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Enhanced Rural Resilience in Yemen
Joint Programme

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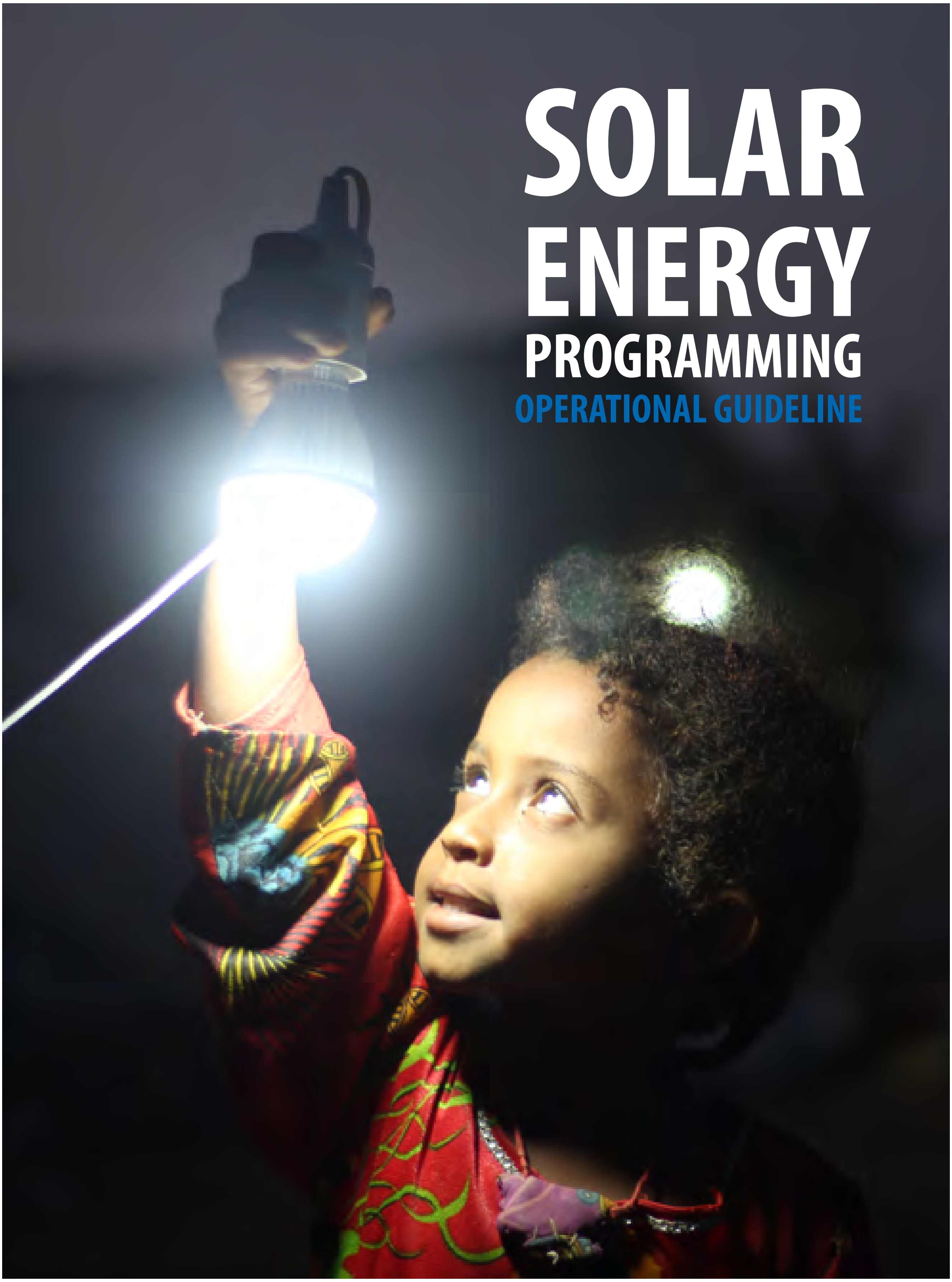
SOLAR ENERGY PROGRAMMING

OPERATIONAL GUIDELINE



SOLAR ENERGY PROGRAMMING

OPERATIONAL GUIDELINE

Submitted by:

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IDEAS FOR SUCCESS

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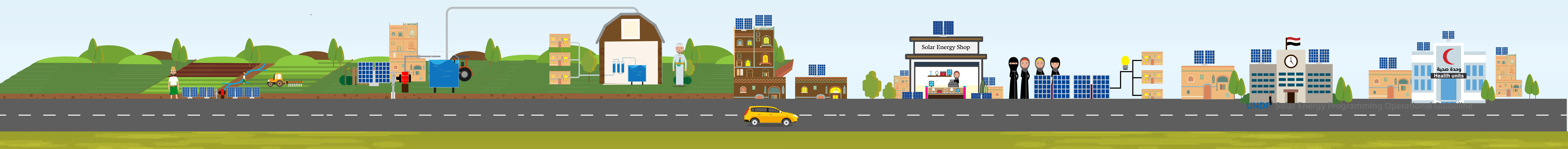
Abbreviations

AC	Alternating Current
AWD	Acute Watery Diarrhea
DC	Direct Current
DVD	Digital Video Disc
ERRY	Enhanced Rural Resilience in Yemen Programme
GARWSP	General Authority for Rural Water Supply
HFs	Health Facilities
HP	Hours Hour
LED	Light Emitting Diode
M&E	Monitoring and Evaluation
O&M	Operations and Maintenance
PSH	Peak Sun Hours
PV	Photovoltaic
TDH	Total Dynamic Head
TV	Television
UN	United Nations
UNDP	United Nations Development Programme
USD	US Dollar
W	Watt
WASH	Water, Sanitation, and Hygiene
WHO	World Health Organization
WMCs	Water Management Committees
WUAs	Water Users' Associations
YER	Yemeni Rial

Units of Measure

Ah	Ampere-hour
CO_2	Carbon dioxide
kVA	Kilovolt-ampere
kWh	Kilowatt hour
kWp	Kilowatt peak
Lm/W	Lumens per watt
m/s	Meters per second
MWp	Megawatt peak
V	Volt
Wh	Watt hour
Wp	Watt peak



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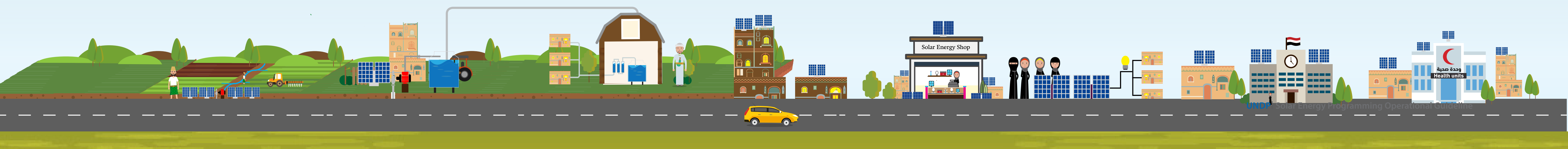
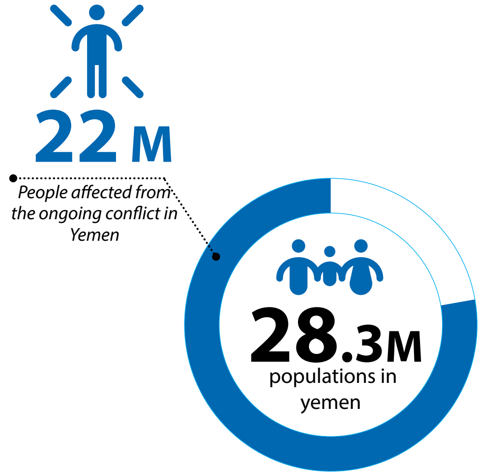
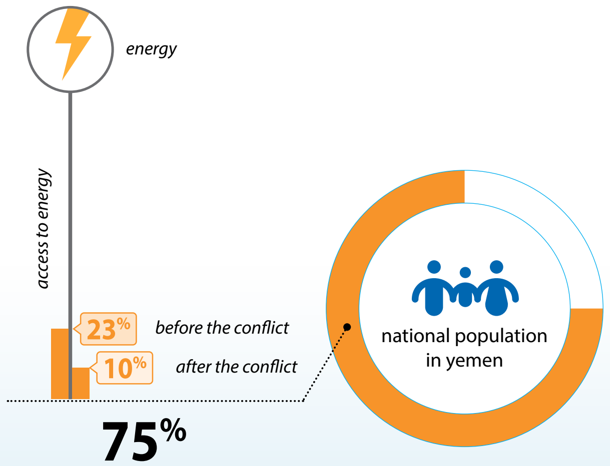


INTRODUCTION

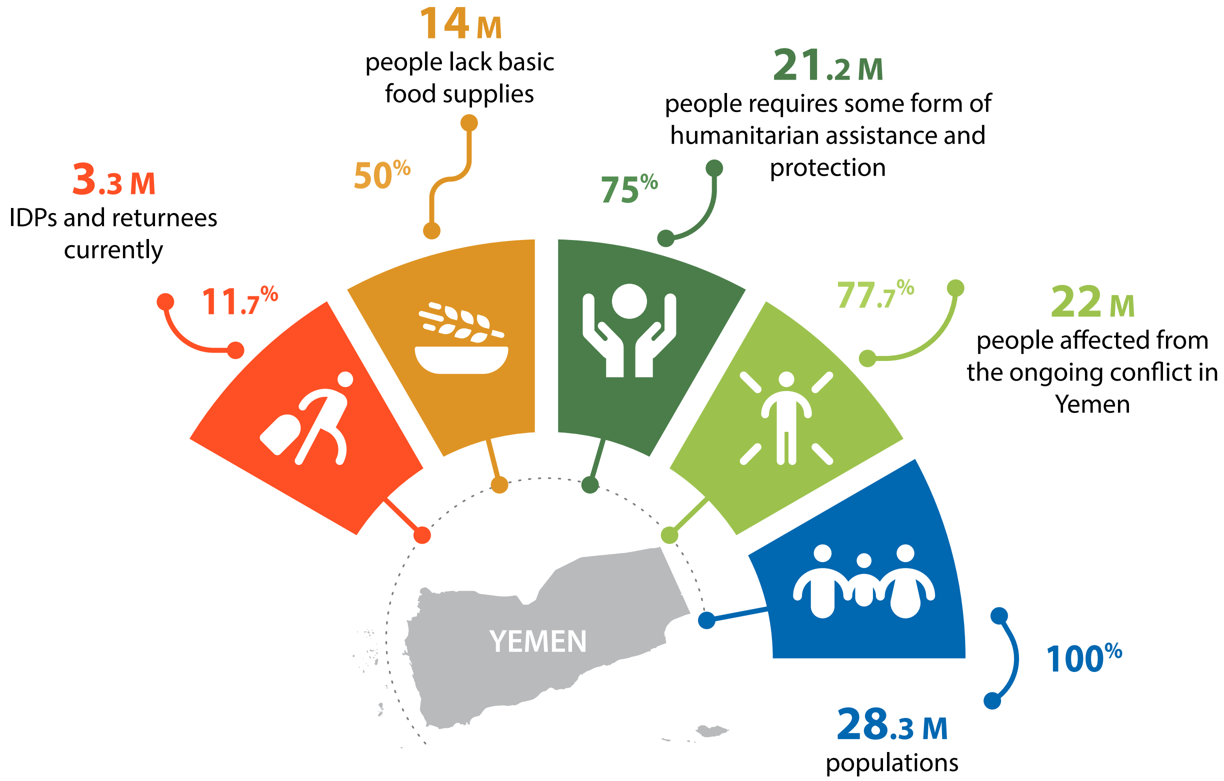
1. *Background*



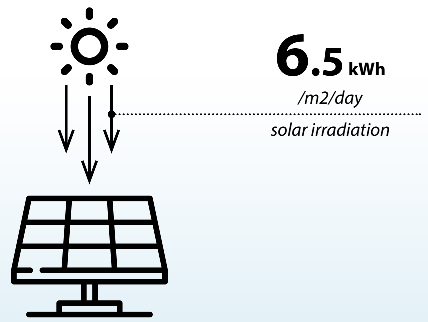
The ongoing conflict in Yemen has affected more than 22 million people out of the 28.3 million populations. Nearly 75 percent of the entire population requires some form of humanitarian assistance and protection, around 14 million people lack basic food supplies, making Yemen the world's most serious food insecurity crisis , and over 3.3 million IDPs and returnees currently, an unprecedented situation in the country›s history and now one of the world's most devastating humanitarian crises.



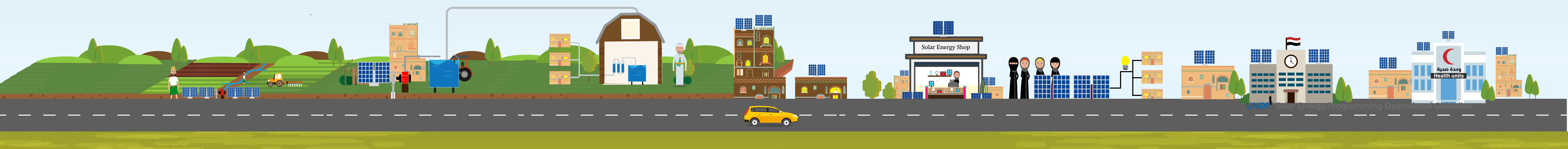
Yemen, is now one of the world's most energy insecure and poor country, with most of the country lacking sustainable access to energy. Even before the conflict, rural areas holding 75% of the national population had only 23% energy access rates.
The ongoing conflict has made the situation dramatically worse, it is estimated that the access to electricity had dropped to below 10 percent due to extensive damage to the national grid and fuel shortage across the country. In general, energy supply in Yemen for many years has been very limited due to weak generation capacity, limited access, high electricity losses from the grid, and increasing demand. Energy access in Yemen has been heavily dependent on local diesel generators to meet the needs of social services, businesses, as well as irrigation pumping needs of farmers. The collapse of electricity combined with price and the severe shortage of fuel needed to operate social services, businesses and household generators (for those who can afford them) has restricted most people access to basic social services such as healthcare, water supply, education, as well as lighting and the ability to power home electric appliances. Yemen is therefore left with the option of solar systems, serving better-off households, farmers, small to medium-sized enterprises; however, it is still used in small-scale.



Irradiation Data

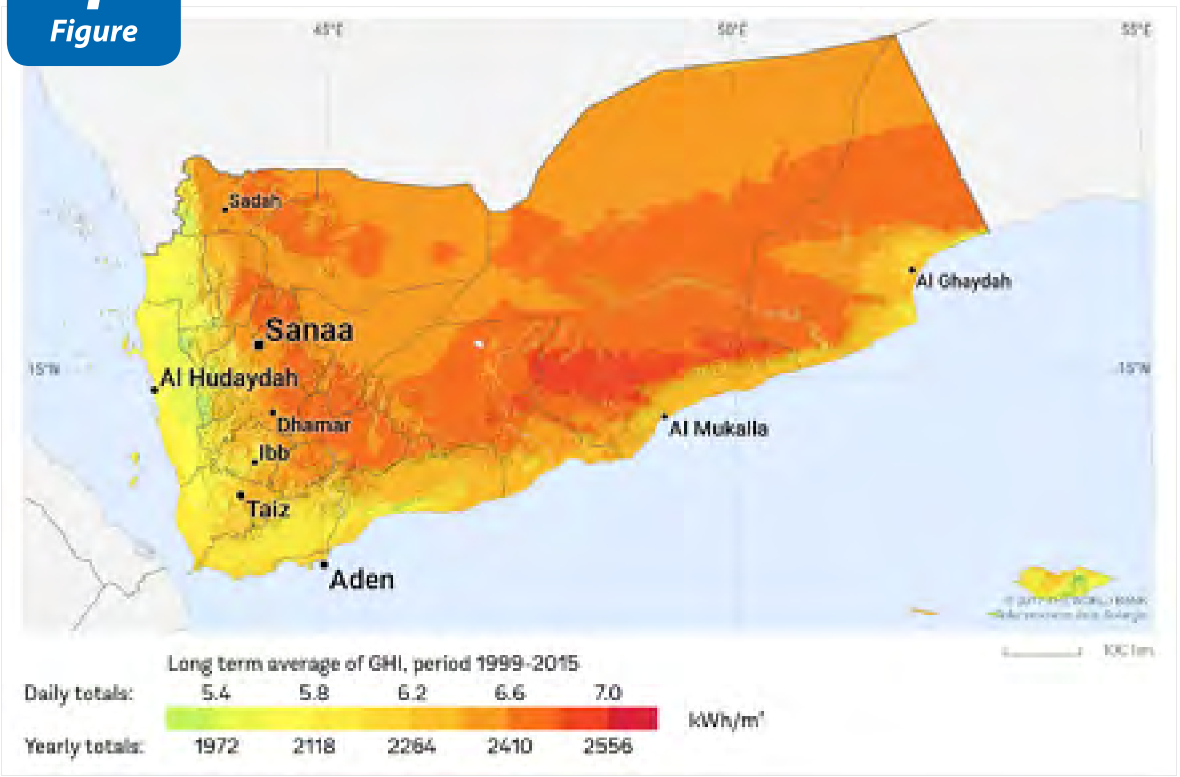


The very first prerequisite to utilize solar projects is the availability of solar resource. Yemen is one of the regions in the world with high levels of solar irradiation. The annual average global solar irradiation ranges from 5.2 to 6.8 kWh/m2/day.
High insulation levels are experienced in the highlands with the highest average of 6.8 kWh/m2/day in Al Beida and Dhamar governorates. Other areas in the highlands particularly in Sana›a, Ibb, Al-Dhale›e and southern parts of Amran and Marib have also very high irradiation levels ranging from 6.6 to 6.7 kWh/m2/day.



1 Figure

Yemen Solar Irradiation May



Source: World Bank: https://solargis.com/maps-and-gis-data/download/republic-of-yemen/

2. Purpose of this operational guideline

Some attempts to support affected communities by improving the access to solar energy have been implemented by many humanitarian and development agencies. Implementing agencies can follow the 'learn-as-you-go' approach, but this approach would be costly and time consuming, mainly in the conflict context, as most of the issues would have already been sorted out by someone else somewhere around the world or in Yemen.

UNDP-ERRY program have conducted a study to document good practices and lessons learned of solar energy application which includes details of targeted sectors, usages, cost effectiveness, efficiency, and sustainability and disaggregated impacts identified including on gender and captured as compendium document.

UNDP realized that there is a need to have an operational guideline that will support solar programming in other agencies, private sector, and local communities. The objective is to overcome the operational bottle necks and improve the impact at the community level.

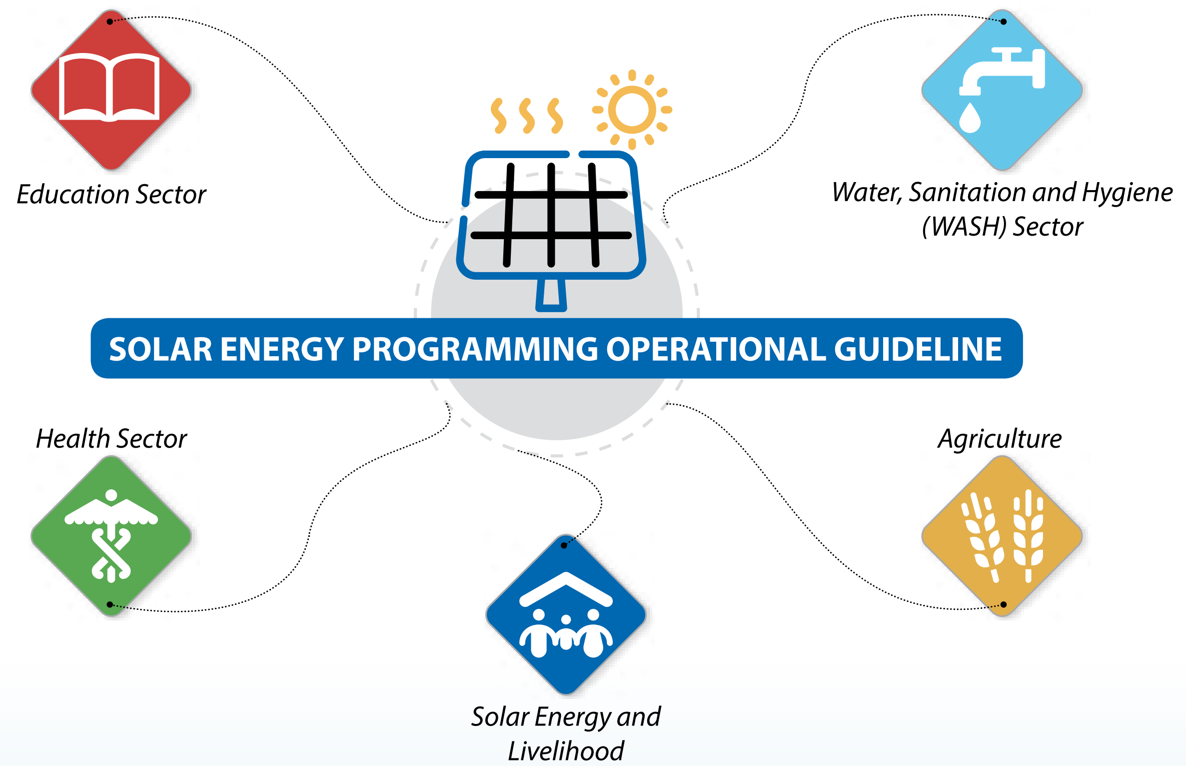
This operational guideline attempts to lay out a comprehensive and efficient solar PV systems implementation support process into a single document. It captures international and national good practices and learning. The guideline also captures how to program, plan, and implement the solar energy application in the conflict context with the emphasis on needs, bottlenecks/challenges and constraints for service providers and end users, external environment and security situation.

3. Operational Guideline Organization

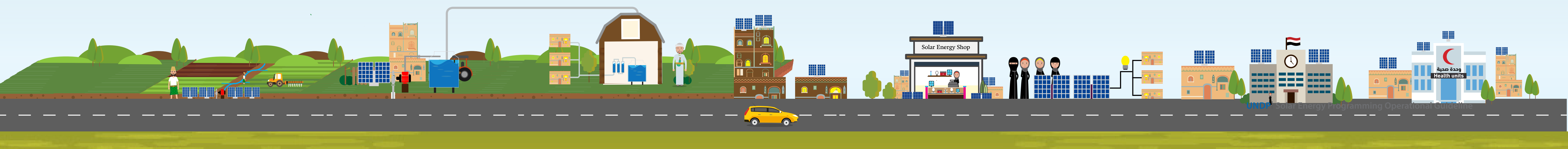
Sustainable energy is a critical element for achieving goals of immediate recovery and longer-term resilience in fragile and crisis contexts. Nowhere is this more apparent than in the Arab region, where countries have experienced an expansion of conflict, drought and an unprecedented level of displacement. The ability of communities to cope with and rapidly recover from crisis hinges in many ways on their ability to regain sustainable access to energy. Energy fuels communities access to water, to social services like health and education, to transport and communication needs, and is critical for regenerating livelihoods and local economies. But too often countries affected by crisis are unable to bring back online the type of energy systems needed for an effective recovery. In such contexts, decentralized energy solutions are now receiving greater attention, as a way of meeting the needs of affected communities and setting the foundations for resilience.

As countries seek new bridges between humanitarian and development interventions, and new resilience-based approaches to crisis recovery, the role of sustainable energy solutions has come into greater focus. Sustainable Development Goal 7 (SDG 7) on energy calls on countries to "ensure access to affordable, reliable, sustainable and modern energy for all." *

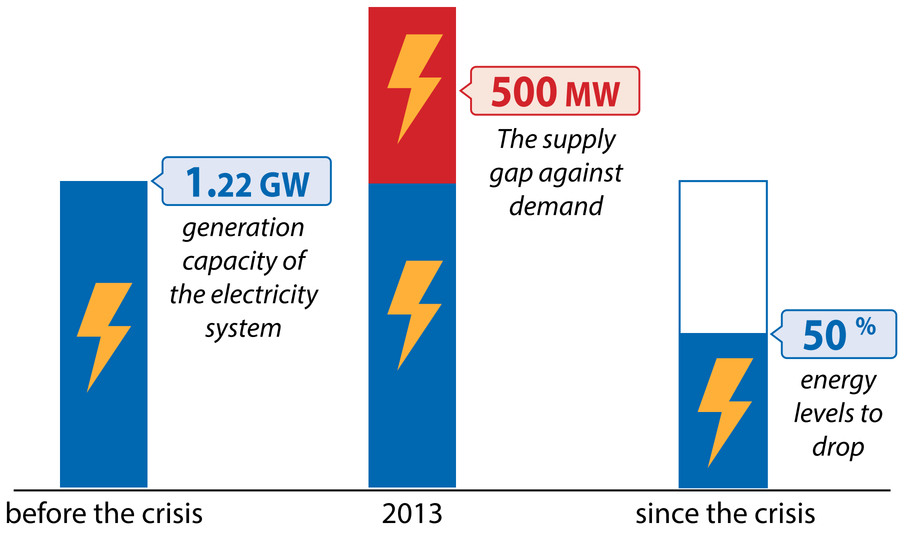
This document provides a guideline to execute solar programs It covers the how to implement solar programs, across different sectors. These sectors include educational facilities, health facilities, water pumping for households, water pumping for irrigation and households for lighting systems.



* UNDP Energy for Crisis Recovery in the Arab States.



Energy supply in Yemen is very limited nationwide in general



In rural areas, the increasing demand for energy and the limited availability of fuel is among the top challenges communities face. The total generation capacity of the Yemeni electricity system before the crisis was about 1.223 GW. The supply gap against demand was estimated at 500 MW in 2013. Damage to the energy sector since the crisis has caused energy levels to drop more than 50 percent, which in turn has affected the health, education, employment, water, solid waste management and private sectors, as well as vulnerable households, women and the poor. Rates of using fuel wood have increased rapidly, causing negative environmental impacts.

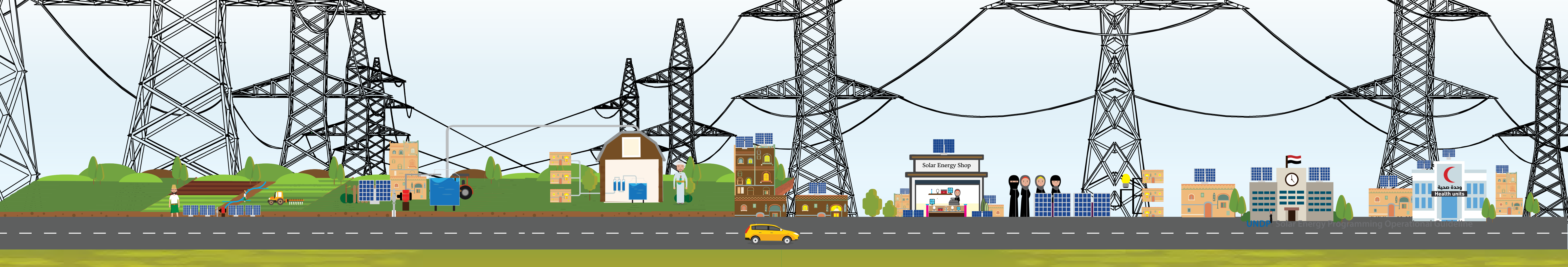
Before the conflict, the lives of the many Yemenis, especially in rural and peri-urban areas, were characterized by lack of access to basic infrastructure and service facilities. Impacts of the collapse of public electricity have been devastating: Electricity is becoming a binding constraint for critical service facilities that do not have the means to invest in alternative energy sources, including health facilities and vaccine cold chain, water supply and sanitation, food supply, banking services and more. Even where diesel generators have been adopted for emergency power supply during the conflict, fuel shortages are leading to severe constraints to service delivery, including in the water and health sectors where prolonged power outages are contributing to the spread of the Cholera epidemic . Businesses also cite electricity shortages as the second most important constraint after conflict and political instability. Continued lack of electricity access is likely to contribute to a decrease in productivity, deterioration of the business environment, and reduction in the country's GDP.

Particularly in rural and peri-urban areas, the collapse of electricity and fuel supplies has severely impacted employment and household incomes due to the dependence on agriculture and energy-intensive groundwater extraction for irrigation. Immediate effects on household budgets of the lack of electricity supply also include the increased dependency on scarcely available and expensive liquid fuels. Social impacts include limits to children's ability to study in the evenings and limited functionality of schools. The collapse of power supply and nighttime lighting has also added to security concerns, especially among women for whom the lack of lighting on the way to shared latrines exacerbates risks to gender-based violence (GBV). Due to the lack of electricity for water pumping, many rural households have been forced to travel long distances to fetch water – a task that falls disproportionately on women and children . Health effects on households include indoor air pollution from using liquid fuels to power appliances and kerosene for lighting, and reduced access to health services that depend on electricity. Fuel shortages have also caused prices to spike, with the price of cooking gas rising by 66 percent compared to pre-crisis times , and many women have reportedly resorted to cooking with plastic, which releases severely harmful chemicals. *

For each of the sectors, the following guideline addressed the targeting checks that can assure the best practices and build on the lessons learned from past-experiences. The parameters used to identify best practices include effective targeting and selection of deployment sites and communities, target community participation and involvement, the efficiency and effectiveness of the system to achieve its objectives, the expected outcomes of the system, and the sustainability of the intervention. Solar interventions are long-term capital-intensive projects that require the assurance of the system to last and this needs additional checks. Some of these checks include the long-term behavioral changes among local communities due to solar installation, the ownership of such systems, their future maintenance, and accessibility to service providers.

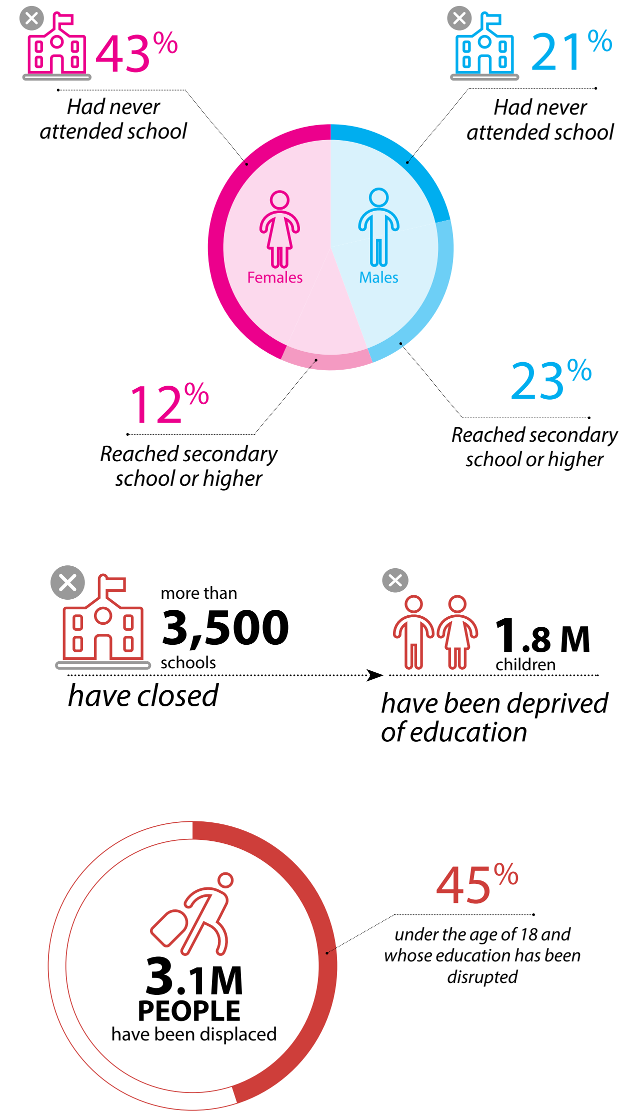
The following guidelines are meant to provide a direction for future interventions in different sectors. Guidelines are being provided to draw the attention of future interventions. It brings opportunities and risks associated with the system implementation within the Yemen context and based on the UNDP ERRY project intervention.

* world bank,2018



EDUCATION SECTOR

1.1. Introduction of Education Services in Rural Areas in Yemen

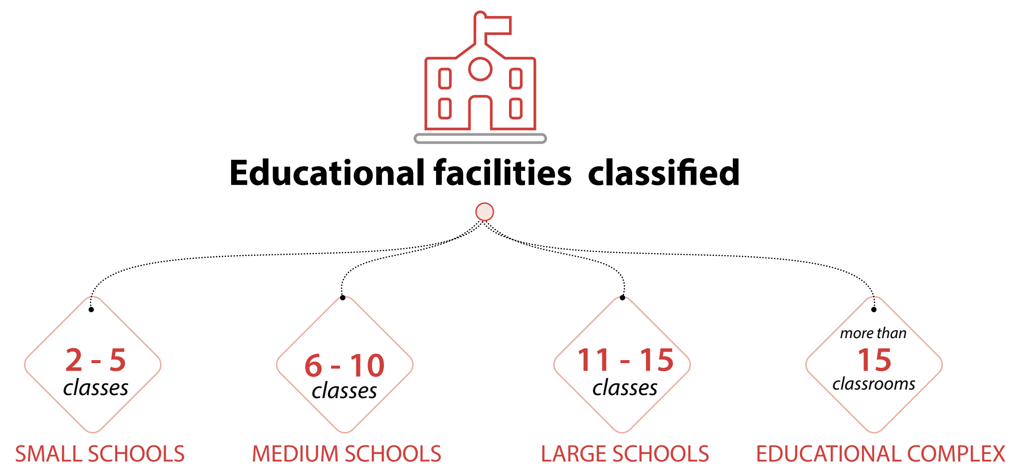


Basic education in Yemen consists of 9 compulsory years for children within the ages of 6–14 years old. It is followed by 3 years of general secondary education.

The education system in Yemen is generally weak, mainly in rural areas. It is not compulsory in Yemen for parents to send their children to school. Before the current conflict, around 43% of females and 21% of males had never attended school; 12% of females reached secondary school or higher, compared with 23% of males. Rural people were about twice as likely as their urban counterparts to have no education.[1] Cultural norms, long distances to schools, lack of female teachers, lack of schools' infrastructure (e.g., WASH and energy), security situation, and unpaid salaries for public school teachers, particularly in the rural areas since 2016, reduced access to education.

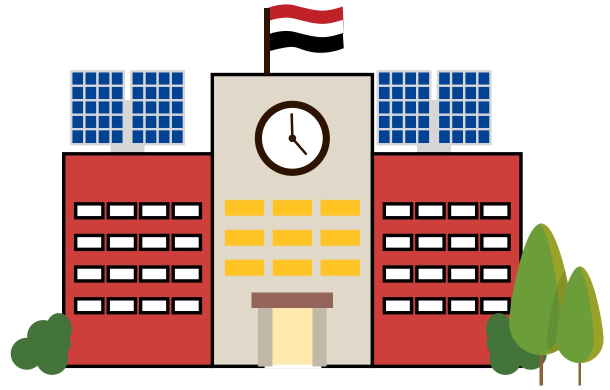
The escalation of the conflict beginning in March 2015 has affected education sector in Yemen. While Yemen has suffered from chronic underdevelopment and a series of localized conflicts, this level of emergency and the magnitude of the impact on children's education as well as the schools and education facilities is beyond what the education sector was prepared to handle. Within the last four years, more than 3,500 schools have closed, either due to damage or destruction, occupation by armed groups, or because they have been turned into collective centers for IDPs.[2] Therefore, an estimated 1.8 million children have been deprived of education. In addition, over 3.1 million people have been displaced, 45% of whom are under the age of 18 and whose education has been disrupted.[3]

Educational facilities can be classified to four types depending on the number of classrooms and students. Small schools usually have from 2 to 5 classes, while medium schools have from 6 to 10 classrooms, a large school has from 11 to 15 classrooms. And educational complex which has more than 15 classrooms is usually a primary and secondary school.[4]



4. MoPHP (2015), Ministry of Public Health and Population and Central Statistical Organization, National Health and Demographic Survey 2013.
5. UNOCHA (2017), The humanitarian Situation in Yemen in Facts and Figures, September 2017: https://www.unocha.org/sites/unocha/files/dms/FF_updated_13092017.pdf
6. Yemen: Humanitarian Response Plan January-December 2018: https://www.humanitarianresponse.info/en/operations/yemen/document/yemen-education-clusterstrategy-20162017-
7. UNDP (2016). Social-economic and Energy Assessment

1.2. Education Services Energy Infrastructure in Yemen

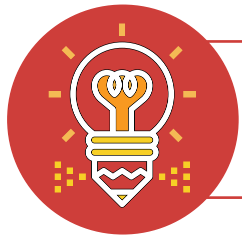


Educational facilities function more effectively with energy. Energy needs in educational facilities varies, depending on the size and nature of appliances at the educational facilities. While some small schools may get along without any electricity due to limited appliances and the environment in which they operate in. In fact, some 3 room schools built in rural areas many not even be built with any electrical supplies. Schools with capacity to provide radio, labs, and operate for longer hours need more energy. Hot areas require fans for students to have relief to study and teachers to deliver material. Pumps in schools assure water circulation functions. Table 1 shows the schools' priority ranking and energy services.

Table 1: Priority ranking of school and energy services

(● High ● Medium)

	Ceiling fans	LIGHTS	COMPUTERS	PRINTER	CELL PHONE CHARGER	RADIO/ CASSETTE PLAYER	WATER PUMPING	TV
Classrooms	High	Medium	Medium (LAB)					
Office	High	High	Medium	High	High			
Staff housing	Medium	Medium			Medium	Medium		Medium
General purpose		Medium				High	Medium	



NOTE

There are different electrical equipment in schools, including class equipment, offices' equipment, and management equipment. Table 2 shows the energy requirements for each of the electrical equipment in schools, which also provide an indication of the peak demand for power in schools

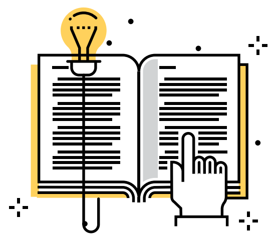
Table 2: Indicative energy requirements of main electrical devices for schools

Education services	Electrical devices	Indicative power rating (W) operation mode	AC power supply	DC power supply or battery port
Classrooms	Ceiling fan	30-100 W	220V AC	12 V DC
	Incandescent lamp (10-20 lm/W)	40-100 W	220V AC	12 V DC
	Halogen lamp (15-20 lm/W)	20-50 W	220V AC	12 V DC
	LED lamp (70-90 lm/W)	5-13 W	220V AC	12 V DC
	Mobile phone battery (charging)	5-20 W	220V AC	12 V DC
Offices and Management	Basic lighting requirements: Incandescent lamp (10 - 20 lm/W)	40-100 W	220V AC	12 V DC
	Halogen lamp (15-20 lm/W)	20-50 W	220V AC	12 V DC
	LED lamp (70 - 90 lm/W)	5-13 W	220V AC	12 V DC
	Mobile phone battery (charging)	5-20 W	220V AC	12 V DC
	Desktop computer	15-200 W	220V AC	12 V DC
	Radio	15-200 W	220V AC	12 V DC

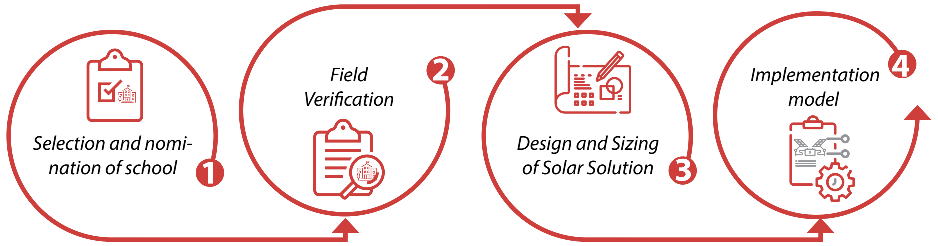
NOTE

The majority of schools in Yemen work between 4 to 6 hours per day in the morning, while some schools work two shifts from 7 to 12 hours per day, and some schools have activities at evening such as adult education classes.

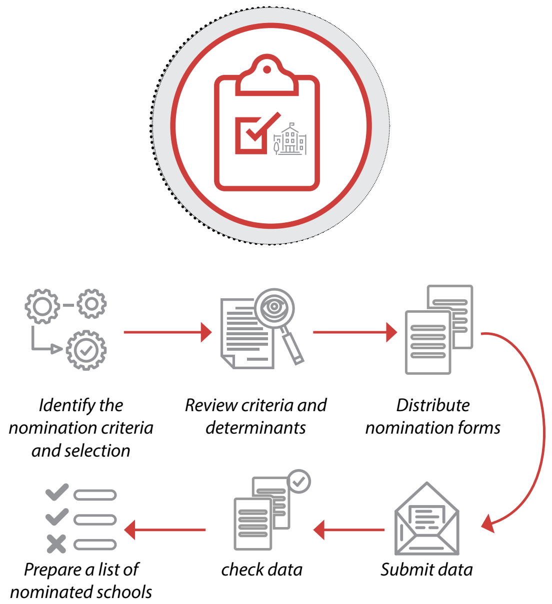
1.3. Solar Energy Programming Guideline



The following sections provide an over view of the steps that can be taken into consideration when powering educational facilities.



1.3.1. Selection and nomination of Schools



A set of procedures, by which intervention sites are nominated through a transparent selection mechanism, based primarily on the involvement of beneficiaries or their representatives such as the local authority and competent education executive offices.

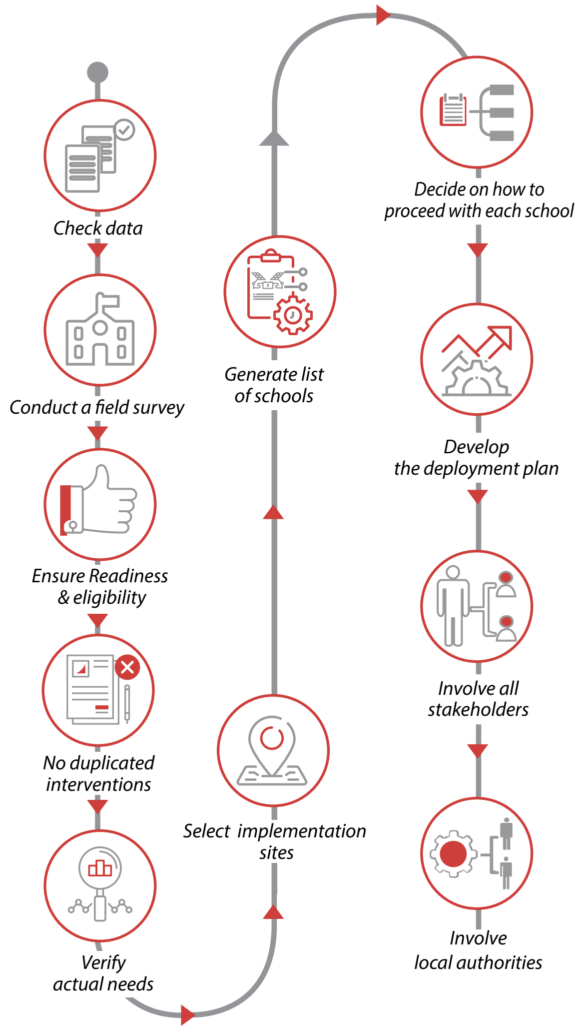
Nomination checklist

- Identify the nomination criteria and selection mechanism in close coordination with key stakeholders.
- Review criteria and determinants and print them out as a form (see schools nomination form: annex 1).
- Distribute nomination forms to relevant agencies including local authorities and education authority office at the governorate and district levels.
- Submit data (nomination form) and initiate the analysis process.
- Cross check all required data as provided.
- Prepare a list of nominated schools (target schools' sites data)

1.3.2. Field Verification

- Check data of nominated schools (the long list of nominated sites for implementation).
- Conduct a field survey to:
  - Collect information about the selected schools such as enrollment, locations, physical infrastructure, school layout, and energy requirements.
  - Conduct wide stakeholder consultations (e.g., local authority, education authority executive offices at the governorate and district level, school headmaster, teachers, local community, etc.).
  - Assess the current capacity of the school for solar system deployment.
    - Is there proper cabling for power? If current infrastructure is poor, a replacement may be necessary before system deployment.
    - Are current lights energy efficient? If current lights and bulbs are not energy efficient, a replacement must be done before system deployment.

Field Verification



- Are current equipment and appliances energy efficient? Appliances may not be the most efficient, a judgment call can be made as of what to replace. The best practice is to replace all equipment with the most energy efficient possible and available. This will save energy on the long term.
- Conduct energy need assessment to evaluate the current needs and energy requirements of the schools.
- Check future needs for energy.

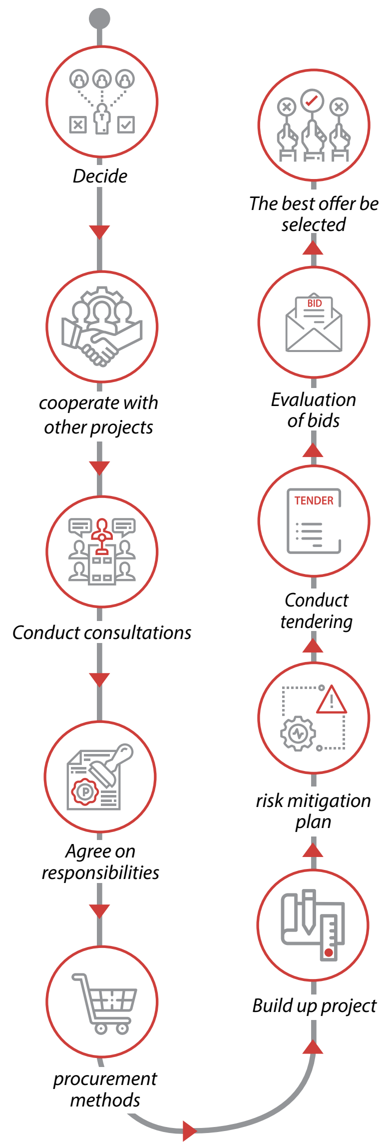
- Ensure readiness and eligibility of all schools' sites for installation.
- Ensure no duplicated interventions in any of these schools.
- Verify actual needs as well as the environmental, geographical, social and technical conditions at the selected schools.
- Select the implementation sites according to actual needs.
- Generate list of schools (main selected list, backup selected list, excluded list).
- Decide on how to proceed with each school based on the assessment of current power needs, current infrastructure, current appliances and equipment and future needs.
- Develop the deployment plan. Check the sample school's needs.
- Involve all stakeholders including local authorities, education authority offices, headmaster, teachers, students, and representatives of local community who will assist in the planning, implementation and monitoring of the project.

1.3.3. Design and Sizing of Solar Solutions

- Conduct rapid market assessment to check the available solar technology and quality of system components in the local market.
- Analyze energy demand behaviors of the school based on energy assessment's information. Expected load in near future must be considered in this step.
- Take in consideration the geographical and environmental condition in the design process. Apply all correction factors to compensate the energy losses caused by geographical and installation mistakes.Determine solar system components for each of selected schools.
- Study all possible options technically and financially. The best option must be chosen as the best economic solution.
- Determine system technology, type, capacity for all components and other installation requirement.

1.3.4. Implementation model

The information collected during the planning stage, and past experiences with solar energy should be carefully reviewed before setting on an implementation model. Regardless of the capacities, weaknesses, or opportunities that the data may suggest, the reality is that the choice of implementation model for providing solar systems for schools is largely determined by the policies and procedures of the lead implementing organization and the key stakeholders.



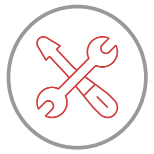
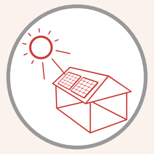
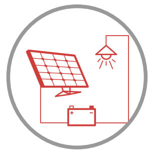
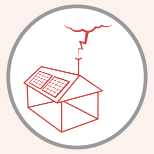
- **Key steps in the implementation model include:**
- Decide on implementation model, institutional, and technical details.
  - Identify opportunities to cooperate with other projects and organizations.
  - Conduct multiple consultations with stakeholders on all aspects.
  - Agree on responsibilities for supply, installation, maintenance, financing, ownership and any links with market development.
  - Determine procurement methods.
  - Build up project budgets, schedules, and draft procurement packages, including technical specifications and terms of reference for capacity building, implementation support and system performance tracking.
  - Develop a risk mitigation plan.
- Conduct proper tendering that includes
  - Tender announcement and reception of bids
    - Launch informational activities to create awareness among as large of a pool as possible of qualified bidders.
    - Conduct clarification process and pre-bid meeting.
  - Technical and financial evaluation of bids
    - Set up a technical and financial analysis committee comprising of solar engineer, project officer and procurement officer.
    - Technical offers to be submitted to this committee for technical and financial evaluation.
    - The committee should consider all comments and queries by suppliers and raise them fully and clearly to the project team to respond to applicants.
    - Specifications of all items contained in the technical offer must comply with the attached catalogs and same for quality assurance and verification.
    - Only qualified bidders who passed the technical evaluation should be selected for financial evaluation process.
    - The best offer technically and financially should be selected.

1.3.5. *Potential Bottlenecks, risks and mitigation*

Without strong institutional arrangements, the challenges and problems that inevitably arise with solar project, as with any other power sources' project, cannot be effectively addressed. The important aim should be sustainability, which at the minimum is a reliable, cost-effective operational system over its design lifetime. Any solar system presented at the design stage as the least-cost solution for powering a school will only succeed as least cost if it operates over the long term.

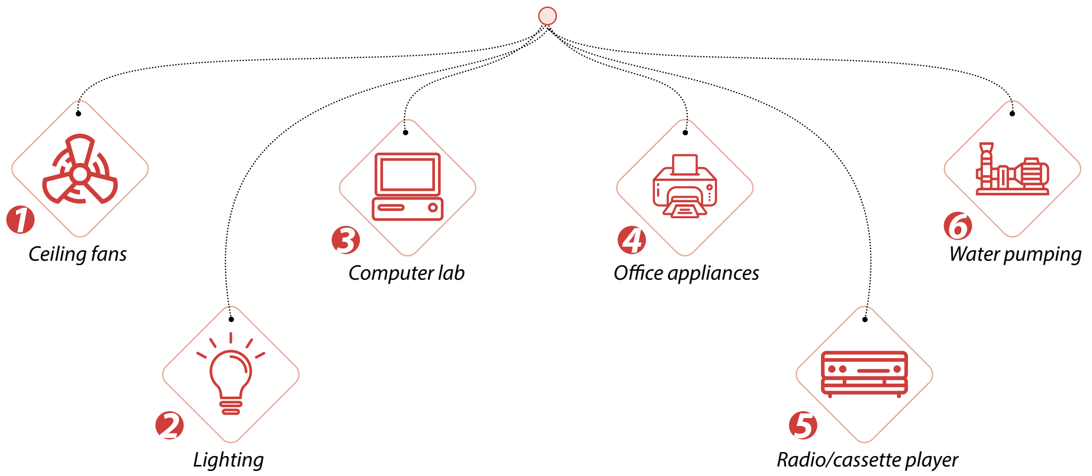
Table 3 below offers basic guidance on sound practices for mitigating the risks of developing and implementing solar system projects in the rural social services facilities.

Table 3: ***Potential Bottlenecks, risks and mitigation***

Risk	Guidance
 Procurement and implementation rollout delays	• Involve/build PV procurement capacities of lead organization and funder early on and persist throughout the design and preparation stages. • Design contracts with detailed technical specifications and strong certification, warranty, and commissioning conditions. • Standardize to as few "building blocks" as possible. • Closely supervise equipment supply and installations.
 Poor-quality, inefficient designs and equipment Over- or under-investment in wrongly-sized systems of too high or low quality	• Ensure technical system design by well-qualified PV specialists aware of current best practices and not linked to potential suppliers. • Consult with off-grid PV specialists and seek independent review. • Design PV systems via an iterative process, considering: o current and near-term energy use (the introduction of electricity may result in such unanticipated demands). o best available solar resource data from vicinity or databases that extrapolate resources. o energy-efficient lights and appliances. o good-quality components, using international or equivalent standards for panels, batteries, controllers, and energy-saving lights. o budget capacities to meet the recurrent costs of maintenance, repairs, and component replacements. o Local O&M capacities, including suppliers and maintenance providers at central, regional, and local levels.
 Lack of funds for battery replacements result in system shutdown Misuse, poor maintenance, and lack of maintenance or troubleshooting skills "Sudden" failures due to lack of system performance tracking and supervision	• Include community participation in preparation. • Establish system ownership. • Secure firm commitments for recurrent budgets for maintenance and component replacements. Consider beneficiary participation in funding O&M. • Decide on in-house or outsourcing maintenance, and build local-service capabilities accordingly. • Fix and enforce rules for system use and maintenance. • Be clear on the limitations of PV systems (e.g., they are not for air-condition or heating). • Ensure user training in appropriate use and load-management practices. • Track PV system maintenance and performance to anticipate and address problems before failures occur. • Closely supervise contract implementation, maintenance, and performance.
 Adverse environmental impacts. Theft and vandalism.	• Arrange recycling or disposal of light bulbs and batteries. • Identify any security risks and mitigating measures. • Consult and create strong awareness to align community and staff expectations with sustainability of PV systems.
 Installation Risks	• Visit the site and finalize the layout of the equipments. • Solar array to be installed at a location that is free from any shading throughout the day. • Keep the distance between system components as small as possible to reduce energy losses. • Controls and inverter should be placed in such a way that access is controlled. • Batteries to be located in cool and dry and well ventilated place. • Check the installation location is safe from kids, animals, water sources and the like.
 Engineering design margins	• Include margins for temperature effects, component degradation over time, and other causes of losses in the performance and lifetime of components and systems.
 Lightning Protection	• Ask vendors or suppliers to install full earthing system to protect all system component from lightning strike and make sure that all components are connected to earthing busbar.

1.3.6. Sample Energy Plan for Schools

Typical energy needs in a school includes the following:



1. *Small Schools:* 1 - 5 class

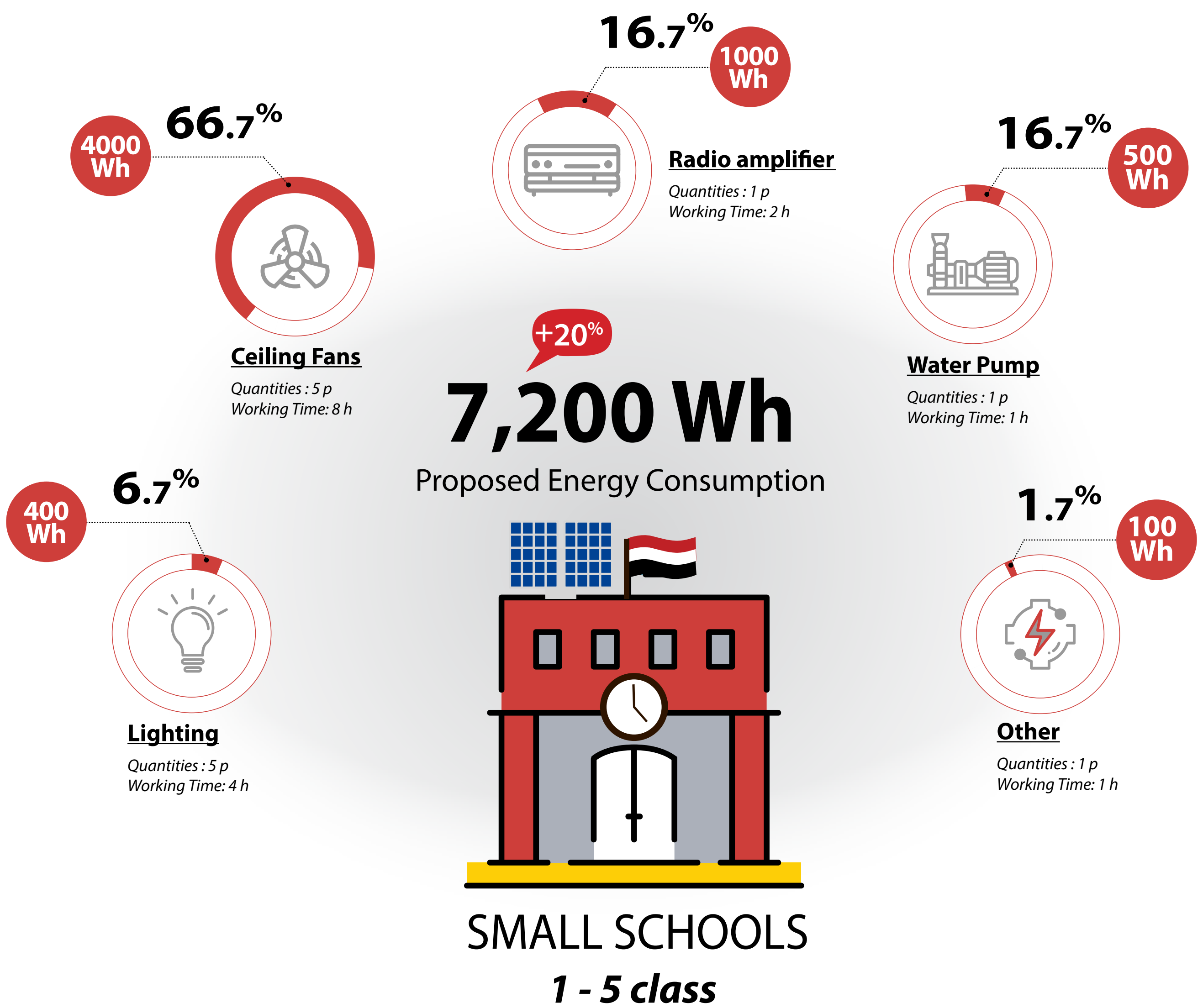


Table 4: Energy plan for a small school

Facility Type	Loads	Expected Quantities	Rated Capacity (W)	Total Capacity (W)	Working Time (h)		Energy Consumption (Wh)/Day			Note
					Day	Night	Day	Night	Total	
Small Schools	Lighting.	5	20	100	3	1	300	100	400	
	Ceiling Fans.	5	100	500	8	0	4000	0	4000	
	Radio amplifier	1	500	500	2	0	1000	0	1000	
	Water Pump	1	500	500	1	0	500	0	500	
	Other	1	100	100	1	0	100	0	100	
	Peak Load (w)			1700			5900	100	6000	
Compensated Values		+20%		2040					7200	

Solar System Information:			
Expected Solar System Capacity	Watt	1,000 to 1,500	Take in account the Solar Radiation Rate and Period in sunny Day.
Operation Capacity (inverter)	Watt	2,400	Take in account the Starting current for dynamic loads such as ceiling fans (150% of the Peak Load).
Storage Capacity	Watt Hour	2,400	Small energy storage capacity (batteries) as most loads are operating at daytime.
Solar System Type	OFF Grid		All loads are fulfilled by the solar panels directly, rest energy will go to charge batteries.

NOTE

Two (2) shift operation, the System Capacity = One (1) shift operation system capacity × 1.5. The Capacity of Solar System when operating with two (2) shift, will be increment around 50% of the system capacity when operation one (1) Shift.

2. *Medium Schools:* 6-10 class

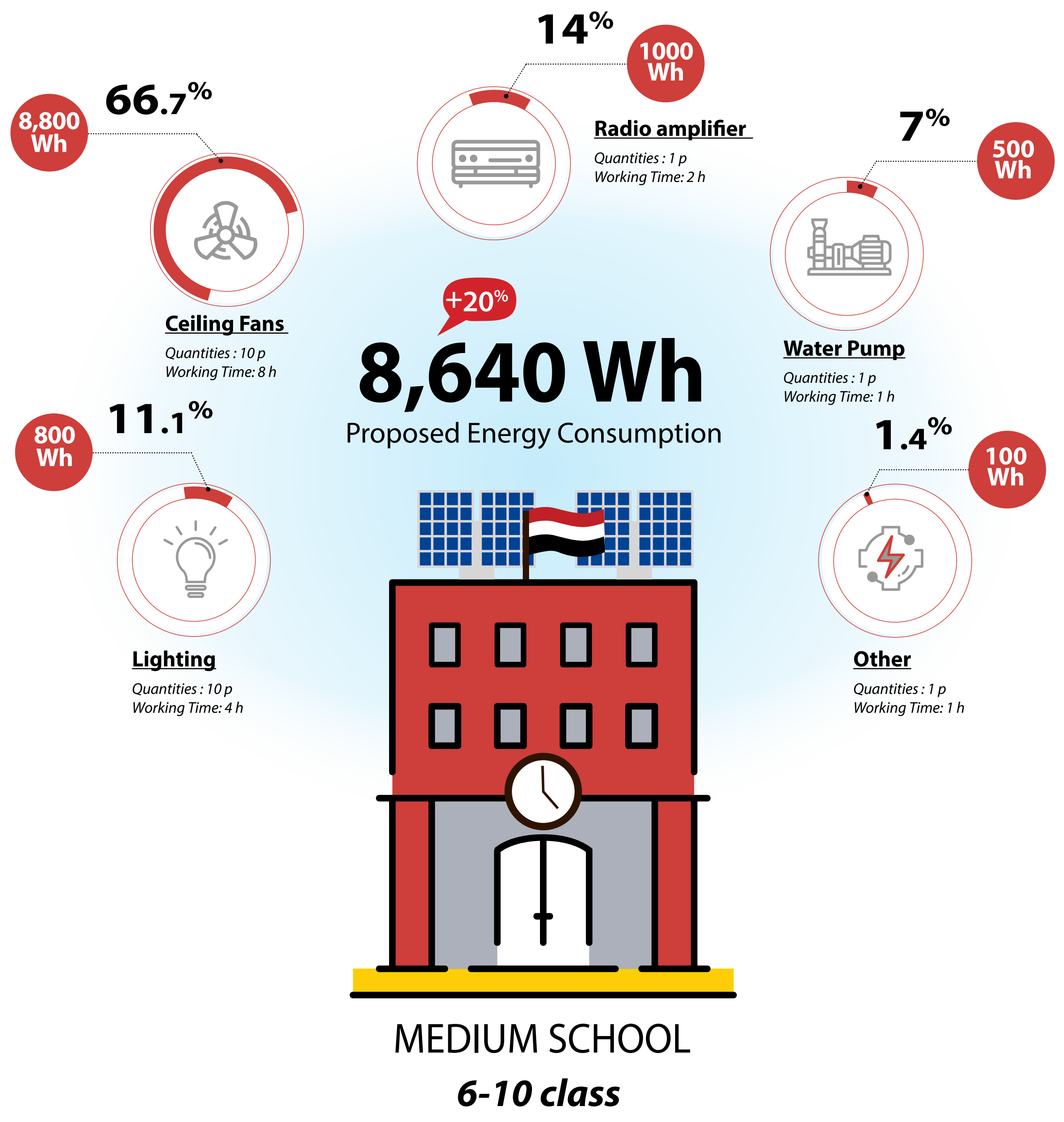


Table 5: Energy plan for a medium school

Facility Type	Loads	Expected Quantities	Rated Capacity (w)	Total Capacity (W)	Working Time (h) Day	Working Time (h) Night	Energy Consumption (Wh)/Day Day	Energy Consumption (Wh)/Day Night	Energy Consumption (Wh)/Day Total	Note
Medium Schools	Lighting.	10	20	200	3	1	600	200	800	
	Ceiling Fans.	10	60	600	8	0	4,800	0	4,800	
	Radio amplifier	1	500	500	2	0	1,000	0	1,000	
	Water Pump	1	500	500	1	0	500	0	500	
	Other	1	100	100	1	0	100	0	100	
		Peak Load (w)		1,900			7,000	200	7,200	
Compensated Values		+20%		2,280					8,640	

Solar System Information:			
Expected Solar System Capacity	Watt	1,800	Take in account the Solar Radiation Rate and Period in sunny Day.
Operation Capacity (inverter)	Watt	3,000	Take in account the Starting current for dynamic loads such as ceiling fans (150% of the Peak Load).
Storage Capacity	Watt Hour	2,400	Small energy storage capacity (batteries) as most loads are operating at daytime.
Solar System Type	OFF Grid		All loads are fulfilled by the solar panels directly, rest energy will go to charge batteries.

NOTE

Two (2) shift operation, the System Capacity = One (1) shift operation system capacity × 1.5. The Capacity of Solar System when operating with two (2) shift, will be increment around 50% of the system capacity when operation one (1) Shift.

3. *Large Schools:* 11-15 class

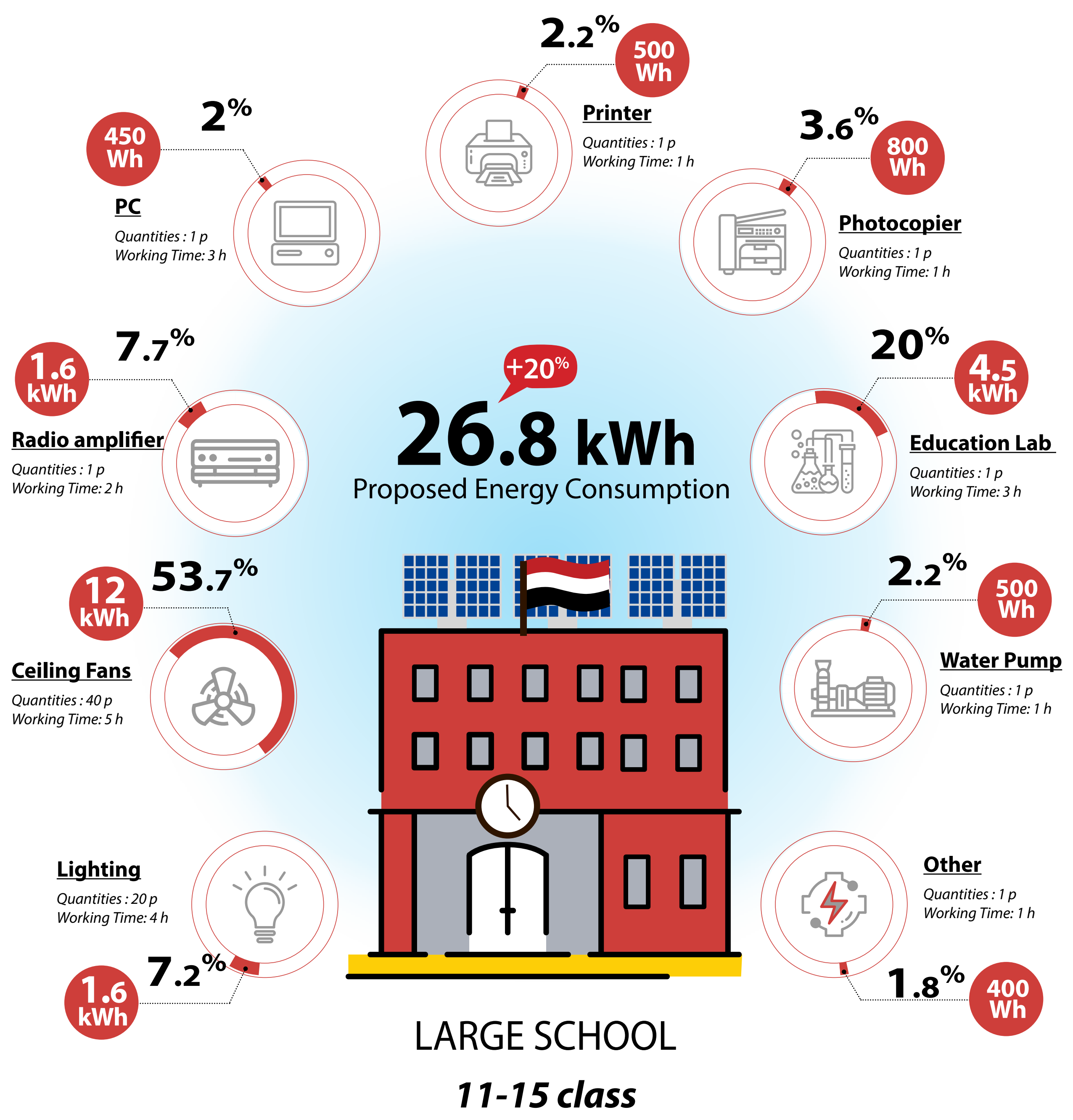


Table 6: ***Energy plan for large school***

Facility Type	Loads	Expected Quantities	Rated Capacity (w)	Total Capacity (W)	Working Time (h)		Energy Consumption (Wh)/Day			Note
					Day	Night	Day	Night	Total	
large school	Lighting.	20	20	400	3	1	1,200	400	1,600	
	Ceiling Fans.	40	60	2,400	5	0	12,000	0	12,000	
	Radio amplifier	1	800	800	2	0	1600	0	1600	
	PC	1	150	150	3	0	450		450	
	Printer	1	500	500	1	0	500		500	
	Photocopier	1	800	800	1	0	800		800	
	Education Lab.	1	1,500	1,500	3	0	4,500		4500	
	Water Pump	1	500	500	1	0	500	0	500	
	Other	1	400	400	1	0	400	0	400	
	Peak Load (w)			7,450			21,950	400	22,350	
Compensated Values		+20%		8,940					26,820	

Solar System Information:

Expected Solar System Capacity	Watt	4,000 to 6,000	Take in account the Solar Radiation Rate and Period in sunny Day.
Operation Capacity (inverter)	Watt	10,000	Take in account the Starting current for Refrigerator and ceiling fans (150% of the Peak Load).
Storage Capacity	Watt Hour	7,200	Small energy storage capacity (batteries) as most loads are operating at daytime.
Solar System Type	OFF Grid		All loads are fulfilled by the solar panels directly, rest energy will go to charge batteries.

NOTE

Two (2) shift operation, the System Capacity = One (1) shift operation system capacity × 1.5. The Capacity of Solar System when operating with two (2) shift, will be increment around 50% of the system capacity when operation one (1) Shift.

4. *Educational complex:* More than 15 class

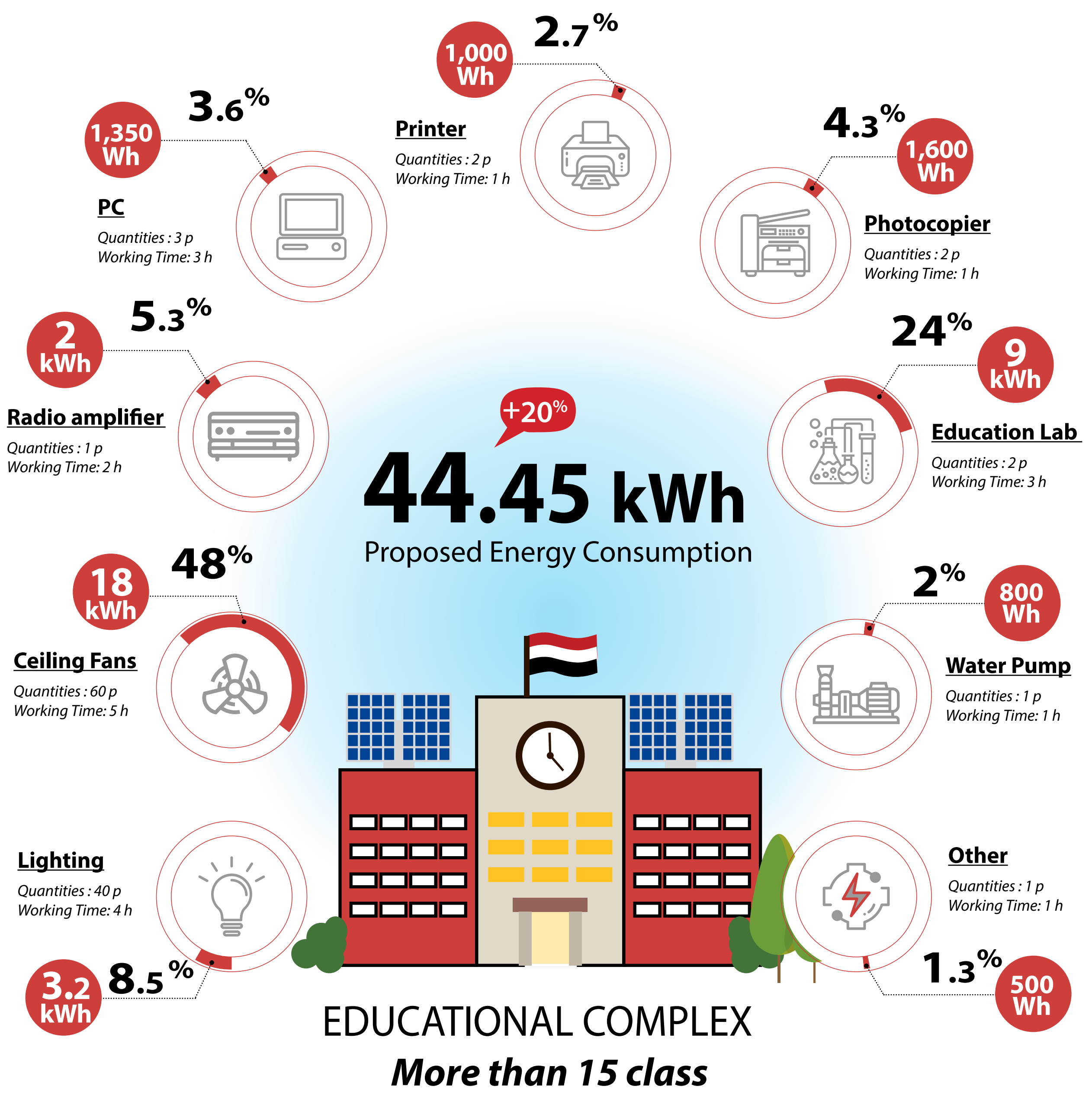


Table 7: ***Energy plan for educational complex***

Facility Type	Loads	Expected Quantities	Rated Capacity (w)	Total Capacity (W)	Working Time (h) Day	Working Time (h) Night	Energy Consumption (Wh)/Day Day	Energy Consumption (Wh)/Day Night	Energy Consumption (Wh)/Day Total	Note
educational complex	Lighting.	40	20	800	3	1	2,400	800	3,200	
	Ceiling Fans.	60	60	3,600	5	0	18,000	0	18,000	
	Radio amplifier	1	1,000	1,000	2	0	2,000	0	2,000	
	PC	3	150	450	3	0	1,350	0	1,350	
	Printer	2	500	1,000	1	0	1,000	0	1,000	
	Photocopier	2	800	1,600	1	0	1,600	0	1,600	
	Education Lab.	2	1,500	3,000	3	0	9,000	0	9,000	
	Water Pump	1	800	800	1	0	800	0	800	
	Other	1	500	500	1	0	500	0	500	
		Peak Load (w)		12,750			36,650	800	37,450	
	Compensated Values	+20%		15,000					44,940	

Solar System Information:

Expected Solar System Capacity	Watt	10,000	Take in account the Solar Radiation Rate and Period in sunny Day.
Operation Capacity (inverter)	Watt	15,000	Take in account the Starting current for Refrigerator and ceiling fans (150% of the Peak Load).
Storage Capacity	Watt Hour	9,600	Small energy storage capacity (batteries) as most loads are operating at daytime.
Solar System Type	OFF Grid		All loads are fulfilled by the solar panels directly, rest energy will go to charge batteries.

HEALTH SECTOR

2.1. Introduction of Health Services in Rural Areas in Yemen

Health facilities (HFs) in the rural areas may provide a wide range of health services, such as obstetric care, vaccinations, basic emergency treatment and surgical services. HFs in Yemen consists of three categories including:

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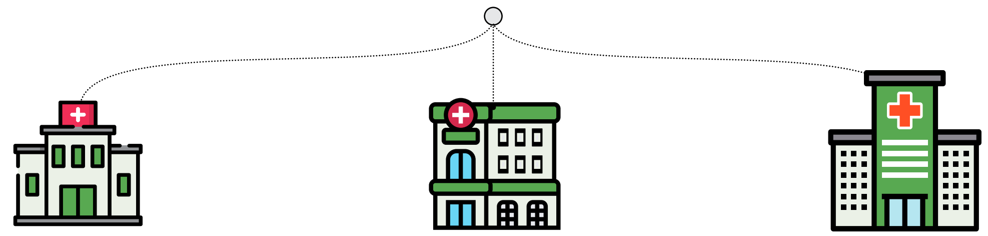


HEALTH UNIT

Rooms: » 2 to 5
Basic items: » communication equipment, lights, and occasionally, a vaccine refrigerator.
Works: » around 6 hours/day, in the morning.

A health unit consists of 2 to 5 rooms completely dedicated to providing health services, including the treatment of minor illnesses, and the treatment of minor injuries. Patients with more serious problems are referred to the local district hospital. Moreover, health units have only the most basic items, communication equipment, lights, and occasionally, a vaccine refrigerator. It usually works around 6 hours/day, in the morning.

HEALTH CENTER

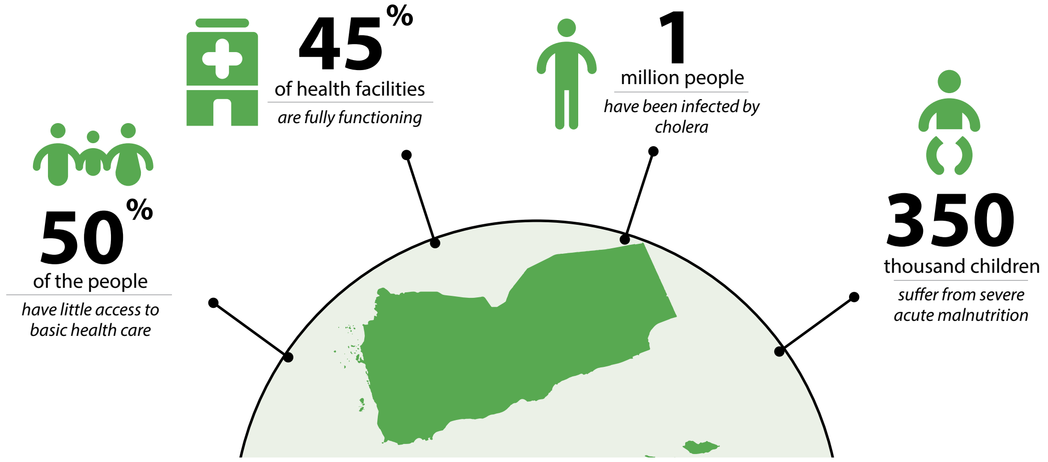
Rooms: » 3 to 7
Basic items: » vaccine refrigerators, simple laboratory (centrifuges and microscopes).
Works: » around 6 hours/day, in the morning.

Health center is a larger facility than the health unit, usually has from 3 to 7 rooms. A health center offers a wider array of services than a health unit. These facilities are more likely than health units to have items such as vaccine refrigerators, and some of them have simple laboratory equipment such as centrifuges and microscopes. It usually works around 6 hours/day, in the morning.

RURAL HOSPITAL

Rooms: » 9 to 50
Basic items: » surgery, rehabilitation, and laboratory and radiological services.
Works: » 24 hours per day.

The large health facility in the district level is a rural hospital, which usually has from 9 to 50 rooms, each room with a dozen beds. Most of rural hospitals have doctors and nurses. Moreover, hospitals offer services such as surgery, rehabilitation, and laboratory and radiological services. It usually works 24 hours per day.



Health sector in Yemen has been affected by the current conflict and war

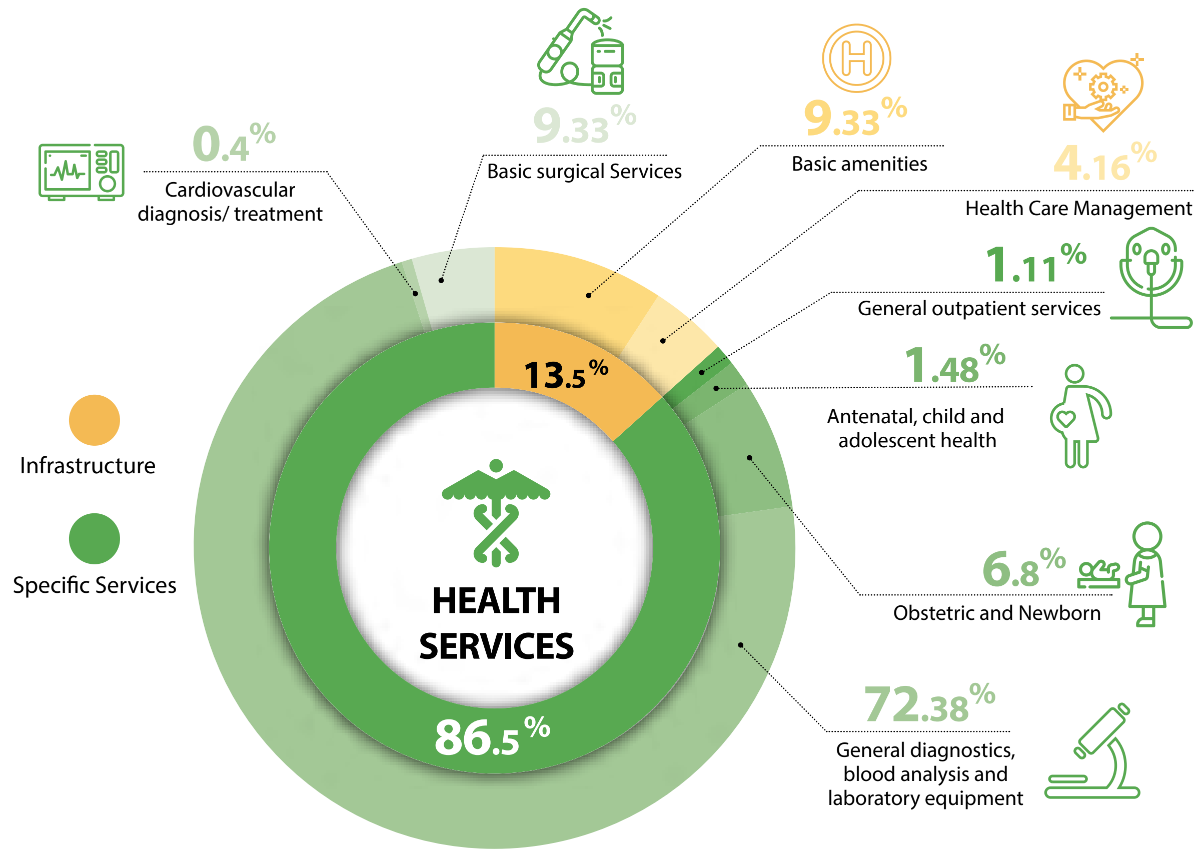
Health sector in Yemen has been affected by the current conflict and war. According to the WHO, more than half of the people have little access to basic health care, and less than 45 percent of health facilities in Yemen are fully functioning.[8] Over 1 million people have been infected by cholera. More than 350,000 children suffer from severe acute malnutrition.[9]

8. WHO (2017). http://www.who.int/hac/crises/yem/appeals/who-donorupdate-april2017.pdf

9. World Bank (2017). https://www.worldbank.org/en/news/feature/2018/09/10/world-bank-brings-electricity-back-to-the-largest-hospital-in-yemen

2.2. Health Services Energy Infrastructure in Yemen

Most of the health facilities have maximized their dependence on the national grid by installing diesel generators, with the fuel been supplied by the government or international organizations. Health facilities, however, relied on diesel-based power generators, which are not only expensive but also vulnerable to shortages of fuel in the country. Table 8 shows the health facilities' energy requirements.



Indicative power requirements of main electrical devices for health services

Table 8: Indicative power requirements of main electrical devices for health services

	Health services	Electrical devices	Indicative power rating (W) operation mode	AC power supply
Infrastructure	Basic amenities	*Basic lighting requirements: Basic lighting requirements for health clinics are estimated at: ~l62 lux (lumens/m²), which may be achieved by various types of lamps:* Incandescent lamp (10-20 lm/W)	W 40-100	220V AC
		Halogen lamp (15-20 lm/W	20-50 W	220V AC
		LED lamp (70-90 lm/W)	5-13 W	220V AC
		Mobile phone battery (charging)	5-20 W	220V AC
		Desktop computer	15-200 W	220V AC
		Ceiling fan	30-100 W	220V AC
		Security lighting, outdoors (LED)	10-100W	220V AC
		Laptop computer	20-60W	220V AC
		Internet- Ethernet	12-400W	220v AC
		Printer, ink jet	60-100W	220V AC
		Printer, Laser jet	500-1000W	220V AC
		Portable air conditioner (AC & DC variants)	1000-1500W	220V AC
		Water Pump	300-1000W	220V AC

Health services	Electrical devices	Indicative power rating (W) operation mode	AC power supply
Health Care Management	Dry heat sterilizer	1000-1500W	220V AC
	water purifier	270-570W	220V AC
General outpatient services	Micro-nebulizer	2.5-30W	220V AC
	Nebulizer	80-90W	220V AC
	Oxygen concentrator	270-310W 70W	220V AC
	Pulse ox meter	50W	220V AC
	Pulse ox meter (AA battery- operated)	2-3W	220V AC
Antenatal, child & adolescent health	Vaccine refrigerator (polio, measles, DPT-Hib+HepB, BCG & tetanus toxoid) designed to perform at 43° C: -Vest frost VLS200 AC (electric mains) refrigerator, 100 liters (WHO/PQS: E003/031).	115W	220V AC
	-Domestic TCW 3000 DC (solar-charged, battery-driven) vaccine refrigerator, 110 liters WHO/PQS-E003/008.	250W PV Array	
	-Sure Chill BLF100DC (solar direct-drive) vaccine refrigerator, 99 liters (WHO/PQS: E003/019	370W PV Array	
Obstetric and newborn	LED light for phototherapy treatment of neo-natal jaundice	440W	220V AC
	Suction apparatus	90-200W 33W	220V AC
	Vacuum aspirator or D&C kit	36-96W	220V AC
	Neo-natal incubator	800-1035W	220V AC
	Neo-natal infant warmer	125-550W	220V AC
	Fetal heart monitor (Doppler)	1.5-3W	220V AC
	Ultrasound	800-1000W	220V AC
	Portable ultrasound	22-28W	220V AC
General diagnostics, blood analysis and laboratory equipment	Laboratory refrigerator (165 L)	160-300W 40-80W	220V AC
	Centrifuge (low-medium speeds)	250-400W	220V AC
	Mini-centrifuge	25W	220V AC
	Hematology analyzer	230-400W	220V AC
	Blood chemistry analyzer	45-88W	220V AC
	Blood chemistry analyzer (hand-held)		
	CD4 counter	200W	220V AC
	Bright field white light microscope (with LED light)	20-30W	220V AC
	LED microscope (for fluorescence smear microscopy (halogen or LED light)	70W	220V AC
	Mercury/xenon fluorescence microscope	75-200W	220V AC
	X-ray machine	15-30kW	220V AC
	Portable X-ray machine	3-4kW	220V AC
	Laboratory incubator	200W	220V AC
	Vortex mixer	18W	
Cardiovascular diagnosis/ treatment	Portable electrocardiograph (ECG)	45-70W	220V AC
	Defibrillator with ECG	100-130W	220V AC

Specific Services

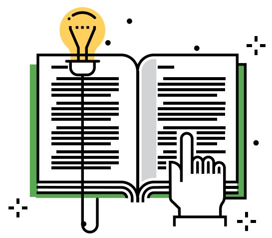
Health services	Electrical devices	Indicative power rating (W) operation mode	AC power supply
Basic surgical services	Suction apparatus (AC)	90-200W	220V AC
	Suction apparatus (DC)	33W	
	Anesthesia machine	1440W	220V AC
	Low-energy anesthesia machine with DC monitor backup	480W	220V AC

Thermal energy needs of health facilities

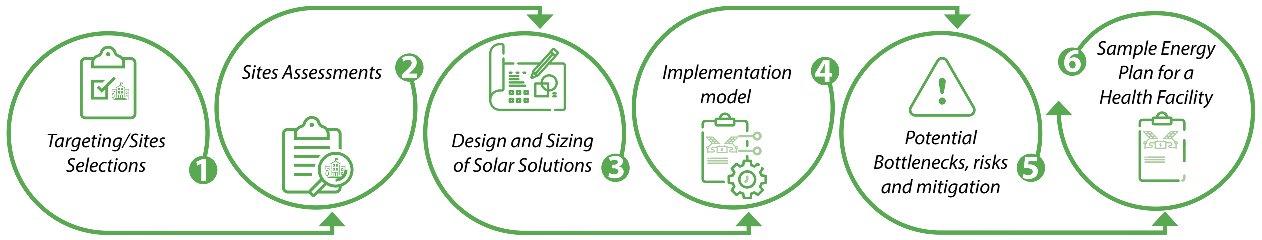
In addition to electricity for medical devices, appliances and facility support functions (such as lighting and water pumping), health facilities have thermal energy needs for cooking and water heating, sterilization, space heating and incineration of medical waste.

Such needs are more significant in larger health facilities delivering more complex health services or offering inpatient services.

2.3. Solar Energy programming guideline



The following section address steps to be taking when solar energy programming for health facilities.



2.3.1. *Targeting/Sites Selections*

A set of procedures by which intervention sites are nominated through a transparent selection mechanism, based primarily on the involvement of beneficiaries or their representatives such as the local authority, and health executive offices.

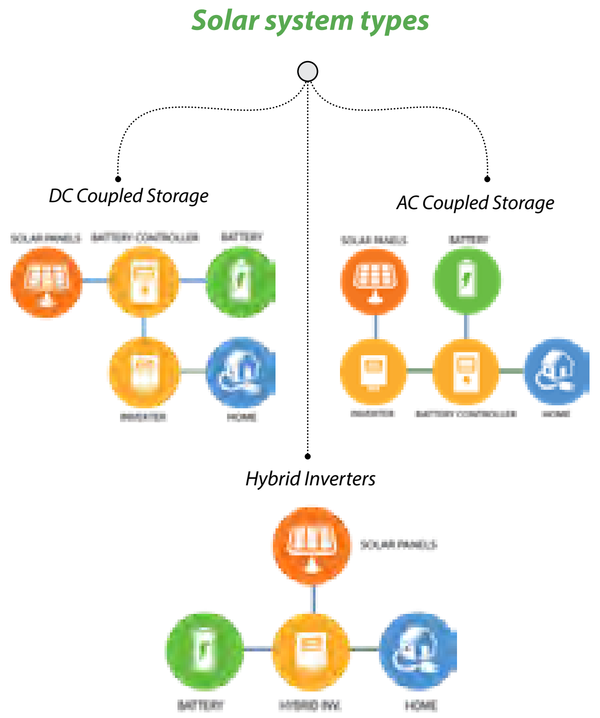
Nomination

- Review criteria and determinants and print them out as a form.
- Communicate these criteria and determinants to relevant agencies and inform them about the nomination and selection mechanism and nomination form.
- Distribute nomination forms to relevant agencies (or individuals) to fill in these forms.
- Submit data (nomination form) and initiate the analysis process.
- Cross check all required data as provided.
- Prepare a long list of nominated health facilities sites.

2.3.2. Sites Assessments

- Decide on how to proceed with each health facility based on the assessment of current power needs, current infrastructure, current appliances and equipment, and future needs.
- Develop the deployment plan, check the sample health facility's needs below.
- Involve all stakeholders including local authorities, health facility staff, representative of local community, who will assist in project deployment and control.
- Involve authority of the health facility to assist in the planning and implementation.
- Involve system guards of the health facility and fulfill their energy needs.
- Collect information and conduct field surveys.
  - Collect data on number of beneficiaries, locations, physical infrastructure, layouts, and energy requirements for types and levels of health facilities, as well as local community and health facility staff information.
  - Update the institutional and market capacity assessment.
  - Conduct wide stakeholder consultations (e.g., local authority, Health authority executive office in the governorate and district level, health facility staff, local community, women, men, etc.) and field surveys at representative facilities. Review health facilities priorities.
- Update rapid assessment data on health facilities and prioritize facilities.
  - Deepen and update information from the rapid assessment on umbers and types of health facilities.
  - Rank energy requirements by the priority of the services they support, with rankings determined by likely impacts. Good practice is to rank these by the priority of the services and likely impacts
- Check the individual needs of each health facility.
- Possible deviations include the following
  - Is the health facility working 24/7, this would require additional battery storage.
  - Does the health facility have special equipment that requires extra ordinary energy such as X-rays or MRIs?
- Assess the current capacity of the health facility for solar system deployment.
  - Is there proper cabling for power? If current infrastructure is poor, a replacement may be necessary before system deployment.
  - Is current lights energy efficient? If current lights and bulbs are not energy efficient, a replacement must be done before system deployment.
  - Are current equipment and appliances energy efficient? Appliances may not be the most efficient, a judgment call can be made as of what to replace. The best practice is to replace all equipment with the most energy efficient possible. This will save energy on the long term.
- Assess the current needs and requirements of the system.
- Check future needs for energy.

2.3.3. Design and Sizing of Solar Solutions

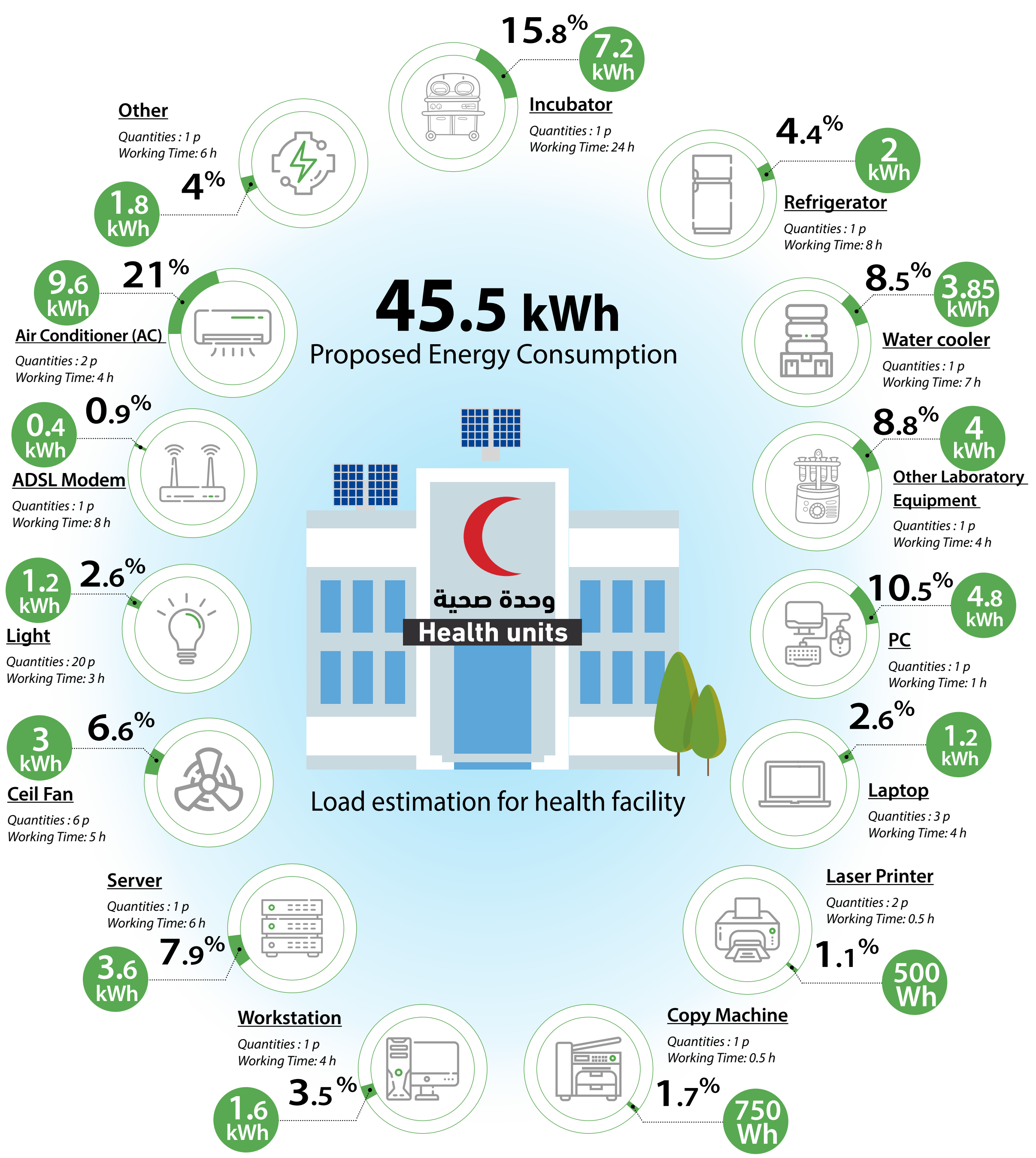


- Conduct rapid market assessment to check the available solar technology and quality of system components in the local market.
- Analyze energy demand behaviors of the health facility based on energy assessment's information. Expected load in near future must be considered in this step.
- Take in consideration the geographical and environmental condition in the design process. Apply all correction factors to compensate the energy losses caused by geographical and installation mistakes.
- Study all possible options technically and financially. The best option must be chosen as the best economic solution.
- Determine system technology, type, capacity for all components and other installation requirement.
  - Determine the required loads and then design the solar PV systems that cover these required loads (see box 1). The solar systems should be classified according to the required loads (large, medium and small).
  - Determine the solar PV systems components (see box 2)
  - Determine the solar system requirements: Following load determination and solution design, the technical, financial, services, warranty requirements for implementation should be identified (see box 3).

Box 1: Load estimation for health facility

No.	Load Name	Qty.	Unit Power (kW)	Total Power (kW)	Operation Period (H)			Total of Energy Consumption kWh per Day Night.		
					Day	Night	Total	Day	Night	Total
		A	B	C	D	E	F	G	H	I
1	Incubator	1	0.30	0.3	8	16	24	2.40	4.80	7.20
2	Refrigerator	1	0.25	0.25	4	4	8	1.00	1.00	2.00
3	Water cooler	1	0.55	0.55	7	-	7	3.85	-	3.85
4	Other Laboratory Equipment	1	1	1	4	-	4	4.00	-	4.00
5	PC	6	0.2	1.2	4	-	4	4.80	-	4.80
6	Laptop	3	0.1	0.3	4	-	4	1.20	-	1.20
7	Laser Printer	2	0.5	1	0.5	-	0.5	0.50	-	0.50
8	Copy Machine	1	1.5	1.5	0.5	-	0.5	0.75	-	0.75
9	Workstation	1	0.4	0.4	4	-	4	1.60	-	1.60
10	Server	1	0.6	0.6	6	-	6	3.60	-	3.60
11	Ceil Fan	6	0.1	0.6	5	-	5	3.00	-	3.00
12	Light	20	0.02	0.4	1	2	3	0.40	0.80	1.20
13	ADSL Modem	1	0.05	0.05	8	-	8	0.40	-	0.40
14	Air Conditioner (AC)	2	1.2	2.4	4	-	4	9.60	-	9.60
15	Other	1	0.3	0.3	5	1	6	1.50	0.30	1.80

No.	Load Name	Qty.	Unit Power (kW)	Total Power (kW)	Operation Period (H)			Total of Energy Consumption kWh per Day Night.		
					Day	Night	Total	Day	Night	Total
		A	B	C	D	E	F	G	H	I
Total Operation Power For System –Peak Load (kW)				10.85	Theoretical Energy Consumption (kWh/day)			38.6	6.9	45.5
Proposed Inverter Capacity (kW)				Z 15	*Compensated Energy Consumption (kWh/day)*			45.16	8.07	53.24
Proposed System Capacity (kW)				8.88	*Compensated System Capacity (kW)*			9.76		
Proposed Storage Capacity Ah @48 VDC				170	Compensated Storage Capacity (Ah) 50% DOD, 80% Discharge efficiency			420		



Box 1: Load estimation for health facility

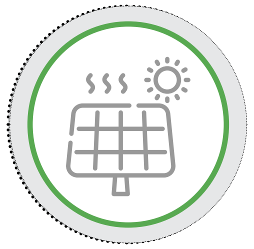
Box 2: Determine the Solar PV Systems Components

Solar Panels							
A-	Sun Radiation						
B-	Sun Radiation Period (H):					*6*	*H*
C-	Total of Energy Consumption					*53.24*	*kWh*
D-	System Total Capacity (W) = (C/B)					*10*	*kW*
E-	Suggested Solar Panel Capacity (W):	◯ 300	◯ 320	◯ 330	◯ 350	*320*	*W*
F-	Quantity of Solar Panels Array Capacity (Panels)= (D / E) the arrangements of panels should be taken in account when determination of panels quantity.					*32*	*Panels*
Operating Capacity (Inverter Capacity)							
G-	Operating Capacity W					*15*	*kW*
H-	AC Distribution Box with Circuit Breakers.				*270 VAC*	*2 pole*	
The inverter voltage system should be calculated according the inverter capacity. 48 VDC					*PV Input Voc = 600 VDC*	*AC Output =230V*	
Storage Capacity of Batteries Bank							
I-	Total Storage Capacity					*20.16*	*kWh*
J-	Number and Capacity of Batteries			*QTY.*	*24 Batteries*	*420 Ah*	*2 V*
Final Suggested Solar System							
Solar System Type:	*ON/OFF Grid Hybrid Solar System (with Backup battery).*						
Total Solar PV Panels Array Capacity:	*10.24 kW*						
Total Battery Bank Capacity:	*20.16 kWh*						
Total Solar Inverter Capacity:	*15 kW, 1PH, 230 VAC*						

Hybrid System

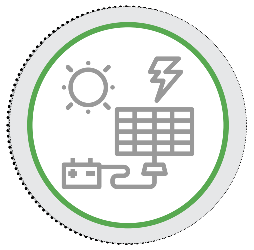
Employ a number of different technologies. A system could include photovoltaic panels, a wind turbine, batteries, and a generator. With reliable solar and wind resources, this system would rarely need to rely on a generator. Since the generator can recharge the batteries during prolonged periods of inclement weather, the battery bank in a hybrid system can be significantly smaller than a PV-battery system, perhaps only needing to store one or two days' worth of energy. The low duty cycle extends generator lifetime.

Box 3: Solar system requirements



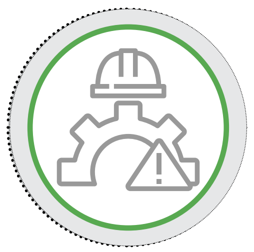
1. Main Technical Requirements

- Solar PV modules
- Solar inverter
- MPPT charge controller
- Storage capacity (Batteries bank)
- Mounting structures
- Junction boxes (DC and AC)
- Earthing system
- Protection devices (Fuses, Load Breakers, Blocking diodes, Surge arrester)
- IR/UV protected cables, pipes, connectors and other accessories
- Box/Rack or container for inverter and batteries



2. Additional Requirements

- Security Fencing
- Fixing and adopting internal wiring system
- Energy efficient devices which planned to be
- Replaced to increase system efficiency
- Warning and hazard signs and guidance posters
- User manuals
- All civil works necessary for implementation



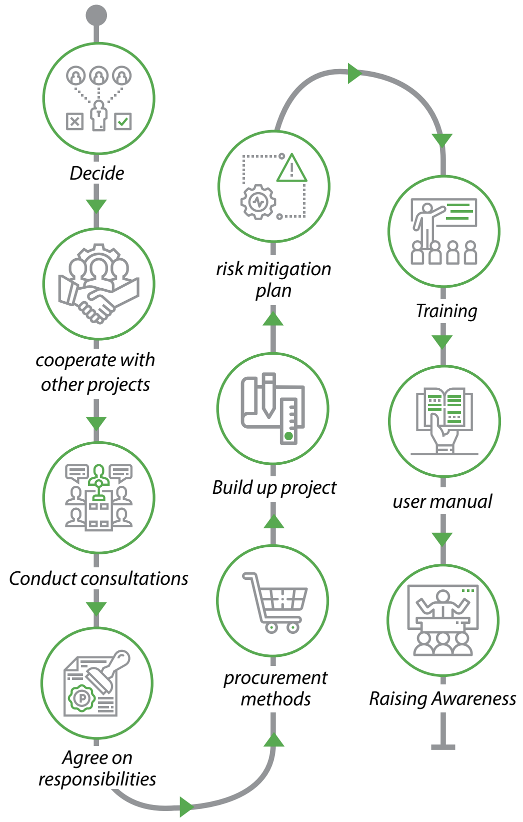
3. Services and Warranty Requirements

- Warranty for all system components
- Maintenance and after sale services
- Monitoring and repairing tools
- Technical training for facility staff on O&M

4. Financial Requirements

- Construct cost estimates and fine-tune least-cost option.
  - Build up investment and operating estimates with unit cost data for components, installation labor and logistics, maintenance…etc. run iterations comparing technical and organizational design options.
  - Customize least-cost assessments and simulations with data on specific technologies and locations.

2.3.4. Implementation model



Key steps in the implementation model include:

- Decide on implementation model and institutional and technical details.
  - Identify opportunities to cooperate with other projects and organizations.
  - Conduct multiple consultations with stakeholders on all aspects.
  - Agree on responsibilities for supply and installation, maintenance, financing, ownership and any links with market development.
  - Determine procurement methods.
  - Build up project budgets, schedules, and draft procurement packages, including technical specifications and terms of reference for capacity building, implementation support and system performance tracking (check the procurements and contract management checklist in the education sector).
  - Develop a risk mitigation plan.
- **Capacity building**
  - Train local staff in installation and regular maintenance, replacing spare parts, checking of the electrolyte in batteries, corrosion cleaning, checking and replacing protection fuses, and short-circuit problems.
  - Prepare a user manual of the PV system for the health facility staff. The manual should illustrate operation, monitoring and energy management of the system.
  - **Raising Awareness:** Rural community members, stereotypically, have a very limited knowledge regarding the use and benefit of solar energy technologies. Therefore, solar project should collaborate with other partners, local media, community groups and other to prepare suitable marketing packages to raise awareness – these will be shared with community, district and targeted areas. These awareness-raising activities should help create realistic and knowledgeable demands to meet electrical requirements through the participatory planning process.

2.3.5. Potential Bottlenecks, risks and mitigation

During the planning and implementation of solar program for health facilities, many challenges and problems that inevitable arise, therefore a risk mitigation plan should be developed. Table 9 below offers basic guidance on sound practices for mitigating the risks of developing and implementing solar system projects in the rural health facilities.

Table 9: Potential Bottlenecks, risks and mitigation

Risk	Guidance
Too few qualified bidders and high prices	• Publicize the proposed specifications early and often beyond tradition sites via local newspapers, network and promote widely *Use qualified, independent solar energy professionals for technical design and supervision*
Procurement and implementation rollout delays.	• Involve/build PV procurement capacities of lead organization and funder early on and persist throughout the design and preparation stage, consulting closely with procurement specialist to ensure that activity is handled appropriately. • Design contracts with detailed technical specifications and strong certification, warranty, and commissioning conditions. • Standardize to as few "building blocks" as possible. • Closely supervise equipment supply and installations.
Poor-quality, inefficient designs and equipment. Over- or under-investment in wrongly-sized systems of too high or low quality.	• Ensure technical system design by well-qualified PV specialists aware of current best practices and not linked to potential suppliers. • Consult with off-grid PV specialists and seek independent review. • Design PV systems via an iterative process, considering: o current and near-term energy use (the introduction of electricity may result in such unanticipated demands): o best available solar resource data from vicinity or databases that extrapolate resources. o energy-efficient lights and appliances (but do not set the number of lights or lighting quantity or quality too low) o good-quality components, using international or equivalent standards for panels, batteries, controllers, and energy-saving lights (don't skimp). o budget capacities to meet the recurrent costs of maintenance, repairs, and component replacements; and o Local O&M capacities, including suppliers and maintenance providers at central, regional, and local levels.
Lack of funds for battery replacements result in system shutdown. Misuse, poor maintenance, and lack of maintenance or troubleshooting skills. "Sudden" failures due to lack of system performance tracking and supervision.	• Include community participation in preparation. • Establish system ownership. • Secure firm commitments for recurrent budgets for maintenance and component replacements. Consider beneficiary participation in funding O&M. • Decide on in-house or outsourcing maintenance, and build local-service capabilities accordingly. • Fix and enforce rules for system use and maintenance. • Be clear on the limitations of PV systems (e.g., they are not for air-condition or heating). • Ensure user training in appropriate use and load-management practices. • Track PV system maintenance and performance to anticipate and address problems before failures occur. • Closely supervise contract implementation, maintenance, and performance.
Adverse environmental impacts. Theft and vandalism.	• Arrange recycling or disposal of light bulbs and lead-acid batteries. • Identify any security risks and mitigating measures. • Consult and create strong awareness to align community and staff expectations with sustainability of PV systems.

Risk	Guidance
Installation Risks	• Check the locations of system deployments • Solar panels setup checks o Is there sufficient space for the solar panels? o Is it safe from wind, theft, lightening, etc.? o Is there sufficient long-term support for the panel? o Is it going to face the sun during summer and winter? • Check the installation location is safe from kids, animals, water sources, rain, and the like. • Make sure the system is well mounted and safe.
Inverter, controller, and/or batteries checks	• Are they within a close distance to the solar panels? Higher distance would lose energy specially DC current. • Inverters require enough ventilation. Limited air circulation around the inventor may cause malfunction or fire. • Check acceptable temperature around any inverters or batteries. Consider summer average temperature.
Infrastructure	• The excessive investments in solar solutions can lower the demand for local grid connectivity; at the same time provide an opportunity for on/off grid solutions.

Energy Efficiency and System Optimization:

SDD refrigerators is more sustainable and reliable option to improve cold chain refrigeration management and optimization in areas with unreliable power supply.

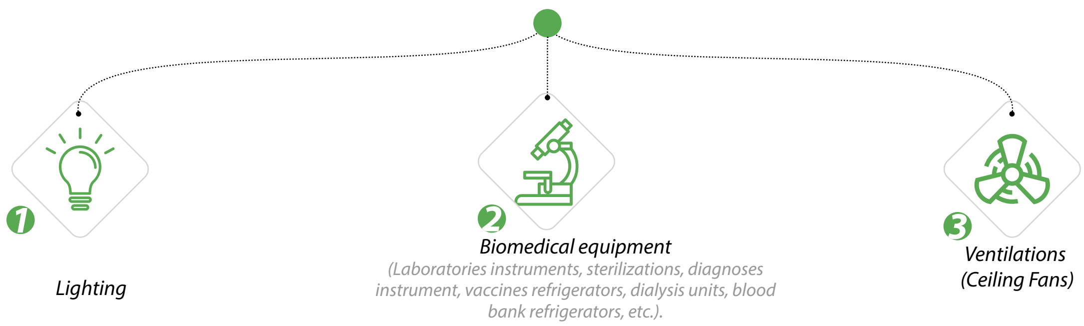
A system design can be optimized through demand side management. Through load shifting, the energy demand can be modified to match the energy supply instantaneously. A simulation analysis shows a significant decrease in PV system costs through load shifting. Medical and non-medical appliances (e.g. Autoclave, jet sonic cleaner, Sterilization) if possible, should put into operation during times of peak solar irradiation and instantaneously utilized the electricity generated by PV modules. In this way, the required battery capacity will decrease due to the reduced amount of energy which must be stored.

Another way to optimize the system and increase its efficiency is to separate the refrigerator from the PV system loads and using a solar vaccine refrigerator which is working through solar direct drive technology.

SDD technology uses solar energy to directly freeze water or other cold storage material and then uses the energy stored in the frozen bank to keep the refrigerator cold during the night and on cloudy days. They are called solar direct-drive because they are wired directly to the solar array. This new technology has the potential to resolve many of the problems of off-grid vaccine refrigeration, enabling national immunization programmes to extend the cold chain into remote rural areas.

SDD refrigerators is more sustainable and reliable option to improve cold chain refrigeration management and optimization in areas with unreliable power supply. SDDs address some of the challenges of alternative technologies, which include higher maintenance requirements, recurring costs, as well as available reliable power supply.

2.3.6. Sample Energy Plan for a Health Facility



1. Health Units Sample:

A health unit is the smallest sized health facility with 2 to 5 rooms only that can deliver basic health services such as minor illnesses or injuries, and vaccinations. The following table provides a sample energy loads and needed capacities.

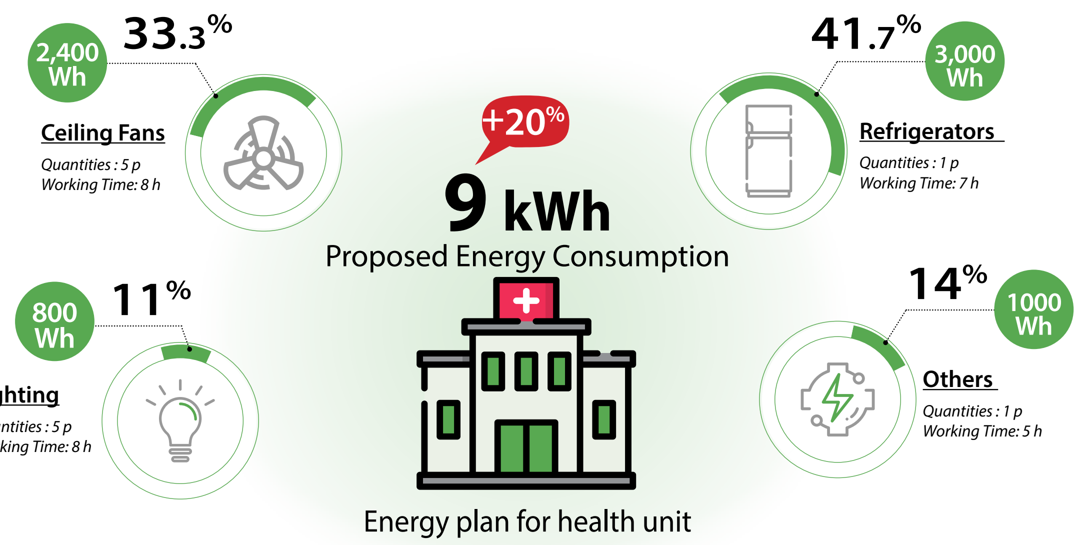


Table 10: Energy plan for health unit

Facilities Type	Loads	Expected Quantities	Rated Capacity (w)	Total Capacity (W)	Working Time – Shifts (h)		Energy Consumption (Wh)/ Day			Note
					Day	Night	Day total	Night Total	Total	
Health Units	Lighting.	5	20	100	7	1	700	100	800	
	Ceiling Fans.	5	60	300	8	0	2400	0	2400	
	Refrigerators.	1	300	300	6	4	1800	1200	3000	
	Others	1	100	100	5	5	500	500	1000	
	Peak Load (w)			800				1800	7200	
Compensated Values		+20%		960					9000	

Solar System Information:			
Expected Solar System Capacity	Watt	1800	Take in account the Solar Radiation Rate and Period in sunny Day.
Operation Capacity	Watt	1500	Take in account the Starting current for dynamic loads such as ceiling fans (150% of the Peak Load).
Storage Capacity	Watt Hour	3600	Small energy storage capacity (batteries) as most loads are operating at daytime.
Solar System Type	OFF Grid		All loads are fulfilled by the solar panels directly, rest energy will go to charge batteries.

Sale of Excess Electricity

The sale of excess electricity offers a promising approach to finance operations. By installing a system with excess capacity, income from the sale of additional power can offset a portion, if not all, of the system's operating costs.

2. Health Centers:

A health center would be a larger than a health unit with 3 to 7 rooms and would have a doctor on duty with basic health services such as laboratory or sterilization. The following table provides a sample energy loads and needed capacities.

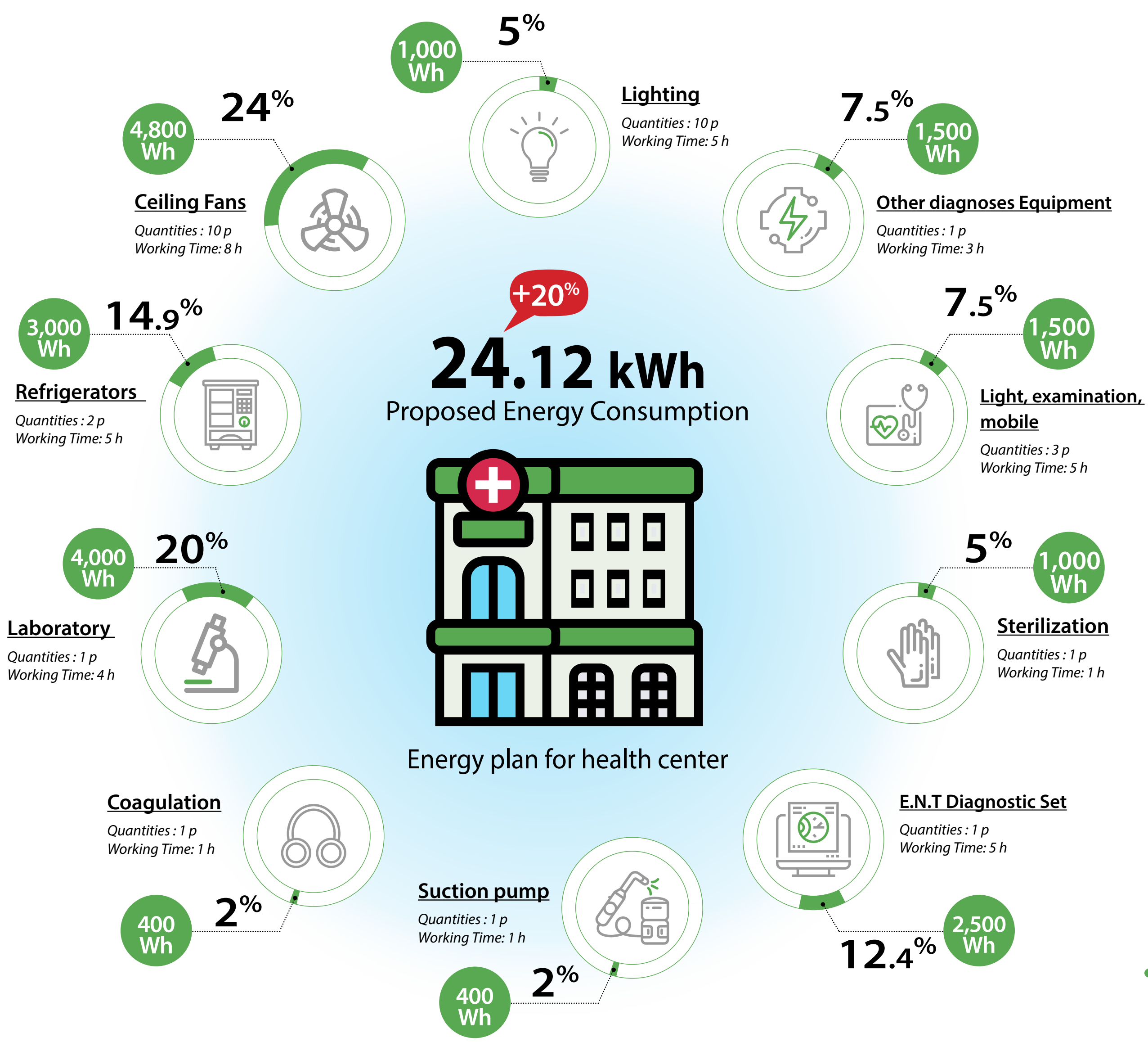


Table 11: Energy plan for health center

Facilities Type	Loads	Expected Quantities	Rated Capacity (w)	Total Capacity (W)	Working Time – Shifts (h)		Energy Consumption (Wh)/ Day			Note
					Day	Night	Day total	Night Total	Total	
Health Centers	Lighting.	10	20	200	4	1	800	200	1000	
	Ceiling Fans.	10	60	600	8	0	4800	0	4800	
	Refrigerators.	2	300	600	4	1	2400	600	3000	
	Laboratory	1	1000	1000	4	0	4000	0	4000	
	Coagulation	1	400	400	1	0	400	0	400	
	E.N.T Diagnostic Set	1	500	500	5	0	2500	0	2500	
	Suction pump	1	400	400	1	0	400	0	400	
	Light, examination, mobile	3	100	300	5	0	1500	0	1500	
	Sterilization	1	1000	1000	1	0	1000	0	1000	
	Other diagnoses Equipment	1	500	500	3	0	1500	0	1500	
	Peak Load (w)			5500			19300	800	20100	
Compensated Values		+20%		6600					24120	

Solar System Information:			
Expected Solar System Capacity	Watt	3500 to 4000	Take in account the Solar Radiation Rate and Period in sunny Day.
Operation Capacity	Watt	5000 to 10000	Take in account the Starting current for Refrigerator and ceiling fans (150% of the Peak Load).
Storage Capacity	Watt Hour	7200	Small energy storage capacity (batteries) as most loads are operating at daytime.
Solar System Type	OFF Grid		All loads are fulfilled by the solar panels directly, rest energy will go to charge batteries.

Note

Two (2) shift operation, the System Capacity = One (1) shift operation system capacity × 1.5. The Capacity of Solar System when operation with two (2) shifts, will be increment around 50% of the system capacity when operation one (1) Shift.

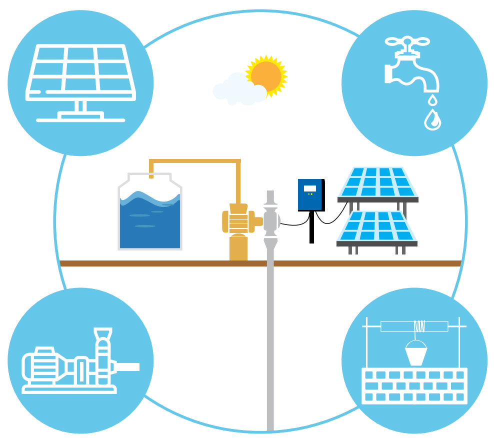
WASH SECTOR

WATER, SANITATION AND HYGIENE

3. Water, Sanitation and Hygiene (WASH) Sector

Water is a basic necessity and a reliable supply of clean water can reduce the amount of water-borne diseases (especially in children); it can contribute to an increase in health, hygiene and convenience and can help liberate time for other activities, especially for women. The supply of drinking water is one of the top priorities of the people in Yemen.

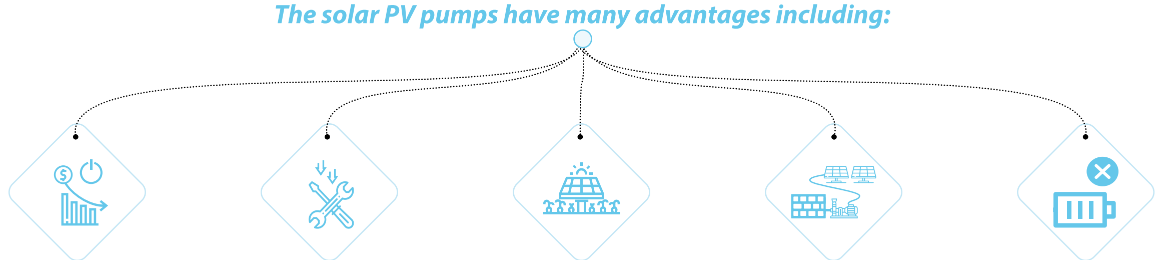
3.1. Why Solar pumping?



The vast majority of people in Yemen highly depend on groundwater, and due to the conflict and shortage of diesel, water supply has been affected, and many people are compelled to purchase water from tankers transferring water to remote areas. The price increased five times than before the current conflict due to the long transportation and fuel costs, and forced many people to use unsafe water sources, which clearly contributed to the recent cholera outbreak in Yemen.

Here solar energy opens up new options for pumping water. Solar PV pumping systems require little service and no fuel. They can offer a reliable and environmentally-sound alternative. Often, they constitute the only reliable solution to the problem of drinking water supply in remote areas, and with shortage of fuel.

The solar PV pumps have many advantages including:



low operating cost

1

since there is no fuel required for the pump like electricity or diesel, the operating costs is minimal;

low maintenance

2

a well-designed solar system requires little maintenance beyond cleaning of the panels once a week;

harmonious with nature

3

another important advantage is that it gives maximum water output when it is most needed i.e. in hot and dry months;

flexibility

4

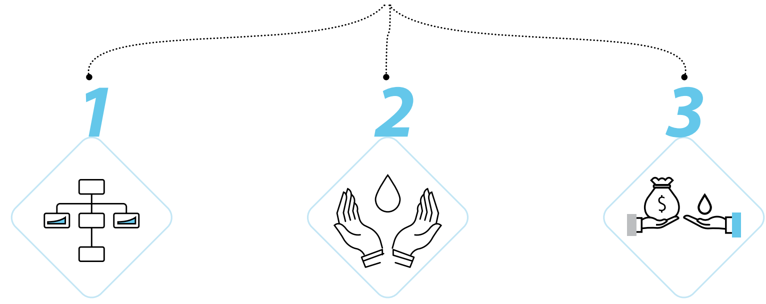
the panels need not be right beside the well. They can be anywhere up to 20 meters away from the well, or anywhere you need the water. These pumps can also be turned on and off as per the requirement, provided the period between two operations is more than 30 seconds. As well as such conditions are supported by 9 - 11 hours of sunlight per day in Yemen, with few cloudy days throughout the year.

not require batteries

5

Solar pumps have a great advantage over other solar PV systems mentioned above is that they do not require batteries. The system can be implemented to work during sunlight only and pumped water can be stored instead of storing the energy for night use.

3.2. Rural Water Supply Institutions in Yemen

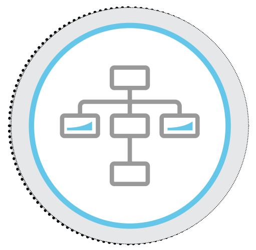


1 *The Regulatory Framework*

2 *Management of water supply systems*

3 *Payment for water*

The Regulatory Framework



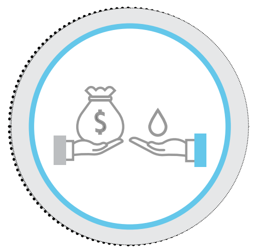
The water sector in Yemen is governed via a number of institutions that operate under the umbrella of the Ministry of Water and Environment (MWE). The National Water Resources Authority (NWRA), the National Water and Sanitation Authority (NWSA), the General Authority for Rural Water Supply and Sanitation Projects (GARWSP) and the Environmental Protection Authority (EPA) are the executing entities. The MWE and NWRA have the mandate to oversee, allocate and monitor the water resources. Water and Sanitation Local Corporations (WSLCs or LCs) have the mandate to establish water tariffs and business plans and are subjected to the approval of the MWE. On the governorate level, LC branches work independently from the NWSA, which oversees only 5% of the urban water supply.

GARWSP aims to provide potable water for rural communities that do not exceed (15,000 persons) and islanders' populations through promoting and supporting public in kind contributions (5-10% of the scheme cost) and providing technical support for sustaining these small scale projects. Its functions related to develop water resources' plans and programs to supply water in rural areas in coordination with local authorize and communities.

Management of water supply systems

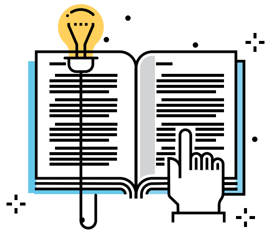
Most of the water supplies in the rural areas have a water committee established to focus on addressing the communities' water needs and problems. Their primary function and responsibility is around the maintenance of the water system so that it functions well. In villages where there are contributions towards water supply costs, where a monthly payment is collected towards buying diesel to pump water and pay the salary of a project coordinator from the borehole, the water committee or its representative is in charge of the collection of money from households. Major repairs to the water supply system infrastructure are the responsibility of GARWSP.

Payment for water

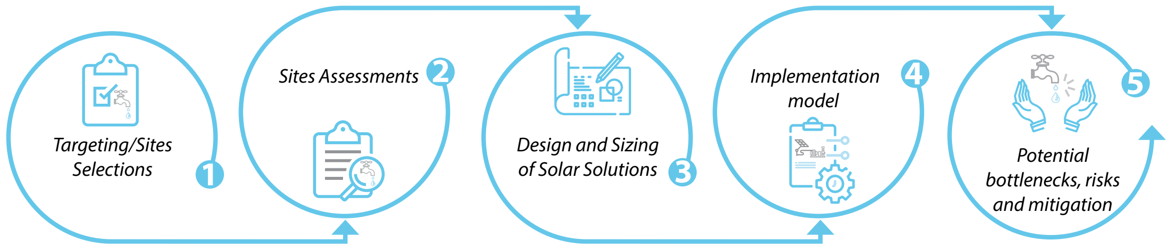


A common regular payment is towards operations of a water supply system, and in most of the cases where these regular payments are made, the money is used to buy diesel to be used for operating the water pump at the borehole. Usually the amount of diesel bought with this money is not enough to enable the pump to run every day, mainly in the past four years due to shortage and expensive cost of diesel. Therefore, some communities have decided to only pump water a few days per week.

3.3. Solar Water Planning



This section provides information about the different elements that are required to plan and design the program including targeting, sites assessments, design and sizing of solar solutions and implementation model.



Preparing the detailed solar pump plan requires abroad range of skills. Whether using in-house or contracted experts, the services of highly qualified specialists, including a solar pump expert for technical guidance, are vital. Project managers may decide whether to hire a consultant to assist with the entire process (sites assessments, design and sizing of solar pump solutions, etc.), as well as procurement through supervision of installations and commissioning, contract a series of consultants, or use in-house expertise. Moreover, project team can have an expertise from General Authority for Rural Water Supply (GARWSP).

Solar pumps could require three engineers to effectively deploy the system. These include a WASH engineer, an electromechanical engineer, and an electrical engineer as described in the site assessment in the following section.

The time required for plan preparation, estimated at 2–3 months, depends mainly on the quality of existing data and how much new information must be generated from the field on the drinking water project site characteristics and energy requirement, as well as security situation. In addition, the needed permits. This phase addresses many of the same questions as the rapid assessment, but at a deeper level.

3.3.1. Targeting/Sites Selections

A set of procedures by which intervention sites are nominated through a transparent selection mechanism based primarily on the involvement of beneficiaries or their representatives such as the local authority or competent executive offices (Water Resources Authority and Water Supply Corporation).

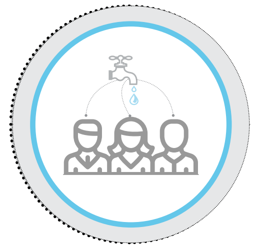
Nomination checklist

- Identify the nomination criteria and selection mechanism with close coordination with key stakeholders.
- Review criteria and determinants and print them out as a form.
- Distribute nomination forms to relevant agencies including local authorities, General Authority for Rural Water Supply (GARWSP) and other key stakeholders.
- Submit data (nomination form) and initiate the analysis process.
- Cross check all required data as provided.
- Prepare a long list of nominated water supplies.

Box 4:

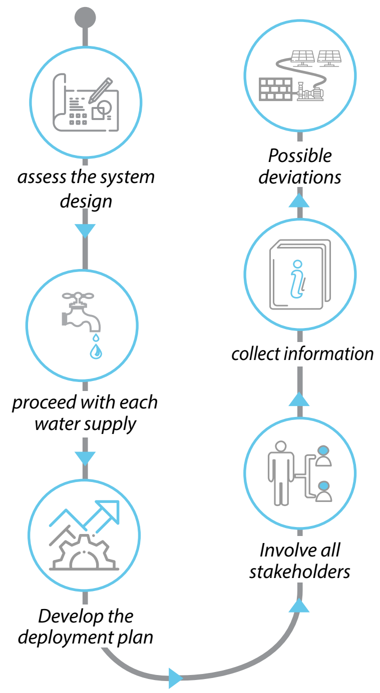
Community participation

The importance of community participation in rural water supply is often emphasized, yet perceptions of what this means vary greatly. Community participation might include any of the following:



- Selection of appropriate locations (water supply).
- Provision of labor for construction of solar system and facilities.
- Management of operation and maintenance.
- Setting and collection of water tariffs.
- Physical maintenance and repair activities.

3.3.2. Sites Assessments



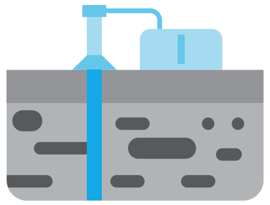
- Solar pumps would require three engineers to assess in the system design and requirements. A WASH engineer would advise on Total Dynamic Head (TDH), system pressures, infrastructure specifications such as pipes and pumps, check water information, water distribution mechanism, water demand, and water tank and storage. An electromechanical engineer would look at the pump specifications and cooling of the system along with the power needed for pumping water as spelled by the WASH engineer. An electrical engineer would check the solar systems power generated and setup the needed electrical circuits to power the system.
- Decide on how to proceed with each water supply based on the assessment of current power needs, current infrastructure, current pumps and equipment as well as future needs.
- Develop the deployment plan.
- Involve all stakeholders including local authorities, GARWSP or Water Management Committees (WMCs), representative of local community, to assist in project planning, implementation and monitoring.
- Conduct field survey to collect information for each water supply source on
  - the volume of water required per day (See Determine Total Dynamic Head below: box 5) and the lift head at each site, as well as data on borehole or well depth, static water level, water rate and dynamic water level, and seasonal patterns, as well as WASH facility staff information.
  - The water jurisdiction and existing borehole and pump condition, ownership, and responsibility.
  - Assumptions on water demand and minimum days of storage, depending on the nature of the demand and uses at the facility, will need to be clarified.
  - Each site will require detailed drawings.
  - Conduct wide stakeholder consultations (e.g., local authority, GARWSP, local community, etc.).
  - Assess the current capacity of selected sites for solar pump system deployment.
    - Is there proper cabling for power? If current infrastructure is poor, a replacement may be necessary before system deployment.

- Is current water source well infrastructure sustainable in terms of casing, covering, free from contamination, and sustainable in the future before system deployment?
- Assess the current needs and requirements of the solar pump systems.

- Suitability of the Site for Solar: The site of the water source must be evaluated for suitability for the installation of the solar-powered water pumping system. The following are specific issues that must be addressed:
  - The solar panels require a south facing location with no significant shading.
  - Locations must be found for the water pump (surface), controllers, storage tank and other system components.
  - The solar array should be as close to the pump as possible to minimize wire size and installation cost.

Box 5:

Determine Total Dynamic Head



The static lift is measured from the solar array to the low water level in the well, pond, or stream. The static height of the storage tank is measured from the array to the top of the tank. Using a topographical map or an altimeter, you can estimate this last value.
Friction losses are the resistance of water flow due to the inside surface of the pipe. In general, the smaller the pipe and the higher the pumping rate, the higher the resistance. Friction losses are expressed in terms of equivalent height and are determined by the pumping rate and the size of the pipe. In order to calculate the pumping rate of the pump in gallons per minute (gpm) or liter per minute (lpm), the following equation can be used:

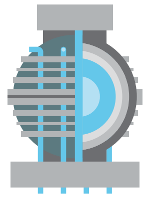
$$\text{GPM/LPM} = \frac{\text{gallons / liter per day}}{\text{peak sun hours per day}} \times \frac{\text{hour}}{\text{60 minutes}}$$

For instance, if you require 1500 gallons per day as calculated at the beginning, and you have determined that the site has 5 peak sun hours per day, you need a pumping rate of 5 gpm. A friction loss table uses the pumping rate and the inside diameter of the pipe to give a friction loss in terms of vertical feet for every hundred feet of pipe. To take the example further, if you are using 300 feet of ¾ inch pipe at 5 gpm, you would need to add 5.78 x 3 = 17.34 feet to the sum of the static lift and height.
The total dynamic head is the distance between the storage delivery points to the submerged depth of the pump in addition head losses through the piping system. It is the summation of elevation head, major losses head, and minor losses head.

3.3.3. Design and Sizing of Solar Solutions

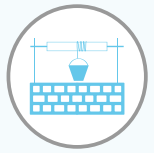
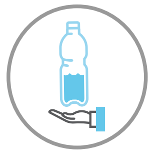
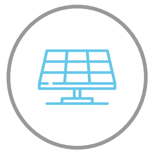
A good solar pumping system is the one properly designed and sized to fit the job requirements. Various designs exist for a variety of applications, requiring research and technical design to avoid system insufficient performance or unnecessary cost incurrence.
During the design phase, system designers need to decide on whether the system is to be on-grid or off-grid, stand-alone solar or hybrid (solar together with another energy source such as diesel generator), with storage in elevated water tanks (encouraged) or without it pumping water directly to the distribution network (discouraged). They need to decide on the type of pump being used and whether the application requires a submersible or a surface pump, using AC or DC power. These all are factors that affect the system performance and feasibility of the proposed solution.
As opposed to diesel-generator systems, when thinking of going solar, systems will be designed considering water requirement per day (m3/day as opposed to m3/h).

1. Solar pump systems sizing



Sizing solar systems is one of the most important steps in planning stage, which over sizing 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, and achieve the desired performance.
To estimate solar array sizes, worst month method will be adopted, that is 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. Table 13 and figure 4 show the steps and their outputs in the sizing process of a solar pump system.

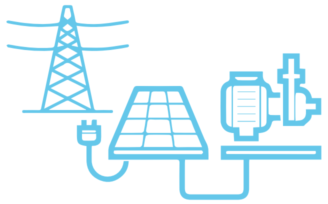
Table 13: Steps and their outputs in the sizing process of a solar pump system

Assessment	Variables	Output
 Water source	- Water depth - Water level - Delivery capacity	- Pump type - Capacity of water available
 Water demand	- Consumption profile (e.g., number of households, number of individual, consumption per day, per person, etc.) - Storage capacity	- Storage size
 Total head	- Static head - Dynamic head	- Pump size
 Solar resources	- Solar radiation in the selected site - Sun peak hours per day	- PV size
 Flowrate		- Pump size

4 Figure

Solar pump systems sizing

On-Grid vs. Off-grid



In solar pumping applications, when the grid is available, some systems are hooked into the grid allowing for a two-way exchange of power, working as such:

1. When solar energy is available, and there is demand for water, water is directly pumped to end use using solar power.
2. When solar energy is available, and there is demand for water but not consuming all the electricity produced, excess electricity is fed into the grid.
3. When solar energy is available, and there is demand for water but requiring more power than what is produced by the solar PV system, extra electricity provided from the grid.
4. When solar energy is available, and there is no demand for water, electricity is fed into the grid.
5. When solar energy is not available, and there is demand for water, water is directly pumped to end use using grid power.

For applications where the utility grid is not available, mainly remote and not electrified areas, the solar system is installed as a stand-alone system, or as a hybrid system typically connected to a diesel generator (solar + generator) depending on the water requirement.

The diesel generator plays the roles (1), (3), and (5) of the grid mentioned above. It provides electricity when needed unless there is a storage system in place. This storage system is allowed to store water to offer availability during night times.

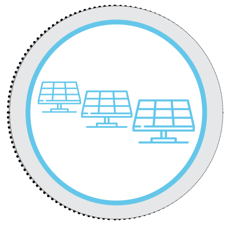
2. Solar pump system components

A solar powered pumping system consists of solar panels, pump, controller/inverter and accessories like cabling and fittings (see box 6)

Box 6:

Solar pump system components

A solar powered pumping system consists of the following parts:

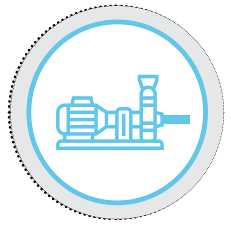


1. Solar array

- The solar array is a set of solar modules which are to be connected in series and possible strings of modules connected in parallel to get the required power to operate the pump.

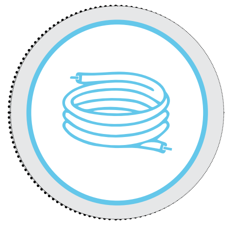
2. controller

- The controller is an electronic device (known as maximum power point tracker or MPPT) that matches the power output from the solar array to the pump motor and regulates the operation of the pump according to the input from the solar array.



3. Pump

- The pump comprises of the motor which drives the movement (prime mover) and the pump impeller, which moves the water under pressure.



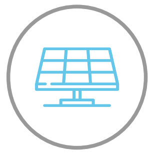
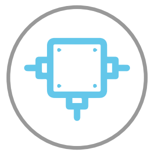
4. Other accessories

- The solar pump system set might include accessories like cabling and fittings.

Solar Systems Component Description

Table 14 shows the technical aspects of the solar pump system components.

Table 14: ***shows the technical aspects of the solar pump system components.***

No	Item	Description
	Electrical Part:	
1	 Solar Module	Solar Panels to producing the sufficient amount of power to operate the pumping systems.
2	 Module Mounting Structure	Fixed Tilt Angle suitable for the quantities of solar panels and the areas.
3	 Sub-Junction Box	This junction between the output of strings and the PV combiner box.

No	Item	Description
4	PV Combiner box	These combiner boxes are equipped with touch DC fuse-holders, DC fuses, reverse protection diodes, lightning induced DC surge arresters and load disconnect switches.
5	Main Distributions Box	Should be equipped with DC Circuit breakers 1000 VDC and a suitable size of reverse protection diodes (The breakdown reverse current and voltage should be adjusted to the max current and voltage of all system blocks or strings).
6	Monitoring System	The individual string currents and voltage should be accurately measured through appropriate technology i.e Shunt Based Technology. Any mismatch should be promptly detected by the system operators and it can be communicated to the main DC Distribution box or to the solar pump inverter due data wire of wireless to allow for quick identification of any fault of the solar panels.
7	Solar Pump Inverter	• Use of Maximum Power Point Tracker (MPPT) is encouraged to optimally use the Solar panel capacity and maximize the water discharge. • The capacity of pump inverter must be at least 40% above the capacity of electrical motor (Inverter Capacity = 1.4 × Motor capacity).
8	Submersible AC panel/ Box	Including AC 3PH MCCB Circuit Breaker 4Poles 450V- 400Amp
9	Genset/ Main Junction Box	Including AC 3PH MCCB Change Over 4Poles 400V- 300Amp, which act to changing between the Main Network and Generator.
10	Synchronize and Control Box	For the operation of additional units such as Water Purification Unit in conjunction with the operation of the solar pump inverter.
11	Grounding Systems	• Complete bonding and earthing of the neutral point of pumping system and non-current carrying metal parts of all electrical equipment and apparatus. • The earthing system should be obtained for AC grid and for DC grid separately.

No	Item	Description
12	**Cabling**	
1	Between PV Panels Interconnections	DC Cable
2	From PV Strings to PV Combiner Boxes	DC Cable
3	From PV Combiner Boxes to Main DC Junction Box	DC Cable
4	From Main DC Junction Box to Solar Pump Inverter	DC Cable
5	Submersible Cable	Between Solar Pump Inverter, Submersible AC panel / Box and Submersible Motor
6	Earthing / Grounding System Cables	DC and AC Cables
7	Synchronize and Control system Cables	AC Cable
8	Data Cables	Data Cable, for PV monitoring System
9	Other AC Cables	For ON Grid system, boosters systems and sensor cable
13	Wiring Pipes	PVC pipe minimum 50mm dia and above depending on No. of wires to be drawn
14	Security Fence *(Chain Link Fabric)*	For safety aspects and to protect solar PV water pumping system
	Electromechanical Part:	
1	**Deep-well submersible Motor-Pump units**	
1	Submersible Pump *(Bore hole Pump)*	Centrifugal multistage type utilizing standard production parts and shall be well proven in design, quality of manufacturer and operational reliability.

No	Item	Description
2	Submersible Motor	The motor shall be NEMA design B squirrel-cage induction type (preferred), whose insulation rating is compatible with VFD operation.
3	Submersible cables	Each motor is to be supplied with flexible cable of suitable dimension to withstand the current required to operate the motor at starting and when running at full load. The cable and sheathing is to be mechanically strong enough, made of 99.9% of copper, coated with double PVC, environmental friendly and undergone quality tested as per IEC standard.
2	Threaded Raiser Pipes	The pipes shall be threaded from both sides 8 threads per inch according to API-5L. Each pipe shall be provided with coupling. Long type coupling 20-25 cm. Threaded from inside must be according to API-5L and provided with the other end with protector to prevent damage of thread.
3	Non-return valve	**Carbon steel flanged non-return valve, (25 bar):** The system should be equipped with 3 to 4 non-return Valves. One installed on the ground level, other should be installed in the borehole riser pipes every 100m.
4	Gate Valve	**Carbon steel flanged Gate valve, (25 bar):** • Non-rising stem • Face to face according to EN 558 or equivalent. • For vertical and horizontal installation
5	Air Valves	Automatic air admission and air release of drinking water pipelines.
6	Mechanical Water Flow Meter	The water meter shall be used to measure the flow rate of the pumping system. shall be placed between the submersible pump and water storage tank.
7	Water Level Sensors	3 Dry running electrodes with 2×1.5mm2 submersible monitoring sensors.

Orientation

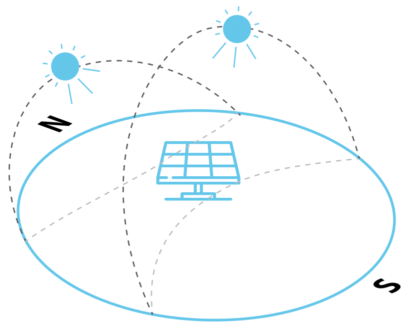
In order to maximize the performance of solar panels in Yemen, it is essential to install them facing true south, with an acceptable tolerance of 15-20 degrees towards east or west that doesn't significantly affect the performance (-0.2% of losses per degree of deviation from true South). For applications needing solar energy in the morning more than it does in the afternoon, a shift towards the east is practical to receive the solar rays as early as possible.

Tilt

The panel can get the best out of the solar radiation when its surface receives the solar rays at a perpendicular angle, allowing for a maximum solar ray density per unit area. However, the sun path varies from day to another, being at higher levels during the summer and lower during winter in relation to the horizon.
Rule of thumb says that the tilt angle needs to be almost as much as the latitude of the location with a 5-degrees tolerance, and being no less than 15 degrees for allowing self-cleaning of panels when it rains.
The optimal solution would be changing the tilt angle on daily basis to match the solar radiation angle, but is not a practical solution and sun trackers (devices that move panels to follow the sun track) are discouraged since they are high maintenance and expensive (due the relative low cost of solar panels, a better solution to increase the energy yield is to increase the number of panels in the scheme).

Other Considerations

Some losses in the solar panel-box-pump system can be minimize if the scheme is well managed (for example: dirt of panels if cleaned regularly, using same model of panels in the scheme, avoiding shadows on the panels, having an optimum inclination and orientation) while others cannot as they are given by factors we cannot influence on (see Table 15).

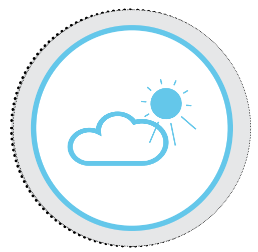


Losses due to	Losses Parentages %
Temperature	3% to 20%
Dirt on Panels	0% to 10%
Inverter Performance/MPPT	3% to 10%
Mismatching	2% to 5%
Cabling	1% to 5%
Reflectance of Panels	2% to 6%
Shadowing	0% to 15%
Bad inclination / Orientation	0% to 10%
Tolerance of panels	0% to 5%
Other tolerance	3%

Energy Production Typical Losses:
Worst Case : -48%
Average Case : -29%
Best Case : -12%
Over sizing would incur unnecessary costs, and under sizing would lead to insufficient performance.

Box 7:

Solar Resources



Assuming that you can place the array in a location that can receive full sun, you then need to estimate the regional solar potential using published data or maps for your governorate.

These sources will tell you what full sun hours per day your area receives.

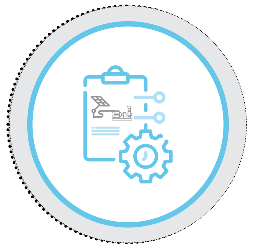
The average for most of Yemen Gov. is 8 hours in the winter, 9 hours in the summer, and 7 hours the average for the year. Multiply the array wattage by this number to get a rough estimate of daily power available at the site.

Safety and security

During the design and installation of solar pump systems, the following precautions should be taken to protect the solar pump system:

- Design the system to withstand strong winds and storms with a velocity up to 150 km/hr. the direction of the wind needs to be observed and the direction of the panels rotated accordingly so that the minimum area of panels comes under wind pressure.
- The array is kept horizontally at 180 degrees during storms or cyclones so that minimum resistance is offered to the wind.
- **Earthing:** The array structure of the PV yard should be grounded properly using adequate number of earthing kits. All metal casing / shielding of the plant shall be thoroughly grounded to ensure safety of the Solar Systems.
- Theft of panels is an issue especially for schemes at community level (not that much at camp level since there is normally a 24h guard by the water point). The single most effective measure to avoid theft is mounting panels on elevated poles, fencing and providing watchman overnight. Other measures documented to minimize this problem are:
  - **For new boreholes:** Try to find a drilling location which is close to the users/beneficiaries or remote from roads.
  - For community water supply, ensure that there is ownership of the water supply system.
  - Mark the modules with the owners' name in non-removable paint.
  - Engrave the name of the owner on the frame
  - Note the serial numbers of all the modules.
  - Put a fence around the solar array installation.
  - If sensible have somebody live at that water supply point.
  - Organize for security personnel in large applications.
  - Use one-way bolts or security screws to fix the modules on the frame.
  - Install the modules on six-meter steel poles with a large concrete block as foundation.
  - Fit razor wire underneath the modules.

3.3.4. *Implementation model*



The following checklist refers to the implementation model:

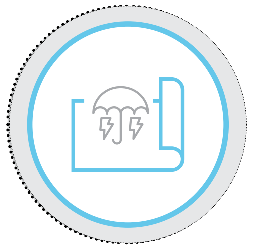
- Decide on implementation model, institutional and technical details.
  - Identify opportunities to cooperate with other projects and organizations.
  - Conduct multiple consultations with stakeholders on all aspects.
  - Agree on responsibilities for supply and installation, maintenance, financing, ownership and any links with market development.
  - Determine procurement methods.
  - Build up project budgets, schedules, and draft procurement packages, including technical specifications and terms of reference for capacity building, implementation support and system performance tracking.
  - Develop a risk mitigation plan

Standard Technical and Quantitative Description

- Review the designs of proposed solutions and categorize them per sizes.
- Prepare designs and requirements (components).
- Examine procurement and bidding regulations.
- Check the preliminary market study, to consider outcomes and local market capacities.
- Invoke relevant international standards.
- Prepare standard technical specifications, and quantities for these systems or designs as categorized.
- Uniform the different systems, and then distribute them into lots based on their size and geographical location.
- Calculate the estimated cost.
- Present the study and discuss it with the project manager and other stakeholders
- Make the necessary changes to these specs - if any - without compromising quality standards

Quality Standards and Electrical Protection

The private market is flooded with solar products of many different manufacturers, and many different qualities. Since the solar technology makes more sense when thinking in the medium and long term, it is strongly recommended to use products that are of good quality, in order to ensure they will last for long years.



- Provide solar panels approved to IEC/EN 61215 and 61730 or UL 1703 certified and listed. All modules must be of a robust design. In case the solar panels are to be mounted elevated on poles, a design of this would be provided by the bidders.
- Control equipment (control box and DC to AC invertors) must meet EN 61800-1, EN 61800-3, EN 60204-1 or internationally recognized equivalent standards. Moreover, control equipment must be housed in a suitable enclosure of robust design, for mechanical and environmental protection to at least IP54 or higher.
- A pump must meet EN 809 and EN 60034-1 or internationally recognized equivalent standards. The pump should be of a design where rotors and impellers are made of stainless steel, with a minimum grade of AISI 304 or higher (unless the chemical nature of the water is so corrosive that plastic or other materials are better suited).
- Besides the electrical protection of any solar scheme is of paramount importance to ensure long life. The system must have dry run protection to protect the system in event of low water levels. Other protection systems should at least include Surge Protection Units (SPUs) and over/ under voltage protection. Each array structure of the PV yard should be grounded properly.
- All metal casing/shielding of the plant should be thoroughly grounded in accordance with applicable electricity rules.

Box 8:

Procurement approaches

Debate: There are two different approaches to procurement. The first approach seeks to hire experts who design the system and identify the exact system requirements. This gives vendors a specific set of equipment to supply. The second approach seeks to set the needed system requirements in terms of water production, and let vendors to design the system. The first approach can be cheaper and easier to evaluate vendor offers. However, it may be riskier if the system is deployed and it does not work. In such cases, system adjustments may be needed. On the second approach, vendors may propose different solutions that may be more expensive, and more difficult to compare, as the analysis would require full understanding of how the vendors designed the entire system. The second option would transfer the risk to the vendor, but may be more expensive and the selected vendor may still not be the best solution.

c Contracting

- Ask the auditor to verify data furnished in the three best offers - technically and financially out of the shortlist (or all of them).
- Set up a committee to make field visits to the best three offers for verification (procurement officer, project representative and project solar specialist).
- Field visits to businesses of the three best offers for verification and to ensure they have the technical and administrative capacities needed (maintenance services i.e. maintenance workshops...etc.).
- Project solar specialist should conduct central technical inspection for the required systems in terms of compatibility with offered specification.
- Inform the supplier (the best offer) to provide the required systems and issuing the contract with this supplier.
- Conduct the initial central inspection for any site agreed to as per the testing and inspection mechanism.

d Supply and Contract Management

- Set up a field technical inspection team from the project.
- Agree on the inspection criteria for systems installed and operated in the target sites.
- Agree on a time framed field implementation plan, and risk management during a meeting between the project's technical team and suppliers.
- Agree on the hand-over mechanism and installation of systems as planned
- Obtain permits from the relevant local authorities (transportation permits - installation permits).
- Provide supplies and start the field installation in the target sites as planned, including raising awareness and training among beneficiaries on operation, regular and preventive maintenance.

Box 9:

Transfer ownership

The transfer of ownership must be clearly indicated in the contract/agreement made between the Program, community based organization (e.g., Water Management Committees (WMCs), GARWSP and supplier. The program/project must be aware of the time frame for the ownership transfer and prepare for it in advanced.

Before the system is transferred, the following aspect should be considered in advance:

Who will be the system owner/operator?

- After the system is transferred to become an asset of the target water supply, all O&M activities will be on the facility owner side. It must be decided if a maintenance contract is to be made with external party or the facility owner will nominate their own personnel to conduct this tasks.

System condition prior to the transfer:

- an inspection of component performance should be conducted in advanced prior to the transfer. This can give a good overview on the systems condition & performance at that time. It also helps the Program/Project to plan for procurement or replacement of certain component in advance.

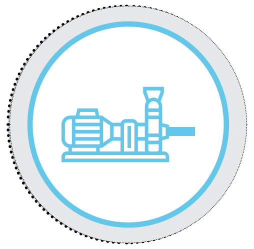
Effect to accounting:

- After the transfer, the solar pump system is an asset of the GARWSP, local authority or WMC. This must be taken into consideration in the accounting system.

e Capacity building

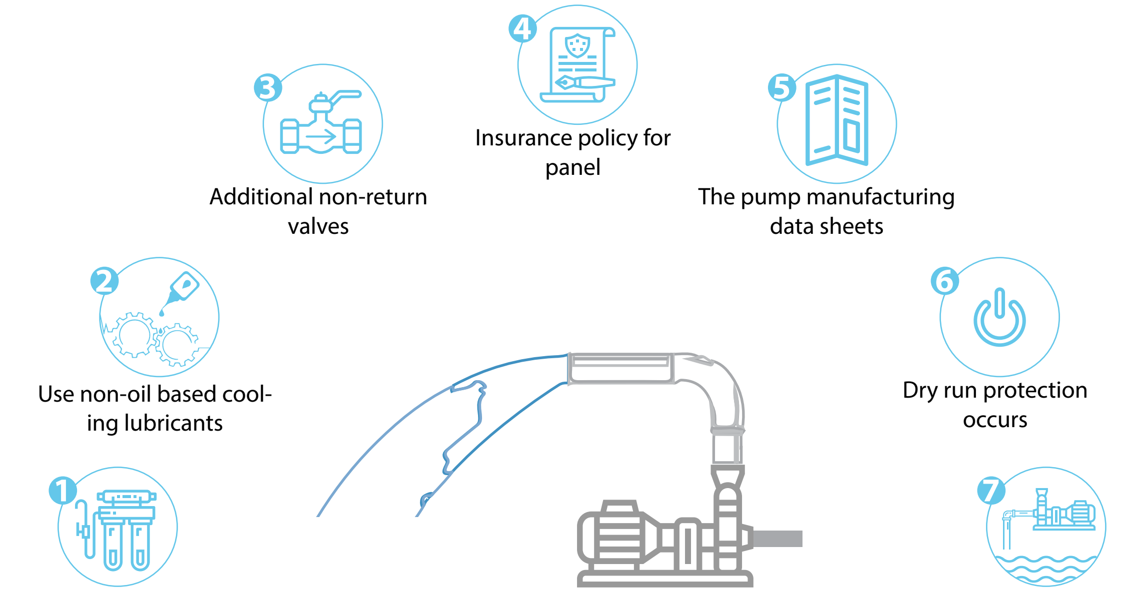
- Ensure that program and its partners personnel are adequately trained to plan, develop and support water supply projects.
- Program and its partners should be capable of working with communities on a participatory basis and on conflict context.
- Assist the community to develop the skills necessary to manage and maintain the project.
- Share experiences and best practices among program team and its partners as well as targeted communities.
- Have a hygiene education component that promotes behavioral change.
- Wherever possible, water projects should be integrated with community health projects.
- To ensure sustainable operation of the solar system, it is crucial that beneficiaries/operator has a good understanding of the system.
- What system operator should know?
  - Fundamentals of solar PV system.
  - Overview of the system (i.e. component, rated capacity, and other parameters, review of single line diagram, etc.).
  - Safety consideration once working with PV system (i.e. risk associated with PV system operator, etc.).
  - Routine inspection / performance monitoring (i.e. understand system parameters, etc.). Use of measurement devices (e.g. clamp meter, etc.) or monitoring system Preliminary troubleshooting.
  - Cleaning of system components.
  - Warranty period, point of contact.

3.5. Potential bottlenecks, risks and mitigation



Water pumping for WASH can face many challenges; few risks to take into consideration include the following:

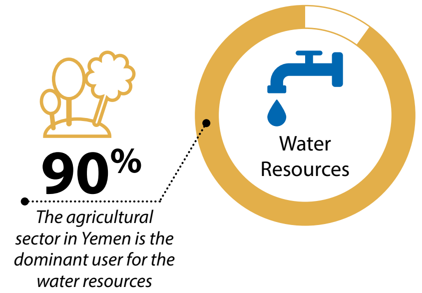
- Water can be contaminated and therefore a water purification unit may be necessary.
- Pumps need to be safe for drinking and use non-oil based cooling lubricants.
- Pumps need to be checked for protection against heat and pressure. Off grid solar energy may vary during the day leading to interrupted power supply. This may lead the water to flow back causing shocks and unexpected pressure on the mechanical parts and thus reduce system expected life time value. Deep well may require additional non-return valves, motor jackets are used to cool pumps.
- Airstrikes and returning bullets are common risks that damage the panels; an insurance policy can cover such risks.
- Careful check of pump specifications, particularly "duty points" to match the required energy. A careful design needs to be taken with the pump manufacturing data sheets. A trade off exists between different output levels and energy levels.
- Dry run protection occurs when the duty point is larger than the safe production yield for the well. Such cases, the water may be interrupted as the well won't have enough water for a while to pump.
- During conflicts, the site location many attracts IDPs leading to insufficient water production.

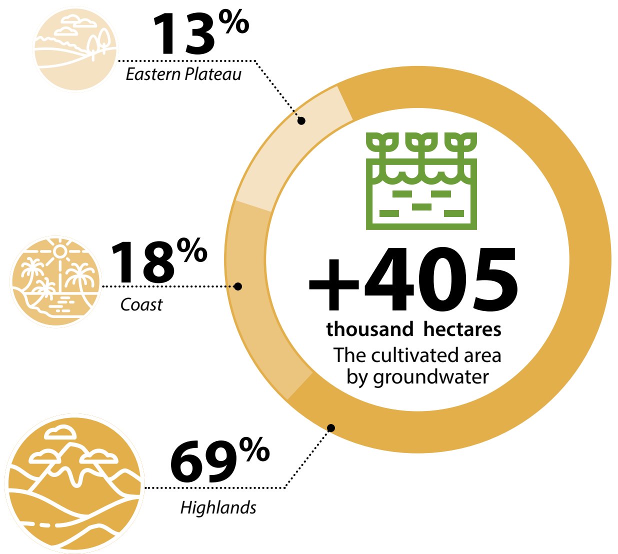


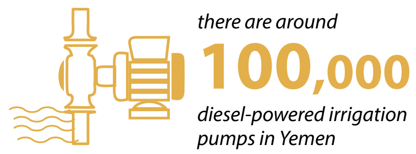
The risks to take into consideration

AGRICULTURE SECTOR

4. AGRICULTURE







The agricultural sector in Yemen is the dominant user for the water resources, which accounts for around 90 percent of the total consumption. The cultivated area of Yemen irrigated by groundwater is estimated 405,264 hectares. Of the total area by groundwater irrigation, Highlands accounts for the largest share, with about 69 percent of the total, followed by Coastal Area with 18 percent and Eastern Plateau with 13 percent. Thus, groundwater resources are vital for Yemen's agriculture. According to International Finance Cooperation (IFC, 2015), there are around 100,000 diesel-powered irrigation pumps in Yemen and a vast majority of which are owned by small farmers with very little access to finance. [10]

Farmers have been struggling to maintain the sustainability of agricultural activities due to increased cost and shortage of diesel supply, which has caused low-quality yields.

The farmers are not able to produce due to limited supply of fuel and increasing energy cost. Land is facing deforestation as a result of climate change, tree removal, and limited supply of energy to pump water. Several farmers have cut their trees as they could not afford their maintenance. Not only diesel prices are skyrocketing, but also the supply is not stable and the cost of replacing a dead tree is very expensive and time consuming. About 70 percent of rural population depends on agriculture for its livelihood. [11]

Alternative renewable energy is highly needed to sustain these farming jobs and continue the supply of local crops to consumers. Solar for agriculture water pumping include additional externalities such as food security and proximity to markets. The following section provides an overview guideline of the associated risks and opportunities for water pumping for agriculture using solar PV systems.

The business nature of farmers adds an additional challenge to the implementation of solar systems. While WASH goes to everyone in the target communities, solar pumps for irrigation goes to those with more land and produce. Therefore, programming for agriculture would require additional considerations.

10. IFC. (2015). Market Assessments for Solar-Powered Irrigation Pumps in Morocco, South Africa and Yemen. Rome. Retrieved January 10, 2017, from http://www.fao.org/nr/water/docs/SPIS/10_Colback.pdf

11. ORSAM (2015).

4.1. Rapid Assessment

Conducting a rapid assessment is important to provide information about the country's commitment regarding the provision of water resources and the general strengths or weaknesses of the policy and institutional environment. This allows the team to evaluate, prior to intervention, whether the panorama is ripe for involvement, or if there is first a need for policy reform. The rapid assessment of the project scope determines if solar powered irrigation system (SPIS) is the most cost-effective solution and the implementation models available.

To conduct the rapid assessment requires a broad range of skills. Project managers may decide whether to hire a consultant or use in-house expertise. The project technical setup is similar to the solar pumps discussed in the previous section. This section adds agriculture concerns to inform the project manager. The time required for rapid assessment is estimated at 1-2 months, depending on the security situation and the quality of existing data.

- Assess energy needs intends to understand:
  - Demographic, social and economic characteristics of the target communities and the extent to which they are accessible.
  - Key problems and challenges facing farmers in the area of energy.
  - Actual energy needs by the target farmers.
  - The cost benefit of the solar solution in terms of the number of farmers and their capacity to pay for operations and maintenance cost.
  - The environmental consequences of the pump in terms of water efficiency use.
  - Implementation potential risks, how to overcome them so they do not happen again.
  - The total capacity of the water source to provide the needed water volumes.
  - Current water distribution infrastructure and needed maintenance.
  - Figures and indicators about the general situation in the target communities (baseline data) needed to measure the project impact.
  - Lessons learned from previous experiences to inform future interventions
- Determine which, where and how many irrigation water supply to cover. Develop concept and initial scope based on discussions with main stakeholders and reviews of readily available data.
- Involve the key stakeholders including local authorities, NWRA (National Water Resources Authority), agriculture authority executive offices in the district and governorate level, local community and other stakeholders in the project planning, implementation and monitoring.
- Address ownership issues and future rules of engagement to cover operations and maintenance cost.
- Consider how financing institutions can participate in such interventions.
- Check the cost benefit of the solar solution in terms of the cost of the system versus the generated benefits of the farm produce.
- Consider the size of intervention given other opportunities to leverage the same long term investment.

4.2. Planning

A solar powered irrigation system (SPIS) should be designed to optimize efficiency and cost. The steps involved in the design process are shown in figure 6.

Figure 6: ***The steps involved in designing and planning a solar powered irrigation system***

Inputs	Steps	Outputs
- Water usage data - Site details	**Conduct site assessment**	- Daily water requirements - Historical solar resource data - Water resource data - Water delivery point details - Location of components
- Solar resource data - Daily water requirements	**Select array tilt & orientation**	Expected solar radiation levels
- Expected solar radiation levels - Daily water requirements	**Calculate flow**	Required flow rate
- Required flow rate - Water resource data - Water delivery point details	**Calculate head**	Required total dynamic head
- Required flow rate - Required total dynamic head -Water resource data	**Select pump and array**	Complete solar pumping system design
	Identify owners of the solar pump system and Management	

1. Site assessment

Solar powered irrigation systems (SPIS) are relatively complex systems and their design requires not only a fit for purpose solar pump system and irrigation infrastructure, but also an assessment of water requirements and irrigation calendar, as well as skills and knowledge of the end user. Crop water requirements change with the weather and as the crop develops. Table 16 shows the various data to take into account when designing a solar powered irrigation system.

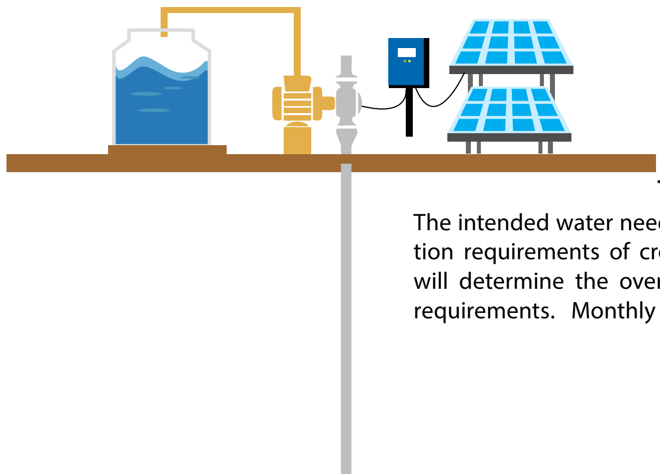
Table 16:

Data requirements

- Meteorological data
  - *Insulation*
  - *Temperature,*
  - *Humidity*
  - *Rainfall*
  - *Evaporation*
- Site data
  - *Longitude*
  - *Latitude*
  - *Altitude*
  - *Water source*
  - *Pumping head*
  - *Shadowing*
  - *Climate*
  - *Terrain*
- Crop data
  - *Crop type and variety*
  - *Growing season*
  - *Crop rotation*
  - *Crop water requirements*
  - *Fertilizer*
  - *Crop protection requirements*
- Soil data
  - *Soil type*
  - *Salinity*
  - *Water holding capacity*
  - *Organic matter content*
  - *Fertility*
- Water data
  - *Availability*
  - *Groundwater recharge*
  - *Water rights*
  - *Salinity*
  - *Temperature*
  - *Sediment content*
- Market data
  - *Selling price*
  - *Market type and distances*

Daily water requirements

The farms' daily water requirements form the central design criterion of a solar pump system. The capability of a solar system to deliver these daily water requirements, given site-specific parameters, will determine the success of the system design. These requirements will influence:



- the delivery point for the pumped water.
- whether water storage is needed or not.
- which types of water pumps will be suitable for the application.
- the required size of the pump.
- the solar array design.

The intended water needs of the irrigation requirements of crop or livestock will determine the overall daily water requirements. Monthly and seasonal variations should be considered in the calculation of daily water requirements, as these will also impact on the solar pump system design.

2. Solar pump system layout

When designing a SPIS layout, it is important that distance between all the system parts are minimized; both electrical cabling and water pipes experience energy loss, therefore, keeping their lengths to a minimum will reduce energy loss in the system and will result in the most efficient solar pump system possible for site and needs.

3. Selecting the array tilt and orientation

The tilt of the array will affect the amount of solar radiation it receives throughout the year and the orientation will affect the amount of solar radiation it receives throughout the day, and that will affect calculations of the flow rate that will be needed for water pumping. Therefore, it is important to determine the array tilt and orientation and calculate the resulting solar radiation levels (check the array tilt and orientation in the WASH sector above).

4. Calculate the required flow rates and total dynamic head

The flow rate is the amount of water that can be pumped within a certain time period (per day or per hour). For a solar system the required daily and hourly flow rates may need to be adjusted to account for variations in levels of solar radiation that are experienced at the site over the course of the day and the year.

The required daily flow rate determines the size of the pump required as well as the size of solar array that will be needed to power the pump. For calculation of the Total Dynamic Head see box 5 in WASH sector.

5. Select the pump/array

To complete the solar pump system design, the solar powered pumping system components (pump and array) needs to be selected. It consists of solar panels, pump, controller/inverter and accessories like cabling and fittings (see box 10)

Box 10:

Solar powered irrigation system components

A solar powered irrigation system consists of the following parts:

1 Solar array

The solar array is a set of solar modules which are to be connected in series and possible strings of modules connected in parallel to get the required power to operate the pump.

2 Pump

The controller is an electronic device (known as maximum power point tracker or MPPT) that matches the power output from the solar array to the pump motor and regulates the operation of the pump according to the input from the solar array.

3 Controller

The pump comprises of the motor which drives the movement (prime mover) and the pump impeller, which moves the water under pressure.

Pump types:

Centrifugal: Centrifugal pump tend to be more suitable for applications requiring large flows and small heads.

Helical rotor: helical rotor pumps best suit applications requiring low flows and high heads.

For the technical aspect of the solar pump system components check the table 14 in WASH sector section.

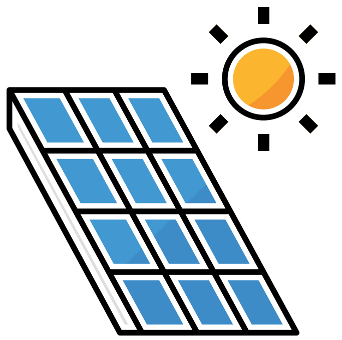
Table 17: The main criteria for selection of the location for installing solar panels and the pump

Preferred location for solar panels	Preferred location for pump
The location for installing solar panels should fulfill the criteria given below: - Even surface for mounting the solar panel structure - Shade-free area (no shade from nearby houses, structures, overhead tanks, trees, mountains, etc.) - Low dust and dirt, low incidence of bird droppings - Easily accessible for cleaning of panels - As close as possible to the pump and water sources - Provision of space for unrestricted tracking movement.	**The location of the pump should fulfill the criteria given below:** - Minimal suction head should be preferred: if the water level is within 10 meters, a surface pump can be installed; water levels below 10-meters depth require installation of submersible pumps. - Low suction lift (vertical distance between the water surface and the surface pump) - Suitable (higher/central) location within the area to be irrigated.

Box 11:

Factors that affect solar system efficiency

Solar pump system efficiency relates to factors that reduce the power/energy output of the modules. Several factors can affect system efficiency; they include:



- **Temperature:** a higher cell temperature will reduce the power output,
- **Shading:** any shading will reduce the power output,
- **Dirt**: any soiling of the modules will reduce the power output,
- **Cable losses:** power is lost as electricity runs through cables,
- **Orientation and tilt losses:** the orientation and tilt of the modules affect the amount of solar radiation that hits the modules, in turn affecting the power output.

6. Solar system Ownership and management

In Yemen, most of the groundwater wells are managed by the individual owner or family, few of them are managed by group of people, such as Water User Associations (WUAs) or Water User Groups (WUGs).

According to the 2002 water Law, a 2011 bylaw defines WUAs/WUGs as "assembly of water users who organize their efforts with the purpose for participation in water resources management and contribution in finance, management, maintenance and operation of water and irrigation projects and structures" which is required "to assist NWRA (National Water Resources Authority) in implementing water rules through dealing with a single community based organization". Other articles strengthen the fact that they are under state authority and do not recognize the self-organizing power of local communities. The community or members should vote in elections to choose the WUA leaders.

WUAs can be set up as associations under the NGO Law. This requires going through a specific set of procedures which are supervised by the Ministry of Social Affairs and Labor. It requires a minimum of forty people, application is made to the Ministry, notice is published in a newspaper, and an organizational meeting, supervised by the Ministry, is held to choose a board and approve a constitution. Based on this, officers are eligible to receive official identification cards confirming their position. This process takes at least several months, and may require traveling to the government or national capital to file documents or follow up on their processing. Once registered, the association has to fulfill requirements including filing annual reports. Some WUAs have been established as cooperatives under the Cooperatives Law, with similar but slightly different requirements.

During the planning stage of solar pump system project, the ownership of the system should be identified, this can be either the Water User Association (WUA) as the NGO owner of the system, or a private individual who own the current water source facility. In addition, how water is managed and distributed should be part of the WUA agreement.

7. Irrigation technology

Most farms in Yemen use the traditional irrigation way (e.g. flood irrigation), which aggravates the already drastic water shortage problem. Therefore, solar pump system project should combine solar pump systems with new irrigation techniques, such as drip irrigation.

4.3. Implementation model

The implementation of a solar pump for agriculture, the technical parts of the solar system are the same as the solar pumps for WASH discussed in the previous section. Therefore, the technical implementation would be the same and therefore, readers are advised to check WASH section. However, the solar pumps for agriculture may still require checking the following issues as they relate to the farming community.

- Decide on implementation model:
  - Identify opportunities to cooperate with other projects and organizations.
  - Conduct multiple consultations with stakeholders on all aspects.
  - Agree on responsibilities for supply and installation, maintenance, financing, ownership and any links with market development.
  - Determine procurement methods.
  - Build up project budgets, schedules, and draft procurement packages, including technical specifications and terms of reference for capacity building, implementation support and system performance tracking.
- Develop a risk mitigation plan.
- Conduct proper tendering, check the tendering checklist in the WASH sector.
- Conduct proper training to systems owners in the location.
- Check installations against possible risks.

4.4. Monitoring and Evaluation

- Conduct a post deployment check by a different party.
- Conduct a baseline and end line assessments in lights of the logical framework or project document.
- Conduct a follow up assessment to check the intervention was able to achieve its objectives.
- Program and its partners should:
  - Work with the water supply committee to monitor the implementation of the project.
  - Assist the water supply committee to develop a plan for the future monitoring of the system.
  - Encourage local technical bureaus if any to monitor project implementation.
- Conduct a post-distribution monitoring
  - Within one to two weeks after an installation, randomly select recipient solar project in the area targeted by the solar pump systems.
  - At each selected water supply, conduct a focused interview, preferably following a predetermined questionnaire.
  - Pay special attention to seek feedbacks directly from beneficiaries of the solar pump system and water.
- Prepare a list of key performance indicators for the project such volume pumped, number of beneficiaries, water for hygiene uses, deforestation, food produced, and others.
- Conduct regular reviews on the performance of the project including issues related to
  - Relevance of the project outcomes.
  - Effectiveness of the intervention in achieving the stated objectives.
  - Efficiency of the system in providing required energy.
  - Impact of the intervention in the community along with success stories and lessons learned.
- Carry out an external evaluation of projects at the completion of the overall program.
- Take lessons learned and put it to good practice in future implementation and disseminate information to others.

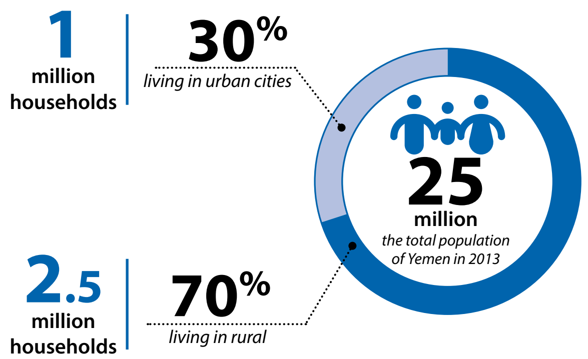
4.5. Potential bottlenecks, risks and mitigation

Solar pumps for irrigations may face several challenges including the following:

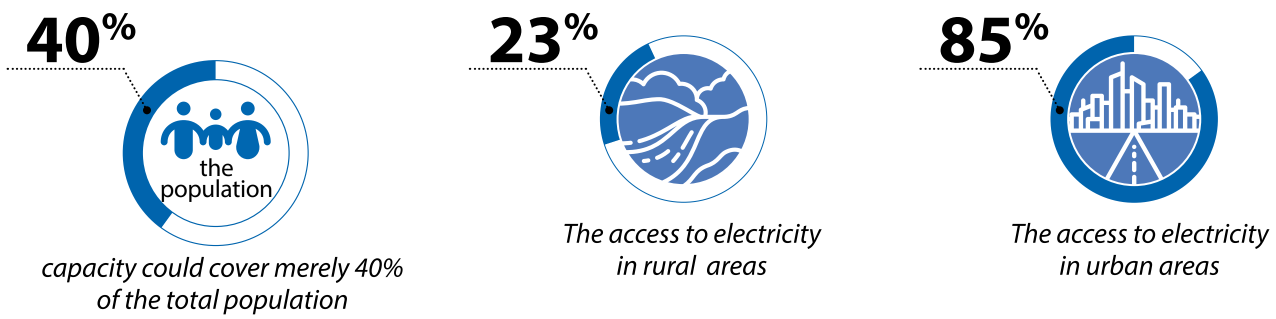
- The pump setup faces the same risks and bottlenecks addressed in the WASH section.
- The cost benefit analysis may not be measured well as farmers tend to be patient about their crops and may not calculate the costs and benefits well.
- Fruits and vegetables vary in terms of the required water and the type of irrigation method such as drip, flow, or others.
- Assessed needed water for irrigation needs may not be enough as the pump may also need to address the needed water for non-irrigation needs such as general WASH.
- Water User Association plays a critical component in the ownership of the system and its role in the maintenance and operations stage.
- Water has been a source of conflict, therefore a comprehensive social and economic analysis to mitigate any social cohesion issues.
- Environmental externalities can have a long term effect such as basin consumptions, forestation, and others.
- WUAs organizing will require an assisted process of establishment and strengthening, as well as provide the necessary capacity building.

SOLAR ENERGY AND LIVELIHOOD

Background



In Yemen and according to government estimates, the total population of Yemen was around 25 million in 2013, with 70% of the population living in rural areas in around 2.5 million households, and 30% of the population living in urban cities in about 1 million households.

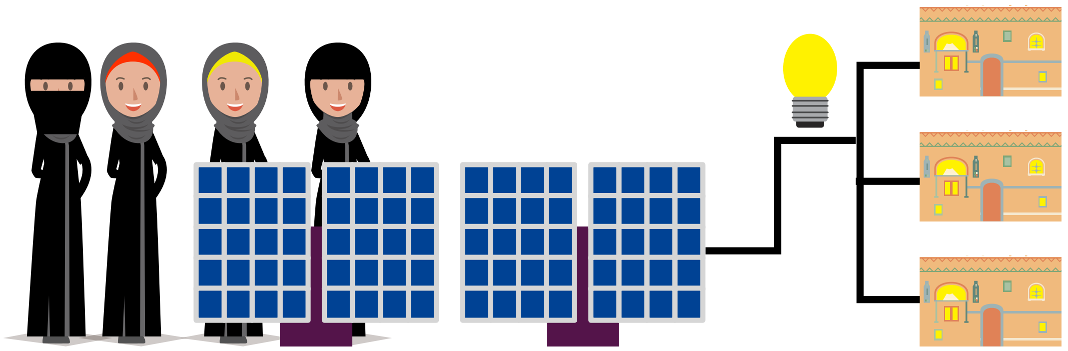


With respect to the electricity profile before the crisis, the total installed capacity in Yemen connected to the main national grid is about 1.5 gigawatt.

This capacity could cover merely 40% of the total population. The access to electricity in urban areas is 85%; however, this rate decreases to as low as 23% in rural areas. Other locations, which are not connected to the main national grid, depend either on community micro grids powered by diesel generators or on privately owned diesel generators.

The political conflicts in the country and the military activities have led to great difficulties, since 2015, in securing the fuel needed for operating power plants as well as in delivering the electrical energy to consumers in southern areas of Yemen. The fuel prices have risen up significantly becoming extremely unaffordable. The electricity generation of the power plants consequently has been considerably stopped in northern areas. The subsequent situation can be described as one of electricity scarcity and power shortages occurring most of the time.

The above described situation has forced citizens to resort to new alternatives. Some consumers, such as commercial shops, deal with diesel-based small independent power producers. Such a scheme is expensive and has discontinuity problems. The other alternative that is rapidly growing is the use of PV systems.



5.1 Introduction

Energy Access and Rural electrification is key for the socio-economic development of non-urban regions in developing and emerging countries. While energy is used for various consumption purposes such as lighting, comfort and entertainment, it is not sufficient by itself to trigger development in rural areas. Since there is a high correlation between energy access and economic growth, the usage of energy should also be aligned in such a way that it will trigger economic development through enhancement of the income generation of the local population. This economic development would further mutually improve the social well-being.

Grid-based electric service has historically served as the primary means of delivering rural energy service. With advances made in lower-cost, more reliable renewable energy technologies, and particularly with solar PV panels, it has become possible to offer an alternative to grid electric service. Given the distances and low population density of some rural areas, there are numerous communities that are not, and may never be, practical candidates for the extension of the electric grid. These communities are typically difficult to access, characterized by dispersed housing clusters, often with low income potential and low rates of energy use. Such communities are not likely to receive grid electric service in the near or medium term. Alternate models and modalities of providing electric service are needed to offer an inclusive energy service strategy for these communities.

This chapter the guideline will addresses the need for reliable energy access for businesses to enable the productive use of clean energy and discuss the sectors of solar interventions that has another impact and effect on rural communities as increasing income, self-employment and opportunities of jobs among youth in solar energy. Through ERRY experiences last years, solar energy interventions in some areas have created jobs, self-employment and increasing income for affected communities through many types of interventions.

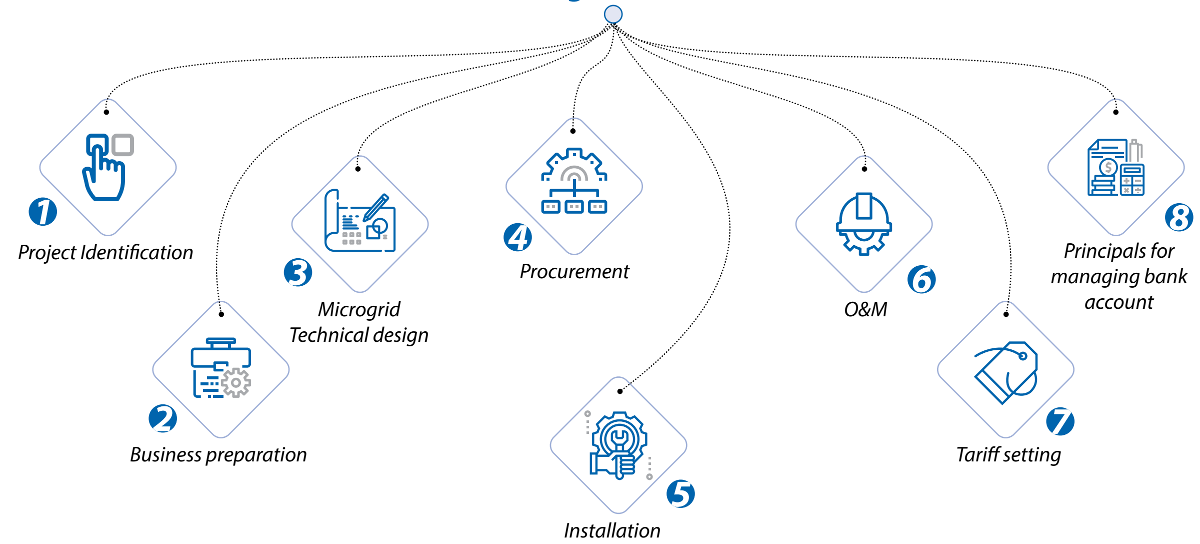
5.2 Solar Micro-Grid:

What is Microgrid?

A micro-grid consists of small-scale electricity generators such as solar photovoltaics (PV) or engines and possibly energy storage systems connected to a distribution network that supplies electricity to a small localized group of customers. Such micro-grids are operated independently and are not interconnected with a national grid. Off-grid power systems can range in size from a few kilowatts (kW) up to 10 megawatts (MW). This section focuses on micro-grids with a capacity of 5–20 kW.

Microgrids represent an exciting electrification solution because they provide high-quality power for an entire village and can provide electricity services to households and businesses even in the most rural parts of Yemen. By providing reliable and affordable electricity to communities, microgrids also enable entrepreneurship and help existing businesses grow. Considering the lower income levels that most often characterize remote communities, and overlaying the need to assure that projects can achieve financial sustainability, it is necessary to assure that adequate steps are taken to enable target communities to obtain the resources necessary to pay for the cost of service – even if the beneficiaries are expected only to pay for operation and maintenance expenses. This means that an integral part of the project development cycle must include an analysis of the ability and willingness to pay for service and concurrently to estimate the levels of energy consumption and demand of the target population. The project preparation process should also evaluate service provider options and how payments will be collected from the beneficiaries to satisfy operating and maintenance expenses.

Solar Microgrid Process Flow:



5.2.1- Project Identification:

Conduct baseline survey

A household energy survey should be conducted to collect and analyze data on individual household energy usage and costs within the project area. The household energy survey not only illustrates what community members are paying now for energy services, but it also provides information required to determine the appropriate size of the solar PV systems. Keep in mind that community members have varying incomes. The survey should analyze the following:

1- Studying energy consumption
2- current energy expenses
3- Power consumer income source
4- Willingness to pay

Community involvement

-Begin with focus group meetings with community leaders and elders. The purpose of these introductory meetings should be to make sure the community leadership favors supporting the project.

-Conduct informative meetings with the whole community to explain the goals, objectives and work methods for the solar PV project under consideration. When defining the informational meetings, the team should be sensitive to the level of economic development present in the community, the level of education, and prevailing cultural biases. Seek to understand the development priorities and expectations of community members. Establish with community members that the project is open to all individuals within the community without discrimination as well as raising awareness on the benefits of Microgrid and how improving energy access level can lead to improve living conditions and income generation of all community members.

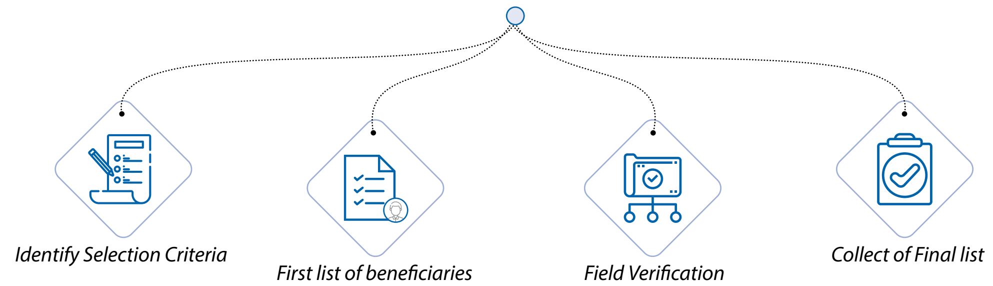
Feasibility Study

For most investments, measuring project feasibility is a straightforward process. A financial cash flow analysis uses estimations of capital and operating costs on the one hand, and projected revenues on the other. These are then used to determine net revenues over the expected project life.

5.2.2 Business preparation

Beneficiaries Selection

Which include the following procedures:



Capacity Building

After selecting the project beneficiaries, capacity building should take place on how to run their own business. Beneficiaries offered to receive three-week training sessions on:

- My First Business (MFB) (for literate beneficiaries),
- I Too Have a Small Business (for semi-literate beneficiaries)
- Financial Literacy.
- Training on microgrid management.
- After receiving these courses, the beneficiaries should create their own business model both technically and financially.

Setting up Management structure

Defining the roles and responsibilities for each one of business partners.

Group leader or Operation Manager

in charge of day-to-day operations of the system. He/she supervises all members.

Accountant

to keep accurate financial records and to advise the Operations Manager on overall cash flow issues and financial management. Register new customers, supervise meter reader, engage with defaulting customers (alerting them of disconnection in the case of nonpayment for example), Collect payments.

Technician

To do Preventive maintenance of system component, connecting customers and installing meters, disconnecting non-paying customers and illegal connections, Keeping an updated asset register and a log book of repairs.

Meter reader

is to keep reading the energy meter of each HHs, shops and delivered it to the Accountant.

5.2.3 Microgrid Technical design

Define the geographic scope of the project

1

- The total number of customers to be served.
- The type of customers (i.e., residential. commercial).
- PSH and insolation level.
- Availability of land.

Estimating Energy Demand:

2

- Develop Daily and monthly load profile.
- forecasting future demand.

Size the system

3

- Determine system capacity.
- Determine capacity for all system components.
- Determine technical specification for each component.

Select system configuration

4

Micro-grids can have three basic configurations:

- Alternating current (AC) coupled.
- Direct current (DC) coupled.
- Hybrid (both AC and DC).

Design distribution system

5

- Design the system layout and select system attributes.
- Model system performance based on the preliminary layout and system attributes.
- Evaluate different conductor sizes based on the load allocated across the distribution system.
- Model variations in line routing, single- versus three-phase service and loads.

5.2.4 Procurement

A well-defined procurement process includes the following information components to facilitate qualified responses to a request for quote (RFQ) or request for proposal (RFP):

Characteristics of the project area

1

- include location, reference conditions (solar insolation levels, ambient conditions, rainfall data, etc.), community size, types of structures on which panels and system components will be mounted, etc.

Evaluation criteria

2

- This defines the basis for bids to be presented, and the qualities that will be examined to select the most attractive proposal.

Description of a bid response format

3

- These instructions describe how proposals should be presented, including the required data and product information, how to present prices, how to present transportation and insurance data, etc. To facilitate comparative evaluation of bids, it is usually best to include tables to be completed by each bidder to provide characteristics and prices of each item included in the bid.

System and component specifications

4

- This section provides a detailed set of specifications of each system component, including references for equivalent products.

Standard contract and payment terms

5

- While a standard contract is not always included, it may facilitate completion of the procurement process. Advise bidders here of the preferred mode of payment.

5.2.5 Installation

Once materials have been purchased and an installation contractor has been hired (if the bid does not include installation services), the project is ready for installation. Provide installation oversight by well-trained inspection technicians to ensure that the solar PV systems are properly installed, that the users are trained to use and care for the solar PV systems, and that all components are functioning properly.

Ideally, the project technicians responsible for maintenance and repair of the PV systems participate in or directly manage this process, but in any case, be sure to train the technicians responsible for the inspection of newly installed systems.

Protect the system components by constructing an iron fence around the system with lockable door.

Ensure the system safety by installing protection devices such as load breakers.

5.2.6 O&M:

Provide extensive training for project technicians in term of preventive and regular maintenance, Panels cleaning and effects of dust on the system productivity, troubleshoots fixing, issues recording, meters reading, monthly bill issuing, financial statements, monthly cash recording, assets registers.

5.2.7 Tariff setting:

The tariffs for electricity supply should reflect the actual cost of providing the service, including the costs associated with the maintenance and replacement of equipment. setting cost per kWh: % capital cost + % maintenance cost +% interest.
It is best practice for communities to pay for Energy on a consumption basis rather than a flat rate, to encourage connection of small households that has small energy demand. This requires metering of all consumption points. The Energy tariff should be reviewed on an annual basis to ensure it is covering real costs related to operations and maintenance.

5.2.8 Principals for managing bank account:

It is recommended that the group keep two separate bank accounts:

- (i) an operations bank account: The management member shall open a bank account to pay for operations (for example paying salaries, office supplies) and to deposit operating revenue. All money should be deposited in the bank as soon as possible. Cash should not be left overnight in the office. Also, they have to make sure to have three signatories (where any two can sign) to authorize withdrawals from the account (the Operations Manager plus two members of the Group).
- (ii) an investment account: This is an account that the group deposits money into on a regular basis after having covered operational costs. It is used to pay for major repairs (emergencies) and investments (expansion). The amount to be allocated to this account is generally determined as a percent of revenue.

5.3- Productive Use of Energy:

it refers to activities that generate income, increase productivity, enhance diversity, and create economic value through the consumption of electricity. More broadly defined, it includes all socio-economic uses of electricity that improve quality of life and local resilience (e.g., electricity for small business, healthcare, and other welfare services). Access to Energy can improve rural livelihoods through the opportunities created for increased income, new businesses and jobs, and access to a more diversified pool of products and services. Any potential livelihood improvement may also increase residential demand and the ability to pay for electricity.

5.3.1 Solar Solutions Types:

1- Stand Alone PV for Productive Associations:

Please refer to:
http://www.ye.undp.org/content/yemen/en/home/library/crisis_prevention_and_recovery/good-practices-and-lessons-learned--solar-interventions-under-er.html
to see the impact of solar systems on Productive Assets and Employment.

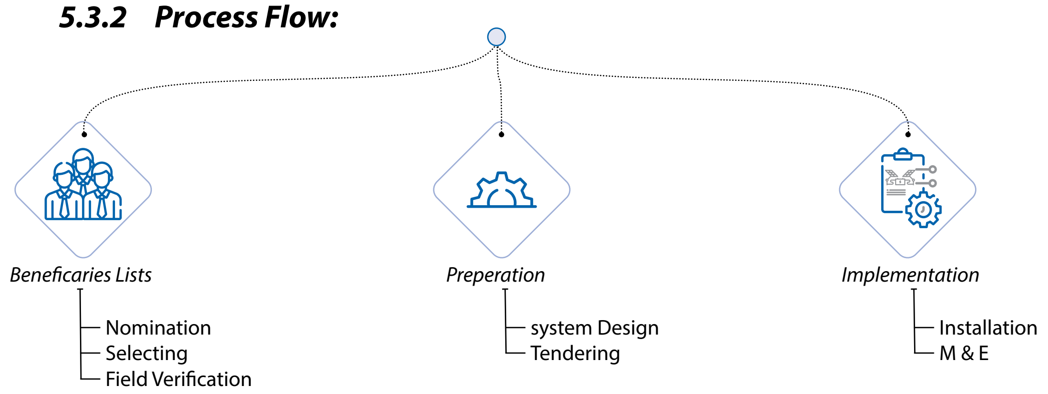
2- SHS for Most Vulnerable People and IDPs:

UNDP-ERRY project has distributed around 5600 solar lanterns for IDPs and most vulnerable people.

Solar lantern is one of solar household solutions, which is small system consist of solar panel integrated with small battery and charging controller, provided with 6 lighting bulbs and external cooling fans. Solar lantern is a cheap alternative solution providing energy for all night hours and can be used in daytime during charging time.

Many case studies have emphasized the impact of PV electrification to improve the socio-economic status of the rural area clean energy supply, protecting indoor air quality and the contribution to greenhouse gasses alleviation from the use of a kerosene lantern or wick lamp for lighting.

5.3.2 Process Flow:



5.3.3 Associated activities:

Capacity Building Program:

Its important to build capacity and skills of youth and women in each district where distribution of SHSs take place, this training program should cover the basic technical subjects in operation and maintenance of solar energy. This training will create new jobs for trainees in the field of solar equipment maintenance for solar lanterns kits and other solar energy systems in the same district. The implementation of capacity building program will help the rural society to create livelihoods opportunities through maintenance of solar systems.

Raising Awareness:

Raising awareness level of rural communities about solar energy technologies, applications and benefits of such energy will encourage those communities to transform from old sources (candles, gasoline, kerosene, firewood and torchlight) to renewable and sustainable energy sources. For that reason, it is important to implement awareness raising program through awareness sessions, printed posters, student's calendars targeting all categories of rural communities.

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