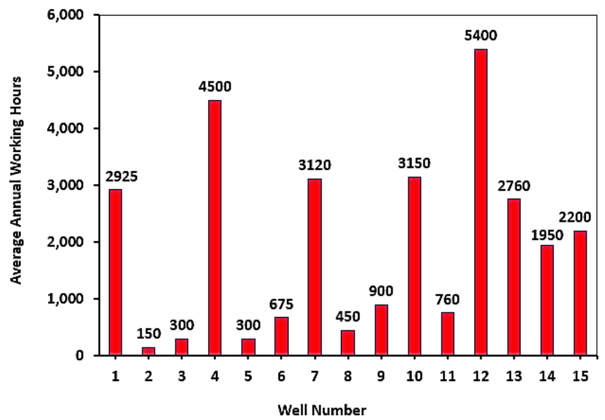

Figure (2): Annual average working hours.

Renewable Energy Regulations in Palestine

Although the use of renewable energy to generate on-grid electricity is a novel practice in Palestine, the Palestinian Electricity Regulatory Council (PERC) [27] has addressed this field and set clear regulations for feeding the grid with electricity from Solar PV panels. It is essential to regulate grid electricity to prevent losses and blackouts. In other words, the necessity of regulations is to systemize the use of RE in electricity generation, which leads to managing the increase of RE share in the energy mix without disruptions. Needless to say, RE sources are not flexible and generate electricity according to weather conditions.

Technical Parameters

The maximum generated power by an RE project shall not exceed 1000 kW, it should not exceed the average yearly consumption rate, and it must be less than the subscribers' evaluated needed power. Moreover, a detailed study must be provided to the electricity distributor in the designated location, setting the final decision to reject or accept the project to the electricity distributor. Additionally, the subscriber must provide measurement data through one of two ways: either using a bidirectional meter installed to the project to measure the total power output of the RE system as well as the total consumption of the appliance, or by installing two meters measuring the input and output power of the system to the grid. Finally, the maximum output power of the designed RE system is calculated using the following Eq. 1.

$$P_{RE_{Max}} = \frac{\text{annual consumption rate}}{1500} \quad (1)$$

Calculation and Tariff

Input and output power calculations are done on an annual basis from the end of March until the start of April in the following year. The electricity distributor has to provide a monthly report measuring the input power of the RE system that was fed to the gridline as well as the consumed energy of the appliance. If the consumed energy is higher than the fed into grid, the subscriber is obligated to pay the difference. On the other hand, if the fed energy is higher than the consumed, the difference is added to the following month's bill. Finally, if the RE project location is different than the appliance, an extra fee is added for the energy transfer cost. Nevertheless, it is important to note that if the project is modified after approval without informing the distributor, suspension from the gridlines is possible. Moreover, all the measurement costs are paid by the subscriber and the PV frame must be made of aluminum or galvanized steel.

Technical Design

This chapter discusses PV solar cells selection criteria, assumptions, and decisions prior to the design. In addition, it overviews the needed components for a successful implementation of on-grid PV system. Lastly, all needed calculations are presented as well as a site overview.

Solar PV Cells Selection Criteria

Simply, the work principle of a PV system is to convert sunlight to Direct Current (DC) electricity. PV cells consist of semiconducting materials. By exposing the surface to sunlight energy, electrons are knocked loose from the atoms, releasing energy to produce electricity [20]. However, to account for the optimal solution for a PV system in Palestine, data was collected from the local market indicating efficiency, output power, cost, and temperature coefficient. The decision was made according to the availability in the local market, as well as most convenient cost. According to interviewed solar companies, Jinko cells proved to be the most competitive in terms of cost and availability. Table 2 presents the available PV cells in the local market. Note that the chosen model for comparison is 60 cells Polycrystalline.

Table (2): PV Cells Models in the local market.

Brand	Efficiency (%)	Power (W_p)	Cost $(NIS/Panel)$	T_{Coeff} (%/℃)
Jinko	17.4	280	312.5	-0.38
Hanawa	17.4	280	312.5	-0.4
Rosen	15-18	280	332.6	-0.39
Risen	16-18	280	332.6	-0.39
Canadian	17-18	285	369.3	-0.38
JA	17.1	290	334.1	-0.4

System Components

The decision to design an on-grid solution instead of off-grid (standalone) is to provide reliable and consistent electrical supply for the agricultural pump. Since pumps are vulnerable to electric fluctuations that might be a side-effect of alternating between using batteries and municipal electricity. In addition, this solution offers cost reduction by eliminating the need to employ high-cost batteries.

Several components play essential roles in ensuring the PV system's functioning and safety. One is the inverter, which converts the DC power produced by the PV cells into AC power that can be utilized by the appliance. Another component is monitoring device, which plays a crucial role in providing continuous data about the system's efficiency, energy demand, and the irradiance on the arrays. Moreover, the monitoring device is connected to special software that helps detecting and predicting defects in the system. Another component mentioned earlier is the meter box, which calculates the output energy by the PV system. Lastly, water-proof cables and wires are used to connect modules together with other devices like fuses, circuit breakers, and earthing systems which all ensure the safety of the system and human beings.

Site View

In order to get a realistic view regarding the well site, multiple comprehensive visits were carried out along with owner interviews. The well operates using two recently installed pumps, with a capacity of 150 hp and 250 hp (see Fig. 3). The owner suggested installing the PV system to cover the energy demands of the pumps on a piece of land of 1300 m2 close to the well location (about 1 KM far). The proposed installation site is currently used as a car garage. The plan is to install the PV arrays on the garage roof. Taking all these factors into account, PVSYST software was used to determine the area's solar characteristics – including monthly solar irradiance, humidity, and temperature.

Figure (3): The agricultural pumps.

PV System Design

The combined capacity of the two pumps = 400 hp which equals 298.4 KWp. According to Abdallah et al. [23], the optimal angle for Palestine is 29°. PVSYST software is utilized to calculate the needed parameters for a PV system that covers half the total power of the two pumps (around 152.5 KWp). Subsequently, the JKM295P model is chosen from Jinko Solar datasheets.

According to the well owner, the two pumps consume 65 NIS/hr and work approximately 5,400 hrs annually. Considering that the price of 1KW = 0.6 NIS in Tulkarm City and power factor for Palestine is 5.5, which generates the following calculations:

$$5{,}400\text{hr} \times 65\ \text{NIS} = 351{,}000\ \ \text{NIS}/year \tag{3}$$

$$\frac{351{,}000}{0.6} = 585\,\text{MW}_\text{h}/year \rightarrow 1602.7\ \ \text{KW}_\text{h}/day \tag{4}$$

$$\frac{1602.7}{5.5} = 291.4\ \text{KW}_\text{day} \tag{5}$$

Since the chosen model of PV modules has an output power of 295 Wp, the needed number of panels to fully cover the energy need is:

$$\frac{291.4\ \text{KW}}{0.295\ \text{kW}_\text{p}} = 987.7\ \text{panel} \tag{6}$$

Accordingly, the available space to install the system is around 1300 m^2, the number of panels that can properly fit in the area is 517 panels, which covers nearly 50% of the well's energy need.

For the number of inverters needed to safely run the system, considering 50% of the total power need of the project with a safety factor of 1.3:

$$\frac{1602.7\ {}^{\text{kW}_\text{h}}/_{day}}{2 * 1.3} = 616.5\frac{\text{kW}_\text{h}}{\text{day}} \rightarrow \frac{616.5}{5.5} = 112\ \text{KW} \tag{7}$$

Which accounts for using 6 inverters with 20 kW capacity.

Finally, according to the dimensions of the used panels (295 Wp Jinko) and utilizing J. K. Coppers' method, the shading analysis is done according to Eq. 8:

$$D = A\,cos(\beta) + \frac{A\,sin(\beta)}{tan(\theta)} = 3.1\,m \tag{8}$$

where:

D = Distance between arrays

A = Panel arc length = 196 cm,

β = tilt angle = 29°

θ = sun elevation angle = 66.5 – Site Latitude = 34.2°

Applying this distance between arrays keeps the whole field clear from shading for two hours prior to noon and two hours after.

Feasibility Study

The feasibility study considers the capital cost of the whole project as per the local market, then calculates annual net cash flow compared to the capital spent to determine the payback period. Table 3 calculates the capital cost and Table 4 calculates the payback period. The total cost of the project is 889,665 NIS. Adding to that the labor cost which varies across different companies. For the payback period, the well owner charges an hourly rate of 100 NIS/hour. This gives a total revenue of 100×5400=540,000 NIS/year. The cost of running the two pumps is 65×5400=351,000 NIS/year. And since the project cuts off half of the running cost, 33×5400=178,200 NIS/year, this means that the saved money from the project added to the original revenue = 367,200 NIS/year. The needed period to recover the capital cost is between the second and third year. In exact measure depending on the table → 2.42 Years = 2 years and 155 days.

Table (3): Capital Cost.

Type	Units	Unit Cost (NIS)	Net Cost (NIS)
PV	517	1225	633,325
Inverter 20KW	7	12208	85,456
Monitoring system	1	1700	1700
Structure	1000	50	50,000
Cables	-	-	95,000
Protection instruments	-	-	20,000

Table (4): Payback Period.

Year	Net Cash Flow (NIS)	Cash Conversion Cycle (NIS)
0	-889,665	-889,665
1	+367,200	-522,465
2	+367,200	-155,265
3	+367,200	+211,935

Conclusion

In conclusion, the implementation of SE projects in Palestine is a promising solution to the country's energy dependency problem, and a key player in energy diversification. This research addressed implementing SE to provide an alternative source of electricity to agricultural appliances that minimizes the operational cost of irrigation. The study collected and analyzed data from a sample of 15 agricultural wells in Tulkarm district to prioritize wells for RE implementation. Moreover, the study demonstrated the technical calculations and aspects needed for the PV system design. The results suggest optimizing the use of available space to implement PV panels. The maximum number of PV panels that can be implemented with optimal distancing for shading consideration is 517, which covers up around 50% of the wells' energy need. Moreover, 6 inverters of 20 KW capacity need to be installed to the system. Lastly, it proved the economic feasibility of the project. Although the capital cost is high, it can be recovered within less than three years. This, however, sets a starting point to funding schemes of all sources to direct their investment into the implementation of RE projects. Therefore, one suggestion for future research is considering the cruciality of diversifying RE applications in agriculture, and its role in alleviating poverty, contributing to sustainable development, and contributing to positive economic growth.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The raw data required to reproduce these findings are available in the body and illustrations of this manuscript.

Author's contribution

The first version of the document was written by Ramadan. Alsurakji was in charge of overseeing the organization of research activities and the primary conceptual ideas. Ramdan, Al-Khalil, and Tobah were the ones who carried out the experiment. Explanation of the data, experimental design, and outcomes Ramadan and Alsurakji. Data curation and manuscript editing were done by Ramadan. The final draft of the work was reviewed by all authors, who also gave their approval.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflicts of interest

The authors declare that there is no conflict of interest regarding the publication of this article

References

1) Ismail, Mahmoud Salah, Mahmoud Moghavvemi, and T. M. I. Mahlia. "Energy trends in Palestinian territories of West Bank and Gaza Strip: Possibilities for reducing the reliance on external energy sources." Renewable and Sustainable Energy Reviews 28 (2013): 117-129.

2) Juaidi, Adel, Francisco G. Montoya, Imad H. Ibrik, and Francisco Manzano-Agugliaro. "An overview of renewable energy potential in Palestine." Renewable and Sustainable Energy Reviews 65 (2016): 943-960.

3) Ibrik, I. "Water-Energy-Food Nexus in Palestine" 5TOI, UNIMED, (2016).

4) Mahmoud, Marwan M., and Imad H. Ibrik. "Techno-economic feasibility of energy supply of remote villages in Palestine by PV-systems, diesel generators and electric grid." Renewable and sustainable energy reviews 10, no. 2 (2006): 128-138.

5) Palestinian Authority, Palestinian Energy and Natural Resources Authority, Ramallah. Sectoral Strategy for Energy in Palestine, (2022), Ministers Cabinet.

6) Naim, Awny N. "Potential of solar pumping in Palestine." In International Water Technology Conference (IWTC). (2010): pp. 1-11.

7) Abu-Madi, Maher O. "Farm-level perspectives regarding irrigation water prices in the Tulkarm district, Palestine." Agricultural Water Management 96, no. 9 (2009): 1344-1350.

8) Nassar, Yasser Fathi, and Samer Yassin Alsadi. "Assessment of solar energy potential in Gaza Strip-Palestine." Sustainable energy technologies and assessments 31 (2019): 318-328.

9) Hamed, Tareq Abu, and Kristiana Peric. "The role of renewable energy resources in alleviating energy poverty in Palestine." Renewable Energy Focus 35 (2020): 97-107.

10) Ibrik, Imad. "Micro-grid solar photovoltaic systems for rural development and sustainable agriculture in palestine." Agronomy 10, no. 10 (2020): 1474.

11) Ibrik, Imad. "Techno-economic impact of Grid-connected rooftop solar PV system for schools in Palestine: a case study of three schools." International Journal of Energy Economics and Policy (2019).

12) Khaldi, Yasser M., and Minna Sunikka-Blank. "Governing renewable energy transition in conflict contexts: investigating the institutional context in Palestine." Energy Transitions 4, no. 1 (2020): 69-90.

13) Khatib, Tamer, Amin Bazyan, Hiba Assi, and Sura Malhis. "Palestine energy policy for photovoltaic generation: Current status and what should be next?." Sustainability 13, no. 5 (2021): 2996.

14) Salah, Wael A., Mai Abuhelwa, and Mohammed JK Bashir. "The key role of sustainable renewable energy technologies in facing shortage of energy supplies in Palestine: Current practice and future potential." Journal of Cleaner Production 293 (2021): 125348.

15) EuroMed. “Background note on energy and water issues in Palestine.” European Union, europa.eu, (2015).

16) Loxsom, Fred, and Pichet Durongkaveroj. "Estimating the performance of a photovoltaic pumping system." Solar energy 52, no. 2 (1994): 215-219.

17) Chandel, S. S., M. Nagaraju Naik, and Rahul Chandel. "Review of solar photovoltaic water pumping system technology for irrigation and community drinking water supplies." Renewable and Sustainable Energy Reviews 49 (2015): 1084-1099.

18) Odeh, I., Y. G. Yohanis, and Brian Norton. "Economic viability of photovoltaic water pumping systems." Solar energy 80, no. 7 (2006): 850-860.

19) Ghoneim, Adel A. "Design optimization of photovoltaic powered water pumping systems." Energy conversion and management 47, no. 11-12 (2006): 1449-1463.

20) Eker, Bülent. "Solar powered water pumping systems." Trakia Journal of Sciences 3, no. 7 (2005): 7-11.

21) Yaseen, Eng Basel. "Renewable energy applications in Palestine." (2009).

22) Khatib, Tamer. "Deign of photovoltaic water pumping systems at minimum." J Appl Sci 10 (2010): 2773-2784.

23) Abdallah, Ramez, Adel Juaidi, Salameh Abdel-Fattah, and Francisco Manzano-Agugliaro. "Estimating the optimum tilt angles for south-facing surfaces in Palestine." Energies 13, no. 3 (2020): 623.

24) Tulkarm Municipality Interview, “Electricity in Tulkarm City”, (2019).

25) Ministry of Agriculture Interview, “Agricultural wells in Tulkarm District”, (2019).

26) Palestines’ GeoMOLG system, Ministry of Local Governorate, geomolg.ps, (2019).

27) Palestinian Electricity Regulatory Council, Ramallah. Laws and regulations in regard of utilizing renewable energy in Palestine, (2015).