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Eswatini

Investment Case for Sustainable Energy in Health and Education Facilities

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Acronyms

CAPEX	Capital Expenditure
CBO	Community-Based Organisation
CCRI	Children's Climate Risk Index
EPC	Engineering- Procurement- Construction
ESARO	Eastern and Southern Africa Regional Office
ESCO	Energy Service Company
ESERA	Eswatini Energy Regulatory Authority
GW	Gigawatts
kW	Kilowatt
kWh	Kilowatt hour
kWp	Kilowatt peak
MW	Megawatt
NGO	Non-Governmental Organisation
O&M	Operation and Maintenance
OPEX	Operational Expenditure
PV	Photovoltaic
PV	Photovoltaic
RE	Renewable Energy
REMP	Rural Electrification Master Plan
REREC	Rural Electrification and Renewable Energy Corporation
SDG	Sustainable Development Goal
TOU	Terms of use
UN	United Nations
UNICEF	United Nations International Children's Emergency Fund
USAID	United States Agency International Development
USD	United States Dollars
WASH	Water Sanitation and Hygiene

Executive Summary

Solar photovoltaic (PV) technology is gaining popularity as a sustainable and cost-effective energy solution, not only for communities that are off-grid, but also for institutions that wish to operate independently due to various reasons such as inadequate service level, high cost of grid-purchased electricity, or a preference for renewable energy sources. This trend is especially significant in countries where the electricity grid is dominated by fossil-based sources, as solar PV offers a cleaner and more environmentally-friendly alternative.

Eswatini, a land-locked country of 1.14[1] million people, has one of the highest rates of electrification in Africa, currently standing at 85%[2] according to state utility Eswatini Electricity Company. However, only 40%[3] of its electricity is generated nationally, with the remaining 60% being imported from South Africa`s main utility Eskom. More than 80%[4] of Eskom`s electricity is generated from coal plants, most of which are more than 50 years old. As a result, the ageing coal plants are unable to provide electricity at the required service. Recently, South Africa has been experiencing months of load-shedding, with some days experiencing Stage 8 load shedding - 12 hrs without electricity per day.[5] This not only places Eswatini in a vulnerable position should Eskom decide to focus on supplying power to South Africa alone, in the meanwhile it traps the country into dependence on unclean electricity. Developing a fleet of renewable based utility-scale plants and decentralized solar systems is thus an imperative

Decentralized solar power is an ideal starting point for powering institutions, particularly schools and health facilities. This report is an attempt at investigating the investment required to solarize health facilities and education institutions in Eswatini with solar PV systems.

This report is based on analysis of key data collected between November and December 2022 for health facilities, and March 2023 for education facilities, by UNICEF in Eswatini. This included a rapid solar assessment summarizing the status of energy in health and schools to provide a deeper analysis of the renewable energy potential in Eswatini and the financial investment needed to electrify demand for both health and education facilities.

From the onset, two conflicts are apparent:

- The rates of electricity access in Eswatini are currently quite high. In fact, all the schools and health facilities surveyed for this investment case had electricity connection through the grid.
- The national domestic tariffs which apply to government institutions are quite low (less than US$0.10/kWh).

However, the relatively high rate of non-renewable electricity, as well as possible issues with power supply, as outlined above, may justify an investment into the solarisation of health and education facilities.

Given an overall electrification rate of 85%, we approximated that not more than 10% of institutions are unelectrified, given the urban-rural split of institutions and the fact that on average, the electrification for institutions is normally higher for institutions than households. From this figure, we arrived at the capacity of solar PV system and financial investment required to electrify the remaining institutions.

[1] USAID. (2023). Eswatini, Power Africa Fact Sheet, United States Agency for International Development.
[2] ESERA. (2023). Electricity Sector, Eswatini Energy Regulatory Authority.
[3] ibid
[4] Reuters. (2021). South Africa's Eskom CEO sees end to crisis in shift from coal, Reuters.
[5] BT. (2023). Stage 8 load shedding hits as South Africa runs out of time, Business Tech, South Africa.

- **It will require 3.6 MW of solar PV, 5.7 MWh battery capacity and 1.7 MW inverter capacity** to electrify the remaining unelectrified institutions (both health and education), of which 1.2 MW of solar PV, 1.9 Mwh battery capacity and 0.5 MW inverter capacity would be foreseen for education facilities, and 2.4 MW of solar PV, 3.8 MWh of battery capacity and 1.2 MW of inverter capacity for health facilities;
- At the present equipment cost, and factoring in operation and maintenance costs for a system built to last for 20 years, the investment required to electrify these facilities is in the order of **8.1M USD overall,** of which **2.7M USD for education institutions** and **5.4M USD for health facilities**. This can be disaggregated as USD 1,795,000 for solar PV, USD 3,300,000 for battery systems, USD 1,605,000 for inverters and USD 1,400,000 for other costs including remote monitoring, transport to site and installation labour.
- This presents the unique opportunity to significantly reduce environmental impact, potentially reducing CO2 emissions by 67,813 tons over the lifetime of the systems.

We further considered a second scenario, whereby all facilities, including grid-connected facilities, are solarised. This is viable given Eswatini's current state of electricity supply: The majority of electricity consumed is imported from Eskom, which is experiencing significant capacity shortages. This necessitates a strategy to wean the country off electricity imports. Solarisation of critical infrastructure such as health and education facilities would therefore be desirable. Under this scenario:

- It will require nearly 10 times the capacity proposed above to solarise all facilities in the country (36 MW of solar PV, 57 MWh battery capacity, 17MW inverter capacity)
- Approximately **81M USD** will be required, **27M USD** for educational institutions and **54M USD** for health facilities.
- This strategy is foreseen to **reduce costs for electricity payments by approx. 1.76M USD per year** for facilities currently connected to the grid

Figure 1: Pictures of Ntjanini Clinic Main Building in Shiselweni Region

Introduction

Background

Electricity in Eswatini is mainly supplied by the vertically integrated state-owned electric utility Eswatini Electricity Company (EEC), formerly Swaziland Electricity Company (SEC). EEC is responsible for generating, transmitting, distributing, importing and supply of electricity. While the company enjoys monopoly status especially on transmission and distribution, some aspects of these functions have been parcelled out to other agencies, especially generation. In 2018, the country inaugurated a comprehensive Independent Power Producers (IPP) policy to guide investments in electricity generation, especially renewable energy like solar, by private developers.[6]

The development of these legislations is geared at increasing the national capacity, which currently stands at 185 MW[7] against a peak demand of approximately 233 MW[8] in 2021 and expected to rise to 330 MW[9] by 2025. The bulk of the deficit is supplemented by imports mostly from Eskom in South Africa and Mozambique. EEC has a total installed capacity of approximately 60MW, mainly from four hydro generation plants and is responsible for supplying in the order 15% to 17% of national electricity consumption.[10] The hydro plants owned by EEC are Maguga (19.8 MW), Ezulwini (20 MW), Edwaleni (15 MW) and Maguduza (5.6 MW)[11]. The other electricity generated nationally comes from five independent power producers (IPPs), especially sugar companies, which utilize biomass to generate electricity mostly for self-consumption. In total, only approximately 40% (624 GWh) of electricity consumed in Eswatini in 2021 was locally generated, with the remaining 60% (901 GWh) being imported from South Africa.[12]

Eswatini has set ambitious targets to increase its renewable electricity base. At the COP 26 Eswatini pledged to increase its share of renewable energy by 50% by 2030 relative to 2010 levels. The current economic crisis and, especially, the energy crisis in South Africa, accompanied by significant spikes in prices for production, distribution, wholesale and retail commerce, have reinstated an even stronger emphasis of the existing national priorities of Eswatini for achieving relevant SDGs and national priorities related to climate and environmental sustainability, including increasing energy efficiency practices, decreasing carbon emissions and footprint overall, and reducing dependence on energy from carbon fuels. These determinations, coupled with UNICEF's well-established experience in facilitating the provision of alternative energy solutions to health facilities worldwide, have given rise to an initiative, supported by the Ministry of Health and Ministry of Education as its principal beneficiary, to investigate the feasibility and the opportunities for alternative power supply options for the primary health facilities (PHCFs) and schools in the country.

Table 1: Eswatini Electricity Sector Statistics[13]

Key Indicator	Value
Peak Demand 2021/22	233 MW
Installed Capacity	
Eswatini Electricity Company	

[6] ibid
[7] ESERA. (2023). Electricity Sector, Eswatini Energy Regulatory Authority.
[8] ibid
[9] GET Invest. (2023). Eswatini Market Information, Get Invest
[10] USAID. (2023). Eswatini, Power Africa Fact Sheet, United States Agency for International Development.
[11] ibid
[12] ESERA. (2023). Electricity Sector, Eswatini Energy Regulatory Authority.
[13] ibid

Key Indicator	Value
Hydro	60.5 MW
Solar	10 MW
Ubombo Sugar Limited (USL)	
Thermal	40.5 MW
Hydro	1 MW
Royal Eswatini Sugar Company Limited (RESCL)	
Thermal	65.5 MW
Wundersight Investment	
Solar PV	0.1 MW
Small Scale Embedded Generation	
Mostly Solar PV	17.4 MW
Electricity Profile 2021/22	
Local Generation	624.4 GWh
Imported Generation	901.1 GWh
Total Energy	1527 GWh
National Electrification	
National Electricity Access	85%

Eswatini has one of the highest electricity access rates in Sub-Saharan Africa, at 85%[14] according to the state utility EEC. The Electricity Sector Regulatory Authority (ESERA) plays a crucial role in the management of electricity in Eswatini. As a category 1 state agency established by the Energy Act of 2007[15], ESERA has various responsibilities, one of which includes regulating electricity tariffs. Currently, the bulk of domestic consumers are charged below US$0.10 per unit (kWh)[16] due to ESERA's efforts.

Objective

The main objective of this investment case is to present an overview of the funding gap, system requirements and implementation modalities required to fully electrify education and health facilities in Eswatini using solar power.

Methodology

To develop this investment case, UNICEF has:

1. Developed a Renewable Energy (RE) Sizing Tool that enables any UNICEF staff, even those without prior technical knowledge, to conduct surveys of health and education facilities for the purposes of solarization, and subsequently estimate system as well as funding requirements.
2. Selected 48 public education facilities and 39 public health facilities in four regions—Hhohho, Manzini, Lubombo and Shiselweni—in Eswatini were surveyed including 27 primary schools and 21 secondary/high schools. All health facilities visited were clinics. The facilities were selected based on WASH- and immunization-related activities having previously been carried out at these facilities by UNICEF.
3. Conducted surveys for solarization at the 87 facilities from November 15th to December 2nd 2022 for health facilities and, 8th and 14th March 2023 for education facilities.

[14] ESERA. (2023). Electricity Sector, Eswatini Energy Regulatory Authority.
[15] ESERA. (2023). About Us, Eswatini Energy Regulatory Authority.
[16] GET Invest. (2023). Eswatini Market Information, Get Invest

4. Extrapolated data from the 87 surveys conducted to generate a country-wide investment case. This extrapolation is also further discussed during the individual sections in the Investment Case chapter.

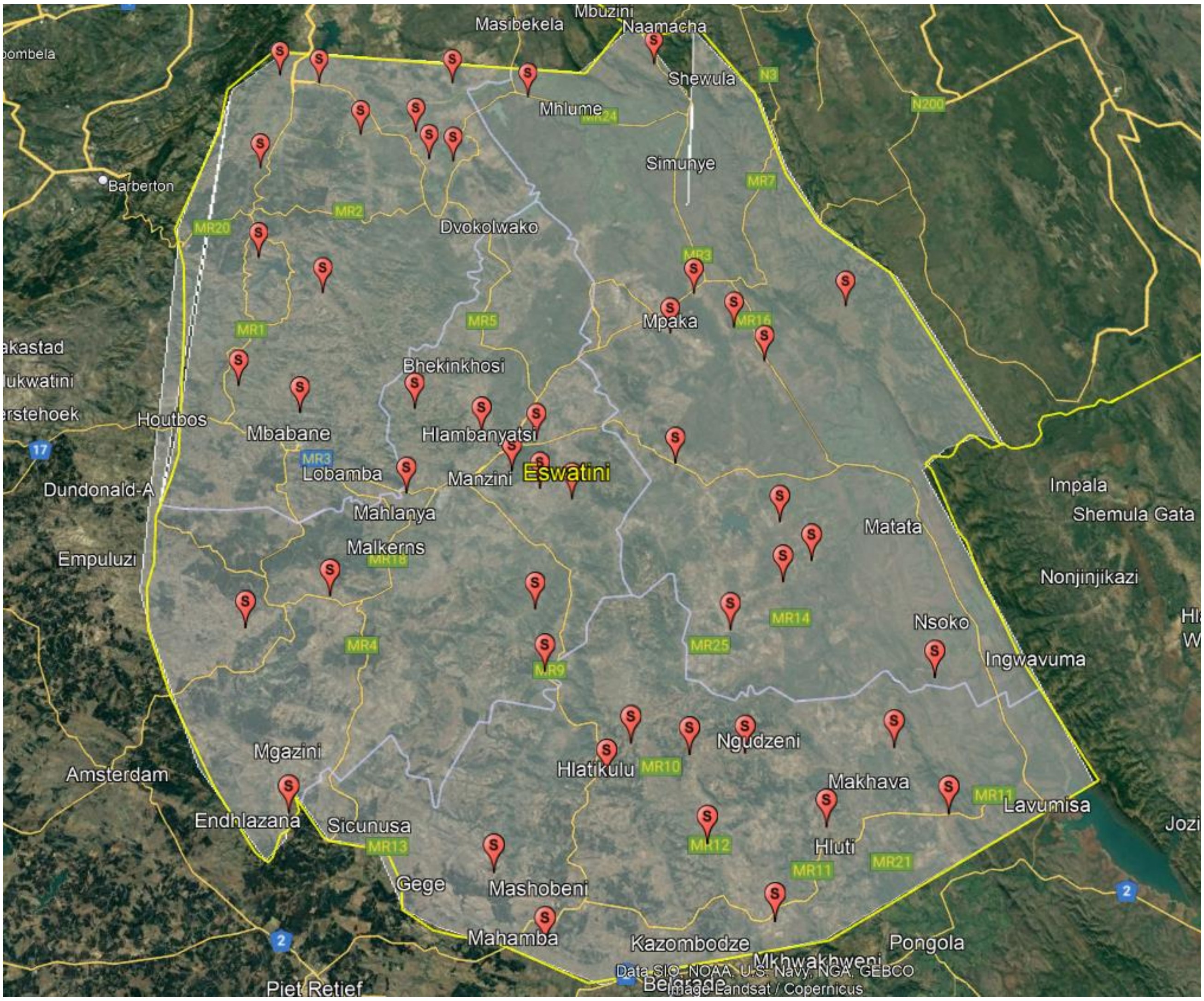

Figure 2: Schools surveyed in Eswatini

Investment Case for sustainable energy in health and education facilities in Eswatini

Categorisation of education and health facilities in Eswatini

Based on data obtained from UNICEF there are approximately 327 health facilities and 909 education facilities in Eswatini. Nearly 70% (628 schools) of the education facilities are primary schools. All the education facilities—both primary and secondary—have varying number of students depending on location`s population size and the infrastructure available in the school. For the purposes of this investment case, schools have been categorized by size as follows:

- ***Category I***: Schools—both primary and secondary—hosting at most 150 students;
- ***Category II***: Schools—both primary and secondary—hosting at least 150 students and a maximum of 350 students; and
- ***Category III***: Schools—both primary and secondary—hosting more than 350 students.

Table 2: Total number of education facilities in Eswatini by category

	Number of students		Primary schools	Secondary schools	Total schools
Category I Education Facility	0	150	70	28	98
Category II Education Facility	151	350	269	90	359
Category III Education Facility	351	Above	289	163	452
Total			628	281	909

Health facilities are quite varied in sizes and functions. There are three types of health facilities—hospitals, health units and clinics—with quite significant distinctions per category. 91% (297) of the facilities can be categorized as clinics though not identical in functionalities and size. A breakdown of these can be seen from the table below.

Table 3: Categories of Health facilities in Eswatini

Facility Type	Number of Facilities
Hospitals	
National Referral Hospital	1
Regional Referral Hospital	5
Specialised Hospital	3
Private Hospitals	9
Health Centres	
Health Center	5
Public Health Unit	7
Clinics	
Clinic with maternity	29
Clinic without maternity	203
Specialised Clinics	65
Total number	**327**

Surveys carried out

The health and education facilities surveyed were intended to represent a mixture of the different categories. This objective was achieved for education facilities, where all categories at the primary and secondary level were surveyed. In total, 48 education facilities were surveyed, as disaggregated in the table below.

Table 4: Type and number of schools visited

Category	Primary Schools	Secondary Schools	Total
Category I (0-150 Students)	3	3	6
Category II (151-350 Students)	13	4	17
Category III (350+ Students)	11	14	25
Total	27	21	48

For the health facilities, only clinics were surveyed, given that they form the bulk of all health facilities. 39 clinics were surveyed. A list of all education and health facilities surveyed are annexed in Annexes 1 and 2 respectively.

The surveys were carried out in four regions in Eswatini from 8th to 14th March 2023 for the education facilities, and in 2022 for the health facilities, using different survey tools. Education institutions were surveyed using a dedicated RE sizing tool developed by UNICEF for this purpose while a sizing tool developed by the UNICEF HQ was used for health facilities. The RE Sizing Tool allows offline data collection using the ODK Data Collection app. The data is then submitted using the app and automatically populates an Excel sheet that sizes PV systems, including batteries and inverters. This Excel sheet is shared with the surveyor via email.

The survey questions[17] contained in the data collection tool covered aspects such as:

- Contact data of facility, interviewee and location
- Accessibility of the institution
- Building sizes and structure
- Current energy supply
- Water supply, demand and WASH-related questions
- Appliances and their usage

Figure 3: Ethembeni Secondary School in Manzini Region

[17] See Annex for a comprehensive list of questions

Electricity demand at health and education facilities

Based on the survey data obtained from the facilities, “representative facilities” were developed for each category of facility. Such a representative facility would contain all the typical appliances used by such facilities and is sized adequately to be able to offer the services as required. For education facilities, we developed four categories of “representative facilities” as:

- Category I Primary and Secondary schools since they had similar appliances;
- Category II and III primary schools given the identical nature of their appliances;
- Category II secondary schools; and
- Category III secondary schools.

The difference in Category II and III secondary schools was largely due to:

- Category III secondary schools had more desktop computers as a result of their numbers; and
- Category III schools seems to be offering some technical education.

All health facilities had a similar number of appliances and size, therefore these are considered within the same category.

The breakdown in appliances for all these categories is as shown in the tables below.

Table 5: Representative appliances in Category I Primary and Secondary facilities

Appliances	Units	Power rating	Hours of usage	Daily Wh
Freezer	1	45	24	1,080
Photocopier	1	65	4	260
Computer	1	60	4	240
Total				**1,580**

Table 6: Representative appliances in Category II and III Primary Facilities

Appliances	Units	Power rating	Hours of usage	Daily Wh
Printers	2	65	1	130
Fridge	2	45	24	2,160
laptops	2	30	8	480
Desktop	2	60	6	720
Total				**3,490**

Table 7: Representative appliances in Category II Secondary Facilities

Appliances	Units	Power rating	Hours of usage	Daily Wh
Photocopier	2	65	6	780
Desktop	30	60	5	9,000
Fridge	1	45	24	1,080
Printers	2	65	1	130
Total				**10,990**

Table 8: Representative appliances in Category III Secondary Facilities

Appliances	Units	Power rating	Hours of usage	Daily Wh
Photocopier	1	65	3	195
Computers	41	60	6	14,760
Laptops	12	30	3	1,080
Printers	4	65	3	780
Fridge	3	45	24	3,240
Hand drill	1	450	1	450
Router	1	176	1	176
Grinder	1	1,000	1	1,000
Total				**21,681**

Table 9: Summary of appliances` for all Education Facilities

Category of Education Facility	Total Daily Wh
Primary and Secondary Category I	1,580
Primary Category II and III	3,490
Secondary Category II	10,990
Secondary Category III	21,681

Table 10: Appliances in Health Clinics in Eswatini

Appliances	Units	Power rating	Hours of usage	Daily Wh
Neo-natal incubator 1,000 W	1	1,000	4	4,000
Countertop autoclave (steam sterilizer) (30 L) 2,500 W	2	2,500	2	10,000
Printer, laser (in use) 500 W	1	500	2	1,000
Refrigerator (AC) 250 Ltr 70 W	1	70	24	1,680
ComputersICT	8	60	3	1,440
Printer, Inkjet (In use) 40 W	1	40	3	120
Printer, laser (in use) 500 W	3	500	2	3,000
Vaccine Refrigerator (SDD) 30 W	1	30	24	720
Vaccine Freezer (AC) (250ltr) 175 W	1	175	24	4,200
Centrifuge 200 W	1	200	2	400
CD4 counter 100 W	1	100	2	200
Refrigerator (AC) 250 Ltr 70 W	1	70	24	1,680
2 Ton air conditioner 2000 W	1	2,000	24	48,000
Portable electric space heater 2000 W	1	2,000	3	6,000
Desktop computer (small display) 60 W	1	60	2	120
2 Ton air conditioner 2000 W	3	2,000	3	18,000
Water Kettel 2000 W	1	2,000	2	4,000
TV LED Approx 37' 60 W	4	60	6	1,440
Refrigerator (AC) 400 Ltr 80 W	4	80	24	7,680
Electronic Delivery Bed	2	35	4	280

Appliances	Units	Power rating	Hours of usage	Daily Wh
Vital Sign Monitor	1	150	3	450
Digital BP Machine	1	15	3	45
Wall Heater	1	2,000	4	8,000
Internet Router	1	50	24	1,200
Total				**123,655**

Renewable energy system sizing

Based on the representative health and education facilities, utilising the RE Sizing Tool, adequately-sized solar PV systems for each of the system sizes were developed. For the derivation of these systems, it was considered that:

- During the month with the worst level of solar irradiation, the system still generates 20% of excess electricity to accommodate for potential demand peaks and demand growth
- The sizing additionally considers a growth of the load by 25% compared to the original representative load for purposes of longevity of the system
- The batteries are based on Lithium-Ion technology, with a depth of discharge of 80%
- The battery bank allows for autonomy of the system for a minimum of 12h in case of cloudy days or days with reduced solar irradiation

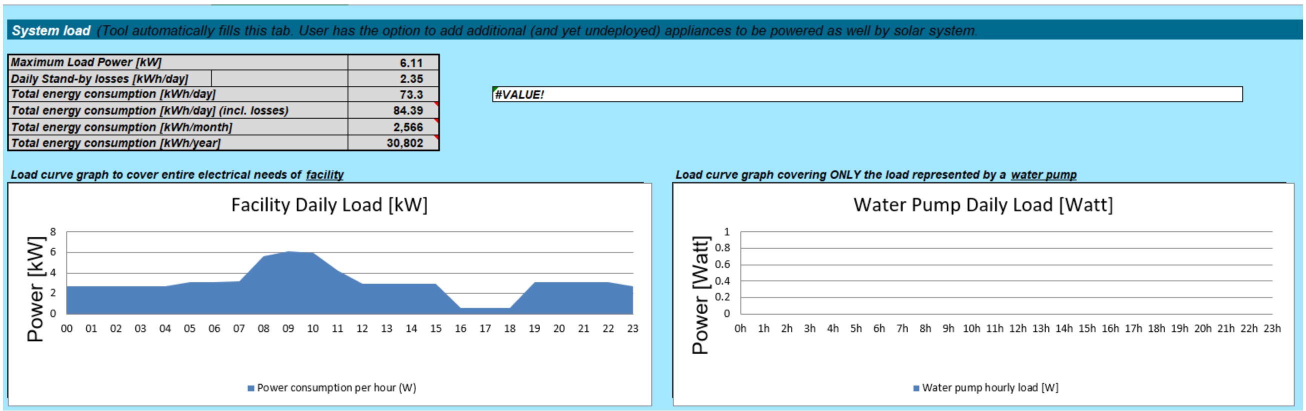

Figure 4: Screenshot of the RE Sizing tool

Utilising the RE Sizing Tool, the following system sizes were derived for facilities in Eswatini.

Table 11: Capacity of Solar PV system for respective facilities in Eswatini

Facility	Solar PV Size (kWp)	Battery Size (kWh)	Minimum inverter power (kW)	Recommended inverter size (kW)
Primary and Secondary Category I	5.1	7.9	2.9	3
Primary Category II and III	9.3	14.6	2.9	3
Secondary Category II	11.4	17.9	4.3	5
Secondary Category III	35.7	55.4	9.8	18
Clinics	80.6	126.6	14	40

Given the existing rates of electrification in Eswatini, we assumed that under the worst scenario only about 10% of facilities are unelectrified. We assumed a uniform distribution of unelectrified facilities across all categories. Applying the values obtained from the sizing tool for each representative facility to the unelectrified facilities, we find that it will require 3.7 MW of solar PV, 5.7 MWh of battery capacity and 1.7 MW inverter capacity to fully electrify all the remaining facilities. Clinics will require the bulk (66%) of this capacity. This is largely due to the high energy requirement compared to schools. A typical clinic will need more than double the capacity of the highest rated education facility.

Table 12: Solar PV System capacity for all unelectrified facilities in Eswatini

Facility	Solar PV Size (kWp)	Battery Size (kWh)	Minimum inverter power (kW)	Recommended inverter size (kW)
Primary and Secondary Category I	51	79	29	30
Primary Category II and III	520.8	817.6	162.4	168
Secondary Category II	102.6	161.1	38.7	45
Secondary Category III	571.2	886.4	156.8	288
Clinics	2,418	3,798	420	1,200
Total	**3,663.6**	**5,742.1**	**806.9**	**1,731**

We have further calculated the capacity required to solarise all health and education facilities in the country, thus attaining 100% solar PV electrification in these facilities. This is viable given the fact that Eswatini imports most of its electricity from South Africa's sole electric utility, Eskom, which is facing significant capacity constraints. More than 80% of Eskom's generation is currently also drawn from coal. In this scenario, the capacity of solar PV, storage, and other balance of system (BOS) equipment is as shown in the table below.

Table 13: Capacity of Solar system required under a 100% electrification scenario

Facility	Solar PV Size (kWp)	Battery Size (kWh)	Minimum inverter power (kW)	Recommended inverter size (kW)
Primary and Secondary Category I	500	774	284	297
Primary Category II and III	5,189	8,147	1,618	1,674
Secondary Category II	1,026	1,611	387	450
Secondary Category III	5,819	9,080	1,597	2,934
Clinics	24,180	37,980	4,200	12,000
Total	**36,714**	**57,542**	**8,087**	**17,352**

Financial requirements

To electrify the health and education facilities, the following CAPEX and OPEX costs were assumed as a baseline. This baseline represents what a facility would likely spend if it was to procure equipment on its own, i.e. without engaging in bulk procurement.

Table 14: CAPEX and OPEX baseline costs as well as lifetime for various solar PV system components

Item	Solar PV (incl. mounting system)	Battery (Lithium-Ion)	(Hybrid) inverter	Others (remote monitoring, transport to site and wiring, not including labour)
CAPEX	350 USD/kW	425 USD/kWh	386 USD/kW	Between 2,432 USD and 15,203 USD depending on system size

OPEX	7 USD/kW/year	10 USD/kWh/year	7.72 USD/kW/year	Between 1,341USD and 12,323 USD for the first five years (total) depending on system size
Lifetime	20 years	15 years	10 years	20 years

It is then assumed that economies of scale will further reduce the costs of the solar PV system components (by 5% for solar PV and batteries and 10% for inverters). To install, operate and maintain the solar system for a period of 20 years will cost in the order of USD 8,103,174. This is inclusive of CAPEX and OPEX costs. OPEX costs include costs of replacing equipment and components like inverters after 10 years and other ancillary services required to ensure the equipment is fully functional all the time.

Table 15: Total CAPEX costs for solar PV systems for public facilities in Eswatini

Item	Solar PV (incl. mounting system)	Battery (Lithium-Ion)	(Hybrid) inverter	Others (remote monitoring, transport to site and wiring, not including labour)
CAPEX (USD)	1,282,260	2,440,393	668,166	802,722
OPEX (USD)	512,904	861,315	935,432	599,982
Total (USD)	**1,795,164**	**3,301,708**	**1,603,598**	**1,402,704**

A breakdown of individual costs for health facilities and educational institutions is shown in the tables below. Health facilities though numerically less that education institutions will gobble a majority of the investments because of their significantly higher power and energy requirements.

Table 16: CAPEX and OPEX costs for education institutions under a 10% scenario

Item	Solar PV (incl. mounting system)	Battery (Lithium-Ion)	(Hybrid) inverter	Others (remote monitoring, transport to site and wiring, not including labour)
CAPEX (USD)	438,700	831,393	206,587	267,574
OPEX (USD)	175,480	283,651	289,222	200,001
Total (USD)	**614,180**	**1,115,044**	**495,809**	**467,575**

Table 17: CAPEX and OPEX costs for health institutions under a 10% scenario

Item	Solar PV (incl. mounting system)	Battery (Lithium-Ion)	(Hybrid) inverter	Others (remote monitoring, transport to site and wiring, not including labour)
CAPEX (USD)	846,300	1,614,150	463,200	535,148
OPEX (USD)	338,520	550,710	648,480	400,039
Total (USD)	**1,184,820**	**2,164,860**	**1,111,680**	**935,187**

Insofar as the second scenario—100% solar PV electrification for all facilities—is concerned, the capital investments and operation costs are summarized below.

Table 18: CAPEX and OPEX under 100% scenario

Item	Solar PV (incl. mounting system)	Battery (Lithium-Ion)	(Hybrid) inverter	Others (remote monitoring, transport to site and wiring, not including labour)
CAPEX (USD)	12,850,005	24,455,435	6,697,872	8,027,220
OPEX (USD)	5,140,002	8,631,330	9,354,320	5,999,820
Total (USD)	**17,990,007**	**33,086,765**	**16,035,980**	**14,027,040**

These can further be broken down by category of institutions. Health facilities will take approximately two-thirds of these investments, 54M USD while educational institutions will take the remaining third, 27M USD, as show in the following tables.

Table 19: CAPEX and OPEX for Education Institutions under 100% scenario

Item	Solar PV (incl. mounting system)	Battery (Lithium-Ion)	(Hybrid) inverter	Others (remote monitoring, transport to site and wiring, not including labour)
CAPEX (USD)	4,387,005	8,313,935	2,065,872	2,675,740
OPEX (USD)	1,754,800	2,836,519	2,892,221	2,000,010
Total (USD)	**6,141,805**	**11,150,454**	**4,958,093**	**4,675,840**

Table 20: CAPEX and OPEX for Health facilities under 100% scenario

Item	Solar PV (incl. mounting system)	Battery (Lithium-Ion)	(Hybrid) inverter	Others (remote monitoring, transport to site and wiring, not including labour)
CAPEX (USD)	8,463,000	16,141,500	4,632,000	5,351,480
OPEX (USD)	3,385,200	5,507,100	6,484,800	4,000,399
Total (USD)	**11,848,200**	**21,648,600**	**11,116,800**	**9,351,879**

Impact on fuel and CO2 emissions

It is further estimated that, compared to powering the facilities with diesel gensets, the installation of solar PV systems to the unelectrified facilities can result in savings of approximately **25 million litres of fuel** and **67,813 tons of CO2 emissions** over the lifetime of the systems.

Table 21: Savings in fuel and CO2 emissions for solar PV systems on all facilities to be electrified

Facility	Savings in CO2 emissions [tons/year]	Savings in diesel consumption [litres/year]	Savings in CO2 emissions [tons/20 years)	Savings in diesel consumption [litres/20 years)
Primary and Secondary Category I	46	17,262	928	345,236
Primary Category II and III	482	179,243	9,643	3,584,857

Facility	Savings in CO2 emissions [tons/year]	Savings in diesel consumption [litres/year]	Savings in CO2 emissions [tons/20 years)	Savings in diesel consumption [litres/20 years)
Secondary Category II	95	35,333	1,900	706,663
Secondary Category III	523	194,539	10,467	3,890,770
Clinics	2,244	834,034	44,874	16,680,690
Total	3,391	1,260,410	67,813	25,208,218

Under the second scenario, where all facilities are to be solarised, a significant reduction in CO_2 emissions is observed. This scenario assumes a situation where the electrified facilities are powered by diesel-based fuel but in reality, this might not be the case. However, given that majority of electricity purchased is produced using coal, these figures are indicative of the savings that would be experienced.

Table 22: Emissions reduction under 100% scenario

Facility	Savings in CO2 emissions [tons/year]	Savings in diesel consumption [litres/year]	Savings in CO2 emissions [tons/20 years)	Savings in diesel consumption [litres/20 years)
Primary and Secondary Category I	455	169,166	9,904	3,383,315
Primary Category II and III	4,804	1,786,027	96,088	35,720,545
Secondary Category II	950	353,332	19,008	7,066,637
Secondary Category III	5,332	1,981,861	106,635	39,637,227
Clinics	22,437	8,340,345	448,740	166,806,906
Total	33,978	12,630,731	679,565	252,614,630

By replacing grid electricity in these facilities, it is estimated that electricity payments of about 1.76M USD per year can be avoided. The current electricity tariff in Eswatini is around 0.055 USD/kWh and the facilities are consuming a combined 33,000 kWh of electricity per day.

When implementing the project, certain aspects may be considered to reduce required costs:

- If there is no provision made for future growth of the demand (set at 25% growth in the base case), it may be assumed that CAPEX and OPEX costs can be reduced by 25%; However, this would mean that facilities will be unable to add additional appliances beyond those already covered in the survey.
- If excess electricity is reduced from the current 20%, CAPEX and OPEX costs will fall linearly with the reduction of excess electricity; However, this may result in the system not generating sufficient electricity to meet the entire demand on days when weather conditions are not favourable, for example during cloudy days or rain.
- Current system autonomy is set at 12h, meaning that the battery is large enough to supply electricity to the facility for a minimum of 12h without sunshine. This could be increased, however with significant impact on the overall system cost. Any doubling of the system autonomy would result in a doubling of the battery CAPEX, which already represents the majority of the CAPEX cost.

There are additional minor tweaks that can impact the system design, such as altering the battery bank depth of discharge. However, these cannot be expected to result in significant differences to the overall design.

Risks and mitigation

Implementing solar projects for health and education facilities in Eswatini has the potential to significantly improve the quality of health and education services delivered. Some of the potential risks in implementing solar projects as well as mitigative measures that could be taken to minimize or eliminate these risks include:

Technical risks

One of the main technical risks associated with solar projects is that they may fail to deliver the expected levels of power output due to equipment malfunction, damage or wear and tear. To mitigate this risk, regular maintenance and repair of the solar panels and other equipment will be required. This also requires planning for suitable operational and maintenance procedures, personnel and budget from the start of the project. Additionally, investing in high-quality equipment and partnering with reputable suppliers can help to reduce the likelihood of technical failures.

Financial risks

There is a risk that the facilities do not have sufficient budget to cover ongoing operational costs as well replacements of equipment. Planning for this budget from the start of the project as well identifying potential additional sources of funding, such as grants or loans, can help reduce this risk.

Implementation and social risks

Solar projects may disrupt the local community's way of life, especially in areas facing other social hardships and pressures. Eswatini is expected to be a relatively calm society with little to non-existent political activity which may delay the process. No serious social risk is contemplated in this process. The minor ones not foreseen, can be mitigated by community engagement and participation during installation.

Environmental risks

There is a risk that solar projects may have unintended negative impacts on the environment, such as increased water usage for cleaning solar panels, lack of recycling facilities and therefore land waste following the breakdown of old equipment. To mitigate this risk, it is important to use sustainable practices, such as water conservation and proper disposal of equipment, where possible, and to monitor the environmental impact of the project over time.

Topographical risks

Eswatini is a very hilly and mountainous place with some facilities siting on undulating landscapes. This would have caused a challenge is the solar systems were to be grounded as it would have necessitated extensive ground excavation but since there are existing roofs, the solar systems can be roof-mounted which reduces the topographical risks substantially.

Recommendations and next steps

Donor-funded initiatives for solar systems in public health facilities and schools typically prioritise the costs of equipment alone. This upfront, mostly grant-based, model is driven by annual budgets, which donors are required to spend to raise funding for the following year. As in many other sectors, this model bears the danger of systems not being operated and maintained adequately, especially if no funding has been set aside to cover ongoing OPEX costs, and there is a lack of planning for who is supposed to maintain the systems and how.

Our recommendation is therefore for the systems to be installed with a particular emphasis on operations and maintenance. This may be achieved through considering the creation of Public Private Partnerships under an Energy Service Company (ESCO) approach. An ESCO is contracted by a customer to supply electricity to the customer over a long period of time (minimum of five years), and is guaranteed to be paid a certain fee as long as the service (electricity) provided meets agreed-upon minimum standards.

Under the ESCO model, the upfront costs for equipment and installation may be shared between the public or the donor as well as the private entity. The benefit of this model is that the ESCO is highly incentivized to continue supplying reliable electricity to the facility. The private entity could be further incentivised to invest in the system by allowing them, with their own funds, to increase the solar generation capacity and build distribution lines to nearby households and productive users, thus generating additional income from the project.

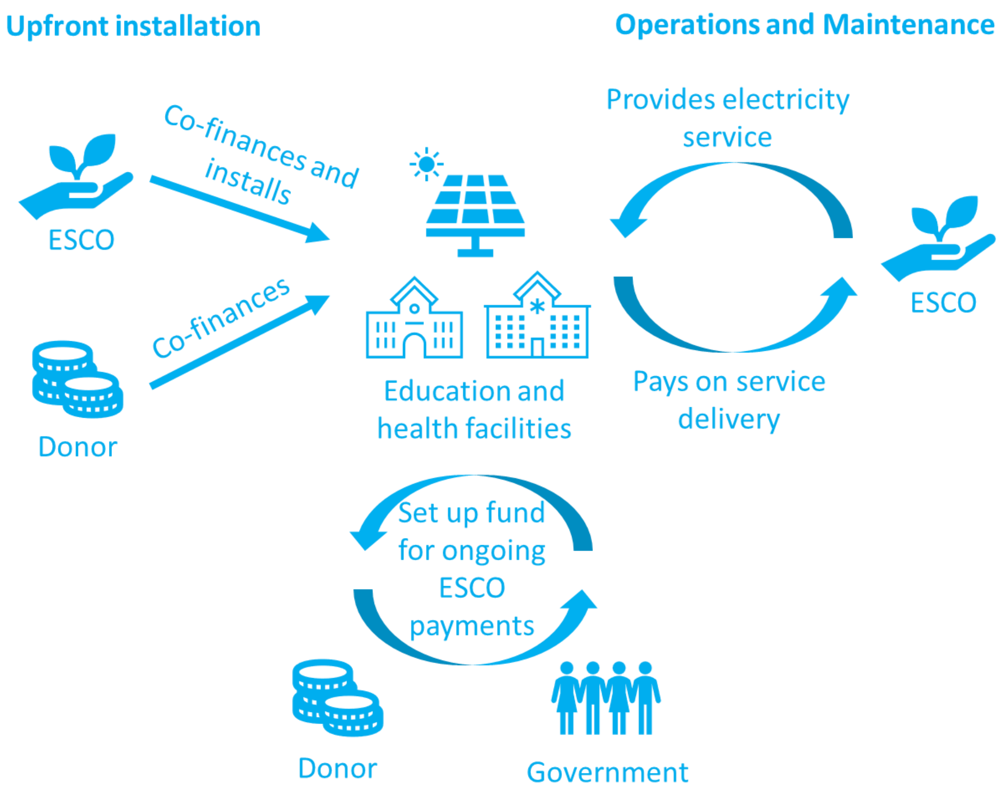

Figure 5: A Visualisation of the ESCO approach envisioned for the implementation and operation of the solar systems at public health and education facilities

UNICEF can play a pivotal role in developing this model for either all or part of the public facilities under this investment case. If successful, this model can then be replicated in other parts of world and specifically the ESARO region.

Delivering the same projects under an EPC model may be easier to arrange but can leave many questions unanswered, especially as relates to maintenance and management of the systems. If this model would be adopted, early engagement of local authorities from project design to implementation will be critical, and maintenance budgets that ought to be set aside from the start.

ANNEX

Annex 1: List of Schools Surveyed

School	Students	Category
Emvembili Primary	346	II
Hawane Secondary	289	II
Hereford high school	516	III
Luhlangotsini Lutheran Primary	280	III
Malandzela primary	694	III
Mangweni high	71	I
Mphofu secondary school	1039	III
Ndlalamphi Primary	501	III
Nyakatfo Nazarene Primary	669	III
Phakamani primary	132	I
Phophonyane Primary	178	II
Sikhunyane High school	368	III
St Philip's secondary school	250	II
Tshaneni primary school	891	III
Ngoni primary school	183	II
Mbokojweni primary school	752	III
Mpolonjeni secondary school	560	III
Nyambo primary school	252	II
Ekumeni primary school	312	II
High school for the deaf	80	I
Sibetsaphi secondary school	492	III
Maloyi primary school	962	III
Manyeveni Nazarene primary school	353	III
Duze high school	650	III
Ebaleni Primary School_0562	149	I
Elwandle Roman Catholic Primary School	350	II
Ethembeni High School_0557	300	II
Gundvwini High School _ 0395	850	III
Inyandza High School_0421	850	III
Lozitha High School_307	880	III
Luhlokohla Primary School_0344	310	II
Maliyaduma Primary School_0325	750	III
Nokuthula Alliance Primary_0458	320	II
Sigombeni High School_0475	427	III
Sikanye High School	180	II
Zamani Primary School_0535	213	II
Christ the king primary	1100	III
Ebenezer high	905	III
Jerusalem high	360	III
Mazombizwe high	388	III
KaMzila primary	435	III

Mantambe primary	325	II
Matsanjeni Community primary	356	III
Mshengu high	363	III
Nkhugwini primary	262	II
Nsingizini high	116	I
Qomintaba primary	585	III
Siphondo Primary	96	I

Annex II: List of surveyed clinics

Name of Clinic	Grid Connection/AC Power
Bhawhini Clinic	Yes
Bhudla Clinic	Yes
Bulandzeni Clinic	Yes
Dwaleni	Yes
Dwalile	Yes
Ezindwendweni Clinic	Yes
Hhukwini Clinic	Yes
JCI Cloinoic	Yes
Khaphunga Clinic	Yes
Khuphuka Clinic	Yes
Kufikeni Clinic	Yes
Lomasha Clinic	Yes
Lundzi	Yes
Mafutseni Clinic	Yes
Magubheleni Clinic	Yes
Lobamba Clinic	Yes
Mambane Clinic	Yes
Mangcongco Clinic	Yes
Mangweni Clinic	Yes
Maphalaleni Clinic	Yes
Malindza Clinic	Yes
Mashobeni Clinic	Yes
Mkhulamini Clinic	Yes
Musi Clinic	Yes
Mzipha Clinic	Yes
Ndvwabangeni Clinic	Yes
Nhlangunjani Clinic	Yes
Newthulwane Clinic	Yes
Nkalashane Clinic	Yes
Nkonjwa Clinic	Yes
Nsalitje Clinic	Yes
Ntfonjeni	Yes
Ntjanini Clinic	Yes
Sidvokodvo Clinic	Yes
Vusweni Clinic	Yes
Sigcineni	Yes
Sinceni Clinic	Yes
Siphocosini Clinic	Yes
Tsambokhulu Clinic	Yes