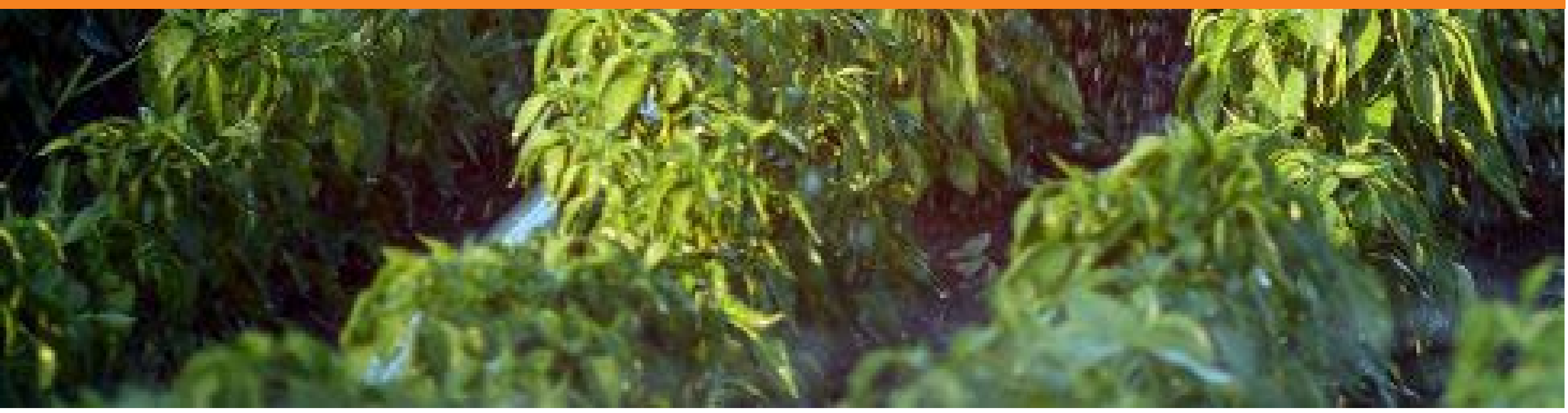
Draft Pre-Feasibility Report for Implementation of Solar pumps in Sri Lanka



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List of Abbreviations

AC	Alternating Current
ADB	Asian Development Bank
AfDB	African Development Bank
AIIB	Asian Infrastructure Investment Bank
CEB	Ceylon Electricity Board
CIE	Department of Commerce, Industry and Environment
CSCRE	Cabinet Sub Committee on Renewable Energy
DC	Direct Current
EBRD	European Bank for Reconstruction and Development
EESL	Energy Efficiency Services Limited
EIB	European Investment Bank
FAO	Food and Agriculture Organization of the United Nations
GCF	Green Climate Fund
GDP	Gross Domestic Product
GoSL	Government of Sri Lanka
GHG	Green House Gas
HP	Horsepower
IEA	International Energy Agency
IPP	Independent power producer
IRENA	International Renewable Energy Agency
ISA	International Solar Alliance
kW	Kilowatt
kWh	Kilowatt Hours
LECO	Lanka Electricity Company
LNG	Liquefied Natural Gas
LoC	Line of Credit
MW	Megawatt
NCRE	Non-Conventional Renewable Energy
NDB	New Development Bank
NFP	National Focal Points
PUCSL	Public Utilities Commission of Sri Lanka
PV	Photovoltaic
R&D	Research and Development
REA	Electricity Regulatory Authority
SPP	Small power producers
SHS	Solar Home Systems
SSAAU	Scaling Solar Applications for Agricultural Use
SSLS	Solar Street Lighting System
SWPS	Solar Water Pumping Systems
UNDP	United Nations Development Programme

UNIDO	United Nations Industrial Development Organization
USD	United States Dollar
UL	Underwriters Laboratories

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1. Executive Summary

Sri Lanka, (formerly Ceylon), is a tropical island lying close to the southeast tip of India in Indian Ocean and separated from peninsular India by the Palk Strait. Its land area is 65,610 km^2 located between latitudes 5°55′ and 9°51′ N and longitudes 79°41′ and 81°53′ E and has a maximum length of 432 km and a maximum width of 224 km. The northern part of the island consists of flat and gently rolling plains, while the south-central region varies from hilly to mountainous.

Sri Lanka Electricity Sector

The Sri Lankan economy has grown at an average growth rate of around 6.4% p.a. over the last 10 years. Electricity demand, in line with the economy's growth rate, has also grown at an average annual rate of around 6% over the past 10 to 15 years and the trend is expected to continue in the foreseeable future.

In recent years, Sri Lanka's power sector has made commendable progress in achieving stated renewable energy targets, near-universal electrification, and reducing transmission and distribution losses. The power sector in the country is currently dominated by hydro power plants, and fossil fuel-based generation from coal and liquid fuels. However, the Government of Sri Lanka (GoSL), through the envisaged renewable energy targets (100% by 2050) and projected generation planning, has been pursuing a shift toward clean generation, including both NCRE and LNG based generation.

Connectivity and Accessibility

Sri Lanka has a road network of approximately 100,000 kilometers enough for meeting 90% of the demand for transportation. Out of the total length of roads, maintenance and development of A and B class national roads and 4,480 bridges are vested with the Road Development Authority (RDA). The only international airport of Sri Lanka is called Bandaranaike International Airport (BIA) and is situated 32 km north of the capital Colombo. Sri Lanka Railways (SLR) is operated by the Sri Lankan Ministry of Transport and serves as the core link between the country's seaports and major inland cities.

Climate and Rainfall

Sri Lanka is tropical and consists of very distinctive dry and wet seasons. The average temperature of Sri Lanka usually ranges from 28 – 32 degrees Celsius which may differ due to global weather conditions as a whole. The temperature can vary from being as low as 16 degrees Celsius in Nuwara Eliya which belongs to the central highlands and to as high as 32 degrees in Batticaloa along the Eastern coast of the island.

Soil

Variations of soil within Sri Lanka reflect the effects of climate, lithology, and terrain on the soil-forming processes. Most of the soils of Sri Lanka are potentially suitable for agricultural use. However, depletion of the natural fertility of the soil has occurred extensively, especially on the rugged terrain of the highlands, owing to poor soil conservation.

Soil types vary depending on the location. Reddish Brown Earths (RBE), Red Yellow Podzolic (RYP) and Low Humic Gley (LHG) soils are the most abundant types in Sri Lanka.

Agriculture

The national gross domestic product (GDP) was $450.35 million in 2018. The per capita GDP in 2018 was 9,574. The agricultural sector contributed nearly 14% of the GDP in 2016 employed 34% of the labor force represented over 65% of total exports.

Agriculture is the main economic activity after services. Most are smallholder farmers practicing a mix of subsistence and cash crop production, they typically grow root crops, which provide food security, employment and income. The main products exported are kava, squash, pumpkins, root crops, coconuts, and fish.

Traditional cash crops include root crops as taro, yams, cassava and sweet potatoes, but also kava, breadfruit, papaya, banana, watermelon and pineapple used in an intercropping system. In more recent years the focus has shifted to export crops including pumpkin squash and vanilla. The former needs irrigation in dry months. The main practice is still subsistence agriculture, but there are several farmers looking to expand agriculture to a more commercial basis, which involves implementation of larger centralized irrigation schemes and higher groundwater abstractions during periods of drought.

Financial Feasibility Assessment

Sri Lanka has submitted demand for 2,000 Nos. solar water pumping systems. At an average price of USD 3,907 per 3 HP pumpset. Sri Lanka requires financing of USD 7.81 million to roll out deployment of 2,000 Nos. solar water pumping systems across the country.

Benefits to Key stakeholders

The estimated benefits to farmers and Government of Sri Lanka due to installation of SWPS are highlighted in the table below

S. No.	Parameter	Units	Value
1.	Average savings in monthly diesel expenses for 20 years due to solar pumpset	USD/month	60
2.	Monthly installment towards loan repayment of solar pumpset (7 years)	USD/month	49
3.	Average monthly savings to farmer during loan tenure (7 years)	USD/month	11
4.	Average monthly savings to farmer after loan tenure (13 years)	USD/month	60
5.	Payback period for solar pumping systems	Years	7
6.	Annual CO_2 emission reduction due to installation of 2000 solar water pumping systems	Tons/annum	3,129
7.	Local technicians trained due to installation of 2000 solar water pumping systems	Nos.	100
8.	Avoided annual diesel consumption for 2,000 Nos. pumpsets	Kilo liters/annum	1,167
9.	Avoided annual expenditure on diesel consumption for 2,000 Nos. pumpsets	USD/annum	1,074,034
10.	Financing requirement for deployment of 2000 solar water pumping systems	USD	7,814,000

Recommendation

Sri Lanka has submitted demand for procurement of 2,000 solar water pumps. The pumps should be adequately sized to meet the crop water requirements of the area. The meteorology of Sri Lanka is characterized as humid maritime subtropical climate with almost consistent rainfall throughout the year. Also, the ground water table depth across Sri Lanka is less than 100 meters. Hence, a smaller sized pump may be able to give enough discharge for the crop as a major portion of water requirement can be meet through rainwater. Considering these parameters, the water requirement can be sufficed by 3 HP pumps.

2. Background

2.1 About ISA

International Solar Alliance was launched on November 30, 2015 by India and France to implement the Paris Agreement and the ISA Framework Agreement came into force on December 7, 2017. The headquarter agreement with India was signed on June 6, 2018 when the ISA Secretariat acquired a judicial personality under the Framework Agreement. ISA held its first Assembly on October 3, 2018 and the second one is being held on October 31, 2019. To date, 79 countries have signed the Framework Agreement. ISA aims to provide a dedicated platform for cooperation among solar resource-rich countries where the global community, including bilateral and multilateral organizations, corporates, industry and other stakeholders can collaborate and help achieve the aim of increasing the use of solar energy in a safe, convenient, affordable, equitable and sustainable manner.

The International Solar Alliance (ISA) has been conceived as an action-oriented, member-driven, collaborative platform for increased deployment of solar energy technologies to enhance energy security and sustainable development, and to improve access to energy in developing member countries. In this respect, ISA has been continuously working towards coordinating joint and collaborative efforts for mobilizing more than USD 1000 billion investments in the solar sector thereby facilitating scaling up of solar deployment in various member countries.

As guided by the Framework Agreement of the ISA, the interests and objectives of the ISA are as follows:

1. To collectively address key common challenges to scale up solar energy applications in line with their needs;
2. To mobilize investments of more than USD 1000 billion by 2030;
3. To take coordinated action through programmes and activities launched on a voluntary basis, aimed at better harmonization, aggregation of demand, risk and resources, for promoting solar finance, solar technologies, innovation, R&D, capacity building etc.;
4. Reduce the cost of finance to increase investments in solar energy in member countries by promoting innovative financial mechanisms and mobilizing finance from Institutions;
5. Scale up applications of solar technologies in member countries, and
6. Facilitate collaborative research and development (R&D) activities in solar energy technologies among member countries.

To expand its reach, the ISA has entered into strategic and financial partnerships with the UNDP, the World Bank, the European Investment Bank (EIB), the European Bank for Reconstruction and Development (EBRD), the African Development Bank (AFDB), the Asian Development Bank (ADB), the Asian Infrastructure Investment Bank (AIIB), New Development Bank (NDB), and the Green Climate Fund (GCF), IEA, IRENA, Climate Parliament and UNIDO on enhancing cooperation on solar energy deployment to further the mandate of the ISA. The United Nations including its organs are strategic partners of the ISA.

On the request of the ISA, the Government of India has earmarked around US $ 2 billion Line of Credit (LoC) to the African countries for implementation of solar and solar related projects out of its total US $ 10 billion LoC under the Indian Development and Economic Assistance Scheme (IDEAS) to various African and other developing countries. India has set up a project preparation facility which will provide consultancy support to partner countries to design bankable projects.

Following these commitments, India has provided $ 1.4 billion concessional financing to 27 solar projects in 15 developing countries so far. As a co-founding member of the ISA, Government of France through the Agence Française de Développement, has also offered €1000 million for solar projects across ISA member countries. 17 projects have been funded by AFD for approximately Euro 300 million. ISA will similarly persuade other countries to contribute to the cause of solar deployment globally.

ISA is currently working towards coordinating a joint and collaborative effort amongst member countries so that strategies suited to the requirements of individual countries can be formed, and feasible solar technologies can be deployed. ISA is acting as a facilitator to contribute to the solar deployment efforts of individual member country. For this, ISA has formed a framework of programs and initiatives to develop a dedicated approach towards scaling up of various solar technologies. All the Programmes of ISA are member driven. The current programmes of ISA are:

1. Affordable finance at scale
2. Scaling Solar Applications for Agricultural Use (SSAAU)
3. Scaling Solar Mini-Grids
4. Scaling Solar Rooftop
5. Scaling solar supported e-mobility and storage
6. Programme for Solar Park

2.2 About SSAAU Programme

ISA's first programme, Scaling Solar Applications for Agricultural Use (SSAAU), was launched in New York, USA on 22nd April 2016. The SSAAU Programme mainly focusses on decentralized solar applications in rural settings. Major focus areas of the programme include Solar Water Pumping Systems (SWPS), solar drying, solar chilling, solar milling, etc. Other activities under the programme include R&D, capacity building, and developing common standards, facilitate transfer of technology etc.

More than twenty-one countries namely Bangladesh, Benin, Djibouti, Ethiopia, France, Guinea-Bissau, India, Kiribati, Mali, Mauritius, Niger, Nigeria, Rwanda, Senegal, Seychelles, Somalia, Sudan, Togo, Tonga, Uganda, Vanuatu have been frequently interacting regarding the programme strategy and implementation through the network of NFPs and country representatives via video conferencing. To understand specific requirements of these countries, needs assessment questionnaires have been developed for Solar Water Pumping System (SWPS) and Solar Street Lighting System (SSLS). These questionnaires have been circulated to all participating and signatory countries of the ISA as a first step towards demand aggregation.

The key activities under the SSAAU programme are as under:

S No.	Category	Key Activities
1	Demand Aggregation	▪ Obtaining data for demand aggregation models from various member countries ▪ Bid process management, fixation of price, identification of manufacturer(s)/ supplier(s) for each of the participating member countries
2	Country Strategy	▪ Developing baseline studies and roadmaps for member nations ▪ Constituting global task force for the programme ▪ Facilitating affordable financing for implementation of solar water pumping programme in participating member countries
3	Facilitating Deployment	▪ Facilitating in setting Standards, Performance Benchmarks, Testing and Certification Protocols through identified test centers ▪ Development of base document for global tendering and best practices for procurement, installation and maintenance ▪ Monitoring and Evaluation
4	Outreach Strategy	▪ Development of media outreach strategy for the programme ▪ Organization of workshops and seminars for promotion of SSAAU programme

Table 1: Key Activities under SSAAU Programme

As a part of the demand aggregation exercise, ISA has aggregated a demand of 272,579 Nos. of off-grid solar pumps to be implemented across 22 countries spanning 4 different continents. The key objective of the demand aggregation exercise was to bring down the costs of the system so as to enable implementation of viable and bankable solar pumps projects in various ISA countries.

The demand aggregation exercise comprised of the following sub-steps:

1. Needs Assessment: In collaboration with National Focal Points (NFPs) and Country Representatives, need assessment questionnaires for Solar Water Pumping Systems (SWPS) were circulated to participating member countries
2. Ascertaining Demand: The filled in needs assessment questionnaires were used to ascertain demand of solar water pumping systems including information on type, quantity and technical specifications in each of the participating member countries
3. Demand Validation: Coordinating with National Focal Points and Country Representatives for obtaining country specific data and information and for validation of demand
4. International Competitive Bidding for Price-Discovery: Energy Efficiency Services Limited was hired for management of International Competitive Bidding for price discovery of various types of solar water pumping systems in participating member countries

The demand aggregation of Solar Water Pumps from ISA Member Countries given in the table below:

Sl. No.	Name of the Country	Demand of SWP (Nos)
1	Benin	50,000
2	Cabo Verde	100
3	Democratic Republic of Congo	80,000
4	Djibouti	100
5	Fiji	27
6	Guyana	111
7	Mali	15,000
8	Mauritius	27
9	Nauru	400
10	Niger	15,000
11	Peru	1,750
12	Senegal	4,000
13	Somalia	500
14	South Sudan	6,800
15	**Sri Lanka**	**2,000**
16	Sudan	50,000
17	Togo	5,000
18	Tonga	258
19	Tuvalu	10,000
20	Uganda	30,000
21	Yemen	1,500
22	Zambia	6
	Total	**2,72,579**

Table 2: Demand received from various ISA member countries for solar pumps

Subsequent to the demand aggregation exercise, International Competitive Bidding was undertaken by EESL on behalf of ISA for price discovery of various types of solar pumps in the participating member countries. The price discovery tender is one of the largest tenders for solar pumping systems globally and is expected to open up huge market opportunity for implementation of solar pump programme in participating member countries. Through this tender, it is expected that local market ecosystem for solar pumps will be developed which will help in greater penetration of technology amongst the farmers. It is envisaged that in the long-run solar pumps would replace the existing diesel pumpsets in these member countries thereby leading to significant reduction in GHG emissions apart from providing a reliable irrigation solution for the farmers. The key features of the International Competitive Bidding for price discovery is summarized as below:

S. No	Category	Description
1	International Standards for Solar Pumps	▪ Internationally accepted IEC and UL standards for various solar pump components
2	Technical and Financial Qualifying Criteria	▪ Technical Qualifying Criteria: Based on experience of supply and installation of solar pump sets and solar power plants ▪ Financial Qualifying Criteria: Based on average annual turnover and net worth
3	Specifications for minimum bidding quantity	▪ Mandatory to bid for 5 countries with a total bid quantity of at least 27000
4	Two separate bid packages	▪ Only supply ▪ Supply and Five-Year Comprehensive Maintenance Contract
5	Two stage evaluation process	▪ Based on technical and commercial evaluation ▪ Award of contract to various bidders based on L1 prices

Table 3: Key features of Internal Competitive Bidding for Price Discovery of Solar Pumps

The price discovery was conducted for two broad service contracts namely:

- Service 1: Supply, Custom clearance, Local transportation, installation, testing and commissioning of complete system & services at Employer's site of Solar PV based Agricultural Pump Set system
- Service 2: Supply Custom clearance, Local transportation, installation, testing and commissioning of complete system at site of Solar PV based Agricultural Pump Set system including Comprehensive Maintenance Contract for 5 years

The roles and responsibilities of the bidder and the respective member nation as a part of the price discovery tender is summarized in the figure below:

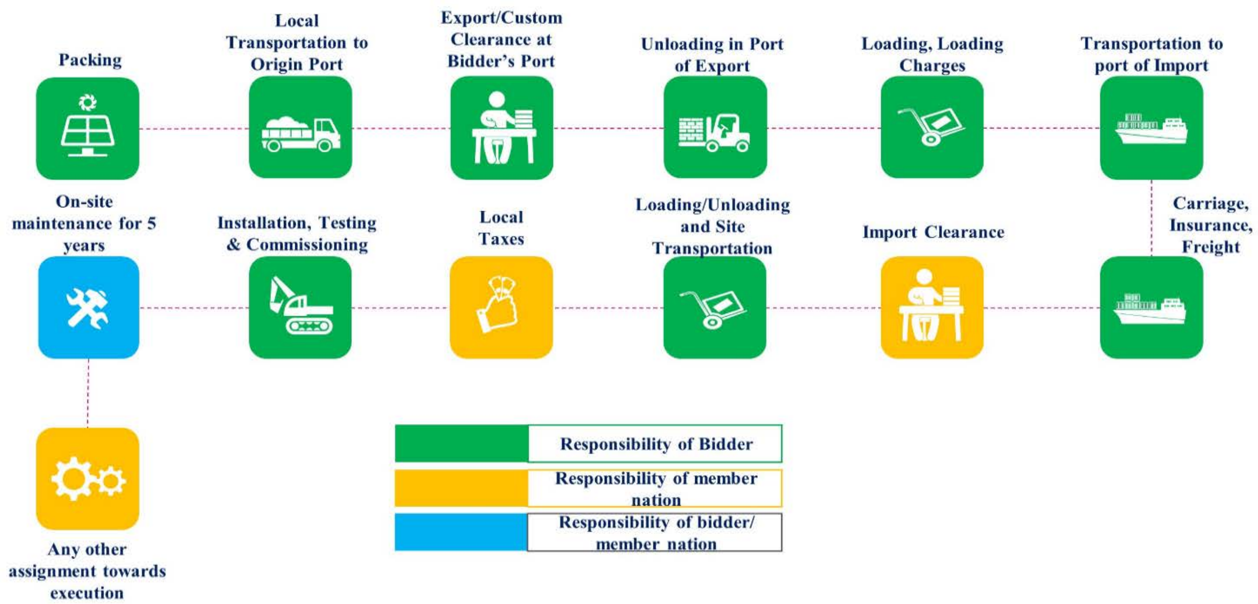

Figure 1: Work Packages and Responsibility Division

Five bidders have participated in the price discovery tender and have submitted the prices for various capacities of solar pumps in the participating member countries.

3. Introduction

3.1 About Sri Lanka

Sri Lanka, (formerly Ceylon), is a tropical island lying close to the southeast tip of India in Indian Ocean and separated from peninsular India by the Palk Strait. Its land area is 65,610 km^2 located between latitudes 5°55′ and 9°51′ N and longitudes 79°41′ and 81°53′ E and has a maximum length of 432 km. and a maximum width of 224 km. The northern part of the island consists of flat and gently rolling plains, while the south-central region varies from hilly to mountainous.

In 1948, after nearly 150 years of British rule, Sri Lanka became an independent country, and it was admitted to the United Nations seven years later in 1955. The country is a member of the Commonwealth and the South Asian Association for Regional Cooperation. Colombo, which emerged as the main urban center during British rule, remains the executive and judicial capital of Sri Lanka; Sri Jayewardenepura Kotte, a Colombo suburb, is the legislative capital. For administrative purposes, the country has been divided into nine provinces and subdivided into 25 districts.

Sri Lanka inherits a culture and a lifestyle friendly to the environment. The legislative framework for the protection of the environment was in place to a large extent in Sri Lanka even before independence. Since independence, Sri Lanka has been implementing national strategies and plans to achieve sustainable economic growth with equity and social development. These programmes for economic and human resources development enabled Sri Lanka to achieve a comparatively high quality of life at low per capita income levels. The national policy to solve the growing problems of poverty and unemployment, compounded by population pressures, was to achieve a faster growth rate through diversification of agriculture as well as developing industry.

The economy that evolved in Sri Lanka under British rule consisted of a modern sector, whose main component was plantation agriculture, and a traditional sector comprising subsistence agriculture. Manufacturing was an insignificant segment of the economy. Banking and commerce were, for the most part, ancillary to plantation agriculture. Nearly all foreign earnings were derived from the three staple plantation crops – tea, rubber, and coconut. The country depended on imports for nearly ¾ of its food requirements and almost all its manufactured goods.

Parameter	Units	Value	Year
Population	Nos.	21,670,000	2018
Country GDP	USD Billion	88.90	2018
GDP growth rate	%	3.2%	2018
Foreign Direct Investment (Net Inflows)	USD Million	1,610.54	2018
World Bank Political Stability Index	Nos.	-0.18	2018
Employment rate	%	94.9%	2019
Retail inflation rate	%	2.1%	2018
Per capita GDP	USD	4,105.5	2018
Corporate Tax rate	%	28%[1]	2017

Table 4: Key Economic Parameters of Sri Lanka[2]

[1] Sri Lanka Tax profile – KPMG
[2] World Bank – World Development Indicators

Figure 2: *Map of Sri Lanka*[3]

3.2 Overview of Energy Scenario

The Sri Lankan economy has grown at an average growth rate of around 6.4%[4] p.a. over the last 10 years. Electricity demand, in line with the economy's growth rate, has also grown at an average annual rate of around 6% over the past 10 to 15 years and the trend is expected to continue in the foreseeable future.

In recent years, Sri Lanka's power sector has made commendable progress in achieving stated renewable energy targets[5], near-universal electrification[6], and reducing transmission and distribution losses[7]. However, sustaining these achievements and keeping pace with demand from a growing economy while meeting the envisaged power sector development needs, will require large sums of new investment. They include large investments in renewables and LNG/gas-based generation.

The power sector in the country is currently dominated by hydro power plants, and fossil fuel-based generation from coal and liquid fuels. However, the Government of Sri Lanka (GoSL), through the envisaged renewable energy targets (100% by 2050) and projected generation planning, has been pursuing a shift toward clean generation, including both NCRE and LNG based generation.

Installed capacity (MW)	2016	2017	2018
Total Installed Capacity	**4,030**	**4,124**	**4,156**

[3] Nations Online – Sri Lanka
[4] Assessment of Sri Lanka's power sector 2017 - ADB
[5] 10% generation share from NCRE & mini hydro was achieved in 2015, a target set under National Energy Policy
[6] Electrification rate of 99.3% in 2016 (CEB Statistical Digest 2016)
[7] Cumulative T&D losses for Sri Lanka have dropped from 13% in 2010 to below 10% in 2016 – Grid Frequency Stability Analysis of VRE in the CEB System by Siemens PTI

	2015	2016	2017
Total Non-Renewable	**2,064**	**2,064**	**2,064**
Fossil fuels	2,064	2,064	2,064
Total Renewable	**1,966**	**2,060**	**2,092**
Bioenergy	24	45	45
Solid biofuels	24	45	45
Hydropower (excl. Pumped Storage)	1,728	1,738	1,741
Renewable hydropower	1,728	1,738	1,741
Solar energy	**83**	**131**	**160**
On-grid Solar photovoltaic	75	123	153
Off-grid Solar photovoltaic	8	8	8
Wind energy	131	146	146
Onshore wind energy	131	146	146

Energy Mix (GWh)	2015	2016	2017
Total Energy Generated	**13,108**	**14,168**	**14,728**
Total Non-Renewable	**6,718**	**9,508**	**10,186**
Fossil fuels	6,718	9,508	10,186
Total Renewable	**6,390**	**4,660**	**4,542**
Bioenergy	38	39	81
Solid biofuels	38	39	81
Hydropower (excl. Pumped Storage)	5,976	4,227	4,011
Renewable hydropower	5,976	4,227	4,011
Solar energy	**32**	**48**	**82**
On-grid Solar photovoltaic	21	37	71
Off-grid Solar photovoltaic	11	11	11
Wind energy	343	345	367
Onshore wind energy	343	345	367

Table 5: Installed Capacity and Energy Mix of Sri Lanka[8]

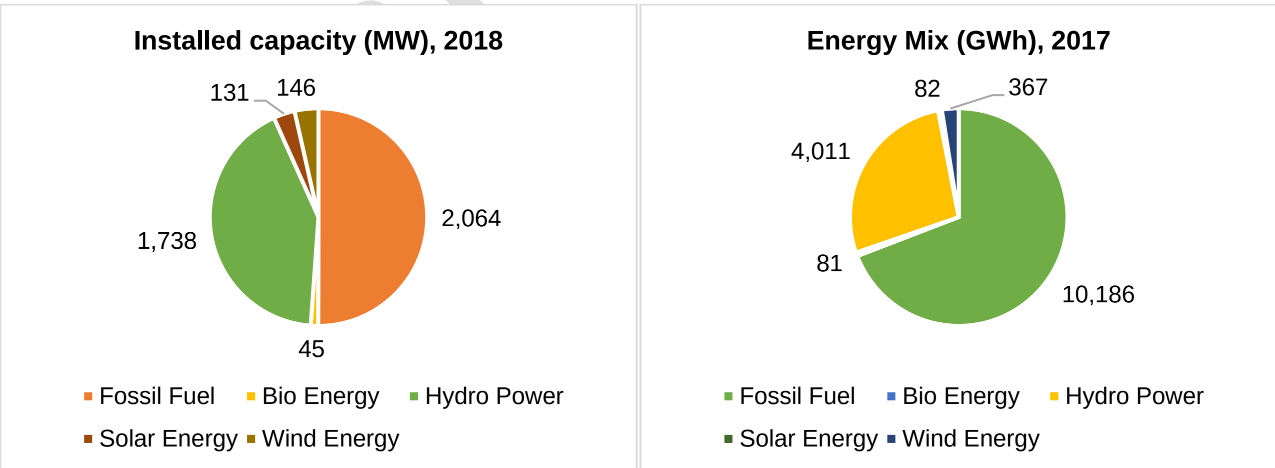

Figure 3: Installed capacity and Power Generation of Sri Lanka[9]

[8] IRENA Stat Tool
[9] IRENA Stat Tool

3.3 Electricity Generation

Electricity generation in Sri Lanka was almost 100% from hydropower until mid-1995. However, with the rapid growth in electricity demand during the last 20 years and the limited potential to develop new large hydropower facilities, the power generation mix in the country has shifted to a mixed hydrothermal system.

Initially, the state-owned CEB was the only entity allowed to engage in power generation, transmission, and distribution activities. After 1996, Sri Lanka allowed the private sector to participate in its Small Power Producers (SPP) program to develop renewable energy based power plants to sell electricity to CEB. Since 1996, the private sector could invest in large generation projects as IPPs.

By the end of 2018, the total installed capacity was 4,156 MW with solar PV installed capacity of and 160 MW. Out of the total installed capacity of 4,156 MW, 42% (1,741 MW) was from hydro (both large hydro and small hydro); 50% (2,064 MW) from thermal; and 8.5% (351 MW) from other renewable sources such as wind, solar, and biomass.[10]

3.4 Electricity Transmission

The CEB acts as the single buyer in the electricity industry, holding the only license issued for power transmission and bulk supply function with transmission voltages of 220 kV and 132 kV. The transmission network consists of 69 grid substations, 601 km of 220 kV overhead lines, at least 2,260 km of 132 kV overhead lines, and 50 km of 132 kV underground cables.

The Northern Province was not connected to the transmission network during the conflict period, but the transmission network was extended to reach Jaffna peninsula. Since mid-2013, the transmission grid has covered the entire country.

The transmission system from Mahaweli hydropower generating stations, coal power station at Puttalam, and combined cycle power plant at Kerawalapitiya to main load centers through Biyagama, Pannipitiya, Veyangoda, and Kotugoda grid substations, is at 220 kV. Additionally, the 220 kV transmission line from the Kotmale power station to New Anuradhapura grid substation is used to facilitate power transfer to the northern and eastern provinces. The 132 kV transmission system interconnects most of the grid substations and transfers power from other power stations. Several 220 kV/132 kV inter bus transformers are installed on the network to facilitate interconnection between two different transmission voltage levels enabling efficient power interchange.

The power system in Sri Lanka is managed by the System Control Centre – a function of the CEB transmission licensee. In 2016, energy loss in the transmission network was at 1.7%,[11] whereas in 2014 it was 2.7%. Transmission development studies are regularly carried out by the transmission licensee, and the transmission development plan is updated every 2 years for a 10-year period. The recently available transmission development plan (2013-2022) has identified several transmission projects including the augmentation of existing grid substations, construction of new grid substations, installation of reactive power compensation equipment, and construction of new transmission lines. Implementation of these projects would ensure capacity adequacy and reliability of the transmission network to cope with the demand growth.

3.5 Electricity Distribution

The Public Utilities Commission of Sri Lanka (PUCSL) has issued five distribution licenses – four to CEB and one to LECO. Sri Lanka is divided into five regions, and both power distribution and supply in every region are carried out by the respective distribution licensee. The four CEB distribution licenses cover more than 97% of the land area of the country and 92% of customers. The share of customer accounts by each distribution licensee are shown in Figure 4.

[10] IRENA Stat Tool
[11] Sri Lanka energy sector assessment, strategy, and road map – ADB

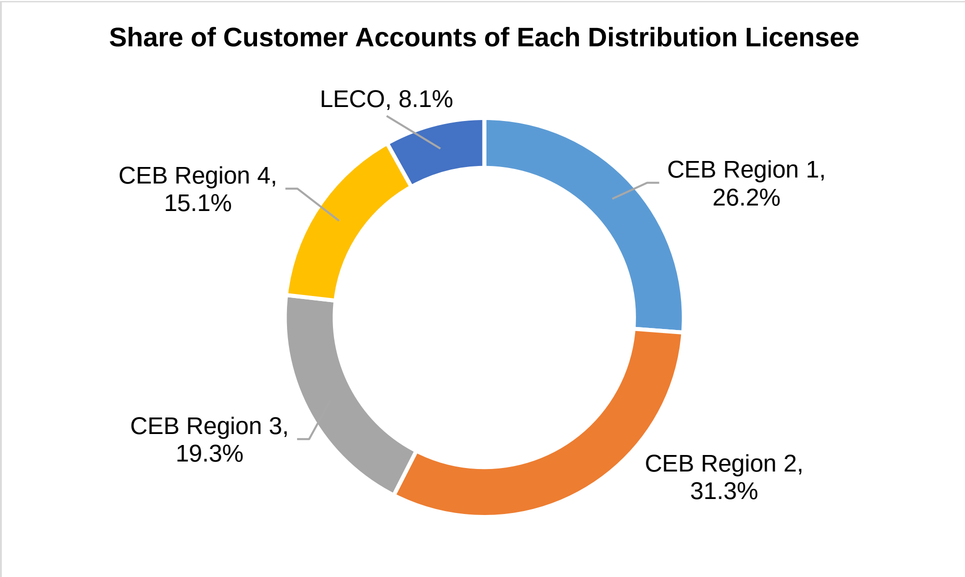

Figure 4: Share of Customer Accounts of Each Distribution Licensee, 2017[12]

3.6 Key Regulations in Power Sector

The power sector in Sri Lanka has witnessed reforms in two phases.

Phase 1: The first phase of reforms was implemented from 1983 to 2008. As early as 1983, the state-owned distribution company, Lanka Electricity Company (LECO) was established, to distribute power in Western coastal regions of Sri Lanka.[13]

In 2000, CEB was divided internally into six divisions — one for generation, one for transmission, and four for distribution. This was done through an administrative CEB decision, without effecting the legal or financial separation of these divisions within the CEB structure

In 2002, the first power sector reform came about with the enactment of the Electricity Reform Act. The act proposed restructuring of CEB by breaking the CEB to several independent state-owned companies to carry out generation, transmission and distribution. This was followed with the creation of the Public Utilities Commission of Sri Lanka (PUCSL) as the power sector regulator, effective July 2003.

Phase 2: Phase 2 included two key reforms – implementation of the Electricity Act 2009 and PUCSL's tariff methodology for the power sector.

Electricity Act 2009. This legislation allowed PUCSL to finally operate as the power sector regulator. However, it authorized less restructuring of the CEB than had been originally proposed in the 2002 Electricity Reform Act. A single-buyer model was introduced, with the CEB transmission entity as the single buyer. In contrast to what is usually done in an unbundling reform, the business units or divisions within the CEB were not spun off as separate entities with independent ownership structure and management.

Tariff Reform. Prior to the Electricity Act 2009, the end user electricity pricing was done in an ad-hoc manner by various governments. This resulted in financial losses and accumulated debt for CEB. In 2009, the PUCSL initiated a tariff reform to address these issues. The new tariff methodology was designed based on two key principles:

- The tariff methodology should reflect separately the costs of each generating, transmission, and distribution licensees; and

[12] IRENA Stat Tool
[13] Sri Lanka Energy Infrastructure Sector Assessment Program

- The tariff methodology should permit each licensee to recover all reasonable costs incurred. However, the implementation of the tariff adjustments for both customer and bulk supply has encountered considerable delays, due to limited adherence to guidelines by sector stakeholders. This has decreased public confidence in the tariff-setting process.

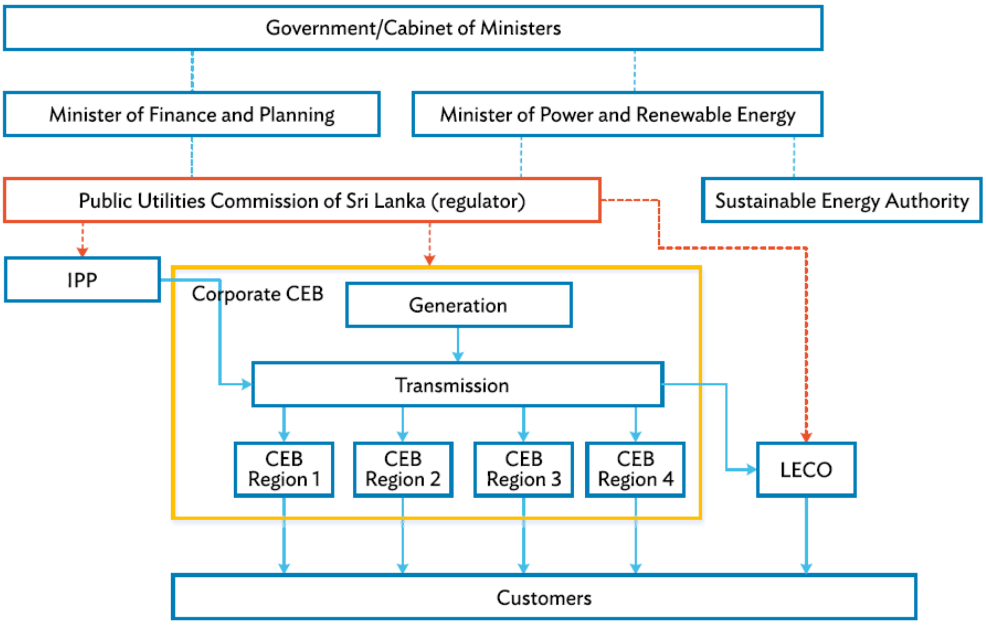

Figure 5: Functionally Unbundled Power Sector Monopoly, 2009–present[14]

The tariff rates approved by the PUCSL for the Island are as following:

Tariff Categories (Low Voltage)	Energy Charge (LKR/kWh)	Fixed Charge (LKR/month)
Domestic Low Users		
0 -30 kWh	2.50	30
31 – 60 kWh	4.85	60
Domestic – Users over 60 kWh		
0-60 kWh	7.85	–
61-90 kWh	10.00	90
91-120 kWh	27.75	480
121-180 kWh	32.00	480
More Than 180 kWh	45.00	540
Religious and Charitable Users		
0-30 kWh	1.90	30
31-90 kWh	2.80	60
91-120 kWh	6.75	180
121-180 kWh	7.50	180
>180 kWh	9.40	240
Hotel		
400/230 Volt (nominal), Contract Demand ≤ 42kVA	21.50	600
Industrial Consumers		
≤ 300 kWh	10.80	
≥ 300 kWh	12.20	600
General Purpose (Shops, offices, banks, warehouses, public buildings, hospitals, educational establishments, places of entertainment and other premises)		

[14] Sri Lanka energy sector assessment, strategy, and road map – ADB

Tariff Categories (Low Voltage)	Energy Charge (LKR/kWh)	Fixed Charge (LKR/month)
≤ 300 kWh	18.30	240
≥ 300 kWh	22.85	
Government Category		
400/230 Volt (nominal), Contract Demand ≤ 42kVA	14.65	600
400/230 Volt (nominal), Contract Demand ≥ 42kVA	14.55	3,000
11kV (nominal)	14.35	3,000

Table 6: Electricity Tariff of Sri Lanka as on 2019[15]

[15] Public Utilities Commission of Sri Lanka – Tariff, 2019
1 LKR = 0.0053 USD

4. Technical Feasibility Assessment

4.1 Solar pump Technology Overview

A PVP (Photo Voltaic Pump) typically consists of the following main components:

1. **Photovoltaic array:** An array of photovoltaic modules connected in series and possibly strings of modules connected in parallel.
2. **Controller:** An electronic device which matches the PV power to the motor and regulates the operation, starting and stopping of the PVP. The controller is mostly installed on the surface although some PVPs have the controller integrated in the submersible motor-pump set:
   - DC controller: usually based on a DC to DC controller with fixed voltage set point operation.
   - AC controller (inverter): converts DC electricity from the array to alternating current electricity often with maximum power point tracking.
3. **Electric motor:** There are a number of motor types: DC brushed, DC brushless, or three phase induction and three phase permanent magnet synchronous motors.
4. **Pump:** The most common pump types are the helical rotor pump (also referred to as progressive cavity), the diaphragm pump, the piston pump and the centrifugal pump. Some years ago, there were PVP models on the market that operated with batteries and a conventional inverter. However, it was soon realized that the cost savings on the pump did not make up for the overall substandard efficiency and the higher maintenance cost due to battery replacements. Instead it became clear that it is more economical to rather store water in a reservoir than electricity in a battery bank.

There are currently three pumping configurations commonly utilized in Africa:

- **DC drive with positive displacement pumps**. This consists of four pump technologies: Diaphragm pump driven by brushed DC motor, Helical rotor pump driven by brushless DC motor, Helical rotor pump driven by surface mounted brushed DC motor, Piston pump driven by surface mounted brushed DC motor
- **AC drive powering a submersible induction motor/centrifugal pump unit**
- **AC drive powering a three phase permanent magnet synchronous motor**. This category consists of: Positive displacement helical rotor pump, Centrifugal pump

The above technologies have specific features which make them suitable for particular applications. Some of the other key technology terms useful for understanding the functioning of a solar powered irrigation system are described in detail as per the table below.

Term	Description
Array Voltage	Some of the pumping systems have high array voltages. This has the advantage that the array may be further from the borehole without significant voltage drop (dependent on cable size and current). Array positioning may be important where there is potential for theft.
AC Motors	The motor operates on alternating current; the direct current produced by solar panels gets converted to AC using the inverter. The conversion from DC to AC leads to loss of power from generation to consumption.AC motors gain importance in applications where higher output/head combinations are required.
DC Motors	DC motors reach efficiencies of up to 80% and are therefore significantly more efficient than sub-kW three phase motors which have efficiencies in the region of 60% to65%.
Brushless DC Motors	This combines the high efficiency of DC motors with low maintenance as opposed to brushed DC motors which require regular brush replacement (approximately every one to two years – head and quality dependent).

Term	Description
Three phase permanent magnet motors	This similarly combines the high efficiency of permanent magnet motors with low maintenance.
Positive displacement vs. Centrifugal pump	Positive displacement pumps have a better daily delivery than centrifugal pumps when driven by a solar PV system with its characteristic variable power supply. This is due to the considerable drop in efficiency of the centrifugal pump when operating away from its design speed. This is the case in the morning and the afternoon of a centrifugal pump driven by a PV array, unless that array tracks the sun (which is why centrifugal PVPs effectiveness improves more with a tracking array than a positive displacement PVP). The efficiency curve of a positive displacement pump is flatter over a range of speeds. However, the efficiency of positive displacement pumps decreases with the shallowness of the borehole (the constant fixed friction losses become a more significant part of the power it takes to lift water). Therefore, it is not surprising that both Grundfos and Lorentz use centrifugal pumps for applications where the lift is less than 20 to 30m but switch to positive displacement pumps for deeper wells.
Surface pump	Surface pumps are installed at ground level to lift water from shallow water sources such as shallow wells, ponds, streams or storage tanks. Surface pumps can also be used to provide pressurized water for irrigation or home water systems. These pumps are suitable for lifting and pumping water from a maximum depth of 20 meters.
Submersible pump	Submersible pumps installed where there is a requirement for the submerged in the fluid to be pumped These pumps can be used in areas where water is available at a greater depth and where open wells are not available. Typically, the maximum recommended depth these systems can pumps is 50 meters.

Table 7: Key technology terms in a solar powered irrigation system

4.2 Assessment Criteria

The feasibility of a solar powered irrigation system depends on a wide array of factors ranging from geographic parameters such as temperature, rainfall, water table depth to site specific parameters such as cropping pattern, land size, planting date, irrigation technique etc. Any feasibility analysis of a solar powered irrigation system would involve both the technical feasibility and the financial feasibility. The technical feasibility would analyze the site-specific conditions to determine whether such system can be installed considering the different technical aspects such as solar irradiance, size availability, panel size, tracking systems, water table depth etc. The technical feasibility would also provide recommendations on the ideal pump size and type considering the dynamics of the site. Once technical feasibility for a given system is established, the costs involved, and the expected returns are calculated using financial feasibility analysis. The below figure summarizes the interplay of various parameters involved in technical and financial feasibility analysis.

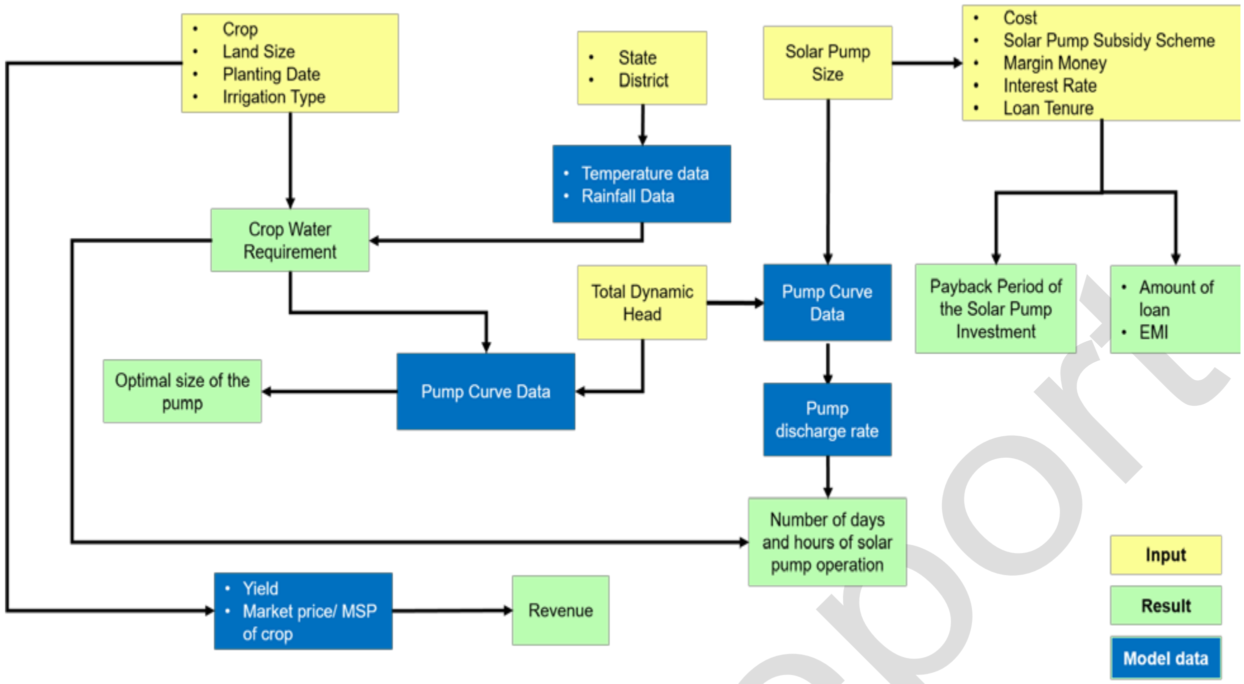

Figure 6: Factors involved in feasibility analysis of solar pump

4.1.1 Total Dynamic Head

The total dynamic head is a very important parameter of a solar pumps which determines the various head losses that the pump must overcome. It is a summation of the suction head, discharge head and the friction losses. The total dynamic head and the desired flow rate of the system are applied to the pump performance curve, which is used for proper pump selection based on required electrical power input and optimum efficiency.

4.1.2 Pump Curves

The pump characteristic is normally described graphically by the manufacturer as the pump performance curve. Other important information for a proper pump selection is also included - like efficiency curves, NPSHR curve, pump curves for several impeller diameters and different speeds, and power consumption[16]. The performance curve indicates the variation in the discharge rate of a pump with a change in required head and input power. The pump curves are analyzed to determine the optimal size of a solar pump for a given manufacturer and also to assess whether the system will be able to the peak demand requirements of the farmer. The performance curves for a 5 HP AC and 5 HP DC pump is shown as below[17]:

[16] System Curve and Pump Performance Curve - The Engineering Toolbox
[17] Shakti Pumps (DC pump: 5 DCSSP 2700/3600/4600; AC pump: SSP 5000-100-11)

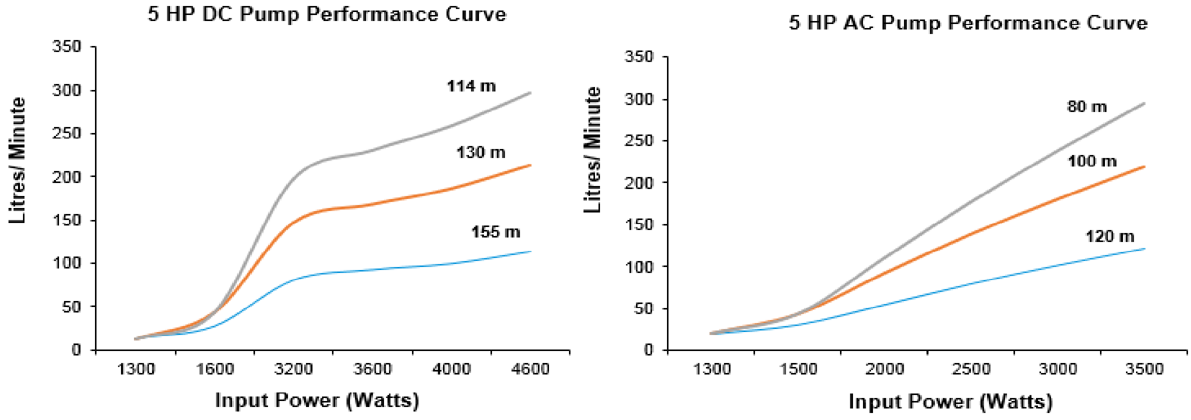

Figure 7: Pump Performance Curves

4.1.3 Crop Water Requirement

The crop water need is defined as the depth (or amount) of water needed to meet the water loss through evapotranspiration. In other words, it is the amount of water needed by the various crops to grow optimally. The crop water need always refers to a crop grown under optimal conditions, i.e. a uniform crop, actively growing, completely shading the ground, free of diseases, and favourable soil conditions (including fertility and water). The crop thus reaches its full production potential under the given environment.

The crop water need mainly depends on:

- **the climate**: in a sunny and hot climate crops need more water per day than in a cloudy and cool climate
- **the crop type**: crops like maize or sugarcane need more water than crops like millet or sorghum
- **the growth stage of the crop**: fully grown crops need more water than crops that have just been planted.

The below table showcases the effect of various climatic factors on the crop water requirement:

Climatic Factor	Crop Water Requirement	
	High	Low
Temperature	Hot	Cool
Humidity	Low (Dry)	High (Humid)
Windspeed	Windy	Little Wind
Sunshine	Sunny (no clouds)	Cloudy (no sun)[18]

Table 8: Effect of major climatic factors on crop water requirement

The highest crop water needs are thus found in areas which are hot, dry, windy and sunny. The lowest values are found when it is cool, humid and cloudy with little or no wind. The influence of the climate on crop water needs is given by the reference crop evapotranspiration (ETo). The ETo is usually expressed in millimetres per unit of time, e.g. mm/day, mm/month, or mm/season. ETo is the rate of evapotranspiration from a large area, covered by green grass, 8 to 15 cm tall, which grows actively, completely shades the ground and which is not short of water[19].

4.1.4 Pump Sizing

Oversizing would incur unnecessary costs, and under sizing would lead to insufficient performance. This is why each component needs to be properly designed and sized to meet the specific requirements of the project. It is the only way to guarantee reliability and system durability to achieve the desired performance. Similarly,

[18] Principles of Irrigation Water Heeds - FAO
[19] Principles of Irrigation Water Heeds - FAO

when sizing a solar system, it is recommended to use the 'worst month method'. By sizing the systems for the month with most adverse conditions in the year, it will be ensured that water supply will be enough for all the other months. The worst month in the year will be that in where the gap between the energy required to supply water and the energy available from the Sun is higher. In case the daily water requirement is the same all the year round (meaning too that the energy required is the same all the year round since pump will run for the same number of hours any day), the worst month will be that with least solar radiation[20].

4.3 Country Assessment

4.2.1. Connectivity and Accessibility

Sri Lanka has a road network of approximately 100,000 kilometers sufficient for meeting 90% of the demand for transportation. Out of the total length of roads, maintenance and development of A and B class national roads and 4,480 bridges are vested with the Road Development Authority (RDA). Approximately another 15,000 kilometers of C and D class roads are under the purview of provincial councils. The balance is maintained and developed by the local governments and other government and private institutions.

The distance between key cities of Sri Lanka are given as below:

Distance between towns	km
Colombo - Galle	116
Colombo - Ampara	350
Colombo - Batticaloa	303
Colombo - Trincomalee	257
Colombo - Vavuniya	254
Colombo - Puttalam	142
Galle - Matara	45
Matara - Hambantota	77
Ampara - Batticaloa	70
Ampara - Trincomalee	206
Batticaloa - Trincomalee	138
Trincomalee - Vavuniya	97
Vavuniya - Killinochchi	80
Killinochchi - Mullatiwu	55
Killinochchi - Jaffna	62

Table 9: Distances from Capital City to Major Towns (km)[21]

The only international airport of Sri Lanka is called Bandaranaike International Airport (BIA) and is situated 32 km north of the capital Colombo. All international flights are coming in and departing from this airport. BIA operates both civil and military traffic.

Sri Lanka Railways (SLR) is operated by the Sri Lankan Ministry of Transport and serves as the core link between the country's seaports and major inland cities. The rail transport in Sri Lanka is mainly aimed at passenger transport while cargo transport has taken a decline over the past decade. Main rail transport activities take place in Colombo suburban areas for commuter transport. This includes a radius of some 30 kilometers from Colombo.

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[20] Basic Guidelines of SWPS – Sun Connect News
[21] Sri Lanka – Logistics Cluster

Figure 8: Road Network of Sri Lanka[22]

4.2.2. Climate and Rainfall

Sri Lanka is tropical and consists of very distinctive dry and wet seasons. The average temperature of Sri Lanka usually ranges from 28 – 32 degrees Celsius which may differ due to global weather conditions. The temperature can vary from being as low as 16 degrees Celsius in Nuwara Eliya which belongs to the central highlands and to as high as 32 degrees in Batticaloa along the Eastern coast of the island. However, there are certain areas along the coast that are cooled by the ocean breezes. The coldest months according to the mean monthly temperature are December and January while the warmest months are April and August[23].

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temperature (°C)	26.0	26.3	27.4	28.0	28.0	27.3	27.3	27.4	27.2	26.7	26.2	25.9
Min. Temperature (°C)	21.9	22	23.2	24.2	25.2	24.9	24.9	25	24.6	23.7	22.7	22.2
Max. Temperature (°C)	30.2	30.7	31.6	31.8	30.8	29.7	29.7	29.8	29.8	29.7	29.8	29.7
Precipitation / Rainfall (mm)	74	73	136	246	360	208	134	103	180	358	317	159

Table 10: Temperature Variation in Colombo, Sri Lanka[24]

[22] Sri Lanka – Logistics Cluster
[23] Lakpura LLC – Sri Lanka
[24] Colombo, Sri Lanka: Climate Data

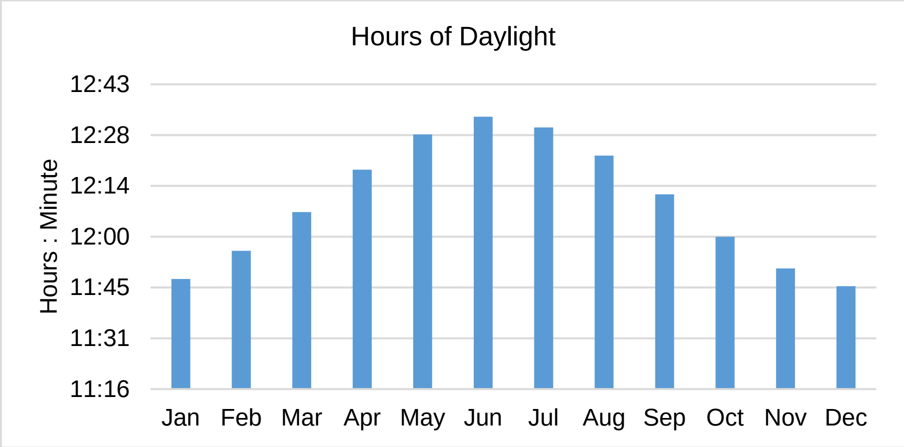


Figure 9: Daylight hours in Colombo, Sri Lanka [25]

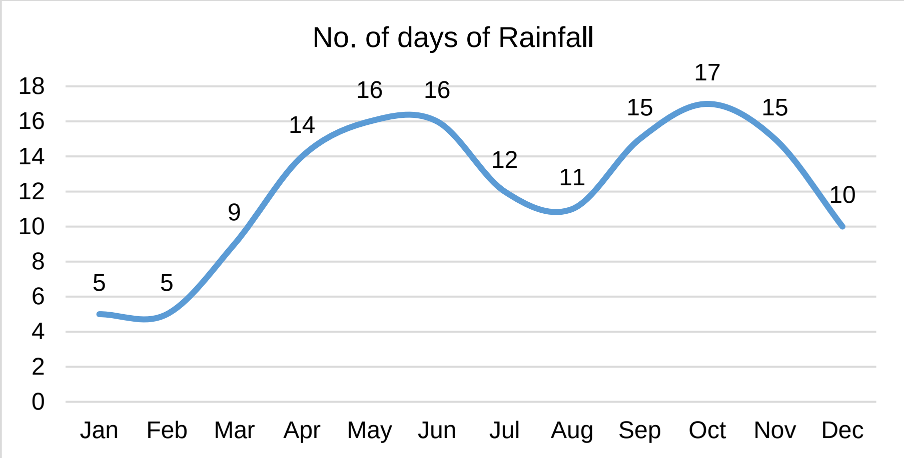


Figure 10: No. of days of Rainfall over the year in Colombo, Sri Lanka [26]

4.2.3. Geology and soils

Variations of soil within Sri Lanka reflect the effects of climate, lithology, and terrain on the soil-forming processes. Most of the soils of Sri Lanka are potentially suitable for agricultural use. However, depletion of the natural fertility of the soil has occurred extensively, especially on the rugged terrain of the highlands, owing to poor soil conservation.

Soil types vary depending on the location. Reddish Brown Earths (RBE), Red Yellow Podzolic (RYP) and Low Humic Gley (LHG) soils are the most abundant types in Sri Lanka. The most common types found in the Project area (dry zone) are described briefly below.

Reddish Brown Earths (RBE): This is the most common soil type in Sri Lanka occupying nearly a quarter of the land area. They are mainly found in the dry zone and occupy the crest and the upper and mid-slopes of the landscape. As their name suggests, RBE are reddish-brown when dry, darkening with moisture. These soils are extremely hard when dry, friable to firm when moist, and sticky when wet.

Low Humic Gley Soils (LHG): This is the soil group that is the second most common in Sri Lanka. The LHG occupies the lower parts of the slopes and upper parts of the bottom of the valleys. These soils 'are wet or have gleying throughout their profile or below the surface.

[25] World Data – Sri Lanka
[26] Colombo, Sri Lanka - Weather Atlas

4.2.4. Groundwater Status

There are six main type of groundwater aquifers demarcated and identified in Sri Lanka. They are shallow karstic aquifers, coastal sand aquifers, deep confined aquifers, lateritic aquifers, alluvial aquifers and shallow regolith aquifers in the hard rock region. Figure 11 shows the distribution of these aquifers within the country. In addition to these main aquifers, a large number of small groundwater pockets can be found throughout the country. These aquifers occur either in isolated patches of soil cover over the bedrock or in the fracture and weathered zones of the underlying metamorphic bedrock.

The average depth of wells reaching the artesian aquifer in the well-defined basins is from 30 to 50 m; and the yields of these wells is around 3 – 10 liters /sec. This aquifer dips towards the sea, and the depth to the aquifer is around 70 – 90 m in some places close to the sea.

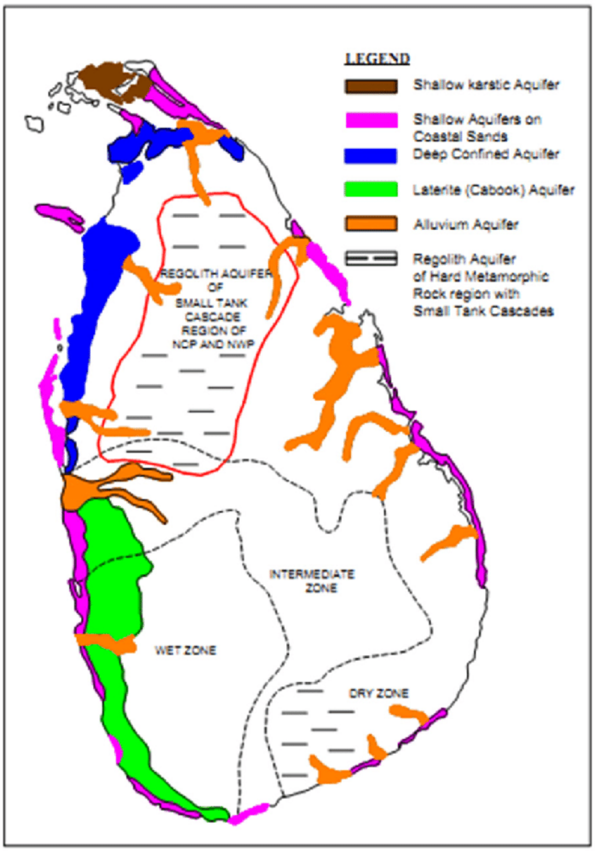


Figure 11: Distribution of the Major Aquifer Types in Sri Lanka[27]

Colombo: The basin hydrology indicates that there is a fair amount of groundwater potential both in the alluvial aquifers and bedrock. The prominent aquifer bedrock types in the basin are quartzite and a few crystalline limestone (marble) bands. The secondary porosity of these formations provides good conditions for deep aquifers. The alluvial sand/gravel aquifers in the basin are recharged by rainfall and seepage from the rivers. High-potential porous residual laterites also contribute to groundwater supplies. During droughts, river water and springs recharge most alluvial aquifers in the basin.

Kandy: Groundwater in Kandy exists mostly in the form of semiconfined aquifers in the first 100 m of the bedrock. This groundwater exits both as small pockets of underground reservoirs and as fissure groundwater. The yields of these aquifers are not very well known and are limited as they recharge very slowly. In addition, there exists high-yielding groundwater resources along the alluvial flood plains of Mahaweli River that are mostly recharged by the river water.

[27] Panabokke and Perera 2005

4.2.5. Agriculture

Total land area is estimated at around 6.5 million hectares (65,610 km^2), including 3.54 million hectares of agricultural land (54 percent), 1.95 million hectares of forest (31 percent), the rest occupied by water bodies and urban areas. The agricultural sector accounts for about 8.5 percent of GDP and employs some 30 percent of the country's workforce. The country's main agricultural product is rice, which is grown under a wide range of environmental conditions, such as different elevations, soils and hydrological regimes. The major cultivation season maha paddy, stretches from September to March, and normally accounts for 65 percent of the country's annual paddy production. The output of this season depends on rainfall from inter-monsoon rains and northeast monsoon. The mostly irrigated secondary yala season lasts from April to September and relies on the southwest monsoon. Maize is also grown during these two seasons in similar scale of paddy. The cropping calendar for these two cereals is shown in Figure 12.

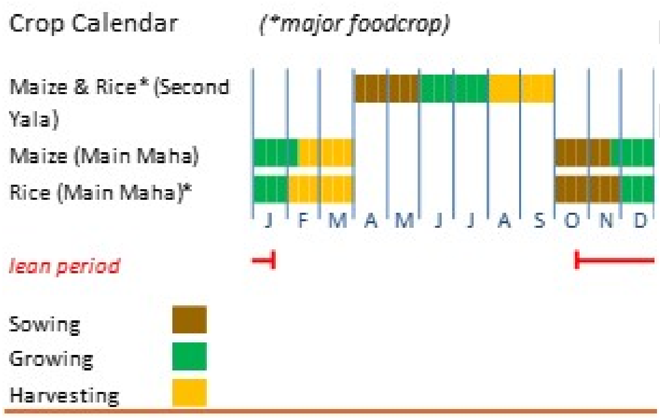


Figure 12: Distribution of the Major Aquifer Types in Sri Lanka[28]

Other agricultural products which are cultivated in large amounts in Sri Lanka, include pulses, oilseeds, spices, vegetables, fruits, sugarcane, milk, eggs, hides, beef and fish. Tea, which occupies more than 222,000 hectares, is a major source of foreign exchange and employs, either directly or indirectly, more than 1 million people. Other plantation crops include rubber (about 125,000 hectares) and coconuts (395,000 hectares).

4.2.6. Solar Irradiance

Solar power is abundantly available in Sri Lanka as the country lies within the equatorial belt. Annual average Global Horizontal Irradiance (GHI) varies from 4.5 – 6 kWh/m^2/day[29] across the country. The Solar Resource Atlas of Sri Lanka, prepared by Sri Lanka Sustainable Energy Authority (2014), provides GHI and Direct Normal Irradiance data across the island with a resolution of 3 kilometers (km) by 3 km.

The solar radiation map for Sri Lanka is shown in the image below.

[28] GIEWS, FAO
[29] Solar Resource Assessment for Sri Lanka and Maldives – NREL

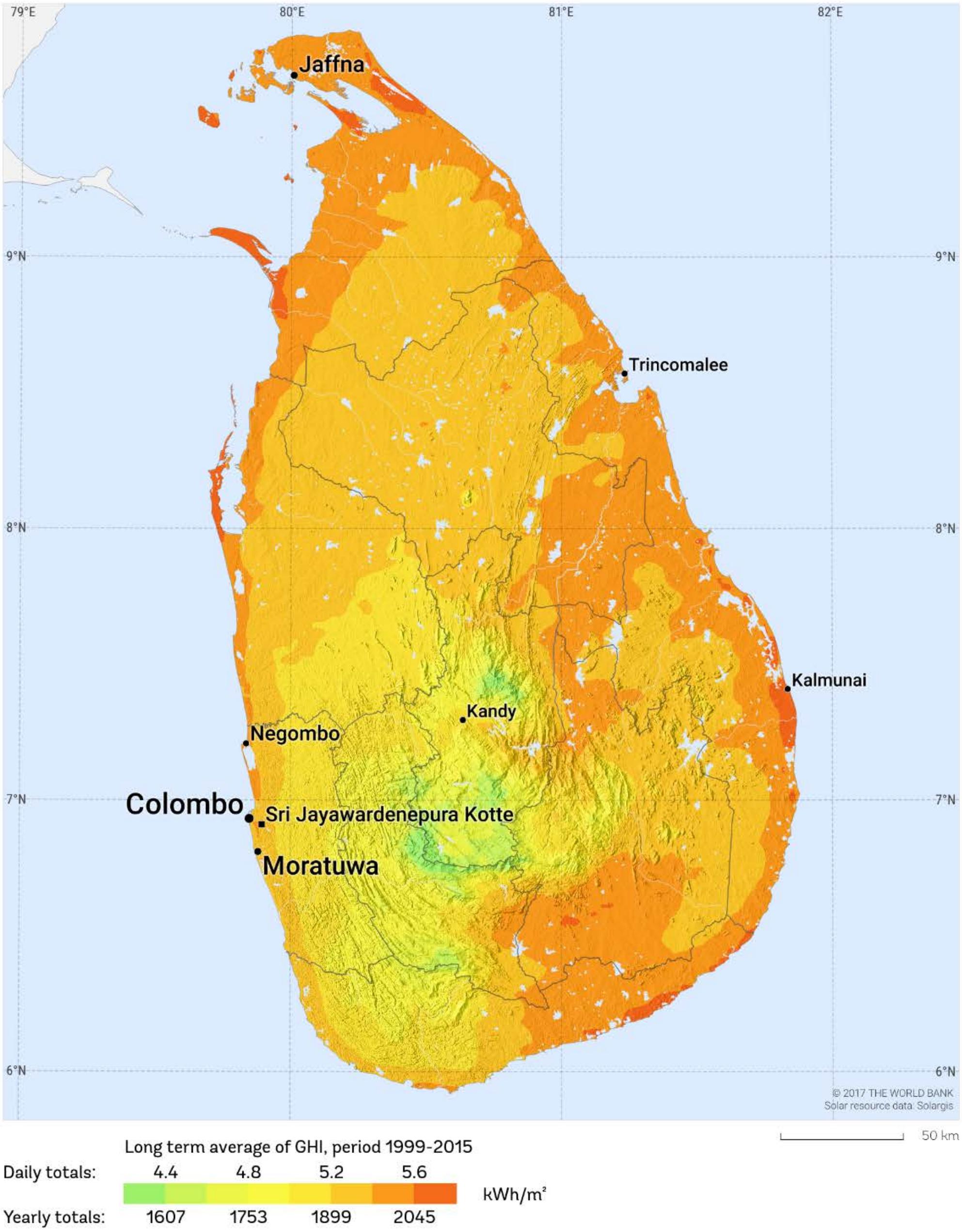


Figure 13: Global Horizontal Irradiation for Sri Lanka[30]

[30] Solar resource maps – ESMAP Solar GIS

5. Financial Feasibility Analysis

5.1 Indicative Inputs

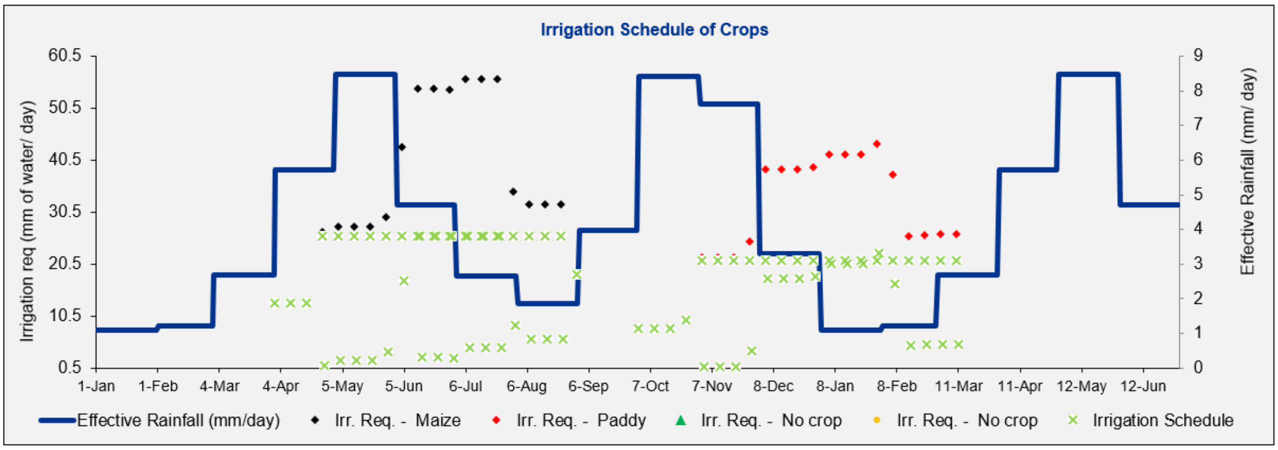
S.No.	Particulars	Unit	Value		Source
1	Crop to be Irrigated		Maize, Paddy		
2	Land Size	hectares	0.5 (for each crop)		
3	Planting date		As per cropping calendar of Sri Lanka		
4	Irrigation type		Flood: Lined canal supplied		
5	Annual average yield of crop	Kg/hectare	Maize	3809	FAOSTAT
			Paddy	3775	
6	Market Price	USD/quintal	Maize	2499	FAO: Food Price Monitoring and Analysis
			Paddy	5820	
5	Selected Size of Solar Pump	HP	3		
6	Total dynamic head inclusive of friction losses	meters	100		
7	Cost of Solar Pump	USD	3,907[31]		Average of L1 prices discovered in ISA tender for various categories of pumpsets
8	Subsidy	%	0 %		
9	Margin Money	%	10 %		
10	Loan Amount	%	90 %		
11	Interest Rate	%	4 %		Assuming concessional financing from MDBs
12	Loan Tenure	years	7		
13	Cost of diesel pump per HP	USD	117		
14	Cost of diesel	USD/litre	0.55		Published reports and articles
15	Hike in diesel prices (y-o-y)	%	3%		Based on global averages
16	Inflation rate	%	4.7 %		International Monetary Fund
17	Living expense of the farmer (as a % of crop revenue)	%	60 %		Based on global estimates, KPMG Analysis
18	Maintenance costs for diesel pump (as a % of capital costs)	%	10 %		Based on global estimates, KPMG Analysis, 2020[32]

5.2 Indicative Crop Water Requirement [33]

Total crop water requirement (m^3)											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
854	551	-	-	-	402	926	478	-	-	-	385
Annual crop water requirement (m^3)					3,596						

[31] Cost of Solar pumpset includes on-site Comprehensive Maintenance Contract (CMC) for 5 years but exclusive of custom import clearance, duties and local taxes as per ISA International Competitive Bid
[32] The toolkit developed by KPMG for Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH was used to undertake the analysis.
[33] Note: This is just an indicative analysis to be used only for reference purposes. We have taken reasonable assumptions wherever reliable data was not available. A more accurate analysis can be conducted after more data has been obtained from the respective nations.

5.3 Indicative Irrigation schedule



Irri. Req. indicates the net irrigation requirement (considering rainfall) for individual crops
Irrigation Schedule indicates the consolidated schedule over the time period for all the crops

5.4 Indicative Outputs

S.No.	Particulars	Unit	Value
1	Amount of subsidy	USD	0
2	Amount of loan to be availed	USD	3,516
3	Yearly installment towards loan repayment	USD	586
4	Monthly installment towards loan repayment	USD	49
5	Savings in monthly diesel expenses on an average basis for 20 years	USD	60
6	Number of hours of solar pump operation required	Hours	681
7	Number of days of solar pump operation required	Days	97
8	Payback of solar pump w.r.t. diesel pump	years	7

Sri Lanka has submitted demand for 2000 Nos. solar water pumping systems. At an average price of USD 3,907 per 3 HP pumpset[34], Sri Lanka requires financing of USD 7.81 million to roll out deployment of 2000 Nos. solar water pumping systems across the country.

[34] Average L1 price of 2 HP AC Surface, AC Submersible, DC Surface and DC Submersible SWPS discovered through International Competitive Bid (ICB) by ISA

6. Advantages of Solar powered irrigation

6.1 Advantages of solar power irrigation to various stakeholders

Socio-economic advantages		Environmental advantages
Farm level	**National level**	
Financing and cost of solar panels continue to drop, making SPIS economically viable and competitive with other sources of energy.	Potential for job creation in the renewable energy sector.	No greenhouse gas emissions.
Rural electrification and access to renewable energy, especially in remote areas.	Contribution to rural electrification and renewable energy targets.	Potential for adaptation to climate change by mobilizing groundwater resources when rainfall patterns are erratic.
Independence from volatile fuel prices and unreliable and costly fuel supplies.	Reduced dependence on energy exports. Energy subsidies for fossil fuels can be reduced while offering an alternative to farmers and rural communities whose livelihoods would otherwise be negatively affected.	Potential for improving water quality through filtration and fertigation systems. Less pollution resulting from inadequate fuel handling from diesel pumps.
Potential for increasing agricultural productivity and income due to improved access to water.	Food security may be improved if introduction of SPIS is accompanied by changes in irrigation technologies and agricultural practices.	
Potential for income diversification due to multiple uses of energy (e.g. feed-in to grid, lighting, cooling) and water (e.g. livestock watering, domestic uses).	Rural development through improved access to water and energy.	
Reduced cost for water pumping in the long run. If system is being modernized for pressurized irrigation, increases in energy costs are offset through use of solar energy.		
Potential time saving due to replacement of labour intensive manual irrigation, which can lead to other income-generating activities. Women and/or children might profit from time not spent on watering anymore.		

Table 11: Advantages of solar powered irrigation

6.2 Benefits to Key stakeholders

The estimated benefits to farmers and Government of Sri Lanka due to installation of SWPS are highlighted in the table below[35]:

S. No.	Parameter	Units	Value
1.	Average savings in monthly diesel expenses for 20 years due to solar pumpset	USD/month	60
2.	Monthly installment towards loan repayment of solar pumpset (7 years)	USD/month	49
3.	Average monthly savings to farmer during loan tenure (7 years)	USD/month	11
4.	Average monthly savings to farmer after loan tenure (13 years)	USD/month	60
5.	Payback period for solar pumping systems	Years	7
6.	Annual CO_2 emission reduction due to installation of 2000 solar water pumping systems[36]	Tons/annum	3,129
7.	Local technicians trained due to installation of 2000 solar water pumping systems[37]	Nos.	100
8.	Avoided annual diesel consumption for 2,000 Nos. pumpsets	Kilo liters/annum	1,167
9.	Avoided annual expenditure on diesel consumption for 2,000 Nos. pumpsets [38]	USD/annum	1,074,034
10.	Financing requirement for deployment of 2000 solar water pumping systems	USD	7,814,000

Table 12: Benefits to key stakeholders with implementation of Solar pumping systems in Sri Lanka

[35] Reduction in CO_2 emission and diesel consumption estimated for 2000 pumpset demand submitted by Sri Lanka for ISA International Competitive Bid for SWPS
[36] 2.68 kgs of CO_2 released from 1 liter of diesel (Source: https://ecoscore.be/en/info/ecoscore/co2)
[37] As per tender conditions of ISA International Competitive Bid for SWPS, Supplier is mandated to train 5 local technicians besides farmer for every 100 Solar pumps
[38] Cost of Diesel assumed at 0.92 USD/liter including transportation and handling charges of Diesel

7. Recommendations for implementation

Following are the recommendations for the implementation of solar pumps in Sri Lanka based on the above analysis and discussions undertaken during the visit of delegation from ISA Secretariat to Sri Lanka:

1. **Location of pumps:** Sri Lanka has submitted demand for procurement of 2,000 solar water pumps. The pumps should be adequately sized to meet the crop water requirements of the area. The meteorology of Sri Lanka is characterized as humid maritime subtropical climate with almost consistent rainfall throughout the year. Also, the ground water table depth across Sri Lanka is less than 100 meters. Hence, a smaller sized pump may be able to give enough discharge for the crop as a major portion of water requirement can be meet through rainwater. Considering these parameters, the water requirement can be sufficed by 3 HP pumps.
2. **Financing:** Government of Sri Lanka may reach out to MDBs/DFIs such as World Bank, The EXIM Bank, ADB etc. to secure financing for implementation of Solar water pumping systems in the country. The potential savings to farmer due to avoided expenditure on diesel consumption may be utilized to payback debt obligations resulted from financing of solar water pumping systems with an estimated payback period of 7 years.
3. **Ecosystem availability:** The ecosystem of trained local manpower for operations and maintenance of Solar pumps is to be developed for better realization of benefits envisaged from solar water pumping programme. The mandate to bidder to train every famer and 5 local technicians for every 100 pumpsets installed shall be critical in strengthening local ecosystem in Sri Lanka.

8. Proposed next steps

1. **Pre-feasibility report**: The pre-feasibility report may be shared with Multilateral Development Banks (MDBs) such as World Bank, EXIM Bank for financing solar water pumping systems in Sri Lanka. This report assesses the feasibility of implementation of solar pumps with reasonable assumptions as detailed in the report. However, to arrive at a detailed feasibility assessment, site specific and other relevant details (such as, applicable taxes, duties, government incentives etc.) are required from the relevant Ministry.

2. **Capacity building**: Post financing arrangement, ISA to facilitate identification of foundations/ institutions in Sri Lanka to assist in the capacity building of farmers and support for various training programs especially for training of technicians may be initiated by pump suppliers and through i-STARCs.

3. **Field preparation**: Field preparation and boring activities are not included in the cost/scope of bidder.

4. **Supply and project monitoring**: Regular project monitoring for supply and installation of pumps may be undertaken by ISA and NFP Sri Lanka basis field reports and feedback from farmers, suppliers / installers and government agencies.