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Discussion Paper

Odisha

IRRIGATION SECTOR

ENABLING STATE LEVEL CLIMATE MITIGATION ACTIONS

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Introduction

India is highly vulnerable to climate change, where a vast population is still dependent on the growth of the agrarian sector. The country like India faces a twin challenge of rapid economic growth while addressing the global risk of climate change. India NDCs pledged to reduce the emissions intensity of its GDP by 33 to 35 percent by 2030 from 2005 level and achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030. India’s NDC goal is to reduce overall emission intensity and improve the energy efficiency of its economy over time, without having any sector-specific mitigation obligation. To achieve NDCs targets, the role of Indian states in promoting renewable energy initiatives, enhancing energy efficiency, and achieving long-term emissions reductions is of central importance. The agriculture sectors (crops, livestock, forestry, fisheries, and aquaculture) are significant contributors to greenhouse gas (GHG) emissions. Therefore, possible mitigation interventions for reducing agricultural GHG emissions can play an essential role in accomplishing India’s NDCs targets.

Odisha is one of the most important states of eastern India with high dependence on the agriculture sector. The agriculture sector in Odisha employs 48 percent of available labour and contributes 19 percent to the state’s domestic product. The average land ownership in Odisha is lower than the national average (Government of Odisha, 2019) The fragmented land holding limits the farmer’s ability to invest in agriculture and related infrastructure. As per agriculture census, 2010-11, of the total irrigated areas, 70.39% area is irrigated by canals, 4.92% tanks, 2.24% wells, 5.64% tube wells, and 16.81% through other sources (Activity Report, Odisha, 2017-18).

During the field survey, farmers revealed that canal irrigation infrastructure in Odisha suffers several challenges such as reduced operation and maintenance, poor canal water management, etc. Many a time water is not available in a canal when they need it for irrigation. Canal irrigation also has an issue with water availability at tail-ends. Therefore, even though the canal is available in the area, many farmers are still forced to run diesel engines to pump groundwater for irrigation. Rising diesel prices, and therefore irrigation cost has severely dented the farm profitability. In the absence of low-cost irrigation alternatives, many farmers grow only one crop in a year during the rainy season and leave the farm uncultivated during other seasons. Several farmers informed that low farm productivity is forcing them to lease their land on rent and look for more remunerative employment.

Limited crop diversification, low cropping intensity due to the unavailability of irrigation infrastructure are important factors for low productivity in the sector. The availability of affordable irrigation facilities can improve agricultural productivity and lead to rural prosperity. It will provide farmers an option to increase cropping intensity and diversify to more remunerative cash crops. Odisha government had introduced many irrigation schemes to assist small and marginal farmers through pumping equipment energised through kerosene and diesel (Greenpeace, 2019). Over time, these schemes did not succeed due to problems in fuel procurement in the faraway areas.Similarly , the bore well scheme launched in 2011 failed because farmers were unable to afford the burden of huge maintenance and operational costs. Regular power cuts and uncertain electricity are a significant irrigation bottleneck, especially in the Rabi season, where the dependency on irrigation is relatively high compared to the Kharif season (Greenpeace, 2019).

There is a growing interest in Solar Powered Irrigation Systems (SPIS)around the world due to its dual purpose for climate change adaptation and mitigation. Solar-powered irrigation pumps can make farmers more resilient against the erratic shifts in rainfall patterns caused by climate change. Solar water pumps offer a viable alternative for irrigation, with significantly lower GHG emissions compared to fossil fuel-based electricity or diesel driven pumps. Solar water pumps are not merely environment friendly, but its operation is much more economical than diesel pumps over its life-cycle. In Odisha, this technology requires special attention in rural areas where grid connectivity is either absent or weak, and farmers have to often resort to diesel pumps for irrigation. Given this background, it is imperative to assess the solar water pumps (SWP) suitability for Odisha agriculture, and also it's potential in contributing to India's NDCs target.

This study aims to assess solar deployment in Odisha and analyse market-based solutions that would facilitate the effective implementation of irrigation policies. This study would support in understanding the feasibility of solar-powered irrigation in the state. The specific objectives of this study are as follow:

- To promote low carbon irrigation, which may assist in achieving India's NDC targets through the adoption of solar water pumps?
- To assess a viable state level policy to incentivise both farmers and DISCOMs.
- To analyse market based solutions that would facilitate effective implementation of irrigation policies.

1.1. Availability of water and need for solar irrigation

As per CGWB, net annual groundwater availability in the state is 21.01 BCM, and the annual replenishable groundwater resource is 23.09 BCM. The state has a cultivated land of 61.80 lakh hectares out of which merely 38.30 lakh hectares had irrigation facilities by March 2017. A major share of cultivated land is predominantly rain-fed, and groundwater constitutes a small share in gross irrigation infrastructure created in the state. The abundance of surface and groundwater resources (high groundwater table) provides an opportunity to increase agriculture productivity by expanding the area under irrigation and, in turn, farmers' income. In the absence of irrigation facilities, farmers grow rain-fed crops only. Many a time, they leave agriculture altogether as growing merely one produce in a year is not remunerative enough for them to stay in agriculture.

Farmers grow kharif rain-fed rice and rabi gram in low lying lands. But the unpredictability of rainfall patterns in the recent years is likely to affect this. Figure 1 shows the monthly distribution of rainfall concentrated during Kharif season even though there is a wide variation across the districts. The rainfall pattern implies that during the Kharif season, water requirement of many crops may be fulfilled by rainfall barring few areas experiencing a long dry spell. However, the use of groundwater is pertinent for irrigation during the rabi and summer season. Unavailability of irrigation facilities limits the farmer's ability to grow crops during these seasons, reflected through the low cropping intensity of the state.

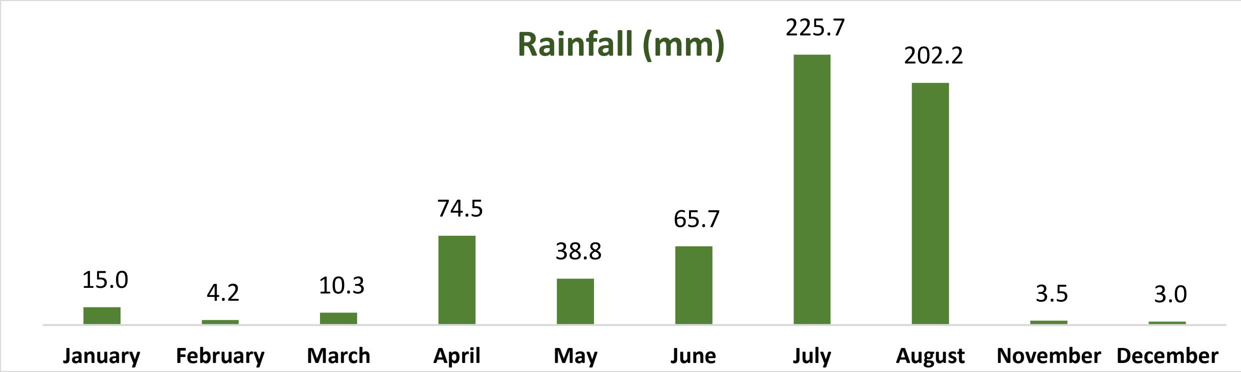

Figure 1: Average monthly distribution of rainfall in districts of Odisha in 2015

Data Source: Indian Metrological Department

In the absence of clean irrigation technology, the use of diesel-powered irrigation pumps leads to substantial environmental costs in terms of emissions and noise pollution. Running diesel pumps is expensive and time-consuming as it requires frequent trips to the market for purchasing fuel resulting in high operating costs. Electricity distribution companies (DISCOMs) are also under pressure owing to the provision of subsidised and cross-subsidised electricity to agricultural farmers.

1.2. Current SWPs policies in Orissa

As an action plan to increase irrigation access and water use awareness, the state government has come out with a set of reforms and policies over the years. Further, the government has introduced plans to capture the state's potential for renewable energy with an emphasis on solar energy use for irrigation. As per the Ministry of New and Renewable Energy (MNRE), the estimated solar potential for Odisha is 25.78 GWp. Odisha receives average solar radiation of about 5.5 kWh per square meter area with around 300 clear sunny days every year.

There are approximately 7,079 solar pumps in the state(MoSPI, 2018). Under the solar water pumping project, 191 solar irrigation projects targeting 886 farmers for irrigation provision had been approved. Two capacity types, 3kWp and 5kWp pumps were provided by Odisha Renewable Energy Development Agency (OREDA) to support irrigation facilities for year-round cropping. Around 53 pumps of 5 kWp and 531 pumps of 3 kWp had been installed till 2017.

The state government had introduced a solar water pump scheme called "Soura-Jalnidhi-Yojana". Under this scheme, dug well-based solar water pumps were provided in remote areas with no access to an electricity supply. This scheme aimed at increasing the irrigation potential and cropping intensity in the remote regions. Approximately 5000 solar water pumps with a subsidy up to 90% would be distributed across the state covering an area of about 2500 acres. In its first phase, the scheme encompasses areas facing an extreme energy crisis. Small and marginal farmers with a minimum of 0.5 acres of land and a dug well would be allowed to benefit from the scheme. The scheme not only aims to increase irrigation access of pump owners but also water buyers who can benefit from the surplus water sold by the solar pump owners.

A pilot project conducted in the Rayagada district found that solar water pumps provided in a combination of loan and subsidy to tribal farmers with small landholdings have the potential to double their income and reduce seasonal migration to distant areas. Prior to solar pumps, agriculture was mostly rain-fed, with irrigation restricted to dug well. With the help of SWPs, farmers could cultivate in the Rabi season as well. Consequentially, the area under irrigation as well as cropped areas, supplemented farmers' income(Chamola, 2017).

2. Methodology

The study utilizes both qualitative and quantitative methods. While the qualitative methods involve stakeholder consultation, expert interviews, and group interviews of farmers, the quantitative method comprises data analysis using both primary as well as secondary data. To achieve the objectives of the study, a framework comprising of stakeholder consultations, district selection, survey designing followed by an appropriate analysis had been chosen (Figure 2).

Stakeholder consultation

Study design and objectives were discussed and improved in consultation with local selected stakeholders such as GRIDCO, CESU, OREDA, Ministry of agriculture, OLIC, civil socities and etc.

Background study and Primary survey

Background study was conducted through review of official documents, grey & published literature. Questioannaire was designed to conduct sample survey with farmers in Dhenkenal, Khorda, Cuttack &Puri districts.

Analysis and report writing

Primary and secondary data collected were analyzed usign speadsheet based analysis techniques, based on the anlysis report was prepared .

Figure 2: Research methodology framework

An inception meeting for stakeholders was organised on January 29, 2019 at Swosti Grand Hotel Bhubaneswar, Odisha. The scope of the study was discussed at the inception meeting with stakeholders representing government representatives from concerned organizations, researchers and academicians, private sectors, and civil society representatives. The study scope was revised to accommodate the feedback received from stakeholders in the inception workshop.

We selected districts based on electric and diesel irrigation availability in the state in consultation with researchers working in the agriculture sector in Odisha. We decided on four adjacent districts, Dhenkanal, Cuttack, Khordha, and Purito, to conduct farmer's survey to capture their perspective. This particular selection criterion was used because the study aims to assess the feasibility of shifting irrigation to SWPs use.

Questionnaire of the study aimed to collect data on cropping patterns, pump types (diesel, electric and solar, if any), cost of irrigation and methods used, problems associated with the current irrigation structures including the availability of electricity near the field and farmers' perception on the current solar pump scheme of Odisha government. This questionnaire enabled better understanding the potential of SWPs and farmers' willingness to adopt the same.

In this study, we have analysed two models: i) Grid connected SWPs in areas where electric supply infrastructure is available and reliable and ii) Community based standalone SWPs for areas where electricity supply infrastructure is not available or poor. In the first model above SWPs would replace grid electricity while also feeding the surplus generated electricity to grids. In the second, it would replace diesel water pumps.

2.1. Conversion of grid connected electric pump to solar pump

The bulk power purchase cost of CESU (DISCOM) is Rs 2.99/unit, while the cost of power supply for agricultural connections is Rs. 4.99/unit[1] (calculated as the ratio of the estimated purchase cost to estimated sales, including transmission charges while excluding distribution losses)(OERC, 2019). The average tariff charged from agricultural consumers is Rs 1.5/ unit. As per the officials at OERC, DISCOMs losses (the difference between tariff and actual supply cost) on account of supplying electricity for agriculture are cross-subsidised by industrial consumers. Unlike many other states of India, Odisha government does not provide any subsidy to DISCOMs for supplying cheap power to agriculture consumers. Therefore, the proportion of the electricity supplied to the agriculture sector through SWPs would imply indirect savings for other consumers of DISCOMs. Every unit of deferred electricity supply to agriculture consumers by DISCOM would save them Rs. 3.49 in the form of a cross-subsidy burden charged to the other consumers.

The net return calculated from the solar water systems under various subsidy scenarios (provided by government) and different evacuation tariff rates paid to the farmers by DISCOM. We have assumed 25 years of life for solar panel; hence the calculation of the net return also takes into account the project life of 25 years. It has been assumed that for the first seven years, system maintenance cost for the farmers would be negligible as system integrator provides free maintenance under installation contract. But after the 7th year of installation, every year, farmers would set aside 15% of the revenue from selling surplus electricity to DISCOM as regular system maintenance cost.

[1]Tariff notification, march 22, 2018 of Central Electricity Supply Utility of Odisha

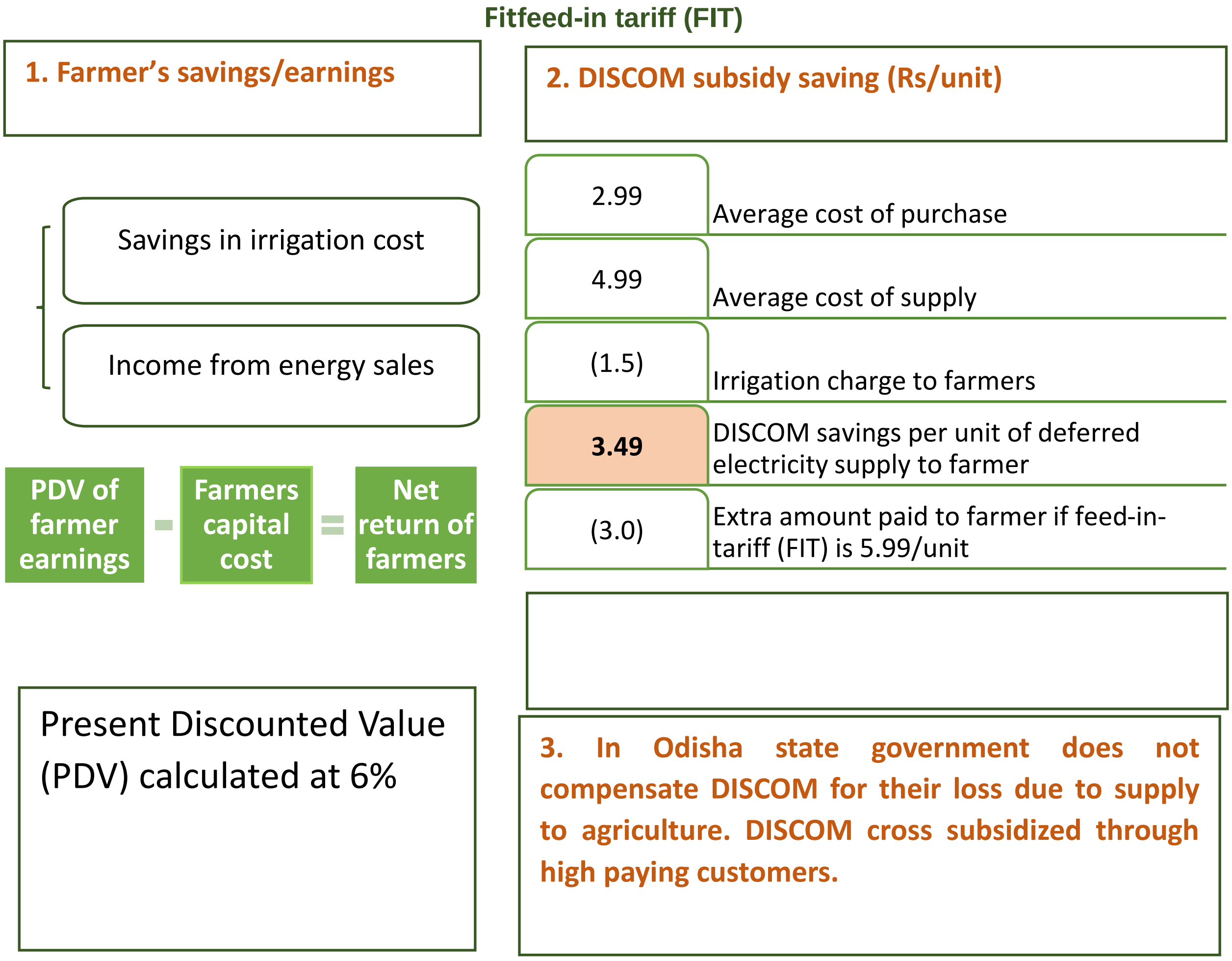

Figure 3: Methods for calculating net returns for grid connected SWP

Considering the relatively better groundwater level in Odisha, even small sized SWP would be able to lift water. We have reviewed 3 solar water systems of panel sizes 5.1 kWp, 10kWp, and 15kWp. The market prices for the selected SWP are as per table 1.

Table 1: SWP price considered for IRR calculation

Module	Solar pump cost (Rs.)
5.1 kW	244800
10.kW	489600
15 kW	660000

Data source: (OREDA, 2018)

To estimate the energy produced by a solar panel,formula given in equation [1] was used.

$$E = A * r * H * PR \;\ldots\ldots\ldots\ldots[1]$$

Where,
E = Energy (kWh) produced by the panel
A = Total solar panel Area (meter^2)
r = solar panel yield or efficiency (%) considered as a constant 15 percent
H = Annual average irradiation on tilted panels (shadings not included).

To calculate "H" we have used average solar radiation received by Odisha i.e. 5.5 kWh/ Sqm/day for 300 sunny days in a year.

PR = Performance ratio, to estimate the PR we have used coefficient for different types of losses which range between 0.9 and 0.5 and a default value = 0.75.

As per our calculations, 1 kW solar panel will generate average annual energy of 1015 kWh effective electricity. Our calculation accounts for the losses such as transmission, inverters and other factors such as site, technology and size of the system, the study took the performance ratio as 0.78 (table 2).

Table 2: Losses details (depend of site, technology, and sizing of the system)

Types of losses	% assumed
Inverter losses (6% to 15 %)	6
Temperature losses (5% to 15%)	8
DC cables losses (1 to 3 %)	2
AC cables losses (1 to 3 %)	2
Shadings 0 % to 40% (depends of site)	3
Losses weak irradiation 3% to 7%	3
Losses due to dust, snow... (2%)	0
Other Losses	0

Source: IRADe's Analysis

The annual solar energy used for irrigation by farmers has been considered to be 40%[2] of the total energy generated by the panels. The effective price of electricity used by farmers for irrigation under agricultural connections is INR 1.50/kW; this has been considered as positive cash flow from irrigating land using SWP. The surplus electricity available for sales to DISCOMs is the difference between total electricity generations by the panel and consumption by farmers either for own irrigation or for selling water to other farmers. Depending on the DISCOM tariff and government support as per scenario, we calculated farmers' cash flow from selling energy back to the grid. Estimated Present discounted value (PDV) of both the savings in irrigation cost and income from energy sales at a fixed rate of 6 percent. Excess of this over the capital investment of farmers has been considered as the net return of farmers.

Comparative calculations performed of the net return for farmers, DISCOMSs as well as the government under three scenarios.. The Sum of returns to three stakeholders makes the net social return.

I. No capital subsidy by the government provided to farmers for purchasing SWP. Farmers get an evacuation tariff of Rs 2.99/unit (which is equivalent to average bulk electricity purchase price of electricity for DISCOM) from DISCOM for surplus electricity sold. A complete market-based model without any external incentive.
II. An upfront capital subsidy of 60% (reduce effective price for farmer) by the government to the farmers on purchase of SWP and farmers gets an evacuation tariff of Rs 2.99/unit.
III. An upfront capital subsidy of 15% provided to the farmer by the government. An evacuation tariff of Rs.5.99 per kWh by the DISCOM for surplus electricity sold by farmers to DISCOM.

[2] SPICE cooperative, Dhundhi data suggests that nearly 35% solar energy, of the total generation, is used for irrigation. We have kept it slightly on the higher side (40%) for our analysis.

Apart from the financial viabilities and financial implications for the stakeholder, emission reduction from the use of SWP has been calculated for solar water pumps of varied capacities.

2.2. Community irrigation model – stand-alone solar irrigation pump

Crop failure held back by lack of access to affordable energy services for irrigating farmland may drive small landholder farmers into a debt trap and push them into poverty. . Community irrigation solution may enable smallholding farmers to access irrigation water year-round whenever required, including during dry seasons.

Under this model for each irrigation communities, we propose a 20-hectare parcel of land irrespective of the number of farmers. Depending upon the existing cropping patterns followed by the farmers in the community, we could specify and install a pump of appropriate size (HP), which would meet the irrigation requirements of the community members.

2.2.1. Water requirement for crop production

The model is an MS-excel based model, which takes into account physical, geographical and economical factors. To calculate the water requirement for crop production, we used equation 2 specified by ICAR[3]:

$$\text{Average water requirement per day } (W_d) = \sum_{c=1}^{n} (A_c \text{ X } W_c)/C_d \qquad (2)$$

Where

W_d= Water requirement (cu.m) per day
A_c = Cultivated area (in hectare) under crop c
W_c = Water requirement for crops (in mm)
C_d = Crop cycle (days) where number of crops grown by farmer in a season is (1......n)

We have considered three seasons namely, Kharif, winter, and summer.In each season, different crops have been cultivated. For instance, in the month of Kharif, we assumed two important crops i.e., paddy and vegetables. Paddy is one of the major crops, cultivated in almost all parts of Odisha. Data on water requirement for each crop grown in a particular season is taken from Odisha Lift Irrigation Corporation (OLIC), which also takes into account the rainfall (mm) in the cropping season. The net water requirement of the crop is the demand for water, which may not be satisfied by the rainfall during the crop cycle. The allocation of land to different crops in a cropping season is done based on the observation of existing cropping patterns adopted by the farmer.

Table 3: Data for the calculation of crop water requirement

Seasons	Crops	Crop cycle (days)	Area (in Hect)	Water requirement of crop, total (in mm)	Water required (cu.m)	Water required (cu.m/day)
Kharif	Paddy	120	16	300	48000	400
	Vegetable	75	4	190	7600	101
Winter	Paddy	100	2	1250	25000	250
	Pulses	90	13	120	15600	173
	Ground nuts	90	1	380	3800	42
Summer	Vegetable	120	4	750	30000	250

Source: *Authors calculation*

[3] http://www.iiwm.res.in/pdf/Bulletin_67.pdf

From table 3, we found that the average water requirement for all three seasons for cultivating crops in 20-hectare land is 406 cu.m/day, and the peak water demand is 501 cu.m/day. Assuming, a transmission loss of about 20% in the water flow process, (pump to the field) a water pump operating for 8 hours in a day and having a flow rate of 17 l/s (litre per second), 21 l/s would be able to meet the average and peak water demand respectively.

2.2.2. Cost of irrigation for pumps energized through different energy sources

The size of the pump exclusively depends on the flow rate required to meet the irrigation needs and hour of operation each day for an agricultural field. Pump efficiency, motor efficiency, bore-well depth, and head are other important factors that determine the pump size. The flow rate is the maximum flow required to meet the water demand of crops within a given crop period. The necessary initial capital for setting up an irrigation system is directly proportional to pump size.

Table 4: Irrigation pump types required to irrigate 20 hectares community land

Pump type	Capital Cost	Operation hour (hour/year)	Energy required (diesel- litre, electricity –kW)
Diesel engine based Pump set (12 HP)	60000	816	2.4
Electric Pump set (9 kW)	90000	816	8.82
Solar Water Pump with Solar panel 12kW	518400	816	8.82

Table 5: Fuel cost for running pump sets

Fuel type	Fuel cost (annual)
Diesel	142838
Subsidized electricity	12586
Not-subsidized electricity	37,307
Solar electricity	32970

Notes: For fuel cost calculation

a) subsidized electricity @ 1.55/kWh and Non subsidized @ 4.99/kWh; Electricity duty 0.05 / KWh; Fixed Charge @ 30 first KW and @ 20 for subsequent kW per month; A fixed Meter rent 100 per month are considered,
b) Diesel @ 72.93/ litre,
c) Annual solar electricity cost is the depreciation cost of solar panel. Panel life considered is 25 years and an annual effective interest rate of 6%.

We have estimated irrigation costs per hectare for each of the available irrigation solution (diesel pump, electric pump, and solar water pump) for comparison. Irrigation cost calculation takes into account capital cost as well as running cost for energy used (table 4a and 4b). Other costs, such as labour involved in irrigation or maintenance cost is not considered as we assume it the same for the different pump types. We propose community engagement in management and ownership of pump whereas ongoing technical support and repairs would be provided by the system integrator.

3. Analysis and results

The cultivated land area cannot be increased; hence irrigation is one of the most critical inputs for enhancing agricultural production to meet the food requirement. Groundwater irrigation is an important means to ensure assured access to irrigation given erratic rainfall and the absence of surface water irrigation systems. Currently, farmers in Odisha either relies on rainfall or uses diesel pump for irrigation as access to an electric pump or solar pump is available to a very small section of farmers. Moreover, the availability of electrical supply for irrigation is mostly erratic and, in many places, it is available only during late night hours when the urban demand is low. Limited and unreliable access to the electricity prompts the farmers to depend on high-cost diesel-fuel generators for water pumping in several places.

Table 6: Current irrigation options available to farmers in Odisha, their advantage and dis-advantage

Irrigation scenarios	Advantages for farmers	Disadvantages for farmers
Purchase water or rent a pump from a neighbour	Zero investment	High cost of irrigation; tariff subject to local market fluctuations; often causing delays in accessing irrigation (due to queuing).
Own a diesel pump	Low capital cost; portability of pumps makes it easier to use on fragmented land-holding and to share.	High operating cost; subject to local availability of diesel; creates noise and air pollution.
Own an electric pump	Low capital cost; low operation cost with subsidized electricity	Availability of grid; intermittency of power availability
Purchase water from a government pumping station	No upfront capital and low operating cost	Very limited availability
Own a stand-alone solar pump	Almost zero operating cost; clean and efficient pump; not portable.	High capital cost; new technology with limited after-sales support; operating hours limited to daylight.
Own a solar pump and sell water to neighbours	Almost no operating cost; clean and efficient pump; revenue for the farmer at no additional operating cost.	High capital cost; operating hours limited to daylight; time component of crop irrigation requirements limit sharing; supply of surplus energy varies seasonally.

With advancements in technology, the reduction in the cost of solar photovoltaic panels is making the application of solar pumping for irrigation more and more attractive. The situation offers a huge potential for solar pumping systems. Replacing existing diesel operated and electric grid connected irrigation pumps would provide a good opportunity to replace low quality pumps with an efficient solar pump. The efficiency of solar pumps is generally higher which helps in partially compensating the cost of replacement. But the replacement of long-established diesel and electricity run pump-sets with solar pumps would need capital investments and other promotional incentives. This analysis looks at the macroeconomic level of the potential benefits to different stakeholders.

3.1. Transforming electric pump to grid connected SWP

Electricity supply infrastructure for irrigation to the agricultural fields is mainly unavailable in Odisha, reflected through the use of electricity for irrigation. As per CEA- Ministry of Power (2018), Odisha’s DISCOMs supplied 327 GWh to the agriculture sector in the year 2016-17. However, electricity demand for the agriculture sector in the state is likely to increase as farmers prefer shifting from costly diesel water pumps to other energy pumps wherever possible.

To start with, we can convert all the grid connected irrigation water pumps to grid connected SWPs. Considering the implementation challenges and the quantum of funds required, we have analyzed it under three different scenarios discussed as follows:

i) Conservative scenarios: conversion of electric pumps corresponding to 10 percent of annual electricity supply for irrigation to grid-connected solar PV irrigation systems and similarly,
ii) Plausible scenario: conversion of 20 percent of annual electricity supply for irrigation,
iii) Optimistic scenarios: conversion of 35 percent annual electricity supply for irrigation.

Under each of these three scenarios we have analyzed implication for three important stakeholders, namely 1) DISCOMs, 2) farmer, and 3) government. Replacement of electric water pump to grid-connected solar water pump would increase the share of renewable in the agriculture sector that will translate into the lower carbon footprint of the agriculture sector. The emission reduction from this is estimated and considered as the positive externalities for the environment.

3.1.1. Clean energy generation and utilization

Solar energy is produced almost every day by a panel with varying wattage depending on sunshine whereas irrigation is not required throughout the year. An analysis of solar electricity generated by DSUUSM cooperative in Gujarat between January 2016 and May 2018, reveals that the cooperative farmers used 36.9 percent for irrigation, and 63.1 percent was fed into MGVCL grid. Even though they claimed that they had irrigated nearly three times more area than with diesel pumps and they are also serving many farmers as a water seller to irrigate their fields. Taking a cue from this study, we have assumed that farmers will consume an estimated 40% of the electricity generated by the solar water pump for pumping water, and surplus 60 percent will be fed into the grid to meet local electricity demand. Figure 4 below depicts the solar electricity consumption by the agriculture sector and availability of surplus energy for the grid under the three scenarios.

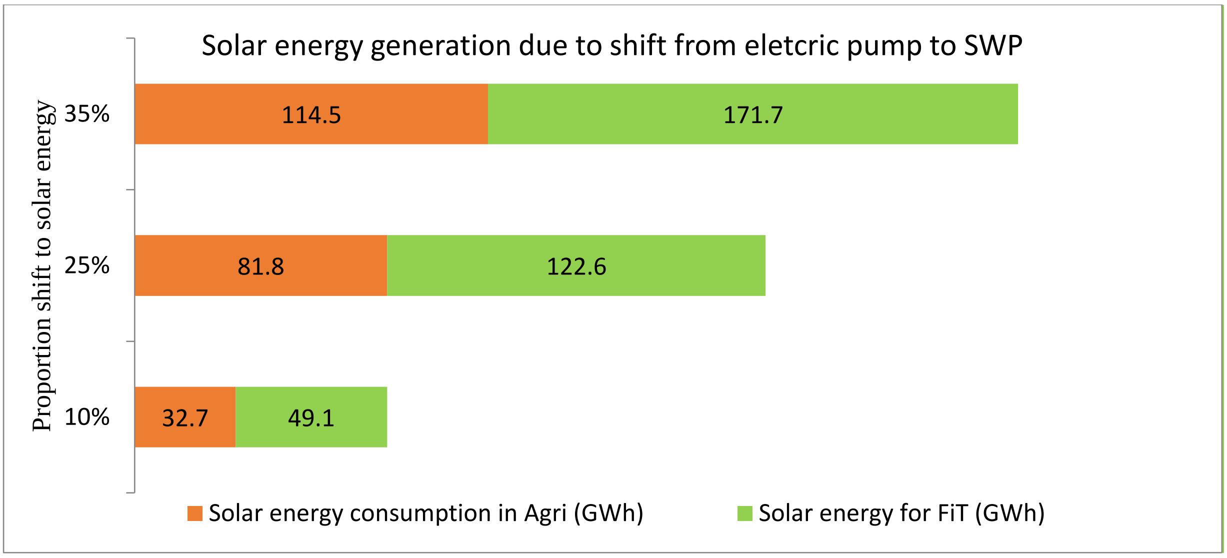

Figure 4: Solar energy in agriculture and FiT (GWh)

Source: IRADe'sanalysis

Based on our calculation that on average, 1 kW panel generates approximately 1015 kWh per annum, the solar PV panel capacity required for the energy generation under these scenarios was estimated. Figure 5 depicts the solar panel load required. Given the market price to install solar powered water pumps of 72 kW, 181 kW and 254 kW need 3189 Rs. Million, Rs. 7973 million and Rs. 11162 million respectively upfront capitals.

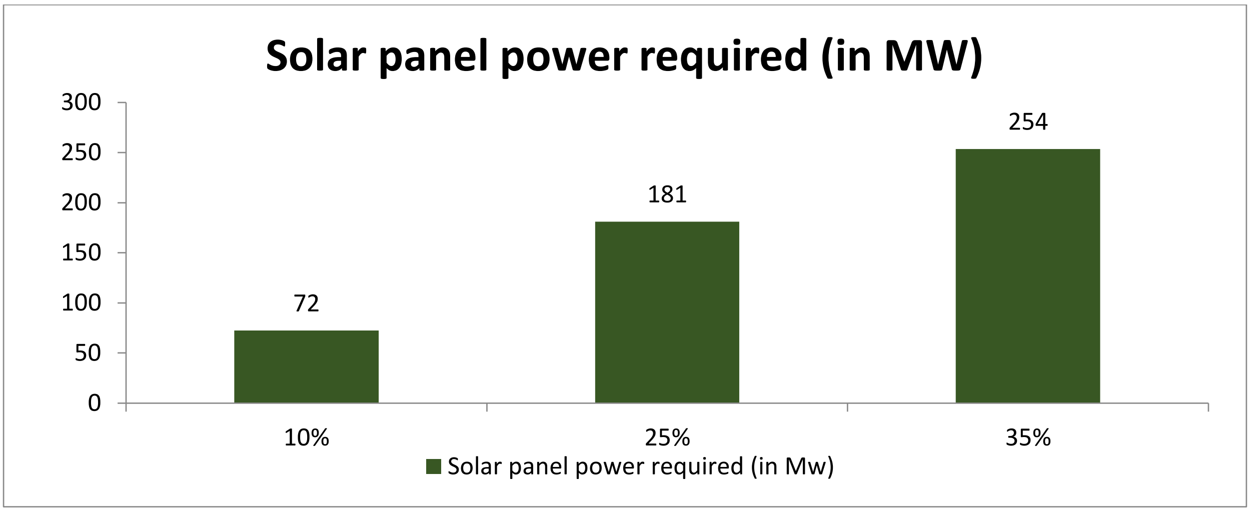

Figure 5: Required Solar PV panel capacity (MW)

Source: IRADe's analysis

3.1.2. Economic impact on DISCOMs

The role of DISCOMs is very important for the successes of grid-connected SWP as they have to evacuate surplus power generated and pay to the farmers. Farmers could use solar energy generated either to meet their irrigation requirement or to sell irrigation services to other farmers. The unpredictability of farmers' electricity consumption demand makes the forecast for surplus electricity available for evacuation a cumbersome task for DISCOMs and also involves monitoring and maintenance cost. Therefore it is important to understand the benefits that DISCOMs may derive with this scheme to come on onboard. Unlike the solar rooftop scheme where higher electricity tariffs make rooftop solar systems more attractive to high-paying commercial and industrial consumer segments therefore DISCOMs fear a decline in revenue from their best-paying consumers. Agriculture consumer subsidized by either government or by DISCOMs through cross subsidy to other high paying consumers. Given the average per unit electricity supply cost at Rs. 4.99 and an agriculture tariff of 1.50 per unit, DISCOMs would be able to save Rs 3.49 per unit on avoided supply to agriculture consumers.

Figure 6 depicts the annual subsidy savings of DISCOMs with solarisation of electric feeders. As mentioned in the methodology section, Odisha DISCOM would be able to save through cross-subsidy provided on the irrigation electricity supply. The annual subsidy saving of DISCOMs is 3.6 percent of the required upfront capital investment for the installation of a solar water pump system. In addition to this, DISCOMs would also benefit by asking customers to surrender their renewable credit and use it either to meet their RPO obligations or earn money by the future market value to Renewable Energy Credits (REC). DISCOM would also be able to save on the transmission and commercial losses on the surplus electricity evacuated from the farmers for supply to other high paying consumers in the local area.

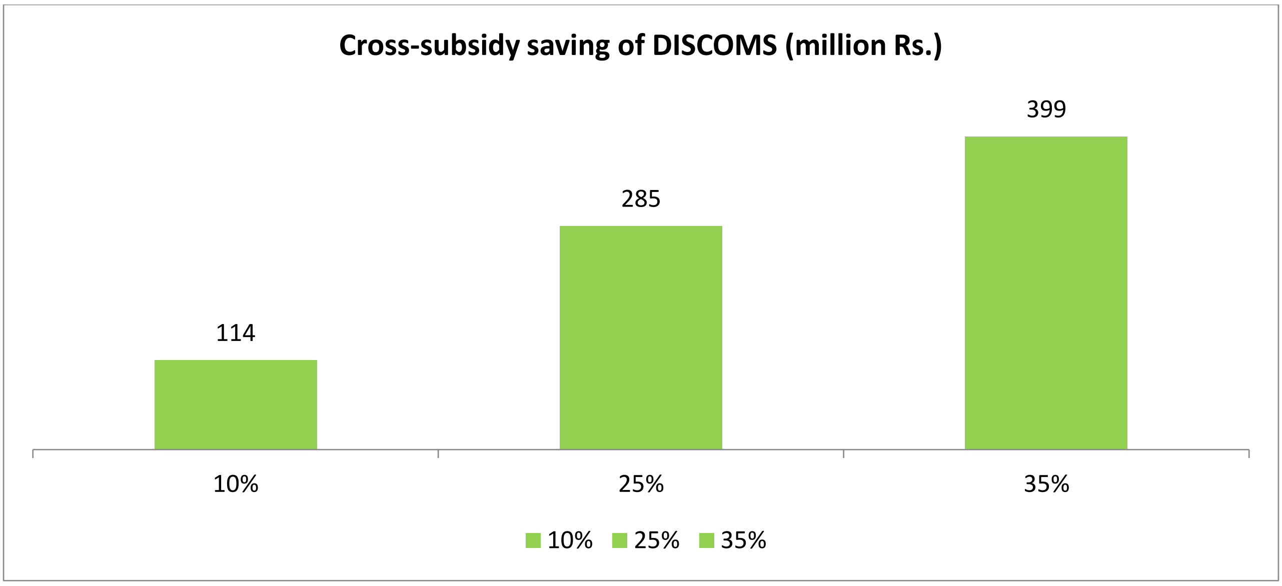

Figure 6: Cross-Subsidy savings of DISCOMs

Source: IRADe's analysis

3.1.3. Environmental impact

The use of renewable energy sources has the potential to decrease emission footprints of the agriculture sector. We have estimated CO_2 emissions from the potential conversion of an electric pump to solar pumps. The analysis uses estimated useful annual energy provided by solar pump or avoided electrical energy utilization in the conventional pump or surplus electricity feed into the grid by solar pump owner. The underlying assumption here is that grid electricity is produced using fossil fuel based energy sources, and the operation of solar water pump is free of GHG emissions.

Therefore, under the mentioned scenarios, there would be two-fold emission savings: 1) emission reduction from irrigation energy use where SWP will replace fossil fuel based grid electricity and 2) emission reduction from the use of the surplus energy generated by the systems and sold to DISCOMs at a pre-determined FiT. In Figure 7, emission savings per annum from both were estimated using the Weighted Average Emission Rate of India i.e.0.82 tCO2/MWh for 2013-14 (CEA-GoI, 2014). The adoption of solar irrigation systems could potentially reduce the GHG emissions from 67.04 thousands tCO2-eq to 234.65 thousands tCO2-eq per year depending upon the share of conversion of an electric pump to a solar pump.The grid-connected solar pump apart from reducing emissions, may also lower agriculture's water consumption as electricity used for irrigation has an opportunity cost in the form of forgone evacuation tariff. The positive externalities in the form of optimal water use efficiency in irrigation would further reduce the irrigation energy demand.

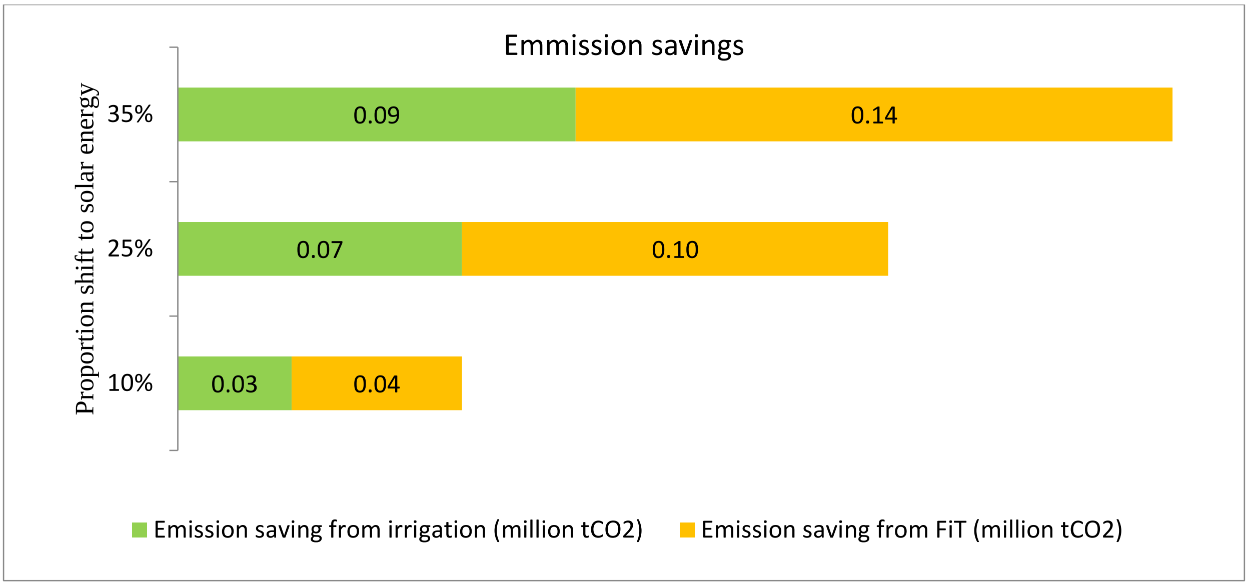

Figure 7: Emission savings per annum (million tCO2)

Source: IRADe's analysis

As per REC data at Indian Energy Exchange (IEX) simple average cleared price for monthly traded solar REC in January 2020 was Rs.2400/MWh. Considering this as a constant price for REC, the values of REC generated by conversion of pumps to SWP varies from Rs 196 million to Rs 686 million per year depending upon the proportion of conversion of an electric pump.

3.2. Economic viability of grid connected SWPs for farmers, DISCOMs and government under different financing mechanism

Figure 9 presents the schematic framework for grid-connected SWP and interlinkage among the stakeholders involved. The study focuses more on the financial aspects of SWP adoption. The principal motivation is to understand GHG emission reduction potential, identify avenues for sustainable income for the farmers, and optimize the use of groundwater for irrigation.

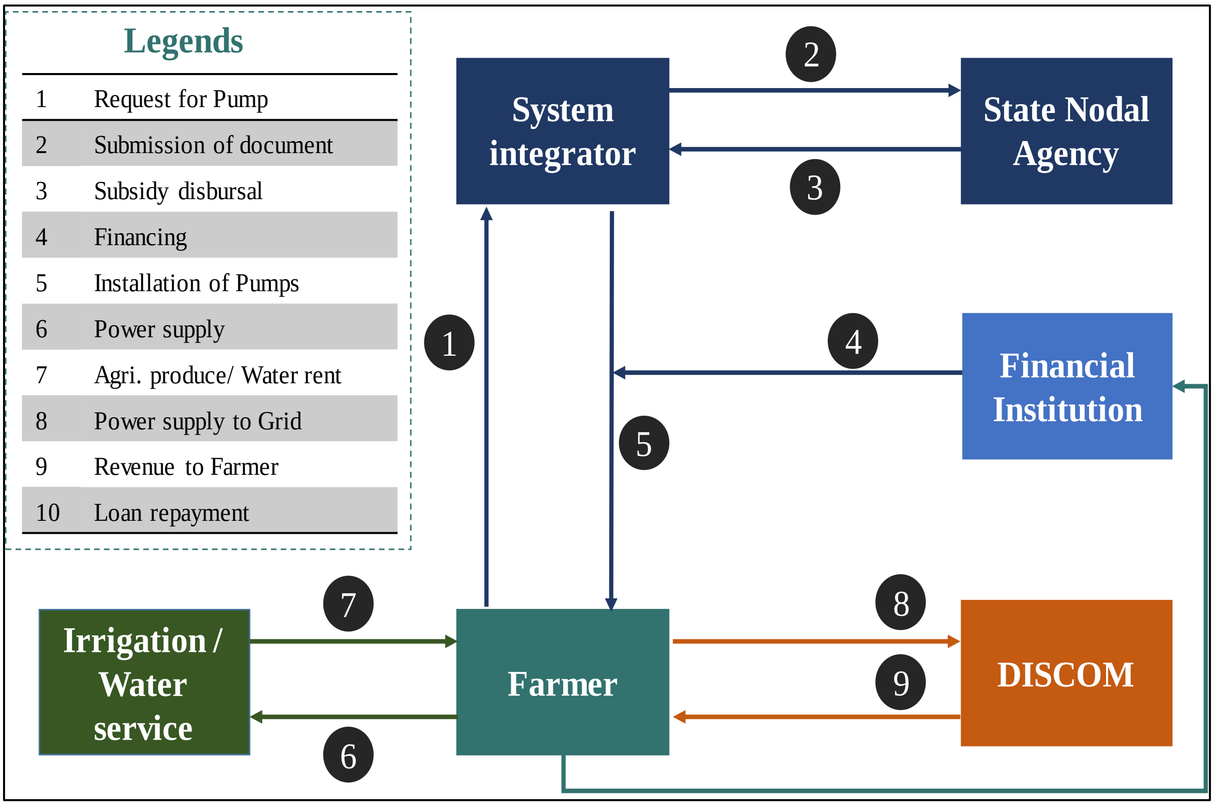

Figure 8 : Schematic framework of grid connected SWP

Source: Created by IRADe

Under this framework, customers (farmers) own, partially finance, and manage the operation of the SWP system. System integrator's role is limited to the installation of the SWP system and provision of technical service in demand to the customer. The government representative, state nodal agency, facilitates the adoption of SWP by formulating suitable policy. The role of a financial institution (Scheduled Commercial Bank/Private financer/any other government-designated agency) would be to provide a part of initial capital for SWP purchase and installation. DISCOM plays an important role in supplying SWP installation permits, evacuation of surplus electricity from SWP, payment for the same to the pump owners, and resolving technical issues related to electricity evacuation. Repayment of interest and capital to the financial institution remains a farmer's responsibility. A farmer may either use generated electricity for irrigation, selling water to irrigate fields or supply it to DISCOMs.

Financial evaluation of net returns from SWP for the stakeholders has been considered under three scenarios. Scenario I (S-I): Solar water system is bought at the market price (no subsidy). Scenario II (S-II): Farmers receive 60% capital subsidy on the solar water system. Scenario III (S-III): Farmers receive only 15% capital subsidy on SWP, but a tariff rate of Rs. 5.99 per kWh by DISCOMs for evacuated electricity. In this scenario, farmers are getting an incentive of Rs. 3.0 per kWh over and above the bulk tariff rate of DISCOMs. Further, it is assumed that after the 7th year of installation, every year farmers spend 15% of revenue as the maintenance cost for SWP similar to other scenarios as the system integrator would be responsible for free maintenance as per contract for initial 7 years.

Table 7: Scenarios under which net returns have been calculated

Scenarios	**Schemes**	**I**	**II**	**III (Proposed)**
	Capital subsidy	0	60%	**15%**
	DISCOM tariff rate (Rs./unit) offered for evacuated electricity from SWP farmer	2.99	2.99	**5.99**

Source: IRADe's Analysis

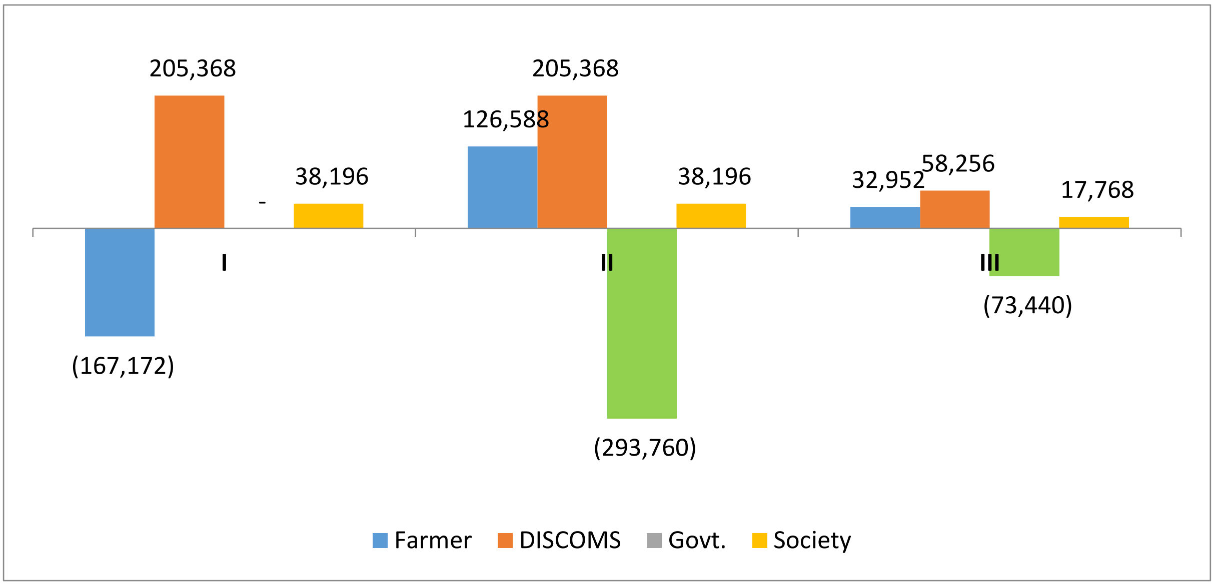

Figure 9: Net return for a 10 kW system among farmers, DISCOM and government

Source: IRADe's analysis

The net return shown in figure 9 is for a 10 kW system. We can see a net positive social benefit (a sum of benefits to each stakeholder) across three scenarios. DISCOM is the absolute gainer in all these scenarios even after paying a high price to farmers for evacuated surplus electricity. In scenario -1 there is no loss to the government, but farmers had to pay an exorbitant price for it. Considering the financial health of farmers, arrangement of huge upfront capital would be difficult for them . This will undermine the scheme to attain its true potential. Under scenario -2, the cost to the government is high and similar to scenario-1 realising the true potential of scheme would be difficult. In scenario -3, the cost to government is low, while the other two stakeholders' i.e., the farmer and DISCOM would gain from it . Under the given scenarios, we propose scenario -3 to unleash the full potential and extend the benefits to a large number of farmers.

3.3. Community Based Solar Pump model

In Odisha, where there is a lack of availability of grid-based power supply to energise irrigation pumps the choices for powering pumps are usually diesel/kerosene even though solar can be a viable alternative to these fuels. There are very distinct differences between the two power sources in terms of cost and reliability. Diesel pumps require a lower initial cost but a very high operation and maintenance cost whereas solar-based pumps require higher initial cost but very low ongoing operation and maintenance costs. In terms of reliability, it is much easier to keep a solar-powered system running than a diesel engine. Farmers need to purchase diesel from a diesel pump station, whereas solar energy is readily available. The availability of diesel in rural areas for irrigation is not always guaranteed, diesel pumps may run dry for several days. Even with a greater degree of reliability, the initial cost of solar is often daunting. It limits the adoption by poor farmers in the absence of any external support.

The pattern of irrigation requirements is also responsible for the low adoption of expensive solar irrigation system. Irrigation water requirements would depend on the cropping pattern adopted by the farmer and rainfall during the cropping season. Solar pumps run on solar energy, and their performance fluctuates based on the intensity of solar radiation. During winter and rainy season, solar radiations are generally low and hence the reduced performance of the solar pump.Fortunately, irrigation requirement for the crops grown during these seasons is also low.

The irrigation water requirement is uneven throughout the year. Crops are generally required to be irrigated only for a limited number of days of the crop cycle. Therefore, the choice of the size of the solar pump is an important consideration. It should be sufficient to meet water demand during peak demand periods; otherwise, farmers would have to opt for other irrigation means, preferably diesel pump sets. However, the higher capacity solar irrigation pump might also have other implications: such as increase in the project cost and underutilized capacity for a significant duration of the year. A larger water storage tank may be an answer where water can be stored for irrigation when required, but it will add to the project cost .If a larger storage tank is not available, the excess electricity can be supplied to the local consumers or can be used in other agricultural energy needs.

This section analyses the economics of irrigation through stand-alone solar water pumps vis.-a-vis other irrigation options available. As per the Agricultural census 2015-16, there were a total 4.86 million operational holdings in Odisha however, the average size of holding was 0.95 hectares. The number of operational holding in small (average size of holding - 1.59 hectare), semi-medium (2.75 hectare), medium (5.56 hectare) and large (21.70 hectare) category in 2015-16 were 3.42%, 7.88%, 19.59%, and 29.69% respectably.

Given the agriculture holding and the current state of energy used for irrigation, we may explore the community based solar pump model as viable irrigation alternatives in Odisha. Community-based "Surface Minor Irrigation" (MI) and "Lift irrigation Schemes" have been formulated by Odisha lift Irrigation Corporation (OLIC). . Under these schemes, an irrigation water-sharing group of farmers is formulated and these groups are provided with an electric based irrigation pump commensurate to meet the community irrigation needs. . Though, there is no restriction on the number of farmers in the community, but the plot size for each farmer's community has been fixed at 20 hectares per community. The formation of the group is such that the farmers sharing irrigation pumps either need to have their land adjacent to the water pump or within the catchment areas, which a pump can cater. For the regions where grid-connected solar irrigation pump is not possible merely because electricity infrastructure is not available in the agriculture field, we propose a similar community-basedirrigation model. We suggest community based solar irrigation pump.

The gross annual water requirement to irrigate would change with the change in 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. A vegetable growing farmer's irrigation requirement is generally high and equally spaced out. For vegetable farmers 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 10 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. Due to the lack of any other viable alternatives, farmers are many a time forced to adopt diesel for irrigation. The cost of diesel is already prohibitive, and it is subject to frequent variations.

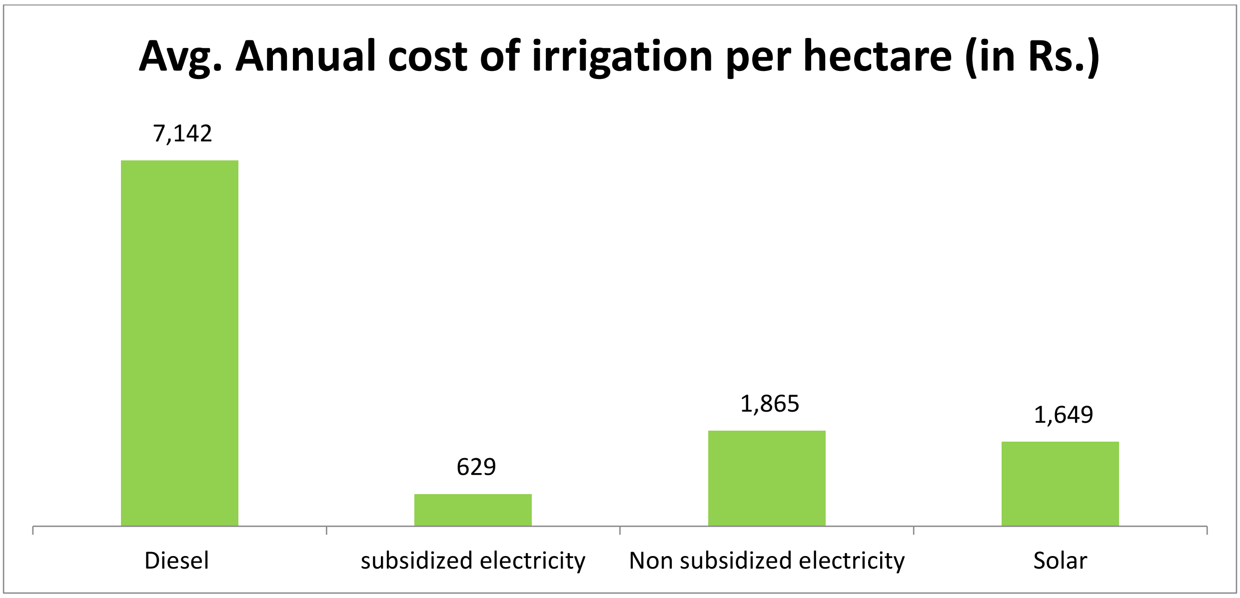

Figure 10: Average annual irrigation cost per hectares

From the above analysis, we may infer that one size fit all solution is not a good proposition. We should have a solution tailored to individual locations. There is a wide variation in the availability of groundwater level within a district. Where pump size should be decided based on the water requirement for irrigation.Irrigation water requirement depends on the size of a land parcel a pump will cater, water level, cropping pattern, and rainfall. During the field survey, we have observed that consumers are attractedby technical specifications rather than the actual capacity need. For example, when we discussed the required size of pumps for irrigation with farmers, almost all of them said they would require a 3 to 5 HP pump because the previous diesel pump was of the same power, and small capacity may not be sufficient.

Stand-alone operation of diesel pumps for irrigation purposes is one of the most expensive irrigation options for farmers in Odisha. Therefore the diesel pump should be replaced with a solar pump. Solar pumps require a substantial up-front investment when compared to diesel pumps. Upfront subsidy by the government will reduce the effective price for the farmers and an arrangement of finance for solar pumps will support in its wider adoption by the poor farmer.. In effect, by purchasing solar pump, farmers would be assured that they are buying many years of electricity up-front. One can predict the future irrigation cost and plan crop accordingly, which is not there is in case of a diesel pump.

4. Implementation Pathway

High water tables and proper water replenishment due to adequate rainfall in Odisha make it a good candidate to use a solar water pump to extend the irrigation coverage. Unlike western states, most of the districts in Odisha do not face the serious concern of groundwater table depletion. In the absence of irrigation, farmers are doing only one crop or two crops in a year. Second or third crop cycle is possible with irrigation security. The analysis conducted in this paper raises several other pointers for policy to design the implementation pathway for solarisation of the irrigation sector in Odisha.

1) Rationalization of subsidy in expanding the coverage of SWP for irrigation
2) Determining the optimal size of Solar panel which should be eligible for a subsidy
3) Expanding electricity line to agriculture field for the evacuation of unused power generated through solar panel installed with SWP
4) A solar community/cooperative would be better to encourage solar adoption by the farmers. Fragmented landholding being one of the primary reasons for low adoptions. Farmers expressed concerns about having faraway lands and hesitant to adopt a solar pump system due to immobility of the system theft. In case of breakdown, it would easy to get repaired for a community vis-a-vis an individual.
5) Absence of any kind of irrigation structures; hence farmers are solely dependent on rainfall. There was only one sowing season, and the farmers stay idle for the remaining eight months with no other job/skill. Therefore, the major focus of the state is on providing “access to irrigation” rather than on the irrigation source. The reason being that majority of farmers in the state do not have any irrigation structure- dug well, well/ bore well, and rely on rainfall. Integration of solar-based irrigation in the government current plan of providing irrigation access will be a good initiative.
6) Sensitization of farmers about solar pumps is significant. Before implementing any large scale scheme, a successful pilot level implementation would be helpful to understand the local challenges and also to make farmers well aware about solar water pumps and its benefits. Understanding of local-level issues will help to adapt the programme as per the local circumstances.

5. Conclusion and Policy recommendations

Converting fossil fuel dominated irrigation systems to solar-based irrigation systems has many direct and indirect benefits to not only the agriculture sector but several other sectors. Doing so will improve energy security, reduce reliance on imported fossil fuels, address noise and air pollution, and lower emissions intensity. For the agriculture sector, it will boost farmer’s income, employ a rural workforce, etc.

The timing for this transformation is right but still there are huge challenges, and so are the opportunities. An informed policy can overcome these roadblocks and can create an enabling environment to fructify the environmental, social, and economic benefits of the transformation. The huge required finance to implement this scheme at a large scale is a severe challenge for a resource-constrained economy. At the same time, other considerations, such as sustainability, environmental benefits, scale-up, government resource optimization etc, should be an equally important consideration. Considering this challenge based on our analysis, we suggest the following business model:

- **Converting electric water pump to solar water pump:** A 15 percent capital subsidy and buyback of surplus power produce by the farmer through a panel at Rs 5.99/kWh for 25 years will keep the upfront capital subsidy requirement at low. The forgone opportunity cost of not selling electricity to the grid encourages farmers to optimize their irrigation water need.
- **Stand-alone solar pump:** In the area which does not have electricity supply in the agriculture field community level standalone solar pump needs to be provided to the farmers. The scheme could be similar to the ongoing OLIC community level irrigation scheme where the pumps are energised using electricity. Solar can replace electricity for powering the pumps.Community-level solar pumps would substantially reduce the cost of irrigation for the farmer, thereby enhancing their net realise return from farming.
- **Improve existing scheme:** 0.5 HP solar pumps currently provided by the government may not be sufficient for irrigation needs. It can supplement the irrigation needs or can be useful to irrigate very small size farm in the areas having an availability of surface water or excellent groundwater situation. Therefore, at least 3 HP pumps are needed instead of 0.5 HP to full fill the irrigation needs of farmers.
- **Not one size fit all solution:** there is a lot of variation in groundwater level among districts and even villages ranging from 20 ft to 150 ft (especially hilly areas). Hence one size fit all solution may not be able to work there has to be flexibility in the programme to adapt as per the local circumstances. There are evidence of overexploitation of water through solar pump deployment for drinking water supply scheme. Hence, while deciding on the size of the pump, one needs to take care of this aspect.
- **Creating Awareness:** Awareness about solar water pumps is also very scattered and varied significantly across villages. In some areas, people were not aware of solar water pumps, let alone the scheme opposed to other areas where farmers knew about the scheme and applied for the same.
- **Implementation challenges:** Farmers who have applied for solar pumps eight months ago under the state government scheme have not received any information on their application. Lack of information has created a sense of despair and doubt in the village about such schemes. To instil confidence among the farmers and for successful implementation of the programme there has to be a time-bound implementation calendar for the scheme.

  There is no agriculture feeder separation taken place in Odisha which makes it difficult for DISCOM to measure the actual electricity requirement by the agriculture sector. Implementation of a grid-connected solar pump model would be difficult.

References

- *Odisha Economic Survey, 2018-19 (2019), Planning and Convergence Department, Directorate of Economics and Statistics, Government of Odisha, June 2019*
- *(Activity Report, Odisha, 2017-18), Department of Agriculture and Farmers Empowerment,Government of Odisha,*
- *Greenpeace, (2019), Solarisation of Agriculture, Greenpeace India, July 15, 2019*
- *(Economic Times, 2018)Subsidised solar pump scheme launched in Odisha, Energy World, the Economic Times, October 30, 2018,*
- *B. Chamola, (2017),Solar pumps bring relief to smallholder farmers in Rayagada,https://www.villagesquare.in/2017/05/10/solar-pumps-bring-relief-smallholder-farmers-rayagada/*
- *OERC (2019), Tariff Notification, Retail supply tariff effective from June 1, 2019, Odisha Electricity Regulatory Commission*
- *Ministry of Power (2018), 24X7 Power for All, A joint intuitive of Government of India and Government of Odisha*