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Practical Challenges of Photovoltaic Systems in the Rural Bedouin Villages in the Negev

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Abstract

Off-grid energy systems are the main electricity source in rural Bedouin villages in the Negev. Due to the need for electricity, Bedouin households took upon themselves the responsibility of buying and installing photovoltaic (PV) systems. This study is the first of its kind to present data on energy poverty and installed PV systems at the recognized and unrecognized Bedouin villages to assess their future electricity needs. Interviews were conducted in four Bedouin villages (Wadi El Neam, Qasr El Sir, Wadi Areha and Ber Hadaj). It was found that although Bedouin households rely heavily on the PV systems to provide them with the electricity needed in their daily lives, they use the diesel generators when the PV system are not able to produce energy. It was also found that the generated electricity from PV systems is limited and insufficient to meet basic needs and it shapes the villagers' daily life. The Bedouin communities use minimum energy consumption associated with their basic necessities. Enlarging the current installed photovoltaic system emerged as an urgent need.

Keywords: Energy poverty; Photovoltaic; Solar energy; Rural development

Introduction

Before the establishment of the state of Israel in 1948, the Negev was populated by a total of 95 tribes who constituted approximately 70,000 Bedouins [1]. These Bedouins are Palestinian Arabs who led a nomadic lifestyle and who were allowed, for most of part, to live their lives without major interruption from or interference by the ruling authorities [2]. During the 1948 war, most of the Bedouins fled or were expelled to Jordan, the Gaza Strip, and Egypt. This left approximately 10,000 Bedouins in the Negev [3] while altering their status from being the indigenous population of the Negev to illegal, scattered entities.

Today, about 230,000 Bedouins reside in the Negev area, in one of the three types of settlements: unrecognized villages, governmental planned towns and recognized villages. There are about 40 unrecognized villages; 7 governmental planned towns; and 11 recognized villages [4]. This paper will focus on Bedouins living in both types of villages; recognized and unrecognized. Although the living conditions of these Bedouins vary across the different villages, still they face common problems. For example according to a survey carried out by the minority rights group International in 2011, 67% of the Bedouins live in poverty, with only about 20% of the community employed [5]. Both recognized and unrecognized villages (unlike townships) lack basic services and infrastructure such as sewage, running water, roads, transportation and electricity [6].

The Negev desert is located, between 29°-31° north of the equator, which is characterized as a subtropical region, between the temperate zone and the tropical zone. The Negev desert is characterized by an arid climate. The rainy season extends from October to early March with an average rain of 100 mm/year. The annual solar radiation in the Negev desert 2100-2400kWh/m2/year. More than half of the Negev Bedouins reside in unrecognized villages.

There is growing evidence that links direct and indirect socioeconomic benefits with access to a reliable and affordable supply of electricity. These benefits range from poverty eradication to health promotion, food production and education [7]. Knowing the importance of energy, there has been an international effort to increase access to it. A reflection of these efforts are the Sustainable Development Goals (SDGs) developed in 2015 by the United Nations and with the involvement of its 193 Member States and global civil society. Specifically, Goal 7 calls to ensure access to affordable, reliable, sustainable and modern energy for all [8].

In order to reach that goal, extensive electrification projects need to take place, and primarily, grid extension electrification is the preferred mode. Yet, Subhes and Bhattacharyya explained that in geographically remote and sparsely populated rural areas where grid electrification is financially unviable or practically unfeasible, off-grid options can be techno-economically viable, and sustainable [9].

Kimani et al. conducted a study to examine the ability of a stand-alone PV system to provide the required electricity for a single household in India. This study collected and calculated the site radiation data and the electrical load data of a typical household. The study showed that the PV systems are considered as the most promising energy source since it is free in its availability, reliable, safe, non-polluting and suitable for long-term investments especially if the efficiency of the PV system is increased and the initial price is decreased [10].

Another study carried out by Qoaider and Dieter examined the economic feasibility of photovoltaic technology to supply the complete energy demands to off-grid irrigated farming-based communities in arid regions. The study concluded that off-grid photovoltaic connection

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is a more cost competitive option to supply energy when compared to diesel generators that are commonly used in arid areas. The study also explained that photovoltaic technology is a solution that can cope with the rapid rising electricity generation costs and the continued rise in fossil fuel prices [11].

Another study carried out by Sarah Feron examined off-grid photovoltaic systems and their ability to ensure electric sustainability in rural areas. Feron explained that sustainability can be achieved only if the four dimensions, which are institutional, economic, environmental and socio-cultural, are assured. A failure in assuring any of these dimensions has been shown to compromise the sustainability of off-grid PV systems [12].

Chmiel and Bhattacharrya, analyzed the off-grid electricity system as an individual source of energy to satisfy a household's electric needs in a community where the main grid is either undeveloped or it is uneconomical to extend it due to remoteness of the location. They claimed that providing reliable off-grid electricity supply is possible but is costly without suitable capital subsidies. Appropriate system design suited to the local condition is vital for developing a reliable system [13].

Development projects in off-grid communities are usually undertaken by a foreign body who hopes to bring development to a certain community. Subsequently such projects are monitored, assessed and evaluated. However, in this case, the Bedouins initiated and brought "development" in the shape of electricity to their own lives. Hence, no assessment was done to the photovoltaic solar systems that they installed in their household. Since the literature lacks such an assessment, this paper will serve as an initial study to fill that gap.

The objective of this paper is to evaluate and document the current status of the existing PV systems used by the Bedouins, to study the impact of the PV systems on the daily life conditions, local perspectives and priorities and finally, to assess the optimal pathways to upscale the system to achieve long-term sustainability and eradication of energy poverty.

This Study was conducted in the Bedouin Villages in the Negev. These villages are not recognized by the Israeli Government. Therefore, any development in these villages will be considered illegal. The only option for energy is PV and traditional biomass. Villagers are not allowed to connect to the national grid neither to build wind turbines. There is no national transmission system development plan neither electricity generation policies and programs, no institutions in different energy areas and electricity generation related to the villages.

Methodology

In general, the Bedouin communities use a typical off-grid PV system that consists of a PV array, battery storage unit, controller and power conditioning unit.

The methodology that was used to collect data is the participatory method. Starting from the assumption that communities are filled with knowledge and information about their needs and ways to solve them, joint work with the community took place [14].

In this paper, a combination of qualitative and quantitative data collection methods were used. Accordingly, interviews were held with randomly selected different Bedouin community representative members. Also it is important to mention that this study relies on a large number of visits and interaction meetings with the Bedouin community.

Interviews were held with ten participants (six males and four females) from four different Bedouin villages which are Wadi El Neam, Qasr El Sir, Wadi Areha and Ber Hadaj (Figure 1). The participants represent the PV system users; they agreed to communicate the experience of their community in using the PV systems as their source of electric power. The villages were chosen based on their access to electricity and the level of PV systems in use.

For the qualitative data, interviewees were asked about the status of their PV system, their satisfaction, the difficulties they face while using these systems and their future needs. For the quantitative data and in order to be able to measure and put the needs of the community into tangible and useable numbers [15], the interviewees were asked about their currently used electric appliances, the amount of electricity generated by the PV systems they currently have and the additional amount of electricity they need. Additionally, measurements of the un-labeled panels and batteries took place in order to estimate their actual capacities.

Results

Socio-economic status

60% of the participants in the survey were males whereas the rest were females. All interviewees were in charge of their households and their ages ranged between 28 and late 50s. 30% of the interviewees finished high school, 10% had a diploma, 20% had a graduate degree or above, whereas the rest (50%) did not finish high school (Figure 2).

On average, each household consisted of six persons where in eight out of the ten households, only one person generated income. 50% of the interviewees claimed that 100% of their income is spent on monthly expenditures whereas the other 50% claimed that on average 82% of their income goes to monthly expenditures (Figure 3).

System usage

The survey showed that the diesel generators that were previously largely used by Bedouin community were replaced by the photovoltaic panels. Today, on average, interviewees use the photovoltaic systems 93% of the time, while they use the generators that were the main source of energy before 2006 only 7% of the times when the photovoltaic

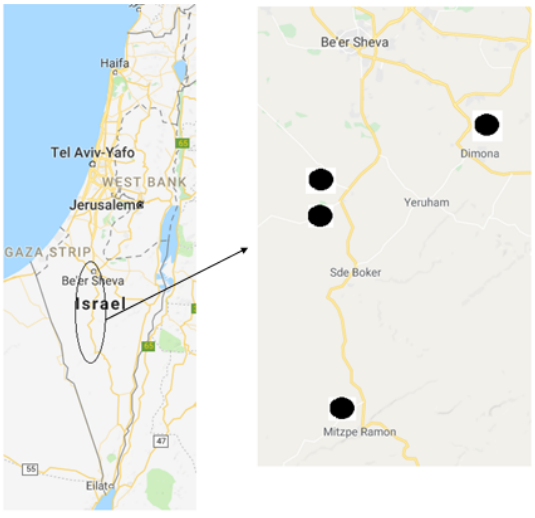

Figure 1: The location of the four Bedouin villages marked in black dots.

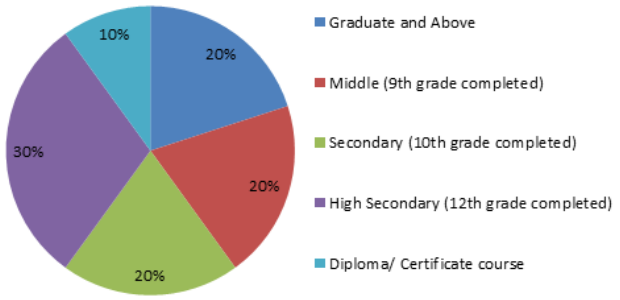

Figure 2: Level of education attained within the interviewees.

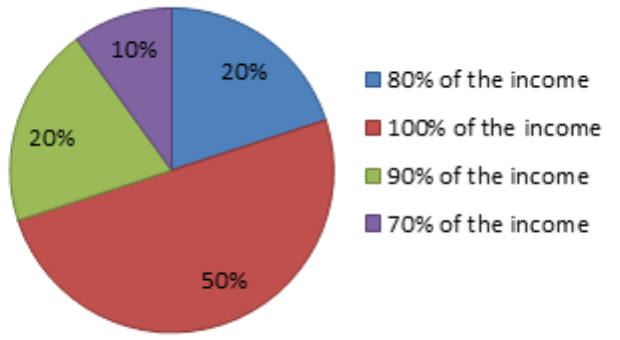

Figure 3: Percentage of income spent on monthly expenditure.

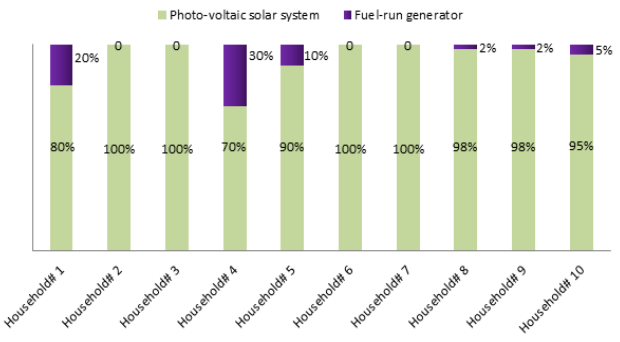

Figure 4: Electricity source in Bedouin households.

systems are not able to provide electricity to the households (Figure 4).

Similarly to the generators, off-grid photovoltaic solar systems do not require permits to be installed. However, they came to be preferred over the diesel generators because they do not require maintenance and a daily fuel supply, hence, they are not a daily burden that requires money, time, and transportation. Additionally, PV systems are not noisy, do not pollute the environment (during their normal operation) and their electricity generation is not limited to 3-4 evening hours as the generators but can continue working as long as the sun shines and after that depending on the batteries capacity. This allowed the Bedouin women, in particular, to use their electric appliances such as washing machines and food mixers during the day, while allowing them time in the evenings to spend with family members watching TV for example.

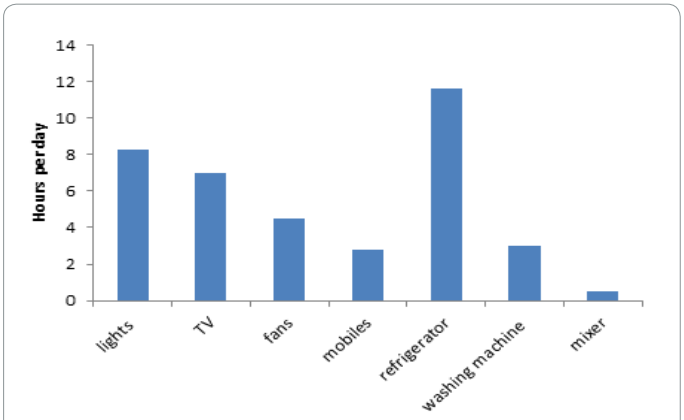

Figure 5: Appliances average usage per day (in hours).

Electricity consumption

The installed peak capacity of the households surveyed ranged between 300 W and 1200 W. On average, the installed capacity per person was 120 W/capita.

All the interviewees used energy-saving appliances. According to the interviewees, the use of the PV systems limits their shopping options to energy-saving appliances. Hence, they need to pay more than grid-connected people who have a wide variety of electronics from which they can buy.

Even after buying these energy-saving electronics, Bedouins still have to monitor how long these electronics work. Figure 5 shows how many hours each appliance is used on average by the interviewees.

According to the interviewees, the refrigerator is the appliance that consumes the highest amount of electricity; that is why they turn it on during the day for only 5-6 hours on average.

Additionally, the use of the photovoltaic system does not allow the use of several appliances that the Bedouins wish to use such as: heaters in winter, automatic washing machines, different kitchen appliances such as microwaves, and construction equipment such as drills or iron cutters.

Operation and maintenance

The interviewees expressed their concern of the environmental and weather conditions that decrease or even stop the electricity generation of the photovoltaic solar system. These conditions include clouds, heat, sand and wind. First, in winter, on cloudy days with limited solar radiation (similarly to cloudy days in any other season), the system is not able to generate enough electricity to charge the batteries. Second, in summer when the weather is too hot, the system becomes overheated and the batteries stop charging. Third, the sand reduces the life span of the batteries and causes them to stop charging if the sand enters the battery sealing and gets to the cells. Therefore, (as explained by the interviewees) the charge control, inverter and batteries are placed either in the house or in a small room that is built especially for them outside. Fourth, the wind can be a major cause of the damage of the panels. If not well installed, the wind might cause the photovoltaic panels to fall and break.

Despite their relative simplicity, regular maintenance and servicing must be executed to ensure the photovoltaic systems long-term benefits.

For example; as explained by the interviewees, the batteries require close attention to the water level in them. They need to be monitored and filled weekly. Lack of water causes them to stop charging and reduces their life span. Moreover, the interviewees explained the lack of knowledge of the amount of electricity that devices consume might cause the charge control to burst if overloaded with equipment. Interviewees explained that they gained such knowledge through practice.

Other than the regular servicing, some parts of the system wore out more quickly than others and need to be replaced more frequently. Batteries were seen by the interviewees as the part that needs to be replaced approximately every three years while other parts such as the charge control and the inverter can last for more than six years and panels (if not broken) last for 20 years.

Eight out of the ten interviewees claimed that they depend solely on the local supplier to fix their system. However, not all the interviewees could afford the maintenance of the system. Hence, if any part is worn out or broken, many people choose to continue to generate electricity without fixing that part. For example, when panels are broken, people continue using the panels that they are left with. When the charge control or a battery stops working, people let the system operate without these parts.

Some interviewees said that they could not afford to buy a new system, which is why they opted to purchase a used one. As a result, systems break down more quickly and required more maintenance. The interviewees believed that the more a person pays, the better system one gets; the more energy it gives and the more time it serves. But with limited income, this is not always possible and people have to make the best of whatever used parts they can afford.

Satisfaction and future needs

All the interviewees expressed the need to enlarge the system they had by at least two panels (500-600 watts). Some were more satisfied with the system they had more than others, and some explained that this enlargement is an urgent need more than others.

Figure 6 shows that one out of the ten interviewees is extremely satisfied, two are somewhat dissatisfied and seven are somewhat satisfied with the electricity supply they currently have. The reason behind this satisfaction is not because the generated electricity is enough for their daily uses, but because now (as opposed to the past when the main energy source was the diesel generators) they are able to use electric appliances for more than 3-4 hours during the evening. As explained by the interviewees, now children can study when darkness falls and the women can do the laundry during the day.

Although the satisfaction levels are "relatively high", all the other interviewees agree that there will be a need to expand their systems in the future. Six out of the ten interviewees explained that the electricity generated by the system is not enough for their daily uses. In other words, although the interviewees are satisfied with the electricity generated by PV systems when comparing it to the generators, this supply is not enough for their daily needs. The other interviewees (except for one) claimed that what makes the electricity enough for their daily usage is the limited amount of the appliances they are currently using and the energy-saving methods they are applying (Figure 7).

The need for the enlargement of future systems arises from two main reasons: first, interviewees are not able to use all the electric appliances they wish such as kitchen appliances and power tools. Second, in winter, electricity cuts out frequently. Thus, if a larger system

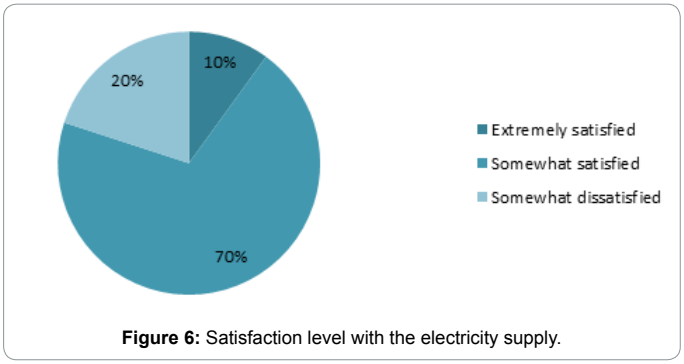

Figure 6: Satisfaction level with the electricity supply.

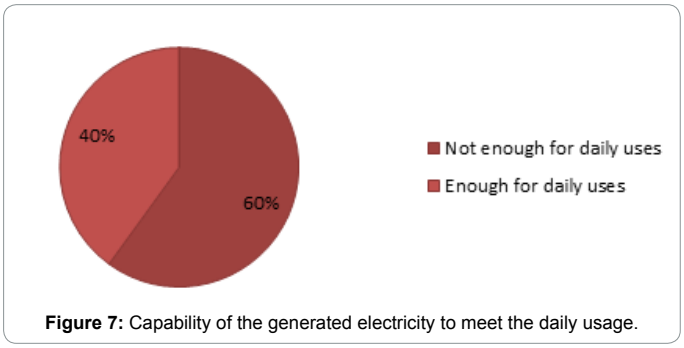

Figure 7: Capability of the generated electricity to meet the daily usage.

is installed, the batteries can save more energy and the electricity can stay on longer.

All interviewees except for one explained that the system improved their household conditions by at least 50%. This improvement rises from the fact that now the interviewees have light, children can study at night, they can watch television and listen to the news, they can charge their mobiles, use the washing machine during the day and use the refrigerator to keep food and medications from spoiling.

Discussion and Conclusion

PV projects in the Bedouin community are unique in the sense that unlike most off-grid electrification programs, these projects were initiated and sponsored by the Bedouin people without assistance; most programs were either implemented through foreign government subsidies or donor agencies. The results showed that there is an urgent need for up-scaling the electricity systems found in the Bedouin community. As noted previously, six out of ten interviewees do not have electricity even for using very basic electric appliances such as television, washing machines and lights. This number rises to nine when interviewees were asked about their electricity supply in winter or when they were asked about their optimal electricity usage. Therefore, it is vital to enlarge the PV systems used by adding additional panels and more batteries in order to be able to generate and save more electricity for daily usage especially in winter when the sun does not shine daily.

The results showed that eight out of ten interviewees lack basic knowledge about the maintenance needed to care for the PV systems. The interviewees depend on their suppliers to provide them with the systems and to fix them as necessary. However, most of the interviewees cannot afford to call the supplier in case of system damage. Therefore, they operate the PV system without the worn out parts. In order to be able to reach long-term sustainability, it is important to empower the community by providing them with the knowledge and the training on the production and maintenance of the PV system. Then, the Bedouins

will be able to operate their systems, identify the problems in their systems and maintain them without needing to wait or to pay for the supplier.

The lack of access to sufficient and affordable electricity and dependence on traditional biomass for heating in the Bedouin villages is a clear indicator of energy poverty and an enduring problem in the Negev. The energy poverty in the Bedouin villages not only limits opportunities for income generation and lessens efforts to escape poverty in general, but also impacts children and women in all these and in additional factors of their lives.

Off-grid solar photovoltaic systems have emerged as an option in rural Bedouin communities for clean lighting and for reduced diesel and kerosene use. Despite the benefits, there are significant barriers facing the installation and maintenance of solar photovoltaic systems due to inadequate training and awareness in low- and middle-income Bedouin communities.

Despite the lack of financial subsidies and the variety of barriers to diffusion and adoption of solar photovoltaic systems, the Bedouin communities took upon themselves the installation of such systems. It was observed that the Bedouin communities had a confidence in the technology for the following reasons:

1. Reliable quality and performance
2. Availability of after-sales repair service
3. Relatively easy to maintain
4. High price of diesel and kerosene
5. Lack of traditional biomass in the desert

It was also observed that the Bedouin communities face the following challenges and barriers that prevent them from using larger or sufficient photovoltaic systems more extensively:

1. High installation costs make off-grid solar systems expensive to purchase.

2. Lack of instruction and training on proper usage and maintenance of photovoltaic systems; this barrier leads to a high number of non-working systems.

3. Speculation about and mistrust in the technology and the payback time of the photovoltaic systems.

Similar conclusions and observations were obtained during the large number of visits and interaction meetings with the Bedouin community (In addition to the interviews).

As explained previously, the Bedouins started using the PV systems more than a decade ago. Prior to that, they used diesel generators to provide them with the electricity needed. These generators are currently used when the PV systems do not generate electricity. However, in order to reach sustainability, other renewable energy technologies can be introduced and adopted by the community if proven to be economically feasible, reliable and safe. An example of such technologies is mini-wind turbines proposed by one of the interviewees as the future electricity source. Furthermore, it is clear that the Bedouins perceive the PV systems as reliable technology and these systems have a very good reputation among the community. But, many did not receive training and know little about the technology. It is clear that more attention has to be paid to provide essential training for Bedouins to use the PV systems. In particular, end users need to be trained to avoid deep discharge of batteries. To this end, trainings have to be gender sensitive if predominately women are using the technology.

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