This programme is funded by the European Union

Enhanced Rural Resilience in Yemen
Joint Programme

UNDP
Empowered lives.
Resilient nations.

GOOD PRACTICES AND LESSONS LEARNED: SOLAR INTERVENTIONS UNDER ERRY PROJECT IN YEMEN

(Abyan, Hajjah, Hodeidah, and Lahj)

UNITED NATIONS DEVELOPMENT PROGRAMME (UNDP)

This assessment/project is funded by the European Union.

Published by the United Nations Development Programme
Economic Resilience and Recovery Unit
UNDP Yemen
PO Box 551
Sana'a, Republic of Yemen
www.ye.undp.org
Published: January 2019

Submitted by AFCAR Consulting
Adnan.qatinah@afcar.net
www.Afcar.net

AFCAR CONSULTING
IDEAS FOR SUCCESS

Responsibility for the content and recommendations highlighted in this report rest with the authors and do not necessarily reflect the policies and/or opinions of the EU/donor, nor UNDP.

Table of Contents

Acknowledgement

This study is segmented into two parts. The first part focuses on the documentation of good practices and lessons learned from the ERRY solar interventions for programme leaders and senior management seeking to implement solar activities in Yemen. The second part, an operational guideline, focuses on the technical and implementation aspects of solar programme support to technical Solar Specialists and front-line staff to be used as a reference document.

This study has been conducted under the advisory support, supervision, and guidance of the UNDP Yemen team. Arvind Kumar (ERRY Project Manager), Fuad Ali (Deputy Team Leader, ERRU), Hyewon Jung (Team Leader, ERRU), and Stephen Gitonga (Regional Sustainable Energy Specialist, RBAS) provided extensive support in conducting the study. We would like to thank representatives from UNICEF, UNOPS, IOM, WHO, UNHCR, GIZ, CARE, OXFAM, and Save the Children for their contribution.

Thanks and appreciation are extended to the participating health facilities, schools, water suppliers, and households - as well as local authorities and key informants - for their time and effort in answering questions. We are most grateful to our field researchers who went to great effort to obtain and collect the data required for this study.

For further information, please contact:

Arvind Kumar
Project Manager
Enhanced Rural Resilience in Yemen (ERRY)
UNDP Yemen
arvind.kumar@undp.org

Hyewon Jung
Team Leader
Economic Resilience and Recovery (ERRU)
UNDP Yemen
hyewon.jung@undp.org

Abbreviations

ACTED	Agency for Technical Cooperation and Development
ADRA	Adventist Development and Relief Agency
AWD	Acute Watery Diarrhea
CARE	CARE International
ERRY	Enhanced Rural Resilience in Yemen Programme
FAO	Food and Agriculture Organization
GIZ	Gesellschaft für Internationale Zusammenarbeit (German International Cooperation)
HFs	Health Facilities
HS	Household Survey
IDPs	Internally Displaced Persons
ILO	International Labour Organization
IPs	Implementing Partners
INGOs	International Non-Governmental Organizations
IOM	International Organization of Migration
kW	Kilowatt
M&E	Monitoring and Evaluation
NGOs	Non-Governmental Organizations
NRC	Norwegian Refugee Council
PV	Photovoltaic
PUNOs	Participating United Nations Organizations
RCH	Reproductive and Child Health
UN	United Nations
UNDP	United Nations Development Programme
UNHCR	United Nations High Commissioner for Refugees
UNICEF	The United Nations Children's Fund
UNOPS	United Nations Office for Project Services
USD	US Dollar
VCCs	Village Cooperation Councils
W	Watt
WASH	Water, Sanitation, and Hygiene
WFP	World Food Programme
WHO	World Health Organization
WMCs	Water Management Committees
WUAs	Water Users' Associations
YER	Yemeni Rial

Executive Summary

In the aftermath of the 2015 crisis in Yemen, the local economy suffered greatly due to the failure of public services, leading to social breakdown and resulting in people being forced to the brink of famine.

The severe shortage of fossil fuel prevented hospitals from saving lives and stopped farmers from feeding the hungry. When people became sick, they had to walk for hours to reach the nearest hospital - only to discover that there were no vaccines due to unreliable electricity to operate the refrigerators. Students ran out of school buildings because they were unable to study in dark and hot classrooms. Water was no longer pumped for drinking, sanitation, and hygiene purposes; people had to wait in long queues in remote locations to receive even a few liters for their households.

The Enhanced Rural Resilience in Yemen (ERRY) solar project has enabled communities to rely on themselves and improve their livelihood through better access to solar energy. Local health centers have reopened and lives have been saved becaue lab services are now powered by solar photovoltaic (PV) systems. Children in the community can now be vaccinated and immunized at the local health facility since it has a refrigerator that can store adequate supplies for two months. Children, who are now vaccinated, can enjoy their education at schools and can even study at night.

Drinking water is now available within 20 minutes instead of having to wait for one-and-a-half hours. Everyone in the targeted rural areas has access to water; people can protect themselves against cholera and other deadly water-borne diseases because clean water is pumped by solar energy. Farmers are paying attention to their crops and harvesting food instead of having to worry about how much money they have to spend on black market diesel prices to pump water.

Today, in part because of the work of ERRY, communities in the targeted rural areas of Yemen are fully aware of solar applications

and usage. They use renewable energy with confidence, knowing that it will be there tomorrow. They can focus on community efforts to learn, work, and live.

Communities are stronger when they can look after their common productive assets such as their farms and solar pumps, instead of having to cut forests and trees. They enjoy the fruits of their work instead of starving to death.

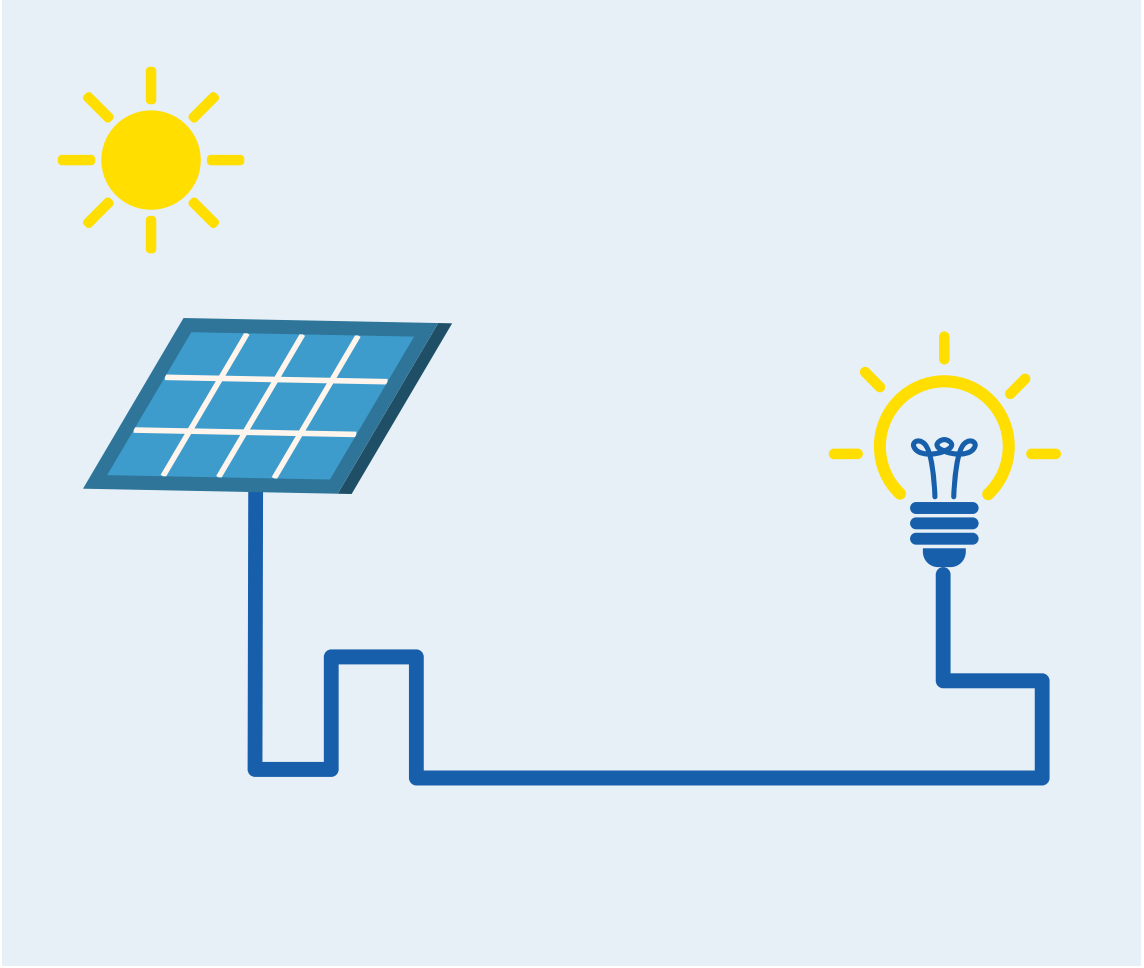
New jobs have been created during this process. Today's market includes many service providers for the solar energy systems - from those who clean the solar panels, to the mega importers of large solar solutions. Technicians are in high demand, and people are aware of the idea of renewable energy.

The project has provided several lessons including the fact that solar projects need to be replicated in more areas in Yemen. These interventions need to properly assess the needs and requirements of the beneficiaries and to take the operations and maintenance of these systems into consideration. The need for more systems seems to be a common theme in solar energy.

Solar systems are expected to work for decades, but the batteries die quickly. Awareness programmes on how to maintain solar systems are important to ensure that they are used to their maximum capacity. Awareness programmes should train participants on precautions, how to handle and fix issues, and where to find help if neccessary.

Good practices include properly assessing needs and requirements to ensure the cabling and appliances using the solar system are more energy efficient.

Solar energy has not only brought light into darkness, it has enlightened people's hearts and minds as individuals and communities. It has provided food, clean water, and a chance at a dignified life to many rural communities in Yemen, while also limiting carbon emissions.



1
Introduction

1.1. Background

The Enhanced Rural Resilience in Yemen Programme (ERRY) is a three-year programme funded by the European Union and implemented by four UN agencies: the United Nations Development Programme (UNDP), the International Labour Organization (ILO), the World Food Programme (WFP), and the Food and Agriculture Organization (FAO). The overarching objective of the programme is to enhance the resilience and self-reliance of crisis-affected rural communities by supporting livelihoods stabilisation and recovery, local governance, and improving access to sustainable energy. The ERRY Programme has been implemented in four governorates: Abyan, Hajjah, Hodeidah, and Lahj.[1]

The 2015 collapse of Yemen's electrical infrastructure - combined with skyrocketing prices and the severe shortage of fuel that is necessary to keep social services, businesses, and household generators functioning (for those who could afford them) - has resulted in a lack of access to basic social services such as healthcare, water supply, and education. Yemen's most viable option now for energy is the solar system. Previously this served only more affluent households, farmers, and small-to-medium sized enterprises.

One of the main aims of the UNDP ERRY solar project is to build community energy resilience in the targeted districts. The main focus of its interventions is to enhance community-based access and the application of sustainable solar energy across rural communities in the targeted districts. Priority has been given to basic services such as health, education, drinking water, and social productive assets that contribute and build community energy resilience.

As part of its contribution to the ERRY solar interventions, UNDP conducted this study with an aim to identify good practices in Yemen. Such results could bear great significance to the humanitarian and development agencies, resulting in reconsideration of policy and programme design aimed at increasing impact at the community-level. Furthermore, the development of an operational guideline will support agencies, the private sector, and communities to overcome operational bottlenecks.

1 http://www.ye.undp.org/content/yemen/en/home/library/crisis_prevention_and_recovery/enhanced-rural-resilience-in-yemen--erry-.html

1.2. Objectives of the Study

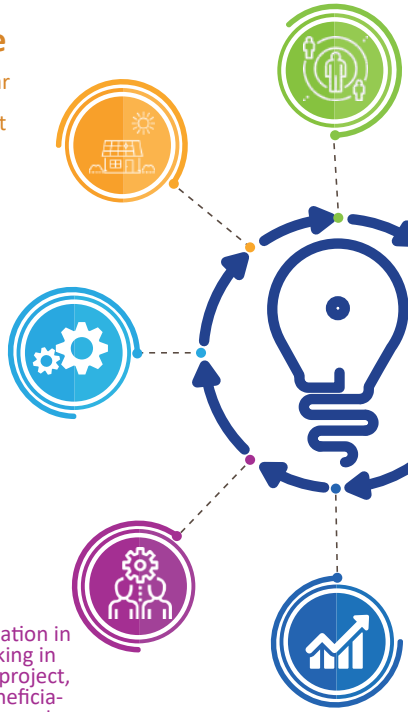
The main objective of this study was to document good practices and lessons learned of solar energy application at both the national and local levels within the ERRY programme and beyond. The study used specific parameters including details of targeted sector, participation, cost effectiveness, efficiency, decentralization, ownership, impact, sustainability, and behavioral influence.[2] Table 1 shows the main parameters that were used for each intervention sector.

Table 1: Good Practice Parameters and Sectors

Parameter	Health Sector	Education Sector	Water Sector	Agriculture Sector	Productive Asset, Market and Employment
Targeted	√	√	√	√	
Participation	√	√	√	√	√
Efficiency	√	√	√	√	√
Cost effectiveness	√	√	√	√	√
Impact	√	√	√	√	√
Decentralization			√	√	
Ownership			√	√	√
Sustainability	√	√	√	√	√
Behavioral influence				√	√

2. A good practice is not only a sustainable energy practice that is good, but also a practice that has been proven to work well and produce good impact for the target communities. Good practices are also projects or initiatives that aim to: (a) meet the needs of target communities; (b) demonstrate a positive contribution of the use of the solar energy and energy efficiency; (c) provide examples of how to overcome barriers/challenges; (d) implement effectively with objectives achieved; (e) contribute to proving the way toward sustainable energy; (f) advocate for the continuing development of synergies between stakeholders aimed at enhancing resilience and access to the sustainable energy; and, (g) enhance resilience of the rural communities.

Defining Good Practice Parameters



Targeted

Measures to what extent the solar systems are suited to the priorities of the target beneficiaries.

Efficiency

Measures the outputs in relation to the inputs. It is an economic term that signifies the fund that uses the least costly resources possible in order to achieve the desired results.

Behavioral influence

Measures the influence of solar systems to change the target community's behavior to adopt solar energy and leave other types of energy dependent on fossil fuel.

Cost-effectiveness

Measures the relationship between investment in solar systems and the desired outcome (e.g. the number of beneficiaries).

Sustainability

Measures the solar system's ability to meet the needs of the beneficiaries in the future.

Decentralization

Measures the level of solar system availability in the local market, as well as for access to solar energy services to remote communities.

Ownership

Measures the direct participation in development decision-making in different stages of the solar project, as well as measures the beneficiaries' willingness to share the costs and benefits of the solar project.

Impact

Measures the positive and negative changes produced by the solar systems intervention, directly or indirectly, intended or unintended, on the local socio-economic, environmental, and in other areas.

1.3. Methodology

Given the study objectives, both qualitative and consultative participatory methods were adopted as key elements to provide a snapshot and rapid study of solar energy applications in Yemen. The study used both primary and secondary data.

Secondary data was collected from a desk-study, and focused on extracting qualitative and statistical data from the literature that is salient to the purpose of analysis. Primary data was collected through qualitative research methods, namely key informant interviews (KIIs), focus group discussions (FGDs), and in-depth interviews (IDIs).

i. Desk Review

The first stage of the study involved a detailed desk review of existing and available information and data on solar programming conducted by: (a) UN agencies (UNDP, UNICEF, UNOPS, WHO, IOM, etc.); (b) international/ national Non-Governmental Organizations (NGOs) (GIZ, Mercy Corps, CARE International, Oxfam, etc.); and, (c) the Yemen private sector to provide an overview of the solar energy applications. Additionally, available literature, reports, and research studies on the issue were reviewed.

ii. Key Informant Interviews (KIIs)

A total of 91 interviews were conducted with: (a) the ERRY solar project team; (b) participating UN organiziations (PUNOs); (c) UN/International non-governmental organizations (INGOs) (e.g. UNICEF, UNOPS, WHO, IOM, GIZ, CARE International, Oxfam, etc.); (d) national NGOs; (e) the private sector; and, (f) local authorities to include the Director General of Education, the Health Ministry, Village Cooperative Council (VCC) representatives, and key leaders in the targeted districts and governorates (e.g. Abyan, Hajjah, Hodeidah, and Lahj) (see Table 2).

This helped to identify the solar component of ERRY, as well as practices from other agencies working in the targeted governorates on solar programming. KIIs provided useful insight, knowledge and experiences relevant to solar project interventions, as well as challenges and lessons learned.

Table 2: Number of key informant interviews

Group	# of interviews
(a) The ERRY solar project team	6
(b) PUNOs	3
(c) UN/INGOs	5
(d) National NGOs	3
(e) The private sector	26
(f) Local authorities	48
Total	91

iii. In-Depth Interviews (IDIs)

Semi-structured interviews were conducted with social sector beneficiaries (health facilities, schools, drinking water, and social productive assets), as well as with solar projects conducted by other agencies in Abyan, Hajjah, Hodeidah, and Lahj.

IDIs were conducted to assess good practice parameters - including the impact of solar energy - to strengthen rural energy resilience in social sectors, as well as to assess solar system use, effectiveness, efficiency, ownership, participation, and sustainability.

The sample of schools, health facilities, drinking water, irrigation projects, and productive assets have been selected randomly from the database of beneficiaries in the selected governorates; 44 interviews were conducted.

iv. Focus Group Discussions (FGDs)

A total of 30 FGDs were conducted with household beneficiaries (50 per cent female) from the UNDP ERRY solar projects and other interventions in the targeted governorates. The lessons learned captured existing practices and served, among others, to: (a) identify the solar energy applications; (b) measure the impact of solar energy to strengthen rural community energy resilience in communities and households; (c) identify the use of solar systems; (d) gauge community participation; (e) assess community ownership; (f) pinpoint behavioral influence; and, (g) analyse livelihood impact.

2
Good Practices and Lessons Learned

2.1. Education Sector

Good Practices

1

Targeting criteria has been proven critical for solar installation, consumption of energy and cost effectiveness. Student were selected from high density areas where energy consumption was high, lowering the risk of equipment (battery or invertor) damage.

2

Engagement of an education authority was found important in the nomination of school-required solar energy. this helps external agencies avoid any structural design intervention or renovation against the Standards of School Structural Design.

3

Solar PV systems have emerged as a long-term, cost-effective solution for providing reliable energy. The increase saving from the cost of diesel is used toward improving the quality of education, sanitation, and hygiene.

The study addressed the role of solar PV panels in the improvement of education and enabling schools to cope with its energy needs. Schools need power for lighting, air circulation, pumping water for bathrooms, and the daily school radio. Several international organizations have engaged in solar interventions targeting the schools in Yemen such as UNICEF, UNDP, UNOPS, and CARE International.

UNICEF, for example, has the largest initiatives for the solar electrification of schools, which targeted schools with solar photovoltaic (PV) systems as part of their interventions. UNDP also targeted schools in the rural areas, mainly those with a high number of students and all-girls schools.

The UNDP ERRY solar project targeted schools conforming with the nomination process prepared and carried out by local authorities, executive offices, and project teams at the district and governorate-levels. The project also targeted schools that have a large number of students, especially all-girls schools.

Most schools participated in the solar project design, implementation and monitoring, while some recommended involving teachers, students, and parents. Moreover, local authorities confirmed their involvement in selecting and identifying schools. Such practices allowed local community project ownership and assistance in pursuing the implementation process of the project.

Belqees School, Abs District, Hajjah (Photo Credit: AFCAR)

Al Wahidi School, Loder District, Abyan (Photo Credit: AFCAR)

Belqees School, Abs District, Hajjah (Photo Credit: AFCAR)

Al Wahidi School, Loder District, Abyan (Photo Credit: AFCAR)

Most schools had a system composed largely of two batteries of 400 Amps with six solar panels. Less than half of the surveyed schools believed that the solar solution was efficient to meet their power needs. One school claimed the system was not working and attributed it to battery dysfunction. Two schools claimed lightning struck the inventor and they had to fix it. Challenges faced were the lack of a budget for system maintenance and the remote distance of maintenance workshops.

The majority of schools claimed dependability on the solar photovoltaic (PV) and stated that they have the user's manual. Almost all schools have been trained on running the system. Staff seems to conduct maintenance activities by themselves with some outsourcing such activities. The least practiced activity is replacing bulbs. School guards seem to be the ones assigned to the task of cleaning the system. Most schools never had to replace any parts of the provided system. A replacement of the inventor has been made in one of the school with a cost of approximately 40,000 YER (approximately USD $68).

Schools that have solar systems are currently functioning in the targeted areas due to the availability of the solar electricity. Activities include literacy classes, social events, awareness programmes, and the like. Only three schools indicated that they still need an alternative power source to cover the school needs. According to a local authority, schools were about to close, but the project allowed these schools to keep operating. The impact is very positive among schools that had solar systems deployed compared with those that have not, according to a local official who wishes all schools had solar systems.

Almost all schools indicated positive change after the installation of the solar PV system. Before, students and teachers suffered from the hot weather, especially with the overcrowding of students in the classroom, leading to high drop-out rates of mainly female students. The

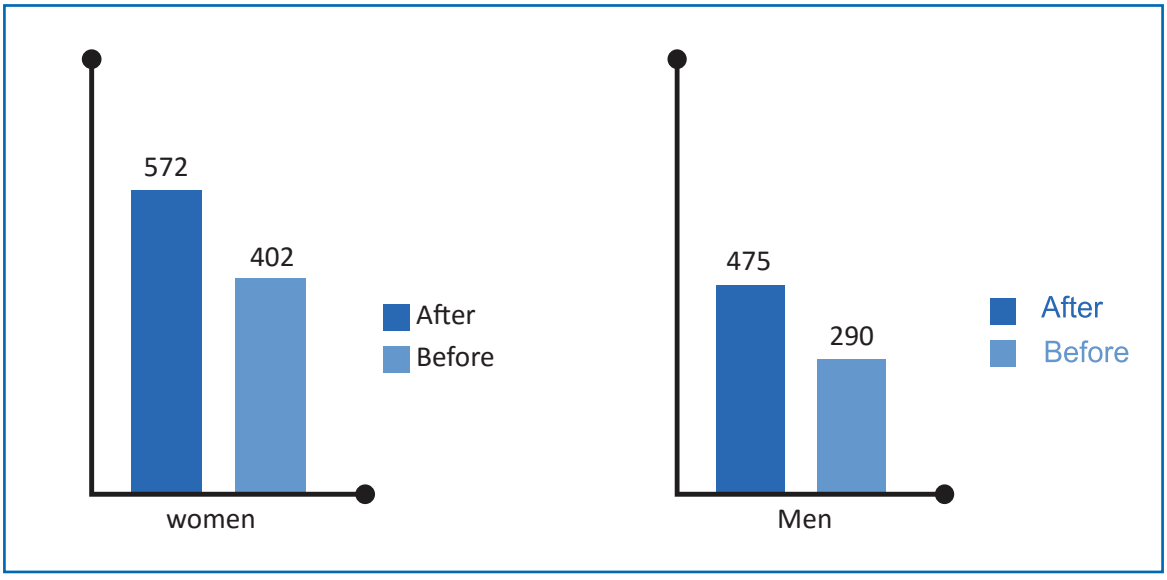
schools had to reduce the number of sessions with students because they were unable to continue until the end of school day due to the heat.

The lack of electricity also led to the decreased performance of teachers and students.

Schools indicated that the average number of students increased 33 precent (from 602 to 901) because of the solar energy and other reasons. Girls have increased by 30 per cent on average in each school, while it was higher among boys at 39 per cent. See Figure 1.

> *"Very hot weather and over crowding in the classrooms forced students to leave the school or drop out. However, after installing the solar system, there was a change in the general temperament of students and teachers - their performance improved and everyone became more willing to attend and listen to the school radio."*
>
> - Mr. Ahmed Hadi
> Tahrir School Headmaster, Al-Zuhra District, Hodeidah

Figure 1: The average number of students before and after the installation of solar systems



The percentage of drop-out students has reduced from 11 per cent to 3 per cent on average. Moreover, the average working hours have increased from 4 to 6.8, with better access to education facilities. Meanwhile, the average number of teachers has increased from 29 to 31 because of the improved work environment and their overall performance has improved.

The UNDP ERRY solar project intervention was able to provide solar energy for schools that also host Internally Displaced Persons (IDPs). While more students have been hosted, energy was effectively used to provide power to the school. Such energy capacity allowed better reception of IDPs in the host communities.

A statement by the local authority indicated that *"thanks to the project, it allowed students, including IDPs, to learn in schools."* For instance, Ms. Nawal Ali, Belquess School Headmaster in the Abs District, Hajjah, reported that eight IDP households (35 female and 24 male) and around 80 students are IDPs.

All participants claimed the education system improved because of the access to energy. Ahmed Hussain, Principle of Abu Bakr School Bajil district, Hodeidah governorate, indicated that teachers are more comfortable now to teach.

> *"We noticed that now students stay until the last class session. In the past, students would run away because of the heat."*
>
> - Ms. Sina Algaderi
> Wahdi School Principle, Larwder District Abyan

Schools normally operate in the morning, but some schools operate in the afternoon and later at night. Some schools are being used as community centers, providing additional educational and training opportunities to others in the communities and/or facilitating community activities where members can come together.

"*Due to availability of electricity, our school is being used as a hub for our village and providing adult classes and facilitating awareness-raising activities."* Ms. Kokab Saleh, Principal of the Al-Kansa Girls School, Bajil, Hodeidah.

Local authorities praised the intervention and confirmed the need for such systems to local communities. They also confirmed the importance of involving them in the process. According to the general manager of the local education office in Lahj, *"Solar systems have improved school administration, students were able to overcome high temperature, as well as staff, it also improved local community's perception of the local administration."* Local authorities encouraged INGOs to assist in solar energy deployments for their critical role in helping local communities.

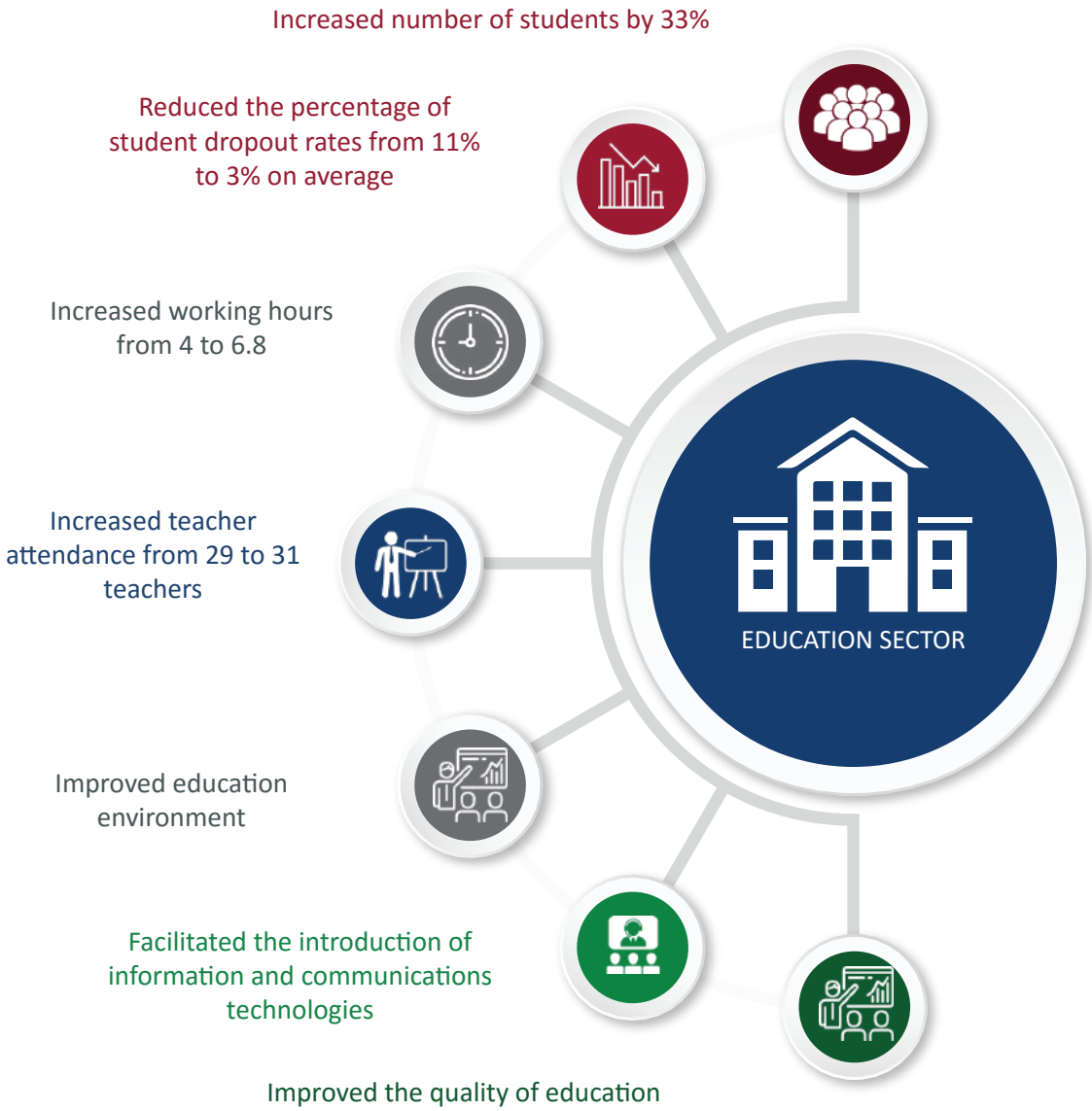
Overall, 54 per cent of schools were very satisfied with the solar solutions and 46 per cent were satisfied, requesting bigger systems and more power to allow several applications to work at the same time.

Schools confirmed that the market provides for their needs should they have the budget. Maintenance is available within an hour of most of the schools, only a few needed more than that. More than 75 per cent of respondents believed the system would continue to work for the coming five years. The main durability factor is the maintenance and good usage of the system.

Lessons Learned

1. Future interventions should evaluate school infrastructure and energy needs prior to system deployment, including whether current power cables are efficient enough. Lights may not be energy efficient and need to be replaced, as well as other school appliances such as fans, computers, and water pumps.
2. Introduce solar energy efficiency systems such as using low Wattage fans for schools since they are essential in hot weather conditions and areas.
3. To ensure sustainability of the solar system, and extend the battery life time, the on/off grid solar systems should be introdued for specific use where solar systems in schools can work without batteries during sunlight hours.

Impact of Solar Systems on the Education Sector



Al Baha Health Center, Bajil District, Hodeidah (Photo Credit: AFCAR)

2.2. Health Sector

Good Practices

1

Solar installation at health centers and facilities has managed to reduce the overcrowding and burden on hospital providies it basic services and support to the centers and facilities to resume basic services, vaccination, and immunization campaigns at scale.

2

The solar systems installed at the targeted health facilities are cost-effective with high opportunity and return. The installed solar systems have enhanced and improved service delivery, including emergency services, obstetrics care and basic emergency services, management of childhood illnesses, cold chain operation, and vaccine storage.

3

The solar refrigerator intervention enhanced the capacity of health facilities to provide vaccination services pivotal in preventing debilitating illnesses and disabilities of thousands of children from preventable diseases including cholera, measles, diphtheria, polio, and pneumonia.

The Health Sector has been affected by the current conflict and war. According to WHO, more than half of the people have little access to basic health care, and less than 45 per cent of health facilities in Yemen are fully functioning.[3] Over one million people have been infected with cholera and more than 350,000 children suffer from severe acute malnutrition.[4]

Most of the health facilities (HFs) have minimized their dependence on the national grid by installing diesel generators with fuel supplied by the government or international organizations. However, others have relied on diesel-based power generation, which was not only expensive, but also vulnerable to fuel shortages. Some health facilities have installed solar PV systems for lighting and to cover their necessary loads such as storing vaccinations and medicines when cold temperature storage is needed.

Several international organizations have engaged in solar interventions targeting the health sector in Yemen including WHO, UNICEF, UNDP, and UNOPS.

The UNDP ERRY solar project, for example, targeted both health centers and health units. The solar systems that have been installed at the HFs consists of PV panels, batteries, and charge controllers. The solar PV panels and batteries vary in size across the different HFs depending on their size and needs. Some HFs have also been provided with solar refrigerators.

WHO has targeted epidemiological monitoring centers in all governorates with solar energy systems, as well as many health facilities with solar refrigerators for vaccine outbreaks. UNICEF also has installed solar systems in many district vaccine warehouses to help maintain the vaccine cold chain. UNOPS also has a solar project that has provided a solar system for one of the biggest hospitals in Sana'a.

According to interviews with the health facilities, the vast majority indicated that the situation in their HFs has changed positively after the installation of the solar PV system. Most HFs (88 per cent) resumed functioning, compared to 44 per cent before. The vast majority of HFs reported that they participated in the design, implementation and monitoring of the solar project, while some of them recommended having more involvement and participation not only from the HF staff, but also their beneficiaries (mainly women). During an interview with UNOPS, they mentioned that the local communities (women and men) also participated in the HF selection process.

The vast majority of the solar PV systems were functional. Eight HFs expressed having encountered minor problems while the systems continue to function, and six HFs never experienced any problems with their solar systems. Only two HFs encountered larger problems with the systems. The main problems included panels damaged due to heavy winds, inverter-related issues, and battery problems.

3. WHO (2017). http://www.who.int/hac/crises/yem/appeals/who-donorupdate-april2017.pdf
4. World Bank (2017). https://www.worldbank.org/en/news/feature/2018/09/10/world-bank-brings-electricity-back-to-the-largest-hospital-in-yemen
5. Rural health facilities (HFs) in Yemen consist of three categories including: rural hospitals, health centers, and health units.
a) A health unit has two-to-five rooms and is wholly dedicated to providing health services such as treating minor illnesses and minor injuries. Patients with serious health problems are referred to the district hospital. Moreover, health units have only the very basic tools, communication equipment, lights, and occasionally vaccine refrigerators. While health centers, which are larger in size, usually have from three-to-seven rooms.
b) A health center offers a wider array of services than a health unit. Compared to Health United, these facilities are more likely to have equipment such as vaccine refrigerators, and some of them have simple laboratory equipment such as centrifuges and microscopes.
c) A rural hospital, the largest health facility at the district-level, has usually from nine to 50 rooms and some a dozen beds. Most rural hospitals have doctors and nurses. Moreover, hospitals offer services such as surgery, rehabilitation, laboratory, and radiological services. Rural hospitals operate, on average, 24 hours a day, while health centers and health units operate for about six hours a day, mostly in the morning.

Al Khashm Health Unit, Al-Zuhrah District, Hodeidah
(Photo Credit: AFCAR)

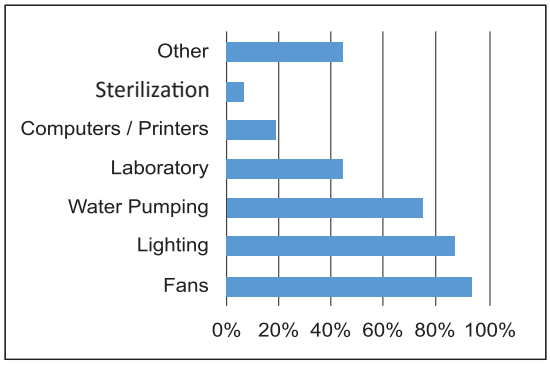
Motherhood and Childhood Center, Tour AlBaha District, Lahj
(Photo Credit: AFCAR)

Solar systems are used to run fans (94 per cent), lighting (88 per cent), water pumping (75 per cent), laboratory (44 per cent), office appliances (e.g., computers, printers) (19 per cent), sterilization (6 per cent) and other uses such as vaccine cooling, charging cell phones, and watching TV (see Figure 2).

Over 75 per cent of HFs surveyed believe solar PV system energy is reliable, 25 per cent view it as unreliable due to solar energy not covering all needs such as laboratory and radiology services and, when cloudy, the electricity goes out quickly. The facilities still need to cover the remaining needs. Nine HFs still use other power sources because sometimes the solar energy is insufficient to cover all needs, particularly if the HF remains open late.

It is important for the end users to understand the basic operation and maintenance services of the system so as to utilise it effectively and maximize benefits. The study found that the vast majority of the HFs reported having received training on the basic operation and maintenance of the solar system, while two HFs have not received any training. And over 56 per cent do not have a solar system user manual. This finding deems it important to raise awareness on the benefits of the solar

Figure 2: What are the solar PV system being used for?



system, as this would help the HF staff to use the solar system in an efficient way, ensuring longevity of the batteries, and the solar PV system as a whole.

Most of HFs (88 per cent) pointed out that it is easy to run and maintain the solar system, while 13 per cent think it is difficult. Moreover, all HFs carry out some sort of maintenance such as cleaning the panels (69 per cent), cleaning the batteries (63 per cent) and replacing lamps (38 per cent), while 38 per cent mentioned that they have a dedicated person tasked with maintaining the solar system.

The study found that the average working hours in HFs increased from eight to 11 hours due to the installation of the solar system. Meanwhile, the average HF staff size has also increased by 44 per cent, from nine before the solar system to 13 staff now.

Most HFs (81 per cent) confirmed that the availability of the solar system enhances and improves obstetric care and basic emergency treatment services, as well as the management of childhood illnesses. This is because of the availability of electricity helping to extend operation hours and/or emergency health services at night, and increasing the ability to store vaccines. Overall, the solar systems at the health facilities have enabled them to better store the medicines and supplements for children in a cool place, perventing damage due to hot weather. They have also allowed increased security at the facilities.

> *"The solar system has made it possible for the health center to manage deliveries at any time, and to work and operate additional hours either day or night."*
>
> - Mr. Othman Al-Tayeb
> HR Officer, Al-Badam Health Center, Abs District, Hajjah

Figure 3: The Average working hours before and after the installion of the solar systens

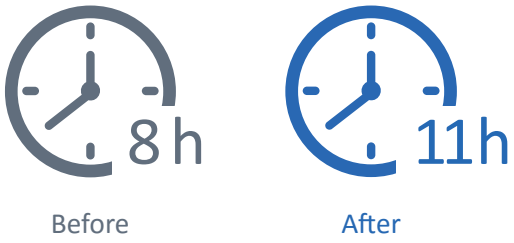


Figure 4: The average staff in the health facilty before and after installation of the solar systems

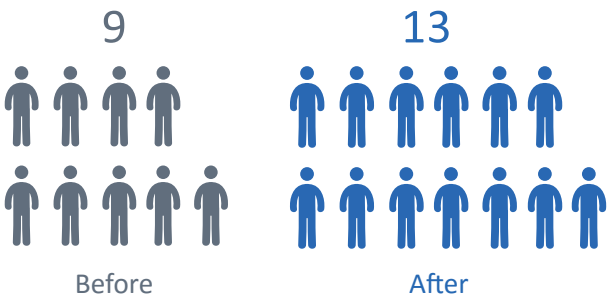
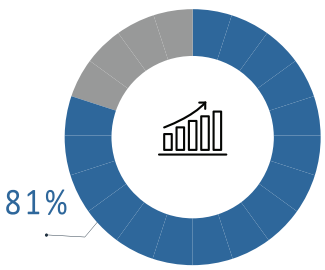


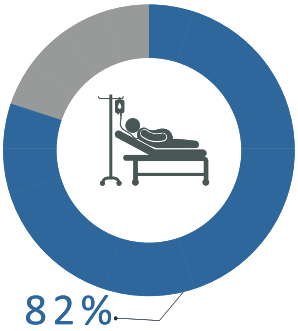
Figure 5: Improved meal, obstetric care, and basic emergency treatment services



Over 50 per cent of the health facilities have initiated evening activities for emergency cholera prevention, obstetrics, accidents, and emergencies. Most HFs indicated that as a result of the cholera outbreak in their areas over the last year, health facilities have become centers for treatment of cholera and acute watery diarrhea (AWD). For instance, Dr. Talal Abdulhamid, Director of Al-Khashm Health Unit in Al-Zharah District, Hodeidah, revealed that the health unit has turned into an emergency center to combat cholera and AWD. More than 3,400 suspected cholera cases have been treated - most of them women and children.

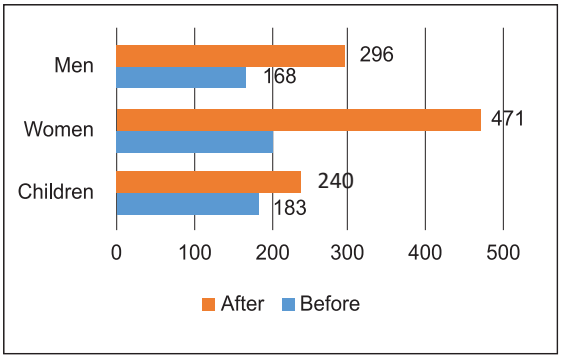
Health facilities reported that the average number of out-patients and clients per month increased drastically by 82 per cent, from 552 to 1007 patients. Female beneficiaries increased by 134 per cent compared to 76 per cent among men and 31 per cent among children (see Figure 7). This is due to extended working hours to provide health services, increased number of staff, as well as the opening of labs and the provision of vaccination services in all HFs.

Figure 6: Increased number of out-patients



> *"The number of patients admitted to the health center has increased from 20 cases to 50 cases a day because of extended operation hours to provide health services, lab work, resuscitation for newborns and the provision of vaccination services."*
> - Ms. Sherin Saleh Hassan
> Head of Al-Kod Health Center, Abyan

Figure 7: Average number of beneficiaries per month



The study found that installing solar PV systems in the health facilities enhances service delivery becasue of the availability of electricity. Over 88 per cent stated that their cold chain and vaccine storage conditions have improved, while 94 per cent confirmed that vaccine services have improved - leading to lower immunization default rates and better coverage, in addition to an increased number of beneficiaries. Vaccines are available in most HFs and they carry out vaccinations at any time. Other benefits include reduced travel costs to get vaccines from nearby health centers by an average of 15,000 YER (approximately USD $26) per trip on average. Now vaccines can be stored and used for up to two months.

Figure 8: Cold chain and vaccine storage conditions improvement

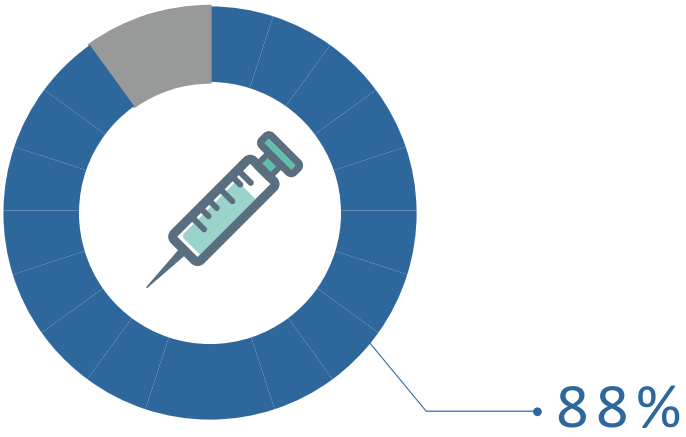
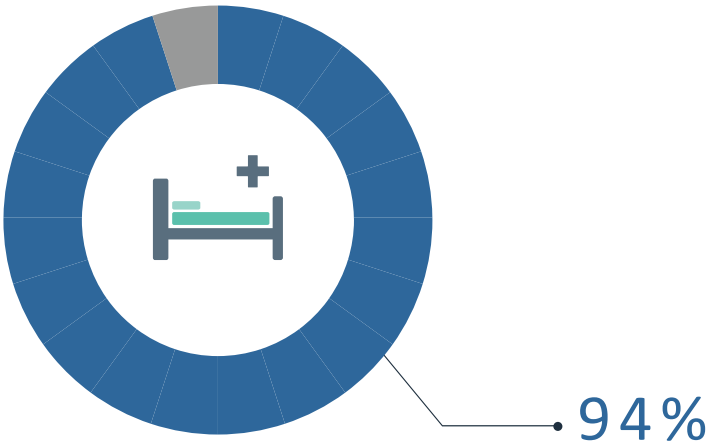


Figure 9: Vaccine service improvement



Over 88 per cent of HFs revealed that having a solar system and solar refrigerator enhances their capacity to provide vaccine services, which are pivotal in preventing debilitating illnesses and disabilities such as cholera, measles, diphtheria, polio, and pneumonia for thousands of children. For instance, Dr. Makia Ahmed, Head of the Health Center in Aslam stated that the number of children who are vaccinated per month increased from 20 to 46 children due to the availability of a solar-powered refrigerator that enabled them to keep the vaccines.

"The solar system and refrigerator that we have received have had a great impact on the level of our services. It improves the provision of vaccine services due to the availability and continuous presence of vaccines in the health unit. The solar system became more important and useful when the cholera epidemic spread and the health unit turned into an emergency center to combat cholera, helping us combat and reduce it in the region."

- Dr. Talal Abdulhamid
Director of Al-Khashm Health Unit,
Al-Zharah District, Hodeidah

The study found that some 69 per cent of HFs indicated that installation of the solar system has contributed to enhanced staff performance because of improved working conditions and environment. It has also made it possible to charge their mobiles and have better communication with others. HFs also reported that the availability of electricity helped manage things better at night and facilitated completion of HF paperwork after sunset by using computers and printers.

The majority of patients observed at the HFs during the field visits were women and children. Therefore, the availability of health services such as immunization and antenatal care in the health centers would ease the burden of travelling or walking long distances - two hours on average - in pursuit of such health services, as well as save an average 5,000 YER (approximately USD $8) per trip. The electrification of rural HFs are able to access services such as night deliveries, as well as address child emergencies.

Observations indicated that solar power is healthier for the local people, patients, and HF staff as it does not generate air pollution nor greenhouse gas emissions, while reducing fire risks associated with kerosene lamps.

"Without the solar system and solar refrigerator, the health center could not have provided safe vaccines and a number of other services. The weather is hot in Aslam, therefore, it is very difficult for staff to stay inside the health center without fans."

- Dr. Makia Ahmed
Director of Aslam Health Center,
Aslam District, Hajjah

Box 1: Life Thrives Again

Following years of suffering and blackout in the area due to the conflict and suspension of health services in the Majel area (Lawdar district, Abyan governorate), life has returned again in the HF. Installing the solar systems and solar refrigerator powers all facilities in the health center such as lighting, equipment, and the water pump.

Before installing the solar system, people used to travel to distant towns and hospitals to seek services and vaccinate their children.

Current beneficiaries of the health center include people from Majel village, 25 kilometers away from the district center, as well as other nearby villages in Al Baidha'a governorate, and IDPs. The health center has become the lifeline for people in the area because it is located in the nearest point of the paved road. It also conducts health education campaigns, especially during outbreaks.

Very recently there was a notable increase people coming to get their children vaccinated.

Most HFs reported that the solar systems have reduced operation and maintenance costs compared with other energy sources (e.g. diesel generators) and saved around 26,500 YER (approximately USD $45) a month that used to pay for diesel or other energy sources, saving money to pay for other operational costs.

Overall, most HFs (94 per cent) are satisfied with the solar solutions and they are asking for bigger systems. The only HF that expressed dissatisfaction indicated the solar system size was not sufficient.

Over half of HFs confirmed that their systems would remain operational for the next five years while the remaining HFs have concerns over the battery life expectancy, humidity and high temperature. Only two HFs revealed that they have had a budget for solar system maintenance.

Lessons Learned

1. Considering the overcrowding and continuous displacement, the load on health facilities is enormous. Therefore the provision of solar facilities could be based on population density the health facility serves.
2. Coordination with medical agencies who are appropriate to target the hospitals for operation and maintenance is a must to provide critical support to facilities.
3. The savings, operation, and maintenance costs need to be regularized by the Director of Health Services, and fiduciary control should be given to Health Facilities to manage the fund.
4. Minimum support versus full coverage: In the context of crisis, minimum support and full coverage should be analyzed based on critical facilities available such as reproductive and child health, immunization, emergency treatment, etc.
5. To enhance impact, installation of solar PV systems should prioritize HFs that operate at night because they are more likely to optimize use of these systems while operating at night to receive and treat emergencies.
6. Evaluate health facility's infrastructure and energy needs prior to system deployment. This includes whether current power cables were efficient enough, energy efficiency of lights, and replacement of bulbs, fans and water pumps.
7. PV panels base should be well fixed on the rooftop or solid foundation on the ground on well-established mounting structures to tolerate wind high speed.

Impact of Solar Systems on the Health Sector

Increased working hours from 8 to 11

Improved the work environment

Increased number of outpatients/clients per month by 82% (from 552 to 1007 patients)

Improved obstetric care, basic emergency treatment services, and management childhood illnesses

Vaccine services improved which led to lower immunization default rates (94%)

Reduced travel costs to get vaccines from nearby health centers by 15,000 YER (approximately USD $26) per trip

HF saved approximtely 26,500 YER (approximately USD $45) a month

Sukan Obeida water project, Khanfer District, Abyan (Photo Credit: AFCAR)

2.3. Water, Sanitation, and Hygiene (WASH)

Good Practices

1

Solar drinking water system installation has proved to be the appropriate replacement of diesel sources in the improvement of water conservation, management, environment friendly, and improving access and quantity of clean water.

2

Solar drinking water with automated chlorination system has ensured the prevention of water-borne diseases by treating the water at the source. The longevity of automated chlorination system is high and can be scaled-up in potentially high incidence (disease) locations.

3

Solar drinking water systems have also brought the financial viability for the Water Management Committee (WMC) to generate revenue (minimum PAY AS YOU GO) to maintain the water system for a longer period without external support.

Yemen continues to be one of the most water-scarce countries as the share per capita is among the lowest worldwide with about 125 m^3 annually.[6] Severe water shortage is caused by massive overexploitation of the resources, mainly irrigation. The drinking water supply is threatened by depletion of groundwater reserves. It is expected that water use will continue to grow with the current trends of population growth.[7]

According to the Regional Representative of the United Nation's Food and Agriculture Organization (FAO), the civil war has left around 20 million Yemenis without access to drinking water.

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 with many people forced to purchase water from tankers operating in remote areas. The price has increased five times more than before the conflict due to the long transportation and fuel costs, forcing many people to use unsafe water sources, and contributing to the recent cholera outbreak in Yemen.

Attention to the solar pump systems intervention has increased, particularly in the last two years because the shortage and the price of diesel, as well as cholera epidemic. Many international organizations have intervened by providing solar pumps to enhance the access to safe drinking water, such as UNICEF, UNDP, UNOPS and CARE International, Oxfam, NRC, Mercy Corps, Save the Children, ADRA, ACTED, and others.

The UNDP ERRY solar project has adopted affordable, scalable, environmentally sustainable approaches to water supply (i.e. solar power pumps with automated chlorination system).

Two of the solar pump systems have been installed in Lahj. The solar systems installed include solar pumps, PV panels, charge controllers, and a chlorination system at the source. The solar pump and panels vary in size across the different areas depending on the needs and number of projected beneficiaries.

UNICEF has installed solar pump systems for wells run by the General Authority for Rural Water Supply Projects on a big scale. For instance, three comprehensive water solar systems with a total capacity of 208 kW were installed by UNICEF to operate three water major boreholes in Sa'ada governorate. They provide safe water for approximately 70,000 beneficiaries and cost around USD $400,000.

IOM, the UN Migration Agency, also has installed a large scale solar water system in Sana'a. CARE International, OXFAM, Mercy Corps and Save the Children have also installed solar pump systems for IDP host communities needs on a small and medium scale.

This study covered UNDP-ERRY solar project and a sample from other organization's interventions in solar pumps for drinking water supplies.

According to the interviews with the Water Management Committees (WMCs) representative, all of them indicated that they relied heavily on diesel-run generators which are not available all the time. Prices have significantly escalated over the past four years due to diesel shortage and price hikes. Yet, the solar energy was the best solution as solar pump systems need less effort and no fuel. In addition, solar pumps can offer a reliable and an environmentally-sound alternative. They often constitute the only reliable solution to problems associated with the drinking water supply in remote areas and at times of fuel storages.

WMCs indicated that the situation of water supplies have changed after the installation of the solar pump systems. The study found that all the solar pump systems were functional. Water supplies that were supported by UNDP have not encountered any problems, while four-out-of-seven other solar water projects encountered problems such as issues related to the pump and controller; most of which were solved. Three-out-of-seven water suppliers

6 GIZ (2014), Water Sector Programme Yemen: https://www.giz.de/en/downloads/giz2014-en-water-sector-programme-yemen.pdf
7 Ibid.

revealed that they have no arrangements with a technician or an organization to support maintenance, while four water suppliers have some sort of arrangements with a technician or an organization (i.e. free warranty for two years from a supplier and local technician).

During the interview with UNICEF and IOM, they noted that to avoid any technical issues related to the water supply, a technical assessment must be conducted to determine the chemical and biological eligibility of the water supply in terms of quantity, quality, and safety of water. The study should also identify the interventions that can be implemented with the solar pump such as changing the pipes, submersible or other necessary interventions, to ensure that it achieves its objectives and prevents contamination of the well.

All WMCs reported receiving basic training on the operation and maintenance of solar pump systems. While over 29 per cent indicted they have not had solar system user manual.

The study found that solar water supplies have had WMCs elected democratically by the local community to focus on addressing the water needs and problems. Their primary function and responsibility revolve around maintaining the water system to function well. It was noted that all WMCs have not included women in any positions, depriving women in decision-making at the community-level.

The study found using solar pump systems in drinking water supplies has a significant impact on rural communities by improving their access to drinking water, saving countless hours that was spent collecting water, improving health and hygiene, education, saving money, and increasing revenues from other livelihoods.

Figure 10: Average number of villages benefiting from water supply befor and after the solar pump system was installed

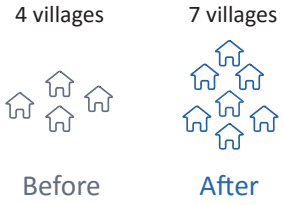


Figure 11: Average number of beneficiaries

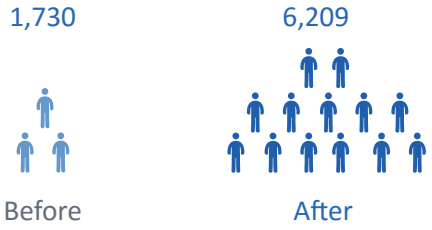


Figure 12: Average quantity of water per individual a day

Figure 13: Average time spent to collect water

All water supplies are functioning compared to only two before the solar system was installed. The average number of villages benefiting from water supply increased from four villages to seven, while the number of beneficiaries increased from 1,730 to 6,209 individuals on average after the installation of the solar system. The quantity of water per individual a day increased from 15 liters per day to around 40 liters per day and the time spent to collect water decreased from around 1.5 hours per round trip to just 20 minutes, a task that falls mostly on women and girls and that yielded better satisfaction and helped liberate time for other activities.

The vast majority of WMCs indicated that using solar pump systems in drinking water supplies, as well as other interventions such as chlorination to water and raising awareness, contributed in reducing the amount of water borne diseases, and that also contributed in promoting health and hygiene.

Aleajirat water project, Aslam District, Hajjah (Photo Credit: AFCAR)

"The installation of the solar system by the UNDP ERRY project has contributed to providing clean water to households in our area on a regular basis, and saves around 15,000 YER (approximately USD $26) a month on average per household that was paid to purchase water through the water tanks. Now, beneficiaries get the water to their houses."

- Mr. Ahmed Abdullah
Director of the water project, Al-Naqain well, Lowder District, Anyan

Figure 14: Operational saving operation and maintenance costs

355,000 YER
(approximately USD $615)
a month

WMCs reported that the solar pump systems have reduced operation and maintenance costs compared with diesel generators and saved around 355,000 YER (approximately USD $615) a month on average which was used to pay for diesel or other energy sources, and helps to pay staff salaries and maintenance. It also has contributed to increase income for some beneficiaries, as they are able to save some money used in the past to buy water tanks.

The study also found that women are now able to grow vegetable gardens near their houses and have livestock due to access to water from the solar pumps. This contributes to the food security of their households and generates income when they sell vegetables or livestock on the market.

Overall, the solar powered water pumping systems contributes to strengthen resilience of their communities, where they have more ability to manage shocks and stressors the related to water, leaving them less dependent on fuel supply. All respondents expressed satisfaction with the solar solution.

Most WMCs indicated that there were solar system suppliers in their districts for new purchases and replacements of solar pump systems equipment, while there were few installation and maintenance service providers. More than half of respondents stated that it is difficult to get maintenance services when the pumps stop and that they have to wait around 17 hours to get the service.

More than 71 per cent of the respondents agreed that the solar pump systems would remain operational for the next five years and the remaining 29 per cent said no and

"The solar pump system has contributed to alleviating the suffering of citizens and providing clean water for drinking, especially in the hot weather we live in, as well as with high prices of diesel. The project also contributed to the children going to school instead of going to collect water".

- Mr.Hassan Abdullah
  Head of Water User Committee, Al-Dhiaibi village, Bajil District, Hodeidah

Al-Dhiabi water project, that conducted by UNFICEF, Bajil District, Hodeidah (Photo: AFCAR)

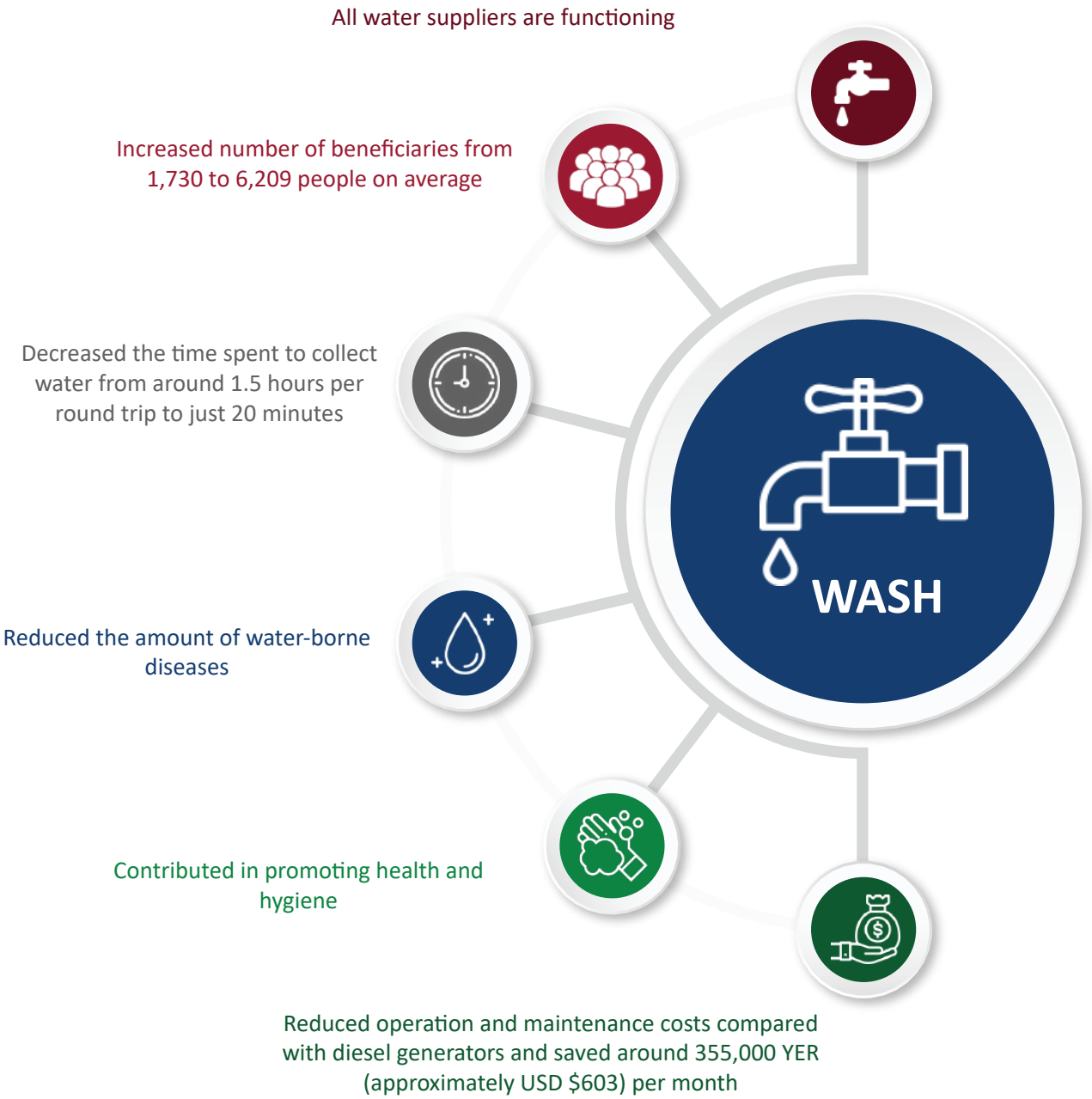
the reasons include concerns over availability of spare parts, float failure and problems triggered by lightning. The vast majority of WMCs reported that they allocated budget for solar pump system maintenance up to 230,000 YER (approximately USD $399), on average, which would be saved from fees charged to beneficiaries.

Local authorities considered water solar pumps as the most important contributions and applications to help local communities. At the end of the day, water is more important than anything whether it is for health, education, or farming.

Lessons Learned

1. Technical assessment should be conducted to determine the chemical and biological eligibility of the water supply in terms of quantity, quality and safety of water. The assessment should also identify the interventions that can be implemented with solar pump such as changing pipes, submersible or other necessary interventions to ensure that the solar pump achieves its objectives and prevents contamination of the well.
2. Women should be represented in WMCs, that will lead to shared decision-making and positive changes in gender dynamics at the community-level, as well as household-level, and increase women's skills in water management and leadership.
3. The solar pump systems should be maintained properly and regularly by WMCs to avoid complications and extra costs.
4. The financial sustainability of solar pump systems highly dependent on the successful collection and management of user fees by WMCs.
5. The solar service chain should be improved to fill the gaps in spare parts, installation and maintenance services at the local-level, therefore, capacity building for local suppliers and technicians is vital.

Impact of Solar Systems on the WASH Sector



Irrigation solar pump project, AL Solemanah village, AL Mrawa District, Hodeidah (Photo Credit: AFCAR)

2.4. Agriculture

Good Practices

1

Farmers have participated in the design, implementation, and maintenance of the systems and were fully aware of the associated risks. They make the extra effort to improve the system durability and efficiency.

2

Solar PV pumps have very positive opinions since it creates opportunities for farmers in terms of job creation, food security, water for drinking and hygiene, livestock feed, as well as irrigation.

3

Provision of solar pump input and creation of Water User Association (WUA) have emerged as a long-term cost-effective solution for providing reliable energy and to protect farmers from rising energy costs.

The agricultural sector is the dominant user of the water resources, accounting for around 90 per cent of the total consumption. The cultivated area of Yemen irrigated by groundwater is estimated to be approximately 405,264 hectares (1,001,429 acres). Of the total area irrigated by groundwater, the highlands account for the largest share with about 69 per cent of the total, followed by the coastal area with 18 per cent and the Eastern Plateau with 13 per cent. Groundwater resources are vital for Yemen's agriculture.

Most of the groundwater pumps in Yemen depend on diesel-powered generators that require difficult-to-deliver and expensive fuels for their operation, particularly in the last four years due to the shortage of diesel and the increase in its price five times. Only a few groundwater pumps operate by grid electricity in Lahj and Abyan for several hours a day.

The study found that farmers are not able to produce due to a limited supply of fuel and increasing energy costs. The land is facing deforestation given climate change and tree removal. Several farmers have cut their trees as they can not afford the maintenance. Not only are diesel prices skyrocketing, but the supply is also not stable and the cost of replacing a dead tree is very expensive and time consuming.

Alternative renewable energy is highly needed to sustain farming jobs and continue the supply of local crops to consumers. Therefore, attention to this type of intervention has increased and some international organizations have intervened by providing solar pump systems for irrigation to small farmers, such as FAO, IOM, and UNDP.

The UNDP ERRY project included solar pumps for irrigations that were intended to replace dependency on fossil fuel and empower farmers to become self-reliant and improve their resilience. This is one of the synergies between UNDP and FAO, whereby FAO identified the target beneficiaries and trained them, while UNDP conducted the technical assessment and supported farmers with the solar systems. It targets WUAs that include small farmers.

The study found that small farmers and micro-farmers who are part of the WUAs tend to be small land-owners. They are also part of the 80 per cent of the population who are in need of assistance. As water is pumped cheaply, more land can be planted, which generating many jobs for local communities.

All installed solar pump systems have WUAs to address the water supply needs and problems, as well as management of beneficiaries' rations. The community voted to choose the WUA leaders. They also signed an agreement to protect the system and coordinate its use. This intervention is one of the synergies and close coordination between UNDP and FAO.

WUAs stated that the situation of the irrigation and farmers changed after the installation of the solar pump irrigation system. All the solar irrigation systems were functioning compared to a few partially functioning systems. Most of solar pump systems have been recently installed.

Before the solar water pumps, farmers were very conservative in pumping water and only those who paid the fuel cost used the pumped water for their own needs. After the solar pumps, water is more available for the community.

The study found that none of the systems have encountered any significant problems and all have some sort of arrangement with a technician or an organization, such as free warranty for two years from a supplier and local technician.

According to the interviews with UNDP and FAO, specific assessments for each irrigation system have been conducted. WUAs indicated that they have participated in the design, implementation, and maintenance of the systems, and were fully aware of the associated risks. They went above and beyond to improve the system durability and efficiency.

The majority of WUAs reported receiving basic training on the operation and maintenance of the solar pump systems, while they do not have a solar system user's manual. Comprehensive training should be provided on system operations and maintenance, improved irrigation techniques, crop selection, cropping

calendars, farming methods, as well as on water accounting the field, scheme and basin-level. Moreover, water efficiency at the field and/or farm level is needed to enhance the knowledge and skills of farmers to understand the current status and trends in water supply, demand, accessibility, and use.

The study found different financing schemes of solar pump irrigation systems, such as providing subsidies or loans and other financing schemes that provide funding. For instance, during the interview with FAO, they indicated that FAO assisted some farmers in Hodeidah with the first installment of around USD $4,250 and connected them with Cooperative and Agricultural Credit Bank to have the USD $8,500 amount funded as a loan.

Subsidies and loans tend not to target small and marginal farmers, women and other vulnerable groups, as they are often tied to conditions that are hard to fulfill. They may need proof of land ownership, be registered as an enterprise or have collateral, which a small farmer often does not have. IOM and UNDP solar project support and target small and marginalized farmer in the areas.

WUAs indicated that using solar-powered water pumps have had a significant impact by providing a great opportunity for farmers and their families to improve their livelihoods, economic prosperity, and food security.

Most of the WUAs reported that solar pump systems improve access to water for irrigation, improve their capacity to produce vegetables, grain and livestock feed, and increase incomes. Some farmers indicated that solar pumps have been used to expand the coverage of the land by 30 per cent. Most of the WUAs stated that solar pumps have reduced the cost of water pumping to farms and thereafter they could afford or manage food needs. In addition, as the supply of water is more secure, jobs in farming can also be sustained.

Some WUA participants indicated that the stability of water supply have reduced tensions among the communities and people have been able to get together behind common good. Pumped water was not only a water source for irrigation and local crops production, but also provided crops to feed livestock.

> *"My total farming land has increased during the past eight months and my income also increased since the solar system was installed."*
>
> - Mr. Yassin Katery
> WUA member, Hodeidah

One water pump improved livelihood opportunities for over 80 households and an average savings of over 800,000 YER (USD $1,358) per month that was previously spent on diesel. In addition, the water pumped is used as drinking water for communities free of charge that used to be sold. One farmer indicated that over 50 households depend on the pumped water. All WUAs expressed high satisfaction with the solar solution.

Box 2: Life Thrives Again

Mohamed Al-Sheree one of the beneficiaries indicated that he is a Water User Association leader. He and other farmers benefited from a solar pump solution provided by the ERRY project. The community is very keen for the return of the system. *"We were not able to find diesel, and its price was so high. Some our cows have died, and our farms were almost dead and we do not know what would happen to our farms and livestock without sport of the ERRY project."*

Mohammed Al-Sheree, AL Mrawa District, Hodeidah
(Photo Credit: AFCAR)

What was evident in the previous discussion is that borehole owners were willing to give water free to those who need it. This also provides evidence for the social cohesion component as people are more accepting to help others in need once they have access to less abundant resources.

Most farmers still use traditional irrigation (e.g. flood irrigation) which aggravates the already drastic water shortage problem, as well as wasting water and energy resources. They revealed that the new techniques, such as drip irrigation, requires a lot of investment and is expensive for them.

Lessons Learned

1. Using traditional irrigation techniques may lead to ground water over exploitation and wasteful use of water and energy resources. Therefore, a comprehensive assessment of: (a) techno-economic feasibility; (b) social and environmental impacts; (c) policy and regulatory frameworks; and, (d) cultural contexts are required for solar irrigation that will be used. Moreover, combined solar pump systems with new irrigation techniques, such as drip irrigation and subsidy, can potentially play a regulatory role.
2. The promotion of innovative irrigation techniques should be part of the solar pump intervention, which may increase water and energy use efficiency. Shifting to innovative irrigation techniques such as drip irrigation requires a substantial behavioral change.
3. Subsidies and loan financing schemes tend not to reach small and marginal farmers, women and other vulnerable groups, as they are often tied to conditions that are hard to fulfill. They may need proof of land ownership, be registered as an enterprise or have collateral, which a small farmer often does not have. Therefore, it is important to design financing schemes that more appropriate with small farmers and vulnerable groups mainly in the conflict context.

Impact of Solar Pump Systems on the Agriculture Sector

Reduced operation and maintenance costs compared with diesel generators and saved around 800,000 YER (approximately USD $1,358) a month

Contributed to improve livelihood opportunities for over 80 households

Contributed to sustain farming jobs and continue the supply of local agriculture productions

Ahmed Hatem Family, Bajil District, Hodeidah (Photo Credit: AFCAR)

2.5. Productive Asset, Market, and Employment

Good Practices

1

Provision of solar lanterns has helped the targeted individuals, including IDPs, to improve access to energy and resume household level income generation activities.

2

Support of solar PV systems to productive assets was able to create livelihood opportunities for many and reduce the cost of production, as well as increase income.

3

Intervention of solar systems contributed to improving education and health of beneficiaries. It also contributed to augmenting social capital and enhancing interaction within communities.

Energy access in Yemen strongly reflects the country's high-level of poverty, as well as strong differences between Yemen's regions, particularly in relation to the urban-rural divide. Before the war began in March 2015, Yemen had the lowest rate of access to electricity (40 per cent) compared to the region (85 per cent).[8] Inequalities in terms of access to electricity exist among rural and urban households.[9] On the Yemeni grid, electricity services have been provided to only 23 per cent of rural households, due to the lack of finance and the difficult geography and topography of the country.[10]

Solar energy has become more of an option in the past four years in homes. UNDP has provided solar lanterns for more than 5,600 households, such as the most vulnerable and IDPs in Abyan, Hajjah, Hodeidah, and Lahj. The UNDP ERRY solar project also targeted Productive Associations such as diary, handicraft, and local markets. These interventions were mostly to women in Abyan, Hajjah, Hodeidah, and Lahj governorates. The Diary Associations selected in Hodeidah have received training by FAO within ERRY, another synergy between UNDP and FAO.

The study found that less than 10 per cent of the participants indicated that their solar systems have not worked, due to improper use of the system or damaged parts such as battery, charger plugs, or switches. The Productive Associations have had some challenges, such as issues with proper, and the quality of the solar system deployed.

All users claimed that the system is easy to use, but training could be used in changing bulbs, maintaining batteries, or enabling locals to maintain the systems. Participants agreed on the availability of solar panels, inverters, wires, switches, and installation services. The most needed suppliers were maintenance service providers.

During the interview with GIZ, they mentioned that they provide vocational training for youth to build their capacity and skills in the solar systems maintenance. ILO also has vocational training and apprenticeship programmes for youth.

The study found that over 60 per cent of households indicated that they have received training on how to maintain the system. All productive associations reported having received training on the basic operation and maintenance of the solar systems and pointed out that it is easy to run and maintain solar system, while no one has received a solar system user manual.

Overall, the majority of households are satisfied with the solution and they desired a bigger system.

All interviewed Productive Associations indicated that the solar system energy is reliable and covers all their needs. The Productive Associations from Abyan and Lahj still use the public grid, which runs several hours a day, while associations in Hodeidah rely entirely on solar energy.

The solar intervention was able to contribute to people's incomes, jobs, and employment opportunities. Households who accessed solar lanterns were able to work at night, providing livelihood opportunities to rural community members who are at the bottom of the pyramid. The targeted communities who benefited from the solar lanterns, reported savings of around 5,600 YER (approximately USD $10)of energy costs per month on average.

Access to energy at the household-level has allowed two main positive contributions to women in the targeted communities. First, it allowed for increased income for women as indicated by 60 per cent of study participants due the additional nine hours of light. Second, women no longer have to collect water from a

8 World Bank (2014), Readiness for Investment in Sustainable Energy: file:///C:/Users/E440/Downloads/RISE%20Pilot%20Report%20(1).pdf
9 UNDP (2014), Policy Note: Prospects of Solar Energy in Yemen
10 Joint Social and Economic Assessment for the Republic of Yemen (2012)

distance.

Working in the solar systems market was another source of jobs for many youth and unemployed. The increasing use of solar systems in different sectors has created opportunities for jobs and employment. Maintenance was among the top needed services for all sectors.

Solar power seemed to encourage communities to engage, collaborate and create opportunities. Over 30 per cent indicated that their neighbors and relatives also benefit from these systems during their visits. Benefits are mainly charging mobile phones, listening to the radio, and watching television. Half of the respondents indicated that their experience with solar solutions has encouraged their friends and relatives to install a similar system. This has raised awareness, capacity building, and social participation.

Figure 15: Households average cost saving per month

The efficiencies added by the intervention to local communities included access to communications. Radio connects communities not only for awareness and news, but also for opportunities and announcements.

Employment in the solar sector seems to be in demand at all levels - starting from the mega importers to the small shops in the districts. Vendors look for experienced employees whether in sales or maintenance.

The exposure to solar solutions is an effective strategy to create interest and basic knowledge working with solar systems to elevate the targeted communities to work in the solar system marketplace. Around half of participants indicated that they have not had problems with the solar system since its installation. Less than a quarter reported they have had issues, but they were minor such as fuse and bulb replacements, as well as main switch problems.

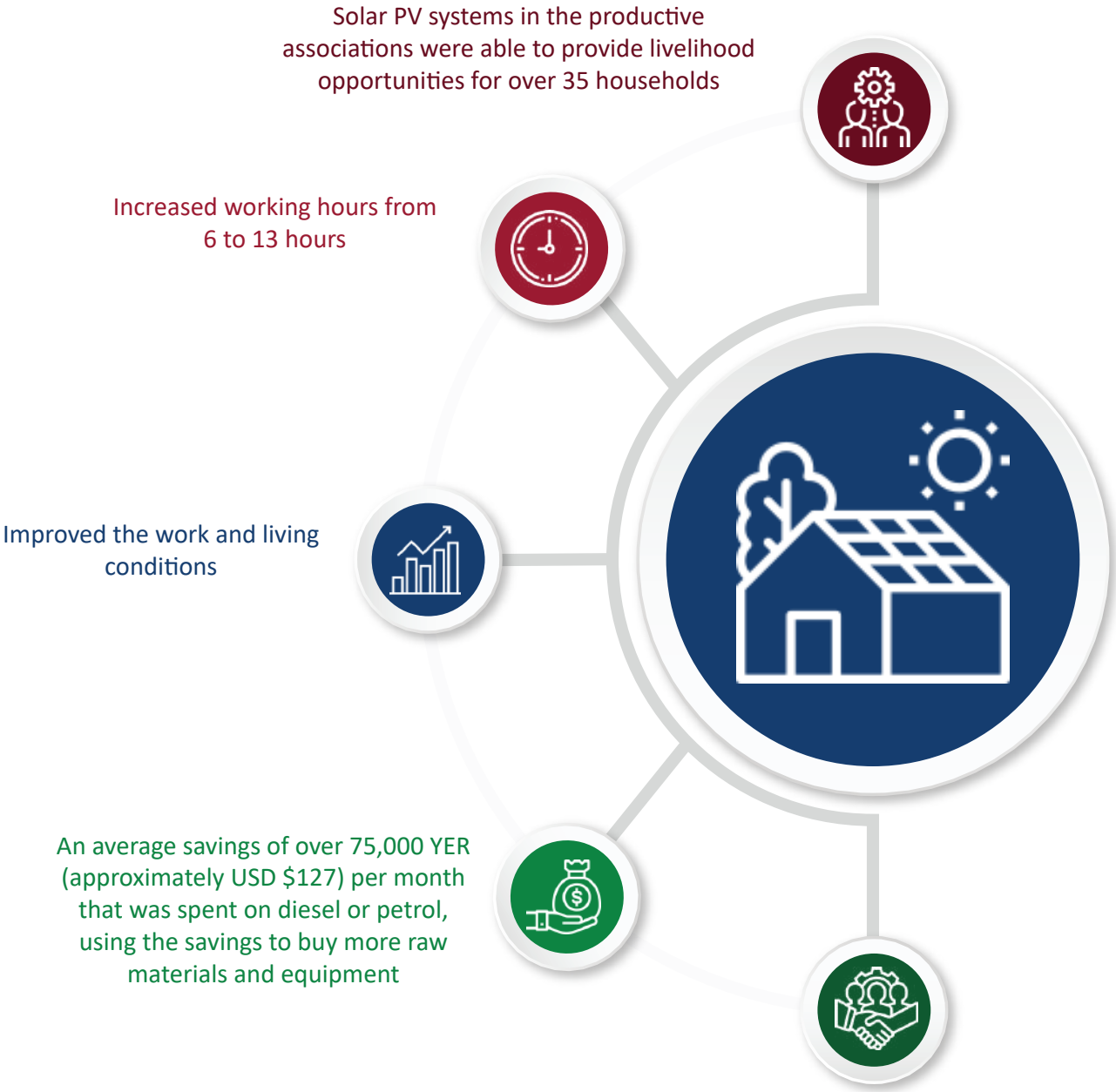
Solar systems have required attention to quality both at the system usage level as a whole, and the installation practices. The intervention has provided beneficiaries to have first-hand experience with challenges associated with solar systems. Study participants who faced problems reported issues of improper installation such as wind blowing the panels off the ground and animal movement around the system.

For the Productive Associations, most of them indicated that their situation has changed positively after the installation of solar PV systems and with more business recovery. The average working hours increased from six hours before the installation of the solar system to 13 hours, mainly in the dairy Productive Association in Hodeidah, which most of their work is at night. Women's associations in Abyan reported that the number of workers/ beneficiaries increased due to solar systems. Whereas, dairy Associations in Hodeidah reported that most household members, especially women, are working.

> *In the past, we used to rely mainly on the electric generator and public electricity, which we received some hours a day. Now we have completely stopped using the generator and rely on the solar system.*
>
> *The solar system that was installed in our association has helped to increase our activities and working hours in the evening mainly in sewing and handicrafts activities. We have also added new activities such as cooking and wool crafts trainings, as well as new skills like antiques made up of seashells."*
>
> - Ms. Manal al-Dabba
> Heda of the Women's Association, Khanfer District, Abyan

Solar PV systems in the productive associations were able to provide livelihood opportunities for over 35 households and 245 individuals (56 per cent female and 44 per cent male). There is an average savings of over 75,000 YER (approximately USD $127) per month that used to be spent on diesel and/or petrol. The productive associations use the savings to buy more raw materials and equipment, as well as to cover household expenses of food, education, and health needs.

Impact of Solar Systems on Productive Assets and Employment



A supported Productive Association in Bajil who received a solar system to power a refrigerator was able to absorb the increasing prices of inputs (milk) and maintain the selling prices of dairy products.

Ms. Loul Al-Ans dairy association, Bajil district, Hodeidah (Photo Credit: AFCAR)

> *"Milk prices increased from 250 YER (approximately USD $0.42) a liter to 300 YER (USD $0.51) a liter, however, we sell our products at the same prices as before for several reasons, this includes being supported by solar energy. The solar system helps us to grow our income due to increased production and sales and that resulting from good product refrigeration and improving the quality of the products, as well as attract more customers."*
>
> - Ms. Loul Al-Ansi
> Bajil district, Hodeidah

The study found that installing solar systems in the Productive Associations improved the work and living conditions and overall atmosphere due to quality lighting and fans.

Solar systems seem to increase the social cohesion within the Productive Association's communities. Some of the interviewees indicated that the Productive Associations are being used as community hubs, providing additional training opportunities to others in the communities and facilitating community activities when members can come together. During the interview with the Women's Association in Abyan, they reported that they facilitate different social events at night. For example in the last World Cup, the association opened its doors for young people to watch the matches, and they provide different kinds of training opportunities for the community's members such as raising awareness of health aspects and acquiring some life and technical skills.

The study found that less than 30 per cent of households agreed that their systems would remain operational for the next five years. Reasons for their expectations included concerns over the small size of the system making the high demand for power lower its lifetime expectancy. The humidity and high temperature were also cited. Some indicated

that the change of performance during the past few months indicate that it would not last for five years.

Whereas, the vast majority of Productive Associations confirmed that solar systems would remain operational for the next five years, some of them have concernes that the battery life expectancy and humidity and high temperature will affect operational capacity of the systems.

Lessons learned:

1. Awareness raising, capacity building can be improved during system installations. More people in the household should be asked to attend the training since many would be using the system. Handouts should be distributed to assure awareness among the community.
2. Installations of household equipment should make sure that setup is safe and well mounted against winds, animals, water, and children.
3. Capacity building in maintenance and sales of solar systems can accompany household level solar lantern distributions to leverage solar experience among youth and create jobs and employment.

Published by the United Nations Development Programme

UNDP Yemen

PO Box 551

Sana'a, Republic of Yemen

www.ye.undp.org

January 2019