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SOLAR IRRIGATION FOR AGRICULTURAL RESILIENCE IN SOUTH ASIA (SoLAR)

International Water Management Institute

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List of abbreviations

AC	Alternate current
ADB	Asian Development Bank
AEPC	Alternative Energy Promotion Center
BADC	Bangladesh Agricultural Development Corporation;
BARI	Bangladesh Agriculture Research Institute
BBS	Bangladesh Bureau of Statistics
BC	Black Carbon
BCM	billion cubic meter
BD	Bangladesh
BMDA	Barind Multipurpose Development Authority
BREB	Bangladesh Rural Electricity Board
BRRI	Bangladesh Rice Research Institute
CEEW	Council on Energy, Environment and Water
CSIRO	The Commonwealth Scientific and Industrial Research Organisation
DAE	Department of Atomic Energy
DFID	Department for International Development
DGVCL	Dakshin Gujarat Vij Company Limited
DISCOMs	Electricity Distribution Company
DOE	Department of Energy
DPs	Development partners
EGIS	Energy-Groundwater Interaction Settings
ENSSURE	Enhanced Skills for Sustainable and Rewarding Employment
FAO	Food and Agriculture Organization
FATA	Federally Administered Tribal Areas
FGD	Focused Group Discussion
FWMC	Federal Water Management Cell
GCF	Green Climate Fund
GERMI	Gujarat Energy Research and Management Institute

GESI	Gender equality and social inclusion
GHG	Greenhouse Gases
GIZ	The Deutsche Gesellschaft für Internationale Zusammenarbeit
GoN	Government of Nepal
GUVNL	Gujarat Urja Vikas Nigam Limited
GW	Giga-watt
HEIS	High Efficiency Irrigation Systems
HP	Horsepower
ICAR	Indian Council for Agricultural Research
ICIMOD	International Centre for Integrated Mountain Development
IDB	Islamic Development Bank
IDCOL	Infrastructure Development Company Limited
IDE	International Development Enterprises
IFAD	International Fund for Agricultural Development
IN	India
IRENA	International Renewable Energy Agency
ISA	International Solar Alliance
IWMI	International Water Management Institute
JNNSM	Jawaharlal Nehru National Solar Mission
KfW	Kreditanstalt für Wiederaufbau
KUSUM	*Kisan Urja Shakti evam Utthan Mahabhiyan*
kWp	kilo watt peak
MGVCL	Madhya Gujarat Vij Company Limited
MMT	Million Metric Tones
MNRE	Ministry of New and Renewable Energy
MoEWRI	The Ministry of Energy, Water Resources and Irrigation
MT	million metric tons
MW	Mega Watts
NABARD	National Bank for Agriculture and Rural Development

NDC	Nationally Determined Contributions
NEA	Nepal Electricity Authority
NGO	Not for Profit Organisation
NP	Nepal
NRREP	The National Rural and Renewable Energy Programme
NSM	National Solar Mission
NWFP	North-West Frontier Province
PARC	Pakistan Agricultural Research Council
PCRWR	Pakistan Council of Research in Water Resources
PGVCL	*Paschim Gujarat Vij Company Limited*
PK	Pakistan
PL	Project Leader
PMU	Program Management Unit
PSC	Project Steering Committee
PV	Photovoltaic
QMS	Quality Management System
RDA	Rural Development Academy
RETs	Renewable Energy Technologies
RPO	Renewable Purchase Obligation
SAARC	South Asian Association for Regional Cooperation
SDC	Swiss Agency for Development and Cooperation
SDG	Sustainable development Goals
SE4ALL	Sustainable Energy for All
SIPs	Solar Irrigation Pumps
SIRO	Scientific and Industrial Research Organization
SKY	Suryashakti Kisan Yojana
SLCPs	Short lived, climate forcing pollutants
SoLAR-SA	Solar Irrigation for Agricultural Resilience in South Asia
SPaRC	Solar Power as Remunerative Crop

SPICE	Solar Pump Irrigators’ Cooperative Enterprise
SREDA	Sustainable and Renewable Energy Development Authority
UGVCL	Uttar Gujarat Vij Company Limited
WB	The World Bank
WEF	World Economic Forum

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Executive summary

Solar Irrigation for Agricultural Resilience in South Asia (SoLAR-SA) aims to sustainably manage the water-energy and climate interlinkages in South Asia through the promotion of solar irrigation pumps (SIPs). The main goal of the project is to contribute to climate-resilient, gender-equitable, and socially-inclusive agrarian livelihoods in Bangladesh, India, Nepal and Pakistan by supporting government efforts to promote solar irrigation. In the process, the project will also pave the way for sustainable and equitable groundwater governance by tackling some of the policy distortions related to solar irrigation, such as perverse electricity subsidies which have created the negative interlinkages between the water and energy sectors in South Asia. This project will be implemented in the aforementioned four countries in partnership with government agencies who have the mandate to implement policies and programs related to SIPs. The duration of the project is four years: December 2019 through December 2023.

Increased reliance on irrigation is one of the main ways in which farmers adapt to climate change. In much of South Asia, the only reliable source of irrigation that offers on-demand water control is groundwater. Yet, in spite of historical gains such as increased food production, the consequences of South Asia's over-dependence on groundwater have had deleterious impacts on long-term groundwater and energy sector sustainability. The recent decline in unit costs and resultant popularity of solar irrigation in the region promises an opportunity to resolve some of the undesirable energy sector consequences (e.g., mounting losses of electricity utilities), but at the same time poses a threat to the long-term sustainability of groundwater resources. Can we design win-win solutions wherein current opportunities for sustainable renewable energy transition in the region's irrigation sector are leveraged to deliver sustainable groundwater and GESI outcomes? The main objective of the SoLAR-SA proposal is precisely this – to help promote policies and strategies for sustainable, gender-inclusive and equitable renewable energy transition in the irrigation sector without exacerbating the problem of groundwater over-exploitation.

South Asia is the world's largest user of groundwater, using approximately 250 km^3 of groundwater annually for irrigation. However, the groundwater-energy systems in the region are not uniform. There are three major typologies of energy-groundwater systems in the region.

1) Areas with high groundwater depletion coupled with free electricity supply for farmers. These systems cover northwest and peninsular India (except Kerala), Balochistan, Federally Administered Tribal Areas (FATA) and the North-West Frontier Province (NWFP) in Pakistan.
2) Areas of relative groundwater abundance, where water tables are shallow, but ironically, most farmers use expensive diesel pumps due to lack of electricity infrastructure. This zone covers Bangladesh, the eastern Gangetic plains in India, and the Terai zone in southern Nepal.
3) Areas of diverse geography where combined use of surface and groundwater is common. These areas include Punjab and Sindh Provinces in Pakistan.

This diversity in systems has led to very distinct problems that affect groundwater and energy sectors differently and thus, solar-irrigation solutions have to be different and context-specific. As all countries in South Asia have made international commitments to develop more clean energy sources (e.g., nationally-determined contributions or NDCs), this project proposes that SIPs can turn the vicious cycles of water-energy-climate interlinkages into virtuous ones, if deployed along with the right policies, institutional support, and financial models.

The SoLAR-SA project aims to undertake relevant interventions in all the typologies described above. In areas with electric grid-connected or diesel-powered irrigation pumps, the project will pilot SIP interventions to reduce groundwater exploitation, while not adversely affecting farmers' incomes. In areas with under-developed groundwater resources and a diesel-dependent groundwater economy, the project will pilot SIP interventions that encourage more intensive use of groundwater for agriculture. All the proposed interventions will have GESI and groundwater sustainability components and will be deployed in close partnership with the following government agencies:

- **Bangladesh**: Infrastructure Development Company (IDCOL)
- **India**: Gujarat Energy Research and Management Institute (GERMI)
- **Nepal**: The Alternative Energy Promotion Centre (AEPC) and Nepal Electricity Authority (NEA)
- **Pakistan**: The Ministry of National Food Security and Research (MNFS&R), the Federal Water Management Cell (FWMC), and the Pakistan Agricultural Research Council (PARC).

This project responds to government commitments to transition to clean energy pathways in agriculture. All countries in this project have NDC commitments to reduce greenhouse gas (GHG) emissions and SIPs can play a significant role in reducing emissions in agriculture. The project also has synergies with a number of other international and donor-funded programs on SIPs, including solarization of agriculture initiatives from DFID, the World Bank, the Islamic Development Bank, the Asian Development Bank, and the International Solar Alliance (ISA).

The SoLAR-SA project will evaluate its success according three outcomes:

1. Generating improved empirical evidence to support the development of climate-resilient, gender-equitable, socially-inclusive, and groundwater-responsive solar irrigation policies;
2. Validating innovative actions and approaches for promoting gender-equitable, socially-inclusive, and groundwater-responsive solar irrigation; and
3. Increasing national and global knowledge and capacity for developing gender-equitable, socially inclusive, and groundwater-responsive solar irrigation policies and practices.

These outcomes will be achieved through the execution of three work packages, each one designed to produce specific deliverables to fulfill the individual outcomes.

1.0 Context

Solar Irrigation for Agricultural Resilience in South Asia (SoLAR-SA) aims to sustainably manage the water-energy and climate interlinkages in South Asia through the promotion of solar irrigation pumps (SIPs). The main goal of the project is to contribute to climate-resilient, gender-equitable, and socially-inclusive agrarian livelihoods in Bangladesh, India, Nepal and Pakistan by supporting government efforts to promote solar irrigation. In the process, the project will also pave the way for sustainable and equitable groundwater governance by tackling some of the policy distortions related to solar irrigation, such as perverse electricity subsidies which have created the negative interlinkages between the water and energy sectors in South Asia. This project will be implemented in the aforementioned four countries in partnership with government agencies who have the mandate to implement policies and programs related to SIPs. The duration of the project is four years: January 2020 through December 2023.

South Asia is the world's largest user of groundwater for agriculture, withdrawing approximately 250 km^3 of groundwater annually. It is estimated that there are approximately 21 million water extraction mechanisms, or pumps, in Bangladesh, India, Nepal and Pakistan, of which roughly 12 million are electric and 9 million are diesel[i]. Because no other part of the world depends as much on groundwater irrigated agriculture as South Asia, this region has a unique water-energy connection. This unique connection emerges from four facts:

1. The irrigation economy in South Asia is overwhelmingly dependent on groundwater, and the intensity of groundwater extraction is, in turn, influenced by access to subsidized electricity.
2. Pockets of groundwater over-exploitation overlay neatly with regions that provide subsidized electricity to farmers and often at the cost of poor financial health of the electricity company/utility.
3. Areas with rich groundwater endowments and high recharge potential are also home to some of the poorest people in the region (figure 1). In these places, agricultural groundwater use can be further intensified through proper energy-side interventions for agricultural growth and poverty alleviation without compromising groundwater resource sustainability.
4. Groundwater irrigation in the region is carbon intensive and accounts for up to 20% of total carbon emissions from agriculture. SoLAR-SA aims to capitalize on this unique interrelationship between water, energy and climate to promote solutions that address this nexus in ways that are context-specific and policy-relevant.

In India alone, diesel-powered irrigation pumps burned approximately 2.4 billion liters of fuel in 2011 (MoPNG, 2013). Paliwal et al. (2016) estimate that approximately 7,550 tons of black carbon (BC) were emitted by diesel irrigation pumps in India. In all four countries in this study, both diesel and electricity are subsidized to varying extents. In Bangladesh, approximately USD 900 million is spent annually on diesel for irrigation purposes (IDCOL, 2015), while in Nepal, 10.5% of its total petroleum imports (or USD 90 million) is used in the agricultural sector[ii] (Nepal Energy Forum, 2017; WECS, 2010). In 2012, electricity subsidies for agricultural pumping in India totaled nearly INR 450 billion or ~USD 9 billion[iii] (Gulati and Pahuja, 2012). As a consequence, heavy use of diesel and dirty thermal electricity for groundwater pumping is very high in the region. South Asia's agriculture is heavily dependent on fossil fuel and generated high levels of short-lived, climate-forcing pollutants (SLCPs) such as BC. So, as agriculture in the region is largely dependent on groundwater irrigation, and much of this irrigation requires diesel power, there are far reaching energy and climate implications of intensive groundwater use. The energy-intensive base of irrigation has given rise to unique and complex water-energy-climate interlinkages, wherein policies in one domain can negatively affect outcomes in other domains.

In September 2018, the Swiss Agency for Development and Cooperation (SDC) and the International Water Management Institute (IWMI) formed a regional partnership – SoLAR-SA – with the objective of addressing the challenges of promoting a clean energy transition in irrigation without compromising equity and groundwater sustainability. By adopting a 'Water-Energy-Climate' interlinkage approach, SoLAR-SA will identify, field test, and mainstream climate-smart solar irrigation promotion strategies across South Asia in ways that are GESI compatible and take into account groundwater sustainability issues.

Throughout this project, SoLAR-SA will draw from expertise among several other regional and international programs on clean solar-based energy transitions in agriculture. This groups include:

- Asian Development Bank (ADB) – regional support
- Council on Energy, Environment and Water (CEEW) – regional support
- Department for International Development (DFID) – Nepal
- Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) – India
- Food and Agriculture Organization (FAO) – regional support
- Indian Council for Agricultural Research (ICAR) -- India
- International Centre for Integrated Mountain Development (ICIMOD) – regional support
- International Fund for Agricultural Development (IFAD) – India
- International Renewable Energy Agency (IRENA) – regional support
- International Solar Alliance (ISA) – regional support
- Islamic Development Bank (IDB) – Pakistan
- Kreditanstalt für Wiederaufbau (KfW) – Bangladesh
- South Asian Association for Regional Cooperation (SAARC), particularly, SAARC Agriculture Centre (Dhaka, Bangladesh) and SAARC Energy Center (Islamabad, Pakistan) – regional support
- World Bank (WB) – regional support.

SoLAR-SA will also create knowledge partnerships with other relevant SDC-funded projects in the region (see section 1.3 for further details).

The unique interrelationship between water, energy, food, and climate in South Asia is a product of the political and socio-economic context dating back to the early 1960s. In that decade, much of South Asia was plagued by food insecurity and faced threats of imminent mass hunger due to low agricultural production. In response, governments in the region adopted Green Revolution technologies (high-yielding seeds, chemical fertilizers, and assured irrigation) as the primary strategy to improve agricultural yields.

Groundwater and groundwater extraction technologies became vitally important in this shift. Compared to surface water canals, drilling and pumping offered more effective, flexible, and cost-efficient means to support irrigation. What made groundwater irrigation even more attractive were the pro-farmer energy policies. For example, in India, subsidized and flat-rate electricity connection were provided to farmers on a priority basis in the states of Punjab, Haryana, Gujarat and Rajasthan. Together these areas would be known as the “cradle” of the Green Revolution in the region. A similar trajectory of expansion of Green Revolution technologies and electric-powered groundwater extraction followed in southern India, even though irrigation had to overcome hard rock aquifers. Later, in the 1980s, the Green Revolution spread to eastern India, where alluvial groundwater aquifers were more well-endowed compared to aquifers in northwestern and southern parts of the country. Here, because the groundwater tables were shallower, diesel groundwater pumps were favored. Diesel subsidies in pre-liberalized India (pre-1991) meant that diesel pumps were just as cost effective as electric pumps. Diesel was also more popular in East India because these states lacked the basic infrastructure and political clout to lobby for rural electrification. The case for diesel pumping was similar in Bangladesh and Nepal, as these countries lacked the necessary resources for universal grid expansion.

This historical trajectory of irrigation and agricultural production coupled with unique hydrogeological formations throughout South Asia has created three distinct water-energy typologies in South Asia (figure 1). Using the eight Energy-Groundwater Interaction Settings (EGIS) identified by Shah et al. (2018), the SoLAR-SA Entry Proposal (IWMI, 2018) classifies its four project countries into three broad geographies:

Groundwater Depletion Zones receive low rainfall and are characterized by groundwater over-exploitation, primarily due to highly-subsidized or free electricity for farmers and low inherent groundwater recharge potential. In these zones, solar pumps will reduce the carbon footprint of the groundwater irrigation economy, but could also lead to even more groundwater abstraction. For this reason, sustainable groundwater management trainings should be a key priority for climate-smart solar irrigation promotion policies in these zones. Groundwater depletion zones are found in Balochistan, northwest and peninsular India (except Kerala), and the Federally Administered Tribal Areas (FATA) and North-West Frontier Province (NWFP) in Pakistan. Most of the 180,000 SIPs already installed in India are located in this region.

Groundwater Abundance Zones sit stop one of the world's largest aquifers that extends across Bangladesh, the Nepal Terai, and the eastern Gangetic plains in India. However, these areas also lack electricity supply and infrastructure, so irrigation systems are heavily reliant on diesel-based irrigation that limits groundwater development and agrarian prosperity. In these zones, SIPs can play an important role in delivering equitable and affordable irrigation access. Groundwater quality and the effect of arsenic pollution in affected pockets are key policy concerns in this region.

The Rest of South Asia is the third zone and covers a diverse geography that includes:

a. **The Himalaya** – Asia's water towers where water use in agriculture is limited but solar energy can play an important role in providing affordable energy access to remote villages;
b. **Punjab and Sindh provinces in Pakistan** – surface and groundwater use are both common in this area. Solar pumps could replace millions of diesel pumps currently in use ; and
c. High-value agriculture areas in **Kerala and Sri Lanka** where farmers already pay commercial or near-commercial tariffs for farm power.

Figure 1. Three distinct SoLAR geographies in South Asia: 1: Groundwater Depletion Zone; 2: Groundwater Abundance Zone; 3: Rest of South Asia.

SoLAR-SA project starts from the premise that these three typologies have led to distinct problems that affect groundwater and energy sectors differently. Therefore, hence solutions must be different and context-specific, as well as demand driven and policy relevant for sufficient uptake. Given that countries in South Asia have made commitments to reducing carbon emissions (e.g., NDCs) and promoting renewable energy, the right policies combined with appropriate financial and institutional models can promote SIPs to restore healthy and sustainable relationships between water-energy-climate in South Asia.

SoLAR-SA will execute relevant interventions in all the typologies described above. In typologies 1 and 3, groundwater over-exploitation is driven by diesel and electric grid-connected pumps. For these areas, SIP interventions will focus on reducing groundwater over-exploitation, while not adversely affecting farmers' incomes. In typology 2, groundwater use is under-developed in some areas, while diesel pumps dominate in others. For these areas, SIP interventions will encourage more intensive use of groundwater for agriculture with intent to improve farmer livelihoods and incomes.

All proposed interventions will be deployed in close partnership with relevant government agencies, and will have significant GESI and groundwater sustainability components (see Section 4).

1.1 SITUATION ANALYSIS

Our situation analysis is built upon 1) reviews of scholarly literature related to all aspects of irrigation and SIP-related policies; 2) reviews of relevant groundwater and agricultural policies that intersect with SIP policies and programs; and 3) data collected from consultations with major stakeholders during the preliminary research phase of this project.[iv]

Because SIPs offer a promising alternative to diesel and electric pumps, they can address current water, energy, food and climate interlinkages issues in several ways. For one, by replacing diesel pumps in areas with limited access to grid electricity but abundant groundwater (e.g., eastern India, Nepal Terai), SIPs reduce the cost of irrigation for small farmers, and incentivizes them to maximize their cropping intensity and sell irrigation services to others (Shah, 1993; Mukherji 2007; McDonald et al. 2016). Second, any reduction in diesel usage also reduces SLCP emissions. SLCP emissions are known to decrease wheat yields in India by up to 36% (Burney & Ramanathan, 2014). Third, increased adoption of SIPs can reduce reliance on fossil fuels and pave the way for a clean energy future. Finally, widespread adoption of SIPs as encouraged by regionally-differentiated policies can help reduce groundwater over-exploitation in some places and stimulate a higher trajectory for agricultural production in other places.

The use of SIPs in agriculture in South Asia appears to be on the verge of a major take-off as national governments are including SIPs in their agricultural support programs and more private sector companies are entering the market (IRENA, 2016). There are three primary reasons for this positive outlook. First, prices of photovoltaic (PV) panels (figure 2) have fallen sharply from $76.67 USD per watt in 1977 to $0.36 per watt in 2014 (Brown, 2015). In India, between 2013 and 2019, solar panel prices fell 71%, even with duties imposed by some major panel exporting countries like China. As a result, generation costs have also fallen. In May 2017, solar power tariffs in India hit a new low at INR 2.44[v] per unit (~0.037 US cents) (Live Mint, 2017). At the same time, benchmark prices for SIPs are getting lower each year. In Madhya Pradesh in 2017, the state government offered solar pumps at prices between 9-17% lower than the benchmark prices set by the Ministry of New and Renewable Energy (MNRE). In Andhra Pradesh, the cost of a five horsepower alternate current model SIP fell from INR 4,90,000 to INR 2,50,000 between 2014-2019. In Nepal, the price for a standard 1.5 kWp (kilo watt peak) SIP system fell from USD 3,500 in 2015 to less than USD 2,000 in 2017. As panel costs are typically 60-70% of the total cost of a SIP irrigation system, these sharp reductions in price help farmers reach the break-even point for their investments in less than three years in many instances.

Secondly, the opportunity to reduce expenditures on energy subsidies is motivating governments – especially state governments in India – to focus more strongly on SIPs. Finally, international funding for climate change mitigation is creating an attractive environment for investments in all green technologies, including SIPs.

With significant improvement in panel efficiency and declining unit costs, solar PV technology has been growing rapidly around the world. With an addition of nearly 100 GW in the year, the world's total solar PV capacity crossed 500 GW in 2018, up from only 15 GW ten years ago (figure 3). Initially Europe and US dominated the solar economy, but today they have been surpassed by Asian countries, especially China, Japan and India. Among the Asian solar giants, India is the smallest, but India is probably the global leader in solar PV installations in agriculture, particularly solar irrigation pumps (SIPs). All four countries in South Asia have embarked on ambitious renewable energy programs, and SIPs have become an increasingly important part of that strategy. Table 1 summarizes the salient features of the SIP landscape in the region.

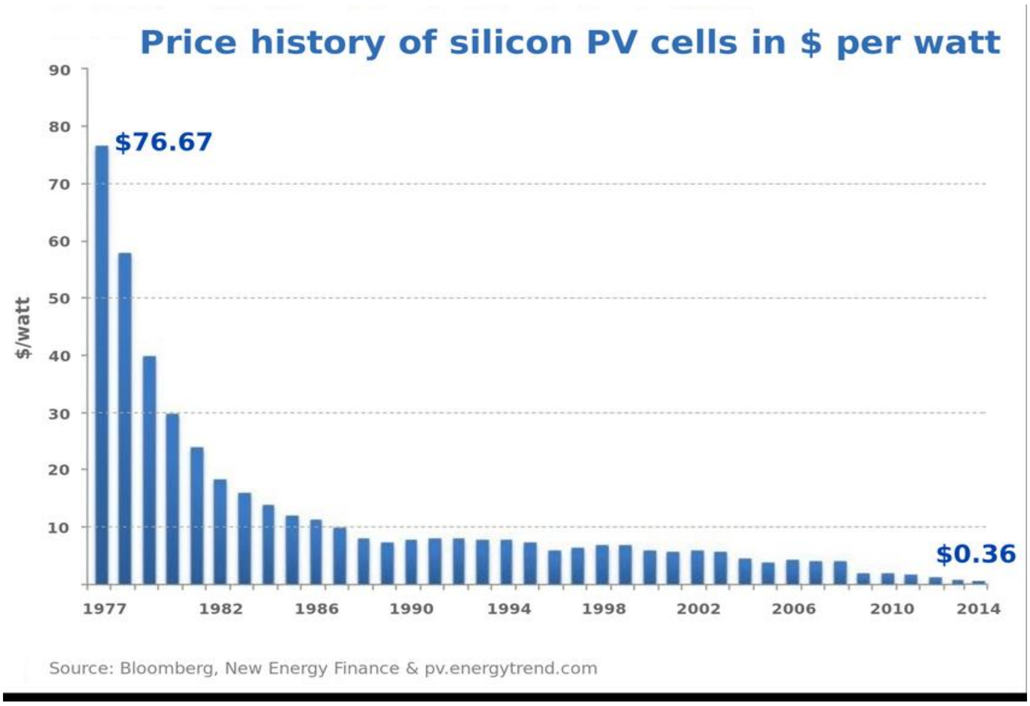


Figure 2. Price history of silicon PV cells from 1977-2014

(Source: Source: Bloomberg New Energy Finance & pv.energytrend.com; downloaded from https://upload.wikimedia.org/wikipedia/commons/7/71/Price_history_of_silicon_PV_cells_since_1977.svg

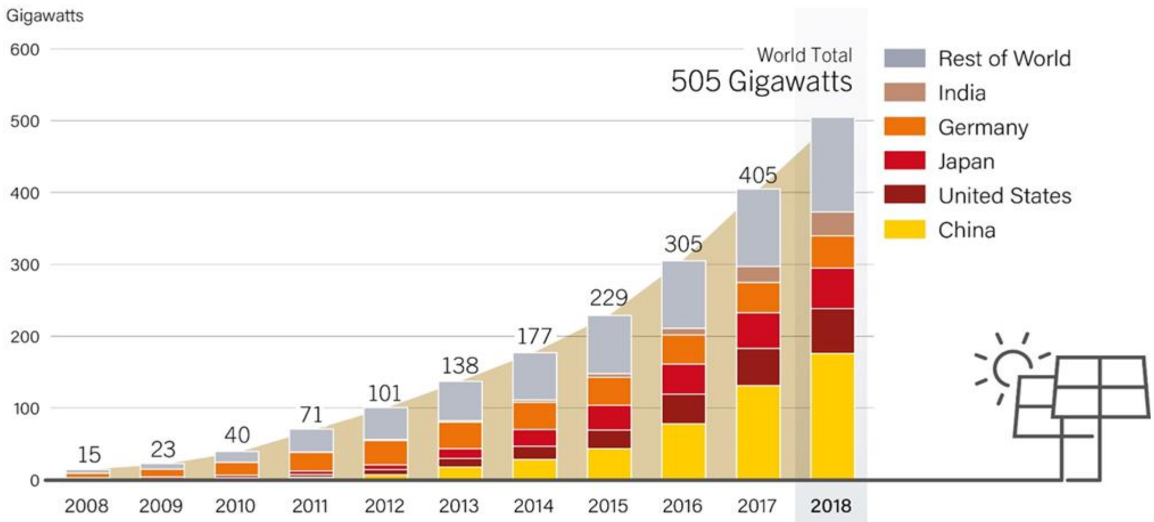


Figure 3. Solar PV Global Capacity by country and region, 2008-2018

Source: REN21 (2019)

Table 1. Salient features of the SIP landscape in South Asia by country

Parameters	Bangladesh	India	Nepal	Pakistan
Number of SIPs	~1,600	~180,000	~1,300	~2,800
Financial models				
No grant/subsidy				✓
Only grant	✓	✓	✓	
Grant-cum-loan	✓	✓		
Rental	✓			
Special discounts or provision for women and marginal farmers?				
Yes			✓	
Does private sector play a significant role in shaping the SIP landscape?				
Yes			✓	✓
Type of ownership				
Individual farmer	✓	✓	✓	✓
Collective (farmers) or NGO	✓	✓	✓	
Private entrepreneurs	✓	✓		
Self-use v. selling water to others				
Self-use		✓	✓	✓
Water markets	✓	✓		
Size of SIP				
Small (< 1 HP)		✓	✓	
Medium (1 HP to 10HP)	✓	✓	✓	✓
Large (> 10 HP)	✓		✓	✓
Equity impact				
High	✓		✓	
Low		✓		✓
Off grid v. grid-connected with net metering				
Off grid	✓	✓	✓	✓
Grid-connected		✓	✓	
Threat of groundwater overexploitation				
High risk		✓		✓
Potential of mitigating short-lived climate pollutants with SIPs				
High	✓			
Medium		✓		✓
Low			✓	

Sources: Secondary data and SoLAR stakeholder meetings

1.1.1 CURRENT STATUS AND POLICIES FOR SIPs IN BANGLADESH

Bangladesh has 1.6 million pumps, of which approximately 21% are electric-powered and the remainder diesel-powered. In 2016-17, these pumps irrigated 75% of the 7.4 million hectares of total irrigated area in the country[vi].

Bangladesh has witnessed steady growth in agriculture to achieve self-sufficiency in cereal production. Based on estimates from the Bangladesh Bureau of Statistics (BBS), food grains production increased from 36.8 million metric tons (MT) in 2011-12 to 41.6 MT in 2018-19. Approximately 88% of total food grain production is rice, with *boro* rice being the most important variety (~47%). *Boro* rice is central for achieving food security in Bangladesh and almost entirely irrigated using diesel pumps.

Bangladesh spends approximately USD 2.6 billion per year on imported diesel, in spite of the country's pledge to make a 15% "conditional reduction" and a 5% "unconditional reduction" of GHG emissions by 2030. Similarly, the Renewable Energy Policy of Bangladesh, 2008[vii] has set a target to obtain least 10% of its power needs through renewable sources by 2020.

Currently, Bangladesh has installed 628 MW of renewable energy, of which 394 MW is solar, and only 30 MW from 1,377 solar pumps specifically (SREDA[viii]). Of those solar pumps, approximately 1,241 are financed through an autonomous government financial agency, the Infrastructure Development Company Limited (IDCOL), and the rest through a variety of sources, such as the Bangladesh Agricultural Development Corporation, Bangladesh Rural Electricity Board (BREB), and the Barind Multipurpose Development Authority (BMDA) (table 2).

Table 2. Solar pumps in Bangladesh through 2018

Implementing Agency	Number of pumps	Target
Bangladesh Rural Electrification Board (BREB)	40	2,000
Barind Multipurpose Development Authority (BMDA)	54	290 by 2021
Infrastructure Development Company Limited (IDCOL)	1241	50,000 by 2025
Bangladesh Agricultural Development Corporation (BADC)	40	-
Other agencies (e.g., DOE, RDA, DAE, BRRI, BARI)	~10	-

To optimize the implementation of SIPs, the Bangladesh Solar Powered Development Programme (2013) suggests the following locations as the most effective sites: Presence of diesel-powered irrigation, but absence of grid electricity

- Agricultural areas where three to four crops are cultivated per year
- Areas where groundwater levels are not depleted, or where surface water is available for irrigation
- Continuous agricultural land (100 to 150 bigha or 13.37 to 20.067 ha)
- Land that remains flood free during annual inundations
- Areas with no arsenic contamination in the groundwater

While the Bangladeshi government has made strides toward replacing diesel pumps with SIPs, they are also extending fossil fuel-based grid electricity to all corners of the country. The availability of subsidized and rapidly extending grid electricity may discourage farmers from adopting solar pumps, which have high installation costs. In this context, grid connection of SIPs emerged as an important issue during the country consultation held in Dhaka on 25 June 2019.

A second challenge relates to the large solar panels needed to power SIPs. Because Bangladesh is relatively land poor in terms of area, all fertile land is top priority for production. Therefore, the panels that cover fertile land discourage farmers from adopting this technology in spite of the environmental benefits potentially gained.

While overall, groundwater sustainability has not been a major issue in Bangladesh, some farmers around Dhaka and in the Barind tract region expressed concerns about SIPs lowering the water table within their confined aquifers.

IDCOL is the main financer and implementer of SIP programs in Bangladesh and they are partners in this project. IDCOL's implementation models are of particular interest because as market leaders, they set the tone for future pathways for SIP adoption in the country. Solar pumps installed through IDCOL are mostly in the northwest region of Bangladesh within the Barind tract (figure 4). These areas, not coincidentally, are also areas with less flooding, low arsenic levels, high *boro* cultivation, and a high density of diesel pumps.

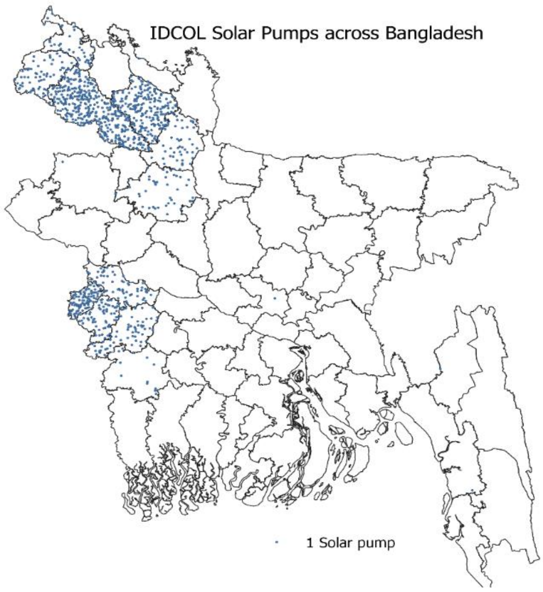


Figure 4. IDCOL-distributed solar pumps across Bangladesh

IDCOL has two models for promoting solar pumps: ownership and fee-for-service. In the fee-for-service scheme, IDCOL partners with a local organization (or "sponsor"), which pays 20% of the SIP cost up front, receives 50% of the cost from ICDOL as a grant, and pays back 30% of the cost as a loan. The sponsor then sells water to farmers in exchange for a fee (e.g., 3,000 taka per bigha during *boro* rice season) to recover their own investments and pay back the loan to IDCOL.

In the ownership model, the sponsor sells the SIP directly to farmers rather than selling the water. As in the fee-for-service model, ICDOL provides 50% of the cost of the pump as a grant. The farmer is then required to put some money up front for purchase and then pays back the remaining cost to the sponsor as a loan. Until the loan is fully repaid, the sponsor remains the owner of the SIP. Under the ownership model, the SIPs will be substantially smaller in size because they will be for individual farmer use.

IWMI and ICDOL will work together to test various financial incentive schemes for the ownership model.

1.1.2 CURRENT STATUS AND POLICIES FOR SIPs IN INDIA

Within the sub-continent, India has been at the forefront of renewable energy uptake. The Government of India launched the "Jawaharlal Nehru National Solar Mission" (JNNSM) in January 2010. The main objective of this mission was to establish India as a global leader in solar energy by creating the right policy conditions for its quick diffusion. Two phases of JNNSM have been completed and currently the third phase is underway (table 3).

Table 3. Phases and targets of the Jawaharlal Nehru National Solar Mission

Phase	Target
Phase I (2010-2013)	• 1,000 MW of grid-connected PV (including rooftop) • 200 MW of off-grid solar PV applications
Phase II (2014-2017)	• 4,000 – 10,000 MW of grid-connected PV (including rooftop) • 1,000 MW of off-grid solar PV applications • > 25 solar parks established and 40 GW of solar PV from the Ultra Mega Solar Power Projects
Phase III (2017-2022)	• 100,000 MW of grid-connected PV (including rooftop) • 2,000 MW of off-grid solar PV applications

Source: Ministry of New and Renewable Energy (MNRE) website

The JNSSM had an initial overall target of 20 GW of grid-connected solar power by 2022, but that was revised to 100 GW in 2015. Since its inception, the JNSSM has focused on increasing the grid-connected solar capacity in off-grid areas. SIPs formed only a small portion of JNSSM work in the early phases due to the high cost of installation and the low paying capacity of the beneficiaries.

Prior to 2010, SIPs were not a financially-viable option to replace diesel pumps because the PV panels and initial SIPs were all direct current, which was too expensive for most potential buyers. In 2010, however, 7,495 SIPs were installed and that number continued to rise as the prices of PV modules began to fall steadily. In Rajasthan and Maharashtra states, 1-2 HP SIPs were installed for experimentation and demonstration. For example, in 2011, the Department of Horticulture in Rajasthan announced a DC SIP scheme in which farmers engaging in hi-tech agriculture could obtain 3 HP SIPs at an 86% subsidy.

The development of SIPs to run alternating current (AC) from solar PV was second large breakthrough. This innovation enabled the cost of SIPs to fall even lower and between 2012-2014, more states began executing small SIP projects.

The Government of India released the “National Solar Pumping Scheme for Irrigation and Drinking” in 2014, using the event to announce its intentions to support 1 million SIPs by 2020-21. Similar guidelines were released in Rajasthan. By 2016, a majority of the states had begun state-level solar pump schemes. In all, central government assistance to state-level pump schemes was close to 30 percent of the capital cost and matched by an equal or higher level by the state government. Therefore, the schemes promoted SIPs by through high capital subsidies. Also, many NGOs, research organizations, and multilateral donors experimented with different technical, financial, and institutional models for SIPs during this phase. Most of these pilots sought to develop scalable models that would need fewer subsidies and result in increased social benefits.

Between 2016-18, the share of SIPs in JNNSM’s entire off-grid solar PV deployment increased significantly. As the cost of SIPs fell dramatically, SIPs became a viable alternative to conventional subsidized grid connection, even in areas where grid was already present. During this time, the Government of India announced its *Kisan Urja Shakti evam Utthan Mahabhiyan* (KUSUM) program for solarizing agriculture. The KUSUM scheme acknowledged the potential impact SIPs on groundwater, an aspect of SIP usage that was not addressed in any earlier policy or scheme. Also, the Government of India increased its Solar Energy Renewable Purchase Obligation (RPO) to 8 percent. Some states (e.g., Gujarat, Maharashtra) began using SIPs to fulfill their RPOs, which otherwise were only meant for grid-connected systems, making SIP promotion more attractive for distribution companies. Figure 5 shows the distribution of SIPs across India.

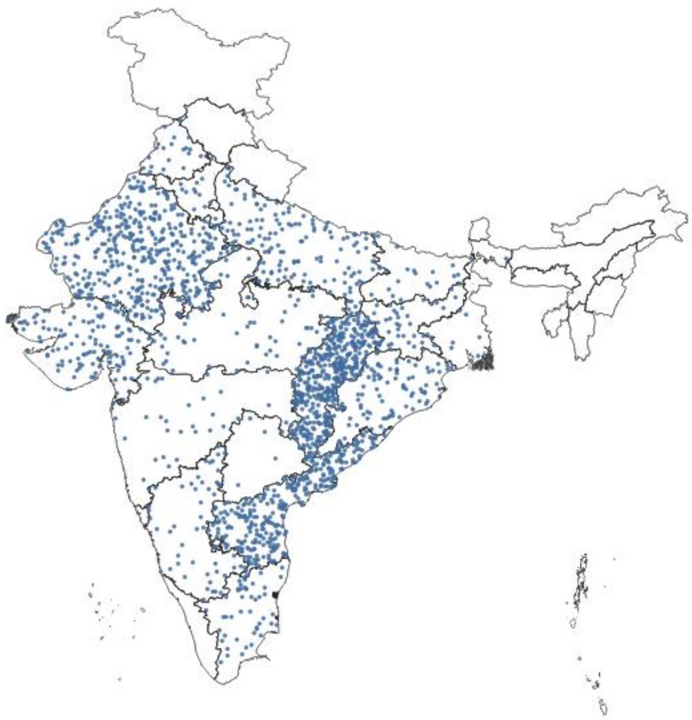


Figure 5. Distribution of SIPs in India (1 dot = 100 pumps)

As the affordability of SIPs increased, the potential socio-environmental threats of SIPs evolved. With reduction in price, SIPs became an attractive alternative to diesel pumps especially in regions where farm power supplies were poor. But SIPs also expanded quickly in regions where electricity grid was dense and farm power supply relatively better. As the price of SIPs reduced even further, their viability significantly improved in comparison to the existing farm power connections. SIP promotion from the central government provided an opportunity for state governments to reduce their existing farm power subsidy burdens. In the electricity sector, as the relevance of the SIPs increased, the threat to groundwater over-exploitation increased as no existing SIP policies acknowledged the potential threat in groundwater – until KUSUM.

Overall, two issues emerged prominently during stakeholder discussions and IWMI's pilot studies in Gujarat and Bihar. One, a majority of SIPs were being promoted in states were groundwater was already scarce, thus exacerbating the risk of groundwater over-exploitation. IWMI's experiment in Dhundi showed it was possible to incentivize farmers to inject more power into the grid rather than using that power for pumping more groundwater). However, this incentive would only work in areas where SIPs were connected to the grid and farmers were offered reasonable buy-back tariff. Second, in parts of India where groundwater is abundant, IWMI's Chakhaji experiment found it was possible to create a market for selling water services through investment in proper infrastructure (e.g., underground pipelines and overlapping command areas of SIP) and incentive structures (e.g., incentivizing farmers to sell water services to others).

India has an active private sector in SIPs and the downward movement of prices in solar panels and associated equipment has meant that new private sector players can and will enter the market. However, given that much of the Indian SIP market is subsidy driven, the role of private sector, for now, will be confined to supplying subsidized pumps instead of driving the market direction.

1.1.3 CURRENT STATUS AND POLICIES FOR SIPS IN NEPAL

The Government of Nepal (GoN) has been supporting promotion and development of Renewable Energy Technologies (RETs) for over two decades with support from national and multi-lateral development partners

[DPs]. The GoN and DPs have been providing financial and technical support to increase energy access in the rural areas for both household consumption and productive end uses (APEC, 2018). To date, Nepal has approximately 1,600 SIPs, 75% of which have been financed and installed by AEPC, and the remainder by a number of NGOs and INGOs such as IDE, ICIMOD, Winrock, and Practical Action. More recently the GoN and provincial Nepali governments have been installing SIPs as well.

Solar energy provisions have been embedded in the overall alternative energy plans and policies in Nepal. Alternative energy includes hydroelectricity, solar energy, bioenergy and wind energy. According to the three-year interim plan 2007-2010, Nepal has a potential to generate 1,132.7 MW of solar energy. According to the 15th plan approach paper (2019/20-2023/24), alternative energy currently accounts for 55 MW of production and benefits 36 lakh households. 17% of the total population in Nepal benefits from renewable technologies and this sector has generated 30,000 jobs and contributed 3.2% of the total clean alternative energy in the country.

An extensive review of policies on renewable energy in Nepal shows a gradual evolution of solar energy in national policies and plans. In the beginning, the use of solar energy was limited to specific sectors such as drying, communications, and water heating. In recent years, solar energy has expanded into irrigation and drinking water schemes. Solar technology was integrated with irrigation and drinking water for the first time under the Rural Energy Policy, 2006. This policy also marked the first time when plans were formulated to integrate rural energy development programs (including solar) with an aim to improve the situations of women and marginalized groups. In addition, a Rural Energy Fund was created to mobilize grants for Solar Energy and the Nepal Rural Renewable Electricity Policy (NRREP) set a target to establish institutional solar power systems including solar pumping systems.

Until the start of the 13th Plan (2013-2016), the use of solar energy for irrigation and drinking water was limited to hilly and remote areas. The 13th Plan incorporated ideas for solar energy for irrigation in the Terai. In recent years, solar energy has become a major force in the Terai, as central and provincial governments have prioritized SIP projects, as evidenced in the 14th Plan (2017-2020) and the 2018-19 budget speech. In the 2018-19 budget, the central government allocated NPR 350 million (~USD 3.5 million) as grants for SIPs and pledged additional support to renewable energy production if initiated by cooperatives and local communities in collaboration with the local government. The budget also included provisions to provide federal matching grants to all local levels to encourage alternative energy generation, including solar.

The 14th Plan also initiated a subsidy for solar drinking water and irrigation systems at the individual, community, and institutional (i.e., private sector) levels. The policy entails a maximum subsidy amount of 60% of the total costs, but not to exceed NPR 1,500,000 per PV drinking water system and NPR 2,000,000 per PV irrigation system for agricultural land managed by a community or private company. An additional subsidy of NPR 4,000 per household has also been provisioned for "targeted beneficiary groups," which includes farmers who belong to federally-recognized disadvantaged groups. Another provision for a 20% subsidy (on top of the original subsidy amount) has been earmarked for solar pump drinking water systems in earthquake-affected areas. The Alternative Energy Promotion Center is the main institution responsible for the implementation of Renewable Energy Subsidy Policy, 2016.

The total allocated budget for solar energy in the 2019/20 budget has been increased to NPR 960 million. This money has been allocated with the intention of developing two large solar projects in every province and to promote solar energy for lift irrigation in collaboration with provincial and local governments. The money will also be used to draft plans for Terai-Madhesh solar energy groundwater irrigation services and a special program under the Terai-Madhesh collective groundwater and surface irrigation project.

Collectively, the plans and policies also carry ambitious aspirations to connect the excess energy to the national grid system and distribute it through a net payment system (15th Approach Plan Paper, 2019/20 -2023/24;

MoEWRI White Paper, 2018]. Nepal is committed to its Nationally Determined Contribution (NDC) and plans to generate 2,100 MW of solar energy by 2030 with infrastructure in place for grid distribution [NDC, 2016].

- Following Nepal's 2015 Constitution, under new federal arrangements, local level governments have been entrusted with responsibilities for implementing renewable energy and other local development projects. The Constitution also notes renewable energy as an important development priority. Local irrigation, drinking water, small electricity, alternative energy, WASH, watershed management and wetlands are the exclusive rights of local governments.

Nepal also has committed to the internationally-agreed goals in Sustainable Energy for All (SE4ALL), the Sustainable Development Goals (SDG), and the NDCs related to the Paris Climate Change Agreement.

In addition to the AEPC, a number of government organizations are working to promote and implement SIP projects in Nepal. The majority of solar projects have been implemented in provinces 2, 3, and 4. The installed SIPs have been employed to serve a wide range of uses: drinking, irrigation, fruit cultivation, livestock, fisheries, homestays, and diversified vegetable and crop farming.

The private sector plays a very important role in Nepal, given that subsidy delivery modality is driven by the private sector. Every year, the AEPC calls for applications from farmers applying for the 60% subsidy for solar pumps. The private sector assists farmers in completing those applications, serving as an effective communication bridge between farmers and the government.

1.1.4 CURRENT STATUS AND POLICIES FOR SIPs IN PAKISTAN

The Government of Pakistan has embarked on a large-scale effort to increase the country's use of solar energy. However, until 2015, there were no federal level schemes for SIPs. However, there is evidence of SIP adoption by large farmers in parts of Punjab. Then in 2015, the federal government of Pakistan announced a scheme for subsidizing small farmers (> 12.5 acres of land) for buying SIPs (Government of Pakistan, 2015). Preference was given to farmers who had also installed high-efficiency irrigation systems (HEIS). The government set a target of 30,000 SIPs installed on a budget of USD 93.2 million over 5 years; however, this scheme has not yet been implemented. Instead, a year later, the provincial government of Punjab launched a similar scheme in collaboration with ADB that provided an 80% subsidy for installing SIPs for operating HEIS on 20,000 acres of agricultural land (Directorate General Agriculture and Water Management, 2016).

Pakistan still does not have a specific policy on SIP. However, Pakistan does have a number of policies that have bear on SIPs for groundwater pumping in agriculture. The National Water Policy makes a number of references to groundwater pumping and it promotes solar pumping in rain-fed areas where groundwater depth is shallow. There is also the Policy for Development of Renewable Energy for Power Generation but this policy does not discuss solar irrigation in particular. Given that Pakistan is a federation of four provinces and administrative units (Gilgit-Baltistan, Azad Jammu and Kashmir, Islamabad Capital Territories) each province has its own responsibilities for governing water resources and each province has embarked on different trajectories to deliver on the National Water Policy. For example, the province of Khyber Paktunkhwa is developing an integrated water resources management plan. The Punjab has drafted its own Water Act, which is now under consultation. Balochistan has the Balochistan Ground Water Rights Administration Ordinance 1978 is looking to update this Ordinance.

In addition to the various laws and policies that impact on groundwater and renewable energy, there are a number of development investments in solar technology for groundwater pumping in agriculture. The largest investment is the Punjab Irrigated Agriculture Productivity Improvement Program Project, which seeks to stimulate the use of drip irrigation technology through capital cost subsidies. These drip systems are typically coupled to groundwater pumps and/or on-farm reservoirs receiving canal water. A follow-up project supported by the ADB aims to convert or replace diesel prime movers with electric motors and PV panels by providing an 80% subsidy on capital costs.

The World Bank is heading another initiative in the Sindh to introduce drip irrigation systems coupled with solar technology. As the Sindh has low quality groundwater, these solar systems be used primarily for pumping canal water stored in on-farm reservoirs. In Balochistan, groundwater depletion is a serious concern due to the fact that all tube wells are grid-connected and electricity is charged at a flat monthly tariff. To this end, a number of alternatives are being suggested, including subsidies on capital costs to encourage farmers to convert to solar technology. Uptake of this alternative would reduce the costs of supplying electricity rather than address any water management/groundwater management issues. A number of pilots have also been undertaken by the Pakistan Council of Research in Water Resources (PCRWR) and the Pakistan Agricultural Research Council (PARC). These groups have been piloting demonstration sites to show how PV technology and submersible DC pumps are suited to and reliable for agriculture.

Most water professional in Pakistan are concerned that converting diesel pumps to PV solar will result in indiscriminate pumping and eventually lead to further groundwater depletion. This opinion is largely informed by the experience in Balochistan where electricity is provided at a flat rate to farmers and therefore there is no financial (electricity costs) constraint to pumping. PCRWR has undertaken some studies to look at how daylight hours/solar irradiation will constrain pumping. However, this knowledge has not been widely acknowledged nor accepted and there is some criticism that pumping does not only depend on energy availability but also the installed capacity. Also, farmer behavior has not been studied in any detail. It is this lack of knowledge and alternatives that constrain investments in solar technology for groundwater pumping in agriculture.

Currently, groundwater utilization in Pakistan meets 60% (or 68 billion m^3) of the total irrigation water requirements of the country. Across the country, there are ~1.3 million tube wells of which 83% are diesel-powered; most of these tube wells are installed at shallow depths, between 12-18 meters. The average farm size where diesel-powered tube wells are installed is less than 5 ha and these constitute approximately 5% of the total farms in the country.

Solar-powered irrigation systems provide a promising alternative to diesel-powered tube wells but adopting this technology at scale has faced many challenges in Pakistan. For one, farmers are unable to invest in solar due to high initial costs as well as the low discharge capacities of solar pumps as compared to diesel-powered pumps. Secondly, more than 90% of the irrigation in Pakistan is carried out through flood irrigation and not with pumping. Despite efforts by provincial governments to promote solar through HEIS, most farmers are not prepared to shift from flood irrigation to HEIS techniques.

As mentioned earlier, different provinces have provided different incentives to promote solar irrigation for purposes of bringing down CO_2 emissions. Current estimates state that diesel-powered tube wells are contributing almost 5.025 million metric tons of CO_2 emissions annually (FAO, 2019). Punjab is promoting solar technology by providing a 60% subsidy on the installation of an HEIS system, and an 80% subsidy for a solar system if it is coupled with HEIS. However, this program requires farmers to use solar pumps only with HEIS and this combination may not be appropriate for certain existing cropping patterns. The government of Khyber Pakhtunkhwa has also initiated projects through their Directorate of Agricultural Engineering to provide a 50% subsidy on SIPs to be used in rain-fed and water scarce areas. The Sindh government has launched several schemes for installing solar-powered tube wells and pumping stations as part of an effort to strengthen the province's agriculture sector. To date, PKR 802 million has been earmarked for providing SIPs and tube wells on subsidized rates to farmers, but the success of this program is yet unknown. Finally, in Balochistan, the only province where tube wells are connected to the grid, these pumps consume 900 MW of power on an annual basis and are depleting the water table rapidly due to prolonged drought conditions and excessive groundwater pumping. The Balochistan government is providing PKR 23 billion in electricity subsidies to farmers using grid-connected tube wells. In 2017, the federal government and Balochistan agreed to replace 30,000 grid-connected tube wells with SIPs to decrease the burden on the provincial government. But, to date, this project has not materialized.

Of all four countries in the region, Pakistan's private sector has played the strongest role in popularizing SIPs. Given that until recently there were no subsidy programs for SIPs, only large-scale farmers could afford to invest in SIPs, which were provided by the private sector. The majority of farmers who adopted SIPs were large-scale farmers who used their own funds. Given the large landholdings of these farmers (> 10 ha) and deep-water tables (> 25 meters in places where SIPs have been installed), the farmers have purchased large-sized SIPs greater than 5 HP. These systems cost between USD 9,000-20,000, but prices have been falling rapidly in recent years.

1.2 ANALYSIS OF DRIVERS AND RESTRAINERS OF CHANGE (POLITICAL ECONOMY ANALYSIS)

A situation analysis shows that the main drivers of changes in SIP-related policies in the sub-continent are as follows:

- All countries are making strides toward cleaner energy production through their NDCs;
- Steep declines in PV panel prices have created more favorable conditions for solar energy production;
- Potential of saving electricity and diesel subsidies make SIPs a feasible option for replacing grid-connected electric pumps and off-grid diesel pumps; and
- More attractive financial models (e.g., subsides, government budget allocations, concrete renewable energy production targets) have spurred uptake of SIPs in the region and motivated greater international donor interest in program to promote SIPs.

However, in spite of these favorable developments, many challenges remain, including:

- High upfront costs for SIP installation;
- Lack of information among farmers (esp. small- and mid-scale) about the effectiveness and benefits of SIPs;
- Lack of coordination among agencies promoting SIPs, but with different objectives;
- Insufficient budget allocation in federal and provincial governments for SIP promotion;
- Lack of available insurance policies that cover SIPs;
- Lack of trained local mechanics to service SIPs when malfunctioning; and
- Lack of forward and backward supply chain linkages related to SIPs.

1.3 LINKS TO INTERNATIONAL/NATIONAL POLICIES / RELEVANT LEGAL AND POLICY FRAMEWORKS / POVERTY REDUCTION STRATEGIES (PRS) / DEVELOPMENT / HUMANITARIAN PROGRAMS AND SDGS.

The outcomes, outputs, and activities of SoLAR-SA will have many synergies with a number of other programs and projects, including various SDC-funded projects in the region.

All countries have NDC commitments that priorities reducing GHG emissions – a goal that SIPs can help achieve. Some countries, like India and Bangladesh, also explicitly mention solar in general, and SIPs, in particular, in their respective NDC submissions. Each country's National Adaptation Plans include various provisions and programs on efficient water management and, while there is no explicit mention of SIPs in these NAPs, there is a general consensus that links SIP promotion with efficient agricultural water management practices, such as HEIS and micro irrigation.

Encouragingly, many international donors already support SIP programs in the region. These groups include:

- ADB in Bangladesh
- GIZ, IFAD and World Bank in India
- DFID and KfW in Nepal
- ADB and World Bank in Pakistan

As well, there are numerous agencies conducting research on SIPs with whom we will forge knowledge partnerships, including FAO, IDE, CEEW, IRENA, Winrock, ICIMOD, and the Syngenta Foundation. Our knowledge partners in Bangladesh (IDCOL) and Nepal (AEPC) have been accredited by the Green Climate Fund (GCF).

As a part of its NDC commitment, India took a lead role in setting up the International Solar Alliance (ISA). We will work closely with ISA through this project, especially in delivering our capacity building components.

We will also connect with other SDC-funded projects in the region. These projects include:

- Integrated Water Resources Management in Barind Tract, Bangladesh;
- Skills for Employment Investment Program and Bangladesh Agriculture and Disaster Insurance Program;
- Clean Energy Policy Program, India;
- Small Irrigation Project, Nepal;
- SHE Leads, Nepal (project to empower elected women leaders)
- Nepal Agricultural Services Development Program; and
- ENSSURE and Vocational, Nepal (training and education for disadvantaged people).

1.4 USE OF SDC STEERING INSTRUMENTS, SUCH AS CONFLICT SENSITIVE PROJECT MANAGEMENT (CSPM) OR 'FIT FOR FRAGILITY', TO ASSESS THE CONTEXT IN A FRAGILE PROJECT PARTNER COUNTRY.

While none of the four project countries in our project are officially classified as fragile, diplomatic tensions between India and Pakistan could pose potential risk. To mitigate this condition, and to ensure that project implementation is as decentralized as possible, IWMI country offices in India, Nepal and Pakistan will manage and implement the country activities of the project (including budget) in close cooperation with the regional team based in Sri Lanka and project management unit based in the IWMI India office. Since IWMI does not have an office in Bangladesh, the Bangladeshi activity will be also managed by the IWMI India office. All regional capacity building events will be held in Nepal, Bangladesh, Sri Lanka or any other country (e.g., Dubai in UAE), where project participants from all countries can participate.

2.0 Results and lessons learned

2.1 SUMMARY OF RESULTS FROM THE ENTRY PHASE

The following activities were conducted during the entry phase (September 2018-August 2019)

- Desk review of relevant literature and policy documents
- Five stakeholder meetings:
    - Dec 2018 – entry phase inception meeting (Anand, Gujarat)
    - Feb 2019 – Nepal consultation meeting in (Kathmandu)
    - April 2019 – Pakistan consultation meeting (Islamabad)
    - June 2019 – Bangladesh consultation meeting (Dhaka)

    - July 2019 -- Entry phase final regional consultation meeting (Kathmandu)
- Four field visits (one in each country) and several one to one meetings with main stakeholders

The main outputs of the entry phase include:

- Scoping report (already submitted)
- Five workshop reports – one regional and four national (see Annex 1)
- Brief policy and situation analysis status reports from all four countries (summarized in this document)
- The ProDoc document (current document)

Main outcomes of the entry phase include:

- Improved understanding of SIP policies and SIP-related institutions across all four countries;
- Recruiting national country partners in all four countries; and
- Developing an agreement on the broad contours of the first phase of SoLAR-SA, as outlined in this document.

As a result, the proposed project is well-aligned to meet the specific needs and priorities identified in the respective national policies. As well, we have established shared ownership of the project through consultation with stakeholders in all four countries.

2.2 LESSONS LEARNED AND THEIR IMPLICATIONS FOR THE NEW PHASE

Main findings from the entry phase of the proposal include:

- While all four countries fall within the two major typologies of water-energy interlinkages, the needs of the countries are somewhat different, and depends on their respective institutional policy landscapes. The activities in each country, therefore, need to be context-specific and appropriate. For example, while designing the best financial model for encouraging small farmers to own SIPs is an important policy question in Bangladesh, Nepal is more focused on understanding how financial incentives and other modalities will need to respond to the country's new federal structure.
- A few common themes have emerged. In all countries, there are groundwater sustainability concerns, though they may vary by degree of concern. For example, in Pakistan, groundwater sustainability concerns have prevented further investments in SIPs, while in Bangladesh, SIPs have a stronger relation to groundwater quality issues. Therefore, in our project, understanding groundwater sustainability issues will require a cross-cutting focus.
- Similarly, GESI issues will form another central cross-cutting issue and we will undertake pilots and studies to address GESI concerns.
- All countries have expressed interest in piloting grid-connected SIP options, even though the motivations for doing so varies by country. In western India and Pakistan, grid-connected SIPs with suitable tariff structures are seen as a feasible way of reducing groundwater over-exploitation by incentivizing farmers to sell electricity back to the grid, instead of pumping more groundwater. In Nepal and Bangladesh, grid connection is seen as a way of fulfilling idle SIP capacity.
- This project can lay the groundwork for long-term fundamental changes in groundwater governance in the region by helping remove some counter-productive policies such as high electricity subsidies, that have led to the current state of unsustainable groundwater use.

We have designed the first phase of the project based on the lessons learned with assistance from numerous stakeholders representing a wide variety of relevant roles (e.g., farmers, government officials, and electricity sector representative).

3.0 Objectives

3.1 PROJECT OBJECTIVES

The main goal of the project is to contribute to climate-resilient, gender-equitable, and socially-inclusive agrarian livelihoods in Bangladesh, India, Nepal, and Pakistan by supporting government efforts to promote solar irrigation. This project aims to achieve three broad outcomes:

1. Generating improved empirical evidence to support the development of climate-resilient, gender-equitable, socially inclusive, and groundwater-responsive solar irrigation policies;
2. Validating innovative actions and approaches for promoting gender-equitable, socially inclusive, and groundwater-responsive solar irrigation; and
3. Increasing national and global knowledge and capacity for developing gender-equitable, socially inclusive, and groundwater-responsive solar irrigation policies and practices.

Table 4 shows all the activities mapped under each of these outputs and are described in greater detail in our log frame (Annex 2).

Table 4. Outcomes, outputs, and activities for SoLAR-SA

Outcomes	Outputs/guiding policy questions	Activities	
Outcome 1: Generating improved empirical evidence to support the development of climate-resilient, gender-equitable, socially-inclusive, and groundwater-responsive solar irrigation policies; Work Package I	**Output 1.1**: Impact of solar irrigation on livelihoods of women and men farmers and climate resilience documented and shared with policymakers **Policy question**: How have current SIP policies and programs fared in terms of their impacts on farmers' livelihoods and gender equity?	1.1.1	Impact evaluation and GESI case studies of existing and new SIP programs in Bangladesh
		1.1.2	Impact evaluation and GESI case studies of existing and new SIP programs in Nepal
	Output 1.2: Impact of large-scale SIP adoption on groundwater sustainability documented and shared with policymakers **Policy question**: What are the possible impacts of large-scale adoption of SIPs on groundwater resources?	1.2.1	Groundwater-related studies embedded in demonstration pilot in Bangladesh (also see activity 2.2.1)
		1.2.2	Groundwater-related studies embedded in scale pilot in India (also see activity 2.2.2)
		1.2.3	Groundwater-related studies embedded in demonstration pilot in Pakistan (also see activity 2.2.4)

Outcome 2: Validating innovative actions and approaches for promoting gender-equitable, socially-inclusive, and groundwater-responsive solar irrigation; and Work Package 2	**Output 2.1**: GESI-responsive, pro-poor and groundwater-aware financial models for solar irrigation promotion demonstrated and documented **Policy question**: Which financial model generates maximum willingness among small-scale and marginal farmers to adopt SIPs?	2.1.1 Scale pilot for testing the best financial modality for ownership of SIP by individual farmers in Bangladesh (activities 1.1.1 to 1.13 also contributes to output 2.1)
	Output 2.2: Demonstrated and documented technical and institutional modalities for grid connection of SIPs in different water-energy regimes **Policy question:** What kinds of technical and institutional modalities work best for grid connection of SIPs and how can these modalities be optimized for better groundwater governance in the long term?	2.2.1 Demonstration pilots for grid connection of SIPs in Bangladesh
		2.2.2 Scale pilot for testing institutional modalities for implementation of the Government of Gujarat's SKY project, and its implications on groundwater resources.
		2.2.3 Demonstration pilots on grid connection of SIPs in Nepal
		2.2.4 Demonstration pilots and simulation of grid-connected pumps through heat sinks in Pakistan
	Output 2.3: Technical and institutional modalities of grid connection of SIPs in different water-energy regimes demonstrated	2.3.1 Administration of innovation funds
Outcome 3: Increasing national and global knowledge and capacity for developing gender-equitable, socially inclusive, and groundwater-responsive solar irrigation policies and practices.	**Output 3.1**: A cadre of women and men farmers and technicians trained and water-energy-agriculture experts in the region sensitized on cross-sectoral linkages	3.1.1 Training of local technicians in Bangladesh, India and Nepal; training for farmers in Pakistan
		3.1.2 Training of groundwater, energy and agriculture

	Output 3.2: Multi-stakeholder forums for global, regional and national exchange of knowledge on best practices in GESI-responsive and groundwater-aware solar irrigation policies and practices **Policy question**: How do we create technical, institutional and financial know-how needed to help in energy and groundwater governance transitions needed for long term adoption of SIPs in the region?	officials in all four countries 3.2.1 Regional knowledge and policy forums 3.2.2 National policy forums

3.2 DESCRIPTION OF THE IMPACT HYPOTHESIS

SIP as a technology is well-developed and its benefits are well-known, and the barriers to adoption are no longer only technology related. Therefore, further technology-related piloting is unlikely to be useful. Similarly, there has been a number of stand-alone pilots on various financial and institutional models, and yet the lessons learned from those pilots have not always been integrated into policies, partly due to the fact that all pilots have been conducted in close association with government-implementing agencies. In addition, if we look at SIPs as a stand-alone solution for transition to clean energy without understanding its impacts on groundwater, the long-term social, gender, and agricultural outcomes are not likely to be achieved as all these systems – water, food, energy and livelihoods – are closely interconnected. Finally, renewable energy policies, of which SIP policies are a sub-set, are evolving very rapidly, and this point in time offers a unique opportunity to gather evidence that can influence these policies.

The main impact hypothesis for this project is that promoting SIP as an instrument for managing the region's negative interlinkages among water, energy and agriculture will require working directly with implementing agencies to help improve their ongoing programs. All the activities in this project have been developed in a collaborative and consultative mode with national government partners. The secondary impact hypothesis is that this project will provide compelling reasons for discontinuing many of the perverse policies (e.g., free power) that distort incentives for farmers to manage groundwater sustainably and, in doing so, we hope this work will pave the way for sustainable and equitable groundwater governance in the future.

3.3 DESCRIPTION OF THE POOR AND VULNERABLE TARGET GROUP

In this project, we will work directly with government implementing partners (see section 4). A major focus of this project will be on inclusion and groundwater sustainability. Through these efforts, we will influence SIP policies to help enhance the outreach of SIPs to the vulnerable groups. Currently, only ~10% of SIPs are owned by small and marginal farmers and less than 5% are owned by women farmers. At the conclusion of this project, and through changes in corresponding SIP policies, we hope at least 30% of SIPs will be owned by small and marginal farmers, and 10% will be owned by women farmers in each of the countries. Groundwater over-exploitation disproportionately affects the poor and marginal farmers, as they often buy water from richer well-owning farmers. Through research and pilot interventions, we will demonstrate that it is possible to reduce groundwater extraction by up to 20% if farmers are provided with the right incentives for selling more electricity back to the grid, instead of pumping more groundwater for irrigation.

3.4 OUTREACH

Our direct beneficiaries are the government organizations who are our partners in this project. We will work in four countries – in northwest Bangladesh; in Gujarat state in India; in the Terai (plains) provinces of Nepal (1 and 2); and in Punjab Province in Pakistan.

We will work with the following agencies to either formulate SIP-related policies or implement SIP project:

- Infrastructure Development Company Limited (IDCOL) in Bangladesh;
- Gujarat Energy Research and Management Institute (GERMI) in India;
- Alternative Energy Promotion Centre (AEPC) and Nepal Electricity Authority (NEA) in Nepal; and
- Federal Water Management Cell (FWMC) and Pakistan Agricultural Research Council (PARC) in Pakistan.

We will also reach out directly to approximately 5,000 farmers in all our project countries through information dissemination on financing models (in Bangladesh), through formation of 10 solar cooperatives (in Gujarat); and through grid connection experiments in all four countries.

Through this project, we will influence policies and practices of our main partners, who, in turn, through their projects, will reach out to thousands of farmers. We will also directly reach out to approximately 400 male and female farmers and solar technicians through annual training programs. Through the innovation grants that this project will offer, we hope to reach an additional 10-15 innovators, whose work, if upscaled, could impact thousands of additional farmers.

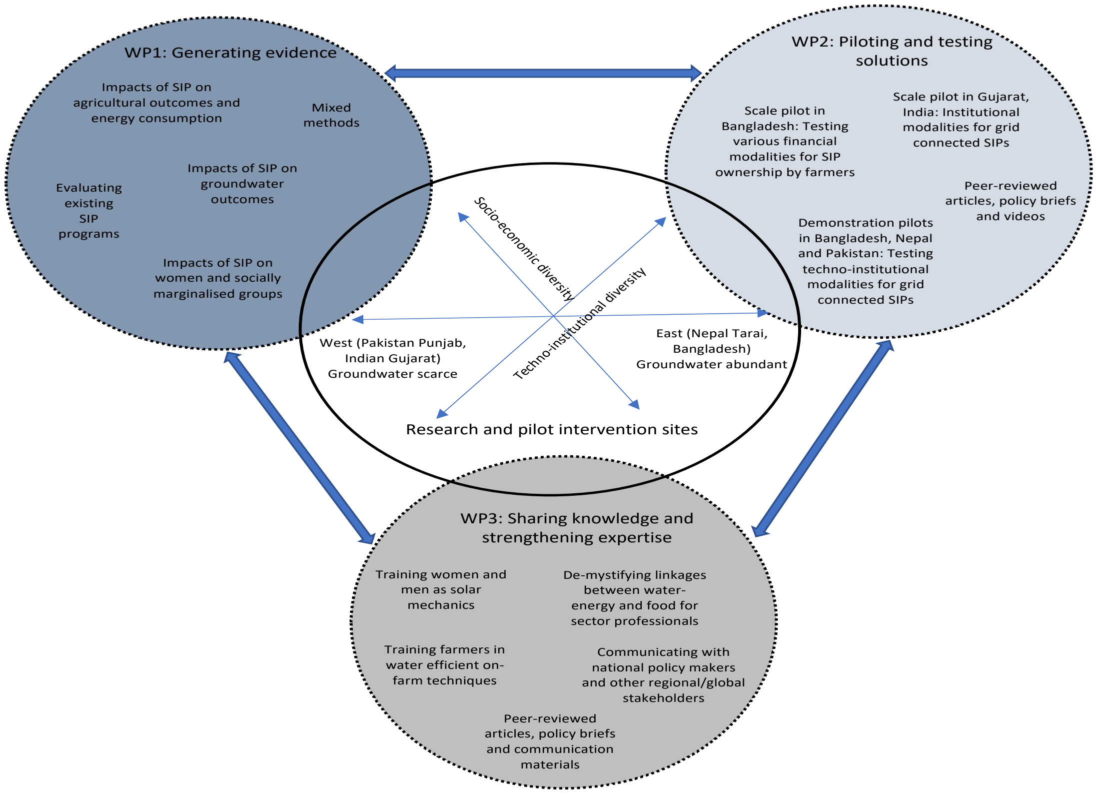
3.5 LEVEL OF THE INTERVENTION (MICRO, MESO, AND MACRO)

The interventions in this pilot are primarily at the micro level – villages and small numbers of transformers. One exception will be our scale pilot in Bangladesh (Activity 2.1.1) where we will reach out to farmers in up to 120 union parishads – the lowest administrative unit in Bangladesh – through information campaigns on different financial modalities. We will also work closely with government partners in all countries, who will then work at meso- and macro- levels for further promotion of SIPs.

4.0 Implementing strategy: Description of the intervention approach, methodology and instruments

This project has three main objectives (outcomes). Figure 6 provides a pictorial diagram of the three work packages that have been designed to inform each of these outcomes. All activities in this project has been co-designed with our implementing partners and based on analysis of gaps and needs. In this section, we describe each of the work packages, outputs, and activities.

Figure 6. Schematic diagram of the project framework



4.1 WORK PACKAGE 1: IMPACT EVALUATIONS, GESI AND GROUNDWATER CASE STUDIES

Activities and outputs in this work package will contribute to Outcome 1 of mainstreaming of climate-resilient, GESI-responsive, and groundwater-sustainable solar irrigation promotion policies through improved empirical evidence. This work package will contribute to two outputs.

4.1.1 OUTPUT 1.1: IMPACT OF SOLAR IRRIGATION ON LIVELIHOODS OF WOMEN AND MEN FARMERS

We will conduct rigorous impact evaluations on some selected SIP programs of our government partners. Government partners associated with this project have requested IWMI to evaluate their SIP programs and provide them with recommendations on how the implementation and outcomes of these programs can be improved. We will conduct this impact evaluation using quasi-experimental methods. The main outcome variables of interest are:

1. agricultural and nutritional outcomes, with a special focus on women and children;
2. on energy savings, consumption, and GHG emissions; and
3. on groundwater withdrawals.

We will use the existing monitoring data provided by our partner agencies, and supplement those with primary field data collected through measurements and survey instruments. This activity will be undertaken in Bangladesh and Nepal. In India, we will conduct a qualitative assessment of SKY feeders in Gujarat as part of scale pilot (see activity 2.2.2) and assess existing SIPs in Pakistan as part of groundwater-related studies (see activity 1.2.3) and demonstration pilot (see activity 2.2.4).

ACTIVITY 1.1.1: IMPACT EVALUATION AND GESI CASE STUDY OF IDCOL'S SIP PROGRAMS

The agrarian economy of Bangladesh is dependent on groundwater and groundwater irrigation, which is entirely dependent on imported diesel. Diesel is not only a 'dirty' fuel, but also very costly for small farmers and imposes a huge subsidy burden on the government's exchequer. The Bangladeshi government views solar irrigation as a cheaper and cleaner substitute for expensive diesel-based irrigation. Electricity is also cheaper than diesel and the government is committed to expanding electricity connections across the country. But electricity generation is primarily dependent on 'dirty' fossil fuels; solar irrigation would be a cleaner alternative and help Bangladesh achieve its intended NDCs under the UNFCCC.

In this context, it is imperative to understand the impact of solar pumps on irrigation accessibility, GHG emissions, and groundwater sustainability. We will undertake impact evaluation of the ~1,200 existing SIPs installed by IDCOL in Bangladesh. The majority of these SIPs are in the northwestern Rangpur district. We will select a smaller subset of SIPs (~100) and use quasi-experimental methods to select farmers who have access to SIPs, electric, or diesel pumps for irrigation on different plots. The study will be based on cross-sectional data collected from farmers operating under these different irrigation regimes by comparing farmers' behavior, water usage, and agricultural outcomes in plots serviced by solar pumps vis-à-vis plots serviced by diesel and electric pumps. The quantitative survey data will be complemented by qualitative studies and monitoring data from SIPs managed by IDCOL.

Through both qualitative and quantitative methods, we will also assess the extent to which current SIPs in Bangladesh are inclusive by analyzing the characteristics of farmers with access to SIPs as compared to farmers who use electric and diesel pumps. We will focus on how SIPs are affecting access to irrigation and impacting livelihoods for marginalized farmers (i.e., women farmers, landless farmers and tenant farmers).

Deliverables from this activity will include:

1. cross sectional data from a representative sample of SIPs, electric, and diesel pumps;
2. one impact evaluation report;
3. one GESI case study report;
4. one journal article analyzing impacts of SIPs in Bangladesh on agricultural outcomes; and
5. at least one policy brief outlining the main findings and policy implications (including concrete suggestions) that emanate from our research findings.

These findings will be communicated pro-actively to IDCOL and other partners during national workshops and steering committee meetings.

ACTIVITY 1.1.2: IMPACT EVALUATION AND GESI CASE STUDIES OF SIP PROGRAMS IN NEPAL

Since 2016, AEPC has supported installation of more than 1,200 SIPs with a 60% subsidy. A majority of these SIPs are in Province 2. However, apart from a one-time post-installation survey, AEPC has not undertaken detailed impact evaluation of the SIPs it has supported. ICIMOD has also implemented 54 SIPs in Province 2 and has been monitoring the performance of those pumps and collecting data on number of agricultural outcomes since 2017.

Province 2 has the largest number of SIPs in the country and we will conduct our impact evaluation activity in this district.

In this activity, we will use quantitative (e.g., propensity score matching) and qualitative methods to measure the impact of SIPs on agricultural and nutritional outcomes. We will randomly select up to 150 farmers who have installed SIPs funded by AEPC in province 2 and match them with another 150-200 farmers who unsuccessfully applied to AEPC for the subsidy. We will statistically test to learn if farmers with SIPs have better outcomes in terms of crop incomes, crop production, land and water productivity (kg/ha, kg/m^3 of water used), lower use of diesel, cropping patterns and diversification, and nutritional outcomes for women and young children.

In addition, we will conduct qualitative case studies with in-depth interviews of at least 30 women who own SIPs for agriculture and 30 women who farm but do not own SIPs to understand if and how SIPs lead to changes in GESI outcomes. This study will be complemented by a review of policies and programs of the Nepali government at the federal, provincial, and local levels.

Deliverables from this activity will include:

1. panel data from over 300 respondents spanning at least 2 years;
2. one impact evaluation report;
3. one GESI case study report;
4. 1-2 journal articles;
5. 3-4 news articles; and
6. at least one policy brief which will be communicated with AEPC and other stakeholders during national forums.

4.1.2 OUTPUT 1.2: IMPACT OF LARGE-SCALE SIP ADOPTION ON GROUNDWATER SUSTAINABILITY DOCUMENTED

It is often hypothesized that access to pumps with zero marginal cost, such as SIPs, will lead to increased groundwater abstraction and may further deplete groundwater resources in areas which already experience lowered groundwater levels. We will test this hypothesis about solar irrigation expansion and groundwater sustainability in selected demonstration pilot sites of Bangladesh (Barind tract), in Gujarat, India, and in demonstration pilot sites in Punjab province of Pakistan. All these three sites have reported declines in groundwater tables and country partners have expressed the need to urgently understand the impacts of SIPs on groundwater. Country activities in this pilot will attempt to answer three common questions:

1. How does farmer irrigation pumping behavior change after installation of SIPs under different deployment strategies (off-grid vs. on-grid)?
2. Does solar irrigation with efficient on-farm water management help in improving groundwater sustainability?
3. How will groundwater sustainability be affected if SIPs were to be upscaled, while also accounting for other changes, such as climate change?

ACTIVITY 1.2.1: GROUNDWATER RELATED STUDIES EMBEDDED IN DEMONSTRATION PILOT SITE IN BANGLADESH

At our demonstration pilot site in Bangladesh (see activity 2.2.1) we will look into the question of groundwater sustainability under SIP schemes for both on-grid and off-grid pumps. Sample farmers/pumps for this study will consist of both off-grid and grid-connected SIPs along with non-project farmers using major groundwater pumping systems in the region (electric or diesel). Sub-activities will include:

1. Groundwater abstraction taking place under different groundwater abstraction sets (e.g., SIP, electric and diesel) will be measured;
2. Data on available solar energy, hydrogeology characteristics and other parameters (e.g., cropping patterns and water management practices), along with secondary data on water levels will be collected;
3. Simple instrumentation, including flow meters, will be installed on sampled tube wells (2 for each type) to measure water abstractions from solar and electric/diesel pumps of different capacities to develop a empirical metrics through which energy consumption (kWh) can be translated to water discharge (cubic meters). Based on this empirical metrics, groundwater abstraction monitoring based on energy consumption would be employed; and
4. For the region under study, groundwater balance models will be developed to understand current situations and the implications of upscaling solar irrigation under various scenarios (e.g., different irrigation pumping behavior, various field level water management practices) along with other potential changes (e.g., climate change, socio-economic trends) on groundwater regimes and sustainability.

ACTIVITY 1.2.2: GROUNDWATER RELATED STUDIES EMBEDDED IN SCALE PILOT SITE IN GUJARAT, INDIA

In India, groundwater sustainability studies will be done as a part of a larger study on solar cooperatives in the SKY scheme of Gujarat (see activity 2.2.2). Activities will include:

1. Measure of groundwater abstraction taking place under different groundwater abstraction sets (e.g. areas with on-grid and off-grid solar pumps);
2. Collect of data on available solar energy, hydrogeology characteristics, and other parameters (cropping pattern, water management practices), along with secondary data on water levels;
3. Develop simple instrumentation (including flow meters) to sample wells and tube wells (2 of each type) to measure water abstraction from solar and electric/diesel pumps of different capacities, which would be used to understand the relationship between energy consumption (kWh) to water discharge (cubic meters). Based on the empirical relationship between energy consumption and groundwater extraction, and data retrived from SIPs, (e.g. data on cumulative irradiance, power consumption from variable frequency drives (VFD) etc.), quantum of goundwater extracted for irrigation will be calculated.
4. Develop a groundwater balance model for the area to understand the current situation and the implications of upscaling solar irrigation considering the scenarios mentioned above (e.g., irrigation pumping behavior, water management practices) along with other potential changes (e.g., climate change, socio-economic trends) on groundwater regimes and sustainability.

ACTIVITY 1.2.3: GROUNDWATER-RELATED STUDIES EMBEDDED IN DEMONSTRATION PILOTS IN PAKISTAN

In Pakistan, there is an active debate on whether SIPs will further aggravate the problem of groundwater over-exploitation. Although SIPs have near zero operational costs, which may appear to remove a significant constraint to groundwater pumping, the total available energy during the day remains a constraint: Groundwater pumps rarely employ batteries as these would be too expensive. Hence, solar technology for groundwater pumping in agriculture only operates during daylight hours when there is sufficient solar irradiation to operate pumps. PCRWR conducted a study between 2012-2014 to calculate the average solar hours across the year and they reported a maximum of six hours of peak solar irradiation during the months of May and June. Similarly, PARC conducted the same study with only slightly different figures: a peak of 6.5 hours during the month of May and reducing to around 5.9 hours in June. In a recent study, FAO reported the average sunshine hours during a year 6.3 to 6.8 hours per day). There are other constraints such as the land area and crop water requirements, which limit the use of solar technology. However, given these concerns and constraints, there has been no rigorous study that tests the hypothesis that SIPs would lead to more groundwater pumping compared to diesel or electric pumps.

To test this hypothesis, we propose to undertake a survey of different types of pump owners (SIP and diesel) using a matched sample methodology in the province of Punjab. The control group in this experiment would be farmers who use diesel operated groundwater pumps and the treatment group would be farmers who have invested in SIP. An appropriate sample size will be selected so that results are statistically valid. These two groups will be observed over a period of at least one calendar year to capture temporal variations. A small subset of tube wells may require some form of instrumentation to monitor actual water use and later use it to confirm the actual usage reported through the survey findings. This instrumentation would allow calibration of less expensive techniques such as using farmers' ability to recall tube well use.

Whether or not, SIPs lead to increased groundwater extraction is an important policy question and the results of this study can help inform policymakers about whether to replace diesel pumps with SIPs. This study will have large impact because 83% of the existing 1.2 million tube wells in Pakistan are diesel-powered. There is large potential at the policy level to decrease the oil import bill and promote SIPs with additional incentives. This development would help Pakistan to contribute to the sustainable development goals (SDGs) by contributing to the green economy and bringing down the average annual CO_2 emissions of 5.025 million metric tons from diesel pumps (FAO, 2019) through the replacement of diesel-powered tube wells with SIPs.

The deliverables from this research component will be our data set, one research paper/report, and at least one policy brief which will be proactively shared with relevant policymakers.

4.2 WORK PACKAGE 2: SCALE AND DEMONSTRATION PILOTS

Activities in this work package will contribute to outcome 2 of improved livelihoods of women and men farmers through access to solar irrigation as a result of GESI-responsive and groundwater-aware solar irrigation policies. We will implement two types of pilots to derive our outputs and outcomes. Scale pilots are those that are implemented with government partners as a part of their ongoing project/program activity. The aim of these scale pilots would be to improve the efficiency, equity, and sustainability of ongoing government SIP programs. Demonstration pilots, in contrast, will try to exhibit how a certain technical or institutional innovation (e.g., grid-connected SIPs) can be used to answer relevant policy questions. Demonstration pilots will be smaller in scale and will cover one or two villages, or a few transformers, at most.

4.2.1 OUTPUT 2.1: DEMONSTRATE AND DOCUMENT GESI-RESPONSIVE, PRO-POOR AND GROUNDWATER-AWARE SOLAR IRRIGATION FINANCIAL PROMOTION MODELS

The cost of solar panels has fallen sharply in recent years, making SIPs more and more affordable. However, for a large section of small and marginal farmers, SIPs are still expensive. Given that upfront costs are relatively high, and that there are several benefits of shifting from dirty energy to clean energy, governments often provide subsidies for the adoption of SIP. IDCOL – our partner in Bangladesh – plans to implement a new financial model for SIP ownership. This plan gives us an opportunity to test various financial models and see which one generates the most demand from small and marginal farmers.

ACTIVITY 2.1.1: SCALE PILOT IN BANGLADESH

This scale pilot will answer two policy relevant questions:

1. Which "financial model" (e.g., grant + loan + equity; grant + equity; or grant + loan) generates the highest likelihood of famers willing to adopt SIP for individual ownership?

2. What are the characteristics of farmers who apply for the pumps under alternative financial models?

Relevance of policy questions

IDCOL is the main financier of solar pumps in Bangladesh and currently uses the "fee-for-service" model for promoting solar pumps. But there is another model that IDCOL will introduce soon, which is being referred to as the "ownership" model. In this model, individual farmers will buy solar pumps directly from sponsors through a combination of loan and equity payments. To ensure that the financial model for individual ownership of solar pumps generates the maximum demand and does not become exclusionary, it is important to understand how different financial models will affect farmers' willingness to apply for ownership. This question forms the basis of our scale pilot in Bangladesh.

Target group of the intervention

Through this pilot study, we will reach out to ~5,000 farmers in at least 120 union parishads in one or two districts of Bangladesh. Our main objective is to help IDCOL design the best financial model for the promotion of individual SIPs to generate maximum demand from farmers, including from small and marginal farmers.

Description of the pilot

In the "fee for service" model, local private group sell water to farmers. In the "ownership" model, by contrast, the sponsor (the entity which gets loan/assistance from IDCOL) will sell solar pumps to farmers. In the ownership model, 50% of the pump cost will be covered by grant from IDCOL, which is equivalent to the payment required in the fee for service model. The farmer who buys the solar pump will have to pay some upfront payment (equity) to the sponsor. The remainder of the cost will be considered a loan from the sponsor. Until that loan is paid back to the sponsor, ownership will remain with sponsor and the farmer will have to service the loan through yearly payments. The sponsor, in turn, will take a loan from IDCOL with some part as equity payment. IDCOL provides the loan to the sponsor based on a bank guarantee at 6% interest with a 10-year tenure. The pumps under "ownership" model will be substantially smaller than their "fee-for-service" model pumps, because these will be bought by individual farmers.

The amount of loan vis-à-vis the equity payment has not yet been finalized. IDCOL is interested to understand how farmers' demand for solar pumps will be affected by different combinations of loan and equity - namely, grant + loan + equity; grant + equity and grant + loan. These financial models will not only affect the demand for solar pumps, but also the types of farmers who are able to apply under each of these financial models.

In our scale pilot, we will offer these alternative financial models to farmers and observe the willingness to apply for solar pumps generated under each one. And we will study the characteristics of the applicants under each regime. IDCOL is currently working in three divisions - Rangpur, Rajshahi and Khulna. The scale pilot will be implemented in a maximum of two districts in any one division. The final selection of districts will be based on discussions with IDCOL, to understand their priorities, and on the socio-economic characteristics of regions that are best suited to promote individual ownership of solar pumps.

Methodology

We will use either randomized control trial (RCT) or choice experiment method for assessing three alternative financial models: "grant + loan + equity", "grant + loan" & "grant + equity". In our selected districts, union parishads (the lowest administrative unit in Bangladesh) will be matched into groups of three based on social and agricultural characteristics to ensure similarity. Next, one of the three financial models will be assigned to each of the matching triplets. At least 120 union parishads will be included in the RCT, meaning each financial model will be tested 40 times. In each union parishad, similar information dissemination activities and mobilization efforts will be undertaken to educate farmers about the available model for that area. Over a given time period, applications for solar pump ownership will be collected from farmers and pumps will be allocated according to the terms of each financial regime. This random assignment of financial models to different parishads and consequent comparison of the demand generated under these different models will ensure that we avoid potential biases in treatment assignment.

GESI component

In order to encourage applications for solar pumps from marginalized sections of society, we plan to introduce additional financial incentives (e.g., lower interest rates or lump sum subsidies) for certain applicants (e.g., landless or tenant farmers, or female landowners as applicants). Additionally, the project will encourage groups of farmers (self-help groups (SHGs)/other informal groups) rather than individual farmers to apply for ownership of solar pumps through targeted marketing. This work will encourage smaller farmers to become solar pump owners by pooling their resources and operating as a service provider. It also ensures that subsidy benefits for solar pumps and low operating costs reach marginal and women farmers.

Main outputs

- One policy brief outlining our findings and making recommendations to IDCOL about the best financial model; and
- One journal article using rigorous econometric methods to show the impact of different financial models in generating demand for SIPs.

IWMI and IDCOL will co-design the study. The demand generation activities and mobilization efforts will be implemented through sponsors working with IDCOL with support from IWMI and IDCOL. Finally, the applications received under different financial regimes in the RCT will be provided with solar pumps at agreed terms through the sponsors and with financing from IDCOL.

4.2.2 OUTPUT 2.2: TECHNICAL AND INSTITUTIONAL MODALITIES FOR GRID CONNECTION OF SIPS IN DIFFERENT WATER-ENERGY REGIMES

In all four project countries, grid connection of SIPs has emerged as an important policy option. In the Indian state of Gujarat, grid connection of SIPs is already a reality through the state government's SKY scheme. In Bangladesh, Nepal and Pakistan, our government partners are interested to learn more about grid connection by co-investing in demonstration pilots related to this topic.

ACTIVITY 2.2.1: DEMONSTRATION PILOT ON GRID-CONNECTED PUMPS IN BANGLADESH

This demonstration pilot in Bangladesh will answer three policy questions:

1. How does grid connection of solar pumps affect the irrigation service business of IDCOL sponsors in terms of capacity utilization of solar PV, price of water, and changes in water schedule?
2. What will be the impact on water buyers when sponsors are able to connect their SIPs to the grid? What changes will this make in terms of water received from schemes, changes in cropping pattern, total water usage, and income from agriculture?
3. Can solar pump irrigation service providers/owners be incentivized to pump less groundwater in groundwater-stressed regions like Barind tract in Bangladesh through additional tariff incentives?

Relevance of policy questions

In Bangladesh, solar pumps are used primarily in four months of summer (*boro* season) and they remain mostly idle the rest of the year. Consequently, capacity utilization for these solar pumps is very low. Additionally, one of the distinctive characteristics of solar pumps installed to date through IDCOL financing is that they tend to be large with significantly extra solar PV capacity built in. The main reason for this excess capacity is to maintain same discharge rate throughout the day. So, it becomes important to find ways to increase capacity utilization of these solar pumps. Some SIP owners use this excess capacity to power cold storage or to power tractors. A more useful long-term solution would be to connect these solar pumps to the electricity grid to evacuate the excess energy to the grid.

There have been promising developments for this potential. For one, the Bangladeshi government is planning to purchase excess electricity from solar pumps. A draft policy on net metering of solar pumps is being prepared and will be finalized after stakeholder discussions. As the policy takes shape in Bangladesh it will be important to understand the technical feasibility of grid connection and the policy and institutional changes that will be required for its success. Also, grid-connection will have important implications on irrigation water usage, the price of water, and the impact on farmers' income. Thus, this demonstration pilot will yield key insights into the to inform better technical, institutional, and tariff policies for grid-connected solar pumps.

Target group of the intervention

As the market leader in solar pumps, IDCOL will have a crucial role to play in mainstreaming grid-integration of SIPs in Bangladesh. The lessons gleaned from this demonstration pilot will be disseminated through IDCOL and will help that organization overcome technical and institutional hurdles for grid integration. Similarly, in terms of net metering tariff rates and other policy issues, the power sector in Bangladesh will be another target group for policy influence and knowledge dissemination. Some of these organizations include the Sustainable and Renewable Energy Development Authority (SREDA), which is the nodal agency for renewable energy policies and laws; the Power Division under the Ministry of Power, Energy and Mineral Resources; and the country's private electricity distribution companies. All of these groups participated in our consultation meeting in Dhaka in June 2019.

Description of the pilot

For the demonstration pilot, we will select between 10-20 existing IDCOL-financed SIP schemes that are selling water directly to the farmers. The selected schemes will be from both water-scarce and water-abundant districts. After obtaining mandatory clearances from electricity utilities and SREDA, these schemes will be connected to the grid for evacuation of excess electricity from SIPs. Based on the net metering guidelines of the government, these schemes will receive a particular tariff for each unit of electricity evacuated to the grid. In some *upazillas* (sub districts) where groundwater levels are critical, a higher tariff than the government mandated rate will be offered from IWMI's side as an add-on bonus for energy evacuated to the grid. Thus, we will have a second group of treatment schemes with a higher tariff rate.

This demonstration pilot will help us understand the technical and institutional feasibility of grid connection and provide evidence on how grid integration of SIPs may affect individual farmer's income and access to irrigation. Moreover, there is a growing concern for groundwater usage for irrigation purposes in Bangladesh. Since the marginal costs of generating electricity with SIPs are zero, there is some apprehension about the effect of SIPs on groundwater abstraction. In such a scenario, connecting solar pumps to the grid to sell electricity at a sufficiently higher rate per unit could incentivize the user to pump less and sell more to the grid. Our second treatment group with higher tariff rates will shed light on this question.

Along with the technical and economic aspects, IDCOL is also interested to know what will be the best institutional setup for grid-integration of SIPs. We will conduct some case studies on single unit grid integration versus a cluster-based approach. This comparison will help in identify different constraints and opportunities.

Methodology

We will use a difference-in-difference method to estimate the effects of grid-connection. We will evaluate three types of schemes in this pilot:

- Solar pumps not connected to the grid (control, C);
- Grid -connected solar pumps with feed-in-tariff based on the decision of the power department (treatment 1, T1); and
- Grid -connected solar pumps with higher tariff rate (treatment 2, T2).

In the difference-in-difference method the effect of grid integration will be estimated by comparing the changes in outcomes over time (i.e., before and after intervention) between the control and treatment groups. This method removes biases that might affect any comparison after the intervention between control and treatment group, which could be result of some unobservable permanent differences between those groups. This method will also remove biases from just before-after comparisons of the treatment groups due to trends attributable to some other cause, which is common to all.

For the first two policy questions, our unit of observation will be at the scheme level. We will have baseline information on pump operation, water schedules, and water prices at the scheme level from the records maintained by the sponsor. Based on post-intervention data at scheme level we can estimate the effect of grid-connected solar pumps at two different tariff levels. For the third policy question regarding farmer behavior and the possible effects of grid connection, baseline and endline information will be collected from the beneficiaries serviced by these schemes.

Groundwater component

Through this demonstration pilot we will also explore the question of groundwater sustainability under SIP schemes (both on-grid and off-grid). Sample farmers/pumps for this study would consist of both off grid and grid-connected (both in critical and non-critical blocks) SIPs along with non-project farmers using major groundwater pumping systems in the region (electric or diesel). See activity 1.2.1 for further details.

Main outputs

- One policy brief on net metering and grid-connected solar pumps in Bangladesh;
- One publication providing a detailed outline on technical and policy reforms for grid-connected solar pumps; and
- One publication on the relationships between groundwater sustainability and off-grid and on-grid SIPs in Bangladesh.

IDCOL and IWMI will co-design this pilot and conduct experiments regarding water management practices. IDCOL will be crucial in identifying the selected sites and recruiting sponsors to be part of this demonstration pilot, including the necessary legal clearance from relevant stakeholders (SREDA, power department, and electricity utilities) for facilitating grid-connection of SIPs. For this demonstration pilot we will use existing SIPs (including all the hardware) under different sponsors who are working with IDCOL.

ACTIVITY 2.2.2: SCALE PILOT ON INSTITUTIONAL ASPECTS OF GRID-CONNECTED SIPs IN GUJARAT, INDIA

This scale pilot will answer the following policy questions:

1. Do grid-connected solar pumps with feed-in-tariff (as implemented under SKY in Gujarat) incentivize behavioral changes in pumping, and lead to improved energy and groundwater conservation among tube well owners?

2. Are these water and energy saving behaviors intensified if farmers are organized through a feeder-level institution (e.g., cooperative, private company, or farmer-producer organization)?

Such systematic evidence on changes in pumping behavior will also inform and encourage other water-scarce states in India to proactively consider including a SKY-like program in their groundwater governance toolkit. IWMI will also use the evidence to stimulate a national debate on solar pump promotions as part of a larger strategy on groundwater demand management.

Context and relevance of policy questions

Since 2012, IWMI has argued that SIP promotion through high capital cost subsidies will exacerbate groundwater depletion, especially in western and southern India, by making quality daytime power available to farmers for free. IWMI also argues that perverse incentives of free or subsidized farm power supply that have been responsible for unsustainable groundwater use in western India can be partly eliminated by promoting grid-connected SIPs, replacing existing electrified pumps, and by offering SIP owners a remunerative feed-in-tariff (FiT) for surplus solar energy generated.

It is further hypothesized that such a strategy would yield additional multi-sectoral benefits, such as:

1. Uninterrupted day-time power supply for irrigation to farmers;
2. A reduced farm power subsidy burden on electricity distribution companies (DISCOMs)
3. A reduced carbon-footprint from groundwater irrigation;
4. A new, climate-resilient income source for farmers; and
5. Strong incentive for farmers to conserve energy and water, which will result in reduced groundwater withdrawal for irrigation over time.

In order to demonstrate how such a strategy might work, IWMI created and piloted a Solar Pump Irrigators' Cooperative Enterprise (SPICE) in Dhundi in which nine solar pump owners have been connected through a micro-grid to the national electricity grid[ix]. Madhya Gujarat Vij Company Limited (MGVCL) signed a 25-year contract with the Dhundi SPICE to purchase their surplus solar energy at a FiT of ₹4.63/kWh. In this scheme, each SIP is separately-metered; however, MGVCL decided to meter-pool evacuation by the SPICE micro-grid at a single point and make monthly payments, and which SPICE redistributes to its members on a pro-rata basis. This initiative was supported by SDC though Dhundi SPICE initiative which has been operational since January 2016. Data from IWMI's monitoring of Dhundi SPICE shows that farmers' groundwater pumping behavior underwent significant change after May 2016 when power-buyback came into effect.

In the 2018 Union Budget, the Finance Minister of India announced the launch of *Kisan Urja Shakti evam Utthan Mahabhiyan* (KUSUM), an ambitious USD 17 billion scheme for solarizing irrigation. One of its three components to solarize existing grid-connected water pumps – was inspired by Dhundi SPICE (PIB, 2019[x]).

While KUSUM remained on paper through 2018, the Government of Gujarat activated a large-scale pilot to validate the Dhundi model under the name SKY (*Suryashakti Kisan Yojana*) for 137 agricultural electricity feeders of the state with an initial target of solarizing 12,400 farmers within a year. Buoyed by farmers' initial response to SKY, the government has now revised the target to solarize 100,000 farmers by the end of 2019. IWMI researchers took part in all discussions that led from Dhundi to SKY and were instrumental in shaping the policy.

However, the key gains farmers may expect from SKY – in terms of additional income from surplus solar energy sales – can be greatly dissipated by poor maintenance of the feeder and/or power theft. Technical and commercial losses on rural feeders have been rampant to date, and these costs are borne by society at large. On SKY feeders, as per the current policy, any transmission and distribution losses in SKY feeders that exceed 5% will be distributed among SKY farmers on a pro-rata basis (in proportion to their grid-connected solar generation capacity). Therefore, the social dynamic on SKY feeders can be expected to be vastly different from the rest of the feeders. If large number of honest farmers have to bear losses due to the malfaesence of a few, it will create an environment of distrust and might create perverse incentives. IWMI has argued that SKY must not be implemented as a mere "technological fix." In order to exploit its full potential, a farmer-participatory institutional vehicle should be created to enable SKY farmers to manage their new business of producing and selling surplus solar energy in an efficient, equitable, and sustainable manner. With the help of an exploratory SDC grant, IWMI-Anand has deployed a team of young field workers who organize farmers into feeder-level solar cooperatives (FL-SPICE) prior to their joining SKY. A team in Anand-Kheda districts has formed and registered seven such FL-SPICEs; another small team in Saurashtra has registered 3 FL-SPICE.

Target group of the intervention

The direct target group of this intervention will be the electricity utilities in Gujarat. Evidence from the pilot will be shared with Gujarat Urja Vikash Nogam Limited (GUVNL) to highlight the importance of feeder-level organizations of farmers and to help the Government of Gujarat maximize the net positive outcomes from SKY. This is where our pilot partners – GERMI and GUVNL – will contribute to translating the results from the scale pilot to suggest appropriate revisions in the SKY implementation protocol.

The indirect target groups of this intervention are the other state electric utilities. In the wake of federal government's KUSUM scheme, several Indian states are considering large-scale expansion of solar irrigation pumps through different technical, financial, and institutional models. While some states will continue to focus exclusively on small, off-grid SIPs for individual farmers, others have shown serious interest in developing a variant of IWMI's SPaRC (Solar Power as Remunerative Crop) model. Andhra Pradesh has already experimented on one feeder (with technical assistance from IWMI and the World Bank), while Haryana and Rajasthan have developed a plan for piloting solarization of agriculture. Punjab and Maharashtra have also shown interest in doing the same. We will work in up to 30 feeders in Gujarat, while also actively engaging with governments in other water-scarce regions to inform them about the impact of implementing grid-connected solar pumps on farmers' incomes and groundwater sustainability; and help them develop SKY-like policies of their own to pilot and implement programs and schemes with similar objectives.

Description of the pilot

Every new technology opens up a new institutional pathway, and, similarly, solar pump technology can create a whole new energy-groundwater nexus, one that is more virtuous and benign than currently existing Gujarat and western India. SKY is a big step in this direction. However, to help SKY reach its logical end, it is critical to implement this program as informed by a socio-technical framework. Socio-technical theory emphasizes the interaction between society's technology, complex infrastructure, and human behavior. This theory argues that the nature of interaction between society and technology gives birth to conditions for successful or unsuccessful outcomes. Optimizing each aspect (social or technical) alone leads to failure or sub-optimal outcomes while joint optimization increases the chances of joint success. Joint optimization is about designing social and technical systems in tandem so they work smoothly together.

In partnership with GERMI and GUVNL, the scale pilot in India will explore the complex socio-technical dynamics emerging in Gujarat in the context of SKY implementation by studying three distinct categories of agricultural feeders:

Business as Usual (BAU) Feeders: In 2005-2006, Gujarat became the first state to have dedicated agricultural feeders that supply 8-hours of 3-phase power to farmers according to a fixed schedule. The BAU feeders will be those that supply 8-hours of subsidized farm power supply – sometimes during the day and sometimes at night.

SKY Feeders: These feeders will be in locations where more than 70% of connected farmers have agreed to solarization and the Government of Gujarat has implemented SKY – but without a feeder-level farmers' institution.

SKY SPICE Feeders: These feeders will be from the SKY program where a feeder-level solar cooperative has been registered and is operational.

The scale pilot will work in 10 feeders from each category and test five specific hypotheses (table 5).

Table 5. Five test hypotheses for solarization pilots in India

	Hypothesis	Unit of Analyses	Method(s)
1	Irrigators connected to SKY and SKY SPICE feeders are more satisfied with quality (e.g., voltage, number of interruptions, daytime availability), timeliness, and reliability of energy availability for irrigation compared to irrigators on BAU feeders	Individual farmers (both well-owners and water buyers)	Focus group discussions (FGD) and sample surveys (baseline, endline)
	Tube well owners on SKY and SKY SPICE feeders display stronger signs of 'energy-water saving' behavior compared to those on traditional feeders in terms of crop choice, field water management, and adoption of water saving practices and technologies.	Individual farmers – pump owners	Monitoring of pumps and sample wells (groundwater abstraction data monitoring)
3	Aggregate technical and commercial (AT&C) losses below the sub-station per installed HP capacity are highest on BAU feeders, followed by SKY and SKY SPICE feeders	Agricultural Feeders – BAU, SKY and SKY SPICE	Secondary Data from DISCOMs (continuous feeder data monitoring)
4	Average energy use for groundwater irrigation (per installed HP capacity and per Ha irrigated area) are highest on BAU feeders, followed by SKY and SKY SPICE feeders . (Both metrics can be interpreted for analyzing behavioral change.)	Agricultural Feeders – BAU, SKY and SKY SPICE	FGD and Continuous Feeder Data Monitoring
5	Annual net economic surplus accruing to farmers from own irrigation, water sales and energy sales per installed pump HP is	Individual farmers – pump owners	Sample surveys (baseline, endline)

	significantly higher on SKY and SKY SPICE feeders compared to BAU feeders		

Methodology

As discussed above, the scale pilot will test five key hypotheses through a combination of qualitative and quantitative research methods. The sampling at the feeder level will include five feeders in each of the three categories in two hydro-geologically distinct regions of Gujarat (Saurashtra and Central Gujarat). In Central Gujarat, the aquifers are alluvial and generously recharged by the Mahi canal irrigation systems. In Saurashtra, on the other hand, the aquifers are hard rock with little inter-year storage and highly responsive to both pumping and recharge. Sampling in both the situations will allow us to understand the variable impact of large-scale SIP adoption through SKY in different hydro-geological conditions.

The following sub-activities are planned:

1. **Identification of sample feeders.** We will identify up to 30 agricultural feeders in Central Gujarat and Saurashtra. SKY SPICE feeders will be those where IWMI has organized farmers into feeder-level cooperatives as part of its on-going partnership with SDC. One SKY and BAU feeder each will be identified near each selected SKY SPICE feeder, preferably in the same block.

2. **Continuous feeder data monitoring**. On a monthly and bi-monthly basis, the team will monitor feeder-level data on a set of carefully selected parameters. The data collection protocol for this continuous data monitoring will be developed in collaboration with GERMI and GUVNL, and in consultation with local DISCOMs.

3. **Groundwater withdrawal data monitoring**. This activity will be part of a larger, regional activity on the impact of solar irrigation promotion on groundwater sustainability. The study will involve intensive data collection and monitoring of a small sample of well-owners in five agricultural feeders in Saurashtra and five in Central Gujarat. This monitoring of groundwater withdrawal will be used to establish a robust relationship between energy use and groundwater pumped. The relationship will then be used to extrapolate groundwater withdrawal over a larger sample of farmers from which we will collect energy use data. There are two reasons for proposing this component in both Central Gujarat and Saurashtra: 1) to analyze the variable response of aquifers to pumping in the two locations owing to different hydrogeology; and 2) because there is significant interference from canal recharge in Central Gujarat, which is less prominent in Saurashtra and elsewhere.

4. **Baseline survey (2019-20)**. IWMI has already completed baseline surveys in three SKY feeders as part of its on-going partnership with SDC. Under SoLAR-SA, and with help from the local DISCOMs (MGVCL in central Gujarat and PGVCL in Saurashtra, more baseline surveys will be collected for secondary, feeder-level information on each of the selected 30 feeders. The team will also conduct baseline surveys of at least 30 tube well owners and 30 water buyers in each of the selected feeders for a total of approximately 900 tube well owners and an equal number of water buyers, if possible. The surveys will capture baseline information on farm power supply regimes and agricultural practices (e.g., crops grown, irrigation regimes, and pumping behavior).

5. **Endline survey (2022-23)**. In the third year of the project, the team will conduct an endline survey. By this time, feeder-level cooperatives in SKY SPICE feeders would have sufficiently matured and we will be able to test the null hypothesis: that these institutions will help member farmers maximize their income from solar by offering services that help farmers maximize solar energy generation and maximize evacuation by using energy and groundwater efficiently.

6. **Focus group discussions (FGD).** In addition to the data collected above, the team will conduct FGDs with well owners and water buyers in all three categories of feeders to understand adequacy and reliability of irrigation and energy access, changes in pumping behavior, and (in the case of SKY SPICE feeders) the evolving role of feeder-level solar cooperatives.

The expected deliverable from these activities include:

- process documentation and 'protocol' for organizing SKY farmers at the feeder level – including steps and costs – for rapid scaling-up;
- three journal articles;
- three research and policy briefs; and

There are two expected outcomes from this scale pilot:

We will gather systematic evidence to

- support (or reject) IWMI's hypothesis that grid-connecting SIPs and offering a non-trivial feed-in-tariff leads to pumping behavior change among groundwater irrigators; and
- show that SKY feeders with investment in organizing farmers into a feeder-level institution (SKY SPICE feeders) leads to better results as evidenced by improved farmer incomes and more efficient energy and groundwater use.

The scale pilot in Gujarat will test one of the implicit assumptions behind SKY – that grid-connected SIPs with feed-in-tariff for evacuating surplus solar power will make farmers efficient in their energy and groundwater use. Further, our hypothesis is that feeder-level institutions can help farmers adapt their farming systems and farming practices in such a way that their income is maximized in resource-efficient ways. While our hypothesis suggests this would happen automatically, we will further stimulate this response in some SKY SPICE feeders. With the help of Arid Communities and Technologies (ACT) and other partners, we will develop a training-and-capacity-building module on "participatory and sustainable groundwater management" for SKY farmers in at least five SKY SPICE feeders.

ACTIVITY 2.2.3: DEMONSTRATION PILOTS ON GRID-CONNECTED SIPS IN NEPAL

The demonstration pilot in Nepal will answer the following policy questions:

1. Given that Nepal will achieve energy self-sufficiency through hydropower and subsequent expansion of the national grid, how can off-grid SIPs be integrated so that they are not made obsolete once the grid reaches heretofore unreached farmers?
2. What is the best techno-institutional model for grid connection of SIPs in Nepal?

Context and policy relevance

Within the next decade, Nepal could be generating an energy surplus from its hydropower production. Because the Nepal Electricity Authority (NEA) has a net metering policy in place, consumers can install solar panels that can feed into and draw from the national grid. The consumer then pays only for his or her net consumption of electricity. Despite this capacity, only two projects with capacity of 680 kW and 960 kW are currently connected to the national grid. However, there are at least 10 more projects of various sizes that made power purchase agreements (PPA) with NEA and are expected to be connected to the grid in next 1-2 years injecting approximately 53 MW of electricity to the national grid.

However, the NEA and AEPC (and any other organizations who implement SIPs) have yet to implement net metering for SIPs. There are approximately 1,600 SIPs operating Nepal, a majority of which have been implemented by AEPC, and operated in the Terai, primarily in Province 2. SIPs offer strong prospects for grid connection, which will enable farmers owning these SIPs to evacuate extra solar energy to the grid.

There are several advantages of grid connection of SIPs. For one, the cost for solar irrigation can be potentially reduced and reliable power supplied to rural areas through micro-grid technology. Second, SIP-to-grid technology helps to provide stable power to the system so that voltage fluctuations that damage pumps can be reduced. Third, SIP-to-grid facilitates optimal use of solar energy by selling it to national grid or other end-users at times when irrigation is not needed. And if appropriate tariffs are provided, farmers can earn additional income during off-seasons, or in years when crop cultivation is affected due by flood or drought. Finally, net metering and connections to a mini-grid or national grid also improves sustainability outcomes in the long run by ensuring that stand-alone, off-grid pumps are not abandoned when national grid reaches these off-grid areas.

Despite these considerable advantages, there have been no pilot tests of SIP to grid connections to date in Nepal. This lack provides an opportunity to generate evidence that demonstrates the potential benefits for wider replication. Both NEA and AEPC have pledged support to this pilot.

Target group for the intervention

The direct target groups are NEA and AEPC. The aim is to bring 15-20 off-grid SIPs to grid-connection in collaboration with NEA and AEPC. In addition, farmers will benefit from the added income and local governments will learn how to replicate this intervention for their own communities.

Description of the pilot

Micro-grid technology (figure 7) is simply a localized group of electricity sources and loads that normally operates connected to and synchronous with a traditional wide-area synchronous grid (macro-grid). Micro-grids can also disconnect to “island mode” when conditions dictate. Several solar pumps will be connected to a micro-grid and this micro-grid will be connected to the to the national grid (through net meter. When there is excess solar power, solar pump connected micro-grid supplies to the national grid. The micro-grid system is programmed in a way that it accounts for all energy generated and supplied. An entire database of energy transmission can be accessed remotely through a server by simple installation of a 3G simcard. For this work group, we propose to demonstrate a 15-30 kW micro-grid system that connects 15-20 pumps in Provinces 1 or 2. The actual sites will be finalized after a follow-up field visit and another round of consultation with AEPC, the NEA, and provincial and municipal governments.

Methodology

Between 15-20 SIPs will be connected to national grid through a micro-grid system (figure 7). Another 15-20 SIPs that are not connected to national grid will be monitored as the control group. The change in a selected set of indicators between the two groups before and after the intervention will be evaluated. The indicators may reflect aspects of productivity, profitability, and sustainability of the SIPs. NEA will facilitate with connection of the SIPs to the national grid. We will test the following hypotheses:

- Grid-connected SIPs are more stable than non-grid-connected SIPs in terms of voltage and durability;
- Farmers who have the opportunity to sell power back to the grid will use their SIPs for more hours than farmers without this opportunity and earn more profit by spending less on irrigation by virtue of selling power to the grid; ad
- Other uses of energy generated from SIP through micro-grid technology will emerge.

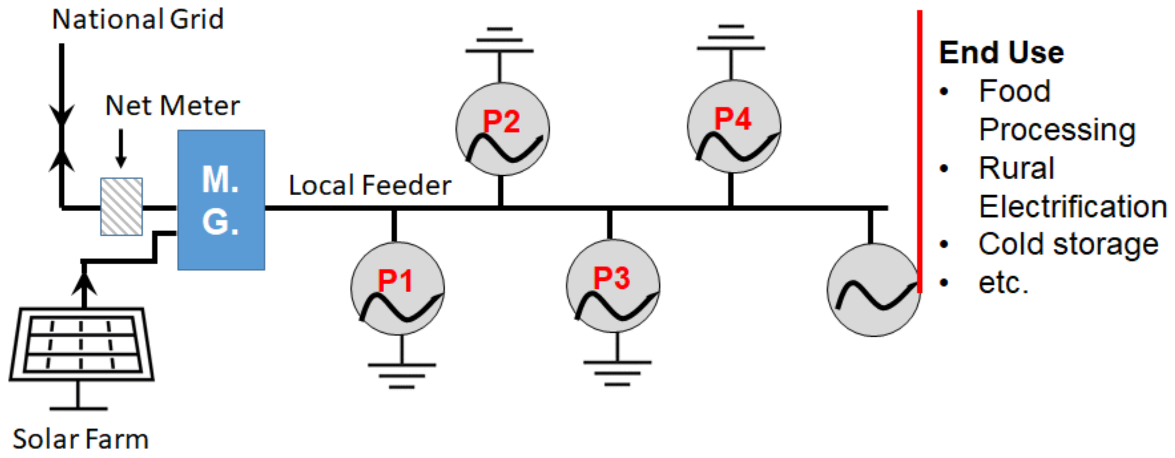


Figure 7. Illustration of an electricity micro-grid (M.G. = micro-grid)

Groundwater and GESI components

We will monitor pumping data for both groups (off-grid and grid-connected SIPs) to determine which group pumps more water. We will also evaluate GESI aspects for both groups. Evaluation of groundwater and GESI aspects will be carried out by conducting an impact evaluation survey. We will provide extension and training services to both groups so that only the difference between the two groups will be the connection, or lack thereof.

Main Outputs

The deliverables from this project will include:

1. A baseline and scoping study report;
2. A technical report on grid connection;
3. An evaluation report of the technical and socio-economic impacts and feasibility of grid connection; and
4. policy briefs.

IWMI will co-design this pilot with the NEA and AEPC and grid connection will be implemented at site recommended by these two organizations.

ACTIVITY 2.2.4: DEMONSTRATION PILOTS ON THE SIMULATION OF GRID-CONNECTED PUMPS IN PAKISTAN

This demonstration pilot seeks to answer the following question:

1. Does a farmer's groundwater pumping behavior change if he or she has the option to feed electricity to the national grid?

Context and policy relevance

The Policy for Development of Renewable Energy for Power Generation has paved the way for what is referred to as 'net-metering'. This technology monitors how, and in what amount, an individual or organization who has solar technology can feed surplus energy to the national grid. The meter then rotates in reverse and the individual/organization accumulates electricity credits which are then adjusted against electricity debits when the individual/organization draws electricity from the national grid. Farmers with tube wells have not been able to exploit net metering because in the Punjab, tube wells are diesel-operated and not grid-connected. In this context, we want to test the hypothesis that if farmers were offered reasonable feed-in-tariffs, they would choose to sell electricity rather than use more electricity to run pumps and irrigate fields.

Methodology

To test this hypothesis, we will use the group of farmers (identified in activity 1.2.3) who are currently using SIPs. A random sample of 30-60 farmers from this population will be selected as the control group and their pumping behavior measured. A second sample of 30-60 farmers will be provided the option to 'sell' electricity. Because it would be too expensive and time consuming to connect pumps to the grid and negotiate with electricity suppliers, we propose to simulate feed-in-tariffs by having a heat/energy sink. The farmer will have the choice to flip a switch to run his or her pump or to send the electricity to the heat sink with the understanding that s/he will be paid at a given tariff for the electricity diverted.

In this scenario, we will set different tariffs to observe the effect of feed-in-tariffs on farmer behavior. This test will be conducted with 10-20 farmers randomly selected from the larger group of 30-60 farmers while the data from the other 20 farmers will be collected using choice experiments.

Choice experiments represent an alternative to analysis of revealed preference or contingent valuation exercises and avoid the weaknesses or pitfalls associated with both. We hypothesize that farmer behavior will respond to feed-in-tariffs, but in a non-linear fashion: at low feed-in-tariffs the behavior will be invariant but at higher feed-in-tariffs, farmers would switch to 'selling' electricity and perhaps only undertake minimal farm activities for self-consumption purposes.

If our hypothesis proves true, it will offer considerable potential for groundwater pumping to be managed through feed-in-tariffs rather than through licensing and/or pumping exclusion zones. The implication of this hypothesis also suggests that providing opportunities to farmers with salinic groundwater and minimal access to canal water will enable them to earn more money by selling electricity to the grid. It is expected that farmers who can sell electricity to the grid will revert to subsistence agriculture and utilize the remaining proportion of their land to earn a decent living. This development would help reduce the carbon footprint off irrigation.

The expected deliverables for this project are:

1. A reconnaissance and baseline assessment report
2. Scoping and piloting reports;
3. Analysis of the feed-in tariffs thresholds
4. Journal articles; and
5. Policy briefs.

This pilot will be co-designed with PARC and FWMC.

4.2.3 OUTPUT 2.3: TECHNICAL, FINANCIAL AND INSTITUTIONAL INNOVATIONS DEMONSTRATED

ACTIVITY 2.3.1 ADMINISTRATION OF INNOVATION FUNDS

The Innovation Fund (IF) will support the development and field-testing of technical, financial and, institutional innovations to address the constraints and challenges of upscaling solar irrigation, with a special focus on the constraints faced by small, marginal, and women farmers. The IF will especially support innovations and practices that can influence policy or be expanded and integrated into regular programs and practices with the support of additional funding sources. The objectives of the IF are as follows:

- To support innovations to bridge any identified gap that hampers adoption, use, and upscaling of SIPs in South Asia;
- To support innovations targeted at reducing barriers for adoption by small, marginal, and women farmers; and
- To support innovations that are cost-effective and have potential for scaling up.

Starting in 2020 and for the next four years, IWMI will administer a SoLAR-SA innovation fund worth USD 400,000. Through this fund, the project seeks to support 6-8 innovations total at an approximate level of USD 50,000-USD 60,000 per innovation for a maximum duration of 24 months. However, proposal for one-year projects will be preferred.

Three broad groups of innovations will be supported by the IF: technological, financial and institutional. Table 6 includes a list of the types of innovations we would like to support. However, ideas not included in this table will be considered as they meet the above three broader objectives.

Table 6. Some example innovations the SoLAR IF would support

Technical	Financial	Institutional
Ways to improve panel efficiency while reducing cost per watt-peak Low-cost and locally-fabricated frames for SIPs Improving grid management protocols for distributed generation Re-use of defunct/waste solar panels Use of cost-effective sensors and Internet of Things (IoT) for efficient water and energy use Improving data and payment compliance through use of remote monitors Theft prevention of solar panels from the field Innovations in smart meters, grid-connected meters, and reverse meters.	Appropriate and cost-effective insurance products for SIPs Appropriate loan and other financial products for farmers and SIP business entrepreneurs Self-sustainable and financially-viable business models that benefit small, marginal, and women farmers	Combining solar irrigation with other livelihood options Alternative use of excess solar energy from SIPs, including alternate energy markets for solar entrepreneurs Creating self-sustaining groups of landless and/or women SIP irrigators/service providers

Funding and selection protocol

An open and transparent competitive process will be followed. Based on the proposals received and screened, a maximum of 3-4 grants per year will be made during the first two years of the project through annual invitation calls.

The call for proposals will be made once a year in the first quarter of the calendar year for the first two years of the project. The call will be disseminated through IWMI and SDC channels and through our partners and other associated stakeholders such as ISA and SAARC. Assuming January 2020 as the starting date of the project, the first call for IF grant proposals will be issued in March 2020, with a plan to award the first grant in July 2020. A similar cycle will be followed in the following year.

Approximately 4-6 weeks of time will be given for receiving proposals from the applicants from the date of issuance of the call. The Project Management Unit (PMU) will invite the proposals and coordinate the process under the guidance and supervision of the Project Leader and IWMI's India representative.

The IF Grant will be open to all NGOs, CG Centres, universities, technical institutes, research institutes, public sector enterprises, and government agencies and laboratories.

Shortlisted proposals will be judged on the following criteria:

- Nature of the innovation
- Relevance of the proposed project
- Strategic and innovative value of the proposed projects
- Logic and clarity of the design
- Technical, social, institutional, and financial feasibility
- Relevance to a key issue (technological, financial or institutional)
- Potential for replication
- Relevance to climate change concerns
- Value for money and cost-effectiveness
- Expertise and qualifications of the project team
- Background and experience of the lead and partners in handling similar projects

Innovation teams led by women, or with a female majority of members, will be given priority.

A special Expert Committee will be formed in consultation with the Project Steering Committee (PSC) for:

- finalizing the selection criteria;
- finalizing the proposal invitation;
- selecting the shortlist of proposals for presentation; and
- making the final selection of proposals after their presentations;

Detailed guidelines and selection criteria will be issued with the call for proposals (table 7).

Table 7. Individual steps for an IF grant

Announcement of the IF call	The IF will be announced to receive applications through email, research networks, and advertisements.
Initial screening of application	The Project Management Unit (PMU) of SDC-SoLAR will screen applications, and consults country PIs as needed, based on stated criteria.
Application shortlist created and semi-finalists invited to make a presentation	A panel of experts from SoLAR and SDC will conduct a detailed review of the shortlisted applications. The panel creates a shortlist of innovations for the final round of the IF grant and invite them to make a presentation to the selection panel
IWMI signs contracts with each selected project and its lead institution	PMU will draw contracts with each of select innovators to provide the financial support for the project, and to ensure agreement about the work expectations.
Release of payment	IWMI will disburse the funds as agreed upon regarding the deliverables and milestones. PMU and country co-leads will jointly monitor the progress of each project.

4.3 WORK PACKAGE 3: CAPACITY BUILDING AND KNOWLEDGE SHARING

This work package will contribute to Outcome 3: to increase regional knowledge and capacity building for GESI-responsive and groundwater-aware solar irrigation policies and practices. This work package has three outputs, described in sub-sections below.

4.3.1 OUTPUT 3.1: TRAININGS, CAPACITY BUILDING, AND EXPOSURE VISITS

Under this activity, each of the country teams will organize various trainings, including trainings for local farmers and technicians.

ACTIVITY 3.1.1 TRAINING OF LOCAL TECHNICIANS AND FARMERS (WOMEN AND MEN)

In our preliminary research, all of our partner organizations expressed the need for a cadre of local technicians or trained farmers who can repair and maintain SIPs. Currently, all the projects funded by national governments and donors include a 2-3 year of maintenance contract with the SIP vendor. However, these initial contracts are nearing expiration in all the partner countries and thus there is an urgent need to train local technicians, including young electrical engineering diploma holders. In doing so, the project will pay extra attention to ensure that at least 33% of the technicians trained are women. We will also work closely with the national implementing agencies to ensure these trained mechanics are closely allied with the private sector players and existing SIP programs so they can find gainful employment.

These SIP repair and maintenance trainings will be conducted by national partners in collaboration with IWMI country offices. In addition, other need-based trainings in aquaculture, vegetables cultivation, and efficient field water management will be organized on a regular basis. And IWMI country offices will facilitate regular national dialogues with local elected representatives to monitor our progress and gather feedback on project developments.

In Bangladesh and Nepal, we will organize a 3-5 day annual technician training with 15-20 participants in each training. We will work closely with government-approved technical training colleges and encourage them to include solar technology related content in their regular curricula.

In India, we will conduct lead farmer training and farmer-to-farmer training workshops. Over years of electric and diesel pump use, there exists a near-expert capacity in even remote villages to maintain and repair electric and diesel-powered irrigation pumps. The same is not true, however, for solar irrigation systems. For SIPs to scale effectively and gain wider adoption, there needs to be a strong and capable presence of service providers to ensure that SIP systems can be locally maintained. This issue becomes even more important with grid-connected SIPs where any down-time has a direct and significant impact on farmer incomes. In IWMI's solar pilots, we found a few enterprising farmers had already built expertise in resolving day-to-day problems with help from IWMI and GERMI. In India's scale pilot, we will develop a protocol for creating an enabling ecosystem of services in the SKY SPICE feeders. This work will involve annual trainings and capacity building of lead/enterprising farmers, who will then conduct farmer-to-farmer training workshops for maximizing SIP generation efficiency and minimizing solar PV downtime.

In Pakistan, SIP have been always promoted in conjunction with micro-irrigation, and this has resulted in a lower uptake of this technology as many farmers growing field crops are reluctant to invest in micro-irrigation. A feasible alternative to micro-irrigation is well-designed surface precision irrigation. There is considerable scientific knowledge (Anwar et al., 2016) to guide farmers in devising precision surface irrigation or engineered surface irrigation, where they can achieve very high levels of application efficiency and uniform distribution. Although precision surface irrigation may not achieve the high levels of application efficiency on par with drip irrigation, improved inefficiency is desired to ensure that water is available for leaching salt out of the soil. In fact, it does occur with drip irrigation that one needs to deliberately introduce inefficiency to ensure there is sufficient leaching.

In this activity, IWMI Pakistan and PARC will develop a computer model using WinSRFR (developed by USDA) to simulate an irrigation event using typical field parameters. Then multiple PARC demonstration fields will be configured and tested to corroborate the numerical modelling. These experiments will continue over the course of the project with one prototype tested each year. From the findings of this research, we will develop comprehensive guidelines for the policymakers for the uptake of precision surface irrigation coupled with Solar irrigation. Up to 30 farmers will be trained to use precision surface irrigation on their fields and 30 professionals will be trained to use WinSRFR software and how to design of fields using this software.

ACTIVITY 3.1.2 REGIONAL TRAINING OF GROUNDWATER, ENERGY, AND AGRICULTURE OFFICIALS

The premise of this project is that water, energy and agricultural issues are deeply interlinked, but often these linkages are not well understood. As a result, work on one element by itself – say, water – can have unintended negative impacts on energy or agriculture. For example, highly subsidized SIPs in groundwater over-extracted areas pose immediate and long-term threats to groundwater sustainability. Professionals from each of these sectors are often not aware of the trade-offs and potential synergies. In view of this, we will organize regional training events where energy professionals will be trained in the basics of hydrogeology. And water and agriculture professionals will be trained in the basics of SIP technology. We will conduct two regional trainings over the course of the project.

4.3.2 OUTPUT 3.2: MULTI-STAKEHOLDER FORUMS FOR GLOBAL AND REGIONAL KNOWLEDGE EXCHANGE

ACTIVITY 3.2.1 REGIONAL KNOWLEDGE AND POLICY FORUMS

All SoLAR-SA partners and IF grant recipients will meet each year to share information on progress. In the first year (2020), this gathering will take the form of an inception meeting. The SoLAR-SA Steering Committee will also attend this meeting to review project progress and provide feedback. The annual meetings will be a platform for the project partners to come together and exchange information and knowledge on various aspects of their work. Whenever feasible, field visits to SIP operating sites will be organized.

At these annual regional SoLAR-SA meetings we will also be joined by relevant global and national stakeholders such as ISA, IRENA, FAO, ADB, World Bank, ADB, IFAD, SAARC, MNRE, India, CEEW and private solar companies. These groups will be invited to participate and showcase their work solar power in agriculture.

All country representatives from the Swiss Embassy and SDC representatives from the four project countries will be invited to these regional forums. And all IF grant recipients and private companies will be encouraged to set up exhibition booths to showcase their products and innovations. These events will be supported through various knowledge dissemination products such as videos, newsletters, and policy/issue briefs.

ACTIVITY 3.2.2 NATIONAL POLICY FORUMS

The project countries will regularly organize national policy forums to solicit feedback from national, provincial and local policymakers, and to disseminate information to these groups. The frequency of these national policy forums will be need-based, but no fewer than three policy consultation forums will be held in each country during the 4-year span of the project.

4.4 SUMMARY OF ACTIVITIES, OUTCOMES, AND OUTPUTS

Table 8. Summarized description of activities, outcomes, and outputs for SoLAR-SA

	Short description	**BD**	**IN**	**NP**	**PK**
Outcome 1: Improved empirical evidence to support development of climate-resilient, gender-equitable, socially-inclusive, and groundwater-aware solar irrigation policies. (WP1)					
Output 1.1	Impact of solar irrigation on livelihoods of women and men farmers and climate resilience documented and shared with policymakers	✓		✓	
Output 1.2	Impact of large-scale SIP adoption on groundwater sustainability documented and shared with policymakers	✓	✓		✓

Outcome 2: Innovative approaches for gender-equitable, socially-inclusive, and groundwater-aware solar irrigation are validated. (WP2)					
Output 2.1	GESI-responsive, pro-poor and groundwater-aware financial models for solar irrigation promotion demonstrated and documented	✓			
Output 2.2	Technical and institutional modalities of grid connection of SIPs in different water-energy regimes demonstrated	✓	✓	✓	✓
Output 2.3	Technical, financial, and institutional innovations demonstrated	✓	✓	✓	✓
Outcome 3: Increased national /global knowledge and capacity for gender and socially inclusive and groundwater responsive solar irrigation policies and practices. (WP3)					
Output 3.1	A cadre of women and men farmers and technicians trained and water-energy-agriculture experts in the region sensitized on cross-sectoral linkages	✓	✓	✓	✓
Output 3.2	Multi-stakeholder forums for global, regional and national exchange of knowledge on best practices in GESI-responsive and groundwater-aware solar irrigation policies and practices	✓	✓	✓	✓

BD = Bangladesh; IN = India; NP = Nepal; PK = Pakistan; WP = work package

4.5 DESCRIPTION OF THE PARTNER ORGANIZATIONS, THEIR ROLES, EXPERIENCE, ADDED VALUE, CAPACITIES, AND LIMITATIONS

All activities mentioned in previous sections will be implemented in close collaboration with government partners in each of the four partner countries. Below is a description of our partner organizations and their roles.

4.5.1 PARTNERS IN BANGLADESH

Infrastructure Development Company Limited (IDCOL) is our partner for scale (activity 2.1.1) and demonstration (activity 2.2.1) pilots.

IDCOL is a government-owned financial institution established in 1997. IDCOL encourages private sector participation in infrastructure and energy projects and they are currently the largest financier for renewable energy projects in Bangladesh. IDCOL is also the primary agency supporting the mainstreaming of solar pumps: to date, over 90% of the solar pumps installed in the country have been financed through IDCOL and they have a target of installing a total of 50,000 solar pumps by 2025. Most of the donor aid and government funding for the promotion of solar irrigation goes through IDCOL, which finances the purchase of solar pumps through a mix of loans and grants. Being the market leader in promotion of solar irrigation, IDCOL is crucial in shaping policies that will guide the growth of SIPs in the coming years. Their policy is to ensure that the growth of solar irrigation is socially-inclusive and does not lead to unsustainable use of groundwater. Since the objective of the SoLAR-SA is to use solar irrigation to address the unique relationships between water-energy-food (WEF) and climate in

South Asia, IWMI's partnership with IDCOL can provide answers to important need-based policy questions regarding optimum financial models for promoting SIP or the potential for grid-connecting SIPs in the future.

As a financier, IDCOL cannot give loans directly to individual farmers. Instead, they use local "sponsors" (NGOs or private companies) that channel the loan to farmers either by selling SIPs directly to farmers or by becoming water sellers themselves. IDCOL works with all relevant stakeholders in the solar irrigation sector including NGOs, SREDA, academics, private companies, the federal government, solar pump manufacturers, development partners, and the farmers of Bangladesh. IDCOL is an approved GCF affiliate/grantee. IDCOL's vast experience in this sector, coupled with a capable workforce and extensive network with both local- and national-level stakeholders make them an ideal partner for working in Bangladesh.

For this partnership, IWMI and IDCOL will sign an MoU indicating the common plan of action in Bangladesh over the next four years, including details about how the work and finances will be shared.

4.5.2 PARTNERS IN INDIA

Our main partner in India is **Gujarat Energy Research and Management Institute** (GERMI). We will also work with **Gujarat Urja Vikas Nigam Limited** (GUVNL).

GERMI is promoted by Gujarat State Petroleum Corporation Limited (GSPCL) as a center of excellence in the energy sector. It has four key mandates: training, education, consultancy, and research and development. GERMI is a registered Society and Trust under the Societies Registration Act, 1860, and the Bombay Trust Act, 1950. It is also a recognized Scientific and Industrial Research Organization (SIRO) by the Department of Scientific and Industrial Research (DSIR), Government of India. GERMI has been a key player in the design of the Government of Gujarat's solar policies, including the Dhundi-inspired *Suryashakti Kisan Yojana* (SKY). IWMI and GERMI have been working closely on climate-smart promotion of solar irrigation in Gujarat since 2013-14.

As an advisor to the Energy and Petrochemicals Department of the Government of Gujarat, and as one of the key architects of SKY, GERMI is keen to track its performance and help the government improve its SIP implementation. GERMI also has strength in developing and conducting training programs on solar – including design, operation, and maintenance of solar PV modules. GERMI will thus play a key role in helping the project develop the "lead solar farmers' training program" (activity 3.1.1).

Gujarat Urja Vikas Nigam Limited (GUVNL) is the share holding company for the state electricity corporation, transmission corporation, and four subsidiary distribution companies – Madhya Gujarat Vij Company Limited (MGVCL), Uttar Gujarat Vij Company Limited (UGVCL), Paschim Gujarat Vij Company Limited (PGVCL) and Dakshin Gujarat Vij Company Limited (DGVCL). Along with the Gujarat Energy Development Authority (GEDA), GUVNL is the key stakeholder and decision-maker for energy and renewable energy in Gujarat. As the nodal agency for implementing SKY, IWMI's partnership with GUVNL will be crucial for carrying out project activities in SKY feeders and for sharing insights and results for improved SKY uptake and effectiveness (activity 2.2.2).

4.5.3 PARTNERS IN NEPAL

In Nepal we will partner with the **Alternative Energy Promotion Center** (AEPC) and **Nepal Electricity Authority** (NEA).

AEPC is a government institution established in 1996 with the objective of developing and promoting renewable energy technologies in Nepal. It works under the Ministry of Energy, Water Resources, and Irrigation. AEPC functions independently and has a board with representatives from the government, industry, and non-governmental organizations. The mission of AEPC is to make renewable energy a mainstream resource through increased access, knowledge, and adaptability that contributes to improving the living conditions of people in

Nepal. AEPC has supported over 1,200 pumps for solar irrigation over the last three years with a 60% subsidy. AEPC is keen to collaborate with this project to evaluate the impact of projects implemented so far and to identify suitable models for moving forward. AEPC will be support SoLAR SA with data and information, access to project implementation sites, and advice regarding needs and gaps in SIP promotion.

NEA was created in 1985 after the merger of the Department of Electricity of Ministry of Water Resources, Nepal Electricity Corporation, and related development boards. The primary objective of NEA is to generate, transmit, and distribute adequate, reliable, and affordable power by planning, constructing, operating, and maintaining all generation, transmission, and distribution facilities in Nepal's power system, both interconnected and isolated. NEA has established a net metering policy (2074 BS); however, it has yet to implement this metering for SIPs, primarily because the technology is new and people will need more education about the technology before adopting it. Therefore, NEA, AEPC and SoLAR-SA have an opportunity to demonstrate SIPs through a pilot so that we can provide evidence for wider replication. NEA will establish a demonstration pilot for the purpose of promoting grid-connected SIPs.

4.5.4 PARTNERS IN PAKISTAN

The proposed project will be implemented under the auspices of the IWMI's host ministry in Pakistan: The **Ministry of National Food Security and Research** (MNFS&R). And we will work directly with two other partners – the **Federal Water Management Cell** (FWMC) and the **Pakistan Agricultural Research Council** (PARC).

MNFS&R is primarily responsible for policy formulation and economic coordination and planning for food grains and agriculture. It is also responsible for procuring fertilizer and food grains, stabilizing import prices for agricultural produce, and liaising internationally with other countries and institutions for framing agricultural policies. There are multiple organizations with MNFS&R that perform other functions in support of this overarching mission and they will be key implementing partners in the proposed project.

FWMC was established in 1979 and it provides strategic support to MNRS&R for formulating policies at the federal level in consultation with the respective provinces. FWMC focuses on irrigation water sector problems, solutions, and generating solutions for water resource development projects, agricultural mechanization policies & strategies and land development projects prepared in consultation with the stakeholders for ensured food security on sustainable basis.

The role of FWMC in this project will be to provide technical guidance, review project progress, ensure its implementation helps the government to formulate better policies in the solar irrigation and agriculture sector. Moreover, they will host all the project related events, workshops/seminars and represent the Government of Pakistan in all the national and international events.

The main research partner for the proposed project will be PARC. PARC is the apex national organization that works in close collaboration with other federal and provincial institutions to provide science-based solutions to agriculture. PARC also functions under the MNFS&R. Its primary functions include:

- Undertake, aid, promote and coordinate agricultural research
- Arrange expeditious utilization of research results
- Establish research establishments to fill in the gaps in existing agricultural research
- Arrange the training of high-level scientific manpower
- Generate, acquire, and disseminate information
- Establish and maintain a reference and research library

PARC will provide its facilities for activity 3.1.1, in which IWMI will test different scenarios for precision surface irrigation using solar technology. Moreover, PARC will also contribute to the formulation of project outputs in the form of research manuscripts, policy briefs, and strategy documents.

4.6 FORM OF COOPERATION AND COORDINATION BETWEEN INVOLVED PARTNERS

We will enter into formal Memorandums of Understanding (MoU) and Letters of Agreement (LoA) (or any suitable partnership agreement) with each of our partners, in which we will specify the terms and conditions of the partnership, including roles, responsibilities, and resource sharing arrangements. During the inception workshop, we will set aside one day for a workshop on partnership building, where we will deepen our shared understanding of this project and our collective responsibility to deliver the outputs. In addition, the senior representative from all the government partners will be a part of the project steering committee (section 5.2) and take part in all high-level decisions.

4.7 ADDRESSING DRIVERS AND RESTRAINERS OF CHANGE

We have designed this project keeping in mind the drivers and restrainers of change. One of the main drivers for changing the solar landscape of this region is the pro-active role of relevant government institutions responsible for renewable energy promotion. For SoLAR-SA, these organizations include IDCOL in Bangladesh, GERMI and various electricity utilities in India, AEPC and NEA in Nepal, and FWMC and PARC in Pakistan. These organizations have a mandate for change and by working closely with them, we hope to enable some changes in the financial and institutional modalities to include GESI norms, while enabling SIP programs that pay more attention to groundwater impacts. In sum, our activities have been designed to take advantage of these enabling conditions

Our activities are also designed to address many of restrainers of change, such as high up-front costs, lack of GESI-compatible policies, lack of attention to groundwater sustainability issues, and a general lack of awareness about interconnectedness among water-energy and food sectors.

4.8 MEASURES TO ENSURE THE SUSTAINABILITY OF BENEFITS AND SCALING UP

IDCOL is the largest financier of solar pumps in Bangladesh and our partner in our scale (activity 2.1.1) and demonstration pilot (activity 2.2.1). Both interventions have been designed based on their need to assess different financial modalities and to test the possibility of grid-connected SIPs. The results from scale pilot will provide critical inputs in the design of financial products as they are scaled up across the country. Having IDCOL help design and implement this scale pilot from the beginning ensures that the lessons learned will be translated into actual policy for Bangladesh. IDCOL also has ties with SREDA, the power department, and other relevant stakeholders in Bangladesh. Since IDCOL shares our interest in the success of this program, we are confident this demonstration pilot will provide crucial evidence and knowledge for generating effective SIP integration policy for the Bangladesh government.

In Gujarat, GUVNL is one of our partners. Evidence from scale pilot (activity 2.2.2) will be shared with GUVNL to highlight the importance of feeder-level organizations of farmers and to help the Government of Gujarat maximize the net positive outcomes from SKY. At this point the pilot partners – GERMI and GUVNL – will translate the results from the scale pilot into appropriate revisions for the SKY implementation protocol. In the wake of Government of India’s KUSUM scheme, several Indian states are considering large-scale expansion of SIPs through different technical, financial and institutional models.

In Nepal, AEPC and NEA will co-supervise with us the impact evaluation of AEPC pumps (activity 1.1.2) and demonstration pilot (activity 2.2.3) at the AEPC sites It is therefore expected that results from both activities will be directly ingested by these organizations and incorporated in their policies and programs.

In Pakistan, we will work with FWMC and PARC and our findings will be directly used by these organizations to feed into national planning processes.

In summary, our overall strategy is to work directly with government partners and, in the process, ensure that relevant findings from the project activities are taken up by the relevant agencies. We hope that a successful first phase of the project will lead to a successful second phase of activities, where the emphasis will be focused on upscaling and mainstreaming of some of the lessons learned in phase one.

5.0 Organization, Management, and Administration

5.1 INITIAL TIME FRAME AND TENTATIVE YEARLY BREAKDOWN OF THE PHASE

This will be a four-year project, starting in December 2019 and ending in December 2023. The tentative yearly breakdown of activities is shown in table 9.

Table 9. Project yearly timeline for proposed project activities

Activity	2020				2021				2022				2023			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1.1.1																
1.1.2																
1.2.1																
1.2.2																
1.2.3																
2.1.1																
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3.1.2																
3.2.1																
3.2.2																
3.3.1																

5.2 MANAGEMENT OF THE PROJECT

5.2.1 ROLES, TASKS, AND RESPONSIBILITIES

This project will be implemented by a team of inter-disciplinary researchers and practitioners from IWMI and the partner organizations. Short biographies of all project members is Annex 4.

The inter-disciplinary 'core team' of researchers has been constituted to plan, steer, and implement the project in collaboration with identified partners in India, Bangladesh, Nepal and Pakistan. The inter-disciplinary team includes senior scientists and researchers with expertise in energy, hydrology, hydrogeology, public policy, rural livelihoods, water institutions, water resources management, environmental and development economics, and governance and project management.

Dr. Mark Smith, IWMI's Deputy Director General (DDG), will ensure that the project has access to appropriate (human and operational) resources across IWMI's regional offices in South Asia. Regional coordinators will also ensure that IWMI's offices and relevant projects elsewhere – including in Southeast Asia and Sub-Saharan Africa – are sufficiently informed about the progress in the project to avoid duplication of efforts and promote cross learning.

Dr. Aditi Mukherji is the Principal Researcher, stationed in the IWMI's New Delhi office. She will be the IWMI Regional Project Leader and assume responsibility for day- to-day operations of the project.

The work in Bangladesh will be led by Dr. Mukherji and **Mr. Archisman Mitra,** both of IWMI-India office, in collaboration with staff from IDCOL. IWMI will also hire a national consultant for coordination of activities in Bangladesh, and this consultant will be based in Dhaka and liaise closely with IDCOL.

The work in India will be led by **Mr. Shilp Verma**, a Researcher with IWMI-Anand, and in collaboration with staff from GERMI and electricity utilities.

The work in Nepal will led by **Dr. Vishnu Pandey**, Researcher with IWMI-Nepal office, in collaboration with the AEPC and NEA.

The work in Pakistan will be led by **Dr. Azeem Shah**, a Researcher with IWMI's Pakistan office, and in collaboration with colleagues from FWMC and PARC.

The cross-cutting regional groundwater components will be led by **Dr. Alok Sikka** – the country representative of the IWMI-India office, while the cross-cutting regional components on GESI will be led by **Dr. Manohara Khadka**, the country representative of the IWMI-Nepal office.

Overall communications and M&E support will be provided by the Communications Manager, **Farah Ahmed**, in the IWMI, New Delhi office. The entire project management unit will be based out of the IWMI-New Delhi office, which will work closely with IWMI HQ in Colombo.

5.2.2 ORGANIZATIONAL STRUCTURE AND STEERING MECHANISM

A **Project Steering Committee (PSC)** will supervise, guide, and advise the project implementation. The PSC will be co-led by the SDC Head of Cooperation, India, and IWMI's Deputy Director General.

The remainder of the committee includes:

- IWMI Regional project leader;
- IWMI country representative from India;
- Representatives from our government partners in all four countries: IDCOL (Bangladesh), India (GERMI), Nepal (AEPC), and Pakistan (MNFS&R) and a representative from International Solar Alliance (ISA)

The PSC will meet twice a year (once remotely, once during the annual Regional Forums) and discuss project progress, approve project annual work plans, and provide advice on course correction, if needed. The co-opted members will meet once, during the face-to-face meeting of the PSC, and their feedback will be sought on country components.

In addition, there will be a **country level project management committee** (C-PMC) in each project country. Members of these committees will include:

- IWMI Country Representatives;
- IWMI Country Project Managers;
- IWMI Regional Project Leader; and
- Representatives from key project partners.

C-PMCs will meet (remotely, or in person) every quarter and discuss project progress against the agreed work plan and resolve any country-specific project implementation issues. Participation of representatives from SDC

India and the respective country Swiss Embassy/SDC Representatives is desirable, but optional. The representatives of the Swiss Embassy/SDC from the respective countries will also be invited to the national and regional knowledge exchange forums.

The **project review** process will be initiated 12 months before the end of phase 1.

5.2.3 ADMINISTRATIVE ARRANGEMENTS (ACCOUNTING, FINANCIAL MANAGEMENT, AND EXTERNAL AUDITING)

All IWMI projects are governed by the organization's pro-active Quality Management System (QMS). The QMS underpins IWMI's approach to implementation of research and development projects. IWMI has institute-wide systems and policies for quality, people, project, financial, risk, and environmental management. Program processes and procedures are mainstreamed by IWMIs corporate services for contracting, procurement, people management, quality assurance, information technology, and financial management and accounting. IWMI has demonstrated its capacity to manage several bilateral and multilateral projects and programs in a flexible manner and to respond to emerging project issues, changing project directions, staffing and outputs cost effectively.

Financial Management

IWMI uses SAP financial accounting, project systems, asset accounting and material management. IWMI also complies with CGIAR financial guidelines for accounting and is fully compliant with IFRS requirements.

Financial statements and other management reports are prepared monthly. Monthly reports include Statements of Financial Position, Statements of Activities, Statements of Changes in Equity, Cash-flow Statements, and notes to the financial statements. Donor financial reports are prepared per the given deadlines in the donor agreements and donor receivables are monitored regularly.

IWMI's head of internal audit reports functionally to the Audit Committee of the IWMI Board of Governors and administratively to the IWMI Director General. The internal audit department prepares a risk-based audit plan. The following items are the planning considerations that the Internal Audit takes into account while developing the audit plan for IWMI: risk assessment information; dollar materiality (budget amounts and spending); quality of internal controls; degree of stability (organization restructuring / change in management); completed and planned external assurance reports; changes in laws and regulations; areas which had not been audited and/or included in the previous audit plans; and expectations of Board of Trustees and Management.

IWMI's annual external audit is currently undertaken by KPMG Sri Lanka. IWMI prepares its financial statements based on CGIAR's financial guidelines and its financial statements are based on IFRS. Recommendations of auditors are implemented and followed up regularly through established controls. IWMI's annual financial reports are publicly available on our website: www.iwmi.org .

6.0 Risk Analysis

6.1 ASSESSMENT OF MAIN RISKS FOR THE PROJECT AND/OR RISKS RESULTING FROM THE INTERVENTION; MEASURES FOR MITIGATION, INCLUDING MONITORING

IWMI has an effective Institute-wide risk management process that guides how the Institute deals with uncertainty and proactively responds to both risks and opportunities with the rigor expected of an international public organization. IWMI's Risk Management Policy provides the framework to IWMI staff on implementing an Institute-wide risk management process, comprised by the following elements:

- Communicating the Institute's overall risk management strategy;
- Defining the responsibilities within the Institute for risk management; and
- Implementing a framework for identifying potential events, assessing risks and opportunities and selecting responses, thereby reducing the occurrence of surprises and related costs or losses while at the same time ensuring opportunities are not inadvertently missed.

The risk policy framework provides, among other things:

- a basis for more explicit consideration of the acceptable levels of risk (the "risk appetite") in the Institutes' strategy setting and implementation;
- a method for assessing the interrelated impacts of risks in different areas. Risks for individual departments may be within the departments' risk tolerances, but taken together may exceed the risk appetite of the Institute as a whole;
- guidance on how the analysis of risks that are jointly managed with other CGIAR Centers and System units, and entities external to the CGIAR, should be incorporated into the Institute's risk assessments;

We will report the results of risk management activities within the Institute and to external stakeholders. An initial risk assessment for this project has been undertaken during the design phase, including specific risk analysis topics during design workshops with the project team and partners. There are a number of risks that could impact the success of the project and these have been identified in annex 7. In mitigating these risks, early identification and analysis, as well as the involvement of SDC and government agencies in each of the implementation countries, in the identification of the most appropriate solutions will be essential. The risks and proposed mitigation strategies presented below stem both Project Team's understanding of the SoLAR-SA and these risks will be reviewed and revised, if necessary, during the inception phase.

The key risks for this project can be classified into three types:

1. **Contextual risks** may emanate from natural disasters (floods), political fragility, and diplomatic tensions. Pilot interventions and capacity building events will be restricted to regions that are not disaster-prone or politically-sensitive. In order to avoid on-going diplomatic tensions between India and Pakistan, IWMI country offices will directly implement project activities in partnership with the national partners while the knowledge exchange events will be organized in Nepal or Bangladesh.

2. **Institutional risks** include lack of commitment of partners, and will be countervailed by forging formal agreements with all key partners to increase buy-in to the work and uptake of the project findings. The inception workshop will include a partnership workshop for building trust and confidence.

3. **Programmatic risks**: Manging a multi-country project with multiple national partners poses numerous challenges in terms of logistics and communication. The IWMI Regional Project Leaders will closely coordinate with country offices and country partners to mitigate this risk.

All risks will be monitored through our quarterly country-project management committee meetings, and then shared with the PSC if not resolved. We will take advice from the PSC and from SDC on the best ways of to mitigate any additional emergent risks.

7.0 Monitoring and Evaluation

7.1 M&E PLAN INCLUDING RESULT-ORIENTED REPORTING SYSTEM

This statement of approach to monitoring and evaluation (M&E) is intended to set out the core principles and key aspects of the M&E system design to be applied specifically for to SoLAR-SA. M&E is central for tracking and adapting the implementation of this project. M&E is also crucial for supporting partnership learning and knowledge sharing, for promoting accountability in the project, and strengthening efforts to scale up successful approaches within the each of the implementation countries.

Our M&E approach for SoLAR-SA has the following objectives:

- To provide to SDC, IWMI and our project partners consistent information and analysis about the progress and quality of implementation of the project and to indicate where changes in design and management are required;
- To provide our partners with lessons learned from project design and implementation strategies for better planning, possible replication, and sustainability of interventions and engagement; and
- To strengthen our systems and mechanisms to ensure accountability to our beneficiaries and government partners in all the interventions designed and implemented.

Central to IWMI's approach for M&E will be the Project Log frame included as Annex 2. The project log frame provides the operational framework for planning and management of the project. The project log frame is structured so as to detail activities, outputs, and outcomes aligned with the overall goal to contribute to climate-resilient, gender-equitable, and socially-inclusive agrarian livelihoods in Bangladesh, India, Nepal and Pakistan by supporting government efforts to promote solar irrigation. Progress associated with project outputs and outcomes will be evaluated every six months with respect to progress made and the path forward. Key indicators are linked to the project log frame. They are differentiated by levels related to impact, outcome and output, and across the three outcome categories of the project.

The project leader and a nominated M&E expert will provide guidance on M&E tools, methods and approaches. Processes such as partner and team briefings and annual planning processes will ensure that M&E is integrated effectively into project management and decision-making mechanisms.

The M&E system will be instrumental to ensure the project succeeds in achieving its objectives to build awareness and country-led scaling-up of solar irrigation. Secondly, M&E will ensure that interventions are effectively implemented, monitored, analyzed, and reported against. The M&E System will be finalized in the first three months of the project using a participatory approach with our partners.

The logical framework provides the outcome and outputs to be achieved under the program (Annex 2). It also provides for initial assumptions that are key to SDC-SoLAR's theory of change. A formal quarterly assessment of progress on milestones in the individual country plans will take place every quarter during meetings of the country project management committee. The project management unit (PMU) will request information on progress against milestones from the country PIs. The PMU will work with the country leads to establish a streamlined template. This work will be collated into an ongoing dashboard of progress and will be shared with all team members. This information sharing will be a regular activity, and the project's M&E lead will help coordinate this process. Evidence from this monitoring will be fed into bi-yearly reports as appropriate and addressed more fully in the annual reviews.

IWMI will report against the project log frame. Six monthly technical reports will be prepared that will review the project context and relevant changes and provide a summary of progress towards the outcomes. Assumptions and risks included in the log frame will also be reviewed regularly and updated based on the current in-country situational analysis. Given the significant role of government partners for uptake and scaling-up of project findings, the project team will work closely with the responsible government agencies. On a yearly basis, IWMI will convene a partner workshop to reflect on the project's successes and limitations against the impact and outcome statements.

IWMI will provide annual financial statements to SDC which will be linked to the project work plan and log frame.

Towards the end of the project, as per our log frame and activity plans, we have scheduled a number of uptake events and will measure if and how the project outputs have changed knowledge, perceptions, or any behavior of the key partners. This work will be done through a specific technique called 'outcome mapping' (after IDRC, 201xi), which looks at behaviors and practices of key stakeholders known as 'boundary partners'. Boundary partners include the individuals, groups, or organizations with which the program interacts directly and can anticipate opportunities for influence. In the case of SoLAR-SA, boundary partners include individuals and institutions such as local government, key members of the scientific community, and key energy, water, and agriculture departments. By the second quarter of Year 4, each country leader will have identified a select number of direct (influenced by the work) and indirect boundary partners (influenced through interaction with the direct boundary partners) drawn from institutions engaged in respective activities. Subsequently, interviews will be scheduled with boundary partners to assess achievements against the agreed progress markers. Each country lead will be responsible for respective outcome mapping processes, supported by the project leader and M&E lead, who will provide guidance, training, and oversight.

Endnote

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i India has 11.05 million electric pumps and 6.30 million diesel pumps (MoWR, 2006-07). In Pakistan, there are 0.31 million electric pumps and 0.83 million diesel pumps (Ayaz, 2015). In Bangladesh, there are 0.27 million electric pumps and 1.34 million diesel pumps (IDCOL, 2015); while in Nepal, there are 0.13 million pumps, of which roughly 80% are diesel pumps.

ii 1 USD ~ NPR 100

iii We use the exchange rate prevalent is 2012, which was 1 USD =INR 50.

iv Annex 1 features the country consultations reports for Nepal, Pakistan and Bangladesh, and the final from the regional consultation meeting held in Kathmandu in July 2019. India's consultation report has been already submitted to SDC as an interim deliverable under the Entry Phase of this project.

v 1 USD ~ INR 65

vi Ministry of Agriculture, Bangladesh. Brief report on irrigation 2016-17. Retrieved January 14, 2020, from https://moa.gov.bd

vii Power Division, Ministry of Power, Energy and Mineral Resources, Government of the People's Republic of Bangladesh. (2008). Renewable Energy Policy of Bangladesh.
http://www.sreda.gov.bd/d3pbs_uploads/files/policy_1_rep_english.pdf

viii Sustainable and Renewable Energy Development Authority, GoB. National Database of Renewable Energy. Retrieved January 14, 2020, from http://www.renewableenergy.gov.bd/index.php

ix In collaboration with Madhya Gujarat Vij Company Limited (MGVCL) and Gujarat Energy Research and Management Institute (GERMI)

x http://pib.nic.in/newsite/PrintRelease.aspx?relid=188499

xi Earl et al, 2001, Outcome Mapping: Building Learning and Reflection into Development Programs, IDRC/2001-01-01. http://www.idrc.ca/EN/Resources/Publications/Pages/IDRCBookDetails.aspx?PublicationID=121