Indo-German Energy Programme

SOLAR WATER PUMPING FOR IRRIGATION

OPPORTUNITIES IN BIHAR, INDIA

Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

INFINITE OPPORTUNITIES | GERMANY + INDIA

Ministry of New and Renewable Energy
Government of India

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Disclaimer

The present document is an attempt to put together relevant information to stimulate thinking and raise basic knowledge on the status and potentials for solar water pumps in India in general and Bihar in particular. Note that this document is neither exhaustive nor complete on the topic of solar water pumps. The information has been compiled from reliable documented and published references/ resources, as cited in the publication. Mention of any company, association or product in this document is for informational purposes only and does not constitute a recommendation of any sort by GIZ.

EXECUTIVE SUMMARY

Scarcity of electricity coupled with the increasing unreliability of monsoon rains and prevalentcostly diesel pumping systems pose an economic risk to small and marginal farmers. A complex set of factors including global warming, competitive land use and lack of basic infrastructure is creating new challenges for India's vast agrarian population. The ever increasing mismatch between demand and supply of energy, and electricity in particular, is posing challenges especially to farmers in remote areas. This coupled with the increasing unreliability of monsoon rains is forcing farmers to look at alternate fuels such as diesel for running irrigation pump sets. Currently, India uses 12 million grid-based (electric) and 9 million diesel irrigation pump sets (C-STEP 2010). However, the high operational cost of diesel pump sets forces farmers to practice deficit irrigation of crops, considerably reducing their yield and income.

Solar water pumping systems constitute a cost-effective alternative to irrigation pump sets that run on grid electricity or diesel. Solar Photovoltaic (SPV) sets constitute an environment-friendly and low-maintenance possibility for pumping irrigation water. Studies estimate India's potential for Solar PV water pumping for irrigation to be 9 to 70 million solar PV pump sets, corresponding to at least 255 billion ltr/year of diesel savings (HWWI 2005). However, solar PV water pumping systems remain a rather unknown technical option, especially in the agricultural sector. They have not yet been seriously considered in agricultural planning in the country, nor has the private sector taken an active lead.

The Indo-German Energy Programme (see chapter 1.2, Box 1) is supporting the development of favourable market conditions for solar irrigation systems in Bihar. Regulatory and market related framework conditions need to be improved to incentivise private investors to provide access to clean energy in rural areas. This study is a first step. It provides an overview of the current usage of solar water pumps for irrigation, along with opportunities and challenges for their usage in India and Bihar in particular. The findings provide strategic inputs to the Indo-German Energy Programme for the preparation of project activities to support the solar water pumping sector in Bihar.

Water gushing from a solar water pump in Bihar
Picture Courtesy: Nilanjan Ghose

Solar pumping technology has been continuously improved since the early 1980s. There are three main solar water pumping configurations used in India:

1 **Brushless Direct Current (DC) pump:** Highest efficiency, low maintenance, but higher cost compared to other pumping technologies.

2 **DC positive displacement pump:** Less efficient than brushless motors but performs well under low power conditions, and can achieve high lift.

3 **AC centrifugal pump:** Not as efficient as DC pumps, yet, reasonably priced, easily available/ serviced and deep reaching, making it currently the most preferred choice among users and system integrators.

The first signs of a developing solar PV water pumping market in India were seen in 1993-94 with the Ministry of New and Renewable Energy (MNRE) promoting solar PV water pumping systems for irrigation and drinking water. Capital subsidies, low cost financing and 100% depreciation in the first year were meant to incentivise farmers to purchase the Solar PV systems at a concessional rate, as low as 10% of the actual equipment cost (e.g. farmers in Punjab availed 1,850 solar pump systems for agricultural use under the programme). However, with the Income Tax Department redefining the parameters for claiming accelerated depreciation, the financial incentives became redundant. The MNRE Programme was unable to achieve its objective. As of March 2012, 7,771 solar PV water pumping systems, compared to the targeted 50,000, had been installed.

In 2010, solar water pumping became part of the off-grid and decentralised component of the Jawaharlal Nehru National Solar Mission (JNNSM). Besides the capital subsidies from MNRE (30% subsidy) and state governments (equivalent to 56-60%), there are no other specific financing schemes for supporting farmers' acquisition of solar PV water pumping systems.

The strong government promotion/ subsidies have limited the initiative of the private sector in solar PV pumping systems to being linked with the government programmes rather than developing the market by themselves according to the customer needs. Yet, there has been a recent emergence of new private sector players. Claro Energy Pvt. Ltd. and Atom Solar Systems are two of these that are promoting solar PV water pumping systems for irrigation in Bihar.

Solar PV water pumping for irrigation is a suitable option for Bihar, which has ample availability of surface and ground water (in particular in Northern Bihar), suitable agricultural practices, and sufficient solar radiation conducive for solar PV water pumping. Thus, solar PV water pumping constitutes an option to address the principal

1,800 Wp surface pump in Landra village, Punjab.
Picture Courtesy: Thomas Pullenkav

constraint of electricity for irrigation to ensure agricultural growth to its full potential. Yet, the small operational landholdings (2 ha and less) and leasing of land also poses challenges to the deployment of solar pumping for irrigation.

Tapping Bihar's huge solar PV water pumping potential remains limited by regulatory, market and technology related challenges, keeping most private actors in a watch and wait position. The WISE report *"Renewable Energy Potential Assessment and Renewable Energy Action Plan for Bihar"* (2011) has estimated the potential for solar PV water pumping to be 2,665 MWp upto 2022. This assessment is based on net irrigated area in the state and an assumption that a solar array of 0.6 kWp is required to power a SPV pump that can irrigate 1 ha of land. HWWI in their study of the *"CDM Potential of SPV Pumps in India (2005)"* has estimated a potential of 11 million solar PV pumping systems in Bihar. Key challenges and potential solutions for tapping this solar water pumping potential are:

Market Related Barriers

Current Barriers/Obstacles	Potential Corrective Measures
High Upfront Cost	Smart Subsidies/Innovative Finance
Lack of Finance Mechanisms	Innovative Consumer/Business Finance Mechanisms
Low Awareness Among Consumers and Other Relevant Stakeholders	Awareness Campaigns
Lack of Maintenance and Support	Localised Service Infrastructure
Lack of Market Intelligence and Information	Provision of Adequate Resources/Market Data
Danger of Theft	Portable/Community Owned Systems and Insurance

Regulatory Issues

Current Barriers/Obstacles	Potential Corrective Measures
Restricted Financial Engineering	Innovative Policies and Financial Engineering
Maze of Government Departments	"Single-Window" Approach
Lack of Market-Oriented Policies	Policies providing a Level Playing Field with diesel pumps
Concealed Tenancy and Small Landholdings	Tenancy Reform, Leasing Mechanisms & Group Investments

Technology Related Barriers

Current Barriers/Obstacles	Potential Corrective Measures
Lack of Standardisation and Quality Assurance	Standardised Products that Cater to Local Needs
Lack of local Manufacturers	Promotion of Local Manufacturing

Even though solar PV is a competitive option in the face of diesel (64.2% of the cost of diesel pumps over ten years), its adoption is contingent to the ease of access to subsidies and/or mechanisms that reduce the initial investment costs to the level of conventional pumps. This needs to go hand in hand with awareness campaigns on SPV pumps and supportive government policies. The study concludes, that policy makers, the private sector and other facilitating stakeholders like GIZ and financial institutes need to come together and address the regulatory, market- and technology related barriers to large-scale deployment of the solar PV water pumping systems in Bihar.

Group of farmers using a solar water pump in Gonkura village of Nalanda District, Bihar
Picture Courtesy: Nilanjan Ghose

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GLOSSARY

AC	Alternating Current
AVG/M	Average per Month
Bcm	Billion cubic metres
BIS	Bureau of Indian Standards
BLDC	Brush Less Direct Current
BMZ	Federal Ministry for Economic Cooperation and Development, Government of the Federal Republic of Germany.
BREDA	Bihar Renewable Energy Development Agency
BSSY	Bihar Saurkranti Sinchai Yojana
CDM	Clean Development Mechanism
CEA	Central Electricity Authority
CREDA	Chhattisgarh State Renewable Energy Development Agency
C-STEP	Centre for Study of Science, Technology and Policy
DC	Direct Current
DG	Diesel Generator
FI	Financial Institutions
GI	Galvanised Iron
GIZ / GIZ GmbH	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
Ha	Hectare
HAREDA	Haryana Renewable Energy development Agency
HDPE	High Density Polyethylene
HOMER	Hybrid Optimization Model for Electric Renewables
Hort.	Horticulture / Horticultural
HP	Horse Power
Hr(s)	Hour(s)
HWWI	Hamburgisches Welt Wirtschaftsinstitut
IEC	International Electro technical Commission
IGEN- RE	Indo-German Energy Programme - Renewable Energy Component
IHD	Institute for Human Development
IREDA	Indian Renewable Energy Development Agency
JISL	Jain Irrigation Systems Limited

JLG	Joint Liability Group
JNNSM	Jawaharlal Nehru National Solar Mission
KREDL	Karnataka Renewable Energy Development Limited
kVA	Kilo Volt-Ampere
kWh	Kilo Watt Hour
kWh/m2	Kilo Watt hour per square metre
kWp	Kilo Watt Peak or Peak Kilo Watt
MFI	Micro-finance institution
Mm	Millimetre
MPPT	Maximum Power Point Tracker
Mtrs.	Metres
MNRE	Ministry of New and Renewable Energy, Government of India
MW	Mega Watt
MWp	Mega Watt Peak or Mega Peak Watt
MWRD	Minor Water Resources Department, Govt. of Bihar
NABARD	National Bank for Agriculture and Rural Development
NASA	National Aeronautical and Space Administration
NBFC	Non-Banking Finance Companies
NEDCAP	New and Renewable Energy Development Corporation of Andhra Pradesh
NGO	Non-Government Organisation
NPK	Nitrogen, Phosphorus and Potassium
NREL	National Renewable Energy Laboratory
p.a.	Per Annum
PEDA	Punjab Energy Development Agency
PV	Photovoltaic
R&D	Research and Development
RE	Renewable Energy
RFID	Radio Frequency Identification
RKVY	Rashtriya Krishi Vikas Yojana
SELF	Solar Electric Light Fund
SHG	Self Help Group
SME	Small and Medium Enterprise
SNAs	State Nodal Agency(ies)

SPV	Solar Photovoltaic
STC	Standard Test Conditions
Sq.m	Square meter
TDH	Total Dynamic Head
TEDA	Tamil Nadu Energy Development Agency
UPNEDA	Uttar Pradesh New and Renewable Energy Development Agency
US$	United States Dollar
V	Volt
VFD	Variable Frequency Drive
WISE	World Institute for Sustainable Energy
Wp	Watt Peak or Peak Watt

1. INTRODUCTION

1.1. Backdrop

A complex set of factors including global warming, competitive land use and lack of basic infrastructure is creating new challenges for the vast agrarian population in India. The ever increasing mismatch between the demand and supply of energy in general and electricity in particular, is posing challenges to farmers located in remote areas. The scarcity of electricity coupled with the increasing unreliability of monsoon rains is forcing farmers to look at alternate 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 damaging of crop, thereby, reducing yields and income. Hence, using conventional diesel powered pumping systems poses an economic risk to the farmers.

1,800 Wp surface pump in Landra village, Punjab
Picture Courtesy: Thomas Pullenkav

Environment-friendly, low-maintenance, solar photovoltaic (SPV) pumping systems provide new possibilities for pumping irrigation water. However, they constitute a rather unknown technical option, especially in the agricultural sector. Thus far they have not yet been seriously considered in agricultural planning in the country.

1.2. Objective

Given this backdrop, the Indo-German Energy Programme- Renewable Energy component (IGEN-RE) (for further information see *Box 1*) decided to assess the technical maturity and the market potential for solar powered water pumping for irrigation. This report provides an overview of the current usage of solar water pumps for irrigation, along with opportunities and challenges for their usage in India in general and Bihar in particular. The findings constitute strategic inputs to GIZ and MNRE, jointly preparing a pilot project to support the solar water pumping sector in Bihar.

Box 1: Indo-German Energy Programme, Renewable Energy Component (IGEN-RE)

The Renewable Energy Component of the Indo-German Energy Programme (IGEN- RE) is a bilateral technical co-operation measure between the Federal Ministry for Economic Cooperation and Development (BMZ), Government of the Federal Republic of Germany; and the Ministry of New and Renewable Energy (MNRE), Government of India. IGEN-RE aims at improving the conditions for private investment in providing access to clean energy in rural areas from renewable energy sources. BMZ has commissioned the Deutsche GesellschaftfürInternationaleZusammenarbeit GmbH (GIZ), a federal enterprise based in Eschborn, operating in more than 130 countries worldwide, with the implementation of the programme.

2. METHODOLOGY

The study was conducted in five stages depicted below.

Stage 1

Secondary research and data collection	Review of existing literature on solar water pumping in India, as well as, telephone and one-to-one interviews with stakeholders from the solar pumping sector.

Stage 2

Expert interviews to validate data	One to one interviews / expert consultations with the private sector (manufacturers, system integrators); Govt. officials of Bihar and other states' nodal agencies/ Individuals using SPV pumps for irrigation/ drinking water and/or implementing SVP programmes; and the civil society promoting RE and/or agriculture.

Stage 3

Development of a draft status paper	The paper illustrates the potential for solar water pumps in India in general, and Bihar in particular.

Stage 4

Stakeholder workshop, Patna 9/11/12	Presentation and validation of the study's findings on solar water pumping in Bihar. The stakeholders' feedback on the potential and challenges in rolling out solar water pumps in Bihar was collected.

Stag 5

Development of a final status paper	The findings of the study and the feedback from the stakeholder's consultation programme assists in finalizing the paper on the potentials for solar water pumps in India in general, and Bihar in particular.

Atom Solar Pump installed in Bihar
Picture Courtesy: Greenpeace

2.1. Interview Structure

The unstructured interviews contained open questions of general nature. This permitted the key informants to freely articulate their views on the challenges and potential for using solar PV water pumps for irrigation in Bihar. The questions/check list used to guide the one-to-one interviews and expert consultation is attached in *Annexure 3.*

2.2. Scope and Limitation

Since the key objective of the study was to provide strategic inputs for the preparation of a pilot project on solar PV water pumping for irrigation in Bihar, only a general overview of the present potential for solar PV water pumps for irrigation in India was undertaken. The study was done with a greater focus on the potential and challenges in the case of Bihar. Further, focus of the study is primarily on the use of solar PV water pumping systems for irrigation. Although consideration has been given to the potential use of solar PV water pumps in other areas (i.e. fisheries, animal husbandry, drinking water, etc.), this study does not comment on or reviews the application in those sectors. This report also does not comment on or reviews the use of other renewable energy options for water pumping (i.e. windmills and dual-fuel engines using biogas or producer gas).

3. SOLAR PV WATER PUMPING - TECHNOLOGY OVERVIEW

A Solar PV water pumping systems is essentially an electric pump running on electricity generated by a solar photovoltaic array.

Components of a solar PV water pumping system:

1 **Solar PV array:** The Solar PV array is a set of photovoltaic modules connected in series and possibly strings of modules connected in parallel.

2 **Controller:** The Controller is an electronic device which matches the PV power to the motor and regulates the operation of the pump according to the input from the solar PV array.

3 **Pump Set:** Pump sets generally comprise of the motor, which drives the operation and the actual pump which moves the water under pressure.

Water pumping motors are "alternating current' (AC) or 'direct current' (DC):

1 **AC Motors:** AC Motors require inverters to convert DC to AC. Solar pumping systems use special electronically controlled variable-frequency inverters, which optimises matching between the panel and the pump.

2 **DC Motor:** The DC Motors with permanent magnet are generally more efficient. DC Motors may be with or without carbon brushes. DC motors with carbon brushes need to be replaced after approximately every 2 years. Brushless designs require electronic commutation. Brushless DC Motors are becoming popular in the solar water pumps.

Main solar water pump technologies:

1 **Centrifugal Pump:** Centrifugal pump uses high-speed rotation to suck in water through the middle of the pump. Most AC pumps use such a centrifugal impeller.

2 **Positive Displacement Pump:** The positive displacement pump is currently being used in many solar water pumps. The pump transfers water into a chamber and then forces it out using a piston or helical screw.

Positive displacement pumps generally pump slower than centrifugal pumps but have good performance under low power conditions and achieve high lift. However, when operating at low power, the performance of the centrifugal pump drops dramatically.

DC Surface Pump
Picture Courtesy:
www.madhurisolarpune.com

Centrifugal Pump
Picture Courtesy:
www.enggcyclopedia.com

DC Drive with Brushless DC Motor
Picture Courtesy:
Jain Irrigation Systems Limited

Types of Pump

1. **Surface Pump:** Placed besides the water source (lake, well, etc.).
2. **Submersible Pump:** Placed in the water source.
3. **Floating pump:** Placed on top of the water.

Surface pumps are less expensive than submersible pumps but they are not well suited for suction and can only draw water from about 6.5 vertical meters. Yet they are excellent for pushing water over long distances.

More details on technical specifications of MNRE for solar PV water pumps and the sector's technological development can be found in *Annexure 2* and *Chapter 5.6.*

Solar pump with tracking system by Claro Energy Pvt Ltd.
Picture Courtesy: Claro Energy Pvt Ltd.

Box 2: Summary of Common PV Pumping Configurations in India

Solar PV water pumping in India commonly uses three pumping configurations:

1. DC drive powering a brushless DC motor.
2. AC drive powering a centrifugal pump unit.
3. DC drive with brushed positive displacement pumps.

Each of the above technologies has specific features that make it suitable for particular applications. The efficiency of positive displacement pumps decreases with the shallowness of the borehole, while DC drive powering a brushless DC (BLDC) motor has the highest efficiency and least requirement for maintenance even under low power conditions. Yet, AC drives powering a centrifugal pump unit have a deep reach, are easily available, reasonably priced and can be serviced by the existing trained manpower. This explains why AC drives are the preferred choice among users and system integrators.

4. POTENTIAL FOR SOLAR IRRIGATION IN INDIA

The potential of solar PV water pumping in India is huge and the market has clearly started to develop. There are reportedly more than 12 million electric and 9 million diesel irrigation pump sets in operation. The potential has been estimated by different previous studies as below.

Centre for Study of Science, Technology and Policy (C-STEP). ***"Harnessing Solar Energy – Options for India"*** **(2010)** estimates that 9 million diesel water pumping sets are in use in India. If 50% of these diesel pumps were replaced with solar PV pump sets, diesel consumption could be reduced to the tune of about 225 billion litres/year.

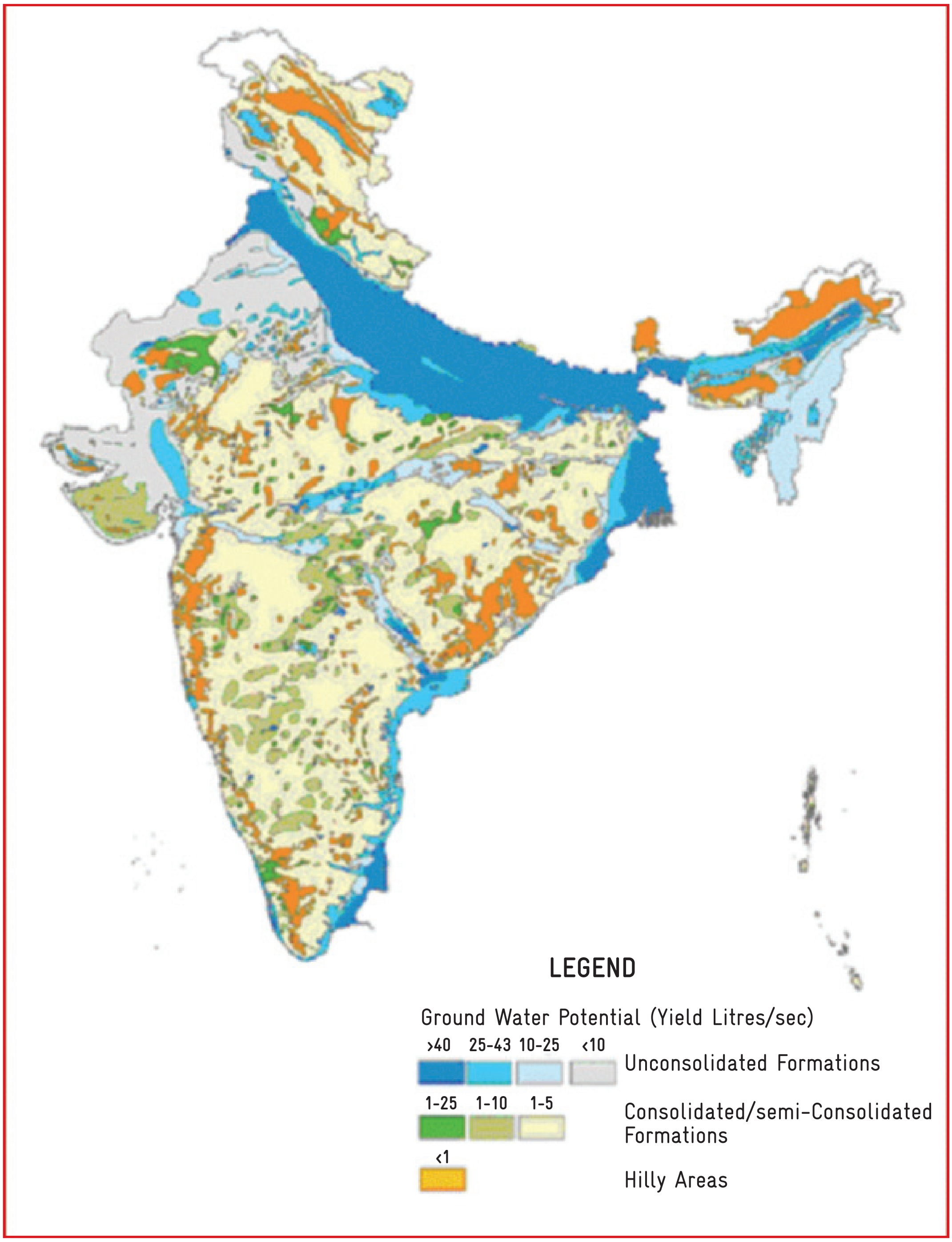
As per the study conducted by **HWWI**, titled ***"CDM Potential of SPV Pumps in India" (2005)*** about 70 million solar PV pumps can be installed by 2020. Of these, 14 million are likely to be installed in Uttar Pradesh and 11 million in Bihar.

The **KPMG** report titled ***"The Rising Sun" (2011)*** estimates solar-powered agriculture pump sets to be approximately 16,200 MW by 2017-22. However, the potentials as mentioned above are likely to be realized depending upon the extent of government support and market conditions.

4.1. Geographical Areas Suited for Solar Irrigation

The ground water situation in India is highly complicated due to diverse geological formations (lithological and chronological variations, complex tectonic framework, climatological dissimilarities and various hydrochemical conditions.)

Map 1: Hydrological Map of India



Picture Courtesy: Groundwater Year Book 2011-12

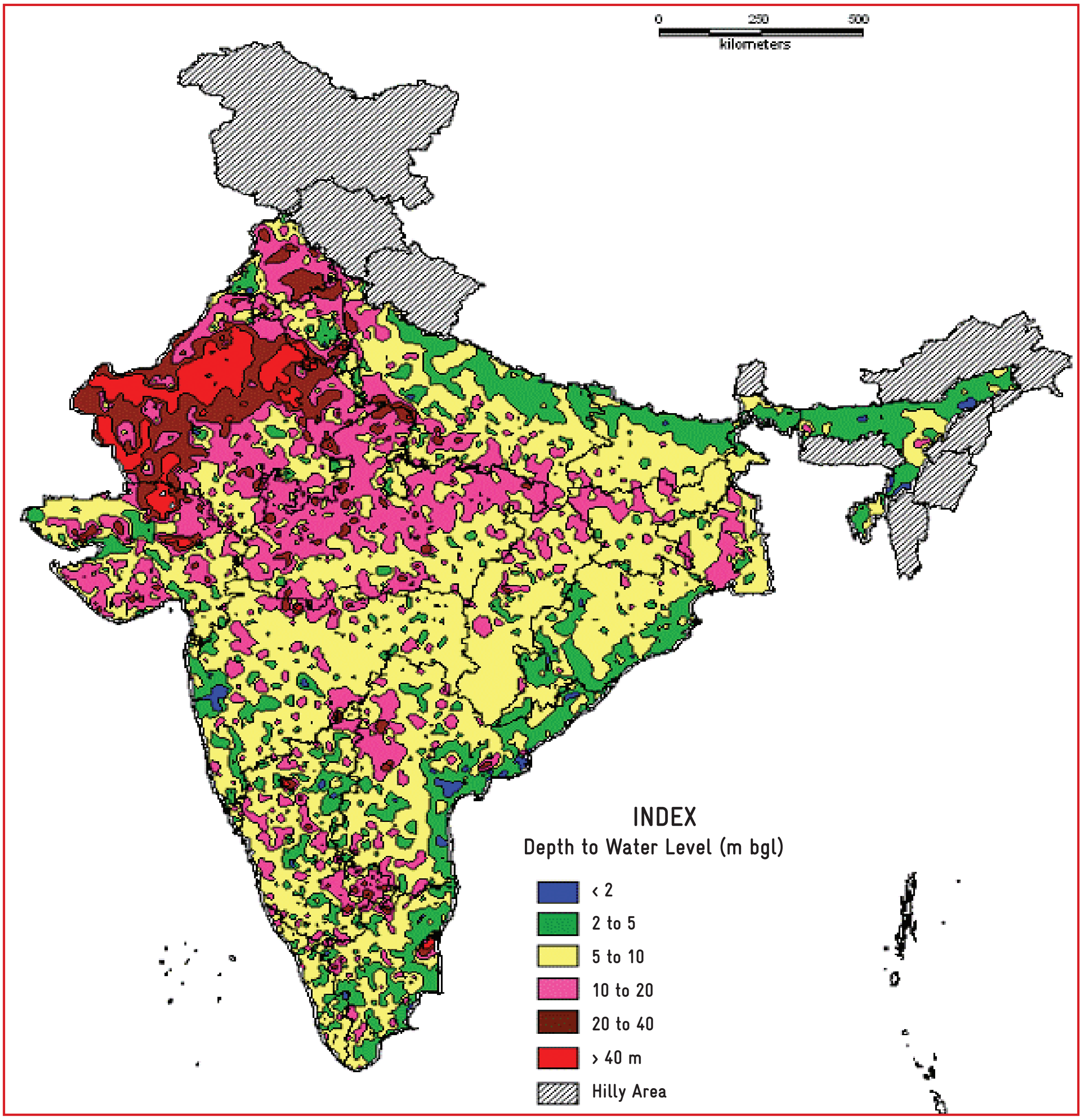
The geographical distribution of hydrogeological units along with their ground water potential is given in *Table 1*.

Table 1: Ground Water Aquifer System in India

System	Area/Coverage	Ground water Potential
Unconsolidated formations - Alluvial	Indo-Gangetic & Brahmaputra Plains	Enormous reserves down to 600m depth. High rainfall ensures recharge.
Unconsolidated formations - Alluvial	Coastal Areas	Reasonably extensive aquifers but risk of saline water intrusion.
Unconsolidated formations - Alluvial	Parts of Desert Area: Gujarat & Rajasthan	Scanty rainfall. Negligible recharge. Salinity hazards. Ground Water availability at great depths.
Consolidated/ semi-consolidated formations (sedimentaries, basalts and crystalline rocks)	Peninsular Areas	Availability depends on secondary porosity developed due to weathering, fracturing etc. Scope for ground water availability at shallow depths (20-40 m) in some areas and deeper depths (100-200 m) in other areas. Varying yields.
Hilly	Hilly States	Low storage capacity due to quick runoff.

Generally, the depth to water level varies from 2 to 5 meter below ground level (mbgl) throughout the year in the Sub-Himalayan area, North of river Ganges; the North Eastern part of the country in the Brahmaputra valley; and Eastern coast of Odisha, Andhra Pradesh and Tamil Nadu state (GoI 2012). The annual water level fluctuation in these areas was also less than 2 to 5 meters below ground level (mbgl) during the analysed time period.

Map 2: Depth to Water Level Map (Pre Monsoon - 2011)



Picture Courtesy: Groundwater Year Book 2011-12

Box 3: Summary of the Potential for Solar Water Pumping for Irrigation in India

The data shows that the Indo-Gangetic and Brahmaputra plains have the maximum potential for the use of ground water for irrigation. The depth to water level is 2-5 meters below ground water level (mgbl) and fast recharge is ensured, making this area/region ideal for the use of solar PV water pumping systems.

5. STATUS OF SOLAR WATER PUMPING IN INDIA

5.1. Previous Experiences

1993-2010: MNRE – Promotion of solar PV water pumping systems for irrigation and drinking water.

The first signs of a market for solar PV water pumping in India became visible in 1993-94. MNRE (then called the Ministry for Non-Conventional Energy Sources or MNES) felt that the solar PV water pumping was a technically proven product and could be suitable for replacing diesel powered pumps at unelectrified locations, provided the ecosystem for the delivery of the systems was strengthened. Consequently, MNRE initiated a programme for the deployment of 50,000 solar PV water pumping systems for irrigation and drinking water across the country. Key aspects of the programme were:

- **Objective:** Commercialization of solar PV water pumping systems over a five year period across 29 states by strengthening the production base and creating the required institutional infrastructure for marketing and after sales support.
- **Assumption:** The programme was based on the assumption that the economies of scale and technology up-gradation would drive down the costs of SPV water pumping systems, making the system economically viable.
- **Implementing Agencies:** Indian Renewable Energy Development Agency (IREDA) and State Nodal Agencies (SNAs).
- **Intermediaries:** Mainly non-banking finance companies (NBFCs), which procured the system from the manufacturers and channelized the financing, capital and interest subsidies from IREDA to the end users.
- **Financial Assistance:** MNRE subsidised the capital cost of the solar pump and the interest costs. Besides channelizing this financial assistance to the end user, IREDA provided financing for the unsubsidised portion of the system costs from its own funds. In case of SNAs channelizing MNRE's financial assistance, the IREDA financing was not available to the end user. From 1993 -2000 the programme was implemented mainly by IREDA, using the NBFC intermediaries. The latter took advantage of the availability of capital subsidies, low cost financing and 100% depreciation in Year 1, in order to provide the end users the system at a concessional rate. However, after 2000 the programme was mainly implemented through the SNAs. The SNAs were able to bring in a component of subsidy from the respective state Governments. The subsidies component received through SNAs was reduced after the initial stage from Rs. 135/Wp to Rs. 100/Wp.

Financial assistance available under the programme is summarized below in *Table 2:*

Table 2: Financial Assistance for the MNRE Solar PV Water Pumping Programme

Financial Year(s)	Subsidy Applicable	Other facilities
1993-94 to 2000-01	Rs. 170/Wp, subject to a maximum of 70% of the system cost.	Soft loan for unsubsidized system cost from IREDA at an interest of 2.5% p.a. with a 10 year repayment period and 1 year moratorium.
2001-02 to 2002-03	Rs. 110/Wp, subject to a maximum of Rs. 0.25 million or 90% of the system cost.	Soft loan at an interest of 5% p.a.
2003-04 to 2004-05*	Rs. 75/Wp, subject to a maximum of Rs. 0.2 million.	Soft loan at an interest of 5% p.a.
2005-06*	Rs. 30/Wp, subject to a maximum of Rs. 0.05million	Soft loan at an interest of 5% p.a.

* Applicable only for community drinking water projects

- **Private Sector Vendors:** The programme worked with nine empanelled vendors, namely TATA Power Solar Systems Ltd., Bharat Heavy Electricals Ltd., Central Electronics Ltd., Renewable Energy Systems Ltd., Sairam Solar Systems, Udhaya Semiconductors Ltd., Polyene General Industries Pvt. Ltd., Kirloskar Brothers Ltd., Siemens Ltd.
- **Programme Results:** In the first year, the programme was considered as a demonstration programme with a target of 1,000 Solar PV pumping systems. However, less than 500 solar PV water pumping systems were installed during the first year of the programme. From 2004 the programme was modified: it became applicable only for community drinking water projects. Solar PV water pumping for irrigation was no longer applicable under the programme. As of March 2012, 7,771 solar PV water pumping systems had been installed against the targeted 50,000 systems.

Box 4: The Case of Punjab

The Punjab Energy Development Agency (PEDA) facilitated the installation of 1,850 solar pumps in Punjab for agricultural purposes. They used a mix of MNRE subsidies, soft loans from IREDA, state Government subsidy support and the 100% depreciation benefit through lease financing of the asset. This facilitated that farmers could avail of the system at 10% of the actual equipment cost.

State Wise Results: Under the MNRE Programme, many SNAs installed solar water pumping systems for agricultural purposes as indicated in *Table 3.*

Table 3: PV pumps installed by different SNAs under the PV Water Pumping Programme

State	Implementing Agency	Pumps installed
Punjab	Punjab Energy Development Agency (PEDA)	1,850
Karnataka	Karnataka Renewable Energy Development Ltd. (KREDL)	700
Tamil Nadu	Tamil Nadu Energy Development Agency (TEDA)	285
Chhattisgarh	Chhattisgarh State Renewable Energy Development Agency (CREDA)	130
Andhra Pradesh	New and Renewable Energy Development Corporation of Andhra Pradesh (NEDCAP)	70

Solar Water Pumps Installed at Nalanda District of Bihar
Picture Courtesy: Claro Energy Pvt. Ltd.

5.2. Ongoing Programmes

2010-2017: Jawaharlal Nehru National Solar Mission (JNNSM)

With the launch of the Jawaharlal Nehru National Solar Mission (JNNSM) in 2010, the solar water pumping programme of the MNRE was clubbed with the off-grid and decentralised component of the JNNSM. Key aspects of the programme are as follows:

- **Objective:** Commercialization of solar PV water pumping systems.
- **Financial Support:** Solar PV water pumping systems are eligible for a financial support from MNRE through a capital subsidy of 30%. Currently, the financial assistance available is 30% subsidy subject to a benchmark price of Rs. 190 per peak watt (Wp).
- **Private Sector Vendors:** The farmers are free to procure systems from any of the empanelled manufacturers that agreed to supply the pumps as per the rate approved by the programme. These include M/s. Topsun Energy Ltd.; M/s Waaree Energies Pvt. Ltd.; M/s. Jain Irrigation Systems Ltd.; and M/s. Rajasthan Electronics and Instruments Ltd.
- **Results:** Several states have taken up initiatives to implement solar PV Water pumping programmes using the financial assistance available under JNNSM and funds from the respective state Government budgets. The states of Gujarat, Chhattisgarh, Uttar Pradesh, Maharashtra, Tamil Nadu and Bihar have programmes in their pipelines.

Box 5: The Case of Rajasthan - 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% of the system cost. The Rajasthan Renewable Energy Corporation is providing a 30% subsidy from MNRE under JNNSM while the State Government under RKVY is providing the remaining 56% subsidy

Under the 2011-12 programme, 1,600 number of 2,200 Wp and 3,000 Wpsolar PV water pumping systems are proposed.

Box 6: The case of Bihar- Bihar Saurkranti Sinchai Yojana (BSSY):

The Bihar Renewable Energy Development Agency (BREDA) is proposing to install 560 numbers of 1,800 Wp solar PV Water pumping systems in 10 blocks of 5 districts of Bihar during the current financial year, using budgetary allocations of FY 2011-12 and 2012-13. Beneficiaries are expected to pay 10% of the system cost, with the balance 90% being provided through JNNSM and by the state government

Diesel powered pump in rural Bihar
Picture Courtesy: Thomas Pullenkav

5.3. Activities of the Private Sector

Since most of the activities in the area of solar PV water pumping systems for irrigation and drinking water have revolved around the MNRE and other Government funded/subsidised programmes, most of the activities in this area by the private sector have also been linked to these programmes. The strong government promotion/subsidies have limited the initiative of the private sector in the area to being linked with the government programmes rather than developing the market by themselves.

Box 7: Key players:

1. TATA Power Solar Systems Ltd. (formerly TATA BP Solar India Ltd.)
2. Topsun Energy Ltd. (also operates under the name of Vimal Electronics)
3. Waaree Energies Pvt. Ltd.
4. Jain Irrigation Systems Ltd.
5. Kirloskar Brothers Ltd.
6. VRG Energy India Pvt. Ltd.
7. Udhaya Semiconductors Ltd.
8. Photon Energy Systems Ltd.
9. Premier Solar Systems Pvt. Ltd.
10. Titan Energy Systems Ltd.
11. ICOMM Tele Ltd.
12. Sungrace Energy Solutions Pvt. Ltd.
13. Claro Energy Pvt. Ltd.
14. Atom Solar Systems
15. Rajasthan Electronics and Instruments Ltd.
16. Bharat Heavy Electricals Ltd.
17. Central Electronics Ltd.

5.4. Finance Mechanisms

The initial years of the MNRE solar PV water pumping programme saw the systems being financed through a complex scheme of subsidies, low cost financing and tax benefits by utilising the 100% accelerated depreciation available for renewable energy technologies in the first year, to provide the system to the end users at an affordable rate. However, this financial engineering became redundant in the late nineties when the accelerated depreciation was reduced from 100% to 80% and the Income Tax Department redefined the parameters for claiming the accelerated depreciation.

Thereafter, all programmes for solar PV water pumping have been financed mainly through capital subsidies from MNRE and the State Governments. Besides these subsidies, there are currently no specific financing schemes for supporting the acquisition of solar PV water pumping systems by the farmers.

5.5. Activities of Agricultural Universities

The academic community has so far played only a small role in developing solar PV water pumping in India. While there have been some studies conducted by agricultural universities into the benefits of solar water pumping for irrigation, in general, the academia has not played a major role in the development of the technology or its application in agriculture.

5.6. Technology Development

Since most of the activities in the area of solar PV water pumping systems for irrigation and drinking water have revolved around the MNRE and other Government funded/ subsidised programmes, the specifications of the system, including capacity of the pump and the size of the solar array were determined by the programme design. Hence, there has not been much innovation in this field by the private sector.

Technical specifications under MNRE

During the early days of solar PV water pumping in India, the 900 Wp solar array with the 1HP centrifugal DC mono-block surface pump was the only approved specification. Later, falling water tables and the need for larger quantities of water for irrigation, as the pumps were mainly acquired by large farmers who had large landholdings, led to the addition of larger capacity surface pumps, submersible pumps and large solar PV arrays. During the second half of the MNRE solar PV water pumping programme, the 1,800 Wp solar PV array with the 2HP centrifugal DC mono-block surface pump and submersible pumps of 1 HP and 2 HP motors with 1200 Wp and 1800 Wp solar PV array respectively were added to the list of approved pumps. Under the JNNSM support for solar PV water pumping systems, MNRE has broadly specified that the capacity of solar PV array should be in the range of 200 Wp to 5,000 Wp and the capacity of the motor pump set should be 1-5 HP. MNRE specifications also allow the use of submersible pumps based on the technical need of the particular case. The table 4 below provides the indicative technical specifications provided by MNRE (please see *Annexure 2* for full details).

Table 4: MNRE Indicative Technical Specifications for Surface Pumps and Submersible Pumps

Description	Model 1	Model 2	Model 3	Model 4
Centrifugal DC monoblock				
Solar PV Array	900 Wp	1,800 Wp	2,700 Wp	n/a
Motor Capacity	1 HP	2 HP	3 HP	n/a
Max. TDH*	10 mtrs.	15 mtrs.	25 mtrs.	n/a
Submersible motor with electronic controller				
Solar PV Array	1,200 Wp	1,800 Wp	3,000 Wp	4,800 Wp
Motor Capacity	1 HP	1 HP / 2 HP	3 HP	4.6 HP
Max. TDH*	70 mtrs.	70 mtrs.	120 mtrs.	160 mtrs.

**Max. TDH – Maximum Total Dynamic Head*

Solar pumping technology has been continuously improving since the early 1980s. The typical solar energy to hydraulic (pumped water) energy efficiency was only 2% in 1980. Yet efficiency increased for PV arrays from 6-8% to 12-14% and for motor pump sets from 25% to 70% by using positive displacement pumps with high pump and power conditioning). Diaphragm pumps have an efficiency of around 45% and centrifugal pumps of 20%.

5.7. Challenges and Barriers for Growth of Solar PV Water Pumping in India

Many factors hamper the scaling up of the Indian Solar PV water pumping market. Barriers can be market and technology related as well as of regulatory nature:

Market Related

- Higher upfront capital cost for the farmers as against to the low capital cost of conventional pumps.
- Lack of awareness about the technology and the products among consumers and other stakeholders (e.g. financial institutions).
- Lack of relevant infrastructure support, i.e. networks for market promotion and infrastructure for after-sales service.
- Danger of theft of solar modules/pumps.

Regulatory

- Lack of market oriented policies.
- Free/highly subsidised electric power supply for agriculture.
- Restrictions for innovative finance, i.e. accelerated depreciation, carbon financing etc.

Technology Related

- The 'one-size-fits-all' approach discourages research and development (R&D). Most manufacturers fail to meet the specific needs of the end user (the farmer) as their customers are the SNAs and Government programmes.
- Lack of standardisation and quality assurance as most system integration efforts are led by programme specifications rather than the end user's needs.

6. POTENTIAL FOR SOLAR IRRIGATION IN BIHAR

The utilization potential of solar PV water pumping for irrigation in Bihar depends on several factors such as availability of surface and ground water; resource availability i.e. solar radiation; agricultural practices and alternatives for powering of pump sets.

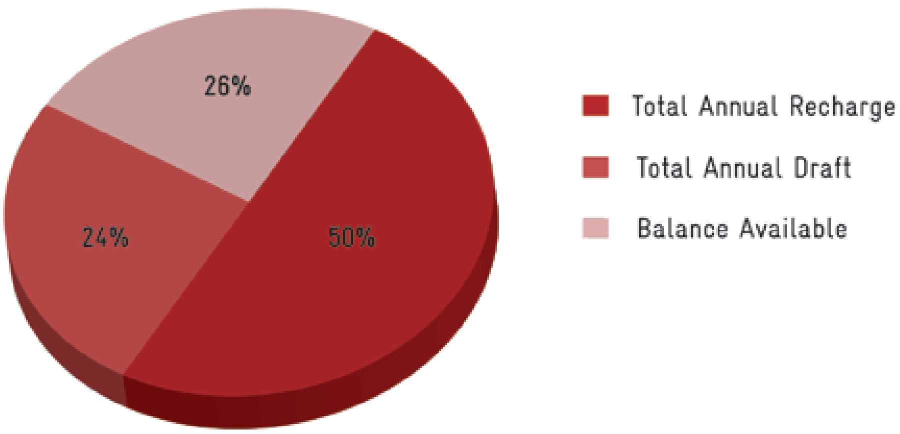
6.1. Surface and Ground Water Levels in Bihar

Analysing the ground water situation in Bihar (GoI 2011) shows that in most parts of Bihar the depth to water level is 2-5 meters and ground water potential is greater than 40 litres/second. The annual replenishable ground water resource is 28.62 billion cubic metres (bcm) while the annual ground water draft, including the natural discharge during the non-monsoon season, is only 13.77 bcm. Thus, 14.85 bcm of ground water is available for irrigation and other uses.

An analysis of 269 wells across Bihar during the 2011 pre-monsoon period revealed that the depth to water level ranged between 1.16-15 metres, with more than 92% of the wells having water levels between 1-10 metres (GoI 2011).

A similar analysis of 192 wells across Bihar between the 2010 and 2011 pre-monsoon period also revealed that in 57.81% of the wells the annual fluctuation in water levels resulted in a fall of water levels. Yet, in the remaining 42.19% of wells, the annual fluctuation resulted in a rise of water levels. The fall of the water level ranged between 0.01 to 4.57 meters.

Figure 1: Bihar's Groundwater Status



Source: Ground water year book 2011-12

Hydrogeologically, the main alluvial tract covers entire north Bihar and a sizeable area in south of the Ganga River. These alluvial formations constitute prolific aquifers where the tube well can yield between 1.2 to 2.5 lakh litres per hour. Even in the hard rock areas of South Bihar, bore wells located near the lineaments/fractures can yield between 10,000 to 50,000 litres per hour.

Box 8: Summary of the Potential for SPV Water Pumping for Irrigation in Bihar

Bihar, as a part of the Indo-Gangetic plains, is an area with extremely good potential for tapping surface and ground water sources. Thus, prima facie the availability of surface and ground water in Bihar clearly points to the suitability of the use of solar PV water pumping systems.

6.2. Solar Radiation in Bihar

The state of Bihar has about 280 - 300 sunny days in a year. As per MNRE data, the state receives an annual average solar radiation of 5.04–5.42 kWh/m2 (IMD 2009).

This is further corroborated by data from the NASA website and IMD, whose figures of annual average solar radiation is 4.88–5.27 kWh/m2 and 4.79 respectively. Thus, it can be concluded that the average annual global solar radiation in the state comes in the range of 4.79–5.42 kWh/ m2.

Data from the NASA website also shows that at an equator pointed tilt angle of 25°, the average annual radiation (22-year average) is 6.33 kWh/ m2. The monthly averages are:

Table 5: Annual Radiation (AVG/M)

Month	Radiation	Month	Radiation
Jan	6.34	Jul	4.81
Feb	7.42	Aug	5.24
Mar	7.73	Sep	5.29
Apr	7.43	Oct	6.52
May	6.79	Nov	6.54
Jun	5.78	Dec	6.16

Box 9: Summary of Solar Radiation in Bihar

Analysis of the monthly average radiation at the 25° tilt angle shows that the average monthly radiation in Bihar is sufficient for the development of solar PV power projects. Further, solar PV water pumping systems require energy mainly during the non-monsoon months. Since the periods of low solar radiation in Bihar coincide with the availability of rainfall (June to September), the availability of sufficient solar radiation to energise the solar PV pumping system is ensured.

6.3. Agriculture in Bihar

Bihar is primarily an agriculture based state with 88.7% of the population living in the rural areas (GoB 2008). The agricultural land holding pattern is characterized by an overwhelming majority of marginal, small and semi-medium farms as shown in *Table 6.* Almost 60% of all operational land holdings are less than 2 hectares.

Table 6: Landholding in Bihar

Category of Farmers	No. of Holdings	Operational Holdings (Heotares)
Marginal (0-1Ha)	86,45,932 (82.9%)	27,87,789 (40.8%)
Small (1-2Ha)	10,05,650 (9.6%)	13,00,667 (19.0%)
Semi-medium (2-4Ha)	5,90,970 (5.7%)	15,82,279 (23.1%)
Medium (4-10Ha)	1,78,295 (1.7%)	9,75,355 (14.3%)

Source: Govt. of Bihar, Economic Survey, 2006-07, March 2007, p.13

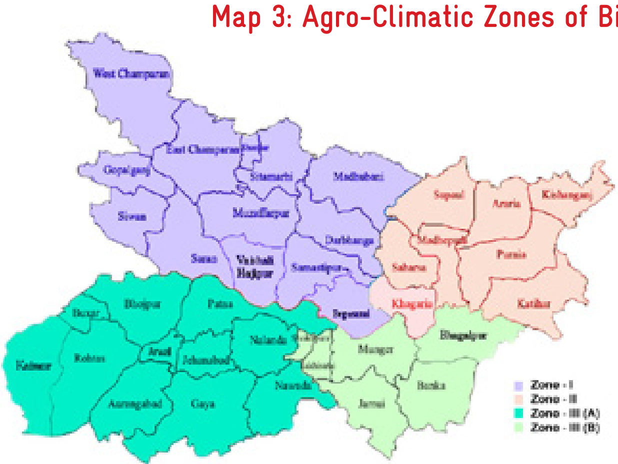
The agriculture operations in Bihar are divided into two main crop seasons – the Kharif and the Rabi. The Kharif (monsoon) season is from July to October. The Rabi (winter) season is from October to March. The main Kharif crops are paddy, maize, pulses and oilseeds. The main Rabi crops are wheat, maize, pulses, oilseeds and vegetables. With irrigation, a third crop of paddy, maize or vegetables can also be grown between March and June (summer crop locally called garma).

While the Kharif crop is mainly rain fed, the Rabi and the summer crop require irrigation. Currently, irrigation is mostly dependent on diesel operated tube wells. The high operational cost of diesel engine pump sets forces farmers to practice deficit irrigation of crops. As a result, the yields of all crops are much lower than their potential.

Agriculture in the State is prone to natural calamity. Bihar's Northern districts are affected by recurrent floods. The Southern districts are prone to lack of rainfall. Almost 41% of the geographical area of the State is flood prone. On the other hand, 40% of the geographical area of South Bihar is drought prone.

Agro-climatically, the state has three distinct zones. The details of the soil condition and rainfall in these zones have been given in Table 7.The soil in the state is fertile with rich soil cover, mainly alluvial with medium nitrogen, phosphorus and potassium (NPK) content. The state is also very rich in water resources with adequate rainfall all over, a network of perennial and semi-perennial rivers, and a sufficient supply of ground water at low depth.

Map 3: Agro-Climatic Zones of Bihar



Source: http://krishi.bih.nic.in

Table 7: Agriculture in Bihar

Agro-Climatic Zone	Zone –I North West Alluvial Plains	Zone - II North East Alluvial Plains	Zone - III South Bihar Alluvial Plains
Districts	Bettiah, Siwan, Motihari, Seohar, Gopalganj, Vaishali, Muzaffarpur, Samastipur, Madhubani, Dar-bhanga, West & East Champaran	Purnea, Katihar, Saharsa, Madhepura, Araria, Kishanganj, Supaul, Khagaria, Begusarai	Patna, Gaya, Buxar, Kaimur, Jehanabad, Nawada, Munger, Bhagalpur Jamui, Nalanda, Rohtas, Bhojpur, Banka, Aurangabad, Lakhisarai, Shekhpura
Area Cultivated (Ha)	Net: 2,281,000 Gross: 3,260,000	Net: 1,147,000 Gross: 1,677,000	Net: 241,000 Gross: 3,408,000
Average Rainfall (mm)	1234.7	1382.2	1102.1
Soil and Topography	Medium acidic, heavy textured, sandy loam to clayed, flood prone. (Large area remains under water called Chaur, Maun& Tal lands)	Light to medium textured, slightly acidic, sandy to silty loam (large area comprise of Tal and Diara lands)	Old alluvium to sandy loam.
Main Crops	Rice, Wheat, Maize, Arhar Hort. Crops: Litchi, Mango, Makhana, Water, Chestnut.	Maize, Mustard, Jute, Sugarcane Hort. Crops: Mango, Bel, Banana, Papaya, Cucurbit, Chilly, Turmeric, Potato	Rice, Gram, Wheat Hort. Crops: Mango, Guava, Banana, Bael, Jackfruit, Onion, Potato, Chillies, Marigold

Source:http://krishi.bih.nic.in

The issue of tenancy and antiquated land records has been a continuous bane on agriculture in Bihar. Though the reported incidence of tenancy as per the secondary sources in the state is very low, the actual incidences compound to be close to 40%. According to a survey conducted by the Institute for Human Development (IHD) in 1999-2000, about 36% of all rural households and about half of the cultivating households leased in land and about one-fourth of the cultivated land was tenanted land. An overwhelmingly large percentage of the landless and marginal-small landholders leased land.

6.4. Requirement of Water for Major Crops of Bihar

Paddy, wheat, maize and sugarcane are some of the major crops cultivated in Bihar. The growing period and the water requirement varies from crop to crop. The requirement of irrigation and the total growing period for the major crops in Bihar are mentioned below:

Table 8: Irrigation Requirement and Growing Period for Major Crops of Bihar

Crop	Growing Period	Water requirement	No. of Irrigations currently done
Paddy	130-150 days	900–1,500mm	6-7
Wheat	120 -150 days	450-650mm	4-6
Maize	100 days	500-800mm	3-6
Sugarcane	365 - 500 days	1500-2,500mm	8-12

Source: Discussions with agriculturists and ICAR Scientists

6.5. Availability of Power

The power availability scenario in Bihar in the year 2000 (post bifurcation) became significantly critical, as several power generation plants fell within the newly created State of Jharkhand. Currently, Bihar's power system has a peak of about 1,500 MW under the constrained demand scenario, whereas, the availability is about 950 MW (GoB 2012). As per the Central Electricity Authority's Anticipated Power Supply Position in the Country during 2012-13, Bihar will have an energy deficit of 20.2% energy deficit and a peak deficit of 31% i.e. 774MW during 2012-13. The situation leads to wide-scale rationing of power to all categories of consumers. The current power availability barely covers 50% of the villages with only 16.4% of households in the state having access to electricity as per the 2011 census. Of the current demand, approximately 32.5% of the power within the state is utilised for irrigation.

6.6. Existing Stakeholders in the Solar PV Water Pumping Sector

There has been very limited activity in the solar PV water pumping sector in Bihar. The few solar PV pumping systems that were installed under the Solar PV Water Pumping Programme of MNRE, were installed by suppliers like TATA Power Solar India Ltd. (formerly known as TATA BP Solar India Ltd.). Recently, in 2011, a company called Claro Energy Private Ltd. (Claro) has set up operations in Bihar in this sector. Claro Energy has installed around 70 solar PV water pumping systems, with 34 systems being installed in collaboration with the Minor Water Resources Department as replacement for the DG sets that are currently being used to power irrigation pump sets.

Another recent development in the field of solar PV water pumping in Bihar has been the installation of three demonstration solar PV water pumping systems in Bihar by Greenpeace, the environmental NGO. These solar pumps are manufactured by Atom Solar Systems have been installed by Greenpeace with support from the Indian Grameen Services. The demonstrations were done by Greenpeace to prove that solar PV water pumping systems can provide a cost-effective alternative to diesel/ electricity based irrigation pump sets.

In addition to Claro Energy, Atom Solar and TATA Power Solar Systems Limited, other private sector players active in the sector include SELCO, Solar Light Private Ltd and Dudwa Power Industries, Patna who reportedly are interested in developing a product line around solar PV water pumping. Others like Gautam Polymers, Kirti Solar from Kolkata, Minda New Gen Tech Ltd. of the Minda Group and the Jain Irrigation Systems Ltd. are companies that have adopted a watch and wait approach and could become potentially large players in the solar PV water pumping market in Bihar. More details about the activities of Claro Energy Private Ltd., Atom Solar Systems and Jain Irrigation Systems Ltd. are mentioned in *Annexure 6.*

6.7. Potential for Solar PV Water Pumping in Bihar

Solar PV water pumping for irrigation is a suitable option for Bihar: The ample availability of surface and ground water in Bihar (even with ground water levels in North Bihar are at a much higher level than that in the South Bihar), the land holding pattern and agricultural practices, coupled with the availability of sufficient solar radiation are conducive for solar PV water pumping. Moreover, solar PV water pumping also constitutes an option to address the principal constraint of electricity for irrigation to ensure agricultural growth to its full potential.

Box 10: Bihar's estimated solar PV water pumping potential

The WISE report *"Renewable Energy Potential Assessment and Renewable Energy Action Plan for Bihar"* has estimated the potential for solar PV water pumping to be 2,665 MWp over the next 10 years i.e. upto 2021-22. This is assessment is based on net irrigated area in the state and an assumption that a solar array of 0.6 kWp is required to power a SPV pump that can irrigate 1 ha of land. HWWI in their study of the *CDM Potential of SPV Pumps in India* has estimated a potential of 11 million solar

Solar Pump combined with drip irrigation installed near Pune
Picture Courtesy: Atom Solar Systems

7. NEEDS ASSESSMENT

To implement a solar PV water pumping programme in Bihar, there are many barriers – regulatory, market- and technology related – that need to be overcome. The below section lists the key barriers identified in this study and provides potential solutions to the same as discussed and verified in the workshop conducted in Patna in November 2012.

7.1. Market Related Barriers and Potential Solutions

Current Barriers/Obstacles	Potential Corrective Measures
High Upfront Cost Solar PV is a competitive option in the face of increasing diesel prices Yet, it requires the farmers to incur a high upfront cost when compared to the much lower capital cost of conventional pumps. Moreover, diesel pumps are available on rent, reducing the investment cost even further.	**Subsidies/Innovative Finance** Solar PV water pumping systems' adoption is depending on the ease of access to subsidies and/or mechanisms to bring the costs of acquiring solar PV water pumps at par with the costs of conventional pumps. Subsidy should be based on the market price (not benchmark price), and the time lag between installation and release of subsidy should be minimised. MNRE should include solar PV water pumping systems along with other off-grid systems for which subsidies are offered through NABARD and the banking sector. **Leasing Mechanisms** Leasing out solar PV systems facilitates in developing a new revenue stream and is also suitable for small-scale agricultural practices.
Lack of Finance Mechanisms Lack of suitable finance mechanisms for end user and also for business finance.	**Innovative Consumer/ Business Finance** Need for a well-designed loan product at reasonable rates of interest and repayments linked to savings from diesel/ income from selling of crops; smart business finance for Small and Medium Enterprise (SMEs) to facilitate the entry of multiple players in this sector.
Low Awareness Among Consumers and Other Relevant Stakeholders Often farmers are not even aware about the existence of a solar powered option for irrigation or perceive them to be very expensive and hence, there is low demand for the solar water pumps.	**Awareness Campaigns** Inform farmers, financial institutions and other stakeholders about solar PV being a competitive option and its benefits vis-a-vis diesel powered irrigation pump sets.

Current Barriers/Obstacles	Potential Corrective Measures
Lack of Maintenance and Support Lack of support infrastructure and maintenance that would be required for the large-scale deployment of solar PV water pumping systems.	**Localised Service Infrastructure** Market promotion and improved local after-sales infrastructure (training of existing local pump technicians/sales outlets) to build confidence among farmers and financial institutions.
Lack of Market Intelligence and Information Private sector companies are often not aware about the market potentials for solar water pumps in Bihar. Currently all market intelligence is very generic and does not provide specific information about the demand and need of the market.	**Provision of Adequate Resources/ Market Data** Adequate resources and market intelligence data is required to motivate investment choices of the many 'watching and waiting' companies to actually invest in building the sales and service infrastructure in Bihar.
Danger of Theft Solar PV water pumping systems are installed outdoors, distant to the farmers' houses, making theft an issue.	**Portable/Community Owned Systems and Insurance** Portable and/or community owned systems as well as an insurance mechanism can facilitate mitigation of the risk.

A portable solar module
Picture Courtesy: Atom Solar

7.2. Regulatory Issues and Potential Solutions

Regulatory Issues

Current Barriers/Obstacles	Potential Corrective Measures
Restricted Financial Engineering Accelerated depreciation, carbon financing, and other fiscal benefits for renewable energy were offered to promote its deployment. However, many restrictions in this regard make the offerings redundant.	**Innovative Policies and Financial Engineering** Policies, regulations and procedures are required to help the private sector innovate financially and thereby, reduce costs.

Current Barriers/Obstacles	Potential Corrective Measures
Lack of Market Oriented Policies Bihar lacks an adequate policy and regulatory framework that encourages renewable energy application in general and solar PV water pumping in particular.	**Policies for a Level Playing Field** Policies, regulations and procedures are required to create a level playing field for solar PV water pumping vis-à-vis conventional irrigation systems (electricity/diesel powered pump sets).
Maze of Government Departments Lack of a 'single-window' approach for solar PV water pumping is one of the key challenges. While renewable energy is the domain of the energy department and the Bihar Renewable Energy Development Agency (BREDA), small scale irrigation is taken care of by the Minor Water Resources Department; agricultural extension work is handled by the Agriculture Department; cooperative banks come under the Cooperative Department. Hence there are different departments within the state government looking at the solar water pump from multiple angles.	**Single-Window' Approach** For solar PV water pumping to be promoted on a large-scale, a 'single window' led by a joint 'mission' is required. All the different ministries and departments need to have a unified approach to cover the different aspects of bringing the solar PV water pumping system to the farmer.
Concealed Tenancy and Small Landholdings Tenancy and small land holdings come in the way of efficient agricultural management. Tenancy laws in Bihar have either banned tenancy completely or have imposed such restrictive conditions that leasing out of the land was rendered virtually impossible. This has paved the way for concealed tenancy, where neither the landlord nor the tenant benefit. This insecurity does not allow long-term planning for land development and impedes small farmers from entering into contract farming agreements to build economies of scale.	**Tenancy Reform** Agricultural management including the deployment of solar PV water pumping systems will immensely benefit from tenancy reforms. **Leasing Mechanisms** Leasing out solar PV water pumping systems will allow tapping into the market even for a short period and small-scale agricultural practices. **Group Investments** Designing a water pumping model which can be owned by a women self-help-group (SHG) or a joint liability group (JLG) (which is recognized by the banks).

Pump installed under MNRE Solar Water Pumping Programme,DadriMajra Village, Punjab
Picture Courtesy: Thomas Pullenkav

7.3. Technology Related Barriers and Potential Solutions

Current Barriers/Obstacles	Potential Corrective Measures
Lack of Standardisation and Quality Assurance The current 'one size fits all' approach for solar PV water pumping systems for irrigation does not provide the right mix between customisation and standardisation required for large-scale deployment.	**Standardised Products that Cater to the Local Needs** Technology providers need to standardise products to minimize failures. Yet, they also need to offer different types and sizes to cater to the different market segments of farmers (surface and submersible pumps, etc.).
Lack of Manufacturers There is a lack of (Brushless Direct Current) BLDC solar pump manufacturers in the country. Presently all solar BLDC pumps used in the country are imported, which increases the cost of the pumps and making operation and maintenance a big challenge.	**Promotion of Local Manufacturing** To decrease cost and enhance post sales services, locally manufactured BLDC motors need to be promoted.

ANNEXURE 1: ECONOMICS OF SOLAR PV WATER PUMPING VIS-A-VIS DIESEL POWERED WATER PUMPING SYSTEMS

With the cost of solar PV falling steadily and the price of diesel soaring, solar PV water pumping has emerged as an economically feasible idea. The table below shows a very basic analysis of the economics of a 1 HP pump powered by a 2kVA DG set vis-a-vis an equivalent solar PV water pumping system (both capable of irrigating 1ha of land).

Table 9: 1 HP Pump Powered by a 2kVA DG Set vis-as-vis a Solar PV Water Pumping System

Assumptions	
Cost of 1 HP diesel powered pump set	Rs. 25,000.00
Cost of equivalent Solar PV water pump (unsubsidized)	Rs. 2,00,000.00
No. of operating hours per year (200 days x 5 hours/day)	1,000 hours
Cost of diesel/litre	Rs. 50.00
Fuel consumption/hr. Of 2kVA DG set	0.75 litres
Average increase in fuel prices per annum	5%
Maintenance cost/year for diesel pump	Rs. 2,000.00
Maintenance cost/year for solar pump	Rs. 500.00
Life cycle period (in years)	10 years
Discount rate	10%

Table 10: Comparison of 10 years of Life Cycle Cost

	Capital Cost	Net Present Maintenance Cost	Net Present Fuel Cost	Total
SPV Pump	200,000	3,072	Nil	203,072
Diesel Pump	25,000	12,289	278,993	316,282

When compared to diesel powered pumping systems, the cost of solar PV water pumping system without any subsidy works out to be 64.2% of the cost of the diesel pump, over a life cycle of ten years.

Based on the above assumptions, it is also seen that a farmer investing in a solar PV water pumping system can pay back the cost of the solar PV water pumping system from his savings on diesel in approximately 4 years' time. If the existing subsidy for solar PV water pumping systems under JNNSM is taken into account, this will come down to less than 3 years.

Various other studies have also shown the economic feasibility of solar PV water pumping systems over diesel pumps. C-STEP in their Harnessing Solar Energy – Options for India report have estimated the cost per kWh for solar PV water pumps and diesel powered pump sets as shown below:

Table 11: Cost Comparison at kWh level between Diesel and Solar PV Pump of 1 HP Rating

	Capital Cost	Operating Cost/ year	Net Present Cost	Cost/kWh
SPV Pump	259,702#	1,500	293,793	Rs. 8.60
Diesel Pump*	25,000	24,187	471.575	Rs. 13.90

** Diesel at Rs. 50/litre.*

#The price of the solar PV pump in this table is replicated from the CSTEP report. If the price of the Solar PV pump is assumed to be Rs. 200000, the cost at kWh becomes even lower.

As per the C-STEP report, when compared to diesel generators, solar PV pumps worked out to almost half the cost over a life cycle of twenty-five years, even at unsubsidised rates.

The Solar Electric Light Fund (SELF) in 2008 used the NREL HOMER (Hybrid Optimization Model for Electric Renewables) model to choose a pumping system designed to pump 5,000 gallons per day from a TDH of around 100 feet. It compared a solar array of 1,900 Wp against a 4 kW diesel generator. Both powered an equivalent pump of approximately 1 horsepower. SELF deduced from the simulation that in the worst case scenario for solar, the solar option is one fourth the net present cost of the diesel option.

The Desert Research Foundation of Namibia in a study commissioned by Bernt Lorentz GmbH & Co. KG in 2008 calculated that the actual all inclusive cost over 20 years is US$ 12,750 for a solar pump and US$ 73,750 for a diesel pump (at a diesel price of US$ 1.30/ltr). With the increased diesel prices and the steadily falling PV prices, this scenario is currently all the more favourable for solar PV water pumping for irrigation.

ANNEXURE 2: JNNSM TECHNICAL SPECIFICATIONS FOR SOLAR PV WATER PUMPING SYSTEMS

I. Definition

A solar photovoltaic (SPV)water pumping system consists of a PV array, a DC/AC surface mounted/ submersible/floating motor pump set, electronics, if any, interconnect cables and an "On-Off" switch. PV Array is mounted on a suitable structure with a provision of tracking. Electronics could include Maximum Power Point Tracker (MPPT), Inverter and Controls/Protections. Storage batteries will not constitute a part of the SPV Water Pumping System.

Components and parts used in the SPV water pumping system including the PV modules, pumps, metallic structures, cables, junction box, switch, etc. should conform to the BIS/ IEC/international specifications, wherever such specifications are available and applicable.

II. Performance Specifications and Requirements (Duty Cycle)

The Solar PV Water Pumping System should provide a minimum of 85 litres of water per watt peak of PV array used per day under average daily solar radiation conditions of 5.5 KWh/m2 on a horizontal surface, from a total head of 10 metres (suction head up to a maximum of 7 metres).

For Deep Well Pumps, the water discharge should be a minimum of 28 litres of water per watt peak of PV array capacity used per day from a total head of 30 metres. In case of High Head, Deep Well Pumps, the water discharge should be a minimum of 17 litres of water per watt peak of PV array capacity used per day from a total head of 50 metres.

Use of a tracking system to enhance the availability of solar radiation to lift desired quantity of water is desirable. It should be specified whether the minimum water output is achieved directly or through tracking of PV Array. The actual duration of pumping of water on a particular day and the quantity of water pumped could vary depending on the location, season, etc.

III. PV Array

The SPV water pumping system should be operated with a PV array capacity in the range of 200 Watts peak (Wp) to 5,000 Wp, measured under STC.

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 with following features should be used in the PV array for the SPV water pumping systems:

- Modules supplied with the SPV water pumping systems should have certificate as per IEC 61215 specifications or equivalent national/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 13% 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.
- Each PV module must use a RF identification tag (RFID), which must contain the following information:
  - i Name of the manufacturer of PV module
  - ii Model or type number
  - iii Serial number
  - iv Month and year of the manufacture
  - v I-V curve for the module
  - vi Peak wattage of the module at 16.4 volts
  - vii Im, Vm and FF for the module
  - viii Unique serial no. and model no. of the module

Until March 2013, the RFID can be inside or outside the module laminate but must be able to withstand harsh environmental conditions. However, from 1st April 2013 onwards, RFID shall be mandatorily placed inside the module laminate. A distinctive serial number starting with NSM will be engraved on the frame of the module or screen printed on the tedlar sheet of the module.

IV. Motor Pump-Set

Following types of motor pump sets could be used in the SPV water pumping systems:

- i Surface mounted DC motor pump-set
- ii Submersible DC motor pump set
- iii Submersible AC motor pump set
- iv Floating DC motor pump set
- v Any other motor pump set after approval from Test Centres of the Ministry.

The "Motor Pump Set" should have the following features:

- The mono block DC/AC centrifugal motor pump set has its driving unit and impeller mounted on a common shaft, thereby giving it a perfect alignment. The pump should be provided with specially developed mechanical seals, which ensure zero leakage.
- The motor is of 1-5 HP having spring loaded carbon brushes in case of DC motor pump sets. The suction and delivery head will depend on the site specific condition of the field.
- Submersible pumps could also be used according to the technical need of the particular case.
- The suction/delivery pipe (GI/HDPE), electric cables, floating assembly, civil work and other fittings required to install the system.
- The following details should be marked indelibly on the motor pump set
  - a Name of the manufacturer or distinctive logo
  - b Model number
  - c Serial number

V. Mounting Structures and Tracking System

To enhance the performance of SPV water pumping systems, it is desirable to use a tracking system. Manual, passive and auto tracking are permitted. The PV modules will be mounted on metallic structures of adequate strength and appropriate design, which can withstand load of modules and high wind velocities up to 150 km per hour. The support structure used in the pumping system will be hot dip galvanized iron (G.I).

Facilities to be provided in the structure:

- Seasonal tilt angle adjustment and
- Three times manual tracking in a day

The G.I. structures for mounting the solar panels could be designed as such that these can be manually/auto adjusted for optimal tilt throughout the year. A simple provision is to be provided so that the panel can be manually adjusted three times a day

(East-South-West) to face the sun optimally. This adjustment could be done in the early morning, noon time and afternoon to increase the total input solar radiation on the solar panel surface substantially. This provision helps the motor pump set to start early in the morning and function efficiently till late in the afternoon, thereby, increasing the total output of the pumping system.

The "Mounting Structure" should have the following features:

- The modules support structure shall be mild steel, hot dipped galvanized (120 micron) iron for holding the PV modules. The size of angle iron should not be less than 50x50x5 mm.
- Each panel frame structure shall be fabricated to be grouted on ground or roof on its legs. It will withstand severe cyclone/storm with speed of 150 km/hr.
- Each panel frame structure shall have provision to adjust its angle of inclination to the horizontal between 10 to 40 degrees with a step of 10 degree, so that the inclination can be adjusted at the specified tilt angle whenever required.
- Each panel frame shall be complete with a weatherproof junction box as per the relevant BIS specifications, where the module terminals shall be interconnected and output taken.
- All nuts and bolts should be of very good quality and should be corrosion resistant.
- The structure should be designed to allow easy replacement of any module.
- The array structure shall be so designed that it will occupy minimum space without sacrificing the output from the SPV panels.

VI. Electronics and Protections

- Use of Maximum Power Point Tracker (MPPT) is encouraged to optimally use the solar panel and maximize the water discharge.
- Inverter could be used, if required, to operate an AC Pump.
- Adequate protections should be incorporated against dry operation of motor pump set, lightning, hails and storms. Full protection against open circuit, accidental short circuit and reverse polarity should be provided.

VII. On/Off Switch

A good reliable switch suitable for DC/AC use is to be provided with the motor pump set with a sufficiently long cable to connection the PV array and the motor pump set.

VIII. O/M Manual

An Operation and Maintenance Manual, in English and the local language, should be provided with the solar PV pumping system. The following minimum details must be provided in the manual:

1. About photovoltaics
2. About solar pump
3. About PV module
4. About motor pump set
5. About tracking system
6. Clear instructions about mounting of PV module.
7. About electronics used in AC motor pump sets, if any
8. DO's and DONT's
9. Clear instructions on regular maintenance/ trouble shooting of the pumping system
10. Name and address of the person or centre to be contacted in case of failure or complaint

IX. Indicative Technical Specifications

General Information

This information is indicative only and the designer must satisfy himself regarding quantity and quality wise supply of Solar Modules/Panel, Solar Photovoltaic (SPV) Pump, and GI support structure as well as all aspects of commissioning of solar infrastructural facility. The scope of work includes supply, installation and commissioning of **Solar PV Water Pumps** on bore-well of minimum 4" diameter (to be provided by the user) at various sites as per the technical specification mentioned below. The whole system including submersible/surface pumps shall be **warranted for 5 years.** The PV Modules must be warranted for output wattage, which should not be less than 90% at the end of 10 years and 80% at the end of 25 years.

Table 12: Technical Specifications of Solar Shallow Well Pumping Systems

Description	Model-I	Model-II	Model-III
Solar PV array	900 Wp	1,800 Wp	2,700 Wp
Motor pump set type	Centrifugal DC monoblock	Centrifugal DC monoblock	Centrifugal DC monoblock
Motor capacity	1 HP	2 HP	3 HP
Operating voltage	60 V DC (nominal)	60 V DC (nominal)	90 V DC (nominal)
Max. Suction Head	7 metres	7 metres	7 metres
Max. total dynamic head	10 metres	15 metres	25 metres
Module mounting structure	MS hot dipped galvanised, three times manual tracking facilities	MS hot dipped galvanised, three times manual tracking facilities	MS hot dipped galvanised, three times manual tracking facilities
Shadow free area	30 sq. metres	75 sq. metres	120 sq. metres
Water Output *	77,000 LPD from a TDH of 10 metres	154,000 LPDfrom TDH of 10 metres	115,000 LPD from TDH of 20 metres

** Water output figures are on a clear sunny day with three times tracking of SPV panel when solar radiation on horizontal surface is 5.5 kWh/sq.m/day*

Table 13: Technical Specifications of Solar Deep Well Pumping Systems

Description	Model I	Model II	Model III	Model IV
Solar PV array	1,200 Wp	1,800 Wp	3,000 Wp	4,800 Wp
Motor pump set type	Submersible with electronic controller	Submersible with electronic controller	Submersible with electronic controller	Submersible with electronic controller
Motor capacity	1 HP	1 HP / 2 HP	3 HP	4.6 HP

Max. total dynamic head	70 metres	70 metres	120 metres	160 metres
Module mounting structure	MS hot dipped galvanised, three times manual tracking facilities	MS hot dipped galvanised, three times manual tracking facilities	MS hot dipped galvanised, three times manual tracking facilities	MS hot dipped galvanised, three times manual tracking facilities
Shadow free area	45 Sq. metres	75 sq. metres	120 sq. metres	200 sq. metres
Water Output *	34,000 LPD from a TDH of 30 mtrs.	51,000 LPD from a TDH of 30 mtrs.	51,000 LPD from TDH of 50 mtrs.	82,000 LPD from TDH of 50 mtrs.

** Water output figures are on a clear sunny day with three times tracking of SPV panel when solar radiation on horizontal surface is 5.5 kWh/sq.m/day*

ANNEXURE 3: CHECK LIST / GUIDE FOR INTERVIEWS AND EXPERT CONSULTATIONS

Questions for Existing Users of Solar PV Pumps/SNAs/ Organizations with activities in the area of solar PV water pumping

1. What has been the experience of using solar PV water pumping systems for irrigation?
2. What were the challenges to rolling out the programme/acquiring and using the solar PV water pumping system?
3. In hindsight, what facilitated and hampered the programme implementation/acquiring and using the solar PV water pumping system? (Get detailed responses for each of the areas viz., technological maturity, access to finance, capacity building and regulatory issues).

Questions for BREDA/Line Depts./Organizations proposing activities in the area of solar PV water pumping in Bihar

1. What are the challenges and opportunities to rolling out of SPV Pumps in Bihar?
2. What are the barriers that need to be addressed to enable the scaling of the sector? (Get detailed responses for each of the areas viz., technological maturity, access to finance, capacity building and regulatory issues).
3. What is expectation that the private sector has from BREDA and other Govt. Depts. that are involved promoting RE and irrigation? What is missing? What are steps that need to be taken by the policy makers?
4. What are the expectations from the private sector? What is missing? What are steps that need to be taken by the technology providers to ensure scaling of the sector?
5. What external programmatic support would help support the scaling up of the rolling out of SPV Pumps in Bihar?

ANNEXURE 4: STAKEHOLDER WORKSHOP

A stakeholder workshop was organised in Patna on 9th November 2012, wherein the findings of the study was presented to different stakeholders from the Government, financial institutions, private sector organisations dealing in solar equipment and/or solar PV water pumping systems, farmers' organisations and civil society.

Mr. Manish Kumar IAS, Director BREDA at the Stakeholder workshop
Picture Courtesy: GIZ

The presentation was followed by discussions on the challenges and opportunities identified by the initial study and validation of the findings based on the actual field experience of the stakeholders. The discussions were followed up with a break out session, breaking up the stakeholders into two groups.

The first breakout group consisted of BREDA, the line departments and the financial institutions. This group discussed the challenges and opportunities from the policy makers in rolling out of solar technology based water pumps. Feedback from the first breakout group was as follows:

Issues Relating to the Technology

- Standardization of the solar water pumps in an important issue. There are debates around the best parameters/indicators for assessing the efficiency of the pumps. The official tendering process should have a balance between the size/power of the technology along with the output potentials from the pumps.
- The solar water pump needs to be integrated with the existing diesel/grid based pumps. At present there is a mismatch between the output from the existing pumps and the solar water pumps. There needs to a technical assessment conducted on the efficiency of the pumps by a suitable department (most probably by BREDA) and the results should be available in the public domain. It is important to determine the high quality pumps existing within the market. Awareness generation regarding the same will be very important.
- Water level varies across the state of Bihar. While the North Bihar has a comparatively higher water table, the South of Bihar has lower water levels. Hence it would be unjustified to classify the water table in a uniform manner. This also takes us to look at different technologies of surface and submersible pumps in different locations. The size and capacity of the pumps would also vary accordingly.

Issues relating to Finance

- There is often a mismatch between the available benchmark price set by the government/regulators and the market price for the product. This often leads to confusion between the end user and the financial institutions. The end user feels that that the subsidy should be as per the market price but actually it is based on the benchmark price leading to lack of trust between service providers and end users.
- There is often a substantial time lag between launching of the programme and releasing of the subsidy. This often leads to uncomfortable situation for the beneficiary and often increases the interest burden for him/her.

Other Issues

- Necessary innovations need to be mainstreamed along with the solar water pumps based on the water tables, capacity of the pump and the topography. For example creation of water structures for storing of water may be necessary in some parts to make solar water pumps work successfully.
- 60% of the farmers own land that is less than 2 bighas. There are lots of small and medium farmers in the state of Bihar. Representatives from Jeevika were keen to try out a water pumping model which can be owned by a SHG or a joint liability group (JLG) (which is recognized by the banks). The minor irrigation is going to have a pilot project and there are potentials for collaboration.

A cross-section of the participants at the stakeholder workshop
Picture Courtesy: GIZ

The second breakout group consisted of the private sector companies, farmers' organisations and civil society. They discussed issues regarding technological maturity, access to finance, capacity building and regulatory issues in rolling out of solar technology based water pumps. Feedback from the second breakout group was as follows:

Issues relating to the Technology

- While standardization of the solar water pumps is important, the product should be suited to customer need. Different types of pumps required to meet different needs.
- There are no local suppliers for good quality, efficient pumps. All BLDC pumps need to be imported, thereby, increasing costs and making them difficult to service locally.
- Lack of localised service creating problems for technology suppliers. Localised infrastructure is required. Training for existing local pump technicians and sales outlets should be undertaken.
- Pumps are being rated on SPV array capacity. Output/discharge of the pump should be the main criteria for pump evaluation, as ultimately the farmer is buying the pump for water.

- Ensure better value from solar PV water pumping system by linking with drip irrigation and rural electrification.

Issues relating to Finance

- Affordability is the biggest issue with regard to solar water pumping. Need for consumer financing that is similar to costs being incurred for owning and using diesel pumps. The use of accelerated depreciation, carbon financing, etc. to reduce costs should be looked into.
- Clarity is required regarding delivery of subsidy. If subsidy is going to be released in lots (bundling of systems) as done in the case of large systems under JNNSM, it will not be possible for suppliers to bear the burden of the increased costs due to increase in interest burden. Subsidy should be done on individual basis and the time lag between installation and release of subsidy should be minimised. MNRE should include solar PV water pumping systems along with the other off-grid systems for which that subsidy is offered through NABARD and the banking sector.

Regulatory Issues

- Single window approach required for solar pumping, both for technology suppliers as well as customers. The "Bihar Solar Pumping Mission" approach proposed in the presentation should be adopted so that all the different ministries and departments looking at the different aspects of reaching the solar PV water pumping system to the farmer complement each other rather than working at cross purposes.

Other Issues

- Need to create awareness among the farmers, financial institutions and Govt. officials about the technology and its robustness.
- With theft and vandalism being a major issue, ways to overcome these should be looked into. This could either be by using portable systems or community owned systems.
- Where landholdings are very small and fragmented or where tenant farmers are in large numbers, larger farmers could be motivated to buy solar water pumping systems and sell water to the smaller farmers.

The learning and feedback from the stakeholder workshop, especially the barriers, potential solutions and the key areas for programmatic intervention have been incorporated into this study.

Brainstorming during a breakout session
Picture Courtesy: GIZ

Agenda of Stakeholder Workshop

IGEN-RE Stakeholder Workshop on Solar Water Pumping for Irrigation Agenda

Date: 09 November 2012,
Venue: Hotel Gargee Grand, 825, Exhibition Road, Patna, Bihar.

10:00	**Registration** Tea/Coffee
10:30	• Welcome Note – GIZ • Introduction to IGEN-RE project – Mr. Michael Blunck, Team Leader, IGEN-RE, GIZ • Address by Mr. Manish Kumar Director, Bihar Renewable Energy Development Authority (BREDA)
11:00	**Discussions and sharing** • Policies & Programmes on Solar water pumping for irrigations in Bihar: BREDA. • Opportunities and challenges for solar water pump for irrigation in Bihar - Findings from the overview paper: Mr. Thomas Pullenkav.
11:45	Tea / Coffee
12:00	**Analysis of framework conditions for rolling out of solar water pumps for irrigation in Bihar** Breakout Group 1: BREDA and line departments (Challenges and opportunities from the policy makers in rolling out of solar technology based water pumps) Breakout Group 2: Private sector involved with solar water pumps (Technological maturity, Access to Finance, Capacity building, Regulatory Issues)
13:00	Summary & Discussion of working group results in the plenary by Mr. Thomas Pullenkav and Mr.Nilanjan Ghose.
13:40	Vote of Thanks- GIZ
13:45	Buffet Lunch

Table 14: List of Participants at the Stakeholder Workshop

Sl. No.	Name	Organisation
1.	Mr. Manish Kumar	Bihar Renewable Energy Development Agency
2.	Mr. M. P Roy	Bihar Renewable Energy Development Agency
3.	Mr. B. P. Suman	Bihar Renewable Energy Development Agency
4.	Mr. A. A. Pandit	Bihar Renewable Energy Development Agency
5.	Mr. Raj Mohan Jha	Bihar Renewable Energy Development Agency
6.	Mr. Santosh Kumar Sinha	Minor Water Resources Dept., Govt. of Bihar
7.	Mr. Kishore Kumar	Minor Water Resources Dept., Govt. of Bihar
8.	Mr. Vidyabhushan Prasad	Minor Water Resources Dept., Govt. of Bihar
9.	Mr. Ajit Kumar Sinha	Minor Water Resources Dept., Govt. of Bihar
10.	Mr. Krishna Bihari	Agriculture Dept., Govt. of Bihar
11.	Ms. Nikita Bankoti	Jeevika/BRLPS
12.	Ms. Archana Chandola	Jeevika/BRLPS
13.	Mr. Mithilesh Kumar	NABARD Patna
14.	Mr. P.K. Jaiswal	Bihar Gramin Bank
15.	Mr. Pradip Bhosale	Jain Irrigation Systems Limited
16.	Mr. Sujeet Kumar	Jain Irrigation Systems Limited
17.	Mr. R. K. Sinha	Jain Irrigation Systems Limited
18.	Mr. Vishal Kumar	Claro Energy Pvt. Ltd.
19.	Mr. Abhishek Sharma	Claro Energy Pvt. Ltd.
20.	Mr. Sanjar Azmi	TATA Power Solar Systems Limited
21.	Mr. Gopal Kumar Singh	SELCO Solar Light Pvt. Ltd.
22.	Mr. Pawan Kumar	Triveni Sales Corp. / Gautam Polymers
23.	Mr. Ashim Bonal	ONergy / SwitchOn
24.	Ms. Elizabeth Peyton	ONergy / SwitchOn
25.	Mr. Naveen Kumar	Greenpeace
26.	Mr. V.K. Diwakar	Astha
27.	Ms. Sushmita Goswami	SEWA Bharat
28.	Mr. H.P. Singh	Indian Grameen Services/BASIX
29.	Mr. Ravi Ranjan	The Green Mantra
30.	Ms. Anuradha Das	The Green Mantra
31.	Ms. Tanushree Bhowmik	MoP-UNDP Access to Energy Project
32.	Ms. Seema Singh	MoP-UNDP Access to Energy Project
33.	Mr. Michael Blunck	GIZ
34.	Mr. NilanjanGhose	GIZ
35.	Ms. Meenakshi Kapoor	GIZ
36.	Mr. Thomas Pullenkav	GIZ

ANNEXURE 5: LIST OF ORGANISATIONS/CONTACTED

The following people were contacted as part of the interview process/expert consultations:

1 Mr. Ajay Nayak, Principal Secretary, Dept. Of Energy, Govt. of Bihar.

2 Mr. Alok Kumar Sinha, Agricultural Production Commissioner and Principal Secretary, Dept. Of Agriculture, Govt. of Bihar.

3 Mr. Raj Mohan Jha, Dy. Director, BREDA.

4 Mr. Rajesh Bari, BEE Head, BREDA.

5 Mr. Debaraj Bahera, State Project Manager – Livelihoods, Jeevika/Bihar Rural Livelihoods Project Society.

6 Officials of the Minor Water Resources Dept., Govt. of Bihar.

7 Scientists at the ICAR Research Complex for the Eastern Region, Patna.

8 Mr. Hemant Lamba, Aurore, Pondicherry.

9 Mr. Jaspal Singh, Sr. Manager, Punjab Energy Development Agency, Chandigarh

10 Mr. C.S. Bedi, Director, Solera Energy Systems (India) Pvt. Ltd., Chandigarh.

11 Mr. Harbans Singh, Agriculturist, Village Landra, Fatehgarh Dt., Punjab.

12 Mr. Ranjeet Singh, Agriculturist, Village Jhanjeri, Ropar Dt., Punjab.

13 M/s. Gopal Nursery, Village Majad, Ropar Dt., Punjab.

14 Mr. Randeer Singh, Agriculturist, Village Dadri Majra, Fatehgarh Dt., Punjab.

15 Mr. GautamMohanka, Gautama Polymers Group, New Delhi.

16 Mr. Rahul Arora, Dy. Chief of Party - Renewable Energy, Nexant, New Delhi.

17 Mr. R. K. Vimal, Asst. General Manager (TS), IREDA, New Delhi.

18 Mr. T.C. Tripathi, Solar Energy Consultant (Former Advisor & Head, MNRE).

19 Mr. Amit Kumar, Addl. GM, TATA Power Solar Systems Limited, New Delhi.

20 Mr.Gopal Kumar Singh, Asst. Manager – Energy Services and I/c Bihar Project, SELCO Solar Light (P) Limited, Patna.

21 Dr. Harish Hande, Managing Director, SELCO Solar Light (P) Limited, Bangalore.

22 Mr. Pratyush Kumar, Regional Manager, Bihar & Jharkhand, Claro Energy Pvt. Limited, Patna.

23 Mr. Vishal Kumar, Asst. Manager – Bus. Development, Claro Energy Pvt. Limited, Patna.

24 Dr. S.P. Gon Chaudhuri, NBIRT, Kolkata.

25 Mr. R.B. Jain, President, Jain Irrigation Systems Ltd., Jalgaon

26 Mr. J.J. Kulkarni, President – Technical Support Services, Jain Irrigation Systems Ltd., Jalgaon.

27 Mr. Charitra Jain, Sr. Vice President, Jain Irrigation Systems Ltd., Jalgaon.

28 Mr. Sanjeev Phadnis, Sr. Manager – Technical, Jain Irrigation Systems Ltd., Jalgaon.

29 Mr. Pradip Bhosale, Jr. Manager – Technical, Jain Irrigation Systems Ltd., Jalgaon.

30 Mr. Vivek Mundkur, Atom Solar Systems, Pune.

31 Mr. Arjun Mundkur, Atom Solar Systems, Pune.

32 Mr. Sajal Jassal, Atom Solar Systems, Pune.

33 Prof. Sanjeev Ghotge. Jt. Director & Head (CCSP), World Institute of Sustainable Energy, Pune.

34 Dr. Sudhir Kumar, Jt. Director & Head (Solar Energy), World Institute of Sustainable Energy, Pune.

35 Mr. Ashwin Ganbhir, Prayas Energy Group, Pune.

36 Mr. Mihir Sahana. CEO, Indian Grameen Services (Basix), Pune.

37 Mr. Manish Ram, Greenpeace.

38 Mr. Naveen Kumar, Greenpeace

39 FGD with farmers (users of Claro Solar pumps) at Mubarakpur and Dhaulatpur.

40 FGD with farmers (users of Atom Solar Pump) at KalyanBigha.

41 The study also included visits to the field for discussions with project implementers and users.

Table 15: Field Visits

Period	Places Visited	Achievements
August 4th week	Pondicherry	Discussions with Aurore. Visited pump users In Auroville and Pondicherry.
September 1st week	Chandigarh	Discussions with PEDA and Solera Energy Systems. Visited solar pumps installed under MNRE Solar Water Pumping Programme.
September last week	Patna, Nalanda, Kolkata	Discussions with BREDA, Agriculture Dept., Energy Dept., Claro Energy, SELCO, Minor Water Resources Dept., ICAR Scientists, Indian Grameen Services, Greenpeace and Dr. S.P. GonChaudhuri. Visited Claro Pump installations.
November 2nd week	Patna	Discussions BREDA and Energy Dept. Stakeholder Workshop.
November last week	Jalgaon, Pune.	Discussions and site visit to Jain Irrigation Systems Limited. Discussions and site visit to Atom Solar Systems. Discussions with WISE, Pune and Prayas Energy Group.

ANNEXURE 6: CASE STUDIES OF EXISTING BUSINESS MODELS FOR SOLAR PV WATER PUMPING

I. Claro Energy Pvt. Ltd.

Claro Energy Private Limited (Claro) is a private limited company offering solar powered water pumping solutions to meet irrigation and drinking water needs in the rural areas. Though, the company is a Delhi based start-up, as of now, the company is mainly active in Bihar but has plans to expand to other states in India.

Sensing a great business opportunity in the JNNSM, Claro Energy was set up by Kartik Wahi, Gaurav Kumar and Soumitra Mishra in 2010. The company soon homed in on the opportunities that off-grid, decentralised generation such as solar-pumping offered. To start off, Claro Energy decided to target Bihar as it had high power deficits and, being in the Gangetic plains, has a very high water table compared to the rest of the country.

At present, Claro Energy caters mainly to the Government and public sector market, as powering of irrigation pump sets using solar power is expensive and cannot be easily afforded by the rural people. Some large farmers have also bought into Claro offering of powering their irrigation pump sets with solar energy.

Claro Energy's main focus currently is on retrofitting the existing irrigation pump sets powered by diesel generators (DG) with solar energy. This initiative will also go a long way in building awareness in the Government and market on the feasibility of solar power to run irrigation pump sets. Business wise, the potential for replacing/retrofitting DG powered pumps with solar power is very large. The Minor Irrigation Department, with whom Claro Energy has already installed about 34 solar PV pumps, has a potential of more than 5,000 pumps. In addition, there are thousands of pumps with PHED, other Govt. schemes and more than a million private tube well users that could potentially use Claro's solutions.

With 80% of all land holdings in Bihar being of less than a hectare, Claro Energy's biggest challenge will be to find ways of making solar affordable to the small and marginal farmer. Claro Energy is talking to banks and other financial institutions to try and bring in an innovative financial package, which will bring down the upfront cost to the farmer.

II. Atom Solar Systems

Another company that sensed an opportunity in the area of solar water pumping for irrigation in the energy deficit areas of the country is Pune based Atom Solar Systems. Incorporated as a partnership firm less than a year back by four friends Arjun Mundkur, Sajal Jassal, Abhijit Gangoli and Milind Katti, based on some innovative experimentation in water pumping done by Arjun and his father Col. Vivek Mundkur, Atom Solar Systems intends to cater to the niche market for small solar pumping solutions required by the small and marginal farmers.

Solar-powered irrigation systems can be the right solution for the farmers especially in the water rich areas of the Indo-Gangetic plains and bring about an agricultural revolution. This can not only solve the problem of unavailability of electricity for agriculture, the huge consumption of subsidised diesel but also increase the agricultural productivity and rural livelihood options.

Atom Solar's system is lightweight and can be manually installed in any open well or borewell. It delivers 1,500-2,000 litres of water per hour for 6-8 hours on a sunny day. For better water management and maximising returns, Atom Solar recommends that the systems should be combined with a drip irrigation system.

As of November 2012, Atom Solar has sold less than 25 solar PV water pumping systems. The last year was spent in experimenting with different types of pump and motors. Initially Atom Solar started with DC pump sets, imported from China, but soon abandoned this due to supply and service problems. They now intend to promote locally manufactured, high efficiency AC pumps coupled with a customised solar array and VFD.

Atom Solar, in association with Greenpeace, has installed three demonstration systems in Kalyanbigha in Nalanda district;Basaha village in Purnia district and Khalsa village in Vaishalidistrict to demonstrate to the effectiveness of the solar water pumping solutions to the policy makers and farmers.

III. Jain Irrigation Systems Ltd.

Jain Irrigation Systems Ltd has a multi product industrial profile and manufactures drip and sprinkler irrigation systems and components; PVC, polyethylene (HDPE, MDPE) and polypropylene piping systems; plastic sheets (PVC and PC sheets); agro processed products including dehydrated onions and vegetables; processed fruits (purees, concentrates and juices); tissue culture, hybrid and grafted plants; greenhouses, poly and shade houses; bio-fertilizers; green energy systems including solar photovoltaic (solar lighting and appliances, solar pumping systems), solar water heating systems and bio-energy sources.

JISL has identified solar PV water pumping as a new and promising business and has come out with a wide range of models ranging from 150W to 4,000W in the submersible type and 150W to 1800W in the surface type. The company has on offer 70 different solar pump models.

JISL is a strong believer in the use of high efficiency pumps even if they are slightly more expensive initially. Keeping in line with this belief, JISL uses only BLDC type pumps since they are far more efficient and rugged. JISL is also a strong promoter of the use of tracking mechanisms to ensure that maximum power is generated from the solar array.

JISL is one of the leading suppliers of solar pumps in India and has installed over 1,600 solar pumps in past 3 years in 14 states. Major installations are in Rajasthan, Maharashtra and Chhattisgarh. Due to the other complementary lines of business that JISL is involved in, the company also has an extensive network of dealers and agents across all geographies that can provide the required sales and service support needed for promoting solar PV water pumping solutions for irrigation.

JISL is keenly aware of the challenges in promoting solar PV powered water pumping solutions due to the high upfront cost. JISL is in the process of devising a financial package, which will bring down the upfront cost to the farmer.

BIBLIOGRAPHY

In the preparation of this report, a number of documents, research papers, publications and websites have been extensively referred to. All of which have been listed below:

1 AURORE, (2002). “Best Practices in Solar Water Pumping”: Auroville Renewable Energy (Aurore)

2 BAMETI, (undated). “Status of Agriculture in Bihar”: State Profile published by Bihar Agriculture Management and Extension Training Institute. Available at http://www.bameti.org/pdf/state_profile.pdf

3 C-STEP, (2010). “Harnessing Solar Energy: Options for India” Centre for Study of Science, Technology and Policy (C-STEP).

4 Em Con, (2006). “Feasibility Assessment for the Replacement of Diesel Pumps with Solar Pumps Final Report: Barrier Removal to Namibian Renewable Energy Programme” (NAMREP). Ministry of Mines and Energy. Available at :http://www.mme.gov.na/energy/pdf/Solar%20PV%20water%20pumping%20study%20-%20FINAL%20REPORT%20%28Single%20sided%29.pdf

5 FAO, (1986). “Irrigation water needs”: Irrigation water management Training Manual 3 Available at http://www.fao.org/docrep/S2022E/S2022E00.htm

6 GoB, (2012). “Bihar Saur Kranti Sinchai Yojana”: Government of Bihar Available at http://energy.bih.nic.in/docs/Solar-Revolution-Booklet.pdf

7 GoB, (2012).12th Five-year plan document of the energy Dept. Government of Bihar Available at http://energy.bih.nic.in/docs/12th-5YP-2012-17.pdf

8 GoB, (2008). “Bihar’s Agriculture Development: Opportunities & Challenges: A report of the Special Task Force on Bihar”: Government of Bihar published in April 2008.

9 GoI, (2012). “Report of the Working Group on Major & Medium Irrigation and Command Area Development for the XII Five Year Plan (2012-2017)” Government of India.

10 GoI, (2011). “Ground Water Year Book – India 2011-12”: Central Ground Water Board, Ministry of Water resources, Govt. of India.

11 GoI, (2012). Press release by Press Information Bureau, Government of India on The Minister of New and Renewable Energy, Dr. Farooq Abdullah, statement in the Lok Sabha dated 24 August 2012. Available at http://pib.nic.in/newsite/pmreleases.aspx?mincode=28

12 GREENPEACE, (Undated). “Empowering Bihar: Policy Pathway for Energy Access”: A GREENPREACE Report Available at http://www.greenpeace.org/india/Global/india/report/Empowering-Bihar-Policy-pathway-for-energy-access.pdf

13 HWWI, (2005). “CDM potentials for SPV pumps in India” Hamburgisches Welt Wirtschafts Institut (HWWI), Research Paper No 4. Available at http://www.hwwi.org/uploads/tx_wilpubdb/HWWI_Research_Paper_4.pdf.

14 India Infrastructure Report, (2011). “Water: Policy and Performance for Sustainable Development” Oxford University Press.

15 IMD, (2009). “Solar Radiation Energy over India” India Meteorological Department, Ministry of Earth Sciences, New Delhi.

16 Kakarla, M.et al (2012). “Solar Pumping”: International Journal of Engineering Science & Advanced Technology Volume-2, Issue-5, pp.1435 – 1439. Available online at http://www.ijesat.org/Volumes/2012_Vol_02_Iss_05/IJESAT_2012_02_05_36.pdf

17 KPMG, (2011). "The Rising Sun - A point of view on the Solar Energy Sector" Available at http://www.kpminstitutes.com/global-energy institute/insights/2011/pdf/the-rising-sun-may-2011.pdf

18 Kumar, A & Kandpal, C.T. (2007). "Renewable energy technologies for irrigation water pumping in India: A preliminary attempt towards potential estimation":Energy, Volume 32, Issue 5, Pages 861–870

19 Nobel, N.(2002).Technical Brief on "Solar (Photovoltaic) Water Pumping" : Practical Action Available at http://practicalaction.org/solar-photovoltaic-waterpumping-1

20 Odeh, I & Yohanis, Y.G. (2006). "Economic viability of photovoltaic water pumping systems": Solar Energy, Volume 80, Issue 7, Pages 850–860.

21 Oldach, R. (2003). "Solar water pumps—the Past, Present and Future": Journal of Solar Energy Engineering, Volume 125, Issue(1), pages 76-82.

22 Shah, T & Kishore, A (2012). "Solar-Powered Pump Irrigation and India's Groundwater Economy A Preliminary Discussion of Opportunities and Threats": Water Policy Research Highlights: 26. IWMI-TATA Water Policy Program Available at http://www.iwmi.cgiar.org/iwmi-tata/PDFs/2012_Highlight-26.pdf.

23 TERI, (2004). "Enhancing Sustainable Production: Financing Model for Solar Water Pumping Systems in Agriculture: Good Practices Inventory" TERI.

24 WISE, (2011). "Renewable Energy Potential Assessment and Renewable Energy Action Plan for Bihar" World Institute of Sustainable Energy, Pune Available at http://energy.bih.nic.in/docs/RE-PA-AP-Bihar.pdf.

25 Xenarios, S et al (2011). "Research Analysis on the Effects of Agricultural Water and Landholdings to Rural Livelihoods in the Indo-Gangetic Basin with emphasis on Bihar State". An IWMI, ICAR, NAIP Publication. Available at http://www.indiaenvironmentportal.org.in/files/rural%20livelihoods%20in%20indo-gangetic%20basins.pdf.

WEBSITES

1 Ministry of New and Renewable Energy: www.mnre.gov.in

2 Ministry of Power: www.powermin.nic.in

3 Central Ground Water Board: www.cgwb.gov.in

4 Indian Renewable Energy Development Agency: www.ireda.gov.in

5 Dept. Of Agriculture, Govt. of Bihar: www.krishi.bih.nic.in

6 Documents available on Energypedia
- https://energypedia.info/index.php/Photovoltaic_(PV)_Pumping
- https://energypedia.info/Photovoltaic%20%28PV%29%20Pumping%20in%20India
- https://energypedia.info/index.php/Design_of_Photovoltaic_(PV)_Pumping

7 International Water Management Institute: http://www.iwmi.cgiar.org/

8 Agriculture Information Bank: http://www.agriinfo.in/default.aspx?page=topiclist&superid=1&catid=11

9 ClimateTech Wiki: http://climatetechwiki.org/technology/jiqweb-swp

10 Surface Meteorology and Solar Energy NASA: https://eosweb.larc.nasa.gov/sse/

11 Energy Department, Government of Bihar: http://energy.bih.nic.in

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