Solar Irrigation in Nepal

A Situation Analysis Report

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About SoLAR

Solar Irrigation for Agricultural Resilience (SoLAR) in South Asia 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. 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.

About IWMI

The International Water Management Institute (IWMI) is an international, research-for-development organization that works with governments, civil society, and the private sector to solve water problems in developing countries and scale-up solutions.

Through the partnership, IWMI combines research on the sustainable use of water and land resources, knowledge services and products with capacity strengthening, dialogue and policy analysis to support the implementation of water management solutions for agriculture, ecosystems, climate change and inclusive economic growth. Headquartered in Colombo, Sri Lanka, IWMI is a CGIAR Research Center.

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The Swiss Agency for Development and Cooperation (SDC) is the agency for international cooperation of the Federal Department of Foreign Affairs (FDFA). Swiss international cooperation, which is an integral part of the Federal Council's foreign policy, aims to contribute to a world without poverty and in peace, for sustainable development. SDC, through its Global Programme Climate Change and Environment (GPCCE), helps find solutions to global challenges linked to climate change. It engages in global political dialogue and manages specific projects in the fields of energy, climate change adaptation, sustainable development of mountainous regions and prevention of natural hazards that are likely to influence regional and international policy.

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Project

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Swiss Agency for Development and Cooperation (SDC)

Partners

Alternative Energy Promotion Centre (AEPC)

Nepal Electricity Authority (NEA)

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AC-PVWP	Accelerated Commercialization Solar Photovoltaic Water Pumping
AEPC	Alternative Energy Promotion Centre
CUF	Capacity Utilisation Factor
DAGs	Disadvantaged Groups
DoA	Department of Agriculture
DP	Development Partners
DWRI	Department of Water Resource and Irrigation
EP	Electric Pump
GoN	Government of Nepal
HP	Horse Power
ICIMOD	International Centre for Integrated Mountain Development
iDE	International Development Enterprises
IWMI	International Water Management Institute
MoA	Ministry of Agriculture
MUS	Multiple water use systems
PAYGO	Pay as You Go Model
RETs	Renewable Energy Technologies
RETS	Renewable Energy Test Station
SDGs	Sustainable Development Goals
SIP	Solar Irrigation Pumps
SPV	Special purpose vehicle

Executive Summary

This report presents a synthesis of Nepal's solar irrigation policies. It provides a detailed picture of the country's renewable energy transition journey, highlights the current issues faced by the energy and water sector in the context of solar irrigation, and describes how the SDC-SoLAR (Swiss Development Corporation-Solar Irrigation for Agricultural Resilience) project led by the International Water Management Institute (IWMI) aims to navigate these complex issues through its research activities.

Nepal is an agrarian economy where the agriculture sector contributes to one-third of the GDP. The majority of the farmers in Nepal are smallholders who rely on traditional rain-fed agriculture. Of the estimated 2.6 million hectares of arable land in Nepal, only 69% of it is irrigable, and 39% is actually equipped with irrigation currently. Most of the irrigated land in Nepal lies in the Tarai, where the topography is flat. Both surface water and groundwater are used for irrigation. Farmers who use groundwater rely on diesel pumps because grid electricity is not available everywhere. Irrigation using diesel pumps is both expensive and harmful to the environment. The agriculture sector (including irrigation) alone accounts for around 10.5% of the total diesel consumption in the country. Moreover, despite employing 80% of the population in the agriculture sector, Nepal is not food self-sufficient and imports food from other countries. Hence, making agriculture more productive is imperative, and irrigation can help.

Solar-powered Irrigation Pumps (SIPs) have emerged as a viable alternative to diesel pumps. The decentralised nature of SIP technology makes it suitable for rural farms which are far away from the main electricity grid. Though globally panel costs have declined rapidly, standalone off-grid SIPs still remain expensive from small and marginal farmers in Nepal. High upfront capital costs need subsidisation. Through continued efforts from the Government of Nepal (GoN), Development Partners (DPs), the private sector, and other stakeholders, SIP technology has gained popularity and momentum in Nepal. Several projects with innovative business models have been piloted. However, studies show that for SIP to be financially feasible, the Capacity Utilization Factor (CUF) of SIP needs to be increased.

In 2016, the GoN introduced the Renewable Energy Subsidy Policy 2016 and the Subsidy Delivery Mechanism Guidelines 2016 to be implemented by the Alternative Energy Promotion Center (AEPC). Guided by these policies, AEPC began providing subsidies to SIPs in 2016. Currently, there are over 1900 SIPs installed across Nepal. However, a rapid assessment of the subsidy delivery mechanism conducted by IWMI highlighted that majority of the subsidised SIPs went to well-off farmers simply

because small and marginal farmers did not apply for these SIPs. Among those who applied, AEPC selected more female farmers, and farmers with small land sizes.

Though envisioned to increase access, solar irrigation subsidies are captured by elite farmers enabled by their social capital. Women and disadvantaged groups (DAGs) lack networks to lending institutions, and with limited prior earnings, are left behind when it comes to accessing SIPs. For example, AEPC received a lesser number of applications from women and DAGs. The requirement for land ownership title for SIP eligibility also effectively limits the participation of women and other marginalised farmers. Despite best efforts by AEPC, without targeted programming, access for smallholders to such renewable energy technologies (RETs) may continue to remain elusive.

As the government struggles to fulfil the massive demand for these pumps, weak linkages in the supply chain and poor operation and maintenance pose a threat to adopting these climate-friendly technologies. Greater coordination between and among stakeholders in the newly formed federal Nepal will be needed. For example, using grid integration of SIP to improve the CUF and integrating technologies such as drip irrigation to decrease the per-unit cost of the irrigation water from SIP could help achieve greater agricultural productivity.

1. Introduction

1.1 Country Overview

Nepal is a landlocked country in South Asia located between India and China which shares its border with India to the east, west, and south and China to the north. The geographic area of Nepal is 147,181km^{2,} with an estimated population of 28 million (World Bank, 2021). The country has a three-tiered government system divided into seven provinces as per Nepal's Constitution adopted in 2015.

Nepal can be divided into three distinct topographical zones. These zones are the mountains (4877m to 8848m altitude above sea level), Hills (610 to 4876m altitude above sea level), and Tarai (less than 610m altitude above sea level) (Ministry of Health (Nepal), New ERA, and ORC Macro, 2001). Mountain, Hilly, and Tarai occupy 15%, 68%, and 17% of the total area, with each topographical zones having varied climatic conditions (NPC, 2013). Tarai, because of its relatively flat terrain, is Nepal's food basket. Due to the diverse nature of geographic, climatic, and hydrological characteristics seen in Nepal, the agriculture land use and cultivation patterns in Nepal is also very diverse (IBN, 2019).

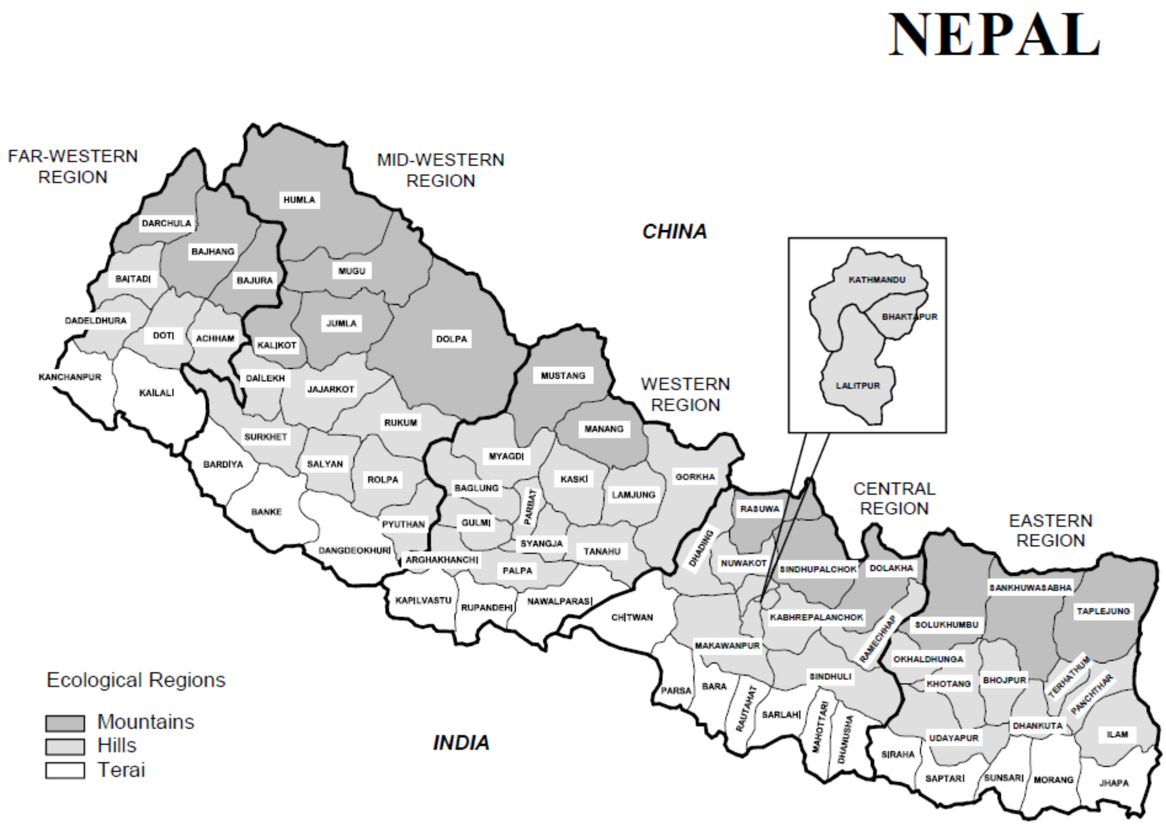

Figure 1 Physiological map of Nepal (Ministry of Health (Nepal), New ERA, and ORC Macro , 2001)

The GDP of Nepal has grown from US$ 5.49 billion in 2000 to US$ 30.64 billion in 2019 (World Bank, 2021). According to World Bank, the per capita GDP of Nepal in 2019 was US$ 1,071. However, because of the national lockdown arising out of the Covid-19 pandemic, the economic growth rate of Nepal slowed down to 0.02% in 2020, with an average inflation rate of 6.2% (World Bank, 2020).

Nepal has an agrarian economy that employs around 80% of the total population, and the agriculture sector contributes to one-third of the GDP (WorldBank, 2019). Remittances from Nepali migrants also contribute to a large share of GDP. The service sector is currently one of the significant contributors to GDP, followed by the agriculture and industrial sectors, respectively (Gaudel, 2015). The country is categorised as a low-income nation, and the ease of doing business rank is 94, with an average score of 63.2 (World Bank, 2020).

Nepal contributes to only 0.027% of global CO_2 emissions, but it is one of the most vulnerable countries in terms of the impact of climate change (GoN, 2020). Therefore, Nepal is committed to international initiatives and internationally agreed goals such as Sustainable Energy for All (SE4ALL), Sustainable Goals (SDGs), and Paris Climate Change Agreement, to name a few. As part of the Paris Climate Change Agreement, Nepal submitted its first NDC in 2016 and a revised second NDC in 2020 with a target to cut the CO_2 emissions by 28% by 2030 (GoN, 2020).

1.2 Agricultural Background

Nepal’s geography makes it suitable to grow high-value off-seasonal crops along with medicinal herbs and edible oils. The major cash crops in Nepal are oilseed, potato, tobacco, sugarcane, jute, cotton, and rubber. In addition, paddy, maize, millet, wheat, barley, and buckwheat are the major cereal crops of Nepal. The agriculture sector has around US$ 338 million in foreign investment in about 180 agriculture projects (FNCCI, n.d.).

Nepal has around 2.6 million hectares of arable land, and only 69% is irrigable (IBN, 2019). Around three-fourths of the irrigable land is in the Tarai Region. Only 39% of the land has year-round irrigation facilities (GoN, 2019). According to the 15th periodic plan (2019/20-2023/24), the GoN plans to increase year-round irrigation to up to 50% by 2024 and 80% by 2030 (NPC, 2020). Groundwater and lift irrigation systems powered by solar and other technologies will be developed in collaboration with provinces to promote commercial agriculture. Tarai is the food basket of Nepal. The main crops in the Tarai region are rice, wheat, maize, sugarcane, jute, and vegetables. Only 20% of the land is currently cultivated in the hilly area, mainly producing wheat and maize. Due to the harsh climatic conditions and challenging terrain in the mountainous region, only 5% of the land in this region is suitable for cultivation, and livestock farming is the main agricultural activity.

The agriculture sector is dominated by smallholder farmers mainly engaged in subsistence farming (Thapa, et al., 2019). Although a large section of Nepal's population is involved in the agriculture sector, there is a negative trade balance in this sector, contributing to the national trade deficit. One of the main reasons being low agricultural productivity with traditional farming practices and land fragmentation. Nepal's agriculture sector lacks quality infrastructure for year-round irrigation facilities. Most smallholder and commercial farmers depend on monsoon rainfall that usually occurs between June and September. Rice and wheat are grown with the help of irrigation in limited areas of the country (Pradhan, Parajuli, & Khanal, 2017). Due to this heavy dependence on monsoon rain, the productivity of Nepali farmers is uncertain, and production from multiple crop cycles is not always possible. Therefore, Nepal needs to improve its agricultural productivity and reduce import of agricultural products from outside (Gaudel, 2015). Nepal shares an open border with India, providing it with a massive potential for the duty-free market to approximately 350 million people for its agriculture products (IBN, 2019).

Department of Agriculture (DOA) under the Ministry of Agriculture and Livestock Development, and the Department of Water Resource and Irrigation (DWRI) under the Ministry of Energy, Water resource and irrigation are the primary agencies involved in the agriculture and irrigation sector of Nepal, respectively.

1.3 Energy Sector Background

After the decade-long power cuts officially ended in 2018, Nepal has seen a significant shift in its energy sector. GoN plans to increase electricity generation by adding 5,000MW in five years and 15,000MW in 15 years (MoEWRI, 2018). With several large hydro projects under construction, Nepal is on track to becoming energy self-sufficient in the next few years. But Nepal's per capita electricity consumption is low compared with other South Asian countries. Nepal Electricity Authority (NEA), the state-owned utility provider, plans to improve the per capita electricity consumption to 700 units by 2022. This resonates with the National Planning Commission's 15th periodic plan to increase the per capita electricity consumption to 1500 units by 2030 (NPC, 2020). Access to electricity in Nepal in the FY 2018/19 was only 78%, and the GoN aims to achieve 100% electrification by the year 2022 (MoEWRI, 2018). This target is in sync with the Paris Climate Change Agreement of attaining universal energy access by 2030.

In 2018, Renewable Energy (RE) contributed to only 3.5% of the total energy generation. GoN is targeting to increase the share of RE energy to its energy mix to 12% by 2024 (AEPC, 2019). The NPC's 15th periodic plan also targets to achieve around 4000MW of generation from renewable energy resources by 2030 (NPC, 2020). In addition, the government plans to increase the share of solar energy generation through private sectors with a target of generating over 550MW by 2024 (ibid). Furthermore, as part of the NDC target, Nepal plans to supply 15% of the total energy demand through clean energy sources, adding 2100MW of solar energy to the national grid by 2030 (GoN, 2020).

According to the 2019/20 budget, the GoN plans to develop at least two large hydroelectricity and solar projects in each province. Province 2, which does not have any hydroelectricity resources, will mainly focus on solar energy technologies. Solar power will also develop lift irrigation and groundwater irrigation through the provincial and local governments.

2. Current Scenario of solar irrigation in Nepal

2.1 History

The first Solar powered pumping system in Nepal was installed in Sundharighat, Kathmandu, in 1993, which was a 4KW system (Renewable World, 2018). A few larger SIP systems of 40-60kWp were established in subsequent years, but the adoption was not widespread. Several isolated programs installed SIPs through the GoN subsidies or grants from the development partners.

Around 2015, solar-powered pumps emerged as a potential solution for drinking water and irrigation in rural Nepal. The decentralised nature of technologies made it ideal for reaching farmers who lacked grid access. In 2015, the USAID Accelerated Commercialization Solar Photovoltaic Water Pumping (AC-PVWP) three-year project designed to expand the commercialisation and adoption of PVWP was implemented by Winrock International (Foster et al. 2017). This project was implemented in two phases wherein the first phase, 69 PVWP systems were piloted in 16 districts with a combined capacity of 53.15kWp benefiting 392 farmer groups. Additional 120 systems were installed in the second phase in 2017. International Centre for Integrated Mountain Development (ICIMOD) piloted 1.2-2.4kWp SIPs in 2016 in the Saptari, Bara, Sarlahi and Ruatahat districts in Tarai (Mukherji et al. 2017). Winrock International and International Development Enterprises (iDE) promoted small-scale solar water pumps (80-300Wp systems), targeting smallholder and marginalised farmers (Bastakoti et al., 2019). In collaboration with its implementation partners, International Water Management Institute (IWMI) installed 80Wp SIPs in the Saptari district of Nepal.

As guided by the Renewable Energy Subsidy Policy 2016 and Subsidy Delivery Mechanism Guidelines 2016, AEPC started promoting SIPs in 2016. Since then, a great demand for SIPs has been established, especially in the Tarai region of Nepal. AEPC has already implemented over 1900 subsidised SIPs where AEPC provided 60% subsidy, and farmers had to pay the rest. AEPC received demand several times over the number of SIPs it was able to allocate, showing that there is a huge unmet demand, especially in the Tarai. As per the 15th periodic plan, the GoN plans to increase SIPs to over 6500 cumulative installations from 2021 to 2024 through AEPC (NPC, 2020), but this number may still fall short of the total demand.

2.2 Solar Irrigation Pumps in Nepal

Nepal has good potential for solar energy with average solar radiation of 4.4 kWh/m^2 to 5.5 kWh/m^2 and around 300 sunny days per year (Solargis, 2019). The majority of SIPs that are being installed in Nepal are in the Tarai region because of its high groundwater potential and intensive agricultural activities. There is also a high correlation between water demand and solar generation, which means SIPs can irrigate at maximum capacity during the dry seasons when the crop water requirements are highest (Foster et al., 2009). The off-grid SIP technologies make it ideal for power irrigation systems in areas with low electricity access with no irrigation infrastructure.

The rapid decline in the cost of SIPs and low operation and maintenance costs have provided an opportunity for SIP technologies to be financially feasible across the world. But it still needs significant upfront capital cost investments. Small and marginal farmers cannot afford to pay the up-front costs even though the long-term running costs of SIPs is close to zero. Fortunately, the GoN is very supportive of SIP technology which can be seen by the gradual increase in the budget allocated for subsidising the SIPs. But the average rate of subsidy approval was only 31% of the total demand in 2019, and it has fallen further in 2020 due to higher demand and lower budgetary allocations (Pandey et al., 2020). There is a significant demand for SIP in Nepal, and if the government can allocate a larger subsidy budget, widespread adoption of SIP can be accelerated. But the subsidy policies and subsidy delivery mechanisms need periodic review and needs to reach more marginalised communities.

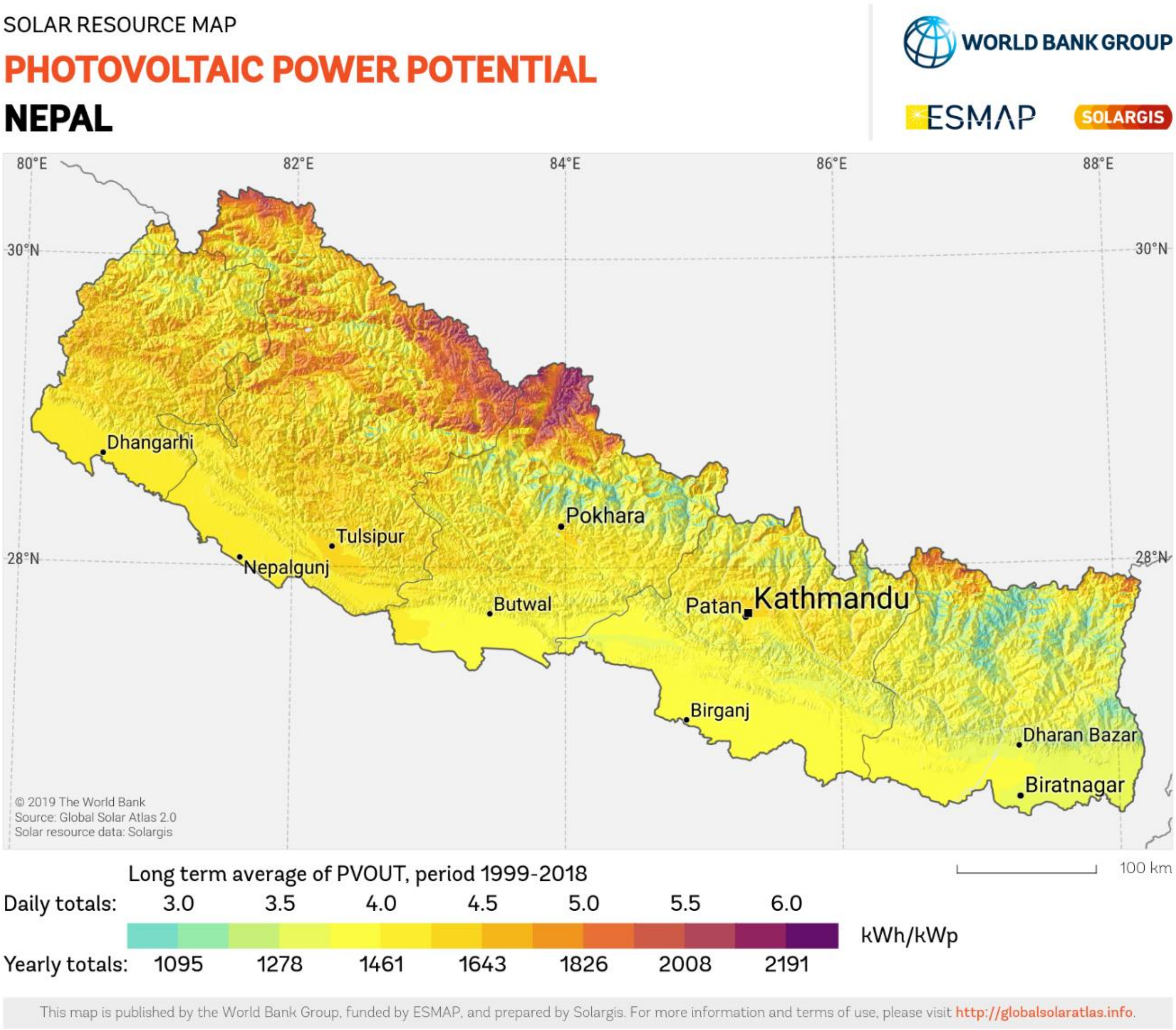

Figure 2: Photovoltaic Electricity Potential
Source: Solargis, 2019

Many factors inhibit the widespread adoption of SIP in Nepal. One of the significant factors is the post-sales maintenance of the SIPs. SIPs are a relatively new technology, and local technicians who repair diesel and electric pumps are not yet trained to repair them. The AEPC subsidised SIPs come with two years of O&M services support. But due to the lack of an established supply chain of SIPs and unavailability of trained local technicians, the useful life of the SIP beyond the O&M period is limited. Also, improper system sizing either increases the cost of SIP or cannot deliver enough water output required by the farmers. Another critical factor is the lack of optimised CUF of the SIPs that makes the per-unit cost of water more expensive than the electric pumps. In some cases, the per-unit cost of SIPs is more expensive than even diesel pump.

Low returns due to the poor agriculture supply chain also affects the adoption of SIP in Nepal. The farmers may not be motivated to invest in SIP technologies even though they have access to finance and subsidies from the government without the assurance of a good market for their produce. There also seems to be a lack of awareness amongst farmers about the environmental benefits of SIPs over diesel pumps, and farmers may not even be motivated to adopt SIPs due to its environmental benefits.

The main factors for driving and constraining the SIP ecosystem in Nepal's context are listed in Table 1. Despite many constraining factors for the widespread adoption of SIPs in the country, the advantages of SIPs from a food-energy-water nexus and its direct implication to food security cannot be overlooked. In addition, SIP is a climate-resilient zero-carbon technology that will help to reduce the import of fossil fuels and help Nepal reduce its trade deficit.

Driver	Constrainer
• Rich in solar energy resource • Lack of established traditional irrigation infrastructure • The decline in the cost of solar PV • Government subsidies for SIPs • Lack of grid access • Commitment to international initiatives • Socio-economic factors • GoN commitment • SIPs generate electricity during times that matches irrigation demand • Climate-resilient technology	• The high upfront cost of SIPs • Inadequate budget to meet subsidy demand and adequately reaching marginalised communities. • Lack of supply chain of SIP and unavailability of local technicians • Lack of awareness about SIPs amongst farmers • Low CUF of SIP • Low return on agriculture in general • Improper sizing of SIPs

Table 1:Driver and restrainer of change of SIP in Nepal

2.2.1 Major Stakeholders

Government

Several government institutions that work in the water, irrigation, and agriculture sectors play a vital role in overall SIP and groundwater development and management. At the federal level, these are the Ministry of Energy, Water Resources, and Irrigation (MoEWRI), the Ministry of Physical Infrastructure Development, and the Ministry of Agriculture. There are various relevant sub-departments under these ministries – a snapshot of which can be observed in figure 3. The direct line ministry involved in the renewable energy and irrigation sector is the MoEWRI.

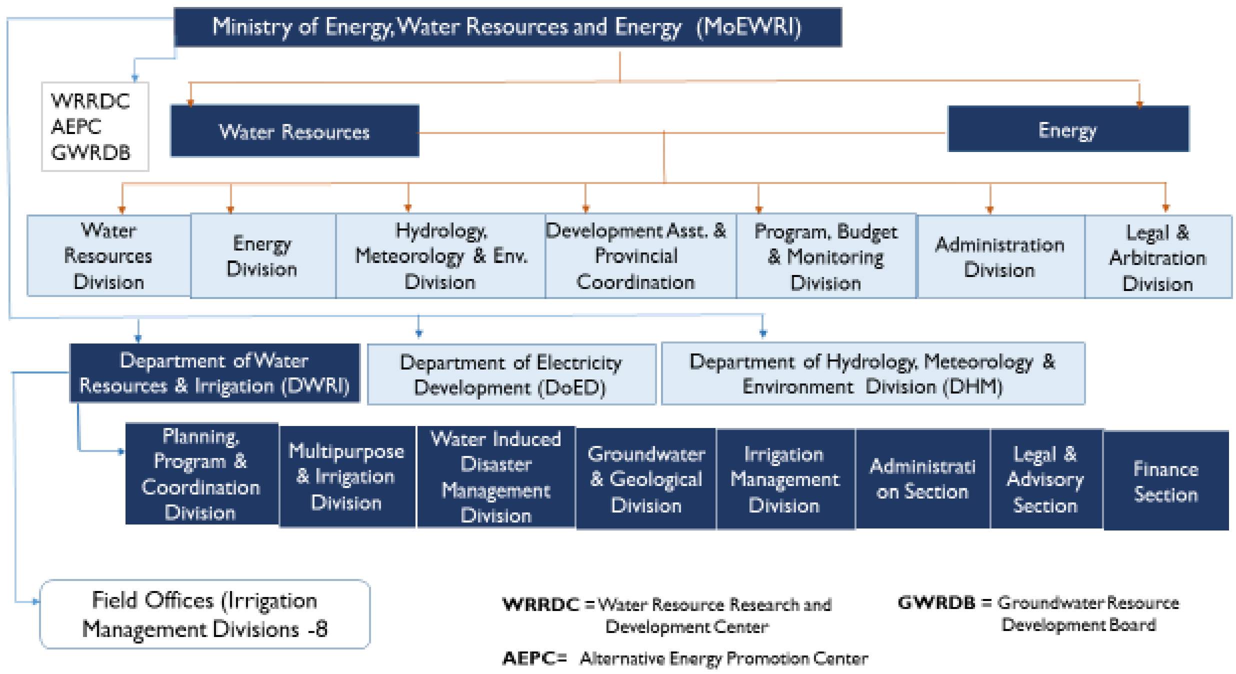

Figure 3: Governance structure for water at the federal level (Manohara, Forthcoming)

AEPC, established in 1996, is a semi-autonomous national entity under the MoEWRI with the primary objective of promoting renewable energy technologies (RETs) across the country. AEPC is involved in a short-, medium-, and long-term policy and plan formulation and is a nodal organisation for implementing renewable energy policies. AEPC mainly focuses on rural electrification through systematic coordination with various government organisations, DPs, NGOs, INGOs, and private sectors. Since 2015, APEC has been heavily involved in the promotion of SIPs with subsidies.

DWRI, under MoEWRI, is a government organisation with a mandate to plan, develop, maintain, operate, manage, and monitor different modes of environmentally sustainable and socially acceptable Irrigation Projects. Their mandate included surface and groundwater or water resources projects with irrigation as a major component (DoWRI, n.d.). In addition, DWRI is involved in various river management projects to provide year-round irrigation facilities to the farmers of Nepal. Since irrigation is integrated with the agriculture sector, the Ministry of Agriculture (MoA) and the Department of Agriculture (DoA) under MoA are significant government stakeholders.

According to the 2015 Constitution, the three-tiered government system in Nepal provides more resources to the local governments to develop SIP projects at the local level. In the current scenario, the local governments are highly involved in working with the community to facilitate SIP projects locally. In addition, certain local water and irrigation management authorities have also been handed over to local governments who oversee agriculture and irrigation as part of their sectoral departments.

Development Partners and INGOs

Solar-powered irrigation has been gaining traction around the world since the mid-2000s. INGOs and DPs have played a significant role in introducing SIP technology in Nepal by conducting various pilot projects and exploring viable business models.

Organisations like ICIMOD and Winrock International, with support from their project partners, developed pilot projects with medium-scale SIPs to increase the demand and accelerate the commercialisation of the same in Nepal. While other organisations like IWMI and iDE promoted small-scale SIPs, practical action with support from WISON developed two large-scale community-based solar lift irrigation systems in the mid-hills of Nepal.

ICIMOD pilot SIPs (three in number) had cumulatively operated for 1,575 hours from August 2015 to November 2016, and in the process, saved 1000 litres of diesel and irrigated 17.3 ha of land compared to 13.1 ha in 2014-2015 when irrigation was done using diesel and electric pumps. Overall, the gross and net irrigated area rose by 25% and 30% respectively, there was an increase in the cultivation of dry season vegetables, and a doubling of the number of water users, from 15 to 31. These pumps were installed for demonstration purposes and generated huge interest among farmers in Saptari, leading to several enquiries for purchasing these pumps (Mukherji et al., 2017).

These pilot projects were vital to prove that SIP was technically viable for groundwater irrigation in the Tarai and lift irrigation in the mid-hill regions. The pilot projects also indicated that SIPs needed financial support from the government to counter the high upfront costs to make it financially feasible for Nepalese farmers. The experience sharing of the initial work from the DPs and INGOs across various platforms helped the GoN develop subsidy policies for SIP in Nepal.

Private Sector

Nepal's private sector is heavily involved in the solar energy sector. Many of the private organisations partnered with INGOs to develop pilot projects to introduce SIPs in the country. Over the years, the private sector has introduced many innovative business models collaborating with DPs, financial institutions, INGOs, and various levels of government.

AEPC worked closely with the private sector to promote SIPs and disseminate SIP subsidies to the farmers. A study conducted by IWMI on the GoN's subsidy delivery mechanism indicates that more than 80% of applications for SIPs are received through private SIP service providers (Pandey et al., 2020). In addition, the private sectors are helping farmers prepare all the documentation needed to apply for a subsidy, conduct feasibility studies and generate reports required to obtain the subsidies from AEPC (ibid). A drawback of private sector involvement in this context has been their focus on collecting applications from well-off farmers, thereby undermining some of the GESI goals.

Every year AEPC prepares a roster of solar energy companies for providing installation services. These listed solar companies are allowed to install AEPC subsidised SIPs. There are currently over 50 pre-qualified solar energy companies in Nepal.

Gham Power, a leading SIP service provider in Nepal, surveyed 30 SIPs installed in Bara, Rautahat, and Sarlahi district (Gham Power, 2019). They found that after the SIPs were installed, the agricultural production increased by 10.24%, and the farmers' income increased by 16.32%. The farmers shifted to vegetable farming, and the majority of the farmers moved from subsistence farming to commercial agriculture. 90% of the farmers were satisfied with their installed SIP system, which reduced their agriculture expenses by 7.57%.

Financial Institutions

Most farmers in Nepal find it challenging to manage the non-subsidised cost of SIP that they need to pay upfront. Hence the role of financial institutions to improve access to finance for these farmers is crucial. Nepal has a relatively diverse number of financial institutions active compared to its economy. Different financial institutions are working here, such as commercial banks, finance companies, cooperatives, microfinance institutes, etc.

Some large commercial banks have established a dedicated department to deal with financing renewable energy projects. Some agriculture-focused cooperatives and microfinance institutes can be seen partnering with private SIP service providers to issue financing services to the farmers. In some cases, where the SIP service provider delivers project financing, the cooperatives and microfinance institutions also collect monthly payments from the farmers. For example, in the case of ICIMOD pilots, one commercial bank tied up with the project and provided finance to farmers to pay their equity shares.

2.3 SIP Ecosystem in Nepal

The context of SIP has evolved with the falling prices of Solar PV technologies around the world. Even though the current SIP market in Nepal is subsidy-driven, the sustainability of the pumps depends on the overall SIP ecosystem. Therefore, the solar and agriculture sector needs to create an integrated approach for developing a sustainable SIP ecosystem. But the country’s agriculture sector has multi-layered problems, and while developing the SIP ecosystem in Nepal, other value chains of the agriculture sector need to be streamlined (Malla, 2021).

SIPs require continued market building efforts to exploit their full potential with critical factors such as

(i) Distribution Channels, (ii) Delivery model and access to finance, (iii) Policy and regulatory framework, and (iv) Awareness raising and capacity building (IRENA, 2016).

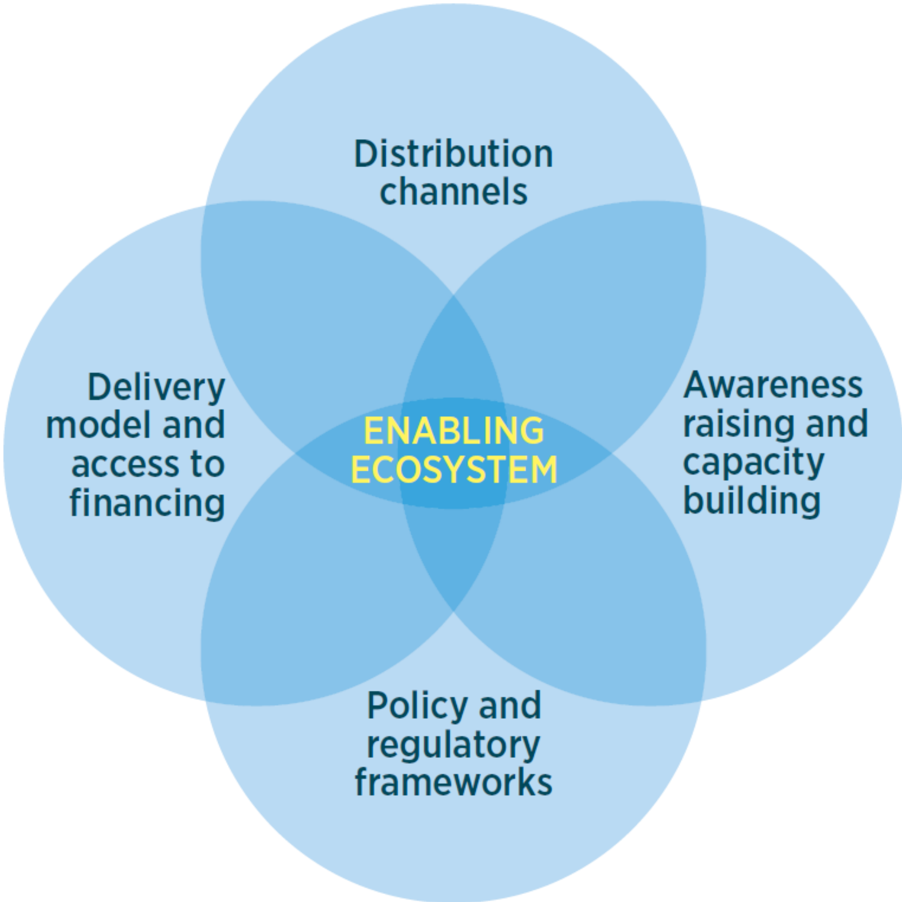

Figure 4: Building Blocks of an Ecosystem to Support Solar Irrigation Solutions
Source: IRENA, 2016

2.3.1 Distribution Channels

One of the keys to a sustainable SIP ecosystem is to develop a market with established distribution channels where the farmers can access quality equipment at competitive prices. The other important aspect for a new technology like SIP is the after-sales service networks to ensure the uninterrupted operation of SIP.

In Nepal, both the agriculture and the solar sector have not matured yet. So, it presents an opportunity for the SIP market to grow with the agriculture sector while supporting each other's growth. But one of the many challenges in working in both these sectors is that it requires diverse expertise. The system size of SIP is generally determined by the type of crop that is being cultivated by the farmers and its seasonal water requirement. Other factors such as groundwater table, quality of water, area of the farm, etc., dictate the selection of pumps used in SIP.

The conventional fuel-based pumping systems have the advantage of an established rural distribution network (IRENA, 2016). However, despite being expensive and harmful to the environment, the farmers in Nepal still prefer diesel pumps for groundwater irrigation, as skilled technicians to perform O&M are available locally. Therefore, SIP companies need to utilise this existing distribution network of diesel and electric pumps or build a similar distribution network dedicated to SIPs. Through SDC-SoLAR project, IWMI plans to train some of these existing technicians in repair and maintenance of SIPs.

Most of the SIPs provided by AEPC are subsidised. SIPs have a mandatory warranty of two years where the solar company is obliged to provide O&M services to the farmers. But due to the lack of locally available skilled technicians, the SIP providers usually mobilise technicians from Kathmandu. Bringing in technicians from Kathmandu increases the response time for O&M. This delay can be detrimental for the farmers if they cannot get enough irrigation water and may affect their entire crop cycle. Also, most of the SIP technicians employed are males and usually do not speak the local language. This might limit the ease of communication, especially with female farmers in Nepal's Tarai region.

The significant component of SIP is the pump, solar panels, and inverter. Most of these components are imported from India or China, which takes approximately four to eight weeks. Hence if enough stocks are not maintained, the installation could take a long time and pose some challenges for keeping the pumps operational if one of the components breaks and requires replacement.

Most of the sea freight comes to Nepal through the Kolkata port in India. The Birgunj customs office at the Raxual border is the most significant entry point for shipments to Nepal from India. All the air freight shipments come to the TIA customs office in Kathmandu. Most of the private companies are based in Kathmandu, with some regional offices. The SIP providers usually have decentralised storage facilities for short-term supplies based on projects and location, but long-term inventories are generally stored around Kathmandu (Malla, 2021).

The GoN has several fiscal incentives to ease custom tariffs on the SIP component to make it more affordable. Solar modules and DC pumps are currently charged 1% customs, and the VAT is exempted on recommendation from AEPC defined by the Financial Act amendment 2077 – Schedule 1 (Forthcoming CSISA Report). These need to be certified by the Renewable Energy Test Station (RETS), which assesses equipment quality. However, the capacity to test a wide range of equipment at RETS needs to be improved.

The Covid-19 pandemic has had a significant impact on the distribution channels of SIP providers. Most of the manufacturers based in India and China cannot meet the demand and send supplies in time due to backlogging. This means there are significant delays in implementing the pipeline SIP projects. In addition, the cost of silicon used in the manufacture of solar panels has increased due to the pandemic. Also, several supplies bound for Nepal are stuck at the Kolkata port, increasing the shipment cost. As a result, the overall price of SIP may rise in Nepal, which means that the SIPs will be even more unaffordable for the farmers, and the profit margin for the SIP providers will be slim.

2.3.2 Delivery models and access to financing

SIP ownership seems to be linked to prestige and 'status' for more well-off Nepali farmers (as noted by one of the stakeholders for the rapid assessment). At the same time, most smallholders struggle even to purchase micro-irrigation equipment. The SIPs in Nepal are not fully subsidised, and the farmers who can afford the 40% upfront cost of SIP apply for the AEPC subsidy. Smallholder farmers involved in subsistence farming usually have constrained cash flows closely linked to the cropping seasons (IRENA, 2016) and cannot afford to pay for this upfront cost. Hence, an innovative business model is needed on top of the grant/subsidies provided to the SIP and improve access to finance. These business models need to be customised according to the requirements of the targeted beneficiaries.

Several microfinance companies are working in the agriculture sector to improve access to finance for the farmers in Nepal. Several SIP projects piloted looked into different innovative business models to make SIPs more affordable for the farmers. SIP providers worked with farmer cooperatives to install them with affordable financing of three years term while the cooperatives collect monthly payments from the farmers (SunFarmer, 2015). In many of these pilots, the SIP acted as the collateral for the loan, and after the successful completion of the 3-year term, the system is handed over to the farmer. For example, ICIMOD installed 53 SIPs in province 2 with three different financial models such as Grant, Grant-Loan, and Grant- pay as you go (Mukherji et al., 2017). In ICIMOD projects, the farmers needed to present the land documents to the local cooperatives to access financing. All those SIPs have been now handed over to the farmers. But there are not many standout models that are very successful with potential for scalability. One of the challenges for a financial institution is that SIP does not generate revenue immediately and only makes sense in the long run due to the savings from operational costs.

Commonly, farmers access irrigation water from informal water markets by either renting diesel pumps from other neighbouring farmers or buying water from them, usually on an hourly contract. Similar models can be used by SIP entrepreneurs that can be employed to rent SIPs to farmers depending on their water requirements. In this rental model, the farmer does not have to worry about the high upfront cost and can access irrigation water as per their requirement. But two main issues with this model are that the entrepreneurs cannot access government subsidies easily, and the large SIPs are not movable, limiting the area where the SIP entrepreneurs can distribute irrigation water. Hence to encourage an innovative business model, the subsidy policy may need to be revisited.

2.3.3 Policy and regulatory frameworks

Solar Energy was first acknowledged in the 9th periodic plan and was presented as an alternative to the conventional forms of energy in the 10th periodic plan. The Rural Energy Policy 2006 was introduced to contribute to rural poverty reduction and environmental conservation by ensuring access to clean, reliable, and appropriate energy in rural areas (MoEWRI, 2018). The use of renewable solar energy was limited to heating applications like solar driers and water heating. Due to the rapid fall of the prices of solar photovoltaic technologies, solar energy technologies emerged as one of the major technologies for rural electrification with off-grid solar PV. Also, the Rural Energy Policy 2006 established Rural Energy Fund to help channel funds for the deployment of RETs at the local level.

The use of solar energy for drinking water and irrigation soon became popular in rural Nepal. The popularity grew significantly in the areas where access to the national grid was limited and lacked the infrastructure for drinking water and irrigation. But, until 2016, the use of solar energy for energy and drinking water was only limited to the mid-hill areas. The 13th plan tried to integrate SIPs into the Tarai regions. In 2016, the GoN introduced favourable policies for SIPs such as the Renewable Energy Subsidy Policy 2016 and Subsidy Delivery Mechanism Guidelines 2016. Renewable Energy Subsidy Policy 2016 replaced the Renewable Energy Subsidy Policy 2012 and focused on scaling the RETs. AEPC is the central government agency responsible for the implementation of renewable energy subsidy policy, 2016.

Over the years, SIP has become very popular, and the central government allocated NPR 350 million as a grant for SIP in the 2018-19 budget. In the 2019-20 budget, the total allocated budget for SIP increased to NPR 960 million. In addition, special programs for developing ground and surface water irrigation in the Tarai region were envisioned in the 2019/20 budget.

The 14th periodic plan developed subsidy provision for SIPs. The subsidy is provided under four categories, which are (i) Individual farmers, (ii) Private company that owns and has leased lands, (iii) Community based or group of farmers, and (iv) Special Purpose Vehicle (SPV) (Bastakoti, Raut & Thapa, 2019). Additionally, in the 15th periodic plan, an integrated energy special programme aims to provide irrigation facilities to 10,000 hectares of cultivable lands in mid-hills through solar lift irrigation (NPC, 2020).

The renewable energy subsidy policy 2016 provides subsidies up to 60% of the total cost of SIP but not exceeding NPR 2,000,000 per system for community-managed SIPs. For solar water pumping systems for drinking water, a maximum subsidy of up to 60% of the total cost but not exceeding NPR 1,500,000 per system is provided to the community or private company. Additional subsidy of NPR 4,000 per household is provided to 'targeted beneficiary groups' (MoPE, 2016).

Building on the success of other initiatives in the renewable energy sector, the GoN introduced the National Renewable Energy Framework in 2017 that established a cross-sector integrated approach in promoting clean and renewable energy in the federal structure of Nepal (MoEWRI, 2018). Moreover, through the 2018 white paper, the GoN plans to develop policies to connect the excess energy from the solar into the national grid (ibid).

2.3.4 Awareness raising and capacity building

There are always barriers to the adoption of new technologies (IRENA, 2016). In Nepal, like everywhere else, the market is driven by the cost of technology. The higher upfront cost needed for acquiring SIP requires a comprehensive awareness campaign for widespread adoption. Through various initial projects piloted by INGOs, DPs, and the private sector in coordination with GoN has undoubtedly increased awareness in Nepal. Thus, the demand for SIP has been growing gradually. The ICIMOD pilot project in Saptari indicates that demand generation through demonstrating the technology with the farmer was more effective (Mukherji, et al., 2017).

Although the demand for SIP has increased over the years due to continuous efforts from the GoN and other stakeholders, yet the ecosystem of SIP is in a nascent stage. Farmers who are the end-users need capacity-building activities to make optimum use and ensure the long-term operation of SIP. The farmers also need to be aware of the size of SIP installed at their farms to cater to their water requirement to eliminate over-investment in the system (Bastakoti et al., 2019). In addition, awareness campaigns about other complementary technologies to support SIPs, such as drip irrigation, rainwater harvesting, and groundwater recharge, will benefit the farmers.

Besides irrigation, the other primary application of SIPs is drinking water, livestock, fisheries, vegetable, crop farming, etc. For example, in the Chitwan district, a female dairy entrepreneur who owned a 300Wp SIP used it to clean cow sheds and used the slurry from the shed to irrigate vegetables (Winrock, n.d.). Water from the same SIP was also used to improve water sanitation and hygiene in her house.

Another significant issue with SIP is the lack of skilled technicians available locally for O&M of SIP. Capacity building of the local technicians is a crucial aspect of building an ecosystem, especially for technologies like SIP. In addition, information and understanding about SIP technologies amongst Nepali farmers are still inadequate, and they lack the economic means to adapt to newer technologies (Hartung, 2018). Theft and vandalism of solar panels often installed in open and unprotected areas is another major issue for SIP adoption. This needs to be addressed through major awareness-raising campaigns in Nepal.

2.4 Current status of SIP

Since the AEPC-supported SIP program took off in 2016/17, the demand for the technology and progressively granted SIPs had been supported in 2018/19 (Pandey, et al., 2020). In 2019/20, 525 SIPs were installed through AEPC despite the problematic situation due to the Covid-19 lockdown. According to the list published by AEPC for 2020/21, an additional 590 farmers have been selected for installation during the same year.

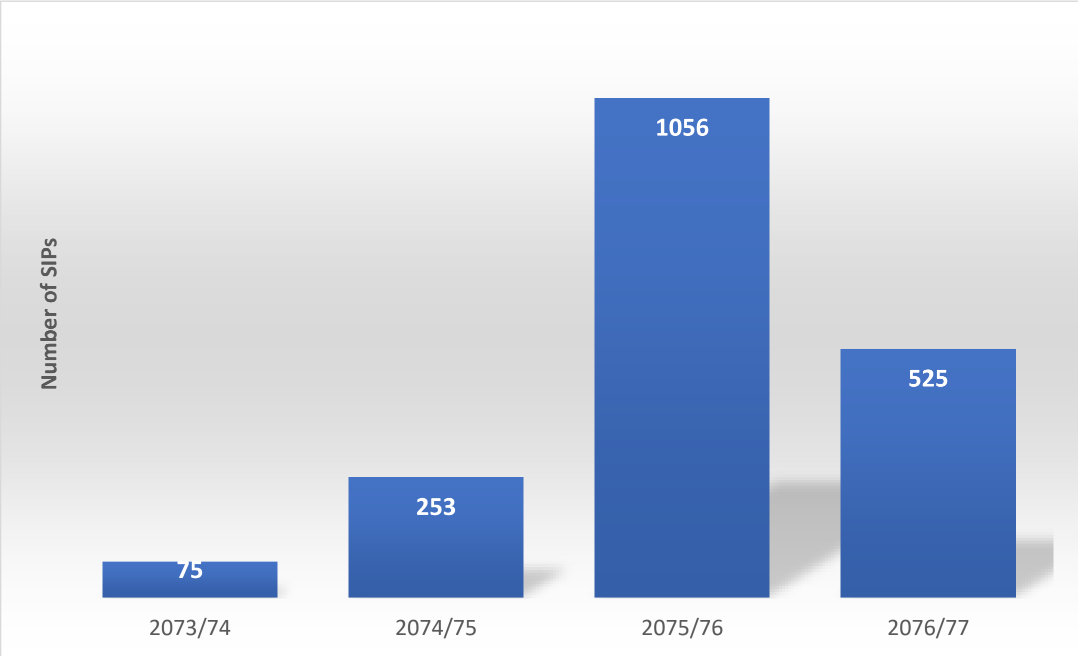

Figure 5: Number of SIPs supported by AEPC over last four years

Most of these SIPs are deployed in the Tarai region. Province 1, Province 2, and Lumbini accounted for more than 74% of the applications in 2019 and were granted more than 85% of the SIPs. This is obvious with the Tarai receiving abundant sunlight, having plenty of groundwater reserves, and highly fertile lands. This section summarises findings from the 2020 Rapid Assessment report on the SIP subsidy delivery mechanism (Pandey, et al., 2020) submitted to AEPC.

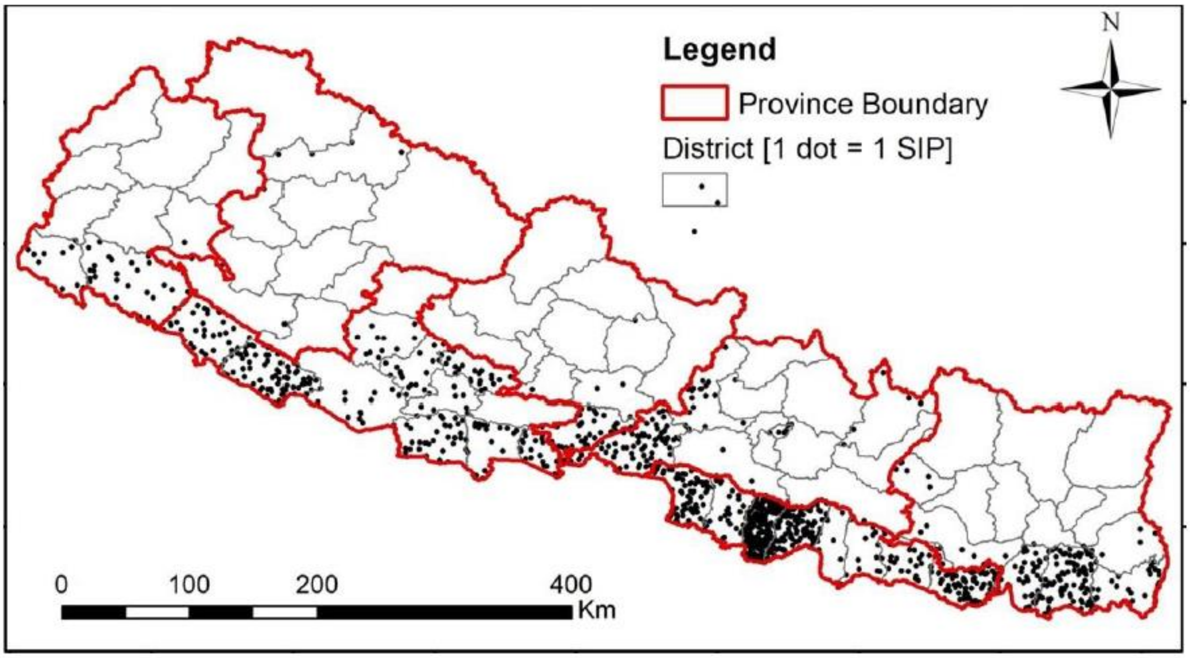

Figure 6: SIPs distribution in Nepal
Source: (Pandey, et al., 2020)

District level segregation (figure 7) shows that 13 out of the major 15 districts that were recipients of the grant were in the Tarai region. Sarlahi had the highest number of applicants, while Rautahat received the highest number of SIPs. Other central recipient districts were Sarlahi, Saptari, and Morang. From figure 6, it can be observed that the majority of SIPs were installed in the eastern and central Tarai region.

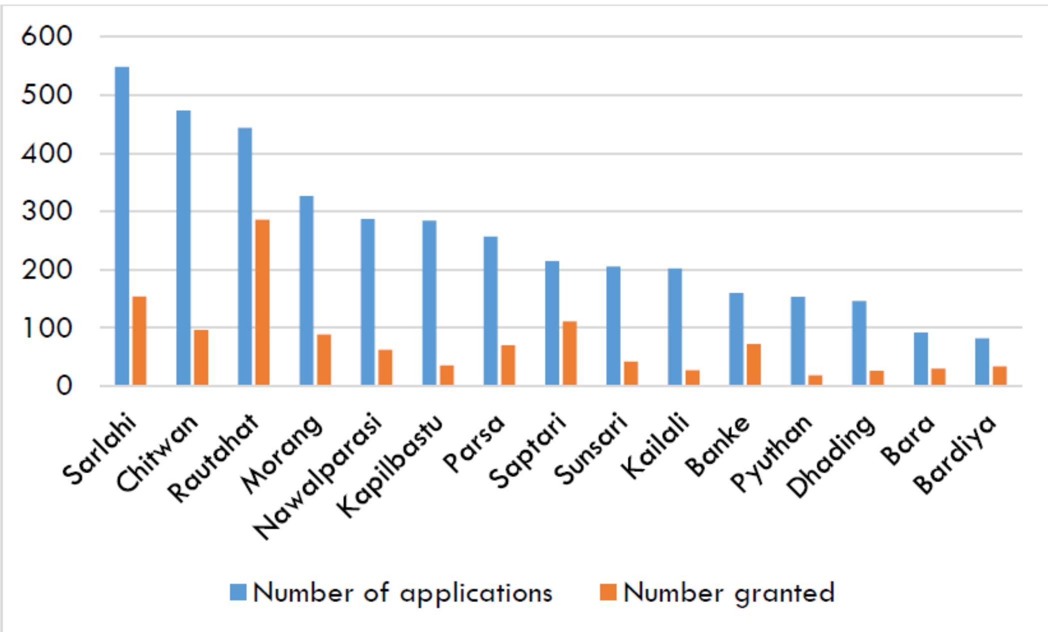

Figure 7: Major 15 districts that applied for and were granted SIPs
Source: (Pandey, et al., 2020)

AEPC adopted a GESI inclusive criteria for selecting beneficiaries of the scheme. Overall, the AEPC selected applicants with relatively lower land size – those applying had an average land size of 3.4 ha while those granted SIPs averaged at 1.7 ha. The pattern holds for all provinces except Karnali, where the land size of farmers who got SIPs was much larger than the rest. Additionally, while land title or lease agreement is mandated by policy, a total of 478 farmers who were not able to submit land title were also granted the SIP. However, tenant farmers were not typical applicants. Women grantees made up to 22% of the total applicants[1]. However, this may not be a very robust indicator of the gender inclusivity of the program as these grantees may or may not be able to exercise ownership and management rights that men of the household may overtake.

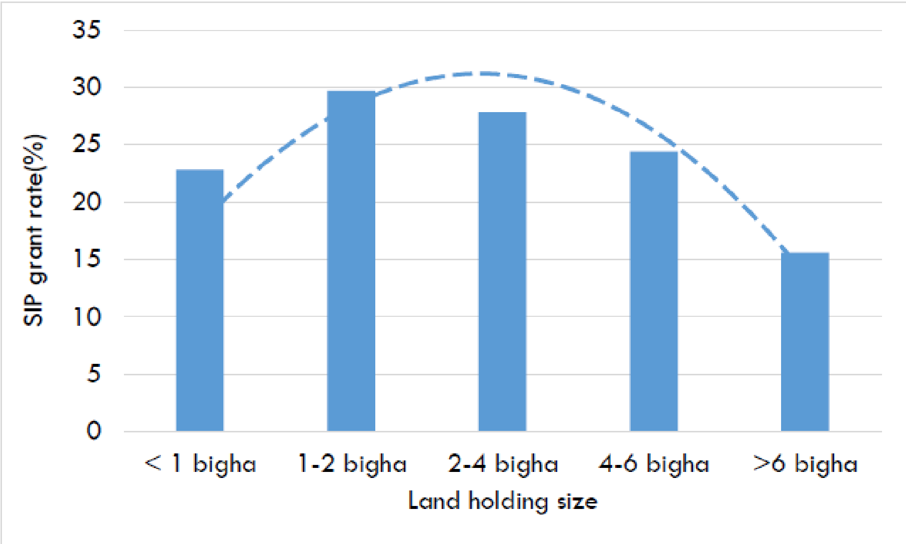

Figure 8: SIP grant rate in proportion to landholding size
Source: (Pandey, et al., 2020)

Most pumps were between the sizes of 1 horsepower (HP) and 2 HP and granted to three *Tarai* provinces – Provinces 1, 2, and 3, as shown in Table 2. The SIPs were also primarily managed individually. Groundwater (62%) was a common irrigation water source for all provinces, except Karnali, where river water was the primary source. Groundwater was the most common source in Province 1, where 77% of farmers stated they used boring or tube well as their primary irrigation water source.

Province	Pump Size (HP)						Total
Province 1	4	57	91	1	6	-	**159**
Province 2	-	322	279	68	1	1	**671**

[1] Report data was based on disaggregating the grantees' name list and so may not be fully reflective of actual data as some of the names may have been unisex.

Bagmati	-	80	1	-	43	3	**127**
Gandaki	-	11	2	-	-	1	**14**
Lumbini	-	172	15	2	57	8	**254**
Karnali	-	-	-	-	7	1	**8**
Sudurpaschim	-	11	-	-	-	1	**12**
TOTAL	**4**	**653**	**388**	**71**	**114**	**15**	**1245**

Table 2:SIP distribution according to pump size
Source: Pandey, et al., 2020

Note: Pump sizes are unknown for 149 SIPs

In terms of price, the average cost of SIP was high for all pump sizes across all the country's provinces. The average cost of a SIP was calculated at NRs. 659, 482 (5,450 USD)[2]. With a 40% contribution by the farmer, this would come up to an average of NRs. 263, 793 (2,180 USD) for an SIP. The cost of the SIP proportionally increases with the pump size; - a one HP SIP cost NRs. 3,93,000 (US$3,248) and a two HP SIP cost NRs. 4,80,900 (3,975 USD). These prices are higher than market prices in India, and even with a 60% subsidy, most farmers cannot afford the upfront costs.

2.5 Subsidy delivery mechanism

As shown in Figure 9, the process for subsidy allocation first begins with AEPC determining a selection criterion for eligibility and then announcing the call through national newspapers, radio, television, and other sources. The requirements usually remain flexible and may vary with every call. Farmers then apply for the call, usually with the support of private vendors who help with form-filling, application submission, and following up with AEPC. These are typically agents who reach out to the farmer with the required information.

The evaluation committee evaluates received applications in AEPC made up of representatives from procurement, technology, planning, and finance departments. In practice, the selection lists are usually not published quarterly though stated by the policy mechanism (as either quarterly or need-based) and often experiences delays. The MRP is then determined by the AEPC based on a review of local and international markets, prices in the previous year, the price quoted in the tender document, and the price suggested by the Association of Private Companies.

Successful applicants are informed of their selection by AEPC. Then, a feasibility study needs to be conducted, and a report submitted to the Solar Energy Technical Committee of AEPC would authorise approval. Based on the Public Procurement Act 2007, the feasibility is undertaken only for systems costing higher than NRs. 500,000.

Not all those listed in the first instance will receive installations – for example, in 2019, demand was over 5000, and 1574 applicants were granted SIPs, but only 862 pumps were installed (Pandey, et

[2] Exchange rate 1 USD = 121 NRs

al., 2020). This could be because of an information mismatch between the form and the actual field condition and the farmer not having a water source ready (ibid).

Upon post-approval, installations are carried out by verified private vendors and an installation report is submitted to AEPC. The farmers pay the remaining capital cost (which is not covered by the subsidy) to the company). AEPC verifies the installation within thirty days of installation, after which 90% of the subsidy is released to the private company. 10% is retained and released after the SIP functions for two years. The whole process usually takes about 7 to 8 months.

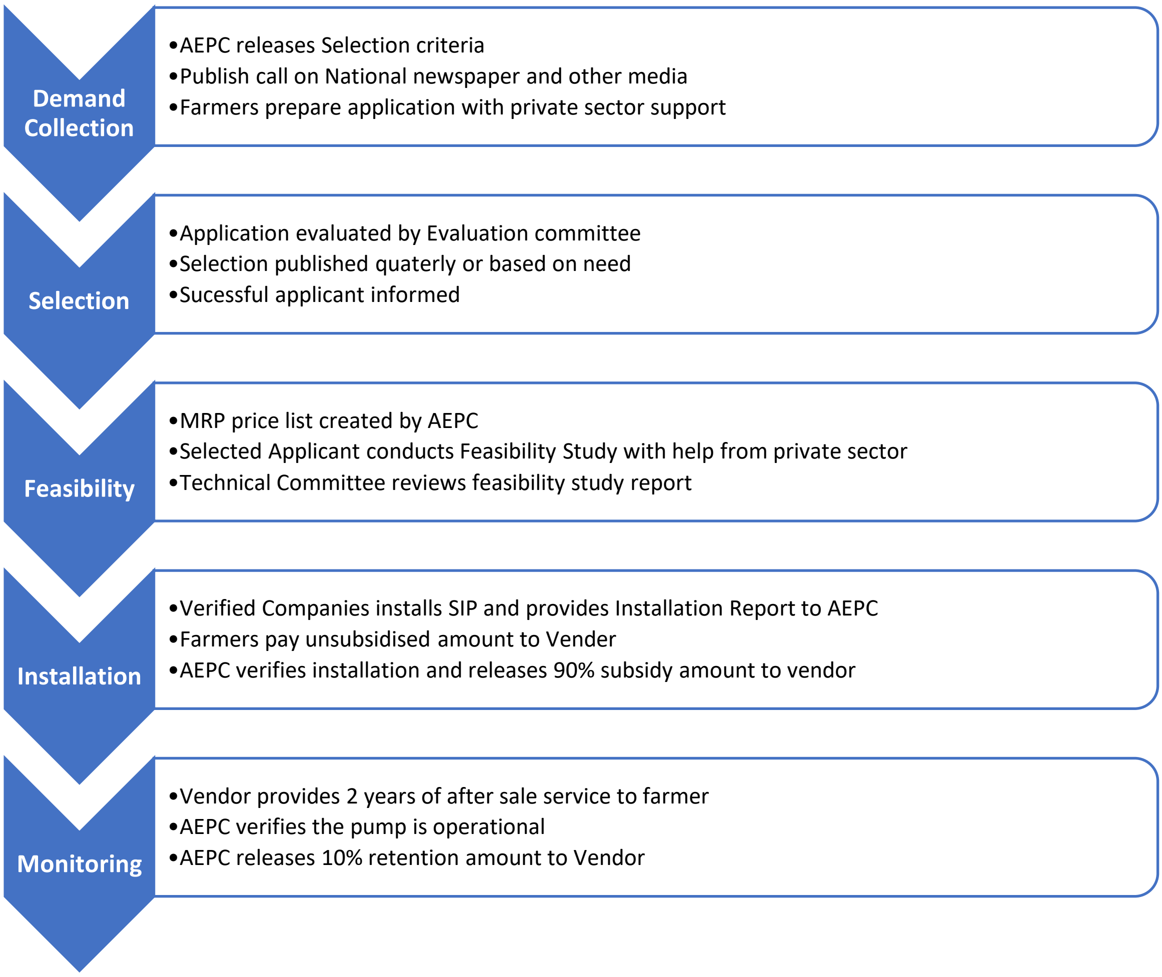

Figure 9: Process flow of AEPC's subsidy delivery mechanism

2.6 Limitations of the subsidy delivery mechanism

Despite critical advances made by the SIP subsidy delivery mechanism, especially regarding technology awareness, the approach is not without limitations. (Pandey, et al., 2020) identified a number of these challenges as listed below:

1. Monitoring the program is relatively weak; even though the policy stipulates monitoring every trimester, this is not well-practised, possibly due to financial and human resource constraints.
2. The percentage of subsidy and how MRP is set needs to be revisited based on changing market conditions and field-level findings. For example, it is also the case that the MRP of SIPs set by AEPC is often over-estimated substantially, meaning that there may have been many cases where farmers did not pay any upfront amount at all. This practice then eventually benefits relatively larger farmers who ultimately participate in the program.
3. Most of the SIPs reach relatively larger farmers than poor smallholders in spite of best attempts by the AEPC. Part of the reason is eligibility criteria. Land lease certification criteria also disallow many landless and those with land, but without land, titles to participate in the program. Even though this criterion may not always be met, subsidies are still granted (Pandey, et al., 2020).
4. There is a lot of discretionary power to the implementer in allocating pumps. This discretionary power has been used in a GESI positive way in the initial years, program implementer's flexibility and 'benevolence' and may mean different things for different kinds of applicants over the years (Kafle et al. in preparation).
5. Lists are often published late and not in every quarter, and there are considerable delays in the actual installation.
6. In practice, the feasibility test is conducted by the same vendor, who is later the installer, inviting problems of non-transparency and a potential conflict of interest.

2.7 Business models for SIP

Various business models have been piloted with SIPs in Nepal through private sectors, INGOs, DPs, and GoN. The majority of the business models are based on individual ownership schemes, but the ownership varies by the type of project, financial models, land size, financial capacity of farmers, etc. Targeted schemes for marginalised and landless farmers are not widespread, and only ICIMOD implemented projects with an additional 10% subsidy for women farmers and made it mandatory for the land to be transferred in the name of women farmers for them to avail of the 10% additional discount (Mukherji, et al., 2017).

Grant model

In the Grant model, a certain percentage of the project cost is made available as a grant or subsidy, usually by the government or project sponsor. The farmer or the user group pays the remaining amount upfront. The Grant model can also be very effectively used for the promotion of SIP during the initial stages. From the government and donor's perspective, the transactional cost is low, and there is a potential for immediate impact upon deployment (IRENA, 2016). But this model may not be sustainable in the long run as it required considerable funds to provide grants and requires government and donor involvement.

Under the renewable energy subsidy policy 2016, AEPC also provides a 60% grant to farmers based on the pre-described MRP price of the SIPs, while the farmers need to bear the remaining 40% cost of SIPs and pay that cost upfront. ICIMOD SIP project under the Grant model received around 20% of applications during the demand generation phase (Mukherji, et al., 2017). This project provided a 60% grant to male farmers and a 70% grant to female farmers, while the male and female farmers had to bear 40% and 30% of the project cost, respectively. Additional grants for women and marginalised farmers significantly impact on lessening structural inequities in land ownership (Mukherji, et al., 2017). In ICIMOD projects, the land ownership was transferred to women farmers for them to access additional 10% subsidies. For the AC-PVWP project, Winrock International implemented around 29% of the project that was funded under this model, where the SIP was purchased with cost-share (Foster et al. 2017).

Grant-loan

In the grant-loan business model, a certain percentage of the project cost is made available as a grant, while the remaining project cost is paid through a combination of loan and equity by the farmer. The main advantage of this business model is that the project design can be tailored according to the economic condition of the targeted farmers and incentivise the farmers for the continued operation of SIPs until the loan is paid off (IRENA, 2016). However, suppose the farmers receive the SIPs without any equity investment upfront; in that case, the long-term operation of the SIP may be affected due to a lack of ownership from the farmer, and the loan amount might be at risk.

In ICIMOD SIP projects in Saptari, this financial model was the most popular amongst farmers and had 46% demand compared to Grant-model and Rental-model (Mukherji, et al., 2017). ICIMOD's version of the Grant-Loan business model, male farmers, received a 60% grant, and the remaining payment was made through 20% equity from farmers and 20% loan with a monthly instalment of NPR 2,300 per month for three years. At the same time, the female farmers under the same model had to pay NPR 1,750 per month for three years (70% Grant, 15% Equity, and 15% loan). Guaranteeing access to finance, especially for the marginalised and women farmers, is vital for this business model. Therefore, the financial institutes need to be incentivised to provide loans to farmers at an affordable rate.

Under a similar model in the AC-PVWP project, Winrock International implemented 23% of the project (Foster et al., 2017). In one of the cases, 1.4kW SIP was installed, and a local farmer co-operative provided a loan for 60% of the cost of SIP at an annual interest rate of 18%. In addition to this loan, the farmer group also received financial support from the USAID Kissan project, local municipality, and Winrock International (Kunen, et al., 2015). For the projects implemented by SunFarmer under this model, 60% of the project cost was provided as a grant, and 20% of the project cost is provided as a loan at an interest rate of 5% by SunFarmer for the repayment period of 3 years (SunFarmer, 2015). The remaining 20% of the project cost needs to be paid upfront by the farmers.

This business model also promotes financial inclusion for marginalised and landless farmers who do not have any collateral. In many cases, the SIP itself can act as collateral for the loan, and the system ownership is transferred to the farmer after the loan term is over successfully.

Rent to own model

This business model is also known as the Pay as You Go Model (PAYGO), where the farmer does not need to pay any upfront payment and can rent the SIP as per their needs on a fixed monthly or seasonal payment for a certain number of years. After successful completion of the renting period initially agreed, the farmer eventually owns the system.

In the AC-PVWP project, 48% of the SIP project was implemented under this business model, and it was the most popular business model (Foster et al. 2017). In ICIMOD, SIP projects also received high demand of 34% for this business (Mukherji, et al., 2017). In the ICIMOD SIP project, the initial grant amount went out to the SIP service provider, who then invested the remaining amount in the SIP systems. These systems were then rented to the farmers in which the male and female farmers needed to pay NPR 4,600 and NPR 3,500 monthly rental charges respectively for three years to own the system eventually.

Nepal has several instances where private SIP service providers partner with donors and financial institutes to implement SIP projects in the rental business model. For example, SunFarmer Nepal, a SIP service provider, adopted this business model to partner with local agriculture focus cooperatives to provide affordable financing for a three-year term (SunFarmer, 2015). The farmers needed to pay monthly rent, which was collected by the cooperative on behalf of the SIP service provider. SunFarmer’s model aimed to create opportunities to make SIPs available to Nepali farmers through innovation in technology, financial model, and long-term after-sale service commitment for the project's sustainability (Kunen, et al., 2015).

Water Entrepreneurship model

In the Water Entrepreneurship model, the water entrepreneurs acquire the SIP through various subsidies and financing and set up irrigation businesses near the farms to sell water to the farmers. One of the advantages of this system is that the farmer does not have to pay the upfront cost of SIP and need not worry about the technical aspect of SIP operation. The farmers only need to pay for the irrigation water, which is metered by the SIP entrepreneurs and who can access the water when their crop needs irrigation. The water entrepreneurs distribute water to multiple farms, thereby increasing the utilisation factor of the pump and reducing the per-unit cost of irrigated water. There is also an option to connect the SIP to the grid for a net-metered system to export excess energy back to the grid, which will provide additional sources of income to the water entrepreneurs.

This model is very popular in neighbouring countries like Bangladesh, which is yet to be adopted widely across Nepal. Given Nepal's smaller average landholding size, this model can be utilised to make irrigation water through SIP more affordable. One of the pilot projects implemented by ICIMOD in Saptari was managed by a water entrepreneur who operated the SIP and sold the irrigation water to the farmers (Thapa, et al., 2019). However, the challenge for this business model is that the SIP is usually fixed, limiting the number of plots where the irrigation water can be sold. Also, there can be issues with the farmer community on water distribution, which may require a strong social mobilisation team.

2.8 How SIP compares with other technologies in Nepal?

Diesel pumps are very popular with Nepalese farmers, especially in the Tarai regions, due to their established supply chain networks and lower upfront costs. There are around 120,000 shallow tube wells in Nepal’s Tarai region, and about 90% of them use diesel pumps to irrigate water, making water-intensive crop cultivation uneconomic (CGIAR-WLE, 2014). The agriculture sector accounts for around 10.5% of diesel consumption in Nepal (WECS, 2010). In the areas where there is access to reliable grids, the grid-connected electric pumps are widely used. The electricity in agriculture is mainly used for lift irrigation (CMS, 2013), either from surface water or groundwater. From a technological point of view, SIP is a proven and mature technology suitable in Nepal’s context and is also competitive with diesel pumps due to its near-zero operational costs. Table 3 compares the three technologies concerning technical performance, ease of use, availability, affordability, demand, environmental impact, and safety.

Parameter	Electric Pump (EP)	Diesel Pump (DP)	Solar Powered Pump (SIP)
Performance	• Unreliability of the grid may hamper the performance.	• Unavailability of fuel may impact the performance.	• On non-sunny days, the pump may not be operational.

			• But water requirement is also low on such days
Ease of Use	• Need Semi-skilled technicians to install EP • One can quickly start the pump with a switch	• Need Semi-skilled technicians to install DP • Need physical strength to start the pump, less suitable for women farmers	• Need skilled technicians to install SIP • Automated Operation
Availability	• Established Supply Chain • Technicians are readily available locally	• Established Supply Chain • Technicians are easily available locally	• The supply chain hasn't matured yet • Lack of skilled technicians at the local level
Affordability	• Affordable upfront cost • Low operational cost • Low electricity tariff • The lifecycle cost of an EP is the cheapest • EP is cost-effective	• Affordable upfront cost • High Operational Cost • High fuel cost • The lifecycle cost of diesel pumps is higher than electric pumps • Cost-effective if used for a short period	• High upfront cost • Very low operational cost • No Fuel Cost • The lifecycle cost of SIP is higher than EP and DP for lower CUP in short term • Cost-effective if used for an extended period
Demand	• Due to the affordability of EP, the demand is generally high where there is access to the grid	• Demand is high due to the established supply chain at the local level and farmer's familiarity with technology	• Due to the introduction of subsidies and successful pilots, the demand for SIP has increased significantly
Environmental Impact	• Depends on source of electricity; if thermoelectric, then high carbon emissions. • Possibility of groundwater over-extraction due to low electricity tariffs	• Air and sound pollution • Emission of black carbon and GHG emission	• Possibility of groundwater over-extraction due to zero marginal costs of pumping
Safety	• A properly installed Electric pump shouldn't possess safety issues	• Usually, diesel pumps are rented and operated with makeshift wiring, which may include a safety concern	• An adequately installed SIP should not possess safety issues

Table 3:Comparison Matrix of SIP with other pumping technologies in Nepal

Although the demand for SIPs is growing due to the efforts made at the policy level, diesel and grid-connected electric pumps still dominate the market. Diesel pumps are the most unsustainable technology due to higher operating costs, insecure fuel supply, and environmental unfriendliness. In contrast, SIP and grid-connected electric pumps (provided electricity is sourced from hydropower) are categorised as the most sustainable technologies in Nepal (Dhital et al., 2014). SIPs have the potential to become the first choice pumping technology in Nepal with improved access to finance, an integrated approach, better technology, and higher awareness (Renewable World, 2018). However, different methods are needed to be adopted to improve the CUF of SIP to improve the payback period.

Renewable World conducted a case study in the Saptari district in 2018 to compare SIP, diesel pumps, and grid-connected electric pumps based on the lifecycle cost assessment of different technologies (Renewable World, 2018). The study's most commonly used solar pumping unit has 1,200Wp solar panels, a 1.5HP pump, and a 5-meter lift height (Bastakoti et al., 2019). The study shows that the per-unit water cost varied depending on the CUF of different pumping technologies. SIPs had the maximum cost variation per unit of water among the three pumping technologies as the CUF changes.

The study shows that for SIP to be cost-effective, the CUF needs to increase. At a CUF of 50%, the per-unit cost of water from SIP becomes cheaper than irrigation water from the diesel power pumps. The SIP needs to be operated at 90% CUF to become more cost-effective than the grid-connected electric pumps. A 22.4kWp SIP installed in the Nawalpur district only uses 30% of the energy for irrigation, and the remaining energy is not used (Manandhar, 2021).

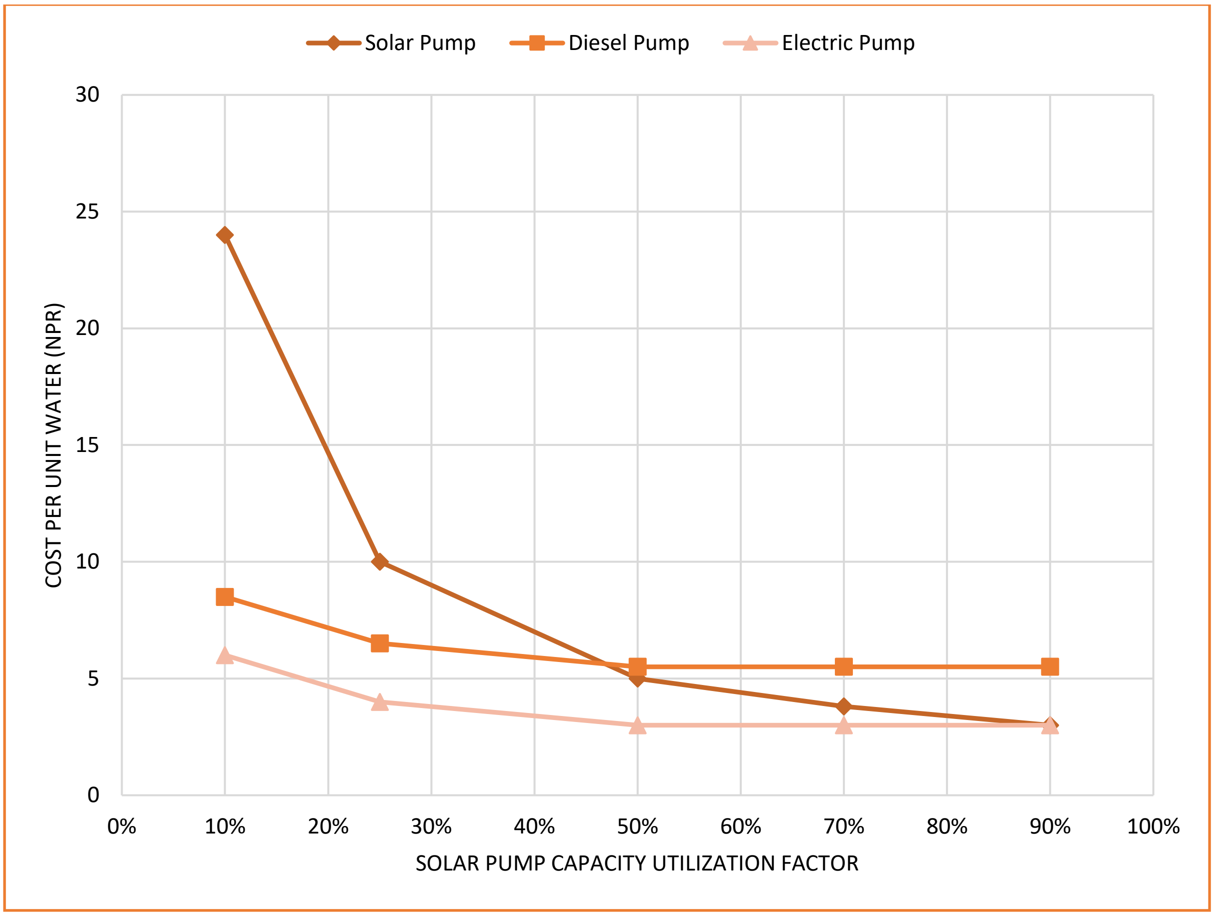

Figure 10: Cost per unit water in different pumping technologies in Nepal
Source: (Renewable World, 2018) l

Integrating SIP with a net-metered system connected to the grid will help evacuate excess energy to the grid and improve the utilisation factor. In addition, other technologies like drip irrigation systems will help to reduce the size of SIP needed, which will subsequently reduce the per-unit cost of water from SIP. Due to the available subsidies for SIP, farmers are interested in installing SIP, and there is high demand. But most of these SIPs are installed as a supplement to the existing diesel and grid-connected pumping technologies (Thapa, et al., 2019) and does not completely replace diesel or electric pumps. Installing SIPs can be more economical than grid-connected pumps if the land size is four hectares and the grid extension needed is 1km (Karki & Lohani, 2020). As the land size increases, the cost difference between SIP and grid-connected pumps through grid extension decreases (ibid).

2.9 Case Studies

A summary of typical technical and financial specifications of SIP projects in Nepal is shown in the table below. This table shows that SIPs used in Nepal are of wide variety in terms of size, type, and costs used in Nepal to meet the farmers' demand.

Size of pumps	0.5HP, 1.5HP, 2HP, 3HP, 5HP, 7HP
System size (kWp)	0.3kWp-14.18kWp
Major Pump Companies	Kirloskar, Pedrollo, Lorentz, Grundfos, Taifu, Rotosol, etc.
Head	36m to 96m
Type of Pump used	**Submersible Pumps:** Generally used for solar water lift projects **Surface Pumps:** Generally used in Tarai districts where the head is low.
Use of SIP	Aquaculture, Wheat, Paddy, Summer Paddy & Wheat, Mango, Vegetables, livestock farming, drinking water, and hygiene.
Price of SIP system without subsidy	
ICIMOD (Saptari)	NPR 3,80,000*
ICIMOD Rautahat., Bara, Sarlahi Systems	NPR 2,85,000*
iDE	NPR 10,17,215 – 70,61,662
LiBird	NPR 10,16,050
Winrock	NPR 40,000 or above
AEPC (Morang)	NPR 250,000

Table 4:Summary of technical and financial specification of SIPs in Nepal

** Including fencing, three-year warranty, and O&M service*

This section will look at two early SIP projects in Nepal as a case study to understand the opportunities and challenges of SIPs in the country. This case study will also explore the business models used, productive uses of SIPs, and the policy level impact of these projects.

2.9.1 ICIMOD SPIP Project

ICIMOD, in partnership with Sun Farmer Nepal (a solar energy company), installed 53 SIPs, including three demo installations. CGIAR's research program funded the project under the Water, Land, and Ecosystems, i.e., WLE's Ganges Regional Program and implemented in Saptarai, Sarlahi, Rautahat, and Bara district in Province 2 of Nepal. Sabal Nepal was the local NGO partner in the Saptari district, while EPC Nepal was the local NGO partner in Bara, Rautahat, and Sarlahi districts.

The project proposed to research the following (ICIMOD, n.d.):

1. Understanding the demand for SPIPs under different financial packages for men and women, primarily when additional financial incentives are provided to women farmers.
2. Understanding the impact of SPIPs on agricultural outcomes for SPIP owners.

For the pilot projects, the Saptari district was chosen due to the following reasons (Paul-Bossuet, 2017):

- The district ranked second among the Tarai districts for vegetable production but is one of the worst for productivity.
- Women's land ownership is particularly low.
- The district had the highest male migration rate among the Tarai districts.
- The electricity access was very low, and only 42 per cent of households use electricity.

ICIMOD used 1HP and 2HP pumps with respective 1.2kWP and 2.4kWp Solar and implemented three SIP pilots. They used two modalities: (i) Community managed and (ii) Water entrepreneur managed, as shown in table 5 (Bastakoti et al. 2019).

Pilot 1	**Pilot 2**	**Pilot 3**
Managed by: Community Pump Size: 1HP Panel Size: 1.2kWp Location: Haripur Village System Cost: US$3,800	**Managed by:** Women farmers Association **Pump Size:** 1HP **Panel Size:** 1.2kWp **Location:** Raipur Village **System Cost:** US$3,800	**Managed by:** Water Seller **Pump Size:** 2HP **Panel Size:** 2.4kWp **Location:** Hardiya village

Table 5:Detail of the Pilot Projects

Source: Bastakoti, Raut, & Thapa, 2019)

Between August 2015 to July 2016, positive impacts from these pilot projects were observed as the crop area increased by 28-30% (Paul-Bossuet, 2017). As a result, the use of diesel pumps was reduced to 206 hours from 792 hours, and the savings from diesel amounted to more than US$ 1,000 (Mukherji, et al., 2017). During the demand generation phase of the project, ICIMOD found that demand generation through demonstration was more effective for SIP. The farmer preferred individual ownership over group ownership and grant alone was not sufficient for the widespread adoption of SIP. Most of the farmers who applied for the installation for SIP already had access to diesel and electrical pumps.

ICIMOD installed additional 50 systems in two phases. In the first phase, twenty systems were installed in the Saptari district; wherein there were submersible pumps with a water output of 70,000 litres/day. Additional 30 systems were installed in phase 2 in Bara, Rautahat, and Sarlahi. These 30 pumps were surface pumps with a water output of 100,000 litres/day. Three financial models were used for the installations of 50 new systems: (i) Grant model, (ii) Grant-loan model, and (iii) Grant Pay as you go, model, as shown in Table 6 below.

Business model	Male Farmers	Female Farmers
Grant Model	60% - Grant 40% - Farmer**	70% - Grant 30% - Farmer**
Grant-loan	60% - Grant 20% - Loan* 20% - Farmer**	70% - Grant 15% - Loan* 15% - Farmer**
Grant-pay as you go***	60% - Grant Monthly rent for a 3-year tenure	70% - Grant Monthly rent for a 3-year tenure

Table 6:Business Model for ICIMOD SPIP project

Source: Mukherji, et al., 2017

** Paid over three years at an interest rate of 5% per annum*
*** Upfront Cost*
**** Farmer owns the system after having paid the rent for three years*

ICIMOD received 65 applications through promotion campaigns, and 77% of the applicants were women due to an additional 10% grant that was offered to women farmers. During the demand collection, 20% of demand was for the grant model, 46% for the grant-loan model, and 34% for the grant-pay-as-you-go model (Mukherji, et al., 2017). In addition, the ICIMOD SPIP project demand generation activities showed potential for the rental models in Nepal where the farmers can rent out the SIPs when they require water for irrigation and pay the monthly or seasonal rent.

2.9.2 Winrock and USAID AC-PVWP Project

The Accelerated Commercialization Solar Photovoltaic Water Pumping (AC-PVWP) Project was funded by USAID and was implemented by Winrock International from 2015-2017. This project was also designed to support KISAN managed by Winrock International and funded by USAID (Winrock, 2013). Other significant stakeholders for this project were the private sector and financial institutions. The private sectors were involved in system design, installation, and O&M. The financial institutes like banks, microfinance, and cooperatives were involved in improving access to finance for the farmers to purchase SIPs.

The project's main objectives were to accelerate the commercialisation and adoption of solar water pumping for Nepal's irrigation, livestock, and community water supply. This project intended to make quality solar water pumping technology available for the farmers in Nepal by building the market for SIPs through the private sector and piloted three innovative financial models. Three financial models were used in the AC-PVWP project, which is Rent-to-own (48%), credit financing

(23%), Direct purchase with cost-share (29%) (Foster et al. 2017). The AC-PVWP project is summarised in table 6.

The project installed 189 Solar water pumping systems across 16 districts of Nepal. In addition, there were 26 systems installed in the Chitwan district.

Project Objective	**To expand the commercialisation and adoption of PVWP**
Project Duration	3 Years (2015-2017)
Business Models	Credit Financing, Rent to Own, Water Entrepreneurship, Vendor Financing
Stakeholders	The private sector, Banks, Financial Institutions
Phase 1 (2016)	69
Phase 2 (2017)	120
Beneficiaries	392 farmer groups
Districts	Jhapa, Morang, Siraha, Rautahat, Makwanpur, Chitwan, Kathmandu, Kapilvastu, Syangja, Dang, Banke, Surkhet, Dailekh, Bardiya, Kailali and Kanachapurt.
CASE STUDY 1	
Community: Sitaram Krishi Samuha Members: 16 Location: Taule Village, Surkhet district Project Model: Cost Sharing System Cost: USD 4,766 End-Use: Vegetable Farming	**Community based 1.2 kWp System** Nine units of 140Wp modules Pump: 1.26kW Grundfos pump Dynamic Head: 60m Water Output: 10,000 liters/day
CASE STUDY 2	
Farmer: Ms Bhundi Chaudhary Location: Maijui Village, Chitwan district Project Model: Rent to Own System Cost: USD 3,350	**Single owner 750Wp system** Three units of 150Wp modules Pump: 600W Solartech Submersible Dynamic Head: 4.2m

End-Use: Fish Farming and Irrigation	Water Output: 20,000ltrs/day
CASE STUDY 3	
Community: Jagaran Krishak Samuha Members: 16 Location: Odalta Village, in Surkhet district System Cost: USD 5,170 End-Use: Rice irrigation	**Community-based 2.34kWp** Nine units of 260Wp-modules Pump: 2HP Pedrollo Surface

Table 7: Summary of AC-PVWP
Source: Foster et al., 2017

This project showed that through synergy between the government, private sector, DPs, and financial institutions, SIP could be used effectively for the productive end-use such as irrigation, livestock, drinking water, fish farming, etc. This pilot project was an important milestone that showcased that SIP is adaptive which can be used to irrigate water in the Tarai region and lift water in the hilly areas of Nepal. The easy access to irrigation water encourages smallholder farmers to shift from subsistence farming to commercial farming to high-value crops (Foster et al., 2017). One of the significant achievements of these projects at the policy level was the inclusion of a solar water pumping system for irrigation in Subsidy Policy 2073.

3.Groundwater Situation in Nepal

Currently, only 39% of cultivated land in Nepal has year-round irrigation (GoN, 2019). Out of the 48% of net cultivated land with some irrigation system,9% is dependent on surface water, 22% is dependent on groundwater, and 19% is derived from conjunctive use (GoN, 2019). Almost 67 per cent of agriculture depends on rain-fed cultivation; therefore, weather conditions play a crucial role in determining agricultural outputs (Shrestha N., 2014). Despite substantial reserves in groundwater, the contribution of groundwater to total irrigation is only 26% in Nepal (Pandey., et al., 2021). In these circumstances, the goal of reaching towards massive year-round-irrigation increments as envisioned by the IMP 2019 (from current 39% to 55% by 2025 and further to 66% by 2030 and a 100% by 2045) may be challenging to achieve if only focusing on surface irrigation schemes (Pandey et al., 2021).

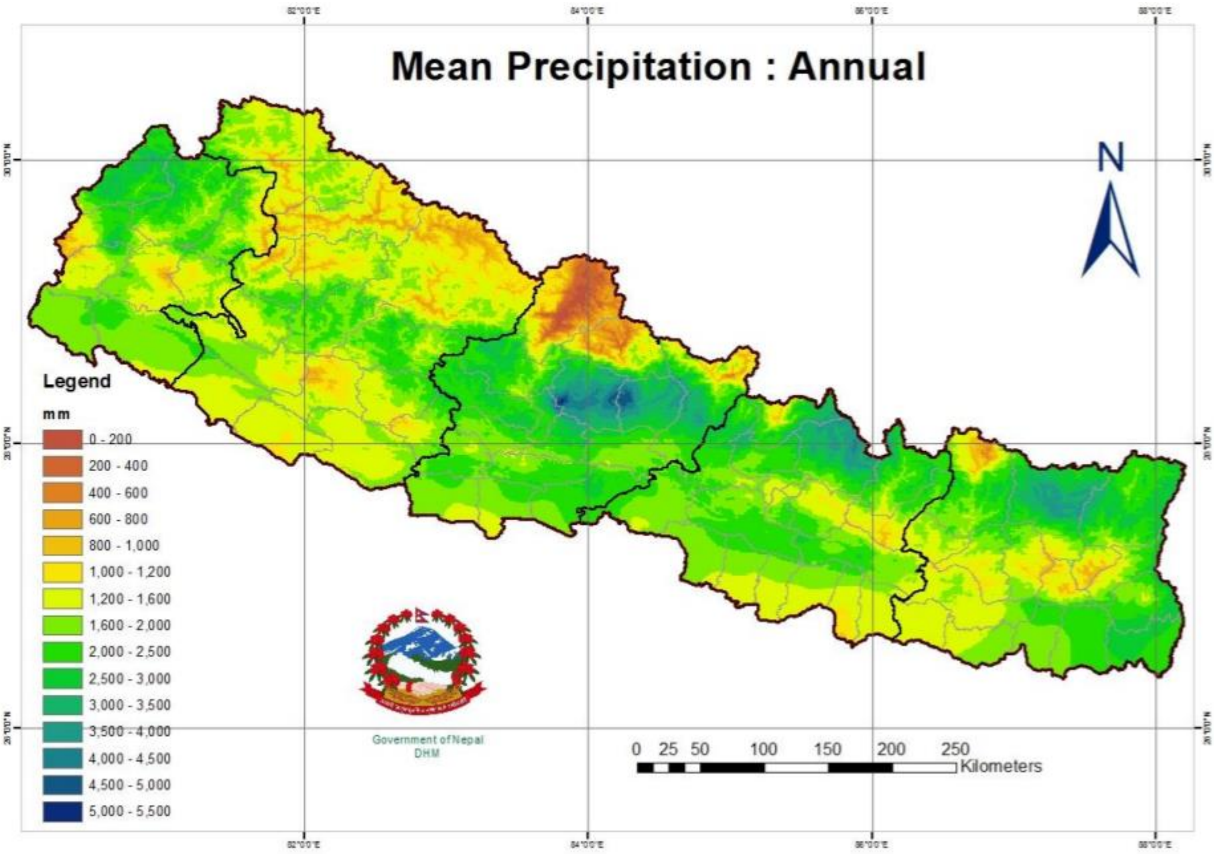

Figure 11: Mean Annual Precipitation variation across Nepal

Source: GoN, 2015

Nepal is seeing a declining investment in large canal infrastructure while diesel-powered shallow tube wells are growing in number (Urfels et al. 2020). Smallholders are often, however, dissuaded from these investments due to season cash liquidity constraints, high costs of pumping (fuel, electricity) (ibid), and the fact that tenant farmers often do not wish to invest in tube wells and pump equipment when their land tenancy rights rely on oral contracts that are not well protected (Sugden, 2014).

Groundwater in the Tarai region is dependent on direct rainfall and recharge from the Bhabar Zone (northern edge of the Tarai) along the Siwalik foothills (Shrestha et al., 2018 in Pandey et al., 2021). Nepal generally follows the monsoon pattern reflective of regional rainfall patterns; rivers are subject to high flow from July to September and start to recede from October to November and reach lower levels between December and April (Bricker et al.,2014). Though increased precipitation has been predicted for the country through climatic models, rainfall often tends to be erratic, causing unpredictability in water availability (Yadav, 2018). Thereby increased conjunctive use, rather than only relying on surface water schemes alone, is imperative to reduce rain-fed agricultural dependence mainly as groundwater is much more readily available for farmers when required (ibid).

3.1 Tubewells in Tarai

Mainly two types of aquifer systems exist in the Tarai – shallow aquifers (0-46-meter depth) and deep aquifers (>46-meter depth) (Pandey et .al, 2021). More than 800,000 shallow tube wells (STW) in the Tarai – out of these, 70,000 were supported by the government, while 30,000 are private (Yadav, 2018). There are also 20,000 treadle pumps installed that draw water from shallow wells (ibid). It has been estimated that about 1,000 deep tube wells (DTW) are being used for irrigation and drinking water purposes (ibid). Most districts in the Tarai show high concentrations of iron and ammonia in shallow groundwater (Shrestha et al., 2018). The ammonia concentration could be related to excessive fertiliser use, while a higher concentration of iron suggests an anaerobic condition of aquifers (ibid).

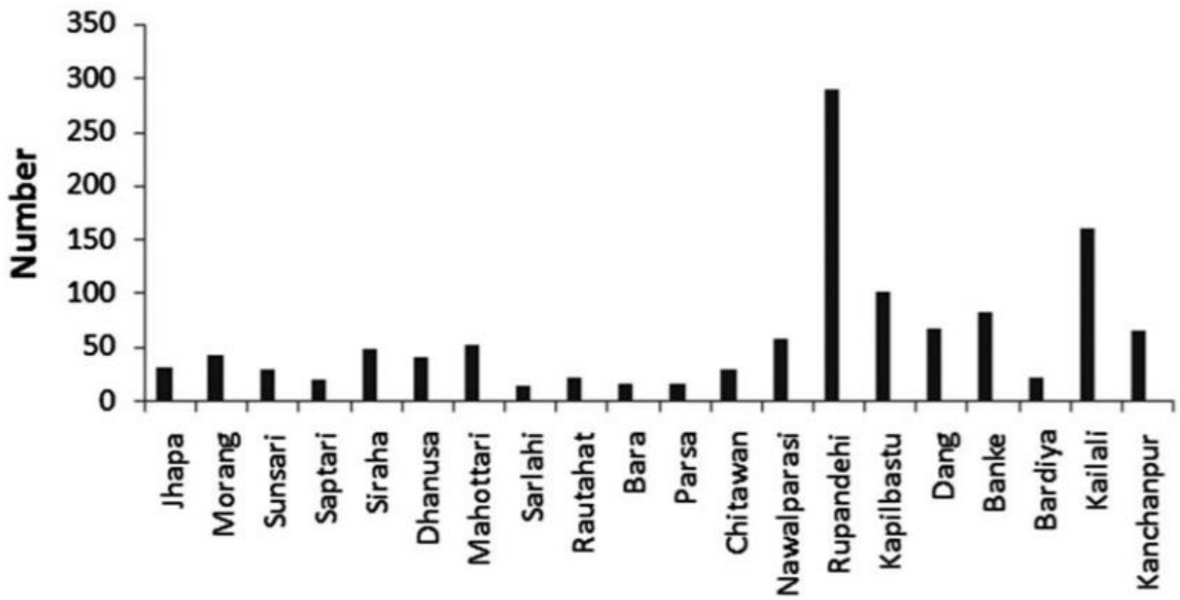

Figure 12: Distribution of deep tube wells in select districts of Tarai

Source: Pathak, 2018

3.2 Institutions- governance mechanisms and actors

Despite institutional bodies in place for groundwater oversight in the country, there is an actual lack of dedicated policy frameworks on groundwater sustainability (Yadav, 2018). However, groundwater does occupy a prominent space in irrigation and water-related policies. The National Water Policy 2020 provisions control overexploitation of groundwater while the Water Resources Bill, 2020 looks at groundwater conservation management plan, preparation and use, and the allowance for local-level data management concerning groundwater (Article 22.2). In particular, the Irrigation Master Plan 2019 shows a strong interest in groundwater management and mentions that a new Groundwater Use Act and Rules would be in the works (Article 56). The plan also cites an interest in clean energy-specific technologies for irrigation, including developing solar and electric pumping wherever feasible and investing (such as by granting subsidies) on low-cost technologies such as solar-powered tube wells (Article 296). Sustainable use and management of groundwater require several prerequisites – understanding existing aquifer systems, their hydro-geological characteristics, and the spatio-temporal distribution of groundwater (Pandey et al., 2021). This can be strengthened by concrete institutional measures that make groundwater monitoring and research a priority.

The Groundwater Resource Development Board falls under MoEWRI. It has several objectives, including identifying potential groundwater area in the Tarai region through geophysical surveys and research, exploiting shallow and deep aquifers in Tarai for irrigation and drinking water needs, developing related human resources, and regular monitoring of tube wells for better understanding groundwater reserves and water quality among others (GRDB, n.d.). It also works to carry out projects based on agreements between the government and international donors; a look at the Board's portals reveal at least 11 completed groundwater-related projects supported by a host of DPs, including the World Bank, the Asian Development Bank, the International Fund for Agriculture Development and the European Union (GRDB, n.d.).

4. GESI in Solar Irrigation in Nepal

SIPs are seen as an essential female-friendly RET because of their design; operation is relatively simple and does not need to be hauled everywhere like diesel pumps. This also means reduced work field hours. However, the subsidy mechanisms have not been able to successfully penetrate poor and marginalized households due to barriers of social capital (such as barriers of access to information) and economic capital (inability to put up up-front cost, lack of access to banks) (Pandey et al., 2020).

Private actors such as SIP service providers also see GESI as a governance issue and not a business issue. They claim to take a gender-blind approach, which could be said for most banking institutions surveyed for the rapid assessment who did not have any inclusivity criteria for lending. As a result, women and disadvantaged groups (DAGs) often lack networks to lending institutions, and with limited prior earnings, they are often left behind when accessing SIPs.

Women often own smaller farms than men, which could certainly be supplemented with SIPs to increase yield and productivity. It is imperative for its success to provide additional targeted subsidy mechanisms for pumps for irrigation and deploying local governments and other local agencies to ascertain that these subsidies reach the poorest. Disseminating information in local languages using radio stations (which is expressed in the policy but lacking in practice) could help information reach wider audiences. Soft loans for women and DAGs for RETs such as SIPs and making the mechanism easier to access and understand by tying up with local micro-finance institutions could enable better returns. Training and hiring many female technicians, especially deployed to work in areas where women find it hard to talk to men outside of the family, would strengthen communication between the project and beneficiaries, resulting in increased productivity for women farmers.

No country in South Asia has so far experimented with gendered financial models, the only exception being ICIMOD's pilot in Tarai (Mukherji et al., 2017). Still, there is a scope to do so, particularly in Nepal, where male-out-migration is very high (Mukherji, et al., 2017). This could be an area for future evidence-based research.

The Agriculture Development Strategy 2015-35 also recognizes the necessity for making agricultural extension service GESI responsive across the country and improving agricultural and non-agricultural input (irrigation, credit) access a reality for all those in all socio-economic classes and genders. The SIP subsidy granting policies – the Renewable Energy Subsidy Policy 2016 and the Renewable Energy Subsidy Delivery Mechanism 2016 – also briefly identify the need to increase women's productive hours and generally improve rural livelihoods but awards no additional benefits or subsidies for solar pumps for irrigation meant for the target groups. Additionally, the requirement for land ownership title also effectively limits participation. Farmers' Consumer Committees also require land ownership proof to partake in communal irrigation schemes, and these committees also have no GESI-related criteria in the formulation.

AEPC GESI policy 2018 is a comprehensive GESI policy exercise in the renewable energy sector. Its broad framework would shape its GESI response to all its projects, including those related to solar energy. The policy's vision is to increase energy access, opportunity, and benefits to men and women affected by a host of socio-economic factors that could otherwise hinder this process. It aims to use RETs to successfully reduce dependence on traditional sources of energy, increase employment opportunities, and improve the livelihoods of rural women, the rural poor, and marginalized communities. SDC-SoLAR projects aims to look into gendered dimensions of solar irrigation as a part of its activities.

5. Conclusion

This report presents a brief analysis of the current status of SIPs in Nepal with the historical evolution of the SIP ecosystem, along with the guiding policies and frameworks and mentions how the ongoing SDC-SoLAR project would fill up some of the knowledge gaps.

The GoN has been gradually increasing the budget allocated for subsidizing SIP, which can be seen in the 2018/19 to 2020/21 budget. But the current approval rate is meagre, and the budget allocated needs to be significantly increased to meet all the demand. The current model of flat subsidies may not be sustainable in the long run, and other viable models have to be designed.

SIPs prove to be a mature technology to replace the diesel pumps currently being used in the rural farms where the farmers do not have access to the grid. But it is observed that the CUF of SIP installed in Nepal is low, and it needs to be improved significantly to decrease the per-unit cost of irrigation water and make the technology economically viable.

As per the plans of GoN to achieve 100% electrification through the rapid expansion of the grid in the near future, there is a realistic chance of these expensive SIP equipment becoming obsolete. Once the grid reaches the rural farms, the farmers could turn to cheaper electric pumps and abandon the SIP installed in their farms. On the other hand, the demand for subsidized SIPs has soared since its inception, and the number of cumulative SIPs is expected to increase in the next few years. This will eventually impact the groundwater table.

For Nepal to achieve 100% year-round irrigation, groundwater-based irrigation needs to complement existing surface irrigation infrastructure. But we need to make sure the groundwater resources are not overexploited. Hence, the GoN needs to be vigilant to develop policies to prevent over-abstraction of the groundwater and incentivize farmers to export additional electricity from SIP to the grid (once the farms are connected to the grid).

There is a trend of male outward migration in Nepal, and female farmers have a more prominent role in agriculture. Although there has been a progression in recognizing gender in renewable energy policies over the years in the country, there seems to be low penetration of SIP amongst women and marginalized farmers. One of the main reasons could be that the female and marginalized farmers have limited land ownership or own smaller farms, which can hinder the approval of the subsidized SIPs. The current framework does not have a special provision for additional subsidies to reach the farmers who cannot afford the SIP even after the current 60% flat subsidies. There seems to be an urgent need to update the current policies and framework to make it more GESI responsive based on detailed studies through the GESI lens on RET policies and framework.

As part of the SoLAR project, IWMI plans to implement a micro-grid connected SIP pilot project in coordination with AEPC and NEA. This pilot project is expected to provide practical policy feedback and necessary evidence to confirm if connecting the existing SIPs to the grid would yield any benefits to the utility service provider and encourage farmers to feed additional power to the grid with an opportunity to earn an extra income through net-metering and prevent ground-water over-extraction. The project's research findings would provide a significant steppingstone in policy formulation that would guide the future of SIP in Nepal. The other project component includes an impact evaluation aspect where we will evaluate the impact of AEPC SIPs on farmers, and incorporate GESI aspects in future SIP programs.

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