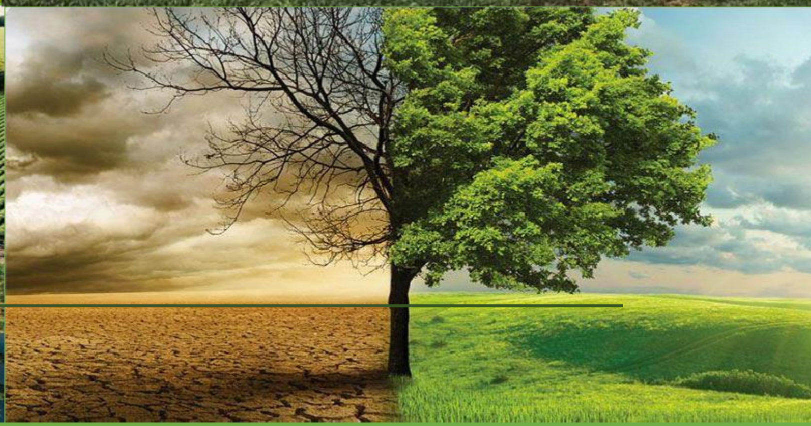
POLICY BRIEF

IRRIGATION SECTOR

ENABLING STATE LEVEL CLIMATE MITIGATION ACTIONS



20 YEARS Integrated Research and Action for Development IRADe

MacArthur Foundation

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Policy Brief

Irrigation Sector

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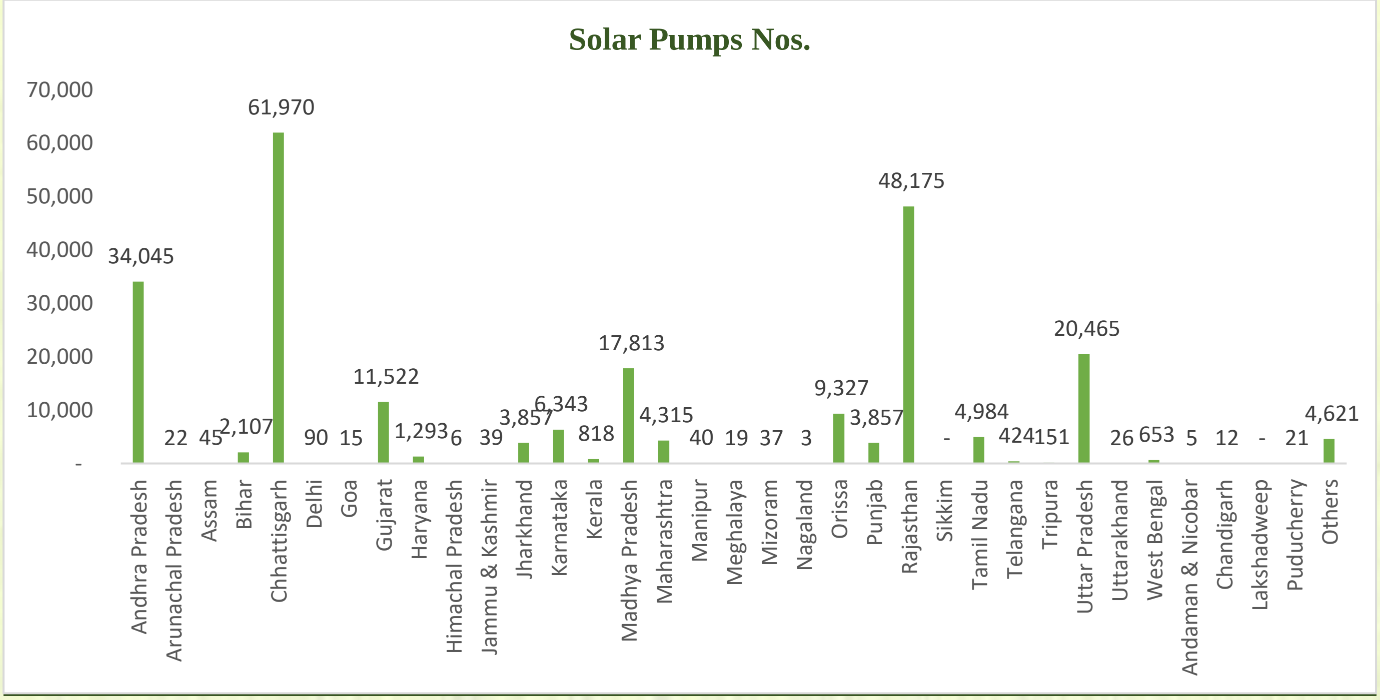
Policy Brief- Agriculture Sector

1. Introduction

India is blessed with solar insolation in abundance and is striving to become a true world leader in the use of solar energy. The government of India and State Governments are making concerted efforts through different initiatives and schemes for extensive use of solar energy in various sectors of the economy, including in the agriculture irrigation sector. Both Central and state governments have been increasingly promoting solar irrigation pumps (SIPs) through different schemes to achieve multiple objectives such as access to assured irrigation for farmers, reducing electricity subsidy burden, reducing the carbon intensity of food production, etc. These schemes aim to meet solar energy for irrigation, drinking, and other water requirements. The progress made under these schemes are non-uniform. Chhattisgarh has the highest number of installed solar pumps whereas eastern states have fewer SIPs installed (Fig 1).

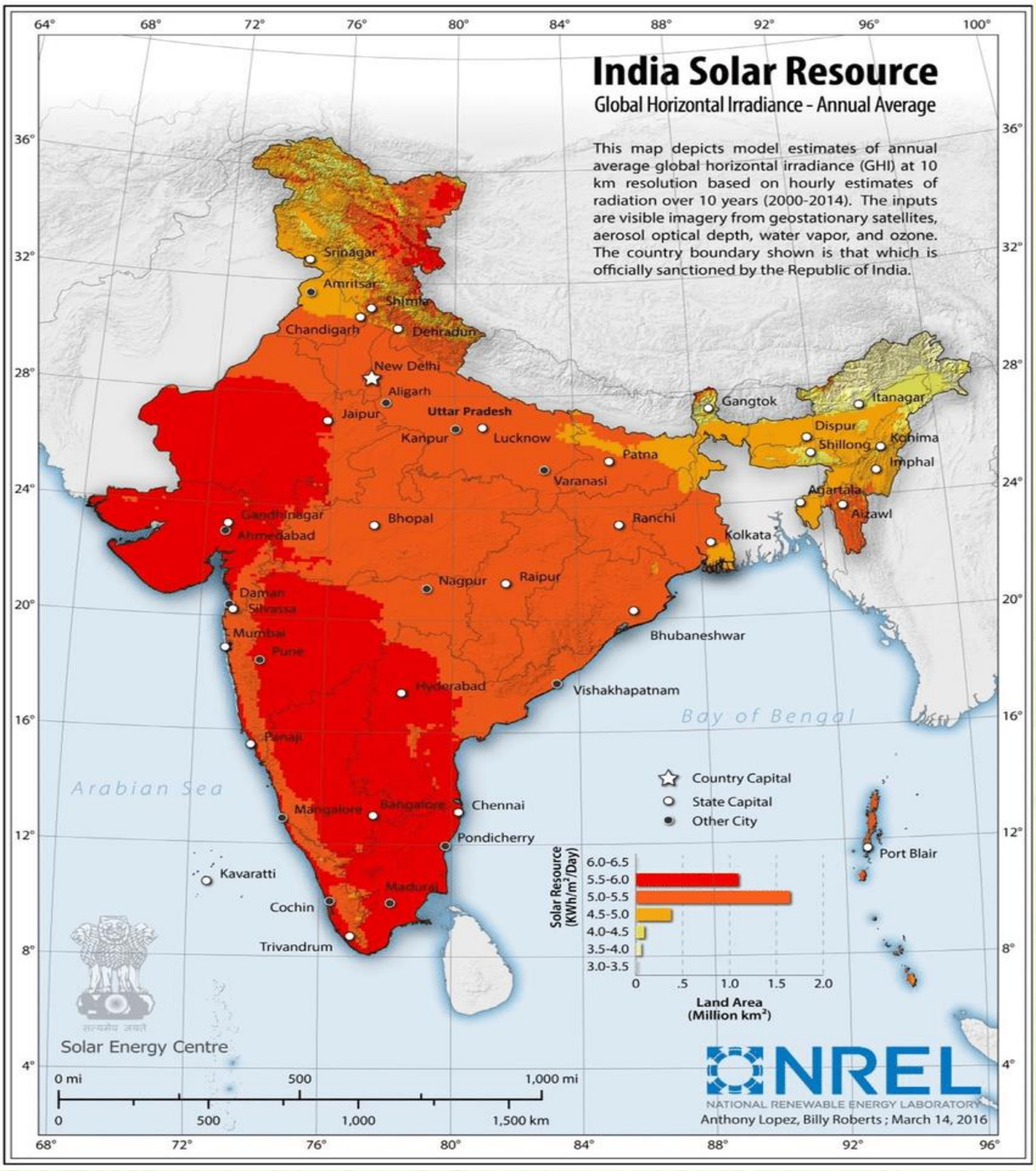
Figure 1: State-wise Cumulative Capacity installed off-grid Solar Pumps up to 2018-19



Data source: MNRE

Figure 2 shows India's annual average global horizontal irradiance at 10 km resolution based on hourly estimates of irradiation over 10 years (2000-2014). The map depicts a good potential for solar energy generation across India with most parts receiving 5-6 kWh per sq. meter per day except in the north-eastern states. This means solar photovoltaic power can effectively be harnessed in these areas.

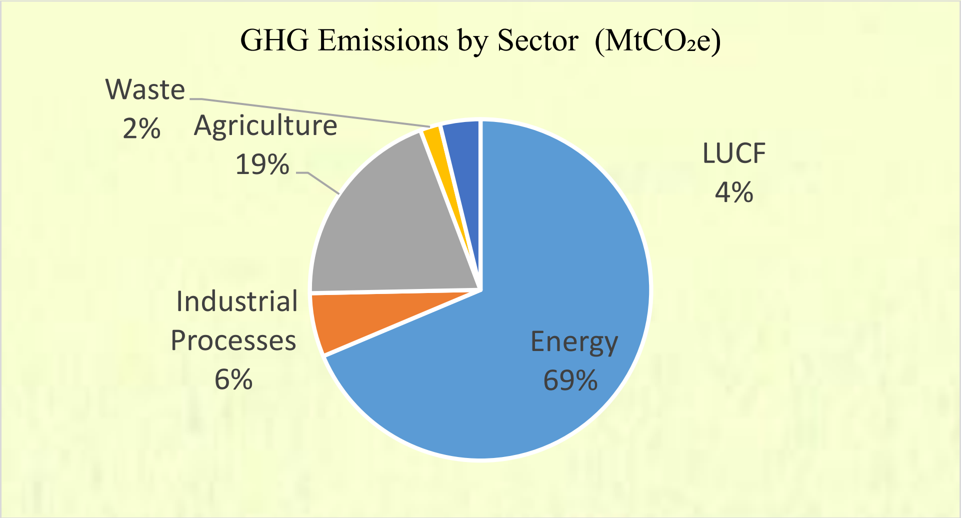
Figure 2: India's solar resource annual average (GHI)



Source: National Institute of Solar Energy (NISE)

It is estimated that the country has around 20 million irrigation pumps, of which 70 percent are electric-powered and 30 percent are powered by diesel (MNRE, 2017)[1]. The agricultural sector consumes about 22 percent of the total electricity and 15 percent of the diesel for pumps, tractors and equipment, in the country (IEA, 2015)[2]. The agriculture sector is the second largest emitting sector after energy, contributing 19 percent of total GHG emissions (MtCO2e) (Fig 3).

Figure 3: GHG emission by sector for 2013



Source: WRI CAIT

Solar irrigation can address the twin challenge of providing uninterrupted clean energy during the daytime to farmers for irrigation and help India meet its global climate commitment. Reduction in electricity demand for irrigation will help financially strained DISCOMs reduce their losses because of subsidized electricity supply to the farmers. Moreover, grid-connected solar can become an additional source of revenue for farmers, which is in line with the government's well-stated position of augmenting farm income. Given this background, this study has set out the following three specific objectives:

- How much can low carbon irrigation may assist in achieving India's NDC targets through the adoption of solar water pumps
- To assess a viable state-level policy to incentivize both farmers and DISCOMs.
- To analyze market-based solutions that would facilitate the effective implementation of irrigation policies.

[1] MNRE Annual report, retrieved from https://mnre.gov.in/knowledge-center/publication
[2] IEA, 2015, India energy outlook -special report (https://www.iea.org/reports/india-energy-outlook-2015)

The policy brief draws from the three state-specific pilot studies conducted for Gujarat, Odisha, and Assam, for a viable state-level policy to promote low carbon irrigation, which may assist in achieving India's NDC targets. The policy brief is focused on standalone and grid-connected irrigation pumps. A market-based solution would facilitate the effective implementation of solar-based irrigation policies in the different states of India.

2. Benefits of Solar irrigation

2.1 Reduced GHG emissions

SIPs have the direct potential to reduce greenhouse gas (GHG) emissions in irrigated agriculture by replacing fossil fuels for power generation or replacing diesel water pump sets with a renewable energy source, i.e., solar energy. The operation of the SIPs is free of GHG emissions; however, Lifecycle assessments (LCA), taking into account the cradle-to-grave approach, GHG emissions are involved primarily in the production, distribution, and disposal of PV panels. LCA indicates a potential reduction in GHG emissions per unit of energy used for water pumping (CO2-eq/kWh) of 95 to 97 percent for grid electricity (global average energy mix) and 97 to 98 percent for diesel pumps (GIZ 2016)[3]. This improvement in GHG emissions savings is significant given the number of irrigation pumps required for irrigation in India. The per unit (water pumps) energy demand is comparatively tiny, but the total reduction in GHG emission from irrigated agriculture would be significant on an aggregate level.

2.2 Energy independence in remote areas

Solar PV can provide a reliable energy source for pumping irrigation water during the daytime. It is more important for areas that are either not connected to the electricity grid, or electricity supply is irregular, or the quality of electricity is not convenient to operate the water pump. A regular supply of diesel is also not guaranteed in remote areas. Solar PV can make farmers immune from the regularly changing diesel price or electric load shading for irrigation. The distribution of excess electricity over local grids can also contribute to rural electrification and productive use applications. Energy independence will help diversify production, especially cash crops, to complement staple crops. Cropping intensity will also improve, which in turn improves food availability.

3. Challenges to the adoption of SIPs

[3] GIZ, (2016) Solar Powered Irrigation Systems (SPIS) – Technology, Economy, Impacts. Gesellschaft für Internationale Zusammenarbeit (GIZ), Retrieved from: https://energypedia.info/images/temp/2/23/201606301225 44!phpeKHVUr.pdf

SIPs have proven to be a technically viable and economically competitive option with an attractive return on investment. However, the high capital cost for equipment and lack of suitable funding schemes are significant challenges to the largescale adoption, especially by the small and marginal farmers. In many cases, solar pumps are used for only a limited number of months (days) of the year. Developing a water market and ways to use the energy generated during the off-irrigation season could significantly improve economic viability. This study suggests several financial, investment, and business models that offer different options for farmers to overcome potential funding gaps.

4. What should policy do

A well-designed policy can generate significant environmental, social, and economic benefits, which outweigh the implementation costs and contribute to social well-being. The financial considerations for government-supported schemes are of utmost importance for a resource-constrained economy. At the same time, other concerns, such as sustainability, environment, the pace of scaling out, minimizing inclusion and exclusion errors, etc., should also be addressed. Replacing diesel and electric water pumps with solar pumps will provide cheap and reliable energy for farmers to run a water pump with nearly zero marginal cost. This may have potentially adverse impacts on groundwater particularly if water markets are developed. Therefore, exploring the ways to minimize the potential impact of groundwater depletion should also be considered in the policy design. Scaling heavily subsidized schemes to a large set of beneficiaries may allow the elite to capture the funded projects and exclude the poor. Thus the policy objectives should be to make adoption of SIP in the interest of all stakeholders, the farmers, DISCOMs, and the Government.

5. Business model for solarisation of irrigation

The accelerated adoption of the SWPs could be facilitated by creating enabling frameworks that include supportive institutional, innovative financing schemes, and viable market-driven mechanisms. Increased access to irrigation water is based on a need to increase water supply to smallholder farmers for irrigated agricultural production. The business models can be viewed from an individual farmer (or group of farmers) or a supplier (e.g., solar pump service provider). We propose three models: 1) Individually purchased grid integrated SIP, 2) Community irrigation model- standalone pumps and 3) Irrigation entrepreneur model.

5.1 Individually purchased- grid integrated SIP

The business model is for a standalone SIP where a farmer invests in an irrigation pump. The local DISCOM agrees to purchase electricity from the farmer at an agreed price. The model assumes that farmers will be motivated to invest in solar irrigation technology if it profitable. In addition to getting better yields by irrigating the crops and generating income from crop sales, farmers can consider selling excess water to either the local DISCOM or neighbouring farmers. For small and marginal farmers own irrigation needs could be met by a certain number of hours per day of operation of a solar pump. Additional abstracted water could be sold to other farmers to increase the use of the solar panels and also generate income for the SIP owner. However, since the farmer could sell the electricity to the DISCOM, the price at which water will be sold to the neighbour would be higher than if the DISCOM alternative is not there. Selling electricity to DISCOM provides a stream of income in the off season when there is no need for irrigation. It also motivates the farmer to optimize his irrigation and would reduce the stress on ground water.

Availability of finance at a low rate and upfront government subsidy will minimize the effective cost of acquisition for the farmer. Financial institutions may come forward to provide loans to the farmer against the SIP at a concessional rate. A lower interest rate for SIP could catalyse the adoption of the solar irrigation pumps.

Figure 4. shows the schematic framework for grid-connected SIP and interlinkage among stakeholders. Under this framework, farmers own, partially finance, and manage the operation of the SIP system. The solar pump supplier's, System Integrator-Solar pump provider role is limited to the installation of the SIP system and the provision of technical services on demand to the customer. The government representative, a state nodal agency, facilitates the adoption of SIP by formulating suitable policies. The role of a financial institution (Scheduled Commercial Bank/Private financer/any other government-designated agency) would be to provide a part of the initial capital for SIP purchase and installation. DISCOM plays an important role in providing SIP installation permits, evacuation of surplus electricity, payment for the same to the pump owners, and resolving technical issues related to electricity evacuation.

The key characteristics of this business model

- **Farmer**: increased access to water for irrigation throughout the cropping seasons; additional income to the farmers by selling surplus electricity generated by SIP.
- **Capital required**: Capital requirement depends on size of the panel which is function of land area to be irrigated; ground water level; crop type and cropping intensity
- **DISCOM**: will receive distributed renewable energy generated by SIPs.
- **Environmental impact**: reduced fossil fuel consumption and GHG emissions. Reduced water withdrawals and optimal use of water for agricultural intensification.
- **Socioeconomic Impact**: Food security and increase in farmer's income.

The repayment of interest and capital to the financial institution remains the farmer's responsibility. A farmer may either use generated electricity for irrigation, sell water to irrigate fields or supply it to DISCOMs.

An analysis carried out for a 15kW system showed that;

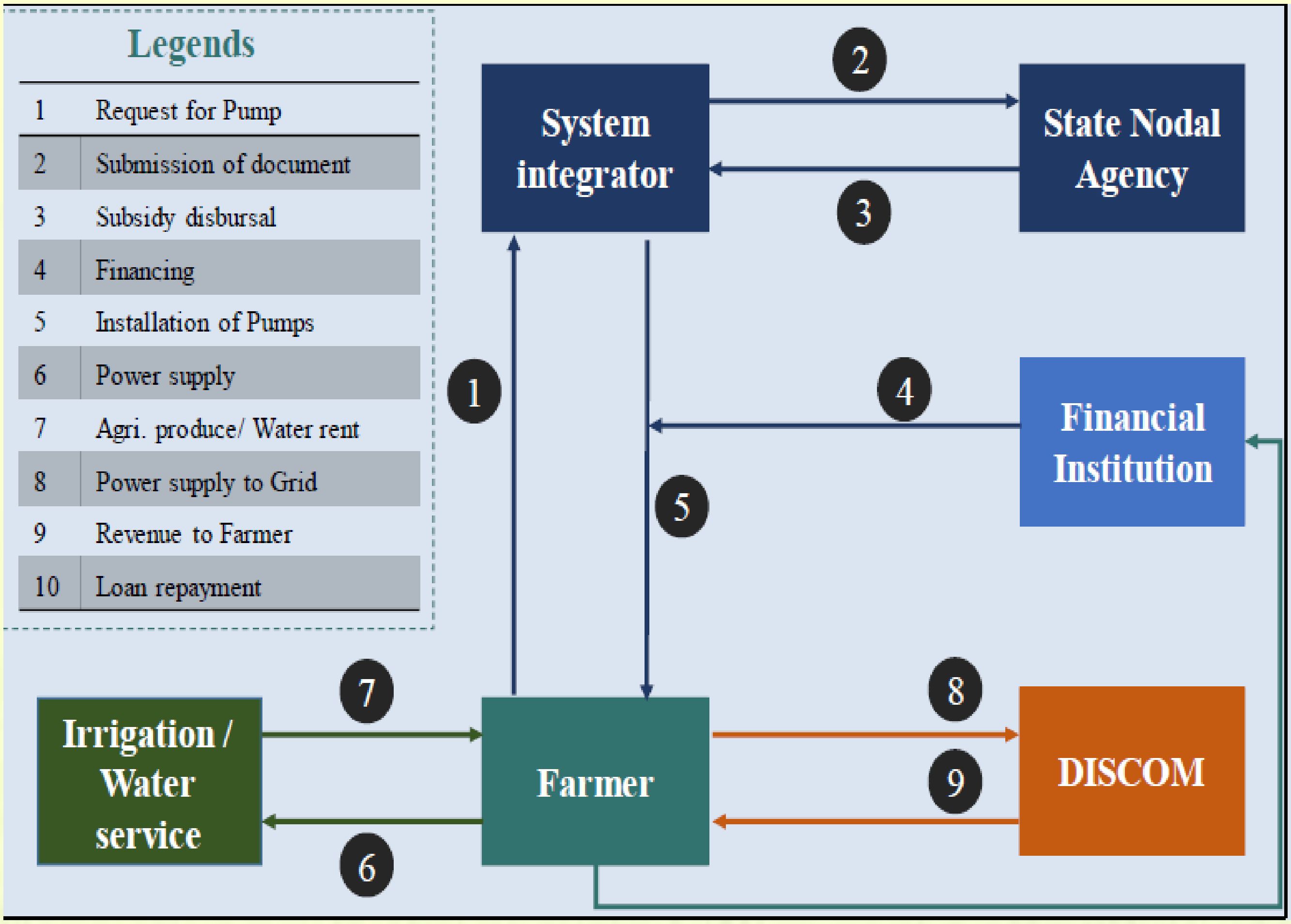
- with a 15% upfront capital subsidy from the government;
- feed-in-tariff (FiT) of Rs 5.75 per unit by DISCOM for additional electricity evacuated from SIP;
- interest rate on the borrowed capital at 6% per annum;
- the project payback period would be approximately 42 months.

At the same time, the government's expenditure on power subsidy to agricultural consumers is lower and the DISCOM will also benefit as the cost of supplying electricity to rural areas is much more than Rs. 5.75. It reduces the amount supplied to rural areas as it uses the electricity purchased from farmers to other rural consumers. It is thus a win-win-win proposition.

This value proposition is based on the concept of using solar pump technology for the dual purpose of irrigation and energy generation. This business model framework will be good for groundwater conservation. The scheme incentivizes energy-water conservation as farmers if they were to pump excess water they forgo the opportunity to sell surplus electricity to DISCOM. It will also be good for DISCOMs since the pay-outs are spread over a long period and inflation will moderate it as years go by. Financial institutions will also find it attractive as they can foresee a clear cash flow path.

Grid-connected solar irrigation may become a major positive disruption yet to happen in India. It holds immense potential to achieve saving electricity, saving water, and augmenting farmer income as the direct benefits and emission saving as positive externalities. It may address multiple issues such as augmenting farmers' income, reducing recurrent subsidy outflow on electricity to agriculture, increasing the share of green energy in the agriculture sector, and many more.

Figure 4: Schematic framework of the business model for grid-connected SIP



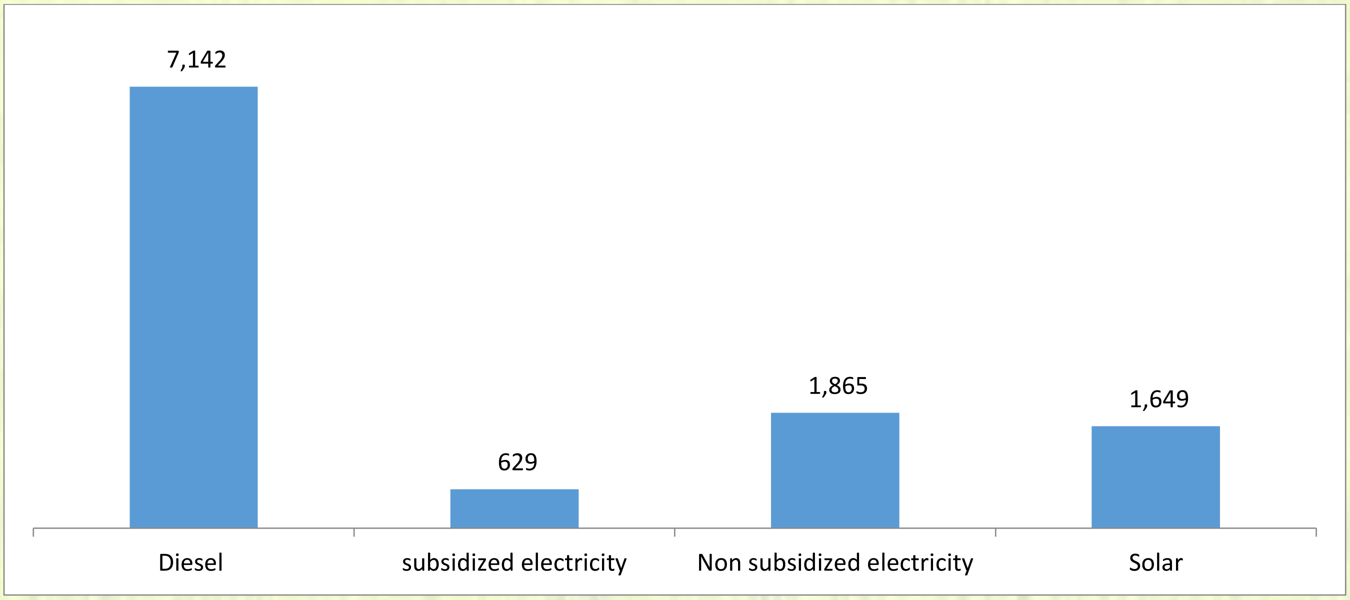
To encourage small and marginal farmers a provision for a high upfront capital subsidy can also be considered. In this scenario a progressive subsidy rate (reducing subsidy rate) for each additional kW solar PV system installed beyond a floor capacity set for each geographical location based on the groundwater level condition in the location. Alternatively, there should be a cap in the form of kW of load which will be eligible for subsidy under the government schemes for farmers. This can help realize the Government of India's objective of doubling farm incomes: after all, paying farmers a decent price for the energy they produce is a better way of increasing their incomes than providing doles.

5.2 Community irrigation model

The fragmented landholding is one of the primary reasons for the low adoption of SIP. Farmers expressed concerns about having faraway lands and are hesitant to adopt a solar pump system due to the immobility of the system. Capital to finance a SIP would also be a big challenge for the small or marginal farmer. To address both these challenges the proposed business model is a cost-sharing model where a group of farmers pools their funds to invest in a solar irrigation pump. The inherent sustainability driver for a cost-sharing model is mitigated investment risk for individuals. Joint partnership investments allow smallholder farmers to better negotiate lower interest rate loans from financial institutions.

An irrigation water-sharing group of farmers is formulated and this group would own the SIP of the capacity commensurate to meet the community irrigation needs. The formation of the group will be in such a way that all the farmers have their respective land parcels situated in such a way that a SIP can cater to their farms without requiring much additional capital expenditure on pipes for the transportation of water. The gross annual water requirement for irrigation depends on crop area sown and area sown allocated to different crops. Therefore, crop selection is an important determinant for spacing out irrigation requirements throughout the year. For example, a vegetable growing farmer's irrigation requirement is generally high and equally spaced out. For vegetable grower farmer's assurance of irrigation water at the appropriate time to prevent crop mortality is more important than the economic incentive of the lower price of irrigation water. Figure 5 compares the cost of different available irrigation technology for groundwater extraction and shows that subsidized electricity is the most economical irrigation option for the farmer, followed by solar pumps while diesel is the most expensive option for irrigation. However, subsidized electricity supply to agriculture puts a huge cross-subsidy burden on the industrial and other consumers. The cost of diesel is already prohibitive, and it is subject to frequent variations.

Figure 5: Average annual irrigation cost (includes capital + maintenance + operation) (in Rs) per hectares



Stand-alone diesel pumps are one of the most expensive irrigation options for farmers. Therefore, diesel pumps should be replaced with community solar pumps which will optimize the use of pumps to achieve better commercial viability. In effect, by purchasing solar pumps, farmers would be assured that they are buying many years of assured electricity for irrigation up-front. Predictable future irrigation costs would help farmers to plan their future accordingly.

5.3 Irrigation entrepreneur model

This business model is based on the notion that revenue by selling irrigation water to the farmers would outweigh the cost of investment. The model proposes an entrepreneur would provide irrigation to contracted farmers, as they do with other agricultural inputs, as well as technical support to strengthen capacity in operating and maintaining the solar pump. A contract between farmers and the entrepreneur proving irrigation is important because water delivery systems, water storage technologies, etc. involve additional investment. This is a pay-as-you-go (farmers pay for use) model and the supplier/entrepreneur retains ownership and responsibility for maintenance. The development of the water market is an intrinsic characteristic of this model. It mitigates the capital investment risk that the farmers face but an individual farmer still risks being price-takers, with a larger share of the consumer surplus going to the entrepreneur providing irrigation solutions.

6. Other aspects related to the largescale implementation of SIP

- **Monitoring of Ground Water situation**: SIPs' impact on groundwater needs to be monitored. With the increase in electricity access through SIPs, there has been an increase in water access. This creates a need for monitoring groundwater overuse. The policy should be implemented in a way to encourages prudential use of water. To this aspect, paying farmers for energy not used for pumping groundwater is a good way of incentivizing groundwater conservation. The high opportunity cost for using electricity for irrigation would persuade them to optimize water use and motivate them to use micro-irrigation techniques.
- **Training for farmers**: Further, there exists a need to provide adequate training to the farmers. While operating SWPs is easy, understanding the energy trade with DISCOM requires some training in operating the meter.
- **Upgradation of electricity infrastructure**: for grid-connected SIPs, adequate resources for monitoring each feeder in order for it to work as an express feeder should be provisioned by the DISCOMs. DISCOMs should need to have dedicated manpower to address farmers' complaints within a short span. Transmission companies' operators need to be educated about the concerns with

voltage shifts. Improving the infrastructure and educating the operators would assist in reducing frequent breakdowns. Prior to the solarisation of the grid maintaining and refurbishment old lines is a necessity. If not, the problems such as power interruption, and failure of inverters would persist. This would lead to losses both for DISCOM and farmers.

- **Mobile application for monitoring production and use of solar energy**: similar to the facility in the solar rooftop scheme, farmers owning SIPs should also be given a facility to digitally keep a tab on the energy generation and use it on a real-time basis. This is of utmost importance to farmers whose farms lie at a significant distance from their houses. This would also inform them about the breakdowns especially in monsoons when they rarely visit fields.
- **Maintenance of the system**: the responsibility of maintenance (wear and tear) of the systems should be borne by the system manufacturer and integrator for an initial period of time.

6. Conclusion

Agriculture in India is carbon-intensive as diesel and coal-based electricity are the mainstay energy sources for irrigation. Solar irrigation may be explored to decarbonize the irrigation sector. Gradually falling prices of the solar provide an opportunity to increase investment in creative ways to deploy SIP across the country for providing sustainable irrigation solutions to the farmer and also to meet the country NDC commitment.

This report proposes three business models to supply water to farmers for irrigation. The business model scenarios could be analyzed further to consider context-specific viability. Grid integrated solar pumps would be more suitable for the conversion of electricity grid-based irrigation pumps to SIPs. It will minimize the recurring losses for DISCOM and electricity subsidy for the government at the same time considerably augment the supply of green electricity in the rural areas. The community irrigation model is suitable for the areas does not have electricity supply infrastructure available in the agriculture field. The irrigation entrepreneur model would be a viable solution only if it will generate a positive RoI (Return on Investment) for the entrepreneur setting up SIP in a particular location.

The shift in the source of energy from conventional to solar would result in emission savings. For the grid-integrated SIPs there would be two-fold emission savings: 1) emission reduction from irrigation energy use where SIP will replace fossil fuel-based grid electricity and 2) emission reduction from the use of the surplus energy generated by the SIP and sold to DISCOMs at a pre-determined FiT. Whereas, for conversion of diesel-powered irrigation pump to SIP it would be on account of reduction in diesel uses. Considering the total electricity supplied to the agriculture sector in Gujarat in the year 2016-17, if merely 35 percent of it would be replaced by SIP would result in a saving of 12 million tCO_2 equivalents per annum.

The study assumes a rural context both with electricity and without electricity infrastructure. It excludes the potential of mini-grid solar systems, which could simultaneously provide electricity for localized irrigation. At present, farmers, governments, private sector actors, and development investors show much interest in SIP as a solution to improving food and energy security and meeting climate commitment. The interest needs to be converted into action for expected outcomes.

About IRADe

IRADe is an independent advanced research institute which aims to conduct research and policy analysis to engage stakeholders such as government, non-governmental organizations, corporations, academic and financial institutions. Energy, climate change, urban development, poverty, gender equity, agriculture and food security are some of the challenges faced in the 21st century. Therefore, IRADe research covers these, as well as policies that affect them.

IRADe's focus is effective action through multi-disciplinary and multi-stakeholder research to arrive at implementable solutions for sustainable development and policy research that accounts for the effective governance of techno-economic and socio-cultural issues. Being Asia Center for Sustainable Development, we have been carrying out policy research and its implementation for enabling socio-economic growth and charting pathways for sustainable development in South-Asia.

IRADe was established under the Society's Act, in 2002 at New Delhi. It is certified as a Research and Development Organization by the Department of Scientific and Industrial Research (DSIR), Ministry of Science and Technology (MoST). It has also been selected as a Center of Excellence by the Ministry of Urban Development (MoUD) for urban development and climate change. In addition, it provides expertise to other ministries, national and international institutions and partners with other reputed organizations.

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