Renewables for Refugee Settlements: *Sustainable energy access in humanitarian situations*

Emanuele Taibi
Power Sector Transformation Strategies
IRENA Innovation and Technology Centre
Bonn, Germany
ETaibi@irena.org

Aakarshan Vaid
Associate Professional
IRENA Innovation and Technology Centre
Bonn, Germany
AVaid@irena.org

***Abstract*— Currently about 71 million people are forcibly displaced from their homes and among them are nearly 26 million refugees. Most refugees and displaced persons rely on energy resources that are unsustainable and that pose high risks to their health and well-being. The United Nations High Commission for Refugees (UNHCR) and its partners mostly rely on conventional diesel generators to provide refugee settlements with electricity for common everyday needs, such as lighting, as well as to operate the infrastructure and services in the settlements. For some refugees, access to electricity is still unavailable and cooking takes place using traditional biomass. Apart from the environmental and health-related drawbacks, this also results in potential safety and security risks for refugees in the collection process. Renewable energy in refugee settlements can help in quickly spurring socio-economic development in addition to enhancing safety, security, productivity, and health for refugees, host countries and humanitarian organizations.**

For this purpose, IRENA supported UNHCR in addressing the issue of efficient, clean, affordable and reliable energy supply in refugee settlements. The main objective of this collaboration was to assess the current and expected energy consumption in four camps in Ethiopia and Iraq, and identify the optimal renewable energy solutions that would provide the camp facilities and the refugees with clean, reliable and affordable energy for their everyday needs and concurrently reduce the cost of electricity from diesel.

This paper summarizes the study with its findings and recommendations from the energy assessments of the four refugee settlements. The energy assessments have also highlighted the benefits that can be achieved with the deployment of renewable energy solutions, including hybrid power systems. Large solar arrays and standalone solar systems in Iraq can largely reduce the voltage fluctuations in the local grid and provide reliable and cost-effective electricity to the refugees, humanitarian organizations and host communities. Solar mini-grids in Ethiopia can aid in reducing the high cost and pollution from diesel generators in the settlements and provide the refugees with reliable electricity for everyday purposes.

I. INTRODUCTION

The world is witnessing an unprecedented level of human displacement. The latest Global Trends report from the office of the United Nations High Commissioner for Refugees (UNHCR) confirms that 70.8 million people globally have been forced to leave their homes. Among these nearly 25.9 million are refugees, out of which more than half are under the age of 18 [1].

Together with the refugee crisis, energy access also remains a serious challenge in countries that usually host refugees. As of 2018, around 850 million people worldwide still did not have access to electricity [2], making the deployment of sustainable and low-carbon electrification solutions crucial, both to achieve universal access for all (SDG 7) and fulfil the Paris Agreement. Of the current population living without access to electricity, around 95% is in Asia and sub-Saharan Africa.

The latest global roadmap prepared by IRENA [3], illustrates that even though the power sector has seen a significant amount of decarbonisation, the progress of the energy transition needs to be accelerated, and the global energy system must undergo a profound transformation to replace conventional fossil fuels.

Most displaced persons and refugees often have little to no access to clean and reliable electricity. Moreover, they also rely on energy sources that can be detrimental and pose risks to their safety, health and well-being. In times of crisis, when faced with multiple urgent needs, humanitarian organizations may overlook addressing requirements related to access to clean, reliable and cost-effective energy for refugees. Current energy practices in refugee settlements are usually unsustainable, polluting and unsafe for the users as well as for the surrounding environment. This can be explained by the lack of funding and limited policies and practices on clean energy provision in humanitarian settings.

UNHCR and other humanitarian organizations that help in supporting refugees and displaced persons, rely highly on conventional polluting fossil fuels such as diesel generators to provide refugees with electricity for their common everyday purposes such as lighting and operating the infrastructure and services in the settlements. Using diesel generators for electricity supply does not only come with environmental drawbacks but also results in elevated costs, confirming the necessity of delivering reliable and cost-effective sustainable energy solutions in such settings. In terms of costs, UNHCR spends annually more than USD 35 million on procuring diesel fuel for the generators as well as the funds given to partners for the same. Other

expenditure incurred by UNHCR includes costs for the operation and maintenance of the generators, costs for security and for logistics. In most refugee settlements, the generators are mostly oversized with minimal controls or monitoring, and many issues exist with regard to generator maintenance and fuel theft, resulting in higher replacement and fuel costs. The methods used by UNHCR and its partners to generate and consume electricity do not make the best use of modern technologies, equipment and potential efficiencies.

A viable solution to deliver quick returns in humanitarian settings is through access to clean and sustainable energy, such as enhancing protection, safety, security, productivity, and health for refugees, host communities, humanitarian organizations and the environment. It can also serve as a powerful means for bridging the gap between humanitarian response and development; create opportunities to pursue education, businesses and social enterprises; and spur innovation.

To this extent, IRENA supported UNHCR in performing detailed energy assessments for four specific settlements (2 in Iraq and 2 in Ethiopia) and identifying the ideal renewable energy solutions for providing refugees with clean, reliable and cost-effective energy [4].

The objective of this study was to assess the current and future/expected energy consumption of four specific refugee settlements and determine the ideal renewable energy solutions to provide the refugees and humanitarian organizations with clean, affordable and reliable energy for everyday use. The aim of this collaboration was to identify cost-efficient environmentally friendly solutions for lighting, cooking and commercial activities in households and institutional settings in the settlements. Furthermore, the adoption of various market-based business models to achieve further cost reductions was also explored. A key objective of this study was to propose a methodology for humanitarian organizations to conduct energy assessments, that could be used as a blueprint for conducting further assessments in such settings globally.

II. METHODOLOGY

The geographical scope of the mission consisted of two UNHCR country operations, in Ethiopia (two refugee settlements) and Iraq (two refugee settlements). The study focused on two main types of situations or stages of a refugee settlement. The two settlements in Iraq are currently in a post emergency or early development phase, while the settlements in Ethiopia are in the development or protracted situation stage. Table 1 gives an overview of the selected UNHCR settlements where the detailed energy assessment and surveys for this collaboration took place.

TABLE 1: OVERVIEW OF REFUGEE SETTLEMENTS

Refugee settlement	Location	Estimated population	Refugee operation stage
Darashakran	KRI, Iraq	11,608	Post emergency/early development
Domiz 1 and 2	Duhok, KRI, Iraq	42,487	Post emergency/early development
Sherkole	Assosa, Ethiopia	10,619	Development (protracted situation)
Tsore	Assosa, Ethiopia	14,153	Development (protracted situation)

This paper presents the study conducted for four refugee settlements to illustrate how such initiatives can be expanded upon to achieve four strategic priorities outlined in the UNHCR global strategy for sustainable energy [5]: addressing households' energy needs; improving access to cooking energy; expanding household electrification; and expanding sustainable electrification of community and support facilities.

The missions to the refugee settlements took place from 7 to 20 September 2019 for the Darashakran and Domiz settlements in Iraq, and from 22 September to 4 October 2019 for the Tsore and Sherkole settlements in Ethiopia. In order to collect the most detailed data possible, the assessment consisted of a household survey of the refugees, focus group discussions with community leaders, interviews with humanitarian organizations and government representatives, as well as detailed assessments of compounds operated by humanitarian organizations.

A number of renewable energy solutions were considered for both electricity and cooking in the refugee settlements. The different solutions evaluated for providing a clean supply of electricity to the refugee settlements in Iraq and Ethiopia in addition to the various offices and infrastructures present in the settlements included solar lighting kits, solar home systems, mini-grids with solar PV and battery storage, the grid plus renewable energy and solar water pumping solutions. Solar lighting kits are very versatile and can be used for different applications including for rural settings to provide displaced persons with clean, reliable cost-efficient lighting. As opposed to the polluting and fire hazard prone kerosene lamps, solar lighting kits do not pollute and are cheaper to run. Solar home systems are standalone PV systems with battery storage that can provide clean and cost-effective electricity to rural households. Such systems are generally used to power individual households and small businesses. A key option considered in this study for providing UNHCR offices and the refugees with clean, reliable and cost-effective electricity and reduce the exorbitant cost of diesel was through the possible deployment of mini-grids. Such systems can provide clean, sustainable energy to rural communities in remote areas where there is no access to electricity or modern energy services [6]. The study also considered the possibility of extending the grid in the locations assessed for integration with the future mini-grid. Finally, solar water pumping solutions were also considered for providing the refugees with clean and reliable energy services, including a reliable water supply, irrigation and improved crop yields.

With regard to clean cooking, two main solutions were considered for replacing the current traditional firewood which poses a great threat to the health, safety and security of refuges, mainly women and children. These include ethanol and biomass briquettes. Cook stoves based on ethanol have several advantages compared to traditional firewood. Firstly, they are more efficient and less polluting. Secondly, they provide faster cooking and do not produce any smoke. Biomass briquettes were considered in this study because due to their low moisture content and high

energy density, they do not produce any soot or smoke and are more efficient than firewood.

In order to design the ideal renewable energy systems to provide the settlements and refugees with clean, reliable and cost-efficient energy, the HOMER Pro software was used. HOMER is an optimisation tool used to design and technically and financially evaluate options for off- grid and on-grid power systems for remote, stand-alone and distributed generation applications. It allows the user to consider numerous types of technology options to account for energy resource availability and other variables. The model's ultimate goal is that of simulating and providing the user with the most inexpensive and viable solution for all possible combinations according to the initial system inputs. Depending on the inputs, HOMER can simulate hundreds or even thousands of viable systems.

The energy data collected during the assessments through the aid of energy meters, was inputted in HOMER as the baseline load. An optimization was performed in HOMER to determine the ideal size of the mini-grid that would cost-efficiently provide the offices and refugee settlements with clean and reliable energy for everyday use.

III. Results

A. Darashakran

The results from the energy assessment of the mission to the Darashakran settlement in Iraq have provided a better view on the proportion of electricity consumed by the various entities. Figure 1 shows the overall electricity consumption in the Darashakran settlement. The figure shows that approximately 94% of the total electricity consumption of the settlement comes from the households of the refugees and the residences of the humanitarian staff present in the settlement.

The results of the HOMER optimization for the Darashakran settlement can be seen in Table 2. The table shows the four least-cost hybrid solar PV systems that would allow UNHCR to decrease their high diesel cost and provide the refugees with clean, reliable and cost-efficient electricity.

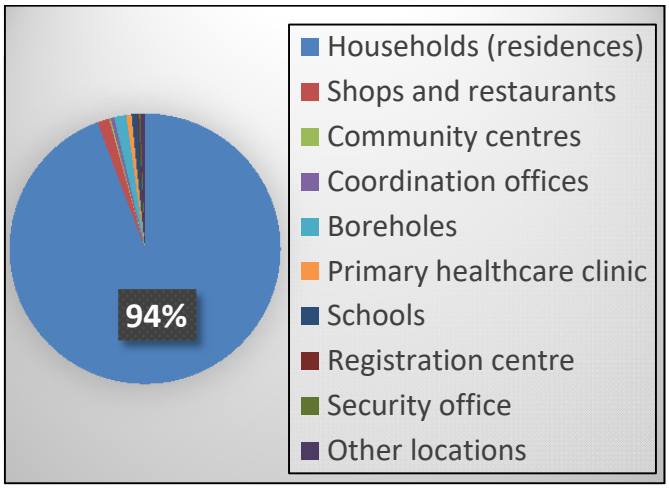

Figure 1: Electricity consumption in Darashakran settlement

TABLE 2: PROPOSED RENEWABLE ENERGY SOLUTIONS IN DARASHAKRAN SETTLEMENT

Facility	PV (kW)	Storage (kWh)	Diesel (kVA)	Annual Savings on Diesel (USD)	Cost of energy (USD /kWh)	RE share (%)	Investment cost (USD)
Intersos community centre	16	14	15	2,500	0.15	100	45,000
Registration centre	40	43	45	10,000	0.14	83	120,000
Camp coordination	69	75	60	11,000	0.18	82	180,000
Camp mini-grid	3500	4000	0	500,000	0.14	100	6,000,000

The results of the optimization show that deploying a mini-grid in Darashakran, with 3.5 MW of PV capacity and a battery storage system of 4 MWh, would potentially save USD 500,000 annually on diesel fuel.

B. Domiz 1 and 2

Figure 2 illustrates the overall electricity consumption for Domiz 1 and 2 settlements. The pie chart shows that similarly to the Darashakran settlement, about 91% of the total electricity consumption comes from the households. While the remaining 9% is consumed from the different facilities and infrastructure present in the settlements.

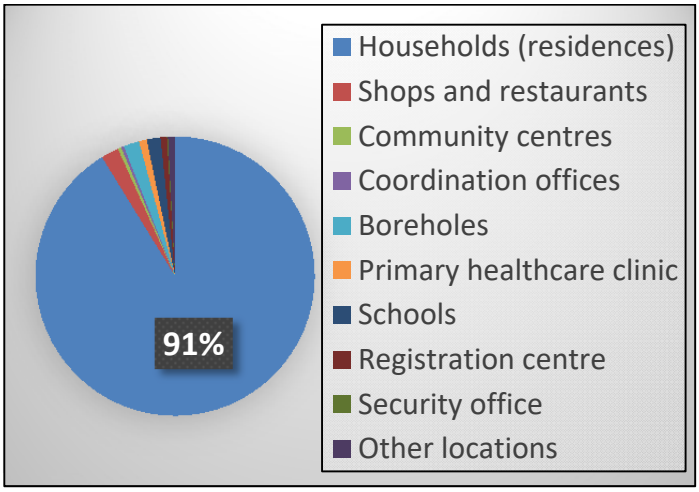

Figure 2: Electricity consumption in Domiz 1 & 2 settlements

Table 3 shows the proposed renewable energy solutions for the Domiz 1 settlement, based on the HOMER optimization performed during the study. The table shows that with a possible installation of a 6.6 MW solar PV system along with 6 MWh of battery storage, UNHCR can achieve annual savings of USD 1.1 million on diesel fuel.

TABLE 3: PROPOSED RENEWABLE ENERGY SOLUTIONS IN DOMIZ 1 SETTLEMENT

Facility	PV (kW)	Storage (kWh)	Diesel (kVA)	Annual Savings on Diesel (USD)	Cost of energy (USD/kWh)	RE share (%)	Investment cost (USD)
Town Hall	240	250	275	65,000	0.25	31	600,000
Registration	120	159	80	50,000	0.16	85	310,000
PHCC	117	154	80	33,000	0.18	88	270,000
Sarbasti Health Clinic	42	46	40	12,000	0.15	85	105,000
Harikar	24	22	15	12,500	0.15	86	55,000
Settlement solar mini-grid	6600	6000	0	1,100,000	0.13	100	9,200,000

The optimization results and proposed renewable energy solutions for the Domiz 2 settlement can be seen in Table 4. The table shows how UNHCR could potentially save USD 500,000 annually on diesel fuel with a 2.5 MW solar PV system with 4 MWh of storage.

TABLE 4: PROPOSED RENEWABLE ENERGY SOLUTIONS IN DOMIZ 2 SETTLEMENT

Facility	PV (kW)	Storage (kWh)	Diesel (kVA)	Annual Savings on Diesel (USD)	Cost of energy (USD/kWh)	RE share (%)	Investment cost (USD)
Coordination office	50	158	40	15,000	0.23	75	170,000
PHCC	62	95	80	25,000	0.17	85	170,000
Settlement solar farm	2,500	4000	0	500,000	0.13	100	4,500,000

Figure 3 shows a birds-eye view from Helioscope tool for the two proposed solar PV systems for both Domiz 1 and 2 settlements. The figure also shows the proposed location for the two systems.

Figure 3: 6.6 MW solar PV installation in Domiz 1 (left) and a 2.5 MW solar PV installation in Domiz 2 (right)

C. Sherkole

Figure 4 shows the overall electricity consumption in the Sherkole settlement in Ethiopia. The pie chart shows that most of the electricity consumption in the settlement comes from the ARRA mini-grid (29%), the community kitchen (21%) and the UNHCR office (20%).

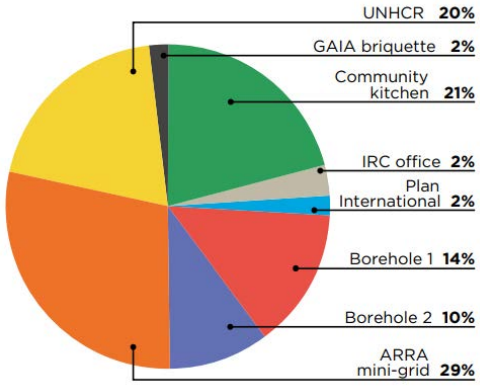

Figure 4: Electricity consumption in Sherkole settlement

The results of the HOMER optimization for the Sherkole settlement can be seen in Table 5. The table shows how UNHCR could potentially save USD 75,000 annually on diesel fuel with the installation of a 183 kW solar PV-based hybrid mini-grid.

D. Tsore

For the Tsore settlement in Ethiopia, the detailed energy assessment conducted, has shown that most of the electricity consumption in the settlement comes from the borehole (86%). This can be seen in Figure 5.

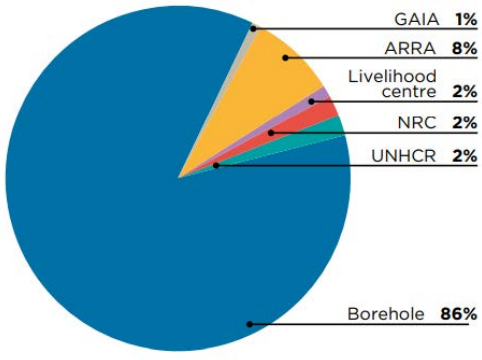

Figure 5: Electricity consumption in Tsore settlement

Table 6 illustrates the proposed renewable energy solutions which resulted from the HOMER optimization conducted for the Tsore settlement. The table shows how with the deployment of a 65 kW solar PV hybrid mini-grid, UNHCR could potentially save annually USD 13,000 on diesel fuel. The results of the optimization also show the cost of energy and the renewable energy share for each proposed system.

TABLE 5: PROPOSED RENEWABLE ENERGY SOLUTIONS IN SHERKOLE

Facility	PV (kW)	Storage (kWh)	Diesel (kVA)	Annual Savings on Diesel (USD)	Cost of energy (USD/kWh)	RE share (%)	Investment cost (USD)
Schools	0.03-0.05	0.15-0.6	No			100	150-400
Pre-schools	0.03-0.05	0.15-0.6	No			100	150-400
Vocational centres	0.03-0.05	0.15-0.6	No			100	150-400
Community centres	0.03-0.05	0.15-0.6	No			100	150-400
Community kitchen	0	0	0	0	0.02		0
ARRA office and guesthouse	60	175	40	24,000	0.22	91	190,000-220,000
UNHCR Compound	50	146	22	17,000	0.23	92	155,000-175,000
Plan Int	4	25	3	500	0.45	100	16,000
IRC Compound	6	35	3.7	800	0.4	100	24,000
Settlement mini-grid	183	433	80	75,000	0.16	91	480,000-550,000

SETTLEMENT

TABLE 6: PROPOSED RENEWABLE ENERGY SOLUTIONS IN TSORE SETTLEMENT

Facility	PV (kW)	Storage (kWh)	Diesel (kVA)	Annual Savings on Diesel (USD)	Cost of energy (USD/kWh)	RE share (%)	Investment cost (USD)
Borehole	50	0	50	7,000	0.232	45	80,000
Schools	0.03-0.05	0.15-0.6	No			100	150-400
Pre-schools	0.03-0.05	0.15-0.6	No			100	150-400
Community centres	0.03-0.05	0.15-0.6	No			100	150-400
Women's centre	0.03-0.05	0.5-0.8	No			100	200-500
GAIA briquette	0	0	25	3,000	0.33	0	12,000
ARRA office and guesthouse	16	26	30	9,000	0.21	100	45,000
UNHCR office	6	10	10	1,700	0.16	100	17,000
IRC compound	4	20	0	2,000	0.3	100	16,000
NRC compound	4	25	0	1,800	0.35	100	17,000
Settlement mini-grid	65	108	0	13,000	0.2	100	160,000

IV. Discussion

Based on the results obtained from the detailed energy assessments conducted during the missions, the household surveys, the focus group discussions and the optimization in HOMER, several key recommendations were provided to UNHCR for each settlement considered in this study.

For the Darashakran refugee settlement in Iraq, several parallel activities were recommended to reduce the exorbitant costs and provide the refugees with clean, reliable electricity for their everyday use. The recommendations include improving energy efficiency at the settlement, continuing to install renewable energy at community and support facilities in the settlement and discussing with the local government the possibility of increasing the transformer capacity in the sub-station serving Darashakran. Households in Darashakran settlement make up an estimated 94% of the overall electricity consumption in the settlement, and insulation can greatly reduce electricity use for heating and cooling during the winter and summer. To further improve the insulation of houses, reducing air flow should be considered. This can entail simple procedures such as plugging leaks around doors and windows, ensuring that doors and windows are tightly closed, and closing any major cracks. Continuing to install renewable energy systems such as solar arrays at boreholes is a good model for location with grid connection such as Darashakran. The installation of correctly sized solar systems with batteries at the settlement co-ordination office and the registration office will reduce fuel consumption by limiting the use of the oversized diesel generators to occasional battery charging. Finally, the energy assessment at the settlement has also shown that increasing the transformer from 10 MW to 16 MW would greatly reduce voltage fluctuations and would eliminate the requirement for load shedding to the settlement and neighboring communities.

Key recommendations provided to UNHCR for the Domiz 1 and 2 settlements in Iraq included installing renewable power plants on the feeder lines to the settlements to compensate for the lack of electricity supply, facilitate any investments in infrastructure for the refugee settlement to take place in ways that reduces UNHCR's technical and financial risk and push for meters to be installed at households in the Domiz settlements and for refugees to pay for the electricity similarly to the host community, on a kWh basis. The results of the optimization in HOMER have shown that with the installation of a grid-tied 6.5 MW solar PV power plant in Domiz 1 and a grid-tied 2.5 MW solar PV power plant in Domiz 2, the overall electricity requirements of the settlements would be covered during the peak hours of the summer months when the use of air conditioners is highest. Energy storage could be added to increase the power quality and the number of hours covered by the solar system, although this would greatly increase the cost of the installation. Furthermore, with the use of a power purchase agreement (PPA), UNHCR could specify the amount of electricity to be delivered without being required to provide the technical specification of the plant or the investment required to cover the installation. The results also showed that the average household in the Domiz settlements with a monthly consumption of 330 kWh, would pay on average USD 36 monthly for electricity, compared to USD 21 for 3 hours of connection to the diesel generators.

From the results of the analysis, different parallel activities were also recommended to UNHCR for the Sherkole refugee settlement in Ethiopia. These include promoting and supporting the use of fuel-efficient stoves, considering a transition to a market-based approach for sustainable biomass cooking and rehabilitating the forest and land nearby. Distribution through cash or voucher-based programmes would allow refugees to choose their preferred type of stoves. The results of the study have shown that access to clean cooking is a major problem in the Ethiopian settlements, with refugees also having issues with the neighbouring communities for the collection of firewood. Improved cook stoves that use ethanol or briquettes could potentially solve this problem. Moreover, UNHCR should need to consider scaling up forest plantations with 100 hectares of fast-growing biomass.

Based on the optimization results and the various surveys and assessments conducted in the Tsore settlement, various recommendations were provided to UNHCR to improve the current situation for the refugees. A key recommendation is to establish a mini-grid in the settlement. This could increase the efficiency of the diesel generators by an estimated 50% and greatly reduce maintenance costs, by avoiding running multiple diesel generators at very low load and instead optimizing the dispatch of the fleet of existing generators to serve the combined load. A 60-kW solar plant with a 150-kWh battery bank would decrease diesel consumption in the Tsore settlement by an estimated 60%, or around 2,500 litres of diesel per month. The mini-grid could eventually be expanded to provide the refugees with access to electricity. Another recommendation provided to UNHCR in this study was to initiate market-based solar lamps access initiatives in the settlement to provide refugees with access to improved lighting as well as charging for small appliances such as phones and radios. Furthermore, the increase in usage of solar street lights is also recommended in the Tsore settlement. This would definitely increase the security and safety of refugees, especially women and children. A final key recommendation provided to UNHCR after the detailed assessments was to apply for a grid connection with Ethiopian Electric Power.

V. Conclusion

This paper highlights the findings of the detailed energy assessments and study conducted for UNHCR's four refugee settlements in Iraq and Ethiopia. The main objective of the analysis was to conduct detailed energy assessments for the four settlements and identify the ideal renewable energy solutions that would provide the humanitarian organizations operating in the settlements and the refuges with clean, reliable and cost-efficient energy.

The data collected during the energy assessments and missions was inputted into HOMER to perform an optimization analysis to design the least-cost renewable energy solutions that would aid UNHCR in achieving the

set goal of the study. The results have shown that indeed renewables are key for affordable, reliable climate-safe access to modern energy services.

More data needs to be collected to support decision-making on energy-related questions. The assessments conducted in the four settlements have confirmed that diesel generators are greatly oversized compared to the actual loads they serve, leading to great inefficiencies. Therefore, a key recommendation for all settlements analysed in this study is to make use of energy loggers to enable themselves to properly scale and deploy solar systems and optimise diesel generators, thus generators, thus creating savings that can be employed in improving the quality of services delivered to the refugees.

Finally, the study has illustrated that there are considerable synergies to be gained from the collaboration between humanitarian organizations such as UNHCR and specialised agencies on renewable energy such as IRENA in improving the access to sustainable energy for refugees.

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