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Solar Electrification of the Health System in the Gaza Strip: Opportunities & Challenges

Assessment Findings & a Strategy for Energy Transition

June 2019

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1 | Acknowledgements

This report was jointly conceived and produced by the technical teams at WHO and UNDP, and the Ministry of Health for the State of Palestine. The report was partly enabled by a grant from the Government of Japan and is the outcome of institutional commitments by WHO and UNDP management, and the leadership at the Ministry of Health for the State of Palestine.

2 | Abbreviations

Acronym	Detail
A	Ampere (unit for current measurement)
AC	Alternating Current
DC	Direct Current
DG	Diesel Generator
EE	Energy Efficiency
ESS	Energy Storage System
GP	General Practitioner (Physician)
HeRAMS	Health Resource Availability Mapping System
kVA	Kilo-volt Ampere
kW	Kilo-Watt
kW AC	Kilo-Watt AC (Alternating Current)
KWp	Kilo-Watt peak
L	Litre
MMU	Materials Monitoring Unit
MoH	Ministry of Health
MWp	Mega-Watt peak
NCD	Non-Communicable Disease
NGO	Non-Governmental Organization
OCHA	Office for Coordination of Humanitarian Affairs
PBP	Pay-Back Period
PHC	Primary Health Care
PMU	Project Management Unit
PV	Photovoltaic
UNDP	United Nations Development Programme
UNOPS	United Nations Office for Projects Services
UNRWA	United Nations Relief and Works Agency
VRLA	Valve-regulated lead-acid
W	Watt (unit of electrical power)
WHO	World Health Organization

3 | Executive Summary

The energy crisis affecting the Gaza Strip in recent years has had a significant impact on the delivery of a wide array of critical services, including in the health sector. Operating the electricity grid and diesel generators at rationed hours has created a dependency on fuel within the health system. In this context, over the past decade renewable energy, particularly solar photovoltaic technology, has emerged as a suitable and reliable alternative source of power. Nevertheless, in light of the lack of a comprehensive assessment of the potential capacity for, and feasibility of, the solar electrification required as part of a successful energy transition, the WHO, UNDP and the Ministry of Health commissioned a team to assess the Gazan health system's potential for transitioning to renewable energy. The assessment was conducted over the October 2018-May 2019 period, and the team's findings and recommendations are outlined in the present report.

The assessment primarily examined public health facilities managed by the Ministry of Health, as the latter provides the majority of health services in Gaza. A total of 15 hospitals and 59 Primary Health Care (PHC) facilities were assessed, of which 14 hospitals, 51 PHC facilities, and other MoH facilities were identified as suitable sites for solar PV system integration. A solar PV capacity of 1.028 MWp is projected to be required for the solar PV transition of all PHC facilities (including EE measures), corresponding to an investment of US$ 4.23 million. An estimated solar PV capacity of 3.41 MWp is required for solar PV integration of the 15 hospitals under consideration, corresponding to an investment cost of US$14 million The proportion of daily energy demand projected to be met by the proposed solar PV systems will vary across individual hospitals and PHCs, and is primarily dependent on the availability of physical space for solar PV deployment. Overall, the introduction of solar PV systems, combined with additional energy efficiency measures, is expected to yield combined annual savings in electricity costs of US$ 2.6 million including US$ 2.1 million of savings for hospitals and US$ 514,000 for PHC facilities.

While the renewable energy transition programme proposed in this report will not resolve the electricity crisis in the Gaza Strip, nor the myriad wider issues affecting the health system, it will nevertheless significantly enhance the resilience of health service delivery through reducing both fuel consumption and fuel dependency, as well as ensuring the continuous provision of all critical services, even in the absence of fuel or regular grid supply.

To that end, the report proposes a collaboration and coordination framework which seeks to engage all relevant stakeholders to secure an effective and successful transition of the Gazan health system from fuel-based energy precarity and insecurity to renewables-based energy resilience. Such a framework would coordinate and streamline the resources, actions and involvement of all interested donors, project-implementing entities, international agencies, and relevant local authorities, principally through identifying and adopting a shared set of technical and administrative protocols and processes, effectively mobilising resources, and rolling out projects according to evidence-based priorities and needs.

4 | Introduction and Background

The Health System in the Gaza Strip

There are currently 15 public hospitals in the Gaza Strip, distributed over five governorates, staffed by 5,327 health workers and offering a total capacity of 2,333 beds. The fifteen hospitals provide an estimated total of 2.8 million medical reviews a year. At the primary health care level, there are 71 operational PHC facilities, which are managed by the Ministry of Health (MoH), UNRWA, and the NGO community.

The public PHCs, managed by the MoH, account for 69% of the total number of facilities. PHCs are classified into four 'levels' according to the services they provide. The majority of PHCs are Level-2, with a total of 25 PHCs. Level-2 services are primarily preventative, and thus include maternal, child health care and immunization services. Some Level-2 clinics additionally offer laboratory tests and services. There are currently 15 Level-3 facilities in Gaza, where GPs and specialists provide medical care, family planning and dental services, as well as Level-2 preventative services. Supplementary services covered by Level-3 facilities include health education and laboratory tests. There are currently nine main Level-4 PHCs, which serve almost 60,000 patients a month. Level-4 facilities offer all of the services offered by Level-3 PHCs, but also provide services such as Gynaecology and Obstetrics Care, Radiology, health education and emergency medical services (EMS). Table 1, below, provides an overview of the number of facilities managed by the MoH and UNRWA, respectively, for each level:

Table 1 - Overview of UNRWA and MoH PHC facilities[1]

Governorate	Total number of PHCs		Level-2		Level-3		Level-4	
	MoH	UNRWA	MoH	UNRWA	MoH	UNRWA	MoH	UNRWA
North Gaza	7	4	2	0	4	0	1	4
Gaza	16	6	5	0	6	1	5	5
Middle Zone	13	4	10	1	2	2	1	1
Khan Younis	9	3	6	0	2	1	1	2
Rafah	4	5	2	2	1	1	1	2
Total	**49**	**22**	**25**	**3**	**15**	**5**	**9**	**14**

In addition to challenges relating to access to electricity, one of the main life-threatening factors facing the Gazan health sector is the lack of drugs and medical consumables, notably for non-communicable diseases (NCDs) and emergency patients. The access gap to essential drugs has recently gone beyond the critical threshold, with the available stock in December 2018 being only 47% of the required stock, a gap that is approximately double the one recorded for 2014[2]. Out of 600,000 patients suffering from chronic diseases, an estimated 200,000 are acutely vulnerable and lack access to their treatment, putting their health at severe risk[3]. Although the number of patients seeking permits to access healthcare outside the Gaza Strip has more than doubled since 2014, access to treatment for patients getting referred outside Gaza is becoming ever more restricted, while approval rates through the Israeli-controlled Erez crossing continue to decline dramatically. The impact of these restrictions can be life-threatening, imposing greater pressures on Gaza's health infrastructure. These conditions call for an urgent strengthening of the health system in the Gaza Strip.

1 Health Facilities in the Gaza Strip Report, WHO, 2018
2 WHO and Health Cluster Gaza Special Situational Report, oPt 2017
3 MoH The Annual Report; Hospitals in the Gaza Strip; issued April 2017

The Energy Crisis: Renewable Energy Transition

While the occupied Palestinian territory as a whole faces serious energy security challenges, this is especially severe in the Gaza Strip, where there is a significant energy deficiency, with the gap between the demand and supply of electricity estimated to be at least 250 Mega Watt (MW). A host of factors, including unrectified damages to the electricity system after recurrent hostilities, high restrictions on the entry of relevant materials, and a partially operational Gaza Power Plant (GPP), have all contributed to deepening this energy crisis. As a result of the dysfunctional nature of the grid, generators have become the primary source of electricity, leading to further dependency on fuel. However, due to challenges affecting the cost, access and availability of fuel, severe restrictions on electricity access have resurfaced, significantly affecting and compromising the functionality of public services in the Gaza Strip, especially health, education and water services.

In terms of the health system in the Gaza Strip, securing the availability of energy has been a recurring concern for all stakeholders involved, due to the critical role of energy in the provision of essential health services. While all of Gaza's health facilities are connected to the utility grid, they have been experiencing severe rationing of electricity access, with daily power outages lasting from 8 to 20 hours. During the outage hours, facilities are still expected to remain functional, to offer normal levels of service provision and to operate at peak workload.

As such, ensuring reliable access to electricity remains a compelling challenge for the health sector in the Gaza Strip. Humanitarian agencies have been providing fuel (funded by donors) to operate generators during the long hours of power-outage, and thus prevent the collapse of numerous critical, life-saving facilities. All of the Gaza Strip's, health facilities, including hospitals and health care centres, are now highly dependent on fuel. According to OCHA statistics, over the 2013-2018 period, Gaza's health facilities, including UNRWA and Government-managed ones, received **20.24 million litres of fuel**, at a total cost of approximately **US$25 million**[4] . The use of generators cannot thus be considered a sustainable solution for the electricity crisis in the health sector.

In order to address this substantial and chronic electricity shortage, a number of advanced and decentralized solutions have been considered, including those based on renewable energy technologies, principally solar photovoltaic (PV) technology. Such solutions not only provide a reliable and sustainable source of electricity, but also offer the co-benefits of providing a clean source of energy, particularly when compared to diesel generators, thus presenting a low-carbon option for the healthcare system. Solar photovoltaic systems for electricity generation are considered cost effective in comparison to the use of generators, especially in the long term.

Since 2013, as the costs of solar panels started to drop significantly, several efforts and initiatives have been undertaken to introduce and deploy solar power systems for health facilities in the Gaza Strip. However, a coherent, consistent and systematic approach for transforming energy infrastructure of the health system is yet to emerge. The field assessment conducted in the present report has identified 32 solar power systems that were deployed between 2012 and 2018, offering only partial-coverage to specific departments within 11 hospitals and 21 PHCs. The design approach taken by the implementing entities often focused on separating critical departments, to ensure continuous energy provision from the solar power system, which yielded tangible savings in fuel consumption. With the energy-crisis coming to a new phase, a strategy to harmonize and systematize the transition of the health system was devised and adopted by all relevant stakeholders, and is based on creating a road map guided by an updated assessment of the feasibility of the health system and its compatibility with solar power systems at each facility.

4 https://app.powerbi.com/view?r=eyJrIjoiNzgxYzE5MTAtM2U3Ny00ZGZlLWFhNDMtMzRlNmMyZmU3OWUxIiwidCI6IjBmOWUzNWRiLTU0NGYtNGY2M-C1iZGNjLTVlYTQxNmU2ZGM3MCIsImMiOjh9

The technical committee, comprised of UNDP, WHO and Ministry of Health, developed a data collection tool and field data collection process, which was performed between October and December 2018 by the surveying team. Between February and April 2019, the analysis was performed jointly by a team representing the technical committee to determine the solar power potential and feasibility for public health facilities using a pre-defined data analysis framework.

The report outlines the methodology used in the assessment, detailing the data analysis assumptions, technical considerations, and framework. The section that follows will describe the assessment findings, placing them in the context of current energy consumption and the potential for solar electrification, for both hospitals and primary health care centres, in each of Gaza's five governorates. A set of strategic recommendations is offered to build upon the assessment findings, and a road map is suggested that considers all of the contextual variables. The road map's objective is to ensure a systematic, harmonized, and inclusive transition of the health system from fuel dependency to renewable energy, through a collaborative framework that engages all relevant stakeholders and organizations.

5 | Assessment Methodology

5.1 Overview

In order to produce a comprehensive and thorough strategy for transitioning the health system from diesel fuel dependency to renewable energy, the assessment was identified as a primary step of the planning. As such, the assessment and the methodology were developed to determine the potential for solar electrification, the economic feasibility, and the impact that would result from it, for each individual facility. The assessment process broadly took place over three phases: planning, data-collection, and analysis. These can be described as follows:

1. **Tool development and assessment planning:** The facilities targeted in the data collection process were identified as including all public primary health care facilities, all hospitals, and three warehouses in the Gaza Strip. The facilities were grouped according to geographical proximity and location, and technical teams used the custom-developed data-collection tools to perform the survey. The developed questionnaire and tool were customised for PHCs and hospitals respectively in order to accommodate and reflect the differences in the analysis process specific to each of the two categories. A data analysis framework was also developed to meet the analytical requirements and objectives of the assessment. This was reflected both in the structure of the questionnaire and the nature of the data collected.

2. **Data collection:** The data collection process was conducted by five (5) teams, each operating across one of Gaza's five governorates, and comprising 18 engineers from the MoH and UNDP technical staff. The teams used the digital data collection tool (*Kobo Toolbox*) for the data-entry process. In addition, existing data sets for the rooftop and facility layouts were obtained from the MoH's database. UNDP engineers produced all missing layouts.

The on-the-ground data collection process took place over two months, from November to December 2018, and also included the deployment of electronic meters to measure actual energy consumption in hospitals, to ensure greater precision in quantifying daily energy demand and to better inform the sizing of PV systems.

The following information[5] was collected for each facility:

- *General*: Identification data for the facility, its location, GPS coordinates and the contact person.
- *Health*: Data about the health services provided at the facility, its impact, beneficiaries, operation in emergency context, any available maintenance and security features.
- *Space*: Details about the physical space availability, and the relevant shading potential.
- *Infrastructure*: Details about the electrical network and the current loads at the facility, its condition and general layout, in addition to the availability and viability of space to be repurposed for electric and energy storage.
- *Energy Sources*: Details about the facility's sources of energy, existing solar PV systems, grid availability and capacities, generator availability and its fuel consumption level.

3. **Data Analysis and visualization:** In accordance with the data analysis framework and processes described to quantify the required analytical outputs, the data analysis was performed by the technical committee through a collaborative approach, and was conducted independently for the hospitals and PHCs, respectively.

5 A detailed version of the data-collection questionnaire can be accessed in Annex 3.

The analysis process, framework, technical assumptions and considerations for PHCs and hospitals, respectively, are elaborated on in the following sections.

5.2 Data Analysis for PHC facilities

1. Design Considerations and Assumptions

The design considerations for system planning must include several key features that are required to ensure optimal functionality. The assumptions for the system planning of PHCs consider the following:

1. *Grid Connection*: The system sizing and setup assumes the availability of grid access for three (3) hours in conventional circumstances and that the solar PV system would have a grid connection upon deployment, with an energy storage system being available for use when the grid is not functional (including when the grid is rationed).
2. *Operational Hours:* The majority of PHCs are expected to operate official opening hours of 6-8 hours during the day. As most of the energy consumption and demand will be during the day, PV generation capacity is thus sized to meet the daily energy demand of the average daily winter solar yields for a maximum of six (6) hours.
3. *System Classification:* The solar PV systems have been classified into two categories, System I and System II, according to the proportion of daily energy coverage they offer:
    - *System I:* This solar PV system covers more than 70% of the daily energy demand (kWh/day). Accordingly, there is no requirement to operate the diesel generator.
    - *System II:* This solar PV system covers 20% to 70% of the facility's daily energy demand. As a result, the diesel generator must continue to operate during the day, using a PV-Diesel hybrid system to reduce the fuel consumption. The generator is only turned off when the consumption level is below the energy yield of the solar PV system.
4. Diesel Generator (DG) Integration:
    - *The use of Diesel Generators as Back*-up: The DG should be considered an integral part of the facility's energy mix. The system design assumes DG availability and use as a back-up source whenever the level of solar radiation fails to meet the daily energy requirements.
    - *Hybridization:* In cases where the PHC facility's space availability limits its potential solar PV capacity, and the energy demand exceeds the PV's possible load, the PV-Diesel hybrid model (which is classified as a System II) is considered as an operational scenario.
5. *Energy Storage:* In the analysis, estimated financial costs and benefits of both conventional lead-acid and advanced lithium batteries are taken into consideration. Based on the projected resource mobilization, the lithium batteries are assumed to be accessible.
    - *Battery Compatibility*: The proposed PV system must allow for compatibility with, and the possible future integration of, the use of advanced non-VRLA batteries *(such as lithium batteries or other advanced batteries)*. Costing assumptions for ESS integration assume the accessibility of lithium batteries, as they offer a service life of at least ten (10) years, compared to an average of five (5) for VRLA.
6. *Segmentation*: The facility's electrical network, whether featuring System I or System II, would accommodate future segmentation between critical and non-critical loads, which allows for critical loads to be connected to the solar PV power supply in case of electricity outage.
7. *Energy Efficiency:* All non-LED lighting fixtures in the target facility are to be replaced with energy-efficient ones. This is expected to lead to a marked reduction in the respective loads and, consequently, the energy demand at the facility. As this was the basis for quantifying the daily energy demand for solar PV system sizing, similar retrofits can be performed to the air conditioning system within the same targeted facility, which will eventually yield further reductions in the energy demand.

Detailed specifications of the data analysis framework and processes used for the calculations performed here are outlined in the Annexes, including a complete description of each process and the methodology applied to it.

2. PHC Health Impact: Categorization and Grouping

The 'Health Impact' criteria used for the categorization of Primary Health facilities in this report was developed in consultation with health specialists and stakeholders from the MoH and the WHO. The analysis considers a total of four primary characteristics:

- **Penetration Grouping:** This refers to the level of energy penetration of solar power use in proportion to the total energy demand, and thus varies between facilities depending on the availability of space and consumption level. A higher weight is allocated to facilities offering more optimal levels of penetration, with different weights being given to System I and II facilities.
- **Service-Level Grouping:** The health facility's 'Service Level' categorization is adopted by the stakeholders to indicate the scale, type, and focus of health service provision at the facility, whereby Service Level 4 corresponds to a higher weight than Service Level 2 as it reflects a higher impact service group.
- **Emergency Grouping:** Emergency services availability at the facility is an important indicator of the health service's impact, and is thus included as one of the key factors.
- **Essential Grouping:** In each governorate, a number of health facilities are deemed 'essential' and will thus continue to be treated as highest-priority in cases of emergency or war scenarios. Whereas services and access would commonly be restricted or suspended in such cases, 'essential' facilities would continue to be operational and to provide critical health services in their area.

Each of the above-listed factors was allocated a weight according to its importance and relevance in consultation with health specialists. The description and allocated weight for each of the four criteria is provided in Table 2 below:

Table 2 - PHC Health Impact Prioritization

Criteria	Level Description	Weight (%)
A. PV system penetration *rate* to adjusted loads rank *(total: 40%)*	System 1: 70-100 % Solar penetration of adjusted loads	40
	System 2: 20-70 % Solar penetration of adjusted loads	15
	Back-up: less than 20 % solar penetration of adjusted loads	7
	Zero % of solar penetration to adjusted loads	0
B. Service Level *(total: 15%)*	Level-4	15
	Level-3	10
	Level-2	5
C. Emergency Services *(total: 20%)*	Emergency point	20
	Non-Emergency point	0
D. Essentiality *(total: 25%)*	Essential	25
	Non-Essential	0

3. System Costing, Energy Efficiency and Project Savings

According to data collected for solar projects developed and implemented between 2016 and 2018, and taking into consideration local market prices, the basic cost for a solar PV system with a battery bank is estimated to be around US$ 3.7 per installed Watt ($/W) for VRLA-based systems, and a maximum of $4/Watt for Lithium battery systems. The assessment and cost quantification undertaken in this report are based on the assumption lithium batteries will be accessible upon resource mobilization, which has so far been a limitation due to border restrictions.

For PHC energy efficiency cost estimates, it is assumed that of the primary basic appliances only lighting will be retrofitted to LEDs, which is estimated to yield a 30% reduction in consumption (as compared to regular lighting). While these savings are relatively conservative in scale, they reflect baseline rather than maximal estimates. The costs of EE measures associated with LED adoption are assumed to be within the estimated $4/watt investment. For each PHC, it is assumed that two regular air-conditioning units will be replaced with more efficient (i.e. inverter type) models. The cost of deploying these new models at all 59 facilities is estimated at around US$ 1000 per unit, requiring a total additional investment of US$ 120,000.

5.3 Data Analysis: Hospitals

1. Design Considerations and Assumptions

The design considerations adopted in the system planning require a number of features to ensure optimal functionality. These features include:

1. **Grid Connection and Access:** The system sizing and setup require the availability of grid access of three hours daily in conventional circumstances. The hospital PV system must operate on the basis of the available grid-connection, and the hours of electricity available from the grid. The cost of electricity from the grid is assumed to be US$ 0.16 per unit of energy ($/kWh).
2. **Bi-directional Power Flow:** The proposed systems would accommodate potential future integration into full-grid-connected systems with battery back-ups, thus enabling facilities to be renewable energy sources of distributed power generation when the full-capacity grid becomes available.
3. **Energy Storage System (ESS):** The ESS at each hospital has been taken into consideration to ensure maximal impact of solar energy use both in terms of *economic savings*, and *resource resilience*. Three classifications are used in this regard, which can be summarized as follows:

- **Class A:** This refers to an ESS with a capacity that allows for multiple hours of load discharge during the night at the target facility. The ESS can be charged during the day from the grid, PV panels or PV-diesel hybrid resource, and discharge during the night when the load is within an accepted range that accommodates resource availability. Furthermore, the solar-plus-storage system would supply energy for the critical loads at the facility in times of emergency and fuel outage.
- **Class B***:* This refers to an ESS that allows for full solar power utilization during the day, whereby the power-production from solar PV meets consumption demand for several hours. The diesel generator during such hours can thus be turned off, while having approximately 0.5-2 hour capacity of energy storage with a power discharge capacity matching the load, in order to harmonize the integration of the solar with the demand levels. This ESS category is considered ''lean storage'' as it allows for maximum penetration of the solar resource at the facility during the day. In addition, a Class B ESS would use solar-plus-storage only when the energy supply for critical loads is needed and in the absence of a functional diesel generator or grid, during the day or night.
- **Class C:** In certain facilities, the PV-diesel hybrid amply meets the demand, and there is no need for using an ESS as backup. This is notably the case for facilities that are at the highest priority level for fuel allocation. The system modality in this scenario thus assumes the continuous availability of fuel and/or grid connectivity.

For all ESS classifications, lithium batteries have been identified as the best technology in terms of economic competitiveness and longevity, offering a service lifetime of at least ten (10) years, as well as flexible charging and discharging rates and depths.

4. **Optimal PV Penetration:** The solar PV system is to be sized so as to maximize the rate of PV penetration into the energy mix (Diesel/Grid) while exploiting all possible physical spaces.
5. **DG Integration and Hybrid Functionality:** Hybrid (PV-Diesel) system functionality is required for all classes of systems used in hospitals. The diesel cost assumed in this context is US$ 1 per litre of fuel.
6. **Penetration and Energy Coverage Quantification:** As a key indication of the impact on the health facility, the average penetration of solar energy into the energy consumption was determined for each facility over the year (summer and winter). The load profile was simulated based on the data collected for the electrical loads quantified through the digital network analysis. The measured degree of energy penetration thus indicates the annual saving provided by the solar energy system from the overall consumption.

2. System Costing, Energy Efficiency (EE) and Project Savings

According to data from solar projects developed and implemented between 2016 and 2018 and taking into consideration local market prices, the basic cost of a solar PV-diesel system is estimated to be around US$2.3 per installed Watt ($/W). This estimate includes the costs of electrical network rehabilitation at the hospital, and the creation of a new emergency network that is compatible with using solar PV system energy in cases of emergencies and fuel outages.

Assuming a base-cost of US$2.3/watt, the total costs (per watt) for various ESS classes is summarized in Table 3 below:

Table 3 - ESS Classification and Costs

ESS Type	Overview	Additional Cost ($/Watt) [6]	Total ($/Watt)
Class A	Full-ESS (5-6 hours capacity)	$ 1.50	$ 3.80
Class B	Partial-ESS (0.5-2 hours)	$ 0.80	$ 3.10
Class C	No ESS (only PV-Diesel)	--	$ 2.30

For storage costs, a simplified rate of cost per watt is assumed, which can include a lithium storage solution in case access to the Gaza markets is permitted.

For energy efficiency, it is assumed that the primary measures include two basic parameters: Conventional split-units Air-Conditioning (AC) and conventional lighting. The first can be retrofitted to inverter technology, which can result in estimated energy savings of 10% during the summer months, and the second can be replaced with LEDs, which can result in 25% energy savings over the whole year (compared to regular lighting). These efficiency and savings estimates are relatively conservative, though they only refer to the impact of primary measures. In terms of costs, it is estimated that upgrading from conventional AC cooling to inverter technology requires an investment of US$55 per unit of energy demand (kWh). Meanwhile, an investment of US$34/kWh is required to retrofit LEDs in replacement for conventional lighting.

Table 4 - Cost Assumptions for EE Measures (hospitals)

Primary EE Measure	Cost of Retrofit ($/kWh)
LED Retrofit ($/kWh)	$ 34.00
EE AC Retrofit ($/kWh)	$ 55.00

Total costs for primary EE measures at each hospital are estimated based on their air-conditioning and lightning consumption. An additional amount of US$ 80,000 per hospital was estimated for potential *secondary* EE measures, which include lighting control systems, insulation for heat/air dissipation, boiler-efficiency retrofitting, and other medical equipment EE replacements.

Hours of diesel generator operation and grid availability are also taken into consideration. The cost of diesel fuel is assumed to be US$ 1/litre[7], while the cost of electricity from the GEDCO local grid is estimated at US$0.16/kWh. Solar PV penetration is based on 3 hours of grid availability per day (reflecting grid-provided electricity costs), while the remaining 21 hours are supplied through diesel generators (reflecting fuel electricity costs).

6 Additional ESS costs are based on the availability of fuel generators and the assumption they are fit to be used in the hybrid (PV-Diesel) system.
7 The fuel price of US$1/liter is the cost of tax-exempted fuel available to UN Agencies.

The projected annual savings achieved through the introduction of a solar PV system, combined with those of energy efficiency retrofitting, the total value provided in this assessment report. The level of annual savings, and in turn the simplified pay-back-period *(PBP)*, will thus vary in line with any changes to these variables.

5.4 Limitations of the Proposed Methodology

While the proposed methodology is highly effective for identifying needs and requirements, it faces a number of limitations in precisely quantifying solar PV sizing. Some of the key limitations are as follows:

- **Quantification of daily energy demand for hospitals:** Data for the quantification of daily energy demand has been obtained from the network analyzers deployed between November and December 2018. The data covers between two and five days of the winter months, and is used to produce the winter average. For the purposes of estimating the summer load profile, a factor was taken into consideration. Daily consumption during the summer months may vary, both within and between facilities. This variation would only affect the rate of energy penetration, and not the sizing of the PV system, as the latter is primarily constrained and subordinate to space limitations. The data provided by the network analyzers covered only eight of the 14 hospitals, and were then used to extrapolate the corresponding values for the remaining facilities.

- **Quantification of daily energy for PHC facilities:** The quantification of energy demand for PHCs was based on multiple readings during site visits, and on the existing loads at each facility. This presented a limitation in that the actual demand level may vary between seasons, and between different days and hours of the same season. Therefore, the extrapolation made from the existing data does not present an actual data set taken over a period of time, but only estimates covering the assessment period. The calculation results indicated whether the proposed solar PV system at the PHC would cover most of the estimated energy needs, or only part of them (i.e. requiring the use of a hybrid model).

- **Energy Efficiency Quantification:** The quantification of primary and secondary energy efficiency measures can offer higher degrees of precision upon additional efficiency-specific on-the-field verification. Moreover, quantifying secondary measures such as lighting control systems on a facility-by-facility basis may achieve a greater degree of accuracy.

6 | Assessment Findings

6.1 Overview

As outlined at the outset of this report, the assessment findings aim to provide the necessary overview to effectively mobilize key resources based on the identified needs and requirements. The data relating to the sizing of the solar PV systems, the sizing of the energy storage systems, and the anticipated savings can serve as the basis for identifying priorities and planning. Upon mobilizing resources and allocating funding for specific identified groups of facilities, a follow-up validation and verification field assessment process is required to finalize the engineering phase, and prepare for deployment by the implementing entity.

Hospitals: The potential for solar electrification has been estimated at 3.41MWp, with 79% of the potential capacity located across three (3) major hospitals. The size and generation capacity of solar PV systems ranged from 600 to 1300 kWp. The accumulated potential PV capacity for the remaining 11 hospitals thus accounts for 21% of the total capacity, with systems ranging from 30 kW to 100 kWp. When considering solar electrification alone, the savings are expected to be of US$1.5 million annually, at an investment cost in solar PV systems estimated at US$10 million. Furthermore, implementing primary energy efficiency measures at all 14 hospitals is estimated to cost around US$3.1 million, while secondary measures will cost around US$880,000, with the annual expected savings from EE measures of US$606,002. Overall, solar PV electrification and EE measures at the 14 identified public hospitals will cost a combined total investment of approximately **US$ 14 million,** and are expected to yield annual savings of at least **US$ 2.1 million a year**.

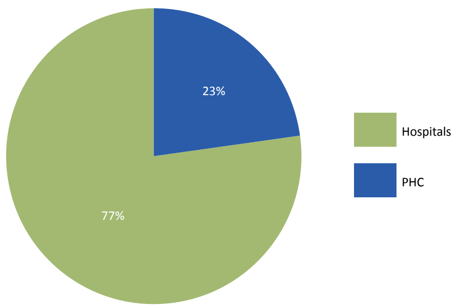


Chart 1: Solar PV Potential Capacity Breakdown (hospitals & PHCs)

PHCs: The combined potential capacity is estimated to be 1.028 MWp for all 51 PHCs. The majority of the recommended solar PV systems will cover most of the energy demand at the facilities for more than 80% of the year. A quarter of the facilities are classified as System II, operating a hybrid PV-diesel system with energy storage back-up. While such systems can meet part of the demand during the day, they cannot provide the full daily energy consumption required by the facility. In cases of emergency or after official hours, the combination of the solar PV system and storage can supply the electricity needed for critical departments (such as the vaccine and medicine fridges for example) throughout the 24-hour cycle.

In summary, as indicated in Table 5 below, the total combined potential solar capacity for both hospitals and PHC facilities is estimated to be 4.44 MWp, with PHC-based capacity estimated at 1.028MWp (23%) and hospital-based capacity estimated at 3.41 MWp (77%).

Table 5 - Potential Solar PV Capacity and Cost Breakdown

Type	Solar Capacity (MWp)	Cost (US$)
PHC	1.028	4,314,977.7
Hospitals	3.410	13,992,521.4
Total	**4.44**	**$18,307,499.1**

Review of infrastructure: Currently installed solar PV systems

Figure 1: Example of Existing Installation at Nasser Hospital

Several solar PV systems have already been deployed across health facilities in the Gaza Strip, both in hospitals and primary health care facilities, with the earliest identified deployment taking place in 2012.

For hospitals, the traditional approach for introducing solar PV systems at a health facility involves identifying a candidate department and isolating it from the rest of the electricity network, hence ensuring that the solar PV system with the battery back-up provides 100% of the energy requirement at the targeted department of the facility. However, the alternative model identified in this report (namely a PV-Diesel hybrid system) has been found to be a more optimal approach for implementing solar PV systems in health facilities. Consequently, integrating and re-purposing existing PV systems into the potential proposed solar PV-diesel systems could prove highly effective. Overall, a total combined capacity of **623 kWp** has already been installed across 11 hospitals, with the systems ranging in size between 10 and 300 kWp, at an average of 32 kWp. Solar PV systems have also been found to be operating at a total of 21 PHC facilities, offering a total capacity of around **207 kWp**, with the majority (14 out of 21 PHCs) being used to power vaccine or insulin fridges at a system size of under 2.5 kWp.

Electrical Grid: Multiple electrical supply lines to hospitals

There are currently plans under examination for adding an extension transmission power line to the three major hospitals in Gaza, namely the Nasser Medical Complex, the European Hospital, and Al Shifaa Hospital. The proposed extension lines would allow a continuous 24/7 power supply to the hospitals from the electrical grid. Until recently, the regular electricity connection was rationed at only 3/21 (3 hours on and twenty one hours off), before moving to an extended hours regime of 8/8 (eight hours on and eight hours off), which was enabled by a Qatar-funded fuel grant. As stated in the methodology section, the technical assumptions underpinning the financial savings analysis include a 3/21 scenario as the conventional mode of operation across all hospitals.

In this context, all future and planned solar PV systems can be designed so as to offer compatibility with a fully functional grid-connection, which the system can be connected to as a net-metering system when the grid is available but with interruptions. This would allow for maximal utilization of the solar energy generated at the facility.

6.2 Solar PV potential for Hospitals

OVERVIEW

Of the 15 hospitals that were examined in this assessment, one (1) facility was deemed non-suitable for solar PV system implementation. Four (4) hospitals — the Rantisy, Ophthalmic, Paediatric, and Psychiatric hospitals — were considered as part of one medical complex, the Nasr Medical Complex, sharing a single solar PV-diesel hybrid system. A total of eleven (11) solar PV systems were identified for all public hospitals. **Three (3) hospitals account for 79%** of the estimated potential solar PV capacity, as illustrated in Chart 2 below. These hospitals are Nasser Medical Complex, European Gaza Hospital (EGH), and Al-Shifa Hospital. The total estimated PV capacity for all 11 hospitals at the three identified classes is **3.41 MWp,** taking into consideration the variations in energy requirements and physical space availability across the facilities. The results also take into consideration the on-going project implementation in Nasser Hospital, and assumes a yet-to-be-funded capacity (550 kWp out of 1.2 MWp potential).

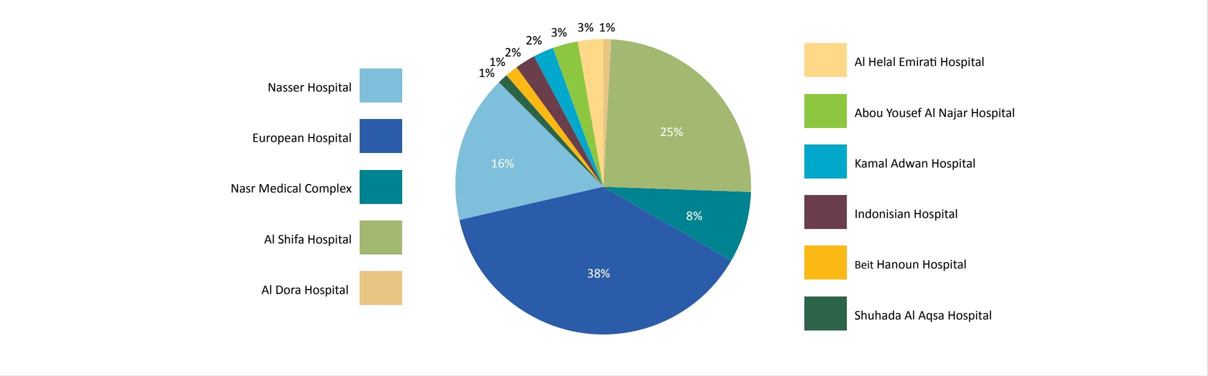


Chart 2: Solar PV Potential for Hospitals (Overview)

The expected required investment for all **11 hospitals** is estimated to be **US$14 million.** The estimated funding would cover solar PV system deployment, as well as implementing primary and secondary energy efficiency measures. The total potential annual savings from the solar PV system and the energy efficiency savings are approximately **US$2.117 million**, while the estimated simplified PBP for the investment is between 6 and 7 years, with the solar PV system's major components having a service life of 20 years. An overview of the investments and savings estimates relating to the proposed hospital solar PV systems is provided in Table 6 below.

Table 6 - Overview of Investments and Savings (Hospitals)

Hospital Investment	Cost (US$)	Annual Savings (US$/Y)
Solar PV Electrification	$ 10,003,000.00	$ 1,511,888.78
EE Measures (Primary)	$ 3,109,521.40	$ 606,002.60
EE Measures (Secondary)	$ 880,000.00	
Total	**$ 13,992,521.40**	**$ 2,117,891.38**

Table 7 below highlights the solar PV capacity at each hospital, the percentage of energy coverage provided by the solar PV for each facility (after EE measures), the facility's ESS class, as well as the initial costs and annual expected savings.

Table 7 - Hospital Proposed Solar PV Summary

No	Hospital Name	Gov.	PV System Capacity (kWp)	ESS Class	PV Coverage (w/EE)	Potential Savings of solar PV w/EE (US$/year)	Total Investment US$ (PV + EE)
1	**Beit Hanoun Hospital**	North	40	Class A	5%	$ 35,062.03	$ 277,010.00
2	**Indonesian Hospital**		80	Class B	11%	$ 67,912.48	$ 477,400.00
3	**Kamal Adwan Hospital**		80	Class B	14%	$ 67,893.00	$ 458,864.00
4	**Al Dorra Hospital**	Gaza	30	Class A	6%	$ 22,522.47	$ 239,070.00
5	**Al Shifa Hospital**		850	Class C	17%	$ 614,901.91	$3,067,402.40
6	**Nasr Medical Complex**		260	Class B	15%	$ 188,316.46	$ 1,230,839.00
7	**Shuhada Al Aqsa Hospital**	Middle	40	Class B	3%	$ 91,004.20	$ 388,026.00
8	**European Hospital**	Khan Younis	1300	Class B	48%	$ 613,207.02	$ 4,525,800.00
9	**Nasser Hospital**		550	Class B	15%	$ 279,272.35	$ 2,283,960.00
10	**Abo Yousef Al Najar Hospital**	Rafah	90	Class B	15%	$ 67,499.22	$ 510,310.00
11	**Al Helal Emirati Hospital**		90	Class A	31%	$ 70,300.22	$ 533,840.00
					Total	**$ 2,117,891.38**	**$ 13,992,521.40**

Energy Storage Classification:

Classifying a hospital's energy storage integration was undertaken within the context both of *reducing the dependency on fuel and generators*, and *achieving resilience* against power-outages, fuel unavailability and other unforeseen circumstances that could prevent the use of onsite generators.

- **ESS Class A** is considered the maximum storage capacity for a hospital, allowing the ESS to be used to power the night-shift low-load energy demand in a regular PV-diesel hybrid scenario. Such a system also enables utilization of the solar PV system with ESS — i.e. without diesel generator operating — for the critical loads, supplying electricity exclusively through this solar-plus-storage system. A total of three (3) hospitals out of 11 were identified as being *Class A*. The hours of operation of solar-plus-storage (i.e. without generator) would range from five to seven hours a day, depending on the load and rate of consumption at the facility, as well as the season of the year.

- **ESS Class B** has a more 'lean-storage' capacity, typically fulfilling twelve hours of demand daily. This approach allows for a solar PV-diesel system to operate at more optimal levels when the solar power penetration is high relative to the load (thus achieving higher fuel savings). The system can also use solar-plus-storage to provide energy for a low-demand emergency network for a certain number of hours during the day, depending on consumption levels. A total of seven (7) hospitals out of 11 were identified as Class B.

- **ESS Class C** refers to a facilities with no energy storage, typically because they would always enjoy priority in emergency access to fuel in all circumstances, and are currently prioritized for the additional electricity supply-line from the grid. Only one hospital — Al-Shifaa — of the eleven under review was identified as a Class C.

Table 8 below provides an overview of the geographical distribution of PV capacity across the Gaza Strip's five governorates. More than half of the PV capacity is estimated to be located in Khan Younis, with two of the largest systems (European Hospital and Nasser Hospital Complex) located in the governorate.

Table 8 - Hospital PV Capacity Geographic Distribution

Governorate	PV Capacity (kWp)
North	200
Gaza	1140
Middle	40
Khan Younis	1850
Rafah	180
Total (KWp)	3410 (3.41 MWp)

As illustrated in Chart 3 below, it is estimated that **54**% of the potential solar PV capacity is located in Khan Younis, **34**% in Gaza, while the three other governorates share the remaining **12**%.

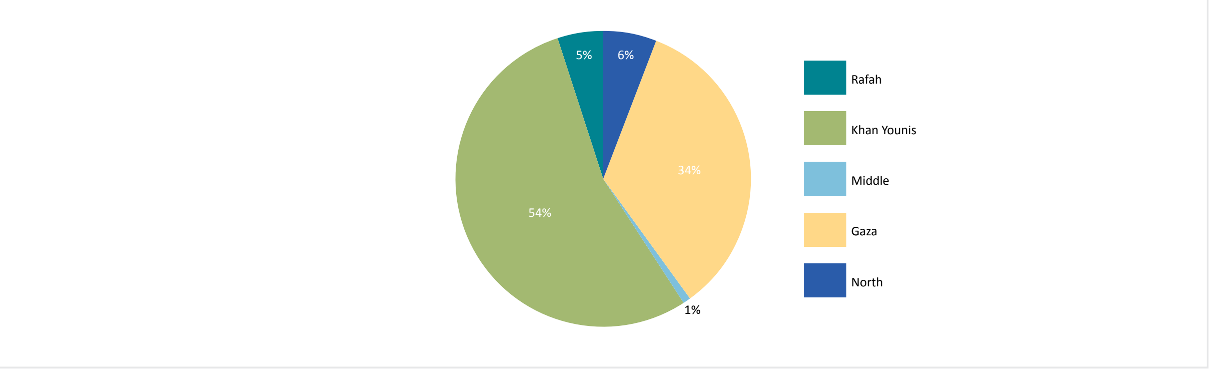


Chart 3: Solar PV Potential Capacity per Governorate (hospitals)

Energy Efficiency in Hospitals: A Strategic Opportunity

The primary energy efficiency measures considered in hospitals are twofold: Upgrading regular air-conditioning units (split units) and upgrading conventional lighting. The former can be achieved through retrofitting the AC units with inverter AC technology, and the latter with high efficiency LED lighting. For inverter AC technology, a 10% reduction in consumption in summer months is predicted, while the use of LED lighting is estimated to result in a 25% reduction in consumption for lighting loads throughout the whole year. In addition to these primary energy efficiency measures, *secondary energy efficiency measures* are also considered. Such measures — including further insulation works, lighting control system with motion sensors, as well as other demand-control measures — are expected to achieve additional savings. Beyond the initial investment, estimated to be around **US$ 3.1 million** for the primary retrofit, an additional **US$ 880,000** is required for the secondary measures, representing a total investment of **US$ 3.99** million in energy efficiency measures at all 11 hospitals. An overview of EE measures is presented in Table 9 below.

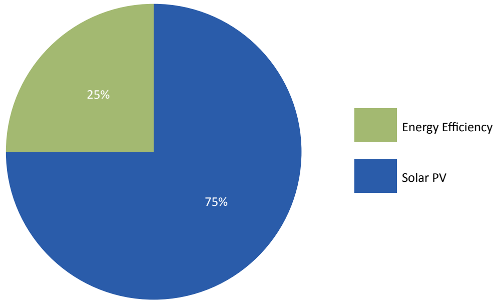


Chart 4: Annual Savings Breakdown for Hospitals

Table 9 - EE Overview for Hospitals

Energy Efficiency Overview of Hospitals	
LED EE Savings	25%
AC Inv. Savings (%)	10%
Total EE savings per annum	$ 606,002.6
Primary EE Investment ($)	$ 3,109,521.40
Secondary EE Investment ($)	$ 880,000
Total EE investment ($)	$ 3,989,521.4

The proposed Energy Efficiency measures represent a significant opportunity for reducing the overall energy demand. As shown in Chart 5 below, the proposed EE investment is around **24**% of the total proposed fund (which includes solar PV). However, the combined annual savings resulting from EE measures and solar PV are estimated to be at least **25**% of current costs.

In total, seven (7) hospitals have potential solar PV capacities between 30 kWp and 100 kWp, while four (4) hospitals were within the 260 kWp-1.3 MWp range. Due to physical constraints, the proposed solar PV systems cover only part — ranging from 4% to 30% — of the annual energy demand in ten hospitals. However, one hospital offers enough space to host a PV system that cover 48%-50% of its annual energy needs.

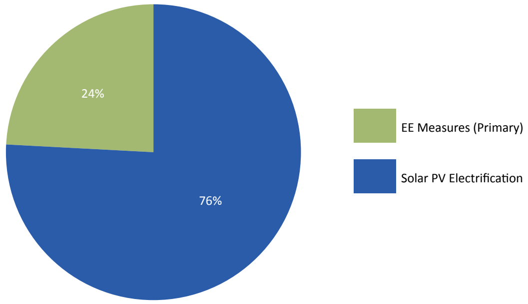


Chart 5: Breakdown for Investment Requirements (hospitals)

When taking into consideration the primary energy efficiency retrofits, both the savings as well as the PV penetration are expected to increase, which will be reflected in higher annual energy demand coverage.

Figure 6 below outlines the potential increase in solar energy demand coverage, enabled by the primary EE measures, for each of the hospitals assessed (excluding Nasser Medical Complex):

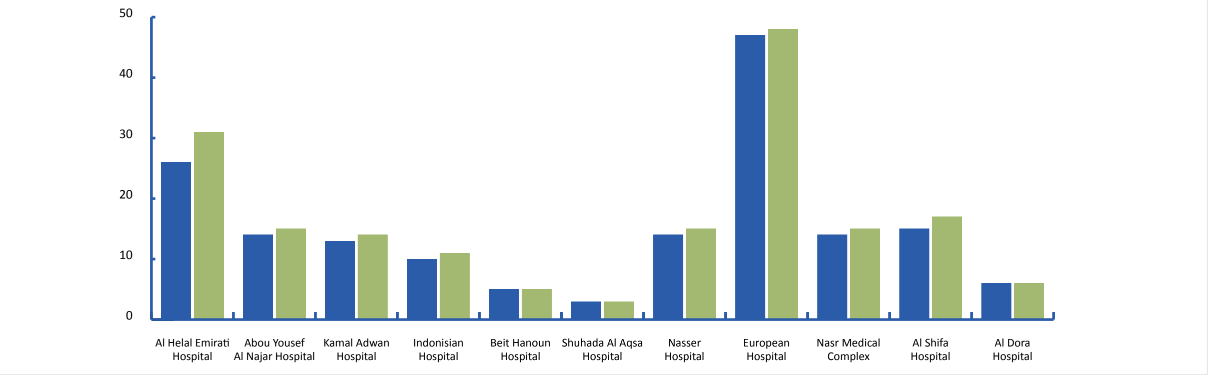


Chart 6: PV Energy Penetration in Hospitals (with and without EE)

In summary, the hospital solar PV requirement of 3.41 MWp, combined with effective energy efficiency measures is an impactful approach for increasing the resilience of the network of public hospitals in the Gaza Strip, reducing its dependency on fuel and diesel generators, and resulting in more than US$2.1 million of savings per year while ensuring critical services continue to be provided in cases of emergency.

The following sections will highlight in greater detail some of the key features and findings for each of the 11 hospitals under examination.

1 | Beit Hanoun Hospital | Governorate: North

Beit Hanoun Hospital is one of the three hospitals with a Class *A* ESS, which reduces dependency on generators during the evening hours. The potential system operates at around 40 KWp, and the annual cost savings from energy efficiency measures equal those of adopting the solar PV-diesel hybrid system, as illustrated in the below table.

The expected simplified PBP is estimated to be around **7.5 years** for the solar energy and energy efficiency initial investment. The technical and financial specifications can be summarized in the below table:

Technical Specifications	
PV System Size (KWp)	40
ESS Classification	Class A
Annual PV Energy Coverage pre-EE (%)	4.9%
Annual PV Energy Coverage with EE (%)	5.2%
Total Energy Savings (MWh/year)	123

Financial Specifications	
Solar PV System Cost ($)	152,000
Energy Efficiency Retrofit Cost ($)	125,010
Total EE & PV System Costs ($)	277,010
Total Fuel Savings (Litre/year)	32,692.25
Total EE & PV Annual Savings ($/year)	35,062.0
Simplified Pay Back Period (PBP) - years	7.5

Health Impact: Beit Hanoun hospital serves an estimated 6000 patients a month. The services provided include essential trauma care, laboratory services, ICU (adult and neonatal), imaging (CT, MRI, X-ray), and a blood bank, amongst other services.

2 | Indonesian Hospital | Governorate: North

The potential solar PV capacity at the Indonesian hospital is estimated to be around 80 kWp. The system covers approximately 11.2% of the annual energy demand at the facility. However, an existing solar PV system of 30 KWp capacity can be integrated with the proposed 80 KWp, to achieve a 120 KWp total capacity. The integration will allow for an optimal operation of the system and maximize the energy savings at the facility. The energy efficiency retrofitting will contribute to around 48% of the potential savings, as illustrated in the below table.

The expected simplified PBP is estimated to be around 7 years for the initial investment (solar energy and energy efficiency measures). The technical and financial specifications can be summarized in the below table:

Technical Specifications	
PV System Size (KWp)	80
ESS Classification	Class B

Technical Specifications	
Annual PV Energy Coverage pre-EE (%)	10.3%
Annual PV Energy Coverage with EE (%)	11.2%
Total Energy Savings (MWh/year)	239

Financial Specifications	
Solar PV System Cost ($)	248,000
Energy Efficiency Retrofit Cost ($)	229,400
Total EE & PV System Costs ($)	477,400
Total Fuel Savings (Litre/Year)	63,329.83
Total EE & PV Annual Savings ($/year)	67,912.5
Simplified Pay Back Period (PBP) - years	7.0

Health Impact: The hospital serves approximatley 15,000 patients a month, and offers emergency services, specialized surgery in various specialties, as well as numerous clinical services.

3 | Kamal Adwan Hospital | Governorate: North

The solar PV system at the Kamal Adwan Hospital is estimated to operate at 80 KWp and thus cover approximately 14.3% of the total annual energy demand at the facility. The energy efficiency measures are expected to yield approximately 48% of the annual savings, which almost equals the value of the savings in fuel cost associated with adopting the solar PV system, as illustrated in in the below table.

The expected simplified PBP is estimated to be around **6.7 years** for the initial investment (solar PV energy and EE measures). The technical and financial specifications can be summarized in the below table:

Technical Specifications	
PV System Size (KWp)	80
ESS Classification	Class B
Annual PV Energy Coverage pre-EE (%)	12.8%
Annual PV Energy Coverage with EE (%)	14.3%
Total Energy Savings (MWh/year)	239

Financial Specifications	
Solar PV System Cost ($)	248,000
Energy Efficiency Retrofit Cost ($)	210,864
Total EE & PV System Costs ($)	458,864
Total Fuel Savings (litre/year)	63,311.73
Total EE & PV Annual Savings ($/year)	67,893.0
Simplified Pay Back Period (PBP) - years	6.7

Health Impact: The Kamal Adwan hospital is one of two public hospitals in the North of Gaza, and treats approxiamtely 14,000 patients a month. The services it offers include imaging, ICU, emergency and electrive surgery, amongst other serivces.

4 | Al-Dorra Hospital | Governorate: Gaza

Al-Dorra hospital is one of three (3) hospitals in the governorate of Gaza, along with Shifa hospital, and the Nasr Medical Complex.

Al-Dorra hospital is one of three (3) hospitals in the governorate of Gaza, along with Shifa hospital, and the Nasr Medical Complex. Al-Dorra hospital has a **30 kWp** PV capacity and is one of three hospitals with a *Class A* ESS, which can provide energy for the emergency network in case of full power outage. It is expected that the adoption of the solar PV system will account for **59**% of the predicted annual savings, while **41**% of savings will result from EE measures. The solar PV system is expected to cover around **6**% of the total annual energy demand of the hospital.

The expected simplified PBP is estimated to be around 10.6 years for the solar energy and energy efficiency initial investment. The technical and financial specifications can be summarized in the below table:

Technical Specifications	
PV System Size (KWp)	30
ESS Classification	Class A
Annual PV Energy Coverage pre-EE (%)	5.8%
Annual PV Energy Coverage with EE (%)	6.0%
Total Energy Savings (MWh/year)	79

Financial Specifications	
Solar PV System Cost ($)	114,000
Energy Efficiency Retrofit Cost ($)	125,070
Total EE & PV System Costs ($)	239,070
Total Fuel Savings (litre/year)	21,012
Total EE & PV Annual Savings ($/year)	22,522.5
Simplified Pay Back Period (PBP) - years	10.6

Health Impact: Al Dorra hospital benefits approximately 7,500 monthly patients through various health services provided.

5 | Al Shifa Hospital | Governorate: Gaza

Al-Shifa hospital is the largest hospital in the Gaza Strip, and provides health services to the entire Gazan population. It has a potential solar PV capacity of 850 kWp, primarily through a PV-diesel hybrid system which reduces the dependency on fuel-based generators. As the most critical health facility in the Gaza Strip, this facility will always have priority in terms of access to fuel reserves, and the solar PV system would be primarily utilized to achieve savings in humanitarian-supplied fuel.

The system is expected to fulfil approximately **16.7**% of the total annual energy demand at the hospital. The existing solar PV systems at Al-Shifa hospital can be integrated into the new PV-diesel hybrid system to optimize savings, which is a possible scenario for all existing solar PV systems already installed at hospitals in the Gaza Strip. The cost savings are illustrated in the below table.

The expected simplified PBP is estimated to be around 5.0 years for the solar energy and energy efficiency initial investment. The technical and financial specifications can be summarized as follows:

Technical Specifications	
PV System Size (KWp)	850
ESS Classification	Class C
Annual PV Energy Coverage pre-EE (%)	15.2%
Annual PV Energy Coverage with EE (%)	16.7%
Total Energy Savings (MWh/year)	2142

Financial Specifications	
Solar PV System Cost ($)	1,955,000
Energy Efficiency Retrofit Cost ($)	1,112,402.4
Total EE & PV System Costs ($)	3,067,402.4
Total Fuel Savings (Litre/year)	573,779
Total EE & PV Annual Savings ($/year)	614,901.9
Simplified Pay Back Period (PBP) - years	5.0

Health Impact: Al Shifa hospital benefits approximelty 122,440 monthly patients, and provides the most diverse range of health services in the Gaza Strip. The hospital is considered to be the most critical and impactful hospital in the Gaza Strip, especially in times of conflict.

6 | Nasr Medical Complex | Governorate: Gaza

As stated earlier, the Nasr Medical complex combines four hospitals that were assessed individually for energy consumption, space availability and other variables. The data for the four hospitals were combined in the design of a single solar PV system which would integrate into a single electrical network connecting all four hospitals together. The total solar PV potential is estimated at **260 KWp** and is expected to cover approximately 14.9% of the total consumption. An overview of the annual savings is provided in the below table.

The expected simplified PBP is estimated to be around **6.5 years** for the solar energy and energy efficiency initial investment. The technical and financial specifications can be summarized in the below table:

Technical Specifications	
PV System Size (KWp)	260
ESS Classification	Class B
Annual PV Energy Coverage pre-EE (%)	13.7%
Annual PV Energy Coverage with EE (%)	14.9%
Total Energy Savings (MWh/year)	656

Financial Specifications	
Solar PV System Cost ($)	806,000
Energy Efficiency Retrofit Cost ($)	424,839.0
Total EE & PV System Costs ($)	1,230,839.0
Total Fuel Savings (Litre/year)	175,721.42
Total EE & PV Annual Savings ($/year)	188,316.5
Simplified Pay Back Period (PBP) - years	6.5

Health Impact: When combining the health services and patients data for the four hospitals comprising the *Nasr Medical Complex*, the impact and catchment population is amongst the highest in the Gaza Strip. It is estimated that approximately 26,412 patients benefit from the complex's services monthly. These services notably include pediatric and maternatiy care, mental health, as well as other general services.

7 | Shuhada Al Aqsa Hospital | Governorate: Middle

The Shuhada Al Aqsa hospital offers a total of 40 kWp of potential solar PV capacity. The penetration rate is relatively low when compared to the total energy demand at the facility. However, there is an existing solar PV system of 75 kWp which can be integrated into the new proposed solar PV system for higher energy optimization. Furthermore, an additional area of land was recently (2019) assigned to the hospital by the MoH but was not taken included in the assessment, bringing the potential solar PV system total size to an estimated **150 kWp** (including the proposed 40 kWp and the existing 75 kWp). The proposed energy efficiency measures are expected to contribute significantly to reducing the energy consumption at the facility, and the corresponding cost savings are illustrated in the below table.

The expected simplified PBP for the solar energy and energy efficiency initial investment is estimated to be around **4.2 years**. The technical and financial specifications can be summarized in the below table:

Technical Specifications	
PV System Size (KWp)	40
ESS Classification	Class B
Annual PV Energy Coverage pre-EE (%)	2.9%
Annual PV Energy Coverage with EE (%)	3.2%
Total Energy Savings (MWh/year)	330

Financial Specifications	
Solar PV System Cost ($)	124,000
Energy Efficiency Retrofit Cost ($)	264,026.0
Total EE & PV System Costs ($)	388,026.0
Total Fuel Savings (Litre/year)	84,665.55
Total EE & PV Annual Savings ($/year)	91,004.2
Simplified Pay Back Period (PBP) - years	4.2

Health Impact: The Shuhada Al Aqsa hospital serves an estimated 18,000 patients a month, who benefit from a wide array of health services, includling trauma care, imaging, Intensive-Care-Units, as well as emergency and elective surgery.

8 | European Gaza Hospital | Governorate: Khan Younis

The European Gaza hospital (EGH) is amongst the most important hospitals in the Gaza Strip. With significant EE measures already implemented at the hospital, the majority of the predicted cost savings will be generated by the solar PV system, as outlined in the below table. The proposed system at EGH integrates a Class B 'lean storage' system that allows for full power penetration during the day, when the sun is shining. As a result, the generator can be switched off during the day for several hours, securing greater savings. The proposed system is expected to fulfil around 49% of EGH's total annual energy demand.

The expected simplified PBP is estimated to be around **7.4 years** for the solar energy and energy efficiency initial investment. The technical and financial specifications can be summarized in the below table:

Technical Specifications	
PV System Size (KWp)	1,300
ESS Classification	Class B
Annual PV Energy Coverage pre-EE (%)	46.9%
Annual PV Energy Coverage with EE (%)	48.2%
Total Energy Savings (MWh/year)	2,067

Financial Specifications	
Solar PV System Cost ($)	4,030,000.00
Energy Efficiency Retrofit Cost ($)	495,800.00
Total EE & PV System Costs ($)	4,525,800.00
Total Fuel Savings (Litre/year)	573,528.69
Total EE & PV Annual Savings ($/year)	613,207.00
Simplified Pay Back Period (PBP) - years	7.4

Health Impact: The European hospital serves an estimated 17,500 monthly patients, and is one of the three main referral hospitals in the Gaza Strip. The health services provided at EHG include laboratory services, imaging services (CT, MRI, X-ray), intensive care units (adult and neonatal ICU), specialized surgery in various areas, as well as a wide range of other services.

9 | Nasser Hospital | Governorate: Khan Younis

The Nasser Hospital currently operates a solar PV system of 300 KWp (composed of 2 separate systems of 250 kWp and 50 kWp respectively), with a further 350 to 400 KWp capacity currently under implementation and expected to be completed by the summer of 2019. The total potential capacity, based on current space availability at the hospital, is estimated to be 1.2 MWp. Therefore, the maximal capacity of any additional system is 550 KWp. However, it is worth noting that additional future expansion of the solar PV system remains possible if additional space were to be allocated to the hospital by the Ministry of Health.

The expected simplified PBP is estimated to be around 8 years for the solar energy and energy efficiency initial investment. The technical and financial specifications can be summarized in the below table:

Technical Specifications	
PV System Size (KWp)	550
ESS Classification	Class B
Annual PV Energy Coverage pre-EE (%)	14.5%
Annual PV Energy Coverage with EE (%)	14.8%
Total Energy Savings (MWh/year)	948

Financial Specifications	
Solar PV System Cost ($)	1,705,000
Energy Efficiency Retrofit Cost ($)	578,960.0
Total EE & PV System Costs ($)	2,283,960.0
Total Fuel Savings (Litre/year)	261,077.90
Total EE & PV Annual Savings ($/year)	279,272.4
Simplified Pay Back Period (PBP) - years	8

Health Impact: Nasser hospital is amongst the most critical hospitals in the Gaza Strip, particaurlly for patients in the Khan Younis governorate. It serves approximately 27,000 patients on a monthly basis.

10 | Abo Yousef Al Najjar | Governorate: Rafah

Abo Yousef Al-Najjar hospital is amongst the key hospitals in the southern governorate of Rafah. The potential solar PV system capacity is estimated to be 90 KWp, which is expected to fulfil a minimum of 15.1% of the hospital annual energy demand. The breakdown of the projected annual savings is illustrated in the below table.

The expected simplified PBP is estimated to be around **7.5 years** for the solar energy and energy efficiency initial investment. The key technical and financial specifications can be summarized in the following table:

Technical Characteristics	
PV System Size (KWp)	90
ESS Classification	Class B
Annual PV Energy Coverage pre-EE (%)	13.8%
Annual PV Energy Coverage with EE (%)	15.1%
Total Energy Savings (MWh/year)	236

Financial Characteristics	
Solar PV System Cost ($)	279,000
Energy Efficiency Retrofit Cost ($)	231,310.0
Total EE & PV System Costs ($)	510,310.0
Total Fuel Savings (Litre/year)	62,975.31
Total EE & PV Annual Savings ($/year)	67,499.2
Simplified Pay Back Period (PBP) - years	7.5

Health Impact: The hospital is amongst the most critical hospitals in the Rafah governorate, in the south of the Gaza Strip. In cases of emergency and road closures, the hospital acts as the main referral hospital serving the Rafah governorate. It is estimated that the hospital serves approximately 11,000 patients on a monthly basis.

11 | Al Helal Al Emirati | Governorate: Rafah

The Helal Al Emirati hospital has a solar PV system potential of 90 KWp and is one of three hospitals with a Class A ESS, reducing its dependency on diesel generators during the evening hours. The system is expected to operate in an optimal way to reduce fuel consumption, while also providing critical departments at the hospital with a continuous source of energy for when fuel is not available. The system is expected to fulfil a minimum of 31% of the hospital's annual energy demand. Annual savings are illustrated in the below table.

The projected simplified PBP is estimated to be around **7.6 years** for the solar energy and energy efficiency initial investment. The technical and financial specifications can be summarized in the following table:

Technical Characteristics	
PV System Size (KWp)	90
ESS Classification	Class A
Annual PV Energy Coverage pre-EE (%)	25.7%
Annual PV Energy Coverage with EE (%)	31.2%
Total Energy Savings (MWh/year)	246

Financial Characteristics	
Solar PV System Cost ($)	342,000
Energy Efficiency Retrofit Cost ($)	191,840.0
Total EE & PV System Costs ($)	533,840.0
Total Fuel Savings (Liter/year)	65,577.60
Total EE & PV Annual Savings ($/year)	70,300.2
Simplified Pay Back Period (PBP) - years	7.6

Health Impact: The hospital serves an estimated 2300 patients a month from across the southern governorate of Rafah, providing imaging services (*X-ray and Ultrasound*), child health services, and other clinical services.

6.3 Solar PV potential for PHC facilities

6.3.1 Overview

As outlined earlier in this report, one of the key prerequisites and enablers of healthcare delivery and service is the availability of, and access to, electricity. Based on our assessment, 55 out of the 59 PHCs and health facilities surveyed have reported a 100% unstable and irregular power supply. Of those without regular supply, 18% have no diesel generator or solar PV back-up for the facility's operation.

PHC facilities that depend on Diesel Generators (DG) have access to varying capacities of generator power, ranging from 5 kVA to 650 KVA, with diesel fuel consumption rates that range from 1.2 to 172 Litres/Hour. The total daily diesel fuel consumption varies in line with the number of hours during which the grid is available, as well as fluctuations and patterns of the facility's energy demand. In all cases, most PHCs depend heavily on diesel fuels for their day-to-day operations, which is proving to be a costly and logistically challenging resource to secure. Such fuel dependency jeopardizes the health service provision in the Gaza Strip, making the current arrangements are unsustainable and ineffective.

A total of 21 PHCs were identified as having existing solar PV systems. The majority (14 out of 21) of existing systems offer a maximum capacity of 2.5 kWp and are being used for small refrigeration applications, notably for the storage of vaccines or other medicines which require 24/7 stable temperature. The remaining seven facilities have solar PV-hybrid off-grid systems with capacities that range between 3kWp and 85 kWp. Of these, only four are able to meet the full daily energy needs of the facility.

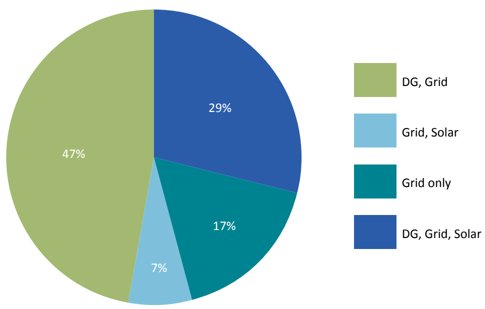


Chart 7: Proportion of Energy Sources Supplying PHCs

In order to understand the energy needs of the 59 PHCs, an energy audit was conducted as part of the survey, which detailed the load and power requirements of the various departments and electrical equipment at each facility. In order to provide a better understanding of the energy demand profiles at each PHC facility, electrical loads were classified into the following five primary categories:

1. Lighting
2. Medical Equipment
3. Air Conditioning and Ventilation
4. Heating
5. Information and Communication Technology (ICT)

Figure 8 below provides a breakdown of the energy consumption for each of the five categories. The category with the highest demand is that of AC and ventilation (27%), followed by heating (24%), with the two categories accounting for a combined 51% of the total energy demand. The remaining categories — medical equipment (23%), lighting (18%), and ICTs (8%) — account for a combined 49% of the total PHC demand.

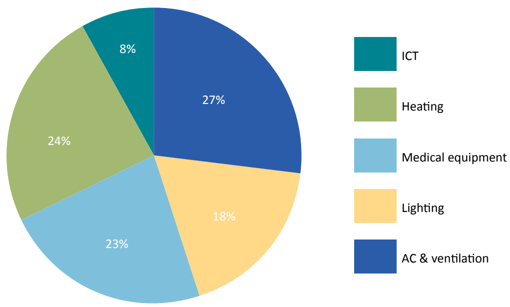


Chart 8 : Load Category Breakdown at PHC Facilities

The load categories at the PHC facilities are further elaborated on as follows:

- **Lighting:** In the context of PHC facilities, lighting is normally classified as either ambient (general space lighting), task (lighting for special tasks which is generally focused and brighter) or security (outdoor space lighting around buildings and pathways). According to the dataset collected during the assessment, PHC lighting accounts for 18% of the original energy demand, which corresponds to a total energy consumption of 3.15 MWh/day.

As stated earlier in the methodology, energy efficiency measures have been adopted for the purpose of sizing solar systems. This includes a number of assumptions being taken into account, such as adjusting behavioural practices, which correspond to a reduction in lighting operation from 7 to 5.5 hours, and retrofitting conventional Lighting to LED lights. EE lighting currently constitutes less than 8.5% of the total lighting in use at PHCs. The proposed combined EE measures for lighting in PHCs would reduce the lighting energy demand to less than half of the original demand, reaching 1.5 MWh/day.

- **Medical Equipment:** Medical equipment used in PHCs includes an extensive list of devices and apparatuses serving patients, including but not limited to X-ray, sterilization, and ultra-sound machines, dental care units and laboratory equipment. The medical equipment's original load represents 23% of the total load. However, when adjusting for the working hours of high consuming appliances and omitting the X-ray machines (for efficiency purposes), the overall medical equipment energy demand is reduced to 2.8 MWh/day. This has been adopted as the basis for the solar PV system design and the quantification of the penetration rates.

- **Air conditioning and Ventilation:** Air conditioning and ventilation account for the largest proportion of the total energy demand at PHCs, followed in second place by heating. As all surveyed PHCs use conventional split Air conditioning units, their load proportion reaches 27% of the total original load. Such significant cooling requirements are linked to increasing demand for comfort in rooms, especially in the summer season, coupled with high internal loads.

- **Heating:** Heating accounts for a large proportion of the energy used in PHCs. In the course of the assessment, all PHCs were found to be using decentralized electrical heaters. It was also observed that 25 PHCs had no solar water heating units. This presents an opportunity for retrofitting them with Solar Water Heating units (SWH), which provide greater efficiency and a relatively short pay-back-period (PBP). The heating load's share of the original load is almost equal to that of medical equipment, which highlights the need for strategically deployed heating alternatives that take into account the technical and behavioural features of the PHCs.

- **ICT:** Computers and ICT devices were found to show a higher load than expected, which was principally attributed to the excessive daily use of printers. As such, a minimal adjustment of printers' operating hours is projected to result in a load reduction from 1,394 to 1,293 kWh/day. In this context, efforts to encourage the efficient use of computers, including the digitization of records to reduce dependency on printers and in turn reduce demand on energy, can contribute to the overall objective of enhancing the health system's energy resilience.

The energy demands of the different load categories in PHCs, taking EE measures into account, are outlined in Table 10 below:

Table 10: Energy Demand per Category (after EE measures)

Load Category	Daily Energy Demand (KWh/Day)	Proportion of Total Demand
AC & Ventilation	916.93	14%
LED lighting	1525.28	23%
Medical Equipment	2827.13	43%
ICT equipment	1293.49	20%
Total	**6562.83 (6.5 MWh)**	**100%**

6.3.2 Solar PV Potential in PHC facilities

The total potential capacity of solar PV systems across all government-supported PHCs is estimated to be 1.028 MWp. This is projected to fulfil approximately 47% of the PHCs' total energy demand, assuming the proposed energy efficiency measures are implemented. Out of the 59 PHCs and health centres that were examined and assessed, only 51 facilities were deemed to be compatible with solar PV, with an average solar PV system size and capacity of 20 kWp per (eligible) facility.

The breakdown of the total PV capacity over the five governorates is consistent with the geographic distribution of the PHCs themselves. Accordingly, the Gaza governorate accounts for an estimated 42% of the total potential capacity, with 435 kWp of solar PV. Each of the Middle and North governorates accounts for an estimated 20% of the total potential capacity, at 200 kWp each. The two southern governorates boast the least potential PV capacity, with approximately 10% of the total each, corresponding to 103 and 97 kWp for the Rafah and Khan Younis governorates, respectively. Figure 9 below presents the capacity allocated to each of the five governorates.

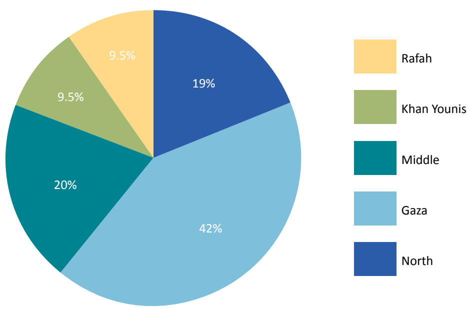


Chart 9: PHCs' Solar PV Potential Capacity for each Gaza Strip Governorate

The methodology used for this analysis is based on estimates of rooftop and ground PV potential, using current data on the existing use of the space available and its status. The analysis found the main reason for excluding non-compatible PHCs was a lack of sufficient space for PV implementation.

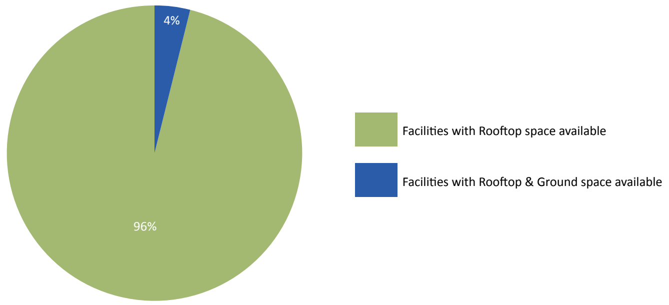


Chart 10: Land Availability at PHCs with Solar Potential

Analysis of rooftop and ground space availability at PHC facilities compatible with solar PV system shows the following:

- 31 facilities have adequate roof space for solar PV installation
- 18 facilities have adequate roof space but require minor repairs
- 2 facilities have adequate roof space but require major repairs

6.3.3 Energy Storage Classification for PHC facilities

The categorization and classification of solar PV systems for PHC facilities was conducted with the objective of reducing reliance on diesel fuel while meeting the primary loads. The classification was based on the extent to which the potential solar PV system can meet the facility's daily energy demand (i.e. the energy penetration). For all scenarios and types of systems, facility loads have been adjusted so as to exclude x-ray machines and oxygen stations. The facilities excluded had either insufficient or incompatible space for solar PV; had existing solar PV systems already making full use of the available space; or were expected to discontinue services in the near future at the assessed location. The three types of solar PV systems considered for PHC facilities can be summarized as follows:

- **System 1:** This type of solar PV system can meet 70-100% of a the PHC's daily energy demand for most of the year. The system will be able to utilize the solar PV system with the ESS, requiring no use of diesel generators unless in cases of emergency or excessive load, such as X-Rays or Oxygen Stations. A total of **36** PHCs, out of **51,** were identified as being System **1**.

- **System 2**: This solar PV system can meet 20-70% of the facility's daily energy demand. It is thus considered a hybrid system, integrating three to four sources in order to meet the facility's energy demand, while primarily depending on a combination of solar PV-diesel power when the grid is not available. During fuel shortages, or when the diesel generator is not operational, the PHC's critical loads can be met through the solar PV system and its ESS back-up. A total of **13** PHC facilities have been identified as System **2**.

- **System 3:** This solar PV can meet less than 20% of the facility's daily energy demand. The PHC would thus always have to receive electricity supply either from the utility grid or a DG. As with System 2, a System 3 solar PV system with ESS can meet the facility's critical loads in cases of fuel shortage or unavailability, or a non-operational DG. Accordingly, the System 3 type have also been classified as 'back-up'. A total of only two PHC facilities have been identified as System 3.

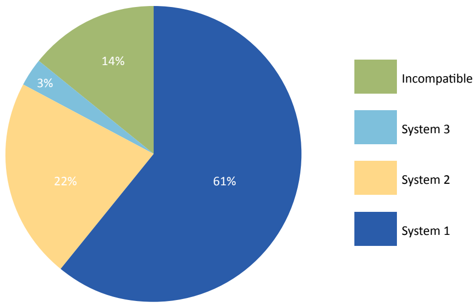


Chart 11: PV System Types for PHC Facilities

6.3.4 PHC Solar PV: Potential Costs

Overall, the proposed solar PV systems for compatible PHC facilities requires US$ 4,112 million in upfront costs, including both procurement of equipment and installation costs, when lithium batteries are used. If VRLA batteries are selected, the total initial investment would be slightly lower at around US$ 3,803 million These estimates reflect the differences in the cost per energy unit (watt) of using VRLA batteries ($3.7/Watt) and Lithium batteries ($4/Watt). While the present report is principally based on lithium battery costings, the projected resources mobilized can cover additional partial battery replacement costs in case of access difficulties to Lithium batteries.

The cost estimates provided above encompass the procurement and installation of the power system at each facility. The two US$-per-Watt unit costings were used to generate an investment range, considering the battery type (VRLA and Lithium Batteries) for each system which takes into account national tax regimes, component costs, transport, and installation fees. In additional to the base investment for solar PV, an additional US$120,000 is estimated to be a required investment for AC (Air-Conditioning) retrofitting, assuming two (2) units at a minimum will be replaced in each PHC facility. In addition US$ 82,977.70 will be the cost of lighting retrofit in all PHCs facilities. The total funding requirement for the proposed PHC solar PV and basic EE measures programme is US$ 4,315 million.

As an indicator of the impact of equipping PHCs with solar PV systems, and thus taking into consideration only the solar PV system costs, the average investment cost per beneficiary is US$1.92 over all governorates, with the investment being paid back within eight years.

Depending on the implementation model chosen, it will be important to consider which stakeholders (e.g. donors, governmental, private operators) will meet the ongoing maintenance costs, including battery replacement. Where public sector support is required for system maintenance, the system's long-term sustainability may be subject to budgetary constraints, including the longevity of a donor-funded program. Whereas a 'commercial' (private sector-based) maintenance solution may offer advantages in terms of longevity, efficiency and other aspects, if an adequate and sustainable financing mechanism can be put in place. (e.g. community fund, revolving fund, non-core revenue source on site).

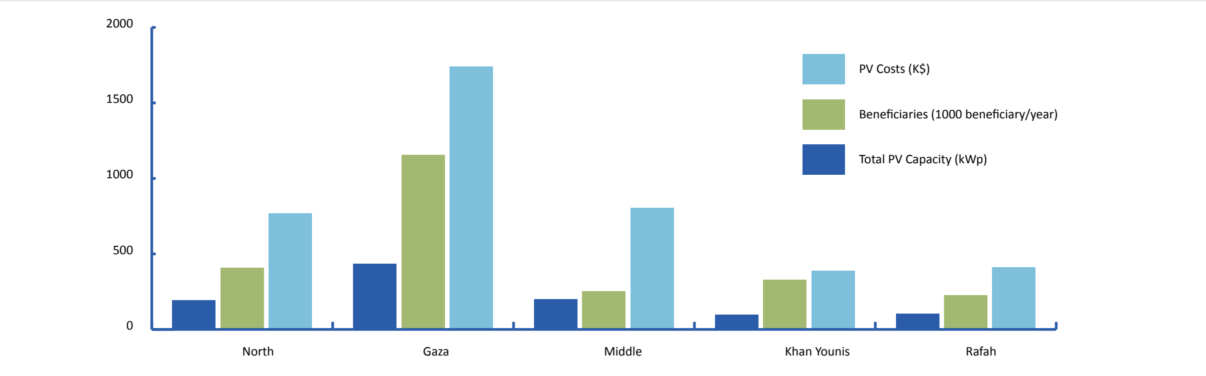


Chart 12: PHCs Solar PV Potential Capacity Breakdown per Governorate Vs. Investment cost per Governorate

In the next section, the potential solar PV for each facility is outlined for each of the five governorates. For each facility, the solar PV system capacity is provided, as well as the energy demand projected to be fulfilled by the solar PV system. Furthermore, the investment per beneficiary is also highlighted, which considers the total investment required and the number of monthly beneficiaries at the respective facility. The health-impact categories are also highlighted, as discussed in the methodology. Finally, a ranking system provides a weighting for each of the facilities, in order to better inform key stakeholders' prioritization and decision-making processes.

G1: North Governorate

The following table outlines the solar PV potential rankings for the North governorate PHCs, where nine (9) facilities were found to be suitable for solar PV system integration. Based on each facility's roof availability and demand levels, the solar PV systems range in size between 8 KWp and 33 KWp, with an average energy penetration of 66% of the PHC's total daily demand. The average investment per beneficiary in the North governorate is approximately US$1.98.

Health Facility Name	Monthly Beneficiaries	PV System Size (KWp)	PV Average Energy Penetration (100%)	Service Level (1-4) EM: Emergency ES: MoH Essential	Total Rank (Out of 100%)
Shuhada Jabalia Clinic	10000	14	25	4 (EM, ES)	67
Abu Shebak Medical Center	9000	29	100	3	50
Al Saifa (Al Atatra) clinic	2790	22	71	3	50
Old Shuhada Beit Lahia (Hala Shawwa)	2500	14	90	3	50
Hijazi Clinic	1000	22	100	2	45
Ezbat Beit Hanoun	1308	8	100	2	45
jamila Ashi (Temp)	1000	33	45	3	25
Beit Al Maqdes Clinic	1000	23	37	2	20
Beit Hanoun Clinic	5500	27	23	2	12

G2: Gaza Governorate

Gaza Governorate PHCs and Health Centres showed high solar PV potential, with an average solar PV energy penetration of approximately 66%. With respect to system capacity, it is noted that the maximum PV system size proposed for serving PHCs is limited at 35 kWp. Nevertheless, in specialized Health Centres or administrative facilities, the solar PV system size may reach up to 50 KWp. The average investment per beneficiary in the Gaza Governorate is projected to be US$1.54.

Health Facility Name	Monthly Beneficiaries	PV System size (KWp)	PV Average Energy Penetration (100%)	Service Level (1-4) EM: Emergency ES: MoH Essential	Total Rank (Out of 100%)
Sabha Medical Center and Health Lab.	7500	27	100	4 (EM, ES)	100
Shuhada Al Zaytoun Clinic	14000	30	95	3 (EM, ES)	95
Al Qoba Clinic	12000	18	79	3 (ES)	75
Al Surani Clinic	10000	35	74	4 (ES)	80
Al Hurria Clinic	2900	15	100	3	50
Shuhada Al Shate' Clinic	5000	34	100	3	50
MoH Labs Building	900	50	49	2 (ES)	45
Khaled El Alami Clinic	1350	14	100	2	45
Physically HandiCaped Clinic	800	18	82	2	45
Drugs Warehouse	-	59	79	2	45
Shuhada Al Remal Clinic	13000	44	15	2	37
Al Salam Clinic	6000	9	62	3	25
Physically Handi-Caped Clinic	1700	38	45	2	20

Health Facility Name	Monthly Beneficiaries	PV System size (KWp)	PV Average Energy Penetration (100%)	Service Level (1-4) EM: Emergency ES: MoH Essential	Total Rank (Out of 100%)
Shuhada Aldaraj' Clinic	5500	9	12	3	17
Ambulance and Emergency Station	15000	35	20	2	12

G3: Middle Governorate

In the Middle Governorate, the average solar PV system size is 14 kWp, with a relatively high average energy penetration of 85%. Table below highlights the main prioritization factors. The higher average penetration rate relative to other governorates is attributed to the lower service level provided by most Middle Governorate PHCs, which in turn leads to lower demand and land accessibility for small scale PV systems. The average investment per beneficiary in the Middle governorate is estimated to be around US$ 3.32.

Health Facility Name	Monthly Beneficiaries	PV System Size (KWp)	PV Average Energy Penetration (100%)	Service Level (1-4) EM: Emergency ES: MoH Essential	Total Rank (Out of 100%)
Shuhada Dair Al Balah Clinic	6000	43	83	4 (EM, ES)	100
Al Bureij New Clinic	1518	14	100	2 (ES)	70
Al Maghazi Clinic	1815	13	100	2 (ES)	70
Al Bureij Central Clinic (old Bureij)	1342	9	97	2 (EM)	65
Shuhada Al Nuseirat Clinic (New nus.)	3000	31	39	3 (ES)	50
Wadi Al Salqa Clinic	1200	7	100	2	45
Psychiatric Clinic	300	6	100	2	45
Al Berka Clinic	1000	9	88	2	45
Al Khawalda Clinic (Swarha)	750	4	76	2	45
Al Msadar Clinic	500	6	100	2	45
Heker Al jame Clinic	1200	8	100	2	45
Nusirat Al Gharbeya Clinic	998	11	75	2	45
Al Moghraqa Clinic	1118	11	100	2	45
Juhr Al Deik Clinic	427	29	34	2	20

G4: Khan Younis Governorate

Table below highlights the solar PV potential ranking for Khan Younis governorate PHCs. A total of nine (9) facilities were deemed compatible for solar PV system integration. Based on each facility's roof availability and demand level, the solar PV systems range in size from 4 kWp to 17 kWp, with an average energy penetration of 80% of the daily demand. The higher penetration rate is principally due to the low service level provided by most PHCs in the governorate, which in turn leads to a lower demand and land availability for small scale PV systems. Nevertheless, despite their low service level, the PHCs serve a large number of beneficiaries, leading to a comparatively lower investment cost per beneficiary of US$1.30.

Health Facility Name	Monthly Beneficiaries	PV System size (KWp)	PV Average Energy Penetration (100%)	Service Level (1-4)	Total Rank
				EM: Emergency ES: MoH Essential	(Out of 100%)
Bani Suheila Clinic	4500	16	70	3 (EM, ES)	70
Shuhada Khan Younis Clinic (Bandar)	12000	17	40	4 (EM, ES)	75
Al Qarara Clinic	3960	8	76	2 (ES)	70
Abassan Al Kabeera Clinic	230	14	80	3	50
Abassan Al Jadeeda Clinic	1930	12	83	2	45
Al Fokhari Clinic	1000	7	79	2	45
Al Zana Clinic	880	4	100	2	45
Jourt Allout Clinic	1540	12	94	2	45
Khaldia Al Agha Clinic	1460	7	100	2	45

G5: Rafah Governorate

In the Rafah governorate, the average solar PV system size is 25.75 KWp with a noteworthy average penetration rate of 75%. The average investment cost per beneficiary has been estimated to be US$1.99. Table below highlights the main prioritization factors for each facility.

Health Facility Name	Monthly Beneficiaries	PV System size (KWp)	PV Average Energy Penetration (100%)	Service Level (1-4)	Total Rank
				EM: Emergency ES: MoH Essential	(Out of 100%)
Tal Al Sultan Clinic	5000	43	93	3 (EM, ES)	95
Shuhada Rafah Center	11000	35	28	4 (EM, ES)	75
Al Shabora Health Center	1000	14	77	2	45
Al Shokah Clinic	2000	11	100	2	45

7 | Transition Strategy & Recommendations

As the assessment findings of the present report show, there is significant potential for the implementation and expansion of renewable energy systems and energy efficiency measures to strengthen the public health system in the Gaza Strip. The solar photovoltaic potential, when combined with effective energy efficiency measures, can considerably reduce the dependency on imported fuel and diesel generators, while also increasing the resilience of the health system through ensuring that services continue to operate without interruption, even without fuel. In this light, a transition towards a more sustainable energy infrastructure for the health system, based on full utilization of renewable energy, seems advisable both in economic and technical terms.

However, in order to build on the assessment findings, a comprehensive approach is required for coordinating project development and implementation efforts — an inclusive, transparent, and cooperative process, which engages all relevant stakeholders and underpinned by a full understanding of the possibilities and opportunities on offer. The two primary pillars of such an approach are thus:

A) A coordination framework
B) A planning and implementation strategy

A. Collaborative Coordination Framework (for harmonization)

A successful strategy for building upon the assessment findings requires concentrated efforts of cooperation and coordination among all stakeholders in the process, to maximise the scale and range of mobilizable resources, as well as ensure they are deployed and used effectively and optimally.

General Level: A stakeholder coordination mechanism should be put in place to ensure resources are mobilized and allocated according to pre-defined priorities. The latter must also be updated in a dynamic, continuous way through a shared public platform that tracks the progress of the Gazan health system's solar energy transition. A dynamic online dashboard[8] was developed as part of this report; and offers a summary of its findings, as well as of the potential solar PV systems according to defined classifications and design approaches. The dashboard is designed to serve the cooperation and coordination process, to help stakeholders identify the progress-status for various facilities, and to allocate resources where an un-met priority is identified. Stakeholders potentially include local authorities who can help shape and decide priorities, together with all relevant multi-lateral agencies, donors, NGOs, and other entities.

Such stakeholder engagement can take place in the form of a working group, coordination mechanism, or a cooperation platform that provides the space, with defined roles to achieve the required functions.

Technical Level: As part of the general level coordination, technical coordination and cooperation is necessary to ensure the technical planning and implementation of solar electrification projects within the proposed framework are conducted in a coherent and harmonized approach by all relevant stakeholders and according to the highest technical standards and taking the specificities of the local context and needs into consideration.

Stakeholders are likely to include technical specialists and officers from relevant entities, who can contribute accordingly towards achieving the overall objectives set by the stakeholder cooperation framework.

8 Illustrative examples of the dashboard's content are provided in Annex 5 .

Moderating and leading the group at both levels (general and technical) requires the consent of all stakeholders engaged in the process and must take place within clearly defined terms of reference.

Required Functions: At both aforementioned levels the following functions are required to ensure effective project planning and implementation within the scope of solar electrification for health facilities proposed in this report:

- *Tracking of Project Progress:* The tracking of the project status can facilitate the prioritization and resource allocation dimensions of the project. The tracking dashboard can be used by stakeholders to visualize the funding status and unmet needs on a system-by-system and facility-by-facility basis, which can help prevent duplication of efforts and inadequate resource allocation, and offers clear visibility of each intervention's health impact, economic savings, and other key aspects.
- *Development of Knowledge Resources:* The identification, development and adoption of relevant *knowledge resources* is essential for the effective planning and implementation of the proposed projects. Such resources can streamline the design and engineering of solar PV systems, provide guidance and standards for their planning and installation, achieving consistency of systems across all health facilities in the Gaza Strip. Such a strategy by extension would contribute to streamlining operation and maintenance functions post-installation, and would contribute to operational sustainability, excellence, and longevity. A list of resources is provided in Annex 6.

B. Planning and Implementation Strategy

In line with the assessment findings, as well as the coordination framework outlined above, the steps that follow fund mobilization, where multiple stakeholders are engaged in the same activity, can be prepared for implementation. **A planning and implementation strategy** is absolutely critical in leveraging the coordination framework and its outputs, as well as the proposed objectives of this report. This strategy would build upon the coordination framework, and follow the following three steps or phases:

Resource Mobilization and Allocation → ***Planning and Verification*** → ***Procurement and Installation***

- **Resource Mobilization and Allocation:** Coordination among donors, the health authorities, and the implementing entities enables an approach of project identification informed by the database developed in the assessment. The funding allocation can be geared towards the higher priority facilities and projects, taking into consideration the health impact, geographic distribution, and beneficiaries. Upon the allocation of funds, the project can formally progress to the next phase of engineering, which requires comprehensive technical planning and verification.

- **Planning and Verification:** Upon the allocation of funding for a defined project(s), a process of careful and precise planning is required. The process would start by determining the available space resources with the facility management and health authorities, and compare it against the space recorded during the assessment for greater reliability. Furthermore, a validation process for the energy consumption and sources would be necessary to ensure optimal quantification, as this process would inform the design, engineering and feasibility understanding of each of the solar PV systems. An economic feasibility and assessment must also be undertaken for each facility upon the mobilization of resources.

After the verification of all relevant physical parameters and quantified energy requirements, the sizing of the solar PV system, its classification and type according to the categorization mentioned in this report, are performed. The implementing entity may engage technical professionals or companies at this stage but must ensure all performed work is in conformity with the standards set by the technical level coordination team. All coordinating stakeholders can remain updated on progress within this stage through the tracking dashboard.

- **Procurement and Installation:** The procurement and installation process should be based on the verified data produced by the technical planning process mentioned above. It is recommended that all stakeholders taking part in procurement and installation planning must use the same best-practice and standards for the equipment selection and installation processes, in order to ensure the highest quality of workmanship and engineering is achieved. Using a common knowledge resource as the standard for procurement and installation is highly recommended, and its development would be one of the main tasks set for the proposed collaborative coordination framework.
- A comprehensive energy transition for the health system can be achieved through a clearly defined coordination framework that engages relevant stakeholders. Based on this coordination framework, an implementation strategy that considers optimal resource mobilization and allocation is essential — a strategy which integrates all technical planning parameters, and is geared towards sustained operational continuity and excellence.

Conclusion

In conclusion, it is recommended that the results of the assessment are taken into consideration for the mobilization of resources in order to introduce solar PV systems with the highest projected impact, with the goal being to deploy such systems wherever it is economically and technically feasible to do so.

Upon the allocation of funds for any facility or group of facilities, the process of engineering and implementation is recommended to take place in line with the guidelines that would harmonize the works of all entities engaged in the energy transition, for both hospitals and Primary Health Care centres. Energy efficiency measures must be prioritized, as they are likely to yield considerable savings with minimal requirements compared to other investments. Furthermore, the emergency network deployment should be a key component of the solar electrification of any facility that receives funding. The knowledge resources and standards that would inform the sizing, planning, and implementation of the project should be developed accordingly.

The electricity crisis in the Gaza Strip, and the fragility of public service provision of power, has multi-dimensional root causes, primarily related to the political and logistical constraints resulting from Israeli restrictions.

The proposed solar energy programmes will reduce diesel fuel consumption and dependency, and increase the resilience of critical health facilities across the Gaza Strip, notably by ensuring continuity of service during fuel shortages or grid outages. However, even in cases of full utilization of solar energy in public health facilities, as proposed in this report, both diesel fuel and the electricity grid will continue to be necessary, core elements of the Gazan energy system. What solar energy can do, however, is increase the independence of the health sector as effectively as the physical constraints of space and climate allow. To ensure full energy resilience, a more comprehensive approach — one that considers all electrical infrastructure, including all generation and distribution components across the Gaza Strip, — will be necessary to successfully resolve this urgent problem at the scale required.

8 |Annexes

Annex 1 | Primary Health Care Facilities Analysis Framework

The analysis framework for the PHC facilities is outlined in the following flowchart, which reflects the processes required and outputs expected:

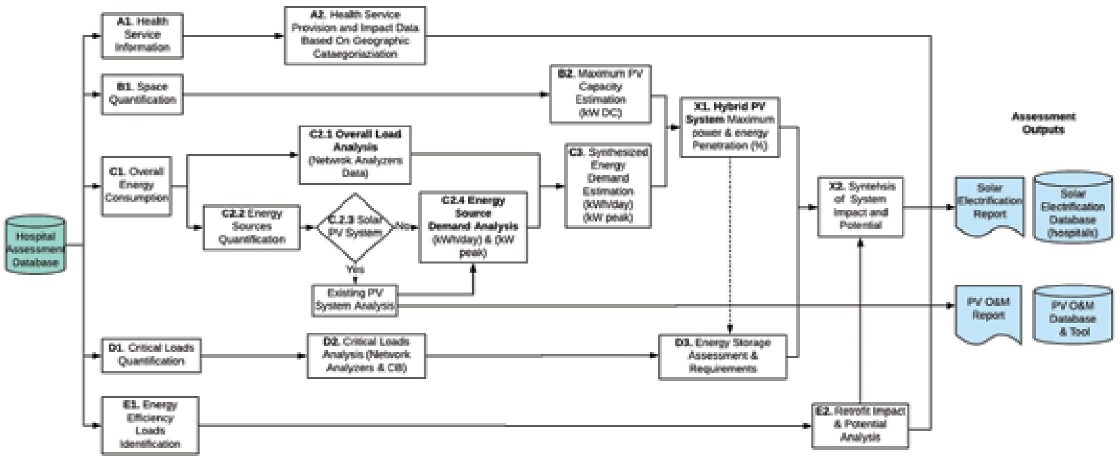


Figure 2: Analysis Framework and Processes (PHCs)

Process Description

A1. Energy Information: The information available would be organized into two primary sections: The energy sources available to provide electricity for the facility, and the energy demand calculated from the existing loads at the facility. Both approaches and sections are then reconciled and synthesized in ordere to obtain a single approximation of the daily energy demand (kWh/day).

A2. Energy Source Estimation: The energy source estimation and quantification would take into consideration the various sources available at the facility on any particular day (private DG, grid, subscription of local DG), whereby the daily energy demand (kWh/day) would be the combined consumption across various sources in a single day.

A2.1 Functional PV System Availability: Should there be a functional PV system available in the facility that meets (whether partially or fully) the electricity requirements, then all the parameters are documented and organized, as well as for the hospital's existing PV systems.

A2.2 PV System Documentation: The documenting of the PV system parameters would be performed in order to populate the O&M database for the PHCs. This would detail the battery age and functionality, the preventative maintenance measures required, and the remaining lifespan of the various components.

A3. Load Profile Calculation: The *load profile calculation* approach enables the determination of theoretical energy needs based on electrical load quantification and hours of use, which can offer a large degree of accuracy if performed with precision. In theory, this method is the standard for the quantification of energy consumption and for sizing PV systems. In general, in small PHC applications, this is conducted in parallel with the diesel fuel quantification of energy consumption (kwh) and the 'energy sources estimation' elaborated on in Section A2.

A4. **Daily Energy Need Quantification:** The synthesis of energy demand (in kWh) based upon the diesel and load profile data would be possible upon estimation of each of them individually. For diesel generators, an estimation for a yield of 3 kWh/litre with an indicative range, that varies with the efficiency of the generator, its size, and the percentage of load applied to it from its total capacity. As for determining it from the load profile, it is possible to calculate it based on the loads, hours of use, and total energy consumption for the facility.

A5. **Size of PV System Needed:** A basis for estimation is the target of securing the 'daily energy demand – kWh' in winter conditions. Therefore, a factor for the winter daily kWh/kWp can be the basis for solar yield sizing. However, this varies depending on the solar insolation (thus informed by the geographic location). For example, in Syria an average winter PV yield is assumed to be 3.5 kWh/kWp (as a winter average). As such, a facility with a quantified daily *energy demand of 35kWh* would require 10 kWp:

$$\text{PV system Size (kWp)} = \frac{\text{Energy Demand Daily (kWh)}}{\text{PV Yield Factor (} 3.5\,\frac{\text{kWh}}{\text{kWp}}\text{)}}$$

$$\text{PV system Size (kWp)} = 35 / 3.5 = 10 \text{ kWp}$$

B1. Rooftop and Space Info: The space available at the PHC facility or accessible adjacent space, informs the potential maximum PV capacity that can installed at the facility. The compatible spaces should be South-facing and non-shaded when taking into consideration the various structures that can be integrated into the building.

B2. Space Compatibility with PV: The space available must have sound structural integrity which would withstand weights and pressure over extended periods of time; and must not be shaded by higher structures such as trees, or nearby buildings. When the facility falls in shaded areas with higher structures and buildings around it, the facility's space is deemed incompatible with solar. The facility is then excluded from the list of target facilities, and instead moved to the list of incompatible facilities.

B3. Size of PV System possible: PV space is assumed to be nine square meters for each one KWp PV capacity, and constant in all locations. From the total non-shaded, South-facing, structurally-sound area (whether rooftop or adjacent), the available space is assumed to be 90%, whereby 10% would be allocated for walkways, entrances/exits and safety perimeters. For example: for a 100-square meter total space, 90-square meters is the space available for the PV system. To determine the potential PV capacity possible: we divide 90m^2 over the constant (9m^2):

Possible PV Capacity for a total area of 100-meter square **= 90/9 = 10 KWp**

C1. Health Info Quantification: The health information would highlight the facility's service provision and beneficiary numbers.

C2. Impact and Geography Integration: The beneficiaries' statistics and the health services (possibly categorized and grouped based on priority) would be collected for each facility, and then collated for each proposed PV system and associated investment. An example of impact measurement is quantifying the USD investment per beneficiary on an annual basis. For example, a PV system approximated at $36K for a facility with 3000 monthly patients (36,000 annually), would result in a $1/beneficiary investment to transition to solar energy. Categorization based on governorates and districts would also be taken into consideration to reflect equitable distribution and service coverage.

X1. Synthesis of PV System Model and Impact: The final process synthesizes the PV system set-up and size and reconciles the PV system within the constrained space, and the PV system required to meet the full demand on a daily basis (for most of the year). In case the space available could only accommodate a PV system that covers between 25-70% of the daily energy demand (kWh/day), then the hybridization of the system (integration with the existing DG) would be the model proposed. Otherwise, if the system can cover 70-100% of the daily energy consumption, then a regular PV-plus-storage system would be the model suitable for such applications. Upon selection of the system and quantifying the investment required, as well as the health impact associated, the outputs would then be summarized in the assessment report taking into consideration the overall geographic distribution of the facilities.

Annex 2 | Hospitals Analysis Framework

The analysis framework for the hospital is a more complex one compared to the primary health care facilities. More variables are considered as those systems are hybrid PV-diesel in most cases, and storage may be used in certain cases where there is a valid justification for critical departments or low-loads in specific seasons.

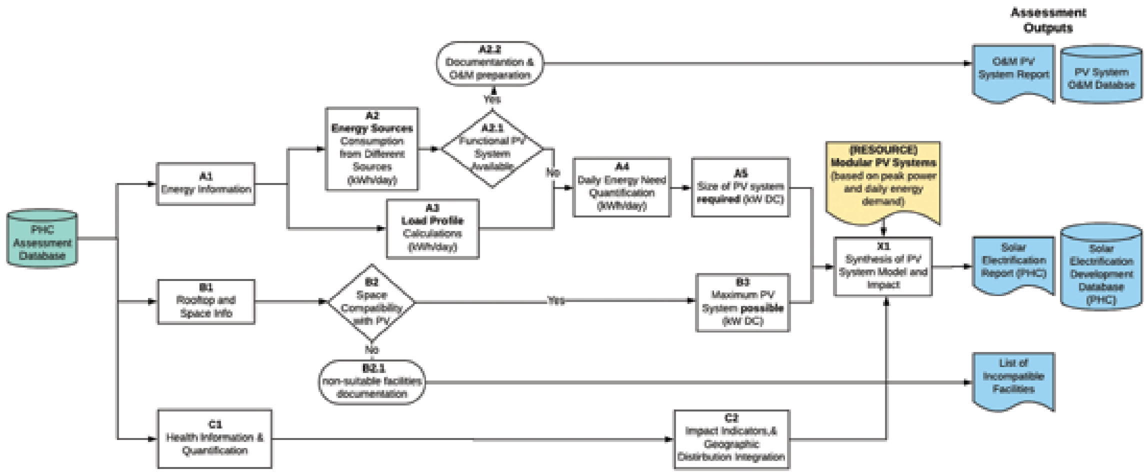


Figure 3 - Analysis Framework and Processes (Hospitals)

Process Description

A1. Health Service Identification: Health service identification includes verifying and validating the existing health services available at the facility.

A2. Health Service Provision Analysis: The information obtained from the analysis would be sorted and organized, whereby certain services may be grouped by order of priority, based on WHO/MoH standards. This resulting grouping would be outlined for each facility/system impact from both a service and beneficiary perspective.

B1. Space Quantification: The spaces would be quantified and verified based on the layouts of the building, taking into consideration the non-shaded areas which are available for use for solar PV.

B2. Estimation of Maximum PV Capacity: The estimation of the maximum PV capacity is based on the technical assumption that 8 square meters are required for every kW DC. The maximum usable space (in square meters) that meets the conditions would be divided by the identified factor in order to estimate the maximum PV system capacity that can be deployed at the assessed facility.

C1. Energy Demand Identification: Energy demand identification includes both tracks of sources (DG, grid, etc.), and loads (network analyzers), which results in quantified daily energy consumption (kWh/day).

C2.1 General Load Analysis: The network analyzer data is examined in order to quantify the average daily energy demand for the facility (kWh/day). This value can be determined by measuring the average daily electricity consumption of several days at each facility.

C2.2 Energy Source Quantification: The energy sources quantification is based on determining the various energy sources (diesel generators, electrical grid, solar PV, etc.), and the estimation of the demand on each source on a daily basis.

C2.3 Solar PV System: When there is a solar PV system at the facility, it would be identified from the assessment. The resulting elements (in the case of hospitals), would give an indication of the status of the system, its functionality, and the required O&M measures.

C2.4 Energy Source Demand Analysis: The analysis of the energy sources is based on quantifying the daily energy demand (kWh/day) for each facility. The mix of energy sources would be quantified and estimated individually, and then summed in order to have the accumulative daily energy consumption from the various sources combined. For example, when a 100 kVA operates for eight hours at a 60% average, and another DG 60 kVA operates for 10 hours on 50% load (both DGs on 0.8 PF), then the consumption would be 384 kWh/day from DG1 and 240 kWh/day from DG2, totalling 624 kWh/day. The fuel consumption (L/day) would thus also be a reflection of the energy consumption.

C3. Synthesis of Energy Demand: The synthesis of the energy demand takes into consideration the daily energy demand quantified from the load data (network analyzers' daily demand averages in kWh/day) and compared to the energy source demand analysis. In case there is no variation, the average is assumed to be the synthesis. However, when the load data is available from a data-logger, then the data reliability would be higher for it when compared with the energy source demand quantified. The latter would be the primary source in case of no-valid data-logger data being available. When available, this will be used to validate the obtained data set.

X1. Hybrid PV System Capacity Estimation: The determination of the level of penetration is based on the maximal rate a PV system can be integrated into an electrical grid that primarily depends on a diesel generator. The maximum PV system size possible would be determined from (B2) in kW DC capacity. The daily power penetration in different seasons would result from comparing the PV yield profile and the consumption profile from the DG-set. The latter would either be determined from the network analyzer data, or an average would be used based on the DG operational profile.

D1. Critical Loads Quantification: The critical load quantification is based on the departments identified with the critical services provided at the facility.

D2. Critical Loads Analysis: The critical loads would be identified for relevant services at each particular facility. It will not consider the departments/services already equipped with existing PV systems (solar + storage). The critical loads would be determined from the current ratings measured during the site visits, and from any data-logger info collected. The assumption here is that the critical loads would have a specific number of daily operating hours (8 in total). The resulting two central values for each department/service and the facility's overall critical load is the daily energy demand (kWh/day) and the peak load (kW AC).

D3. Energy Storage Assessment and Requirements: The energy storage value would be based on the three primary rational points. The sizing of the storage system is informed by the PV system size identified and limited by the yield available. The following storage models may be assumed, depending on the facility and requirement (based on load and coverage):

- Energy Storage for Critical Loads: Coverage of 24 hours for critical loads within the facility
- Energy Storage for low-load (Facility wide): Coverage of night shifts where the loads are within the threshold of AC discharge capacity of ESS
- Energy Storage for high penetration: Approximation of 0.5-1.5 hour of dispatch of constant load that cover the overall facility requirements

E1. Energy Efficiency Loads Identification: A number of loads have been identified and segmented for possible energy efficiency (EE) retrofitting. The loads identified may include lighting and cooling/heating units at the assessed facility.

E2. Retrofit Estimation and Impact Analysis: The energy currently consumed by the identified loads is compared to the energy that may be consumed in a case of an EE retrofit (by replacing 200 Compact Florescent Bulbs of 100W with 200 LEDs of 20 W), and the impact is quantified. The results are then outlined for each assessed facility and integrated with the possible PV system impact and potential analysis.

X2. Synthesis of System Impact and Potential: The synthesis of hybrid PV-system, the energy storage requirements, and the energy efficiency retrofits would result in outputs that can be summarized as follows:

- PV System Size (kW DC, kW AC)
- PV System Impact on the energy consumption: percentage of power/energy penetration
- Return on fuel savings compared to investment
- Health service continuity and beneficiary impact (due to storage)
- Energy Efficiency Impact and Savings (in kWh and/or financial savings)

Annex 3 | Data collection tool

Development of Renewable Energy for Health Facilities in the Gaza Strip
Assessment Questionnaire

World Health Organization — State of Palestine Ministry of Health — UNDP Empowered lives. Resilient nations.

A. General Information	
A01. Health Facility Name	
A02. Facility Type	
1. ☐ Hospital	2. ☐ Clinic
A03. Facility Code No.	__ __ __ __ __ __ __ __
A04. Location Governate 1.☐ North 2. ☐ Gaza 3. ☐Middle Area	
4. ☐ Khan Younis	5. ☐ Rafah
A05. Locality	
A06. Full Address:	
A07. GPS Coordinate	N __ ____ __________ E __ ____ __________
A08. Contact Person Information	
a. Name :	
b. Title :	
c. Contact Person Mobile Number	059/__ __ __ __ __ __ __ __
d. Contact Person Telephone Number	08/ __ __ __ __ __ __ __
B. Facility Service	
B01. Service	
a. Health service provided	Multiple choice
b. Hours of operation	_______________ Hour
c. Availability of emergency service (24 Hours)	1.☐ Yes 2.☐ No
d. Health Departments available in the facility	
e. Number of beneficiaries	_________ capitia per Month
B02. Emergency usage	
a. Facility used as shelter for civilians in emergencies before	1.☐ Yes 2.☐ No
b. Facility planned to be used as a shelter for civilians in emergencies	1.☐ Yes 2.☐ No
B03. Technical capabilities	
a. Availability of technical maintenance personnel in the facility working part-time or full time	1.☐ Yes 2.☐ No
b. Availability of technical personnel from electrical background (electricians)	1.☐ Yes 2.☐ No
C. No. of technicians with electrical background work at the facility, if any	___________ technicians
B04. Security	
a. Availability of security guards all day	1.☐ Yes 2.☐ No
C. Spaces for Solar Systems Analysis	
C01. Availability of suitable space for solar PV (from a structural and shading prospective)	1.☐ Yes 2.☐ No
C02. Sort of available space for solar PV installation	1.☐ Ground 2.☐ Roof Top
C03 . Rooftop Space Information	
a. Condition of Rooftop	1.☐ Adequate 2.☐ Needs minor repairs 3.☐ Needs major repairs
b. Available **free of shading** roof area for solar system installation ________________ m2	
c. Periphery's height	____________ cm
d. Accessibility of the roof	1.☐ Yes 2.☐ No If yes, Specify: 1.☐ Eternal stairs 2.☐ External Ladder
e. Need of special structure for PV rooftop installation, (if roof full of obstacles)	1.☐ Yes 2.☐ No
f. Scheme roof top layout	Upload
g. Rooftop picture 1&2	Upload
C04 . Ground space Information	
a. Available free of shading ground area for solar system installation ________________ m2	
b. Scheme ground area layout	Upload
c. Ground area picture 1&2	Upload
C05. Battery room Information	
a. Availability of empty room for hosting batteries	1.☐ Yes 2.☐ No
b. Area of the available room	____________ m2
c. Source of ventilation in the available room	1.☐ Natural 2.☐ Mechanical , specify: _____
e. If No, availability of suitable place to construct room	1.☐ Yes , specify place : _____ 2.☐ No

f. Distance between the Main Distribution Board (MDB) and the existing or proposed Battery Room	______________ m
g. Distance between the Main Rooftop and the existing or proposed Battery Room	_______________ **m**
h. Distance between the ground mount location (if available) and the existing or proposed Battery Room	_______________ **m**
D. Energy Sources	
D01. Available energy sources supply the facility	1. ☐ Utility Grid Subscription 2. ☐ Solar PV system 3. ☐ Facility Diesel Generators
D02. Utility Grid Subscription Information	
a. Availability of utility Grid subscription	1.☐ Yes 2.☐ No
b. No. subscription feeding the facility from GEDCO	1.☐ One 2.☐ Two 3.☐ Three
c. Amperes per each subscription	1st Subscription: _______ Amps 2nd Subscription: _______ Amps 3rd Subscription: _______ Amps
d. Availability of Electricity feeding facility from GEDCO Subscription	_______________ hours for all subscriptions/day
e. Exitance of Future Plans for upgrading subscription	1.☐ Yes 2.☐ No Specify: ___________________
D03. Diesel Gensets Information	
a. Number of active Generators available in the facility	_______________ Gensets
b. Diesel Consumption of All Gensets	_______________ Liter / Day
c. Gensets Models & Capacity	1st Gen. Model : _____________ 1st Gen. Capacity: ________ KVA Others: ___________________
	2nd Gen. Model: ___________ 2nd Gen. Capacity: _______ KVA
	3rd Gen. Model: _____________ 3rd Gen. Capacity: _______ KVA
	Others:

d. Availability of Electricity feeding facility from Each Gensets	_______________ hours/day per genset1
e. No. of Gensets under maintenance, if any	_______________ Gen.
f. Expected duration maintained Gensets shall back to operation	________________ months
g. Period Functioning Diesel Gensets are out of diesel 2017-2018	________________ months
D04. PV Solar Systems Information, If any	
a. Existence of Solar PV system in the facility	1.☐ Yes 2.☐ No
b. Type of installed PV solar system	1.☐ off grid 2.☐ on grid 3.☐ on grid with back up
c. Installed Solar PV & battery system size	__________ KWp (PV) ___________ KWH (battery)
d. PV solar system functionality	1.☐ Yes 2.☐ No, If No, specify : ____________________________
e. Department or service's Load covered by PV system	__________________Department
f. Date of first operation of the system	___/___/20___
g. Facility Electricity and Diesel savings after solar system installation	________ NIS/ month from Electricity Bill __________ liter / month from Diesel consumption for Gensets.
h. Responsibilities of Monitoring the solar system	1.☐ specialized technician from the facility 2.☐ administrative employee from the facility 3.☐employee from the MOH 4.☐ others , _______________
i. Solar PV system photos1&2	Upload
E. Electrical Network	
E01. Electricity network set up	1.☐ 1 phase 2.☐ 3 phase

E02. Availability of separate main distribution board for various department and SDB for each section	1.☐ Yes 2.☐ No, If No, specify : ___________________________
E03. Main Distribution Boards MDB Information	
a. Status of the Main Distribution Board (MDB) of the facility	1.☐ Good 2.☐ Bad (needs rehabilitation) 3.☐ Non-existent 4.☐ Need space for future expansion
b. Main MDB Breaker Rating or capacity	___________ Ampere
c. Availability of Separation between essential and non-essential loads	1.☐ Yes 2.☐ No
d. Main current rating of the Essential Loads, If any	____________ Ampere
e. Availability of change-over switch between multiple energy source	1.☐ Yes 2.☐ No
f. Status of the change-over switch	1.☐ Good 2.☐ Bad (functional) 3.☐ Non-functional
g. Main current rating of the changeover switch	____________ Ampere
h. MDB photos 1&2	Upload
E04. Earthing and Lighting Protection	
a. Availability of adequately installed grounding (with good depth for burial)	1.☐ Yes, specify: ____________ 2.☐ No
b. Availability of lightning protection system in place at the facility	1.☐ Yes, specify: ____________ 2.☐ No
E05. For Hospitals Only, Main distribution Panel for each Department Information	
a. Department	
b. Status of the Main Distribution Board (MDB) of the Department	1.☐ Good 2.☐ Bad (needs rehabilitation) 3.☐ Non-existent 4.☐ Need space for future expansion

c. Main MDB Breaker Rating or capacity	___________ Ampere
d. Availability of Separation between essential and non-essential loads	1.☐ Yes 2.☐ No
e. Main current rating of the Essential Loads, If any	____________ Ampere

F. Load of The facility

F01: Facility's Load, For Public Health Clinics (PHCs) only

Department:_____________

Load Name	Critical / non critical	Load Consumption (watt)	No. of units	Hours of operation (hour)	Total consumption (Wh)
Load1					
Load 2					
Load 3					
Load 4					
Load 5					
Load 6					
Department estimated Load			___________ KWh		
Department measured Load			1st measure. : ___ KW* ___ h		
			2nd measure. : ___ KW* ___ h		
			3rd measure. : ___ KW* ___ h		

F02: Lighting Load For Public Health Clinics (PHCs) only

Lighting Type	Indoor /outdoor	Load Consumption (watt)	No. of units	Hours of operation (hour)	Total consumption (Wh)
Florescent lamp					
LED lamps					
Halogen lamp					

a. Expected Energy efficiency share of replacing light to LED	_________ %
b. Scheme of Distribution of lighting units in each department	Upload
F03: Water Heating For Public Health Clinics (PHCs) only	
a. Availability of solar Water Heaters in the facility	1.☐ Yes 2.☐ No
b. Size and capacity of solar water heaters	_____________ heaters _____________ liter/heater
c. Solar water Heater system functionality	1.☐ Yes 2.☐ No, specify: ________________

F04: Facility Load For Hospitals only	
a. Power Analyzer data of the Full Hospital	Upload
b. Estimated Main Hospital Loads	

Load Name	Load Consumption (KW)	No. of units	Hours of operation (hour)	Total consumption (KWh)
Heating				
Cooling				
Lighting				

c. Estimated Lighting Load

Lighting Type	Indoor /outdoor	Load Consumption (watt)	No. of units	Hours of operation (hour)	Total consumption (Wh)
Florescent lamp					
LED lamps					
Halogen lamp					

Expected Energy efficiency share of replacing light to LED	__________ %

d. Measured Departments Loads

Department : _____________	1st measure. : ___ KW* ___ h	___________ KWh
	2nd measure. : ___ KW* ___ h	___________ KWh
	3rd measure. : ___ KW* ___ h	___________ KWh
Department : _____________	1st measure. : ___ KW* ___ h	___________ KWh
	2nd measure. : ___ KW* ___ h	___________ KWh
	3rd measure. : ___ KW* ___ h	___________ KWh
Department : _____________	1st measure. : ___ KW* ___ h	___________ KWh
	2nd measure. : ___ KW* ___ h	___________ KWh
	3rd measure. : ___ KW* ___ h	___________ KWh
Department : _____________	1st measure. : ___ KW* ___ h	___________ KWh
	2nd measure. : ___ KW* ___ h	___________ KWh
	3rd measure. : ___ KW* ___ h	___________ KWh
Department : _____________	1st measure. : ___ KW* ___ h	___________ KWh
	2nd measure. : ___ KW* ___ h	___________ KWh
	3rd measure. : ___ KW* ___ h	___________ KWh
Department : _____________	1st measure. : ___ KW* ___ h	___________ KWh
	2nd measure. : ___ KW* ___ h	___________ KWh
	3rd measure. : ___ KW* ___ h	___________ KWh
Department : _____________	1st measure. : ___ KW* ___ h	___________ KWh
	2nd measure. : ___ KW* ___ h	___________ KWh
	3rd measure. : ___ KW* ___ h	___________ KWh
Department : _____________	1st measure. : ___ KW* ___ h	___________ KWh
	2nd measure. : ___ KW* ___ h	___________ KWh
	3rd measure. : ___ KW* ___ h	___________ KWh

Annex 4 | Existing Solar PV Systems

List of Existing solar PV systems for hospitals:

Health Facility	Solar PV Size (KWp)	Battery System Size (KWh)	Date of First Operation
Al Dora Hospital	10	57.6	2016-07-14
Al Shifa Hospital	30	192	2014-03-28
Beit Hanoun Hospital	50	259	Phase 1 in 2018-05-25 and phase 2 in 31-03-2019
European Hospital	25	120	2015-01-01
Hasan Al Harazen Hospital	12	30.24	2012-03-03
Indonisi Hospital	30	211	2018-01-01
Nasser Hospital	300	601.9	Phase 1 in 2015-01-03 and Phase 2 in 30-04-2019
Shuhada Al Aqsa Hospital	75	409	Phase 1 in 2017-12-13 and Phase 2 in 31-03-2019
Specialized Pediatric Hospital	31	305.28	2016-10-20
Al Helal Emirati Hospital	20	109	31-03-2019
Abou Yousef Al Najar Hospital	40	229	31-03-2019

List of existing solar PV systems for PHCs:

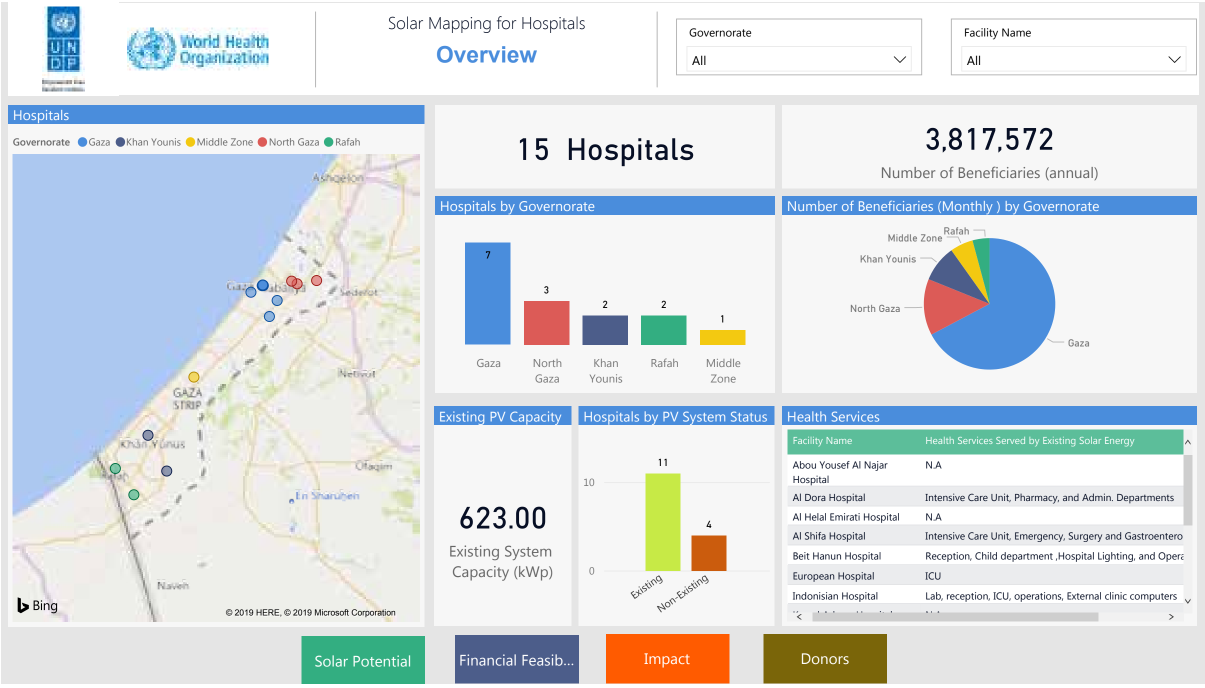
Facility Name	Governorate	Solar PV size (kWp)	Service's Load covered by PV system	Date of first Operation
Shuhada Al Sheikh Radwan Clinic	Gaza	85	All essential loads excluding AC, X rays and heating loads	2016-05-27
MoH Labs Building	Gaza	1	Drugs ref	2015-05-01
Sabha Medical Center and Health Lab.	Gaza	1	Drugs ref	2016-05-01
Al Qoba Clinic	Gaza	1	Drugs ref	2016-05-01
Al Hurria Clinic	Gaza	1	Drugs ref	2016-11-27
Al Falah Clinic	Gaza	10.15	Essential loads	2018-02-25
Khaled El Alami Clinic	Gaza	2	Lighting	2016-03-10
Atta Habib Clinic	Gaza	26	Lighting and Essential loads	2017-02-02
Shuhada Al Zaytoun Clinic	Gaza	0.96	N/A	2016-06-26
Physically HandiCaped Clinic	Gaza	2	Solutions fridge	2018-01-01
Abassan Al Kabeera Clinic	Khan Younis	0.75	Injections refrigerator	2016-01-04
Shuhada Khan Younis Clinic (Bandar)	Khan Younis	0.786	Refrigerator inoculations	2017-01-01

Abassan Al Jadeeda Clinic	Khan Younis	0.75	Vaccination refrigerator	2016-01-01
Al Qarara Clinic	Khan Younis	0.75	Vaccination refrigerator	2017-01-07
Bani Suheila Clinic	Khan Younis	0.75	Vaccination refrigerator	2017-01-01
Jourt Allout Clinic	Khan Younis	0.75	Vaccination refrigerator	2016-06-01
Al Bureij Central Clinic (old Bureij)	Middle	3	LED lighting, four socket	2016-05-01
Juhr Al Deik Clinic	Middle	14	Lighting, Fans, laboratory devices	2017-11-26
Shuhada Beit Lahia center (Shayma)	North	20.8	Lighting, fans, computers	2018-08-01
Shuhada Jabaliya Clinic	North	20	Lighting, fans, computers, lab, dental clinic	2016-08-08
Jamila Ashi (Temp)	North	15	Lighting, fans, computers, pharmacy.	2016-09-20

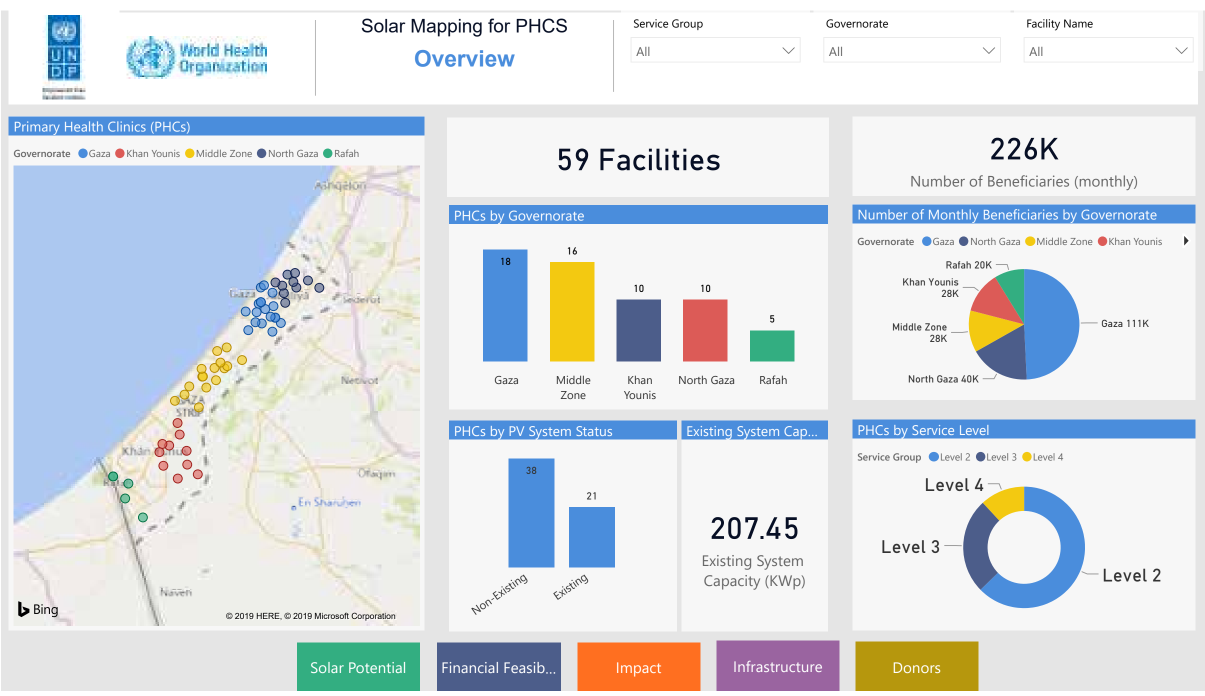
Annex 5 | Tracking Dashboard Samples

The proposed dashboard would act as a tracking instrument within the coordination framework, with a publicly accessible website for viewing the status of solar electrification at each facility whether a hospital or a PHC.

Hospital Tracking Dashboard:



Primary Health Care Facility Tracking Dashboard:



Annex 6 | Knowledge Resources

List of Knowledge Resources for Effective Planning and Deployment of Solar PV Systems:

Knowledge Resource	Description
Guidelines for system planning and design	Planning guidelines would outline the relevant processes for facility verification, quantification of energy demand, and sizing of the solar power system based on technical best-practices. It would include the following: • System verification and quantification of energy requirement • Thresholds for energy storage system classification, type, and sizing • Protection planning in the system (lightning protection, circuit interruption, SPD, etc) for selection and sizing • Design processes for determining threshold for PV-diesel hybrid systems and rates of penetration
Technical specification for recommended equipment	This resource would outline the minimum technical standards for the solar power equipment suitable for health facilities, taking into consideration their quality, integration level, functionality, and durability. The technical specifications would include those for the standard items used in a PV system: • Solar PV modules (test requirements, warranties, electrical and mechanical characteristics) • Batteries (type, standards, number of cycles, accreditation, testing) • Inverters (type, protection, accreditation, testing) • Wires (ratings, insulation, protection, accreditations)
Technical requirement for services procurement and contracting	This outlines the proposed guidelines for the best-practices for contracting and contractor management, based on the contextual necessities in the Gaza Strip, considering the economic and logistical constrains. It would include: • Minimum experience required for installers • Minimal level of human resources for implementation • Technical certifications required (if any) • Modality for project supervision and management
Installation Best Practices and Standards	Such practices and standards would ensure that all stakeholders engaged in the installation of solar PV systems for health facilities follow the same optimal approach and technical standards. The conformity to such practices will contribute to consistency for the operations and maintenance and minimize probabilities for post-installation failures.

Annex 7 | List of Recommended Energy Efficiency Measures

Increasing the energy independence of the health system requires identifying energy sources that the electrical system can depend on. However, a key strategic consideration for enhancing energy resilience, beyond pursuing sustainable energy sources, is the reduction in consumption through energy efficiency measures. In many cases, the return of investment produced by energy retrofitting is highly attractive, and in some cases a better consumption pattern may be introduced simply through specific control systems, or better behavioural awareness.

A number of key considerations in this regard include:

- **Digitization:** In some health facilities, the excessive use of printers requires a significant amount of energy that would otherwise be unnecessary if technology is leveraged effectively. The printers in the drugs warehouses require a significant amount of energy, which in turn requires a much larger investment in a solar power system that can meet the demand. However, introducing digitization is projected to lead to energy cost savings.

- **Lighting Retrofitting:** Adopting more energy-efficient health facility lighting is amongst the simplest approaches for long term investment in energy efficiency. Retrofitting existing lighting in hospitals and PHCs with affordable, lower-cost LED lighting rather than traditional Compact Florescent lighting can help reduce energy consumption considerably.

- **Automation:** Automating power at particular departments or load groups to be turned off after a particular hour, or according to a specific condition (controller command), can help preserve energy when required. Moreover, introducing motion-sensor activation can help reduce waste in usage. These are amongst several potential uses of automation that can be considered within planning for an Energy Efficiency strategy for the health system in Gaza.

- **Heating and Cooling Considerations:** Adequate insulation for summer and winter conditions can help preserve heat in the winter, and cool temperatures in the summer.

- **Behavioural Measures:** There are several measures for the effective management of electricity usage that can be enforced by users. For example, turning off electrical appliances (and keeping them on standby instead), which would otherwise waste energy from connected loads, can result in considerable savings on the overall energy consumption. Such energy efficiency measures do not require retrofitting, but rather greater awareness by management, staff and users, and a facility-level policy of turning off loads that are on standby when not in use. Other behavioural measures can target the scale of heating/cooling units in use and their duration.

Annex 8 | Sizing of Solar Potential for Hospitals: Kamal Adwan Hospital as a Case Study

The data and tables below were used in the context of the Kamal Adwan hospital for the simulation of loads and the yield of the PV system within the limitations imposed by the physical space availability. The same simulation process is performed for all hospitals examined in the analysis.

Summer Adjust. Factor	1.94
PV Capacity (kWp)	80
Load Data Source	DATA LOGGER

Kamal Adwan Hospital						
Hour	Winter Load (kW)	PV Yield (kW AC)	Load on DG & Grid (kW AC)	Summer Load (kW)	PV Yield (kW AC)	Load on DG & Grid (kW AC)
12:00 AM	85.2	0.0	85.2	165.3	0.0	165.3
1:00 AM	83.7	0.0	83.7	162.4	0.0	162.4
2:00 AM	79.4	0.0	79.4	154.0	0.0	154.0
3:00 AM	78.4	0.0	78.4	152.0	0.0	152.0
4:00 AM	83.8	0.0	83.8	162.5	0.0	162.5
5:00 AM	83.5	0.0	83.5	161.9	0.0	161.9
6:00 AM	74.5	0.3	74.2	144.5	4.6	139.8
7:00 AM	83.0	7.0	76.0	161.0	15.6	145.4
8:00 AM	77.8	21.0	56.8	150.9	28.3	122.5
9:00 AM	81.9	32.1	49.8	158.9	39.4	119.5
10:00 AM	100.4	39.6	60.7	194.7	47.9	146.8
11:00 AM	104.4	43.6	60.8	202.5	51.9	150.6
12:00 PM	95.9	42.9	52.9	186.0	52.6	133.5
1:00 PM	93.6	39.0	54.6	181.6	48.6	132.9
2:00 PM	98.8	31.1	67.7	191.7	41.4	150.3
3:00 PM	91.4	20.4	71.0	177.3	31.3	145.9
4:00 PM	94.1	10.2	84.0	182.6	18.9	163.7
5:00 PM	104.0	2.1	101.9	201.7	7.5	194.2
6:00 PM	109.0	0.0	108.9	211.4	2.3	209.1
7:00 PM	96.2	0.0	96.2	186.7	0.0	186.7
8:00 PM	86.2	0.0	86.2	167.2	0.0	167.2
9:00 PM	86.6	0.0	86.6	168.1	0.0	168.1
10:00 PM	85.7	0.0	85.7	166.2	0.0	166.2
11:00 PM	83.9	0.0	83.9	162.8	0.0	162.8436
Total (kWh/day)	**2141.1**	**289.4**	**1851.8**	**4153.8**	**390.5**	**3763.3**

Analysis Parameters and Process Summary (Kamal Adwan Hospital as an example):

Peak Power (kW AC)	211.4
Average Daily Demand (kWh/day)	2832.7
PV Capacity (kWp)	80
Daily Penetration (%) | Winter	13.5%
Daily Penetration (%) | Summer	9.4%
Energy Penetration (Average Year)	12.8%
Fuel Savings (L/year)	33,188.57
Energy Savings (kWh/year)	118,800.00
Solar PV Annual Savings ($/year)	$ 35,470

Winter Load Parameters	
Average Load (kWac)	89.21
Max Load (kWac)	108.96
Max/Average Ratio	1.2
Minimum Load (kWac)	74.46
Min/A Ratio	0.83

AC Spliter Cooling (kWh/day)	1776
General Lighting (kWh/day)	976
Post EE Retrofit	
AC Savings (kWh/day)	177.6
LED Savings (kWh/day)	244
EE - AC Split Demand (kWh/day)	1598.4
LED Lighting Demand (kWh/day)	732
Total Energy Demand - Summer (kWh/day)	3732.2
Total Energy Demand - Winter (kWh/day)	1897.14
Summer Savings (kWh/day)	421.6
Winter Savings (kWh/day)	244
EE Daily Average Savings - Summer (%)	10.1%
EE Daily Average Savings - Winter (%)	11.4%
New Daily PV Penetration - Summer (%)	10%
New Daily PV Penetration - Winter (%)	15%
Average Penetration (%)	14%
Fuel Savings from EE only (L/year)	30,123.15
Energy Savings from EE (kWh/year)	119,808.00
Total Fuel Savings from PV+EE (L/year)	63,311.73
Total Energy Savings from PV+EE (kWh/year)	238,608.00
Annual Savings ($/year) for Solar PV + EE	$ 67,893.00

Energy Efficiency Annual Savings ($/year)	$ 32,423.47
Initial EE Investment (AC Inverter) - USD	$ 97,680.00
Initial EE Investment (LED) - USD	$ 33,184.00
EE Total Retrofit Costs - USD	$ 130,864.00
EE Total Retrofit Costs - USD (P + S)	$ 210,864.00

Annex 9 | Data Analysis for PHC Facilities (2 facility case studies)

	Facility Code		GP703430	GP703445
General Data	Health Facility Name		Abassan Al Jadeeda Clinic	Abassan Al Kabeera Clinic
	Monthly Beneficiary		1930	230
	Hours of Operation		7	7
Space Availability	Space Available?		Roof Top	Roof Top
	Available Space (m^2)	Non-shaded	150	150
Energy Sources	Available Energy Sources		Grid / Solar PV / DG	Grid / Solar PV / DG
Existing Solar PV system	Type of Installed	PV solar system	Off grid	Off grid
	Installed	Solar PV size (KWp)	0.75	0.75
	Battery System	size (KWh)	4.5	4.5
DG	No. of DGs		1	1
	Size of DG (kVA)		27	44
Energy Demand (Field Readings)	Reading 1	(Amps)	10.8	4.6
	Reading 2	(Amps)	3.7	4.6
	Reading 3	(Amps)	4.5	7.5
	Average Reading	(Amp)	6.4	5.6
	Energy Demand	(Site Readings) (kWh/day)	23.74	20.78
Load Data	Energy Load	(kWh/day)	63.8	72.6
	D/L Ratio		0.37	0.29
	Lighting Load	(KWh/day)	22.72	16.33
Energy Demand w/ EE	Lighting with EE (KWh/day)		14.2	10.21
	Synthesis Energy Requirement (kWh/day)		40.54	46.65
Solar PV System Features	Maximum	PV Capacity (KW DC)	15	16.9
	PV System Required	(kW DC)	11.6	13.3
	Recommended	PV System (kWp)	12	14
	Penetration	Ratio (%) for loads	82%	79%
	Nominal Battery Bank size (KWh)		49	58
	Comments	(Case by Case)	-	-
	Network		3 Phase	3 Phase
	Comments on Land		20% of area is shaded	10% of roof area left for pathways

Annex 10 | PHCs Load Adjustment Criteria

A number of energy efficiency measures are assumed for PHC facilities which is primarily user-behavior related.

Adjustments performed on original load tables *(PHC Loads sheet)*

- **Autoclaves:** Reduced all units operating hours to 2 hr.
- **Neonatal units**: Reduced hours of operation from 24 to 12
- **Fridges:** Reduced hours of operation from 24 to 8
- **Pharm. Fridges:** Reduced hours of operation from 24 to 11
- **Air Conditioning:** 2 hours for small AC system , 0.5 hour for large AC system
- **Flood Light & LED Lighting:** No additional changes
- **Printers:** reduces to 3 hours of working and 1 hour of working for facilities (having over 20+ printers on site)
- **Sterilizers:** Operating a number of them on 2 hours per day
- **Fan:** reduced units to operate 2 hours and 1 hour for facilities (having over 30 + fan on site)
- **Water cooler**: reduce working hours to 2.5 hours
- **Lighting:** reduce the indoor lighting fluorescent from 7 to 5.5 hours

Behavioral

- **Space Heaters**: Removed all units from operation
- **Oxygen Generator:** Excluded from all facilities
- **X-Ray Devices:** Reduced all hours to zero (excluded from all facilities)

Original non adjusted Energy Consumption (without adjustments nor EE measures): **18 MWh / Day**
Total estimated energy Consumption (from measured average current readings)**: 5.8 MWh/day**
Adjusted Energy Consumption: **7.7 MWh/day** *(with exclusion of specific loads as described above) For PV System Sizing Calculation. With the EE measures for LED replacement, the total new daily demand is estimated around 6.5 MWh/day.*

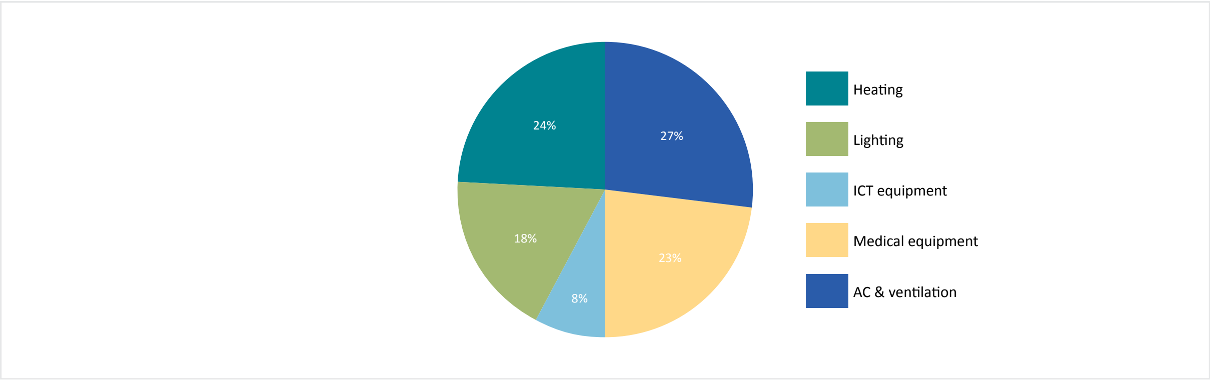
Adjustments performed on original load tables *(PHC Loads sheet)*

- **Autoclaves:** Reduced all units operating hours to 2 hr.
- **Neonatal units**: Reduced hours of operation from 24 to 12
- **Fridges:** Reduced hours of operation from 24 to 8
- **Pharm. Fridges:** Reduced hours of operation from 24 to 11
- **Air Conditioning:** 2 hours for small AC system , 0.5 hour for large AC system
- **Flood Light & LED Lighting:** No additional changes
- **Printers:** reduces to 3 hours of working and 1 hour of working for facilities (having over 20+ printers on site)
- **Sterilizers:** Operating a number of them on 2 hours per day
- **Fan:** reduced units to operate 2 hours and 1 hour for facilities (having over 30 + fan on site)
- **Water cooler:** reduce working hours to 2.5 hours
- **Lighting:** reduce the indoor lighting fluorescent from 7 to 5.5 hours

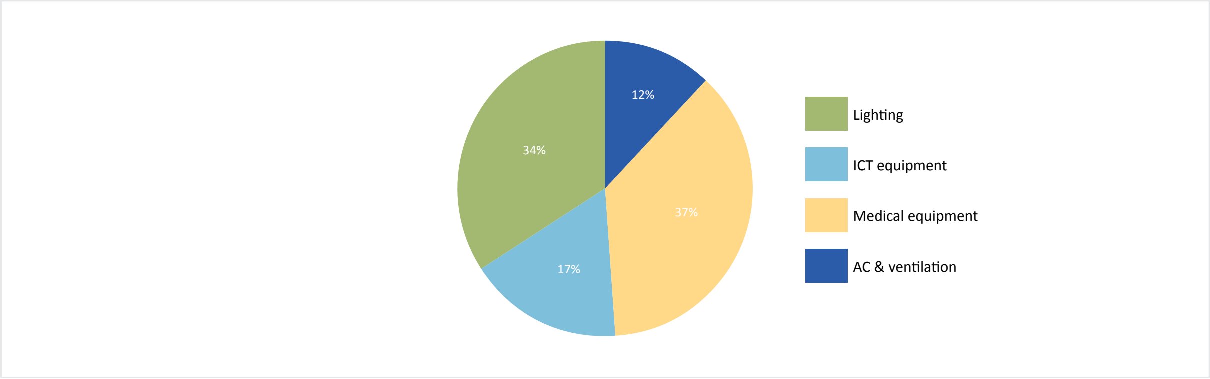
Behavioral

- **Space Heaters:** Removed all units from operation
- **Oxygen Generator:** Excluded from all facilities
- **X-Ray Devices:** Reduced all hours to zero (excluded from all facilities)

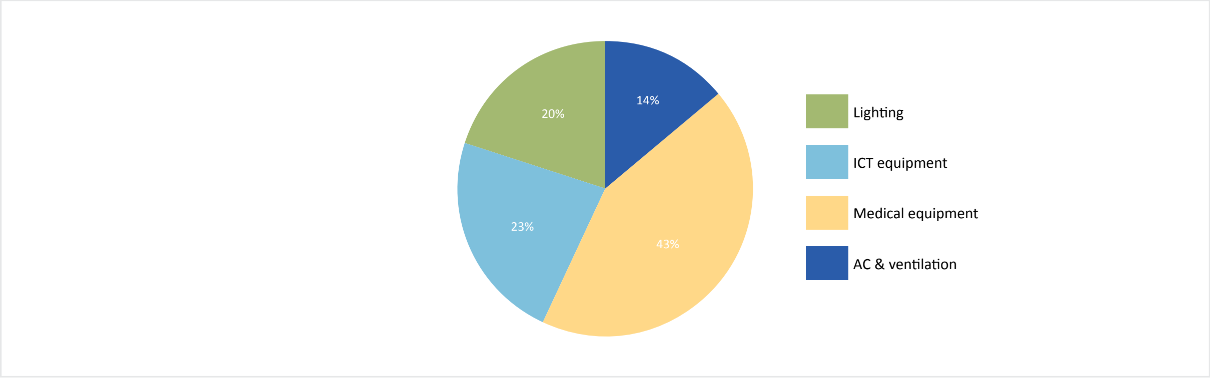
Original non adjusted Energy Consumption (without adjustments nor EE measures):**18 MWh / Day**
Total estimated energy Consumption (from measured average current readings)**: 5.8 MWh/day**
Adjusted Energy Consumption: **7.7 MWh/day** *(with exclusion of specific loads as described above) For PV System Sizing Calculation. With the EE measures for LED replacement, the total new daily demand is estimated around 6.5 MWh/day.*



PHCs original load classification

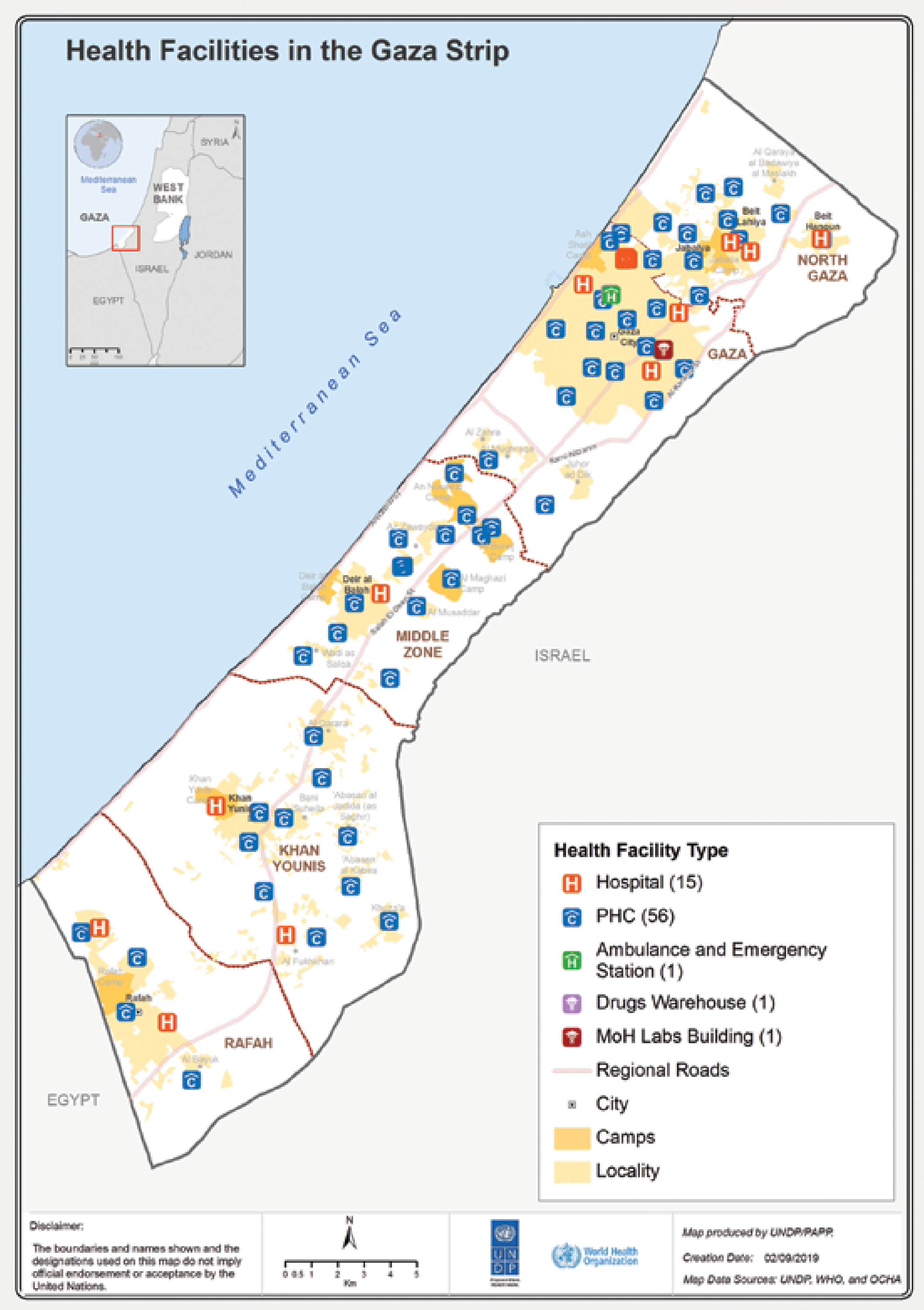


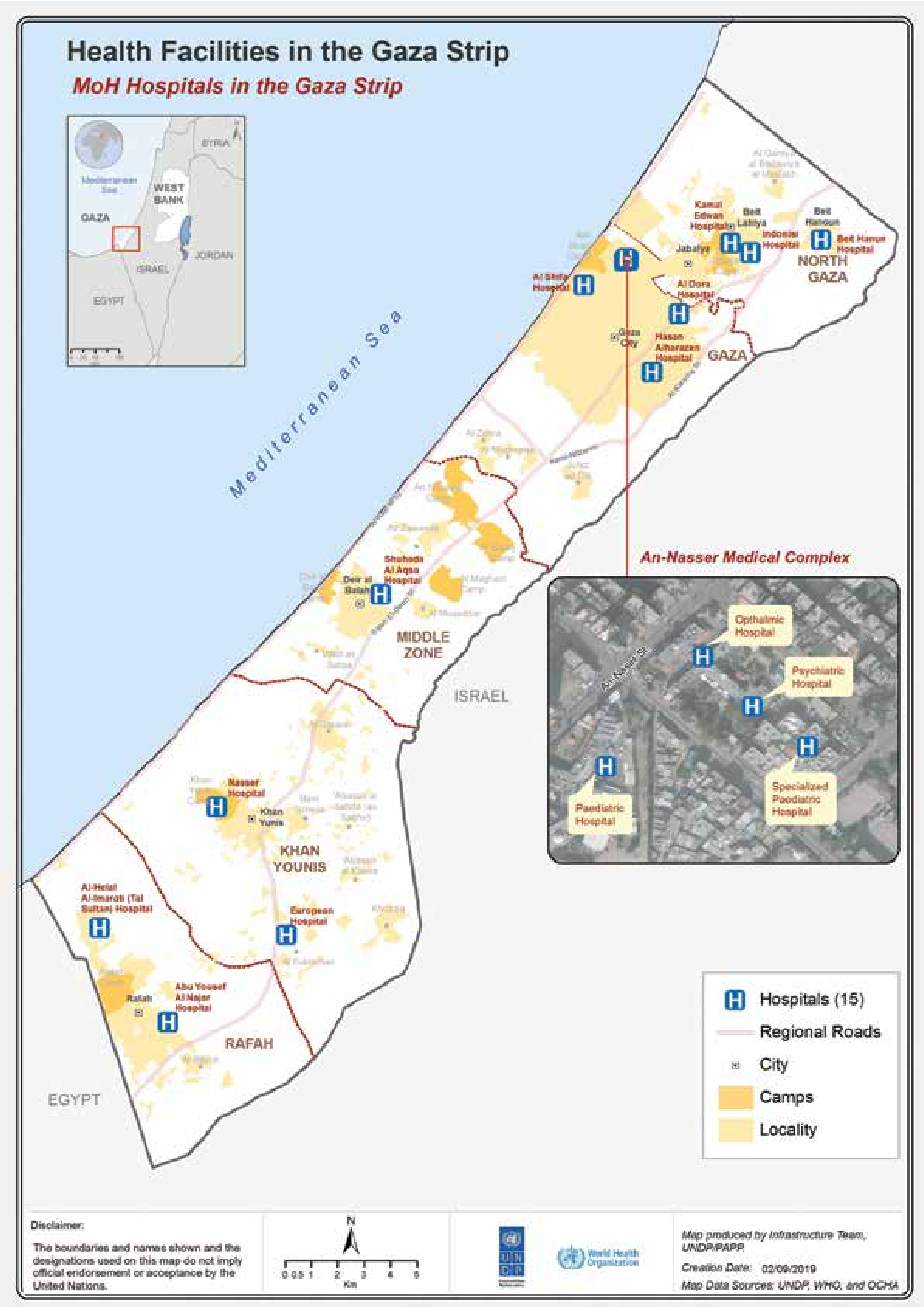
PHCs adjusted load classification



PHCs adjusted load classification with EE

Annex 11 | Supporting Maps




Health Facilities in the Gaza Strip
MoH Hospitals in the Gaza Strip
WEST BANK
GAZA
SYRIA
JORDAN
ISRAEL
EGYPT
Mediterranean Sea
Kamal Edwan Hospital
Beit Lahiya
Indonisi Hospital
Beit Hanoun
Beit Hanun Hospital
Jabalya
NORTH GAZA
Al Shifa Hospital
Al Dora Hospital
Gaza City
Hasan Alharazen Hospital
GAZA
An-Nasser Medical Complex
Opthalmic Hospital
Psychiatric Hospital
Specialized Paediatric Hospital
Paediatric Hospital
An Nasser St.
Shuhada Al Aqsa Hospital
Deir al Balah
MIDDLE ZONE
ISRAEL
Nasser Hospital
Khan Yunis
KHAN YOUNIS
European Hospital
Al-Helal Al-Imarati (Tal Sultan) Hospital
Rafah
Abu Yousef Al Najar Hospital
RAFAH
EGYPT
Hospitals (15)
Regional Roads
City
Camps
Locality
Disclaimer:
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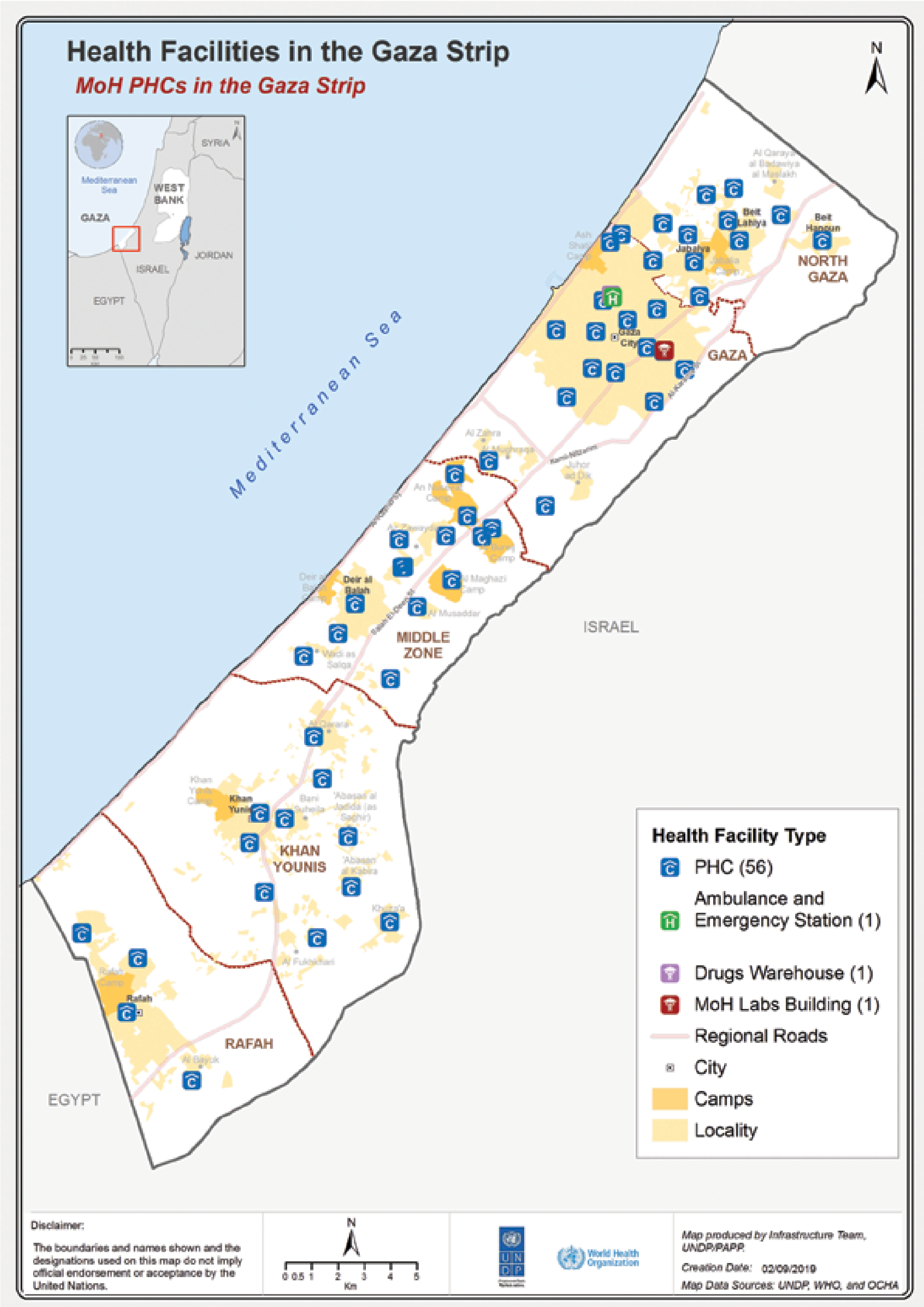
N
0 0.5 1 2 3 4 5
Km
World Health Organization
Map produced by Infrastructure Team, UNDP/PAPP.
Creation Date: 02/09/2019
Map Data Sources: UNDP, WHO, and OCHA


Health Facilities in the Gaza Strip
MoH PHCs in the Gaza Strip
Mediterranean Sea
NORTH GAZA
GAZA
MIDDLE ZONE
KHAN YOUNIS
RAFAH
ISRAEL
EGYPT
Health Facility Type
PHC (56)
Ambulance and Emergency Station (1)
Drugs Warehouse (1)
MoH Labs Building (1)
Regional Roads
City
Camps
Locality
Disclaimer:
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Map produced by Infrastructure Team, UNDP/PAPP.
Creation Date: 02/09/2019
Map Data Sources: UNDP, WHO, and OCHA

Health Facilities in the Gaza Strip
Status of PV System in Hospitals
SYRIA
Mediterranean Sea
WEST BANK
GAZA
JORDAN
ISRAEL
EGYPT
Mediterranean Sea
Kamal Edwan Hospital
Beit Lahiya
Beit Hanoun
Indonisi Hospital
Beit Hanun Hospital
Jabalya
NORTH GAZA
Al Shifa Hospital
Al Dora Hospital
Gaza City
Hasan Alharazen Hospital
GAZA
An-Nasser Medical Complex
Opthalmic Hospital
Psychiatric Hospital
Paediatric Hospital
Specialized Paediatric Hospital
An Nasser St
Shuhada Al Aqsa Hospital
Deir al Balah
MIDDLE ZONE
ISRAEL
Nasser Hospital
Khan Yunis
KHAN YOUNIS
Al-Helal Al-Imarati (Tal Sultan) Hospital
European Hospital
Abu Yousef Al Najar Hospital
Rafah
RAFAH
EGYPT
Hospitals- PV System Status
Non-Existing, With Potential (4)
Existing, With Potential (10)
Existing, No Potential (1)
Regional Roads
City
Camps
Locality
Disclaimer:
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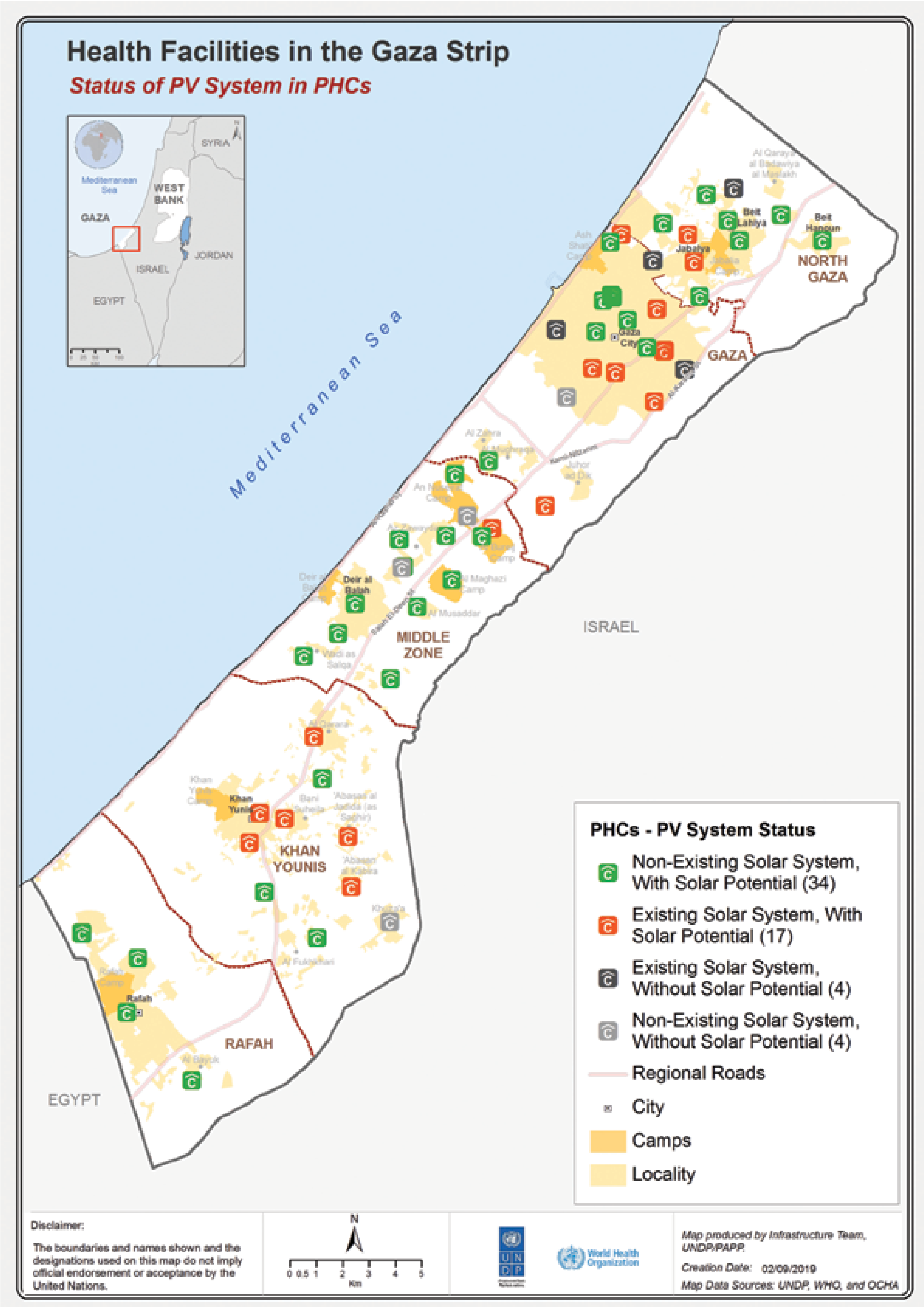
World Health Organization
Map produced by Infrastructure Team, UNDP/PAPP.
Creation Date: 02/09/2019
Map Data Sources: UNDP, WHO, and OCHA


Health Facilities in the Gaza Strip
Status of PV System in PHCs
SYRIA
Mediterranean Sea
WEST BANK
GAZA
JORDAN
ISRAEL
EGYPT
Mediterranean Sea
NORTH GAZA
Beit Lahiya
Beit Hanoun
Jabalya
Gaza City
GAZA
MIDDLE ZONE
Deir al Balah
ISRAEL
KHAN YOUNIS
Khan Yunis
RAFAH
Rafah
EGYPT
PHCs - PV System Status
Non-Existing Solar System, With Solar Potential (34)
Existing Solar System, With Solar Potential (17)
Existing Solar System, Without Solar Potential (4)
Non-Existing Solar System, Without Solar Potential (4)
Regional Roads
City
Camps
Locality
Disclaimer:
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N
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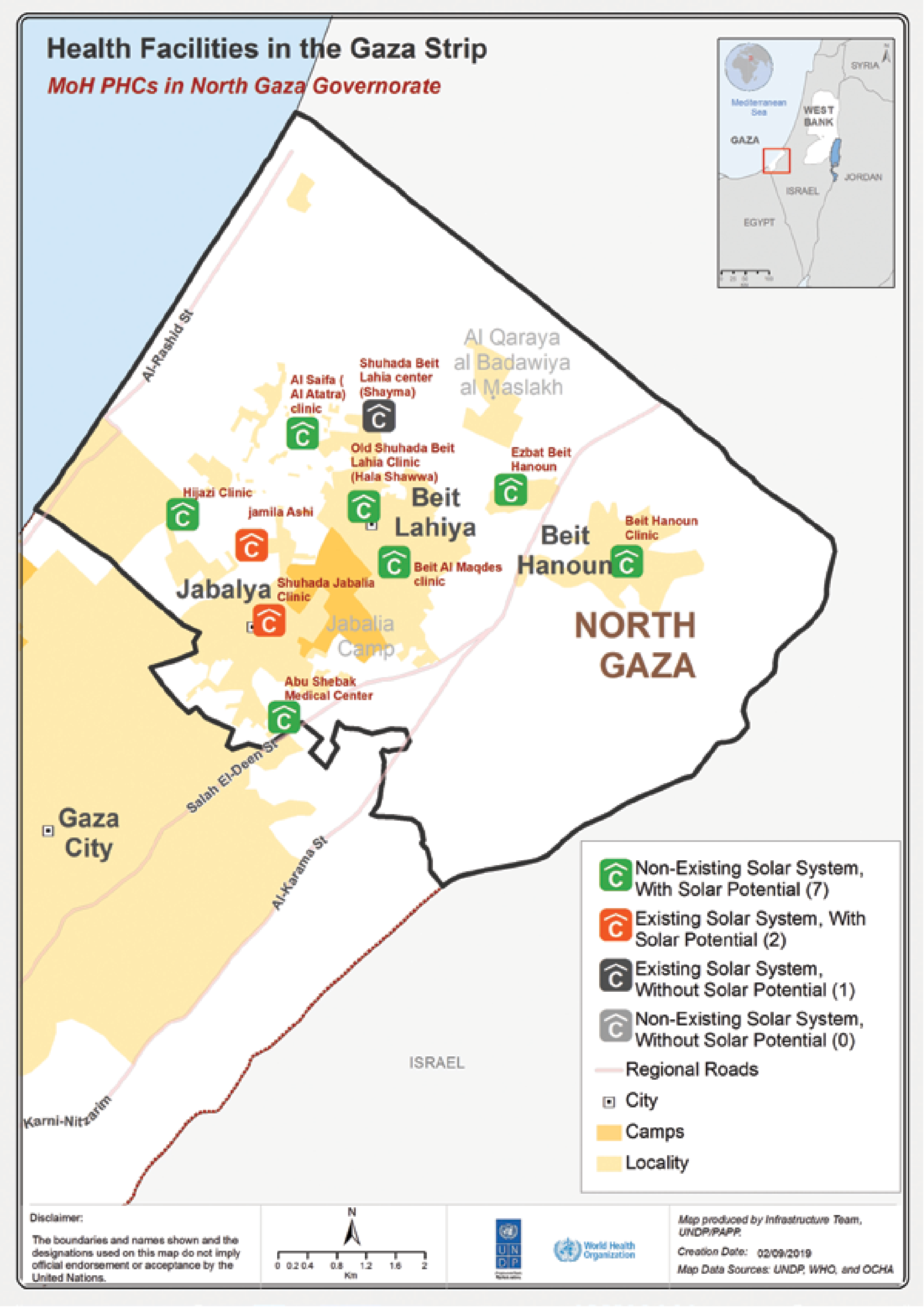
Km
World Health Organization
Map produced by Infrastructure Team, UNDP/PAPP.
Creation Date: 02/09/2019
Map Data Sources: UNDP, WHO, and OCHA


Health Facilities in the Gaza Strip
MoH PHCs in North Gaza Governorate
Al Saifa (Al Atatra) clinic
Shuhada Beit Lahia center (Shayma)
Al Qaraya al Badawiya al Maslakh
Old Shuhada Beit Lahia Clinic (Hala Shawwa)
Ezbat Beit Hanoun
Hijazi Clinic
jamila Ashi
Beit Lahiya
Beit Hanoun
Beit Hanoun Clinic
Beit Al Maqdes clinic
Jabalya
Shuhada Jabalia Clinic
Jabalia Camp
NORTH GAZA
Abu Shebak Medical Center
Al-Rashid St
Salah El-Deen St
Al-Karama St
Gaza City
Karni-Nitzarim
ISRAEL
Non-Existing Solar System, With Solar Potential (7)
Existing Solar System, With Solar Potential (2)
Existing Solar System, Without Solar Potential (1)
Non-Existing Solar System, Without Solar Potential (0)
Regional Roads
City
Camps
Locality
Disclaimer:
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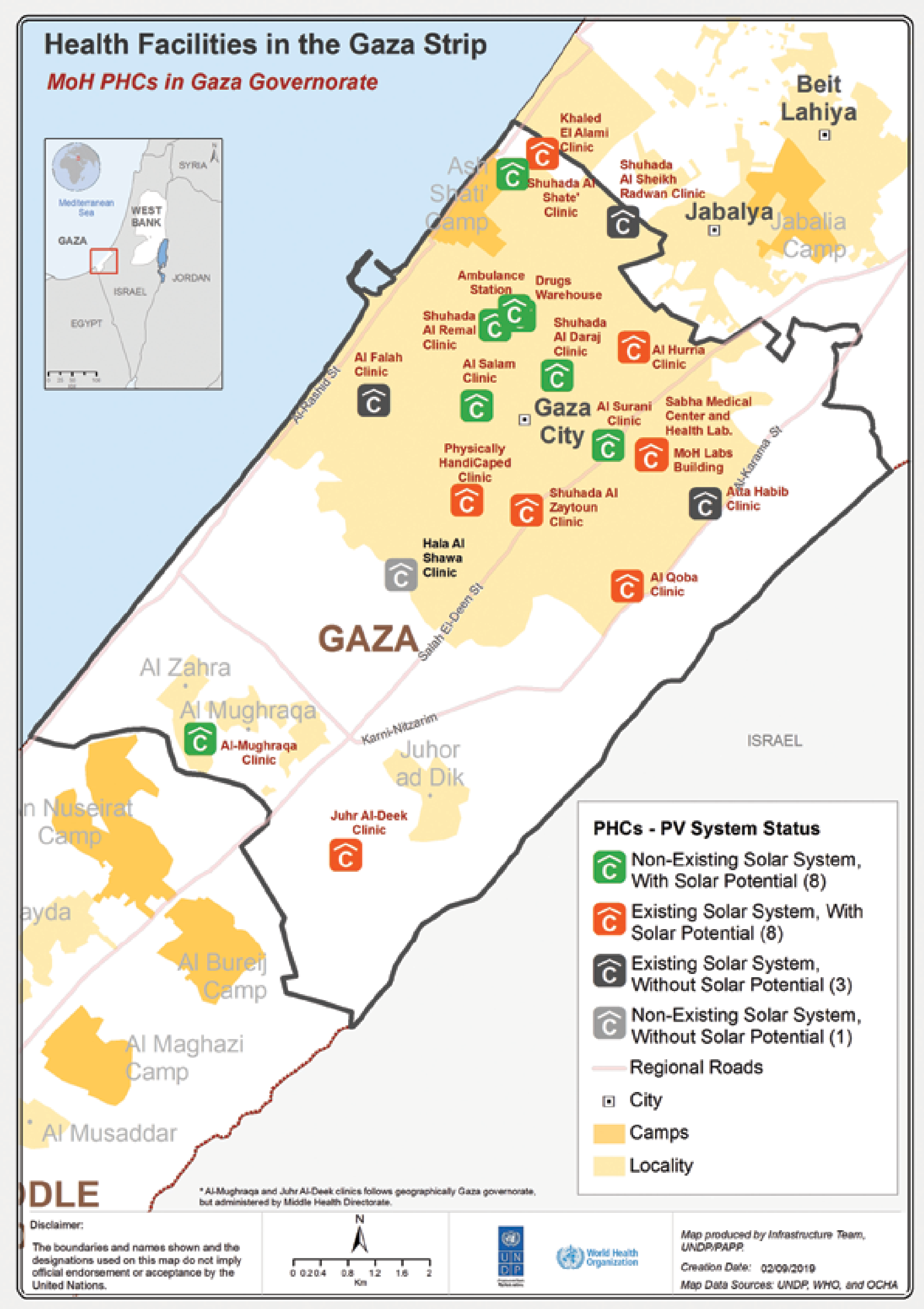
Map produced by Infrastructure Team, UNDP/PAPP.
Creation Date: 02/09/2019
Map Data Sources: UNDP, WHO, and OCHA


Health Facilities in the Gaza Strip
MoH PHCs in Gaza Governorate
Beit Lahiya
Khaled El Alami Clinic
Shuhada Al Shate' Clinic
Shuhada Al Sheikh Radwan Clinic
Jabalya
Jabalia Camp
Ash Shati' Camp
Ambulance Station
Drugs Warehouse
Shuhada Al Remal Clinic
Shuhada Al Daraj Clinic
Al Hurria Clinic
Al Falah Clinic
Al Salam Clinic
Gaza City
Al Surani Clinic
Sabha Medical Center and Health Lab.
MoH Labs Building
Physically HandiCaped Clinic
Shuhada Al Zaytoun Clinic
Atta Habib Clinic
Hala Al Shawa Clinic
Al Qoba Clinic
Al-Rashid St
Al-Karama St
Salah El-Deen St
Karni-Nitzarim
GAZA
Al Zahra
Al Mughraqa
Al-Mughraqa Clinic
Juhor ad Dik
Juhr Al-Deek Clinic
Nuseirat Camp
Al Bureij Camp
Al Maghazi Camp
Al Musaddar
ISRAEL
SYRIA
Mediterranean Sea
WEST BANK
GAZA
JORDAN
ISRAEL
EGYPT
PHCs - PV System Status
Non-Existing Solar System, With Solar Potential (8)
Existing Solar System, With Solar Potential (8)
Existing Solar System, Without Solar Potential (3)
Non-Existing Solar System, Without Solar Potential (1)
Regional Roads
City
Camps
Locality
* Al-Mughraqa and Juhr Al-Deek clinics follows geographically Gaza governorate, but administered by Middle Health Directorate.
Disclaimer:
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N
0 0.2 0.4 0.8 1.2 1.6 2
Km
World Health Organization
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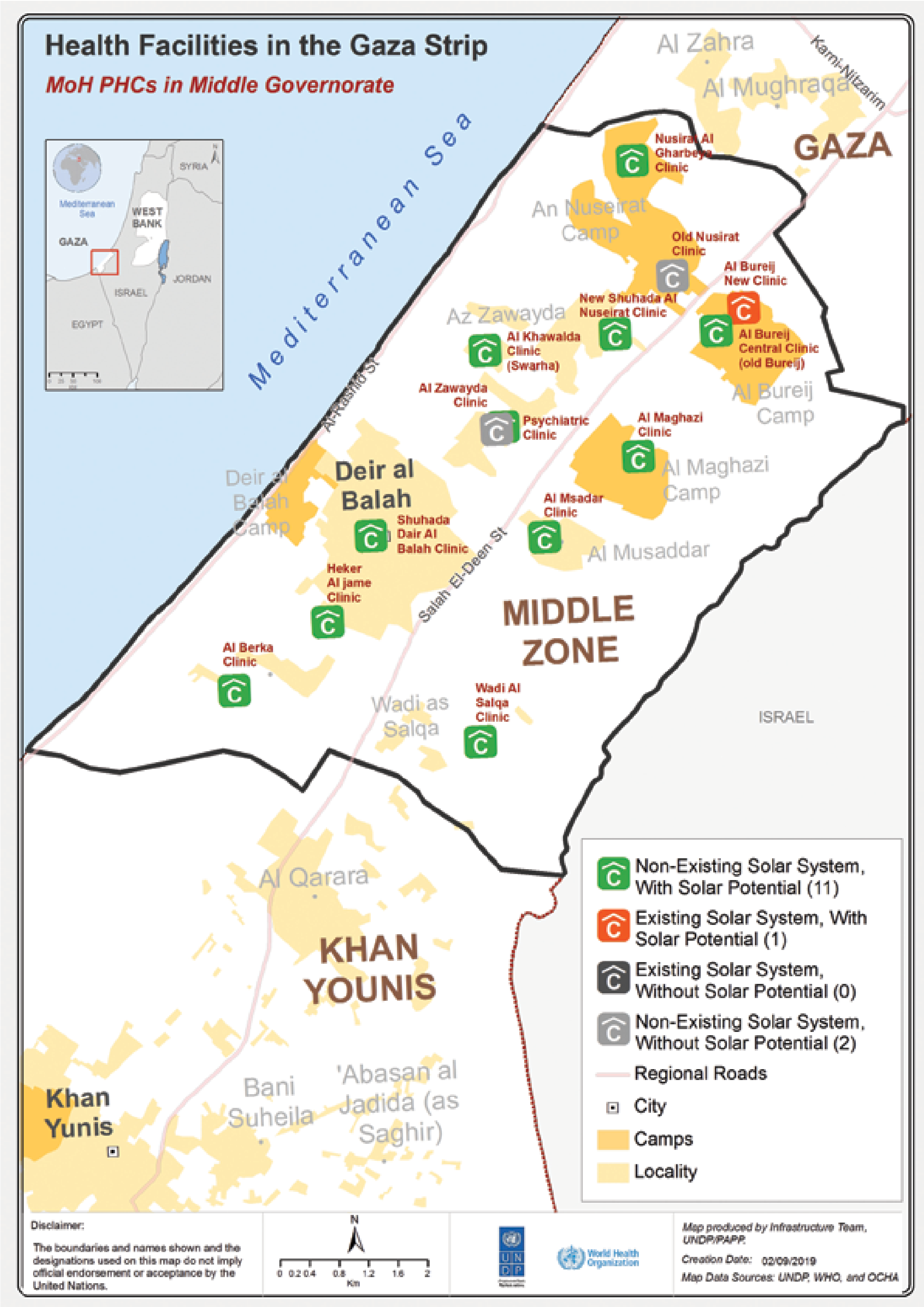
Health Facilities in the Gaza Strip
MoH PHCs in Middle Governorate
Mediterranean Sea
Al Zahra
Al Mughraqa
Karni-Nitzarim
GAZA
Nusirat Al Gharbeya Clinic
An Nuseirat Camp
Old Nusirat Clinic
Al Bureij New Clinic
New Shuhada Al Nuseirat Clinic
Az Zawayda
Al Khawalda Clinic (Swarha)
Al Bureij Central Clinic (old Bureij)
Al Bureij Camp
Al Zawayda Clinic
Psychiatric Clinic
Al Maghazi Clinic
Al Maghazi Camp
Al-Rashid St
Deir al Balah Camp
Deir al Balah
Shuhada Dair Al Balah Clinic
Al Msadar Clinic
Al Musaddar
Salah El-Deen St
Heker Al jame Clinic
MIDDLE ZONE
Al Berka Clinic
Wadi Al Salqa Clinic
Wadi as Salqa
ISRAEL
Al Qarara
KHAN YOUNIS
Khan Yunis
Bani Suheila
'Abasan al Jadida (as Saghir)
Non-Existing Solar System, With Solar Potential (11)
Existing Solar System, With Solar Potential (1)
Existing Solar System, Without Solar Potential (0)
Non-Existing Solar System, Without Solar Potential (2)
Regional Roads
City
Camps
Locality
SYRIA
Mediterranean Sea
WEST BANK
GAZA
JORDAN
ISRAEL
EGYPT
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N
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Km
World Health Organization
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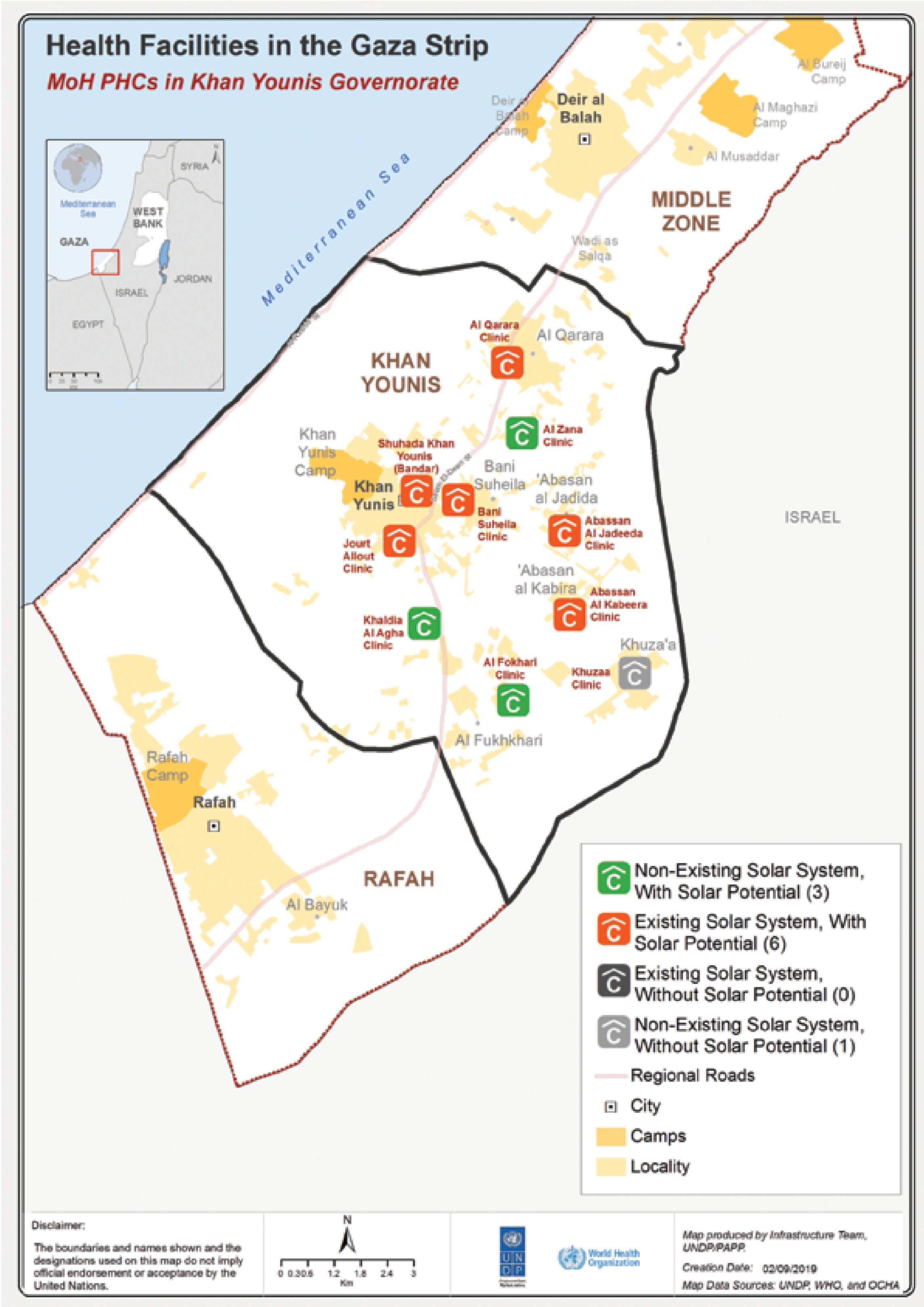
Health Facilities in the Gaza Strip
MoH PHCs in Khan Younis Governorate
Mediterranean Sea
SYRIA
WEST BANK
GAZA
JORDAN
ISRAEL
EGYPT
Deir al Balah
Deir al Balah Camp
Al Bureij Camp
Al Maghazi Camp
Al Musaddar
MIDDLE ZONE
Wadi as Salqa
Al Qarara Clinic
Al Qarara
KHAN YOUNIS
Al Zana Clinic
Khan Yunis Camp
Shuhada Khan Younis (Bandar)
Bani Suheila
'Abasan al Jadida
Khan Yunis
Bani Suheila Clinic
Abassan Al Jadeeda Clinic
Jourt Allout Clinic
ISRAEL
'Abasan al Kabira
Abassan Al Kabeera Clinic
Khaldia Al Agha Clinic
Khuza'a
Al Fokhari Clinic
Khuzaa Clinic
Al Fukhkhari
Rafah Camp
Rafah
RAFAH
Al Bayuk
Non-Existing Solar System, With Solar Potential (3)
Existing Solar System, With Solar Potential (6)
Existing Solar System, Without Solar Potential (0)
Non-Existing Solar System, Without Solar Potential (1)
Regional Roads
City
Camps
Locality
Disclaimer:
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N
0 0.3 0.6 1.2 1.8 2.4 3
Km
World Health Organization
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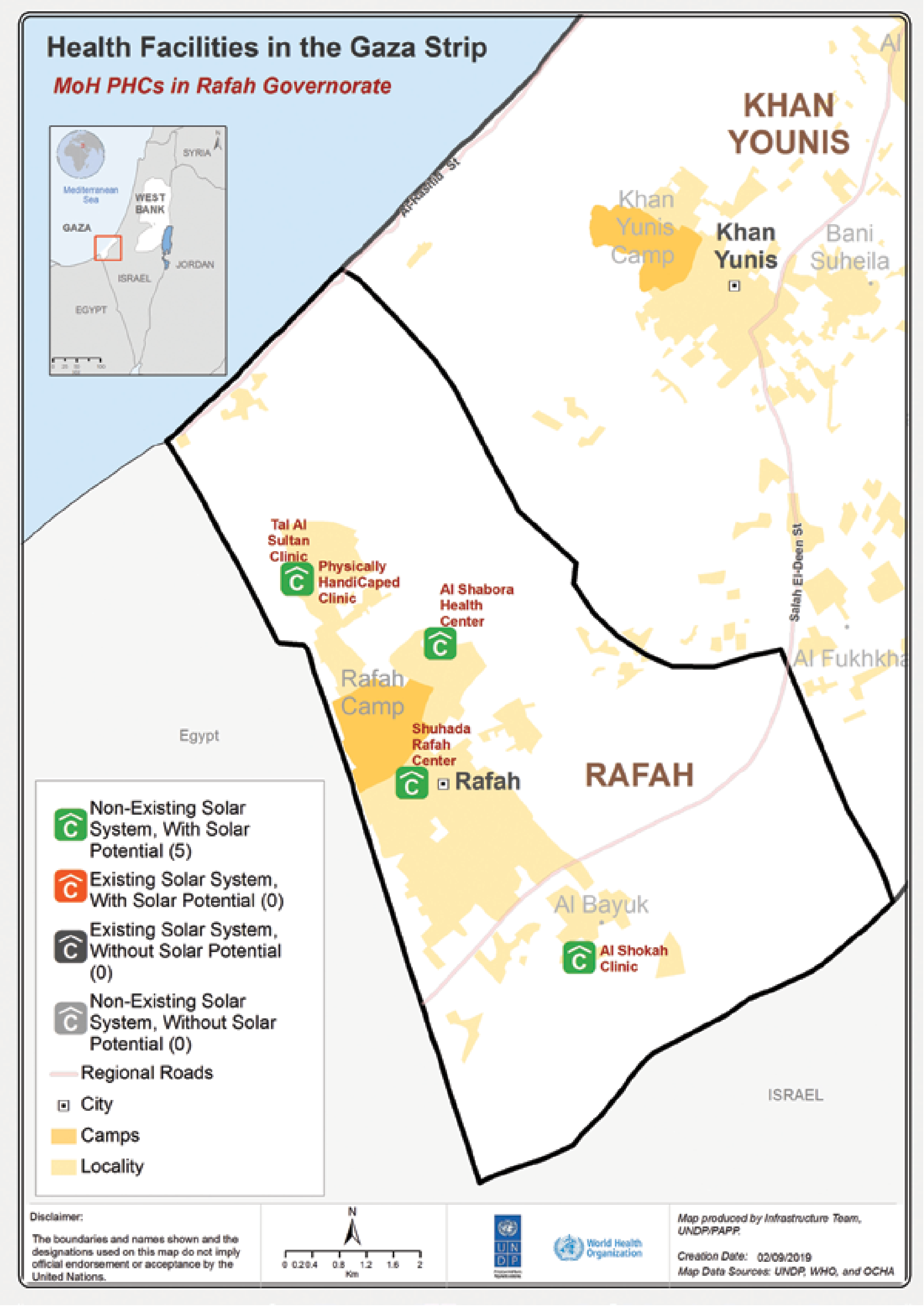
Health Facilities in the Gaza Strip
MoH PHCs in Rafah Governorate
Mediterranean Sea
SYRIA
WEST BANK
GAZA
JORDAN
ISRAEL
EGYPT
KHAN YOUNIS
Khan Yunis Camp
Khan Yunis
Bani Suheila
Al Rashid St
Salah El-Deen St
Tal Al Sultan Clinic
Physically HandiCaped Clinic
Al Shabora Health Center
Rafah Camp
Shuhada Rafah Center
Rafah
RAFAH
Al Fukhkha
Egypt
Al Bayuk
Al Shokah Clinic
ISRAEL
Non-Existing Solar System, With Solar Potential (5)
Existing Solar System, With Solar Potential (0)
Existing Solar System, Without Solar Potential (0)
Non-Existing Solar System, Without Solar Potential (0)
Regional Roads
City
Camps
Locality
Disclaimer:
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N
0 0.2 0.4 0.8 1.2 1.6 2
Km
World Health Organization
Map produced by Infrastructure Team, UNDP/PAPP.
Creation Date: 02/09/2019
Map Data Sources: UNDP, WHO, and OCHA

Solar Electrification of the Health System in the Gaza Strip: Opportunities & Challenges

Assessment Findings & a Strategy for Energy Transition