Solar Water Pumps:

The Case of Egypt's Desert

Egypt Network for Integrated Development

Case Study 003

Solar Water Pumps: The Case of Egypt's Desert

Introduction:

Analysis and forecast of Egypt's energy resources and needs till 2050 shows the inability to depend on national oil and gas reserves for electricity generation that meetsestimated targets at that time. Efficient utilization of energy resources requires a major policy shift towards theuse of non-fossil techniques for electricity generation [12]. This requires existence of a balanced mixture of conventional and renewable energy resources, taking into account the environmental impacts resulted from energy production and consumption and its effects on health [6].

According to the national strategy wind andsolar power are to be used to cover ~20% of installed power by 2027. Hence a carefullybalanced mix is to be adopted with morereliance on the introduction of concentrated solar technologies. Egypt belongs to the global sun-belt. The country is in advantageous position with solarenergy. In 1991 solar atlas for Egypt was issued indicating that the country enjoys 2900- 3200hours of sunshine annually with annual direct normal energy density 1970-3200kilowatt-hours per square meter (kWh/m^2). Egypt was among the first countries to utilize solar energy [12].

Box 1: Need for Renewable Energy Resources

Oil was traditionally the major source of fuel and power, but as production levels have continued to drop from the high of 1996 (935,000 barrels a day), Egypt has had to use its developing gas reserves as a substitute. The dominance of these energy resources is highlighted by the fact that 95 per cent of Egypt's energy needs are being met using oil and gas. Since 2006 almost all of the Egypt's oil has been consumed domestically, with around 60 per cent of its natural gas production also being utilized to meet the country's growing energy needs.

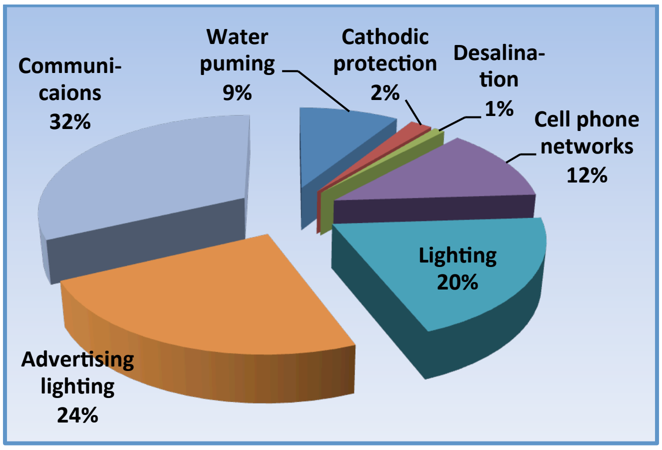
Egypt's demand for electricity is growing rapidly and the need to develop alternative power resources is becoming ever more urgent. It is estimated that demand is increasing at a rate of 1,500 to 2,000 MW a year, as a result of rapid urbanization and economic growth. Egypt is now struggling to meet its own energy needs. Egypt has been suffering severe power shortages and rolling blackouts over the past years, necessitating the requirement to look to alternative energy options to help meet increasing demand [5].

Renewable Energy Resources and Potentials in Egypt

Egypt is one of the sunbelt countries that enjoys one of the largest potentials of solar energy applications. The concept of renewable energy (RE) is not new to Egypt. Development of the renewable energy has become a priority over recent years. Egypt's present energy strategy aims at increasing the share of renewable energy to

20% of Egypt's energy mix by 2020. The RE resources with the greatest potential for widespread application in Egypt are solar and wind, both of which are substantial in the country. The total installed capacity of solar photovoltaic (PV) systems in Egypt is around 10 MW for lighting, water pumping, wireless communications, cooling and commercial advertisements on highwaysas shown in Figure 1[5].

Figure 1: PV Applications in Egypt by Usage

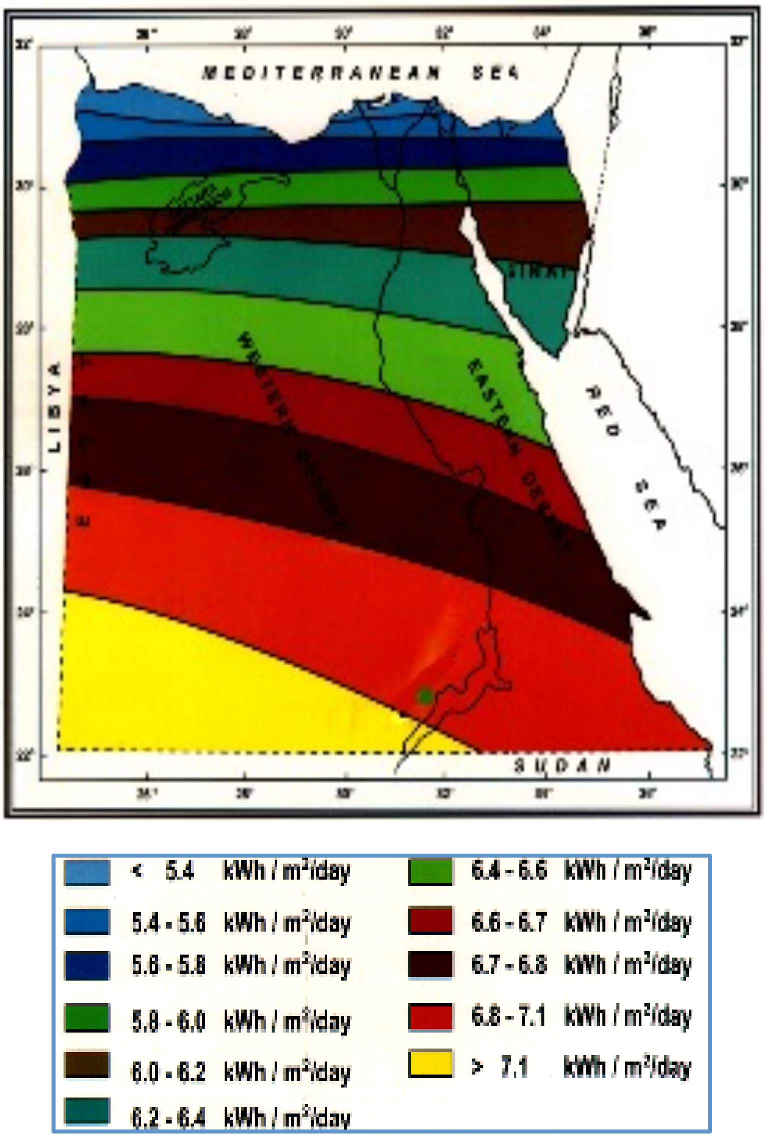


In Egypt, the government has exerted tremendous efforts indeveloping rural and remote areasthat suffer from lack of access to grid electricity and water. The main challenge facing those efforts is the inability of current energy to catch up with the rapid increase in population. Aneffective approach adopted to meet the challenge of scarceenergy is the utilization of renewableenergy sources and especially solar energy to produce needed energy for developing those communities [4].

Egypt lies in a high solar insulation band andis blessed with high intensities of solar radiations and longer durations of sunshine hours and is endowed withabundant solar energy and good weather conditions most of theyear [2].Accordingto the 1991 *Egyptian Solar Radiation Atlas*, the country averages between 5.4 and more than 7.1 kilowatt-hours per square meter (kWh/m^2) of annual daily direct solar radiation, from north to south(Figure 2). The annual direct normal solar irradiance ranges from 2,000 to 3,200 kWh/m^2, rising from north to south, with a relatively steady daily profile and only small variations in resource. Such conditions are supported by 9–11 hours of sunlight per day, with few cloudy days throughout the year [5].

Thus, Egypt has very favorable solar resources for a variety of solar energy technologies and applications. It is estimated that Egypt's economically viable solar potential in the range of 74 billion MWh per year, or many times Egypt's current electricity production.

Figure 2: Egypt Annual Average of Direct Solar Radiation



Source: Egyptian Solar Radiation Atlas

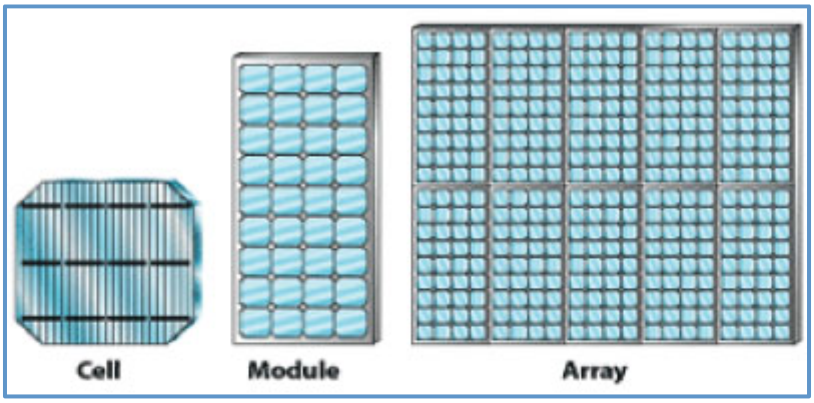
The Energy Research Center at Cairo University's Faculty of Engineering estimates that 6 MW of solar PV are currently installed in Egypt. In addition, a 150 MW integrated-solar combined-cycle power plant is under construction in Kureimat, with a solar component of 30 MW. Egypt is recognised as having vast potential for solar energy application, but the investment cost of solar power plants is currently very high in comparison with oil and gas fired power plants.

In the field of solar energy, New and Renewable Energy Authority's (NREA) future plan includes implementation of 100 MW solar thermal plant (financed in co-operation with KfW, World Bank and African Development Bank). KomOmbo site was selected to host the project. In addition, there are also two Photovoltaic plants with capacity of 20 MW in Hurghada and KomOmbo in co-operation with Japan and AFD, respectively [6].

SolarPhotovoltaic Power

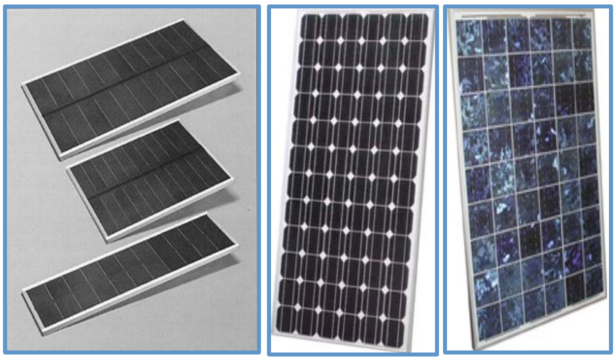
Solar or photovoltaic (PV) cells are made of semiconducting materials that can convert sunlight directly into electricity. When sunlight strikes the cells, it dislodges and liberates electrons within the material which then move to produce a direct electrical current (DC). This is done without any moving parts. Individual cells make up a module. An array consists of sets of modules as shown in Figure 3 [3].

Figure 3: Individual cell, module and array



Most commercial PV cells are made from silicon, and come in three general types. Figure 4 presents examples of the types of PV modules: a) amorphous; b) monocrystalline; and c) polycrystalline [3].

Figure 4: Examples of the types of PV modules



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Photovoltaic modules have been around for more than 50 years and have been mass-produced since 1979. Due to improvements in manufacturing technology and economies of scale, the cost of PV has fallen by 90% since the early 1970s. PV arrays are installed so that they maximize the amount of direct exposure to the sun. That usually means placement in an area clear of shading from buildings and trees[3]. In spite of being an expensive technology, PV systems are considered the most appropriate energy application for rural and remote areas of small scattered loads which are far away from national grid.The cost of producing electricity in remote areas is high since there is no connection to the national power grid, and transportation of oil fuel is quite expensive [9].

Solar Irrigation Systems - Photovoltaic Power Systems

A solar irrigation system is the device that uses the solar cell from the sun's radiation to generate electricity for driving the pump. A photovoltaic (PV) pump consists of an array of photovoltaic cells and pumps water from a well or reservoir for irrigation. They usually consist of an array of ***solar cells***, a ***power converter***, a ***control unit***, a ***pump*** and a ***well*** or reservoir. The operating principle is that the photovoltaic cells are capable of generating to electricity for driving the pump. Figures5and 6present examples of solar pump configuration[1].Water pumps, powered by photovoltaic (PV) panels, are being used frequently to pump water for domestic usage, to irrigate crops and landscape, to cattle, and provide potable water [2].

The solar water-pumping technology is commercially available, has-proven record of reliability, require, minimal skilled manpower once in operation, and operation and maintenance cost is also very minimal and affordable. PV-powered water-pumping systems have been installed and are operational in various parts of the globe including Egypt, and some of these installation dates back to early 1990s [2].

Figure5: Examples of Solar Pump Configuration

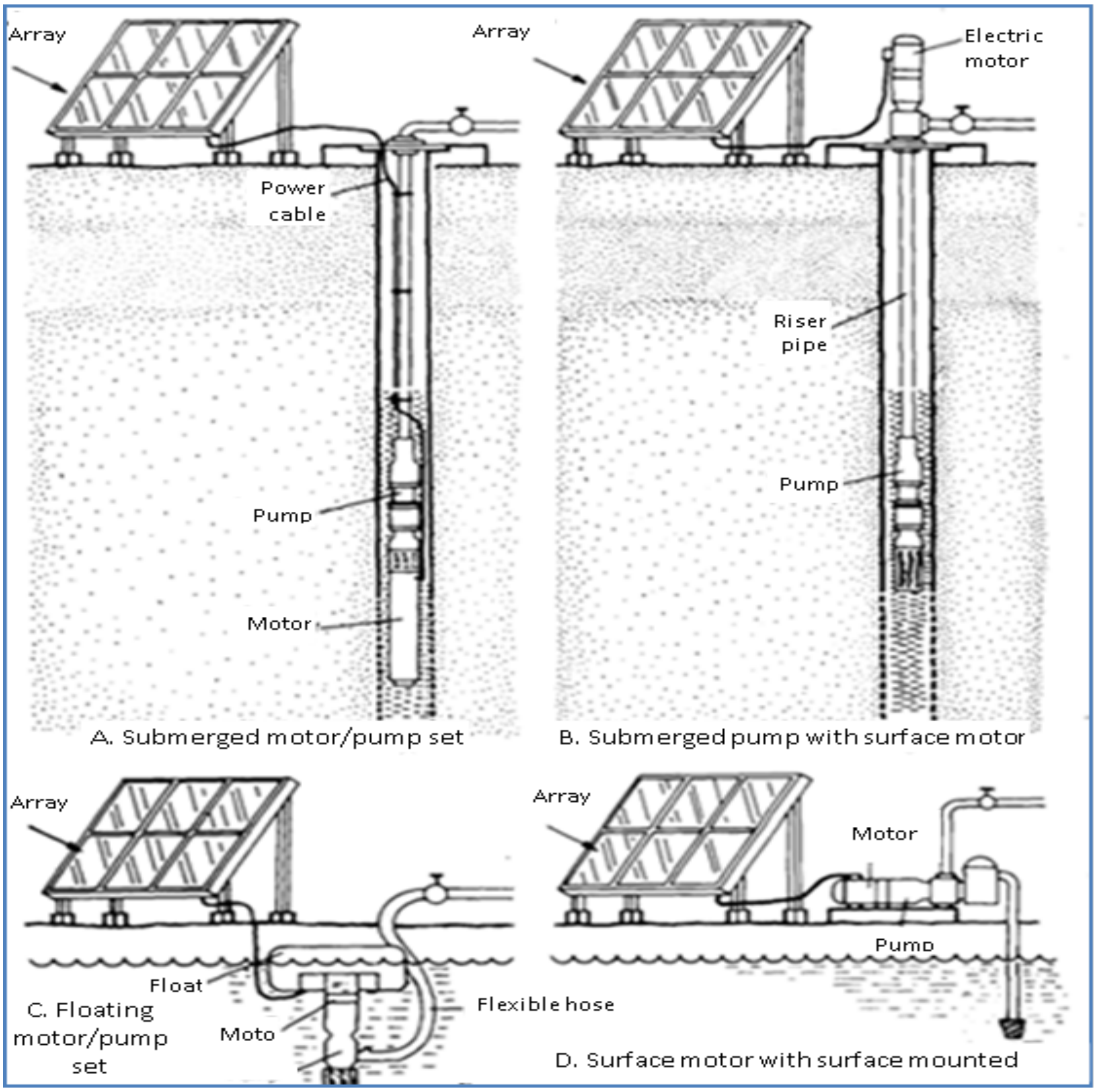
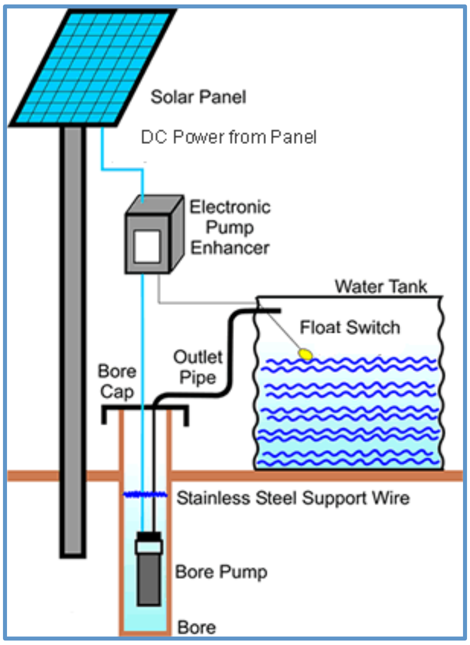


Figure 6: Solar Pump Components

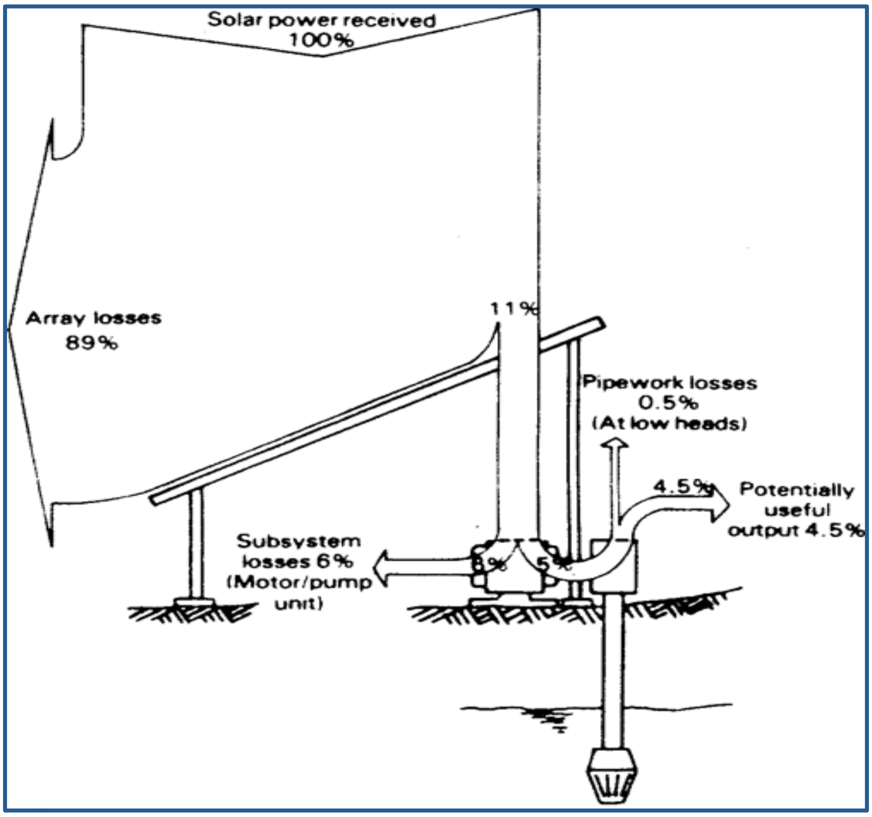


Source: Suntech-solar-water-pumps

As always, each component causes a loss (photovoltaic modules 11%; motor-pump unit, cables and controls 45%). Therefore the actual hydraulic output, ignoring pipe losses will be about 5% of the power of the sun arriving through the window of the array. Pipe lossesmay be another 0.5% of the total input, giving at best an overall efficiency of 4.5%. Figure 7 illustrates the power flow through a typical photovoltaic pumping system

The photovoltaic pumps have many advantages including they operate on freely available sunlight and therefore incur no fuel or electrical costs. They are also environmentally friendly, reliable and have a long working life [1]. The advantage of using solar energy for pumping the water is that major quantities of water are required during day time and that too during time when the sun is on top of our head, and during these times the PV panels produce maximum energy and hence the water quantity. These solar pumps can be installed in locations which are not connected to national electric grid [2].

Figure: 7 Losses in a Typical Solar PVPumping System



Advantages

- ***Low operating cost***: One of the important advantages is the negligible operating cost of thepump. Since there is no fuel required for the pump like electricity or diesel, the operating costis minimal.
- ***Low maintenance***: A well-designed solar system requires little maintenance beyond cleaningof the panels once a week.
- ***Harmonious with nature***: Another important advantage is that it gives maximum water outputwhen it is most needed i.e. in hot and dry months.
- ***Flexibility***: The panels need not be right beside the well. They can be anywhere up to 20meters away from the well, or anywhere you need the water. These pumps can also be turned on and off as per therequirement, provided the period between two operations is more than 30 seconds.

Limitations

- ***Low yield***: Solar pumping is not suitable where the requirement is very high. The maximum capacity available with solar is very low. However, the output of the solar DC pump is more than a normal pump.
- ***Variable yield***: The water yield of the solar pump changes according to the sunlight. It is highest around noon and least in the early morning and evening.
- **Theft**: Theft of solar panels can be a problem in some areas. So the farmers need to take necessary precautions. Ideally, the solar system should insured against theft as well as natural hazards like lightning.

Potential of Solar Water Pumping in Egyptian Desert

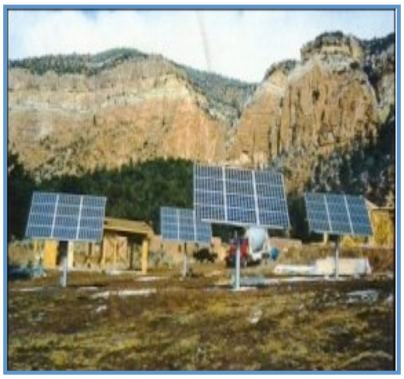
The big problem currently facing agriculture in reclaimed Egyptian desert far away from an electrical grid is dependence on diesel powered generators that require difficult to deliver and expensive liquid fuels for their operation. Off-grid[1] solar water pumps that recover underground water from deep wells for agricultural uses using solar energy applications serve the unique needs of Egyptians who live in desert landscapes.

Solar water pumps offer Egyptians the opportunity to live in off-grid desert communities and have access to essential groundwater resources will help to pull population away from an overcrowded Nile and take advantage of the desert's abundance of sun and soil. It will open up a chance for Egyptians to find a new ways of making a living without having to depend on an unreliable electrical grid[7].

Still there are remote areas and smaller cities and towns which are not yet connected to ***national electricity grid*** and are dependent on power supply from diesel generating power stations and have isolated grids. Diesel engines are not only unreliable, but particularly harmful to the environment. Previously, off grid renewable energy solutions were not financially feasible to compete with these engines. Ground water is available in most of these areas but they require electricity and equipment to pump the water for domestic usage, irrigation, and cattle. Water pumping has regularly been a technical challenge [2].

Recently some farmers have begun to move outwards into the western desert to exploit the vast expanses of land, using diesel-powered pumps to pull up the groundwater for their crops. Diesel is cheap (the government subsidizes it) and the pumps run 20 hours a day. But they are noisy and polluting, and transporting diesel to these remote areas is costly and hard[8].

[1]"Off grid" refers to areas that are off of Egypt's main power grid, which provides electricity to most of the country.



In the Egyptian desert, arable land is scarce and water almost nonexistent, so farming is a tough business. One resource you know you can rely on in a desert is plenty of sunshine, so some farmers in Upper Egypt have turned to harvesting the energy from the sun for irrigation.In Wadi El Natrun, situated far from mains electricity grids, the dry-climate fruits and vegetables grown are watered from wells deep underground. Once farmers used diesel generators to pump water for the fields, but now a self-contained concentrated photovoltaic (PV) system controls and manages an entire irrigation system.Where there is no public power grid, the PV systems currently operate cost-effectively, due to their low operating cost.

PV systems for the pumping of groundwater are also used in Upper Egypt, proving that the cost of the water unit pumped by PV systems is significantly lesser than that pumped by diesel systems [1].Solar water pumps were first introduced for water provision in off-grid areas. The technologyhas developed around many different designs. Solarpumps are easy to install, require no nonrenewable energy, operate autonomously and aregenerally “good” for the sustainability of boreholes due to their low extraction volumes spread over eight to ten hours a day.

The initial capital cost is high due to the cost of the photovoltaicmodules. The maintenance requirements differ and range between annual and five yearmaintenance intervals. A perceived limiting factor of solar pumps is that they do not easily caterfor fluctuating water demands or increased water demand although solutions for this are beingoffered.

Unlike conventional diesel or electrical pumps, solar photovoltaic (PV) pumps are powered byan array of solar panels. Solar PV pumps are designed to operate on DC power produced by solarpanels. Solar PV pumps are becoming a preferred choice inremote locations to replace hand-pumps, grid-connected electrical pumps and diesel pumps. Insuch places, solar PV pumps are even viable economically in comparison to conventionally runpumps [11].

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