Report No: ACS17058

West Bank and Gaza

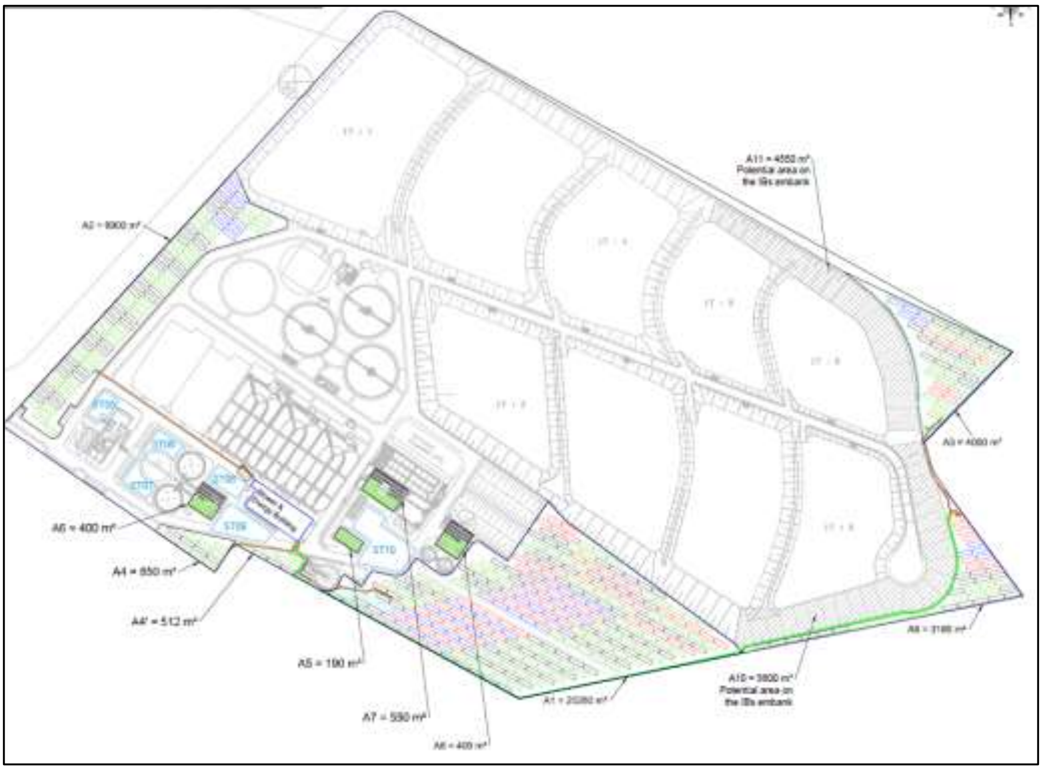
Feasibility Study Report

Power Generation (Solar PV) for North Gaza Emergency Sewage Treatment Plant

March 22, 2016

The World Bank Group
Energy and Extractives Global Practice

Middle East and North Africa



Contract 7173578

Final Feasibility Study Report

Power Generation (Solar PV) for North Gaza Emergency Sewage Treatment Plant

22 March 2016

Employer:

The World Bank
1818 H Street, N.W
Washington, DC 20433

Consultant:

intec
GOPA International Energy Consultants

GOPA-International Energy Consultants GmbH
Justus-von-Liebig-Str. 1, 61352 Bad Homburg, Germany
Phone: +49 (6172) 1791-800; Fax: +49 (6172) 944 95 20
eMail: info@gopa-intec.de; www.gopa-intec.de
Palestinian Hydrology Group (PHG) for Water and Environmental Resources Development
P.O.Box 565
Ramallah – West Bank - The Palestinian Authority

Table of Contents	Page

Table of Contents	Page

Table of Contents	Page

Table of Contents Page

List of Tables

List of Figures

Abbreviations Used

Acronym	Definition
AC	Alternating Current
ASTM	American Society for Testing and Materials
BLWWTP	Beit Lahia wastewater treatment plant
BOOT	Build Own Operate Transfer
CAD	Computer Aided Design
CAPEX	Capital Expenditures
CB	Circuit Breaker
CIS	Copper, Indium, Selenide cell
COP	Continuous Power
DC	Direct Current
DISCO	Distribution Company
DSL	Digital Subscriber Line
DUC	Dynamic Unit Cost
EIA	Environmental Impact Assessment
EQA	Environment Quality Authority
ESIA	Environmental and Social Impact Assessment
GEDCO	Gaza Electricity Distribution Corporation
GHI	Global Horizontal Irradiation
GPGC	Gaza Power Generating Company
GPP	Gaza Power Plant
GW	Giga Watt
HV	High Voltage
HVAC	Heating, Ventilating, and Air Conditioning
IAM	Incidence Angle Modifier
IB	Infiltration Basin
IEC	International Electro technical Commission
ILS	Israeli Shekel
ISO	International Organization for Standardization
kV	Kilo Volt
KW	Kilo Watt
LCOE	Levelized Costs of Electricity
LID	Light Induced Degradation
LV	Low voltage
MEnA	Palestinian National Authority Ministry of Environmental Affairs
MENR	Palestinian Ministry of Energy and Natural Resources
MPP	Maximum Power Point
MTF	Mean Time to Failure
MV	Medium Voltage, in this case also referred to as HV by PWA
MVA	Mega Volt Ampere
MW	Mega Watt
NE	North-East
NGEST	Northern Gaza Emergency Sewage Treatment
NW	North-West
OHL	Over-head line
OPEX	Operational expenditures
PA	Palestinian Authority
PEA	Palestinian Energy Authority

Acronym	Definition
PEC	Research Centre of PENRA
PENRA	Palestinian Energy and Natural Resource Authority
PF	Power Factor
PHG	Palestinian Hydrology Group
PNA	Palestinian National Authority
PV	Photovoltaic
PWA	Palestinian Water Authority
RE	Renewable Energy
SCADA	Supervisory Control and Data Acquisition
SE	South East
TMY	Typical Meteorological Year
TPS	Terminal Pumping Station
USD	US Dollar
VA	Volt Ampere
VAT	Value Added tax
W	Watt
WB	World Bank
WWTP	Waste Water Treatment Plant

Executive Summary

Study Context and Objectives

The North Gaza Emergency Sewage Treatment (NGEST)**,** with its Wastewater Treatment Plant (WWTP) and Recovery Scheme (RS), **requires cost-efficient and reliable power supply** to operate. The Palestinian Water Authority (PWA), with the support of the World Bank (WB), the French Development Agency (AFD), the Government of Belgium, the European Commission and the Swedish International Development Agency, has been developing the NGEST project with the aim of improving sanitation in the Northern Gaza Governorate. The project is also to alleviate the complexity surrounding the old Beit Lahia Wastewater Treatment Plant (BLWWTP) and the random lake formed around it due to capacity limits. The NGEST project includes a WWTP with an initial daily capacity of 35,600 m³ (expandable to 65,700 m³) and an RS of 29 recovery wells to refill the ground water aquifer with treated water and retrieve the infiltrated water for agricultural purposes. The WWTP processing loads at the WWTP and the pumps at the RS have relatively high-energy consumption rates. But overall power supply in Gaza is limited due to political obstacles, lack of power and fuel supply options, high cost of fuel, and an inefficient and fragmented distribution network. All these are factors that hinder the operation of the NGEST plant.

Given the limited electricity supply in Gaza, the PWA, together with the Palestinian Energy and Natural resource Authority (PENRA) and with support from the World Bank, sought to identify and assess the most viable, long-term, and sustainable power supply options for operating NGEST. The objective of this study is to review the already planned power supply options, suggest improvements to these options, propose a photovoltaic system, and identify the most viable, long-term, and sustainable power supply option for the NGEST plant (assuming that an external solution to the issues may be difficult to achieve in the short to mid-term).

The **WWTP is almost ready for commissioning** and the **RS is planned for development.** At the time of writing, construction of the NGEST WWTP was around 95% complete. All buildings on site have been completed and equipment is installed. During the site inspection in March 2015, the facility was in good condition and solid workmanship was observed.

NGEST **project site encompasses areas suitable for the installation of PV systems.** No barriers to the PV installation or the combined biogas/PV based on-site generation, supported by the grid and the emergency gen-sets were identified during the site visit. While no major technical risks exist, NGEST and the potential PV system are exposed to external threats due to the political situation, similar to other infrastructure in Gaza. Since NGEST is located close to the border with Israel, any changes in the local security setting might affect its operation.

Technical Assessment Results

Through the comprehensive analysis of the design loads and energy consumption, the project demand profile was drawn up for the different project phases and two locations. The peak load of the WWTP and RS together in 2018 is estimated to be 9 MVA with a daily energy consumption of 102 MWh (128 MVAh) resulting in an annual energy consumption of 37,286 MWh (46,608 MVAh). In 2025, the peak load is estimated at 15 MVA with a daily power consumption of 173 MWh (216 MVAh) resulting in an annual energy consumption of 63,271 MWh (79,089 MVAh).

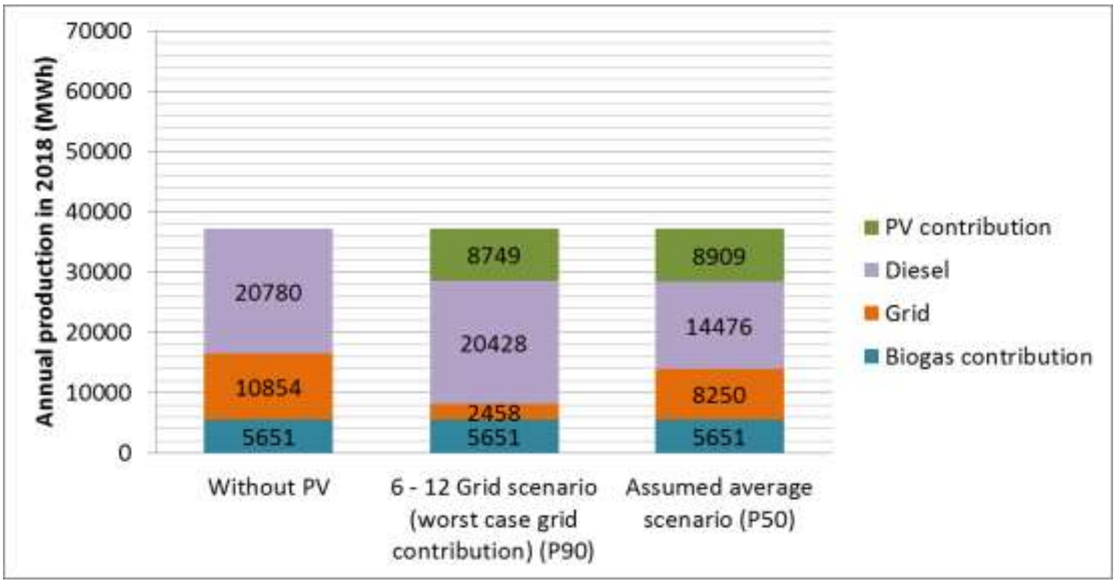
Current **power supply has been designed to cope with the constraints** of the power supply in Gaza. The existing power supply options include an external supply from the Gaza Electricity Distribution Corporation (GEDCo) grid via a 22 kV overhead feeder line and on-site generation from emergency diesel generators with sufficient capacity to cover the load of the facility. Additionally, the local biogas as a by-product of the sludge treatment cycle is used for electricity production.

The **grid-based supply faces several obstacles impeding a reliable and cost-efficient operation of the plant**. These are **mainly issues concerning power sourcing and payment structure** of the utility. Due to the **shortfalls in the distribution network, on-site generation needs to bridge the demand gap**. GEDCo's current situation underlines the need for optimising on site power supply and only emphasises the importance of a PV system in creating a more reliable and autonomous operation of the WWTP. The existing portfolio of on-site generation should be expanded to include a PV system in the designated areas within the NGEST plant to allow for a more cost-efficient, sustainable, and reliable power supply.

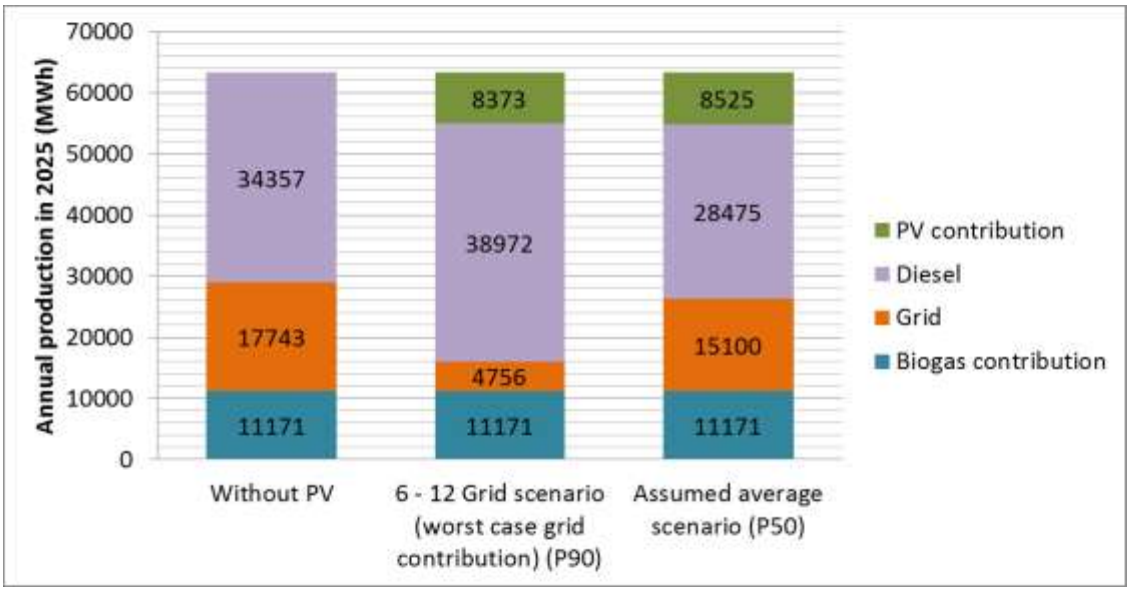
The proposed PV system design uses proven and market standard technologies. The configuration generates high-energy yields in a cost-efficient way. **The PV system uses arrays composed of poly-crystalline modules with a total rated power of 5.1 MWp.** The fixed-mounted structure with a 25 degree tilt angle is adapted in its azimuth angle to the geometry of the areas. The assessment concluded that this configuration has the lowest specific costs per installed module power and out of all evaluated PV system variants; this option provides a high annual production at lowest costs. Decentralized inverters with sizes suitable for each installation area were chosen to avoid mismatch losses between areas with different orientation and to ease maintenance. The system generates an average of 8,442 MWh annually over the project's lifetime totalling to 214,291 GWh over a period of 20 years. Investment costs (CAPEX) are estimated at USD 1,350 /kWp which amount to a total value of USD 6,897,993 . The OPEX appraisal resulted in an estimate of USD 9.44 /kWp totalling to USD 48,856 /annum.

With the optimised energy set-up for NGEST, the **PV system increases energy independence, reduces expenses on costly diesel fuel, and reduces greenhouse gas emissions.** By incorporating the PV system into the NGEST project, the annual supply from the grid in 2018 is reduced by 24% to 8250 MWh, and the required annual energy from the emergency diesel is decreased by 27% to reach 14,476 kWh. This reduces the diesel consumption by 30% and as a result, 1,293,615 litres of diesel fuel would be saved.

The energy mix in 2018 is estimated to have the following structure: (i) a PV share of 8,909 MWh representing 23.89% of the total annual power generation, (ii) diesel backup with 14,476 MWh (38.82%), (iii) grid-based supply with 8,250 MWh (22.13%), and (iv) biogas contribution of 5,651 MWh (15.16%). The following graphs show the energy mix for 2018 and 2025.



Graph 1: NGEST Energy Balance Scenarios for 2018



Graph 2: NGEST Energy Balance Scenarios for 2025

Environmental and Social Impact Assessment

For the preliminary Environmental and Social Impact Assessment (ESIA) of the proposed PV system, Palestinian laws and World Bank guidelines were used as the main reference. The outcome of the preliminary ESIA was reviewed by PWA's ESIA expert and World Bank's safeguard team and no concerns were identified. **The areas allocated for the PV system installation are part of the overall NGEST terrain and have been already covered by a previous ESIA study.** Nevertheless, the new investigation of the impact of the proposed PV system on the local environment and the community demonstrated that there would be **no permanent negative impact beyond smaller disturbances during the construction period.**

Economic and Financial Analysis Results

An economic and financial analysis was conducted with the objective of identifying the costs and benefits of the installation of a solar PV plant as a power supply option for NGEST. The financial analysis in particular examines closely the investment profitability and the different potential financing scenarios.

Results of the economic and financial analysis at a glance:

1. The economic and financial analysis of the different supply options concluded that a system with the PV option is the most reliable, cost efficient and sustainable option.
2. The calculation resulted that the LCOE is USD 0.23/kWh for a system without PV, and the LCOE is USD 0.20 /kWh for a system with PV. This demonstrated that financial savings could potentially amount to USD 15,627,543 over a period of 20 years when solar PV is included into the energy mix for NGEST. Along with the cost saving potential, the installation of PV would lead to a higher autonomy in power supply, granting the emergency sewage treatment independence over 16% of its annual overall electricity need.

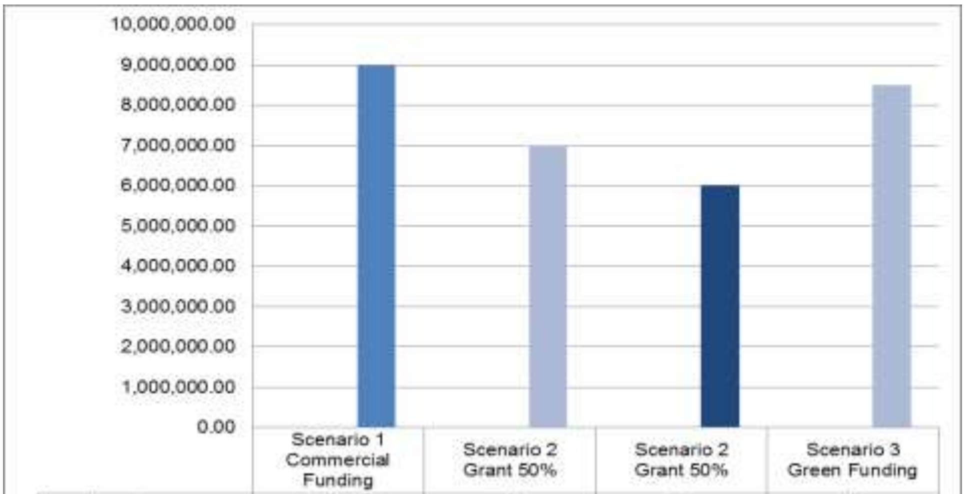
The total investment cost of USD 9.7 million was considered for the calculations and the different scenarios. This is due to the fact that the power supply options (PV, biogas, and diesel) are interrelated and those options combined could only generate enough electricity to meet NGEST's energy demand.

	Unit	Grand total
Total Energy demand NGEST (20 yrs.)	kWh	1,062,279,708
Investment (CAPEX PV)	USD	7,423,868
Investment (CAPEX biogas)	USD	872,077
Investment (CAPEX diesel)	USD	1,454,395
Total investment costs (PV, biogas, diesel)	**USD**	**9,750,340**
Total investment costs (only PV and biogas)	USD	8,295,945

Table 1: Investment cost break down

In order to determine the most favourable financing scenario, different financing scenarios were calculated and evaluated.

The most favourable from each scenario being the following:



	Scenario 1 Commercial Funding	Scenario 2 Grant 50%	Scenario 2 Grant 50%	Scenario 3 Green Funding
Loan term in yrs	15	20	20	20
Interest rate	3%	6%	3%	0.43%
Total debt/costs in USD	8,997,545	7,001,134	6,009,238	8,508,124

Graph 3: Most favourable funding options for NGEST.

Recommendations

Based on the feasibility assessment, **the installation of PV systems at the two NGEST sites can be recommended**:

- The integration of the PV system into the existing electrical infrastructure is feasible
- Additional local electricity generation contributes to the autonomy of the overall power supply.
- The PV system reduces fuel consumption and grid reliance leading to emission reduction.
- The PV plant lowers the cost per energy unit and allows for cost savings over the project lifetime.

Consequently, the technical feasibility as well as economic and financial viability of the PV system is confirmed. However, prior to the procurement and instalment of the PV plant, a **few outstanding issues are yet to be solved**.

The following **technical aspects should be clarified**:

1. GEDCo should be consulted on the proposed design and modifications to the network connection at the point of common coupling;
2. Update of the recovery scheme design to the proposal of the new contractor[1];
3. Development of the final grid connection design and update of the power supply agreement with GEDCo.

The **investment and operational budget needs to be secured** by clarifying relevant issues:

1. The final commercial set-up needs to be decided upon.
2. Given the ownership and risk structure it is recommended:

[1] The EPC contractor ("Stulzgruppe Planaqua GmbH") that built the NGEST facility, more specifically the WWTP, almost to the finish went into bankruptcy in 2014. Consequently, a new Contractor had to be identified for finalising the construction and commissioning of the facility. Since this new company would have to guarantee for the works to a certain extent, it is very likely that there are minor modifications to the WWTP. In addition, whichever contractor will be responsible for building the recovery scheme will probably revise the existing design and drawings in order to reflect the latest status of the project. This offers the opportunity to integrate the PV plant in the design.

   a. the project be procured as a turn-key EPC bidding process and
   b. NGEST be the staff responsible for the operation.
3. Alternatively, the new contractor may be requested to propose a subcontract as addendum order to reduce interfaces.
4. The budget shall also foresee suitable contingencies for unforeseen expenses during:
   a. construction, e.g. additional expenses for system integration at the point of connection interruption of works due to administrative procedures;
   b. operation, e.g. training of staff, repair of external damages.
5. The funding of the system needs to be confirmed by the institutions responsible for NGEST's budget.
6. A suitable structure for financing needs to be decided upon.

Since **the installation of the PV system depends as well on external procedures**, these must be followed-up in parallel:

1. Facilities at the Recovery Scheme (Stage 1) must be installed.
2. Local permits and licenses must be available.
3. Non-objection certificates from Israeli authorities must exist.

If these conditions are met, the implementation could commence. The proposed activities are outlined below:

1. Update of information basis and project condition:
   a. Identification permit, legal and security requirements with impact on implementation;
   b. Definition of principal technical restrictions;
   c. Update of drawings, if necessary.
2. Preparation of bidding documents
   a. Drafting of the structure in compliance with World Bank guidelines and Palestinian regulations;
   b. Elaboration of commercial definitions including contractor's guaranties;
   c. Definitions of interfaces and responsibilities of NGEST's contractor and other external entities such as authorities and institutions.
3. Specification of technical requirements including interfaces, BoQ, data sets and drawings for bidders:
   a. PV system(s);
   b. Modification and optimization of existing energy supply;
      i. Control and monitoring via SCADA;
      ii. Integration with WWTP.
   c. Final review of design drawings and proposal of changes in the existing NGEST design to improve interfacing with PV. This relates mainly to the Recovery Field, which is still in advanced planning.
4. Bidding phase
   a. Finalization and approval of bidding dossier;
   b. Publication of bidding dossier;
   c. Bidding and clarification period;
   d. Bid evaluation;
   e. Contract award.
5. Training of stakeholders
   a. PV system installation;
   b. Operation and maintenance.

1. Introduction

1.1 Background on the NGEST Project

The Palestinian Water Authority (PWA) is developing the North Gaza Emergency Sewage Treatment (NGEST) project in North Gaza to improve sanitation in the Northern Gaza Governorate and alleviate the complexities around the old Beit Lahia Wastewater Treatment Plant (BLWWTP) and the random lake, which was formed due to capacity limits at the BLWWTP.

The NGEST project was designed with three main components:

a) **Part A**: The installations of the Terminal Pumping Station (TPS) located at the BLWWTP, the construction of a 7 km pressure pipe line to conduct the wastewater from the BLWWTP to the NGEST WWTP site to eliminate the risk from the random lake and the building of nine infiltration basins (East to Al-Shuhada Cemetery).
b) **Part B**: The construction of a waste water treatment plant (WWTP) adjacent to the infiltration basins with an initial daily capacity of 35,600 m^3 (expandable to 65,700 m^3) to treat the influent coming from the TPS and to provide long-term, sustainable solution to the sanitation services in North Gaza.
c) **Part C**: A recovery scheme (RS) of 29 recovery wells to refill the ground water aquifer with the treated water and retrieve the infiltrated water for agricultural purposes by using it for irrigation of 1500 ha in the eastern part of the North Gaza Governorates. This measure shall help to achieve a positive impact by reducing the pressure on the limited coastal aquifer and by provision of good quality irrigation water for the local community.

The processing loads at the WWTP and the pumps at the RS have relatively high-energy consumption rates. Thus, reliable and economically sound power supply is a key requirement for operating NGEST. The overall power supply, however, in Gaza is limited due to the Israeli blockade and constraints on fuel entry into the Gaza Strip. High cost of fuel, limited capacity and fragmentation of the grid are yet additional predicaments hindering the Gaza Power Plant from operating at full capacity. As a result of these challenges, the PWA, in collaboration with PENRA and with support from the World Bank (WB), is seeking to identify the most viable and sustainable power supply option for the NGEST facility during its whole life-cycle.

This feasibility study assesses power supply of Part B and Part C, because the TPS and connected facilities grouped under Part A are already implemented and are operational. Further, the location of these components that is 7 km away from the WWTP and RS, renders their inclusion into the integrated power supply system impossible.

1.2 NGEST Project Timeline

The different expansion stages of the NGEST project, driven by increased loads are grouped into two main phases: Phase I is planned to be completed by 2018 and Phase II shall be incorporated by 2025 (Table 1-1). Within Phase I, there are separate stages characterised by the annual increase of volume of treated wastewater and effluent pumped at the recovery scheme. The uptake volumes are then reflected in the respective power demand and energy consumption at the two locations. The corresponding energy profiles are assessed in the load and demand analysis of this report.

Part A is completed and in operation since 28 April 2009. The construction of Part B is completed to about 95%. Due to an insolvency of the joint-venture leader of the treatment plant contractor, the project is currently stalled waiting for conclusion of construction and final commissioning. The start of regular operation is expected for the first quarter of 2016. The installation of Stage I of the recovery scheme is expected by the end of 2016. Likewise, the implementation of Stage II is expected to take place towards the end of 2017. In Phase 2 another expansion of the recovery scheme is envisaged.

	Phase I									Phase II
Facility Section	Start-Up	Stage 1		Stage 2	normal operation under Phase I					extension
	2015	2016	2017	2018	2019	...	...	...	2024	2025
Waste Water Treatment Plant	2.5	2.75	3	3	3	3	3	3	3	5
Recovery and Reuse Scheme		2	2	6	6	6	6	6	6	10

Table 1-1: Power Requirements in MVA under the different phases and expansion stages

This report thus separates the power supply situation into two main phases:

1) Phase I with the planning horizon 2018 (to be completed by the end of 2017), where
    a. the main treatment plant is to be completed and commissioned by the end of 2016;
    b. the recovery scheme Stage 1 and Stage 2 to be completed.
2) Phase II with the planning horizon 2025 (to be completed between 2019 and 2024) where
    a. an expansion of the treatment plant and an expansion of the infiltration basins;
    b. an extension of the recovery scheme.

The potential addition of the PV system is planned to be procured and installed within Phase I by mid-year 2017. The assumption behind this scheduling is that the planning, detailing of the concept, system specification and financing may easily take until the end of 2015 or later. The procurement will require at least the first semester of 2016 and implementation including executive design, construction and installation may take another year. Thus any power supply system with contribution from a PV system would most likely be operational sometime in 2017. Although this would lead to the design horizon of 2018, full operation of PV already in 2017 is assumed in the study in order to assess the different conditions during the upscaling of NGEST's operations. Some areas designated for installation of PV modules are on the recovery fields and connected facilities. Consequently, the implementation of the recovery facilities is a precondition to the installation of the PV system at this location.

This particular timeline also explains the principal difference of the assessment of the power supply from other projects currently in planning by the Palestinian Authorities. At NGEST, planning of the whole system including basic power supply had been conducted in the past years and major components of the system are already installed. The study presents a re-assessment of the designed and installed structures and proposes modifications aimed at reducing interference with the existing project to a minimum. In contrast to this, other projects, such as the Gaza Central Desalination Plant or the Gaza Central Wastewater Project are still on the planner's desk, which might potentially allow for integrating more recent and advanced renewable energy technologies right from the start.

1.3 Power Supply Conditions

The principal objective of any power supply concept for NGEST is defined by the need to safeguard the continuous and uninterrupted operation of the WWTP and the effluent recovery scheme.

The main reasons for analysing and reviewing the supply options are:

a) The technical instability and unreliability of the local distribution grid, which render it unable to provide steady power supply.
b) Projected high operational expenses from the on-site emergency diesel generators due to grid shortfall.
c) Uncertainty of fuel supply, needed for running the diesel generators.

It is assumed that the current adverse conditions of the power supply system in Gaza will prevail at least for the mid-term. Thus, the intermittent and constrained supply from the local distribution network is the key driver behind any investigation into alternative solutions that could potentially bridge the supply gap arising from the regular load shedding. This insecurity is what compels developers and operators of critical infrastructure projects with high-energy consumption, such as the water sector, to ensure constant operation by incorporating alternative sources of power supply into the exiting systems. Diesel generators are normally used as a primary on-site emergency solution because the gen-sets provide flexible and reliable energy to cover the loads. But this strength comes with a huge price tag and increased emissions, as the facility requires a large amount of fuel to run the facility when in off-grid mode. The high price of fuel needed for the diesel generators will further increase the operational budget of the facility. In addition, the large reliance on diesel increases the overall environmental footprint of the project. As a consequence of the high fuel costs, there is need to identify alternative solutions in order to ensure sustainable power supply. The biogas as by-product of the sewage treatment process has already been considered as an alternative fuel source in the design of the NGEST WWTP. Given the availability of spare land within the areas of NGEST's jurisdiction and given the good solar resource in Gaza, incorporating a photovoltaic system into NGEST's energy portfolio seems to be a logical step.

Consequently, the NGEST project stakeholders aspire to catch the two ends of this challenge through an optimisation of the existing set-up and the inclusion of a PV system:

- Higher independence from intermittent grid-based supply;
- Fuel cost saving during times when the grid is unavailable.

The consumption of NGEST is determined by the fixed load and variable process consumers. The operation of the wastewater treatment plant and its flows is the leading driver for the fluctuations of the variable demand:

- When wastewater inflow is high, power demand from the different components will rise and vice versa;
- The production of biogas depends on this process flow and its cycles.

The general power network situation leads to two operational scenarios which the power supply structure must be capable of supporting:

1) On-grid mode – when the facility is mainly supplied from GEDCo network:
    a. All consumers can be supplied and normal operation is ensured;
    b. The embedded captive on-site renewable energy generation (biogas, PV) would reduce costs of energy supplied by GEDCo in an auto-consumer or net-metering fashion.
2) Off-grid mode – when the facility has to self generate the required power:
    a. The limited supply from the grid may necessitate the management and curtailment of some loads, e.g. the non-priority consumers such as some wells in the recovery scheme;
    b. The embedded captive on-site generation (biogas, PV and diesel) would need to ensure the provision of the required power and heat. Renewable power from biogas and PV would serve as fuel-saver for the emergency diesel displacing costly fossil fuel as much as possible through operation as auto-producer.

The technical analysis and economic evaluation will therefore need to:

- verify if and how these envisaged operational set-ups can be sustained;
- assess the consequences for the technical concept design and operation;
- evaluate the associated costs and economic viability.

1.4 Objectives of the Feasibility Study

The objective is to review the planned power supply, to propose improvements to it including the assessment of the installation of a photovoltaic system and, finally, to identify the most viable, long-term sustainable power supply option for the NGEST facility under the expectation that an external solution to the issues may be difficult to achieve in the medium term.

Guiding questions of the study:

1. Which supply option ensures a reliable and sustainable operation of the NGEST plant on a long-term basis?
2. How would a more autonomous generation supported by PV with less GHG emissions need to be designed and implemented?
3. Which approach shall be adopted to finance the energy supply and potential PV plant of the NGEST plant, and how should the project be commercially structured?

The study answers these questions through (1) evaluation of the loads and consumption of the sewage treatment facility and effluent recovery scheme, (2) review of the existing supply options; (3) assessment of the share of each supply option on the total demand; (4) development of a conceptual PV system design to be added to the portfolio of local generation sources; (5) optimisation of the utilisation of renewable sources (biogas and solar PV); (6) analysis of the economic implications and financing options; and finally (7) proposal of a suitable project structure with a way forward to implementation. Each of these assessment steps are regarded as decision gates, where available options or variants are evaluated and recommendations based on the results of analysis are provided.

The assessment is complemented by a preliminary environmental impact analysis, an outline of the implementation strategy as well as an appraisal of the effects on the local political economy.

2. Site Conditions

2.1 Localisation of the Site

The NGEST plant site and recovery fields are located south east of Jibalya municipality and west of the Israeli border as shown on the satellite imagery in Figure 2-1. The main NGEST plant is situated closer to the border and south -east of the al-Shuhada cemetery. The effluent recovery and reuse scheme is planned on the north east side of the al-Shuhada cemetery. At both locations there are electrical loads required to drive the processes and operation of the facility. For the local electrical supply during off-grid periods, generators are foreseen as backup power at the two locations. Within the two boundaries of the two sites, certain areas have been designated by PWA for the installation of PV systems.

The construction of Phase I of the NGEST plant has been completed to about 95%. All buildings have been completed, and equipment is installed. During the site inspection, the PWA had given proof that there are no major obstacles which would block the commissioning of the facility although some minor punch list items would still have to be finished. These items involve mainly non-critical civil or mechanical work.

The recovery scheme is then planned to be added at the later Stages 1 and 2 of Phase I and then finally expanded in Phase II. Currently, this Waqf[2] land (common property) lies fallow but is rented out on a seasonal basis for farmers for cultivation of seasonal crops.

[2] Definition of Waqf: An endowment made by a Muslim to a religious, educational, or charitable cause.

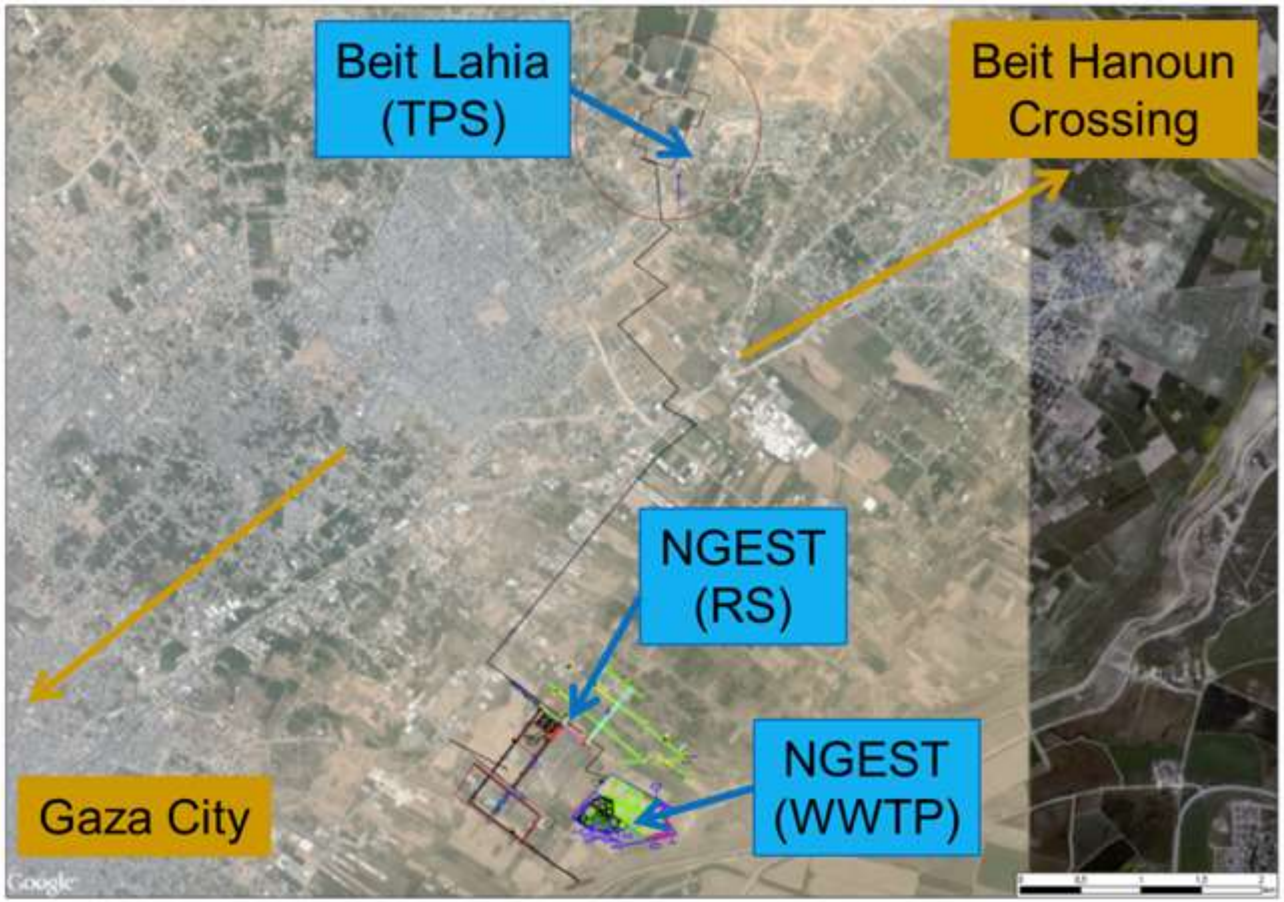


Figure 2-1: The site localisation including the pressure line from TPS, imagery by Google Earth and drawing by NGEST

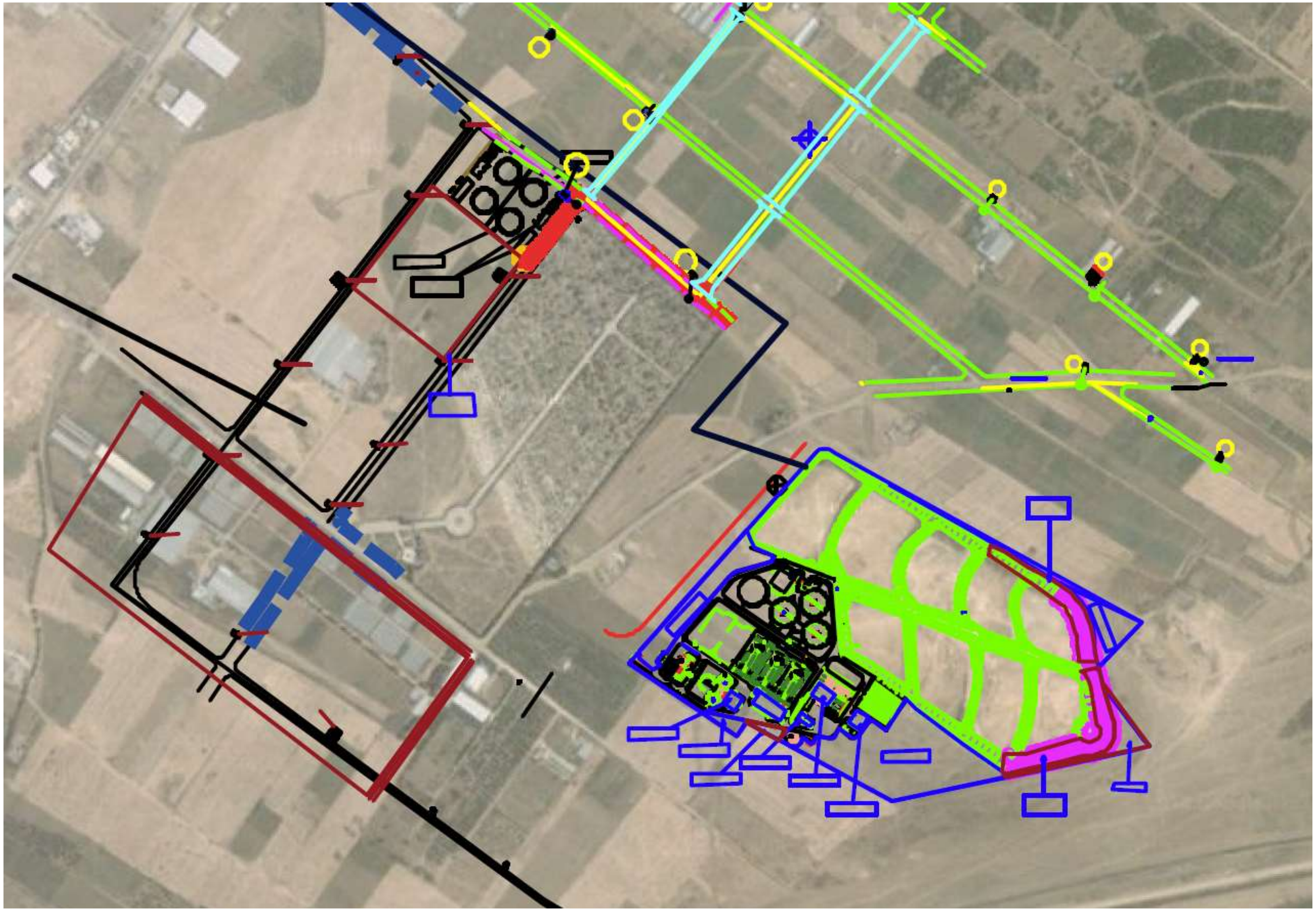


Figure 2-2: Detailed view of the area located south east of Jibalya, imagery by Google Earth and superposed drawing by NGEST

2.2 Overview of the Areas Designated for PV Systems

The areas of the NGEST project potentially considered for the design and installation of PV systems were identified by the PWA using site drawings of the facility[3]. The drawing[4] identifies the areas within the current boundaries of the treatment plant and additional areas on the recovery scheme. An overview of these areas is provided in Table 2-1.

Table 2-1: Designated areas for PV systems

Area Code	Brief description and localisation	Type of PV installation	Size [m²]
A1	Southern edge	ground-mounted	20,280
A2	Closed to road	ground-mounted	6,900
A3	NE corner	ground-mounted	4,000
A4	Next to Digester & Thickener Building	ground-mounted	850
A4'	Next to Digester & Thickener Building (small)	ground-mounted	512
A5	Workshop	rooftop	190
A6	Digester & Thickener Building	rooftop	400
A7	Preparation & Primary Clarifiers	rooftop	550
A8	Sludge Dewatering Building	rooftop	400
A9	SE corner	ground-mounted	3,180
A10	IB embankments	ground-mounted	5,600
A11	IB embankments	ground-mounted	4,550
Total WWTP areas			**47,412 m²** (47 ha)
A12	Waqf land for recovery scheme	ground-mounted	30,000
A13	Mechanical Room at recovery scheme	rooftop	391
A14	Electrical Building at recovery scheme	rooftop	217
Total Recovery Scheme			**30,608 m²** (31 ha)
Grand Total			**78,020 m²** (7.8 ha)

Most of the abovementioned areas have been visited and assessed during the site visit, except for areas A3, A9, A10 and A11, where access was not possible during the short time of the site visit and due to security reasons. But all areas were visually screened from high-standing points.

It is not expected that the terrain and characteristics differ from the other areas. This assumption is based on existing data on the areas, i.e. from the digital elevation model of the area, topographic survey and topographic maps, the slope and shape of the terrain can be confirmed.

[3] All suitable locations from the designated area presented by PWA were taken into account when designing the PV system. On the roof-top locations only installed facilities (HVAC / water tanks) were excluded. There is no other available adjacent land to expand the plant. The NGEST plant itself is built close to the green zone. Additionally, land is extremely scarce in Gaza, and this designated land is available because it cannot be built on, and is Waqf land.

[4] CAD-file “01 - Updated DWG - Final Grid Survey 23.2.2015_Coord Isr 1989 17.3.2015.dwg” submitted on 17.03.2015 by PWA

2.3 PV Areas within Treatment Plant Boundary

Within the treatment plant, suitable space is available on the rooftop of all major buildings with the exception of the power house ("Blower and Energy Building"). The areas around the facilities' installations (open space for ground-mounted systems) are available at the boundaries of the plant. The areas are shown in Figure 2-3.

Figure 2-3: Designated areas within treatment plant boundary

2.4 PV Areas at Recovery Scheme

The second location with designated PV areas is the effluent recovery scheme behind the cemetery. It can be reached either via an untarred road from Jibaliya or by following the road along the plant's fence and then branching left at the northern site corner. These areas are illustrated in Figure 2-4.

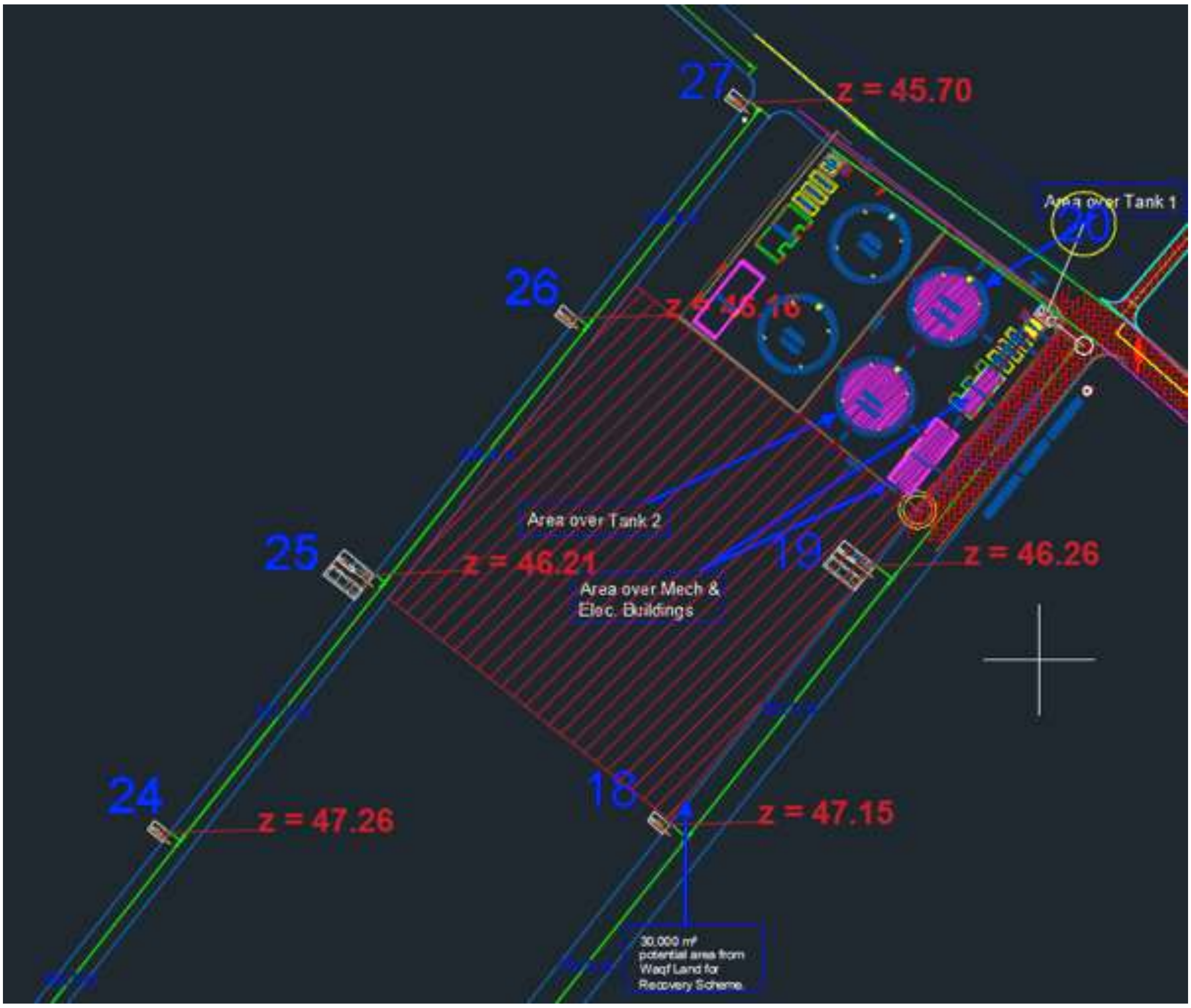


Figure 2-4: Designated areas at the recovery scheme

Figure 2-5 below shows the planned locations of the recovery and reuse scheme wells. The Google Earth screenshot was provided by PWA.[5] It separates the wells into 15 wells to be constructed in Stage 1 depicted in yellow, while the 14 wells, marked in green, are proposed for Stage 2. The PV areas to the west of the cemetery are part of Stage 1. This explains that the implementation of Stage 1 of the recovery scheme is a pre-condition for the PV system at that location.

[5] 02.04.2015, via email

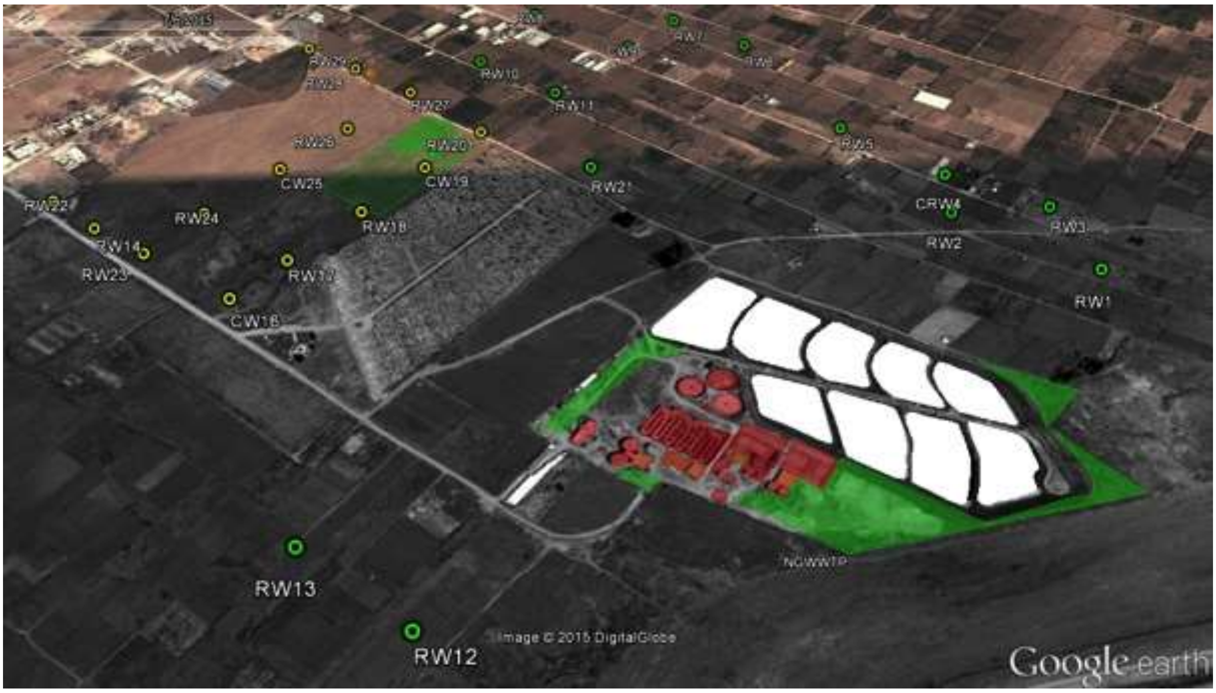


Figure 2-5: Recovery scheme wells for stage 1 (yellow) and for stage 2 (green)

2.5 Suitability of the Site

A more detailed documentation of the site including photos of the principal consumers of the treatment plant and the existing power supply infrastructure is provided in the ANNEX section 12.1.

The key findings, especially with regard to the suitability for the installation of a potential PV system, are summarised in Table 2-2.

Table 2-2: Summary of key facts and major findings

Parameter	Characteristic
Basic data	
Coordinates in Lat. (N) / Lon. (E)	31.5056 / 34.5102
Next village/town	Jibaliya/Gaza City
Next seaport	Gaza City Port / Port of Ashdod/ Port Al Aresh
Next airport	Ben Gurion, Israel/ Al Aresh, Egypt
General Characteristics	
Climate	Semi-arid Mediterranean climate
Area type	Brownfield ground-mounted / rooftop on existing building
Terrain/area topography	Flat with slight slopes
Soil/ground condition	Backfilled material – suitable for ramming

Parameter	Characteristic
Earthquake risk	Medium (similar to the east Mediterranean region)
Natural hazards	No
Environmental constraints (Lightning strikes, flash flood, dust, bush-fires, etc.)	Dust from landfill and collection lorries, particles from the charcoal production closed by, seasonal dust from agricultural activities
Approximate area	77740m² / 7.774 hectares (77.740 dunums)
Current use of site	Mainly unused, some plantations
Land ownership	Government (NGEST) and community Waqf land (recovery scheme)
Site identification	NGEST treatment plant / NGEST effluent recovery scheme Individual areas are numbered as A1-A14
Infrastructure and Interfaces	
Road access for transport	Tarred road
Water	Currently groundwater
Grid access	MV OHL 22 kV on-site Connection of PV AC output to power house or building specific LV panels
Telecommunication infrastructure	DSL line of NGEST SCADA, combined use for PV monitoring to be clarified
Supply infrastructure	via Gaza City for mechanical/civil spare parts or other items via Israel
Restrictions and risks	
On-site objects	No objects on the brownfields All roofs have air-conditioning and water tanks
Surroundings (buildings, roads, external shadowing objects)	None, except for a few lighting poles.
Other external impacts	Proximity to the border with Israel
Summary – **positive (advantages)**	• Terrain is already secured and prepared • Good infrastructure • High radiation potential • No external shading objects
Summary – **negative (Risks)**	• Scattered areas, many of them rather small • Roofs with facilities reducing the effective area and casting (limited) shadow • Electrical infrastructure (e.g. cable trenches, panels, boards) already installed without consideration of PV • Potential high dust emission from landfill, charcoal production and roads

Parameter	Characteristic
Conclusion and Recommendation	• Construction of WWTP shows quality and good workmanship • Installation of PV systems is possible • Combination with biogas as on-site hybrid generation plant is possible • Grid support, or operation of emergency diesels, may still be necessary depending on the demand curve and the expansion sizes of the NGEST project • A tight coordination of the PV system implementation and the NGEST expansion to Phase II is necessary; this applies especially for the effluent recovery scheme where the PV arrays are to be built on areas used by the recovery scheme, i.e. PV installation depends on the recovery scheme installation. • Recommended to use PV panels tested and certified resistant against ammonium corrosion (IEC 62716) against emissions from the treatment plan • Use a suitable terrain cover to reduce dust emission • Plantation of shrubs towards the border can prevent dust • Consider upgrading the road • Re-assess of some cable trenches could be used • Use the same design configuration at least for similar areas; for ground-mounted and for roof-top to facilitate O&M • Review the capability of the overhead feeder for future phases

2.6 Environmental Conditions and Resources

2.6.1 General Climate Conditions

Gaza Strip enjoys typical Mediterranean weather conditions with one wet and one dry season. The wet season extends from October to April and the dry season extends from May to September. The average rainfall varies from less than 200 mm in the south to nearly 500 mm in the north. Average rain intensity is 45 mm/hr, but often exceeded in storm events (60 mm/hr). The average is 25°C (min 11.6 - max 31) while average humidity is at 68%.

The ANNEX section 12.2 contains a more comprehensive description of the environmental conditions and climate.

2.6.2 Reference Irradiation and Temperature

The P50 and the P90 TMY provided with the Solar Atlas have been used for simulation of the PV system and calculation of the energy production.

The TMY data set corresponding to the probability of exceedance of 50% (P50) for a representative site in Gaza was used as meteorological input data. The data for this site was generated as part of the Solar Atlas. The location has a distance of about 4 km to the NGEST site as shown in Figure 2-6. Based on the previous research[6], the data generated for this representative location can be used for the design without significantly increasing the uncertainty.

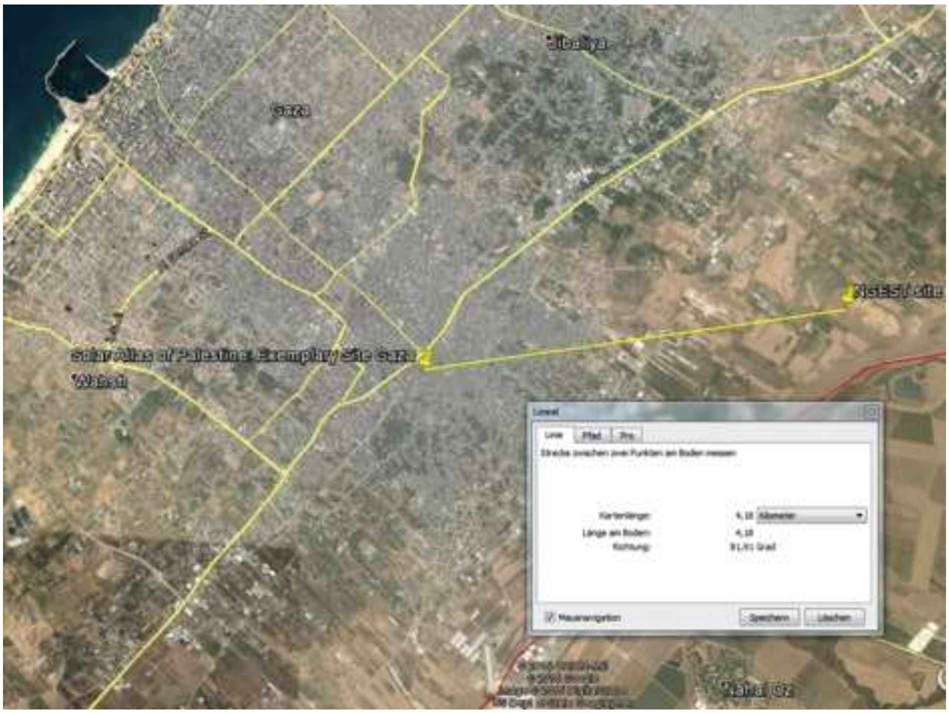


Figure 2-6: Distance of NGEST site to Gaza data location from Solar Atlas

The monthly values of the data used for the design and energy yield simulations are shown in Figure 2-3.

6 Zelenka A, Perez R, Seals R, Renne D (1999): Effective accuracy of the satellite-derived hourly irradiance, Theoretical and Applied Climatology, 62:199–207

Month	P50		P90	
	GHI P50	**TEMP P50**	**GHI P90**	**TEMP P90**
January	129	15	119	14
February	164	14	156	14
March	228	15	201	14
April	277	18	257	19
May	308	21	307	21
June	344	24	342	24
July	335	26	331	26
August	307	27	303	27
September	261	26	253	25
October	196	24	191	23
November	153	20	131	20
December	122	17	111	16
Annual	**2823**	**21**	**2703**	**20**

Table 2-3: TMY data for P50 and P90 case for Gaza City

The annual course of irradiation and temperature as the most important meteorological parameters are shown in Figure 2-7.

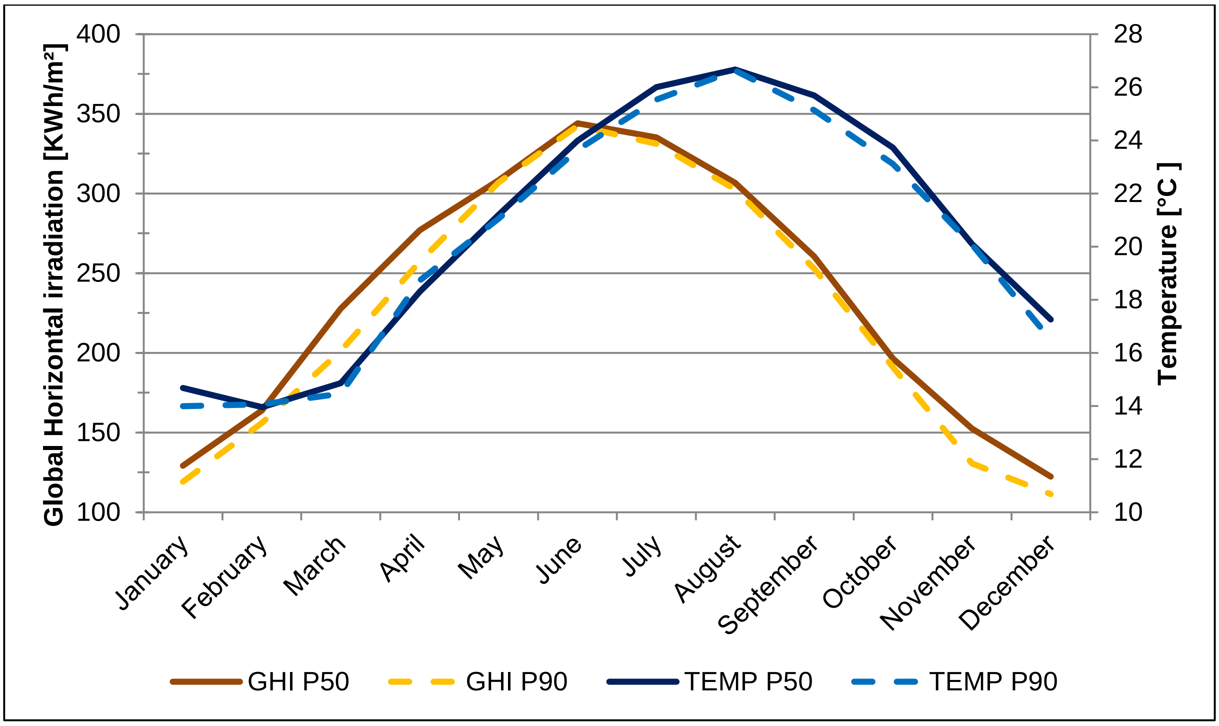


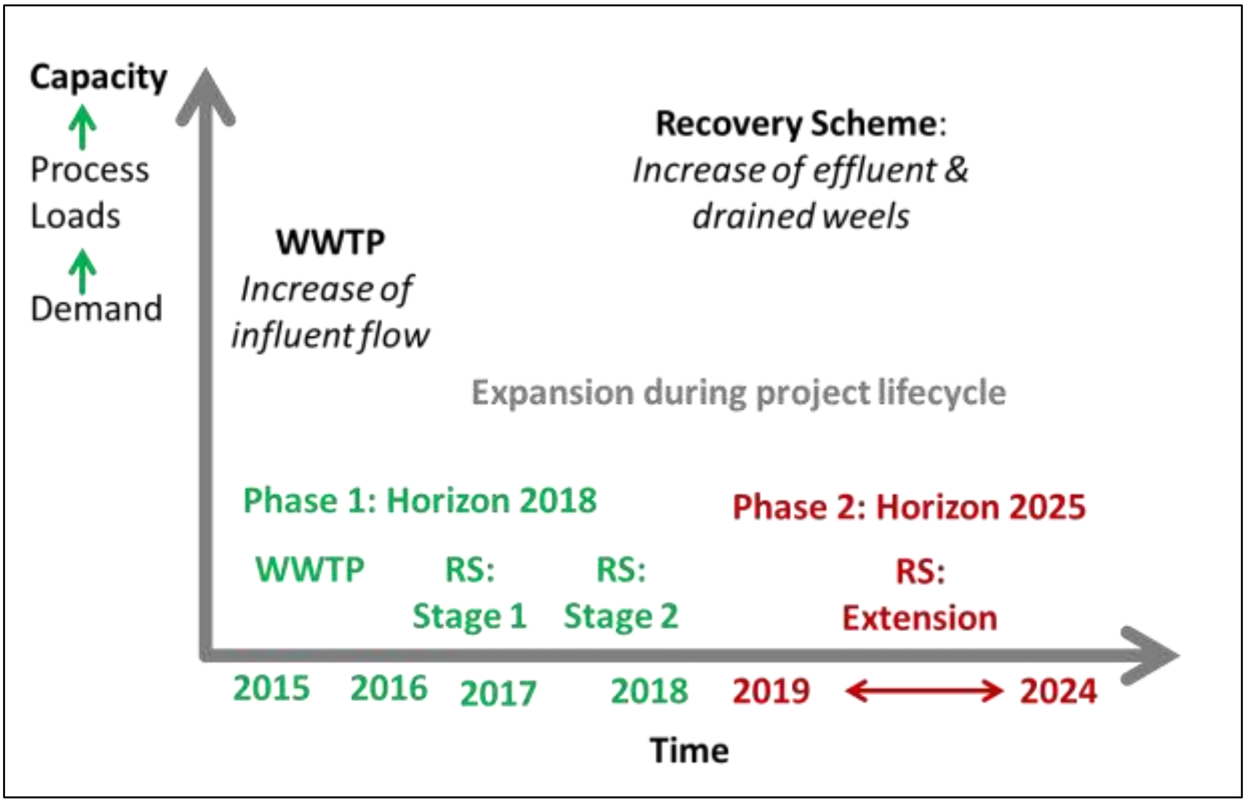
Figure 2-7: Annual course of irradiation and temperature

3. Analysis of Loads and Consumption

3.1 Design Loads

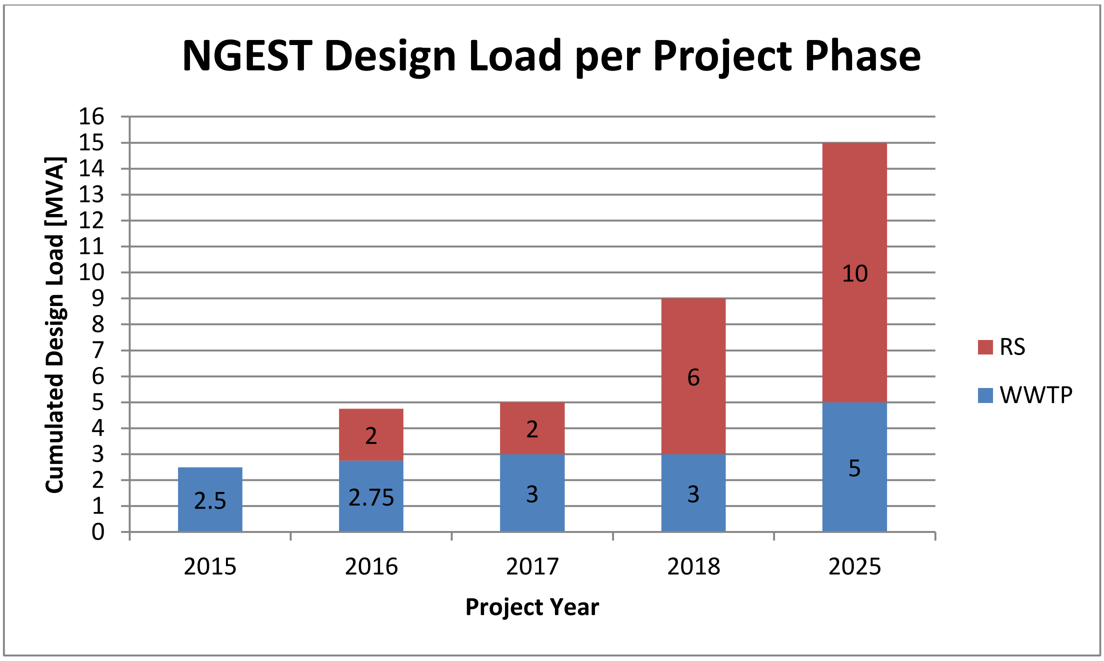
As outlined in the introduction, the capabilities of the wastewater processing and the volume of effluent pumping will be scaled up during the project phases and extension stages. Likewise, energy consumption increases proportionally and requires an upgrade of the capacities. This development of energy demand, process loads and the subsequent requirement on increased generation capacity during the project lifecycle is illustrated in Figure 3-1.

Figure 3-1: Energy demand, process loads and power requirements over project lifecycle



During the planning and design of the WWTP and RS, the individual process components had been selected in accordance with the estimated inflow volume. Based on the power consumption and operation time of each device the total design load of each phase was determined. As shown in Figure 3-2, the total design loads will reach 9 MVA in Phase 1 (until 2018) and 15 MVA in Phase 2 (until 2025).

Figure 3-2: Installed and projected design loads during project lifecycle



The details of the demand profiles of the two locations at each phase are discussed in the following sections. This demand analysis forms the basis for the later energy balance described in section 7.2.

3.2 Waste Water Treatment Plant (WWTP)

The file "Consumers rev.01.10" received from PWA lists the demand details of the water treatment processes related consumers in the WWTP. For extracting the load profile of these consumers, some assumptions are taken into consideration:

- The profile of the inflow from the TPS is the single driver for the flow pattern at the WWTP.
- The daily profile is developed using the given hours of and load factors listed in the file. According to the discussion with PWA, the components of the WWTP which do not work continuously for 24 hours are estimated to form a peak load during the noon time. The starting time of each consumer was then set according to its daily operation hours, e.g. consumers with 8 hours of operation start at 08:00, consumers with 4 hours of operation start at 10:00 …etc.
- According to information provided by PWA, the inflow does not have any significant seasonality. The design of the WWTP does not show that greywater from street gullies and roofs will be treated at the WWTP. Consequently, the daily consumption profile of the WWTP is assumed to have similar characteristics throughout the whole year.
- Assumed power factor of 0.8 was applied to all design loads and power sources within NGEST[7].

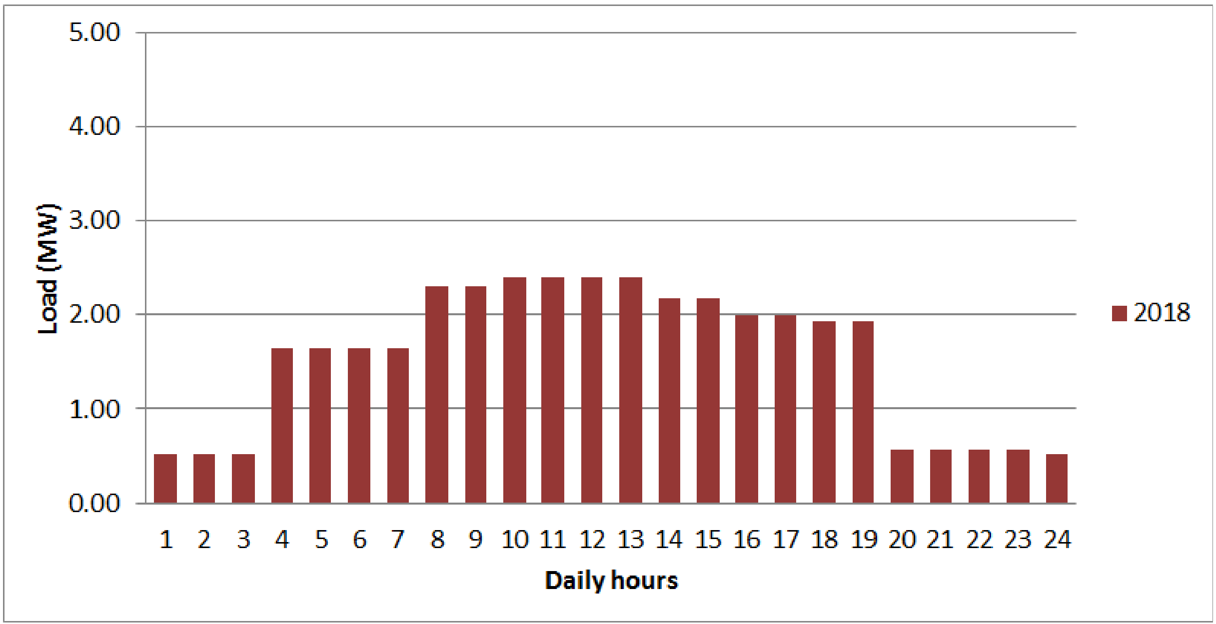
The demand of the WWTP per day for Phase 1 has a daily peak load of 1.3 MW and a daily energy consumption of 19.75 MWh. This process based demand was scaled from 1.3 MW to match the total design load values, e.g. 2.5 (2015), 2.75 (2016) and 3 (2017), provided by PWA in Table 12-15 for each

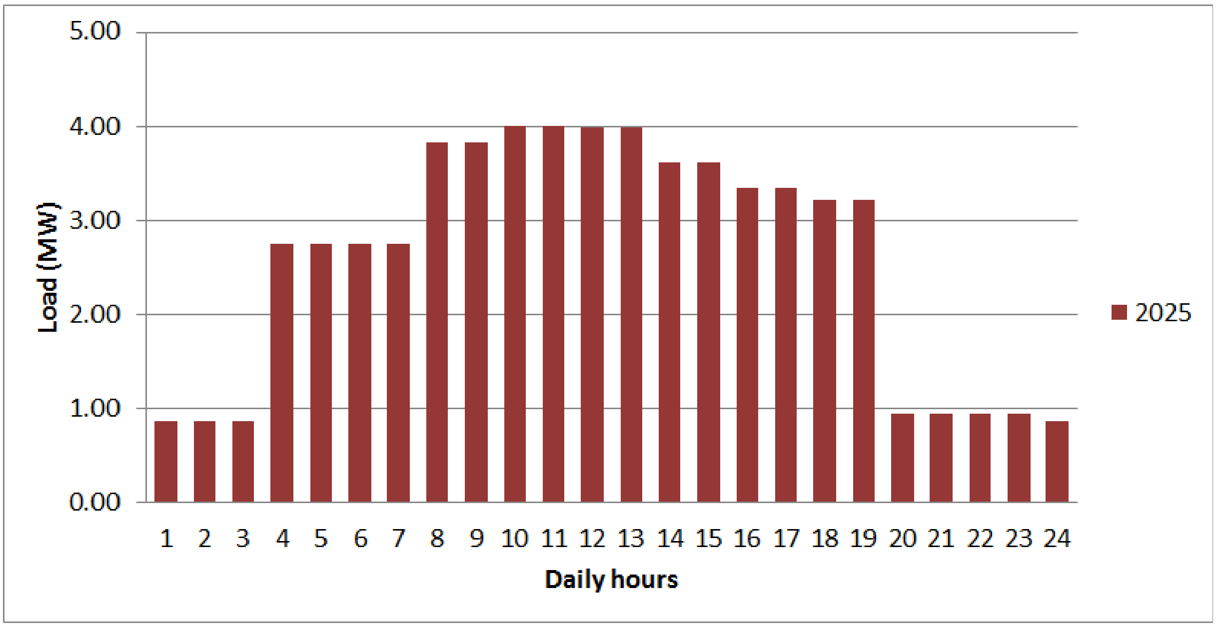
[7] Information and data on total design load [MVA] by PWA assumes the power factor 0.8 whereas the consumer data states demand of daily energy [kWh/d]

year (see also Figure 3-1). The scaling difference makes up the fixed consumption for lighting and security system, HVAC, control and general purpose sockets.

The daily profiles of the years 2018 and 2025 are shown in Figure 3-3. The resulting power consumption in 2018 is 37.31 MWh (46.63 MVAh), while the consumption in 2025 is 62.18 MWh (77.72 MVAh).

Figure 3-3: Daily load profile at WWTP for horizons 2018 and 2025

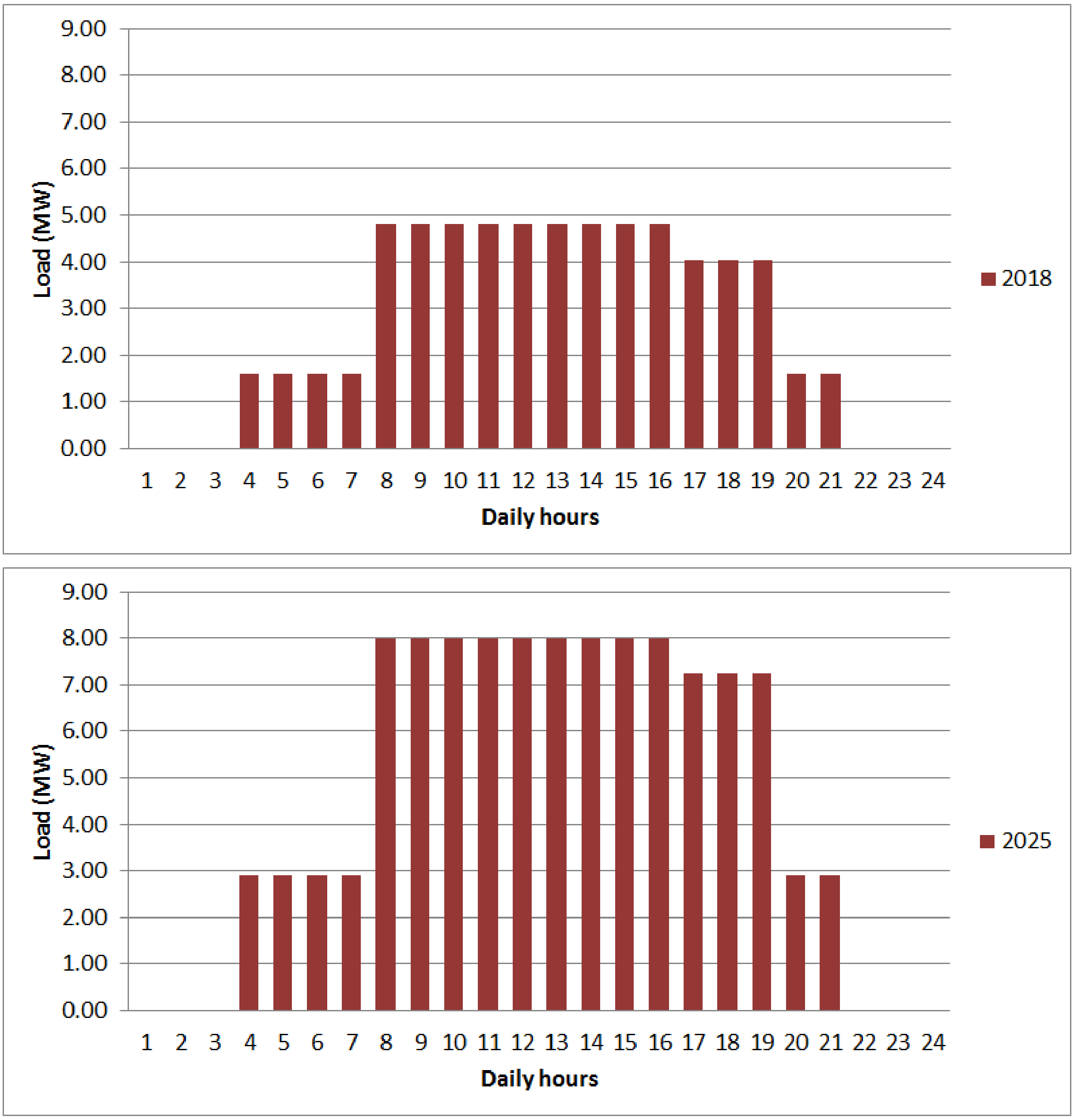




3.3 Recovery and Reuse Scheme

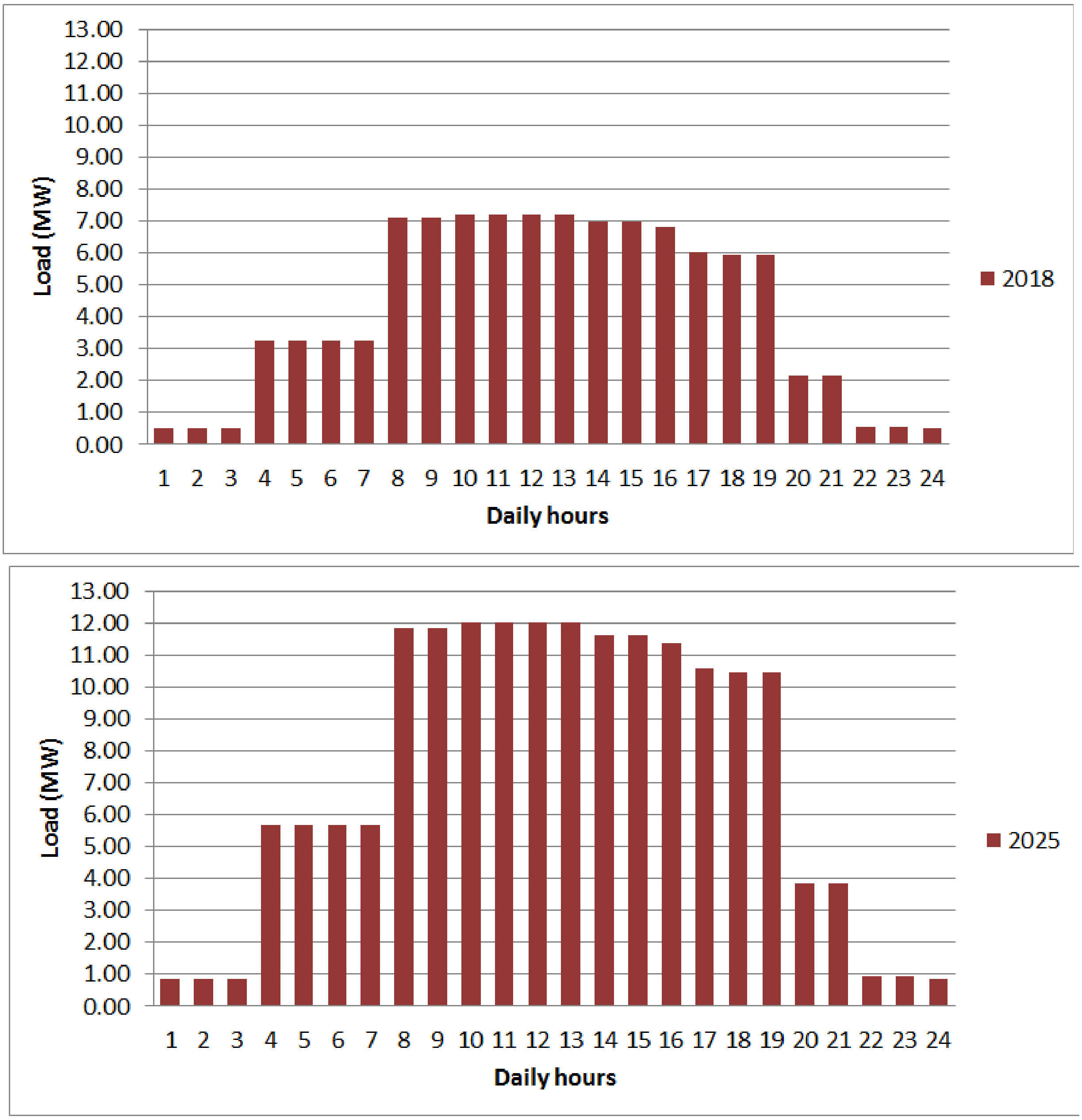
Based on the data received from PWA (Table 12-15), the designed load for the recovery and reuse scheme is 2 MVA for Stage 1, 4 MVA for Stage 2 and 4 MVA for the extension resulting in 10 MVA for the whole scheme. The demand at the RS is made up of two functions, the strong booster pumps and the recovery wells. The consumption of the wells is calculated directly from the provided data (55 kW/unit working for 6 hours per day). The total consumption of the pumps has been scaled in such way that consumption tops up the demand of the wells and thus reaches the designed load frame mentioned before (10 MVA) while applying the different utilisation factors of the devices. The total of the daily load profiles of the wells and pumps in the recovery and reuse scheme in Stages 1 and 2 expected for 2018 is plotted in Figure 3-4. The total energy consumption per day is 64.85 MWh (81.06 MVAh). After the implementation of the Recovery Scheme extension in 2025, the resulting daily consumption is shown in Figure 3-4 and totals to a daily energy consumption of 111.17 MWh (138.96 MVAh).

Figure 3-4: Daily load profile of recovery and reuse scheme for 2018 and 2025



On the basis of the individual load profiles of each of the two locations, the total load profile for NGEST has been derived by adding the loads and consumption at two locations. Figure 3-5 elaborates the total daily demand of NGEST in 2018 and 2025. As shown in the figure Figure 3-5, daily peak load reaches 9 MVA in 2018 and power consumption is 102.15 MWh (127.69 MVAh), while in 2025, daily peak load reaches 15 MVA and power consumption is 145.21 MWh (181.52 MVAh).

Figure 3-5: Daily profile of the total demand of NGEST in 2018 and 2025



Since no seasonality is taken into consideration and a constant power factor of 0.8 is assumed, the annual demand can be calculated as shown in Table 3-1. The total annual energy demand in 2018 is 37,286 MWh and in 2025 it is 63,271 MWh.

3.4 Annual Consumption

The annual energy consumption of the WWTP is 13.6 GWh and 23.7 GWh at the recovery scheme totalling to 37.3 GWh in 2018. The consumption of the NGEST project reflects the expansion in the planning horizon 2025, the consumption at the WWTP increases to 22.7 GWh per annum and the extension of the RS leads to 40.6 GWh annually resulting in a total demand of 63.3 GWh in 2025. The project demand is summarised in table Table 3-1.

Table 3-1: Annual demand summary of NGEST in 2018 and 2025

NGEST Components	Annual Energy Consumption			
	2018		*2025*	
	MVAh	*MWh*	*MVAh*	*MWh*
WWTP	17022	13617	28369	22696
Recovery Scheme (Stages 1 & 2)	29586	23668	29586	23668
Recovery Scheme Extension	0	0	21134	16907
Total	**46607**	**37286**	**79088**	**63271**

4. Current Power Supply

4.1 Current Power Supply Concept and Design

The current power supply concept – as a result of the general concept and the Contractor's design – consists of the following components:

1) External supply from the GEDCo grid via a 22 kV overhead feeder line (assessed in section 4.2)
2) On-site generation from emergency diesel generators described and reviewed for their capability to support further diversification of the generation portfolio in section 4.3.1.
3) On-site generation from biogas as by-product of the sludge treatment cycle described in section 4.3.2.

After review of existing designs and related documents (design review report, engineer's approval notes, and data sheets) the design process for the above components can be described as follows:

- The design load was derived from the maximum consumption resulting from the total of the fixed consumption of the general operation and the variable demand arising from the treatment plant process components.
- The diesel generators were designed to cover the fixed and variable load under the assumption that not all components are operating at the same time and even consumption would follow different patterns throughout the day (e.g. no lighting during day time, less need for HVAC during night).
- The dimensions of the biogas engine and related components like gasholder and gas flare are derived from the estimated daily gas production from sludge processing.
- The grid supply was installed to meet the full design load at Phase 1.

This means that the current design assumes that:
- supply is largely dependent on the grid;
- maximum possible utilisation of the existing biogas .

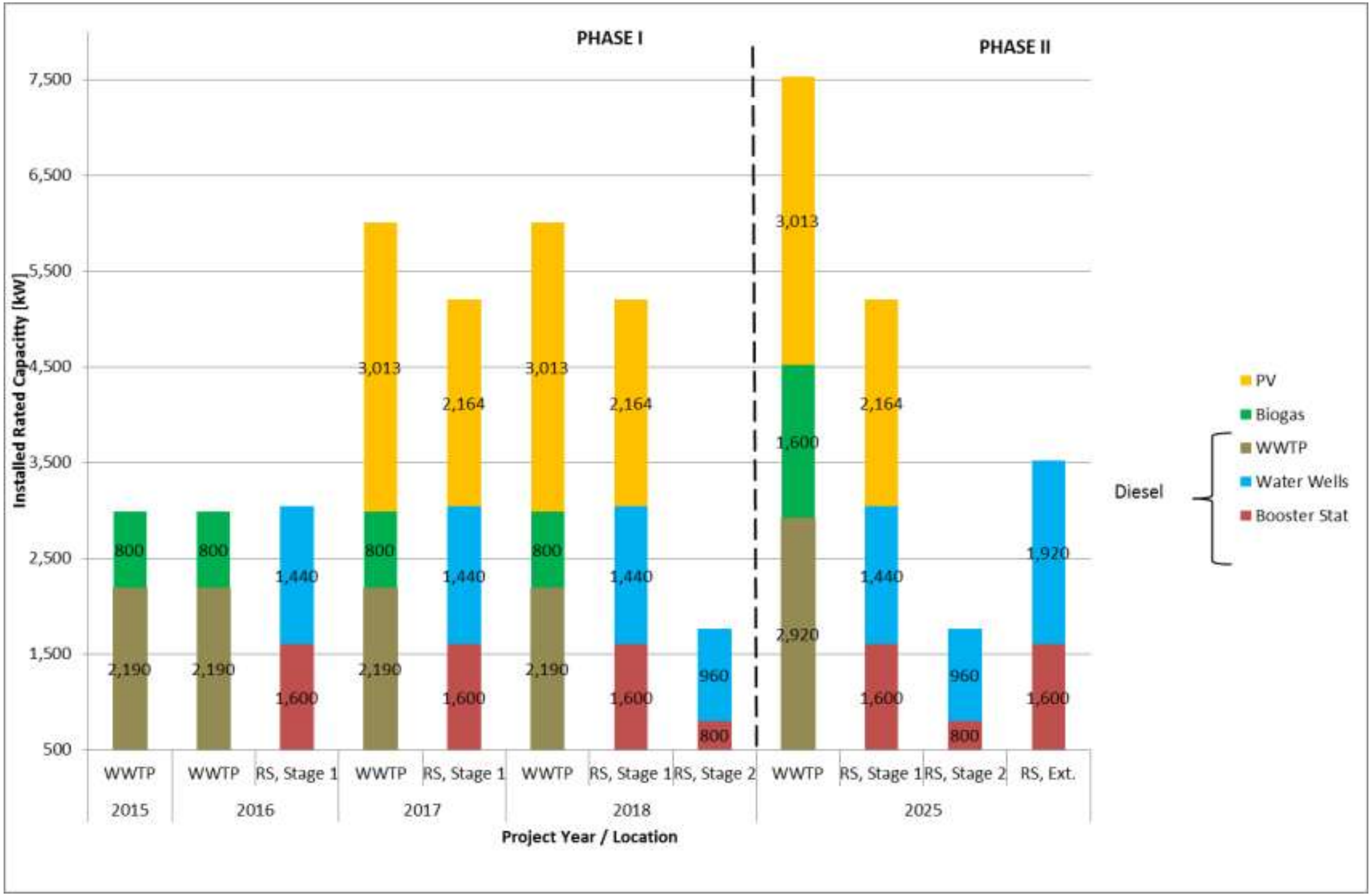
In the next Section 5.1, the modification of this setup by adding a PV system as additional on-site generation option is briefly described.

The number of planned generation units and the individual power rating corresponding to each unit are listed in Table 4-1. The illustration of the resulting on-site generation capacities in Figure 4-1 provides a good overview of the power sources installed at NGEST.

Table 4-1: Overview on generation units and capacities corresponding to the project timeline

Phase / Horizon		Phase I / 2018								Phase II / 2025			
Installation year		2015	2016		2017		2018			2019			
Number of units / sub-systems (rating per unit / sub-system)		*WWTP*	*WWTP*	*Recovery Scheme*	*WWTP*	*Recovery Scheme*	*WWTP*	*Recovery Scheme*		*WWTP*	*Recovery Scheme*		
				Stage 1		*Stage 1*		*Stage 1*	*Stage 2*		*Stage 1*	*Stage 2*	*extension*
Diesel	WWTP [kW]	3 (730)	3 (730)		3 (730)		3 (730)			4 (730)			
	Booster Station [kW]			2 (800)		2 (800)		2 (800)	1 (800)		2 (800)	1 (800)	2 (800)
	Water wells [kW]			3 (480)		3 (480)		3 (480)	2 (480)		3 (480)	2 (480)	4 (480)
Biogas [kW]		1 (800)	1 (800)		1 (800)		1 (800)			2 (800)			
PV [kWp]					12 (3012.88)	3 (2164.24)	12 (3012.88)	3 (2164.24)		12 (3012.88)	3 (2164.24)		

Figure 4-1: Total installed generation capacity per project year and location



4.2 External Supply: GEDCo Distribution Network

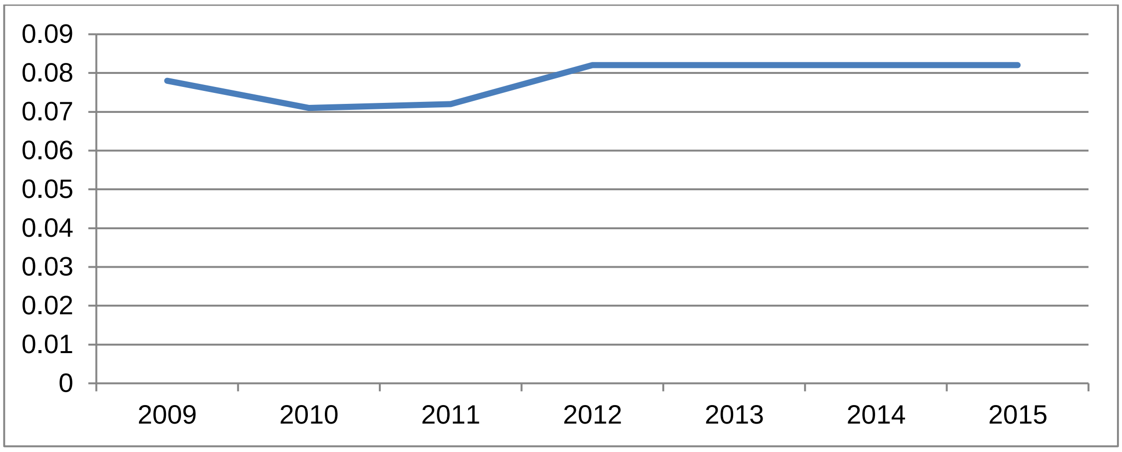
4.2.1 Brief Description of GEDCo

GEDCo is mandated to distribute electricity to all areas within the Gaza Strip under the control of the Palestinian Authority. Its responsibilities reach from billing, technical supervision and maintenance works, to improvement of the supplying system of the low voltage (0.4 kV) and the medium voltage network (22 kV). GEDCo is the sole provider of electricity services in Gaza.[8]. This means that based on Palestinian Law, any new Power Purchase Agreements with Israel must be done by the Palestinian National Authority (PA) with PETL[9] in the West Bank. In Gaza, GEDCo is the PA's partner. Consequently, such initiatives are political and legal matter in the hands of the PA but surpass the scope of a single project like NGEST.

GEDCo is a private limited company that is 50% owned by the Palestinian National Authority (PNA) and the other 50% by local municipalities and councils. The corporation was established in 1998 by ministerial decree and all duties of electrical energy distribution were transferred from the different municipalities in the Gaza Strip to GEDCo. Overall, the corporation delivers services through 5 branches in the Northern district, Middle area, Khan Yunis, Rafah and Gaza city, distributing energy to 1.8 million Palestinians.

GEDCo's distribution system is supplied from the IEC, the GPP and a small portion of energy is purchased from Egypt.[10] Due to GEDCo's control over the only three external power supply options in Gaza, it also has a price monopoly. While the Palestinian Territories have a unified sales tariff, GEDCo sets its own tariffs. As shown in Figure 4-2, these tariffs did not fluctuate over the last 3 years:

Figure 4-2: Average sales price Gaza (excl. VAT/in USD)

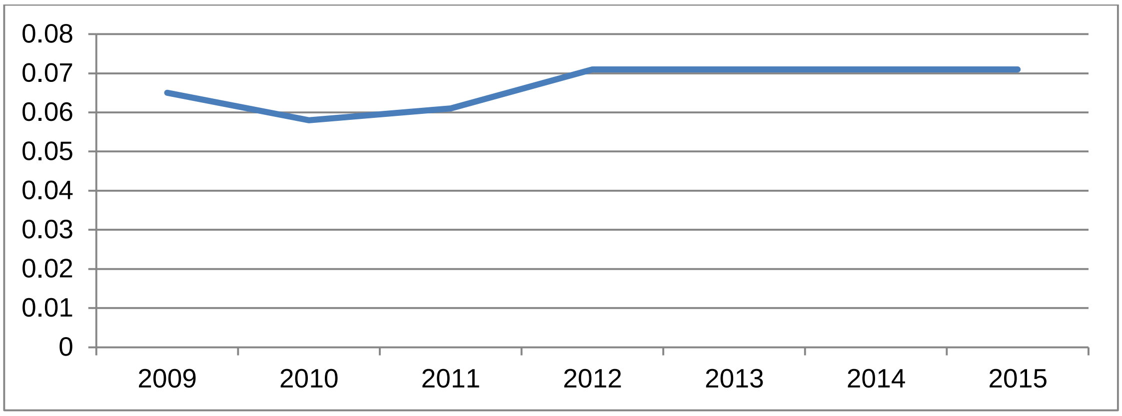


GEDCo's mark-up price and margin are particularly low when compared to the tariffs in the region, mostly due to the daily electricity cuts of 6-12 hours. Moreover, political reasons also influence the low retail price policy.

[8] http://www.gedco.ps/en/index.php, accessed on 30 March 2015
[9] Palestinian Electricity Transmission Company Ltd (PETL)
[10] World Bank Report, West Bank and Gaza Energy Sector Review, (2007)

The tariff margin – the difference between the purchase and the sales price – in Gaza is currently at 16%[11]. This margin should allow the conclusion that the purchase prices over the last couple of years looked as in Figure 4-3.

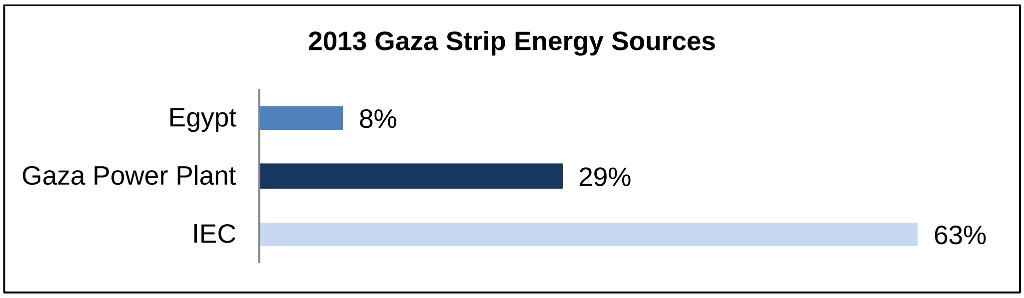
Figure 4-3: Average purchase price Gaza (excl. VAT/in USD) [12]



4.2.2 Power Purchase Sourcing

The Gaza strip has three different energy sources. The different share of these types on the total supply is presented in Figure 4-4 for 2013.

Figure 4-4: Share of energy purchase sources on total supply



There was unfortunately no information available on the sales tariff structures of GEDCo's three energy sources. GEDCo only clusters its customers in three categories but does not indicate the different source-purchase prices behind the overall tariffs as shown in Table 4-2.

[11] World Bank Report, Assessment and Action Plan to improve payment for electricity services in the Palestinian Territories, (2014)

[12] The data for the calculation of the average sales and purchase prices incl./excl. VAT were taken from the World Bank Report, Assessment and Action Plan to improve payment for electricity services in the Palestinian Territories, (2014) and is based on the assumption that GEDCos tariff margin is 16%

Table 4-2: GEDCo's customer categories and corresponding tariffs

Category	Users[13]	Range	Tariff (03/2015)[14] incl. VAT	Tariff (03/2015) excl. VAT
1	Residential	1-200 kW	0.11 USD/kWh	0.09 USD/kWh
2	Commercial	>201 - <1000 KW	0.13 USD/kWh	0.10 USD/kWh
3	Industrial users connected at low voltage level, industrial users connected at medium level, water pumps, agricultural areas, street lights and temporary services	>100 - <500 KW	0.15 USD/kWh	0.13 USD/kWh

Nonetheless, the following chapters 4.2.2.1, 4.2.2.3 and 4.2.2.2 will highlight the most important influencing factors of each source on NGEST's energy supply.

4.2.2.1 Domestic Production by Gaza Power Plant (GPP)

29 % of electrical energy used in the Gaza Strip is generated by the diesel fuel operated Gaza Power Plant.[15] The plant however, suffers from inadequate fuel supply due to sanctions from Israel on the amount of fuel permitted to enter Gaza, and due to high taxes imposed on fuel imports. These obstacles limit the overall electricity production of GPP to 50%. The power station requires a minimum of 400,000 litres of industrial fuel per day[16] to produce 65 MW[17],[18] while at least 450,000 litres per day are required to produce at its full capacity of 80 MW[19] with the current status of the facility. Due to the lack of fuel, there is a broad load shedding scheme, and severe continuous blackouts. Another source for the shortfall in generation is the effectively availability capacity at the plant. According to PENRA, the original capacity of the power plant is 130MW. After damages arising from bombardments the defective components were replaced. The newly installed transformers had a smaller capacity and thus it was not possible to recover the full capacity of the plant[20]. End of 2014 PEC reported to have repaired the plant

13 World Bank Report, Assessment and Action Plan to improve payment for electricity services in the Palestinian Territories, (2014)

14 Information on current tariff received from GEDCo Customer Service by phone

15 World Bank Report, Assessment and Action Plan to improve payment for electricity services in the Palestinian Territories, (2014)

16 United Nations Office for the Coordination of Humanitarian Affairs occupied Palestinian territory – OCHA (2013): PROTECTION OF CIVILIANS, WEEKLY REPORT 5 - 11 NOV 2013 , page 4, http://www.ochaopt.org/documents/ocha_opt_protection_of_civilians_weekly_report_2013_11_15_english.pdf

17 http://www.irinnews.org/news/2008/12/03/how-gaza-gets-power-analysis

18 Also confirmed by
Office for the Coordination of Humanitarian Affairs occupied Palestinian territory – OCHA (2014): The humanitarian impact of Gaza's electricity and fuel crisis, http://www.ochaopt.org/documents/ocha_opt_gaza_electricity_factsheet_july_2015_english.pdf
NOTE: released before the last damages during 2014 which also affected GPP as reported IDF strikes Gaza power plant , Haniyeh's home - Operation Protective ... - http://www.jpost.com/Operation-Protective-Edge/IDF-strikes-Gaza-power-plant-Haniyehs-home-369383

19 Office for the Coordination of Humanitarian Affairs (2009): Field Update on Gaza From the Humanitarian Coordinator, http://www.ochaopt.org/documents/ocha_opt_gaza_humanitarian_situation_report_2009_01_18_english.pdf

20 Office for the Coordination of Humanitarian Affairs occupied Palestinian territory – OCHA (2010): Gaza's Electricity Crisis: The Impact Of Electricity Cuts on The Humanitarian Situation, the report contains also an overview on the energy supply situation, http://www.ochaopt.org/documents/ocha_opt_gaza_electricity_crisis_2010_05_17.pdf

which now achieves a peak power of 92.40 MW[21].

Since GEDCo is incapable of guarantying constant power to consumers in Gaza, it also stated its inability to supply NGEST's full demand for electricity, in its power supply agreement with PWA signed in September 2013[22]. Therefore, the grid will not be able to be used as the only power source for NGEST.

4.2.2.2 Sourcing from Egypt

A share of up to 8% of the electricity consumed in the Gaza Strip is imported from Egypt[23]. GEDCo purchased 124,521 MWh from the neighbouring country in 2012 at the cost of 7,318,119 USD (purchase price 0.05 USD/kWh).[24]

While power shortage remains a key predicament in Gaza, additional electricity imports from Egypt seem highly unlikely in the next couple of years due to energy shortages in Egypt, and as the political tensions persist between the administration in Gaza and the current Egyptian government.

4.2.2.3 Sourcing from Israel (IEC)

In addition to domestic power production, GEDCo is supplying NGEST with electricity imported from Israel. The Palestinian territories are largely dependent on imported energy from neighbouring countries. Around 88% of the energy consumed in both the West Bank and the Gaza Strip comes from Israel through IEC.

Purchasing electricity from Israel has been challenging due to the issue of non-payment for electricity services in the years from 2010-2013. Around 37% of the bills from IEC to electricity distributers in West Bank were not paid in 2013. In Gaza, non-payment to the IEC is 100%. GEDCo was the largest non-payer in the Palestinian territories from 2010 – 2013, accumulating a staggering debt of USD 471 million.[25]

This non-payment or the so-called net lending has reduced the PA's available revenues by an estimated USD 280 million in 2012. In February 2014, the debt amounted to a total of USD 330 million. Even if this debt were to be reduced or dropped by IEC through common agreement with the PA, new debt would accumulate over the next couple of years.

Therefore, actions need to be taken to address and resolve the underlying problems of non-payment for electricity services in the Palestinian Territory. In addition IEC supply is not sufficient to meet the demand in GEDCo's grid and therefore it does not grant NGEST autonomy over its energy supply.

---

21 Palestine Electric Company (2015): Finance performance – Results for 2014, http://www.pec.ps/index.php?lang=en&page=headline&id=T1dWbVlUZzNaVEUyTkRrNU5XRTNOelF6WldOaE9XRmtOak13TWpsbVlUUk5WR2N6NDAzMDQxZWQzZTFjZTlhNzcyNTAyNzQ5Mzg0MjM1ZjI

22 Power Purchase Agreement GEDCo/PWA of 23 September 2013, supplied to Consultant by PWA officials

23 World Bank Report, Assessment and Action Plan to improve payment for electricity services in the Palestinian Territories, (2014)

24 Estimate based on a kWh price of 0.45 EGP (exchange rate EGP/USD 0.1306)

25 World Bank Report, Assessment and Action Plan to improve payment for electricity services in the Palestinian Territories, (2014)

4.2.3 Economic Review

Based on the information gathered and presented above, an economic review of GEDCo's tariff structure was conducted. The following inputs were considered:

Global data:

Assessment period:	20 years
First year of assessment:	2015

GEDCo tariff to NGEST:[26]

0.15 USD/kWh incl. VAT
0.13 USD/kWh excl. VAT

Specific financial parameters:

Discount rate:	7%
VAT:	18%

The Levelized Cost of Electricity was obtained using this formula:

$$LCOE = \frac{I_0 + \sum_{t=1}^{n} \frac{A_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{M_{t,el}}{(1+i)^t}}$$

LCOE	Levelized cost of electricity in Euro/kWh
I0	Investment expenditures in Euro
At	Annual total costs in Euro in year t
Mt,el	Produced quantity of electricity in the respective year in kWh
i	Real interest rate in %
n	Economic operational lifetime in years
t	Year of lifetime (1, 2, ...n)

Variation of LCOE: +/- 5% to +/- 10%

NGEST is currently paying 0.15 USD/kWh (0.6 ILS/kWh incl. VAT) as agreed upon in the power purchase agreement between GEDCo and PWA. The NGEST tariff is the equivalent to GEDCo's category 3 sales tariff for "industrial users connected at low voltage level, industrial users connected at medium level, water pumps, agricultural areas, street lights and temporary services".

The end user tariff of GEDCo has been analysed by a calculation of the economic Levelized costs of Electricity (LCOE) over an assessment period of 20 years, starting in 2015 under consideration of GEDCo's tariff excl. VAT of 0.13 USD/kWh offered to NGEST.[27]

This approach shows what the LCOE would look like if GEDCo had to supply the full energy demand of

[26] Tariff according to Sept. 2013 Agreement between GEDCo and PWA

[27] It should be noted that in absence of some relevant information, in particular the percentage of operation costs in relation to the costs of the energy purchased by GEDCo they were estimated at 20%

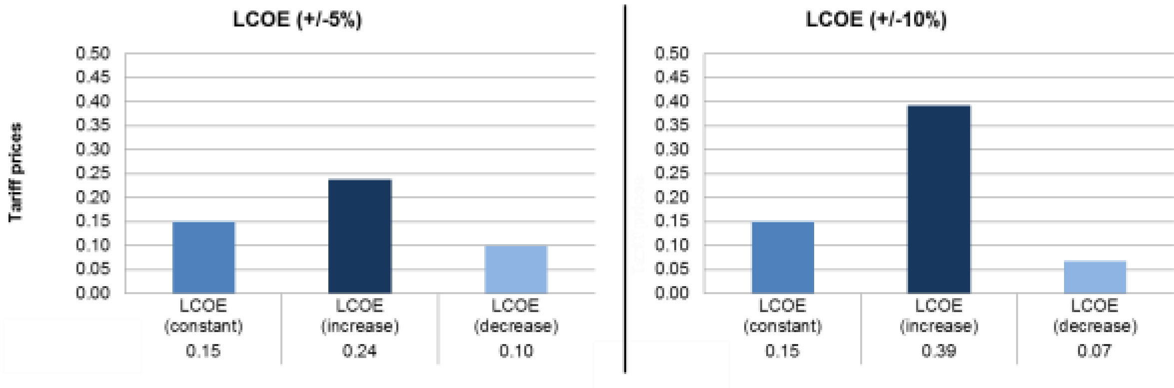
NGEST. The equivalent evaluation corresponding to the different supply options assessed can be found under section 0 of this report.

For the LCOE the following variants were considered:

- Constant
- Increase (5 and 10%)
- Decrease (5 and 10%)

The fluctuations were put into place in order to show different price variables and give a better insight into possible future developments, i. e. changes on the agreement between GEDCo and PWA for the power supply of NGEST. Of course the variations in price levels cannot conclusively be assessed over a period of 20 years but the levelization gives a comprehension of constant price, increased price and decreased price. The differences of the LCOE's are shown in Figure 4-5 below.

Figure 4-5: Levelized Costs of Electricity +/- 5 and 10% (prices indicated in USD/kWh excl. VAT)



The constant economic price of 0.15 USD/kWh (excl. VAT) can be predicted for the energy tariff from GEDCo if the price guarantee remains as is. In the variation "increase" it ranges between 0.24 USD/kWh at 5% and 0.39 USD/kWh at 10%. In the variation "decrease" it ranges between 0.10 USD/kWh at 5% and 0.07 USD/kWh at 10%.

4.2.4 Technical Capacity of the OHL Connection Line

As described under site conditions, in Section 2, the WWTP and RS are connected to GEDCo network by one 22 kV OHL exclusively built for supplying the project. Based on information provided by PWA, the network connection is exactly designed to provide the design load of 13 MVA targeted for Phase 2. A brief check of the dimensioning of the conductor (3x150/25 mm² ACSR Conductor Type Rabbit) reveals that the line capacity would only be reached if very high ambient temperatures are observed or additional power is routed through this line. Once NGEST is complete (including Phase 2), there will be no room for feeding of excess energy, i. e. surplus PV power, from NGEST facilities back to the network during the periods of high-energy demand at the site or during high temperatures. The solution proposed in Section 12.4 fulfils this constraint.

4.2.5 Technical Availability of the Grid

Even though the capacity of the connection line is sufficient, the actual capability of the network to supply the required power cannot be confirmed. As mentioned before the availability of electricity from GEDCo is not guaranteed at all times due to political reasons. The distribution company therefore responded to this constraint by implementing a rotational load shedding scheme throughout the Gaza Strip. GEDCo network is subject to cuts and connects as follows:

- 6 hrs ON and 12 hrs OFF or
- 8 hrs ON and 8 hrs OFF (depending on fuel availability for the GPP)

All consumers are thus forced to either remain idle during the blackout times or to compensate for the deficit of the grid by installing on-site generators. This pattern is used in the calculation of the energy balance in section 7.2 to assess the extent to which the demand could be covered by the regular network.

4.3 On-site Generation

4.3.1 Emergency Diesel Gen-sets

The three diesel gen-sets installed at WWTP are of the characteristic presented in Table 4-3.

Table 4-3: Diesel engine characteristics

Parameter	Value
Manufacturer	FG Wilson as container installation
Electrical output	380-415V, 50 Hz
Speed	1500 rpm
Engine make & model	Perkins 4006-23TAG2A
Alternator from	Leroy Somer, LL7024L
Rating by operational mode (*ratings at 0.8 power factor)	
Prime	730 kVA / 584 KW*
Standby	800 kVA / 640 kW*

For the diesel fuel quality the following standards shall be respected:

- ASTM D7467
- EN 590

When assessing the igniting quality, the cetane index may serve as reference. In comparison to the biogas engines the diesel engines can be easier to operate due to the quick response to an immediate charging or discharging.

4.3.2 Biogas-based Generation

4.3.2.1 Biogas Engine and Sewage Gas

The biogas-based electricity production capacity was designed by the NGEST Contractor and was based on data on the volume of waste water to be treated in NGEST (and hence resulting sludge).

A gas engine generator set with the key properties shown in Table 4-4, taken from the datasheet dated 16.04.2012, is currently installed. Another machine with the same characteristics is planned to be added in the next phase.

Table 4-4: Properties of the gas engine

Parameter	Value(s)
Engine:	MWM TCG 2016 V16 C
Speed	1500 rpm
Generator	Marelli MJB 400 LC4
Voltage / voltage range / cos φ	400 V+/ -5% / 1
Frequency	50Hz
Electrical power (COP) acc. ISO 8528-1	800 kW

The fuel for operation of the engine is the sewage gas produced by the water treatment process. In order to allow a smooth operation of the generator, the gas has to adhere to certain properties. The sewage gas shall be dry, when entering the storage tank. Furthermore the sulphur content has to be eliminated by a special process-technology. Otherwise the “inside atmosphere” of the gas engine will create sulphurous acid (H2S) and sulphuric acid (H2SO4) which will cause extensive corrosion problems and shorten the life-cycle.

An important characterising figure is the Methane index. The methane index describes the ignition quality of a fuel gas. A methane value of 100 is presented by methane CH4, a gas with a very high ignition quality resulting in smooth burning without any knocking. In this case it is not necessary to equip such an engine with knocking sensors. A methane number of 0 is presented by hydrogen, which shows a very poor combustion quality with precipitated uncontrolled ignitions.

In terms of ignition quality sewage gas is a very good and acceptable fuel gas. However the high CO_2 content makes the engine very slow in taking step charges. Thus, differing heating values have to be considered. It needs to be mentioned that reciprocating gas engines tend to load fluctuations which are difficult to be handled and eventually will cause vibrations.

4.3.2.2 Biogas Production

The average gas production is 6,576 m^3/d, while the peak gas production is 7,307 m^3/d based on the scenario of 2018. In order to obtain the biogas production value for the 2025 scenario, the above values are scaled based on the increased capacity of the WWTP in 2025 from 3 MVA to 5 MVA; resulting average gas production is 10,960 m^3/d while the peak gas production is estimated at 12,178 m^3/d.

4.3.2.3 Electricity Generation from Biogas

According to the provided biogas generator catalogue, the electrical output capacity of the generator is 800 kW, with operating hours of 20 hours/day, resulting in an energy generation of 16,000 kWh. The annual electricity production totals to 5,840 MWh/year. An additional biogas generator will be installed by 2018 to be ready for operation in 2019 and onward, increasing the electrical output capacity to 1,600 kW and annual electricity production to 11,680 MWh/year, provided that the required gas amount is available.

4.3.2.4 Gas Storage

With an electrical efficiency of around 43%, the input energy is 37,420 kWh. The amount of fuel supply needed for satisfying the energy input can be calculated from the fuel specific energy content, which is 6.5 kWh/m^3. Accordingly the amount of fuel required per day is 5,757 m^3/d.

In 2018, the average annual storage amount of biogas is 819 m^3/d, while in 2025, the average annual storage is -600 m^3/d, which leads to a lack of gas required to operate the generator at full load.

As a result, the potential of gas storage is low; the stored amount is less than 15% of the used amount for fuel input. This amount is too small to justify the addition of an additional generator in Phase 1 or even enlarging the storage. In 2025, gas storage potential is of a negative value. Both values lead to the conclusion that biogas generation has been sized well to fit the estimated gas production.

5. Photovoltaic System

5.1 Intended Modification by Adding a PV System

The existing power supply summarised in the previous sections shall be modified by installing a PV system on suitable free areas of the project. The aim of the modification is to

- reduce the operation times and effective load of the emergency diesel generators in order to save fuel during load shedding hours;
- increase the share of energy from renewable energy sources and thereby to reduce GHG emissions.

Consequently, the proposal for modification of the existing design consists of:

1) Installation of a PV system on the available areas within and around the NGEST site (as described and assessed in section 5.1);
2) Analysis of the potential for an increase of the biogas holder in order to store the produced gas during times of high PV production and balancing of the variable PV output in times of low generation (e.g. evening hours, during cloud cover), described in section 7.2 and;
3) Analysis and identification of adjustments in the energy management and control of the generation systems for optimisation of the interplay of components, especially during times when the project is in off-grid (island) mode as evaluated in section 7.3.3

5.2 Approach for the PV Design

The design uses the results of previous assessments on solar energy and application of PV technology in the Palestinian territories:

- A dedicated study on the general market potential of solar power in The Palestinian territories and strategies[28] for its adoption.
- The solar resources and energy generation potential[29] have been analysed on country level in the Atlas of Solar Resources.
- The renewable energy generation including solar PV technologies were assessed for their contribution to energy supply in The Palestinian territories.[30]
- A draft renewable energy law has been formulated by the Government in 2015.[31]

The report on renewable energy sources[30] provides a good introduction to the technologies, general system set-ups and comparison of typical design variants. Thus, this section on PV design variants presents possible solutions for the requirements of the NGEST project.

The PV plant design itself was developed in a two-step approach:

1) Assessment of variants: definition, description and ranking of possible design variants;

[28] PENRA (2012): Palestine Solar Initiative, Project Report by PwC
[29] PEA (2014): Atlas of Solar Resources – State of Palestine by SolarGIS/GeoModel
[30] PENRA and World Bank (2011): Assessment of Renewable Energy Sources
[31] World Bank (2015): General RE strategy law

2) Elaboration of concept design (Basic Design): a design as input to a functional specification for the most favourable variant.

5.3 Planning Target and Design Conditions

The design target for the PV system is to achieve maximum output though a cost-effective configuration, while maximizing the use of the allocated areas.

More specifically, the PV plant will be designed to adhere to the following technical design conditions:

- The plant should be designed as grid-connected PV plant tied-in to the existing network and managed by the NGEST SCADA – meaning that the grid will be built and managed by another component and the PV system will synchronise thereon;
- It is critical to optimise the use of the designated and available areas for ground mounted generators and roofs of the major buildings as provided by PWA/NGEST and so the PV plant will encompass several sub-systems;
- It should employ only proven technology for the system components;
- It should have maximised yield using the available areas by the choice of:
    - appropriate technologies for key components;
    - a suitable connection to the LV and HV distribution panels;
    - an optimum plant geometry: tilt angle, and azimuth.
- The plant should be developed in a way that maintenance can be performed easily by trained and skilled local technicians and where the requirement for specialised spare parts is reduced as much as possible.
- It should allow for an uninterrupted operation of the treatment plant facilities itself and seamless co-operation of all components of the power supply system through tight integration with the existing electrical infrastructure of NGEST.

5.4 Design Variants

5.4.1 Technology Selection for Key Components

The technologies for the main components, modules and inverters, are pre-selected based on the following considerations. For instance, crystalline silicon (c-Si) technology is regarded as preferred cell technology for the PV modules, based on (1) the track-record; (2) current market share of such modules; and (3) the average rated power.

The higher rated capacity of the c-Si modules when compared to other technologies such as thin film modules would also lead to a higher yield per available area. Nevertheless, the potential higher output of c-Si based PV arrays is demonstrated by comparing simulation results of the c-Si variant with the highest production against the results of an alternative configuration using thin-film modules.

Small and light but yet well performing de-central multi-string inverters are regarded as the most appropriate choice for NGEST. This type offers simple handling and thus allows for easier maintenance procedures. The resulting topology of the PV arrays would allow for a high level of flexibility in the design and installation. Since the inverters are attached to the mounting structures or installed on the roof-top space need for DC cabling over long distances is reduced and the outgoing AC cables could be connected at any suitable location in the electrical infrastructure of the NGEST project (e.g. the LV panels of buildings). The small multi-string units facilitate connecting lower (partially shaded rows) to a dedicated MPPT input and therefore reduce impact of shading.

The use of smaller rated inverters, in comparison to one or two central inverters per each array, leads to a quite significant number of inverters. They are managed by the PV monitoring system, which also provides the necessary functions to identify and localise faulty equipment. The SCADA system concept is described in section 5.5.4. The modularity of the configuration leads also to a higher redundancy. This means that the impact of maintenance failures and shortcomings as well as external damages (e.g. by vandalism or missiles) is reduced and replacement can be carried out easily. Central inverters require highly skilled and specialised technicians. Such work is usually conducted by the staff of the manufacturer and would be affected by the issues that make trips to the project location difficult, e.g. because of security concerns or closings of the crossings. Market trends have shown that the multi-string segment has become more and more powerful in the recent years in both performance and power rating. Its efficiency is more or less on par with the central inverter and the price difference between the two types has decreased significantly.

The selected inverter type is suitable for outdoor installation because its housing is IP 65 protected. It does not require to be placed in dedicated technical rooms. The inverters will be attached to the back side of the mounting system. This makes a dedicated heat evacuation obsolete, as the units have on-board ventilation and wind can circulate around. This is regarded as advantage in this project with its scattered installation areas.

5.4.2 Description of Possible PV System Configuration Options

The basis for the development of the PV variants is the CAD drawing[32] with the designed PV areas defined by PWA.

With the key components defined (section 5.4.1), the possible PV design variants are mainly determined by the adaptation of PV arrays and structures to the geometry of the designated areas and the different mounting structures. They are distinguished by variations in the main configuration parameters of the mounting system: the tilt angle and the azimuth.

The possible configuration options for the rooftop areas are:

1) Fixed structures with optimum orientation at azimuth 0° – i.e. modules facing true south – and using the optimum tilt angle;
2) Fixed structures with geometry adjusted orientation where modules are aligned to follow the geometry of the area (i.e. in parallel to the roof edges) and the tilt angle is modified in such a way as to maximise installation capacity, if appropriate;
3) Fixed structures but with East-West orientation and a lower inclination angle.

For the brownfield areas, where ground-mounted structures will be used, more mounting options are available:

1) Fixed structures with optimum orientation at azimuth 0° – i.e. modules facing true south – and using the optimum tilt angle;
2) Fixed structures with geometry adjusted orientation where modules are aligned to follow the

[32] 01 - Updated DWG - Final Grid Survey 23.2.2015_Coord Isr 1989 17.3.2015.dwg

geometry of the area (i.e. in parallel to the main area borders) and the tilt angle is modified in such a way as to maximise installation capacity, if appropriate;

3) Fixed structures but with East-West orientation and a lower inclination angle;
4) A series of 1-axis tracker arrays;
5) Two-axis trackers, which can be installed on all available areas and additionally the banks between the infiltrations basins.

5.4.3 Preliminary Qualitative Evaluation of PV System Configuration Options

After an initial qualitative evaluation of the above listed configuration options, the following set-ups and areas can be discarded:

- The roof spaces on the silos and towers are not considered due to the circular geometry and small area.
- The East-West configuration, depicted in Figure 5-1, which became increasingly popular in the recent years, mainly for roof-top systems, offers the advantage of installing high module capacities by considerable saving on row-to-row space. Due to the lower tilt angle and orientation towards East-West, this configuration has a smother daily generation profile – both effects that are generally favourable for NGEST. This configuration was discarded from further detailed evaluation due to the following reasons:
    - High packing density leads to reduced space between the module rows. This makes it more difficult to access to the modules and string cabling and requires profound experience in maintenance.
    - The same technicians who will be responsible for the PV plant maintenance will probably also be in charge other components at NGEST. Therefore, access to the components for fault detection and defect remedy should be easy and all areas should have similar configuration. This would not be possible with the East-West variant
    - Since the areas are not strictly oriented in East-West/North-South direction and do not have a rectangular shape, the effect of higher capacity would not be leveraged on all areas.
    - East-facing modules would potentially lead to glare and blending of the military border installations of the Israeli military.
    - The variants in this feasibility study shall demonstrate the range of potentially feasible solutions in order to select the degrees of freedom for technical requirements of the bidding documents. E-W configuration is regarded as possible and can potentially be allowed as possible solution in the bidding phase.
- One-axis trackers, similar to the two-axis trackers, enable to achieve higher yields by tracking the sun position in one or two dimensions throughout the day. Consequently, such configurations would theoretically increase the share of PV penetration in the power supply. But due to space requirements, trackers show their benefit only in larger multi-megawatt power plants, where the available area is not the limiting factor. In such projects and in contract to NGEST, investors aim to optimise the return on investment rather than the total system output. Apart from this general observation 1-axis trackers have minimum requirements on width of the installation area because one or many module tables are connected to one or more central motors via a gear or lever arms. The geometry and size of the given areas hardly meet this requirement. However 1-axis trackers are included in the further analysis to demonstrate this effect and to support the evaluation of variants with actual results.
- The situation with the 2-axis trackers is slightly different. Similar to 1-axis trackers a considerable space is required around each tracker structure to avoid that shadow from one tracker is casted on other trackers installed around. Thus the distance between structures is higher than

for the fixed structures. Since 2-axis trackers use single-pillar foundations instead of the multiple pole foundations aligned in longitudinal rows used by 1-axis trackers, this mounting option gives more flexibility in the placement of the units. The trackers could potentially be installed at locations, where other mounting structures would not fit, i.e. the high slopes of the infiltration basin embankments or the dams between the basins.

Summarising, the two mounting types – 1-axis tracking and 2-axis tracking – are not regarded as suitable for the design conditions. The E-W option as a variant of the fixed installations is regarded as feasible but not assessed further based on the reasons provided above. The tracked variants are included in the comparison of variants in order to substantiate the statements above. With this, the evaluation of variants includes the most promising configurations but also those variants that represent corner cases in this particular project.

Figure 5-1: East-West orientation on a rooftop, press photo by manufacturer Renusol[33]

5.4.4 Definition of the Evaluated PV System Variants

The complete PV system variants have been formed by a combination of the corresponding roof-top and ground-mounted configuration options explained in the previous sections. Based on the qualitative evaluation in section 5.4.3 and taken into consideration the design conditions, the following variants have been defined for further evaluation:

1) **Variant 1 – fixed structures with orientation true south with c-Si modules**
   a. *Roof-top area:* fixed structures with optimum orientation at azimuth 0° – i.e. modules facing true south – and using the optimum tilt angle;
   b. *Ground mounted***:** fixed structures with optimum orientation at azimuth 0° – i.e. modules

[33] Taken from http://www.bestforeastwest.com/, accessed in 03.09.2015

facing true south – and using the optimum tilt angle;

c. *Characteristic:* maximised output per capacity installed.

2) Variant 2 – fixed structures with geometric adaptation with c-Si modules

a. *Roof-top area***:** fixed structures with geometry adjusted orientation, where modules are aligned to follow the geometry of the area (i.e. in parallel to the roof edges) and tilt angle is modified in a way to maximise installation capacity, if appropriate

b. *Ground mounted:* fixed structures with geometry adjusted orientation, where modules are aligned to follow the geometry of the area (i.e. in parallel to the main area borders) and tilt angle is modified in a way to maximise installation capacity, if appropriate

c. *Characteristic:* maximised capacity per available area

3) Variant 3 – one-axis tracker with c-Si modules

a. *Roof-top area:* fixed structures with optimum orientation at azimuth 0° – i.e. modules facing true south – and using the optimum tilt angle;

b. *Ground mounted:* 1-axis tracker arrays;

c. *Characteristic:* optimised output on free field areas.

4) Variant 4 – 2-axis tracker with c-Si modules

a. *Roof-top area:* fixed structures with optimum orientation at azimuth 0° – i.e. modules facing true south – and using the optimum tilt angle;

b. *Ground mounted:* 2-axis tracker array, including dams and embankments of infiltration basins;

c. *Characteristic:* optimised output on free field areas with flexible arrangement.

5) Variant 5 – fixed structures with geometric adaptation with CIS modules

a. *Roof-top area:* fixed structures with geometry adjusted orientation, where modules are aligned to follow the geometry of the area (i.e. in parallel to the roof edges) and tilt angle is modified in a way to maximise installation capacity, if appropriate;

b. *Ground mounted:* fixed structures with geometry adjusted orientation, where modules are aligned to follow the geometry of the area (i.e. in parallel to the main area borders) and tilt angle is modified in a way to maximise installation capacity, if appropriate;

c. *Characteristic:* maximised performance per available area

Detailed parameters and corresponding values for these variants are presented in Table 5-1 supplemented by an explanation of the configuration angles in Table 5-1.

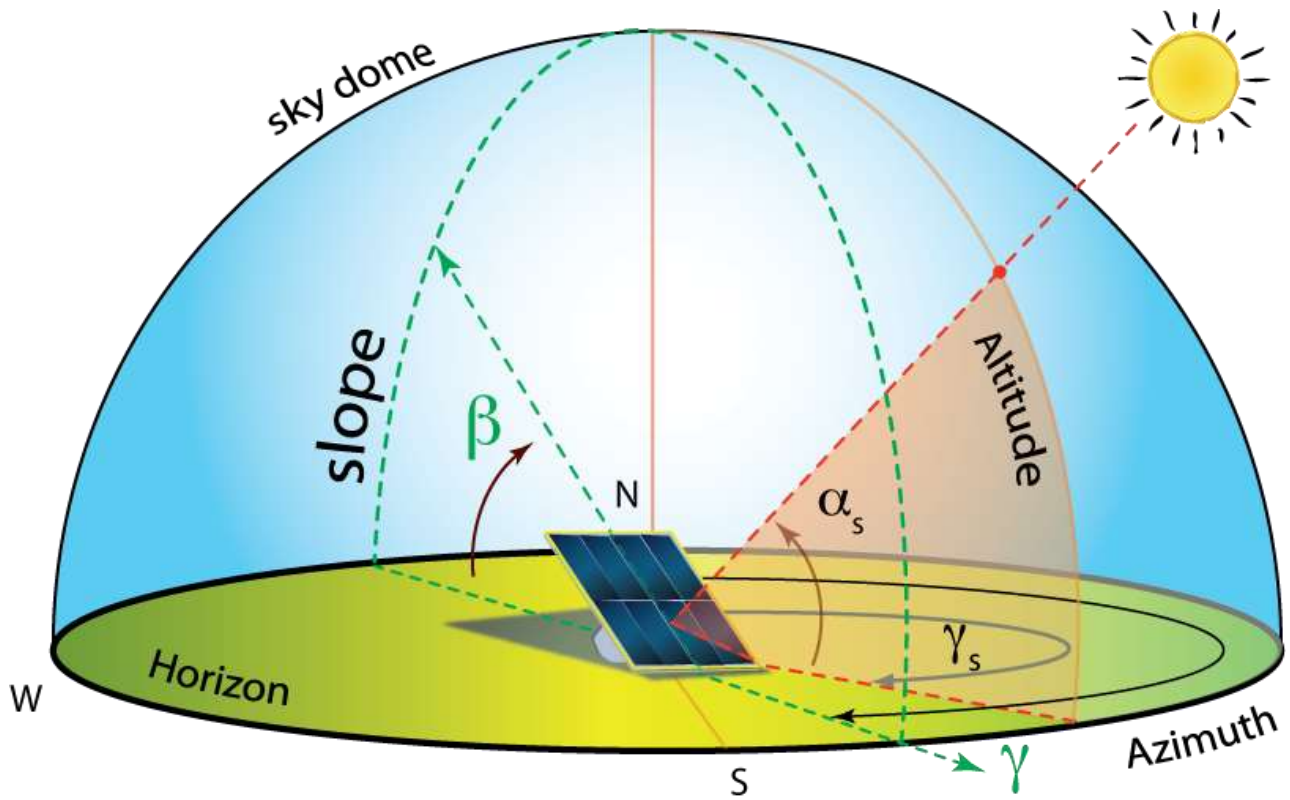
Key system indicators were derived and performance results were calculated for the defined variants in order to compare and rank the variants, and to finally select the preferred option. The details of the five variants and the methodology of comparison are explained in the ANNEX, section 12.3.1. The summarised results are provided in the next section.

Table 5-1: Key configuration parameters and values for the defined variants

Type of Instal-lation	Location	Area Code	Variant				
			1	2	3	4	5
			true south	follow the geometry	1-axis tracked	2-axis tracked	geometry
			c-Si	c-Si	c-Si	c-Si	CIS
ground-mounted	WWTP	A1	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 28.6$	$\beta = -45/45$ & $\gamma = -90/90$	$\beta = 0.0/80$ & $\gamma = -120/120$	$\beta = 25$ & $\gamma = 28.6$
ground-mounted		A2	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 42.3$	$\beta = -45/45$ & $\gamma = -90/90$	$\beta = 0.0/80$ & $\gamma = -120/120$	$\beta = 25$ & $\gamma = 42.3$
ground-mounted		A3	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 25.3$	$\beta = -45/45$ & $\gamma = -90/90$	$\beta = 0.0/80$ & $\gamma = -120/120$	$\beta = 25$ & $\gamma = 25.3$
ground-mounted		A4	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 34.6$	$\beta = -45/45$ & $\gamma = -90/90$	$\beta = 0.0/80$ & $\gamma = -120/120$	$\beta = 25$ & $\gamma = 34.6$
ground-mounted		A4'	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 28.6$	$\beta = -45/45$ & $\gamma = -90/90$	$\beta = 0.0/80$ & $\gamma = -120/120$	$\beta = 25$ & $\gamma = 28.6$
roof-top		A5	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 34.4$	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 34.4$
roof-top		A6	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 34.4$	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 34.4$
roof-top		A7	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 34.4$	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 34.4$
roof-top		A8	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 34.4$	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 34.4$
ground-mounted		A9	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 11.5$	$\beta = -45/45$ & $\gamma = -90/90$	$\beta = 0.0/80$ & $\gamma = -120/120$	$\beta = 25$ & $\gamma = 11.5$
ground-mounted		A10	$\beta = 25$ & $\gamma = 0$			$\beta = 0.0/80$ & $\gamma = -120/120$	
ground-mounted		A11	$\beta = 25$ & $\gamma = 0$			$\beta = 0.0/80$ & $\gamma = -120/120$	
ground-mounted	Recovery Scheme	A12	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 38.4$	$\beta = -45/45$ & $\gamma = -90/90$	$\beta = 0.0/80$ & $\gamma = -120/120$	$\beta = 25$ & $\gamma = 38.4$
roof-top		A13	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 39.2$	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 39.2$
roof-top		A14	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 39.2$	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 0$	$\beta = 25$ & $\gamma = 39.2$

β = module tilt angle γ = array azimuth (0 means towards equator / South, in this case)

Figure 5-2: Angle definition for description of PV collector configurations[34]



α	= solar altitude angle	β	= module tilt angle	γ	= array azimuth (0 means towards equator / South, in this case)

[34] Graphics by Jeffrey Brownson (2014): of Solar Resource Assessment and Economics, Penn State's College of Earth and Mineral Sciences, https://www.e-education.psu.edu/eme810/node/576

5.4.5 Assessment and Ranking of Variants

Using the system parameters and results as input (see the details on the variants in the ANNEX, section 12.3.2), variants 1 to 5 were compared. The key characteristics of the configuration are summarized again here to illustrate the differences in the configuration:

1) Variant 1
   a. a polycrystalline 60 cell module with a 25 kVA 3 phase inverter.
   b. Modules orientated to true South (Azimuth 0).
2) Variant 2
   a. a polycrystalline 60 cell module with a 25 kVA 3 phase inverter.
   b. Modules orientated to maximize space utilization instead of maximum yield.
3) Variant 3
   a. a polycrystalline 60 cell module with a 25 kVA 3 phase inverter mounted on a single axis tracker (N-S axis) to achieve a higher output.
4) Variant 4:
   a. a polycrystalline 60 cell module with a 12 kVA 3 phase inverter mounted on a double axis tracker to achieve the highest possible output by following the sun path.
5) Variant 5:
   a. a CIS module with a 25 kVA 3 phase inverter mounted.
   b. Modules orientated to maximize space utilization instead of maximum yield.

A summary of the key results and qualitative rating is shown in Table 5-2.

Table 5-2: Summary of the key results for all variants

Criterion	Variant 1	Variant 2	Variant 3	Variant 4	Variant 5
Total Capacity (kWp)	4821	5177	2058	1868	4148
Installation	+	+	-	-	+
Maintenance	+	+	-	-	+
Specific Yield kWh/kWp/year	1668	1635	1744	1783	1726
Confidence in PV Technology	+	+	+	+	0
Energy Generation MWh/ Year	8021	8502	3665	3440	7146

When comparing the space utilization, a significant difference between the fixed mounted systems and the tracker installations is identified. The lower capacity of the tracker installation is a result of the requirement for higher distances between the individual trackers needed to avoid shadows from one moving module area to the other in the morning/evening. Although the 2-axis tracker of Variant 4 can compensate some of this capacity deficit by its flexibility in positioning – the device can also be installed between the basins where all other kinds of PV lack ground area are to be mounted – it cannot even catch up with the single axis tracker in terms of installed capacity.

The rooftops only contribute with 154 kWp (Variant 1) to maximum 172 kWp (Variant 2) to the installed capacity. Due to this relatively small amount it might make sense to exclude them completely and concentrate on the ground mounted system. This would facilitate the execution of the project in several ways: less variety of components, no need for working in heights, elimination of the existing but technically manageable risk of water leaking through the roof.

The installation of Variants 1, 2 and 5 is relatively easy as there are no moving parts and modules are in comfortable working height. Variant 3 and 4 have motors so that the modules can follow the sun. Installation of this structure is more sophisticated compared to fixed ones.

The maintenance of trackers requires more effort. Motors can fail and every moving part needs more frequent inspection and maintenance. As a rule of thumb, maintenance of trackers can be regarded as twice as cost intensive as maintenance of fixed PV arrays.

The tracker-based solutions show the highest specific yield. Due to the sun tracking, more energy can be produced with the same amount of modules. Nevertheless, it is recommended to start with employing fixed mounted systems in new upcoming PV markets. The lower specific investment and operational costs are an advantage. Likewise the lack of understanding on how to install and maintain trackers can lead to malfunction of trackers, which would then reduce the actual yield significantly.

When comparing the specific yield of the fixed solutions the improved performance of the CIS technology based on thin film modules stands out clearly. Thin film modules in general are attributed to work better with diffuse irradiation and under high temperatures. In comparison with other thin film technologies, CIS modules show higher efficiency. But also this type of thin-film technology cannot be compared with polycrystalline modules technology when it comes to specific yield. The higher output is due to the higher conversion efficiency of c-Si modules. Consequently, the total energy output by polycrystalline modules is still higher than of thin film modules because this technology achieves more capacity on the same ground area.

Developed in the 1990s and in mass production since 10 years, CIS is a very promising but it is still considered the youngest generation of PV module technologies[35]. Critical effects like "light-soaking" are rarely discovered but they are hardly tested on field. An available field test only covers a few years.

The polycrystalline module used in the other variants is one of the oldest PV technologies, installed and approved in many GW of PV plants.

Finally, when comparing Variant 1 and Variant 2 it may be highlighted that by installing 7% of extra power, 6% more energy can be produced, which is a good compromise if maximizing energy production is the highest aim of this PV plant.

With the results from the preliminary design of the variants 1 and 2, the possible capacity and generation by the E-W configuration can be roughly estimated. Assuming a module tilt angle of 10° and using the

[35] Another thin-film module technology largely employed in utility scale projects is CdTe. In such settings, the technology achieves very low LCOEs. In the context of this particular project the technology is not regarded as suitable due to the following reasons: (a) The cadmium tellurite material is quite stable as long as the module is left intact. Concerns may arise that the toxic cadmium can be dissolved when the material is exposed to extreme heat (e.g. under a fire). Due to this reason the technology is less recommended for manned buildings and in areas with high risk of fire. (b) 2. Limited number of suppliers may lead to reduced choices of/for bidders (c) The comparison of variants aims to show the different configurations (fixed, orientation to follow area, tracked). The best configuration can equally be equipped with c-Si or thin-film. This depends on the specification and the contractor. And since the design target of the project is high energy output on the designated areas, higher installed power can be achieved with current silicon based module technologies. Even if the performance of (any) thin film is theoretically better than crystalline modules, this effect is outweighed by the higher area efficiency of c-Si modules

total net installation area of 75,68 m², the system capacity can potentially reach 8 MWp. This increase of capacity leads also to higher CAPEX. Due to the higher capacity, the E-W variant would not reduce the excess renewable energy generation observed during the peak hours (see section 7.2). This is because although the daily profile is smoothened by the orientation towards morning and evening hours, the additional capacity increases the daily peak leading to an increase of surplus energy at the WWTP during these hours. The annual yield for an E-W configuration is estimated at 10,926 MWh by scaling the specific generation for the exemplary area A7 with the potential capacity. Specifically on the largest roof area A7, an estimated capacity of about 57.2 kWp would generate 93 MWh/year, which results in a yield factor of 1638 kWh/kWp/year. The Variant 2 fits 43.7 kWp on the same roof but has a specific production of 1714 kWh/kWp/year, which yields 74.86 MWh/year. This shows that the configuration of Variant 2 is the most efficient in both – output, use of available space, and ultimately installation costs per generated energy unit. The E-W configuration maximises the available space and therefore offers the highest total annual output in absolute numbers. Since it still adheres to the design conditions it may be allowed as a possible variant in the bidding documents.

5.4.6 Selection of Preferred PV Design Variant

As a result of the assessment of configuration options and the comparison of the variants, Variant 2 is recommended as the preferred variant for the Concept Design. The advantages are summarized:

- highest installable capacity for the available area while maintaining quasi optimum configuration;
- Highest annual production;
- Moderate CAPEX;
- Relatively trouble-free operation due to absence of moving parts and facilitated maintenance with a fixed structure that can be repaired by local staff and contractors;
- Shows that in this case where absolute output is of more importance than financial return, fixed structures show clear advantages over trackers.

5.5 Conceptual Design for Preferred Variant

5.5.1 General Plant/Array Layout

The proposed 5.1 MWp design uses the concept of the selected Variant 2 and is mainly characterised by the following components:

- Arrays composed of poly-crystalline modules offering high efficiency at low cost;
- The fixed 25-degree racking structure is easy to install and has lower maintenance cost compared to tracking systems. The azimuth of the PV arrays was adapted to the designated areas instead of aligning all modules straight to south. This allows for maximizing the installed capacity and by that also yielding per area, expressed in kwh/m². The resulting higher installation capacity (+7%) outweighs the losses (-1%) in comparison to an optimal alignment of the system towards South.
- A decentralized inverter with sizes between 15 and 25 kVA was chosen not only to avoid mismatching losses between differently aligned areas, but also because of its simplicity in maintenance. These inverters can be exchanged by one single person, if necessary.

The 5,109 kWp PV plant can be divided into 2 different structure types. Free field - ground mounted systems, which holds with 18,986 modules (4,936.36 kWp) the major part of the installed power and rooftops with 663 modules (172.38 kWp). The electrical schematics can be found in the Drawing 010. In the free field always 22 modules in series create a string and are mounted on one table (independent mounting structure). For the rooftop in general also 22 modules make up one string but this rule is more flexible and, in order to reach the highest utilization of the roof-top space, sometimes strings with fewer modules are allowed. In any case the strings were designed in such a way as to never exceed the limiting inverter parameters like maximum and minimum MPP voltages, max system voltage or currents, considering local maximum and minimum temperatures.

Row spacing of 2.20 meters for free field and 1.10 meters for rooftop is necessary to avoid major shadowing from one row to the other. The above mentioned distances were defined to avoid row shading on the shortest day in the year (21st of December) for at least 4 hours, assuming a PV plant aligned to the South. Besides shadowing the row spacing is important to ensure good work flow in installation and maintenance. Both values leave enough space for installers to move between rows and if necessary even drive in vehicles.

The existing infrastructure at the NGEST facility can be used as temporary storages during the time of the installation of the PV plant as in Drawing 001 and Drawing 002 which are mainly already prepared and can be used.

There are three different types of connection for the separate PV areas to the electrical system of the NGEST facility:

1. The roof-tops sub-systems are connected on LV directly to the connection point of the building using the existing electrical infrastructure. This means no additional AC wiring is required to connect the roof-top to the electrical network. By choosing connection locations, the PV generation will reduce the building consumption to a lower residual demand (net balance).
2. The free field sub-systems are connected to the main switchgear of each location, i.e. the Blower and Energy Building of the WWTP and the Electrical Room at the RS:
    a. Using AC combiner boxes, the LV cables are guided to this panel.
    b. Due to the long distances between the areas A3 / A9 and the power house an extra transformer at A9 is included to elevate voltage allowing transferring the energy to the powerhouse at 22 KV, where it will also be connected in medium voltage. By using the higher voltages, the otherwise enormous cable losses could be avoided.

Since Gaza is located in a relatively humid area, all types of structures, racking, module frames, connectors, etc. should be made out of aluminium or galvanized steel.

5.5.2 Electrical Design

5.5.2.1 DC Side

- Due to the decentralized inverter solution, DC circuits are very simple. Depending on the inverter size, between 3 and 5 strings lead to one inverter. A string holds between 14 and 20 modules. The standard cable is a 6 mm² copper solar cable. This is sufficient to keep energy losses on DC and AC cabling in STC conditions below the established limit of not more than 2%. In places with extremely long distances 2 x 6 mm² solar cable or 1 x 10 mm² can be used.
- The inverter serves, apart from its principle function of converter of DC power into AC power, as the control unit brain of the PV array. Most of the protection and monitoring tasks are executed by it. The design limits itself to three different inverter sizes, 15, 20 and 25 kVA, in order

to keep complexity of the installation low.

- The inverter type used for all three sizes chosen in this conceptual design have an "All-pole sensitive residual-current monitoring unit" which substitutes the string fuse and a DC surge arrestor type II to protect against electrical surges and spikes. With this solution there is no need for external DC boxes between modules and inverter which simplifies installation and maintenance as well as reduces costs. A less sophisticated inverter would need a string box with a DC surge arrestor and 12 A to 15 A DC string fuses to secure the string against over and reverse currents that might occur during installation by switching positive and negative pole of one string in the system.

5.5.2.2 AC Side

- AC cabling starts with 16 mm² cables at the inverter and goes to a local AC combiner box positioned in a short distance to the inverter. These local combiner boxes gather cabling of up to 5 inverters and transfer the energy to the connection point. In the case of the rooftop systems, the energy distribution box of the proper building serves as the connection point. In case of the free field areas, and due to longer distances, cabling diameters of 240 mm² copper will be needed and in some places two cabling systems will have to be installed in parallel.
- The long distance of 650 m from area A3 and A9 to the point of connection creates a challenge for the transmission of energy. Long low-voltage cables shall be avoided because of the high losses. The voltage drop along long cables can lead to a mal-function where the inverter is not capable of recognizing the low voltage as the grid voltage. If no alternative solution was chosen, every combiner box would need at minimum 3 cable systems in parallel with 300 mm² copper each cable to keep losses below 1%. For the 4 AC combiner boxes this configuration would result in ca. 30 km of single core 300 mm² copper cable, which needs an enormous cable trench. Although technically possible a more suitable solution was found in the implementation of a local transformer at area A9, which elevates the voltage to 22 kV and transfers the energy from A3 and A9 using a 35 mm² cable with only 0.03% of energy losses to the point of connection.
- The cable from the inverter to the local AC combiner box is relatively short. This setting allows for using only 50 A circuit breakers in the combiner box, which in its turn permits to spare another breaker at the AC side of the inverter. Indeed, this configuration implies proper signalling on the equipment. All other cables are protected at the beginning and at the end with circuit breakers that have an over current protection as well as the possibility to be turned off and on under load. This is well depicted in Drawing 019, where the 250 A circuit breakers can be found in the AC boxes and the medium voltage box to protect the cable from over-currents as well as for disconnecting the cable section from both sides in case of maintenance.
- To ensure grounding of the PV plant, all rows are connected to each other by a Ø 10 mm galvanized round bar steel underground. Connections between the tables are made with a Ø 8 mm Aluminium grounding jumper over ground as shown in Drawing 011. To ground the PV module frame a special grounding clamp is used. The grounding system should also be connected to the already existing grounding system.
- Lightning protection as in Drawing 012 is foreseen to avoid strikes into the modules or DC cabling. Sufficient arrestors are distributed in the fields to cover all areas and with a height of 7 m these overtop even the highest rooftop by more than 3 m.

5.5.2.3 Connection to existing Electrical Infrastructure of the Facility

As shown in Drawing 017 and Drawing 018, the incoming AC cables from the free-field sub-systems connected to the main switchgear are split among different bus bars and LV/MV transformers due to capacity limits of the individual bus bars and transformers. Starting with Drawing 019, the set of SLDs shows at first the single-line-diagram of the PV sub-system. In the subsequent drawing, an SLD detailing the connection of that very system part to the NGEST grid. Area 1 is connected to transformer EMT 11 of the Blower and Energy Building, Areas A2, A4 and A4' are connected to trans-former EMT 21. Areas A3 and A9 are combined using an MV line, as described in section 5.6.2.2, which is connected to the same bulbar as EMT 11 and EMT 21. Area 12 of the recovery scheme had to be split up because of its size and is hence connected to the 3 transformers: TRF-06, TRF-07 and TRF-08.

The rooftop areas A5, A6, A7 and A8 of the WWTP have relatively small PV power and are connected directly to the incoming bus bar of the LV panel of the particular building before the main circuit breaker, as shown in Drawing 029 and Drawing 030. The Fuse of the panel board, which is connected to the PV plant is usually defined by the size of the PV plant which is very small with 40 kWp (A7). The expected maximum currents from the PV plant to the bus bar are around 58 A per phase on the 35 mm² cable. This is why as the first suggestion 70 A was applied for a fuse. For the buildings at the RS hosting the rooftop areas A13 and A14 no details on the LV system are available but the same concept applies.

All inverters have anti-islanding protection and are delivered with the corresponding country code. The switch gears and all AC boxes are to be equipped with appropriate warning signals showing operating and maximum voltages and currents as well as necessary instructions for installation and maintenance teams.

To protect the PV plant from surges and spikes from the grid side AC surge arresters are implemented in all main combiner boxes.

5.5.3 Mechanical and Civil Works

Drawing 001 and Drawing 002 show maintenance paths and exits. Due to the already existing structures a lot of roads and access points can be utilized for the PV plant. Only for A12 and A1 a significant amount of additional roads was planned due to the large size of these PV areas. All the rooftops are easily accessible, for example by ladder or scaffolding and allow use of a standard forklift.

Ramming posts are foreseen as foundation at all the free fields (see Drawing 015). As for the rooftop system, the appropriate solution to fix the system onto the roof is to cast concrete blocks as a foundation. The rooftop structure can be mounted on these blocks using concrete anchors. The free mechanical load of the rooftop should be checked prior to applying this solution.

Usually certain batches of delivered equipment like AC combiner boxes, modules or inverters accumulate during construction works. It is therefore recommended to guard the items in containers on the predefined storage areas to ensure the well estate of these components. Some extra containers for the installation crew, tools and toilets help to keep the site in order during installation.

Layout Drawing 13 shows typical cuts of cable trenches. Solar cable is usually protected by conduits, thicker cable can, if authorized by the manufacturer, be buried directly in the ground. The width and depth of cable trenches as well as conduit size are always a compromise between cost and installation ease as well as electrical safety. Generally, cables can lie closer together in PV systems than in other installations because PV systems do not deliver energy for 24 hours. Since there is no electricity production at night cables can cool down. So heat conduction is not as big of an issue as in other systems, where cables can conduit energy for 24 hours a day. The drawing also shows the grounding conductor that is usually laid 10 cm below the power cables and the warning tapes, which are necessary to warn against potential damage during future excavations.

As long as solar cables run parallel to the mounting structure ducts, plastic hooks or cable ties are the preferable solution to fix the solar cable. Once the cable leaves the structures, trenches with conduits are the more elegant solution to save space and leave the surface free for lawn mowing and other maintenance labour.

Even though water does not affect cables and the modules directly because of the IP 67 protected junction box, a surface drainage system is planned to avoid the accumulation of water, especially next to the racking structure where water could influence the statics (see Figure 12-2). Critical paths are expected to be next to the slopes near the basins and next to sealed areas (roads).

Fences are only foreseen for areas A12, A9 and A3, as they are outside of the main area which is already fenced. Access to area A12 will be provided via two gates (see Drawing 002).

5.5.4 SCADA and Monitoring System

5.5.4.1 Basics of PV performance monitoring

Monitoring is crucial to utility scale sites with high performance requirements. It alerts the operator to take action on underperforming areas of the solar facility. By comparing the output of different inverters installed at the same site, underperforming parts can be identified. Monitoring can be configured up to different levels of detail. The most comprehensive finest solution would be monitoring each module; the most basic solution would only monitor the output of the whole plant. The chosen concept of monitoring each inverter is the compromise between the two extremes and leverages the advantages of the distributed set-up representing cost benefit wise the adequate solution. Since some strings are combined with DC combiner boxes, the acquired aggregated monitoring data represent at maximum units of 28.6 kWp. Since most inverters can provide data for each input connector and each MPPT, higher resolutions of data are even possible.

5.5.4.2 General Concept

Drawing 014 provides an overview of the topology of the proposed concept for the SCADA system. A main cluster controller can communicate with a maximum number of 75 inverters and can be connected to the local communication network, which could be connected to the extranet. This enables to integrate the PV SCADA System into the already existing SCADA System. The whole system, PV plant and sewage treatment can be monitored and controlled from one, or more, control rooms (NGEST administration and station building / remote O&M Contractor's control centre) and inverter power can be reduced or shut down, if necessary. Besides the data of the inverter, the cluster box can also read out irradiation, wind and temperature sensors, which would act as an independent source to evaluate the efficiency of the plant.

5.5.4.3 Failure Identification

The monitoring system comprises functionality to detect obvious failures on its own. For example, a non-working inverter would trigger an immediate alert. Issues with system output and under-performance can be identified by comparing output of different inverters with each other or with the irradiation sensor over a certain time interval. Smaller errors like "dirt on modules" or "loose connections" can be identified with this method. It is recommended to mount at least one array sensor for every area with a different azimuth and module tilt allowing a comparison between similarly configured irradiation sensors and PV arrays.

6. O&M Requirements

6.1 O&M Strategy

During the lifetime of the PV system, maintenance is required to ensure reliable operation. Since PV is foreseen to form an integral part of the power supply, a permanent monitoring of the operation and performance is required. Local technical staff of the NGEST operations team should be able to take action on underperforming parts of the plant according to alerts of the monitoring system. Moreover, NGEST PV-plant – as part of the overall power supply – is exposed to high instability of grid supply. This requires a qualified personnel that is able to coordinate well with GEDCo and to keep NGEST operational under the variable GEDCo supply system. The main elements of NGEST PV-plant O&M strategy are:

- Cost effective O&M deployed human resources (engineer, technician),
- Monitoring plan and data processing,
- Periodic and emergency maintenance,
- Safety instructions,
- Maintaining warrantee compliance,
- Budget needed for NGEST PV-plant's successful O&M strategy.

6.2 Human Resources Needed for O&M Strategy

There are two categories of activities during operation:

- High-level supervision and general trouble-shooting to be conducted by a trained engineer;
- Lower level maintenance and repair tasks executed by technicians.

There are two options for the engineer's position. The operation of the PV system can be added to the responsibilities of the existing electrical engineer position, or an additional electrical engineer could be employed, who would oversee the power supply component of the facility. Given the small size of the PV installation, there is no justification for a dedicated additional resource. The technical assistance can be provided by the existing technicians within the team. Their effort would probably amount to a one day per week for routine checks at the PV-plant. The technical staff involved in operation of the PV systems is:

- One electrical engineer with essential knowledge in solar engineering - the engineer is PV-plant's operations manager, he/she monitors the performance and control measures as well as the meteorological station, follows up on periodic cleaning, determines maintenance requirements and actions for emergency cases, evaluates the deviation levels of actual and planned energy generation, and reports to management level.
- One technician – for cost effective O&M strategy this technician is part of the general NGEST staff and possesses strong PV knowledge. The technician assists the engineer and maintains cleaning and maintenance.

Reporting to management level should include weather conditions, generation performance, analysis of lost energy (kWhrs) and critical incidents as well as maintenance activities including spare parts inventory.

The PV plant engineer is also responsible for data documentation, follow-up on the key performance ratios (PR), PV plant availability, monitoring of energy losses particularly on the DC side, and unscheduled outages. In addition to that the engineer should maintain database of external experts and O&M service providers working in the solar sector and possible involvement in specific cases. Database prepared by the engineer should include spare parts requirements and manufactures in a clear spreadsheet tables with listing of equipment and quantity.

For the NGEST PV plant, a division of responsibilities (DOR) should be developed. It can be included as special sheets in the manual. DOR is needed to identify who is responsible for monitoring, reporting, scheduled maintenance and corrective maintenance. These sheets show the responsibilities of the engineer, technician, and management level, in addition to identifying cases when NGEST needs an external O&M provider.

6.3 Staff Training

In addition to basic solar knowledge, NGEST PV plant technical staff (mainly the engineer) is essentially to be trained on:

1. Large scale solar plants;
2. Grid-connected systems; available systems for grid-connection, grid electrical indicators, synchronic electrical indicators between grid and PV plant,
3. Use of monitoring system at the plant,
4. Dynamic management of NGEST electrical loads under variable GEDCo supply,
5. Preventive, breakdown and predictive maintenance, conditional wear monitoring,
6. PV systems performance measurements and thermal analysis of the PV plant components.
7. Knowledge in sizing of DC cables and the impact of under-sizing on plant performance during maintenance processes,
8. Engineer reporting skills.

6.4 O&M Manual

An O&M Manual should be prepared to include the following:

1. Use of the entire PV system and components description, this includes all guidelines for the operation of the PV plant.
2. Use of the entire monitoring system
3. NGEST PV plant preventative maintenance schedule to be maintained on periodic and dynamic basis, depending on changing weather conditions or prominence of any new polluting source around NGEST.
4. Cases when NGEST needs external maintenance provider,
5. Procedures to be taken when unscheduled incidents occur,
6. Annexes containing electrical and mechanical drawings of the PV plant at NGEST.

7. Special sheets describing the technical specifications of provided solar modules, inverters with a space to add changes in case of repairing with components having other specifications.
8. PV plant's safety regulations.

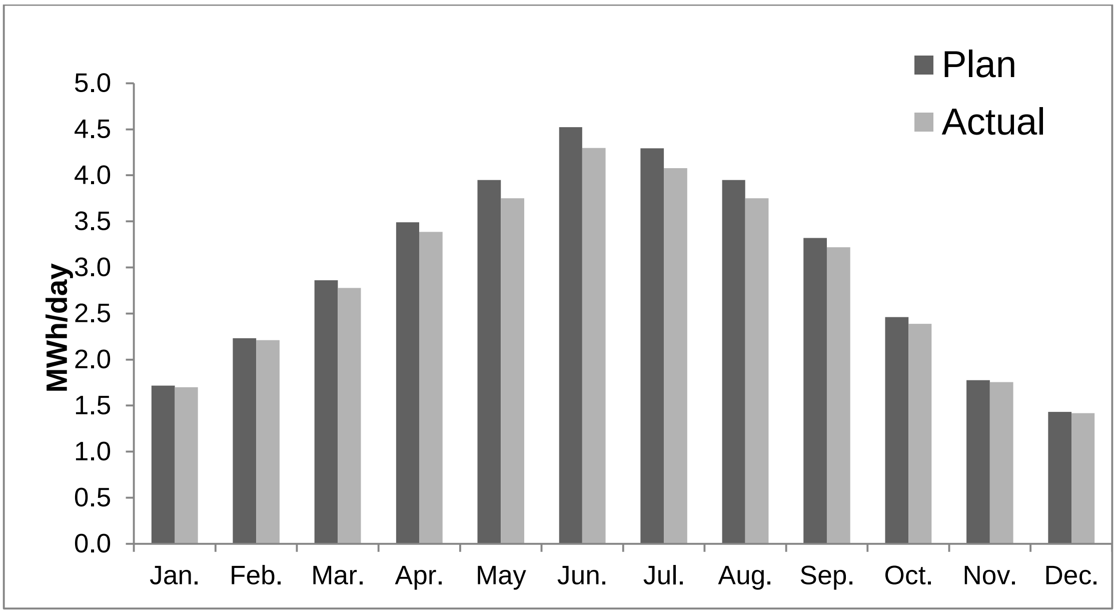
6.5 Monitoring Plan and Data Processing

The Monitoring plan consists of:

1. Reading and documenting the control appliances (voltmeters, ampere meters) installed for both DC generation side and AC consumption side.
2. Daily readings of energy meters; special attention should be given to kWh meters as a main performance indicator of the plant.
3. Monitoring the compliance of cleaning cycles as planned,
4. Alerts of the monitoring equipment and documenting maintenance actions made,
5. Data entry in a special software,
6. Monitoring of the locally installed meteorological station,
7. Documentation of new polluters around the plant, and measuring the level of added dust.
8. Monthly reports to NGEST manager; each report records all important indicators from the above mentioned points. These indicators will be reflected in NGEST PV plant revenue enhancement.

The Monitoring plan should conserve the energy generation process of NGEST PV plant in a range of 95-99% of planned among the 4 seasons as described below in Figure 6-1. Deviation of PV plant's generation from the mentioned levels indicates incompliance of the monitoring system. These levels consider differences of shadow caused by dust particles during different seasons, in addition to equipment obsolescence.

Figure 6-1: Exemplary comparison of actual vs. expected electricity production



6.6 General Safety Regulations

Operating instructions contained in the manual lists are the most important instructions on how to operate the PV plant safely. Operating the NGEST treatment plant includes other non-electrical and non-mechanical hazards in regard to liquids, pools, the use of chemicals in the work area. All these hazards are indicated in the manual and staff should refer to all safety instructions in NGEST.

All safety operating instructions generally in NGEST and particularly in the PV plant must be always at hand in the NGEST work area. The staff must be aware that the relevant Palestinian rules and regulations for accident prevention shall be complied with the eventual NGEST internal regulations.

NGEST management level must allow to work within the facility only people,

- who are well acquainted with regulations concerning safety and accident prevention,
- who have the knowledge on how both NGEST and PV plant function,
- who have read and understood the operating instructions.

Safety warnings like slogans must be marked in red and large enough to be seen, with danger symbols and placed on the sites and equipment containing dangers.

It is the responsibility of the management level to ensure that these cautions mottos always exist in a place of danger. Any modification or addition of parts like NGEST phase II and phase III must be accompanied with addition and modification of danger cautions. These changes and additions must be done by an external safety consulting provider.

Consequences of non-compliance with safety regulations may lead to serious hazards as follows:

- Danger for staff or visitors by mechanical or electrical influence,
- Failure of prescribed methods of maintenance and repair,
- Failure of the whole process of energy generation at the NGEST PV plant.

6.7 Maintenance and Repair

6.7.1 Procedures

PV plants have a reputation as low maintenance power plants, nevertheless some actions should be considered to ensure the highest possible output of the system.

All inspection work and maintenance is to be carried out according to the instructions:

- Preventative maintenance: testing of equipment and systems based on a schedule or conditional wear monitoring.
- Breakdown maintenance: when maintenance is initiated on an as-needed basis with alerts from monitoring equipment.
- Predictive maintenance techniques: how to initiate a plan for lifecycle maintenance e.g. PV plant cleaning cycles depending on Gaza specific weather conditions/any other sources of modules pollution in the area and replacing of repair parts.

For all maintenance, repair and inspection work power supply of the PV plant or its parts and power from the grid is to be turned off, and breakers of power supply are to be made secure against an unexpected restart. In addition to that, a warning plate against restarting should be placed.

6.7.2 Module Cleaning

The tilt angle of 25 degrees already secures a very good self-cleaning effect. Most of the dirt or snow will slip down the module and rain will wash down the rest. For very dry seasons there should be the possibility to wash the modules using only water and soft brushes. To avoid power losses all cleaning or maintenance actions should be scheduled for the early morning hours or late afternoon when the system is producing on a low scale.

Depending on the site conditions module cleaning can be done in certain periods, like every month, or can be established as the first measure when a significant power loss is recognized by the monitoring system.

6.7.3 Site Maintenance

Typical maintenance work that should be done on a quarterly basis is cutting vegetation and inspection. Bushes and high grass can cause shadowing and should be trimmed or cut completely in certain time intervals. Also inspections of modules, inverters and AC combiner boxes are recommended to prevent failures and keep the output of the PV plant constantly on a high level.

6.8 Protective Equipment

Before the PV-plant is operated, all protective equipment must be installed and prior to maintenance, operations related protective equipment must also be checked. Manual switchgears must be kept in a closed non-operational position, and access should only be granted to authorized persons. Power supply connections and breakers are to be kept secure against unexpected restart and a warning label must be attached against restarting.

In addition to that, protective devices must be serviced regularly according to the manufacturer's instructions.

Works on electrical instrumentation and protective equipment must be carried out only by a qualified engineer and technician/s. Staff is not allowed to continue with maintenance unless the functional state of protective equipment is ensured. Thus, the NGEST maintenance provisions will need to include the required personnel protective equipment like electrically isolated rubber gloves and tin hat when working with mechanical reconstructions as well as protective work clothing. The NGEST Administration Building can accommodate potential additional staff during their duties and has a changing room.

Main NGEST PV plant protective equipment and systems are:

- DC and AC circuit breakers,
- Manual switchgears,
- Earth leakage and earthing system,

- Short circuit protection system,
- Lightning rod system,
- On-grid connected inverters and PV and grid frequency regulation,
- Switches and separating breakers.

This protective equipment can only be removed under the direct supervision of the PV plant engineer and after they have been protected against switching on again.

In addition to the mentioned above, loose connections and scorched cables must be removed immediately.

The PV-plants control room must contain all safety measures as follows:

- firefighters,
- free of flammable materials,
- natural and artificial ventilation,
- under the eyes of NGEST safety guards,
- secured door/s against unintentional closing during inspection work and maintenance,
- emergency exit window.

6.9 Security

All PV areas will be fenced and integrated in the overall security concept with 24/7 presence of manned guards.

6.10 Disposal of Parts

The PV plant can contain dangerous parts during disposal, like electrical dangers of charged batteries and condensers, chemical dangers of acids, scrap metals and other mechanical dangers. Any substances and materials used are to be handled with and disposed of appropriately in accordance with the existing rules. This concerns in particular all waste materials, such as waste of electrical appliances, oil, acids and other chemical waste.

6.11 Spare Parts

The availability of spare parts is crucial for a swift remedy of defects and reliable operation. The spare parts requirements can be estimated based on the quantity of the components and the procurement strategy: In a commercial project at a very accessible site, minimum numbers of spare parts are required to keep the major part system in operation.. After replacement of equipment, the spare part store would be refilled with a brand new device purchased with the means set aside in the so-called maintenance reserve account (MRA). Thus, the project can benefit from the technical innovation and potential price decrease and this avoids having large unused spare parts at the end of the lifetime. Systems built and operated by public entities (bound to rather long procurement procedures) or located in a difficult location (remote access, import restrictions), more conservative numbers are used in order to prevent supply issues and procurement constraints to block repair and thus operation. This applies especially to the

NGEST project, where security approvals with only 6 month validity are required for importing goods to the site and a strict OPEX budget is established. The parts used by the free field and the rooftop systems differ slightly (e.g. different inverter sizes). But when quantifying the spare parts, the PV sub-systems can be regarded as one unit and therefore reductions on gross quantities can be applied. The assumption made hereto is that a module clamp can be applied equally on either type of the system.

Table 6-1 lists the share of spare parts on the total number of units per each component that are assumed in the CAPEX estimate of the PV system. The additional column shows the deviation of the assumed quantities to a typical investor-driven or commercial project. Due to the location of the NGEST site and the public procurement procedures PWA is subject to it is recommended to increase the spare part share for crucial parts.

Table 6-1: Spare part assumptions for PV system costing

Item	Share of Spare Parts on total Quantity	Deviation from typical commercial projects
PV modules	7%	High
Inverter	9%	High
Mounting structure	2%	Medium
DC Cabling	5%	Medium
AC Cabling	~1%	Medium
Communication & Monitoring system	1%	Normal
Conduits	1%	Normal

7. PV Electricity Production and Energy Balance

7.1 Energy Generation from PV System

7.1.1 Site Information and Meteorological Data

The system location is configured based on the site coordinates mentioned in the site description in section 2.5. Both the data sets for the exemplary site in Gaza and the Solar Atlas of Palestine are used as meteorological input data sets for the P50 and the P90 scenario.

7.1.2 PV Plant Design Parameters

7.1.2.1 Components

A standard module with poly crystalline silicon cells and a preferable low temperature coefficient has been used as example for the yield calculation. The key data is listed in Table 7-1.

Table 7-1: Characteristics of the PV module selected for the yield simulation

Characteristic	Value	Unit
Nominal Power	260	W
Vmpp (Voltage at Mpp)	30.4	V
Impp (Current at Mpp)	8.56	A
Voc (Open Circuit Voltage)	37.5	V
Icc (Short Circuit Current)	9.12	A
Module Efficiency	15.85	%
Operating Temperature	- 40 to + 85	°C
Max, System voltage	1000	V
Power Tolerance	+5	W
Cell Type	Poly-crystalline	
Cell size	6	Inch
Module dimension	1638x982x40	mm
Weight	18	kg
Connectors	MC4 comparable	
Temperature Coefficient (Pmax)	-0.43	%/°C
Temperature Coefficient (Voc)	-0.34	%/°C
Temperature Coefficient (Isc)	0.065	%/°C

An industry standard decentralised multi-string inverter solution has been chosen. The key data of the inverters is listed in Table 7-2.

Table 7-2: Characteristics of the inverters selected for the yield simulation

Characteristic	Inverter 25 kVA	Inverter 20 kVA	Inverter 15 kVA	Unit
Max. DC power	25.550	20.440	15.340	W
Max. input voltage	1000	1000	1000	V
MPP voltage range	390 to 800	320 to 800	360 - 800V	V
Rated Ac Power	25.000	20.000	15.000	W
AC nominal voltage	3/N/PE; 230/400	3/N/PE; 230/400	3/N/PE; 230/400	V
AC voltage range	180 V - 280V	180 V - 280V	180 V - 280V	V
Frequency	50 or 60	50 or 60	50 or 60	Hz
Rated output current	36.2	29	24	A
THD	<3	<3	<3	%
Max efficiency / European efficiency	98.3 98.1	98.4 98.0	98.2 97.8	% %
DC Switch	Yes	Yes	Yes	
DC Surge Arrester (Type II)	Yes	Yes	Yes	
Dimensions	661 x 682 x 264	661 x 682 x 264	665 x 690 x 265	mm
Weight	61	61	59	kg
Operating temperature	-25 to 60	-25 to 60	-25 to 60	°C

With the above components, the array configuration shown in Table 7-3 was used in the simulation.

Table 7-3: Array configuration

Orientation type	Ground mounted	Roof-top	Unit
Plane tilt	25	25	°
Azimuth	-11.5 to 42.3	34 to 39.2	°
Mounting	Fixed	Fixed	
Modules / string	22	9 to 22	
PNom	4936,36	172.38	kWp
Effective module area	30,539.28	1966.45	m²
PV array	863 strings	37	
	22 modules in series	9 to 22 modules in series	
Total	18,986	663	Modules
Inverters	163 / 10	2/10	
Each	25 / 20	20/15	kWac
Total	4,275	190	kWac
PNom Ratio	1.15	0.91	

7.1.3 Losses and Uncertainties

The following losses have been considered in the simulation of the energy yield:

- **Losses due to the environment (irradiation, shading and soiling):**
  - Horizon
  - Near shading losses
  - IAM factor on global / reflection

    - Soiling losses
- **Losses due to modules characteristics:**
    - LID (Light induced degradation)
    - Loss due to irradiance level
    - Loss due to temperature
    - Mismatching losses at MPP
    - Module Quality loss
- **System losses:**
    - DC cabling losses at STC/Ohmic wiring losses
    - Inverter Loss during operation
    - Inverter Power Limitation
    - AC LV losses
    - Transformer Loss
- **Further losses:**
    - Internal consumption / parasitic loads
    - AC circuit
- **Operational losses:**
    - Annual degradation,
    - Technical unavailability

It is assumed that soiling may have a considerable impact, as the location is dusty and prone to sand storms.

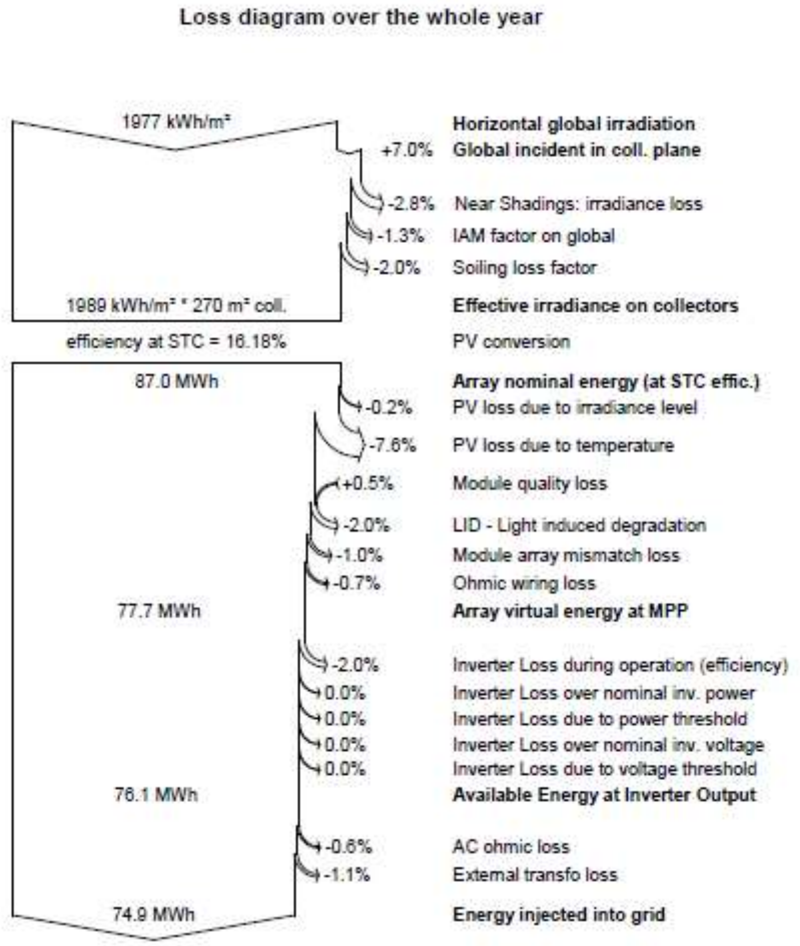
Technical unavailability includes downtime of the plant during normal production hours for repair or maintenance. It further includes times, when the plant is ready to produce electricity, but the national grid is unable to accept the power.

Table 7-4: Assumed losses and uncertainties

Parameter	**Description**	**Impact (gain/loss), [%]**	**Uncer-tainty**	**Source of uncertainty**
Meteorological Data			4.5%	generation of resource data
			1.2%	inter-annual variability
Global Tilted Irradia-tion		**9.30**	**0.0%**	**Conversion to inclined surface**
Losses due to the environment (irradiation, shading and soiling)				
Horizon	By far shading objects	0.00	0.0%	Losses due to far shading objects
Near shading losses	Caused by rows placing	-2.90	1.0%	Near shading losses caused by rows plac-ing
IAM factor on global	reflection	-1.20	0.5%	
Soiling losses		-2.00	3.0%	
Losses due to modules characteristics				

Parameter	Description	Impact (gain/loss) , [%]	Uncer-tainty	Source of uncertainty
Loss due to irradiance level	Deviation of irradiation from STC irradiation	-0.20	1.0%	
Loss due to tempera-ture	Deviation of module tempera-ture from STC value	-7.70	2.0%	
Mismatching losses at MPP	Varying module characteris-tics in string	-1.00	1.0%	
Module Quality loss	Deviation of module effi-ciency from specifications	-0.50	1.0%	
LID	Light induced degradation (1rst yr.)	-2.00		
System losses				
DC cabling losses at STC	Ohmic wiring losses	-0.80	0.5%	
Inverter Loss during operation		-3.30	1.0%	
Inverter Power Limita-tion		0.00	1.0%	
AC LV losses		-0.60	0.5%	
Transformer Loss	Model value: -0.4	-1.1	0.5%	
Further losses				
internal consumption	parasitic loads	-0.20	1.0%	
AC circuit		-0.50	0.5%	
Operational losses				
Degradation	annual over lifetime	-2	0.5%	
Technical unavailabil-ity		-2.00	3.0%	
Total			***7.2%***	

Figure 7-1: Loss diagram over the whole year



7.1.4 Yield Prediction Methodology

The PVSyst software is a PV system modelling tool. It is based on many years of experience in PV simulations and performance assessment and is commonly used worldwide to design and evaluate the energy produced by PV grid-connected solar power plants.

The simulation software PVSyst (Version 6.31) was used to simulate the system behaviour and energy production of areas with similar orientation and configuration separately.

The following models have been used for the PVSyst:

<table>
<tr><th>Simulation Step</th><th>Model</th></tr>
<tr><td>Irradiation transposition</td><td>Perez-Ineichen model</td></tr>
<tr><td>Near shadings</td><td>• Unlimited sheds for areas without significant shadings
• 3D Drawings for areas with shading objects</td></tr>
<tr><td>Reflection (IAM)</td><td>User defined profile supplied by module manufacturer:
Incident Angle / IAM:
<table>
<tr><td>Inc. Angle</td><td>0</td><td>10</td><td>20</td><td>30</td><td>40</td><td>50</td><td>60</td><td>70</td><td>80</td><td>90</td></tr>
<tr><td>IAM</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0,99</td><td>0,92</td><td>0,74</td><td>00</td></tr>
</table></td></tr>
</table>

Power factor adjustment or curtailment of the grid on evacuation were not considered here. The production of the total PV plant was calculated by summing up the hourly results of the separately simulated areas. From the output on the PVSyst model, further plant losses were deduced:

- Ohmic losses in the MV circuit between the outlet of the inverter-transformer stations at the individual blocks and the revenue meter;
- Parasitic loads and internal consumption.

The resulting value corresponds to the expected output at commissioning.

During continuous operation, further losses occur. This is mainly due to:

- technical unavailability;
- degradation of modules and system components.

These operational losses during the lifetime of the project are considered in the production calculation over the lifetime of the project.

7.1.5 Long-Term Expected Energy Production

For prediction of electricity production from the PV power plant for a period of 20 years, degradation (ageing) of nominal power (conversion efficiency) of PV modules has to be assumed. Since not only the modules are subject to ageing, the overall performance of the power plant depends also on cabling and performance of inverters during the lifetime. Another possible source of uncertainty is non-uniform degradation of individual modules, which results in higher mismatch losses.

Table 7-5 shows the weighted long-term expected energy production as annual net energy output in GWh per year. The calculation of P90 assumes the 19-years inter-annual variability of GHI and all combined uncertainties as described above. In other terms it refers to the multi-year probability.

Table 7-5: Long-term expected Energy Production, Annual Net Energy Output [GWh/a]

Variant 2	Fixed Structures			
PoE-Level	P50		P90	
Aggregation Method	Specific Yield [kWh/kWp]	Annual Net Energy Output [MWh/a]	Specific Yield [kWh/kWp]	Annual Net Energy Output [GWh/a]
Average	1,653	8,442	1,502	8,292
Sum [GWh]		214,291		174,812

Specific yield values in kWh per kWp for P50 and P90 are further detailed in the Annex. PV production, including degradation and further technical losses are used in the next section to build the energy balance for each project year as input to the economic and financial cash-flow calculations.

The project has good potential for solar energy utilisation with stable electricity production during the year with only slightly seasonal weather changes. Therefore, stable electricity production is expected throughout the year.

7.1.6 Sensitivity of Energy Production to Azimuth Angle

There are military border installations in the South and South-East of the site. According to information by World Bank, COGAT[36] expressed the concern that the PV modules might lead to glare on the watch-towers of Israeli military. Since the requirements are stipulated explicitly thus a general sensitivity evaluation has been conducted to demonstrate the actual designed azimuth and the sensitivities of an adjustment of the azimuth angle on annual energy production.

As a general remark, some simulation tools, such as PVSyst express azimuth angles in degrees deviation from the optimum with 0° for South on the northern hemisphere and with -90° for East and +90° for West. In standard cartography and engineering, 0° refers to straight North and 180° to South as shown in the reference compass rose in Figure 7-3.

During the analysis of the possible variants, refer to section 5.4, different orientations were assessed. This may already give a good indication of the impact any change in orientation has on the design and energy yield.

The concept design developed has azimuths of 192° to 222° meaning that PV panels are facing a range between South-South-West and South-West (see Figure 7-2). These orientations already reduce the glare. An analysis with the glare analysis tool by SANDIA[37] confirmed that there is no risk of glare for two arbitrary locations at the border line.

[36] http://www.cogat.idf.il/894-en/Matpash.aspx

[37] Solar Glare Hazard Analysis Tool - https://share.sandia.gov/phlux/sghat/

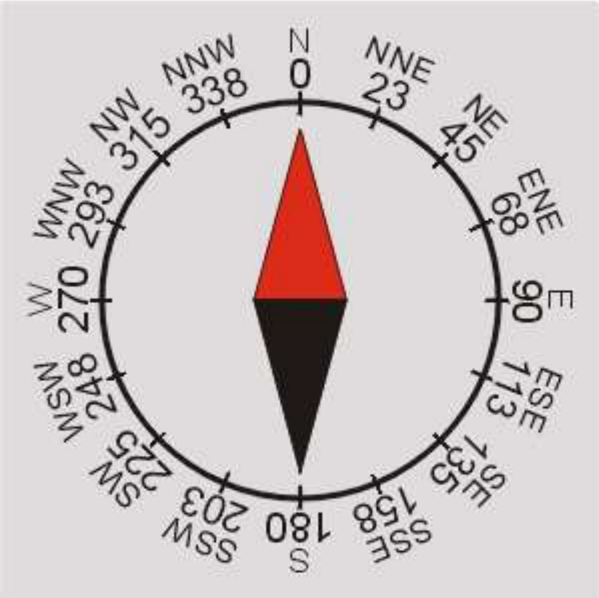


Figure 7-2: Compass rose

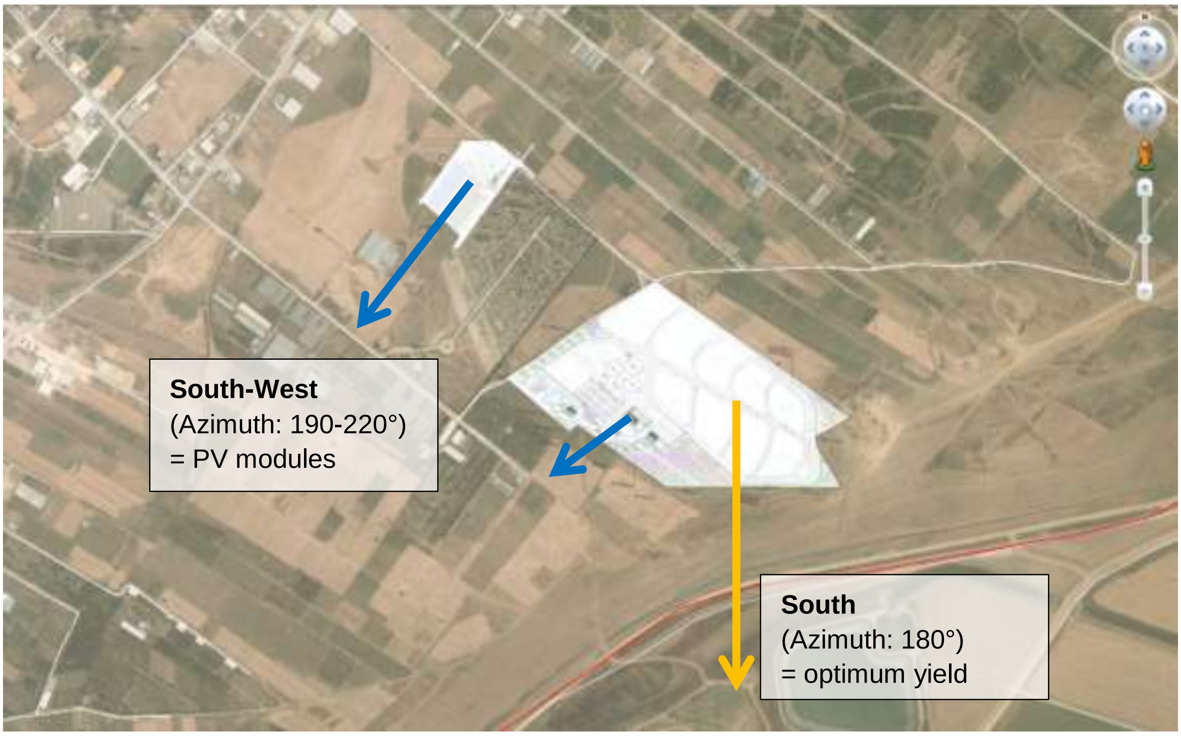


Figure 7-3: Concept design layout overlaid on Google Earth with indication of azimuth angles

The impact of turning the azimuth angle from the optimum angle South (180°), towards East 270°) is shown in Table 7-6 in relative values (% of change)

Table 7-6: Reduction in relation to optimum

Orientation	Compass Bearing	Tilt Angle 10	15	20	25
South	180	-3.63%	-1.86%	-0.66%	**0.00%**
PV Array Range	190	-3.62%	-1.85%	-0.63%	***0.03%***
	200	-3.78%	-2.08%	-0.93%	**-0.34%**
	210	-4.10%	-2.55%	-1.55%	***-1.11%***
	220	-4.58%	-3.26%	-2.51%	***-2.25%***
	230	-5.21%	-4.21%	-3.74%	***-3.72%***
	240	-5.96%	-5.33%	***-5.19%***	-5.46%
	250	-6.83%	***-6.60%***	-6.83%	-7.44%
	260	***-7.77%***	-7.99%	-8.63%	-9.61%
West	270	***-8.77%***	-9.45%	-10.55%	-11.95%

Table 7-7 translates in absolute values for the average annual output over the assumed project life-time.

Table 7-7: Average Annual Energy Production [MWh/a]

Orientation	Compass Bearing	Tilt Angle 10	15	20	25
South	180	8,136	8,285	8,387	**8,442**
PV Array Range	190	8,137	8,286	8,388	***8,445***
	200	8,123	8,267	8,364	**8,414**
	210	8,096	8,227	8,311	***8,348***
	220	8,056	8,167	8,230	***8,252***
	230	8,002	8,087	8,127	***8,128***
	240	7,939	7,992	***8,004***	7,981
	250	7,866	***7,884***	7,865	7,814
	260	***7,786***	7,768	7,713	7,631
West	270	***7,702***	7,644	7,552	7,433

When changing the azimuth angle there is a certain threshold after which the tilt angle also needs to be adjusted. Since the intensity of solar irradiance depends on the azimuth angle and incidence angle the inclination of the PV module is reduced for azimuth angles that go far beyond the optimum in order to keep the irradiance high during most part of the day. This effect is shown in the two tables by the tilt angle columns. Since the available installation space is constrained by well-defined areas, any turning of the PV modules will have impact on the actual installable capacity as explained in section 5.4.

7.2 Energy Balance of the Energy Supply System

7.2.1 Annual Demand and Supply Balance

Chapter 3 discussed the energy demand of each component of NGEST; the annual demand summary is calculated as shown in Table 3-1. The total annual energy demand in 2018 is 37,286 MWh and 63,271 MWh in 2025.

In the following sections, the energy balance is calculated between the calculated energy demand of the WWTP and the RS (Stages 1 & 2) versus the external power supply and components installed on-site. Based on the technical analysis of the current power supply in Chapter 4 and the potential electricity generation with PV in Chapter 5, the energy balance of the WWTP in 2018 and 2025 is calculated showing the amount of shortages that will be covered by the grid and diesel sets.

The drawing up of the energy balance follows the overall objectives defined for the power supply system (independent, cost effective and sustainable), which defines the internal merit order of the supply options for satisfying the demand leading to the following ranking:

1. Cost effective sources increasing autonomy through renewable energy sources (biogas, PV)
2. Cost effective sources with insecurity in supply (external network)
3. Sources allowing higher level of autonomy safeguarding operation (diesel)

The aim for sustainable supply and reduced emissions (in the case of PV) or at least emission-neutral (in the case of biogas) are not given direct preference in this study, but this aspect is considered indirectly in criterion (1) above which aims to optimise the use of local renewable energy based generation sources.

The balance presented in the following sections focuses primarily on the PV system's contribution and capacity to meet NGESt's partial energy. This same balance also includes the contribution of other energy sources needed to cover the residual demand first with the external supply from the network and finally the remaining gap caused by the load shedding with the costlier diesel generation.

Based on the technical availability of the grid discussed in Section 4.2.5, it will be assumed that the two grid scenarios occur for during a total duration of 6 months (half a year) for each one. This is either:

- 6 hrs ON and 12 hrs OFF (for 4380 hours/year)
- 8 hrs ON and 8 hrs OFF (for the other 4380 hours/year),

The the diesel generators will replace the GEDCo network during the off-grid hours. This scenario will be called the average grid contribution.

The PV yield scenarios (section 7.1) are combined with the grid scenarios. So the P50 scenario for the hybrid power supply will include the scenario of the average grid contribution described above, while the P90 scenario will include the worst-case grid contribution.

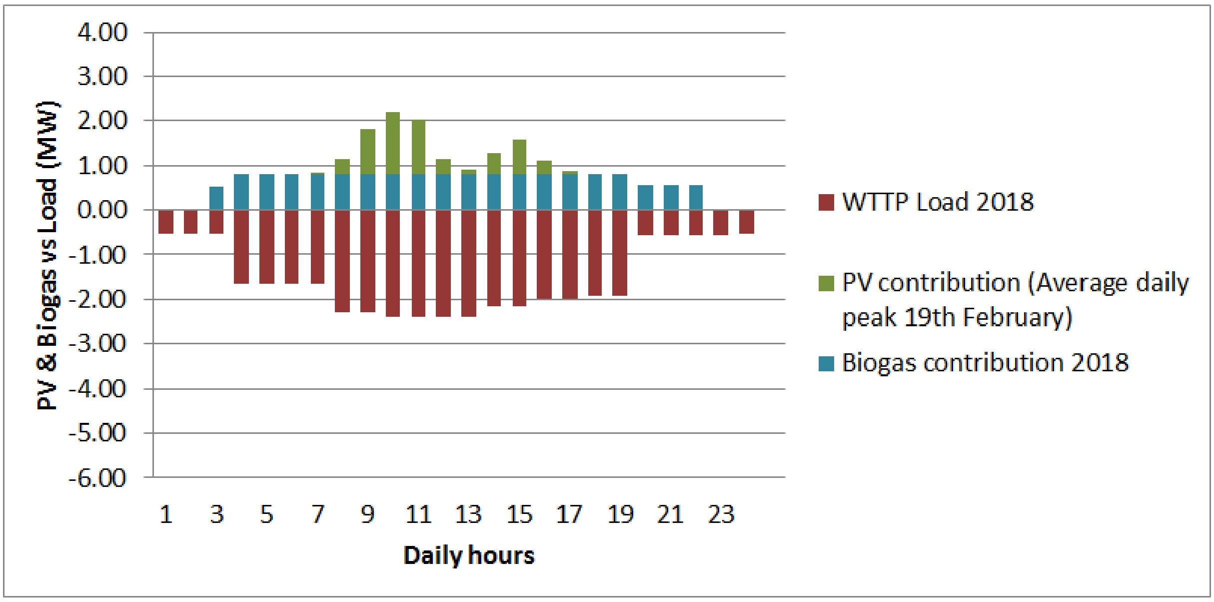
The evaluation of the annual energy mix of the scenarios with and without PV shows that the PV-based supply reduces mainly the power supply from the external network and then displaces the generation of the emergency diesel (refer to Figure 7-2 for 2018 and Figure 7-13 for 2025). The reasons for limited possibility to offset the diesel-based generation is the assumptions on the current load shedding scheme and the continued high load at the facility during these off-grid periods. This limit of displacing the fossil fuel consumption and indispensable role of the diesel gensets is emphasised by the P90 scenario (i.e. worst case with low annual grid availability and low annual PV production) where a higher share of the local generation during a network outage leads to an increase in the diesel contribution.

7.2.2 Waste Water Treatment Plant (WWTP)

7.2.2.1 Typical Daily Profiles

The average daily energy balance of the WWTP is shown in Figure 7-2 for 2018and Figure 7-3 for 2025.

Figure 7-4: Average daily profile and balance of the WWTP in 2018



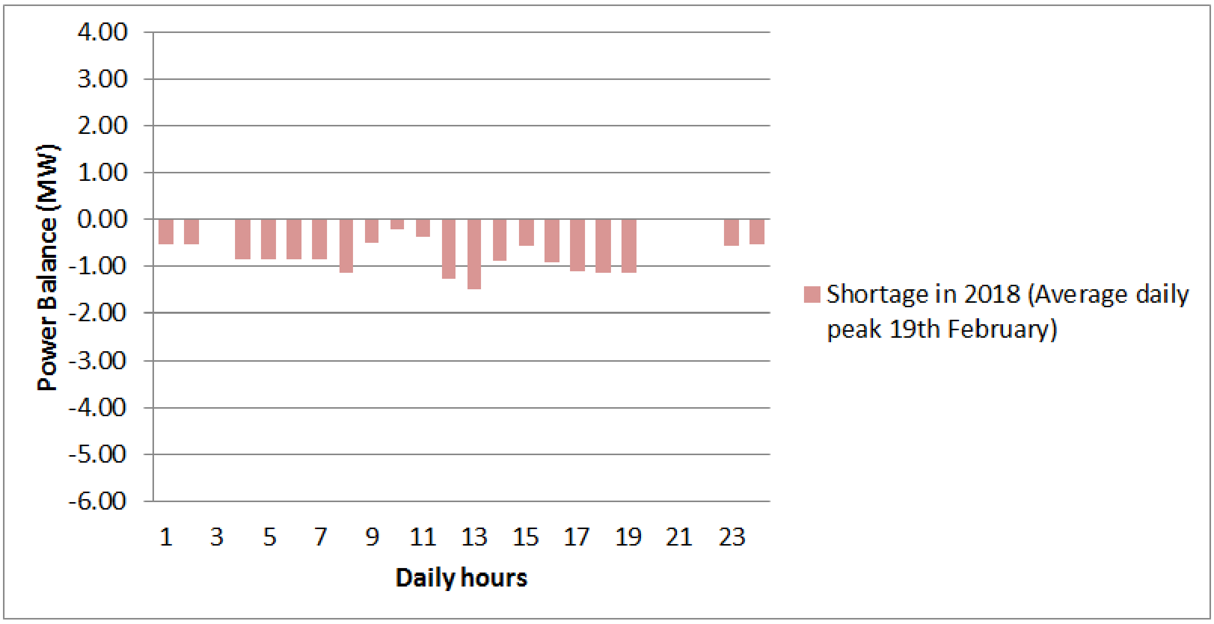
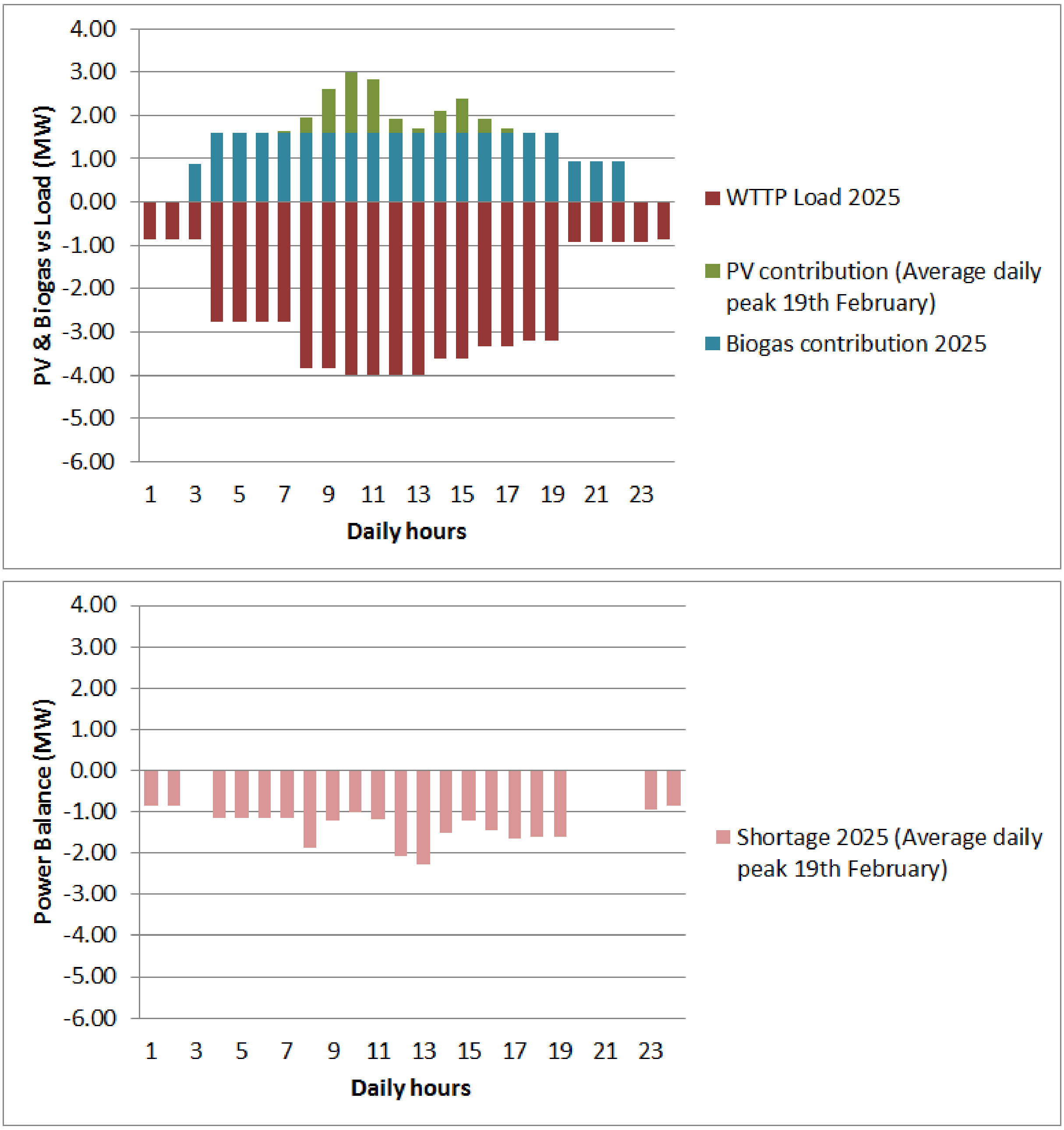


Figure 7-5: Daily profile and balance of the WWTP in 2025



As concluded from the figures, electricity produced from the installed capacities of the PV and biogas generators is not sufficient to cover the design demand. Hence, the supply gap needs to be met by the grid and the diesel generators.

Under normal conditions the WWTP would be supplied from the GEDCo network via two transformers that are of 1600 kVA each. The WWTP has load sharing governors and an auto synchronizing system, which controls the three diesel and the gas generators.

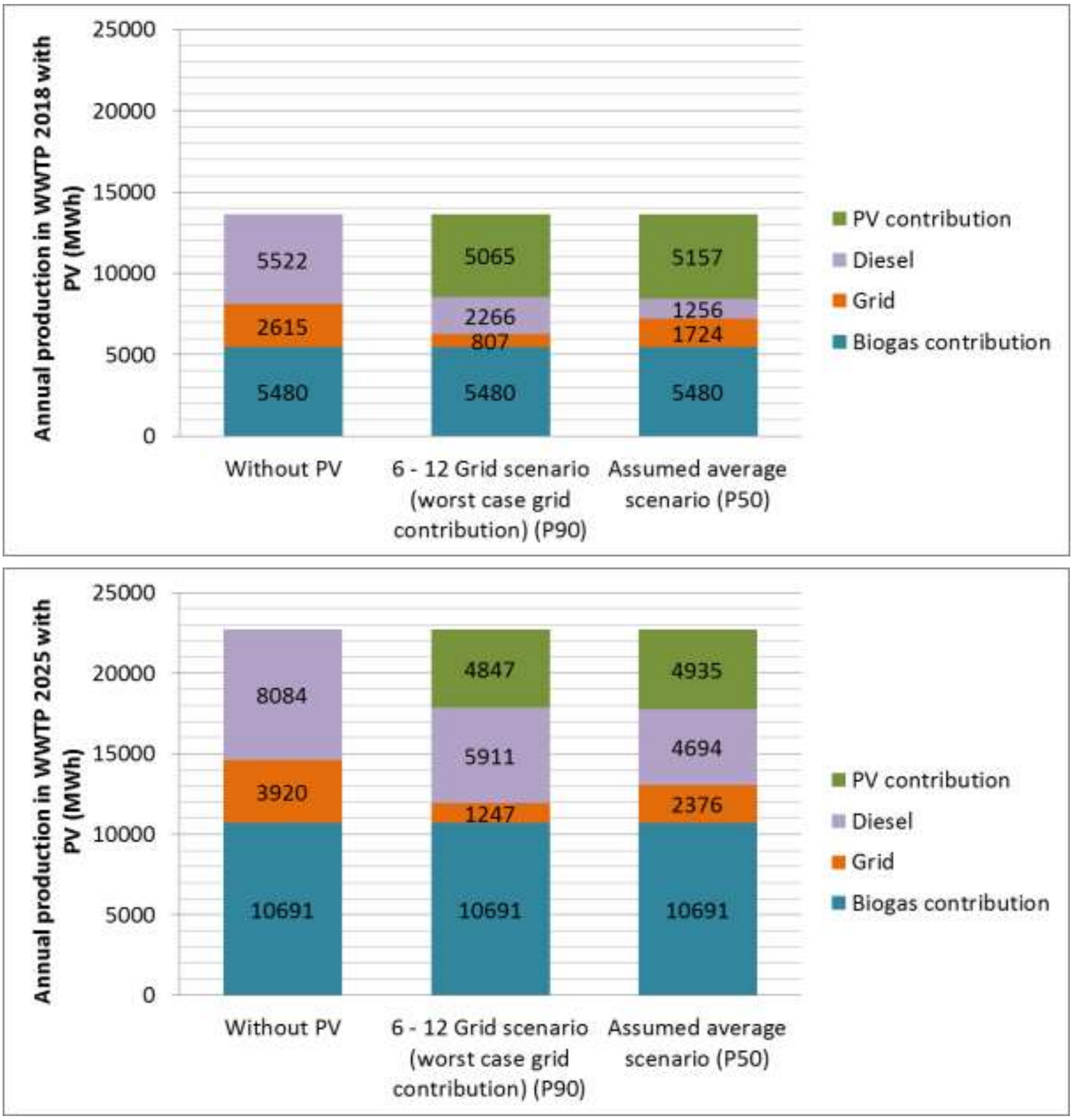
In 2018 and 2025, the PV system capacity remains the same while its contribution to the energy balance is reduced due to degradation. The contribution of the biogas generator is doubled in 2025 because the processing volume of the WWTP increases and another generation will be added to utilise the additional amount of gas. The share of the grid and diesel generated power is increased to satisfy the higher deficit occurring in 2025 in comparison to 2018.

The resultant annual energy balance for 2018 and 2025 is elaborated in Figure 7-4 showing the P50 and P90 scenarios in addition to the current design without PV ("Without PV" case). Table 7-6 shows the percentages of the contributions in the P50 scenario (the typical case).

Table 7-8: Annual energy mix of the WWTP (P50)

Years	2018		2025	
Total	MWh	%	MWh	%
(Demand)	13617	100%	22696	100%
PV	5157	37.87%	4935	21.74%
Diesel	1256	09.22%	4694	20.68%
Grid	1724	12.66%	2376	10.47%
Biogas	5480	40.24%	10691	47.11%

Figure 7-6: Annual energy mix at the WWTP in 2018 and 2025

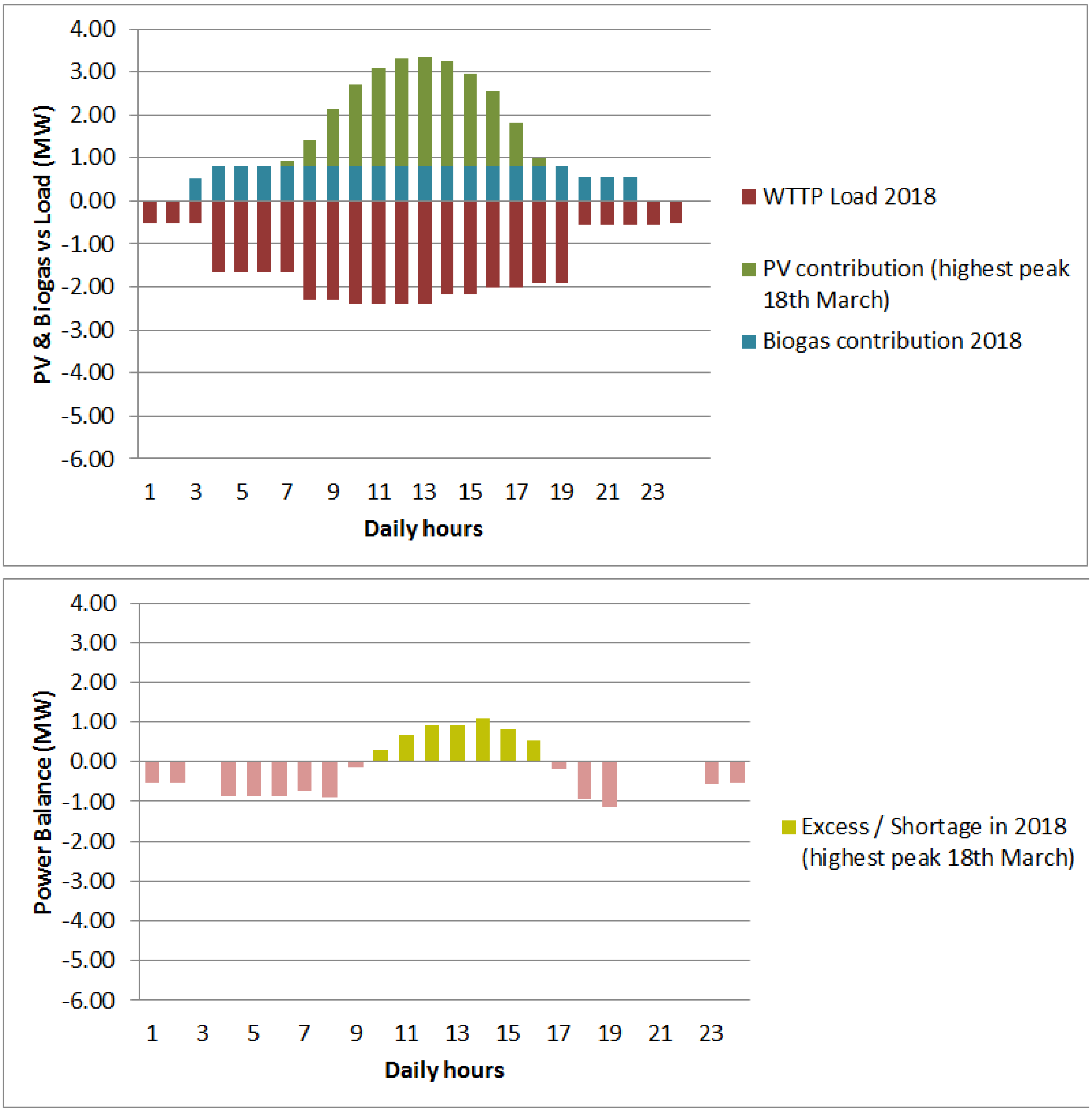


7.2.2.2 Selected Daily Profiles

On certain days excess power generation from the biogas and PV occurs at the WWTP. Since the main target of the local energy supply is to cover NGEST's demand and not to export electricity to the grid, the operation and interplay of components would need to be optimised for these situations. The absence of regulations allowing net-metering in the Palestinian territories makes it even more necessary to find a solution that does not interfere with the constraints of the GEDCo network.

According to the provided meteorological data and the selected design, the PV power generation reaches for a typical meteorological year its peak of 2.5 MW on the 18th of March as shown in Figure 7-5.

Figure 7-7: Daily profile and energy balance at the WWTP on 18th of March



7.2.2.3 Excess local Generation during peak times

In the off-grid situation, the diesel generators are used to build and stabilise the grid (voltage/frequency control). Thus, at least one diesel generator from the gen-set will work at 30% of its rated full load capacity, which is equals to 0.220 kW MW of the 730 kW. If the WWTP is run in isolation from the grid (and the RS), it results in offsetting the biogas generator in these working hours. The gas holder is used to temporarily store the gas produced during these hours for later biogas-based generation. The annual amount of energy corresponding to the required minimum diesel operation is estimated at 472 MWh. Two solutions were suggested to optimize the use of this excess:

1) Battery Storage;

2) Connecting the WWTP to the recovery scheme.

The first alternative is not recommended since the consumption from newly added loads increases in the following years. This reduces the potential of the storage in the future by project lifetime, which would render the investment in storage banks less feasible. In addition, the amount of 10% of excess is not a promising amount for storage given that yet another component would increase the complexity of and the effort for maintenance.

Combining the two project locations as a second alternative has higher potential of implementation. The rationale for this assumption will be further explained after the discussion of the loads and contributions of power sources at the recovery scheme in the coming sections. On the day with the highest peak, the excess power generation reaches 5.25 MWh. The annual excess during the peak hours in 2018 is 938 MWh. Accordingly, the total expected unused excess of power generation in 2018 is 1410 MWh, which represents 10.35% of the total annual energy demand of the WWTP. In 2025, this excess will decrease to 48 MWh due to the increase of the load of the WWTP; this value can be neglected with respect to the total load (22696 MWh).

7.2.3 Recovery Scheme (Stage 1&2)

7.2.3.1 Typical Daily Profiles

The recovery scheme energy balance was calculated as a total of both Stages 1&2 and extension. The same assumptions of the grid availability were also considered here. In the recovery scheme, there is no biogas generator; hence the energy balance is calculated between the loads and the installed PV system as shown in Figure 7-6.

The section 3.3 contains the analysis of the consumption that is the guiding condition for the energy balance.

Figure 7-8: Daily profile and balance of the recovery scheme in 2018

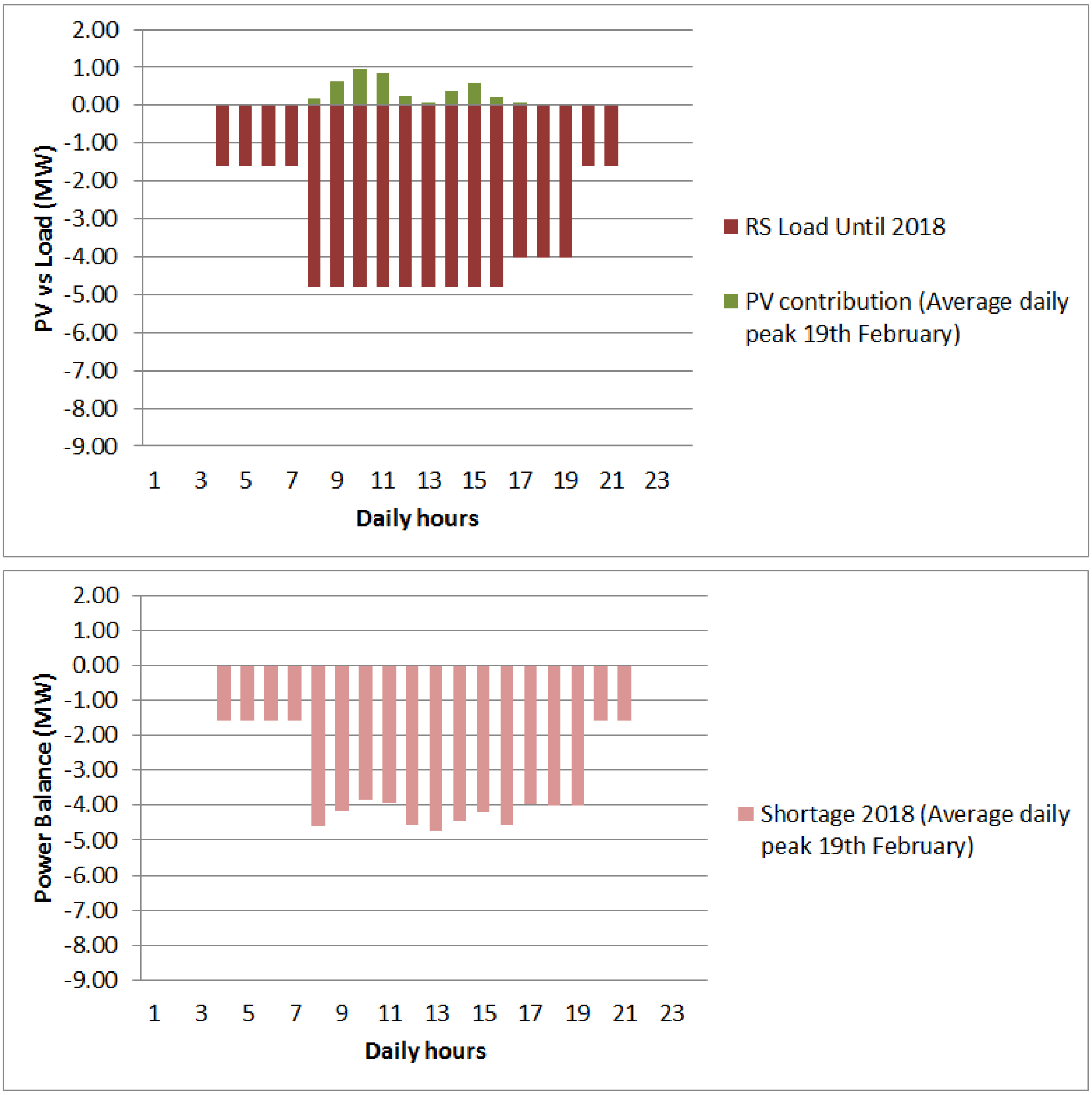
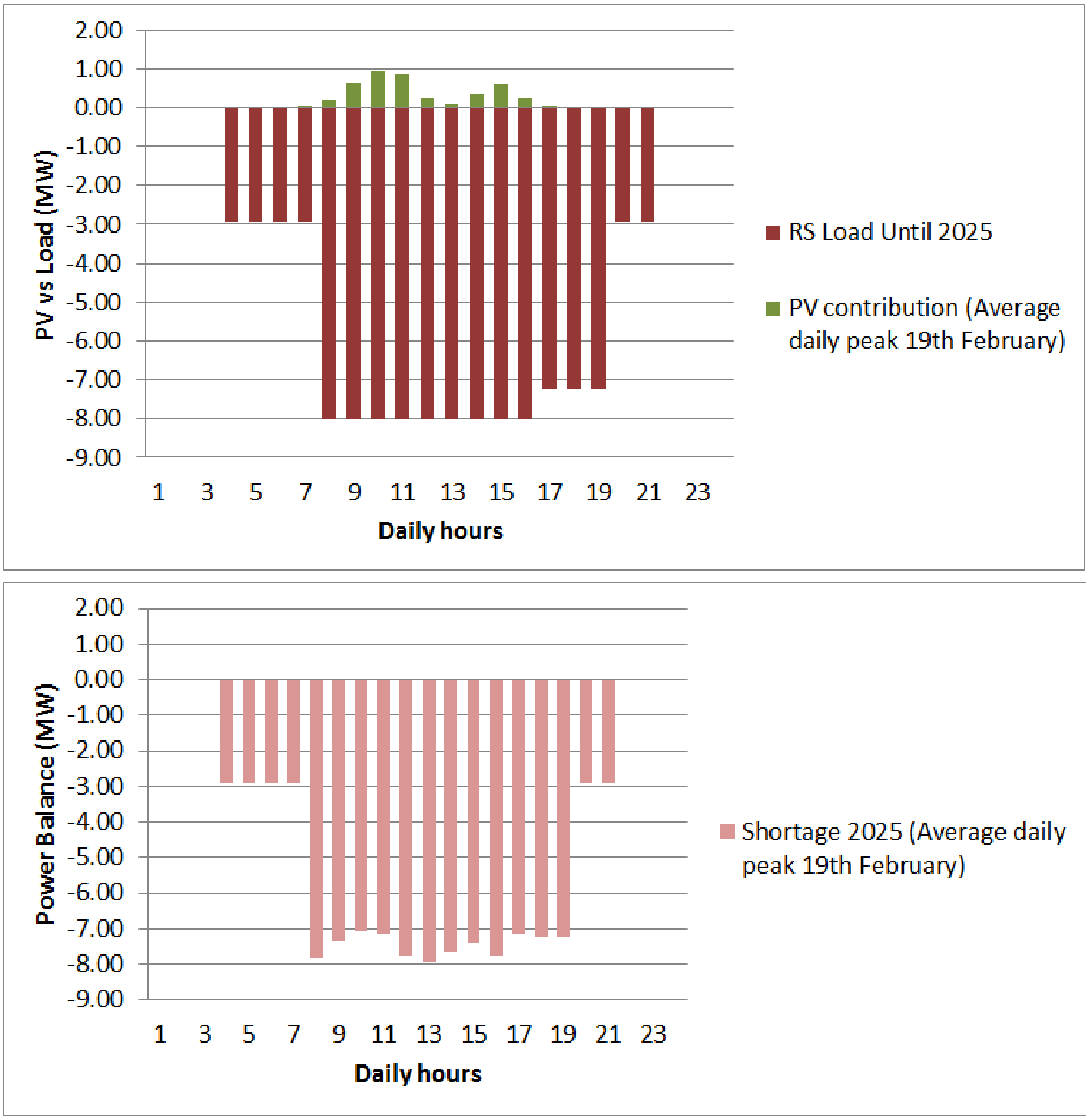


Figure 7-9: Daily energy balance profile of the recovery scheme in 2025



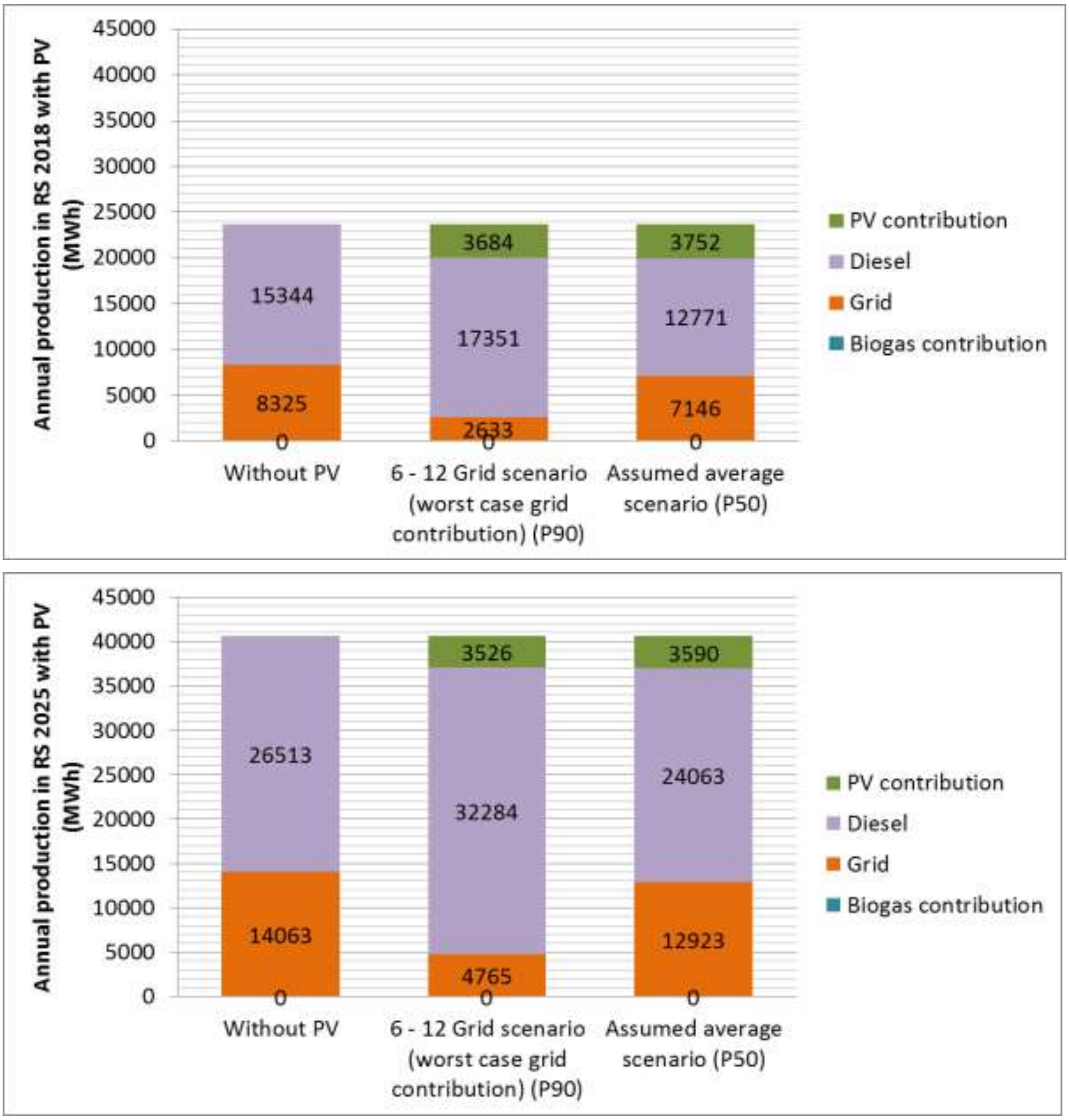
The resultant annual energy mix for the recovery scheme, Figure 7-8, was derived using same assumptions regarding grid availability and PV production mentioned in the last section. .

Table 7-7 shows the percentages of the contributions in P50 scenario (the nominal case).

Table 7-9: Annual energy mix in the recovery scheme

Years	2018		2025	
Total	**MWh**	**%**	**MWh**	**%**
	23668	**100%**	**40575**	**100%**
PV Share	3756	15.87%	3590	8.85%
Diesel Share	12771	53.96%	24063	59.30%
Grid Share	7146	30.19%	12923	31.85%
Biogas Share	0.00	0.00%	0.00	0.00%

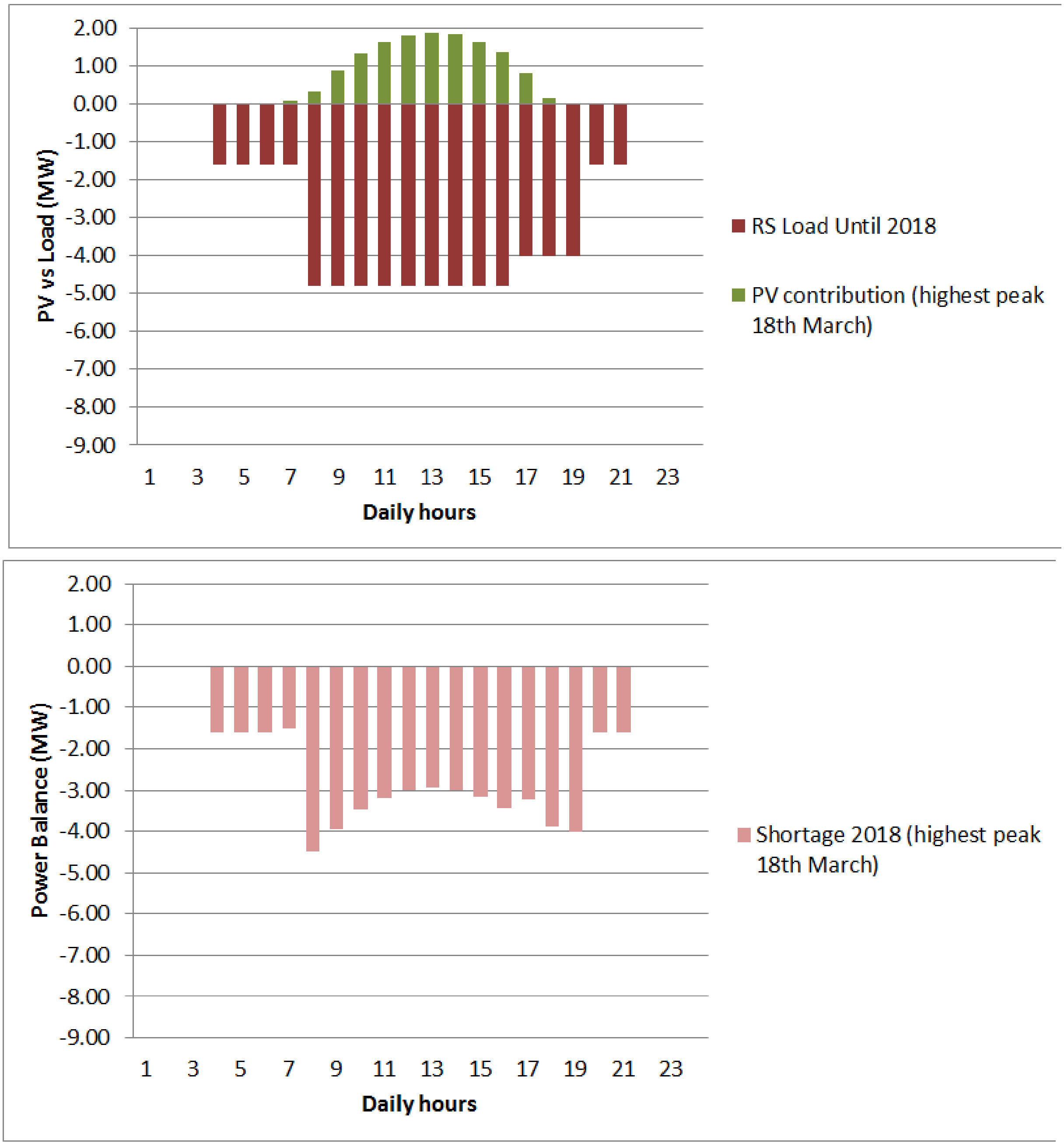
Figure 7-10: Annual energy mix at the recovery scheme in 2018 and 2025



7.2.3.2 Selected daily profiles

For a typical year and the expansion size from 2018 until 2015, the PV power generation reaches its daily peak of 1.8 MW instantaneous power produced at the recovery scheme on the 18th of March, as shown in Figure 7-9.

Figure 7-11: Daily profile and energy balance at the RS on 18th of March



The shortage prevailing over the whole day, also called residual load, shown in Figure 7-9 explains that the peak generation of the PV system does not result in excess as in the previous case in the WWTP. Daily shortage in the RS in the peak day reaches 51 MWh, much higher than the daily excess in the WWTP. The annual residual demand of 19,817 MWh would need to be covered by the external network and the diesel gen-sets.

The configuration described above shows the potential for optimisation of the use of the power generation excess at the WWTP for further reducing the residual load at the RS. Combining both systems together is discussed in the following section.

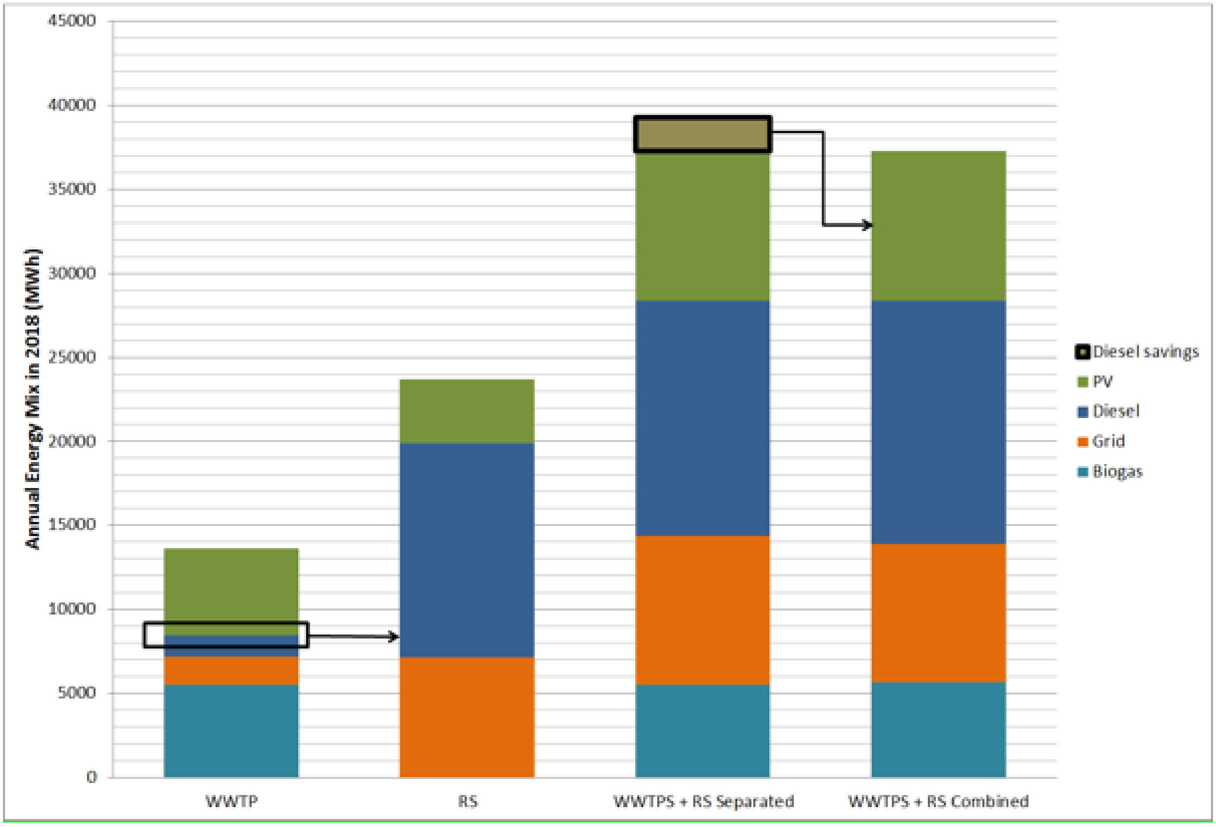
7.2.4 WWTP and RS Combined

The use of the otherwise unused excess power generated at the WWTP in 2018 can be optimised by connecting the electrical systems at the WWTP and the RS together. The technical concept is described in section 7.3.3. The effect of the joint electrical systems is that the overall load at the RS is reduced during the hours, where an excess of local RE generation occurs at the WWTP. This transfer from WWTP to RS leads to a reduction of the relatively high load at the RS and a lower so-called residual load, i.e. the effective load after subtracting the transferred excess power from the total load. This effect is independent of the status of the grid-based supply.

This impact of this combination is illustrated in Figure 7-10. The first bar shows the annual energy mix at the WWTP and the second bar shows the corresponding energy mix at the RS. During the hours of load shedding, the diesel generations are required to operate even during times of excess from RE sources at the WWTP (refer to explanation in section 7.3.3). The corresponding share of diesel supply is included in the sum of the annual balance of both locations for the separated scenario, which is depicted by the third bar. When both locations are connected together the diesel generators at the RS can take over the role of the grid-building component. Consequently, the diesel consumption can be reduced during the times of RE excess at the WWTP. The resulting energy mix displayed by bar 4 has a lower total demand than observed for the separate scenario in bar 3. The difference between bar 3 and 4 represents the saved energy generation by the diesel gen-sets, which could potentially be realised in a combined scenario.

In this context it shall be emphasised that this analysis and optimisation is based on assumptions and conducted without any operational data of NGEST. During actual operation, there may be other conditions that may impact the dispatch of the components. If the excess occurs only for a very short period, e.g. one hour during a day, the diesel gen-sets of the WWTP may well be kept idle or not even be reduced at all for performance reasons. Such situations can arise for instance due to the actual weather forecast or information about a limited shortage in the GEDCo grid.

Figure 7-12: Energy mix in 2018 of the separated and the combined scenario compared



The basis for the energy balance is the combined demand of the WWTP and RS together (Section 3.3).

The average daily energy balance is plotted as shown in Figure 7-11 and Figure 7-12 in 2018 and 2025 respectively.

Figure 7-13: Daily profile and balance in 2018

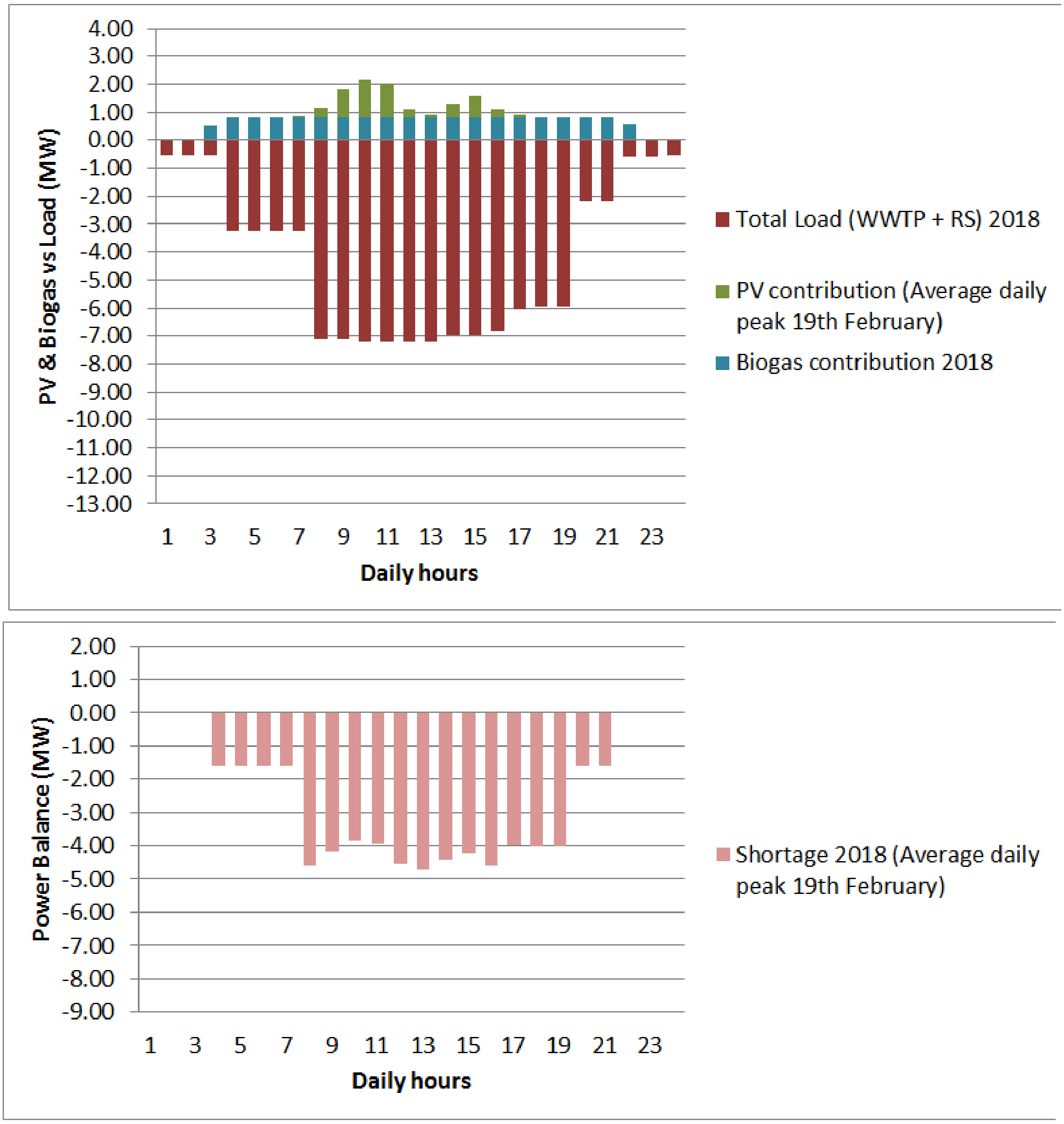
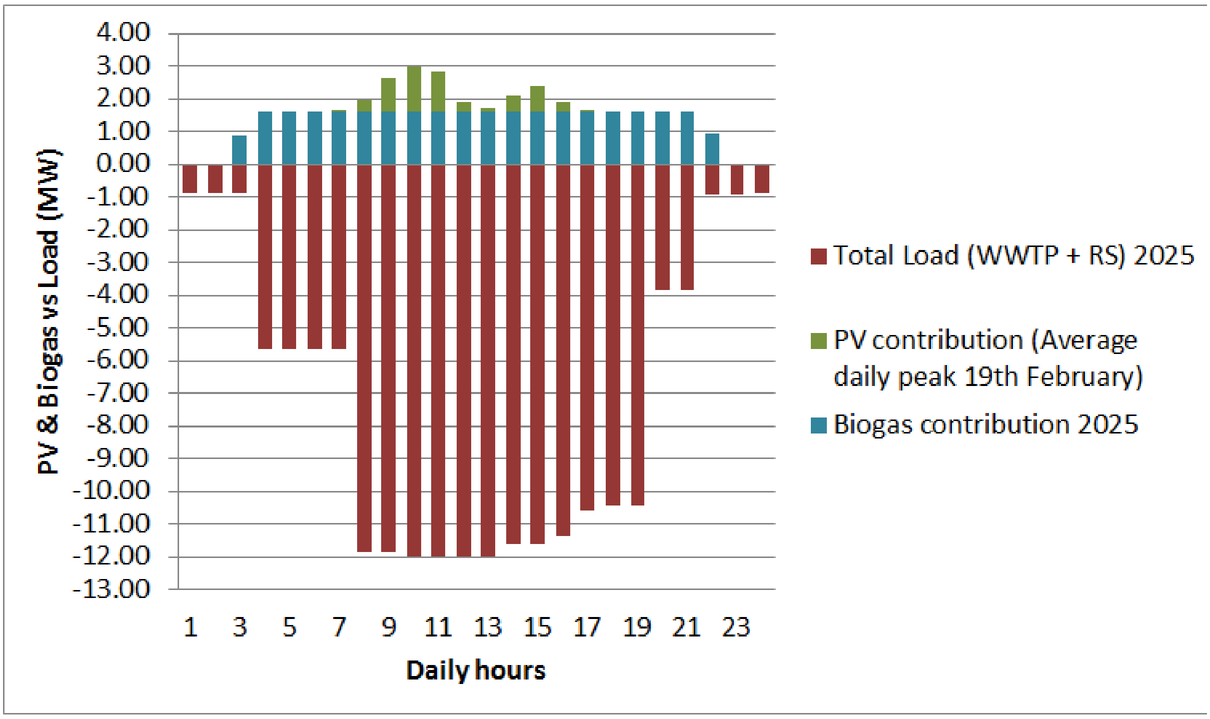
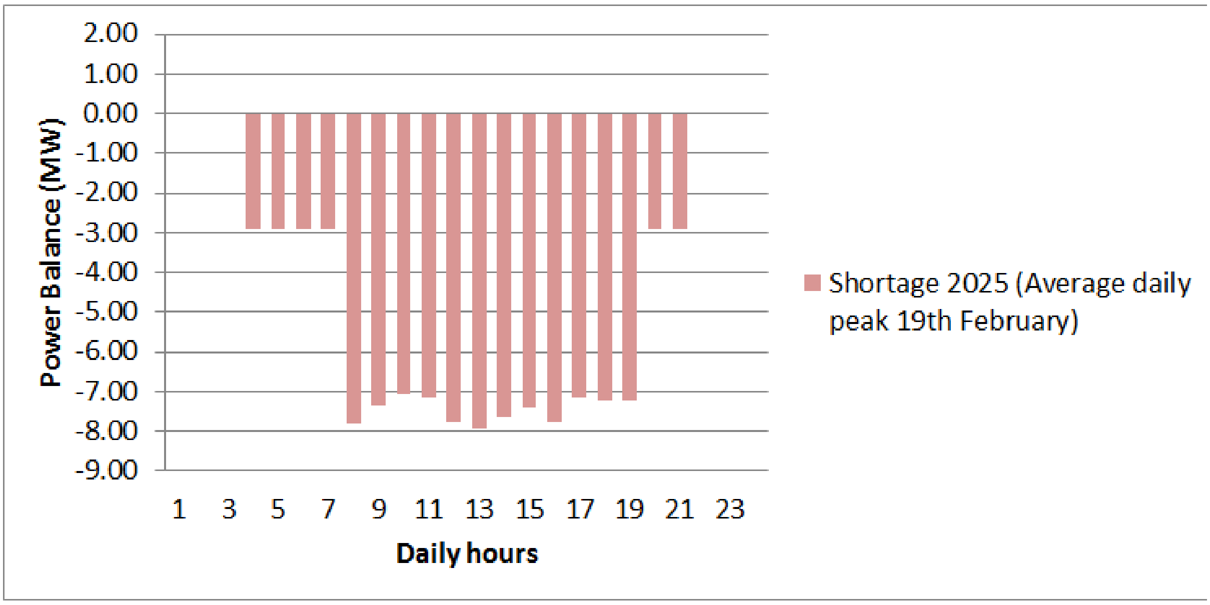


Figure 7-14: Daily profile and balance in 2025





As expected from the integration of the WWTP and RS, the installed capacities of the PV and biogas generators are not sufficient to cover the total project design demand. Hence, the additional supply from the grid and the diesel generators is necessary.

The PV yield estimate scenarios discussed in Section 7.1 and the grid scenarios discussed in Section 7.2 will be put here into consideration. The P50 scenario used the assumed typical grid availability scenario while the P90 scenario uses the worst-case assumptions for unavailability of the network.

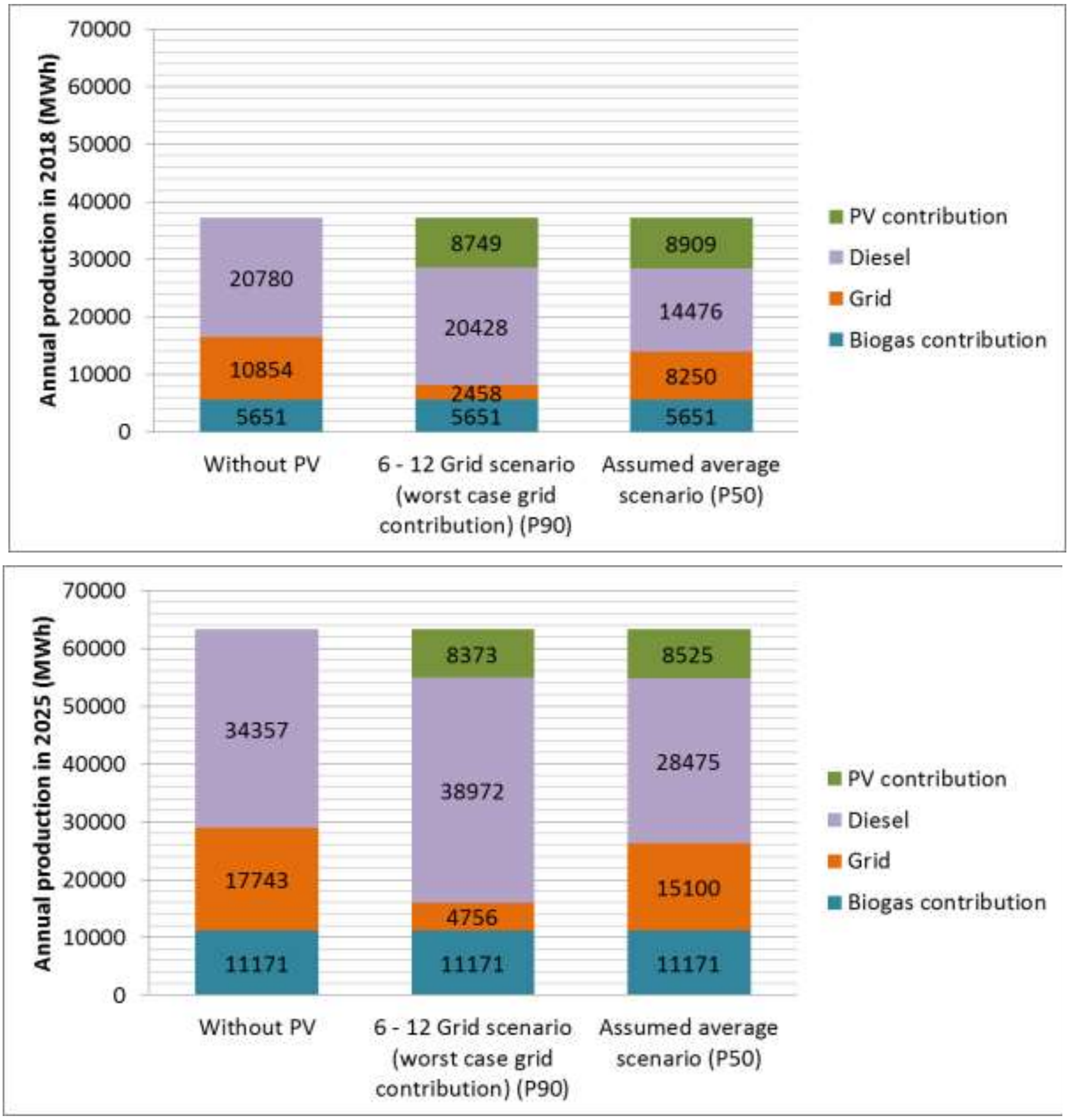
The subsequent annual energy balance for 2018 and 2025 is elaborated in Figure 7-13 showing the

P50 and P90 scenarios in addition to the “No PV” case. Table 7-8 shows the percentages of the contributions in P50 scenario (the nominal case).

Table 7-10: Annual energy mix (P50)

Years	2018		2025	
Total	MW.hr	%	MW.hr	%
	37286	100%	63271	100%
PV Share	8909	23.89%	8525	13.47%
Diesel Share	14476	38.82%	28475	45.00%
Grid Share	8250	22.13%	15100	23.87%
Biogas Share	5651	15.16%	11171	17.66%

Figure 7-15: Annual energy mix at 2018 and 2025



In this configuration, the total amount of the unused generated power at the WWTP is all utilized to contribute to the total demand of both WWTP and RS and no PV power curtailed or biogas flared. Through this measure, the total annual shortage decreases by 171 MWh in 2018, while in 2025 the total annual shortage decreases by 48 MWh.

7.3 Hybrid Plant Operation

7.3.1 Possible Operation Modes

The analysis of the energy balance shows that there will be no or hardly any time when the PV system alone can sustain the energy demand of the project. Since the plant power supply is provided by a combination of fuel-based sources (diesel and biogas) as well as variable and intermittent sources (grid, PV) the interaction needs to be evaluated.

It has to be ensured that the power supply can easily switch over from the on-grid supply into the off-grid supply with the different sources. In case of the off-grid situation, the grid must be maintained (frequency, operating voltage, power level). Since the power supply system as well as sewage treatment plant are not yet commissioned many parts remain to be looked at from only a study perspective.

In order to assess the capability of the existing design to support the integration of the PV plant into the power supply set-up, the different operational situations were evaluated under the following assumptions for the combustion engines:

- 1 gas engine set at max 800 kVA (COP) – power factor 1, as described in Chapter 4.3.1
- 3 containerised diesel gen-sets at max. 800 kVA (Prime) each and 730 kVA (standby) – power factor 0.8, as described in Chapter 4.3.1.

On the basis of the designed power supply and its planned extension (refer to Chapter 5.1) the following three operational situations are theoretically possible when operating in the off-grid mode:

1. 100% supply by the photovoltaic system
2. a hybrid system comprising the photovoltaic system and the gas engine
3. a hybrid system comprising the photovoltaic system and the gas engine and/or the diesel gen-sets.

The overall objective is to achieve minimum generation by the diesel engines in order to reduce fuel costs and to limit gas emissions – especially the burning of gas via the flare.

The operation modes can be split up into “island modes” and “Connected-to-the-grid modes”. Not all conceivable island modes are feasible, due to the fact, that a compensation of the reactive component cannot be realized by the PV-system. In addition, the gas-generator can only create cos φ = 1.

1) Island mode with the conceivable sub-modes:
   a) photovoltaic is running alone, 100% - not possible due to a non-existing compensation of the reactive component - **Not acceptable**!
   b) photovoltaic and the gas engine in parallel - not possible due to a non-existing compensation of the reactive component - **Not acceptable**
   c) photovoltaic, the gas engine and the diesel gen-sets are producing – only possible if a minimum power of diesel gen-sets is respected - **Acceptable.**
   d) gas-engine running alone - not possible due to a non-existing compensation of the reactive component - **Not acceptable**
   e) gas-engine and diesel engines running in parallel - only possible if a minimum power of diesel gen-sets is respected - **Partially acceptable.**
   f) diesel engines are running alone – this solution is of special interest for periods, when the gas engine is in maintenance - **Partially Acceptable**

The evaluation of these results shows that 3 of 6 modes are acceptable or partially acceptable. The only real acceptable mode for longer application is 1c), because it allows for producing a large portion of electricity with the solar panels and the biogas engine, while 1 or 2 diesel engines are turning near to 30% load for compensation of the reactive component.

2) Connected to the grid, e.g. Gaza Power plant, and the sub-modes:
   a) photovoltaic in parallel to the grid – Compensation of the reactive component only possible by the grid. An agreement with the electrical network operator is necessary – **Partially acceptable**.
   b) photovoltaic and the gas engine in parallel to the grid - Compensation of the reactive component is only possible by the grid. An agreement with the electrical network operator is necessary – **Partially acceptable**
   c) photovoltaic, the gas engine and/or the diesel gen-sets in parallel to the grid - possible if a minimum power of diesel gen-sets is respected **– Acceptable –** similar to mode 1c
   d) gas-engine running alone in parallel to the grid - Compensation of the reactive component only possible by the grid. An agreement with the electrical network operator is necessary – **Partially acceptable**
   e) gas-engine and diesel engines running in parallel to the grid. No compensation of the electric component by the grid is necessary – sewage gas will be burnt. An easy switch-over to mode 2c is possible. **Acceptable**
   f) diesel generators are running in parallel to the grid. Compensation of the reactive component by the grid not necessary. Diesel oil is used as the only energy source and is expensive. – **Partially acceptable**
   g) Black start mode – The diesel generators will produce for a short period the electricity for a start-up of the plant - no connection to the grid.
   h) Emergency mode – similar to 1f and 2f - only diesel-engines are running for electricity supply – for example during fire.

All operation modes with grid-connection make an export and import of electricity possible as seen from NGEST.

The only real acceptable mode for longer application is 2c) due to similar reasons mentioned already for 1c).

7.3.2 Electrical Requirements and Grid Operation

7.3.2.1 Dispatchability

NGEST can support the national grid with its diesel engines in periods of mode 2c). NGEST needs the support of the external grid in phases, when a compensation of the reactive component does not exist, i.e. modes 2a, b and d.

7.3.2.2 Black Start Capability

The black start capability can only be guaranteed by diesel engines. The gas-engine is too slow in its response. After a total plant shutdown, a signal will start 1 of the 3 engines as black start diesel. The first task is energising the plant grid within a few seconds, followed by a period of sequential starting of pumps and blowers. The plant status will go over in emergency status. After attaining a stable process situation the emergency status is over. For the black start interval and the emergency period the gen-set will run at maximum with stand-by power. The stand-by power will reduce to prime power after attaining normal situation.

7.3.2.3 Frequency/Voltage Regulation

The tolerated frequency range shall be + /- 2% giving an alarm when out of this zone. The generator tension shall allow a deviation of +/- 5%.

The compensation of the reactive component seems to be an important issue at NGEST. In order to gain some experience the plant shall be operated during commissioning at different power factors; from 0.8 lagging to 0.9 leading.

7.3.2.4 Ability to Run in Partial Load and Limitations on its Share for each Engine

The minimum load shall be at 30%. An operation below this value shall be prevented because of internal soothing. The effect of soothing is stronger at diesel engines than at gas engines. The reduced 30% load will be run by the diesel engines, when used for the compensation of the reactive component.

All 4 engines must be capable to run in parallel. A certain difference exists in power between the gas-engine and the diesel engines.

In case a difference in power is present, the danger exists in one engine taking too much load and trips. However, the installed load sharing could prevent this.

7.3.2.5 Start/stop Times of Engines

Different start and stop times have to be considered for diesel and gas engines. The gas engine has a slower response and needs longer intervals. See estimated values below for 1500 rpm engines in seconds.

Action	Diesel	Gas
Starting	20	40
Synchronising	5	5
Charging	10	25
Decharging and stop	10	15

7.3.2.6 Ability to Run the NGEST Autonomous of the Grid

The pre-condition is: at least 3 of 4 gen-sets are available. The situation of one gen-set is under repair or at maintenance must be considered. The max electrical power demand shall be below this value.

7.3.2.7 Issues Related to grid Re-synchronisation

A synchroscope on each feeder line to and from the grid is necessary.

Energy meters for effective power and reactive power for imported and exported energy are needed.

7.3.3 Concept for Improved Local Supply

A hybrid power supply from different power sources requires a well-elaborated instrumentation and control concept to secure the operation of the varying loads. The conditions under which this can be realised with the designed components are described in ANNEX section 12.4.

The analysis of the energy balance of the two project locations in section 7.2.4 shows that the combined operation of WWTP and the RS brings advantages to the power supply and thus to the operation. This applies especially in the off-grid periods with high production from the biogas and PV components occurring during mid-day, when NGEST's operations have their daily peak.

On this basis it is recommended to optimise the use of the renewable energy generation at NGEST by implementing a Point of Common Coupling (PoCC) in the 22 kV OHL to the GEDCo network ahead of the RS switch gear. This PoCC can be established by installing an additional circuit breaker in the connection line with an energy meter attached to it with signal cables connected to the switchgears at WWTP and RS.

This concept is shown in the schematic diagram in Figure 7-16. It depicts the topology of the current of the power system and then the modified system as after installation of the PV system and PoCC.

In the off-grid case, this measure CB has the following impact:

- The facilities can be completely islanded from the network during load shedding.
- This avoids any negative impact from and to the network including back-feeding.
- The higher loads are installed at the RS. Thus, at no time excess of power is expected at that location. Consequently, the generator gen-sets at the RS would be running constantly during load shedding.
- In the control sequence, these generators would be defined as the master devises, which start first after grid goes off. The master devices would also build the grid whereon the other components would synchronise on.
- With this setting, the diesel at the WWTP could then potentially be shut down.
- The signal cable would allow sending a stop signal to the commercial energy meters located at the low-voltage side (0.4 kV) of each transformer.
    - This is an important commercial aspect because if meters are not halted NGEST would have to pay for any excess power which is transferred from the WWTP to RS.
    - Another option could be to allow the meter at WWTP to reverse and the meter at RS to continue spinning forward. But due to the constant operation of the diesel at the RS (load high and the requirement on the diesel as grid builder) a power flow from RS to WWTP would occur during the very short synchronisation phase.
    - Thus, the metering and billing of energy produced local within the NGEST facilities can only be avoided if meters are stopped during island operation.
- The arrangement shows that NGEST is actually supplied on LV and GEDCo bears the costs of the transformer losses. In case energy is transferred between the two locations, transfer losses occur at either side, e.g. when stepping up at the WWTP and then again when stepping down at the RS. These losses are regarded as minor – also because a connection of both locations on LV level is not viable.

In case the grid is operating during the period the excess at the WWTP occurs, the two facilities would not be disconnected at the PoCC. A commercial solution has to be identified that allows NGEST to export the excess from the WWTP to the RS without being double-charged. Possible solutions are:

- Stopping the energy meter at the WWTP, or
- Allowing the meter to reverse (bi-directional meter) and then subtract the recorded amount from the readings at the RS

This metering issue would be best solved by an agreement with GEDCo that allows NGEST to employ net metering. As shown in the energy balance analysis, net metering in the case of NGEST, with its high net demand, would have no effect for the commercial part of GEDCo, i.e. it would not require implementing a credit system to account for annual import from and export to the network as it was the case for a network-wide net-metering regulation for end-consumers.

With this proposed concept, complexity of the commercial part increases slightly. Grid availability needs to be logged and verified by a proper documentation and verification of metering values in a frequency higher than monthly values, i.e. at least hourly value. The SCADA system and monitoring devices will be of additional help providing an indirect control function, e.g. by logging time the grid is not available or providing the power output of the PV system and biogas engine.

Ideally and under a well-defined load shedding regime, the system could be prepared for non-interrupted transition from grid to off-grid, e.g. the master diesel already synchronises to the grid a short time ahead of the rolling blackout. Also, all consumers need to be protected from the few seconds of interruption in case of sudden break or be able to withstand such short interruption.

The independent operation and metering of both locations would lead to a certain amount of excess, especially until the processing volume at the WWTP is increased in 2025. This is shown in the evaluation of the energy balance shows (compare section 7.2.2 and section 7.2.4). Through installation of battery banks or an expansion of the biogas storage, this excess could be utilised locally at the WWTP. But costs for these measures are expected to be higher than the benefit:

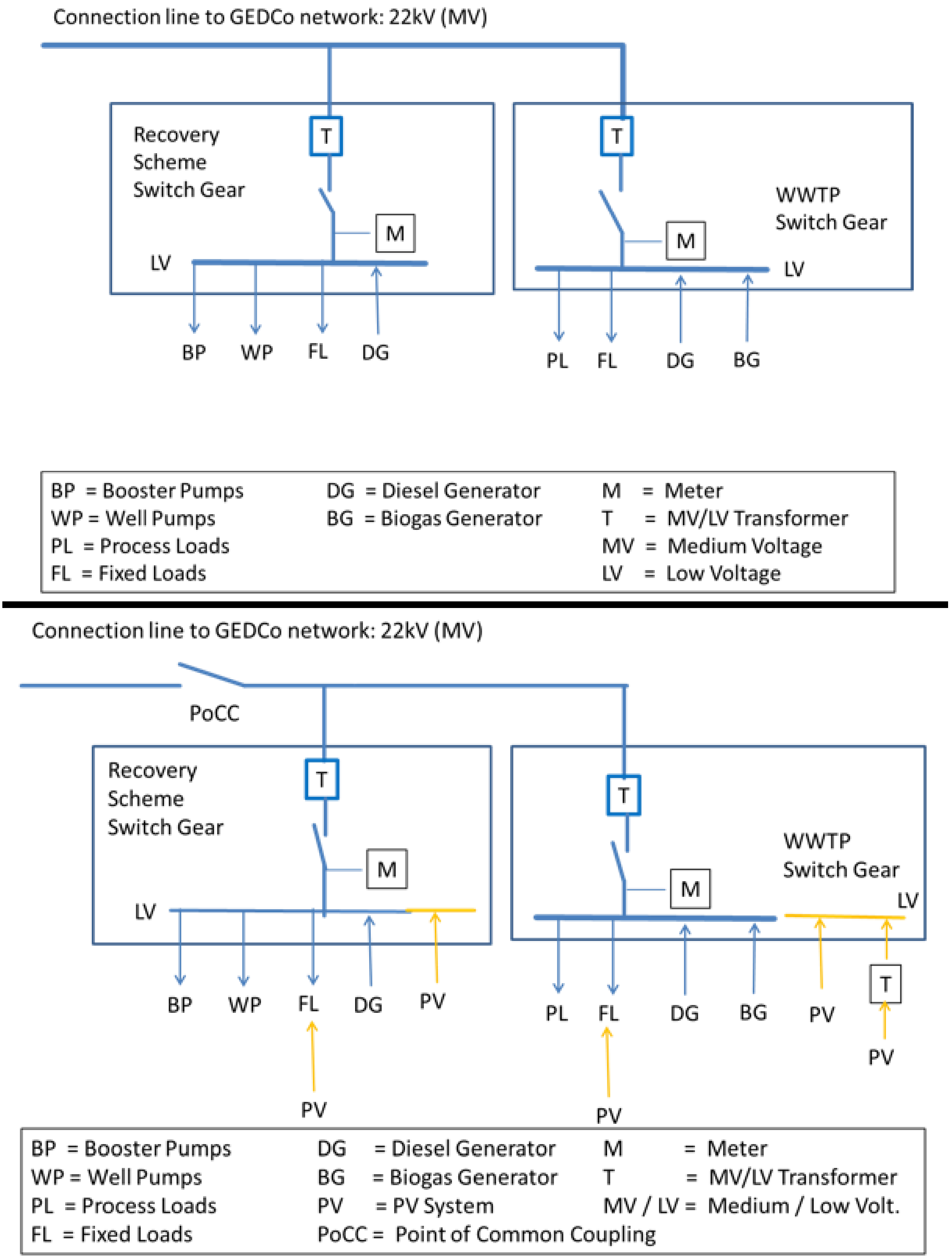
1. The high excess is only observed during Phase 1, meaning that the payoff and utilisation of the measures would be less after 2015;
2. Batteries would increase the total CAPEX of the power supply and add more complexity;
3. Increase of the biogas holder would require a modification of the already installed biogas facilities, incur additional costs and reduce the installation area for PV A1. This option can be adopted if the net-metering for the combined scenario is not accepted by GEDCo.

As conclusion it can be stated, that the described concept would lead to the lowest modification of existing structure and technical design in comparison with other measures (i.e. additional connection line between the two locations or independent management of the two locations). Additionally, it would carry a relatively low impact on GEDCo's network and come with minor commercial implications.

In this context, it shall be noted that it was not possible to obtain the Grid Code for GEDCo's network from the utility nor was it provided by the stakeholders. Tight consultation and coordination with the utility on the next step is recorded as a condition for the success of the project. The final solution can only be identified and agreed upon together with GEDCo.

On the technical level, it is suggested to initiate a discussion with SIEMENS as the NGEST SCADA supplier regarding integration of the control of the PV system into the overall facility administration.

Figure 7-16: Generalised schematic of current design (above) and with PV (below)



7.3.4 Conclusion on the Need for local Storage

The Power supply systems that consist of several sources and run in either grid-connected or island mode need to ensure that the supply is always met and that power is provided with the required quality. In addition to these technical requirements, the operators may want to dispatch the primary sources depending on their cost impact, i.e. utilise the least-cost source of electricity as much as possible and so on.

High frequent changes in PV output can have an impact on the operation of diesel generators during island mode. But given the design information available at the time of study, the volatility of PV output is not regarded as an issue for the operation of the diesel generators because there is always a high share of diesel power in the system. This means that at least parts of the diesel generators would be always running during off-grid times. In the same way as the generator reacts to load changes, e.g. when a pump is switched on or changes its speed the diesel engine reacts to frequency changes in the power supply system and thereby balances the PV fluctuations[38]. Even through the co-operation of PV and diesel may have an impact on the efficiency of the diesel, i.e. genset not running at full load or changing load more often, it is still regarded as more cost-efficient to use the diesel generators to offset any fluctuations of PV power than to use batteries. Batteries have higher investment costs and a shorter life-time than diesel engines. So gensets are less costly than battery systems, especially if not used regularly to their full like in the NGEST case. If evaluation of the final Contractor's design shows that the ramp-rates are too high or the recovery scheme construction delays, a temporary buffer battery could be installed. During the on-grid times, the underserved GEDCo network is always a better storage than any battery installed at NGEST.

NGEST's operation profile leads to a clear day-time profile with peak towards early afternoon. This cycle coincidences well with the PV production and together with short-term storage flexibility offered by the biogas holder, installation of batteries are not needed to increase the share of renewable energy in the whole power supply.

[38] According to further information provided by the engine manufacturer Perkins, the engine recovers from a frequency change within 5 seconds.

8. Preliminary Environmental and Social Impact Assessment

8.1 Objective of the Preliminary ESIA

The main objective of this preliminary environmental and social impact assessment (ESIA) is to assess both the negative and positive social and environmental consequences related to the construction and operation of photovoltaic systems at the NGEST site. Moreover, it shall outline an implementation and monitoring plan for mitigating the negative impacts and define the institutional responsibilities for the implementation of the plan.

More specifically the ESIA will address the following main issues:

1. Environmental and social impact of the project.
2. Potential Land acquisition needed for temporary construction work or for permanent use by the project.
3. Preparing an implementation plan for mitigating the negative impact (if needed).
4. Assessment of the capacity of the implementing institution and recommendation on any capacity building needs (if needed).

8.2 Legal Basis and Reference Guidelines for the Assessment

8.2.1 Palestinian Legislation and Regulations

The relevant laws and policies that govern the conduct of environmental assessments in The Palestinian territories can be summarized as follows:

- Palestinian Environmental Law # 7 issued 1999.
- The Palestinian Legislative Council approved the first Palestinian Environmental Law, which was signed by Chairman Arafat on 28 December 1999.
- The Palestinian Environmental Strategy (PES) which was published in October 1999 by MEnA. It covers the political and social context, the legal and institutional framework, the environmental driving forces, the environmental themes and the strategy elements.
- MEnA (EQA) has issued an Environmental Assessment Policy which provides implementation procedures. The Environmental Assessment Policy will assist in meeting, *inter alia,* the following goals:
  - to conserve the social, historical and cultural values of the Palestinian people and their communities;
  - to ensure an adequate quality of life, health, safety and welfare for the Palestinian people;
  - to preserve natural processes;
  - to maintain the sustainable use and the long-term ability of natural resources to support human, plant and animal life;
  - to conserve bio-diversity and landscapes;
  - to avoid irreversible environmental damage from development activities; and
  - to ensure that the basic needs of the people affected or likely to be affected by a development activity are not jeopardized.

Within the terms of the draft policy, MEnA (EQA) is responsible for the implementation and for the approval and assessment of environmental considerations in relation to proposed developments. It is expected that the EQA will liaise with relevant institutions, such as the PWA, in relation to the proposed developments.

The form of the policy is similar to that of the World Bank (see details below) and it specifies the requirement for comprehensive EIAs (necessary for projects likely to have significant impacts) and an Initial Environmental Evaluation (IEE) for projects, where significant impacts are uncertain, or where compliance with environmental regulations must be ensured. Completion of an IEE may necessitate the conduct of a comprehensive EIA.

The Palestinian Water Law # 14, 2014, and the Palestinian Energy Authority Establishment Law #12, enacted in 1995, form part of the wider legal framework. The latter law sets the main responsibilities of the PENRA and defines the various energy sources including renewable sources that the authority can utilize for the generation of electricity.

8.2.2 WB Reference Criteria Catalogues

The key reference in this context is The World Bank's Operational Policy/Bank Procedures/Good Practices (OP/BP/GP 4.01) and associated documents.

The purpose of undertaking an EIA is to improve decision-making and to ensure that the considered project options are environmentally sound and sustainable. The EIA should identify ways of improving the environmental compliance of projects by preventing, minimizing, mitigating or compensating for adverse impacts. Accordingly WB OP 4.01 identifies that project-specific EIAs should normally cover the following aspects:

- existing baseline environmental conditions;
- potential environmental impacts;
- systematic environmental comparison of alternative investments;
- systematic environmental comparison of alternative sites;
- systematic environmental comparison of alternative technologies and designs;
- preventive, mitigation or management plan;
- environmental management and training; and
- environmental monitoring.

The level of EIA performed should be based on the expected environmental impacts, as determined by the type, location, sensitivity, and scale of the proposed project, as well as the nature and magnitude of its likely potential impacts. Projects are grouped into categories characterising the potential impacts in accordance with the OP.4.01:

- Category A (those that are likely causing significant impact) projects should be subjected to full environmental analysis through the planning and implementation phases.

- Category C: A proposed project is classified as Category C if it is likely to have minimal or no adverse environmental impacts. Beyond screening, no further EA action is required for a Category C project.

- Category B: A proposed project is classified as Category B if its potential adverse environmental impacts on human populations or environmentally important areas – including wetlands, forests, grasslands, and other natural habitats – are less adverse than those of Category A projects.

These impacts are site-specific and few maybe irreversible. In most cases mitigation measures can be designed with less effort than for Category A projects. The scope of EA for a Category B project may vary from project to project, but it is narrower than the one of a Category A EA. Like EA for a Category A project, it examines the project's potential negative and positive environmental impacts and recommends any measures needed to prevent, minimize, mitigate, or compensate for adverse impacts and improve environmental performance. The findings and results of Category B EA are described in the project documentation (Project Appraisal Document and Project Information Document).

- Category FI: A proposed project is classified as Category FI if it involves investment of Bank funds through a financial intermediary, in subprojects that may result in adverse environmental impacts.

When looked at as a standalone project, the current project can be, according to the World Bank operational policies (OP 4.01), classified as category C project. The rationale is that the installed PV modules do not produce any noise, toxic-gas emissions, nor greenhouse gases during their lifetime use of nearly 30 years. The local population is not adversely affected and no resettlement would be required. Therefore, preliminary environmental assessment or environmental screening will be carried out for the project component (PV solar panels) that will be installed at the NGEST location.

Nonetheless, if the project is looked at as a component of the overall wastewater treatment and reuse project (NGEST), it is likely to be looked at in a similar way as the overall project and could be classified under the same category as the main project which in this case is a category A. The preliminary assessment in the next sections shows that the addition of a PV system to NGEST does not adversely impact the overall EA rating of NGEST. The results of the previous assessment remain therefore valid.

8.3 Review of the ESIA Issued for the NGEST Project

8.3.1 Scope

A detailed Supplementary Environmental and Social Impact Assessment Study (SESIA 2013) has been prepared for the NGEST project (Waste Water Treatment Plant and Effluent Recovery Scheme) since it was classified as Category A project, according to the World Bank operational policy, because it involves wastewater production, treatment and reuse as well as recharge to the groundwater, which might entail some environmental and social impact. The risks involved related to the possible groundwater pollution, agricultural land contamination, land acquisition for the construction of the project (infiltration ponds and the treatment plant, etc.). Accordingly, the scope of the ESIA includes the determination of any expected environmental and social impacts and the preparation of an environmental management plan for managing, mitigating and monitoring risks and negative impacts.

Moreover, the ESIA took into account the temporary and permanent land requirement for the project and checked the type of land acquisition foreseen and prepared safeguard instruments in compliance with World Bank OP 4.12 related to involuntary resettlements.

The preparation of the ESIA has taken into consideration the requirements of the EIA policy of the Palestinian Environmental quality authority as well.

However, the ESIA does not address the impact of the surrounding environment on the PV plant.

8.3.2 Areas Covered

The ESIA for NGEST project covers the entire project location and the surrounding areas including the areas currently proposed for the PV solar panels. The ESIA also covers the recovery field areas in the analysis and potential impact. The analysis included potential public health impact and monitoring, groundwater quality and pollution as well as capacity building needs to manage the recovery scheme.

8.3.3 Power Generation from Different Energy Sources

8.3.3.1 Diesel

The ESIA addresses the power generation issue under the section on "energy demand and response plan of energy shortage from the grid".

8.3.3.2 Biogas including gas holder with flare

The generation of biogas is considered as a part of the energy sources envisaged to cover the demand of the plant energy demand within the ESIA. It is assumed that up to 0.8 MVA (40%) of the energy demand is secured from the biogas generation from the two sludge digesters.

8.3.3.3 GEDCo supply

The line route of GEDCo supply is not covered by the ESIA.

8.3.3.4 Power supply and diesel generators at recovery areas

The power supply for recovery and reuse during Phase 1 is assumed to be covered from the grid as well as from the biogas generated in the plant. The two standby diesel generators of 500 kVA each are also considered in case of electricity shortage or failure from the grid.

8.3.4 Gap analysis

The ESIA of the NGEST project has addressed most of the environmental aspects related to the wastewater treatment plant, the infiltration basins and the recovery and reuse schemes. It developed detailed environmental implementation and management plan to tackle potential environmental impacts during construction and operation phases.

However, the ESIA did not anticipate the PV energy generation and therefore did not address the impact of the PV on the environment nor did address the impact of the surrounding environmental conditions as well human interventions on the PV plant proposed for the NGEST project. Accordingly, the main areas that will be covered under this preliminary environmental assessment can be summarized as follows:

1. The environmental and social impact of the PV panels on the NGEST project area and the proposed Waqf land in the future stage. More specifically, the analysis will address the impact of the land use change, land acquisition for the new PV panels, the impact on flora and fauna, the impact on air and water, impact on the local community.
2. The impact of natural conditions and human activities on the PV panels. Specifically, the solid

waste collection vehicle movement around the site using dirt roads, the charcoal factory, the temperature and humidity and other climate conditions and their implications on local environment.

3. Impact of political conditions and wars on the PV plant.
4. Development of an environment management plan to propose mitigation measures of negative impacts and possible costs associated with mitigation.

8.4 Preliminary Social and Environmental Impact of PV on Project Area

8.4.1 Terrain under Investigation

The scope of the current preliminary ESIA is limited to the location of the PV system that will be installed within the fenced boundary of the NGEST project in addition to the proposed future expansion to the Waqf land located to the west of the cemetery. Therefore, the space where the assessment will focus on is very limited. The major part of it is already fenced for the WWTP and covered by the main ESIA report that was developed for the NGEST project.

The use of space within the boundaries of the plant will vary according to the type of PV variant that will be finally selected. However, the space needed for four of the proposed design variants is nearly the same. Only the variant 4 with the two axis tracker differs slightly because it utilizes more space, but places the structures in a less dense pattern as shown in Drawing 001 and Drawing 002.

The total area that will be covered by the PV systems ranges between 35,000 m² to 73,000 m² in the case of the two axis tracker PV system on the NGEST project area. In addition, a free field system will cover around 30,000 m² of the Waqf land.

8.4.2 Potential Impact

Figure 8-1: Example of area within the WWTP

Due to the fact that the PV panels will mostly be installed within the WWTP terrain and that detailed environmental assessment has been carried out for the location, it is logical to assume that installation of additional equipment (PV Panels) that will neither occupy new land outside the location nor produce any harmful emissions (gas and liquid) and will not produce greenhouse gas, will not create additional potential negative impact on the local environment during its lifetime. However, by the end of the PV panels life time they should normally be treated as WEEE (Waste Electric and Electronic Equipment) and therefore should be either considered for recycling or reuse or safe disposal. In this context and since the lifetime of the PV system is estimated at nearly 30 years, it is difficult to predict the situation in Gaza then, what PWA's will be like, and what development in the recycling and reuse technology will take place. A good practice, however, is to consider additional costs for decommissioning. An estimate for the dismantling is to be added to the budget of the project ensuring that by the end of the life time of key components a proper budget for removal and recycling. These considerations relate mainly to the main electrical equipment, the PV modules and inverters, which are expected to be replaced after their life time. The other parts of the system remain functional – given that maintenance is executed correctly.

Although the typical lifetime of commercial PV projects is planned with 20-25 years, the components may last longer while the performance degrades over time. Since NGEST is a facility providing public services and as such planned to remain in place over a longer period it is unlikely that the whole system will be decommissioned. A replacement or repowering of underperforming parts may be the more cost-effective approach. The costs associated with this include the proper decommissioning of the modules to be replaced, the purchase of new products and the labour required for installation and retrofitting. The PV industry has established special networks responsible for the recycling of PV modules but they are currently limited to a certain jurisdiction, e.g. EU as in the case of PV cycle[39]. But some manufacturers or distributors also maintain collection points outside the region. This strongly depends on future market development but brings the decommissioning or replacements costs down to the export and shipping to the collection points (i.e. labour and transport).

The installation area is already closed and reserved for the use by the NGEST facility. The flora on the site is limited to species of local seasonal wild plants, which are commonly available in Gaza with no record of endangered species on the site. The vegetation has filled the areas after covering up the terrain at the end of the main construction activities for the WWTP.

Figure 8-2: Example of area within WWTP on the East side

Moreover, no fauna is expected on the site except some birds and possibly insects and lizards, again there is no record for any endangered species in the area. The impact of the PV installation might cause some disturbance during the construction stage to these creatures but it will be limited and for a short period of time.

39 http://www.pvcycle.org/

The PV panels are free of hazardous materials (liquid, solid or gas) and therefore are not expected to create any risk for the surrounding areas in terms of spillage or emission. The same would apply to the workers' health during installation and operation.

The impact of the PV on the land use will also be limited. The areas inside the NGEST plant are already artificial surfaces covered with roads and paved areas. Only limited areas of the WWTP terrain are currently open space. The impact on the aesthetic view is therefore very limited with no major change in the land use shape and no major excavation or change of morphology in the area. Similarly, the PV installation will have no pollution threat to the air and local water resources in the area.

The expected social negative impact is also very minimal since there is no close community adjacent to the plant. The nearest community is Jabalia at distance of around 5 km. Moreover, the land is not used for any production purpose. However, it is likely that some positive impact can potentially be anticipated during the construction stage and later on during the operation stage especially, when electricity generation from the PV panels will start and the surplus will be fed into the grid. Such surplus will benefit the local communities and they will enjoy more frequent electricity or longer supply hours, which would most likely improve their livelihoods. This effect can only be finally confirmed once a final and reliable energy balance is generated as part of the feasibility study. Moreover, another positive impact during the construction stage could probably arise from job creation for the technicians and local workers who will be involved in the installation of the PV system. Although this impact is for limited period but under the given hard economic situation of Gaza and high unemployment rate it creates a positive impact. Since PV is a new technology in Gaza, workers would gain also from the knowledge transfer during the activities.

The investigated land is owned by the state and therefore, no acquisition procedure is required and no impact on individual land ownership that would require a dedicated safeguard process.

The impact on safety of workers and operators during installation and operation will be low to moderate. Only precautions are needed since work will be carried out mostly inside the plant and next to the steep sides of the infiltration basins and roofs of buildings. Clear work procedures during the installation have to be taken into account by local contractors to avoid any potential work incident.

8.4.3 PV System Impact Mitigation Measures

It is clear that no major mitigation measures are needed since the negative impact is low on various social and environmental constituents of the project area. The only measure needed to ensure safety of workers during installation and operation and to have clear working procedures and take safety measures to avoid falling in the ponds or from the roofs of buildings. In addition, it is recommended to limit the working time during construction to the day time and to consider using light machines to minimize noise and vibration so that no disturbance to local fauna is secured.

To mitigate the impact of PV panels decommissioning at the end of their useful lifetime can be incorporated from the early beginning of the plant construction in a similar way of other electric or electronic installations. Reported practice in this regard can be in the following forms:

- To absorb the decommissioning cost by the responsible utility or authority through the tariff they charge for the electricity produced and to be combined with the related services tariff, for example treating wastewater tariff or reuse of treated effluent tariff.
- To set aside an escrow fund at the system installation to consider using the service or logistic and recycling companies for decommissioning of the system and either recycle locally if the capacity is

available or use the same channels of recycling with the PV manufacturers by shipping the dismantled parts back to them.

8.4.4 Impact of Natural Conditions and Human Activities on the PV Systems

The potential impact of the local environment on the PV panels arises mainly from two sources:

8.4.4.1 Impact of Solid Waste Vehicle Movement on Dirt Roads

Figure 8-3: Lorry carrying municipal waste to the landfill

It was observed that the NGEST plant is surrounded by two dirt roads that are used by solid waste collection vehicles to transfer solid waste to the land fill used by Jabalia to the east of the plant as shown in Figure 8-3. The dust created by vehicle movement will likely lower the efficiency of electricity generation from the PV panels and will require frequent cleaning (e.g. by using water).

8.4.4.2 Impact of the Charcoal Production Site

Figure 8-4: Local charcoal production site

The existence of charcoal factory at nearly 300 m distance to the west of the plant has potential impact on the efficiency of the PV plants. Smoke resulting from the charcoal production might cover the PV panels and reduce the exposure to sunlight. This in turn will reduce the potential electricity production.

8.4.4.3 Mitigation Options for the External Impacts on PV System

The dust created by vehicle movement can be mitigated through the pavement of the roads around the plant. Alternatively, frequent cleaning of the PV panels will be required using large quantities of fresh water. Given that water is scarce in Gaza it might add additional pressure on the already strained water resources and will require more analysis in terms of potential impact.

8.4.5 Impact of Political Conditions and War

The proximity of the plant to the border with Israel renders it vulnerable to any future armed conflict in the area. In fact some fractures of weapons found already around the administrative building from the war of 2014 as reported in the inception report of this project. This triggers the possibility of damaging the PVs in any future armed conflict or war.

8.4.6 Water for Cleaning

The water needed for cleaning the PV panels from the dust will create an additional issue of concern especially in the context of Gaza water crisis. Freshwater availability is already lacking for drinking and domestic use. Therefore, any additional fresh water quantity will put more pressure on the already scarce resources and depends on the quantity needed. This may escalate the demand and hence increase the cost of water for domestic use inside Gaza.

Possible mitigation will only be possible in the case of ceasing the dust emission from the dirt roads or using the water from the recovery wells of the NGEST plant for cleaning. The latter will be subject to the quality of water from the recovery wells.

8.4.7 Proposed Environmental Management Plan

Project Activity	Potential Impact	Proposed Mitigation Measure	Institutional Responsibility	Estimated Cost ($)	Comment
Preparation Stage					
Site clearance prior to installing the PV panels	Safety of workers	Safety procedures followed during the work	Contractor	0$, part of the contract	
	Damage to existing infrastructure inside the NGEST Plant	Review site plans, shop drawings, cross sections and maps available for the infrastructure prior site clearance	Contractor	0$, in case of no damage. Repair any damage at contractor's cost.	
Construction Stage					
Dust emission	Ambient air quality		Contractor		limited
Hazardous waste handling, spills, emission (if any)	Impact on groundwater, soil, air quality	Site waste management plan including collection, storage and proper disposal			No impact foreseen, because no hazardous material All waste must be collected and disposed.
Excavation for the base of the PV tracker systems and regular PV panels	Disturbance of local fauna	Limit the excavation by using light machines with low vibration. Shorten the time of excavation as much as possible.	Contractor		
	Endangering workers from bites by local invertebrates	Safety procedures and precautions followed			
	Damaging local infrastructure at WWTP	Review site plants, shop drawings, cross sections and maps available for the infrastructure prior excavations			

Project Activity	Potential Impact	Proposed Mitigation Measure	Institutional Responsibility	Estimated Cost ($)	Comment
Mounting PV cells and Steel carriers	Impact on workers, possible injury	Safety procedure and plan			
Operation Stage					
Recover water from wells for cleaning of PVs	Health impact on workers / operators	Check quality and ensure it is safe. Train operators on safety measures and procedures. Make proper drainage for the used water. Consider option of mechanical cleaning or pressure air blowers to reduce water use.	PWA	$20,000	Depending on the quantity needed and the quality of recovered water
Maintenance of PVs and related inverters and other devices	Technician health, electric shock	Safety procedures to be followed. Training program on how to do maintenance is a must. Special cloths and protective means (gloves) to be used by them. Detailed operation and maintenance plan to be developed for the PV.	PWA		The contractor should make the training as part of the contract.
Decommissioning of PV system	Electronic components are electronic waste and may harm the environment if not properly disposed. Thin films used by the	Clear procedure for recycling locally or internationally by shipping back to manufacturers or reuse the PV units. Should either recycling	PWA	Cost of labour for installation and transport of PV panels	Logistic and dismantling companies can be assessed and their capacity identified. Conduct training if necessary for them to do the work.

Project Activity	Potential Impact	Proposed Mitigation Measure	Institutional Responsibility	Estimated Cost ($)	Comment
	PV may contain some heavy metals and therefore if not disposed of properly may have some environmental impact	or reuse not be possible, proper and safe disposal of dismantled PV units be planned ahead. In any situation the procedures should be available at the construction phase of the plant. To ensure the implementation and mitigation proper funds should be devoted either through the tariff or escrow fund set aside at the installation time.			

9. Economic and Financial Analysis

9.1 Costing

9.1.1 Diesel Generators

9.1.1.1 CAPEX

The price schedules from the tender process for NGEST (file: "Priced B.O.Q final.xlsx"[40]), conducted in 2010, were used as input for investment costs of the diesel gen-sets. The values quoted therein represent the actual amount spent on the generators. The additional electrical infrastructure contained in the price schedule was not considered as part of the generator's specific costs because it is also required for the operation of the other parts of the WWTP. This price information obtained during the tender is based on offers obtained in 2010 since the equipment installed was procured under the same process as the WWTP. Using the numbers, capacity specific costs had been derived (220.82 USD/kW diesel capacity) which were then applied to the installed and planned diesel capacities at the WWTP and the recovery scheme (listed in Figure 9-1). This specific cost value includes material and works. This additional conversion was necessary because the future diesel engines planned for the recovery scheme do not have the same capacity as the current units at the WWTP. This method still carries a minor uncertainty because prices for diesel engines of different sizes do not scale proportionally. Additionally, a price escalation may need to be considered for the future installed diesel capacities. For the feasibility study, and especially this task, the approach is regarded as acceptable since the emphasis is put on the comparison of different supply options. A potential replacement of the generators after about 15 years was not taken into account.

Table 9-1: Actual and projected CAPEX disbursement for diesel engines

CAPEX	Unit Rate [USD/kW]	2016		2018		2025	
		Quantity [kW]	Total Amount [USD]	Quantity [kW]	Total Amount [USD]	Quantity [kW]	Total Amount [USD]
CAPEX additional units	242	5,230	1,265,638	1,760	425,913	4,250	1,028,482
Total CAPEX (cumulated for all units installed)		5,230	1,265,638	6,990	1,161,580	11,240	2,720,032

9.1.1.2 OPEX

The operational expenses were divided into fixed/scheduled costs and variable costs that were mainly

[40] Provided by PWA on 02.04.2015

influenced by fuel consumption.

The total annual maintenance costs for NGEST have been estimated in earlier assessments[41]. Using typical assumptions for simple routine maintenance works, such as, filter changes, adjustment of valve-tappet clearance, oil change and major overhauls, corresponding annual costs for the maintenance of the diesels were estimated with 11,434 USD. The total fuel costs were calculated in the economic assessment multiplying the estimated amount of annual fuel consumption obtained from the energy balance (see section 7.2) and the price for diesel per litre. At this stage, the reduced efficiency of the diesel engine under 75% or 50% load was neglected. The average diesel price 2013-2015 was estimated at 1.51 USD/l.

The total annual OPEX spending mounts to the values shown in Table 9-2:

Table 9-2: Estimated annual OPEX for the diesel-based generation

Total annual costs in USD	Year			
	2016	2017	2018	2025
Financial Analysis without PV	3,065,909	3,300,534	6,450,239	10,657,014
Financial Analysis with PV	3,065,909	1,463,081	4,496,849	8,834,483

9.1.2 Biogas Generators

9.1.2.1 CAPEX

The values for the biogas engine investment were taken from the tender data sheet, similar to the diesel investment costs (see section 9.1.1.1). Since the devices are all of the same rating and will all be installed at the WWTP, the unit rate of 872,076.51 USD was used for the installed device and the second machines to be added within Phase 2.

Table 9-3: Actual and projected CAPEX disbursement for biogas engines

CAPEX	Unit Rate [USD/kW]	2016		2018		2025	
		Quantity [kW]	Total Amount [USD]	Quantity [kW]	Total Amount [USD]	Quantity [kW]	Total Amount [USD]
CAPEX additional units	1090	800	872,077	–	–	800	872,077
Total CAPEX (cumulated for all units installed)		800	872,077	–	–	1600	1,744,153

41 *Aspa Utilities* (2013): Operation and Maintenance Requirements Review and Recommendations, (file: "O&M final report ASPA Report Jul 2013.docx"), provided by PWA on 02.04.2015

9.1.2.2 OPEX

The maintenance costs for the biogas generation were estimated using the same method as employed for the diesel generators in section 9.1.1.2). The annual value amounts to 3,811.35 USD for included routine and overhaul works was estimated. The price of the electricity generated from biogas was taken over from the aforementioned O&M cost assessment stating a value of 0.07 USD/kWh.

The estimated annual OPEX values are shown in Table 9-4:

Table 9-4: Estimated annual OPEX for biogas generation

	Year			
	2016	**2017**	**2018**	**2025**
Financial Analysis without PV	397,088	397,088	397,088	785,754
Fin Analysis P50 with PV opt	397,088	397,088	397,088	785,754

Although NGEST processing volume is scaled up during Phase 1, the biogas generation does not increase because it operates already from the start to its design load.

9.1.3 Solar PV Plant

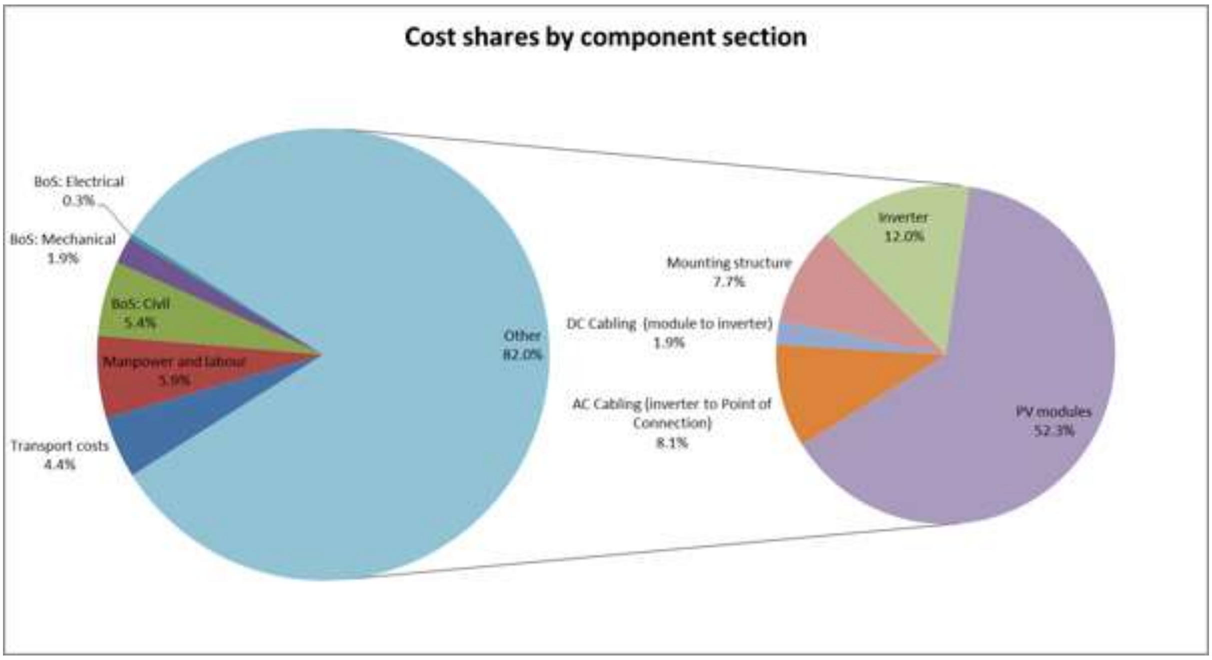
9.1.3.1 CAPEX

The cost estimate for the conceptual design was derived by updating the preliminary cost evaluation used for the evaluation of the variants (see section 12.3.1.3). Based on the actual quantities used in the design and a revised breakdown, the total costs were estimated at 1,350 USD/kWp, which amounts to a total value of 6,897,993 USD. This includes the main system and additional auxiliary facilities such as the monitoring devices. While the PV plant can save costs due to the existing electrical infrastructure, other parts such as SCADA integration to the facility control system were added to account for potential interfacing efforts. This cost estimate assumes the implementation under a typical EPC turnkey contract. Thus, a share for the installation works and transport was included. The second-level breakdown of the costs is shown in Table 9-3 while Figure 9-1 provides an overview of the share of different major positions in the total costs.

Table 9-5: CAPEX estimate of the PV system of 5108,74 kWp

Item	Description	Quantity						
1.0.0	**Main PV system**	**272039**						
1.2.0	***PV modules***	***19649***	**Spare Parts**	**Spare Parts [%]**	**Total**	**Total USD (incl Taxes)**	**Specific costs [USD/kWp]**	**Importation taxes (included in total)**
1.2.0	***Inverter***	***185***	**11062**		**283.101**	**5.144.183**	**1.007**	**170.095**
1.3.0	***Mounting structure***	***898***	***1376***	***7%***	***21.025***	***3.279.900***	***642***	***163.995***
1.4.0	***DC Cabling (module to inverter)***	***185950***	***17***	***9%***	***202***	***751.250***	***147***	***6.100***
1.5.0	***AC Cabling (inverter to Point of Connection)***	***65357***	***19***	***2%***	***917***	***484.783***	***95***	***0***
6.0.0	**BoS: Electrical**	**30437**	***9298***	***5%***	***195.248***	***117.903***	***23***	***0***
6.1.0	***Grounding***	***4394***	***352***	***1%***	***65.709***	***510.347***	***100***	***0***
6.2.	***Lightning protection system***	***72***	**261**		**30.698**	**21.731**	**4**	**0**
6.3.0	***Monitoring, sensors & communication System***	***4579***	***0***	***0***	***4.394***	***2.413***	***0***	***0***
6.4.0	***Conduits***	***21392***	***0***	***0***	***72***	***3.220***	***1***	***0***
7.0.0	**BoS: Mechanical**	**6162**	***47***	***0***	***4.626***	***9.616***	***2***	***0***
7.1.0	**Fence and Gates**	***1053***	***214***	***1%***	***21.606***	***6.482***	***1***	***0***
7.2.2	**Miscellaneous**	***5109***	**0**		**6.162**	**121.598**	**24**	**0**
8.0.0	**BoS: Civil**	**4064**	***0***	***0***	***1.053***	***117.000***	***23***	***0***
8.1.0	***Cable trenches***	***3045***	***0***	***0***	***5.109***	***4.598***	***1***	***0***
8.2.0	***Roads***	***1019***	**0**		**4.064**	**336.150**	**66**	
9.0.0	**Manpower and labour**	**25544**	***0***	***0***	***3.045***	***30.450***	***6***	***0***
10.0.0	**Transport costs**	**278645**	***0***	***0***	***1.019***	***305.700***	***60***	***0***
10.0.0	**Total**				**25.544**	**368.596**	**72**	
10.1.1	***Total installation costs***				**0**	**278.645**	**55**	
10.1.3	EPC Markup (handling fee/margin)	10%			**6.360**	**6.897.993**	**1.350**	
10.1.4	***Grand total***				***5.782***	***6.270.902***	***1.227***	
10.1.2	Portion of potential local content				578	627.090		0

Figure 9-1: CAPEX shares per component category



9.1.3.2 OPEX

The estimated operational expenditures for the PV system are shown in Table 9-4. The cost has been gathered based on a database with typical PV project operational and maintenance costs. In addition, local labour and operations cost structures were considered. The OPEX does not yet consider the actual synergies, which could be leveraged once the PV system is maintained by the same crew that maintains the rest of the facility. Such savings can be accounted for once the contract is finally decided upon.

Table 9-6: Estimated specific OPEX for PV

OPEX for the PV plant	Unit	Quan-tity	Price/ Unit in NIS	NIS	€	$
Cleaning	[/kWp/a]	5,177	10.00	51770.00		12,943
Repair and Maintenance	[/kWp/a]	5,177	15.00	77655.00		19,414
Maintenance Tracking	[/kWp/a]			0.00		0
Operation	[/kWp/a]	13	4000.00	52000.00	10,400	13,000
Insurance	[/kWp/a]			0.00	0	0
Others (provision for re-pair)	[/kWp/a]	1	14000.00	14000.00	2,800	3,500
Total	**[/kWp/a]**	**100,000**	**18025.00**		**13,200**	**48,856**
Specific OPEX	**USD/kWp**					**9.44**

9.2 Economic Evaluation of Supply Options and Variants

The considered power source options for NGEST are as follows:

1. Off-site:
   - Electricity supply through GEDCO (Israel, GPP, Egypt)

2. On-site:
   - Biogas
   - Diesel
   - Photovoltaic, with five possible technical variants that were also economically contemplated.
     - PV-Variant 1: True South
     - PV-Variant 2: Geometric Adaption
     - PV-Variant 3: 1-axis Tracker
     - PV-Variant 4: 2-axis Trackers
     - PV-Variant 5: Thin Film

In order to evaluate the different options the following input data were used:

Table 9-7: Input data[42]

Input Data	Unit	Amount
Economic conditions		
Assessment period (2016 – 2036, solar PV starting 2017)	Years	20
Discount rate	%	7
Exchange rate (annual average 2015 as of 01.01.2015)	USD/ILS	3.9196
	ILS/USD	0.2499
Supply source 1: Off-site via GEDCo (refer to section on GEDCo)		
Energy (purchase price) GEDCo excl. VAT	USD/kWh	0.126
Supply Source 2:		
Current diesel price (03/2015)	ILS/L	5.69
Average Diesel price 2013 - 2015	ILS/L	6.04
Current diesel price (03/2015)	USD/L	1.42
Average Diesel price 2013-2015 excl. tax	USD/L	0.68
Gas excl. subsidies	USD/kWh	0.09

9.2.1 Levelized Costs of Electricity (LCOE) of the Different Supply Options

An economic LCOE was calculated for all possible supply options including their variants. Calculating LCOE makes it possible to compare technologies, different generation and cost. The basic step is to

---

42 Source: The data was compiled by the consultant through information and reports from the Palestinian Water Authority, the World Bank, and GEDCo. Also for some prices current tax rates, subsidies etc. were deducted/added.

form the sum of all accumulated costs for investing in and operating a plant/technology option and divide this figure by the sum of the annual power generation. This then yields the so-called LCOE in USD/kWh.

The different supply options were analysed according to their proportional share in the annual electricity supply to NGEST.

Table 9-8: Overview of LCOE different supply options[43]:

Option	Power Coverage	LCOE in USD/ kWh
Biogas	17%	0.100
Diesel	44%	0.147
GEDCo	23%	0.126
PV	16%	0.061 ~ 0.129
Total	100%	Overall LCOE depends on the selected PV Variant

The highest LCOE has the electricity supply option with diesel at a price of 0.147 USD/kWh. This is followed by the supply through GEDCo with 0.126 USD/kWh and biogas with 0.100 USD/kWh as the cheapest option.

9.2.2 Levelized Cost of Electricity (LCOE) for the Different PV Technological variants 1-5

The LCOE for the different PV variants resulted in the following amounts in USD/kWh:

Table 9-9: Overview of LCOE different PV variants:[44]

Variant	LCOE in USD/kWh	Installed Capacity (kWp)	Present value of Energy (kWh)
1. PV Variant: True South	0.061	4,821	87,749,302
2. PV Variant: Geometric Adaption	0.068	5,109	93,755,189
3. PV Variant: 1 Axis Tracker	0.071	2,059	40,096,237
4. PV Variant: 2 Axis Trackers	0.081	1,868	37,633,823
5. PV Variant: Thin Film	0.129	4,148	35,785,877

The highest LCOE has PV variant 5 "Thin Film" with 0.129 USD/kWh, followed by Variant 4 "2-axis Trackers" and Variant 3 "1-axis Tracker" with 0.081 and 0.071 USD/kWh. The lowest LCOE have the PV variant 2 "Geometric Adaption" and variant 1 "True South" with 0.068 and 0.061 USD/kWh.

For choosing the optimal PV option, it should be mentioned that each variant generates a different amount of energy thus producing different costs of electricity, and of course different initial cost for the different types of technology.

[43] Full version of the calculation can be found in Annex 10.4 (preliminary cost estimates)

[44] Full version of the calculation can be found in Annex 10.3 (preliminary cost estimates)

The sensitivities of the PV options shown in Table 9-8 strengthen the recommendation for the installation of a PV power source as an on-site power supply solution for NGEST.

Table 9-10: Sensitivities of LCOEs PV Power Variant 1-5

	Decrease				Base Case	Increase			
General price comparison (linear)	-20%	-15%	-10%	-5%	0%	5%	10%	15%	20%
Sensitivity in USD/kWh									
PV Variant 1: True South	0.049	0.052	0.055	0.058	0.061	0.064	0.055	0.052	0.049
PV Variant 2: Geometric Adaption	0.054	0.057	0.061	0.064	0.068	0.071	0.074	0.078	0.081
PV Variant 3: 1 Axis Tracker	0.057	0.060	0.064	0.067	0.071	0.074	0.078	0.081	0.085
PV Variant 4: 2 Axis Trackers	0.065	0.069	0.073	0.077	0.081	0.085	0.089	0.093	0.097
PV Variant 5: Thin Film	0.103	0.110	0.116	0.123	0.129	0.136	0.142	0.149	0.155

The sensitivities presented in the table above show that economically the prices for electricity generated with a PV variant stay competitive with other supply options and are even less expensive with an increase of 20% than other supply options like diesel at a price of 0.148 USD/kWh and GEDCo with 0.126 USD/kWh.

Looking at the LCOE of the different variants, economically the prices are comparatively low, as taxes and financing costs were not considered. The variant that is best priced is PV Variant 2 "Geometric Adaption". This variant has next to its relatively low USD price/kWh also the largest capacity (kWp) which holds the largest benefit among the PV variants for NGEST, even if it is not the cheapest version.

Considering the different LCOEs (Table 9-6), with potential contributing factors including, inaccessibility and shortfall of diesel and GEDCo energy supply (chapter 4.2) the installation of PV and particularly PV Variation 2 "Geometric Adaption" is recommended. PV Variant 2 enables more power independence from the grid, and has the most cost saving potential.

This recommendation is further supported by the sensitivities of the present value of energy (PV). It shows that the largest kWh production can be reached with PV Variant 2. Additionally, Variant 2 is competitive to the other variants - even if its production decreases.

Table 9-11: Sensitivities of Present Value of Energy (PV) in kWh

	Decrease				**Base Case**	**Increase**			
General comparison (linear)	-20%	-15%	-10%	-5%	0%	5%	10%	15%	20%
	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
PV Variant 1	70,199,441	74,586,906	78,974,372	83,361,837	87,749,302	92,136,767	96,524,232	100,911,697	105,299,162
PV Variant 2	**75,004,151**	**79,691,910**	**84,379,670**	**89,067,429**	**93,755,189**	**98,442,948**	**103,130,708**	**107,818,467**	**112,506,226**
PV Variant 3	32,076,990	34,081,802	36,086,613	38,091,425	40,096,237	42,101,049	44,105,861	46,110,673	48,115,485
PV Variant 4	30,107,058	31,988,749	33,870,441	35,752,132	37,633,823	39,515,514	41,397,205	43,278,896	45,160,587
PV Variant 5	28,628,702	30,417,996	32,207,289	33,996,583	35,785,877	37,575,171	39,364,465	41,153,759	42,943,053

9.2.3 Total Levelized Costs of Electricity (LCOE) as per Current Design / after Installation of PV

The resulting total economic LCOE as per current design without PV would look as follows:

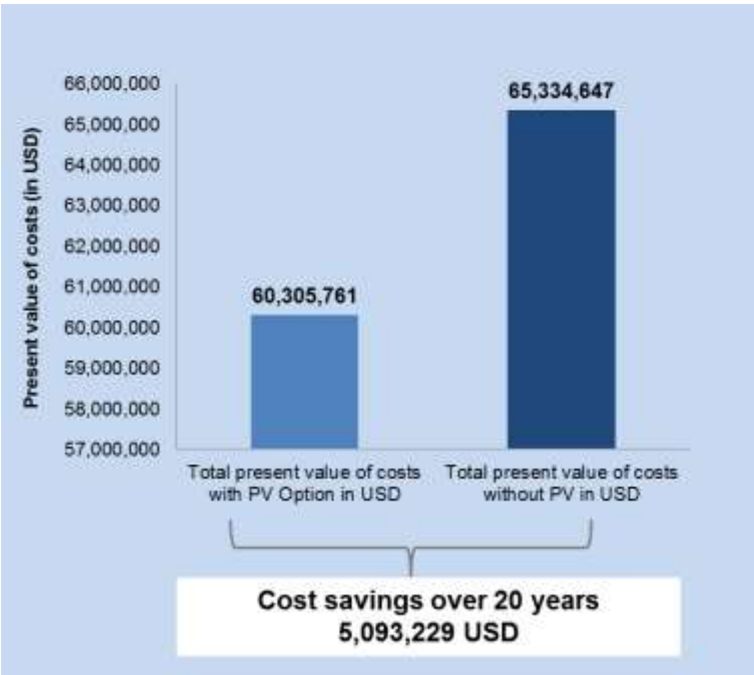
Table 9-12: Overview of economic LCOE for different supply options without PV/ with PV

Option	Power Coverage without PV	LCOE in USD/kWh without PV	Power Coverage with PV (variant 2)	LCOE in USD/ kWh with PV (variant 2)
Biogas	17%	0.100	17%	0.100
Diesel	54%	0.146	44%	0.147
GEDCo	28%	0.126	23%	0.126
PV	no PV	no PV	16%	0.068
Total LCOE	**100%**	**0.131**	**100%**	**0.121**

Without PV the combined electricity costs would be at 0.131 USD/kWh. When including the PV variant 2 into the power supply, the overall LCOE would be at 0.121 USD/kWh. The LCOE includes the fuel purchase costs which change with the different amount of the fuel consumed.

The comparison of the LCOEs without PV and with PV Variant 2 shows the total cost savings over NGEST estimated life time of 20 years.

Figure 9-2: Total difference/economic savings on present value of costs over 20 years



9.3 Financial Analysis

The financial analysis of the investment into a PV system is conducted for the integration of the PV Variant 2 "Geometric Adaption" into the energy supply for NGEST. This financial analysis gives an insight into the total investment costs and the financial levelized costs of electricity (LCOE). Furthermore, three funding scenarios were calculated and elaborated on in chapter 9.3.2.

The input data used for the financial LCOE are as follows:

Table 9-13: Input data[45]

Input Data	Unit	Amount
Assessment period	years	20
Discount rate	%	7
Exchange rate (annual average 2015 as of 01.01.2015)	USD/ILS	3.9196
	ILS/USD	0.2499
Energy (purchase price) GEDCO incl. VAT	USD/kWh	0.150
Current diesel price (03/2015)	ILS/L	5.69
Average Diesel price 2013 - 2015	ILS/L	6.04
Current diesel price (03/2015)	USD/L	1.42
Average Diesel price 2013 - 2015 incl. tax	USD/L	1.51
Gas incl. tax	USD/kWh	0.07

9.3.1 Financial Calculation of Levelized Costs of Electricity

The financial LCOE was calculated to show how taxes influence the prices for the different power supply options. This section gives an overview of the cost development of the supply variant with and without PV.

Table 9-14: Overview of financial LCOE for different supply options without/with PV

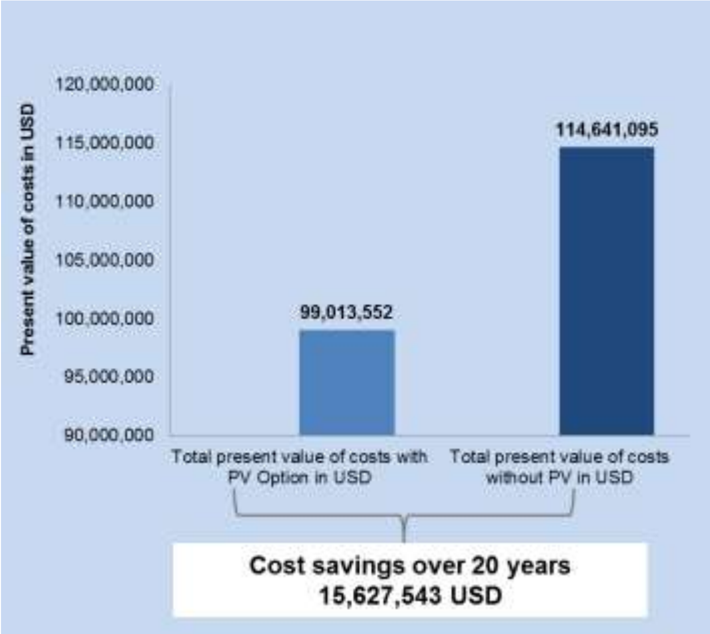
Option	Power Coverage without PV	LCOE in USD/kWh without PV	Power Coverage with PV (variant 2)	LCOE in USD/ kWh with PV (variant 2)
Biogas	17%	0.085	17%	0.085
Diesel	54%	0.319	44%	0.318
GEDCo	28%	0.150	23%	0.150
PV	no PV	no PV	16%	0.081
Total LCOE	**100%**	**0.230**	**100%**	**0.199**

The addition of the PV system reduces the total levelized costs of electricity without PV by 0.031

45 Source: The data was compiled by the Consultant through information and reports from the Palestinian Water Authority, the World Bank, and GEDCo. Also for some prices current tax rates were deducted/added.

USD/kWh. This in turn, lowers the costs by 13% and allows for cost savings over a period of 20 years on the present value of costs of 15,627,543 USD:

Figure 9-3: Total difference/financial saving on present value of costs over 20 years



The cost savings make the project with a PV system financially more attractive and competitive with other power supply options without PV. Power supply through PV is also accessible and it could potentially grant NGEST independence over 16% of its annual overall electricity needs.

Table 9-15: Breakdown of energy costs and savings over lifetime

	Day	Month	Year
Total Ø costs with PV in USD	13,552	412,556	4,950,678
Total Ø costs without PV in USD	15,691	477,671	5,732,055
Ø cost savings with PV in USD	**2,139**	**65,115**	**781,377**

The total cost savings over 20 years of 15,627,543 USD represent cost savings of 2,119 USD per day, 64,519 USD per month and 774,228 USD per year.

The sensitivity analysis concluded for the different supply options (including PV Variant 2), shows that even with a linear increase and decrease of costs between 5-20%, the LCOE stays in an adequate cost frame.

Table 9-16: Sensitivities of LCOEs different supply options incl. PV - Variant 2

	Decrease				**Base Case**	Increase			
General price comparison (linear)	-20%	-15%	-10%	-5%	0%	5%	10%	15%	20%
LCOE in USD/kWh									

Biogas	0.068	0.073	0.077	0.081	0.085	0.090	0.094	0.098	0.102
Diesel	0.255	0.271	0.287	0.303	0.318	0.334	0.350	0.366	0.382
GEDCo	0.120	0.128	0.135	0.143	0.150	0.158	0.165	0.173	0.180
PV Variant 2	0.065	0.069	0.073	0.077	0.081	0.085	0.094	0.108	0.129

Furthermore, the sensitivity for diesel and GEDCo grid prices were tested. Both sensitivities also favour the solar PV option.

The Base Case represents the actual financial calculation that was effectuated for the NGEST project and uses the 2013-2015 average diesel price of 1.51 USD/litre incl. taxes. From this base case sensitivities are shown in the calculation below. The calculation includes a reduction of 55% (representing an exemption from Blue Tax) on the diesel price to show how this would affect the total savings in cost with PV over a time period of 20 years, as well as the overall LCOE with PV and without PV.

Table 9-17: Sensitivities diesel price[46]

	Decrease			Base Case	Increase	
	-55%	-20%	-10%	**0%**	10%	20%
Diesel price USD/litre	0.68	1.21	1.36	**1.51**	1.66	1.81
Overall LCOE without PV (USD/kWh)	0.138	0.197	0.214	**0.230**	0.247	0.264
Total costs in m/USD without PV Options (20 yrs.)	68,542,826	97,878,088	106,259,591	**114,641,095**	123,022,598	131,404,102
Overall LCOE with PV (USD/kWh)	0.127	0.173	0.186	**0.199**	0.212	0.225
Total costs with PV Options (20 yrs.)	63,380,145	86,055,949	92,543,751	**99,013,552**	105,492,353	111,971,154
Difference overall LCOE no PV/with PV	0.011	0.024	0.028	**0.031**	0.035	0.039
Relative difference of LCOE no PV/ with PV	8%	12%	13%	**13%**	14%	15%
Total Savings in cost with PV Option (20 yrs.)	5,162,681	11,822,138	13,724,841	**15,627,543**	17,530,245	19,432,947
	excl. Blue Tax					

[46] More sensitivities of the diesel price can be found in the annex 12.6.6

The analysis shows, that the power supply with PV is the financially favourable option, even with the deduction of the 55% tax, as it generates a lower LCOE with PV of 0.127 USD/kWh in comparison to 0.138 USD/kWh without PV. Total cost savings with PV options would be at USD 5.1 million over a period of 20 years. Even though these savings are not as high as the Base Case scenario, it still favours solar.

Additionally, the annual production from diesel generators at the WWTP alone in 2018 without a PV system is calculated to be 5,522 MWh. With an assumed cost per kWh of 0.23 USD produced using non-exempted diesel the total annual cost of Ø 5,732,054 USD will be reached. In case the diesel is exempt from Blue Tax, the cost per kWh produced will be 0.13 USD and the total annual operational cost will be Ø 3,427,141 USD.

On the opposite, increasing fuel prices make the PV option even more attractive and could raise the cost savings over 20 years up to 19.4 million USD if the diesel price were to increase by 20%. Given the fluctuations in diesel price in the last two years, this is not an all too unlikely scenario.

The impact of fluctuating prices for power supply through GEDCo's grid is trivial, representing the lower percentage of power coverage through GEDCo. However, this could change significantly if the external supply is improved. In this case the technical availability of the network in terms of supply capacity is more important than actual costs.

Table 9-18: Sensitivities GEDCo grid price[47]

	Decrease		**Base Case**	Increase	
	-20%	-10%	**0%**	10%	20%
GEDCo grid price	0.120	0.135	**0.150**	0.165	0.180
Overall LCOE without PV(USD/kWh)	0.222	0.226	**0.230**	0.235	0.239
Total costs in m/USD without PV Options (20 yrs.)	110,440,349	112,540,722	**114,641,095**	116,741,468	118,841,840
Overall LCOE with PV (USD/kWh)	0.193	0.196	**0.199**	0.203	0.206
Total costs in m/USD with PV Options (20 yrs.)	95,633,247	97,323,399	**99,156,538**	100,703,705	102,393,857
Difference overall LCOE no PV/with PV	0.030	0.030	**0.0310**	0.033	0.033
Relative difference of LCOE no PV/ with PV	14%	13%	**13%**	14%	14%
Total Savings in cost with PV Option (20 yrs.)	14,807,103	15,217,323	**15,627,543**	16,037,763	16,447,983

[47] Further sensitivities of GEDCo's grid price can be found in the annex 12.6.7

The Base Case represents the purchase price from GEDCo of 0.150 USD/kWh and the sensitivity testing shows that if this price is increased the investment in PV becomes yet more favourable. Nonetheless, even if the price was to be decreased by 20%, the investment into PV would still generate cost savings of 14.8 million USD over a period of 20 years.

Additional Scenarios:

Next to the two main scenarios with and without PV two more options were considered to show all possibilities in terms of price development. It needs to be mentioned that these additional scenarios are highly unrealistic due to the power shortages and the unavailability of supply through GEDCo.

1. Option "GEDCo": Supply through biogas and GEDCo only
2. Option "GEDCo + PV": Supply only with biogas, GEDCo and PV

Table 9-19: Overview of financial LCOE for different supply options GEDCo and GEDCo + PV

Option	**Power Coverage GEDCo**	**LCOE in USD/kWh GEDCo**	**Power Coverage GEDCo + PV (variant 2)**	**LCOE in USD/ kWh GEDCo + PV (variant 2)**
Biogas	17%	0,085	17%	0,085
Diesel	no Diesel	no Diesel	no Diesel	no Diesel
GEDCo	83%	0.150	67%	0.150
PV	no PV	no PV	16%	0.081
Total LCOE	**100%**	**0.139**	**100%**	**0.128**

As these two options do not include high diesel costs they are cheaper than the option with or without PV – however, GEDCo cannot guarantee the supply which makes these options highly unstable - albeit their favourably low prices. An additional supply line from Israel is highly unlikely to be developed over the next couple of years. Therefore, a solution for the problem of low power supply through GEDCo is not to be foreseen in the near future.

Table 9-20: Complete overview of financial LCOE for different supply options

Option	**Power Coverage**	**LCOE in USD/ kWh**
GEDCo	17% Biogas 83% GEDCo	0,139
GEDCo + PV	17% Biogas 16% PV 67%GEDCo	**0,128**
All supply options without PV	17% Biogas 54%Diesel 28% GEDCo	**0,230**
All supply options with PV	17% Biogas 16% PV 44% Diesel 23%GEDCo	0,199

For better understanding of the complete overview it should be considered, that the load is already set to the maximum peak hours of PV. Furthermore, 17% Biogas are fixed in price and quantity by the operation concept of NGEST (LCOE 0,085 USD/kWh). The 16% PV is the maximum defined the currently available area (LCOE 0,081 USD/kWh). Moreover, also the grid price is fixed by an agreement with GEDCo (0,150 USD/kWh). In the current operational concept diesel always covers all remaining demand (LCOE 0,318 USD/kWh). Therefore, the following conclusions are important:

1. **Biogas as a by-product of the sewage treatment and therefore very economic and always available/set.**
2. **The more PV, the cheaper the energy supply.**
3. **The more grid supply, the cheaper the energy supply.**
4. **No matter in which scenario PV is used it always results in a cheaper overall LCOE.**

It should be noted that due to the unreliability of grid connection the two options were not further analysed and the financing if the following chapter was only considered for the chosen option "All supply options with PV". The addition of PV to the supply options is considered as a stabilising factor that will give NGEST more independence from diesel as well as the grid.

9.3.2 Different Financing Options and Sensitivities

Three different financing options were considered for the project:

1. Commercial funding scenario
2. 50% grant scenario
3. Green funding scenarios

What should be understood concerning the calculation of the financing options is the fact that the power supply options are interrelated and can only together generate enough electricity to meet the energy demand of NGEST. Therefore, all financing scenarios were calculated for the total future investment costs of 9.7 million USD. However, for the green funding scenario, the investment costs of PV and biogas were used for the grant and the diesel costs are to be financed with a loan and thus separated into renewable energy components (keeping it "green") and conventional energy component.

Table 9-21: Investment costs NGEST

	Unit	Grand total
Total Energy demand NGEST (20 yrs.)	kWh	1,062,279,708
Investment (CAPEX PV)	USD	7,423,868
Investment (CAPEX biogas)	USD	872,077
Investment (CAPEX diesel)	USD	1,454,395
Total investment costs (PV, biogas, diesel)	**USD**	**9,750,340**
Total investment costs (only PV and biogas)	USD	8,295,945

9.3.2.1 Commercial funding scenario

For the commercial funding scenario the following financing parameters were applied (the full calculation including the different sensitivities can be found in Annex 12.7.1):

Table 9-22: Commercial funding financing parameters

Parameters*	Unit			
Grant 20%	USD	1,950,068		
Loan 80%	USD	7,800,272		
Debt repayment per year	%	5%		
Interest rate	%	4%	3%	6%
Management fee	%	0.25%	0.25%	0.25%
Service fee	%	0.18%	0.18%	0.18%
Total financing fees	%	4.43%	3.43%	6.43%
Loan term	Year(s)	25/20/15		
Grace period	Year(s)	1		

For the commercial funding scenario the option with a loan term of 15 years and 3% interest rate was the most favourable in terms of total debt, with 8,997,545 USD.

9.3.2.2 50% grant scenario

For the 50% grant scenario the following parameters were applied (the full calculation including the different sensitivities can be found in Annex 12.7.2):

Table 9-23: Grant scenario financing parameters

Parameters*	Unit			
Grant 50%	USD	4,875,170		
Loan 50%	USD	4,875,170		
Debt repayment per year	%	5%		
Interest rate	%	4%	3%	6%
Management fee	%	0.25%	0.25%	0.25%
Service fee	%	0.18%	0.18%	0.18%
Total financing fees	%	4.43%	3.43%	6.43%
Loan term	Year(s)	20		
Grace period	Year(s)	1		

For the 50% grant scenario the option with the loan term of 20 years and 3% interest rate was the most favourable in terms of total debt, with 6,009,238 USD.

9.3.2.3 Green funding scenarios

For the green funding scenario the following parameters were applied (the full calculation including the different sensitivities can be found in Annex 12.8.3:

Table 9-24: Green funding scenario financing parameters

Parameters*	Unit	
Grant 15%	USD	1,462,551
Loan 85%	USD	8,287,789
Debt repayment per year	%	6%
Interest rate	%	0%
Management fee	%	0.25%
Service fee	%	0.18%
Total financing fees	%	0.43%
Loan term	Year(s)	20/10
Grace period	Year(s)	3

Two options were calculated for the green funding scenario, resulting in a loan term of 20 years with total financing fees of 0,43% and a debt of 8,508,124 USD. For a loan term with 10 years the debt was calculated to be 8,626,345 USD.

9.3.3 Summary of Outcomes of Different Funding Scenarios

The three different funding scenarios that were calculated for NGEST are compared in Table 9-25 using the total investment costs including debt repayments and financing costs:

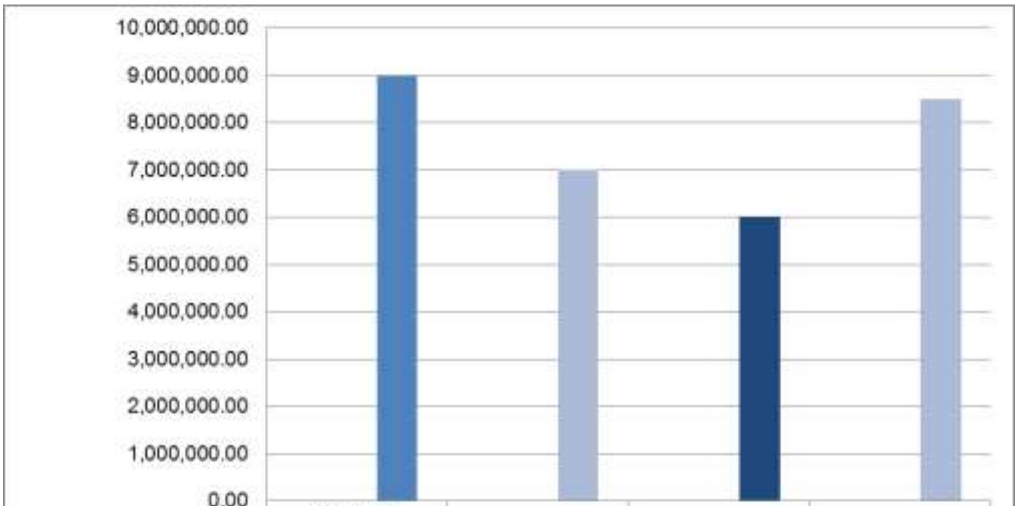
Table 9-25: Summary of outcomes of the different funding scenarios

Scenario 1: Commercial Funding Grant 20%, Loan 80%, Grace period 1 year				
	Loan term 20 years			
Interest rate	0.43%	4%	3%	6%
Total debt/costs[48]		10,143,792	9,614,781	11,201,815
	Loan term 15 years			
Total debt/costs[48]		9,346,604	**8,997,545**	10,044,722
	Loan term 25 years			
Total debt/costs[48]		10,811,053	10,131,419	12,170,322
Scenario 2: Grant 50% Grant 50%, Loan 50%, Grace period 1 year				
	Loan term 20 years			
Total debt/costs[48]		6,339,870	**6,009,238**	**7,001,134**
Scenario 3: Green Funding (only PV and Biogas) Loan 100%, Grace period 3 years, no interest but annual service & management fee				
	Loan term 20 years			
Total debt/costs[48]	**8,508,124**			
	Loan term 10 years			
Total debt/costs[48]	**8,626,345**			

Total debt/cost[48] for the most favourable options look as follows:

[48] Total debt/costs denote in this context the overall cost of the investment for the project. This includes the debt and the financing costs, e.g. interest costs and administration of loan.

Figure 9-4: Most favourable funding options



	Scenario 1 Commercial Funding	Scenario 2 Grant 50%	Scenario 2 Grant 50%	Scenario 3 Green Funding
Loan term in yrs	15	20	20	20
Interest rate	3%	6%	3%	0.43%
Total debt/costs in USD	8,997,545	7,001,134	6,009,238	8,508,124

The four funding scenarios presented are the most favourable ones in terms of overall costs.

Scenario 1, commercial funding, represents a convincing approach with a 20% grant, 80% loan structure, a common way of funding. The addition of 20% grant allows costs of 8.9 million USD, fixing the costs for the beneficiary below the overall investment costs of 9.7 million USD.

Scenario 2, 50% grant, is the cheapest option for the beneficiary as 50% of the costs are financed by a grant. Even with an interest rate of 6%, which is most accurate for Palestine, the costs are low with 7 million USD. Even more favourable, yet less realistic with an interest rate of 3% is also scenario 2 with costs of 6 million USD.

Scenario 3, Green Funding (only PV and Biogas), is also beneficial in terms of costs to be paid by the beneficiary. The Green Funding allows a grant for the "green" components of the project, biogas and PV and offers a loan for the conventional energy component diesel. Due to a marginal management fee of 0.43% instead of an interest rate Green Funding allows costs of 8.5 million USD. These costs are below the overall investment costs of 9.7 million USD. For 10 years loan tenor including the marginal management fee Green Funding allows costs of 8,626,345 USD.

The "best" scenario is a different one for each donor, depending on their financing habits and abilities, thus the consultant refrained from making any definite recommendation on one specific scenario. Nevertheless, the scenarios presented represent a variety from which an option might be chosen. Of course other financing options are possible but were not further highlighted in this report, as that would go beyond the scope. An additional calculation including further contingencies of 10% is included in the annex, section 12.8 to broaden the options and the perspective on the investment. These calculations also highlight adequate project risks.

9.4 Summary Economic and Financial Assessment

An economic and financial analysis was conducted with the objective to identify the costs and benefits of the installation of a Solar PV plant as a power supply option for NGEST. The financial analysis in particular examines closely the investment's profitability and different financing scenarios.

The economic assessment was used to determine the relevant costs and benefits of the different energy flows, excluding taxes to better represent the opportunity costs for the country. It assessed the costs of electricity from biogas, diesel and the GEDCo grid connection as well as the addition of the PV option into the power supply mix. For the PV options 5 technical variants were analysed and their energy generation costs quantified. The economic assessment closely examined the options available and gave an insight into which variants are economically the most attractive.

For this purpose, two main scenarios were compared: NGEST with a PV option and NGEST without a PV option. The comparison allowed to determine which scenario is economically the more cost effective and favourable. The LCOE assessment provided the basis for the recommendation of thePV variant 2 "Geometric Adaption", which proved to be the most beneficial in terms of costs of electricity (USD/kWh) and capacity output.[49]

From the results of the economic analysis, the financial analysis was conducted including the PV option variant 2 "Geometric Adaption"[50]. A cost assessment and the calculation of the levelized costs of electricity were conducted in a cost based approach.

The financial assessment compared the two scenarios NGEST with the PV supply option and NGEST without the PV supply option - over a period of 20 years (2016–2036), based on real prices including taxes and subsidies. Two additional supply options were considered, option "GEDCo": Supply through biogas and GEDCo only as well as option "GEDCo + PV": supply only with biogas, GEDCo and PV.

The two additional options, leaving out the expensive diesel, generated low LCOEs (0,139 USD/KWh and 0,128 USD/ kWh), still favouring the PV option with 0,128 USD/kWh. However, these options are not recommended as the supply via GEDCo / grid is very unstable and would not lead to a more reliable supply of energy for NGEST. An additional supply line from Israel is highly unlikely and therefore also currently not considered a sustainable option for the plants energy supply.

NGEST without PV and the current supply options (biogas, diesel, and GEDCo grid connection) lead to an overall LCOE of 0.23 USD/kWh. NGEST with the PV option installed has an overall LCOE of 0.20 USD/kWh, making it 0.03 USD/kWh cheaper than the no PV option. Regarding the project lifetime of 20 years, these 0.03 USD/kWh generate a saving in the present value of costs of 15,627,543 USD.

Sensitivity testing of the different LCOEs of the supply options, the diesel prices as well as the price of GEDCo's grid connection also favoured the installation of solar PV. Even if the diesel price were to be exempt from the 55% Blue Tax, the PV solar option would still generate cost savings.[51]

An overall investment sum of 9.7 million USD, including three funding scenarios (commercial funding, 50% grant and green funding), were calculated for NGEST. The investment was assessed as a whole

[49] Variant 2, has an economic LCOE of 0.068 USD/kWh and an installed capacity of 5,109 (kWp). For further detail concerning this analysis please refer to chapter 9.2.2).

[50] For the complete calculations please refer to the annex 12.6 et al.

[51] Detailed assessment can be found under chapter 9.3.1

including the conservative power supply options and the solar option. This is owed to the fact that the supply for NGEST can only be sufficiently guaranteed through a mix of all supply options. Sensitivities such as different interest rates and grace periods were included. Depending on the type of financing, a total costs/debt was established to be in the range of 6 million USD and 12.1 million USD[52]. A recommendation for one specific scenario was not given as each donor/investor prefers and sets different financing parameters.

As an overall conclusion, the cost savings as well as the sensitivities examined are proof for the competitiveness of the PV option vs. the power supply without PV. It is highly beneficial that the power supply through PV is secure and grants NGEST independence over 16% of its annual overall electricity need, liberating it from additional power cuts and diesel shortages. Thus aiding to the relief of the water sector and resolving some of its problems, such as overflow of sewage which severely affects life conditions in Gaza. Therefore, due to the cost effectiveness, the savings and the heightened independence in power supply, the investment is deemed favourable and recommendable.

9.5 Commercial Structure of Project Implementation

Given that the addition of a PV plant and the identified modifications of the power supply are finally evaluated as feasible and the stakeholders take a positive decision towards implementation, the commercial structure has to be defined. The commercial structure involves mainly the ownership and responsibility for operation of the PV systems. Depending on the general structure, connected aspects will have to be specified involving mainly the procurement strategy and the financial setup as well as maintenance and support.

The first decision is the question of ownership. The first option (1) is ownership by the NGEST project and consequently PWA. In this case, procurement would be conducted on EPC turn-key basis (i.e. design-build-transfer). The second option would be to keep the ownership with a private entity. In case of private participation, the external participation could be achieved by (2) merely outsourcing installation and operation (i.e. BOOT or alike), also called contracting, or (3) to lease the services from a completely independent party by buying the actual end product under an IPP model.

The decision is mainly influenced by the following criteria: political preference (i.e. provision services by public utilities), economic and financial attractiveness, which is not only determined by the direct (financial) benefits but also the indirect risks, such as, control of operation and stability of demand and power sales.

From a political aspect, there are currently no direct partnerships on operating assets between the public utilities of PA and the private sector. This is understandable given the constrained – island-like – conditions of the economy of the Palestinian territories and the even more limited economic situation in Gaza[53]. The PA may want to maintain direct control of the utilities in order to react to the political changes, develop a coherent infrastructure, increase capacity employment and capacity of the local workforce and to be able to achieve financing of these basic investments together with its partners. Regardless of the political and institutional structures of the project, a financial calculation would need to show if the project in itself is viable. If support by an external partner is searched for, the financials must allow for the incentive that renders participation by a private entity attractive. During the commercial assessment, the financial benefits and trade-offs would need to be evaluated. A state-financing of the

[52] For the detailed assessment please refer to chapters 9.3.2 and 9.3.3 as well as for the detailed calculations annex 12.7)

[53] World Bank (2015): Economic monitoring report to the ad hoc liaison committee, http://documents.worldbank.org/curated/en/2015/05/24525116/economic-monitoring-report-ad-hoc-liaison-committee

investment would benefit from the access to external capital at good conditions but is often constrained by the lack of equity resources. Although a private investor may have easier access to equity, such institutions would regard the venture as vehicle to realize a certain amount of profit – usually defined by the requirements of the shareholders. Consequently, the financials must be able to provide room for stable and reliable revenues, which allow for generating earnings with the targeted margin. But the solar PV plant does not generate revenues or surplus of energy for feed-in purposes. Thus the private investment possibilities are very limited. If a private investment were to be considered, e.g. with a margin imposed on the price/kWh through an investor, this would largely reduce the savings in costs. Additionally, a management fee would be imposed by the investor, which would further lower the savings potential. For these reasons private investment options were not further exploited.

In addition, the private entities would scrutinize the risks associated with the undertaking. In the case of NGEST, the main risks are the lack of control over the operation of the whole NGEST power system driven by the needs of the treatment plant and recovery scheme loads, the general political situation and its potential damaged, the influence of stakeholders (i.e. participants of local sewage system, GEDCo and IEC, farmers) on operation as well as the general timeline of implementation. The single biggest risk for an independent operator is the control of the power supply: The whole operation of NGEST is not driven by the power availability but rather the demand required for the daily operation. The operators of NGEST manage and supervise the electrical system depending on the primary processes (i.e. the wastewater treatment) of the facility. While a typical operation pattern was developed in this study, huge uncertainty yet remains on the actual operation pattern. This applies especially in the years until 2025. During this period, NGEST would still be in expansion while the actual timeline remains uncertain and the operation scheme may therefore be subject to change. Uncertainty arises once more from the fact that NGEST has not started its operation yet, and thus no experience on its actual performance is available.

The power supply is set up in a form of an integrated hybrid supply of the different sources mentioned in this assessment. Thus, any contract with an external entity would also need to define the interfacing and level of integration with the other power sources in order to deliver a combined product, i.e. the electricity that NGEST requires. As explained above, it is rather impossible for an external party to control of utilization of power but also availability of the other components, e.g. the operation hours of the biogas engine. But finally, all these day-to-day changes by NGEST to the operational pattern have an impact on the energy price. The biomass is driven by the sludge and gas production, the grid is a source with high uncertainty and the diesel depends on the import to the strip. Technical aspects of the local supply such as changes in power factor or heat production in case of black start of the treatment plant are additional commercial hurdles. Since NGEST controls the overall power infrastructure it is very difficult to define technical guarantees in such a transparent way that allows a fair evaluation of the performance independent of external impacts.

The definition of performance requirements for an energy contractor is easier if the participation of the private entity is limited to suppling power from the PV system. But within such set-up would the verification suffer from the same constraints outlined above, i.e. power supply follows load requirements; NGEST optimises its own operation. In this case, energy meters would need to be installed at all connection points and not only at the switchgear.

The characteristics and conditions of the mentioned options are summarized in Table 9-22.

Under the described conditions, an ownership by NGEST/PWA and procurement via an EPC tender would be recommended. Such tender would need to choose a sound middle course between a detailed technical specification defining interfaces and requirements of NGEST and a functional minimum requirement for the PV plant allowing a certain level of freedom for the contractor to bring in their own innovation. Such contract could contain requirements for training of local craftsmen and technicians during construction and operation in order to achieve replication of the project at other facilities, e.g. the desalination plant. In addition, local private sector could be supported by contracting skilled companies for the maintenance works.

Table 9-26: Comparison of EPC and IPP approach

Option	1	2	3
Criterion / Model	**NGEST**	**BOO(T)**	**IPP**
		General	
Description	NGEST contracts a skilled installation company and takes over at commissioning. The contractor could even be a subcontractor of the principal NGEST contractor	The contractor is responsible for installation, commissioning and operation of the PV part. The savings in energy costs are shared between the contractor and NGEST according to a defined value The contractor could also be charged with the responsibility to constantly audit and optimize the power supply of NGEST	The (PV) power supplier is all-in-all responsible for the power supply.
Ownership	PWA/PENRA	Privately owned	Privately owned
		Financing	
Financing: CAPEX / Equity	Funds, via balance sheet	Own capital, Shareholders	Shareholders
Financing: CAPEX / debt	Public debt or institutional bonds	Commercial banks	Commercial banks, capital market bonds
Financing: OPEX	User fees	Contracting premium	Sales tariff
Financing: Revenues	Economic savings over life-time	Service fee as contracting premium taken from the total savings per energy unit by adding PV and the final benefit passed on to NGEST budget	Margin between purchase costs (LCOE) and sales tariff
		Commercial	
Procurement	EPC	Service contract	Commodity purchase
Principal technical guarantees	Mainly workmanship and performance at commissioning.	Regularly verified energy saving results	Minimum energy delivery
Commercial / corporate structure	Part of NGEST as project of PWA	Project run by the contractor	Independent project company (SPV)

Option	1	2	3
Criterion / Model	**NGEST**	**BOO(T)**	**IPP**
		O&M	
Operational respon-sibility	NGEST staff	Contractor in cooperation with NGEST staff	IPP
Maintenance	NGEST staff a contracting of technical maintenance is possible	Contractor or sub-contractor	IPP or sub-contractor
		Summary	
Requirements	• Equity or funds →to be arranged by PWA/PA with partners • Capacity to manage the project →possible with some training	• Enough energy saving to allow share of benefits →see financial analysis • Control over minimum output to guarantee the business model →not very likely	• Allowance for an attractive tariff →see financial analysis →not complaint with the requirement of low end user fees and the tight budget. • Control over minimum output to guarantee the business model →not very likely
Likeliness of imple-mentation	High	Medium	Low
Degree of participa-tion by private sec-tor	Low: • Installation • Low-level maintenance	Medium: • Installation • Principal operation • Maintenance	Full • Installation • Operation • Maintenance

10. Potential Impact on the Local Political Economy

10.1 Impact on GEDCo Network

GEDCo as the supplying utility is directly affected by the planned modifications to the NGEST power supply options. The first and direct impact arises from potential feed-back of excess power to GEDCo's network. As explained in section 7.2, there are periods when excess energy from RE generation occurs. The concept for an optimised utilisation of this energy is laid out in section 7.3.3. It foresees to keep impact on the planned network connection and to operations of GEDCo as low as possible. Since the NGEST facilities remain at any time a net-consumer of energy, no export to the wider network is expected under normal operations of NGEST, e.g. when the WWTP or the pumps and wells are not in maintenance.

Consequently, PWA and GEDCo would need to append the existing network connection agreement with details on the proposed concept for coupling of the two project locations. This includes finding consent on metering issues and isolation of the facility via the proposed breaker at the point of common coupling.

The reduction of net energy drawn from the grid is an indirect impact. In the constrained distribution network with limited capacity this will relieve the pressure on GEDCo's network, especially for the suppressed demand. Thus, the electricity supply and service hours to the local communities in Gaza especially the adjacent Jabalia community can be increased. The increase in service hours will allow for more productive use and will therefore, improve overall livelihood and economy in Gaza.

10.2 Options for Fostering Local Content

Requirements of project financing institutions providing capitals to infrastructure projects in the Palestinian territories require typically that a tender with volume of 5 Mil. USD and above must be published as an international tender request. But during procurement (supply), installation and O&M phase support of local companies from Gaza will be needed.

Based on the CAPEX estimate for the PV system, the amount of goods and works procured in the Palestinian territories could approximately be valued at 2 Million. USD. This estimate includes supplies for mechanical structures, civil works and labour. The final value depends on the actual sourcing of the selected contractor. It may be considered to require a certain minimum portion in the tender documents.

Such procurement volume would first increase the technical capabilities of the local companies and therewith it could potentially encourage local companies to start or develop their business in the direction to supply and support facility power systems.

10.3 Competences and Capacity of the Local Economy

The project will use local technicians for the installation of the PV arrays from local PV firms and companies specialised in electro-technical installations. This will ensure building the capacity of those technicians and qualify them to implement similar projects. Based on the available information there are 25-30 technicians and engineers who are already working in this issue in Gaza. It is likely that they will be the ones benefiting from this project in terms of implementation and capacity development. In addition, the capacity of the three small companies in Gaza to deliver and deal with such large projects in this field will be upgraded and will potentially qualify them for other similar contracts. All these will ensure business development and boosting of economy in Gaza.

Today there are three main local firms that work in renewable energy in Gaza, shown in Table 10-1:

Table 10-1: Overview of local PV companies

Name	Size	Comment
Atallah Company	Small	11 employees, of which 2 Engineers
Tic Land	Small	6 employees of which 3 engineers
Annid (Al nid)	Small	5 employees of which 2 engineers

In addition, there is a number of smaller companies who work as subcontractor for these three main ones in Gaza.

Moreover, the project itself may encourage adopting solar energy at a wider scale by the government to produce clean energy and reduce the dependence on the external energy sources, even those produced locally since they depend on imported fossil fuel.

10.4 Potential for Replication

Although there are smaller scale PV plants in Gaza, the scale of this plant will be definitely seen as a case model to be replicated not only in Gaza but also in the West Bank, should it prove feasible and successful. Moreover, the project is in line with the national strategic objective to ensure the generation of electricity from renewable sources. In this line, PENRA has signed a new agreement with an International firm to generate electricity from PV in Gaza. This project will definitely be a guide for the development of similar initiatives in the future.

Similar projects with integrated power supply are already in planning:

- the Gaza Central Desalination Plant, and
- the Gaza Central Wastewater Project

For both projects the use of solar power is planned right from the beginning as part of the system. Again, what makes NGEST a special case is actually the fact that it is already (partially) implemented. By this, a reference case is generated for the refurbishment and upgrade of existing government and public facilities, especially those with constant and high energy demand. With NGEST being ahead in time on the other projects, all stakeholders can gain valuable experience with implementation and operation. If being implemented by the responsible institutions, the transfer of acquired knowledge to other projects can be facilitated.

11. Conclusions and Recommendations

11.1 Feasibility of the PV System

On the technical side, the study confirmed the adequacy of the planning and current design of the power supply system of the facility. This conclusion was reached under the assumptions that water intake and energy consumption data for the NGEST facility are correct. The quality of workmanship at the treatment plant is a very positive indicator. It proves that it is possible to implement a complex project in the adverse conditions of the area and the capability of PWA to supervise large construction activities. This is regarded as a solid basis for potential modifications to the initial design and the inclusion of additional components such as the PV system – although medium-size PV systems do not yet exist in Gaza. The circumstances allow for recommending the NGEST project as the first pilot project for innovative use of PV as power saver for the power supply of a public service facility with high energy demand.

The conditions at the site and the selected areas allow for the installation of several PV systems of different sizes. Altogether they result in a medium sized PV installation, which contributes considerably to the annual energy supply of the project. Together with the biogas generator, the other renewable energy source, PV generation even leads to an excess of energy at the WWTP site during certain hours. A technical solution was identified that optimises the use of this excess in such a way that additional expenses and impact to the network is minimised.

The preliminary environmental and social impact assessment had shown no blockers regarding external stakeholders but rather effects of the environment on the system itself. A set of preliminary mitigation measures was identified which help to address the associated sources of impact.

The use of PV at NGEST offers energy cost savings. Using PV on a public facility does not only increases the technical independence from the constrained network but also enhances the economic security of supply. The PV system can also alleviate the budget by reducing the annual energy supply costs. This set-up is also called auto-consumption or captive generation. The financial analysis has also shown that an investment into the planned system can be recommended and financing through different arrangements is possible.

It can be expected that a PV system would generate a positive impact on the local economy through participation during construction or operation. A more indirect effect is attributed to the chance to gain real local experience with net-metering and power-saving systems on a larger scale. This would benefit integrated energy planning of other facilities as well as GEDCo in their efforts to improve the general supply situation.

11.2 Recommendations for Implementation

Based on the findings of the assessment, the following principal recommendations can be provided:

11.2.1 General Technical Recommendations

The following recommendations shall be considered when defining the minimum technical requirements for the bidding documents of the PV system:

- A standard fixed mounted system with distributed inverter configuration shall be used to reduce the complexity to a minimum.
- The orientation can be either geometry adapted as in the presented conceptual design, True South or even E-W. This may include:

    - Variant 1: Azimuth 0° – True South with optimum tilt angle
    - Variant 2: geometry adapted with optimum tilt angle
    - East-West orientation with lower tilt

- Configurations that achieve higher installation capacity and higher annual energy generation than the conceptual design may be attributed with higher points in the technical evaluation. Since this will have an impact on the bid price and required investment budget, a suitable trade-off mechanism has to be considered when defining the evaluation criteria. This is best illustrated to the stakeholders and financing partners by example calculations.
- Any orientation proposed by the bidder shall achieve an annual energy generation equal or higher than the total annual energy yield estimated for the conceptual design using Variant 2.
- Within these limits, effort could be undertaken to raise efficiency and optimise performance. But the final objective of the design shall be a reliable and trouble-free operation. This would exclude experiments, such as using trackers or similar components requiring higher attention during maintenance. This means in other words: the simpler the design the better – NGEST is not a power generation facility since its core business activity is the water treatment and sanitation.
- The system shall be specified to use qualitative and durable components adequate to the local environment.
- Each inverter unit should
    - be certified for outdoor use;
    - have rating as high as possible;
    - be a multi-string inverter above a minimum power rating, e.g. 30 kVA, or
- Optionally, modular central inverters (i.e. with individual modules mounted in racks) can be used for the ground-mounted areas.
- The integration into the facility control system should be given high importance because this interface guarantees a seamless operation of all power system components.
- A simple but functional solution for the safe isolation during load shedding and the connection of the electricity systems of the two locations will allow to leverage further energy saving and more reliable operation. But this aspect shall be verified and agreed upon with GEDCo.
- For the elaboration of bidding documents, a review of the supply market situation shall be conducted to ensure that only reliable components are procured and that bidders have a sufficient range of products to select from. Marked checks shall be conducted anyway during the following two tasks in the course of documents preparation:
    - A market screening during definition of minimum requirements to suppliers of key components, which will provide input to the formulation of the qualification criteria.
    - An update of the typical module characteristics but also a brief review of the technology roadmap shall ensure that only standard market product may be used and the market trends are considered. Taking modules as an example, this means that increase of rated capacity of the average module should be factored in the bid conditions – either by contract assurance to supply higher rated panels or a price index that allows increasing the module rating and contract amount based on the technology trends. Since it is expected that the period between preparation of bidding documents and actual purchase may take a year or even more, such arrangement ensures that NGEST benefits from technical advances.

11.2.2 Financial and Commercial Recommendations

The key recommendations for the financial and commercial aspects during implementation are:

- Looking at the results of the economic evaluation and financial analysis, the choice of adding a PV system is recommended for the economy of the Palestinian territories and the budget of NGEST as the figures show positive impacts in both cases.
- Given the control and risk structures of the project, the implementation via an EPC-turnkey contract under management of PWA is preferred. This is also based on the observation that the function of the facility as public service for the civil society does not provide much room for involvement of private sector players through other contract forms such as commodity contracting or even purchase of the PV-generated energy from an IPP tasked to operate the PV system.
- The possibility of subcontracting the PV system to the main NGEST contract, maybe worth a closer look. Such configuration would offer the advantage of merging all technical guarantees into one contract and reducing interface coordination tremendously.
- In the short-term, GEDCo's consent on the proposed power share solution should be sought out, as the utility must give consent to the proposed new point of common coupling. In the mid-term, a regulatory solution via a net-metering scheme is regarded as more suitable. It can be expected that all parties will grow confidence in auto-consumer solutions once having gained experience with the operation and performance of the PV/biogas system at NGEST and its impact on the network.
- During the selection of a financing scenario, a sufficient level of contingency may be included to cover for unforeseen impacts from both the complexity of the project itself, the lack of experience of PV installations of such magnitude in Gaza and the actual location in a constrained area.

11.3 Potential Timeline for Implementation

A tentative time schedule has been developed and discussed with the stakeholders. The set of milestones listed in Table 11-1 and outlined in Figure 11-1 may guide the stakeholders through the next steps of decision making and implementation. As emphasised, the tight coordination of the remaining NGEST construction activities and external approval procedures will be crucial.

Table 11-1: Tentative activity list

Milestone	Estimated Duration (in months)	Time	Comment / Risk
PV: Feasibility Study on Power Supply to NGEST	**Completed**	**Q1/2016**	**Delay in financing agreements**
PV: Decision & Financing	**3-6**	**Q2-Q3/ 2015**	**Delay in financing agreements**
PV: Specification & Tender Docs	**3-6**	**Q4/2015**	**Interface w/ NGEST contractor**
PV: Tendering	**3-6**	**Q1-Q3/ 2017**	**Depends on response from market**
PV: Construction	**9-12**	**Q4/2017- Q4/2018**	Depends on local security and restrictions for import of
PV: Commissioning	**3**	**Q4/2018**	

NOTE:

- PV Systems according to the conceptual design are installed in a maximum of 3-4 months.
- This depends strongly on the availability of tools and skilled work force.
- Clearance, importing and transport of components to Gaza may pose a constraint.
- An additional quarter was considered as contingency on the timeline for this issue.
- The timeline may be affected by external influences such as regulations or the security situation.
- The timeline for the implementation of Phase 2, foreseen for the years between 2018 and 2024, is still uncertain. Currently, the funding for Stage 1 of Phase 1 is being applied for and arranged.

Figure 11-1: High-level milestone diagram

Milestone	2016				2017				2018				Comment / Risk
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
PV: Feasibility Study on Power Supply to NGEST	■												
PV: Decision & Financing		■	■										**Delay in financing agreements**
PV: Specification & Tender Docs				■									**Interface w/ NGEST contractor**
NGEST Pre-Commissioning				■									
NGEST Commissioning					■								
PV: Tendering					■	■	■						**Response from market**
NGEST in operation						■							
PV: Award							■						
PV: Executive Design & Permits								■					
Recovery Scheme I									■				Precondition for PV at RS Area
PV: Construction										■	■	■	
PV: Commissioning												■	
Recovery Scheme II												■	minor impacts on PV system

12. ANNEX

12.1 Detailed Site Description

12.1.1 Areas Designated for PV Systems

12.1.1.1 Areas within Treatment Plant Boundary

The largest area is A1 in the South of the facility. It is currently unused and covered with grass and small shrub. A slight slope of about 2-3° towards the inner area of the plant is observed (Figure 12-1 and Figure 12-2).

Figure 12-1: A1 viewing towards West

Figure 12-2: A1 viewing towards East/A10

Since the project was initially planned to be supplied only by the feeder line and on-site biogas with additional support by the emergency diesel when needed, cable trenches are reported to be full and without room for additional cables. Cables for connecting the PV plant to the electrical infrastructure would need to be run down at the outer side of the building, e. g. as seen in Figure 12-3. It is proposed to connect the PV sub-systems of the smaller roof-top sub-systems directly to the LV panels of the respective building to avoid the otherwise long cabling for the connection to the power house. In this case, the PV system would represent a negative load on top of the building's load reducing its net draw of energy from NGEST's total power supply.

Figure 12-3: Backward of the Sludge Dewatering Building

Figure 12-4: Embankment South of IB

The plant still has many but small open areas between the single sewage processing steps as shown in Figure 12-4. These areas could be used to install two axis trackers, if such technology is opted for.

The roofs of all buildings have been used to place typical facilities such as air-condition outlets and water tanks. These are present on all buildings as shown in Figure 12-6 and Figure 12-7. The PV design has to deduct these areas from the total available area and consider some buffer space for maintenance access to this equipment.

Figure 12-5: Roofs of Digester & Thickener Building, and power house

Figure 12-6: Roof panorama

There is a second large brown-field area (A2) located close to the road on the West of the plant pictured in Figure 12-7 and Figure 12-8. Its rectangular shape and size makes it a perfect place for a larger and well performing ground-mounted array. This is the sub-system which would be affected mostly by the dust emitted from the refuse collection lorries passing on the road outside the fence. Fortunately, maintenance access for cleaning will be easy at this place.

Figure 12-7: A2 towards IB

Figure 12-8: A2 towards the main gate

12.1.1.2 Areas at recovery scheme

The second location with designated PV areas is the effluent recovery scheme behind the cemetery as shown in Figure 12-12. It can be reached either via a untarred road from Jibaliya or by following the road along the plant's fence and then branching left at the Northern site corner as illustrated in Figure 12-9.

Figure 12-9: View from Administration Building towards the recovery scheme

Since the recovery scheme is scheduled to be constructed after commissioning of the WWTP in stage 1 and stage 2 of phase 1 and then expanded in phase 2, no structures can be currently found on these areas. The view from the corner close to the cemetery towards the town and the view toward the treatment plant are shown in Figure 12-10 and Figure 12-11.

Figure 12-10: Recovery scheme area towards Jibaliya

Figure 12-11: Recovery scheme area towards East to the plant

Apart from the mechanical and electrical buildings, PWA also selected a larger area of about 32,000 m² on top of the recovery fields for a PV system. The land is currently leased to local farmers on seasonal basis and covered with grass or other crops as depicted in Figure 12-12 and Figure 12-13. A challenge for these areas will be to plan and coordinate the installation of a potential ground-mounted PV system in such a way that the construction of the facilities for the recovery scheme is not hindered.

Figure 12-12: Effluent recovery scheme area with cemetery to the left

Figure 12-13: Effluent recovery scheme area towards Jibaliya

12.1.1.3 External Obstacles

Since the NGEST project is located close to the border, the land around it is used for agricultural purposes. This includes mainly the cultivation of seasonal crops or forage as seen in Figure 12-16. Such land use is generally of advantage because it prevents development of dust which would in return lead to soiling losses during operation.

A few activities around the area are potential sources of dust and dirt, such as the landfill site in the North-East of the treatment plant site and the dust-carts which regularly pass the site on the untarred road as shown in Figure 12-14..

Figure 12-14: Refuse collection vehicle using dirt road at NW

Further, low-intensive human activity which are probably always present in the densely populated Gaza strip, may have an impact on the operation and performance like the charcoal production closed to the cemetery shown in Figure 12-15.

Figure 12-15: Charcoal production close to Northern site corner

Another external source of potential high impact which affects the whole region is the proximity to the border with Israel. Fractures from the armed conflict in 2014 have been observed at the NGEST administration building. Ricochets or other similar objects would obviously also affect PV arrays and may lead to glass breakage on a large scale.

Figure 12-16: Land adjacent to the plant at the Southern border

12.1.2 Electrical Infrastructure

12.1.2.1 Network Power Supply

The treatment plant is currently serviced by an over-head feeder line branched off from the main network in Jibaliya and then guided along the secondary road towards the site (see Figure 12-17 and Figure 12-18). The supply voltage is 22 kV which is usually considered as medium voltage but due to lack of higher voltage levels in Gaza also referred to as high voltage.

Figure 12-17: OHL feeder from Jibaliya

Figure 12-18: OHL towards the plant

The cable is then received by a steel tower with a CB at the Western border of the plant next to PV area A2, shown in Figure 12-19. This tower is currently equipped with a temporary transformer used by the Contractor of the facility. Within the treatment plant, underground cables are used to guide the power to the energy building pictured in Figure 12-20. The localisation of these cables will be important during the potential construction of the PV system on A2 in order to avoid damage of the main power cables.

The effluent recovery scheme is not yet connected to the MV network because these facilities are scheduled to be constructed later in phase 1 of the NGEST project. In case that the PV system is installed before the recovery scheme in order to supply the treatment plant, the contractor of the PV systems would also need to set-up at least a temporary grid connection in the absence of the main electrical infrastructure and additional generators at that location. Such situation may happen if the PV systems are planned to be procured altogether as one lot. Since the PV systems will be planned as grid-connected plants, either a stable network connection or local generator is required to build the grid.

Figure 12-19: A2 with power supply OHL (22 kV) from GEDCo network

Figure 12-20: The Blower and energy building

12.1.2.2 Energy Building

12.1.2.2.1 On-site Generation Facilities

The Blower and Energy Building shown in Figure 12-20 has separated compartments for the two different generation sources.

Figure 12-21: Outside of the blower and electrical building

A spark ignited gas generator set is installed with a capacity of 830 kVA produced by the manufacturer MWM, Germany (refer to Figure 12-22 and Figure 12-23). The cooling water piping of this generator is not yet finished.

Figure 12-22: Biogas-engine

Figure 12-23: Biogas-engine

Three containerised diesel generating sets from FG Wilson with Perkins engines and rated with 800 kVA each are installed as emergency diesel gen-sets.

Figure 12-24: Containerised diesel gen-set

Figure 12-25: Perkins engine

12.1.2.2.2 LV and HV Electrical Installations

The energy building has separate rooms for HV connection and LV connection. These were inspected in order to determine the possibility for the connection of the PV systems, especially the larger sub-systems.

The existent energy Siemens Ring-Main-Feeder switchgear (see Figure 12-26) is planned to control the connection to the grid and to the on-site diesel and biogas generators. Currently, the installed switch gear is only connected to public grid.

Figure 12-26: Ring-Main-Feeder switchgear

The LV supply consists of various switchboards for the main consumers and the incoming supply pictured in Figure 12-27 and Figure 12-28. LV cabling is not yet finished for distribution and supply panels.

Figure 12-27: LV-distribution

Figure 12-28: LV-panels

Both rooms are equipped with sufficient spare space for the installation of additional feeders and switchboards for both feeding high voltage from the larger ground-mounted field PV sub-systems to the HV room and feeding low voltage from the rooftop PV systems directly to the LV system in the LV room.

The rooms have clean cable routing provided by the large underground distribution chambers beneath the floor (Figure 12-30).

The building also accomodates the fire protection system which control unit is shown in Figure 12-29.

Figure 12-29: Fire detection unit

Figure 12-30: Cable trays and channels beneath the floor of the electrical room

12.1.2.3 Main Consumers of the Treatment Plant

Within the sewage processing chain different energy consuming equipment is installed. It was looked at during the site walk-through in order to be able to relate its status and construction to the process description and drawings. The selected steps of the process are briefly described.

For the digester zone, there are no special remarks related to the electrical infrastructure. The digesters are important for the production of the biogas.

Figure 12-31: Future gas holder; storage Facility for biogas

Figure 12-32: Flare near to the gas holder. Sludge silos in the background

The civil works of the gas holder (Figure 12-31) and gas torch (Figure 12-32) seem not to be totally accomplished. Before start of operation a membrane system with a steel plate protection must be mounted. Purpose of the membrane is to keep the gas-pressure constant.

Figure 12-33: Basins for activated sludge on the left side

At the other main processing steps of the treatment plant, the sludge silos and sludge dewatering system, the sludge activating basins (Figure 12-36, Figure 12-37), the sand washing zone (Figure 12-38, Figure 12-39) and the final clarifiers (Figure 12-40, Figure 12-41), no specific observations were made regarding the electrical aspects of these energy consumers.

Figure 12-34: Sludge silos and sludge de-watering building – outside equipment

Figure 12-35: Sludge silos and sludge de-watering building – screw pumps for sludge

Figure 12-36: Sludge handling

Figure 12-37: Sludge activating basin (1 of 3)

Figure 12-38: Sand washing zone

Figure 12-39: Sand washing zone

Figure 12-40: Final clarifier (1 of 3)

Figure 12-41: Final clarifier (1 of 3)

The electrical power demand of the plant together with the application of a factor for simultaneous running of electrical consumers under several power conditions will be assessed. The blowers (Figure 12-42, Figure 12-43) are one of main consumers running rather continuously.

Figure 12-42: Blowers

Figure 12-43: Blowers

On the generation site, the biogas production and its differing for the LHV will need to be analysed.

12.1.3 Additional Site Infrastructure

The design of the treatment plant contains all necessary infrastructure required for the operation. A few aspects may be mentioned here which are important for the PV system and the power supply as a whole.

A meteorological station operated as part of the regional measurement network has been installed (refer to Figure 12-44). The equipment could be easily complemented by radiation measurement sensors for the reference monitoring of the PV system.

Figure 12-44: On-site meteorological station (no radiation measured)

The road network, as shown in Figure 12-45, is well established which facilitates installation and maintenance. The PV installation company will have to consider the normal operation of the treatment plant and ensure that these existing structures are not damaged.

Figure 12-45: Internal road network on site

12.1.4 External Interfaces

Any further expansion of the electrical infrastructure or change in power supply will share the interfaces with the NGEST locations themselves. They are:

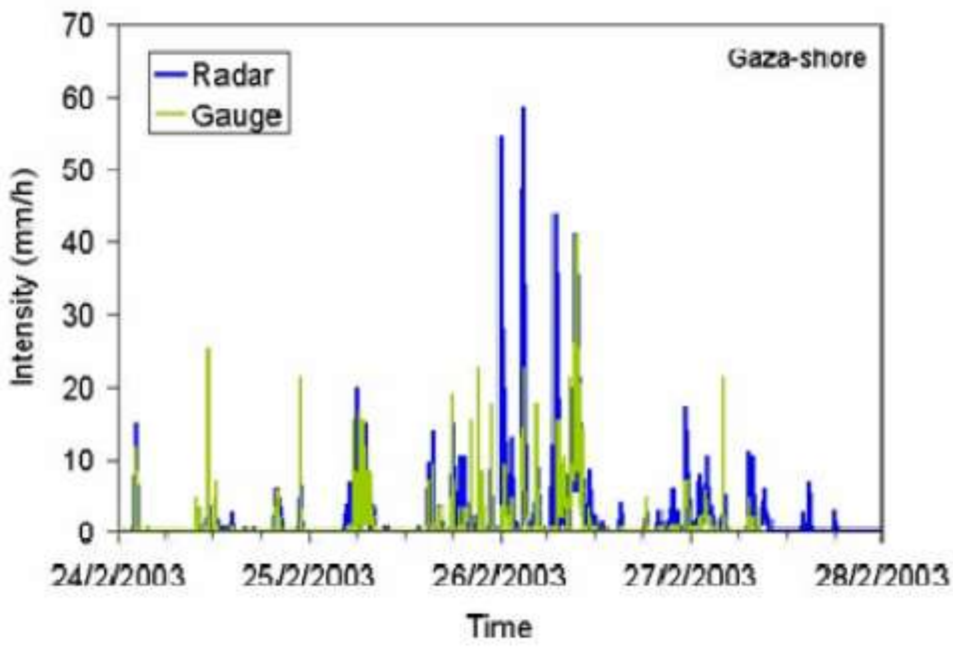
- The treatment plant receives external power supply from GEDCo via a 22 KV MV OHL feeder;
- Telecommunication is provided by the DSL line for the NGEST SCADA, no information is currently available on bandwidth and availability of this line;
- Fresh water currently taken from ground water wells but can be directly taken from NGEST once the systems are up and running.

12.2 Detailed Description of Environmental Conditions

12.2.1 General Climate Conditions

12.2.1.1 Rainfall

Rainfall occurs during winter between the months October - April each year. The annual average rainfall in the project location (Northern Part of Gaza) is nearly 390 mm / year according to Qahman, et al (2011). In addition, the average recorded rainfall intensity over 30 years of record in Gaza was 45.1 mm/hr while this average is exceeded often in storm events such as the case of 2003 as shown in figure below where the intensity was close to 60 mm/hour, Exact (2006).



12.2.1.2 Temperatures

The project sites have a typical semi-arid Mediterranean climate with long hot and dry summer (from 25ºC in summer and 13ºC in winter; the maximum daily temperature can reach 31ºC and the minimum temperature is around 11.6ºC). The proximity of the Mediterranean Sea has a moderating effect on temperatures and promotes high humidity throughout the year.

Table 12-1: Temperature profile using data from the Solar Atlas of Palestine

Month	Temperature °C at 2 m		
	Min	Max	Average
January	11.7	17.4	14.3
February	11.6	18	14.5
March	12.5	20.1	16
April	14.3	23.2	18.5
May	16.8	26.1	21.2
June	20.1	28.6	24
July	22.3	30.6	25.9
August	23	31.1	26.5
September	22.2	29.9	25.6
October	20.4	27.6	23.6
November	17.1	23.6	20
December	13.4	19.3	16

Assessing the effect of temperature on the PV-plant we can conclude that the maximum power point

(MPP) can have attenuation of about 5% in form of voltage drop in the mid-day time only when temperature reaches its maximum value in summer. In the early hours of summer day as well as in late hours MPP is minimally affected. The last minimal effect of temperature is correct too for winter, spring and autumn seasons.

Air should be allowed to circulate behind the back of each PV-module, so the temperature does not rise. This is an essential procedure to conserve the electrical output of the modules. For the detailed design of NGEST PV-plant the influence of temperature should be considered. Related data can be found[54].

12.2.1.3 Relative Humidity

Gaza is a humid area with average monthly relative humidity of nearly 68%. Particles of water vapour are highly concentrated in the lower layers of the coastal atmosphere of Gaza. In the same time the concentration of vapour had no permanent character, it changes by time and air spot. Mediterranean Sea west to Gaza is the huge water surface increasing the humidity. Wind directions limit the concentration of vapours in Gaza atmosphere. Table 12-2 below shows some available measurements of evaporation from Gaza metrological station[55]:

Table 12-2: Evaporation rates in Gaza

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Rate
Evaporation mm/year	1603	1672	1645	1635	1909	-	1583	1698	1543	-	1583	1652

12.2.1.4 Wind

Gaza is the windiest area in The Palestinian territories. The prevailing wind direction is South West with an average speed of 11 km/hour (winter) and from North West (summer) and sometimes from the East. Depending on wind direction, when it blows from the south or west it carries light solid particles from the sandy beach in the west as well as from dry fields in eastern areas of the strip to the atmosphere. Mixing with air the solid particles become as a fixed component of the atmosphere "aerosols". Diffuse of radiation by aerosols occurs in the visible region in addition to ultraviolet region of the solar spectrum. Under high aerosols concentrations the normal blue colour of the sky changes into white and in few cases in Gaza the sky has a colour closer to yellow when southern winds and air temperatures are too high in summer.

12.2.1.5 Storms and Lightning Risk

Storm occurrence has no fixed return period but generally follows the general cycle of nearly 10 years for extreme wet events or storms. However, lightning and thunder occurs during normal rainy days not

[54] R.Foster,M.Ghassami, A.Cota. Solar energy: Renewable energy and the environment.CRS press. Taylor & Francis Group. ISBN: 978-1-4200-7566-3.Pages:138-144

[55]Palestinian Bureau of Statistics, annual report 2008. Arabic edition

only during the extreme storms. Therefore, it is important to consider protective measures through thunder / lightning protectors in the plant to ensure safety.

12.2.2 Soil Conditions

12.2.2.1 Subsoil

The soil cover of the NGEST site is dark brown loamy clay of 7-23 m depth with a well-developed structure laying over marine Kurkar Formation (Calcareous sandstone).

12.2.2.2 Vegetation and Land Cover

The areas surrounding the NGEST site are nearly empty and not cultivated. The nearest tree lines to the site are at 3000 m toward the west. The site is encircled with dirt roads which are heavily used by solid waste collection trucks and therefore are likely to create dust and affect the PV plant.

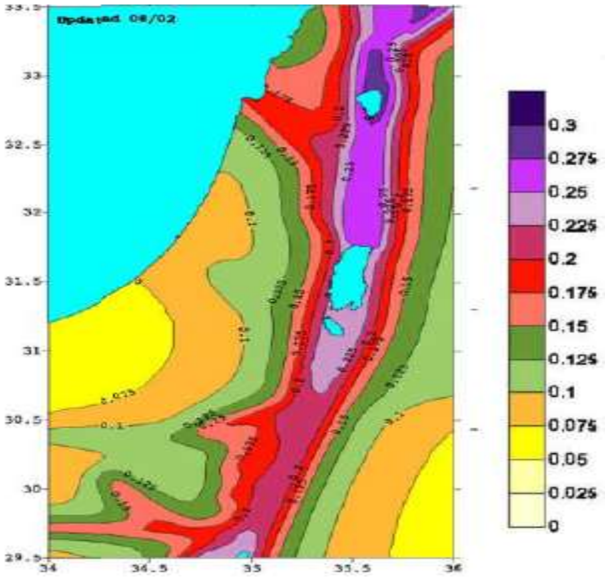
12.2.3 Geotechnical Data and Foundation Considerations

The typical surface and subsurface geological setting of Gaza strip is composed of mainly Kurkar group with a thickness of 200 m and composed of marine and Aeolian calcareous sandstone, silty reddish sandstone and silt inter layers. There is no major structural or faults presence in the area and the foundation is therefore considered stable in a sense that all designs for any overland structure should be based on loose soil foundation criteria.

12.2.4 Seismological Risk

Palestine in general has medium to low seismicity with recorded earthquake of 6 degree of magnitude near Jerusalem early 2000. In addition, for costal area there are no major structural features or faults that may create some potential seismic activity and is classified as inactive seismic area as shown in Figure 12-46, the design factor considered for the NGEST plant was 0.075 as reported in the ESIA (2006).

Figure 12-46: Seismicity Zones in the Region



12.2.5 Solar Resource and Meteorological Input

Solar radiation data and the amount of solar energy in Gaza area are collected and analysed here. This is an essential step for modelling the NGEST PV-plant. Precise knowledge of available historical solar radiation in Gaza is assessed to determine the technical parameters of the NGEST.

Analysed data was acquired from:

1. PENRA issues including Solar Atlas, 2014,
2. Palestinian Bureau of Statistics,
3. Scientific papers,
4. Reports on measured data from the nearest to Gaza Israeli meteorological station.

The PENRA data were taken in 1998, International Journal data are from 2013, Bet Dajan measurements were published in 2010. The period of measurements and data coverage is not clear for all data sources.

No measured solar irradiation data was available from the PA central meteorological department in Ramallah. Due to wars Gaza local meteorological stations were destroyed or not functional, we found no access even to old locally measured irradiation data.

A comparative study of the existing solar irradiation data sources is shown in Table 12-3. These sources show an irradiation daily rate of 5.25 kWh/m^2.

Table 12-3: Daily average of solar radiation on Gaza surface during the year by different references:

Month	PENRA 1998[56]		International journal[57]		Bet Dajan[58]** (measurements)	
	Daily sum [kWh/m²]	Monthly sum [kWh/m²]	**Daily sum [kWh/m²]**	Monthly sum [kWh/m²]	**Daily sum [kWh/m²]**	Monthly sum [kWh/m²]
January	3	91.3	3.36	102.2	2.61	90.9
February	3.9	118.6	3.97	120.8	3.4	114.3
March	5	152.1	4.33	131.7	4.7	142.2
April	6.1	185.5	5.19	157.9	5.86	173.9
May	6.9	209.9	6.46	196.5	6.88	205.2
June	7.9	240.3	7.78	236.6	7.55	235.5
July	7.5	228.1	7.4	225.1	7.29	225.0
August	6.9	209.9	6.76	205.6	6.67	206.1
September	5.8	176.4	5.88	178.9	5.69	176.1
October	4.3	130.8	4.73	143.9	4.25	134.6
November	3.1	94.3	4.31	131.1	3.09	106.5
December	2.5	76.0	5.53	168.2	2.48	106.6
Annual	**2.24**	1913.2	**5.34**	1998.4	**5.04**	1917.0

**Bet Dajan is the nearest to Gaza Israeli metrological station. The solar radiation level of both areas Gaza strip and Bet Dajan are similar according to Ahmed Rabai, Potential of application of PV system for BWRO desalination in Gaza. Jordan, 2009.

Basic solar parameters for Gaza are presented in Table 12-4: Global Horizontal Irradiation (GHI) and Global Tilted Irradiation (GTI). Data in this table were collected based on the Atlas of Solar Resources of the State of Palestine of 2014.

[56] Palestinian Energy Authority.1999-1998 report, page 8.

[57] JumaYousufAlayadi. A parametric study of solar and wind energy in Gaza strip. International journal of scientific engineering research, Volume 4, Issue 12, December 2013.

[58] Mohammed T. Hussein and Sahdi N. Albarqouni.Developing empirical models for estimating global solar radiation in Gaza strip, Palestine.The Islamic university journal Vol. 18.No.2, page 80. 2010

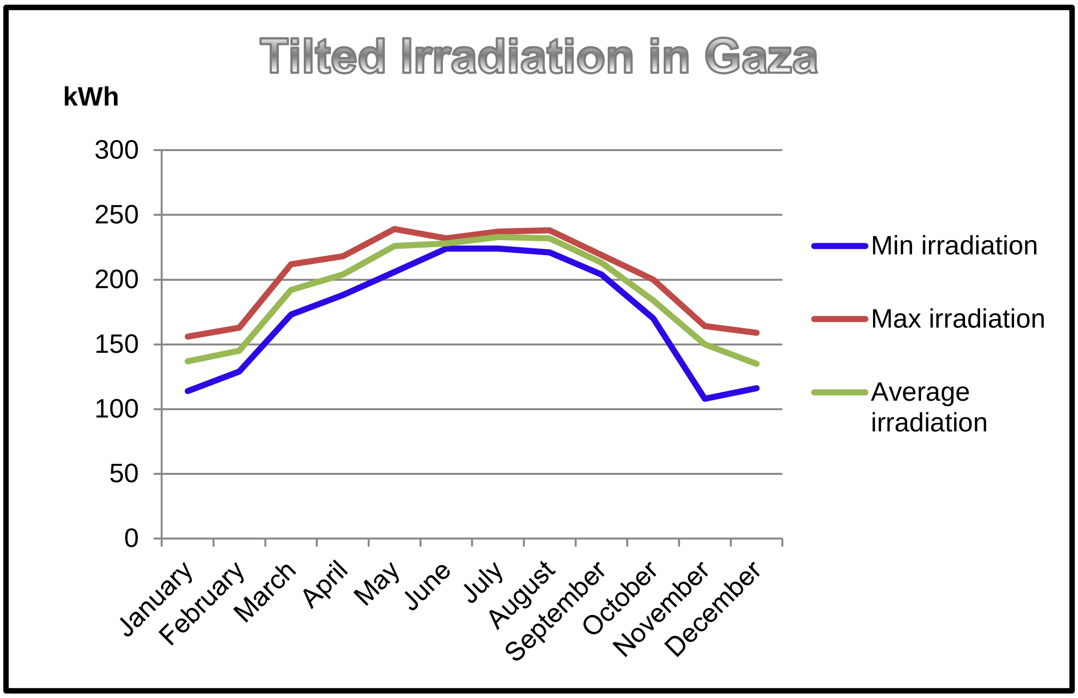
When comparing the data from the Solar Atlas with the local measurement sources and evaluation efforts presented above no significant deviations are found. This conclusion confirms that the Solar Atlas can be regarded as a reliable long-term data source for the PV system design.

Table 12-4: Gaza basic solar parameters

Month	Global Horizontal Irradiation (kWh/m^2)			Global Tilted Irradiation (kWh/m^2)		
	Min	Max	Average	Min	Max	Average
January	83	107	96	114	156	137
February	100	124	113	129	163	145
March	150	181	165	173	212	192
April	180	208	195	188	218	204
May	214	249	235	206	239	226
June	243	253	248	224	232	228
July	237	253	248	224	237	233
August	218	235	229	221	238	232
September	182	193	189	204	219	213
October	137	158	148	170	200	184
November	80	117	108	108	164	150
December	80	103	91	116	159	135
Year			**2065**			**2279**

The most important parameter for NGEST PV-plant is Global Tilted Irradiation (GTI) that is presented in Figure 12-47 with its minimal, maximal and averaged values during the year.

Figure 12-47: Global Tilted Irradiation (GTI)



The factors influencing irradiation values in Gaza are clouds, water vapour and aerosols. Particles of water vapour are invisible, and absorption of solar radiation occurs in the invisible infrared region of the solar spectrum.

Diffuse radiation is intensive under high concentrated aerosols. Radiation attenuates by aerosols depending on the Aerosol Optical Depth (AOD). There are no measurements in Gaza for the AOD. It can be only estimated together with other factors in the Strip increasing the diffuse radiation such as water vapour, industrial dust, pollution caused by burning of agricultural waste and any other air polluting factor.

The data assessment criteria are application-specific and are selected here according to the planned use of the data for NGEST. Data of Global Tilted Irradiance (GTI) in Gaza has a major importance for the NGEST PV-plant. Data of Direct Normal Irradiance (DNI) is valuable for the tracking part of NGEST PV-plant. The NGEST solar power plant uses no concentrated solar technologies (CSP) and therefore the diffuse radiation caused by aerosols and water vapour has no considerable effect on plant's performance. The main radiation indicator for the NGEST plant remains GTI.

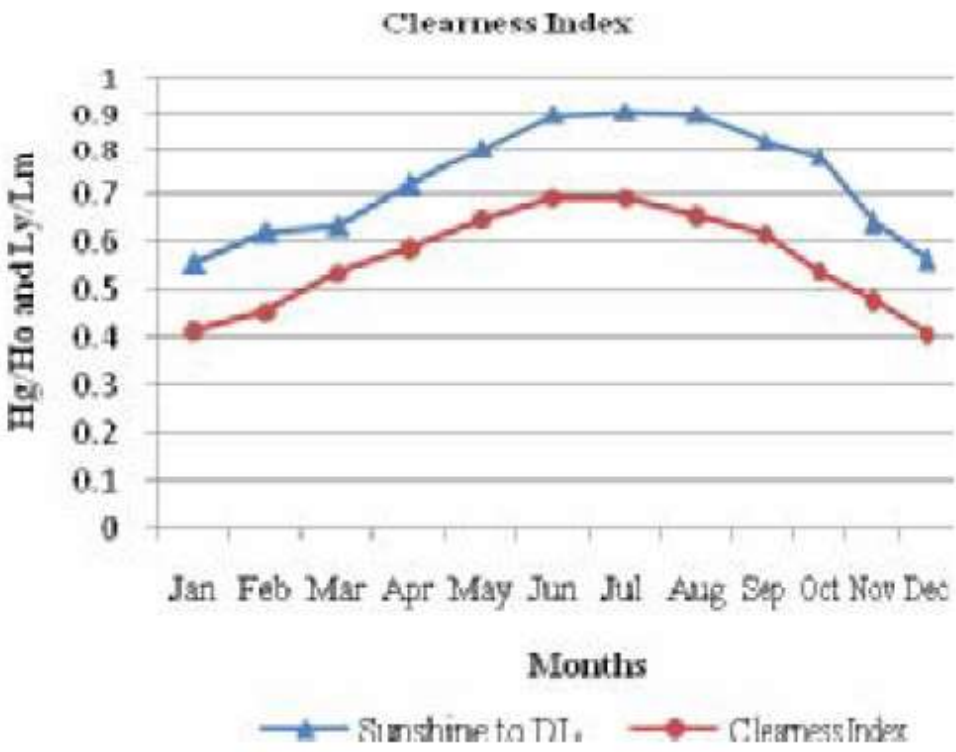
The influence of air temperature on irradiation is analysed from collected data in Table 12-5 below. Average of air temperature on 2m height shows two important indicators:

1. The average temperature all over the year is below 40°C. Performance of PV arrays is in the safe range and nominal capacity of PV plant in general can be ensured.
2. The general tendency of temperature increase from January to August is in accompany with the GTI increase. Only DNI indicates little declination after June, this has a little effect on the tracking part of the NGEST PV plant as this tracking part is small.

Table 12-5: Gaza irradiation averages and temperature values

Month	Average Irradiation (kWh/m²) DNI	GHI	GTI	Temperature °C at 2 m Min	Max	Average
January	124	96	137	11.7	17.4	14.3
February	126	113	145	11.6	18	14.5
March	163	165	192	12.5	20.1	16
April	174	195	204	14.3	23.2	18.5
May	220	235	226	16.8	26.1	21.2
June	253	248	228	20.1	28.6	24
July	246	248	233	22.3	30.6	25.9
August	232	229	232	23	31.1	26.5
September	201	189	213	22.2	29.9	25.6
October	159	148	184	20.4	27.6	23.6
November	139	108	150	17.1	23.6	20
December	130	91	135	13.4	19.3	16

The clearness index for Gaza strip indicates that the Strip in general has a clear sky conditions most of the year. The maximum values of the clearness index are obtained during the period from June to August with maximum shining hours as shown in figure below [59]:



[59] Mohammed T. Hussein and Sahdi N. Albarqouni.Developing empirical models for estimating global solar radiation in Gaza strip, Palestine.The Islamic university journal Vol. 18.No.2, page 80. 2010.

12.3 PV System Variants

12.3.1 Methodology for Analysis of the Potentially Feasible Variants

12.3.1.1 Sources of Information and Input Data

The following information and input data have been used to develop preliminary solar array layouts as well as to assess plant production and system costs.

- The Solar Atlas of Palestine provides
  - general resources information
  - indication on tilt angle
  - data sets as input for the simulation
- NGEST project documents
  - Contractor's design (nearly as-built)
  - Elevation map
  - Designated PV areas
  - Further drawings on the building (roof facilities, height), electrical infrastructure, etc.
- Further data specially for the PV components
  - Market information on technology market share, suitability of components and cost structures
  - Manufacturer's information
    - Data sheets
    - Installation manuals
  - Preliminary price quotes
- Consultant's initial findings and assumptions on
  - System losses (detailed further in the next section)
  - Market share and suitability of components
  - Findings of the site visit including photos
  - Analysis of system costs for The Palestinian territories including fees and levies for Gaza

12.3.1.2 Approach and Assumption for Design and Modelling

The actual configuration for each variant was defined using the CAD software for measuring the dimensions and geometry of the areas as well as the simulation tool PVSyst for simulating the performance and output of the PV generator. P50 TMY dataset described in section 2.6.2 was used as meteorological input data.

In the next step, the orientation was added to the configuration. The geometrical parameters were measured out of the correspondent CAD designs. Exemplar values for Variant 1 are shown in Table 12-6.

Table 12-6: Values for roof-top and ground Mounted

Parameter	Value	Unit
	Roof-top	
Pitch	2,79	m
Coll. Band Width	1,49	m
Azimuth	0	°
Module tilt	25	°
	Ground Mounted	
Pitch	5,17	m
Coll. Band Width	2,97	m
Azimuth	0	°
Module tilt	25	°
With:		
Pitch	*Rows distance (lower front edge of module of first row to lower front edge of module of subsequent row)*	
Collector band width	*the height of the effective PV module area (excluding frame)*	

The spacing between rows was defined in such a way that the yield is maximised while a good accessibility is still maintained. As a general rule the spacing was designed to keep the module tables free of shadow for at least 4 hours on the shortest day of the year (21st of December) corresponding to a shading angle of 27°. A module tilt of 25° is considered as the optimum between yield, racking costs and row spacing.

Any obstacles such as roof-top facilities (e.g. water tanks, HVAC outlets) were excluded from the design.

The PV generator set-up using exemplary components and a typical configuration is shown in Table 12-7.

Table 12-7: Key components and string configuration

Component	Technology	Type	Explanation
Module	c-Si	CS6P 260P (Canadian Solar)	A typical crystalline silicon module as commonly found in the market.
	thin-film	SF160-S (Solar Frontier)	A CIS thin-film module with one of the highest efficiency among thin-film modules and dimensions suitable for installation on roof-top.
Inverter	Multi-string / multi-MPP	STP 25000 (SMA)	High performing device compliant to most grid codes.
Configuration	String with 22 modules 5 strings per inverter		

In some cases shorter strings had to be added in order to fill the complete area with PV panels. Smaller inverters down to the size of 25 kVA were used in this case in order to ensure efficient conversion performance.

For the performance calculations the system losses shown in Table 12-8 were estimated and applied. The Perez-Model was used to transpose the GHI values to the tilted module surface.

Table 12-8: Applied losses

Type of loss	Value	Unit
Field Thermal Loss factor	29,0	W/m²k
Ohmic losses (DC+AC)	2	%
Module efficiency loss	-0,5	%
LID loss factor	2	%
Mismatch losses	1	%
Soiling losses	3	%
IAM Curve (10 to 90°)	1/1/1/1/1/0,99/0,92/0,73/0	
Average output reduction due degradation over 25 years	9	% below initial output

An initial light-induced degradation (LID) of 2% and an annual degradation of 0.72% corresponding to typical manufacturer performance guarantees in the market were assumed for the calculation of the average production over 25 years of the project lifetime. In order to simplify the calculation, the different areas with similar characteristics were grouped together. This reduced the need to run many simulations with just minor variations in the input and output values.

12.3.1.3 Cost Estimation for Potentially Feasible Variants

A preliminary cost estimate was developed breaking the total system costs down to the second level. The CAPEX are split in 15 sub-groups whereas the OPEX were separated in 4 categories. These sub-groups represent the major cost factors of the PV system. All sub-groups were priced separately.

For materials and equipment quotations and databases of similar projects were used, e.g. in case of the PV modules standard pricing of an international Tier 1 manufacturer provided a good basis. The values were then adapted for import duties and local fees. Information from existing solar PV projects in The Palestinian territories was used as input for the local portion of the costing. Since the most systems are rather smaller systems, the quotations were adjusted for economies of scale effects that are expected to be leveraged when procuring a larger system like the planned for NGEST. Examples for such systems are a few relatively small 2-5 kWp grid connected PV systems and the medium-sized PV plant in Jericho (300 kWp). These sources have been supplemented by quotations from local and regional suppliers like Brothers Engineering Co., Bethlehem. Further fees (i.e. importing to Gaza) and local labour costs have been considered.

For items with a higher share of labour like installation or maintenance the necessary man-hours were estimated and then multiplied with the cost of the corresponding local man-hour depending on the required skill level. In certain topics safety margins were applied due to the fact that PV is a new technology in the region and delays and costs will occur because of local staff being unfamiliar with larger commercial scale PV systems.

There are a few places where the costs differ in respect to other recent estimates, such as the reports cited at the beginning of this section on PV or recent similar feasibility studies[60]. This applies especially for modules prices – PV panels are still the largest cost portion – which had been adjusted to reflect the current world market prices. The operation is supposed to be executed by a skilled technician only. A dedicated engineer is not regarded as necessary and will be available for general supervision as part of NGEST operations. The resulting values seem reasonable also accounting for the fact that transformer and switchgear as well as a large part of the electrical infrastructure already exist in the case of the treatment plant, or will be installed as part of the recovery scheme. Cost differences between the fixed mounting and the tracked mounted variants is in line what is usually observed at other projects.

12.3.2 Configuration and Analysis for Potentially Feasible Variants

12.3.2.1 Variant 1 – Fixed Structures with Orientation true South

Variant 1 is a PV system with a fixed 25° racking structure orientated towards South. A typical string has 22 modules of 260 Wp. In general 5 strings are connected to one decentralized 25 kVA inverter. The total rated DC power of the plant is 4821.44 kWp.

An overview of the preliminary array layout for the designated areas within the WWTP site is shown in Figure 12-48, likewise are the arrays for the areas at the recovery scheme shown in Figure 12-49 while Figure 12-50 illustrates an exemplary roof-top space.

The key parameters of the system configuration and obtained results are summarised in Table 12-9.

[60] Fichtner and Madar Consulting Engineers (2014): Assistance to the Palestinian Water Authority (PWA) for the implementation of the Water Supply to Gaza, Seawater Desalination Project (Phase A), EIB Proj. Code: TA2012033 PS F10

Figure 12-48: Variant 1 – overview of the sub-systems at the WWTP

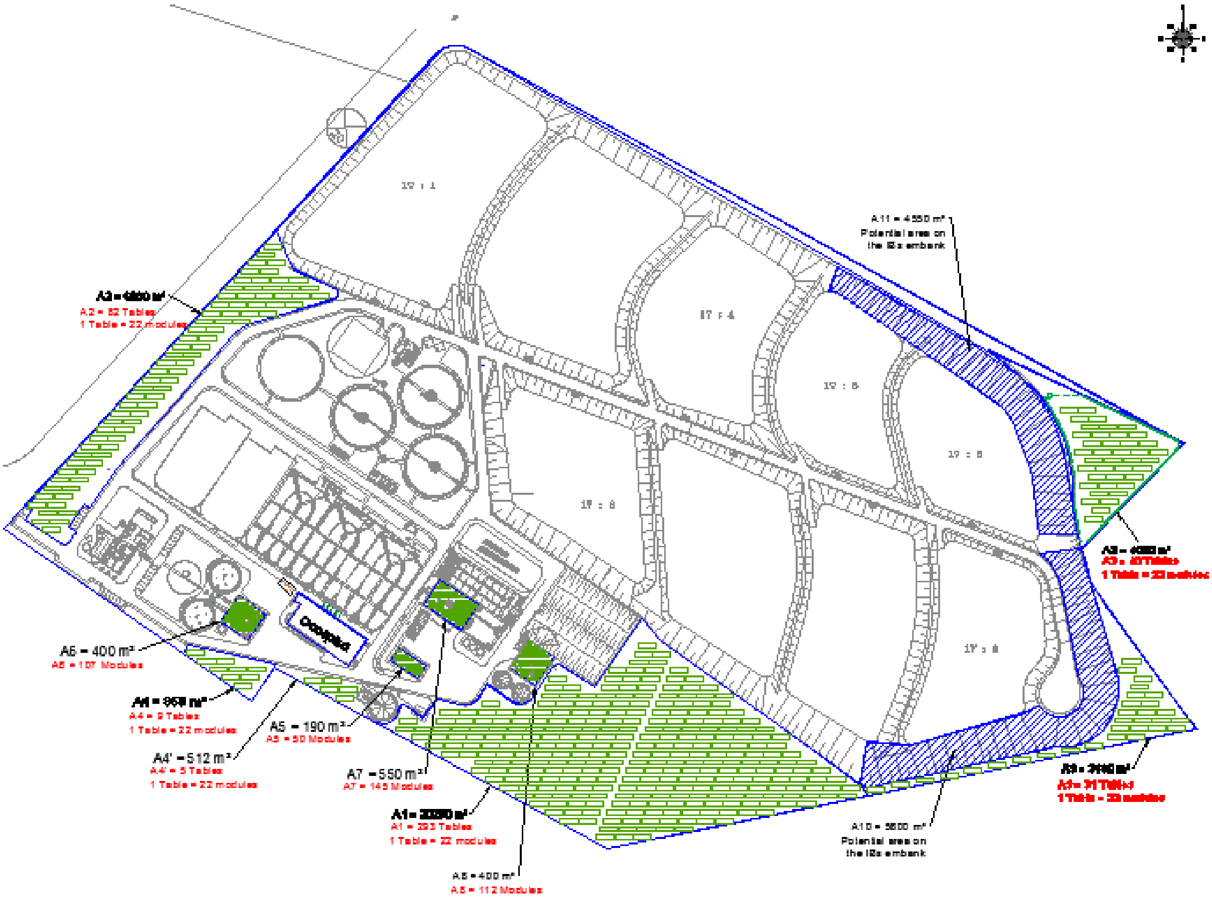


Figure 12-49: Variant 1 – overview of the sub-systems at the recovery scheme

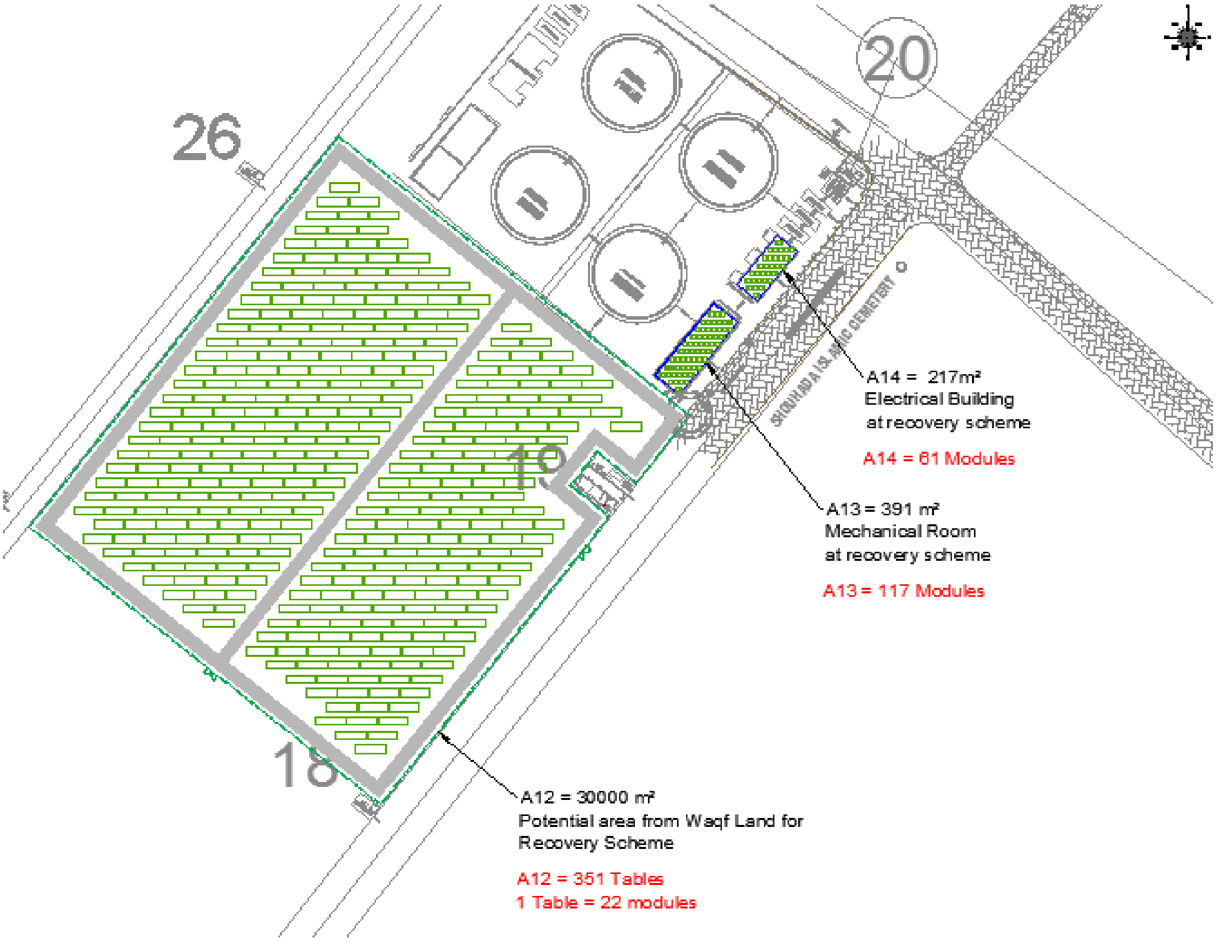


Figure 12-50: Variant 1 – example of a PV array on a roof-top area

Table 12-9: Variant 1 – key system data

Parameter	Value	Unit
Terrain		
Total area	7.80	ha
Effective ground area for PV	5.65	ha
Remaining area	2.15	ha
Orientation		
Tilt angle	25	[°]
Azimuth	0	[°]
Mounting system type	Fixed	
Proposed foundation/fixation Free Field Rooftop	 Ramming posts Anchor	
System configuration		
Total number of modules	18544	
Total number of inverters	175 (5, 10, 12, 15,20, 25 kVA)	

Parameter	**Value**	**Unit**
DC/AC ratio	1.14	
Key system indicators		
Parameter	Value	Unit
Total capacity	4821,44	[kWp]
Specific results		
Capacity / Area Free Field Roof-top	 0.087 0.082	 [kWp/m²/]
Yield Factor Production / Capacity	1668.39	[kWh/kWp/year]
Energy production and power output		
Energy generation	21976.35	[kWh/day]
Peak power (annual minimum)	253.17	[kW/peak time]
Highest daily peak power (annual maximum (h))	4207.98	[kW/peak time]
Annual profile (25yrs average, 25 yrs.)		
Energy generation	8021.37	[MWh/year]
Performance Ratio	80.28	%
Preliminary cost estimate		
CAPEX – specific	1001.78	USD/kWp
CAPEX – total	4,830,002	USD
OPEX – specific	9.67	USD/kWp (annum)
OPEX – total	46,631	USD/annum

12.3.2.2 Variant 2 – fixed Structures With Geometric Adaptation

The PV arrays of Variant 2 have been aligned to be geometrically adapted to the areas by modifying the plane azimuth accordingly. A fixed racking structure with 25° tilt angle is used. One string has 22 modules of 260 Wp. In general 5 strings are connected to one decentralized 25 kVA inverter. The total rated DC power of the plant is 5177.12 kWp.

An overview of the preliminary array layout for the designated areas within the WWTP site is shown in Figure 12-51 likewise are the arrays for the areas at the recovery scheme shown in Figure 12-52 while Figure 12-53 illustrates an exemplary roof-top space.

The key parameters of the system configuration and obtained results are summarised in Table 12-10.

Figure 12-51: Variant 2 – overview of the sub-systems at the WWTP

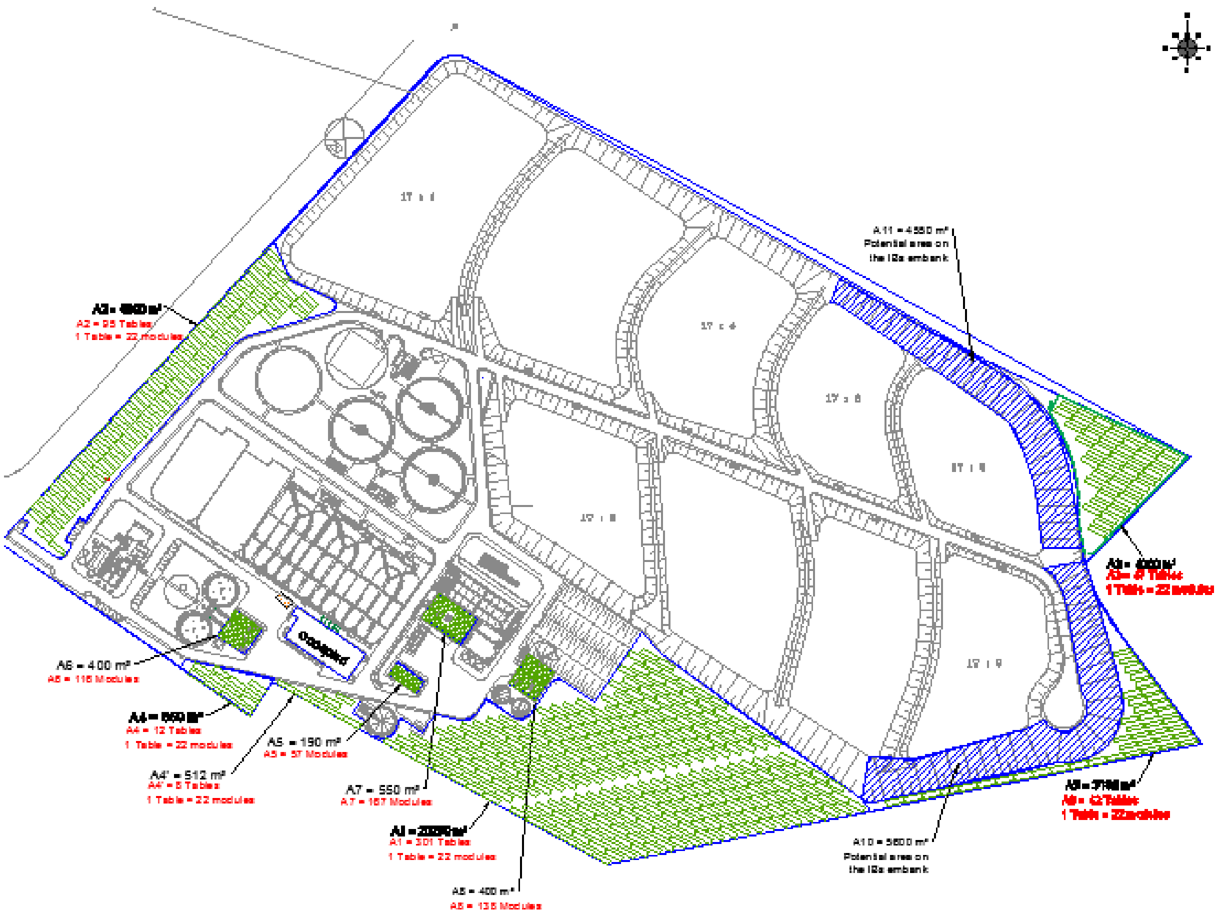


Figure 12-52: Variant 2 – overview of the sub-systems at the recovery scheme

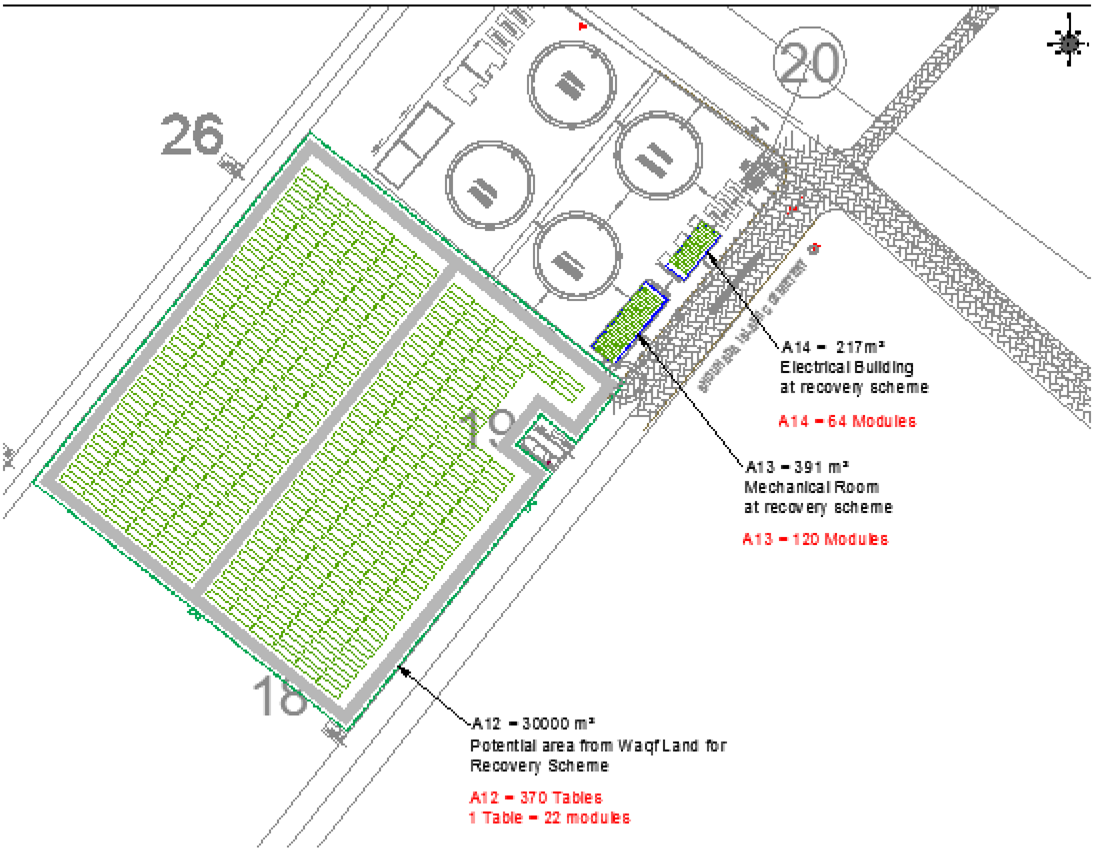


Figure 12-53: Variant 2 – example of a PV array on a roof-top area

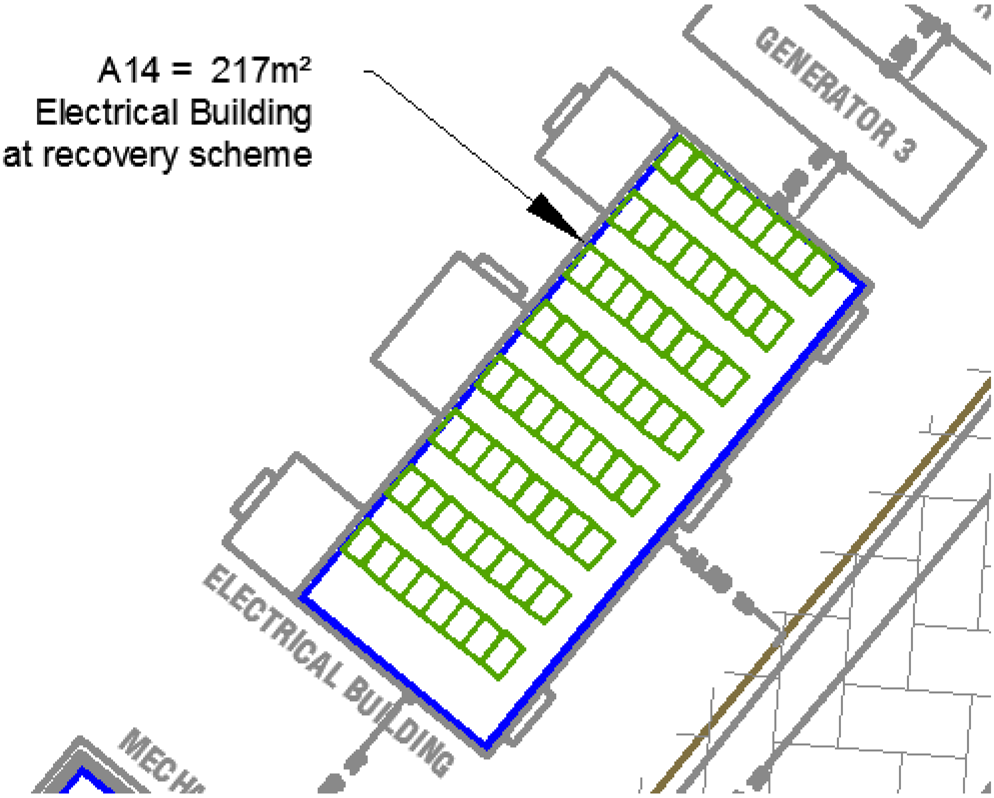


Table 12-10: Variant 2 – key system data

Parameter	Value	Unit
Terrain		
Total area	7.80	ha
Effective ground area for PV	5.73	ha
Remaining area	2.07	ha
Orientation		
Tilt angle	25	[°]
Azimuth	11.5 to 42.3	[°]
Mounting system type	Fixed	
Proposed foundation/fixation Free Field Rooftop	 Ramming posts Anchor	
System configuration		
Total number of modules	19912	
Total number of inverters	187 (5, 10, 12, 15,20, 25 kVA)	
DC/AC ratio	1.14	
Key system indicators		
Parameter	Value	Unit
Total capacity	5177.12	[kWp]
Specific results		

Parameter	Value	Unit
Capacity / Area Free Field Roof-top	 0.099 0.096	[kWp/m²]
Yield Factor Production / Capacity	1635.76	[kWh/kWp/year]
Energy production and power output		
Energy generation	23294.94	[kWh/day]
Peak power (annual minimum)	274.51	[kW/peak time]
Highest daily peak power (annual maximum (h))	4503.27	[kW/peak time]
Annual profile (25yrs average, 25 yrs.)		
Energy generation	8502.65	[MWh/year]
Performance Ratio	80.08	%
CAPEX – specific	1001.13	USD/kWp
CAPEX – total	5,182,972	USD
OPEX – specific	9.44	USD/kWp (annum)
OPEX – total	48,856	USD/annum

12.3.2.3 Variant 3 – One-axis Tracker

In Variant 3 East-West tracking PV arrays have been placed on the free-field areas. The trackers perform an elevation angle of movement with the range of -45 to 45°. One string has 22 modules of 260 Wp and 5 strings are connected to one decentralized 25 kVA inverter. Since the idea of the tracker configuration seeks to optimize the output, the same approach was taken for the roof-top spaces by directing the modules towards South with a fixed racking structure of 25° tilt. There one array has 22 modules of 260 Wp and 5 strings are connected to one decentralized 25 kVA inverter. The rated DC power of this variant totals to 2058.68 kWp.

An overview of the preliminary array layout for the designated areas within the WWTP site is shown in Figure 12-54, likewise are the arrays for the areas at the recovery scheme shown in Figure 12-55 while Figure 12-56 illustrates an exemplary roof-top space.

The key parameters of the system configuration and obtained results are summarised in Table 12-11.

Figure 12-54: Variant 3 – overview of the sub-systems at the WWTP

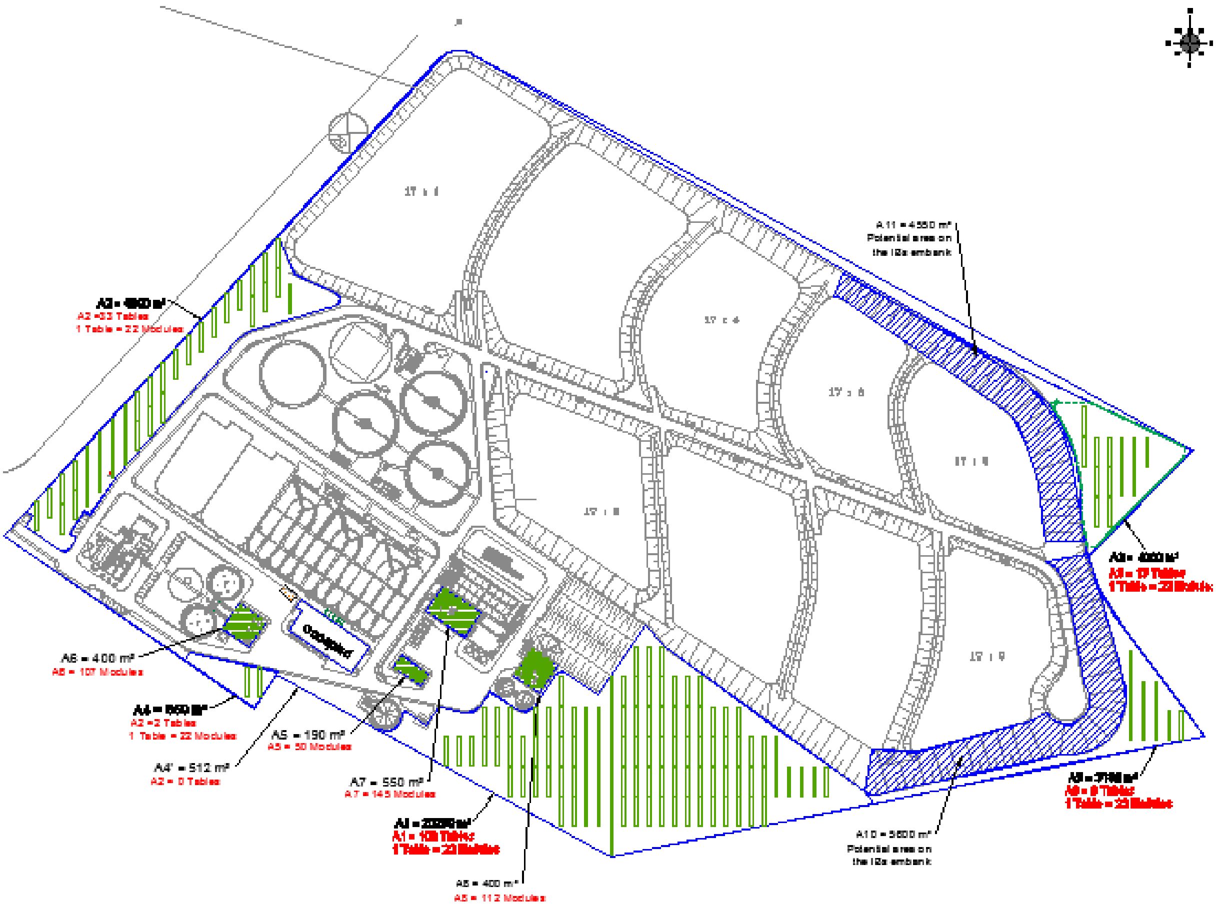


Figure 12-55: Variant 3 – overview of the sub-systems at the recovery scheme

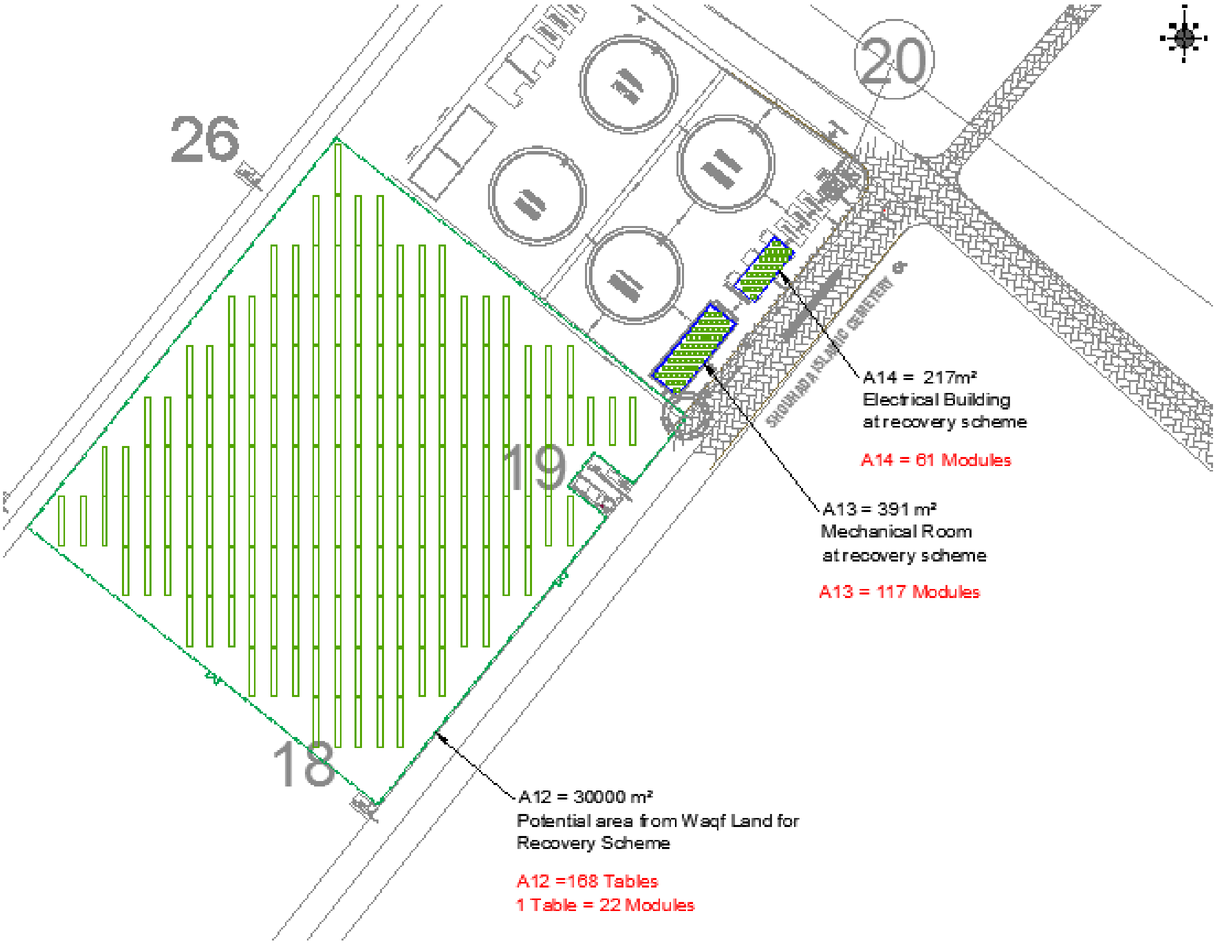


Figure 12-56: Variant 3 – example of a PV array on a roof-top area

Table 12-11: Variant 3 – key system data

Parameter	Value	Unit
Terrain		
Total area	7.80	ha
Effective ground area for PV	5.36	ha
Remaining area	2.44	ha
Orientation		
Tilt angle Free Field Roof-top	 -45 to 45 25	[°]
Azimuth Free Field Roof-top	 90 to -90 0	[°]
Mounting system type Free Field Roof-top	 1 axis tracker Fixed	
Proposed foundation/fixation Free Field Roof-top	 posts anchor	
System configuration		
Total number of modules	7918	
Total number of inverters	78 (5, 10, 12, 15,20, 25 kVA)	

Parameter	Value	Unit
DC/AC ratio	1.14	
Key system indicators		
Parameter	Value	Unit
Total capacity	2058.68	[kWp]
Specific results		
Capacity / Area Free Field Roof-top	 0.045 0.082	 [kWp/m²/]
Yield Factor Production / Capacity	1744.68	[kWh/kWp/year]
Energy production and power output		
Energy generation	10041.89	[kWh/day]
Peak power (annual minimum)	113.37	[kW/peak time]
Highest daily peak power (annual maximum (h))	1494.57	[kW/peak time]
Annual profile (25yrs average, 25 yrs.)		
Energy generation	3665.29	[MWh/year]
Performance Ratio	77	%
Preliminary cost estimate		
CAPEX – specific	1133.17	USD/kWp
CAPEX – total	2,332,830	USD
OPEX – specific	22.56	USD/kWp (annum)
OPEX – total	46,435	USD/annum

12.3.2.4 Variant 4 – Two-axis Tracker

Variant 4 uses a 2-axis tracker instead of the 1-axis tracker on the open space areas. As shown in Figure 12-57, the embankment and dams have also been considered as installation area because the one pole foundations of the 2-axis tracker allow a very flexible installation while the areas underneath remain still accessible for the WWTP staff. The tracker has a 2-dimensional movement with an azimuth angle range of -120 to 120° and a tilt angle movement of 0 to 80°. One string has 21 modules of 260Wp. In general 2 strings are connected to one decentralized 12 kVA inverter. The same configuration as in Variant 1 and Variant 3 was chosen for the roof-top areas in order to achieve maximized performance of the overall plant. Thus fixed structures with 25° tilt angle have been put on the roof-top areas. One array has 22 modules of 260 Wp and 5 strings are connected to one decentralized 25 kVA inverter. The DC power of the plant sums up to 1868.36 kWp.

An overview on the preliminary array layout for the designated areas within the WWTP site is shown in Figure 12-57, likewise are the arrays for the areas at the recovery scheme shown in Figure 12-58 while Figure 12-59 illustrates an exemplary roof-top space.

The key parameters of the system configuration and obtained results are summarised in Table 12-12.

Figure 12-57: Variant 4 – overview of the sub-systems at the WWTP

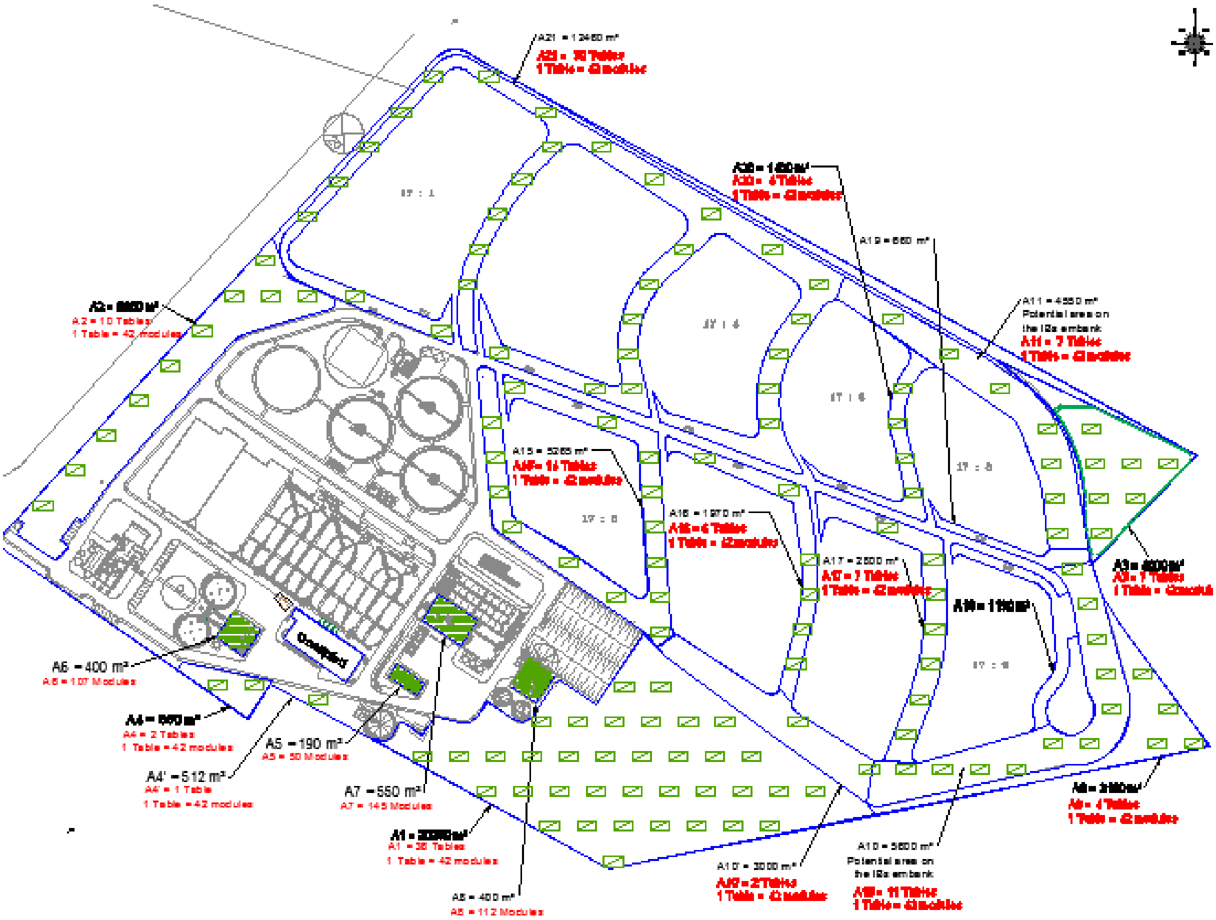


Figure 12-58: Variant 4 – overview of the sub-systems at the recovery scheme

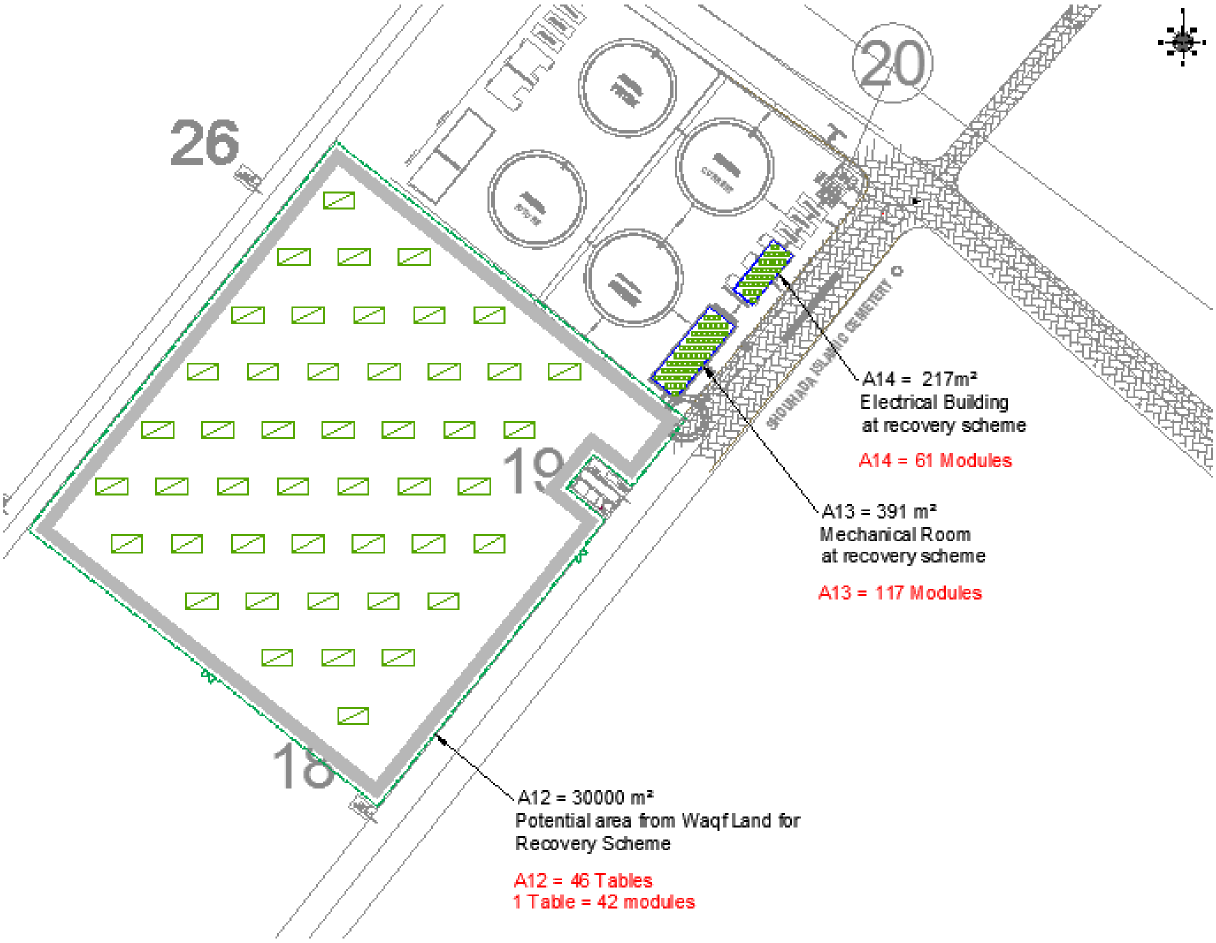


Figure 12-59: Variant 4 – example of a PV array on a roof-top area

Table 12-12: Variant 4 – key system data

Terrain	Value	Unit
Total area	9.43	ha
Effective ground area for PV	6.84	ha
Remaining area	2.59	ha
Orientation		
Tilt angle Free Field: North-South East-West Roof-top	 0 to 80 120 to -120 25	[°]
Azimuth Free Field Roof-top	 120 to -120 0	[°]
Mounting system type Free Field Roof-top	 2 axis tracker Fixed	
Proposed foundation/fixation Free Field Rooftop	 posts anchor	

Terrain	Value	Unit
System configuration		
Total number of modules	7186	
Total number of inverters	166 (5, 10, 12, 15,20, 25 kVA)	
DC/AC ratio	0,91	
Key system indicators		
Parameter	Value	Unit
Total capacity	1868,36	[kWp]
Specific results		
Capacity / Area Free Field Roof-top	 0.053 0.082	 [kWp/m²/]
Yield Factor Production / Capacity	1783.04	[kWh/kWp/year]
Energy production and power output		
Energy generation	9425.19	[kWh/day]
Peak power (annual minimum)	90.29	[kW/peak time]
Highest daily peak power (annual maximum (h))	1731.15	[kW/peak time]
Annual profile (25yrs average, 25 yrs.)		
Energy generation	3440.19	[MWh/year]
Performance Ratio	80.56	%
Contribution to power supply		
Capacity share on total		%
Daily energy production share		%
Annual energy production share		%
Preliminary cost estimate		
CAPEX – specific	1521.39	USD/kWp
CAPEX – total	2,842,506	USD
OPEX – specific	27.21	USD/kWp (annum)
OPEX – total	50,830	USD/annum

12.3.2.5 Variant 5 – Fixed Structures with Geometric Adaptation Using Thin-film Modules

Variant 5 is a modification of Variant 1. The geometrically adapted PV arrays are fitted with thin-film solar modules instead of the previously used c-Si panels. Likewise, a fixed 25°-tilted racking structure is used. Due to different dimensions and electrical characteristics of these modules the string configuration was adapted too. One string consists of 8 modules of 160 Wp and 18 strings are connected to one decentralized 25 kVA inverter. The resulting rated DC power sums up to 4148 kWp.

An overview of the preliminary array layout for the designated areas within the WWTP site is shown in Figure 12-60, likewise are the arrays for the areas at the recovery scheme shown in Figure 12-61 while Figure 12-62 illustrates an exemplary roof-top space.

The key parameters of the system configuration and obtained results are summarised in Table 12-13.

Figure 12-60: Variant 5 – overview of the sub-systems at the WWTP

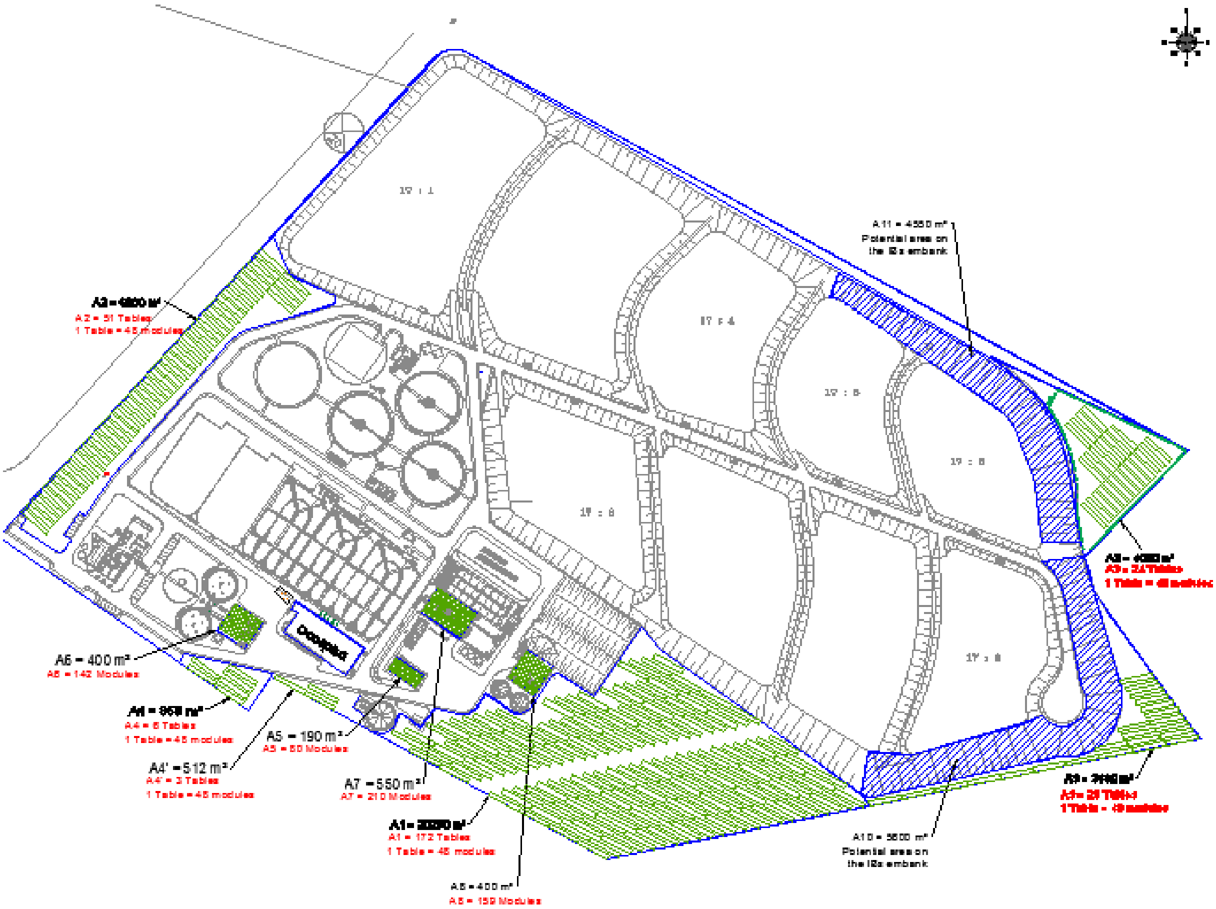


Figure 12-61: Variant 5 – overview of the sub-systems at the recovery scheme

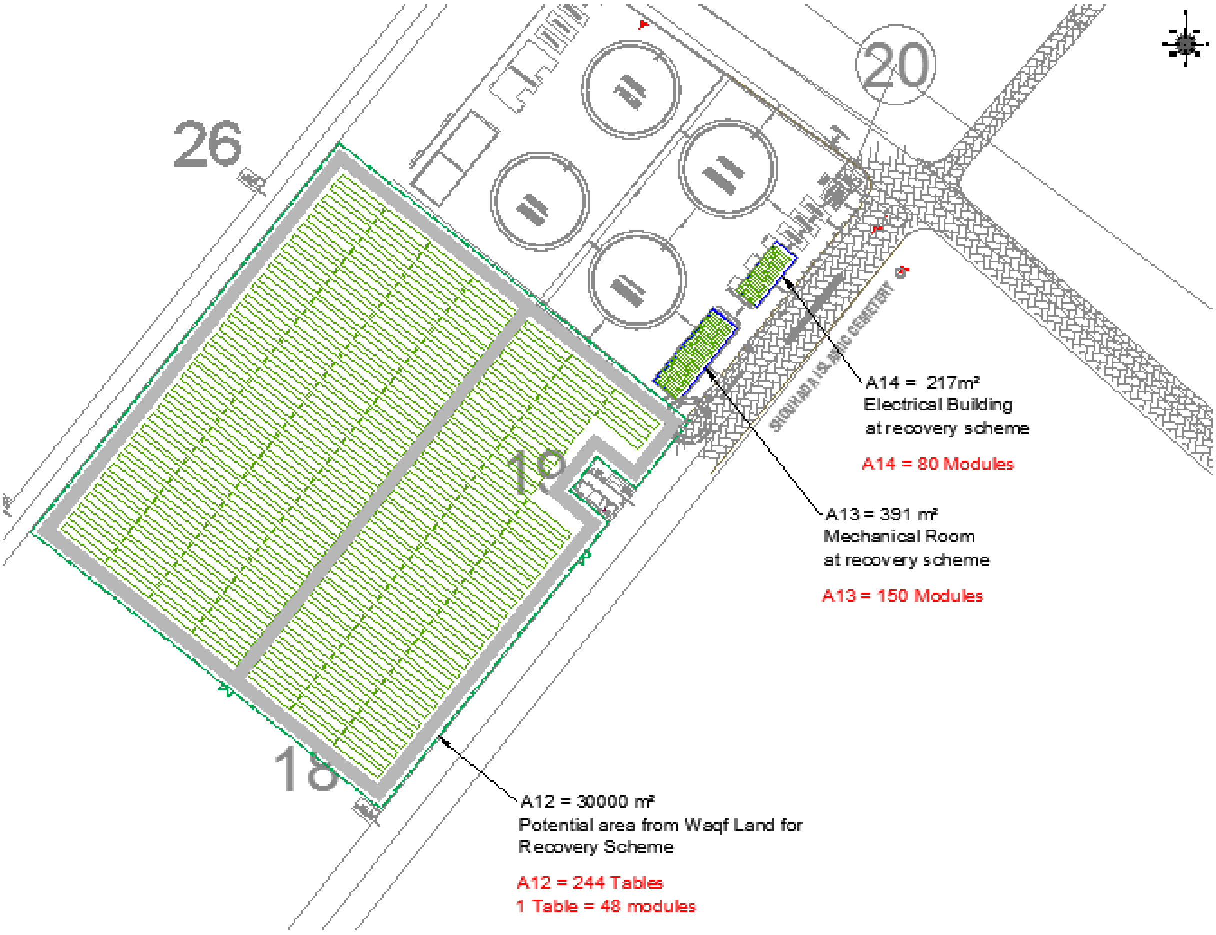


Figure 12-62: Variant 5 – example of a PV array on a roof-top area

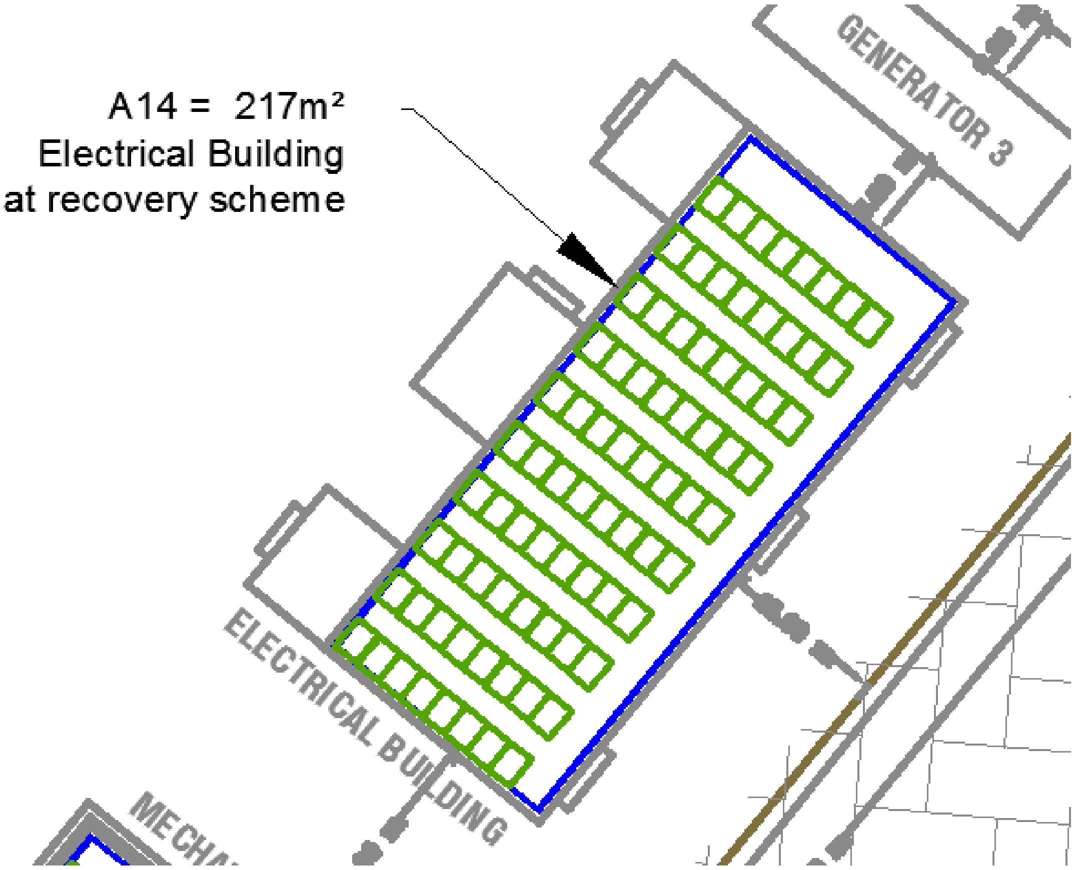


Table 12-13: Variant 5 – key system data

Parameter	Value	Unit
Terrain		
Total area	7.80	ha
Effective ground area for PV	5.49	ha
Remaining area	2.31	ha
Orientation		
Tilt angle	25	[°]
Azimuth	34.18	[°]
Mounting system type	Fixed	
Proposed foundation/fixation Free Field Rooftop	 Ramming posts Anchor	
System configuration		
Total number of modules	25925	
Total number of inverters	185 (5, 10, 12, 15,20, 25 kVA)	
DC/AC ratio	0.91	
Key system indicators		
Parameter	Value	Unit
Total capacity	4148	[kWp]

Parameter	Value	Unit
Specific results		
Capacity / Area Free Field Roof-top	 0.082 0.073	 [kWp/m²/]
Yield Factor Production / Capacity	1726.62	[kWh/kWp/year]
Energy production and power output		
Energy generation	19578.17	[kWh/day]
Peak power (annual minimum)	201.90	[kW/peak time]
Highest daily peak power (annual maximum (h))	4067.40	[kW/peak time]
Annual profile (25yrs average, 25 yrs.)		
Energy generation	7146.03	[MWh/year]
Performance Ratio	85.51	%
Contribution to power supply		
Capacity share on total		%
Daily energy production share		%
Annual energy production share		%
Preliminary cost estimate		
CAPEX – specific	1010.27	USD/kWp
CAPEX – total	4,190,601	USD
OPEX – specific	10.23	USD/kWp (annum)
OPEX – total	42,425	USD/annum

12.4 Long-Term Expected Energy Production

Table 12-14: AEP during project lifetime

Variant 2	Fixed Structures			
PoE	P50		P90	
Year (end of operational year)	Specific Yield [kWh/kWp]	Annual Net Energy Output [MWh/a]	Specific Yield [kWh/kWp]	Annual Net Energy Output [GWh/a]
0	1,790	9,147	1,625	8,981
1	1,755	8,964	1,593	8,802
2	1,744	8,909	1,584	8,749
3	1,733	8,854	1,575	8,695
4	1,722	8,799	1,565	8,642
5	1,712	8,744	1,555	8,588

Variant 2	Fixed Structures			
PoE	P50		P90	
Year (end of operational year)	Specific Yield [kWh/kWp]	Annual Net Energy Output [MWh/a]	Specific Yield [kWh/kWp]	Annual Net Energy Output [GWh/a]
6	1,701	8,689	1,546	8,534
7	1,690	8,634	1,536	8,480
8	1,679	8,580	1,526	8,426
9	1,669	8,525	1,516	8,373
10	1,658	8,470	1,507	8,319
11	1,647	8,415	1,497	8,265
12	1,636	8,360	1,487	8,211
13	1,626	8,305	1,477	8,157
14	1,615	8,250	1,468	8,103
15	1,604	8,195	1,458	8,049
16	1,593	8,141	1,448	7,995
17	1,583	8,086	1,438	7,941
18	1,572	8,031	1,429	7,888
19	1,561	7,976	1,419	7,834
20	1,550	7,921	1,409	7,780
Project Lifetime				
Average	1,653	8,442	1,502	8,292
Sum [GWh]		214,291		174,812

12.5 Economic and Financial Analysis

12.5.1 Economic Analysis without PV

%	Item	Unit		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	Grand Total
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
	Base Data																								
	Energy consumption NGEST	kWh		20,448,614	21,583,386	37,285,686	37,285,686	37,285,686	37,285,686	37,285,686	37,285,686	37,285,686	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	1,062,279,708
	Discount rate	%	7%																						
17%	**Biogas**																								
	Installed capacity	kWP		800	800	800	800	800	800	800	800	800	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	
	Generated energy	kWh		5,618,235	5,618,235	5,618,235	5,618,235	5,618,235	5,618,235	5,618,235	5,618,235	5,618,235	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	184,611,439
	Tax reduction																								
	CAPEX			(715,103)										(715,103)											
	OPEX																								
	Price per kWh	USD	0.09	491,596	491,596	491,596	491,596	491,596	491,596	491,596	491,596	491,596	977,428	977,428	977,428	977,428	977,428	977,428	977,428	977,428	977,428	977,428	977,428	977,428	16,153,501
	Maintenance	USD		3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	80,038
	Total CAPEX + OPEX			1,210,510	495,407	495,407	495,407	495,407	495,407	495,407	495,407	495,407	981,240	1,696,342	981,240	981,240	981,240	981,240	981,240	981,240	981,240	981,240	981,240	981,240	17,663,745
	Discounted generation	kWh		5,618,235	5,224,959	4,859,212	4,519,067	4,202,732	3,908,541	3,634,943	3,380,497	3,143,862	5,813,309	5,406,378	5,027,931	4,675,976	4,348,658	4,044,252	3,761,154	3,497,873	3,253,022	3,025,311	2,813,539	2,616,591	86,776,043
	Discounted costs	USD		1,210,510	460,728	428,477	398,484	370,590	344,649	320,523	298,087	277,221	510,648	821,000	441,659	410,743	381,991	355,252	330,384	307,257	285,749	265,747	247,145	229,844	8,696,690
	Present value of costs (PV)	USD	8,696,690																						
	Present value of energy (PV)	kWh	86,776,043																						
	Levelized costs of electricity (LCOE)	USD/kWh	0.10																						
54%	**Diesel**																								
	Annual diesel consumption	litre		2,022,896	2,178,282	4,264,247	4,264,247	4,264,247	4,264,247	4,264,247	4,264,247	4,264,247	7,050,280	7,050,280	7,050,280	7,050,280	7,050,280	7,050,280	7,050,280	7,050,280	7,050,280	7,050,280	7,050,280	7,050,280	
	Generated energy	kWh		9,858,000	10,615,000	20,780,000	20,780,000	20,780,000	20,780,000	20,780,000	20,780,000	20,780,000	34,357,000	34,357,000	34,357,000	34,357,000	34,357,000	34,357,000	34,357,000	34,357,000	34,357,000	34,357,000	34,357,000	34,357,000	578,217,000
	CAPEX			(1,037,823)		(349,248)							(843,355)												
	OPEX																								
	Maintenance	USD		11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	240,115
	Annual cost of diesel (cal. Ø2013-2015)	USD		1,374,514	1,480,095	2,897,462	2,897,462	2,897,462	2,897,462	2,897,462	2,897,462	2,897,462	4,790,511	4,790,511	4,790,511	4,790,511	4,790,511	4,790,511	4,790,511	4,790,511	4,790,511	4,790,511	4,790,511	4,790,511	80,622,976
	Total CAPEX + OPEX			2,423,771	1,491,529	3,258,145	2,908,896	2,908,896	2,908,896	2,908,896	2,908,896	2,908,896	5,645,300	4,801,945	4,801,945	4,801,945	4,801,945	4,801,945	4,801,945	4,801,945	4,801,945	4,801,945	4,801,945	4,801,945	83,093,518
	Discounted generation	kWh		9,858,000	9,871,950	17,972,622	16,714,538	15,544,521	14,456,404	13,444,456	12,503,344	11,628,110	17,879,764	16,628,180	15,464,208	14,381,713	13,374,993	12,438,744	11,568,032	10,758,269	10,005,190	9,304,827	8,653,489	8,047,745	270,499,099
	Discounted costs	USD		2,423,771	1,387,122	2,817,969	2,339,791	2,176,006	2,023,685	1,882,027	1,750,286	1,627,766	2,937,877	2,324,056	2,161,372	2,010,076	1,869,371	1,738,515	1,616,819	1,503,642	1,398,387	1,300,500	1,209,465	1,124,802	39,623,305
	Present value of costs (PV)	USD	39,623,305																						
	Present value of energy (PV)	kWh	270,499,099																						
	Levelized costs of electricity (LCOE)	USD/kWh	0.15																						
28%	**GEDCo**																								
	Generated energy	kWh		497,200	5,317,000	10,854,000	10,854,000	10,854,000	10,854,000	10,854,000	10,854,000	10,854,000	17,743,000	17,743,000	17,743,000	17,743,000	17,743,000	17,743,000	17,743,000	17,743,000	17,743,000	17,743,000	17,743,000	17,743,000	294,708,200
	OPEX																								
	Tariff GEDCo - NGEST	USD/kWh		0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	
	Cost p.a. of electr. Supplied by GEDCo	USD		62,410	667,406	1,362,427	1,362,427	1,362,427	1,362,427	1,362,427	1,362,427	1,362,427	2,227,155	2,227,155	2,227,155	2,227,155	2,227,155	2,227,155	2,227,155	2,227,155	2,227,155	2,227,155	2,227,155	2,227,155	36,992,661
	Total OPEX			62,410	667,406	1,362,427	1,362,427	1,362,427	1,362,427	1,362,427	1,362,427	1,362,427	2,227,155	2,227,155	2,227,155	2,227,155	2,227,155	2,227,155	2,227,155	2,227,155	2,227,155	2,227,155	2,227,155	2,227,155	36,992,661
	Discounted generation	kWh		497,200	4,944,810	9,387,625	8,730,491	8,119,357	7,551,002	7,022,431	6,530,861	6,073,701	9,233,654	8,587,298	7,986,187	7,427,154	6,907,253	6,423,746	5,974,083	5,555,898	5,166,985	4,805,296	4,468,925	4,156,100	135,550,056
	Discounted costs	USD		62,410	620,687	1,178,363	1,095,878	1,019,166	947,824	881,477	819,773	762,389	1,159,036	1,077,904	1,002,450	932,279	867,019	806,328	749,885	697,393	648,575	603,175	560,953	521,686	17,014,651
	Present value of costs (PV)	USD	17,014,651																						
	Present value of energy (PV)	kWh	135,550,056																						
	Levelized costs of electricity (LCOE)	USD/kWh	0.13																						
	LCOE total	USD/kWh	**0.13**																						

12.5.2 Economic Analysis with Chosen PV Option

%	Item	Unit		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	Grand Total
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
	Base Data																								
	Energy consumption NGEST	kWh		20,448,614	21,583,386	37,285,686	37,285,686	37,285,686	37,285,686	37,285,686	37,285,686	37,285,686	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	1,062,279,708
	Discount rate	%	7%																						
	Exclusion	%	18%																						
16%	PV chosen variant																								
	Installed capacity	kWP			5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	
	Generated energy	kWh			8,963,755	8,908,875	8,853,995	8,799,115	8,744,234	8,689,354	8,634,474	8,579,594	8,524,714	8,469,834	8,414,954	8,360,074	8,305,193	8,250,313	8,195,433	8,140,553	8,085,673	8,030,793	7,975,913	7,921,032	168,847,874
	CAPEX				(5,656,354)														(431,218)						(6,087,572)
	OPEX				48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	964,530
	Total CAPEX + OPEX				5,704,581	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	479,445	48,227	48,227	48,227	48,227	48,227	7,052,102
	Discounted generation	kWh			8,963,755	8,285,254	7,657,820	7,077,629	6,541,142	6,045,083	5,586,420	5,162,349	4,770,275	4,407,795	4,072,689	3,762,899	3,476,523	3,211,802	2,967,107	2,740,931	2,531,881	2,338,668	2,160,098	1,995,069	93,755,189
	Discounted costs	USD			5,704,581	44,851	41,711	38,791	36,076	33,551	31,202	29,018	26,987	25,098	23,341	21,707	20,187	18,774	173,580	16,238	15,101	14,044	13,061	12,147	6,340,045
	Present value of costs (PV)	USD	6,340,045																						
	Present value of energy (PV)	kWh	93,755,189																						
	Levelized costs of electricity (LCOE)	USD/kWh	0.068																						
17%	Biogas																								
	Installed capacity	kWP		800	800	800	800	800	800	800	800	800	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	
	Generated energy	kWh		5,618,235	5,618,235	5,618,235	5,618,235	5,618,235	5,618,235	5,618,235	5,618,235	5,618,235	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	184,611,439
	Tax reduction																								
	CAPEX			(715,103)										(715,103)											
	OPEX																								
	Price per kWh	USD	0.09	491,596	491,596	491,596	491,596	491,596	491,596	491,596	491,596	491,596	977,428	977,428	977,428	977,428	977,428	977,428	977,428	977,428	977,428	977,428	977,428	977,428	16,153,501
	Maintenance	USD		3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	80,038
	Total CAPEX + OPEX			1,210,510	495,407	495,407	495,407	495,407	495,407	495,407	495,407	495,407	981,240	1,696,342	981,240	981,240	981,240	981,240	981,240	981,240	981,240	981,240	981,240	981,240	17,663,745
	Discounted generation	kWh		5,618,235	5,224,959	4,859,212	4,519,067	4,202,732	3,908,541	3,634,943	3,380,497	3,143,862	5,813,309	5,406,378	5,027,931	4,675,976	4,348,658	4,044,252	3,761,154	3,497,873	3,253,022	3,025,311	2,813,539	2,616,591	86,776,043
	Discounted costs	USD		1,210,510	460,728	428,477	398,484	370,590	344,649	320,523	298,087	277,221	510,648	821,000	441,659	410,743	381,991	355,252	330,384	307,257	285,749	265,747	247,145	229,844	8,696,690
	Present value of costs (PV)	USD	8,696,690																						
	Present value of energy (PV)	kWh	86,776,043																						
	Levelized costs of electricity (LCOE)	USD/kWh	0.100																						
44%	Diesel																								
	Annual diesel consumption	litre		2,022,896	961,386	2,970,569	2,979,142	2,987,715	2,996,288	3,004,862	3,013,435	3,022,008	5,843,267	5,843,267	5,843,267	5,843,267	5,843,267	5,843,267	5,843,267	5,843,267	5,843,267	5,843,267	5,843,267	5,843,267	
	Generated energy	kWh		10,319,373	4,684,994	14,476,071	14,517,849	14,559,627	14,601,406	14,643,184	14,684,962	14,726,741	28,475,199	28,530,079	28,584,959	28,639,839	28,694,719	28,749,600	28,804,480	28,859,360	28,914,240	28,969,120	29,024,000	29,078,880	462,538,683
	CAPEX			(1,037,823)		(349,248)							(843,355)												
	OPEX																								
	Maintenance	USD		11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	240,115
	Annual cost of diesel (cal. Ø2013-2015)	USD		1,374,514	653,241	2,018,437	2,024,262	2,030,087	2,035,912	2,041,738	2,047,563	2,053,388	3,970,372	3,970,372	3,970,372	3,970,372	3,970,372	3,970,372	3,970,372	3,970,372	3,970,372	3,970,372	3,970,372	3,970,372	63,923,604
	Total CAPEX + OPEX			2,423,771	664,675	2,379,119	2,035,696	2,041,521	2,047,346	2,053,172	2,058,997	2,064,822	4,825,161	3,981,806	3,981,806	3,981,806	3,981,806	3,981,806	3,981,806	3,981,806	3,981,806	3,981,806	3,981,806	3,981,806	66,394,145
	Discounted generation	kWh		10,319,373	4,357,044	12,520,354	11,677,534	10,891,359	10,158,028	9,473,996	8,835,955	8,240,816	14,818,809	13,808,054	12,866,192	11,988,531	11,170,698	10,408,618	9,698,493	9,036,783	8,420,190	7,845,640	7,310,268	6,811,404	210,658,138
	Discounted costs	USD		2,423,771	618,148	2,057,700	1,637,426	1,527,164	1,424,315	1,328,382	1,238,900	1,155,437	2,511,067	1,927,124	1,792,225	1,666,769	1,550,095	1,441,589	1,340,677	1,246,830	1,159,552	1,078,383	1,002,896	932,694	31,061,145
	Present value of costs (PV)	USD	31,061,145																						
	Present value of energy (PV)	kWh	210,658,138																						
	Levelized costs of electricity (LCOE)	USD/kWh	0.147																						
23%	GEDCo																								
	Generated energy	kWh		4,511,006	2,283,471	8,249,574	8,262,676	8,275,778	8,288,879	8,301,981	8,315,083	8,328,185	15,100,136	15,100,136	15,100,136	15,100,136	15,100,136	15,100,136	15,100,136	15,100,136	15,100,136	15,100,136	15,100,136	15,100,136	246,018,268
	OPEX																								
	Tariff GEDCo - NGEST	USD/kWh		0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	
	Cost p.a. of electr. Supplied by GEDCo	USD		566,235	286,628	1,035,511	1,037,156	1,038,801	1,040,445	1,042,090	1,043,734	1,045,379	1,895,415	1,895,415	1,895,415	1,895,415	1,895,415	1,895,415	1,895,415	1,895,415	1,895,415	1,895,415	1,895,415	1,895,415	30,880,954
	Total OPEX			566,235	286,628	1,035,511	1,037,156	1,038,801	1,040,445	1,042,090	1,043,734	1,045,379	1,895,415	1,895,415	1,895,415	1,895,415	1,895,415	1,895,415	1,895,415	1,895,415	1,895,415	1,895,415	1,895,415	1,895,415	30,880,954
	Discounted generation	kWh		4,511,006	2,123,628	7,135,056	6,646,141	6,190,712	5,766,477	5,371,300	5,003,193	4,660,301	7,858,278	7,308,199	6,796,625	6,320,861	5,878,401	5,466,913	5,084,229	4,728,333	4,397,350	4,089,535	3,803,268	3,537,039	112,676,844
	Discounted costs	USD		566,235	266,564	895,614	834,244	777,077	723,826	674,222	628,016	584,975	986,395	917,347	853,133	793,414	737,875	686,223	638,188	593,515	551,969	513,331	477,398	443,980	14,143,537
	Present value of costs (PV)	USD	14,143,537																						
	Present value of energy (PV)	kWh	112,676,844																						
	Levelized costs of electricity (LCOE)	USD/kWh	0.126																						
	LCOE total	USD/kWh	0.12																						

12.5.3 Economic Analysis with Different PV Options

Item	Unit		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	Grand Total
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
Base Data																								
Energy consumption NGEST	kWh		20,448,614	21,583,386	37,285,686	37,285,686	37,285,686	37,285,686	37,285,686	37,285,686	37,285,686	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	1,062,279,708
Discount rate	%	7%																						
PV Variant 1																								
Installed capacity	kWp			4,821	4,821	4,821	4,821	4,821	4,821	4,821	4,821	4,821	4,821	4,821	4,821	4,821	4,821	4,821	4,821	4,821	4,821	4,821	4,821	96,429
Generated energy	kWh			8,021,367	8,021,367	8,021,367	8,021,367	8,021,367	8,021,367	8,021,367	8,021,367	8,021,367	8,021,367	8,021,367	8,021,367	8,021,367	8,021,367	8,021,367	8,021,367	8,021,367	8,021,367	8,021,367	8,021,367	160,427,342
CAPEX	USD			-4,830,002																				-4,830,002
OPEX	USD			46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	932,620
Total CAPEX + OPEX	USD			4,876,633	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	46,631	5,762,622
Discounted generation	kWh			8,021,367	7,459,871	6,937,680	6,452,043	6,000,400	5,580,372	5,189,746	4,826,464	4,488,611	4,174,408	3,882,200	3,610,446	3,357,715	3,122,675	2,904,087	2,700,801	2,511,745	2,335,923	2,172,408	2,020,340	87,749,302
Discounted costs	USD			4,876,633	43,367	40,331	37,508	34,882	32,441	30,170	28,058	26,094	24,267	22,569	20,989	19,520	18,153	16,882	15,701	14,602	13,580	12,629	11,745	5,340,119
Present Value of Costs (PV)	USD	5,340,119																						
Present Value of Energy (PV)	kWh	87,749,302																						
Levelized Costs of Electricity (LCOE)	USD/kWh	0.06																						
PV Variant 2																								
Installed capacity	kWp			5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	102,175
Generated energy	kWh			8,963,755	8,908,875	8,853,995	8,799,115	8,744,234	8,689,354	8,634,474	8,579,594	8,524,714	8,469,834	8,414,954	8,360,074	8,305,193	8,250,313	8,195,433	8,140,553	8,085,673	8,030,793	7,975,913	7,921,032	168,847,874
CAPEX	USD			(5,656,354)														(431,218)						(6,087,572)
OPEX	USD			48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	964,530
Total CAPEX + OPEX	USD			5,704,581	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	479,444	48,227	48,227	48,227	48,227	48,227	7,052,102
Discounted generation	kWh			8,963,755	8,285,254	7,657,820	7,077,629	6,541,142	6,045,083	5,586,420	5,162,349	4,770,275	4,407,795	4,072,689	3,762,899	3,476,523	3,211,802	2,967,107	2,740,931	2,531,881	2,338,668	2,160,098	1,995,069	93,755,189
Discounted costs	USD			5,704,581	44,851	41,711	38,791	36,076	33,551	31,202	29,018	26,987	25,098	23,341	21,707	20,187	18,774	173,580	16,238	15,101	14,044	13,061	12,147	6,340,045
Present Value of Costs (PV)	USD	6,340,045																						
Present Value of Energy(PV)	kWh	93,755,189																						
Levelized Costs of Electricity (LCOE)	USD	0.07																						
PV Variant 3																								
Installed capacity	kWp			2,059	2,059	2,059	2,059	2,059	2,059	2,059	2,059	2,059	2,059	2,059	2,059	2,059	2,059	2,059	2,059	2,059	2,059	2,059	2,059	41,180
Generated energy (16 MWh p.d.)	kWh			3,665,290	3,665,290	3,665,290	3,665,290	3,665,290	3,665,290	3,665,290	3,665,290	3,665,290	3,665,290	3,665,290	3,665,290	3,665,290	3,665,290	3,665,290	3,665,290	3,665,290	3,665,290	3,665,290	3,665,290	73,305,800
CAPEX	USD			(2,332,830)																				-2,332,830
OPEX	USD			46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	928,700
Total CAPEX + OPEX	USD			2,379,265	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	46,435	3,261,530
Discounted generation	kWh			3,665,290	3,408,720	3,170,109	2,948,202	2,741,828	2,549,900	2,371,407	2,205,408	2,051,030	1,907,458	1,773,936	1,649,760	1,534,277	1,426,877	1,326,996	1,234,106	1,147,719	1,067,379	992,662	923,176	40,096,237
Discounted costs	USD			2,379,265	43,185	40,162	37,350	34,736	32,304	30,043	27,940	25,984	24,165	22,474	20,901	19,438	18,077	16,812	15,635	14,540	13,522	12,576	11,696	2,840,803
Present Value of Costs (PV)	USD	2,840,803																						
Present Value of Energy (PV)	kWh	40,096,237																						
Levelized Costs of Electricity (LCOE)	USD	0.07																						
PV Variant 4																								
Installed capacity	kWp			1,868	1,868	1,868	1,868	1,868	1,868	1,868	1,868	1,868	1,868	1,868	1,868	1,868	1,868	1,868	1,868	1,868	1,868	1,868	1,868	37,360
Generated energy	kWh			3,440,195	3,440,195	3,440,195	3,440,195	3,440,195	3,440,195	3,440,195	3,440,195	3,440,195	3,440,195	3,440,195	3,440,195	3,440,195	3,440,195	3,440,195	3,440,195	3,440,195	3,440,195	3,440,195	3,440,195	68,803,900
CAPEX	USD			(2,842,506)																				-2,842,506
OPEX	USD			19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	382,180
Total CAPEX + OPEX	USD			2,861,615	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	19,109	3,224,686
Discounted generation	kWh			3,440,195	3,199,381	2,975,425	2,767,145	2,573,445	2,393,304	2,225,772	2,069,968	1,925,071	1,790,316	1,664,994	1,548,444	1,440,053	1,339,249	1,245,502	1,158,317	1,077,234	1,001,828	931,700	866,481	37,633,823
Discounted costs	USD			2861615	17771.37	16527.3741	15370.45791	14294.52586	13293.90905	12363.3354	11497.9019	10693.0488	9944.53538	9248.41791	8601.02865	7998.95665	7439.02968	6918.29761	6434.01677	5983.6356	5564.78111	5175.24643	4812.97918	3,051,548
Present Value of Costs (PV)	USD	3,051,548																						
Present Value of Energy (PV)	kWh	37,633,823																						
Levelized Costs of Electricity (LCOE)	USD	0.08																						
PV Variant 5																								
Installed capacity				4,148	4,148	4,148	4,148	4,148	4,148	4,148	4,148	4,148	4,148	4,148	4,148	4,148	4,148	4,148	4,148	4,148	4,148	4,148	4,148	82,960
Generated energy	kWh			3,271,270	3,271,270	3,271,270	3,271,270	3,271,270	3,271,270	3,271,270	3,271,270	3,271,270	3,271,270	3,271,270	3,271,270	3,271,270	3,271,270	3,271,270	3,271,270	3,271,270	3,271,270	3,271,270	3,271,270	65,425,400
CAPEX				(4,190,601)																				
OPEX				42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	848,500
Total CAPEX + OPEX	USD			4,233,026	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	42,425	5,039,101
Discounted generation	kWh			3,271,270	3,042,281	2,829,321	2,631,269	2,447,080	2,275,784	2,116,480	1,968,326	1,830,543	1,702,405	1,583,237	1,472,410	1,369,342	1,273,488	1,184,343	1,101,439	1,024,339	952,635	885,951	823,934	35,785,877
Discounted costs	USD			4,233,026	36,693	34,125	31,736	29,515	27,449	25,527	23,740	22,078	20,533	19,096	17,759	16,516	15,360	14,285	13,285	12,355	11,490	10,686	9,938	4,625,189
Present Value of Costs (PV)	USD	4,625,189																						
Present Value of Energy (PV)	kWh	35,785,877																						
Levelized Costs of Electricity (LCOE)	USD	0.13																						

12.5.4 Financial Analysis without PV

%	Item	Unit		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	Grand Total
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
	Base Data																								
	Energy consumption NGEST	kWh		20,448,614	21,583,386	37,285,686	37,285,686	37,285,686	37,285,686	37,285,686	37,285,686	37,285,686	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	1,062,279,708
	Discount rate	%	7%																						
17%	**Biogas**																								
	Installed capacity	kWP		800	800	800	800	800	800	800	800	800	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	
	Generated energy	kWh		5,618,235	5,618,235	5,618,235	5,618,235	5,618,235	5,618,235	5,618,235	5,618,235	5,618,235	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	184,611,439
	CAPEX			-872,077										-872,077											-1,744,153
	OPEX																								
	Price per kWh	USD	0.07	393,276	393,276	393,276	393,276	393,276	393,276	393,276	393,276	393,276	781,943	781,943	781,943	781,943	781,943	781,943	781,943	781,943	781,943	781,943	781,943	781,943	12,922,801
	Maintenance			3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	80,038
	Total OPEX			397,088	397,088	397,088	397,088	397,088	397,088	397,088	397,088	397,088	785,754	785,754	785,754	785,754	785,754	785,754	785,754	785,754	785,754	785,754	785,754	785,754	13,002,839
	Total CAPEX + OPEX			1,269,164	397,088	397,088	397,088	397,088	397,088	397,088	397,088	397,088	785,754	1,657,831	785,754	785,754	785,754	785,754	785,754	785,754	785,754	785,754	785,754	785,754	14,746,992
	Discounted generation	kWh		5,618,235	5,224,959	4,859,212	4,519,067	4,202,732	3,908,541	3,634,943	3,380,497	3,143,862	5,813,309	5,406,378	5,027,931	4,675,976	4,348,658	4,044,252	3,761,154	3,497,873	3,253,022	3,025,311	2,813,539	2,616,591	86,776,043
	Discounted costs	USD		1,269,164	369,292	343,441	319,400	297,042	276,249	256,912	238,928	222,203	408,915	802,361	353,671	328,914	305,890	284,477	264,564	246,045	228,821	212,804	197,908	184,054	7,411,056
	Present value of costs (PV)	USD	7,411,056																						
	Present value of energy (PV)	kWh	86,776,043																						
	Levelized costs of electricity (LCOE)	USD/kWh	0.09																						
54%	**Diesel**																								
	Annual diesel consumption	litre		2,022,896	2,178,282	4,264,247	4,264,247	4,264,247	4,264,247	4,264,247	4,264,247	4,264,247	7,050,280	7,050,280	7,050,280	7,050,280	7,050,280	7,050,280	7,050,280	7,050,280	7,050,280	7,050,280	7,050,280	7,050,280	
	Generated energy	kWh		9,858,000	10,615,000	20,780,000	20,780,000	20,780,000	20,780,000	20,780,000	20,780,000	20,780,000	34,357,000	34,357,000	34,357,000	34,357,000	34,357,000	34,357,000	34,357,000	34,357,000	34,357,000	34,357,000	34,357,000	34,357,000	578,217,000
	CAPEX			-1,265,638		-425,913							-1,028,482												-2,720,032
	OPEX																								
	Maintenance	USD		11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	240,115
	Annual cost of diesel (cal. Ø2013-2015)	USD		3,054,475	3,289,100	6,438,805	6,438,805	6,438,805	6,438,805	6,438,805	6,438,805	6,438,805	10,645,580	10,645,580	10,645,580	10,645,580	10,645,580	10,645,580	10,645,580	10,645,580	10,645,580	10,645,580	10,645,580	10,645,580	179,162,169
	Total OPEX			3,065,909	3,300,534	6,450,239	6,450,239	6,450,239	6,450,239	6,450,239	6,450,239	6,450,239	10,657,014	10,657,014	10,657,014	10,657,014	10,657,014	10,657,014	10,657,014	10,657,014	10,657,014	10,657,014	10,657,014	10,657,014	179,402,284
	Total CAPEX + OPEX			4,331,546	3,300,534	6,876,152	6,450,239	6,450,239	6,450,239	6,626,861	6,450,239	6,450,239	11,685,496	10,657,014	10,657,014	10,657,014	10,657,014	10,657,014	10,657,014	10,657,014	10,657,014	10,657,014	10,657,014	10,657,014	182,298,938
	Discounted generation	kWh		9,858,000	9,871,950	17,972,622	16,714,538	15,544,521	14,456,404	13,444,456	12,503,344	11,628,110	17,879,764	16,628,180	15,464,208	14,381,713	13,374,993	12,438,744	11,568,032	10,758,269	10,005,190	9,304,827	8,653,489	8,047,745	270,499,099
	Discounted costs	USD		4,331,546	3,069,496	5,947,184	5,188,295	4,825,115	4,487,357	4,287,514	3,881,115	3,609,437	6,081,262	5,157,806	4,796,760	4,460,986	4,148,717	3,858,307	3,588,226	3,337,050	3,103,456	2,886,214	2,684,179	2,496,287	86,226,310
	Present value of costs (PV)	USD	86,226,310																						
	Present value of energy (PV)	kWh	270,499,099																						
	Levelized costs of electricity (LCOE)	USD/kWh	0.32																						
28%	**GEDCo**																								
	Generated energy	kWh		4,972,000	5,317,000	10,854,000	10,854,000	10,854,000	10,854,000	10,854,000	10,854,000	10,854,000	17,743,000	17,743,000	17,743,000	17,743,000	17,743,000	17,743,000	17,743,000	17,743,000	17,743,000	17,743,000	17,743,000	17,743,000	299,183,000
	OPEX																								
	Tariff GEDCo - NGEST	USD/kWh		0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	
	Cost p.a. of electr. Supplied by GEDCo	USD		745,800	797,550	1,628,100	1,628,100	1,628,100	1,628,100	1,628,100	1,628,100	1,628,100	2,661,450	2,661,450	2,661,450	2,661,450	2,661,450	2,661,450	2,661,450	2,661,450	2,661,450	2,661,450	2,661,450	2,661,450	44,877,450
	Total OPEX			745,800	797,550	1,628,100	1,628,100	1,628,100	1,628,100	1,628,100	1,628,100	1,628,100	2,661,450	2,661,450	2,661,450	2,661,450	2,661,450	2,661,450	2,661,450	2,661,450	2,661,450	2,661,450	2,661,450	2,661,450	44,877,450
	Discounted generation	kWh		4,972,000	4,944,810	9,387,625	8,730,491	8,119,357	7,551,002	7,022,431	6,530,861	6,073,701	9,233,654	8,587,298	7,986,187	7,427,154	6,907,253	6,423,746	5,974,083	5,555,898	5,166,985	4,805,296	4,468,925	4,156,100	140,024,856
	Discounted costs	USD		745,800	741,722	1,408,144	1,309,574	1,217,903	1,132,650	1,053,365	979,629	911,055	1,385,048	1,288,095	1,197,928	1,114,073	1,036,088	963,562	896,113	833,385	775,048	720,794	670,339	623,415	21,003,728
	Present value of costs (PV)	USD	21,003,728																						
	Present value of energy (PV)	kWh	140,024,856																						
	Levelized costs of electricity (LCOE)	USD/kWh	0.15																						
	LCOE total	USD/kWh	0.230																						

12.5.5 Financial Analysis with PV

%	Item	Unit		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	Grand Total
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
	Base Data																								
	Energy consumption NGEST	kWh		20,448,614	21,583,386	37,285,686	37,285,686	37,285,686	37,285,686	37,285,686	37,285,686	37,285,686	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	63,270,659	1,062,279,708
	Discount rate	%	7%																						
16%	**PV chosen variant**																								
	Installed capacity	kWP			5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	5,109	
	Generated energy	kWh			8,963,755	8,908,875	8,853,995	8,799,115	8,744,234	8,689,354	8,634,474	8,579,594	8,524,714	8,469,834	8,414,954	8,360,074	8,305,193	8,250,313	8,195,433	8,140,553	8,085,673	8,030,793	7,975,913	7,921,032	168,847,874
	CAPEX				(6,897,993)														(525,875)						(7,423,868)
	OPEX				48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	964,530
	Total CAPEX + OPEX				6,946,219	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	48,227	574,102	48,227	48,227	48,227	48,227	48,227	8,388,398
	Discounted generation	kWh			8,963,755	8,285,254	7,657,820	7,077,629	6,541,142	6,045,083	5,586,420	5,162,349	4,770,275	4,407,795	4,072,689	3,762,899	3,476,523	3,211,802	2,967,107	2,740,931	2,531,881	2,338,668	2,160,098	1,995,069	93,755,189
	Discounted costs	USD			6,946,219	44,851	41,711	38,791	36,076	33,551	31,202	29,018	26,987	25,098	23,341	21,707	20,187	18,774	207,850	16,238	15,101	14,044	13,061	12,147	7,615,954
	Present value of costs (PV)	USD	7,615,954																						
	Present value of energy (PV)	kWh	93,755,189																						
	Levelized costs of electricity (LCOE)	USD/kWh	0.08																						
17%	**Biogas**																								
	Installed capacity	kWP		800	800	800	800	800	800	800	800	800	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	
	Generated energy	kWh		5,618,235	5,618,235	5,618,235	5,618,235	5,618,235	5,618,235	5,618,235	5,618,235	5,618,235	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	11,170,610	184,611,439
	CAPEX			(872,077)										(872,077)											(1,744,153)
	OPEX																								
	Price per kWh	USD	0.07	393,276	393,276	393,276	393,276	393,276	393,276	393,276	393,276	393,276	781,943	781,943	781,943	781,943	781,943	781,943	781,943	781,943	781,943	781,943	781,943	781,943	12,922,801
	Maintenance	USD		3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	3,811	80,038
	Total OPEX	USD		397,088	397,088	397,088	397,088	397,088	397,088	397,088	397,088	397,088	785,754	785,754	785,754	785,754	785,754	785,754	785,754	785,754	785,754	785,754	785,754	785,754	13,002,839
	Total CAPEX + OPEX			1,269,164	397,088	397,088	397,088	397,088	397,088	397,088	397,088	397,088	785,754	1,657,831	785,754	785,754	785,754	785,754	785,754	785,754	785,754	785,754	785,754	785,754	14,746,992
	Discounted generation	kWh		5,618,235	5,224,959	4,859,212	4,519,067	4,202,732	3,908,541	3,634,943	3,380,497	3,143,862	5,813,309	5,406,378	5,027,931	4,675,976	4,348,658	4,044,252	3,761,154	3,497,873	3,253,022	3,025,311	2,813,539	2,616,591	86,776,043
	Discounted costs	USD		1,269,164	369,292	343,441	319,400	297,042	276,249	256,912	238,928	222,203	408,915	802,361	353,671	328,914	305,890	284,477	264,564	246,045	228,821	212,804	197,908	184,054	7,411,056
	Present value of costs (PV)	USD	7,411,056																						
	Present value of energy (PV)	kWh	86,776,043																						
	Levelized costs of electricity (LCOE)	USD/kWh	0.09																						
44%	**Diesel**																								
	Annual diesel consumption	litre		2,022,896	961,386	2,970,569	2,979,142	2,987,715	2,996,288	3,004,862	3,013,435	3,022,008	5,843,267	5,843,267	5,843,267	5,843,267	5,843,267	5,843,267	5,843,267	5,843,267	5,843,267	5,843,267	5,843,267	5,843,267	
	Generated energy	kWh		10,319,373	4,684,994	14,476,071	14,517,849	14,559,627	14,601,406	14,643,184	14,684,962	14,726,741	28,475,199	28,530,079	28,584,959	28,639,839	28,694,719	28,749,600	28,804,480	28,859,360	28,914,240	28,969,120	29,024,000	29,078,880	462,538,683
	CAPEX			(1,265,638)		(425,913)							(1,028,482)												(2,720,032)
	OPEX																								
	Maintenance	USD		11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	11,434	240,115
	Annual cost of diesel (cal. Ø2013-2015)	USD		3,054,475	1,451,647	4,485,415	4,498,360	4,511,305	4,524,250	4,537,195	4,550,140	4,563,085	8,823,049	8,823,049	8,823,049	8,823,049	8,823,049	8,823,049	8,823,049	8,823,049	8,823,049	8,823,049	8,823,049	8,823,049	142,052,452
	Total OPEX			3,065,909	1,463,081	4,496,849	4,509,794	4,522,739	4,535,684	4,548,629	4,561,574	4,574,519	8,834,483	8,834,483	8,834,483	8,834,483	8,834,483	8,834,483	8,834,483	8,834,483	8,834,483	8,834,483	8,834,483	8,834,483	142,292,567
	Total CAPEX + OPEX			4,331,546	1,463,081	4,922,761	4,509,794	4,522,739	4,535,684	4,548,629	4,561,574	4,574,519	9,862,965	8,834,483	8,834,483	8,834,483	8,834,483	8,834,483	8,834,483	8,834,483	8,834,483	8,834,483	8,834,483	8,834,483	145,012,600
	Discounted generation	kWh		10,319,373	4,357,044	12,520,354	11,677,534	10,891,359	10,158,028	9,473,996	8,835,955	8,240,816	14,818,809	13,808,054	12,866,192	11,988,531	11,170,698	10,408,618	9,698,493	9,036,783	8,420,190	7,845,640	7,310,268	6,811,404	210,658,138
	Discounted costs	USD		4,331,546	1,360,665	4,257,696	3,627,484	3,383,244	3,155,422	2,942,918	2,744,703	2,559,818	5,132,796	4,275,733	3,976,432	3,698,082	3,439,216	3,198,471	2,974,578	2,766,357	2,572,712	2,392,623	2,225,139	2,069,379	67,085,016
	Present value of costs (PV)	USD	67,085,016																						
	Present value of energy (PV)	kWh	210,658,138																						
	Levelized costs of electricity (LCOE)	USD/kWh	0.32																						
23%	**GEDCo**																								
	Generated energy	kWh		4,511,006	2,283,471	8,249,574	8,262,676	8,275,778	8,288,879	8,301,981	8,315,083	8,328,185	15,100,136	15,100,136	15,100,136	15,100,136	15,100,136	15,100,136	15,100,136	15,100,136	15,100,136	15,100,136	15,100,136	15,100,136	246,018,268
	OPEX																								
	Tariff GEDCo - NGEST	USD/kWh		0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	
	Cost p.a. of electr. Supplied by GEDCo	USD		676,651	342,521	1,237,436	1,239,401	1,241,367	1,243,332	1,245,297	1,247,262	1,249,228	2,265,020	2,265,020	2,265,020	2,265,020	2,265,020	2,265,020	2,265,020	2,265,020	2,265,020	2,265,020	2,265,020	2,265,020	36,902,740
	Total OPEX			676,651	342,521	1,237,436	1,239,401	1,241,367	1,243,332	1,245,297	1,247,262	1,249,228	2,265,020	2,265,020	2,265,020	2,265,020	2,265,020	2,265,020	2,265,020	2,265,020	2,265,020	2,265,020	2,265,020	2,265,020	36,902,740
	Discounted generation	kWh		4,511,006	2,123,628	7,135,056	6,646,141	6,190,712	5,766,477	5,371,300	5,003,193	4,660,301	7,858,278	7,308,199	6,796,625	6,320,861	5,878,401	5,466,913	5,084,229	4,728,333	4,397,350	4,089,535	3,803,268	3,537,039	112,676,844
	Discounted costs	USD		676,651	318,544	1,070,258	996,921	928,607	864,972	805,695	750,479	699,045	1,178,742	1,096,230	1,019,494	948,129	881,760	820,037	762,634	709,250	659,602	613,430	570,490	530,556	16,901,527
	Present value of costs (PV)	USD	16,901,527																						
	Present value of energy (PV)	kWh	112,676,844																						
	Levelized costs of electricity (LCOE)	USD/kWh	0.15																						
	LCOE total	USD/kWh	0.199																						

12.5.6 Financial Analysis only GEDCo (without PV)

Financial Analysis P50 - without PV only GEDCo

%	Item	Unit		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	Grand Total
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
	Base Data																								
	Energy consumption NGEST	kWh		20.448.614	21.583.386	37.285.686	37.285.686	37.285.686	37.285.686	37.285.686	37.285.686	37.285.686	63.270.659	63.270.659	63.270.659	63.270.659	63.270.659	63.270.659	63.270.659	63.270.659	63.270.659	63.270.659	63.270.659	63.270.659	1.062.279.708
	Discount rate	%	7%																						
17%	**Biogas**																								
	Installed capacity	kWP		800	800	800	800	800	800	800	800	800	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	
	Generated energy	kWh		5.618.235	5.618.235	5.618.235	5.618.235	5.618.235	5.618.235	5.618.235	5.618.235	5.618.235	11.170.610	11.170.610	11.170.610	11.170.610	11.170.610	11.170.610	11.170.610	11.170.610	11.170.610	11.170.610	11.170.610	11.170.610	184.611.439
	CAPEX			-872.077										-872.077											-1.744.153
	OPEX																								
	Price per kWh	USD	0,07	393.276	393.276	393.276	393.276	393.276	393.276	393.276	393.276	393.276	781.943	781.943	781.943	781.943	781.943	781.943	781.943	781.943	781.943	781.943	781.943	781.943	12.922.801
	Maintenance			3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	80.038
	Total OPEX			397.088	397.088	397.088	397.088	397.088	397.088	397.088	397.088	397.088	785.754	785.754	785.754	785.754	785.754	785.754	785.754	785.754	785.754	785.754	785.754	785.754	13.002.839
	Total CAPEX + OPEX			1.269.164	397.088	397.088	397.088	397.088	397.088	397.088	397.088	397.088	785.754	1.657.831	785.754	785.754	785.754	785.754	785.754	785.754	785.754	785.754	785.754	785.754	14.746.992
	Discounted generation	kWh		5.618.235	5.224.959	4.859.212	4.519.067	4.202.732	3.908.541	3.634.943	3.380.497	3.143.862	5.813.309	5.406.378	5.027.931	4.675.976	4.348.658	4.044.252	3.761.154	3.497.873	3.253.022	3.025.311	2.813.539	2.616.591	86.776.043
	Discounted costs	USD		1.269.164	369.292	343.441	319.400	297.042	276.249	256.912	238.928	222.203	408.915	802.361	353.671	328.914	305.890	284.477	264.564	246.045	228.821	212.804	197.908	184.054	7.411.056
	Present value of costs (PV)	USD	7.411.056																						
	Present value of energy (PV)	kWh	86.776.043																						
	Levelized costs of electricity (LCOE)	USD/kWh	0,09																						
0%	**Diesel**																								
83%	**GEDCo**																								
	Generated energy	kWh		14.830.378	15.965.150	31.667.450	31.667.450	31.667.450	31.667.450	31.667.450	31.667.450	31.667.450	52.100.049	52.100.049	52.100.049	52.100.049	52.100.049	52.100.049	52.100.049	52.100.049	52.100.049	52.100.049	52.100.049	52.100.049	877.668.269
	OPEX																								
	Tariff GEDCo - NGEST	USD/kWh		0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	
	Cost p.a. of electr. Supplied by GEDCo	USD		2.224.557	2.394.773	4.750.118	4.750.118	4.750.118	4.750.118	4.750.118	4.750.118	4.750.118	7.815.007	7.815.007	7.815.007	7.815.007	7.815.007	7.815.007	7.815.007	7.815.007	7.815.007	7.815.007	7.815.007	7.815.007	131.650.240
	Total OPEX			2.224.557	2.394.773	4.750.118	4.750.118	4.750.118	4.750.118	4.750.118	4.750.118	4.750.118	7.815.007	7.815.007	7.815.007	7.815.007	7.815.007	7.815.007	7.815.007	7.815.007	7.815.007	7.815.007	7.815.007	7.815.007	131.650.240
	Discounted generation	kWh		14.830.378	14.847.590	27.389.178	25.471.935	23.688.900	22.030.677	20.488.529	19.054.332	17.720.529	27.113.443	25.215.502	23.450.417	21.808.888	20.282.266	18.862.507	17.542.131	16.314.182	15.172.190	14.110.136	13.122.427	12.203.857	410.719.992
	Discounted costs	USD		2.224.557	2.227.138	4.108.377	3.820.790	3.553.335	3.304.601	3.073.279	2.858.150	2.658.079	4.067.016	3.782.325	3.517.563	3.271.333	3.042.340	2.829.376	2.631.320	2.447.127	2.275.828	2.116.520	1.968.364	1.830.579	61.607.999
	Present value of costs (PV)	USD	61.607.999																						
	Present value of energy (PV)	kWh	410.719.992																						
	Levelized costs of electricity (LCOE)	USD/kWh	0,15																						
	LCOE total	USD/kWh	0,139																						

12.5.7 Financial Analysis with GEDCo + PV

Financial Analysis P50 - GEDCo +PV

%	Item	Unit		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	Grand Total
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
	Base Data																								
	Energy consumption NGEST	kWh		20.448.614	21.583.386	37.285.686	37.285.686	37.285.686	37.285.686	37.285.686	37.285.686	37.285.686	63.270.659	63.270.659	63.270.659	63.270.659	63.270.659	63.270.659	63.270.659	63.270.659	63.270.659	63.270.659	63.270.659	63.270.659	1.062.279.708
	Discount rate	%	7%																						
16%	**PV chosen variant**																								
	Installed capacity	kWP			5.109	5.109	5.109	5.109	5.109	5.109	5.109	5.109	5.109	5.109	5.109	5.109	5.109	5.109	5.109	5.109	5.109	5.109	5.109	5.109	
	Generated energy	kWh			8.963.755	8.908.875	8.853.995	8.799.115	8.744.234	8.689.354	8.634.474	8.579.594	8.524.714	8.469.834	8.414.954	8.360.074	8.305.193	8.250.313	8.195.433	8.140.553	8.085.673	8.030.793	7.975.913	7.921.032	168.847.874
	CAPEX				-6.897.993														-525.875						-7.423.868
	OPEX				48.227	48.227	48.227	48.227	48.227	48.227	48.227	48.227	48.227	48.227	48.227	48.227	48.227	48.227	48.227	48.227	48.227	48.227	48.227	48.227	964.530
	Total CAPEX + OPEX				6.946.219	48.227	48.227	48.227	48.227	48.227	48.227	48.227	48.227	48.227	48.227	48.227	48.227	48.227	574.102	48.227	48.227	48.227	48.227	48.227	8.388.398
	Discounted generation	kWh			8.963.755	8.285.254	7.657.820	7.077.629	6.541.142	6.045.083	5.586.420	5.162.349	4.770.275	4.407.795	4.072.689	3.762.899	3.476.523	3.211.802	2.967.107	2.740.931	2.531.881	2.338.668	2.160.098	1.995.069	93.755.189
	Discounted costs	USD			6.946.219	44.851	41.711	38.791	36.076	33.551	31.202	29.018	26.987	25.098	23.341	21.707	20.187	18.774	207.850	16.238	15.101	14.044	13.061	12.147	7.615.954
	Present value of costs (PV)	USD	7.615.954																						
	Present value of energy (PV)	kWh	93.755.189																						
	Levelized costs of electricity (LCOE)	USD/kWh	0,08																						
17%	**Biogas**																								
	Installed capacity	kWP		800	800	800	800	800	800	800	800	800	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	
	Generated energy	kWh		5.618.235	5.618.235	5.618.235	5.618.235	5.618.235	5.618.235	5.618.235	5.618.235	5.618.235	11.170.610	11.170.610	11.170.610	11.170.610	11.170.610	11.170.610	11.170.610	11.170.610	11.170.610	11.170.610	11.170.610	11.170.610	184.611.439
	CAPEX			-872.077										-872.077											-1.744.153
	OPEX																								
	Price per kWh	USD	0,07	393.276	393.276	393.276	393.276	393.276	393.276	393.276	393.276	393.276	781.943	781.943	781.943	781.943	781.943	781.943	781.943	781.943	781.943	781.943	781.943	781.943	12.922.801
	Maintenance	USD		3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	3.811	80.038
	Total OPEX	USD		397.088	397.088	397.088	397.088	397.088	397.088	397.088	397.088	397.088	785.754	785.754	785.754	785.754	785.754	785.754	785.754	785.754	785.754	785.754	785.754	785.754	13.002.839
	Total CAPEX + OPEX			1.269.164	397.088	397.088	397.088	397.088	397.088	397.088	397.088	397.088	785.754	1.657.831	785.754	785.754	785.754	785.754	785.754	785.754	785.754	785.754	785.754	785.754	14.746.992
	Discounted generation	kWh		5.618.235	5.224.959	4.859.212	4.519.067	4.202.732	3.908.541	3.634.943	3.380.497	3.143.862	5.813.309	5.406.378	5.027.931	4.675.976	4.348.658	4.044.252	3.761.154	3.497.873	3.253.022	3.025.311	2.813.539	2.616.591	86.776.043
	Discounted costs	USD		1.269.164	369.292	343.441	319.400	297.042	276.249	256.912	238.928	222.203	408.915	802.361	353.671	328.914	305.890	284.477	264.564	246.045	228.821	212.804	197.908	184.054	7.411.056
	Present value of costs (PV)	USD	7.411.056																						
	Present value of energy (PV)	kWh	86.776.043																						
	Levelized costs of electricity (LCOE)	USD/kWh	0,09																						
0%	**Diesel**																								

12.5.8 Sensitivity Diesel Price

Sensitivity Diesel Price										
	Decrease					**Base Case**	*Increase*			
	-55%	*-20%*	*-15%*	*-10%*	*-5%*	**0%**	*5%*	*10%*	*15%*	*20%*
Diesel Price (USD/litre)	*0.68*	*1.21*	*1.28*	*1.36*	*1.43*	**1.51**	*1.59*	*1.66*	*1.74*	*1.81*
Overall LCOE without PV (USD/kWh)	***0.138***	*0.197*	*0.205*	*0.214*	*0.222*	**0.230**	*0.239*	*0.247*	*0.256*	*0.264*
Total costs in m/USD without PV Options (20 yrs)	***68,542,826***	*97,878,088*	*102,068,840*	*106,259,591*	*110,450,343*	***114,641,095***	*118,831,846*	*123,022,598*	*127,213,350*	*131,404,102*
Overall LCOE with PV (USD/kWh)	***0.127***	*0.173*	*0.179*	*0.186*	*0.193*	**0.199**	*0.206*	*0.212*	*0.219*	*0.225*
Total costs with PV Options (20 yrs)	***63,380,145***	*86,055,949*	*89,295,350*	*92,534,751*	*95,774,151*	***99,013,552***	*102,252,952*	*105,492,353*	*108,731,754*	*111,971,154*
Difference overall LCOE no PV/with PV	**0.011**	**0.024**	**0.026**	**0.028**	**0.029**	**0.031**	0.033	0.035	0.037	0.039
Relative difference of LCOE no PV/ with PV	**8%**	**12%**	**13%**	**13%**	**13%**	**13%**	14%	14%	14%	15%
Total Savings in cost with PV Option (20 yrs)	**5,162,681**	11,822,138	12,773,490	13,724,841	14,676,192	**15,627,543**	16,578,894	17,530,245	18,481,596	19,432,947
	excl. Blue Tax									

12.5.9 Sensitivity GEDCo Grid Price

Sensitivity Grid Price									
	Decrease				**Base Case**	*Increase*			
	-20%	*-15%*	*-10%*	*-5%*	**0%**	*5%*	*10%*	*15%*	*20%*
GEDCo Grid Price	*0.12*	*0.128*	*0.135*	*0.143*	*0.150*	*0.158*	*0.165*	*0.173*	*0.180*
Overall LCOE without PV (USD/kWh)	*0.222*	*0.224*	*0.226*	*0.228*	**0.230**	0.233	*0.235*	*0.237*	*0.239*
Total costs in m/USD without PV Options (20 yrs)	*110,440,349*	*111,490,535*	*112,540,722*	*113,590,908*	***114,641,095***	*115,691,281*	*116,741,468*	*117,791,654*	*118,841,840*
Overall LCOE with PV (USD/kWh)	*0.192*	*0.194*	*0.196*	*0.197*	**0.199**	0.201	*0.202*	*0.204*	*0.206*
Total costs in m/USD with PV Options (20 yrs)	*95,633,247*	*96,478,323*	*97,323,399*	*98,168,476*	***99,013,552***	*99,858,628*	*100,703,705*	*101,548,781*	*102,393,857*
Difference overall LCOE no PV/with PV	0.0300	0.0300	0.0300	0.0310	**0.0310**	0.0320	0.0330	0.0330	0.0330
Relative difference of LCOE no PV/ with PV	14%	13%	13%	14%	**13%**	14%	14%	14%	14%
Total Savings in cost with PV Option (20 yrs)	14,807,103	15,012,213	15,217,323	15,422,433	**15,627,543**	15,832,653	16,037,763	16,242,873	16,447,983

12.6 Funding Scenarios

12.6.1 Commercial Funding Scenario

Financing Commercial 20 yrs

Parameters*	Unit			
Grant	%	20%		
Loan	%	80%		
Debt repayment per year	%	5%		
Interest rate	%	4%	3%	6%
Management fee	%	0.25%	0.25%	0.25%
Service fee	%	0.18%	0.18%	0.18%
Total financing fees	%	4.43%	3.43%	6.43%
Loan term	year(s)	20		
Grace period	year(s)	1		

	Unit		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	Grand total
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
Investment costs	USD			(6,897,993)	(425,913)							(1,028,482)	(872,077)					(525,875)						(9,750,340)
Cumulative debt	USD			(6,897,993)	(7,323,906)	(7,323,906)	(7,323,906)	(7,323,906)	(7,323,906)	(7,323,906)	(7,323,906)	(8,352,388)	(9,224,465)	(9,224,465)	(9,224,465)	(9,224,465)	(9,224,465)	(9,750,340)	(9,750,340)	(9,750,340)	(9,750,340)	(9,750,340)	(9,750,340)	
Grant	USD			(1,379,599)	(85,183)							(205,696)	(174,415)					(105,175)						(1,950,068)
Loan	USD			(5,518,394)	(340,730)							(822,786)	(697,662)					(420,700)						(7,800,272)
1 Interest rate	4%																							
Cumulative loan share	USD			(5,518,394)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(6,681,910)	(7,379,572)	(7,379,572)	(7,379,572)	(7,379,572)	(7,379,572)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	
Repayment of loan (excl. financing fees)	USD				413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	358,813	0
Cost financing fees for repayment of loan	USD				241,245	222,931	204,616	186,302	167,988	149,674	131,359	149,495	162,087	143,772	125,458	107,144	88,830	89,152	70,838	52,524	34,210	15,895	0	2,343,520
Total debt (incl. financing fees)	USD																							**(10,143,792)**
Repayment of loan incl. financing fees	USD				654,659	636,345	618,031	599,717	581,402	563,088	544,774	562,909	575,501	557,187	538,873	520,558	502,244	502,567	484,253	465,938	447,624	429,310	358,813	10,143,792
Debt balance	USD			(10,143,792)	(9,489,133)	(8,852,788)	(8,234,757)	(7,635,040)	(7,053,638)	(6,490,550)	(5,945,776)	(5,382,867)	(4,807,366)	(4,250,179)	(3,711,306)	(3,190,748)	(2,688,504)	(2,185,937)	(1,701,685)	(1,235,746)	(788,122)	(358,813)	(0)	
2 Interest rate	3%																							
Cumulative loan share	USD			(5,518,394)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(6,681,910)	(7,379,572)	(7,379,572)	(7,379,572)	(7,379,572)	(7,379,572)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	
Repayment of loan (excl. financing fees)	USD				413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	358,813	0
Cost financing fees for repayment of loan	USD				186,788	172,608	158,428	144,248	130,067	115,887	101,707	115,749	125,498	111,318	97,138	82,958	68,778	69,028	54,848	40,667	26,487	12,307	0	1,814,509
Total debt (incl. financing fees)	USD																							**(9,614,781)**
Repayment of loan incl. financing fees	USD				600,202	586,022	571,842	557,662	543,482	529,302	515,122	529,163	538,913	524,733	510,552	496,372	482,192	482,442	468,262	454,082	439,902	425,722	358,813	9,614,781
Debt balance	USD			(9,614,781)	(9,014,579)	(8,428,556)	(7,856,714)	(7,299,052)	(6,755,571)	(6,226,269)	(5,711,147)	(5,181,984)	(4,643,072)	(4,118,339)	(3,607,787)	(3,111,414)	(2,629,222)	(2,146,780)	(1,678,518)	(1,224,436)	(784,534)	(358,813)	0	
3 Interest rate	6%																							
Cumulative loan share	USD			(5,518,394)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(6,681,910)	(7,379,572)	(7,379,572)	(7,379,572)	(7,379,572)	(7,379,572)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	
Repayment of loan (excl. financing fees)	USD				413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	413,414	358,813	0
Cost financing fees for repayment of loan	USD				350,159	323,577	296,994	270,412	243,829	217,246	190,664	216,986	235,264	208,681	182,098	155,516	128,933	129,402	102,819	76,237	49,654	23,072	0	3,401,543
Total debt (incl. financing fees)	USD																							**11,201,815**
Repayment of loan incl. financing fees	USD				763,574	736,991	710,408	683,826	657,243	630,661	604,078	630,401	648,678	622,095	595,513	568,930	542,348	542,816	516,234	489,651	463,069	436,486	358,813	11,201,815
Debt balance	USD			(11,201,815)	###########	(9,701,250)	(8,990,842)	(8,307,016)	(7,649,773)	(7,019,112)	(6,415,033)	(5,784,633)	(5,135,955)	(4,513,859)	(3,918,346)	(3,349,416)	(2,807,068)	(2,264,252)	(1,748,018)	(1,258,367)	(795,299)	(358,813)	0	

Financing Commercial 15 yrs

Parameters*	Unit			
Grant	%	20%		
Loan	%	80%		
Debt repayment per year	%	7%		
Interest rate	%	4%	3%	6%
Management fee	%	0.25%	0.25%	0.25%
Service fee	%	0.18%	0.18%	0.18%
Total financing fees	%	4.43%	3.43%	6.43%
Loan term	year(s)	15		
Grace period	year(s)	1		

	Unit		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	Grand total
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
Investment costs	USD			(6,897,993)	(425,913)							(1,028,482)	(872,077)					(525,875)		(9,750,340)
Cumulative debt	USD			(6,897,993)	(7,323,906)	(7,323,906)	(7,323,906)	(7,323,906)	(7,323,906)	(7,323,906)	(7,323,906)	(8,352,388)	(9,224,465)	(9,224,465)	(9,224,465)	(9,224,465)	(9,224,465)	(9,750,340)	(9,750,340)	
Grant	USD			(1,379,599)	(85,183)							(205,696)	(174,415)					(105,175)		(1,950,068)
Loan	USD			(5,518,394)	(340,730)							(822,786)	(697,662)					(420,700)		(7,800,272)
1 Interest rate	4%																			
Cumulative loan share	USD			(5,518,394)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(6,681,910)	(7,379,572)	(7,379,572)	(7,379,572)	(7,379,572)	(7,379,572)	(7,800,272)	(7,800,272)	
Repayment of loan (excl. financing fees)	USD				546,019	546,019	546,019	546,019	546,019	546,019	546,019	546,019	546,019	546,019	546,019	546,019	546,019	702,024	0	7,800,272
Cost financing fees for repayment of loan	USD				235,371	211,182	186,993	162,805	138,616	114,427	90,239	102,499	109,217	85,029	60,840	36,651	12,463	0		1,546,332
Total debt (incl. financing fees)																				**(9,346,604)**
Repayment of loan incl. financing fees	USD				781,390	757,201	733,012	708,824	684,635	660,446	636,258	648,519	655,236	631,048	606,859	582,670	558,482	702,024		9,346,604
Debt balance	USD			(9,346,604)	(8,565,214)	(7,808,013)	(7,075,001)	(6,366,177)	(5,681,542)	(5,021,096)	(4,384,838)	(3,736,319)	(3,081,083)	(2,450,035)	(1,843,177)	(1,260,506)	(702,024)	0		
2 Interest rate	3%																			
Cumulative loan share	USD			(5,518,394)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(6,681,910)	(7,379,572)	(7,379,572)	(7,379,572)	(7,379,572)	(7,379,572)	(7,800,272)	(7,800,272)	
Repayment of loan (excl. financing fees)	USD				546,019	546,019	546,019	546,019	546,019	546,019	546,019	546,019	546,019	546,019	546,019	546,019	546,019	702,024	0	7,800,272
Cost financing fees for repayment of loan	USD				182,240	163,511	144,783	126,054	107,326	88,597	69,869	79,362	84,563	65,835	47,106	28,378	9,649	0		1,197,273
Total debt (incl. financing fees)																				**(8,997,545)**
Repayment of loan incl. financing fees	USD				728,259	709,530	690,802	672,073	653,345	634,616	615,888	625,381	630,582	611,854	593,125	574,397	555,668	702,024		8,997,545
Debt balance	USD			(8,997,545)	(8,269,286)	(7,559,756)	(6,868,954)	(6,196,881)	(5,543,536)	(4,908,920)	(4,293,032)	(3,667,651)	(3,037,069)	(2,425,215)	(1,832,090)	(1,257,693)	(702,024)	0		
3 Interest rate	6%																			
Cumulative loan share	USD			(5,518,394)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(6,681,910)	(7,379,572)	(7,379,572)	(7,379,572)	(7,379,572)	(7,379,572)	(7,800,272)	(7,800,272)	
Repayment of loan (excl. financing fees)	USD				546,019	546,019	546,019	546,019	546,019	546,019	546,019	546,019	546,019	546,019	546,019	546,019	546,019	702,024	0	7,800,272
Cost financing fees for repayment of loan	USD				341,633	306,524	271,415	236,306	201,197	166,088	130,979	148,775	158,525	123,416	88,307	53,198	18,089	0		2,244,450
Total debt (incl. financing fees)																				**(10,044,722)**
Repayment of loan incl. financing fees	USD				887,652	852,543	817,434	782,325	747,216	712,107	676,998	694,794	704,544	669,435	634,326	599,217	564,108	702,024		10,044,722
Debt balance	USD			(10,044,722)	(9,157,070)	(8,304,527)	(7,487,094)	(6,704,769)	(5,957,553)	(5,245,447)	(4,568,449)	(3,873,656)	(3,169,111)	(2,499,676)	(1,865,350)	(1,266,133)	(702,024)	0		

Financing Commercial 25 yrs

Parameters*	Unit			
Grant	%	20%		
Loan	%	80%		
Debt repayment per year	%	4.4%		
Interest rate	%	4%	3%	6%
Management fee	%	0.25%	0.25%	0.25%
Service fee	%	0.18%	0.18%	0.18%
Total financing fees	%	4.43%	3.43%	6.43%
Loan term	year(s)	25		
Grace period	year(s)	1		

	Unit		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
			1	2	3	4	5	6	7	8	9	10	11	12	13
Investment costs	USD			(6,897,993)	(425,913)							(1,028,482)	(872,077)		
Cumulative debt	USD			(6,897,993)	(7,323,906)	(7,323,906)	(7,323,906)	(7,323,906)	(7,323,906)	(7,323,906)	(7,323,906)	(8,352,388)	(9,224,465)	(9,224,465)	(9,224,465)
Grant	USD			(1,379,599)	(85,183)							(205,696)	(174,415)		
Loan	USD			(5,518,394)	(340,730)							(822,786)	(697,662)		
1 Interest rate	4%														
Cumulative loan share	USD			(5,518,394)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(6,681,910)	(7,379,572)	(7,379,572)	(7,379,572)
Repayment of loan (excl. financing fees)	USD				343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212
Cost financing fees for repayment of loan	USD				244,355	229,151	213,946	198,742	183,538	168,333	153,129	174,374	190,076	174,872	159,668
Total debt (incl. financing fees)	USD														
Repayment of loan incl. financing fees	USD				587,567	572,363	557,158	541,954	526,750	511,545	496,341	517,586	533,288	518,084	502,880
Debt balance	USD			(10,811,053)	(10,223,486)	(9,651,124)	(9,093,965)	(8,552,011)	(8,025,262)	(7,513,716)	(7,017,375)	(6,499,789)	(5,966,500)	(5,448,416)	(4,945,536)
2 Interest rate	3%														
Cumulative loan share	USD			(5,518,394)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(6,681,910)	(7,379,572)	(7,379,572)	(7,379,572)
Repayment of loan (excl. financing fees)	USD				343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212
Cost financing fees for repayment of loan	USD				189,196	177,424	165,651	153,879	142,107	130,335	118,563	135,012	147,170	135,398	123,625
Total debt (incl. financing fees)	USD														
Repayment of loan incl. financing fees	USD				532,408	520,636	508,863	497,091	485,319	473,547	461,775	478,224	490,382	478,610	466,837
Debt balance	USD			(10,131,419)	(9,599,011)	(9,078,375)	(8,569,512)	(8,072,421)	(7,587,101)	(7,113,555)	(6,651,780)	(6,173,556)	(5,683,174)	(5,204,564)	(4,737,727)
3 Interest rate	6%														
Cumulative loan share	USD			(5,518,394)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(5,859,125)	(6,681,910)	(7,379,572)	(7,379,572)	(7,379,572)
Repayment of loan (excl. financing fees)	USD				343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212
Cost financing fees for repayment of loan	USD				354,673	332,605	310,536	288,468	266,399	244,331	222,262	253,099	275,890	253,821	231,753
Total debt (incl. financing fees)	USD														
Repayment of loan incl. financing fees	USD				697,885	675,817	653,748	631,680	609,611	587,542	565,474	596,311	619,102	597,033	574,965
Debt balance	USD			(12,170,322)	(11,472,437)	##########	##########	(9,511,193)	(8,901,582)	(8,314,039)	(7,748,566)	(7,152,255)	(6,533,153)	(5,936,120)	(5,361,156)

	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Grand Total
	14	15	16	17	18	19	20	21	22	23	24	25	
Investment costs			(525,875)										(9,750,340)
Cumulative debt	(9,224,465)	(9,224,465)	(9,750,340)	(9,750,340)	(9,750,340)	(9,750,340)	(9,750,340)	(9,750,340)	(9,750,340)	(9,750,340)	(9,750,340)	(9,750,340)	
Grant			(105,175)										(1,950,068)
Loan			(420,700)										(7,800,272)
1 Interest rate													
Cumulative loan share	(7,379,572)	(7,379,572)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	
Repayment of loan (excl. financing fees)	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	249,609	0
Cost financing fees for repayment of loan	144,464	129,259	132,692	117,488	102,283	87,079	71,875	56,671	41,466	26,262	11,058	0	2,931,995
Total debt (incl. financing fees)													**(10,811,053)**
Repayment of loan incl. financing fees	487,676	472,471	475,904	460,700	445,495	430,291	415,087	399,882	384,678	369,474	354,270	249,609	10,811,053
Debt balance	(4,457,861)	(3,985,390)	(3,509,486)	(3,048,786)	(2,603,291)	(2,173,000)	(1,757,913)	(1,358,030)	(973,352)	(603,878)	(249,609)	0	
2 Interest rate													
Cumulative loan share	(7,379,572)	(7,379,572)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	
Repayment of loan (excl. financing fees)	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	249,609	0
Cost financing fees for repayment of loan	111,853	100,081	102,739	90,967	79,195	67,422	55,650	43,878	32,106	20,334	8,562	0	2,270,145
Total debt (incl. financing fees)													**(10,131,419)**
Repayment of loan incl. financing fees	455,065	443,293	445,951	434,179	422,407	410,634	398,862	387,090	375,318	363,546	351,774	249,609	10,131,419
Debt balance	(4,282,662)	(3,839,369)	(3,393,418)	(2,959,239)	(2,536,832)	(2,126,198)	(1,727,336)	(1,340,246)	(964,928)	(601,382)	(249,609)	0	
3 Interest rate													
Cumulative loan share	(7,379,572)	(7,379,572)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	(7,800,272)	
Repayment of loan (excl. financing fees)	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	343,212	249,609	0
Cost financing fees for repayment of loan	209,684	187,616	192,598	170,530	148,461	126,392	104,324	82,255	60,187	38,118	16,050	0	4,255,695
Total debt (incl. financing fees)													**(12,170,322)**
Repayment of loan incl. financing fees	552,896	530,828	535,810	513,742	491,673	469,604	447,536	425,467	403,399	381,330	359,262	249,609	12,170,322
Debt balance	(4,808,259)	(4,277,432)	(3,741,622)	(3,227,880)	(2,736,207)	(2,266,603)	(1,819,067)	(1,393,600)	(990,201)	(608,870)	(249,609)	0	

12.6.2 50% Grant Scenario

Financing 50% Grant

Parameters*	Unit			
Grant	%	50%		
Loan	%	50%		
Debt repayment per year	%	5%		
Interest rate	%	4%	3%	6%
Management fee	%	0.25%	0.25%	0.25%
Service fee	%	0.18%	0.18%	0.18%
Total financing fees	%	4.43%	3.43%	6.43%
Loan term	year(s)	20		
Grace period	year(s)	1		

	Unit		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	Grand total
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
Investment costs	USD			(6,897,993)	(425,913)							(1,028,482)	(872,077)					(525,875)						(9,750,340)
Cumulative debt	USD			(6,897,993)	(7,323,906)	(7,323,906)	(7,323,906)	(7,323,906)	(7,323,906)	(7,323,906)	(7,323,906)	(8,352,388)	(9,224,465)	(9,224,465)	(9,224,465)	(9,224,465)	(9,224,465)	(9,750,340)	(9,750,340)	(9,750,340)	(9,750,340)	(9,750,340)	(9,750,340)	
Grant	USD			(3,448,996)	(212,957)							(514,241)	(436,039)					(262,938)						(4,875,170)
Loan	USD			(3,448,996)	(212,957)							(514,241)	(436,039)					(262,938)						(4,875,170)
1 Interest rate	4%																							
Cumulative loan share	USD			(3,448,996)	(3,661,953)	(3,661,953)	(3,661,953)	(3,661,953)	(3,661,953)	(3,661,953)	(3,661,953)	(4,176,194)	(4,612,232)	(4,612,232)	(4,612,232)	(4,612,232)	(4,612,232)	(4,875,170)	(4,875,170)	(4,875,170)	(4,875,170)	(4,875,170)	(4,875,170)	
Repayment of loan (excl. financing fees)	USD				258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	224,258	0
Cost financing fees for repayment of loan	USD				150,778	139,332	127,885	116,439	104,992	93,546	82,100	93,434	101,304	89,858	78,411	66,965	55,519	55,720	44,274	32,827	21,381	9,935	0	1,464,700
Total debt (incl. financing fees)																								**(6,339,870)**
Repayment of loan incl. financing fees	USD				409,162	397,716	386,269	374,823	363,376	351,930	340,484	351,818	359,688	348,242	336,795	325,349	313,903	314,104	302,658	291,211	279,765	268,319	224,258	6,339,870
Debt balance				(6,339,870)	(5,930,708)	(5,532,992)	(5,146,723)	(4,771,900)	(4,408,524)	(4,056,594)	(3,716,110)	(3,364,292)	(3,004,604)	(2,656,362)	(2,319,567)	(1,994,218)	(1,680,315)	(1,366,211)	(1,063,553)	(772,341)	(492,576)	(224,258)	(0)	
2 Interest rate	3%																							
Cumulative loan share	USD			(3,448,996)	(3,661,953)	(3,661,953)	(3,661,953)	(3,661,953)	(3,661,953)	(3,661,953)	(3,661,953)	(4,176,194)	(4,612,232)	(4,612,232)	(4,612,232)	(4,612,232)	(4,612,232)	(4,875,170)	(4,875,170)	(4,875,170)	(4,875,170)	(4,875,170)	(4,875,170)	
Repayment of loan (excl. financing fees)	USD				258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	224,258	0
Cost financing fees for repayment of loan	USD				116,742	107,880	99,017	90,155	81,292	72,430	63,567	72,343	78,436	69,574	60,711	51,849	42,986	43,142	34,280	25,417	16,555	7,692	0	1,134,068
Total debt (incl. financing fees)																								**(6,009,238)**
Repayment of loan incl. financing fees	USD				375,126	366,264	357,401	348,539	339,676	330,814	321,951	330,727	336,820	327,958	319,095	310,233	301,370	301,526	292,664	283,801	274,939	266,076	224,258	6,009,238
Debt balance				(6,009,238)	(5,634,112)	(5,267,848)	(4,910,446)	(4,561,908)	(4,222,232)	(3,891,418)	(3,569,467)	(3,238,740)	(2,901,920)	(2,573,962)	(2,254,867)	(1,944,634)	(1,643,264)	(1,341,737)	(1,049,074)	(765,272)	(490,334)	(224,258)	0	
2 Interest rate	6%																							
Cumulative loan share	USD			(3,448,996)	(3,661,953)	(3,661,953)	(3,661,953)	(3,661,953)	(3,661,953)	(3,661,953)	(3,661,953)	(4,176,194)	(4,612,232)	(4,612,232)	(4,612,232)	(4,612,232)	(4,612,232)	(4,875,170)	(4,875,170)	(4,875,170)	(4,875,170)	(4,875,170)	(4,875,170)	
Repayment of loan (excl. financing fees)	USD				258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	258,384	224,258	0
Cost financing fees for repayment of loan	USD				218,849	202,235	185,621	169,007	152,393	135,779	119,165	135,617	147,040	130,426	113,812	97,197	80,583	80,876	64,262	47,648	31,034	14,420	0	2,125,964
Total debt (incl. financing fees)																								**7,001,134**
Repayment of loan incl. financing fees	USD				477,233	460,619	444,005	427,391	410,777	394,163	377,549	394,001	405,424	388,810	372,196	355,581	338,967	339,260	322,646	306,032	289,418	272,804	224,258	7,001,134
Debt balance				(7,001,134)	(6,523,901)	(6,063,281)	(5,619,276)	(5,191,885)	(4,781,108)	(4,386,945)	(4,009,396)	(3,615,395)	(3,209,972)	(2,821,162)	(2,448,966)	(2,093,385)	(1,754,418)	(1,415,157)	(1,092,511)	(786,479)	(497,062)	(224,258)	0	

12.6.3 Green Funding Scenario

Financing Green Funding

Parameters*	Unit	
Grant	%	15%
Loan	%	85%
Debt repayment per year	%	6%
Interest rate	%	0%
Management fee	%	0.25%
Service fee	%	0.18%
Total financing fees	%	0.43%
Loan term	year(s)	20
Grace period	year(s)	3

	Unit		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	Grand total
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
Investment costs	USD			(6,897,993)	(425,913)							(1,028,482)	(872,077)					(525,875)						(9,750,340)
Cumulative debt	USD			(6,897,993)	(7,323,906)	(7,323,906)	(7,323,906)	(7,323,906)	(7,323,906)	(7,323,906)	(7,323,906)	(8,352,388)	(9,224,465)	(9,224,465)	(9,224,465)	(9,224,465)	(9,224,465)	(9,750,340)	(9,750,340)	(9,750,340)	(9,750,340)	(9,750,340)	(9,750,340)	
Grant	USD			(1,034,699)	(63,887)							(154,272)	(130,812)					(78,881)						(1,462,551)
Loan	USD			(5,863,294)	(362,026)							(874,210)	(741,265)					(446,994)						(8,287,789)
Cumulative loan share	USD			(5,863,294)	(6,225,320)	(6,225,320)	(6,225,320)	(6,225,320)	(6,225,320)	(6,225,320)	(6,225,320)	(7,099,530)	(7,840,795)	(7,840,795)	(7,840,795)	(7,840,795)	(7,840,795)	(8,287,789)	(8,287,789)	(8,287,789)	(8,287,789)	(8,287,789)	(8,287,789)	
Repayment of loan (excl. financing fees)	USD						497,267	497,267	497,267	497,267	497,267	497,267	497,267	497,267	497,267	497,267	497,267	497,267	497,267	497,267	497,267	497,267	331,512	0
Cost financing fees for repayment of loan	USD						24,631	22,492	20,354	18,216	16,078	17,698	18,748	16,609	14,471	12,333	10,195	9,978	7,840	5,702	3,564	1,425	0	220,335
Total debt (incl. financing fees)				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	**(8,508,124)**
Repayment of loan incl. financing fees	USD						521,898	519,760	517,621	515,483	513,345	514,966	516,015	513,877	511,738	509,600	507,462	507,246	505,108	502,969	500,831	498,693	331,512	8,508,124
Debt balance				(8,508,124)	(8,508,124)	(8,508,124)	(7,986,226)	(7,466,466)	(6,948,845)	(6,433,361)	(5,920,016)	(5,405,051)	(4,889,036)	(4,375,159)	(3,863,420)	(3,353,820)	(2,846,358)	(2,339,112)	(1,834,005)	(1,331,035)	(830,204)	(331,512)	0	

Financing Green Funding 10 yrs

Parameters*	Unit	
Grant	%	15%
Loan	%	85%
Debt repayment per year	%	6%
Interest rate	%	0%
Management fee	%	0,25%
Service fee	%	0,18%
Total financing fees	%	0,43%
Loan term	year(s)	10
Grace period	year(s)	3

	Unit		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Total
			1	2	3	4	5	6	7	8	9	10	
Investment costs	USD			-9.750.340									
Cumulative debt	USD			-9.750.340	-9.750.340	-9.750.340	-9.750.340	-9.750.340	-9.750.340	-9.750.340	-9.750.340	-9.750.340	
Grant	USD			-1.462.551									
Loan	USD			-8.287.789									
Cumulative loan share	USD			-8.287.789	-8.287.789	-8.287.789	-8.287.789	-8.287.789	-8.287.789	-8.287.789	-8.287.789	-8.287.789	
Repayment of loan (excl. financing fees)	USD			0	0	0	-1.381.298	-1.381.298	-1.381.298	-1.381.298	-1.381.298	-1.381.298	-8.287.789
Cost financing fees for repayment of loar	USD			0	0	0	41.577	47.517	53.456	59.396	65.335	71.275	338.556
Total debt (incl. financing fees)													-8.626.345
Repayment of loan incl. financing fees	USD			0	0	0	-1.339.721	-1.333.781	-1.327.842	-1.321.902	-1.315.963	-1.310.023	
Debt balance				0	0	0	-1.339.721	-2.673.503	-4.001.344	-5.323.247	-6.639.209	-7.949.233	

12.7 Funding Scenarios incl. 10% Contingency

12.7.1 Commercial Funding Scenario (10% Contingency)

Financing Commercial 20 yrs

Parameters*	Unit			
Grant	%	20%		
Loan	%	80%		
Debt repayment per year	%	5%		
Interest rate	%	4%	3%	6%
Management fee	%	0.25%	0.25%	0.25%
Service fee	%	0.18%	0.18%	0.18%
Total financing fees	%	4.43%	3.43%	6.43%
Loan term	year(s)	20		
Grace period	year(s)	1		

	Unit		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
			1	2	3	4	5	6	7	8	9	10	11
Investment costs	USD			(7,587,792)	(425,913)							(1,028,482)	(872,077)
Cumulative debt	USD			(7,587,792)	(8,013,705)	(8,013,705)	(8,013,705)	(8,013,705)	(8,013,705)	(8,013,705)	(8,013,705)	(9,042,187)	(9,914,264)
Grant	USD			(1,517,558)	(85,183)							(205,696)	(174,415)
Loan	USD			(6,070,234)	(340,730)							(822,786)	(697,662)
1 Interest rate	4%												
Cumulative loan share	USD			(6,070,234)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(7,233,750)	(7,931,411)
Repayment of loan (excl. financing fees)	USD				444,892	444,892	444,892	444,892	444,892	444,892	444,892	444,892	444,892
Cost financing fees for repayment of loan	USD				264,297	244,588	224,880	205,171	185,462	165,754	146,045	162,786	173,983
Total debt (incl. financing fees)	USD												
Repayment of loan incl. financing fees	USD				709,189	689,480	669,771	650,063	630,354	610,645	590,936	607,677	618,875
Debt balance	USD			(10,948,608)	(10,239,419)	(9,549,939)	(8,880,168)	(8,230,105)	(7,599,752)	(6,989,106)	(6,398,170)	(5,790,493)	(5,171,618)
2 Interest rate	3%												
Cumulative loan share	USD			(6,070,234)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(7,233,750)	(7,931,411)
Repayment of loan (excl. financing fees)	USD				444,892	444,892	444,892	444,892	444,892	444,892	444,892	444,892	444,892
Cost financing fees for repayment of loan	USD				204,636	189,377	174,117	158,857	143,597	128,337	113,078	126,039	134,709
Total debt (incl. financing fees)	USD												
Repayment of loan incl. financing fees	USD				649,528	634,268	619,008	603,749	588,489	573,229	557,969	570,931	579,601
Debt balance	USD			(10,371,988)	(9,722,460)	(9,088,192)	(8,469,183)	(7,865,435)	(7,276,946)	(6,703,717)	(6,145,748)	(5,574,817)	(4,995,216)
3 Interest rate	6%												
Cumulative loan share	USD			(6,070,234)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(7,233,750)	(7,931,411)
Repayment of loan (excl. financing fees)	USD				444,892	444,892	444,892	444,892	444,892	444,892	444,892	444,892	444,892
Cost financing fees for repayment of loan	USD				383,618	355,012	326,405	297,799	269,192	240,586	211,979	236,278	252,531
Total debt (incl. financing fees)	USD												
Repayment of loan incl. financing fees	USD				828,510	799,904	771,297	742,690	714,084	685,477	656,871	681,169	697,423
Debt balance	USD			(12,101,848)	(11,273,337)	(10,473,434)	(9,702,137)	(8,959,446)	(8,245,363)	(7,559,885)	(6,903,014)	(6,221,845)	(5,524,422)

	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	Grand total
	12	13	14	15	16	17	18	19	20	21	
Investment costs					(578,463)						(10,492,727)
Cumulative debt	(9,914,264)	(9,914,264)	(9,914,264)	(9,914,264)	(10,492,727)	(10,492,727)	(10,492,727)	(10,492,727)	(10,492,727)	(10,492,727)	
Grant					(115,693)						(2,098,545)
Loan					(462,770)						(8,394,181)
1 Interest rate											
Cumulative loan share	(7,931,411)	(7,931,411)	(7,931,411)	(7,931,411)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	
Repayment of loan (excl. financing fees)	444,892	444,892	444,892	444,892	444,892	444,892	444,892	444,892	444,892	386,132	0
Cost financing fees for repayment of loan	154,275	134,566	114,857	95,148	95,940	76,232	56,523	36,814	17,106	0	2,554,426
Total debt (incl. financing fees)											**(10,948,608)**
Repayment of loan incl. financing fees	599,166	579,457	559,749	540,040	540,832	521,123	501,415	481,706	461,997	386,132	10,948,608
Debt balance	(4,572,452)	(3,992,994)	(3,433,246)	(2,893,206)	(2,352,374)	(1,831,250)	(1,329,836)	(848,130)	(386,132)	(0)	
2 Interest rate											
Cumulative loan share	(7,931,411)	(7,931,411)	(7,931,411)	(7,931,411)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	
Repayment of loan (excl. financing fees)	444,892	444,892	444,892	444,892	444,892	444,892	444,892	444,892	444,892	386,132	0
Cost financing fees for repayment of loan	119,450	104,190	88,930	73,670	74,283	59,024	43,764	28,504	13,244	0	1,977,806
Total debt (incl. financing fees)											**(10,371,988)**
Repayment of loan incl. financing fees	564,341	549,081	533,822	518,562	519,175	503,915	488,656	473,396	458,136	386,132	10,371,988
Debt balance	(4,430,875)	(3,881,793)	(3,347,972)	(2,829,410)	(2,310,235)	(1,806,320)	(1,317,664)	(844,268)	(386,132)	0	
3 Interest rate											
Cumulative loan share	(7,931,411)	(7,931,411)	(7,931,411)	(7,931,411)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	
Repayment of loan (excl. financing fees)	444,892	444,892	444,892	444,892	444,892	444,892	444,892	444,892	444,892	386,132	0
Cost financing fees for repayment of loan	223,924	195,318	166,711	138,105	139,254	110,648	82,041	53,435	24,828	0	3,707,666
Total debt (incl. financing fees)											**12,101,848**
Repayment of loan incl. financing fees	668,816	640,210	611,603	582,996	584,146	555,540	526,933	498,326	469,720	386,132	12,101,848
Debt balance	(4,855,606)	(4,215,397)	(3,603,794)	(3,020,797)	(2,436,651)	(1,881,112)	(1,354,179)	(855,852)	(386,132)	0	

Financing Commercial 15 yrs

Parameters*	Unit			
Grant	%	20%		
Loan	%	80%		
Debt repayment per year	%	7%		
Interest rate	%	4%	3%	6%
Management fee	%	0.25%	0.25%	0.25%
Service fee	%	0.18%	0.18%	0.18%
Total financing fees	%	4.43%	3.43%	6.43%
Loan term	year(s)	15		
Grace period	year(s)	1		

	Unit		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	Grand total
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
Investment costs	USD			(7,587,792)	(425,913)							(1,028,482)	(872,077)					(578,463)		(10,492,727)
Cumulative debt	USD			(7,587,792)	(8,013,705)	(8,013,705)	(8,013,705)	(8,013,705)	(8,013,705)	(8,013,705)	(8,013,705)	(9,042,187)	(9,914,264)	(9,914,264)	(9,914,264)	(9,914,264)	(9,914,264)	(10,492,727)	(10,492,727)	
Grant	USD			(1,517,558)	(85,183)							(205,696)	(174,415)					(115,693)		(2,098,545)
Loan	USD			(6,070,234)	(340,730)							(822,786)	(697,662)					(462,770)		(8,394,181)
1 Interest rate	4%																			
Cumulative loan share	USD			(6,070,234)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(7,233,750)	(7,931,411)	(7,931,411)	(7,931,411)	(7,931,411)	(7,931,411)	(8,394,181)	(8,394,181)	
Repayment of loan (excl. financing fees)	USD				587,593	587,593	587,593	587,593	587,593	587,593	587,593	587,593	587,593	587,593	587,593	587,593	587,593	755,476	0	8,394,181
Cost financing fees for repayment of loan	USD				257,975	231,945	205,915	179,884	153,854	127,824	101,793	112,212	117,088	91,058	65,028	38,997	12,967	0		1,696,540
Total debt (incl. financing fees)																				(10,090,721)
Repayment of loan incl. financing fees	USD				845,568	819,538	793,507	767,477	741,447	715,416	689,386	699,805	704,681	678,651	652,620	626,590	600,560	755,476		10,090,721
Debt balance	USD			(10,090,721)	(9,245,153)	(8,425,616)	(7,632,108)	(6,864,631)	(6,123,185)	(5,407,769)	(4,718,383)	(4,018,578)	(3,313,897)	(2,635,246)	(1,982,626)	(1,356,036)	(755,476)	0		
2 Interest rate	3%																			
Cumulative loan share	USD			(6,070,234)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(7,233,750)	(7,931,411)	(7,931,411)	(7,931,411)	(7,931,411)	(7,931,411)	(8,394,181)	(8,394,181)	
Repayment of loan (excl. financing fees)	USD				587,593	587,593	587,593	587,593	587,593	587,593	587,593	587,593	587,593	587,593	587,593	587,593	587,593	755,476	0	8,394,181
Cost financing fees for repayment of loan	USD				199,742	179,587	159,433	139,278	119,124	98,969	78,815	86,882	90,658	70,503	50,349	30,194	10,040	0		1,313,574
Total debt (incl. financing fees)																				(9,707,755)
Repayment of loan incl. financing fees	USD				787,334	767,180	747,025	726,871	706,717	686,562	666,408	674,475	678,250	658,096	637,941	617,787	597,633	755,476		9,707,755
Debt balance	USD			(9,707,755)	(8,920,421)	(8,153,241)	(7,406,216)	(6,679,345)	(5,972,628)	(5,286,066)	(4,619,658)	(3,945,183)	(3,266,933)	(2,608,837)	(1,970,896)	(1,353,109)	(755,476)	0		
3 Interest rate	6%																			
Cumulative loan share	USD			(6,070,234)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(7,233,750)	(7,931,411)	(7,931,411)	(7,931,411)	(7,931,411)	(7,931,411)	(8,394,181)	(8,394,181)	
Repayment of loan (excl. financing fees)	USD				587,593	587,593	587,593	587,593	587,593	587,593	587,593	587,593	587,593	587,593	587,593	587,593	587,593	755,476	0	8,394,181
Cost financing fees for repayment of loan	USD				374,443	336,661	298,878	261,096	223,314	185,532	147,750	162,872	169,950	132,168	94,385	56,603	18,821	0		2,462,473
Total debt (incl. financing fees)																				(10,856,654)
Repayment of loan incl. financing fees	USD				962,035	924,253	886,471	848,689	810,907	773,124	735,342	750,465	757,543	719,760	681,978	644,196	606,414	755,476		10,856,654
Debt balance	USD			(10,856,654)	(9,894,618)	(8,970,365)	(8,083,894)	(7,235,205)	(6,424,299)	(5,651,174)	(4,915,832)	(4,165,367)	(3,407,824)	(2,688,064)	(2,006,086)	(1,361,890)	(755,476)	(0)		

Financing Commercial 25 yrs

Parameters*	Unit			
Grant	%	20%		
Loan	%	80%		
Debt repayment per year	%	4.4%		
Interest rate	%	4%	3%	6%
Management fee	%	0.25%	0.25%	0.25%
Service fee	%	0.18%	0.18%	0.18%
Total financing fees	%	4.43%	3.43%	6.43%
Loan term	year(s)	25		
Grace period	year(s)	1		

	Unit		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
			1	2	3	4	5	6	7	8	9	10	11	12
Investment costs	USD			(7,587,792)	(425,913)							(1,028,482)	(872,077)	
Cumulative debt	USD			(7,587,792)	(8,013,705)	(8,013,705)	(8,013,705)	(8,013,705)	(8,013,705)	(8,013,705)	(8,013,705)	(9,042,187)	(9,914,264)	(9,914,264)
Grant	USD			(1,517,558)	(85,183)							(205,696)	(174,415)	
Loan	USD			(6,070,234)	(340,730)							(822,786)	(697,662)	
1 Interest rate	4%													
Cumulative loan share	USD			(6,070,234)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(7,233,750)	(7,931,411)	(7,931,411)
Repayment of loan (excl. financing fees)	USD				369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344
Cost financing fees for repayment of loan	USD				267,644	251,282	234,920	218,558	202,196	185,834	169,472	189,560	204,104	187,742
Total debt (incl. financing fees)	USD													
Repayment of loan incl. financing fees	USD				636,988	620,626	604,264	587,902	571,540	555,178	538,816	558,904	573,448	557,086
Debt balance	USD			(11,666,674)	(11,029,686)	(10,409,060)	(9,804,796)	(9,216,894)	(8,645,354)	(8,090,176)	(7,551,360)	(6,992,457)	(6,419,008)	(5,861,922)
2 Interest rate	3%													
Cumulative loan share	USD			(6,070,234)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(7,233,750)	(7,931,411)	(7,931,411)
Repayment of loan (excl. financing fees)	USD				369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344
Cost financing fees for repayment of loan	USD				207,228	194,559	181,891	169,222	156,554	143,885	131,217	146,770	158,031	145,362
Total debt (incl. financing fees)	USD													
Repayment of loan incl. financing fees	USD				576,572	563,903	551,235	538,566	525,898	513,229	500,561	516,114	527,375	514,706
Debt balance	USD			(10,927,962)	(10,351,390)	(9,787,487)	(9,236,253)	(8,697,687)	(8,171,789)	(7,658,560)	(7,158,000)	(6,641,886)	(6,114,511)	(5,599,805)
3 Interest rate	6%													
Cumulative loan share	USD			(6,070,234)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(6,410,964)	(7,233,750)	(7,931,411)	(7,931,411)
Repayment of loan (excl. financing fees)	USD				369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344
Cost financing fees for repayment of loan	USD				388,476	364,727	340,979	317,230	293,481	269,732	245,983	275,140	296,250	272,502
Total debt (incl. financing fees)	USD													
Repayment of loan incl. financing fees	USD				757,820	734,071	710,323	686,574	662,825	639,076	615,327	644,484	665,594	641,846
Debt balance	USD			(13,144,097)	(12,386,277)	(11,652,205)	(10,941,883)	(10,255,309)	(9,592,484)	(8,953,408)	(8,338,081)	(7,693,597)	(7,028,003)	(6,386,158)

	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Grand Total
	13	14	15	16	17	18	19	20	21	22	23	24	25	
Investment costs				(578,463)										(10,492,727)
Cumulative debt	(9,914,264)	(9,914,264)	(9,914,264)	(10,492,727)	(10,492,727)	(10,492,727)	(10,492,727)	(10,492,727)	(10,492,727)	(10,492,727)	(10,492,727)	(10,492,727)	(10,492,727)	
Grant				(115,693)										(2,098,545)
Loan				(462,770)										(8,394,181)
1 Interest rate														
Cumulative loan share	(7,931,411)	(7,931,411)	(7,931,411)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	
Repayment of loan (excl. financing fees)	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	268,614	0
Cost financing fees for repayment of loan	171,380	155,018	138,656	142,795	126,433	110,071	93,709	77,347	60,985	44,623	28,262	11,900	0	3,187,708
Total debt (incl. financing fees)														**(11,666,674)**
Repayment of loan incl. financing fees	540,724	524,362	508,000	512,139	495,777	479,415	463,053	446,691	430,329	413,967	397,606	381,244	268,614	11,666,674
Debt balance	(5,321,198)	(4,796,836)	(4,288,836)	(3,776,697)	(3,280,919)	(2,801,504)	(2,338,451)	(1,891,760)	(1,461,430)	(1,047,463)	(649,857)	(268,614)	0	
2 Interest rate														
Cumulative loan share	(7,931,411)	(7,931,411)	(7,931,411)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	
Repayment of loan (excl. financing fees)	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	268,614	0
Cost financing fees for repayment of loan	132,694	120,025	107,357	110,561	97,893	85,224	72,556	59,887	47,219	34,550	21,882	9,213	0	2,468,135
Total debt (incl. financing fees)														**(10,927,962)**
Repayment of loan incl. financing fees	502,038	489,369	476,701	479,905	467,237	454,568	441,900	429,231	416,563	403,894	391,226	378,557	268,614	10,927,962
Debt balance	(5,097,767)	(4,608,397)	(4,131,697)	(3,651,791)	(3,184,554)	(2,729,986)	(2,288,086)	(1,858,854)	(1,442,292)	(1,038,397)	(647,171)	(268,614)	0	
3 Interest rate														
Cumulative loan share	(7,931,411)	(7,931,411)	(7,931,411)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	(8,394,181)	
Repayment of loan (excl. financing fees)	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	369,344	268,614	0
Cost financing fees for repayment of loan	248,753	225,004	201,255	207,262	183,514	159,765	136,016	112,267	88,518	64,770	41,021	17,272	0	4,626,853
Total debt (incl. financing fees)														**(13,144,097)**
Repayment of loan incl. financing fees	618,097	594,348	570,599	576,606	552,858	529,109	505,360	481,611	457,862	434,113	410,365	386,616	268,614	13,144,097
Debt balance	(5,768,061)	(5,173,713)	(4,603,114)	(4,026,507)	(3,473,650)	(2,944,541)	(2,439,181)	(1,957,570)	(1,499,708)	(1,065,594)	(655,230)	(268,614)	0	

12.7.2 50% Grant Scenario (10% Contingency)

Financing 50% Grant

Parameters*	Unit			
Grant	%	50%		
Loan	%	50%		
Debt repayment per year	%	5%		
Interest rate	%	4%	3%	6%
Management fee	%	0.25%	0.25%	0.25%
Service fee	%	0.18%	0.18%	0.18%
Total financing fees	%	4.43%	3.43%	6.43%
Loan term	year(s)	20		
Grace period	year(s)	1		

	Unit		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	Grand total
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
Investment costs	USD			(7,587,792)	(425,913)							(1,028,482)	(872,077)					(578,463)						(10,492,727)
Cumulative debt	USD			(7,587,792)	(8,013,705)	(8,013,705)	(8,013,705)	(8,013,705)	(8,013,705)	(8,013,705)	(8,013,705)	(9,042,187)	(9,914,264)	(9,914,264)	(9,914,264)	(9,914,264)	(9,914,264)	(10,492,727)	(10,492,727)	(10,492,727)	(10,492,727)	(10,492,727)	(10,492,727)	
Grant	USD			(3,793,896)	(212,957)							(514,241)	(436,039)					(289,231)						(5,246,363)
Loan	USD			(3,793,896)	(212,957)							(514,241)	(436,039)					(289,231)						(5,246,363)
1 Interest rate	4%																							
Cumulative loan share	USD			(3,793,896)	(4,006,853)	(4,006,853)	(4,006,853)	(4,006,853)	(4,006,853)	(4,006,853)	(4,006,853)	(4,521,094)	(4,957,132)	(4,957,132)	(4,957,132)	(4,957,132)	(4,957,132)	(5,246,363)	(5,246,363)	(5,246,363)	(5,246,363)	(5,246,363)	(5,246,363)	
Repayment of loan (excl. financing fees)	USD				278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	241,333	0
Cost financing fees for repayment of loan	USD				165,186	152,868	140,550	128,232	115,914	103,596	91,278	101,741	108,740	96,422	84,104	71,786	59,468	59,963	47,645	35,327	23,009	10,691	0	1,596,516
Total debt (incl. financing fees)																								**(6,842,880)**
Repayment of loan incl. financing fees	USD				443,243	430,925	418,607	406,289	393,971	381,653	369,335	379,798	386,797	374,479	362,161	349,843	337,525	338,020	325,702	313,384	301,066	288,748	241,333	6,842,880
Debt balance				(6,842,880)	(6,399,637)	(5,968,712)	(5,550,105)	(5,143,816)	(4,749,845)	(4,368,192)	(3,998,856)	(3,619,058)	(3,232,261)	(2,857,782)	(2,495,622)	(2,145,779)	(1,808,254)	(1,470,233)	(1,144,531)	(831,147)	(530,081)	(241,333)	0	
2 Interest rate	3%																							
Cumulative loan share	USD			(3,793,896)	(4,006,853)	(4,006,853)	(4,006,853)	(4,006,853)	(4,006,853)	(4,006,853)	(4,006,853)	(4,521,094)	(4,957,132)	(4,957,132)	(4,957,132)	(4,957,132)	(4,957,132)	(5,246,363)	(5,246,363)	(5,246,363)	(5,246,363)	(5,246,363)	(5,246,363)	
Repayment of loan (excl. financing fees)	USD				278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	241,333	0
Cost financing fees for repayment of loan	USD				127,898	118,360	108,823	99,286	89,748	80,211	70,673	78,775	84,193	74,656	65,119	55,581	46,044	46,427	36,890	27,352	17,815	8,278	0	1,236,129
Total debt (incl. financing fees)																								**(6,482,492)**
Repayment of loan incl. financing fees	USD				405,955	396,418	386,880	377,343	367,805	358,268	348,731	356,832	362,251	352,713	343,176	333,639	324,101	324,484	314,947	305,410	295,872	286,335	241,333	6,482,492
Debt balance				(6,482,492)	(6,076,537)	(5,680,120)	(5,293,240)	(4,915,897)	(4,548,091)	(4,189,823)	(3,841,092)	(3,484,261)	(3,122,010)	(2,769,297)	(2,426,121)	(2,092,482)	(1,768,381)	(1,443,897)	(1,128,950)	(823,540)	(527,668)	(241,333)	0	
2 Interest rate	6%																							
Cumulative loan share	USD			(3,793,896)	(4,006,853)	(4,006,853)	(4,006,853)	(4,006,853)	(4,006,853)	(4,006,853)	(4,006,853)	(4,521,094)	(4,957,132)	(4,957,132)	(4,957,132)	(4,957,132)	(4,957,132)	(5,246,363)	(5,246,363)	(5,246,363)	(5,246,363)	(5,246,363)	(5,246,363)	
Repayment of loan (excl. financing fees)	USD				278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	278,057	241,333	0
Cost financing fees for repayment of loan	USD				239,762	221,882	204,003	186,124	168,245	150,366	132,487	147,674	157,832	139,953	122,074	104,195	86,316	87,034	69,155	51,276	33,397	15,518	0	2,317,291
Total debt (incl. financing fees)																								**7,563,655**
Repayment of loan incl. financing fees	USD				517,819	499,940	482,061	464,182	446,302	428,423	410,544	425,731	435,889	418,010	400,131	382,252	364,373	365,091	347,212	329,333	311,454	293,575	241,333	7,563,655
Debt balance				(7,563,655)	(7,045,836)	(6,545,896)	(6,063,836)	(5,599,654)	(5,153,352)	(4,724,928)	(4,314,384)	(3,888,653)	(3,452,764)	(3,034,754)	(2,634,623)	(2,252,371)	(1,887,998)	(1,522,907)	(1,175,695)	(846,362)	(534,908)	(241,333)	(0)	

12.7.3 Green Funding Scenario (10% Contingency)

Financing Green Funding

Parameters*	Unit	
Grant	%	15%
Loan	%	85%
Debt repayment per year	%	6%
Interest rate	%	0%
Management fee	%	0.25%
Service fee	%	0.18%
Total financing fees	%	0.43%
Loan term	year(s)	20
Grace period	year(s)	3

	Unit		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	Grand total
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
Investment costs	USD			(7,587,792)	(425,913)							(1,028,482)	(872,077)					(578,463)						(10,492,727)
Cumulative debt	USD			(7,587,792)	(8,013,705)	(8,013,705)	(8,013,705)	(8,013,705)	(8,013,705)	(8,013,705)	(8,013,705)	(9,042,187)	(9,914,264)	(9,914,264)	(9,914,264)	(9,914,264)	(9,914,264)	(10,492,727)	(10,492,727)	(10,492,727)	(10,492,727)	(10,492,727)	(10,492,727)	
Grant	USD			(1,138,169)	(63,887)							(154,272)	(130,812)					(86,769)						(1,573,909)
Loan	USD			(6,449,623)	(362,026)							(874,210)	(741,265)					(491,693)						(8,918,818)
Cumulative loan share	USD			(6,449,623)	(6,811,649)	(6,811,649)	(6,811,649)	(6,811,649)	(6,811,649)	(6,811,649)	(6,811,649)	(7,685,859)	(8,427,124)	(8,427,124)	(8,427,124)	(8,427,124)	(8,427,124)	(8,918,818)	(8,918,818)	(8,918,818)	(8,918,818)	(8,918,818)	(8,918,818)	
Repayment of loan (excl. financing fees)	USD						535,129	535,129	535,129	535,129	535,129	535,129	535,129	535,129	535,129	535,129	535,129	535,129	535,129	535,129	535,129	535,129	356,753	0
Cost financing fees for repayment of loan	USD						26,989	24,688	22,387	20,086	17,785	19,243	20,129	17,828	15,527	13,226	10,925	10,738	8,437	6,136	3,835	1,534	0	239,494
Total debt (incl. financing fees)																								**(9,158,311)**
Repayment of loan incl. financing fees	USD						562,118	559,817	557,516	555,215	552,914	554,372	555,258	552,957	550,656	548,355	546,054	545,867	543,566	541,265	538,964	536,663	356,753	9,158,311
Debt balance				(9,158,311)	(9,158,311)	(9,158,311)	(8,596,193)	(8,036,376)	(7,478,860)	(6,923,645)	(6,370,732)	(5,816,360)	(5,261,101)	(4,708,144)	(4,157,488)	(3,609,133)	(3,063,079)	(2,517,211)	(1,973,645)	(1,432,380)	(893,416)	(356,753)	(0)	

Financing Green Funding 10 yrs

Parameters*	Unit	
Grant	%	15%
Loan	%	85%
Debt repayment per year	%	6%
Interest rate	%	0%
Management fee	%	0,25%
Service fee	%	0,18%
Total financing fees	%	0,43%
Loan term	year(s)	10
Grace period	year(s)	3

	Unit		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Total
			1	2	3	4	5	6	7	8	9	10	
Investment costs	USD			-10.725.374									
Cumulative debt	USD			-10.725.374	-10.725.374	-10.725.374	-10.725.374	-10.725.374	-10.725.374	-10.725.374	-10.725.374	-10.725.374	
Grant	USD			-1.608.806									
Loan	USD			-9.116.568									
Cumulative loan share	USD			-9.116.568	-9.116.568	-9.116.568	-9.116.568	-9.116.568	-9.116.568	-9.116.568	-9.116.568	-9.116.568	
Repayment of loan (excl. financing fee	USD			0	0	0	-1.519.428	-1.519.428	-1.519.428	-1.519.428	-1.519.428	-1.519.428	-9.116.568
Cost financing fees for repayment of l	USD			0	0	0	45.735	52.268	58.802	65.335	71.869	78.402	372.412
Total debt (incl. financing fees)													-9.488.979
Repayment of loan incl. financing fee	USD			0	0	0	-1.473.693	-1.467.160	-1.460.626	-1.454.093	-1.447.559	-1.441.025	
Debt balance				0	0	0	-1.473.693	-2.940.853	-4.401.479	-5.855.571	-7.303.130	-8.744.156	

12.8 NGEST Power Requirements

Table 12-15: Projected design load as of current planning supplied by PWA on 10.04.2015

No.	Components Description	Required Power (MVA) Phase 1 (treatment capacity up to 35,600 m³/d) Horizon 2018				Phase 2 (treatment capacity 65,700 m³/d) Horizon 2025
		2015	2016	2017	2018	2025
1	**TPS** (5 pumps, conveyors and 2 racked screens) Pressure line (7 km) 9 Infiltration Basins	1.75	2	2	2	3
2	Waste Water Treatment Plant (includes pretreatment, activated sludge, final clarifiers, digesters, sludge silos, power building, dewatering and sludge storage area)	2.5	2.75	3	3	5
3	Recovery and Reuse Scheme: Stage 1* (under Phase 1) (includes: 15 Recovery Wells,5 monitoring wells, 5 booster pumps, 1 tank and irrigation network for 500 hectares with connections and valves) (this stage will recover 16,500 m³/day)	0	2	2	2	2
	Stage 2* (under Phase 1) (includes: 14 Recovery Wells, 5 monitoring wells, 5 booster pumps, 1 tank and irrigation network for 1000 hectares with connections and valves) (this stage will recover 39,160 m³/day)	0	0	0	4	4
4	Recovery Scheme (extension) (under Phase 2)** (includes: additional 24 Recovery Wells, monitoring wells, booster pumps, collection tanks and irrigation network for additional agri-cultural land) (this stage planned to recover 72,270 m³/day)	0	0	0	0	4
	Total	**4.25**	**6.75**	**7**	**11**	**18**