Solar Powered Irrigation Systems in India:
Lessons for Africa Through a FAO Study Tour

International Commission on Irrigation and Drainage (ICID)
Preface

India is blessed with solar insolation in abundance and is striving to become a true world leader in the use of solar energy. The concerted efforts of the Government of India and different State Governments have made significant progress through different initiatives and schemes. This report highlights important initiatives, their implementation and impacts especially in three States namely, Punjab, Rajasthan and Maharashtra, as a part of the study material for a visiting delegation consisting of Dr. Ayman Elsayed Ibrahim Shahin, Sector Head of Monitoring Systems & Communication, Information and Assets Egyptian Ministry of Water Resources and Irrigation, Mr. Gabouj Ridha, General Director of Rural Engineering and Water Management, Ministry of Agriculture Water Resources and fisheries, Tunis, Tunisia, and Dr. Mohamed Ibrahim Al-Hamid, Senior Land and Water Officer, FAO Regional Office for the Near East and North Africa, Cairo, Egypt.

Solar water pumping for irrigation is being promoted worldwide by the Governments to address the continued demand by farmers to extend the electricity transmission network to all agricultural fields to enable them to avoid the use of expensive diesel for running irrigation pumps. Solar pumping systems offer superior solution to address such issue besides addressing the issues of depleting groundwater and other energy needs at the farm.

If only 50% of the 9 million running diesel water pumping systems are replaced by the solar PV pumps, the diesel consumption may be reduced to the tune of 225 billion liters a year besides significant reductions in CO₂ emissions over 100 million tons.

With the government incentives, solar pumps provide a predictable, more reliable and affordable source of energy at the farm. A field study with small farmers in district Alwar, Rajasthan revealed that solar pumps have improved crop productivity, income and even the livelihoods of small farmers.

Interactions with the farmers using solar pumps confirmed most of the positive perceptions that the visiting team had about the technology and its impact. The success of the solar pump schemes in India may also be gauged through the ever-increasing number of farmers willing to adopt the technology, off course with and through the Government schemes subsiding the capital costs as of now. These subsidies have to be viewed as a cost offset to the grid extensions and saving the costs of generation and transmission over long distances. The solar pump schemes have a huge potential of replicability in most developing nations. The issues of trained man power for installation, repair and maintenance need to be addressed simultaneously.
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<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>AC</td>
<td>Alternating Current</td>
</tr>
<tr>
<td>AD</td>
<td>Accelerated Depreciation</td>
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<tr>
<td>ASKP</td>
<td>Atal Solar <em>Krishi Pump Yojna</em> (Atal Solar Agriculture Pump Scheme)</td>
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<tr>
<td>CADA</td>
<td>Command Area Development Authority</td>
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<tr>
<td>CC</td>
<td>Capital cost,</td>
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<tr>
<td>CFA</td>
<td>Central Financial Assistance</td>
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<tr>
<td>CM</td>
<td>Chief Minister</td>
</tr>
<tr>
<td>CMD</td>
<td>Chief Managing Director</td>
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<tr>
<td>CSP</td>
<td>Concentrating Solar Power</td>
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<tr>
<td>C-WET</td>
<td>Centre for Wind Energy Technology</td>
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<tr>
<td>DC</td>
<td>Direct Current</td>
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<tr>
<td>DISCOM</td>
<td>Local Power Distribution Company</td>
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<tr>
<td>DNI</td>
<td>Direct Normal Irradiance</td>
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<tr>
<td>DRO</td>
<td>District Revenue Officer</td>
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<tr>
<td>EESL</td>
<td>Energy Efficiency services Limited</td>
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<td>EPC</td>
<td>Energy Producing Companies</td>
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<td>FAO</td>
<td>Food and Agriculture Organization of the United Nations</td>
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<td>FC</td>
<td>Fuel cost</td>
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<td>GHI</td>
<td>Global Horizontal Irradiance</td>
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<tr>
<td>GoI</td>
<td>Government of India</td>
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<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<tr>
<td>GSDA</td>
<td>Groundwater Surveys and Development Agency</td>
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<td>GW</td>
<td>Giga Watts</td>
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<tr>
<td>HDPE</td>
<td>High Density Poly Ethaline</td>
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<td>HP</td>
<td>Horse Power</td>
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<tr>
<td>ICIMOD</td>
<td>International Center for Integrated Mountain Development</td>
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<tr>
<td>IEA</td>
<td>International Energy Agency</td>
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<tr>
<td>IEC</td>
<td>International Energy Certificate</td>
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<tr>
<td>IEEFA</td>
<td>Institute for Energy Economics and Financial Analysis</td>
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<tr>
<td>ISA</td>
<td>International Solar Alliance</td>
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<tr>
<td>ISTS</td>
<td>Interstate Transmission System</td>
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<tr>
<td>IWMI</td>
<td>International Water management Institute</td>
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<tr>
<td>JNNSM</td>
<td>Jawaharlal Nehru Solar Mission</td>
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<tr>
<td>KUSUM</td>
<td><em>Kisan Urja Suraksha evam Utthaan Mahabhiyan</em> (Farmer Energy Security and Development)</td>
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<tr>
<td>KV</td>
<td>Kilo Volts</td>
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<tr>
<td>KWh</td>
<td>Kilo Watt hour</td>
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<td>KWp</td>
<td>Kilo Watts peak</td>
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<td>LCC</td>
<td>Life Cycle Cost</td>
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<td>Acronym</td>
<td>Description</td>
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<tr>
<td>SEC</td>
<td>Solar Energy Centre</td>
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<td>SEWA</td>
<td>Self Employed Women’s Association</td>
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<td>SPaRC</td>
<td>Solar Power as a Remunerative Crop</td>
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<td>SPICE</td>
<td>Solar Pump Irrigators’ Cooperative Enterprise</td>
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<td>SPV</td>
<td>Solar Photovoltaics</td>
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<tr>
<td>ST</td>
<td>Scheduled Tribes</td>
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<tr>
<td>STC</td>
<td>Standard Test Conditions</td>
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<tr>
<td>SV</td>
<td>Salvage value</td>
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<tr>
<td>TWh</td>
<td>Trillion-Watt hour</td>
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<td>UNDP</td>
<td>United Nations Development Project</td>
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<tr>
<td>USAID</td>
<td>United States Agency for International Development</td>
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<tr>
<td>UV</td>
<td>Ultraviolet</td>
</tr>
<tr>
<td>VGF</td>
<td>Viability Gap Funding</td>
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<tr>
<td>VOCTEC</td>
<td>Vocational Training and Education for Clean Energy</td>
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<tr>
<td>WBREDA</td>
<td>West Bengal Renewable Energy Development Agency</td>
</tr>
<tr>
<td>WiAP</td>
<td>Women in African Power</td>
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<tr>
<td>Wp</td>
<td>Watts peak</td>
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<tr>
<td>WUA</td>
<td>Water Users Association</td>
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Executive Summary

Need for Solar Powered Irrigation Systems

With the rapid depletion of fossil fuels, the alternative clean sources of energy are beginning to make a solid footing in the energy sector. In recent years, solar energy has emerged as one of the cleanest, environmentally friendly and reliable sources of energy. Energy being one of the main inputs of agriculture, especially for irrigation, is becoming a focus in the agricultural water management agenda. In this respect, Solar Powered Irrigation Systems (SPIS) are promoted worldwide as the alternative to traditional electric or diesel-run pumps. Such pumps provide an environment-friendly opportunity for irrigation because of the significantly lower emissions of greenhouse gases compared to the higher carbon footprint of the fossil fuel-based electricity options. For sustainable agricultural and rural development, the SPIS has proven to be a boon for several pilot and near-commercial scale projects in India. The report elaborates these experiences and describes the local context in terms of policy, technology, business models and required capacities of various stakeholders. The SPIS' provide a reliable source of clean energy to the farmers to irrigate their lands. They reduce the operating cost and provide relief to the farmers from the financial burden of fluctuating fuel prices. The SPIS provide the opportunity to the farmers for an additional income in case of surplus power generation, where the excess electricity may be sold to the national electric grid and the farmers may draw the power back from the grid when required.

Benefits of SPIS

In the rural areas in India, agriculture is the main source of livelihood for the farmers. Since the opportunity cost of the land in such remote locations is minimal, and the connectivity to the electrical grid is very poor, the farmers are unable to have an on-demand power supply to irrigate their crops timely and hence the resultant agricultural activity in these areas is very low. Moreover, the costs of acquisition and maintenance of diesel engine-based pump sets are also not affordable at all levels. With SPIS in place, the farmers have a dependable source of electricity for irrigation and if coupled with a sustainable source of water supply, subsequently a sustained source of livelihood.

Women play a fundamental role in agriculture and thus the impact of SPIS on women is of great importance. SPIS replaces the strenuous physical exercise required during the conventional irrigation with the convenient on/off switches which may be operated remotely as well. SPIS, additionally, opens the door for additional income for the family by the means of backyard vegetable farming for women and other local businesses.

Costs Associated with SPIS and Government Interventions

One of the biggest disadvantages of solar-powered pumping systems is that they require substantial investments during their first installation. This initial capital required for the installation constraints the farmers from adopting the SPIS as a viable option for power generation for irrigation. Although the initial investment costs are very high for the solar energy systems, in the long run, the cost for solar energy is cheaper than the diesel-run pumps during their lifetime. However, with government intervention, the support in the form of subsidies to procure the equipment and support during the initial phase of the projects has proven to be very helpful to the farmers in India.

Within the federal system of governance in India (Centre and States), agriculture and water are the primary responsibilities of the state. The Central Government, however, acts as a facilitator and provides broader policy guidelines for sustainable development of the agriculture sector and necessary
seed-funds or subsidies for wider adoption of technologies that improve agricultural productivity and natural resource conservation. The State Governments in India provide also subsidies to the farmers to promote agriculture and rural development and simultaneously prevent migration of youth to urban areas by creating employment opportunities in the rural sector. These subsidies are offered for the agricultural inputs such as diesel and power to the order of 70-90% in many places, i.e., at a much lower rate which is 70-90% lesser than the rate in the free market without government intervention. Overall the farmers receive subsidies for irrigation, power, fertilizers, seeds and so forth. Furthermore, water is considered a social good in India and hence there is no proper pricing structure for water. Consequently, some land-owning farmers receive water and electricity at almost zero cost. Regarding groundwater, the laws are not regulated by the Indian Government Natural Resources Policy Framework and thus, the users are almost free to abstract as much as possible using the available power in any form. Furthermore, the diesel and power subsidies allow the farmers to withdraw the groundwater with fewer monetary constraints resulting in the rampant abstraction of groundwater in some areas. Hence, these subsidies, especially those related to energy, are proving to be unsustainable to both the central and state governments in terms of environmental protection as well as economically. This burden on government exchequer is another motivation for governments to shift subsidies to more sustainable agricultural practices.

Sudden removal of government-provided subsidies may create a social and political imbalance in the farming communities. Hence, the state governments are coming up with newer models to provide subsidies to the farmers for electricity and irrigation generated by means of sustainable resources. In this respect, several pilot projects on Solar Powered Irrigation Systems (SPIS) are in the working phase in isolated pockets of India. Owing to the initial high investment costs, the SPIS were restricted in the initial stages of introduction. However, more and more states are now looking at SPIS favourably.

**Viable Business Models**

There are several business models that are currently in operation. One of the most successful models entails the involvement of the private sector. The private sector in tandem with the state governments has encouraged the deployment of solar-powered irrigation systems at several locations in India. After the installation, to promote the use of the SPIS, the private sector is actively conducting capacity building programmes for the farmers for several years. In a few large-scale projects, the private sector is mandated to provide after-sale technical support for approximately 7 years. Such a sustained commitment on the part of the governments and the private sector has been very promising in SPIS adoption by farmers.

In some cases, the progressive farmers are working with the private sector as the local dealers of the equipment, for installation as well as the operation and maintenance of the equipment. In certain cases, the farmers who are unable to purchase the equipment opt for the custom hiring of such equipment for irrigating their fields. Contract farming is proving to be another successful model where the farmers receive support from the private sector for the entire production value chain. In almost all the success stories, the catalytic role is played by the private sector in India working on manufacturing of solar-based micro-irrigation equipment, tissue culture of various horticultural crops, contract farming and research & development. The private sector is working closely with the farmers, local extension and irrigation officials, and promotes capacity building of farmers.

One of the successful models for the SPIS includes the approach implemented by the Water Technology Centre (WTC), Indian Agricultural Research Institute, an autonomous organization under the
Department of Agricultural Research and Education, Ministry of Agriculture & Farmers Welfare, Government of India which has been promoting solar-powered micro-irrigation for onion production in the Alwar region of Rajasthan State. The North Indian markets currently buy onions from the Western State of Maharashtra involving a significant transport cost. This makes onion production in Rajasthan highly competitive and as a result, it has captured 25% of the market in a very short span of time. However, lack of surface water-based irrigation sources require pumping efforts for the groundwater and the adoption of SPIS has led to a dependable water resources regime ensuring adoption of other efficient means of water application in the form of micro-irrigation. WTC has evolved a practical business model by identifying progressive farmers and making them local dealers to sell micro-irrigation equipment supplies in a cluster of 4-5 villages each. Based on interactions during the study visits of the FAO delegates to several farms, it was observed that farmers were quite satisfied, and the wider application of the business model seems very promising. Long-term capacity building efforts have been a key to the entire success where comprehensive assistance was always available to the pilot beneficiaries.

**Capacity Building**

The capacity development programmes are needed to support farmers, extension workers, local agri-businesses and others, scientific communication is of utmost importance. A continued adaptive model for modifying the implementation strategies and products is needed to ensure success in greenfield projects. Stakeholders in the water sector need scientifically validated climate change information and its potential impact on human life and natural resources including water in a form which is easily understandable and implementable. To further develop the technical capacity at the farm and community level, sustained interventions from the governments and the private sector are required. The main agenda of these programmes should be to generate awareness amongst the farmers to use water judiciously with an objective to improve productivity and reduce input costs. Also, at the government level, the policies and regulations should be enforced to monitor and curb the over-abstraction of ground or surface water.

**Conclusions and Recommendations**

While implementing SPIS, two major mutually exclusive objectives that of the government and the individual farmers must be addressed. The government aims to reduce the subsidies and reduction of natural resources footprint of the operations while the farmers’ objectives are to improve the production and increase the income with reduced labour to achieve economic prosperity and meet growing demands of his/her family. Introduction of solar power coupled with the adoption of micro-irrigation systems has shown promising results in this regard in all the pilot projects in India.

With the careful implementation of the technology and complementary government policies, SPIS provide an excellent alternative to the diesel or electric-run pumps to withdraw water for irrigation. Dedicated programmes to develop necessary last mile skills with the local entities for leveraging the scale effect post-pilot success is essential. Sustainable successes and widespread of the approach requires such interventions on a commercial scale. To further the knowledge on the subject and tap the vastly abundant solar potential, global platforms should organize conferences and regional seminar/workshops for knowledge exchange and technology transfer.

A much-neglected aspect of solar energy application in agriculture is its other applications in agricultural operations at the farm beside water application. Energy availability at the farm level would also be useful in chaff-cutting, dairying, connectivity to mass media and knowledge resources, post-harvest
activities such as thrashing, cleaning, heating/cooling and a general sense of energy security in the farm family. Energy availability also enhances drinking water filtration capacity for family members.

The main learning outcome of this exercise is the recognition that SPIS is not just a technology-driven activity; it also requires an enabling policy environment, locally-adaptable business models, and adequate capacity of farmers, extension workers and water management professionals, among others. The key to success lies in continued adoption and sustained operations through local skilled and unskilled manpower available and continued operational and financial benefits above the traditional means of energy supply and continued replacement of the parts of the system through owners’ resources and not through subsidy route.
1. Background

In recent years, solar irrigation has become increasingly feasible for countries as a reliable, clean-energy solution for agricultural water management, especially in areas with high-incident solar radiation. As investment costs for solar-powered irrigation systems (SPIS) are decreasing, SPIS technologies are becoming a viable option for many farmers. The conditions for SPIS vary from country to country, including biophysical and climatic suitability, techno-economic feasibility, institutional arrangements, regulations and policy support, financing and economic viability of systems.

Recognising the specific context in each country, the Food and Agriculture Organisation, Office for the Near East and North Africa (FAO-RNE), Cairo, Egypt seeks to explore how the promise of SPIS can be realised, whilst openly addressing the risks and challenges that come with the technology with focus on how this technology can be used to regulate groundwater use, to provide energy access to rural areas, and to promote innovative investment models and organisational structures. Many countries around the world have been experimenting with solar irrigation and it is necessary to first take a closer look at their experiences to understand how governments, banks, businesses, NGOs/CSOs and farmers around the world have managed to realise the promises of and to cope with the risks of solar irrigation technologies.

Keeping the above in view, FAO-RNE sought services of ICID to prepare, organize and support a study tour to India for three high-level stakeholders (Tunisia, Egypt). The study tour to India seeks to strengthen institutional capacities for the focal countries (Tunisia and Egypt). The study tour to India will highlight good practices, provide insights into how the potential of SPIS is realised (through targeted policies, innovative financing and user arrangements, etc. to promote and regulate such systems) and how risks are addressed. The main output of study tour will be to produce, achieve or deliver the following: (1) learning from existing experiences in India to understand how to promote and regulate the use of SPIS; and (2) providing field knowledge from India experiences for technical experts to act as multipliers of knowledge.

Study tour report on Risks and Benefits for the Solar Powered Irrigation Systems in the visited country will be elaborated based on the field visits, meetings and highlighting and taking stock of the experiences with SPIS around the different countries as well as different regions of India. Study tour report will elaborate on risks and challenges that come with the technology with a focus on how this technology can be used to regulate groundwater use, to provide energy access to rural areas, and to promote innovative investment models and organisational structures on and provide answers to the following specific issues:

1. What are the real costs and benefits of SPIS compared with other technologies?
2. What rules, regulations and policies are needed to manage the risks and realize the potential of such systems?
3. What are viable business models?
4. How can small-holders benefit?
5. How can the risk of groundwater depletion be addressed effectively?
6. What types of capacity development programmes are needed to support farmers, extension workers, local private sectors and others?
7. What are the opportunities for knowledge exchange and technology transfer?
This report provides a general overview of solar-powered irrigation systems (SPIS) in India and some of its neighbouring countries with a view on their relevance to geographically similar countries and regions of Africa. It explores the local agriculture conditions and government programs to enhance access to finance, especially for small-scale farmers, as well as the availability of quality SPIS products and services. The report also stresses the importance of water resources assessments and planning to avoid increasing pressures on water resources. Coupling solar pumping system with efficient irrigation methods, such as drip irrigation is included in the report. This report looks at how some countries work to create an enabling environment for solar technologies while managing the risks and challenges that come with it in the agriculture sector applications. Case studies in bore-well command, in canal command and women empowerment, are also included in the report. As such, it is a timely reflection of past, present and future trends and clearly highlights the inter-linkages of the water-energy-food nexus.

2. Solar Energy in Agriculture: Global and Indian Overview

Solar energy is the genesis for all forms of energy which can be used either through the thermal route, i.e., using heat for drying, heating, cooking or generation of electricity or through the photovoltaic route, i.e. converting solar energy into electricity that can be used for lighting, pumping, cooling and running electrical equipment, devices or appliances. Solar energy development programs were undertaken by several advanced countries immediately after the Second World War, the progress, however, slowed down with the coming of the nuclear era in the 1960s. The experiences with nuclear energy and the hike in oil prices in the 1970s once again focused attention on solar energy, a non-polluting abundant source. In Africa, several countries have started experimenting with solar energy systems for agriculture and rural development (Annexure A).

The International Energy Agency (IEA) predicts that solar energy (solar photovoltaic and solar thermal) could satisfy most of the global demand for electrical energy by 2060. Global solar map (Figure 2.1) shows the variation of the daily sum (kWh) and yearly sum (kWp) across different countries. IEA further estimates that the carbon dioxide (CO₂) emissions from the energy sector could come down to approximately 3 GT/year by 2035 compared to 30 GT/year at present and the world’s renewable energy sources could potentially grow 60% by 2035 and 100% by 2060. Which translates into that renewable energy could supply up to four times more energy than at present. With this aim, the Department of Non-conventional Energy Sources, Government of India, (formed in 1982), has started a number of developmental programmes and demonstration projects to harness alternatives.

Solar power is increasingly used in both developed and developing countries and the number of “solar home systems” has increased over the past two decades as the cost of solar technologies has declined due to the economy of scale and new research. In India, the private sector has started investing substantially in renewable energy sources to replace grid-dependence for rural electricity and diesel-run pumps and agricultural equipment. Most developing countries that are endowed with solar energy availability have the opportunity to leapfrog directly instead of heavy investments to expand grid-electricity supply in far-flung remote rural areas. Innovative financing models could assist households and communities in covering the one-time high investments in solar systems.

In the last few decades, prices of photovoltaic (PV) panels have dropped exponentially. As of 2018, the solar modules cost less than US$ 0.75/ Wp. Due to the availability of relatively cheaper solar power for pumping water for agriculture, domestic and other uses, the number of solar water pump (SWP)
manufacturers and suppliers has increased resulting in competition on price, performance, and quality. New pump and motor designs having higher efficiencies and sizes are making significant differences. During 2010-2018, the pumping capacity of solar systems has improved dramatically to reach groundwater as deep as 500 meters and the discharge volume of water up to 1,500 m³/day, competing neck-to-neck with irregular rural grid-supply and polluting diesel-run pumps (“Solar Pumping: The Basics” World Bank, Washington, 2018).

Solar pumping is most competitive in regions with high solar insolation, which includes most of Africa, South America, South Asia and Southeast Asia. Although all these regions have high radiation, the availability and depth of water resources vary significantly.

The Ministry of New and Renewable Energy (MNRE), India set up a Solar Energy Centre (SEC) in 1982, as a dedicated unit for the development and promotion of solar energy technologies. The National Solar Mission (NSM) was launched on 11th January 2010 with the following targets (i) deployment of 20,000 MW of grid-connected solar power by 2022 (ii) 2000 MW of off-grid solar applications including 20 million solar lights by 2022 (iii) 20 million sq. solar thermal collector area (iv) to create favourable conditions for developing solar manufacturing capability in India (v) aggressive R&D to achieve the above targets and make India a global leader in solar energy.

Fifty-one solar radiation resource assessment stations have been installed across India by the MNRE to create a database of solar-energy potential. In June 2015, India began a US$ 5.6 million project to measure solar radiation with a spatial resolution of 3 km x 3 km (1.9 mi x 1.9 mi) as shown in Figure 2.2. This solar-radiation measuring network provides the basis for the Indian solar-radiation atlas. According to National Institute of Wind Energy officials, the Solar Radiation Resource Assessment wing with 121 ground stations measure three critical parameters - Global Horizontal Irradiance (GHI), Direct Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DHI) to assess the solar potential of a region.
Interestingly, India’s installed solar generation capacity has continuously increased from 2,650 MW on 26 May 2014 to over 20 GW as on January 31, 2018, and over 26 GW by 30 September 2018. The 20 GW capacity was initially targeted for 2022 but concerted government efforts achieved the target four years ahead. The country added 3 GW of solar capacity in 2015-16, 5 GW in 2016-2017 and over 10 GW in 2017-2018 (Figure 2.3). The average current price of solar electricity dropped by 18% compared to the average price of its coal-fired counterpart. India’s “Scheme for Development of Solar Parks” has also proven successful and is attracting foreign capital toward construction of the world’s largest ultra-mega solar parks.

To suffice the local energy needs, India is also developing off-grid solar power besides its large-scale grid-connected solar PV initiative. By the end of 2015, more than 1 million solar lanterns, 118,700 solar home lighting systems, 46,655 solar street lighting installations and over 1.4 million solar cookers were installed in India, thereby affirming the rise of solar products to meet the rural needs.

In January 2016, with international support, the headquarters of the International Solar Alliance (ISA) began in North Indian state of Haryana with an aim to focus on promoting and developing solar energy and solar products for countries lying wholly or partially between the Tropic of Cancer and the Tropic of Capricorn. The alliance of over 120 countries was formally announced at the Paris COP21 climate summit. ISA proposes that wider deployment will reduce production and development costs, facilitating the increased deployment of solar technologies to difficult and remote parts and regions.
IRENA is projecting a 59% cost reduction for electricity generated by solar PV by 2025 compared to 2015 prices and this may be a catalyst for wider rural electrification and reducing energy costs for irrigation. As the assured access to water improves, agricultural productivity and incomes of farming communities will have a positive impact.

3. Case for Solar Power in Agriculture Sector of India

3.1 Agriculture Scenario

India is endowed with a rich diversity of natural resources, however, the need for food and nutritional security is increasing due to rapid demographic and dietary changes. The annual food grain requirement is likely to reach 494 million tons by the year 2050. This would result in a significant reduction of per capita availability of land, water, forest and other forms of natural resources. The agriculture sector, the biggest consumer of freshwater, is under constant pressure to use water resources much more efficiently by improving the performance of both irrigated and rain-fed production.

Irrigation has become an important part of global agricultural production, consuming about 70% of global freshwater resources (FAO, 2016). India relies heavily on agriculture but its contribution to GDP has been steadily declining as a proportion of the overall economy (15% of GDP). Agriculture continues to employ about 50% of the country’s workforce (KPMG, 2014). India has 180 million hectares cultivable land. Irrigation is used in about 45% of India’s cultivated area, while the rest relies on monsoon rain (Department of Agriculture and Cooperation, India, 2014). By 2050, the average annual water demand (both irrigation and other uses) is likely to cross the exploitable availability of 1123 Billion Cubic Meter (BCM) of both surface (690 BCM) and groundwater (423 BCM). To achieve the increased food production of 494 million tons by 2050, the irrigated area should increase from 79 million ha to 146 million ha (Soman, 2016). The cultivated land area can also not be increased significantly. India is entering a serious situation where without any possibility for increasing resources like water or land or energy for increased crop production it would be difficult to achieve food security. Irrigation is considered the most critical input for enhancing agricultural production to meet the food and fibre requirement of increasing population. Assured access to irrigation can increase crop yields by up to two to four times and is thus a key priority for both individual farmers and for meeting national development objectives (Shim, 2017).
3.2 Challenges of the Agriculture Sector in India

The projections for future population and food requirement of India indicate that the population of India may stabilize around 1.6 to 1.7 billion by 2050 AD and that would require about 494 m tons of food grain annually. Average national yields of most agricultural commodities in India are about 40 to 50% of the corresponding global averages. Water use efficiency is presently estimated to be only 38 to 40% for canal irrigation and about 60% for groundwater irrigation.

Agriculture via means of irrigation pumps accounts for about 25% of India’s total electricity use and 12% of India’s total diesel consumption, consuming 85 million tons of coal annually, and more than 4 billion litres of diesel. Currently, India has 26 million groundwater electrical pump sets, which run mainly on coal-fired power plants or by diesel generators (Shim, 2017). Out of a total of 26 million agricultural pumps, almost 9 million pumps are running using diesel engines and the remaining from the grid electricity. Electricity to farmers in India is provided at highly subsidized rates and this has led to widespread adoption of inefficient pumps (Desai, 2012). Moreover, the availability of electric supply for irrigation is also mostly erratic and, in many places, it is available only during late night hours when the urban demand is low. These low tariffs are leading to a host of problems in India as farmers have little incentive to save either the electricity or the water being pumped, resulting in wasting both. Limited and unreliable access to the electricity prompts the farmers to depend on high-cost diesel-fuel generators for water pumping in several places. The land is scarce in India, and per-capita land availability is low. Use of land for the installation of solar panels must be justifiable. Green Growth Knowledge estimates that the area required for utility-scale solar power plants is about 1 km² (250 acres) for every 40-60 MW capacity.

3.3 Potential of Solar Powered Systems

India is blessed with an abundant solar resource with clear sunny weather for more than 300 days in a year. The annual range of solar radiation (GHI: Global Horizontal Irradiance) falls between 4-6 KWh/ m²/day. Abundant solar radiation and utilization of higher quantities of groundwater for agriculture in the country, solar-powered irrigation systems (SPIS) are very suitable for India. With advancements in technology, the reduction in the cost of solar photovoltaic panels is making the application of solar pumping for irrigation more and more attractive. At present more than 60 million hectares area depends on groundwater irrigation. The agricultural sector accounts for almost 25% of total electricity consumption. Further, the state government in India budget roughly $6 billion annually for subsidies on groundwater pumps running on diesel or electricity could instead be utilized for investment in solar pumps (Shim, 2017). It is also estimated that the installation of 2,00,000 solar pumps in the next 5 years would require a total investment of about US$ 1.6 billion. As mentioned earlier, the total number of existing irrigation pump population in India is close to 26 million including 17 million grid-connected and 9 million diesel-powered pumps. The situation offers a huge potential for solar pumping systems. Potentially, as per GoI estimates, 9.4 billion litres of diesel could be saved over the life cycle of solar pumps if 1 million diesel pumps are replaced with Solar Pumps. A modest target of Government of India indicates that replacing 50% existing diesel operated and electric grid connected irrigation pumps by 2030 will create a demand of 1.2 million solar pumps per year. The replacement of long-established diesel and electricity run pump-sets with solar pumps would need capital investments and other promotional incentives; however, the potential savings are expected to outweigh the additional cost aspects. The efficiency of solar pumps is generally higher which helps in partially compensating the cost of replacement. For a developing country like India, with plentiful sunlight and limited fossil-fuel resources, solar-powered pumping systems provide promising solutions to meet the irrigation
requirements of land holdings for small and marginal farmers. The dramatic fall in global photovoltaic (PV) prices and soaring diesel prices in recent years have helped further promote solar pumps for irrigation as cost per peak watt PV power is about US$ 14 in India at present (Shim, 2017).

Since 1993, the Ministry of New and Renewal Energy (MNRE) has initiated programs for deployment of solar water pumping systems for irrigation and drinking water across 29 Indian states to commercialize solar systems by creating an enabling policy and financing environment for adoption of solar pumping technology (GIZ, 2013). As a result, India is now an emerging leader in solar pump use, with about 62,000 pumps in operation across India. Such initiatives facilitated installation of 31,472 pumps in the financial year 2015-2016, surpassing the total number installed since the program inception (MNRE, 2016).

### 3.3.1 Adopted models of SPV pump for irrigation

With water storage facilities to avoid expensive batteries, SPV pumps appear more attractive compared to traditional irrigation even when the 10-year economic comparison is made, though the life span of solar systems is about 25 years. With the passage of time farmers have now started showing interest in participating in the Government’s solar pumps scheme. In the scheme, there are two types of systems which are being used include indirectly-coupled pumps and direct pumping systems (Details of the specifications of the solar photovoltaic pumping systems selected for adoption are presented in Annexure B). Some examples of installation types are (a) solar-powered drip irrigation systems with and without water storage facility (Figure 3.1), (b) floating solar panels on water storage ponds or canal tops, (c) community-based centre pivot for larger areas or multiple farms, and (d) solar operated micro-sprinkler systems for orchards and field crops.

![Figure 3.1 Solar-powered drip irrigation system](image.png)

### 3.3.2 Specific Government Incentives for SPIS

The key incentives provided by the Government for larger adoption of the solar pumping technology in India, by the end of 2015, include (MNRE, 2016):

- **Viability Gap Funding**: Under the reverse bidding process, bidders who need least viability gap funding at the reference tariff (US$ 0.066 per unit in 2016) are selected for funding, which was US$ 13333/ MW for open projects.
- **Accelerated depreciation**: For profit-making enterprises installing rooftop solar systems, 40% of the total investment could be claimed as depreciation in the first year (decreasing taxes).
To protect the local solar panel manufacturers, 25% safeguard duty is imposed for two years period from August 2018 on the imports from countries who are suspected of dumping solar panels into Indian markets.

Capital subsidies were applicable to rooftop solar-power plants up to a maximum of 500 kW.

Renewable Energy Certificates (RECs): Tradable certificates providing financial incentives for every unit of green power generated.

Net metering incentives depend on whether a net meter is installed and the utility's incentive policy. If so, financial incentives are available for the power generated.

Assured Power Purchase Agreement (PPA): The power-distribution and purchase companies owned by the state and central governments guarantee the purchase of solar PV power when produced only during daylight. The PPAs offer fair market determined tariff for the solar power which is a secondary power or negative load and an intermittent energy source on a daily basis.

Interstate transmission system (ISTS) charges and losses are not levied during the period of PPA for the projects commissioned before 31 March 2022.

3.3.3 Farmers’ Adoption Behaviour for Solar Pumps

Indian farmers are becoming increasingly aware of the benefits of solar pumps, but its high initial cost is a major bottleneck in its adoption amongst the generally resource-poor farmers. General interactions with farmers have revealed that they are positive and willing to go for the technology mainly because of the ever-increasing cost of diesel for running the diesel engine operated pumping systems and the irregular and limited electricity supplies for running electricity operated pumping systems. Farmers find solar pumps superior as these operate for long day hours and do not require costly diesel for irrigation operation. Surveys of the farmers who have adopted solar pumps early have resulted in positive feedback about the support of system suppliers in after-sales service, repair and maintenance. It appears that the environment for large scale adoption of solar pumps in the country is ripe. Besides financial assistance by the Government for the purchase of solar pumps, the system suppliers have been mandated to train farmers in regular operation and maintenance of the systems, including dusting of solar panels every fortnight.

Solar pumps operate for 6-7 hours during the day-light and it does away with the night irrigation, saving the farmers from inconvenient and at times hazardous activity (including many cases of snake bites in the night during irrigation). In case of surface irrigation systems, this may require the provision of a farm pond or any other community storage so as to balance the mismatch between the canal water supply timings and energy availability timings. To make in-roads into the vastly untapped agricultural solar markets, SPIS manufacturers in India are providing the farmers with additional features such as remote-controlled (through mobile phone) on-off switches, GPRS aided identification of problems at different fields, after-sale technical service support for system components in case of malfunctioning, assistance in completing the government formalities for financing procedures, long-term capacity building in local communities for overall maintenance and operation of SPIS through trainings and demonstrations, and extension services for crop diversification to include vegetables, fruits and exotic herbs/produce.

3.3.4 Economic viability of solar-powered irrigation system- A State-level Example

The Rajasthan State of India had only about 50 solar systems in 2010-11, increasing to about 4,000 units in 2012-13. Most of these pumps were of 3000 Wp each with installed capacity about 12 MWp and
resulted into replacing the grid-electricity generated mainly through conventional fuels like coal and gas. Many of the solar water-pumps have been installed in the areas with less or no grid-connectivity. This has brought an estimated 12,000 ha of additional land under irrigation. With at least two crops every year compared with the earlier scenario of having just one monsoon-fed crop in the entire year, 24,000 ha has been irrigated. Many farmers have started having three crops every year and have diversified to far more remunerative horticulture/cash crops including vegetables and fruits. This initiative has started bringing positive changes in the lives of the farmers and their families as their incomes have increased significantly (Goyal, 2013). Combined with drip irrigation systems, nearly 48 million cubic meter water has been saved. The secondary benefits include savings in 2.4 million litres of diesel; US$ 48 million diesel-subsidy; and US$ 0.64 million foreign exchange are additional annual benefits that help reduce the emission of 3,480 Kg of CO₂ (Table 3.1).

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Items</th>
<th>Unit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Average solar pump capacity</td>
<td>Wp</td>
<td>3000</td>
</tr>
<tr>
<td>2</td>
<td>No. of pumps</td>
<td>Number</td>
<td>4000</td>
</tr>
<tr>
<td>3</td>
<td>Equivalent electric power saved (4000 x 3000 Wp) [the actual value may be lesser owing to the fact that the generation during the day is not uniform and the capacity given here is peak watts which may be available only on a bright sunshine noon period. Also, there will be age-based deterioration of the generating capacity]</td>
<td>MWp</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>Duration in hours a pump runs/day</td>
<td>hr</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>No. of units (KWh) saved per day</td>
<td>KWh</td>
<td>18</td>
</tr>
<tr>
<td>6</td>
<td>No. of days a pump runs in a year</td>
<td>days</td>
<td>200</td>
</tr>
<tr>
<td>7</td>
<td>No. of electric units saved per pump per year 18 x 200</td>
<td>KWh</td>
<td>3600</td>
</tr>
<tr>
<td>8</td>
<td>Cost per KWh of electricity @INR 5 (1US$=INR 71)</td>
<td>US$</td>
<td>0.07</td>
</tr>
<tr>
<td>9</td>
<td>Money saved by solar pump per year 3,600x5</td>
<td>US$</td>
<td>253</td>
</tr>
<tr>
<td>10</td>
<td>Conventional grid, distribution capital cost saved (not considered)</td>
<td>US$</td>
<td>Nil</td>
</tr>
<tr>
<td>11</td>
<td>Diesel cost saved per year (diesel generation is twice costly than electric)</td>
<td>US$</td>
<td>506</td>
</tr>
<tr>
<td>12</td>
<td>Diesel saved per pump per day</td>
<td>Litre</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>Diesel saved per pump per year (3 litre x 200 days)</td>
<td>Litre</td>
<td>600</td>
</tr>
<tr>
<td>14</td>
<td>Diesel saved total, per year (4000 pumps x 600 litre)</td>
<td>million litres</td>
<td>2.4</td>
</tr>
<tr>
<td>15</td>
<td>Foreign exchange saved per year, crude price @ US$ 0.27/Litre</td>
<td>US$ million</td>
<td>0.64</td>
</tr>
<tr>
<td>16</td>
<td>Diesel subsidy saved by Govt. per year</td>
<td>US$ million</td>
<td>0.32</td>
</tr>
<tr>
<td>17</td>
<td>Diesel subsidy saved by Govt. in 15 years</td>
<td>US$ million</td>
<td>4.8</td>
</tr>
<tr>
<td>18</td>
<td>Area irrigated per pump per crop</td>
<td>ha</td>
<td>3</td>
</tr>
<tr>
<td>19</td>
<td>Area irrigated total, 2 crops a year (4000 pumps x 2 x 3)</td>
<td>ha</td>
<td>24000</td>
</tr>
<tr>
<td>20</td>
<td>Water required for surface irrigation per ha</td>
<td>m³</td>
<td>5000</td>
</tr>
<tr>
<td>21</td>
<td>Water saved per hectare with drip irrigation (40% of 5000)</td>
<td>m³</td>
<td>2000</td>
</tr>
<tr>
<td>22</td>
<td>Total water saved, 24,000x2,000</td>
<td>MCM</td>
<td>48</td>
</tr>
<tr>
<td>23</td>
<td>Additional production value due to irrigation through solar pumps</td>
<td>US$</td>
<td>1333</td>
</tr>
<tr>
<td>24</td>
<td>Total Additional production value due to irrigation through solar pumps</td>
<td>US$ million</td>
<td>32</td>
</tr>
<tr>
<td>25</td>
<td>CO₂ Emission for one 1 kWh electricity produced by Diesel</td>
<td>kg</td>
<td>0.29</td>
</tr>
</tbody>
</table>
4. Solar Policy of Central Government of India

It may be pointed out here that India has a federal system of governance. Central Government operates for the entire nation and formulates broader policies and guidelines for the entire country. Critical areas of governance such as Country’s defence and external affairs among a few others are directly the responsibility of the Central Government. But the different States of the country can exercise their authority on the subjects of local focus including, agriculture, water and education, as provided under the constitution of India. On the schemes initiated by the Central Government, different States can exercise their authority and suitably amend for their local needs.

The Ministry of New and Renewable Energy (MNRE) is the nodal Ministry of the Government of India for all matters relating to new and renewable energy. The broad aim of the Ministry is to develop and deploy new and renewable energy for supplementing the energy requirements of the country. MNRE launched a new “credit-linked capital subsidy scheme” in 2014 to replace conventional groundwater pumps with 30,000 more efficient solar irrigation pump sets per year and to enable farmers to reap additional income through higher cropping intensity (MNRE, 2014). The process of bundling the subsidy with financing is implemented through a banking network, with the National Bank for Agriculture and Rural Development (NABARD) playing the role of the subsidy channelling agency.

By August 2016, 2.8 GW was installed compared to the forecast for solar photovoltaic installations was about 4.8 GW for the calendar year. This was more than all 2015 solar installations. India’s solar capacity reached 19.7 GW by the end of 2017, making it the third-largest global solar market. India’s solar projects stood at about 21 GW, with about 14 GW under construction and about 7 GW to be auctioned.

In mid-2018, the Indian power ministry issued a tender call for a 100 GW solar plant at an event in Delhi, while discussing a 10 GW tender due to be issued in July that year (at the time, a world record). The ministry also increased the government target for installed renewable energy by 2022 to 227 GW.

The MNRE has also established targets for the number of solar pumps installed for each state government while encouraging individual banks to set goals for financing solar pumps, give priority to solar loans, and reduce collateral requirements (MNRE, 2016). Progress under the scheme is monitored by NABARD and the MNRE on a regular basis. Eastern India has abundant groundwater potential but lacks the energy to pump it, while the western corridor suffers from groundwater depletion due to perverse electricity subsidies (Shah and Kishore 2012; Pullenkav, 2013). Hence, different approaches have been adopted to promote solar pump adoption in different locations as groundwater and energy availability varies greatly across the country India.

The GoI has boosted India’s solar pump industry not only by aggressively promoting solar PV pumping systems for domestic use but also by expanding the market for the solar water pumps globally. Recently, GoI, jointly with the International Solar Alliance (ISA), announced a pilot program to invite 15-20 countries to promote solar pump use to export solar pumps (provide credit lines where necessary), explain the benefits, and provide training on Indian-developed solar pumps (Chandrasekaran, 2016).
Increased potential, economic opportunities coupled with government promotion have helped expand the number of private sector actors offering solar pumping systems. Currently, there are more than 120 companies operating in India’s solar water pump market (https://mnre.gov.in/manufactures-suppliers-systems) (Chandrasekaran, 2016). Solar potential of India is shown in Figure 4.1. Further information on the state-wise solar potential of India is given in Annexure C, Table C.1.

![Figure 4.1 Solar Potential in India](image)

Different policy initiatives undertaken by the Government of India and various state governments are discussed briefly in the following sections:

**4.1 The National Solar Mission**

National Solar Mission launched in January 2010, is a major initiative of the Government of India and State Governments to promote ecologically sustainable growth while addressing India’s energy security challenge (MNRE, 2010). The Mission targets to create an enabling policy framework for the deployment of 20000 MW of solar power by 2022, through:

- To ramp up the capacity of grid-connected solar power generation to 1000 MW within three years by 2013; an additional 3000 MW by 2017 through the mandatory use of the renewable purchase obligation by utilities backed with a preferential tariff. Based on the learning from own experience, enhanced and enabled international finance and technology transfer, In June 2015, this target was revised upward to 100,000 MW by the year 2021-22.
- To create favourable conditions for solar manufacturing capability, particularly solar thermal for indigenous production and market leadership.
- To promote programmes for off-grid applications, reaching 2000 MW by 2022.
- To achieve 20 million sq. meters solar thermal collector area by 2022.
- To deploy 20 million solar lighting systems for rural areas by 2022.

The key driver for promoting solar power was through a Renewable Purchase Obligation (RPO) mandated for power utilities, with a specific solar component. This pushed up utility-scale power
generation, whether solar PV or solar thermal. The Solar Purchase Obligation was gradually increased while the tariff fixed for solar power purchase declined a little with time. MNRE has launched an ambitious programme to expand research capabilities, possible international collaboration and skilled workforce to support an expanding and large-scale solar energy programme. The aspiration is to ensure large-scale deployment of solar generated power for grid connected as well as distributed and decentralized off-grid provision of commercial energy services. The deployment across the application segments is envisaged as given in Table 4.1.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Application segment</th>
<th>Target for Phase I (2010-13)</th>
<th>Target for Phase II (2013-17)</th>
<th>Target for Phase III (2017-22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Solar collectors</td>
<td>7 million m²</td>
<td>15 million m²</td>
<td>20 million m²</td>
</tr>
<tr>
<td>2.</td>
<td>Off grid solar applications</td>
<td>200 MW</td>
<td>1000 MW</td>
<td>2000 MW</td>
</tr>
</tbody>
</table>

An autonomous Solar Energy Authority was created in 2012 under MNRE to implement this Mission. The Authority/ Mission secretariat is mandated to monitoring technology developments, review and adjust incentives, manage funding requirements and execute pilot projects. The Mission reports to the Prime Minister’s Council on Climate Change on the status of its programme.

4.2 Solar Pumping Programme for Irrigation and Drinking Water

MNRE has been promoting the Solar-Off Grid Programme for two decades. Solar Pumping program was first started by MNRE in the year 1992 and by 2014 approximately 14000 solar pumps were installed. This number is minuscule if compare with the pumps in the agricultural sector. High costs of solar modules during these years resulted in low penetration of solar pumps. However, in recent times the module costs have started decreasing and are presently hovering around one-fourth of the price in those days. As a result, the programme has become more viable and scalable. The scheme broadly outlines the key aspects of the programme with respect to proposed targets, implementing agencies, integration of schemes, potential implementation options, funding sources, key stakeholders, modes of communication, Monitoring and Evaluation of the programme, technical specifications of the programme etc. (Ministry of New and Renewable Energy, Government of India, 2014).

Key objectives are as follows:

i. Development of models that will foster solar power deployment for pumping in rural areas in a scalable manner.

ii. Exploring prospects of solar pump programs to address and support rural development related aspects, over and above the basic service of water.

iii. Improvement in energy access.

The duration of the programme was five years starting from 2014-15 with the target of 100,000 pumps. It is expected that by the year 2020-21, at least 1 million solar pumps will be deployed for irrigation and drinking water purpose. The states shall identify the potential solar pump targets considering some of the factors like water resource availability in various districts considering the pump size, cropping
patterns, affordability of beneficiaries, availability of state funds from various sources etc. while determining the target number of pumps replaceable under the programme.

4.2.1 Types of Solar Pumping Systems Eligible under the Scheme

The following five types of pumping systems are considered eligible under this scheme (Ministry of New and Renewable Energy, Government of India, 2014):

i. **Grid-connected pumping**: In many places, solar power packs can be installed where the pump is being driven by the electricity grid thereby providing a bi-directional power exchange mechanism. The solar power will be the preferred mode for pumping. Irrigation needs are intermittent, between 200 to 250 days in a year, leaving most of the days with additional power available. In collaboration with electricity authorities and local utilities, it could be encouraged to connect solar pumps to feed surplus power back into the grid.

ii. **Solar Pump Mini Grid**: There is a current trend in rural electricity grid to separate irrigation pumping from rural residential homes. A dedicated transformer is connected to a cluster of irrigation pumps supplying power for a fixed number of hours. This has created an opportunity to introduce high-efficiency electric pumps coupled to a transformer based solar PV plants. Each transformer could have PV plant ranging from 25 KWp to 500 KWp jointly in a people, public and private ownership. The PV plant will feed power to the cluster of pumps. If surplus power is available, PV plant will feedback power to the grid. Pumps could act as reliable anchor loads in case of off-grid mini-grids.

iii. **Diesel Pumps**: In many areas that are not grid-connected or if the power supply is not reliable, farmers are incurring a high cost for diesel pump and recurring costs for diesel, making small and marginal farming economically unviable. Additionally, most of these diesel pumps are highly inefficient. A programme that replaces diesel pumps with solar PV pumps would also help in reducing pollution besides immensely benefiting the farmer. Three state governments: Rajasthan, Gujarat and Karnataka have come up with their separate solar policy of replacing diesel with solar. The need for a diesel abating solution is obvious: not only does diesel power cause a lot of pollution, but it is also becoming very expensive. The price of diesel has increased by 300% since 2002 and 46% since 2010. With a lack of in-country petroleum resources, there is also a net outgo of finances beyond the national economy.

iv. **Community solar pumps or water as a service**: In some states, farmers with electricity/diesel connection also sell or barter water with neighbouring farmers who do not have a pumping system. In these situations, either solar pump (along with panels) needs to be portable or water as a service needs to be encouraged. The pumps would thus be owned by large farmers or community and the service of providing water to other farmers shall be charged. This could help to develop local enterprises increasing local employment opportunities.

v. **Micro-solar pumps**: In some cases, farmers grow vegetables on a very small size plot largely using manual irrigation methods like swing bucket, hand pumps or treadle pumps. A small micro-solar pump with less than 75 Wp to 500 Wp with 0.1 hp to 0.5 hp pump of power needed could do a similar function as a manually operated pump. Most of these farmers have no access to electricity. There are applications of micro solar pumps even in rural schools, health centres and drinking water.
4.2.2 Potential Implementation Models for the Programme

The pumping systems eligible under the scheme are provided to the stakeholders through appropriate Central and State Government Agencies (Ministry of New and Renewable Energy, Government of India, 2014). Though the Central Government scheme is the same, different State Governments implement it with suitable modifications in the mode of funding as follows:

i. Through State Governments
   - Conventional model
   - Financing from lending agencies
   - Water as a service model

ii. Through NABARD and banks like RRBs:

iii. Through and along with other Ministries of Government of India

4.2.3 Coordination committee at GOI level

A coordination committee was constituted at Government of India Level with Secretary MNRE as its Chairman and representatives of Ministry of Agriculture and Drinking Water and NABARD. The coordination committee meets quarterly to review the progress of the programme.

4.2.4 Coordination committee at State level

Coordination Committees have been set up by different State Governments under the Chairmanship of Additional Chief Secretary with representatives from the State Nodal Agency, State Agriculture Department, State Horticulture Department, Soil Conservation Department, Drinking Water Department and representative of NABARD. The committee is responsible for effective coordination among the various stakeholder departments/organizations and speedy implementation of the solar pumping programme in the State

4.3 Capital subsidy scheme of GoI for promoting SPV water pumping systems for irrigation purpose

The Solar Photovoltaic Water Pumping Systems can easily meet the irrigation requirements of land holdings for small and marginal farmers. These systems would help farmers to avoid travelling long distances for procuring and transporting diesel and also increasing the cropping intensity. Hence, Govt. of India has launched a programme for promoting 30000 solar pumping systems per year in the country for the purpose of irrigation. State-wise targets envisaged under the scheme are presented in Annexure C, Table C.2.

The scheme involves the provision of loans by Commercial Banks, Regional Rural Banks (RRBs) State and District Central Cooperative Banks, ‘State Cooperative Agriculture and Rural Development Banks (SCARDBs) and NABARD (under direct lending) for installation of Solar PV Pumping systems for the purpose of irrigation and capital subsidy will be provided for the same. Only manufacturers/entrepreneurs empanelled by MNRE, GoI (https://mnre.gov.in/manufactures-suppliers-systems) can participate in the scheme. The empanelled manufacturer/ entrepreneur will raise the invoices for the supplied products. The invoices generated by their dealers will not be eligible for a subsidy. Further, the manufacturer has to give an undertaking with the invoice that systems offered to meet the technical standards/requirements specified by MNRE, GoI. The pattern of assistance will be in the form of capital subsidy at rates indicated in Table 4.2 below.
Table 4.2 Subsidy Pattern by MNRE, Government of India

<table>
<thead>
<tr>
<th>S. No</th>
<th>SPV System</th>
<th>Capacity</th>
<th>Maximum subsidy US$ per hp</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DC Pumps</td>
<td>Up to 2 hp</td>
<td>768</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 - 5 hp</td>
<td>720</td>
</tr>
<tr>
<td>2</td>
<td>AC Pumps</td>
<td>Up to 2 hp</td>
<td>672</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 - 5 hp</td>
<td>576</td>
</tr>
<tr>
<td>3</td>
<td>For 5-10 hp pumps subsidy as US$ 2592 per pump set was fixed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Additional assistance for the same project from State Governments in the form of capital subsidy and interest subvention is allowed. However, state governments are required to directly enter into a suitable arrangement with financing banks for such types of additional assistance. The subsidy will be the same for all categories of borrowers throughout the country. The eligible borrowers shall apply to the banks for sanction of loan for the project. The bank shall appraise the project as per the norms and if found eligible, sanction the loan excluding the margin, subject to technical feasibility and financial viability. Based on the field visit and after satisfactory installation of the unit, the bank shall arrange to make payment directly to the supplier. After sanction of the loan including subsidy and after disbursement of the loan, the bank shall approach NABARD for a capital subsidy. NABARD will sanction and release subsidy subject to the admissibility of the claim and availability of funds from the Government of India.

The progress under the scheme is reviewed by NABARD Regional Offices at State Level on quarterly-basis and by NABARD Head Office/ MNRE at National Level on a regular basis. MNRE, GoI/ NABARD may also undertake visits to the units on a sample basis for assessing the quality of implementation of the scheme.

5. Implementation Schemes of Selected Indian States

Under this section, the policies of three selected Indian states are presented. In case of irrigation and particularly solar operated irrigation schemes, different States have hiked their share of financial assistance to the stakeholders. Also, some states have initiated additional schemes to promote solar operated irrigation systems more intensively in their states. As part of the study tour, the delegation visited three different States of India namely, Rajasthan, Punjab and Maharashtra and held discussions with the state government officials, the private sector and other agencies. Policies on solar pumping systems of these three states are presented in the following paragraphs.

5.1 Punjab State

Punjab has considerable potential in new and renewable sources of energy (NRSE) sector which is being harnessed (NRSE, 2012). To maximize the utilization of these resources, Punjab solar policies are designed with the following objectives:
- To maximise and improve the share of new and renewable sources of energy to 10% of the total installed power capacity in the state by 2022.
- To promote renewable energy initiatives for meeting energy/lighting needs in rural areas and supplementing energy needs in urban, industrial and commercial sectors.
The following major strategic initiatives are taken by the Punjab State Government to achieve the stated objectives:

- To create conducive conditions for attracting private sector investment in NRSE projects along with broader participation by public community/civil society.
- To provide decentralized renewable energy for agriculture, industry, commercial and household sector particularly in rural areas thereby improving the quality of power and reducing transmission & distribution losses.
- To give support to specific NRSE projects and schemes for generating energy and conserving energy through energy efficiency.
- To support research and development, demonstration and commercialization of new and emerging technologies in the renewable energy sector such as fuel cell, hydrogen and chemical energy, alternative fuels for transportation etc.

5.1.1 Solar PV Power Plants on Canal Banks and Canal Tops

MNRE through this scheme proposes to encourage the State Power Generation Companies/ State Government Utilities/ any other State Government Organization/ PSUs to set up grid-connected solar PV power plants of 1-10 MW capacity. Punjab State has been allotted US$30.4 million for 20 MW projects quota for grid-connected Canal top solar power projects. The total cost of the Scheme is US$130 million and the total estimated requirement of Central Financial Assistance (CFA) is US$30.4 million. The solar PV power plants will be developed by the State Power Generation Companies/ State Government Utilities/ any other State Government Organization/ PSUs/ GoI PSUs or GoI organizations, provided that they are operating in power sector or own canal systems, i.e. are into irrigation (MNRE, 2015).

5.1.2 Solar power projects for land-owning farmers

Punjab plans to achieve Solar Capacity 5400 MW by 2022. Allocation of solar power projects will be made to the land-owning farmers with a minimum capacity of 1MWp to a maximum capacity of 2.5 MWp (per landowning farmer) in the state for sale of power to Punjab State Power Corporation Ltd (PSPCL) using PSPCL applicable generic tariff determined by Punjab State Electricity Regulatory Commission (PSERC) on annual basis. These small solar PV systems shall act as a micro distributed utility at the farm level. The solar power generation shall be available for enabling the agriculture pump-sets loads to be operated during the daytime, thereby allowing the utility to dispatch the power so saved from their central generating station to another area.

Punjab Electricity Distribution Authority (PEDA) shall be the nodal agency for implementation of this special scheme. Project application processing and allocation shall be with PEDA while administration of Power Purchase Agreements (PPA) shall be with PSPCL. PEDA will also facilitate the farmers regarding documentation for the projects Capacity Target. The cumulative capacity under this scheme shall be 500 MW. The government of Punjab shall facilitate states the purchase of energy generated under this scheme by PSPCL through power purchase agreements of 25 years duration. The farmer shall bear the total cost of the 11 KV /66KV line for evacuation of power from the outdoor yard of the project to the nearest 66KV sub-station which can be constructed by the farmer through PSPCL on a job work basis (PEDA, n.d.). Further details on the eligibility of the farmers and the terms and conditions for them to participate in the scheme are available in Annexure D.
5.1.3 Solar pumps scheme for farmers

To prevent the excessive use of power for agricultural needs, the PEDA has started a scheme of solar pumps in villages. PEDA has aimed to install 2700 solar pumps in the state this year. The cost of 3 hp to 5 hp solar pumps is between US$ 640 and US$ 1000. Having 1.2 ha of agricultural land is mandatory to get installed a solar pump.

5.1.4 Scheme for matching irrigation water availability and demand for improved productivity through efficient water management

The Scheme has three components including micro-irrigation, soil photovoltaic pump set system and on-farm water storage tank. The financial assistance to the farmers for solar photovoltaic pump sets system component is provided @75% of the cost of the system, The financial assistance provided to the farmers for solar pumping systems under this scheme based on the peak wattage of the system is provided in Annexure D, Table D.1.

5.1.5 Pilot-cum-Demonstration Project for Development of Grid Connected Solar PV Power Plants on Canal Banks and Canal Tops

MNRE through this scheme proposes to encourage the State Power Generation Companies/ State Government Utilities/ any other State Government Organization/ PSUs to set up grid-connected solar PV power plants of 1-10 MW capacity with an aggregate capacity of 100 MW on canal tops / canal banks (50 MW canal-top SPV projects and 50 MW canal bank SPV projects) by providing capital subsidy of US$ 0.4 million/ MW for canal top SPV projects and US$ 0.2 million / MW for canal bank SPV projects; 40% at the time of sanctioning and balance 60% on commissioning of plant (Annexure C, Table C.3). Such projects result in benefits such as gainful utilization of the unutilized space over Canal Tops/ unutilized land on Canal Banks for power generation, enables the plants to meet their Renewable Purchase Obligation (RPO) mandates and provide employment opportunities to the local population. Such projects have been launched in various states of India, the first in Gujarat State, to use the 19,000 km long network of Narmada canals across the state to generate electricity through solar panels. It is proposed to encourage the State Power Generation Companies/ State Government Utilities/ any other State Government Organization to set up such plants, either on their own or through private sector developers and will be the implementing agency. These agencies will meet the balance expenditure through own resources or loan or any other means like developers and will enter into firm, long- term (25 years) tie-up with concerned State Irrigation Department/ relevant organisations for utilization of the Canal Tops/ Banks for setting up the power plants and PPA with State Utility/Distribution Company for purchase of the power generated from their plant at tariffs as mutually agreed or as fixed by the State Electricity Regulatory Commission (MNRE, 2015).

5.2 Maharashtra State Schemes

Maharashtra has abundant sunlight and is ranked the third-best region in India on the basis of solar insolation. Various schemes adopted by the government of Maharashtra are discussed briefly below.

5.2.1 Sakri solar plants

The 125 MW Sakri solar plant is the largest solar power plant in Maharashtra. It was constructed in the Osmanabad region of Maharashtra at an estimated cost of US$190,000 and US$81,000 which was paid as a subsidy by the renewable-energy ministry. A 10 MW solar power plant in Osmanabad was commissioned in 2013. The total power capacity of Maharashtra is about 500 MW.
5.2.2 Atal Solar Krishi Pump Scheme

In 2018, Maharashtra government launched Atal Solar Krishi Pump Yojana (ASKP) for farmers to provide a subsidy of up to 95% on solar agriculture pump sets, distribute 7000 pumps to the farmers to irrigate 14000 ha land under Atal solar agriculture pump scheme. The scheme aims to benefit farmers in increasing their water availability and reducing their energy bills. ASKP scheme aims to reduce subsidy outflow of 8.4 million US$ from state exchequer to supply subsidized power to farmers. This scheme will save 24.7 million US$ from cross-subsidy and would help in channelizing industrial development as power rates would get competitive. Maharashtra govt is struggling to recover farm electricity arrears which had previously announced a long-term plan to shift its 4.5 million farm consumers to the solar grid within 5 years.

ASKP Scheme is planned to promote the use of green energy, reduce pollution and will ensure that farmers have sufficient electricity for farming activities. Farmers with less than 5 acres of land need to pay 5% (160 US$) for a 3 hp pump. Moreover, farmers with more than 2 ha of land need to pay US$ 400 to get 5 hp solar powered pump. The important features and highlights of this solar agriculture pump scheme are as follows:

a. Government will distribute 7,000 solar water pumps for irrigation under AKSP agriculture pump scheme.

b. 25% of solar pumps will be of 3 hp (1750) and 75% of pumps would be of 5 hp (5250).

c. The solar pumps will enable farmers to irrigate their land during the daytime. Out of the proposed 7000 pumps under AKSP, 13.5% are reserved for the weaker sections of the society.

d. The state government has allocated a budget of US$31.99 million for solar pumps distribution.

e. The approximate cost of each solar farming pump of 3 hp is US$ 3200 and for 5 hp is US$ 4333. Central and state government would contribute 95 per cent of funds.

f. Under the solar Agriculture Pump Scheme Maharashtra, the pump distribution work will be handled by MahaUrja (subsidiary of Maha Genco)

5.3 Rajasthan State Schemes

By June 2018, the PV capacity of Rajasthan has reached 2289 MW making it one of India's most solar-developed states. It is also home to the world's largest Fresnel type 125 MW Concentrated Solar Power (CSP) plant at the Dhirubhai Ambani Solar Park. Jodhpur district leads the state with an installed capacity of over 1,500 MW. The Bhadla Solar Park, with a total ultimate capacity of 2,255 MW, is being developed in four phases of which 260 MW capacities were commissioned by NTPC, Limited. Total installed capacity at the end of June 2018 is 745. In September 2018, Acme Solar announced that it had commissioned India's cheapest solar power, 200 MW at Bhadla. The only tower type solar thermal power plant (2.5 MW) in India is in Bikaner district.

Acute water shortage, erratic rainfall and recurring droughts have exacerbated the situation in this desert state. About 70% of irrigation is done through wells/ tube-wells energised mainly with grid-power/ diesel-generators. Nearly 70% of the area is desert and hence electric-grid is not feasible in far-flung areas. A large number of farmers are seeking grid-based electricity connections for irrigation. The groundwater has deteriorated rapidly in the last two decades due to over-exploitation. Out of 249 blocks, nearly 200 are in the highly critical zone. Almost 90% of groundwater withdrawal in the State is utilised through flood / furrow-irrigation methods with a mere 35 to 45% water-use-efficiency.
The solar water pump scheme was scaled up from a low target of 50 in 2010-11 to 500 (900% increase) in 2011-12; to 2,200 (over 340% increase) for 2012-13; and then to 10,000 (354% increase) for 2013-14. Implementation at large scale was initiated in the year 2011-12 when out of 33 districts, 14 districts were covered. Following year (2012-13) the scheme covered all the 33 districts in the State. Plans are in place to install a total of 100,000 solar water pumps in the next five years.

6. Solar Energy for Rural Women Empowerment

The contribution of women in agriculture is generally not given proper recognition. It is believed that women contribute more than men in agriculture production and its post-harvest management. Ploughing and conventional irrigation are laborious and require the farmer to work in postures which are considered inconvenient and strenuous for women. Hence, except for ploughing and irrigation, most operations are dominated by women in the field, especially in India. In many ways, micro-irrigation empowers women in the field of irrigation too as no use of spade and earth moving is needed which is required in conventional irrigation methods. But the inconveniences of switching on and off the motor, which may be quite far from the home of the farmers remain. This problem is also overcome by employing remote on-off switches.

“Women are household energy managers, energy users and suppliers, and budding energy entrepreneurs, including them in energy sector decisions that affect them, can help ensure more effective use of resources and satisfied customers” (ENERGIA.ORG). Experience shows that solar power has been effectively used to power homes, schools and health centres and has provided access to information and communications technology (ICT). It has also been used to pump and purify water: solar-powered water pumping systems with drip irrigation have helped to increase agricultural output in women’s collectives, and allowed women’s businesses to grow, thereby contributing to enhanced food security and women’s economic empowerment. Several models have been attempted in different parts of the world using solar power pumping systems as a focal point for transformation and to empower women particularly in agriculture. Some of such attempts made in India and their impacts are presented in the following paragraphs.

6.1 Women Salt-farmers in Gujrat, India

US-based Natural Resources Defence Council (NRDC) partnered with the Gujarat-based Self-Employed Women’s Association (SEWA) to support thousands of women salt farmers in getting solar-powered pumps to replace their diesel pumps. The successful pilot project with 200 pumps was scaled-up to 400, then to 700 and is now expanding to 15000, helping thousands of families improve their livelihoods.

Based on the above results, the NRDC and SEWA are launching a new project on "Village Level Clean Energy Access" to increase access to clean energy for everything from solar-powered lights to cleaner cookstoves to more efficient appliances. The initiative started with two pilot villages and is planned to cover 10 villages across India. A new case study titled "Worth Their Salt" was also released as a project success story. The families not only just benefit from clean energy in the salt fields but will also benefit from the clean energy in all aspects of their lives, resulting in sustainable living.

6.2 Mousuni Project in Sunderbans (West Bengal State), India

Solar power has brought progress and development to Mousuni-island in the Sunderbans is in the eastern part of India. Not only is it powering the place but has also contributed to the empowerment
of women. Mousuni has around 4500-5000 households and about 20,000 adults. Since the installation of two solar PV systems in two villages in the island, Bagdanga and Ballara of 55 kWp and 110 kWp, respectively in 2001 and 2003, the life in the island has definitely changed for the better. Implemented under West Bengal Renewable Energy Development Agency (WBREDA), this pilot project has brightened the lives of the islanders.

The villagers get to choose from two types of energy supply. They can either opt for just 3 CFLs for US$ 1 per month or go for a connection which provides 3 CFLs, one TV and one fan connection for US$ 1.73 per month. This has contributed to a spurt of development and growth in the island and the nearby areas. Many local businesses such as general stores, video parlours, and jewellery shops have started functioning thereby bringing in more money to the place and contributing to its progress.

But the best part of solar power is the means of financial independence that it has provided the women in the village. The project provides training and capacity building on several techno-commercial aspects of solar power to the women in Sunderbans. This, in turn, has facilitated them to undertake solar PV-based services to remote and interior villages, and repair and maintain existing products and systems. Thus, women have not only become self-reliant, but they have also turned into solar entrepreneurs, engaged in a variety of businesses. Charging and renting of solar lanterns on a daily basis, designing and assembling small electronic items, and repairing solar home systems are some of them. Thus, solar energy is truly lighting up lives in the Sunderbans.

6.3 Solar Energy for Dual Pump Scheme a Boom for Women in Maharashtra State, India

More than 75% of India’s population lives in rural areas and 85% of the rural water supply is groundwater based. Hence bore wells with hand pumps are the most important elements of rural water supply. However, it is also a well-known fact that during summer when the water levels deplete, accessing water becomes much more difficult. If pumping levels deplete below the lifting capacity of the hand pump, 36 meters, it stops working and water scarcity is declared in that area despite water being present in the bore well. In rural areas, generally, women face all these problems. The patriarchal society holds women responsible for such routine tasks hence these women crave for a tap water supply. The Groundwater Surveys and Development Agency (GSDA) of the Water Supply and Sanitation Department of the Government of Maharashtra realized the plight of rural women and came forward with an innovative solution called dual Pump Scheme. In this scheme, a single phase 1 HP powered submersible pump is installed in the existing high yielding bore well having a hand pump. Pumped water is stored in a 5,000-litre tank and water supply is provided to each house through a tap. Rooftop rainwater harvesting is mandatory to make the scheme sustainable. Hence, water supply is restored by either one of the pumps. The scheme comprises of five major components: i) high yielding bore well/tube well (yield not less than 2,000 litres per hour); ii) installation of solar energy powered submersible pump with required photovoltaic panels. iii) HDPE storage tank of 5,000 litre capacity and arrangement for elevating it to 3-meter height to give sufficient head for the distribution system; iv) distribution system for 30 houses with individual tap connections; and v) rainwater harvesting structure. By 2018, 1860 Solar energy based dual pump piped water supply schemes have been completed in small habitations in the state under the technical guidance of GSDA (GSDA, n.d.). There are many success stories of solar energy based dual pump water supply schemes in rural Maharashtra.
7. New and Innovative Business Models

In addition to the several successful schemes mentioned in the previous sections, a few innovative business models are presented below:

7.1 PV Investments as Hedge Against Raising Electricity Tariffs

The 18 MW Tirunelveli solar power plant in Tamil Nadu having 12 blocks @ 0.75MWp and 9 blocks @ 1MWp were developed. It was set up and operated by Sun Edison Company. Investors can purchase one or several blocks and do not need to have technical expertise. Investors enjoy tax incentives (appreciated depreciation) and locked electricity cost for system life-span (net-metering system). Even though the PV products are based on complex processes, the products should be packaged in an easy-to-understand manner.

7.2 The KUSUM Scheme, India

The KUSUM (Kisan Urja Suraksha evam Utthaan Mahabhiyan) scheme provides 1.75 million off-grid solar pumps. The Government of India has planned to solarise every agricultural pump, connecting the entire grid connected pumps with solar power. The farmer will have to bear just 10% of the cost of the panel. The farmer will get the assistance of 30% capital subsidy from the Centre, another 30% from the state and the balance 30% will be financed.

The government will spend US$6400 million over 10 years as central financial assistance (CFA) on the KUSUM scheme aiming to encourage the use of barren land for setting up solar power plants. The solar panels to be provided will have twice the capacity of a grid one, and the farmers will have the option to sell the balance power back to the grid.

The scheme will have four components, including setting up 10000 MW solar plants on barren lands and incentivising the distribution companies) to buy the electricity produced, distributing 1.75 million solar pumps, solarising existing pumps of 7250 MW and government tube wells of 8250 MW capacity. The centre would take necessary measures and encourage state governments to put in place a mechanism that their surplus solar power is purchased by the distribution companies or licences at reasonably remunerative rates. In addition, the government has streamlined the capital allocation towards creating solar parks and associated infrastructure for the sector (Economic Times, 2018).

7.3 NABARD – MNRE Scheme, India

Scheme of MNRE, Government of India for installation of 10000 solar photovoltaic water pumping systems for irrigation purpose is implemented through NABARD. The subsidy is only available through a collateral loan from Nationalised Banks / Private Sector Banks/ RRBs and State Co-Operative Banks with the following conditions:

− The subsidy can be routed only if the project is undertaken by MNRE empanelled manufacturer
− The subsidy can be claimed by farmers, fish farms, salt farms etc.
− 40% MNRE subsidy routed through NABARD
− 20% customer contribution (customer has to deposit 20% amount in the bank)
− 40% Bank loan will be sanctioned to the consumer as per bank guidelines
### 7.4 Solar Parks and Ultra Mega Solar Power Projects, India

The state of Andhra Pradesh has commissioned the largest solar park (1000 MW) in the world in the district of Kurnool, with plans to introduce another massive solar park in the region of Kadapa of the capacity 1500 MW, and two other solar parks to be completed soon. With an additional 2,750 MW of solar energy set to be added to the state’s energy mix, Andhra Pradesh has become one of the leading Indian states in solar energy (Jaiswal & Bhagavatula, 2017). The Central government is further planning the enhancement of capacity from 20000 MW to 40000 MW for development of solar parks and Ultra Mega Solar Power Projects for setting up of at least 50 solar parks each with a capacity of 500 MW and above by 2019-20 with an estimated Central Financial Assistance of US$ 1080 million. The solar parks will be developed collaboratively with the State Governments and their agencies. The nodal agency of MNRE, GoI would be Solar Energy Corporation of India (SECI). SECI will administer the scheme under the direction of MNRE and will also handle funds to be made available under the scheme on behalf of GoI. Solar project developers shall enter into power purchase agreements with buyers interested to buy power from the developers.

### 7.5 Solar Power as a Remunerative Crop (SPaRC) model

The International Water Management Institute (IWMI) initiated a pilot project under the Solar Power as a Remunerative Crop (SPaRC) program in Gujarat’s Anand District which provides farmers a guaranteed option to buy-back the surplus energy generated from the water pump solar panels to the power grid with the help of a local power distribution company. With a solar water pump system with 8-kilowatt peak (kWp), farmers could sell the surplus power at a rate of US$ 0.07 per unit, earning the farmer US$ 112 over four months in 2015. Had this energy been used to pump groundwater, nearly 8 million litres of groundwater would have been unnecessarily extracted. The scheme benefits the farmers by adding to their incomes and provides incentives to conserve groundwater.

To reduce the high transaction costs in the buy-back scheme, a new scheme was launched by IWMI, known as Solar Pump irrigators’ Cooperative Enterprise (SPICE), where the pumps of Dhundi SPICE are connected to a mini-grid to pool metered surplus power to sell to the local power distribution company at a single point, under a 25-year power purchase agreement (PPA). Under the PPA, the SPICE is entitled to an attractive feed-in-tariff. This model provides the farmers with a risk-free, climate-smart ‘cash crop’ while minimizing or removing the burden of subsidies for the governments. This showcases a more effective and manageable solution to groundwater depletion (Shim, 2017).

### 7.6 SPIS in Nepal

International Centre for Integrated Mountain Development (ICIMOD) in collaboration with the local NGO Sabal Nepal and the social enterprise SUNFARMER working to provide the affordable solar energy technologies. The project also aimed to demonstrate the potential of low-cost solar-powered irrigation pumps (SPIP) as an alternative for irrigation. Three pilot solar pump sets were installed in Saptari district, one of them for the women farmers association in Rayapur village. Saptari district was chosen as it ranks second among Terai districts for vegetable production but is of the one of worst for productivity (15th) and women’s land ownership is particularly low.
Following randomized controlled trial, 3 financial models are being offered to farmers in 93 Village Development Committees in Saptari to test their acceptance among farmers. The benchmark model (grant model) mirrors Nepal’s renewable energy policy by offering a 60% grant with the farmer paying 40% upfront. The other two models are a grant cum loan model, where in addition to the 60% grant, farmers also get a loan, and a pay-as-you-go model, where a 50% grant goes to a solar pump entrepreneur who in turn rents out the pump against monthly or seasonal fees. To improve irrigation access for women, the grant is greater for them (70% instead of 60%), on the condition that the land on which the solar pump is installed is transferred to the woman. More than 2,600 farmers attended live demonstrations during a 45-day-long campaign in September and October 2016. About a quarter of the participants were women. This campaign generated 65 demands for SPIP. The grant cum loan model generated 46% of the demand followed by the pay-as-you-go model which generated 33% of demand.

7.7 SPIS in Bangladesh

The Infrastructure Development Company Ltd. (IDCOL) in Bangladesh has set a target to install 50000 solar irrigation systems by 2025, using the microfinance model as a tool to enhance rural household’s ability to afford capital-intensive solar home systems. The implementation arrangement for solar irrigation pumps builds on the successful solar home system programme which reaches almost 20 million people by way of nearly 4 million systems deployed by March 2016.

In this model, IDCOL provides a combination of grant and credit to partner organizations to install and operate the pumps. Under the ownership model, farmers may select to have the pump on their own land and, in some cases, sell water to nearby farmers. In general, farmlands that are not flooded during the rainy season – and therefore are suitable for three crops per annum – are ideal for solar pumps, providing power for about 20 acres of land and three annual crop irrigations.

Given Bangladesh’s fragmented land ownership situation, a group of 20-25 farmers form an association to buy water from one irrigation pump. Adapting to the local conditions, IDCOL is pursuing a fee-for-service model whereby partner organizations can install and operate the pumps and sell the water to the farmers. A total of 168 pumps are now operating, benefiting more than 3500 farmers, with another 277 pumps projected for installation (IDCOL, 2015).

IDCOL has also explored an ownership model with smaller-sized pumps, whereby a combination of grants and credit are provided to the farmers to purchase pumps in instalments rather than buy water from partner organizations. This will overcome the need for small farmers to seek suitable sites that require a sufficiently large land area for larger-sized pumps under the fee-for-service model (IDCOL 2015).

8. Field Visits and Technical Interactions

As part of the agreement between FAO-RNE and ICID, a high-level delegation consisting of officials from FAO RNE, Egypt and Tunisia undertook a study tour to India to visit SPIS projects implemented by the State Governments and interaction with the experts and various officials. The team consisted of the following:

1. Ayman Elsayed Ibrahim Shahin, Sector Head of Monitoring Systems & Communication, Information and Assets Egyptian Ministry of Water Resources and Irrigation
2. Mr. Gabouj Ridha, General Director of Rural Engineering and Water Management, Ministry of Agriculture Water Resources and fisheries, Tunis, Tunisia,
3. Dr. Mohamed Ibrahim Al-Hamid, Senior Land and Water Officer, FAO Regional Office for the Near East and North Africa, Cairo, Egypt

During the study tour team visited Grid powered lift irrigation project, Rajwal (Punjab); Small farmers solar initiatives, Alwar, Rajasthan; and Jain Irrigation System Limited, Jalgaon, Maharashtra. A half-day technical session was organized at the ICID Central Office in New Delhi for presentation on solar power initiatives and interaction with various experts, professionals and progressive farmer. During the field visit and technical session, the following presentations were made:

- **Indian Government Policies on Solar Photovoltaic Pumping Systems**, Dr T B S Rajput, Emeritus Scientist, Water Technology Centre, Indian Agricultural Research Institute
- **Integrated Solar Powered Community Lift Micro Irrigation Project in Kandi-Belt of Talwara and Hajipur Blocks of District Hoshipur in Punjab**, India by Mr Naresh Kumar Gupta, Divisional Soil Conservation Officer Hoshipur and Mr Sukhdeep Duggal, Project Manager, Jain Irrigation Systems Ltd.
- **Challenges and Opportunities for Field Level Coordination and Implementation of SPIS in Haryana**, India, Mr. Neeraj Sharma, Executive Engineer, CAD Division, Kurukshetra, Haryana
- **Financing Solar Irrigation, the India Story** by Ms. Stuti Sharma, World Bank

A brief description of projects visited and interactions during field visits are given below and copies of presentations are available in Annexure F.

### 8.1 Grid Powered Lift Irrigation Project, Rajwal

Kandi Community Micro Irrigation Project is a unique type of irrigation project where solar photovoltaic energy is being used for pumping water from a canal to irrigate area under command with micro-irrigation either by sprinkler or drip irrigation. This is going to be the largest of its type. Canal water is lifted with solar pumps (Figure 8.1). HDPE pipes are being used for the distribution network for 660 ha of the net command area. Salient features of the project are given below.

<table>
<thead>
<tr>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area irrigated</td>
<td>660 ha</td>
</tr>
<tr>
<td>Villages covered</td>
<td>Nagar, Dusaraka, Talwara, Rajwal-I, Rajwal-II and -III, Bhambotar, Tohlu, Dhulal</td>
</tr>
<tr>
<td>No. Of beneficiaries</td>
<td>1200 Nos</td>
</tr>
<tr>
<td>Water source</td>
<td>Kandi canal (Mukharian canal)</td>
</tr>
<tr>
<td>Design Water Requirement</td>
<td>2 mm/ Day</td>
</tr>
<tr>
<td>Total Water Requirement</td>
<td>576 lps /12 Hrs</td>
</tr>
<tr>
<td>Total Estimated Power need</td>
<td>2800 H.P.</td>
</tr>
<tr>
<td>Energy Required per Year</td>
<td>6099296 KWH</td>
</tr>
<tr>
<td>Solar Power Required/to be generated</td>
<td>4000 Kwp (To Compensate electric units)</td>
</tr>
<tr>
<td>Grid Connectivity</td>
<td>11 KV line to every pump house/ sub station</td>
</tr>
<tr>
<td>Main Sump Well</td>
<td>5 Nos</td>
</tr>
<tr>
<td>Main Pump Houses</td>
<td>5 Nos</td>
</tr>
<tr>
<td>Secondary Sump Well/: Pump Houses</td>
<td>17 Nos</td>
</tr>
<tr>
<td>Primary Rising Mains</td>
<td>3 Nos (HDPE DIA 355 TO 500 MM)</td>
</tr>
<tr>
<td>Secondary Rising Mains :</td>
<td>7 Nos (HDPE Dia 140 to 400 mm)</td>
</tr>
</tbody>
</table>
### Distribution Main Lines:
36 Nos (HDPE Dia 140 to 160 mm)-90000 Mtrs

### Section to be Created:
1008 Nos having average size of 1.2 ha
80% sprinkler, 10% inline Drip, 10% online drip

### Automation:
Automation up to 1.2 ha provided with CLOUD, SCADA, TELEMETRY, PLC, RTU, VFD

### Project Cost:
US$ 54 million

### Cost per ha:
US$ 3300

### Maintenance Contract:
7 years

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The solar pumping irrigation project provides for micro-irrigation to the areas which were virtually out of command owing to their elevation above the canal water (Figure 8.2). Pumping of canal water is being done using 1000 KW photovoltaic panels mainly installed along the canal bank.

The project has a web-based wireless irrigation management system. The unique feature is that the company installing the project (Jain Irrigation System Limited) has been entrusted with its operation and maintenance for a period of seven years. The company has also been asked to train the local beneficiaries to enable them to manage the system after seven years. The company has also been entrusted to help organize the beneficiaries into water users’ associations to handle day to day issues of beneficiaries and take over the project management after the company departs from the site. The beneficiaries are new to micro-irrigation therefore efforts are also being made to make them aware of the system and the appropriate cropping pattern etc for efficient use of available irrigation water.

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The delegates visited various components of the project and also interacted with the beneficiaries and water users’ association representatives and farmers Figures 8.3.
8.2 Community Based Solar/ Grid Powered Micro Irrigation CADA (Haryana)

A presentation was made by Mr. Neeraj Sharma on initiatives undertaken by the Government of Haryana in respect of solar power irrigation. A list of solar operated micro irrigation pilot project sites in Haryana state is presented in Table 8.1. A brief description of one such pilot project is given below.

A pilot project has been executed by Jain Irrigation Systems Ltd, Jalgaon in the state of Haryana with Command Area Development Authority (CADA) covering 14 outlet command of 13 districts of Haryana under the scheme of PMKSY “HAR KHET KO PANI” (Water to every field). Design of this scheme is based on actual cultivable command area (CCA), approved discharge normally 2.4 cusecs/ 1000 acres (0.173 cumec/ 1000 ha) and schedule of running of canal outlet by collecting the authenticated data from the Canal Authorities. Each component of this scheme is designed in such a manner that minimum operating pressure of 2.5 kg/cm$^2$ is available to the farmers on their farm gate (Figure 8.4).

The solar pumping system of appropriate size is a vital part of this scheme. Grid-connected solar powered pump has been considered in this scheme to reduce the cost of electricity. The capacity of solar power plant (1 hp equal to 1100 KWp) has been considered. Size of the storage tank has been designed by considering the discharge of the outlet and volume of water accumulated in 24 hours. Filtration units of appropriate capacity for proper filtration of water have been installed nearby community tank. A feeder pipe of appropriate length has been provided from the canal outlet to the storage tank by gravitational flow, further HDPE rising main, HDPE distribution network, Hydrant assembly with butterfly valve at the farm gate of the individual beneficiary at every 4 Acre area or minimum land holding vice versa for equitable distribution of pressurized water with minimum 2.5 kg/cm$^2$ pressure rating at remote hydrant for smooth operation of Micro Irrigation system keeping in view crop & crop rotation. Modified Penman method has been used to find out crop water requirement and compute the peak water requirement in two annual cropping seasons. The total project area was divided an equal block of 40-50 ha area with the separate pumping system. Submersible pumps of 10 to 20 hp capacities were commissioned with the average working of 14 hours/day. The capacities of...
the pump set required are based upon design discharge and total operating head. The total operating head is the sum of total static head; friction loses worked out with Hazen-Williams equation in pipeline network and losses in the filtration unit.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Site</th>
<th>Districts</th>
<th>CCA (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25220/L Sandhola Minor</td>
<td>KKR</td>
<td>59.49</td>
</tr>
<tr>
<td>2</td>
<td>44600/R Paharpur Minor</td>
<td>KKR</td>
<td>168.82</td>
</tr>
<tr>
<td>3</td>
<td>5775-R Mallour Disty</td>
<td>KKR</td>
<td>55.84</td>
</tr>
<tr>
<td>4</td>
<td>25300/L Singhwa Disty</td>
<td>Hisar</td>
<td>158.64</td>
</tr>
<tr>
<td>5</td>
<td>40900/R Naraina Disty</td>
<td>Panipat</td>
<td>346.41</td>
</tr>
<tr>
<td>6</td>
<td>72000-R Motipura Disty</td>
<td>Bhiwani</td>
<td>138.4</td>
</tr>
<tr>
<td>7</td>
<td>7200-R Subana Minor</td>
<td>Jhajjar</td>
<td>96.7</td>
</tr>
<tr>
<td>8</td>
<td>55800-L S.L.C</td>
<td>Jhajjar</td>
<td>209.94</td>
</tr>
<tr>
<td>9</td>
<td>45800/R Gegorani Minor</td>
<td>Fatehabad</td>
<td>285.091</td>
</tr>
<tr>
<td>10</td>
<td>7700/L Salwan Minor</td>
<td>Karnal</td>
<td>203.15</td>
</tr>
<tr>
<td>11</td>
<td>53620-L Ramkali Minor</td>
<td>Jind</td>
<td>39.66</td>
</tr>
<tr>
<td>12</td>
<td>4200-L 2R Baroda Minor</td>
<td>Sonipat</td>
<td>263.77</td>
</tr>
<tr>
<td>13</td>
<td>2.920 R Musepur Minor</td>
<td>Rewari</td>
<td>110</td>
</tr>
<tr>
<td>14</td>
<td>4.000 L Dholi Minor</td>
<td>Mahendergarh</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td><strong>Total area, ha</strong></td>
<td></td>
<td><strong>2230.911</strong></td>
</tr>
</tbody>
</table>

During the implementation of the Pilot project, some lessons have been learnt which are stated below along with suggested improvements:

- Scattered projects lead to an increase in cost and also reduce efficiency in the construction and operation of the project. Moreover, the working time window is very short due to the cropping pattern in Haryana and work in neighbouring areas can increase the coverage and reduce project cost. Therefore, the future project should be developed in a cluster of fields (chaks) in a contiguous area. This will accelerate development, improve efficiencies and reduce cost.

- Since the assured supply of canal water is limited, community tube-wells should also be installed and integrated, where possible, besides exploring other sources, if any. This will not only change the water management pattern from supply to demand but also reduce groundwater abstraction from private tube wells. There will also be a significant reduction in the overall subsidy bill of electricity.

Challenges faced and solution:

- Lack of community participation at all the stages, need to focus on Participatory Irrigation management and on-farm training/awareness program for judicious use of water.

- Hindrances created by the head reach farmers/beneficiaries of nearby outlet command area, since after execution of the project there is no chance of water theft. Need to educate the farmer.
The issue of land constraint for construction of water storage tank and installation of Solar Power Plant. In future Govt. should provide enough space by signing lease agreement or sufficient government land nearby minor or canal outlet.

11 KV HT line was executed under the self-execution scheme of DISCOMs by assigning local Electrical contractor in the project sites. Due to their casual approach commissioning and testing was delayed. In future instead of assigning electrical contractor, the work will be executed by the department only.

8.3 Evaluation of solar pumping systems

In India, farm holdings are small (more than 80 per cent land holdings are smaller than 2.0 ha). The government of India has initiated several schemes (presented in the report elsewhere) to promote solar pumping systems for the benefit of the smallholder farmers. Two small studies undertaken to evaluate the benefits realized by the Rajasthan farmers and their levels of satisfaction are presented under the following heads.

8.3.1 Evaluation of Solar Energy Driven Micro Irrigation System in Churu, Rajasthan (India)

The government of Rajasthan is promoting solar pumping systems on a large scale to overcome the problem of providing electrical connections to many farmers for pumping for irrigation. Smallholder farmers were provided with 3000 Wp solar pumping systems. 126 numbers of solar pumping systems were installed in the district Churu, Rajasthan from 2012 to 2014 (Figure 8.5). Out of which twenty pumping systems were selected randomly to find out their performance and the level of satisfaction of the stakeholder farmers. Data and results of the evaluation study are given in Annex E.

The data was collected through personal interview of the farmers. Personal information, crop details and groundwater table depth of selected pumping systems were collected. Rainfall in the area is 367.6 mm/ annum while potential evapotranspiration is 1771 mm/ annum which is 400% of the rainfall (Annexure E, Table E.1). Water balance of the selected area revealed that each month experiences water deficit. Variations in groundwater table depth (30 to 60 m) during the period 2005 to 2013 were obtained from secondary sources (Annexure E, Table E.2). Information on crops and cropping pattern (Annexure E, Table E.3) followed in the area was collected to estimate the actual water needs of the farmers. Month-wise water needs for the common cropping pattern was estimated (Annexure E, Figure E.1). Discharges of all solar pumps were observed which varied between 6000 to 10000 litres per hour depending on water table depth (GWL), solar intensity and capacity of the pump.
Desired pump capacity for meeting the daily crop demand based on potential evapotranspiration, GWL and type of MI system was estimated for 0.5 ha and 1.0 ha area (Annexure E, Table E.4 and E.5) for 35 m, 45 m, 55 m and 65 m groundwater table depths. Daily operating hours of solar systems were considered 6 hours, pump efficiency 70% and efficiency of a drip system, mini sprinkler and sprinkler were taken as 90, 80 and 70%, respectively. The operating pressure for drip, mini-sprinkler and sprinkler were taken as 20 m, 30 m and 40 m, respectively.

The analysis of expected water supply from 3000 Wp solar pumps and water requirements of crops under the agro-climatic conditions of Churu, Rajasthan revealed large gaps between the benefits accrued and expected out of the scheme. The analysis revealed that pump wattage required for irrigation of 1 ha using drip, mini sprinkler and sprinkler systems were more than 3000 Wp for a large part of the year (Annexure E, Table E.4 and E.5). The study suggested that solar pumping systems should be designed and provided to farmers based on their actual water needs and expected water output of the solar pumps under their agro-climatic and groundwater situations.

8.3.2 Cost-effectiveness of small solar pumping systems – A case study

Seven solar pumping systems have been installed in village Pehal, district Alwar, Rajasthan under the Rajasthan Government scheme. Three of these solar pumping systems were selected for analysis and evaluation for their appropriateness. One such solar pumping system installed in MR Karan Singh’s field is presented in Figure 8.6. Details of three farmers who have adopted the solar pumping systems in the village are presented in following Table 8.2.

<table>
<thead>
<tr>
<th>Farmer name</th>
<th>Village / Mandal</th>
<th>District</th>
<th>Crop sown</th>
<th>Seed Variety</th>
<th>Area under drip irrigation</th>
<th>Type of drip system used</th>
<th>Installation of drip system</th>
<th>Solar pump, hp</th>
<th>Subsidy, %</th>
<th>Farmer’s share, US$</th>
<th>Bore well depth, m</th>
<th>Depth of submersible pump, m</th>
<th>Area irrigated, ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Karan Singh</td>
<td>Pehal</td>
<td>Alwar</td>
<td>Onion, Wheat</td>
<td>Arjun, HD-3059</td>
<td>5.50 ha</td>
<td>0.4 m x 2.4 Lph</td>
<td>2011</td>
<td>3</td>
<td>86</td>
<td>900</td>
<td>200</td>
<td>50</td>
<td>1.50</td>
</tr>
<tr>
<td>Ratiram</td>
<td>Pehal</td>
<td>Alwar</td>
<td>Onion, Wheat</td>
<td>Arjun, HD-3059</td>
<td>1 ha</td>
<td>0.4 m x 2.4 Lph</td>
<td>2011</td>
<td>3</td>
<td>86</td>
<td>900</td>
<td>220</td>
<td>70</td>
<td>1.0</td>
</tr>
<tr>
<td>Jugmaal</td>
<td>Pehal</td>
<td>Alwar</td>
<td>Onion, Wheat</td>
<td>Arjun, HD-3059</td>
<td>2.2 ha</td>
<td>0.4 m x 2.4 Lph</td>
<td>2014</td>
<td>5</td>
<td>50</td>
<td>2560</td>
<td>280</td>
<td>75</td>
<td>2.2</td>
</tr>
</tbody>
</table>

*Figure 8.6.3* 3 HP solar water pumping system installed in Karan Singh’s field, village Pehal
A detailed economic analysis was done including capital, operational and salvage costs of the solar systems as well as that of an equivalent diesel pumping system appropriately incorporating the experience of the farmers. The analysis included lifetime analysis. The lifetime analysis of the two systems with respect to solar pumping systems revealed that solar pumping systems are economical in the long run. (Table 8.3)

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Costs</th>
<th>PV system (US$)</th>
<th>Diesel Engine (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Capital Cost (CC)</td>
<td>6476</td>
<td>320</td>
</tr>
<tr>
<td>2.</td>
<td>Maintenance Cost (MC)</td>
<td>130</td>
<td>640</td>
</tr>
<tr>
<td>3.</td>
<td>Fuel Cost (FC)</td>
<td>-</td>
<td>29586</td>
</tr>
<tr>
<td>4.</td>
<td>Replacement Cost (RC)</td>
<td>-</td>
<td>320</td>
</tr>
<tr>
<td>5.</td>
<td>Total Cost</td>
<td>6606</td>
<td>30866</td>
</tr>
<tr>
<td>6.</td>
<td>Salvage Cost (SC)</td>
<td>727</td>
<td>64</td>
</tr>
<tr>
<td>7.</td>
<td>Life Cycle Cost (LCC)</td>
<td>5879</td>
<td>30802</td>
</tr>
</tbody>
</table>

8.4 Jain Irrigation System Limited

As part of the study tour, the delegation also visited the facilities of Jain Irrigation Systems Limited in the city of Jalgaon in Maharashtra, India. Jain Irrigation Systems Limited (JISL), an integrated agribusiness has more than 12,000+ associates worldwide with revenue of USD 1.14 Billion, is an Indian multinational company with manufacturing plants in 30 locations across the globe.

During the visit to the JISL in Jalgaon, the delegation visited facilities providing solutions to agriculture, piping, infrastructure through manufacturing of Micro Irrigation Systems, PVC Pipes, HDPE Pipes, Plastic Sheets, Agro Processed Products, Renewable Energy Solutions, Tissue Culture Plants, Financial Services and other agricultural inputs.

The delegation also interacted with the local farmers to learn about one of their successful business models: contract farming. Throughout the food value chain, JISL provides support to the farmers for the necessary agricultural inputs such as micro-irrigation systems, seeds, saplings, PVC pipes, and financial assistance. They further provide training to the farmers on best agricultural practices using minimum inputs to produce higher-quality crops. Furthermore, JISL buys this product from the farmers at an assured price (usually higher than the market price) and exports them to the multinational food corporations after processing/dehydrating through their food processing divisions. This model has been very successful in the Jalgaon area of Maharashtra in India and has been in effect for more than 10 years. The delegates also interacted with the farmers to learn the first-hand account of the benefits of this model from the farmer.
9. Summary and Way Forward

9.1 Implementation Challenges

Solar energy is not available during the night or in cloudy weather conditions with little or no solar radiation, rendering solar energy panels, at certain times and in certain situations, less useful. They are also more fragile and require inverters to convert direct current (DC) electricity to alternating current (AC) electricity and/or storage batteries. Alternately, offline storage is required to even out the mismatch between water and power availability. In all the cases having canal irrigation, such provisions have been found necessary.

Generation of solar energy depends upon the available radiation as well as the climatic conditions in the local area. Depending upon the conditions like a number of sunny days available, radiation that can be captured and the dominant load factor for the system, the requirements have to be assessed in advance to balance the units of energy generated versus the demand from the operations annually.

The land area required to install a solar photovoltaic irrigation system is quite significant and that land space remains occupied for many years altogether and cannot be used for other purposes. In India, land availability per person is quite low and is continuously declining in view of the increasing population, industrialization and other land uses. In such a situation sparing large chunks of land for installation of solar panels poses an economic challenge. To mitigate the problems, the land areas occupied by other structures and canals/roads/pathways can be utilised for providing space for solar panels. This may not pose a significant constraint in situations where the populations are sparse and large land parcels are available for farming.

Cost of solar pumping systems is generally considered as a major challenge in popularizing these systems. Economic viability of the use of solar photovoltaic irrigation system depends on the size and configuration of the system (such as filtration, fertigation and water storage), pump selection; the depth of the well; the location of the area; the type of crop/soil to be irrigated; any other uses of the water (livestock and domestic uses); and where the water will be used (in poly-house or open field). Based on a 2012 Indian Planning Commission estimate, the cost of solar kWh dropped from of US ¢ 14-16 to US ¢ 5.7 in the latest round of “reverse auctions” (low bid wins) but still many coal-based power plants were rivalling it at around US¢ 4 kWh. However, the cost of solar power has been continuously declining. Further research is needed to make solar energy a more attractive option.

Dust and high temperatures are contributing to an increase in the cost of operating solar power plants in some states of India. Shortages of a skilled labour force are more general problems faced by the users and industry across the country. Skilled workforce required for cleaning and maintenance is not available in many cases, so companies have to bring them in from other areas and train them. All this result in higher operational costs but solar tariffs in India have fallen tremendously which pose a future risk to the solar industry in general. Several utility companies, the ultimate buyers of power, are in a poor financial condition due to electricity subsidy schemes for farmers and theft. In many cases, governments finally bale such utilities out using tax-payers money. Establishment of an economically and financially viable model, therefore, require accounting for the hidden influencers like subsidies for power and water, transmission and distribution losses including theft of the power at the local levels and also maintaining and operating additional generating capacity like thermal or nuclear for the purpose of agriculture supply alone and costs of maintenance of the transmission infrastructure etc. In the case of solar-powered systems, the maintenance and depreciation expenses are borne by the
beneficiary and the benefit of the above-mentioned losses accrue to the government. Hence, a long-term collaborative regime between the users and the government/ power supply entities is necessary for making the effort a success.

9.2 Remedial Measures

At present only 300Wp and 5000Wp solar pumping systems are provided under the Government schemes. In several field situations, these systems may not be able to meet the irrigation water requirements owing to the large depth of groundwater table and more crop demands. As a remedial measure, the Government should consider providing solar pumping systems of adequate capacity of head and discharge to meet the crops water needs of the farm. Variable solar pumps having an auto-tracker system designed on the basis of groundwater level and crop demand can be installed for optimum benefit.

Dust is a major problem in the desert areas of Rajasthan (India), plains of north India, delta regions of south India and in many areas of Africa and Asia. Depending on the region, the dust may be alluvial, sandy or another type. The sandy dust can be washed away easily with water. To counter the dust problem, companies in India are beginning to employ new technologies such as anti-soiling technology like dust-free glass with self-cleaning hydrophobic nano-coating which stops dust from sticking to the glass of the module. Similarly, to tackle the issues of the hardness of water, technologies such as reverse osmosis (RO) may be used.

On occasions, the delays are reported in repair and maintenance of solar systems and in some cases, farmers lost their crops as there was no other source of water and the repairing of the faulty system took an unduly long time. All the registered companies should have their service centres at the district level to avoid the delays in repairs of the system. All registered companies should also address the problem of lack of skilled manpower for doing repairs and maintenance of the installed systems. Micro-irrigation companies may also keep regular visits to the sites for repair/ replacement of non-functional components of irrigation systems integrated with solar pumping systems.

Capacity building of farmers in the form of training and skill development of unemployed village youth may serve as a big remedial measure for overcoming the problems of repairs and maintenance of solar pumping systems. This will create employment of the rural youth in the region as well as these trained local people will be able to repair and maintain solar pumping systems at reasonable rates. These systems should also be insured to protect against theft, vandalism and other eventualities.

9.3 Major takeaway from Indian Experiences

The pace of growth of solar energy utilization in India is quite a success story. India has achieved this success by systematically addressing the policy issues, firstly operating the schemes in Mission mode e.g. National Solar Mission and by creating administrative infrastructure. The government of India created an autonomous National Institute of Solar Energy under the Ministry of New and Renewable Energy for research, development and training in the field of solar energy. The government of India has encouraged indigenous production through several incentives and imposed a heavy duty on foreign materials of sub-standard quality. Government involved the private sector in PPP mode and encouraged private investment into solar energy right from the beginning. Though the prices of solar energy are decreasing exponentially, the solar pumping systems were out of reach for the Indian farmers for a long time. Central Government, as well as different State Governments, initiated several schemes for providing financial assistance to farmers for adopting solar systems. All these proactive steps of the
Government made it possible for India to achieve an enviable position in terms of solar energy utilization in the world.

In 2018, the cost of solar power in India, China, Brazil and 55 other emerging markets fell to about one-third of its 2010 price, making it the cheapest form of renewable energy. The Indian government reduced the solar PV power purchase price from the maximum allowed US $6.2/KWh to US $5.6/KWh, reflecting the steep fall in the cost of solar power generation equipment. The applicable tariff is offered after applying viability gap funding (VGF) or accelerated depreciation (AD) incentives. Solar PV generation cost fell to US $4.1/KWh for the 750 MW Rewa Ultra Mega Solar power project, which is India’s lowest electricity-generation cost.

Several studies have disproved the myth that solar energy can only be promoted with heavy financial assistance/subsidy. One of such studies confirmed that when compared to diesel pumps, the payback period of unsubsidized solar pumps considering all outlays lies in the range of 4-6 years, while the MNRE subsidy of 30% in India brings down the payback period to 3-4 years. Application of an additional 40% of state subsidy does not alter the payback period much.

Several studies by international agencies indicate that solar irrigation pumps now have a competitive advantage over diesel pumps, involving a total cost of 64.2% for the 10-year life-cycle cost of diesel water pumps, even without the benefits of the subsidy (GIZ, 2013). The breakeven time to replace diesel pumps with solar pumps results in improved agricultural yields for farmers for 4.1 years and 7 years without improved yield (KPMG 2014). Considering the opportunity cost of the waiting time for grid connections and enhanced yields through the reliable solar power supply, it is advisable that the farmers choose solar pumps for irrigation over electric pumps despite their higher net present value (NPV) expenses over 15 years (Agrawal and Jain, 2015).

Both the government and the farmers benefit by SPIS on account of reduced diesel consumption and associated subsidies, savings in foreign exchange for diesel imports, reduced electricity use, reduced CO₂ emissions, and improved crop yields and energy access (KPMG 2014; IRENA 2016).

9.4 Way Forward

Solar pumps, having been around for several decades, are now gaining traction at least in rural heartlands of India. As farming communities become more familiar with the SPIS as they did with grid-driven or diesel pump sets, local innovations in agricultural practices will emerge and pave the way to replace old technology which most believe is not sustainable.

Solar pumping systems are continuously evolving and improving, including configurations with drip irrigation, floating solar panels or purely solar-driven centre-pivot irrigation machines. Suppliers of SPIS are increasingly optimizing the whole system, including solar generator, pump, controller and accessories, plus the irrigation system. Additionally, suppliers now often provide technical support services to satisfy the needs of end users. Another trend goes in the opposite direction: individual components-PV panels, standard irrigation pumps and available controllers-are offered on the market and integrators provide services to connect these components into one irrigation system. This trend will also help in raising the level of competition in the market ultimately resulting in more cost-effective solutions in the long run.

Moreover, digital technologies for remote operations will further improve SPIS and make it more versatile. Monitoring (e.g. groundwater), remote control and extended communication platforms can be expected to be part of even small-scale applications at minimal extra cost. Possibilities exist for
unused electricity (when pumping is not required) to be fed into the electricity grid or to be used for other on-farm productive applications, further increasing the economic viability of SPIS. However, this requires more research and development as well as specific policy and governance decisions to support multiple uses.

To harness the potential benefits, minimize risks and meet the challenges of using solar energy in irrigation, several approaches are discussed in this report as the result of the lessons learned from the applications of SPIS in Asia and Africa. To promote further the use of solar energy in agriculture, the following measures should be taken:

9.4.1 Finance

- SPIS’ have a high initial investment cost and it needs innovative financing models (or subsidies) to overcome constraints to adoption.
- Finance as a major constraint to implementing SPIS needs to be addressed and access to finance especially for small farmers needs to be considered seriously.
- Availing micro-finance is probably the most effective way of making the technology of SPIS accessible for an average farmer in African countries.
- Innovative concepts for distributing costs and usage of a system might be considered
- Funding by national and international donors for projects that promote the use of (SPIS) can raise awareness and help establish these technologies.
- Explicit arrangements for long term commitments on the operation, maintenance and depreciation of the systems established between the end user, power supply agencies and the manufacturers of the equipment is a must for success and spread of the initiative.

9.4.2 Capacity building

- Capacity building for design, installation, operation and maintenance of SPIS and complementary technologies of micro irrigation systems should be considered in a holistic and integrated manner.
- Sharing experience and best practices in SPIS applications from all over the world is an important key for the awareness and capacity building of policy makers, technicians, engineers, users and farmers.
- Public awareness at different levels can play an important role in the large-scale applications of SPIS.
- SPIS implementation is closely linked to modern micro-irrigation techniques as otherwise the quantum of water to be handled become quite large and corresponding generating capacities also become larger leading to problems mentioned above. It is, therefore, necessary that a parallel effort towards integrating the micro irrigation initiatives is also taken up as an integral part of the effort. Efficient and timely extension services are the keys to success.
- Every effort should be made to upgrade and commercialise the required skill sets for the maintenance and troubleshooting of the implemented systems. Skill development along with the seed financing for the establishment of such businesses should also be treated as a part of the capacity building efforts. Therefore, the capacity building efforts cannot remain limited to the farmers alone but should spread to the village or cluster village level artisans and mechanics etc.
9.4.3 Technological Considerations

- Solar powered irrigation systems (SPIS) can provide a reliable source of energy in remote areas, contribute to rural electrification and reduce energy costs for irrigation.
- SPIS should be integrated into sound regulatory frameworks on water conservation to ensure sustainable use and avoid excessive water extraction of groundwater. Using smart water systems are highly recommended.
- Technical support and long-term involvement of agencies as per the needs of users are very important to ensure the sustainability of SPIS.
- To reduce the required size of SPIS, water-conserving and energy-saving micro-irrigation techniques should be used.
- High-value crops should be farmed preferably, so that initial costs pay off quickly.
- The available technologies of SPIS must be promoted to relevant actors and decision-makers, providing information on both benefits and risks.
- Initiatives from the private sector are essential to improve access to technology and to fill niches in the market.
- It is imperative to design a model applicable for small-scale farming that will size a low-cost SPIS for different climatic conditions, soil types and crop types for different irrigation techniques.

Box Message to the policymakers

Solar powered irrigation system (SPIS) are no longer just an option, but a necessary solution due to the challenges of diminishing resources against climate change impacts and risks. SPIS is an important model of the nexus between water, energy and food by utilizing all available existing resources. Therefore, taking actions towards the dissemination of these technologies, increasing the awareness at different levels, building the capacity for technicians, engineers, farmers, private sectors and creating capable new generations, and enabling good environment for financial access specially for small farmers must be the top priorities of the related policies for a sustainable future.

9.5 Issues Discussed During the Field Visits

FAO team comprising of (1). Ayman Elsayed Ibrahim Shahin, Sector Head of Monitoring Systems & Communication, Information and Assets Egyptian Ministry of Water Resources and Irrigation (2). Mr. Gabouj Rodham, General Director of Rural Engineering and Water Management, Ministry of Agriculture Water Resources and fisheries, Tunis, Tunisia, (3). Dr. Mohamed Ibrahim Al-Hamid, Senior Land and Water Officer, FAO Regional Office for the Near East and North Africa, Cairo, Egypt visited the following three sites in India:

i. Grid Powered Lift Irrigation Project, Rajwal (Punjab),
ii. Small farmers initiatives, village Pahal, Alwar, Rajasthan and
iii. Jain irrigation systems, Jalgaon, Maharashtra.

During these visits several issues were raised by the delegates and were discussed thoroughly with the beneficiaries, implementing agencies and the State Government officials. Some of the important issues
raised by the delegates and discussed with all concerned stakeholders are presented in the following paragraphs.

9.5.1 Water saving a myth

Delegates expressed that introducing solar pumping systems and micro-irrigation may not necessarily save water particularly groundwater. Delegates opined that though the introduction of micro irrigation may result in higher water use efficiency, they perceived that farmers tend to increase the irrigated area using the so-called saved water and hence no real reduction in water used takes place. It was revealed through the discussions with the stakeholders that it may be true only if the farmers have more area (unlike the case in India) to irrigate which was not receiving irrigation water earlier.

In India, most farm-holdings are small (more than 80% of the size less than 2 ha) therefore there is hardly any chance for area expansion using the water saved through solar pump integrated micro-irrigation. Therefore, the introduction of micro irrigation effectively saves water more so in the case of groundwater pumping. This perception may prove to be true only in situations where farmers own large lands and are not able to irrigate their entire area through conventional irrigation and will like to extend irrigated area using the available water saved.

9.5.2 Over-exploitation of groundwater

Another very relevant concern was raised by the visiting delegates that solar pumping systems do not depend on the electricity supply and do not need costly diesel and therefore the farmers may keep pumping as long as sufficient solar insolation is available. This is likely to result in excessive pumping which is likely to create a grimmer situation for already overstressed groundwater aquifers. The concern seems obvious as there cannot be any regulation on the operating time of a large number of solar pumping systems scattered far and wide in the country.

At the outset, it can be stated that the over-exploitation of groundwater is the result of lack of opportunity of adequate water supply through other means like surface water for a given agricultural practice. India is a prime example of this fact where the groundwater availability and exploitation are inversely proportional and failures (due to natural or administrative causes) of ensuring adequate supplies of surface water in the needy areas has created overexploited regions in the country. Agriculture practices are tuned by the local economic situations and food and consumption habits of the society.

Overexploitation is strongly related to the ultimate benefits that accrue to the farmer by either expanding the irrigated area and/ or cultivating crops with higher water requirements with high subsidies regime or introduction of artificial skew in prices of crops being grown. Given these factors, the impact of solar power as a factor for over-exploitation of groundwater appears to be smaller. In any case, a cost-benefit analysis involving all the relevant tangible and intangible variables for quantifying the incentive for over-exploitation of groundwater can be carried out and area-specific decisions can be taken.

To address this issue, we put forward the fact that under different pumping schemes the Government is providing only 3 HP and 5 HP solar pumping systems normally coupled with micro irrigation systems. The farmers who adopted solar pumping systems have earlier been using 10 HP or 15 HP diesel
pumping systems for irrigation. Solar pumping systems combined with a micro irrigation system is expected to certainly use much less water to irrigate the same fields in comparison to the diesel pumping systems of much higher capacity with surface irrigation methods. Thus, the introduction of solar pumping systems combined with micro-irrigation is more likely to result in lesser groundwater pumping and not over-exploitation of groundwater.

9.5.3 Sustainability of large solar pumping systems
The Government of India has executed several large solar pumping (lift cum micro-irrigation) projects to irrigate hundreds of hectares, at a substantial cost (Rajwal project is an example). The visiting delegates raised issues of sustainability of such projects in the long run. A World Bank report also questioned the long-term sustainability of such projects (based on 70 years life cycle analysis) particularly after the project execution agency withdraws.

This fear of the delegates was addressed in their interactions with the beneficiaries of Rajwal project. The president of the Federation of the water users’ associations in the command area of the project informed that the water users’ associations have started functioning and have also started collecting revenue from the farmers. The president informed that the project execution agency has been asked to employ the local youth and train them in its operation and maintenance. He also assured that the same local youth will be hired by the Federation of water users’ association to operate and maintain the project after the execution agency withdraws in seven years. It was told that the farmers are agreeable to pay even higher revenue for getting reliable irrigation facility at their fields which were never irrigated earlier. Even then the question remains that whether the revenue collected will be sufficient to meet the operation and maintenance of the project. The president affirmed that with the passage of time and with farmers earning more income from their field it will be possible to collect sufficient revenue for the maintenance of the project. Since the project was launched recently and is still supported by the project execution agency, the results are yet to be seen. However, the farmers seemed hopeful of positive results owing to their increased incomes and increased capacity. The farmers are yet to realize the full benefits of the project and water user associations also need more time to mature.

9.5.4 Operation and management
The lift-cum-micro-irrigation solar pumping system is quite complex in operation and has a wireless operation mechanism. The obvious question raised by the delegates was about its future management, particularly when the company managing the project leaves after 7 years of the contract period. An interaction was arranged between the visiting delegates and the officials of the project executing agency at the project site.

The officials of the company who executed the project explained that they are operating the system with the personnel mainly hired from the project area and the president of the Federation of the water users’ associations confirmed that the federation will be able to collect enough revenue from the beneficiaries to hire the same trained local workforce to manage the day to day affairs of the project, after the project executing company departs. State Government officials present during the discussion also indicated that they will always be there to support the federation and to ensure the project runs smoothly after the seven-year operation contract with the executing agency. The agency is also
agreeable to continue maintaining the project after the stipulated period on a nominal annual maintenance rate contracts basis if agreed by the Federation of the water users’ associations.

9.5.5 Cost effectiveness

There are a very large number of tube wells in the country mainly operated by diesel engines. Extending the electricity grid to each farmer is a herculean task. The Solar pumping systems are expensive and farmers in India are resource-poor that is why the Government of India has initiated several schemes to promote solar pumping systems providing different levels of financial support. Solar pumping systems provide a suitable alternative to meet the energy needs of the farmers particularly for pumping for irrigation. The initial cost of solar pumping systems is very high, but the operation cost is negligible. Also, the useful life of solar pumping systems is more than twice the life of diesel pumping systems. Several life-cycle cost analyses have proven solar pumping systems to be more economical than diesel pumping systems over their life-cycle. Also, solar pumps result in reduced carbon emission. The question of high initial cost is addressed by the Government of India by providing adequate financial support to farmers through several of its schemes. It may also be noted that solar pumping systems even without subsidy have a payback period of only four years whereas its life is supposed to be 25 years.

Summing Up

Looking at the situations in India where the water availability coupled with the sustainability of farming operations for comparable livelihood outcomes provide a situation where the reduction of reliance of farming communities on highly subsidised and centrally managed energy supplies and also the water consumption footprints are both at equal priority. In this context, the solar-powered micro irrigation practices appear to have an edge over other options.

10. References


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Annexure A  Applications of Solar Powered Irrigation Systems in Africa

Today, agriculture accounts for 70% of all water use globally, up to 95% in some developing countries. Objectives such as increasing the efficiency of water use and enhancing agricultural water productivity at all levels of the production chains are becoming priorities in a rapidly growing number of countries (UN Water, 2007).

It is expected that 60% more food will be needed by 2050 to satisfy the demand for an eventual population of more than 9 billion people. The net result is that agricultural water use is increasing the severity of water scarcity in many areas and causing water scarcity even in areas that are relatively well endowed with water resources (FAO, 2008).

Food insecurity among smallholder farmers, driven by drought in southern Africa and much of sub-Saharan Africa, threatens the ability for subsistence farming as well as commercial farming in the marketplace. It was estimated in a report by the Food and Agriculture Organization of the UN that up to 80% of sub-Saharan Africa and Asia rely on smallholder farms for their food. These farmers can increase their yield and income by 45% over rainfed crops.

Irrigation is a direct source of livelihood for hundreds of millions of the rural poor in developing countries because of the food, income options and indirect benefits it generates. There are high political aspirations that agricultural development, particularly across sub-Saharan Africa, which will lift many out of poverty, a few as producers of marketable products, others as wage labourers, and in small enterprises away from the farm (UN Water, 2007).

Water pumping is an energy-intensive process and most of the world’s plants are currently powered by conventional energy and as farmers often face unreliable rain-fed agricultural seasons, but with irrigation, they can irrigate for three seasons in a year. Due to the high costs of running diesel-powered pumps, many farmers, especially in Africa, were unable to afford the costs to operate and maintain diesel pumps for irrigation of their farms.

There is a great irrigation potential in Africa that need to be updated by use of smart solutions like the use of SPIS to face climate change impacts and eliminate hunger and poverty and achieve almost all of the Sustainable Development Goals (SDG’s). The region of North Africa and the Middle East has a high solar potential, where the average global horizontal irradiation (that is the total amount of shortwave radiation received on a horizontal surface) is around 2100 kWh/m² per year (Figure A.1). These areas could profit greatly from the expansion of concentrating solar power (CSP) capacity in the future.

Figure A.1 Global Horizontal Irradiation (GHI) in North Africa and the Middle East
For these reasons, major donors and development agencies have piloted and assessed SPIS in many African countries like Egypt, Morocco, Benin, Ethiopia, Kenya, Malawi, Zambia, and South Africa, among others. Not only has the quality of solar pumps improved and the costs declined, but their use can also help raise farmers’ incomes and allow countries to lower carbon emissions and meet climate commitments. Morocco, for example, is set to install more than 100,000 solar pumps by 2020. Solar-powered irrigation Systems have the potential to overcome the effects of drought throughout Africa as well as grow businesses to help overcome climactic shocks. Along with the promise, however, come perils. In parts of North Africa, where there is a long history of using subsidized electric and diesel pumps for irrigation, over-extraction of groundwater has become rampant. Ignoring or over-estimating the amount of groundwater available where pumps are used and the lack of incentives to use water efficiently are the chief causes for inefficient use of water. The danger with solar technology is that, by providing a steady stream of cheap power, it could make water scarcity worse, jeopardizing the livelihoods of rural communities in the long term, if its use is not regulated with proper regulatory policy interventions.

A.1 Current Applications of SPIS in Africa

Water scarcity is a challenge to many parts of Africa, especially as climate change has contributed to the irregularity of precipitation and an increased number of droughts in recent years. Groundwater is usually an effective solution to fill the gaps in water resources, but it requires energy. Where electricity from the grid is not available, that energy is still mostly provided by diesel generators. As the cost for diesel is high and continuously rising in many African countries, the cost of irrigation is an enormous burden for many farmers, and many can’t afford it at all. Use of solar-powered irrigation systems (SPIS), could be a sustainable alternative for farmers, especially in regions, where solar energy is available in abundance and in areas, that are not connected to the national grid (Freischlad B and Rhein Main H, 2017).

An investigation has been carried out and focused on the research undertaken on solar photovoltaic (PV) and solar thermal technologies for pumping water generally for irrigation of remote rural farms specifically considering the Sub-Saharan African region (Wazeda et al, 2018). SPIS’s have been researched extensively for irrigation purposes due to the rise in oil prices and the upscaling in the commercialisation of PV technology. Based on the literature the most effective PV system is presented for the irrigation of a small scale remote rural farm with respect to the cost, pumping capacity and system efficiency. Similarly, solar thermal systems are reviewed, and the most effective system described. The study identifies that there is a huge potential for solar thermal technology to meet the requirements of the small-scale rural farmer by using a solar thermal water pumping system but the research on these systems are minimal, there is very little data available on the feasibility of these technologies especially for small scale purposes (Wazeda et al, 2018).

Nowadays many pilot projects and applications of SPIS have been carried out in African countries and it is very important to have an overview about the lessons learned to move forward for large-scale applications to achieve the SDGs in Africa. Some of the key learning from different parts of Africa are listed below:

A.1.1 Benin- Case of Women Cooperative

A three Solar Market Gardens have been installed in a pilot project to address the challenges of food security in the Kalale district of northern Benin in 2007. Each garden is about half a hectare, equipped with a solar-powered drip-irrigation system and farmed by a co-operative composed of 35-45 women. Usually, each woman farms one full plant bed, the produce from which she brings home to her family, gives away, or sells. Members pay a weekly membership fee as a contribution to a fund for the amortization of the systems (SELF, 2015).
SPIS provides a safety net for farmers, reducing their daily task to a weekly or bi-weekly activity, saves for each woman up to four hours a day, increases the income for farmers specially in dry season 2013-2014, which enhances the ability of women to feed, educate and provide medical care to their families and the success of this pilot project has led to the replication of eight new Small Market Gardens, estimated to directly benefit 3352 individuals, with another 66000 gaining high-quality produce from these gardens.

A.1.2 Botswana

Botswana which is located south of the Equator opposite to Senegal and consist mostly of landscapes classified as warm desert climate or warm semi-arid climate. Although it has a larger economy due to its plentiful mineral resources, it faces similar problems as Senegal with an underdeveloped agricultural sector and shortages in power supply (CIA, 2017). A study was conducted by Botswana International University of Science and Technology to explore solutions to the comparatively high cost of SPIS, highlighting its benefits and proposing ways to remove the hindrances in its implementation (Freischlad, 2017).

The results from the study points out various potential advantages of using SPIS in Botswana as lower operating cost, more independent from weather conditions, new areas of employment, uplifting of rural communities, as off-grid electricity supply is possible, diversification of economy and improvement of individual’s daily life, and lower risk of groundwater pollution by spillage of diesel and smaller carbon dioxide footprint.

The results also highlighted the inhibiting factors to the spread of SPIS technology in Botswana which are the relatively high prices of equipment, the limitation of financing for initial cost, lack in awareness of the technology and its benefits among the rural population, lack of skilled labourers and service providers for SPIS.

A.1.3 Egypt

The initiative’s research (GIZ, 2014) has identified some main barriers to the implementation of SPIS in Egypt like the need for government policies to adapt subsidies for solar power to those for Diesel, enabling access to financial support, and providing national services to keep solar systems running on the long-term.

Another study was carried out for the economic analysis of diesel and PV water pumping systems for irrigation purposes at Cairo, Egypt (Shouman et al, 2016). The study uses the HOMOR software and theoretical equations governing the photovoltaic operation to get the optimal system design and the related economic analysis. The study considered three systems for water pumping; PV only, hybrid PV-Diesel and Diesel only. The study showed the advantages of the use of photovoltaic energy over that of the diesel generator in terms of the net present cost and the cost of energy. The study showed that SPIS in Egypt is more feasible than diesel engine pumping system, and an economic viewpoint, solar-powered pumps are more cost-effective when it is used on a continuous basis, as the higher capital cost is more effectively used.

In the Nile Delta, Egypt, irrigation canals are frequently located below ground level, necessitating the use of pumps to lift water to the fields. This pumping is dependent on the use of fossil fuels, directly with diesel and indirectly with electricity. Recently, the agricultural sector is facing an energy crisis, as increasing electricity demand from urban areas results in frequent shortages and blackouts. This results in disrupting the regular irrigation scheduling to satisfy the crop-water requirements with the consequence of crop yields decline. In addition, the cost of pumping is expected to increase. Therefore,
a low-cost alternative source of energy is required to ensure farmers have a reliable system to pump and irrigate.

A project was undertaken to support Egypt by bringing solar energy, a renewable and sustainable solution, for lifting water from below-ground conduits to irrigate the crop. This green technology reduces the Delta’s agriculture vulnerability to energy supply, shocks and shortages, and water scarcity concerns. The implementation of solar energy, to provide reliable pumping capabilities at the farm-level, reinforces efforts for optimal irrigation-water resource management. The nexus of food-water-energy is overall strengthened.

Two solar-powered sites for lifting irrigation water was installed for a total capacity of 100.8 kW, irrigation scheduling fully operated on-demand with no disruptions (Figure A.2), farmers and Water User Associations were trained on use and maintenance of the solar-powered irrigation system. 14 pumps are functioning on solar energy and irrigating 488 Acre, and excess solar energy sold to the ‘Electric Utility’ when not utilized for irrigation. SPIS led to reduced negative environmental impact, less soil pollution from diesel spill-over, and less greenhouse gas emission.

The Ministry of Water Resources and Irrigation is elaborating a plan to scale-up the use of solar energy to all other pumping stations in the Nile Delta and undertake assessments of solar energy applications for irrigated agriculture in other countries of the region.

A.1.4 Ethiopia

A paper by Muluken Zegeye, et al., 2017 that deals with the design of PV water pumping, provides details of theoretical studies of photovoltaic and the analysis of electric power requirement for powering pumps for irrigation and recommends that further research needs to be conducted to improve the efficiency of such solar PV water pumping system. They also stressed on the participation of the governmental and nongovernmental on importing the technology and creating awareness about it as well as arranging financial access to loan has to facilitate utilization of this technology which is more economical and environmentally friendly.

A three business model scenarios based on the value proposition to supply water to smallholder farmers for irrigated agricultural production have been proposed in Ethiopia by Otoo et al, 2018. The benefits to be gained from the different scenarios were described, and it was noted that direct farmer purchase of solar pumps is feasible, but out-grower schemes and pump supplier options with bundled financing offer are promising alternatives. It was concluded that the business scenarios model should be piloted to collect detailed data and test their feasibility. In addition, more data and ground-truthing would enhance suitability mapping. A more detailed analysis of the areas with the highest potential for solar pump implementation and economic feasibility would foster sustainable intensification of
agriculture through solar pump irrigation. A few case studies have proposed that women farmers may particularly benefit from solar pump irrigation system (SPIS) and at present, farmers, governments, private sector actors and development investors show much interest in solar pump irrigation as a solution to improving food security and resilience. That interest needs to be matched with systematic study and business models that support the expected outcomes.

A.1.5 Kenya

Case study 1

Irrigation is one of the most powerful techniques of modern farming, but it is rarely used by small Kenyan farms. Most aren’t close enough to rivers or lakes and, even when they are, manually carrying buckets of water limits the amount of land that can be irrigated. Wealthy farmers can afford diesel generators and well pumps, but the upfront cost and the ongoing cost of fuel put these technologies out of reach for most. In 2013, a young company called SunCulture offered a better solution – the use of solar panels to power the water pump (Bill Nussey, 2018). The system consists of a small roof-mounted solar panel, an elevated water tank, a submersible pump that goes in the well or any other water source and enough drip irrigation hose to cover a small field of crops (Figures A.3 and A.4).

![Figure A.3 Applied simple Solar Powered irrigation system in Kenya](image)

![Figure A.4 Drip irrigation hose to cover a small field of crops](image)

The system was made easy to assemble and built a distribution network that could install and maintain the systems for farmers. Before that, farmers were using an expensive diesel generator to pump the water from his well. Now, the daily diesel fuel costs have been cut to half with small regular payments the farmer can make via his mobile phone.
The (SPIS) has changed farmer’s farms and their family’s life. They are no longer dependent on the unpredictable weather and they can farm crops year-round. With the predictability and control of irrigation, they are able to grow a wider variety of crops, all of which fetch a higher market price than commodity corn and beans, and their incomes have been increased (Bill Nussey, 2018).

Case study 2

A study described the community of a small village called Ingotse in Kakamega County in western Kenya. Like most rural, food-insecure communities in sub-Saharan Africa, Ingotse village relied on rain-fed agriculture for the production of staple crops. Rainfed agriculture is limited to a 3–6-month rainy season in the Eastern African region over the year; due to climatic changes the Kenya Meteorological Department has predicted a poor distribution and a reduced amount of rains that are expected to adversely affect the agricultural production and supply. In addition to potential annual caloric shortages, households in Ingotse village faced other challenges. They were forced to stretch their stores of staple crops to the next harvest but because of the late harvest, they had to purchase additional food, mostly at higher prices and their access to micronutrients through home production or purchase diminished significantly during the dry season.

With this predicament, farmers in this village raised some funds to sink a borehole. This was done in collaboration with a non-governmental organization (NGO) known as Water for All which gave the community a solar-powered pump to distribute the water to the homesteads (Ndunga et al, 2016) (Figure A.5).

![Figure A.5 The solar-powered irrigation system in Ingotse](image)

Users of the solar-powered irrigation systems (SPIS) fared relatively well, their standard of living increased relative to non-beneficiaries, their consumption of vegetables increased to the recommended daily allowance and the income generated by the production of market vegetables enabled them to purchase staples and protein during the dry season. Overall, this story shows that SPIS can provide substantial economic, nutritional and environmental benefits to populations in this region. This will be further improved if the members were to invest in the more economical drip irrigation.

A.1.6 Malawi

With no grid electricity in most of the rural areas, vulnerability to oil prices, depletion of fossil fuels, and high maintenance cost of diesel systems; Renewable Energy Technologies provide a viable option. A techno-economic feasibility study was carried out for a case study village: Nlukla Village, Chiradzulu District in Malawi (PHIRI, E., et al, 2015). The results showed that with the favourable sunlight conditions a solar water pumping system is a viable option for the area. Apart from designing an SPIS; the other recommended future area of research for this study is to design a financing mechanism to cover for the high capital costs bearing in mind that for the people living in rural areas of Malawi the capital costs are exorbitantly high.
A.1.7 Morocco

In Morocco, rainfall fluctuates sharply from year to year, and especially summer months are hot. On a citrus tree farm located between Marrakech and Casablanca, the farmer had used a gas engine to power the irrigation system. Replacing the gas tank regularly with a new one required labor work, time and money, and was dangerous due to a high explosion risk. It was also necessary to supervise that the system is working properly. Moreover, irrigation was needed for 5–6 hours a day, and gas is not cheap in Morocco (www.Vacon.com). Vacon helped a citrus farmer to water his citrus trees in a cost-efficient way using Solar-powered pumps driven by VACON (Figure A.6).

Figure A.6 10.5 kW Sunerg solar (PV) panels installed on a rooftop

The SPIS was reliable and enables an increased harvest and cost savings. The new system requires less work and brings also many other benefits such as improved safety, no gas explosion risks and environmental friendliness as it is powered by solar energy.

A.1.8 Senegal

Agriculture plays a significant role in Senegal as in most Sub-Saharan economies. While the range of technologies that increase agricultural productivity is wide, even here energy supply is an inhibiting factor in implementing those. Considering all the possibilities of applying solar energy in agriculture and the related advantages, it is desirable to further spread its use in Senegal, and in global agriculture. But it has also become evident, that further research and improved technologies and shaping of the frame conditions should be reinforced. A research study was carried out by Benjamin Freischlad (2018) to study the potential benefits and challenges of using solar energy in agriculture.

Irrigation, in general, allows off-season production and lowers risk of crop failure by irregular precipitation while raising agricultural productivity, generating income and improving food security. Furthermore, potential benefits from SPIS observed in Senegal are listed below:

− SPIS can be deployed in remote areas, without connection to the national grid;
− SPIS reduces operating cost and financial risks from fluctuating fuel prices, opens up new business opportunities with relatively low additional effort, supports the establishment of micro-grids and it can provide clean water for domestic use thereby benefitting women and children;
− SPIS are generally easy to install, manage and maintain and have a long lifespan as technology is mature, reliable and – under certain conditions - economically competitive
− it is environment-friendly, as emissions of GHG and noise are low and the risk of groundwater pollution by spillage of diesel is reduced.

Challenges and Risks encountered in Senegal are listed below:

− Although it is economically competitive in the long-term, high initial cost may hinder the deployment of SPIS, especially as purchasing power in developing countries like Senegal is generally low and access to financing is often limited;
lack of knowledge within farmers of the variety of new technologies that are already available;  
− lack of a market to access technology, parts, installation and limited maintenance services;  
− lack of the political and legal environment to facilitate the implementation of new technologies;  
− lack of quality assurance, which might impact the efficiency of systems and thus, their economic viability;  
− the risk of over-extracting water, which might cause depletion of water resources and impact soil quality;  
− the high cost of batteries to supplement PV, the risk of the sifting the expensive equipment;  
− and lack of skills that are required from farmers.

A.1.9 South Africa

A literature on the design of SPIS and their economic feasibility in South Africa was carried out by PV PILISO (2017) and concluded that there is a lack of information on the different irrigation systems that solar energy can be integrated with, and the available universal models only determine the size of the SPIS and do not determine the economic feasibility of a system. The lack of information in literature may lead to farmers who are interested in implementing SPIS, either oversizing their system, resulting in unnecessarily high investment cost or farmers not consider the technology, as it is perceived to be too expensive. Therefore, it is imperative to design a model that will size a low-cost SPIS for South African climatic conditions, soil types and crop types for different irrigation techniques.

A.1.10 Tanzania

A study has been conducted as a Minor Field Study (MFS) and focused on solar water pumping for small scale farmers in the Kilimanjaro region of Tanzania. The purpose was to investigate the possibilities for rural farmers to operate their irrigation with solar power instead of their current option of fossil fuels, primarily petrol. The study was conducted in three phases, starting with a preliminary study in Sweden, followed by a field study in Tanzania from January to March 2015. The results indicate that the investment in solar power might be too expensive for the farmers if they do not receive external financial and educational support. If the farmers can obtain a solar water pumping system, results show that they will benefit and save a considerable amount of money over a long period of time. Also, solar water pumping in environmentally friendly compared to the systems in Tanzania (Bengtsson N, and Nilsson J, 2015).

A.1.11 West Africa

A study was carried out to analyze solar-powered drip irrigation as a strategy for enhancing food security in the rural Sudano–Sahel region of West Africa, using a matched-pair comparison of villages in northern Benin (two treatment villages, two comparison villages), and household survey and field-level data through the first year of harvest in those villages (Burney, J., Woltering, L., Burke, M. et al. (2010). The results indicated that SPIS that delivers water directly to plant roots could help ensure food security in Africa, and this irrigation method (drip irrigation) could increase both household income and nutritional intake, particularly during the dry season. Capacity building, increasing awareness and access to technical support and providing the long-term involvement needs for users are very important to ensure the sustainability of SPIS.

A.1.12 Zimbabwe

Solar pumps were used to expand the coverage of the scheme from 40 to 60 hectares in Oxfam’s Ruti Dam Irrigation Scheme, Zimbabwe (Figure A.7) where Two-thirds of the Ruti scheme is based on gravity-fed irrigation, and additional solar booster pumps have been deployed to pump water into a storage reservoir (IRENA, 2016).
SPIS has changed the lives of nearly 270 smallholder farmers, who were previously growing little more than subsistence crops of maize, but now are able to feed themselves, earn a higher income and benefit their neighbours. Farm yields have increased by 25% of maize per hectare, the farmers can grow three crops per annum, household incomes increased by 286% for the very poor, 173% for the poor and 47% for the middle-income groups, and furthermore, employment creation increased as farmers no longer had to target large-scale farm employment in exchange for food, producing instead their own food and new job opportunities on their own land.
Annexure B Specifications of the Proposed Models of SPV Pump for Irrigation

A typical solar-powered pumping system adopted in the country includes a solar array, pump, storage tank and controller. The standards/quality of these is discussed briefly in the following paragraphs. (Ministry of New and Renewable Energy, Government of India, 2014).

I. PV Array

The SPV water pumping system for irrigation and domestic drinking water should be operated with a PV array capacity in the range of 75 Watts peak to 5000 Watts peak, measured under Standard Test Conditions (STC). In the case of municipalities and rural drinking water installations than 5 KWp of array size would be considered. A sufficient number of modules in series and parallel could be used to obtain the required PV array power output. The power output of individual PV modules used in the PV array, under STC, should be a minimum of 74 Watts peak, with adequate provision for measurement tolerances. Use of PV modules with higher power output is preferred.

Indigenously produced PV module (s) containing mono/ multi-crystalline silicon solar cells should be used in the PV array for the SPV Water Pumping systems. Modules supplied with the SPV water pumping systems should have a certificate as per IEC 61215 specifications or equivalent National or International/ Standards. Modules must qualify to IEC 61730 Part I and II for safety qualification testing. The efficiency of the PV modules should be minimum 14% and fill factor should be more than 70%. The terminal box on the module should have a provision for “Opening” for replacing the cable if required.

II. Mounting Structures and Tracking System

The PV modules should be mounted on metallic structures of adequate strength and appropriate design, which can withstand a load of modules and high wind velocities up to 150 km per hour. The support structure used in the pumping system should be hot dip galvanized iron with minimum 80-micron thickness.

To enhance the performance of SPV water pumping systems above 0.5 hp, manual or passive or auto tracking system must be used. For manual tracking, arrangement for seasonal tilt angle adjustment and three times manual tracking in a day should be provided. For smaller pumping system, less than 0.5 hp a fixed mounting structure would be permitted. In areas where security of solar panels is a concern, it would encourage to mount solar pumps on the movable trolley. A portable solar pumping system with the mounting of solar panels on a movable trolley, with tracking for above 0.5 hp pump and without tracking for less than 0.5 hp pumps, would be allowed.

III. Electronics and Protections

Maximum Power Point Tracker (MPPT) should be included to optimally use the Solar panel and maximize the water discharge. The inverter could be used, if required, to operate an A.C. Pump. Adequate protection should be incorporated against the dry operation of motor pump set, lightning, hails and storms. Full protection against open circuit, accidental short circuit and reverse polarity should be provided.

IV. ON/OFF Switch

A good reliable switch suitable for DC / AC use is to be provided with the motor pump set. Sufficient length of cable should be provided for interconnection between the PV array and the motor pump set.
V. Storage

Batteries are usually not recommended for solar-powered livestock watering systems because they reduce the overall efficiency of the system and add to the maintenance and cost. Instead of storing electricity in batteries, it is generally simpler and more economical to install 3 to 10 days’ worth of water storage. Most solar pumping systems require water storage capacity to improve performance and reliability. Reliability is improved when a storage tank is used to store water extracted during sunshine hours to meet water needs at night, or in the event of cloudy weather or system downtime. In general, SWP tanks should be sized to store at least a 2-3 days of water supply.

VI. Controller or Inverter

The pump controller protects the pump from high- or low-voltage conditions and maximizes the amount of water pumped in less than ideal light conditions. An AC pump requires an inverter, an electronic component that converts DC electricity from the solar panels into AC electricity to operate the pump.

Photovoltaic power for irrigation is cost-competitive with traditional energy sources for small, remote applications if the total system design and utilisation timing are carefully considered and organised to use solar energy as efficiently as possible. In the future, when the prices fossil fuels rise and the economic advantages of mass production reduce the peak watt cost of the photovoltaic cell, photovoltaic power will become more cost-competitive and more common.

Technical specifications

The technical specifications of selected pumping systems for D.C. motor pump set with brushes or brushless D.C. (B.L.D.C.) and for A.C. induction motor pump set with a suitable inverter are given below in Table B.1 and B.2 (Ministry of New and Renewable Energy, Government of India, 2014). The actual duration of pumping of water on a particular day and the quantity of water pumped could vary depending on the solar intensity, location, season, etc.

<table>
<thead>
<tr>
<th>DC motor pump</th>
<th>Discharge, litres of water per watt peak of PV array</th>
<th>Dynamic head, m</th>
<th>Shut off head, m</th>
<th>Discharge, litres of water per watt peak of PV array</th>
<th>Dynamic head, m</th>
<th>Shut off head, m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>10</td>
<td>12</td>
<td>90</td>
<td>10</td>
<td>12</td>
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<td>25</td>
<td>50</td>
<td>20</td>
<td>25</td>
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<tr>
<td></td>
<td>35</td>
<td>30</td>
<td>45</td>
<td>32</td>
<td>30</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>50</td>
<td>70</td>
<td>19</td>
<td>50</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>70</td>
<td>100</td>
<td>13</td>
<td>70</td>
<td>100</td>
</tr>
<tr>
<td>AC motor pump</td>
<td>Discharge, litres of water per watt peak of PV array</td>
<td>Dynamic head, m</td>
<td>Shut off head, m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>10</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>10</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>20</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>32</td>
<td>30</td>
<td>45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>50</td>
<td>70</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>70</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table B.2 Shallow well (surface) solar pumping systems with D.C. motor pump with brushes/ brushless D.C.

<table>
<thead>
<tr>
<th>Description</th>
<th>Model - I</th>
<th>Model - II</th>
<th>Model – III</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Array</td>
<td>1 hp</td>
<td>2 hp</td>
<td>3 hp</td>
</tr>
<tr>
<td>Motor capacity, shut off dynamic head</td>
<td>12 metres</td>
<td>15 meters</td>
<td>25 meters</td>
</tr>
<tr>
<td>Module mounting structure</td>
<td>MS hot dipped galvanised, at least three times manual tracking facilities</td>
<td>MS hot dipped galvanised, at least three times manual tracking facilities</td>
<td>MS hot dipped galvanised, at least three times manual tracking facilities</td>
</tr>
<tr>
<td>Water output</td>
<td>90,000 litres per day from a total head of 10 metres</td>
<td>180,000 litres per day from a total head of 10 metres</td>
<td>1,48,000 litres per day from a total head of 20 metres</td>
</tr>
</tbody>
</table>

Water output figures are on a clear sunny day with three times tracking of SPV panel, under the “Average Daily Solar Radiation” condition of 7.15 KWh/ sqm on the surface of PV array (i.e. coplanar with the PV Modules).

### Table B.3 Solar deep well (Submersible) pumping systems with DC motor pump set with brushes or brushless DC

<table>
<thead>
<tr>
<th>Description</th>
<th>Model I</th>
<th>Model II</th>
<th>Model III</th>
<th>Model IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Array</td>
<td>1200 Wp</td>
<td>1800 Wp</td>
<td>3000 Wp</td>
<td>4800 Wp</td>
</tr>
<tr>
<td>Motor pump set type</td>
<td>Submersible with electronic controller</td>
<td>Submersible with electronic controller</td>
<td>Submersible with electronic controller</td>
<td>Submersible with electronic controller</td>
</tr>
<tr>
<td>Maximum total dynamic head</td>
<td>45 metres</td>
<td>45 metres</td>
<td>70 metres</td>
<td>70 metres</td>
</tr>
<tr>
<td>Module mounting structure</td>
<td>MS hot dipped galvanised, three times manual tracking facilities</td>
<td>MS hot dipped galvanised, three times manual tracking facilities</td>
<td>MS hot dipped galvanised, three times manual tracking facilities</td>
<td>MS hot dipped galvanised, three times manual tracking facilities</td>
</tr>
<tr>
<td>Water output</td>
<td>42,000 Litres per day from a total head of 30 m</td>
<td>63,000 litres per day from a total head of 30 m</td>
<td>63,000 litres per day from a total head of 50 m</td>
<td>1,00,000 litres per day from a total head of 50 m</td>
</tr>
</tbody>
</table>

### Table B.4 Shallow well (surface) solar pumping systems with A.C. induction motor pump set and inverter

<table>
<thead>
<tr>
<th>Description</th>
<th>Model I</th>
<th>Model II</th>
<th>Model III</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Array</td>
<td>900 Wp</td>
<td>1800 Wp</td>
<td>2700 Wp</td>
</tr>
<tr>
<td>Motor capacity</td>
<td>1 hp</td>
<td>2 hp</td>
<td>3 hp</td>
</tr>
<tr>
<td>Shutoff dynamic head</td>
<td>12 m</td>
<td>15 m</td>
<td>25 m</td>
</tr>
<tr>
<td>Module mounting structure</td>
<td>MS hot dipped galvanised, at least three times manual tracking facilities</td>
<td>MS hot dipped galvanised, at least three times manual tracking facilities</td>
<td>MS hot dipped galvanised, at least three times manual tracking facilities</td>
</tr>
<tr>
<td>Water output</td>
<td>81,000 litres/day from a total head of 10 m</td>
<td>162,000 litres/day from a total head of 10 m</td>
<td>135,000 litres/day from a total head of 20 m</td>
</tr>
<tr>
<td>Description</td>
<td>Model I</td>
<td>Model II</td>
<td>Model III</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>------------------</td>
<td>------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>PV Array</td>
<td>1200 Wp</td>
<td>1800 Wp</td>
<td>3000 Wp</td>
</tr>
<tr>
<td>Motor pump type</td>
<td>Submersible with electronic controller</td>
<td>Submersible with electronic controller</td>
<td>Submersible with electronic controller</td>
</tr>
<tr>
<td>Maximum total dynamic head</td>
<td>45 m</td>
<td>45 m</td>
<td>70 m</td>
</tr>
<tr>
<td>Module mounting structure</td>
<td>MS hot dipped galvanised, three times manual tracking facilities</td>
<td>MS hot dipped galvanised, three times manual tracking facilities</td>
<td>MS hot dipped galvanised, three times manual tracking facilities</td>
</tr>
<tr>
<td>Water output</td>
<td>38,000 litres per day from a total head of 30 m</td>
<td>57,000 litres per day from a total head of 30 m</td>
<td>57,000 litres per day from a total head of 50 m</td>
</tr>
</tbody>
</table>
Annexure C State-wise Information: India

**Table C.1 State-wise solar potential of India**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Andhra Pradesh</td>
<td>38.44</td>
<td>Maharashtra</td>
<td>64.32</td>
</tr>
<tr>
<td>Arunachal Pradesh</td>
<td>8.65</td>
<td>Manipur</td>
<td>10.63</td>
</tr>
<tr>
<td>Assam</td>
<td>13.76</td>
<td>Meghalaya</td>
<td>5.86</td>
</tr>
<tr>
<td>Bihar</td>
<td>11.20</td>
<td>Mizoram</td>
<td>9.09</td>
</tr>
<tr>
<td>Chhattisgarh</td>
<td>18.27</td>
<td>Nagaland</td>
<td>7.29</td>
</tr>
<tr>
<td>Delhi</td>
<td>2.05</td>
<td>Orissa</td>
<td>25.78</td>
</tr>
<tr>
<td>Goa</td>
<td>0.88</td>
<td>Punjab</td>
<td>2.81</td>
</tr>
<tr>
<td>Gujarat</td>
<td>35.77</td>
<td>Rajasthan</td>
<td>142.31</td>
</tr>
<tr>
<td>Haryana</td>
<td>4.56</td>
<td>Sikkim</td>
<td>4.94</td>
</tr>
<tr>
<td>Himachal Pradesh</td>
<td>33.84</td>
<td>Tamil Nadu</td>
<td>17.67</td>
</tr>
<tr>
<td>Jammu &amp; Kashmir</td>
<td>111.05</td>
<td>Telangana</td>
<td>20.41</td>
</tr>
<tr>
<td>Jharkhand</td>
<td>18.18</td>
<td>Tripura</td>
<td>2.08</td>
</tr>
<tr>
<td>Karnataka</td>
<td>24.70</td>
<td>Uttar Pradesh</td>
<td>22.83</td>
</tr>
<tr>
<td>Kerala</td>
<td>6.11</td>
<td>Uttarakhand</td>
<td>16.80</td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td>61.66</td>
<td>West Bengal</td>
<td>6.26</td>
</tr>
<tr>
<td>UT</td>
<td></td>
<td></td>
<td>0.79</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>748.98 GWp</strong></td>
</tr>
</tbody>
</table>

**Table C.2 State-wise Targets of MNRE Scheme for Promoting SPV Water Pumping**

<table>
<thead>
<tr>
<th>SN</th>
<th>Name of State</th>
<th>Target No. of systems</th>
<th>SN</th>
<th>Name of State</th>
<th>Target No. of systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Andaman and Nicobar Islands</td>
<td>60</td>
<td>16</td>
<td>Punjab</td>
<td>2000</td>
</tr>
<tr>
<td>2</td>
<td>Andhra Pradesh</td>
<td>3000</td>
<td>17</td>
<td>Rajasthan</td>
<td>4800</td>
</tr>
<tr>
<td>3</td>
<td>Assam</td>
<td>750</td>
<td>18</td>
<td>Tamil Nadu</td>
<td>2400</td>
</tr>
<tr>
<td>4</td>
<td>Bihar</td>
<td>1350</td>
<td>19</td>
<td>Uttar Pradesh</td>
<td>6600</td>
</tr>
<tr>
<td>5</td>
<td>Chhattisgarh</td>
<td>600</td>
<td>20</td>
<td>Uttarakhand</td>
<td>750</td>
</tr>
<tr>
<td>6</td>
<td>Gujrat</td>
<td>600</td>
<td>21</td>
<td>West Bengal</td>
<td>1500</td>
</tr>
<tr>
<td>7</td>
<td>Goa</td>
<td>30</td>
<td>22</td>
<td>Sikkim</td>
<td>30</td>
</tr>
<tr>
<td>8</td>
<td>Haryana</td>
<td>900</td>
<td>23</td>
<td>Nagaland</td>
<td>30</td>
</tr>
<tr>
<td>9</td>
<td>Himachal Pradesh</td>
<td>75</td>
<td>24</td>
<td>Tripura</td>
<td>150</td>
</tr>
<tr>
<td>10</td>
<td>Jharkhand</td>
<td>150</td>
<td>25</td>
<td>Arunachal Pradesh</td>
<td>30</td>
</tr>
<tr>
<td>11</td>
<td>Karnataka</td>
<td>1200</td>
<td>26</td>
<td>Meghalaya</td>
<td>30</td>
</tr>
<tr>
<td>12</td>
<td>Kerala</td>
<td>600</td>
<td>27</td>
<td>Manipur</td>
<td>45</td>
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<tr>
<td>13</td>
<td>Madhya Pradesh</td>
<td>850</td>
<td>28</td>
<td>Mizoram</td>
<td>30</td>
</tr>
<tr>
<td>14</td>
<td>Maharashtra</td>
<td>600</td>
<td>29</td>
<td>Jammu and Kashmir</td>
<td>90</td>
</tr>
<tr>
<td>15</td>
<td>Odisha</td>
<td>750</td>
<td></td>
<td><strong>Total</strong></td>
<td><strong>30000</strong></td>
</tr>
</tbody>
</table>
Table C.3 State wise Grid Connected Solar PV Power Plants on Canal Banks and Canal Tops

<table>
<thead>
<tr>
<th>State</th>
<th>Canal top, MW</th>
<th>Canal bank, MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andhra Pradesh</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Gujrat</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Karnataka</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>Kerala</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Punjab</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Uttar Pradesh</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>Uttarakhand</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>West Bengal</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>50</strong></td>
<td><strong>50</strong></td>
</tr>
</tbody>
</table>
Annexure D Punjab State Policy

D.1 Eligibility, Terms & Conditions for the farmers to participate in the government scheme of providing solar powered projects to land-owning farmers

All farmers individually or in groups are eligible to be considered under the scheme for solar-powered projects if they meet the following minimum requirements (PEDA, n.d.).

1. Farmer holding agriculture land in their name having valid and duly certified enters in Jamabandi for the last three years from date of issue of this scheme shall be eligible for allocation of projects. If the land is transferred on succession/will basis than the time of holding of the land of the person from whom land has been transferred on account of succession / Will shall be counted towards eligibility of three-year time period of the applicant.
2. Farmer/Group of Farmers can also form a company for applying and or implementation of the project.
3. The minimum capacity that can be allocated is 1MWp and maximum is 2.5 MWp for each farmer/Company, formed by the farmers.
4. The existing land use as per revenue records should be for Agriculture/Horticulture/ Farming including irrigated & non-irrigated area.
5. The applicant has to furnish the certified copy of the land ownership documents as proof of land holding of the total required land for the applied capacity. The minimum land required is 4.5 acres for 1MWp proportionately of higher capacity.
6. If the landholding is held jointly each of the joint holders is individually also eligible to apply for minimum 1MW to maximum 2.5 MW depending upon the extent of required land. Provided that Husband & Wife will be individually or jointly eligible to apply for max 2.5 MW only.
7. The following committee will scrutinize the application and verify the original documents before the shortlisting of eligible applicants and final recipients: - Director PEDA, Joint Director PEDA, Senior Manager Finance, Representatives of Revenue Department (Not below the rank of DRO.) Representatives of Finance Department (not below the rank of Deputy. Secretary), Representatives of PSPCL (not below the rank of Deputy Chief Engineer).
8. The application fee of Rs.50,000/- (Non-refundable) shall be submitted through Draft with the printed application along with the certified copy of the ownership documents. The farmer has also to furnish a processing fee of Rs. 2,00,000/- per MW to PEDA along with application in the shape of separate demand draft. In case the farmer does not get the allotment, the processing fee shall be refunded.
9. The allotment shall be made by the project allotment committee notified in the NRSE policy 2012. On the basis of discount given on the generic tariff announced by PSERC for 2015-16 along with the application. Higher the discount higher shall be the merit position of the applicant for project allotment.
10. In case, two or more applicants are offering the same tariff of more capacity than the balance leftover capacity, then the selection shall be based on technical capability, understanding or knowledge of the project, resource position, qualification & experience, performance of the applicant during the interview and social support if any extended to the village & its residents. This selection shall be done by the following committee headed by the- Chief Secretary, and comprising Principal Secretary to CM, Principal Secretary Power, Principal Secretary NRSE, Principal Secretary Finance, CMD PSPCL, Chief Executive PEDA (Convener).
11. A List of all eligible applicants and allottees will be displayed on the website of PEDA.
12. In Case the allottee is not given technical feasibility clearance by PSPCL/ Transmission line laying constraints or due to other reasons which are beyond the control of the allottee, then the project allotment committee under NRSE policy 2012 can consider allowing allotted Farmer to implement the project at a new site in the state through a joint venture with other farmers.

13. The farmer can also form a company after project allocation but before the signing of the IA to implement the project. The farmer allotted the project will have to continuously hold 51% equity/share/ownership/stake in the project until 7 years from the date of signing of the PPA.

14. The allottee shall enter into PPA for a period of 25 years (effective from the date of commissioning of the project) at the net availed tariff arrived after giving a discount on the Generic tariff for solar PV projects as determined by PSERC applicable for that year of allocation of the project. The signing of IA shall be completed in 45 days and thereafter signing of PPA will be completed in 60 days from the date of allotment.

15. The allottee shall furnish the financial closure documents, technical feasibility clearance and final technology selection documents within 120 days of the signing of PPA.

16. PEDA and Punjab Bureau of Investment Promotion shall facilitate the grant of statutory clearances to the projects.

17. PEDA will forward the proposals as and when received to MNRE, GoI, for extending Excise & Customs duty benefits etc. as applicable.

18. The allottee must complete the project within the stipulated time as mentioned in the allotment letter; however, the extension can be sought for 30 days in the first instance on the payment of a fee of Rs. 5000/day/MW. Another extension may be granted for another period of maximum 60 days but not later than 31 March on payment of a fee of Rs.10,000/day/MW. After which no further extension shall be given and the PPA shall stand cancelled as the tariff control period expires as per CERC/ PSERC Regulations. However, in case the PSERC extends the applicability of tariff or derives a new tariff for the next control period the PPA will be extended accordingly on a case to case basis.

19. The Change of Land use allowed for Agriculture/ Horticulture land for installation of SPV shall revert back to Agriculture / Horticulture on completion of the Project period or in the event the Project is removed from the site.

20. Canal water connection and supply schedule shall remain as it is in the name of the farmer.

21. In case two or more applicants set up the project in adjoining lands then the power can be evacuated through double circuit 11KV Transmission Lines.

22. The farmers who are successful in getting project allotments shall also have the option to jointly set up an SPV company before signing of IA with controlling shareholding of 51% to be held by the same proportion as the project allotment capacity. In such case, a single IA shall be signed with PED and a single PPA shall be signed with PSPCL by the SPV company for a maximum capacity of 25MW. Power can be evacuated from this project through a 66KV transmission line to the nearest technically feasible PSPCL sub-station. The power evacuation and transmission shall be subject to technical feasibility clearance by PSPCL.

23. Allottees who have projects in the same village or adjoining villages shall also have the option to set up a common 66KV pooling sub-station for evacuation of power from their independent projects through a common 66KV transmission line to the nearest technically feasible PSPCL sub-station. Energy accounting and metering shall happen on the HT side of the pooling sub-station as per applicable regulations.
24. Farmers may also operate their agriculture pumps (Both DC or AC pumps) by taking power from these solar PV Power Plants, which shall be treated as auxiliary power.

25. PEDA shall give information about the scheme through print & electronic media and will also hold interactive meets with farmers to sensitize them about the scheme.

26. All applicable CERC/PSERC regulations and applicable guidelines etc. of PSPCL shall have to be adhered to by the allottee.

27. Other general terms and conditions will be as per NRSE Policy 2012. In case of any conflict, NRSE Policy 2012 shall prevail.

28. Govt. of Punjab, Department of New & Renewable Energy can amend/relax/make addition/interpret provisions under this scheme with due approval of Chief Minister.

D.2 Guidelines for implementation of the project for matching irrigation water availability and demand for improved productivity through efficient on-farm water management

The guidelines for implementation of the project for matching irrigation water availability and demand for improved productivity through efficient on-farm water management are given below (DSWC, n.d.):

1. A complex set of factors including diminishing water sources, competitive land use and global warming is creating new challenges for the vast agrarian population in Punjab. The ever-increasing mismatch between the demand and supply of energy in general and electricity is posing challenges to farmers. The scarcity of electricity coupled with the increasing unreliability of monsoon rains is forcing farmers to look at alternative fuels such as diesel for running irrigation pump sets. However, the costs of using diesel for powering irrigation pump sets are often beyond the means of small and marginal farmers. Consequently, the lack of water often leads to crop damage, thereby, reducing yields and income.

2. To address this situation to an extent, the Department has planned a Project for "Matching Irrigation Water Availability and Demand for Improved Productivity through Efficient On-farm Water Management". This Project aims for Conservation of Irrigation Water by constructing irrigation water storage tanks coupled with solar pumps and micro-irrigation system to provide assured irrigation source to the farmer and enable him to irrigate as per crop requirement without depending upon power availability. The major objectives of the Project are

   − To provide energy security to the farmers for irrigating the crops with no recurring expenditure;
   − To promote the use of Green Energy (non-conventional energy) in the agriculture sector;
   − To improve the water use efficiency using Micro irrigation techniques;
   − Assured irrigation facility to the farmer- no dependency on other sources;
   − To improve the Agricultural Production and Productivity.

3. One of the major constraints in adoption of Micro irrigation system is the unavailability of water either due to the inadequacy of power or assured water source as these systems require watering of plants on a daily basis. The Project endeavours to provide the farmer with a complete solution by providing on-farm water storage tanks, which will help farmers store water and utilize when it is required and Solar Photovoltaic Pump sets, which will insulate farmers completely from power or energy inadequacies besides providing a clean source of interruptible power supply.

4. Assistance under the Project on each of the component these shall be provided to farmers as follows:
a) **Micro Irrigation**: Drip and Sprinkler Irrigation Systems shall be provided under this component to individual farmers. Funds for subsidy shall be obtained from On-Farm Water Management (OFWM) component of CSS National Mission on Sustainable Agriculture (NMSA) as per GoI Guidelines and State Govt Policy. In case of unavailability of funds from NMSA or State Govt scheme, funds can be obtained from under this project.

b) **Solar Photovoltaic Pumpset System**: Under this component complete system of Solar Photovoltaic (SPV) panels with Pumpsets shall be provided to the farmer. Financial assistance under this component will be 75% subject to a maximum for each capacity of the system. This assistance shall be provided from the funds available under the project.

c) **On-farm Water Storage Tanks**: Under this component water storage tanks will be constructed for individual farmers. Funds for subsidy under this component may be obtained from CSS, National Horticulture Mission (NHM) as per GoI Guidelines. This is mostly applicable to the canal-based irrigation system.

*Assistance could also be provided to farmers having tube well irrigation, where construction of on-farm water storage tanks may not be necessary.

5. The estimates under the project may be prepared as per follows:
   a. Assistance under the project shall be provided to farmers from the date of issue of these guidelines.
   b. Sample design sheet for determination of the capacity of the system is provided.
   c. Drip and Sprinkler Irrigation Systems will be provided to the farmer by the companies registered by the Department under the Micro-Irrigation Scheme. The List of companies registered for supply and installation of Micro Irrigation Systems are provided.
   d. Assistance on Drip and Sprinkler Irrigation system will be provided strictly on the basis of On-Farm Water Management (OFWM) component of CSS National Mission on Sustainable Agriculture (NMSA) as per GoI Guidelines and State Govt Policy. Quantum of assistance to be provided on the micro irrigation system, circulated vide letter No. 18792-812/Planning, dated 11.12.2014 is provided.
   e. On-farm water storage tank design and specification should be in accordance with Govt of India Guidelines of National Horticulture Mission, which have earlier been followed in the Department for construction of tanks.
   f. Construction of On-farm Water Storage Tank is not mandatory for availing assistance under the project. Assistance under the project could be provided to a farmer having tubewell connection as water storage tanks are generally required in canal command areas only.
   g. Solar Photovoltaic Pump set system design and capacity should be in accordance with the total water requirement of the crop for the area under micro-irrigation, available head and solar radiation data at the project site.
   h. Solar Panel Structure Design should be incorporated in the estimate.
   i. The list of companies empanelled for supply and installation of Solar Photovoltaic Pump set System and Amount of Assistance to be provided for each capacity of the system are provided.
   j. The technical specification for supply and installation of Solar Photovoltaic Pump set system is provided.
k. The project is demand driven and the farmer has the liberty to choose from any of registered or empanelled companies for Micro-irrigation and Solar Photovoltaic Pump sets Systems.
l. The farmer shall submit an application for availing assistance under the project and deposit beneficiary share with the concerned DSCO, whilst DSCO will release complete payment of system directly to the company or dealer authorized by the company and Department
m. Estimate under the project has to be prepared for complete job i.e. estimate should have details of all the components of the project.
n. The Department shall prepare the estimates which have to be approved by competent authority. The invoices should also be signed by the respective company’s authorized representative.
o. It should also be specified that whether the farmer already has an electric connection and preference under the scheme has to be given to farmers not having electricity connection.
p. The supply and commissioning of each project shall be completed within 90 days from the date of issuance of the work order.
q. The Divisional Soil Conservation officer should ensure that all material/accessories supplied and installed under components of the project should necessarily be BIS marked
r. Minimum 25% of the total cost of the project shall be released only on successful commissioning of the project. 75% of the total cost of the system can be released as running payment after receipt of material, part execution.
s. All the estimates under the project shall be submitted to head office for sanction and release of funds, irrespective of estimated cost.

Table D.1 Subsidy amounts for different solar pumping systems under the scheme

<table>
<thead>
<tr>
<th>S. N.</th>
<th>SPV (Wattage peak) DC/AC Submersible/surface pumping, Wp</th>
<th>Static head, m</th>
<th>Indicated area, Ha</th>
<th>Subsidy amount, Rs.</th>
<th>Subsidy amount, US$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1800</td>
<td>30</td>
<td>0 - 1</td>
<td>2,17,500</td>
<td>2900</td>
</tr>
<tr>
<td>2</td>
<td>2200</td>
<td>30</td>
<td>1 - 1.5</td>
<td>2,51,250</td>
<td>3350</td>
</tr>
<tr>
<td>3</td>
<td>3000</td>
<td>30</td>
<td>1.5 – 2.5</td>
<td>3,26,250</td>
<td>4350</td>
</tr>
<tr>
<td>4</td>
<td>5000</td>
<td>30</td>
<td>2.5 – 5.0</td>
<td>4,87,500</td>
<td>6500</td>
</tr>
<tr>
<td>5</td>
<td>6500</td>
<td>30</td>
<td>5.0 – 6.5</td>
<td>5,88,750</td>
<td>7850</td>
</tr>
<tr>
<td>6</td>
<td>7500</td>
<td>30</td>
<td>6.5 – 8.0</td>
<td>7,11,166</td>
<td>9480</td>
</tr>
<tr>
<td>7</td>
<td>1800</td>
<td>50</td>
<td>0 - 1</td>
<td>2,21,250</td>
<td>2950</td>
</tr>
<tr>
<td>8</td>
<td>2200</td>
<td>50</td>
<td>1 - 1.5</td>
<td>2,62,500</td>
<td>3500</td>
</tr>
<tr>
<td>9</td>
<td>3000</td>
<td>50</td>
<td>1.5 – 2.5</td>
<td>3,48,750</td>
<td>4650</td>
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<td>10</td>
<td>5000</td>
<td>50</td>
<td>2.5 – 5.0</td>
<td>4,87,500</td>
<td>6500</td>
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<td>11</td>
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<td>50</td>
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<td>8000</td>
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<tr>
<td>12</td>
<td>7500</td>
<td>50</td>
<td>6.5 – 8.0</td>
<td>7,20,343</td>
<td>9725</td>
</tr>
</tbody>
</table>
### Annexure E Churu District

**Table E.6 Water balance of district CHURU, Rajasthan**

<table>
<thead>
<tr>
<th>Factors</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>12.5</td>
<td>6.9</td>
<td>5.8</td>
<td>5.1</td>
<td>10.2</td>
<td>42.2</td>
<td>115.3</td>
<td>106.9</td>
<td>49.8</td>
<td>6.3</td>
<td>1</td>
<td>5.6</td>
<td>367.6</td>
</tr>
<tr>
<td>PE</td>
<td>53</td>
<td>75</td>
<td>131</td>
<td>172</td>
<td>237</td>
<td>258</td>
<td>228</td>
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<td>178</td>
<td>125</td>
<td>68</td>
<td>49</td>
<td>1771</td>
</tr>
<tr>
<td>P-PE</td>
<td>-40.5</td>
<td>-68.1</td>
<td>125.2</td>
<td>166.9</td>
<td>-226.8</td>
<td>-215.8</td>
<td>-112.7</td>
<td>-90.1</td>
<td>-128.2</td>
<td>-118.7</td>
<td>-67</td>
<td>-43.4</td>
<td>-1403.4</td>
</tr>
<tr>
<td>APWL</td>
<td>-40.5</td>
<td>108.6</td>
<td>233.8</td>
<td>400.7</td>
<td>627.5</td>
<td>843.3</td>
<td>956</td>
<td>1046.1</td>
<td>1174.3</td>
<td>-1293</td>
<td>-1360</td>
<td>-</td>
<td>9487.2</td>
</tr>
<tr>
<td>Storage</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>S</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>AE</td>
<td>12.5</td>
<td>6.9</td>
<td>5.8</td>
<td>5.1</td>
<td>10.2</td>
<td>42.2</td>
<td>115.3</td>
<td>106.9</td>
<td>49.8</td>
<td>6.3</td>
<td>1</td>
<td>5.6</td>
<td>367.6</td>
</tr>
<tr>
<td>WD</td>
<td>40.5</td>
<td>68.1</td>
<td>125.2</td>
<td>166.9</td>
<td>226.8</td>
<td>215.8</td>
<td>112.7</td>
<td>90.1</td>
<td>128.2</td>
<td>118.7</td>
<td>67</td>
<td>43.4</td>
<td>1403.4</td>
</tr>
<tr>
<td>WS</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

P = Rainfall, mm; PE = Potential evapotranspiration, mm; APWL = Accumulated water loss in different months; Storage = Actual storage of soil moisture; S= Change of actual storage from months to months; WD = Annual water deficit (PE-AE), mm; WS = Annual water surplus

**Table E.2 Groundwater Table Depth (m) in different Tehsils of Churu District**

<table>
<thead>
<tr>
<th>Tehsils</th>
<th>Groundwater Table depth (m) in different years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2005</td>
</tr>
<tr>
<td>Churu</td>
<td>27.63</td>
</tr>
<tr>
<td>Rajgarh</td>
<td>35.17</td>
</tr>
<tr>
<td>Ratangarh</td>
<td>35.38</td>
</tr>
<tr>
<td>Sardarshahar</td>
<td>49.81</td>
</tr>
<tr>
<td>Sujangarh</td>
<td>20.88</td>
</tr>
<tr>
<td>Taranagar</td>
<td>18.01</td>
</tr>
</tbody>
</table>

Source: Central Groundwater Board, [http://gis2.nic.in/cgwb/Gemsdata.aspx](http://gis2.nic.in/cgwb/Gemsdata.aspx)

**Table E.3 Details of crops and their growing periods in Churu district**

<table>
<thead>
<tr>
<th>Name of crop</th>
<th>Season</th>
<th>Sowing period</th>
<th>Harvesting period</th>
<th>Crop duration (No. of days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mustard</td>
<td>Rabi</td>
<td>October</td>
<td>March</td>
<td>140-150</td>
</tr>
<tr>
<td>Gram</td>
<td>Rabi</td>
<td>October</td>
<td>March</td>
<td>150-160</td>
</tr>
<tr>
<td>Wheat</td>
<td>Rabi</td>
<td>November</td>
<td>April</td>
<td>150-160</td>
</tr>
<tr>
<td>Pearl millet/ Bajra</td>
<td>Kharif</td>
<td>June</td>
<td>September</td>
<td>90-100</td>
</tr>
<tr>
<td>Green gram /Moong</td>
<td>Kharif</td>
<td>June</td>
<td>September</td>
<td>80-90</td>
</tr>
<tr>
<td>Moth</td>
<td>Kharif</td>
<td>June</td>
<td>September</td>
<td>70-90</td>
</tr>
<tr>
<td>Cluster bean/gwar</td>
<td>Kharif</td>
<td>July</td>
<td>October</td>
<td>80-100</td>
</tr>
<tr>
<td>Cabbage</td>
<td>Rabi</td>
<td>September</td>
<td>December</td>
<td>110-120</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>Rabi</td>
<td>September</td>
<td>December</td>
<td>100-110</td>
</tr>
<tr>
<td>Okra</td>
<td>Kharif</td>
<td>June</td>
<td>September</td>
<td>90-110</td>
</tr>
<tr>
<td>Brinjal</td>
<td>Kharif</td>
<td>June</td>
<td>December</td>
<td>160-180</td>
</tr>
<tr>
<td>Chillies</td>
<td>Kharif</td>
<td>June</td>
<td>September</td>
<td>110-120</td>
</tr>
<tr>
<td>Cucurbits</td>
<td>Kharif</td>
<td>July</td>
<td>October</td>
<td>80-100</td>
</tr>
<tr>
<td>Cotton</td>
<td>Kharif</td>
<td>June</td>
<td>December</td>
<td>150-180</td>
</tr>
</tbody>
</table>

Source: Horticulture Division, Churu.
Figure 10.1 Estimated pump discharge based on the PET of the district
<table>
<thead>
<tr>
<th>Months</th>
<th>PET, mm/day</th>
<th>Discharge Lps* (Daily operation hour of solar system 6 hours)</th>
<th>Water table depth = 35 m</th>
<th>Water table depth = 45 m</th>
<th>Water table depth = 55 m</th>
<th>Water table depth = 65 m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Drip system (20 m)</td>
<td>Drip system (30 m)</td>
<td>Drip system (40 m)</td>
<td>Mini sprinkler system (20 m)</td>
<td>Mini sprinkler system (30 m)</td>
</tr>
<tr>
<td>January</td>
<td>1.8</td>
<td>0.83</td>
<td>873</td>
<td>1161</td>
<td>1531</td>
<td>1032</td>
</tr>
<tr>
<td>February</td>
<td>2.7</td>
<td>1.25</td>
<td>1310</td>
<td>1741</td>
<td>2296</td>
<td>1548</td>
</tr>
<tr>
<td>March</td>
<td>4.4</td>
<td>2.04</td>
<td>2134</td>
<td>2837</td>
<td>3741</td>
<td>2522</td>
</tr>
<tr>
<td>April</td>
<td>5.7</td>
<td>2.64</td>
<td>2765</td>
<td>3676</td>
<td>4847</td>
<td>3267</td>
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<tr>
<td>May</td>
<td>7.6</td>
<td>3.52</td>
<td>3686</td>
<td>4901</td>
<td>6463</td>
<td>4356</td>
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<tr>
<td>June</td>
<td>8.6</td>
<td>3.98</td>
<td>4171</td>
<td>5546</td>
<td>7313</td>
<td>4929</td>
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<tr>
<td>July</td>
<td>7.4</td>
<td>3.43</td>
<td>3589</td>
<td>4772</td>
<td>6293</td>
<td>4242</td>
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<tr>
<td>August</td>
<td>6.4</td>
<td>2.96</td>
<td>3104</td>
<td>4127</td>
<td>5442</td>
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<td>September</td>
<td>5.9</td>
<td>2.73</td>
<td>2862</td>
<td>3805</td>
<td>5017</td>
<td>3382</td>
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<tr>
<td>October</td>
<td>4</td>
<td>1.85</td>
<td>1940</td>
<td>2579</td>
<td>3401</td>
<td>2293</td>
</tr>
<tr>
<td>November</td>
<td>2.3</td>
<td>1.06</td>
<td>1116</td>
<td>1483</td>
<td>1956</td>
<td>1318</td>
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<tr>
<td>December</td>
<td>1.6</td>
<td>0.74</td>
<td>776</td>
<td>1032</td>
<td>1361</td>
<td>917</td>
</tr>
</tbody>
</table>

**Table E.5 Estimated pump wattage for 1.0 ha area irrigated by drip, mini sprinkler and sprinkler system**
Table E.5 Estimated pump wattage for 0.5 ha area irrigated by drip, mini sprinkler and sprinkler system

<table>
<thead>
<tr>
<th>Months</th>
<th>m³/day for 0.5 ha</th>
<th>Discharge, Lps (Daily operation hour of solar system 6 hours)</th>
<th>Water table depth, m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Drip system (20 m)</td>
<td>Mini sprinkler system (30 m)</td>
</tr>
<tr>
<td>January</td>
<td>9.0</td>
<td>437</td>
<td>580</td>
</tr>
<tr>
<td>February</td>
<td>13.5</td>
<td>655</td>
<td>871</td>
</tr>
<tr>
<td>March</td>
<td>22.0</td>
<td>1067</td>
<td>1419</td>
</tr>
<tr>
<td>April</td>
<td>28.5</td>
<td>1382</td>
<td>1838</td>
</tr>
<tr>
<td>May</td>
<td>38.0</td>
<td>1843</td>
<td>2450</td>
</tr>
<tr>
<td>June</td>
<td>43.0</td>
<td>2086</td>
<td>2773</td>
</tr>
<tr>
<td>July</td>
<td>37.0</td>
<td>1795</td>
<td>2386</td>
</tr>
<tr>
<td>August</td>
<td>32.0</td>
<td>1552</td>
<td>2063</td>
</tr>
<tr>
<td>September</td>
<td>29.5</td>
<td>1431</td>
<td>1902</td>
</tr>
<tr>
<td>October</td>
<td>20.0</td>
<td>970</td>
<td>1290</td>
</tr>
<tr>
<td>November</td>
<td>11.5</td>
<td>558</td>
<td>742</td>
</tr>
<tr>
<td>December</td>
<td>8.0</td>
<td>388</td>
<td>516</td>
</tr>
</tbody>
</table>
ANNEXURE F Presentations

F.1 Government Policies on Solar Photovoltaic Pumping Systems by Dr T B S Rajput, Emeritus Scientist, Water Technology Centre, Indian Agricultural Research Institute

Interactive meet with visiting delegates at ICID, Jan 8, 2019

Government Policies on Solar Photovoltaic Pumping Systems

T. B. S. Rajput, Emeritus Scientist, WTC, IARI, New Delhi- India

Flow of the presentation

Water Energy Food Nexus
Potential of solar energy
Solar pumping systems
Solar policies of Govt of India
Solar policies of 3 selected States
Field study with small farmers
MIT solar pump evaluation highlights
Water Energy Food Nexus
Agriculture is the single largest employer in the world, sustaining the livelihoods of 40 percent population many of whom live in poverty (UN, 2015).

Irrigation is often seen as
- the engine that helps to ensure food security,
- provides jobs and generates incomes
- drives rural development

Energy is a key input for irrigation services.

Resources and Liabilities

Fresh Water Resources – 4 %
Land – 2.3 %
Population – 16 %
Rainfall – 1170 mm
**Irrigation Development in India after Independence**

- **Irrigation potential created**
- **Irrigation potential utilized**

**Five year plan periods**

- [Graph showing irrigation potential over time]

**Overall irrigation efficiency 38%**

- 27% in Krishna Godavari, Kaveri and Mahanadi river systems
- 43 to 47% in Indus and Ganga river systems
- 70 to 80% in areas irrigated by groundwater

**Major ➔ Medium ➔ Minor ➔ Micro ➔ Nano**

- Major ➔ > 10,000 ha
- Medium ➔ 2,000 – 10,000 ha
- Minor ➔ < 2,000 ha

---

**MICROIRRIGATION**

- Saves water
- Saves fertilizers
- Saves labour
- Lesser weeds
- Higher yields
- Higher income

---

**Irrigation Efficiency**

- [Graph showing irrigation efficiency]

**Efficiency**

- Flood
- Furrow
- Sprinkler
- Center Pivot
- Drip

**Irrigation Methods**

**Typical Benefits of Drip**

- Higher yields
- Improved soil quality
- Marginal and small farmers
- Reduced labor costs
- Higher FDI
- Less energy use
- Water saving
- High returns
- Higher sale
- Less energy use
- Water applied

---

[78]
Micro irrigation in watersheds/ un-irrigated areas

Use of harvested water through drip/sprinkler irrigation system

Use of solar pumps and drip irrigation in desert areas

Direct take off from canal

Through balancing reservoirs

Coupled with solar pumping
Potential of solar energy

Global solar map (Source: World Bank)
Solar insolation in India

Total potential

= 5 Trillion KWh/day

In most parts
i. Over 4 KWh/m²/day

ii. Clear sunny days
250-300/ year

Estimated Solar Power Potential

<table>
<thead>
<tr>
<th>State</th>
<th>Solar Potential (Gw)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andhra Pradesh</td>
<td>3.44</td>
</tr>
<tr>
<td>Arunachal Pradesh</td>
<td>0.85</td>
</tr>
<tr>
<td>Assam</td>
<td>0.79</td>
</tr>
<tr>
<td>Bihar</td>
<td>1.26</td>
</tr>
<tr>
<td>Chhattisgarh</td>
<td>1.51</td>
</tr>
<tr>
<td>Delhi</td>
<td>0.00</td>
</tr>
<tr>
<td>Goa</td>
<td>0.89</td>
</tr>
<tr>
<td>Gujarat</td>
<td>2.77</td>
</tr>
<tr>
<td>Haryana</td>
<td>4.55</td>
</tr>
<tr>
<td>Himachal Pradesh</td>
<td>3.81</td>
</tr>
<tr>
<td>Jammu &amp; Kashmir</td>
<td>11.05</td>
</tr>
<tr>
<td>Jharkhand</td>
<td>15.16</td>
</tr>
<tr>
<td>Kerala</td>
<td>24.70</td>
</tr>
<tr>
<td>Karnataka</td>
<td>6.11</td>
</tr>
<tr>
<td>Ladakh</td>
<td>0.11</td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td>44.39</td>
</tr>
<tr>
<td>Maharastra</td>
<td>10.55</td>
</tr>
<tr>
<td>Meghalaya</td>
<td>3.66</td>
</tr>
<tr>
<td>Mizoram</td>
<td>0.49</td>
</tr>
<tr>
<td>Nagaland</td>
<td>7.24</td>
</tr>
<tr>
<td>Odisha</td>
<td>25.78</td>
</tr>
<tr>
<td>Punjab</td>
<td>3.81</td>
</tr>
<tr>
<td>Rajasthan</td>
<td>147.51</td>
</tr>
<tr>
<td>Sikkim</td>
<td>0.04</td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td>17.87</td>
</tr>
<tr>
<td>Telangana</td>
<td>20.42</td>
</tr>
<tr>
<td>Tripura</td>
<td>3.06</td>
</tr>
<tr>
<td>Uttarakhand</td>
<td>22.85</td>
</tr>
<tr>
<td>U.P.</td>
<td>15.50</td>
</tr>
<tr>
<td>West Bengal</td>
<td>9.24</td>
</tr>
<tr>
<td>UT</td>
<td>0.72</td>
</tr>
<tr>
<td>Total</td>
<td>785.84</td>
</tr>
</tbody>
</table>
Annual solar power generation

<table>
<thead>
<tr>
<th>Year</th>
<th>Solar power generation (TWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-14</td>
<td>3.35</td>
</tr>
<tr>
<td>2014-15</td>
<td>4.60</td>
</tr>
<tr>
<td>2015-16</td>
<td>7.45</td>
</tr>
<tr>
<td>2016-17</td>
<td>12.09</td>
</tr>
<tr>
<td>2017-18</td>
<td>25.87</td>
</tr>
</tbody>
</table>

Grid solar power & Off grid solar power
A photovoltaic system/ solar PV power system/ PV system, is a power system designed to supply usable power by means of photovoltaics. It consists of solar panels, solar inverter, mounting, cabling, electrical accessories. It may also use solar tracking system, integrated battery solution.
Types of solar-powered pumping systems

1. Solar panel
2. Electronics
3. Solar pump

Important Applications of Solar Pumping System
- Ground water lowering
- Irrigation systems
- Industrial Application
- Tank / Cistern filling
- Wildlife refuge
- Fountains
- Drip irrigation & sprinkler
- Rural water supply for ranches, cabins, and cottages
Types of Pumps

- **Surface Pump:**
  Placed besides the water source (lake, well, etc.).

- **Submersible Pump:**
  Placed in the water source.

- **Floating pump:**
  Placed on top of the water.

A *hybrid system* combines PV with other forms of generation,

The photovoltaic power generation serves to reduce the consumption of non-renewable fuel.

More than one renewable forms of energy may also be used.

- **PVT system** (hybrid PV/T), Photovoltaic thermal hybrid

- **CPVT system.** A *concentrated photovoltaic thermal hybrid* (CPVT)

- **CPV/CSP system.** CPV/CSP hybrid combining *concentrated solar power* (CSP),

- **PV diesel system.** It combines a photovoltaic system with a *diesel generator*

- **PV wind systems; Pellworm** island in Germany and *Kythnos* island in Greece are notable examples (both are combined with wind)
Solar Pump sets with fix structures

Jaipur 2010-11

Solar pump with auto-tracker
Advantages of Solar pumping systems

- Rugged construction
- Simple installation and maintenance
- Highly reliable
- No conventional grid electricity required
- Long operating life
- Durable
- Easy to operate and maintain
- Eco-friendly
- No fuel cost

Possible disadvantages and mitigation

- High initial capital cost
- Additional cost – Batteries
  - water tank
  - Diesel in hybrid systems.
- Lack of specialized technicians/ providers
- Panel theft in some communities
- Can lead to excessive groundwater extraction.
Challenges for SPV Systems

- Economic viability;
- Access to finance;
- Installation, operation and maintenance;
- Standardization and quality control of products and services;
- Water management;

Solar policies of Govt. of India
Incentives for promotion of solar energy

1. **Viability Gap Funding:** Funding was 0.5Mn USD/MW for open projects on average in 2016.
2. **Accelerated depreciation:** 40 percent depreciation in the first year (decreasing taxes).
3. **To protect the local manufacturers,** 25% duty on the imports from China & Malaysia.
4. **Capital subsidies were applicable** to rooftop solar-power plants up to 500 kW.
5. **Renewable Energy Certificates (RECs):**
6. **Assured Power Purchase Agreement (PPA):**
7. Interstate transmission system (ISTS) **charges and losses are not levied** till 31 March 2022.

1. JN Solar Mission

To make India’s economic development energy-efficient. Over a period of time, to pioneer a graduated shift from economic activity based on fossil fuels to one based on non-fossil fuels.

<table>
<thead>
<tr>
<th>S. N</th>
<th>Application segment</th>
<th>Target for Phase I (201013)</th>
<th>Target for Phase 2 (2013-17)</th>
<th>Target for Phase 3 (2017-22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Solar collectors</td>
<td>7 million sq meters</td>
<td>15 million sq meters</td>
<td>20 million sq meters</td>
</tr>
<tr>
<td>2.</td>
<td>Off grid solar applications</td>
<td>200 MW</td>
<td>1000 MW</td>
<td>2000 MW</td>
</tr>
<tr>
<td>3.</td>
<td>Utility grid power, including rooftop</td>
<td>1,000-2000 MW</td>
<td>4000-10,000 MW</td>
<td>20000 MW</td>
</tr>
</tbody>
</table>
The JNS Mission recommended

- Zero import duty on capital equipment, raw materials
- Excise duty exemption
- Low interest rate loans, priority sector lending
- Special Incentive Package (SIPs) policy to set up integrated manufacturing plants;
- Solar components be covered under Bureau of Energy
- Efficiency’s star rating programme for high standards
- Ease of doing business & Infra & Ecosystem enabling.


Development of at least 50 Solar Parks and Ultra Mega Solar Power Projects with a capacity of 500MW and above by 2019-20; with an estimated Central Financial Assistance (CFA) of Rs. 8100 crore (USD =1.2Bn)

* The solar parks will be developed in collaboration with State Governments/their agencies.
- SECI will be the nodal agency for MNRE and will also handle funds on behalf of GOI.
- Solar project developers shall enter into power purchase agreements with buyers
- The tariff for the sale of power determined by Central Regulatory Commission/State Regulatory Commission or through bidding process.
3. The KUSUM Scheme

"The Kusum (Kisan Urja Suraksha evam Utthaan Mahabhiyan) scheme provides for 17.5 Lakh (1.75 Mn) off grid solar pumps to begin with. "Ultimately Government of India proposes to solarise every agricultural pump and apart from this, connecting all the grid connected pumps with solar power.

The farmer will have to bear just 10 per cent of the cost of the panel, remaining 30 per cent capital subsidy from the Centre + another 30 per cent will come from the state + the balance 30 per cent will be financed.

6.8 Mn USD
- The government to spend Rs 48,000 crore/ 10 years as CFA
- Encouragement for use of barren lands for solar panels
- Solar panels of twice capacity to be provided
- Balance power to be sold to State Electricity authorities

4. Solar Pumping Programme for Irrigation and Drinking Water

1. Development of models that will foster solar power deployment for pumping in rural areas in a scalable manner.

2. Exploring prospects of solar pump programs to address and support rural development-related aspects

3. Improvement in energy access.

The duration of the programme will be five years starting from 2014-15. It was proposed to sanction one lakh pumps for 2014-15 and it is expected that by the year 2020-2021, ten lakhs (1 Million) solar pumps will be deployed for irrigation and drinking water purpose in the country.
Types of systems under the scheme
a. Grid connected pumping.
b. Solar pump mini grid
c. Repacing Diesel pumps
d. Community solar pumps
e. Micro solar pumps

Implementation models for the scheme
a. Through State Governments
   - Conventional model (30% subsidy MNRE)
   - Lending from Financial Institutions (States increase their share of subsidy)
   - Water as a service model
b. Through NABARD and other banks
c. Through and along with other ministries

The pattern of assistance

MNRE scheme for promoting solar photovoltaic water pumping systems for irrigation purpose

<table>
<thead>
<tr>
<th>SN</th>
<th>SPV System</th>
<th>Capacity</th>
<th>Maximum Subsidy (Rs. Per HP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>D C Pumps</td>
<td>Up to 2 HP</td>
<td>57600 (USD 825)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-5 HP</td>
<td>54000 (USD 770)</td>
</tr>
<tr>
<td>2</td>
<td>AC Pumps</td>
<td>Up to 2 HP</td>
<td>50400 (USD 720)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-5 HP</td>
<td>43200 (USD 620)</td>
</tr>
<tr>
<td>3</td>
<td>For 5-10 HP Pumps</td>
<td>subsidy as Rs 1,94,400 (USD 2780)/ Pump</td>
<td></td>
</tr>
</tbody>
</table>

State Nodal Agencies are responsible 100% for monitoring in the field using technological interventions both qualitative and quantitative aspects
5. Development of Grid Connected Solar PV Power Plants on Canal Banks and Canal Tops

State Power Generation Companies/ State Government Utilities/ any other State Government Organization/ PSUs to set up 1-10 MW plants (50 MW Canal Top and 50 MW Canal Bank SPV projects)

Solar Energy Corporation of India (SECI) under the MNRE. Will manage the scheme

<table>
<thead>
<tr>
<th>State</th>
<th>Canal Top</th>
<th>Canal Bank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andhra Pradesh</td>
<td>1 MW</td>
<td>5 MW</td>
</tr>
<tr>
<td>Gujrat</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Karnataka</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>Kerala</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td><strong>Punjab</strong></td>
<td><strong>20</strong></td>
<td>-</td>
</tr>
<tr>
<td>Uttar Pradesh</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>Uttarakhand</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>West Bengal</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>50</strong></td>
<td><strong>50</strong></td>
</tr>
</tbody>
</table>

**Subsidy**
Rs.0.44 Mn USD/MW for Canal Top and Rs. 0.22 Mn USD/MW for Canal Bank Projects;
Private Sector Development

The GoI has boosted India’s solar pump industry not only by aggressively promoting solar PV pumping systems for domestic use, but also by inviting other countries to popularize solar water pumps from Indian manufacturers.

MNRE announced to invite 15-20 countries
- to promote solar pump use,
- jointly with the International Solar Alliance (ISA),
- to export solar pumps (with credit lines if necessary),
- explain the benefits, and provide training on Indian-developed solar pump standards

Solar Policies of 3 selected State Govts
OBJECTIVES

- To maximise and improve the share of new and renewable sources of energy to 10% of the total installed power capacity in the state by 2022.

- To promote renewable energy initiatives for meeting energy / lighting needs in rural areas and supplementing energy needs in urban, industrial and commercial sectors.

1. Solar Power Projects to Land Owning Farmers

The Government of Punjab endeavors to promote solar energy projects by land owning farmers with a minimum capacity of 1MWp to a maximum capacity of 2.5 MWp (per land owning farmer) in the state for sale of power to Punjab State Power Corporation Ltd. (PSPCL) at applicable generic tariff determined by Punjab State Electricity Regulatory Commission (PSERC) on annual basis.

With Solar Power Projects located closer to the agriculture loads in distribution / transmission network, distribution losses will be reduced considerably and voltage drop at peak day time load will be minimized along with power supply and power factor improvement.
Eligibility, Terms & Conditions

1. Farmer holding agriculture land in their name
2. Farmer / Group of Farmers can also form a company for applying
3. The minimum capacity that can be allocated is 1MWp and maximum is 2.5 MWp
4. The existing land use as per revenue records should be for Agriculture/Horticulture
5. The minimum land required is 2 hectares for 1MWp proportionately of higher capacity.
6. The application fee of Rs.50,000/- (USD 720) shall be submitted (Non refundable)

2. Solar Pumps Scheme

To prevent the excessive use of power for agricultural needs, the Punjab Energy Development Agency (PEDA) has started a scheme of solar pumps in villages.

* The PEDA has aimed to install as many solar pumps in the state as may be possible within financial constraints
  • The cost of 3 HP solar pumps is Rs 48,000 (USD 700)
  • The cost of 5 HP solar pumps is Rs 75,000. (USD 1000)
  • Minimum size of land holding is 1hectare mandatory
* Preference will be given to poly houses
3. Scheme for matching irrigation water availability and demand for improved productivity through Efficient water management

The Scheme has three components and assistance under the Project on each of the component these shall be provided to farmers as follows:

a) **Micro Irrigation:**

b) **Solar Photovoltaic Pump set System:** Under this component complete system of Solar Photovoltaic (SPV) panels with Pump sets shall be provided to the farmer. Financial assistance under this component will be 75% subject to maximum for each capacity of system. This assistance shall be provided on first come first served basis from the funds available under the project.

c) **On-farm Water Storage Tanks**

<table>
<thead>
<tr>
<th>Item</th>
<th>Static head, m</th>
<th>Indicated Area Ha</th>
<th>Quantity</th>
<th>Rate inclusive of all taxes</th>
<th>Subtotal Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.3</td>
<td>0.2</td>
<td>1 m</td>
<td>336000</td>
<td>209564</td>
</tr>
<tr>
<td>2</td>
<td>0.3</td>
<td>0.2</td>
<td>1 m</td>
<td>310000</td>
<td>170000</td>
</tr>
<tr>
<td>3</td>
<td>0.3</td>
<td>0.2</td>
<td>1 m</td>
<td>320000</td>
<td>192000</td>
</tr>
<tr>
<td>4</td>
<td>0.3</td>
<td>0.2</td>
<td>1 m</td>
<td>300000</td>
<td>177000</td>
</tr>
<tr>
<td>5</td>
<td>0.3</td>
<td>0.2</td>
<td>1 m</td>
<td>320000</td>
<td>192000</td>
</tr>
<tr>
<td>6</td>
<td>0.3</td>
<td>0.2</td>
<td>1 m</td>
<td>320000</td>
<td>192000</td>
</tr>
<tr>
<td>7</td>
<td>0.3</td>
<td>0.2</td>
<td>1 m</td>
<td>320000</td>
<td>192000</td>
</tr>
<tr>
<td>8</td>
<td>0.3</td>
<td>0.2</td>
<td>1 m</td>
<td>320000</td>
<td>192000</td>
</tr>
<tr>
<td>9</td>
<td>0.3</td>
<td>0.2</td>
<td>1 m</td>
<td>320000</td>
<td>192000</td>
</tr>
<tr>
<td>10</td>
<td>0.3</td>
<td>0.2</td>
<td>1 m</td>
<td>320000</td>
<td>192000</td>
</tr>
<tr>
<td>11</td>
<td>0.3</td>
<td>0.2</td>
<td>1 m</td>
<td>320000</td>
<td>192000</td>
</tr>
<tr>
<td>12</td>
<td>0.3</td>
<td>0.2</td>
<td>1 m</td>
<td>320000</td>
<td>192000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Rate of interest for housing in forward</th>
<th>Interest per annum for lowering pump in forward</th>
<th>1 m</th>
<th>235</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>530 mm</td>
<td>818 mm</td>
<td>1 m</td>
<td>260</td>
</tr>
<tr>
<td>ii</td>
<td>730 mm</td>
<td>1090 mm</td>
<td>1 m</td>
<td>260</td>
</tr>
<tr>
<td>iii</td>
<td>930 mm</td>
<td>1430 mm</td>
<td>1 m</td>
<td>260</td>
</tr>
<tr>
<td>iv</td>
<td>1130 mm</td>
<td>1560 mm</td>
<td>1 m</td>
<td>260</td>
</tr>
</tbody>
</table>
Maharashtra Solar Policy

The 125-MW Sakri solar plant is the world's largest solar-power plant in Maharashtra

It was constructed at Shirdi shrine at an estimated cost of ₹1.33 crore (US$90,000). Besides meeting other energy needs of the temple its used to cook 50000 meals/day

1. Atal Solar Krishi Pump Yojana

(ASKP) for farmers to provide subsidy of upto 95% on solar agriculture pumpsets. Around 7000 pumps will be distributed to the farmers under Atal solar agriculture pump scheme in Maharashtra to irrigate 14,000 Ha land.

Atal Solar Krishi Pump Yojana (ASKP) will promote the usage of solar energy in agricultural activities. Moreover, this will also reduce losses to the state govt. due to non-payment of electricity bills.

Currently, farming electricity dues stands a whopping Rs. 32,000 crore so Govt. wants to shift the paradigm to solar renewable energy.
Atal Solar Krushi Pump (ASKP) Yojana

will promote the use of green energy,
reduce pollution and
will ensure sufficient electricity for farming activities.

MahaUrja Department will handle the scheme

* Farmers with less than 2.5 ha of land needs to pay 5% (Rs. 12,000 USD 170) for a 3 HP pump.
* Farmers with more than 2.5 ha of land needs to pay Rs. 30,000 USD 430) to get 5 HP pump.

3. Rajasthan State Solar Policies

Best solar insolation on earth with 6 to 7 kWh/m2/day with 325 sunny days a year.

- Acute water shortage,
  - erratic rainfall and
  - recurring droughts

Almost every district in the state has drought in one form or the other for half the time.

*Approximately 60,000 farmers in queue and *Expansion of electric-grid is not feasible in far-flung areas;
• In Rajasthan, Solar pumping scheme was clubbed with Rashtriya Krishi Vikas Yojana (RKVY).

• The RKVY is implemented by the Horticulture Department of the Government of Rajasthan covering 16 districts of the state

• Beneficiaries are expected to pay 14%

• The Rajasthan Renewable Energy Corporation is providing a 30% subsidy from MNRE under JNNSM.

• State Govt under RKVY is providing the remaining 56% subsidy

---

Role of Public Agencies:

1. **GoI**: Provided funds through MNRE, NHM, NMMI, RKVY, etc.

2. **Government of Rajasthan**: permitted clubbing of subsidies under various programmes to 86% of the capital cost (30% MNRE + 56% RKVY).

3. **Commissionerate of Horticulture, Rajasthan**: Coordination with all concerned StateDepartments and developed Regulatory framework for effective implementation.

4. **Rajasthan Horticulture Development Society (RHDS)**: RHDS and its district level functionaries execute Scheme. RHDS short-lists and empanels manufacturers-cum-suppliers and selects beneficiaries
<table>
<thead>
<tr>
<th>Year</th>
<th>Project</th>
<th>No of Dist. covered</th>
<th>Target</th>
<th>Achievement</th>
<th>Project cost (Rs. Cr)</th>
<th>MWp</th>
<th>Pump capacity (hp)</th>
<th>Subsidy</th>
<th>Funding source</th>
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<tbody>
<tr>
<td>2008-09</td>
<td>Government Farms</td>
<td>7</td>
<td>14</td>
<td>14</td>
<td>0.75</td>
<td>0.025</td>
<td>1500</td>
<td>10%</td>
<td>RGGVY</td>
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<tr>
<td>2010-11</td>
<td>Pilot Project</td>
<td>8</td>
<td>50</td>
<td>34</td>
<td>1.83</td>
<td>0.096</td>
<td>2200/3000</td>
<td>6%</td>
<td>JNNURM, RGGVY</td>
</tr>
<tr>
<td>2011-12</td>
<td>First major jump</td>
<td>14</td>
<td>500</td>
<td>1,575</td>
<td>95.88</td>
<td>4.996</td>
<td>2200/3000</td>
<td>6%</td>
<td>JNNURM, RGGVY</td>
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<tr>
<td>2012-13</td>
<td>Second major jump</td>
<td>33</td>
<td>2,000</td>
<td>4,418</td>
<td>258.65</td>
<td>12.212</td>
<td>2200/3000</td>
<td>6%</td>
<td>JNNURM, RGGVY, State</td>
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<tr>
<td>2013-14</td>
<td>Third major jump</td>
<td>33</td>
<td>6,000</td>
<td>9,918</td>
<td>584.60</td>
<td>20.736</td>
<td>2200/3000</td>
<td>8%</td>
<td>JNNURM – RGGVY State Resources</td>
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<tr>
<td>2014-15</td>
<td>Support Programme</td>
<td>33</td>
<td>5,200</td>
<td>2,300</td>
<td>350.00</td>
<td>10.229</td>
<td>30,00/5000</td>
<td>71%</td>
<td>JNNURM – NERF, State Resources</td>
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<td>2015-16 (Proposed)</td>
<td>Support Programme</td>
<td>33</td>
<td>4702</td>
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<td>-</td>
<td>-</td>
<td>50,00/5000</td>
<td>73%</td>
<td>JNNURM – NERF, State Resources</td>
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Field study with small farmers
Study Area – Dist Churu Rajasthan

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Months</th>
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<tbody>
<tr>
<td>Max. T (°C)</td>
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<tr>
<td>Min. T (°C)</td>
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<tbody>
<tr>
<td>P</td>
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<td>9.9</td>
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<td>49</td>
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<td>-400.7</td>
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<td>0</td>
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<td>0</td>
<td>1</td>
<td>0</td>
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<td>3.8</td>
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<td>215.8</td>
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<td>90.1</td>
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Tehsil   | Ground water table depth (m) in different years
---------|--------------------------------------------------

Guar under water stressed condition  Pearl millet under water stressed condition
### Solar pumps studied

<table>
<thead>
<tr>
<th>Farmer name</th>
<th>Firm name</th>
<th>No. of solar panels</th>
<th>Pump power, Watts</th>
<th>GWL, m</th>
<th>Solar pump discharge, Lph</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rameshwar Lal</td>
<td>14</td>
<td>3000</td>
<td>54.9</td>
<td>4900</td>
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<tr>
<td>2</td>
<td>Bhaniram</td>
<td>14</td>
<td>3000</td>
<td>44.2</td>
<td>7200</td>
</tr>
<tr>
<td>3</td>
<td>Shishram</td>
<td>14</td>
<td>3000</td>
<td>44.8</td>
<td>6750</td>
</tr>
<tr>
<td>4</td>
<td>Nagarmal</td>
<td>14</td>
<td>3000</td>
<td>44.2</td>
<td>10800</td>
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<tr>
<td>5</td>
<td>Lakshmanrajan</td>
<td>14</td>
<td>3000</td>
<td>33.5</td>
<td>5400</td>
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<tr>
<td>6</td>
<td>Amitu</td>
<td>12</td>
<td>3000</td>
<td>33.5</td>
<td>5400</td>
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<tr>
<td>7</td>
<td>Md. Hussain</td>
<td>14</td>
<td>3000</td>
<td>36.6</td>
<td>15429</td>
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<td>8</td>
<td>Ram Lal</td>
<td>14</td>
<td>3000</td>
<td>36.6</td>
<td>13500</td>
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<td>Pumaram</td>
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<td>3000</td>
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<td>5400</td>
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<td>3000</td>
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<td>Reikaram</td>
<td>14</td>
<td>3000</td>
<td>36.6</td>
<td>10800</td>
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<td>Hariram</td>
<td>14</td>
<td>3000</td>
<td>36.6</td>
<td>9000</td>
</tr>
<tr>
<td>13</td>
<td>Chagan Kaurvar</td>
<td>12</td>
<td>3000</td>
<td>36.6</td>
<td>6750</td>
</tr>
<tr>
<td>14</td>
<td>Rajesh</td>
<td>12</td>
<td>3000</td>
<td>47.2</td>
<td>771</td>
</tr>
<tr>
<td>15</td>
<td>Bauvari Lal</td>
<td>14</td>
<td>3000</td>
<td>42.7</td>
<td>9000</td>
</tr>
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<td>16</td>
<td>Ram Kumar</td>
<td>12</td>
<td>3000</td>
<td>54.9</td>
<td>4500</td>
</tr>
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<td>17</td>
<td>Sultan Singh</td>
<td>12</td>
<td>3000</td>
<td>45.7</td>
<td>1200</td>
</tr>
</tbody>
</table>

### Estimated pump wattage /0.5 ha under drip, mini sprinkler and sprinkler irrigation

**Table:**

- **Month Name**
- **Water table depth = 35 m**
- **Water table depth = 45 m**
- **Water table depth = 55 m**
- **Water table depth = 65 m**

**Challanges:**
- Daily operation hour of solar system 8 hours
- Pump efficiency (70%)
Estimated pump wattage /1.0 ha under drip, mini sprinkler and sprinkler irrigation

<table>
<thead>
<tr>
<th>Months</th>
<th>PET, mm/day</th>
<th>Discharge, Lp**</th>
<th>Drop system (20 m)</th>
<th>Mini sprinkler system (50 m)</th>
<th>Sprinkler system (40 m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>1.8</td>
<td>0.83</td>
<td>875</td>
<td>1181</td>
<td>1533</td>
</tr>
<tr>
<td>February</td>
<td>2.7</td>
<td>0.85</td>
<td>1310</td>
<td>1741</td>
<td>2106</td>
</tr>
<tr>
<td>March</td>
<td>4.4</td>
<td>1.05</td>
<td>2234</td>
<td>2837</td>
<td>3514</td>
</tr>
<tr>
<td>April</td>
<td>5.7</td>
<td>1.20</td>
<td>3763</td>
<td>4887</td>
<td>5863</td>
</tr>
<tr>
<td>May</td>
<td>7.6</td>
<td>1.35</td>
<td>6566</td>
<td>8091</td>
<td>9687</td>
</tr>
<tr>
<td>June</td>
<td>9.6</td>
<td>1.50</td>
<td>12317</td>
<td>15716</td>
<td>18732</td>
</tr>
<tr>
<td>July</td>
<td>7.4</td>
<td>1.05</td>
<td>2389</td>
<td>2972</td>
<td>3580</td>
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<tr>
<td>August</td>
<td>8.4</td>
<td>1.20</td>
<td>3616</td>
<td>4427</td>
<td>5335</td>
</tr>
<tr>
<td>September</td>
<td>5.9</td>
<td>1.05</td>
<td>12317</td>
<td>15716</td>
<td>18732</td>
</tr>
<tr>
<td>October</td>
<td>4.1</td>
<td>1.05</td>
<td>940</td>
<td>1181</td>
<td>1432</td>
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<tr>
<td>November</td>
<td>2.3</td>
<td>1.05</td>
<td>1310</td>
<td>1741</td>
<td>2106</td>
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<td>3.8</td>
<td>1.05</td>
<td>12317</td>
<td>15716</td>
<td>18732</td>
</tr>
</tbody>
</table>

* Daily operation hour of solar system: 5 hours

** Pump efficiency (70 %)

Yellow cells represent the months during which the pump wattage was more than the existing 3000 watts solar pump. In drip, 4 months water deficit, in mini sprinkler 6 months water deficit and in sprinkler 8 months water deficit will be experienced in Chun and Tamanagar (Table 12). Similarly in Sardar Shaker and Ratangarh tehsils, 6 months water deficit in drip, 8 months in mini sprinkler and 9 months in sprinkler will be experienced. Similar, calculations can be made for selection of solar pump with different MI systems based on different GWL data.

Payback period
under Subsidised & Unsubsidized solar pumping systems

<table>
<thead>
<tr>
<th>Pump capacity (HP)</th>
<th>Payback period (years)</th>
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</thead>
<tbody>
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<td></td>
<td>Unsubsidised</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

[104]
### Life cycle cost analysis comparison of the two systems

<table>
<thead>
<tr>
<th>S. N</th>
<th>Costs</th>
<th>PV system (Rs.)</th>
<th>Diesel Engine (Rs.)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Capital Cost (CC)</td>
<td>485717</td>
<td>24,000</td>
</tr>
<tr>
<td>2</td>
<td>Maintenance Cost (MC)</td>
<td>9714.34</td>
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<td>3</td>
<td>Fuel Cost (FC)</td>
<td>-</td>
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<tr>
<td>4</td>
<td>Replacement Cost (RC)</td>
<td>-</td>
<td>24,000</td>
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<td>5</td>
<td>Total Cost</td>
<td>495431.34</td>
<td>23,14,960</td>
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<td>6</td>
<td>Salvage Cost (SC)</td>
<td>54497.44</td>
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<td>7</td>
<td>Life Cycle Cost (LCC)</td>
<td>440933</td>
<td>23,10,160</td>
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</tbody>
</table>

Thanks for your kind attention

tbsraj@yahoo.com

[105]
F.2 Integrated Solar Powered Community Lift Micro Irrigation Project in Kandi-Belt of Talwara and Hajipur Blocks of District Hoshiarpur in Punjab, India by Mr Naresh Kumar Gupta, Divisional Soil Conservation Officer Hoshiarpur and Mr Sukhdeep Duggal, Project Manager, Jain Irrigations Systems Ltd.

Implementing Agency: Department of Soil & Water Conservation, Punjab

Funding Agency: Government of Punjab

Company approved through E-tender: M/s Jain Irrigation Systems Ltd.

Supported by: P.F.D.C. P.A.U Ludhiana
PROBLEMS OF AREA

- SCARCITY OF WATER (DRINKING AS WELL AS AGRICULTURE PURPOSE)
- UNDULATED TOPOGRAPHY
- SOIL EROSION
- BOULDRY SOIL
- POOR LIVESTOCK
- POOR AGRICULTURE AND PRACTICES
- WILD LIFE / STRAY ANIMALS MENACE
- POOR SOCIO-ECONOMIC CONDITIONS

Objectives of the project

- Assured irrigation to the agricultural fields;
- Improving Cropping Intensity;
- Increasing efficiency through judicious use of canal water and fertilizers;
- Increasing yield and Production with better Quality of Horticulture and Non-horticulture produce;
- Reducing water losses due to evaporation etc.;
- saving farm-land and appreciating land value;
- Improving socio-economic condition of the farmers
CHALLENGES

- Land for Solar Panel Structures (Shade Free)
- Land for Sump Wells, Pump Rooms, Training Hall etc.
- Excavation in Each & Every Field for MIS Sub Mains
- RTU Communication
- Solar Power as only source to Run 20-25Hp pumps for water lifting and distribution lines.
- Farmer Interaction Program & Motivation
- Forest Sanction
- Farmer Education (Direct from Radio to Plasma)
- Flood Protection Structures
**PROJECT HIGHLIGHTS**

- **PROJECT NAME:** SOLAR POWERED COMMUNITY MICRO IRRIGATION PROJECT IN KANDI BELT OF TALWARA AND HAZIPUR BLOCKS OF DISTT. HOSHIARPUR
- **VILLAGES COVERED:** 14 NOS.
- **TOTAL AREA:** 734.91 HA.
- **CULTIVABLE AREA:** 664 H.A.
- **NO. OF BENEFICIARIES:** 1200 NOS.
- **PUMPING CAPACITY:** 890 H.P. (46 PUMPS OF 20-25 H.P.)
- **SOLAR POWER GENERATION:** 1100 Kwp
- **TOTAL WATER INTAKE:** 15,374 CUSEC
- **AREA UNDER HDPE PIPE NETWORK:** 8510 MTRS (DIA. 450MM TO 150 MM)
- **AREA UNDER PVC PIPE NETWORK:** 366467 MTRS (DIA. 180 MM TO 63MM)
- **PUMP HOUSES & SUMP WELLS:** 12 NOS.
- **NO. OF ZONES:** 18 NOS.
- **AREA UNDER SPRINKLER SYSTEM:** 596 H.A.
- **AREA UNDER DRIP SYSTEM:** 128 H.A.
- **PROJECT OPERATIONS:** SCADA / CLOUD CONTROL
- **FOREST & SECONDARY FENCING:** 15307 MTRS

---

**Proposed Water available for crops:**

As per availability of water per day from kandi canal is, 2MM per day

**Proposed Cropping Pattern:**

- **Vegetables:** 10%
- **Orchards:** 25-30%
- **Wheat/ Pulses/ Maize:** 60-65%
SCHEME - 3

Total Area: 60.68 Ha
Cultivable Area: 59.70 Ha
Number of zones: 02 no.s
Number of Sections: 42 no.s
Area per Section: 1.75 Ha (Approx.)
Name of village involved:
1. Ghagwal (Partial)
2. Kando Kharora
3. Pani Kharora

Siphon – III
Total discharge required: 40.06 lps
Sump Well at lift point: 01 no. (For Scheme 3, 4 & 5)
Max. Capacity of Sump well: 155.45 cum (For Scheme 3, 4 & 5)
Sump wells at ponds: 01 no.s
Max. Capacity of Sump wells: 37.44 cum
Raising Main: HDPE Pipe
Distribution Line: PVC Pipe

SCHEME - 4

Total Area: 74.03 Ha
Cultivable Area: 70.25 Ha
Number of zones: 02 no.s
Number of Sections: 42 no.s
Area per Section: 1.75 Ha (Approx.)
Name of village involved:
1. Badala
2. Nanmol

Siphon – III
Total discharge required: 47.14 lps
Sump Well at lift point: 01 no. (For Scheme 3, 4 & 5)
Max. Capacity of Sump well: 155.45 cum (For Scheme 3, 4 & 5)
Sump wells at ponds: 01 no.s
Max. Capacity of Sump wells: 37.44 cum
Raising Main: HDPE Pipe
Distribution Line: PVC Pipe
### SCHEME - 5

- **Total Area**: 170.95 Ha
- **Cultivable Area**: 144.10 Ha
- **Number of zones**: 94 no.s
- **Number of Sections**: 84 no.s
- **Area per Section**: 1.75 Ha (Approx.)
- **Name of village involved**:
  1. Dejun
  2. Rejun (Partial)

**Siphon – III**

- **RD 6780** (For Scheme 3, 4 & 5)
- **Total discharge required**: 96.70 lps
- **Sump Well at lift point**: 01 no.
  (For Scheme 3, 4 & 5)
- **Max. Capacity of Sump well**: 155.43 cum
  (For Scheme 3, 4 & 5)
- **Sump well at ponds**: 02 no.
- **Max. Capacity of Sump wells**: 37.44 cum

**Raising Main**

- **HDPE Pipe**

**Distribution Line**

- **PVC Pipe**

---

**Components of Automation System**

- **SCADA** (Supervisory Control and Data Acquisition)
- **PLC** (Programmable Logical Controller):
- **RTU** (Remote Terminal Unit)
- **Flow transmitter**
- **Pressure transmitter**
- **Level transmitter**
- **Solenoid Operated Hydraulic Valves with Orifice Plate for**
- **sump inlet**
- **Pressure Relief Valves at delivery header for bypass**
- **Solenoid operated hydraulic valve at sections**

![Layout plan for Scheme 5](image-url)
Solar System

**Information**
- Total pumping stations - 12
- Individual solar pump capacity 20 and 25 hp
- Total Solar pumps capacity - 990 hp
- Total solar module capacity - 1100 kWp
- Structure - single axis tracker and floating structure

**Features**
- Stand alone solar pumping without support of electricity
- PLC controlled pump operation
- Innovative design of common Solar DC bus
- Maximum and efficient utilization of solar power in morning and evening
- 175 hp solar pumping system for Rising Mains
- Floating structure for village pond

---

Pump Use, Location & distance schematic diagram

Note:
Station Name- P (lift No. Pump No.)
All distances are Azad distances
M- main pump
D- direct pump
S - Secondary pump
Example: - 1 M + 1 D means 1 main pump + 1 direct pump
100-2S means - lift no 1 pump no 8 has 2 not secondary pump
Schematics of Solar Pumping System

As per requirement capacity and no. of pv array, solar pump inverter and pump capacity will change.

Solar pump for Micro Irrigation with fixed Structure

Head – 45 m

Irrigation or field Sections having low head/ discharge can be irrigated during this period and time of irrigation shall be increased to meet total water requirement of these sections.

Water meters are recommended for exact discharge measurement from solar pump.

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FARMERS SUPPORT

- Establishment of Farmers Training Centre in Project Area.
- Training of farmers at P.F.D.C. PAU Ludhiana
- Training of farmers at Regional Research & Training Centre, Dr. Y.S. Parmar University for Horticulture & Forestry, Jachh(H.P.)
- On farm field trainings.
- Distribution of good quality seed/seedling/plants.
- Establishment of Nursery cum Demo Plot to support the farmers.
- Introduction of New Crops
- Buy back arrangements with Unnati Co-operative Society, Talwara.
# PRODUCTION ACTIVITIES

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Crop</th>
<th>Yield Before</th>
<th>Yield after Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wheat</td>
<td>5-7 Qt./Acre</td>
<td>16-18 Qt./Acre</td>
</tr>
<tr>
<td>2</td>
<td>Mustard</td>
<td>2-3 Qt./Acre</td>
<td>6-8 Qt./Acre</td>
</tr>
<tr>
<td>3</td>
<td>Khari Onion</td>
<td>NA</td>
<td>7-8 Qt./Kanal (1/8 Acre)</td>
</tr>
<tr>
<td>4</td>
<td>Rabi Onion</td>
<td>NA</td>
<td>7-8 Qt./Kanal</td>
</tr>
<tr>
<td>5</td>
<td>Green Chilli</td>
<td>NA</td>
<td>2 Qt./Kanal</td>
</tr>
<tr>
<td>6</td>
<td>Brinjle</td>
<td>NA</td>
<td>2 Qt./Kanal</td>
</tr>
<tr>
<td>7</td>
<td>Turmeric</td>
<td>NA</td>
<td>7-8 Qt./Kanal</td>
</tr>
<tr>
<td>8</td>
<td>Ginger</td>
<td>NA</td>
<td>7-8 Qt./Kanal</td>
</tr>
<tr>
<td>9</td>
<td>Okra</td>
<td>NA</td>
<td>3-4 Kg/Kanal</td>
</tr>
<tr>
<td>10</td>
<td>Mary Gold (Flower)</td>
<td>NA</td>
<td>7-8 Qt./Kanal</td>
</tr>
<tr>
<td>11</td>
<td>Berseem (Fodder)</td>
<td>NA</td>
<td>2.5 Qt./Kanal</td>
</tr>
</tbody>
</table>

Other crops introduced (Production yet to be known):
Tomato, bitter gourd, bottle gourd, cucumber, garlic, papaya, mango (amrapali), sugarcane, peach, pulses.

# PROJECT SUSTAINABILITY

- Water User Associations are formed line wise -18 Nos (looks after operations of individual line)
- Shall be federated in Core Water User Association at project level shall be responsible for
- Seven Years Operation & Maintenance shall be done by M/s Jain Irrigation Systems Ltd.
- User Charges to create Corpus
- Power buy back arrangements for surplus power
F.3 Challenges and Opportunities for Field Level Coordination and Implementation of SPIS in Haryana, India, Mr. Neeraj Sharma, Executive Engineer, CAD Division, Kurukshetra, Haryana

Haryana State

- Total area of the state is 44 Lac hectares.
- About 39 Lac hectares area is Arable i.e. 88.63% of total area.
- Agriculture sector is the major user of water-85%.
- Major Crops Rice, Wheat, Cotton, Bajra.....
- Net sown area 35.22 Lac hectare.
- Net irrigated area 29.73 lac hectare (84.4%)
- Intensity of irrigation by Canals is nearly 72% for Rabi & Khairf.
Availability of Water in Haryana

<table>
<thead>
<tr>
<th>River</th>
<th>Share in MAF</th>
<th>Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yamuna</td>
<td>4.645</td>
<td>MOU between partner states (1994)</td>
</tr>
<tr>
<td>Sutlej</td>
<td>4.40</td>
<td>Bhakar Nangal Agreement (1959)</td>
</tr>
<tr>
<td>Ravi-Beas</td>
<td>3.50</td>
<td>As per GOI Notification dated 24/3/1976 &amp; 1981 agreement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total Share: 12.545</td>
</tr>
<tr>
<td></td>
<td>Available ground water: 5.87</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total water available: 18.415</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Present demand: 33</td>
<td></td>
</tr>
</tbody>
</table>

**Canal System**

- Haryana has an extensive irrigation network.
- 1461 channels with length of about 14085 km.
- 247 pump houses commissioned for supplying water to higher areas.
- Bhakhra Canal system – 13.14 lac CCA in the northwestern and western parts of Haryana.
- Yamuna Canal system – 7.44 Lac ha CAA in the northeastern, southern and central parts of Haryana.
- Lift canals – 8.49 Lac ha CCA in the south-western parts of Haryana.
- Gurgaon Canal system – 0.61 Lac ha CAA in south-eastern parts of Haryana.
## Conveyance Losses in Canal Networks & Field Water Courses

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Canal Type</th>
<th>% Loss of Water</th>
<th>Cumulative Loss %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main canals</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Branch canals</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>Distributaries</td>
<td>10</td>
<td>24</td>
</tr>
<tr>
<td>4a</td>
<td>Lined Water Course</td>
<td>20-25*</td>
<td>44 - 49</td>
</tr>
<tr>
<td>4b</td>
<td>Unlined Water Course</td>
<td>40*</td>
<td>64</td>
</tr>
</tbody>
</table>

*Lands lost to canal infrastructure is typically 2-5% of irrigated command area created.* *(The World Bank)*

*Source:* Guideline for computing the water use efficiency of the irrigation projects, Central Water Commission (CWC)

## Water Use Efficiency of Different Systems

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Models</th>
<th>Conveyance Efficiency</th>
<th>Application Efficiency of On Farm Systems</th>
<th>Project Overall Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Unlined Water Course</td>
<td>Lined Water Course</td>
<td>100% Pipe Network</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Efficiency Of The System</td>
<td>60%</td>
<td>75%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Models</th>
<th>Efficiency Of The System</th>
<th>Conveyance Efficiency</th>
<th>Application Efficiency of On Farm Systems</th>
<th>Project Overall Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Unlined Water Course + Flow Irrigation</td>
<td>60%</td>
<td>75%</td>
<td>95%</td>
<td>60%</td>
</tr>
<tr>
<td>2</td>
<td>Lined Water Course + Flow Irrigation</td>
<td>75%</td>
<td>60%</td>
<td>95%</td>
<td>60%</td>
</tr>
<tr>
<td>3</td>
<td>Pipe Network + Flow Irrigation</td>
<td>95%</td>
<td>60%</td>
<td>95%</td>
<td>60%</td>
</tr>
<tr>
<td>4</td>
<td>Pipe Network + Sprinkler</td>
<td>95%</td>
<td>75%</td>
<td>95%</td>
<td>90%</td>
</tr>
<tr>
<td>5</td>
<td>Pipe Network + Drip</td>
<td>95%</td>
<td>90%</td>
<td>95%</td>
<td>90%</td>
</tr>
</tbody>
</table>
Har Khet Ko Pani (Water to Every Field) under PMKSY

- Haryana has taken up a Pilot Project on “Installation of Community Based Solar/Grid Powered Micro Irrigation Infrastructure in Various Canal Commands of Haryana” at a cost of 24.65 Crore from its own resources.
- This is the first of its kind irrigation project in India which has a combination of solar and grid power with bidirectional metering for pressurised surface irrigation ready for drip/sprinkler and will be operated & maintained by the WUAs after its O&m.
- This concept is the true realization of the ultimate goal of ‘Har Khet Ko Pani’ (हर खेत को पानी) as it has the potential to provide irrigation water to all the fields within its command. The first of the 14 sites under this project was inaugurated by Hon’ble Chief Minister, Haryana on 30.07.2017.

More Initiatives of Haryana

- Project for providing micro irrigation infrastructure to use that treated water of Sewage Treatment Plants.
- Project for providing micro irrigation infrastructure in overflowing village ponds.
Necessity of MI

- Conventional method of water conveyance and application by flooding is highly inefficient.
- Growing water crisis and the need to produce more food per drop of water indicate requirement of large scale adoption of water efficient Micro-irrigation technology instead of the conventional flood irrigation.

Objectives of the project

- To improve water use efficiency of the canal outlet supply by an integrated approach in the field water management:
  - Supply management - By increasing the available supply by reduction in conveyance losses.
  - Demand Management – By increasing the field application efficiency with the use of water efficient Sprinkler & Drip Irrigation technology.
- Improving crop productivity.
- Saving farm land and appreciating land use
Design Criteria

- Crop Water Requirement: 2mm/day (Modified Panman Method), minimum velocity 0.6m/sec.
- Frictional Losses (Hazen Williams equation), minimum diameter of pipe 110mm.
- Other losses:
  - 1 hp = 1100 wp
  - Pump Capacity = total head required to maintain 2.5kg/cm² at remote hydrant.
  - HP of pump set = QxH / 75e.
    - Q = Discharge (in LPS)
    - H = head (in meter)
    - e = Pumping efficiency
- One pump for every 50 hectares.
- One hydrant for four acres or lesser area as per holding of farmer.
- Operational time 14 hours.
- Tank Capacity = Availability of design discharge of an canal outlet in 24 hours.
  - 2 no. hydrant will work at same time.
  - 3 to 4 acres will be irrigated (2MM crop water requirement which is sufficient water for the crops) in 30 to 50 minutes, depending upon the type of crop.
  - 25 to 28 hydrants will work in 14 hours and irrigated 75 to 100 acres.
Implementation OF micro irrigation in paddy crop by cada, at (Dera Fateh Singh) Village Gumthala Garhu, Pehowa District Kurukshetra.
use of water in flood irrigation and in Micro Irrigation system

<table>
<thead>
<tr>
<th>Description</th>
<th>Micro Irrigation</th>
<th>Flood Irrigation</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of cultivation</td>
<td>10415</td>
<td>9880</td>
<td>-</td>
</tr>
<tr>
<td>Yield</td>
<td>2.78 ton/acre</td>
<td>2.49 ton/acre</td>
<td>0.29 ton/acre (11.65%)</td>
</tr>
<tr>
<td>Water Savings</td>
<td>24000000/1.94 AF</td>
<td>41400000/3.35 AF</td>
<td>42.02%</td>
</tr>
<tr>
<td>Net Income</td>
<td>33787</td>
<td>29711</td>
<td>4076</td>
</tr>
</tbody>
</table>

Yield with different irrigation methods

[127]
### Result as below

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Irrigation Method</th>
<th>Transplanting Method</th>
<th>Total water used for one acre (Litre)</th>
<th>Water in Acre-Foot (AF)</th>
<th>water saved in comparison to Flood irrigation Method</th>
<th>% of water saved in comparison to Flood irrigation Method</th>
<th>Yield Per Acre (Quintal)</th>
<th>Increase in yield (Quintal)</th>
<th>% increased in yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Flood</td>
<td>DSR</td>
<td>9835105</td>
<td>7.56</td>
<td>-</td>
<td>-</td>
<td>23.25</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manual</td>
<td>8194127</td>
<td>6.64</td>
<td>-</td>
<td>-</td>
<td>26.13</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Drip</td>
<td>DSR</td>
<td>3830335</td>
<td>3.10</td>
<td>5504770</td>
<td>58.97</td>
<td>25.67</td>
<td>2.42</td>
<td>10.41</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mechanical</td>
<td>3895465</td>
<td>3.13</td>
<td>4038457</td>
<td>51.07</td>
<td>24.27</td>
<td>4.47</td>
<td>22.58</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manual</td>
<td>3390593</td>
<td>2.75</td>
<td>4794534</td>
<td>58.51</td>
<td>27.83</td>
<td>1.7</td>
<td>6.51</td>
</tr>
<tr>
<td>3</td>
<td>Sprinkler</td>
<td>DSR</td>
<td>4593460</td>
<td>3.72</td>
<td>4741645</td>
<td>50.79</td>
<td>24.01</td>
<td>0.76</td>
<td>3.27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mechanical</td>
<td>4387769</td>
<td>3.51</td>
<td>3570154</td>
<td>45.15</td>
<td>25.54</td>
<td>5.74</td>
<td>28.99</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manual</td>
<td>3613080</td>
<td>2.93</td>
<td>4581048</td>
<td>55.91</td>
<td>26.37</td>
<td>0.24</td>
<td>0.92</td>
</tr>
<tr>
<td>4</td>
<td>Flood/ Regular</td>
<td>Regular method used by farmer Shri Karanjeet Singh Chatha</td>
<td>11120000</td>
<td>9.01</td>
<td>-</td>
<td>-</td>
<td>27.8</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Conclusion of new experiment on 9 acres

- It is disseminated from the table that there is appreciable amount of saving of water which is more than 50% and increase in yield in all types of transplanting & irrigation methods.
- 2. (i) In case of Shri Karanjeet Singh Chatha for regular flood irrigation method the amount of water used is 11120000 litre or 9AF which is more than our manual flood irrigation method (8194127 litre or 6.64AF water used). It means farmer is using 26.31% more water even in traditional flood irrigation.
- (ii) In case of farmer the yield is 27.8 quintal/acre which is less than our manually transplanted drip irrigated paddy i.e. 27.83 quintal/acre where the use of water is very less with saving of 69% water.
- Hence it is concluded that Micro Irrigation Technology will be very much helpful in saving of water by maintaining the yield which the farmers are getting presently even in water guzzling paddy crop.
Pictures of Paddy experiment

Benefits of Micro Irrigation Project

- Increase in irrigated area
- Tail end farmers have also started getting irrigation water
- Increase in yield & reduction in weed growth
- Day time scheduling
- Reduce the use of tube-wells besides saving of electricity
- Useful in of low irrigation intensity area and where ground water is saline
- Reduce leaching of water with high nitrogen concentrations
- Suitable for uneven land and saving of land
- Diversification of crop
Challenges and lessons learnt

- Scattered schemes
- Assured supply of canal water (community tube–wells)
- Integrated Micro Irrigation System
- PPP Model
- Subsidy pattern
- Direct Benefit Transfer

Recommendations

- An efficient and optimum water utilisation
- Conveyance efficiency
- Integrated Micro Irrigation System
- Transparent robust mechanism for PPP
- Agriculture extension services
- Water User Association
- Financial Resources for the Project & Subsidy
F.4 Financing Solar Irrigation, the India Story by Ms. Stuti Sharma, World Bank
Where do these projects lie on the spectrum of private sector participation? The path to financial sustainability

Overview of Solar Irrigation in India
The solar irrigation market in India
How the market is structured

- Over 400 acres: Solar lift cum micro irrigation
- Individual farmer solar agri-pumps
- Mobile solar vans: Rental models

Most typical capacities:
- Over 800 HP
- 5-10 HP
- Sub 1 HP

Emerging market

The solar irrigation market in India
What factors impact the shift to solar?

- Villages with limited grid connectivity / reliable power
- Diesel access and commodity price
- Improved CBA for governments: power buy-back
Key concerns with solar pumping

REGULATORY
Ability to control / monitor consumption is limited

RESOURCES
Rampant groundwater abstraction

Economics & implementation channels
1. How implementation is financed currently

- Grants and subsidies
  - Federal programs: MNRE off-grid, KUSUM, PMKSY etc.
  - States: Subsidy components and schemes

- OEM & integrators
  - Both local & international players
  - Large no. of integrators, fewer manufacturers

- Cash and carry
  - Pay as you go type models
  - Provision of services

- Down payment
  - Outright acquisition of asset
  - Awareness, access and cash flow availability

2. Limited private finance; but promising starts

- NBFCs
- Foundations / NGOs
- Rural Banks
- Commercial Banks
- Financial Institutions
3 Solar lift cum micro irrigation project

Private investment

IRRIGATION Technology Info. & capacity Value addition. Marketing

Public investment: Hybrid Annuity Model

Viability scenarios
- Full O&M recovery: With sale of power
- Partial O&M recovery: ISF fees

EIRR factors
- Increases in yields: 27 to 50%
- 153% increase in cropping intensity
- Resultant increase in farmer income and savings
- 5% of total cropped area diversified

4 Pay as you go model
Challenging the myth that farmers don’t pay

B2C solutions:
Challenging the myth that farmers don’t pay

Ex. Claro Energy: Providing irrigation as a service
- RFID enabled prepaid cards for irrigation
- Energy meters for electricity supply
- Recharge mechanism transparent and customer friendly