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An-Najah National University

Med-EcoSuRe

Implementation process Report

Implementation process of pilot PV projects and Lamp Replacement at An-Najah National university

An-Najah national university (ANNU)

2023

Project Acronym	Med ECOSURE
Project Name	"Mediterranean University as Catalyst for Eco-Sustainable Renovation" (Med-EcoSuRe)
Project Duration	September 2019- August 2023
Website	www.enicbcmed.eu/projects/med-ecosure
Authors	An-Najah National University (ANNU)
Date	August2023
File Name	Implementation process of pilot PV projects and Lamp Replacement at An-Najah National university report

This project is part of the Mediterranean University as Catalyst for Eco-Sustainable Renovation (Med-EcoSuRe). The project aims to implement full scale experimentation of innovative retrofit technologies, validation and testing in real lifein An-Najah university campuses, in order to allow a relevant energy demand reduction and mitigate greenhouse gas emission.

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1. Literature and Educational –old campus

1.1. Introduction

ANNU through the project has carried out implementation of top-roof PV system in old campus in Nablus, in order to reduce the energy consumption annually of old campus by 11% with available free shadow space on roof around 700 m2.

Table I. Geographical site and roof space- faculty of humanities

Location coordinate	32°13'12.69"N,35°14'37.56"E
Height from sea level	616.7 m
Building occupied area	2968.6 m2
Free shadow, available area	700 m2

Table II. Geographical site and roof space- faculty of Educational Sciences

Location coordinate	32°13'14.09"N,35°14'37.64"E
Height from sea level	612 m
Building occupied area	1719.4 m2
Free shadow, available area	300 m2

Table III. Design parameters of the PV plant

Design parameters	Characteristics
Year of construction	2020/2021
Type of plant	roof-mounted, fixed
Orientation and tilt	South, 27 degree
Installed nominal power	145 kWp
Module type	Monocrystalline
The number of PV module	366 (140 panel3 390Wp & 226 panel3 400Wp)
Inverters	13 ABB PVS-50-SX & 23 ABB PVS-50-SX2

1.2. Major methodology of retrofit technology implementation

Selectionprocess&acquiring devices

After analyzing the site, and according the free shadow space on roof and considering the shadow distance between PV array, the initial design and PV array distribution was shown in fig.1.

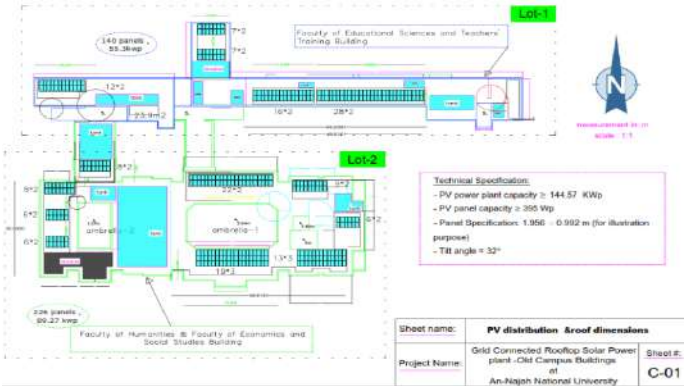


Fig.1PV system initiative design

After checking the system design and yield using PVSol software, it was confirmed that the system distribution on roof has no object around may affect the PV performance negatively, and thus the budgetary estimation was done to analyze the project cost and its feasibility.

Therefore, in order to choose the best offers for devices and civil & electrical site work in terms of technical effectiveness and lowest offers, the tender dossier was prepared as follow:

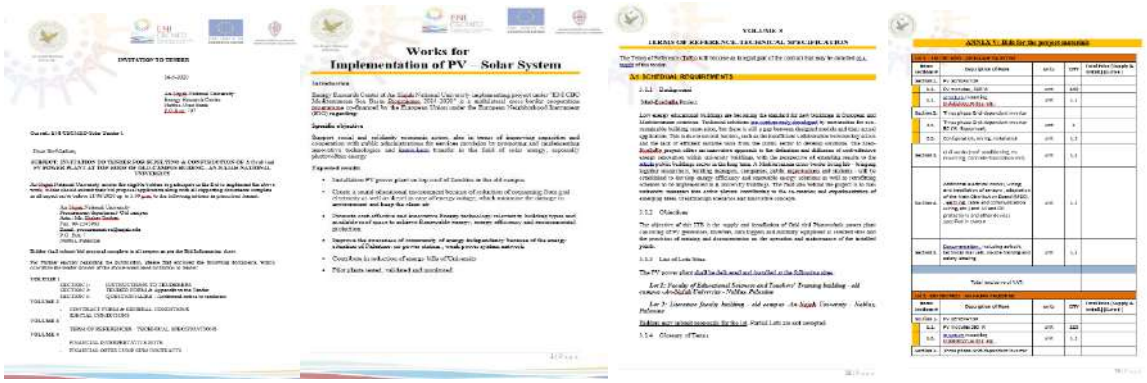


Fig.2 tender dossier

The tender call was published on 14/5/2020 as follow:

https://www.najah.edu/ar/tenders/rfq-12119/

RFQ 12119 اعلان طرح عطاء

تدعو جامعة النجاح الوطنية الشركات المتخصصة والراغبة بالمشاركة في العطاء المذكور بالجدول:

#	رقم العطاء	موضوع العطاء	ثمن نسخة العطاء	موعد الطرح	الموعد النهائي لتقديم عروض الأسعار: التاريخ	الموعد النهائي لتقديم عروض الأسعار: الساعة
1	RFQ- 12119	توريد وتركيب وتشغيل نظام طاقة شمسية كلية التربية والآداب، وحسب المواصفات في نسخة العطاء	500 شيكل	2020/5/14	2020/6/11	PM 13:00

وحسب الشروط التالية:

1. ضرورة إرفاق الرخصة التجارية و السيرة الذاتية للشركة مع عرض السعر
2. يعد العطاء مصحوبا بتامين نقدي او شيك مصدق او كفالة بنكية تعادل (2500 يورو) كفالة دخول عطاء .
3. تكاليف الاعلان على من يرسو عليه العطاء .
4. ثمن نسخة العطاء غير مسترد .
5. فاتورة ضريبية.

على الراغبين بالاشتراك في العطاء المذكور مراجعة دائرة اللوازم والمشتريات / قسم العطاءات مكتب رقم 7120 في مبنى الإدارة العامة الحرم القديم – نابلس. للحصول على نسخة من وثائق العطاء بعد دفع الرسوم المحظورة اعلاه ، او من خلال دفع ثمن كراسة العطاء في احد البنوك تصالح جامعة النجاح الوطنية وارسال صورة الوصل البريد الالكتروني procurement.cu@najah.edu

للاستفسار يرجى الاتصال على

دائرة اللوازم والمشتريات – هاتف 2345113-09-0970 - فاكس: 2345982-0-970+ البريد الالكتروني: procurement.cu@najah.edu

لمتابعة العطاءات يرجى زيارة الموقع الالكتروني لجامعة النجاح الوطنية www.najah.edu

Fig.3 tender call

During the tenderer offers preparation, a tour visit was organized by ANNU on 1/6/2020 to inspect the site and replying their query. And then the tender call was closed on 11/6/2020, and the applicants were as follow:

1- ITEC
2- Excellent Systems
3- Triple R
4- MTSC
5- SATCO
6- Alawael
7- 3K

Then the offers were evaluated technically and financially, to select the best offer for supplying materials and implementing the project.

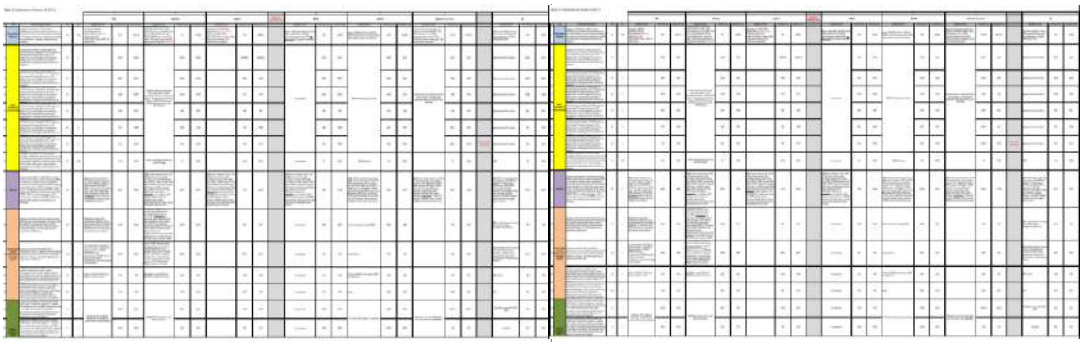


Fig.4 Technical & financial evaluation

Then according to the tender committee, the tender has been awarded to 3K company, and the work agreement /PO was signed between ANU and 3K to start the implementation activity and purchasing the project materials.

Fig.5 Purchasing order agreement

Implementation stage

Work plan and design approval

Before the contractor initiate the implementation process on the site, the work plan, designs and equipment information are sent by contractor in order to get ANNU approval of them and giving an order directly to work to contractor.

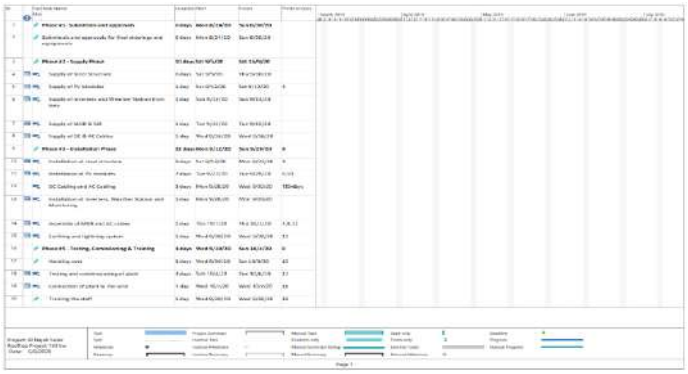
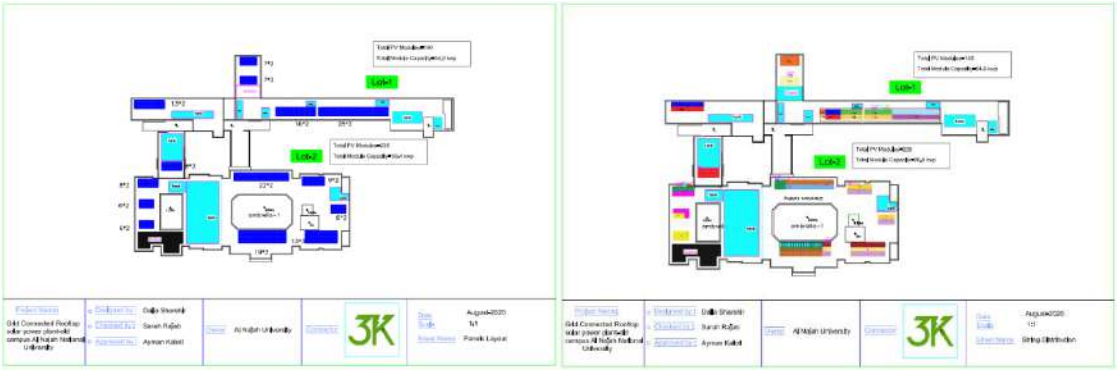


Fig.6 work plan

The design by 3k which include; distribution of array, connection with inverter and MDB of building, was provided as follow:



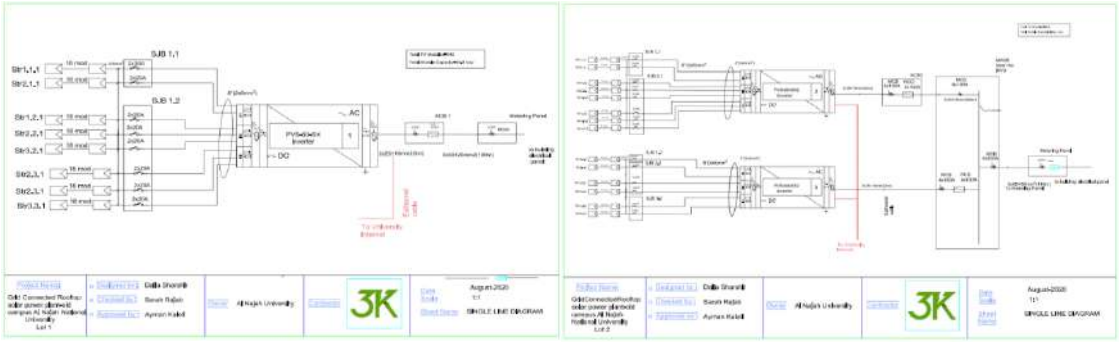


Fig.7 3k connection drawing

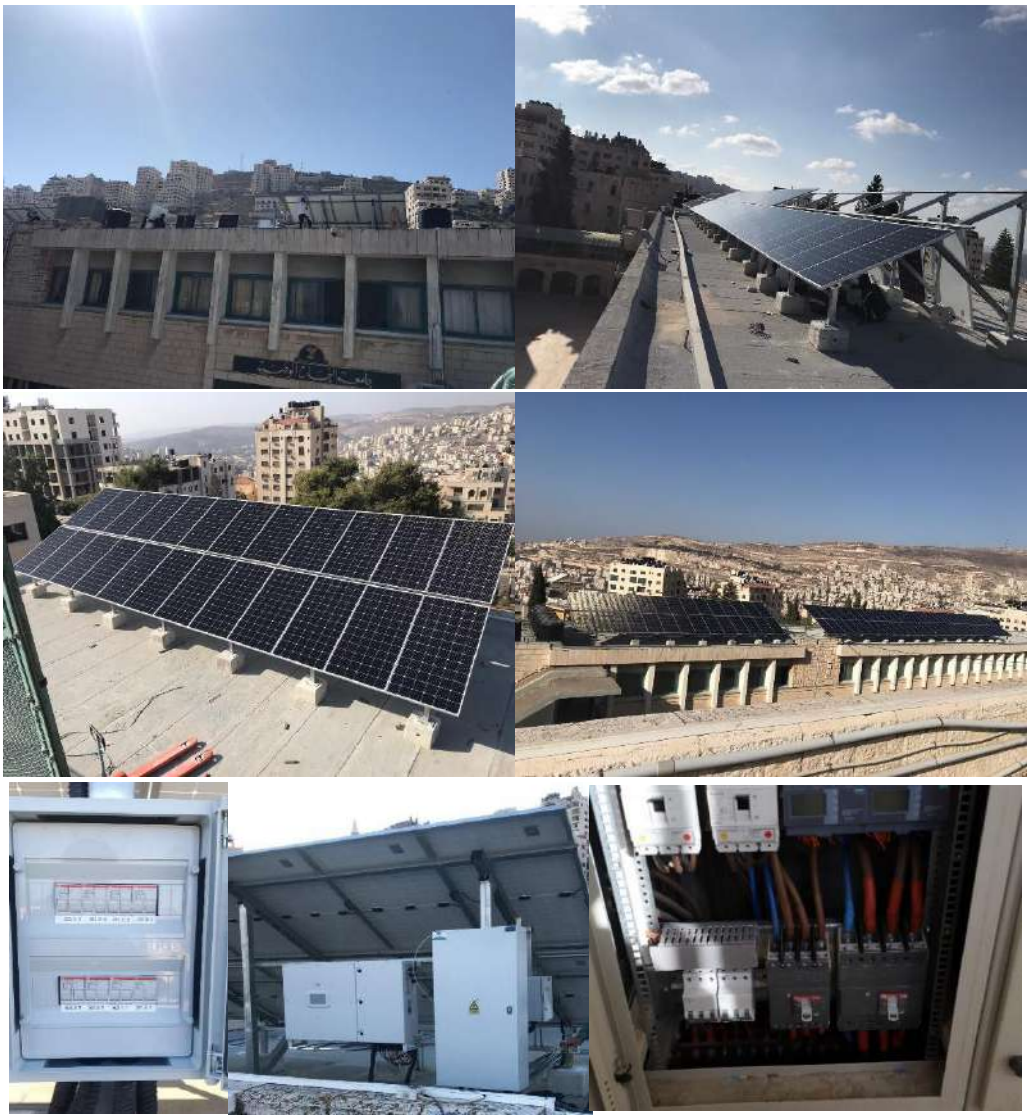
Civil & electrical Site Work

After taking the approval from ANNU, the contractor company start purchasing the components and manufacturing the steel structure and cement base, then they start implementing the project as follow:

1- Delivery of project materials to the siteand distribute the cement foundation

2- Install the steel structure

3- Install PV panels, inverter and connected the main AC cables with university electrical board.



4- All the cables were installed in tranches and trunks for aaesthetic image of the project and facilitate the maintenance work in future

5- Then the DC/AC eacrthing was connected and lightning Pulsar

6- Finally the energy meters, weatherstations sensors were installed and configured with monitoring portal -Aurora Vision® Plant Management Platform for performance monitoring, condition monitoring and data reporting

Fig.8 PV system implementation process

Validation stage

In order to operate the system successfully, the system components were checked and test by civil and electrical engineering in university during the implementation process to inspect the work and then a test was conduct before the system operation completely.

So three levels of commissioning and system testing was conduct as follow:

- **Level-1: site acceptance Inspection**

The acceptance of the site to install the equipment of the PV system is responsibility of the installing contractor (in our case 3k Company) and to start implementing the concrete base, galvanized steel structure.

- **Level-2: Pre-functional testing**

Characteristics and Visual Inspection test

- **Level-3: performing operational test**

In the last point of the project commissioning, the PV solar plant components during operation are checked and the successful operation of project is checked.
Operational test was done according to International Electro technical commission (IEC) recommendation [IEC 62446], to ensure that the system is properly installed and performing optimally.

The test has been carried out as follow:

- ✓ Tests to all DC circuit(s) forming the PV array, which include the following tests:
- ✓ Tests to all AC circuit(s)

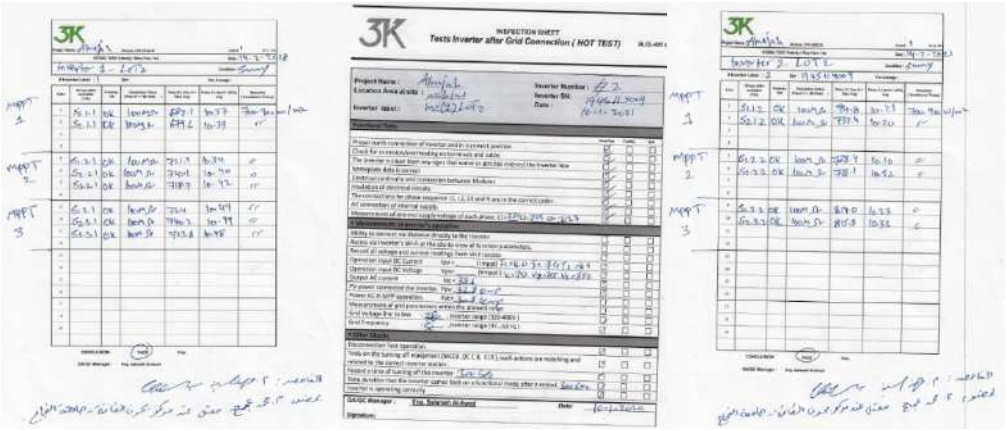
The equipment's that have been used for testing are all calibrated by authorized utility as follow:


Digital Earth resistance test device


Power analyzer device


HT AC clamp meter

The result of test was as follow:



2. Carport-Fine Arts Faculty-New Campus

2.1. Introduction

ANNU through the project has carried out implementation of solar PV carport system in new campus in Nablus, in order to reduce the energy consumption annually and As part of the university's constant endeavor towards increasing the coverage of solar cell systems for the university's total consumption by exploiting the spaces on the one hand, and on the other hand, the university's desire to spread new ideas for the implementation of solar energy projects, the idea of the solar garage was come up..

Table IV. Geographical site of garage

Location coordinate	32°13'38.7"N,35°13'17.1"E
garage occupied area	198 m2
available area for carport	432 m2

Table V. Design parameters of the PV plant

Design parameters	Characteristics
Year of construction	2022
Type of plant	Ground mounted, fixed
Orientation and tilt	South, 10 degree
Installed nominal power	50 kWp
Module type	Monocrystalline
The number of PV module	105 panel3 465Wp
Inverters	13 SMA Sunny Tripower Core1- 50 kwp

2.2. Major methodology of retrofit technology implementation

Selection process & acquiring devices

After analyzing the site, and considering the shadow distance between PV rows, the initial design and PV array distribution was shown in fig.9.

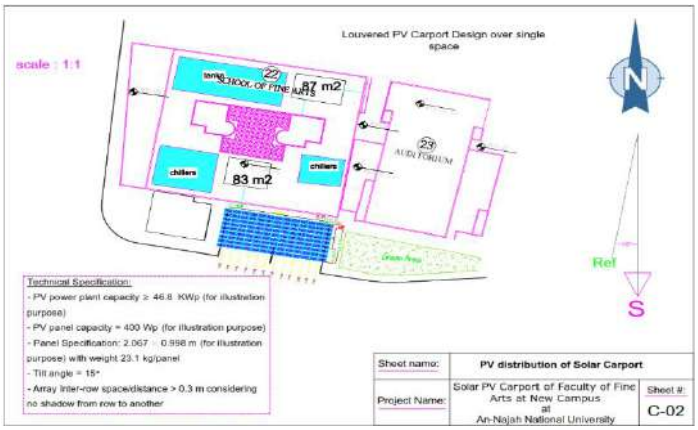


Fig.9PV system initiative design

After checking the system design and yield using PVSol software, and the budgetary estimation was done to analyze the project cost and its feasibility.

Therefore, in order to choose the best offers for devices and civil & electrical site work in terms of technical effectiveness and lowest offers, the tender dossier was prepared as follow:

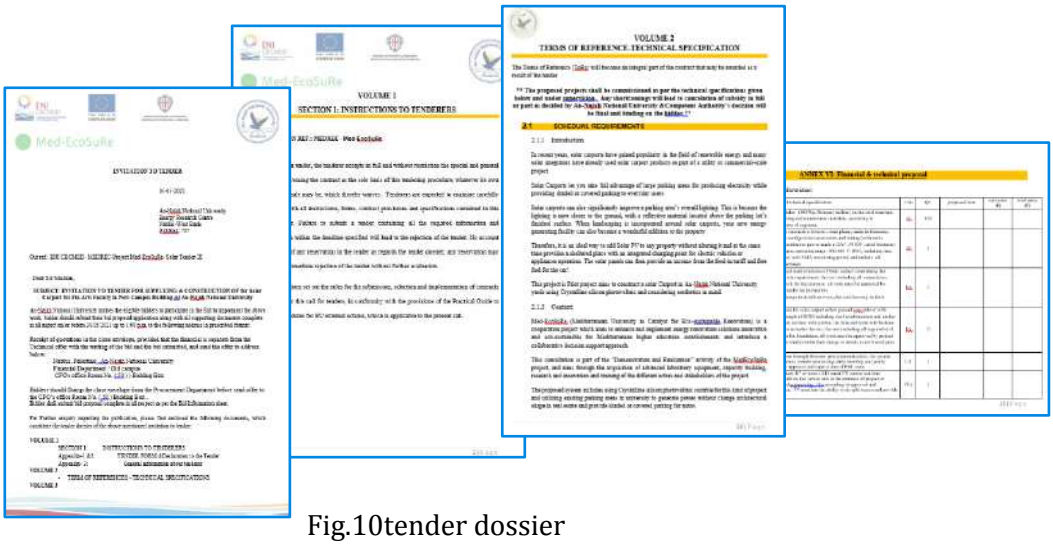


Fig.10tender dossier

The tender call was published on 5/5/2021 as follow:

https://www.najah.edu/ar/tenders/rfq-12348/

Fig.11tender call

During the tenderer offers preparation, a tour visit was organized by ANNU on 17/5/2021 to inspect the site and replying their query. And then the tender call was closed on 30/5/2021, and the applicants were as follow:

8- 3k Solar
9- SATCO
10- Sunergy

Then the offers were evaluated technically and financially, to select the best offer for supplying materials and implementing the project

Fig.12Technical & financial evaluation

Then according to the tender committee, the tender has been awarded to SATCO company, and the work agreement/POwas signed between ANU and SATCO to start the implementation activity and purchasing the project materials.

Fig.13Purchasing order agreement

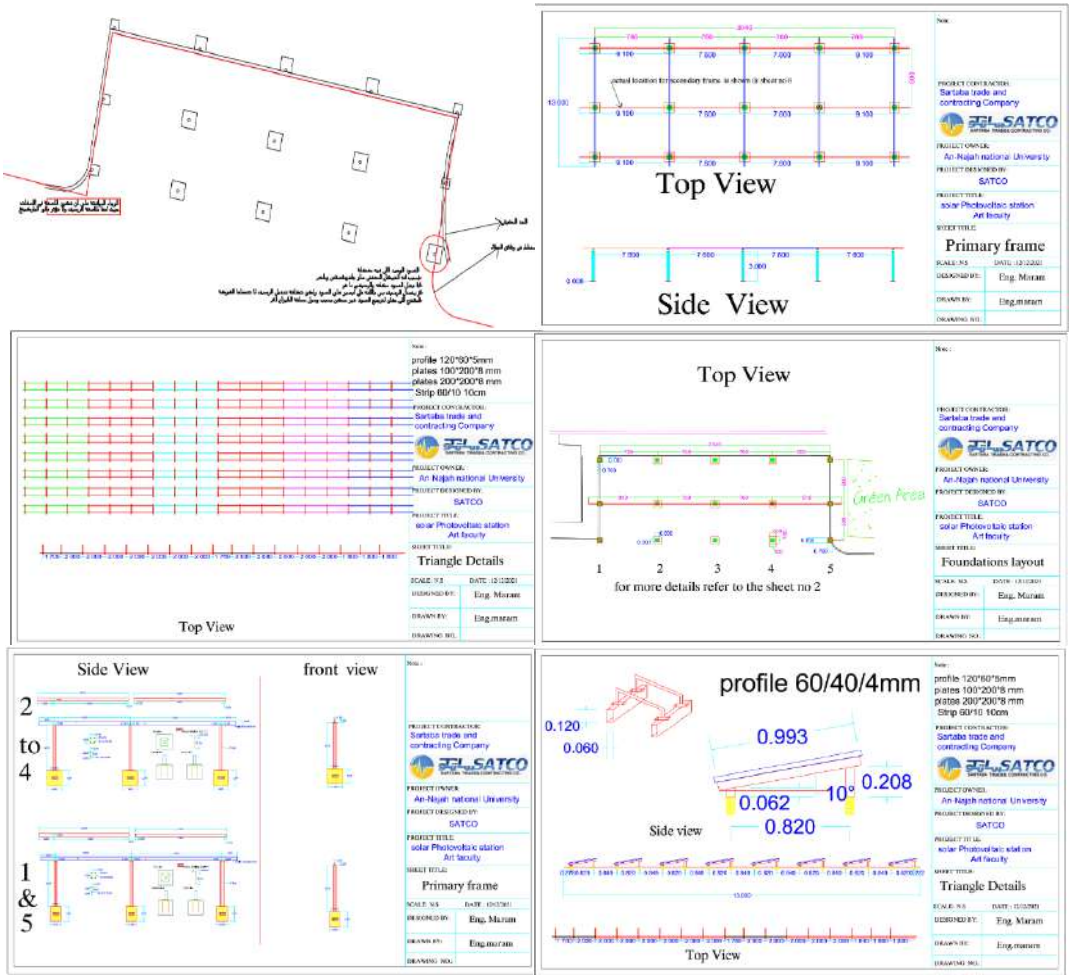
Implementation stage

Work plan and design approval

Before the contractor initiate the implementation process on the site, the work plan, designs and equipment information are sent by contractor in order to get ANNU approval of them and giving an order directly to work to contractor.

Fig.14 work plan

The design by AutoCADwhich include; distribution of array, connection with inverter and MDB of building, was provided as follow:



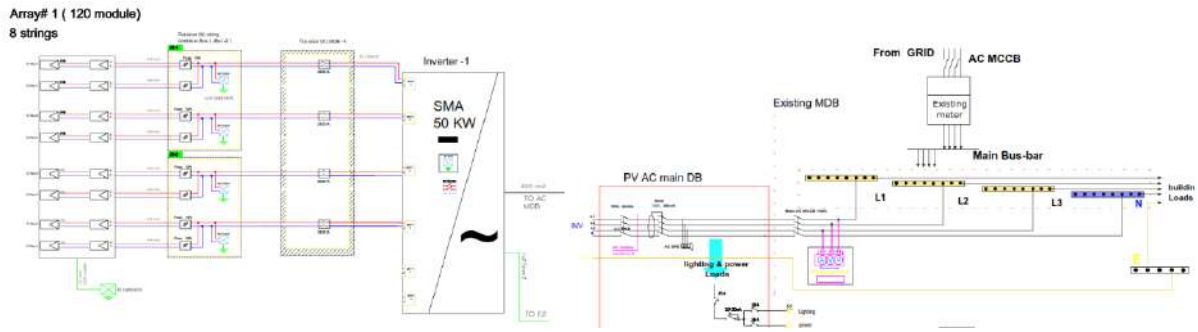


Fig.15 SATCO connection drawing

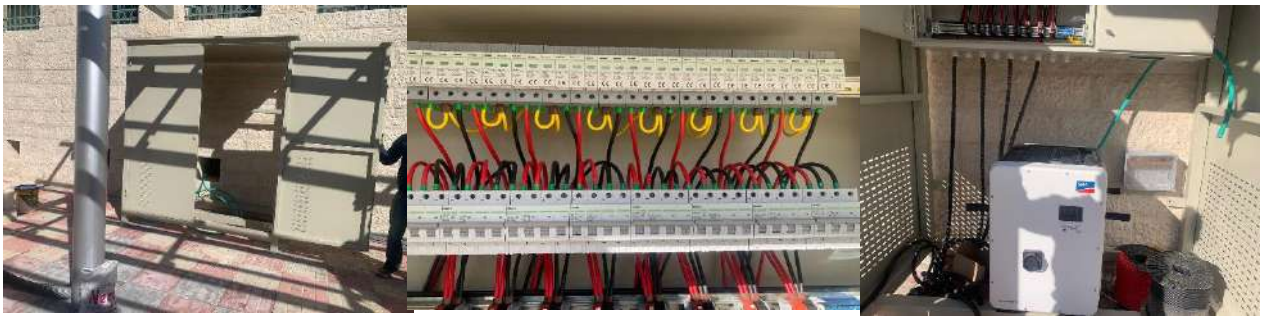
Civil & electrical Site Work

After taking the approval from ANNU, the contractor company start purchasing the components and manufacturing the steel structure and cement base, then they start implementing the project as follow:

7- Delivery of project materials to the siteand prepare distribute the column for foundation preparation

8- Install the steel structure

9- Install PV panels, inverter and connected the main AC cables with university electrical board.



10- All the cables were installed in tranches and trunks for aesthetic image of the project and facilitate the maintenance work in future

11- Then the DC/AC eacrthing was connected and lightning Pulsar

12- Finally the energy meters was installed and configured with monitoring portal –SMA Sunny Portal powered by ennexOSfor performance monitoring, condition monitoring and data reporting

Fig.16PV system implementation process

Validation stage

In order to operate the system successfully, the system components were checked and test by civil and electrical engineering in university during the implementation process to inspect the work and then a test was conduct before the system operation completely.

So three levels of commissioning and system testing was conduct as follow:

- **Level-1: site acceptance Inspection**

The acceptance of the site to install the equipment of the PV system is responsibility of the installing contractor (in our case 3k Company) and to start implementing the concrete base, galvanized steel structure.

- **Level-2: Pre-functional testing**

Characteristics and Visual Inspection test

- **Level-3: performing operational test**

In the last point of the project commissioning, the PV solar plant components during operation are checked and the successful operation of project is checked.
Operational test was done according to International Electro technical commission (IEC) recommendation [IEC 62446], to ensure that the system is properly installed and performing optimally.

The test has been carried out as follow:

- ✓ Tests to all DC circuit(s) forming the PV array, which include the following tests:
- ✓ Tests to all AC circuit(s)

The equipment's that have been used for testing are all calibrated by authorized utility as follow:

Digital Earth resistance test device

Power analyzer device

HT AC clamp meter

The result of test was as follow:

SARTABA TRADE & CONTRACTING CO.

2022/3/2 :التاريخ

اسم المشروع : تزويد وتركيب SOLAR PV Carport في مواقف السيارات الجنوبي لمبنى كلية الفنون الجميلة
رقم المشروع : RFQ-12348

الموضوع: test report

Inverter 50kw	V OC V	V MPPT V	I MPPT A	TIME	resistance value / ohm	NOTE
STRING 1	755	612	13	11:05 AM		
STRING 2	761	614	12.98	11:05 AM		
STRING 3	736	622	12.85	11:05 AM		
STRING 4	736	612	13.05	11:05 AM	1.25	
STRING 5	735	628	13	11:05 AM		
STRING 6	747	605	12.95	11:05 AM		
STRING 7	740	612	12.98	11:05 AM		

شركة سانكو
م. ايمن فوزي بني فضل

العميل/
التوقيع:

شركة سرطبة (سانكو)
للمقاولات والتعهدات العامة العالمية

المنطقة الصناعية – عقربا – نابلس – فلسطين ، هاتف :٨ / ٢٤٩٨٣٠٧ ٠٩ ٠٧٠ + فاكس: ٢٤٩٨٣٢٧ ٠٩ ٠٧٠ +
Industrial zone,Aqraba,Nablus-Palestine, Tel:+970 9 2598307/8, FAX:+970 9 2598637

Fig.17PV system test report

3. Solar Tree-University`s Yard-New Campus

3.1. Introduction

ANNU through Med-EcoSuRe project had conducted Full scale experimentation of innovative retrofit technologies for example **solar tree with technology of PV glass** which is an independent unit that produces green energy and provides a place of comfort and energy for a wide variety of services and thus contribute in:

- Providing visibility of the energy that is being used across campus to facilitate culture change within the ANNU community
- Allowing Academics and Students to use the Estate as a living lab for sustainability research by providing appropriate data

Table VI. Geographical site of garage

Location coordinate	32°13'38.5"N,35°13'21.2"E
available area	All yards of campus

Table VII. Design parameters of the PV plant

Design parameters	Characteristics
Year of construction	2022
Type of plant	Ground mounted, fixed
Orientation and tilt	Azimuth angle 60, 0 , 30 degree, inclination angle 11 degree
Installed nominal power	3.18kWp

Module type	Monocrystalline
The number of PV module	12 panel3 265Wp
Inverter/Charger	13Victron Energy- 48/3000 Wp, 13SmartSolar MPPT 250/60-TR
Battery	Lithium battery-BOX premium LVS 4.0

3.2. Major methodology of retrofit technology implementation

Selection process & acquiring devices

After analyzing the site, and considering the shadow distance from surrounding tree and objects, the initial design and PV array distribution was done.

After checking the system design, the budgetary estimation was done to analyze the project cost and its feasibility.

Therefore, in order to choose the best offers for devices and civil & electrical site work in terms of technical effectiveness and lowest offers, the tender dossier was prepared as follow:

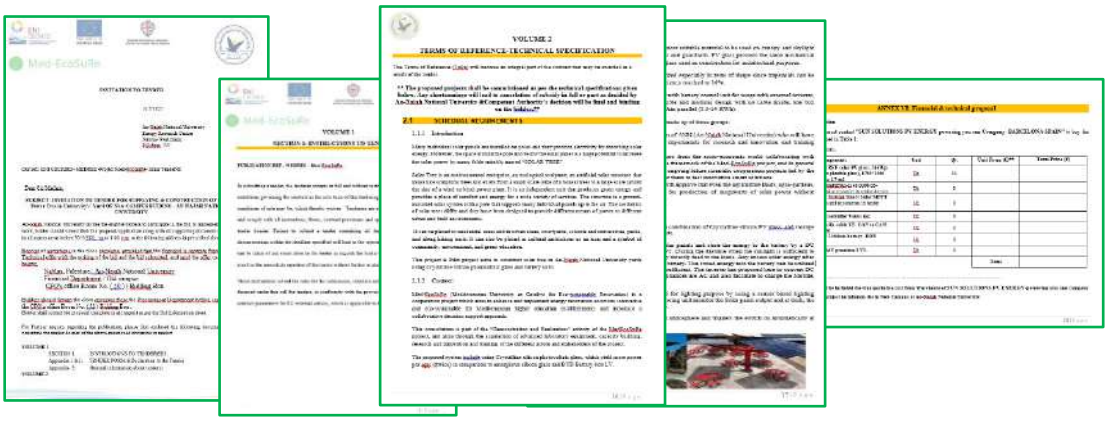


Fig.18 tender dossier

The tender call was published on 10/5/2021, And the bid was resubmitted on 31/5/2021 as follow:

https://www.najah.edu/ar/tenders/rfq-12353/
https://www.najah.edu/ar/tenders/0-23/

Fig.19 tender call

During the tenderer offers preparation, a tour visit was organized by ANNU on 17/5/2021 to inspect the site and replying their query. And then the tender call was closed on 10/6/2021, and the applicants were as follow:

11- 3k Solar
12- SATCO

Then the offers were evaluated technically and financially, to select the best offer for supplying materials and implementing the project.

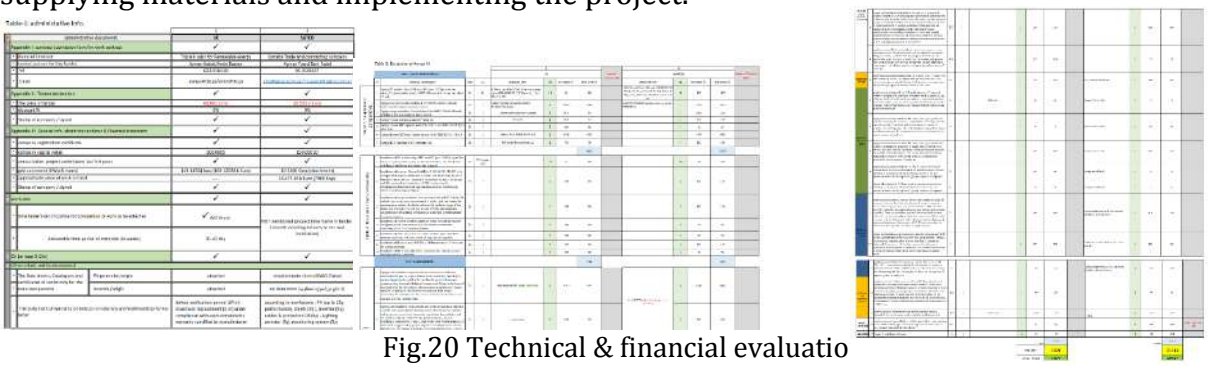


Fig.20 Technical & financial evaluatio

Then according to the tender committee, the tender has been awarded to 3k company, and the work agreement/POwas signed between ANU and 3k to start the implementation activity and purchasing the project materials.

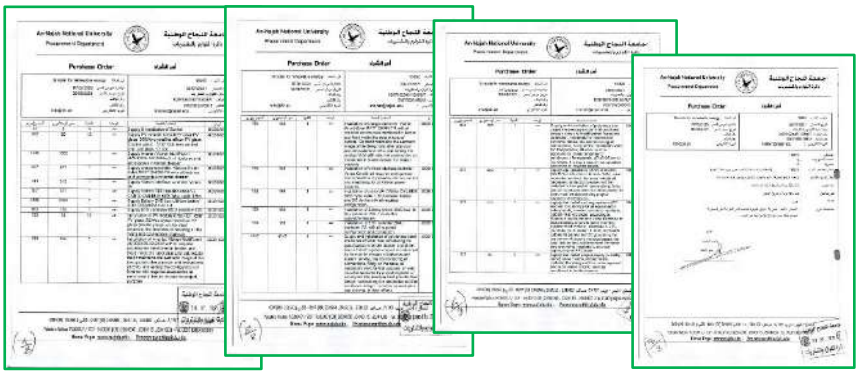


Fig.21 Purchasing order agreement

Implementation stage

Work plan and design approval

Before the contractor initiate the implementation process on the site, the work plan, designs and equipment information are sent by contractor in order to get ANNU approval of them and giving an order directly to work to contractor.

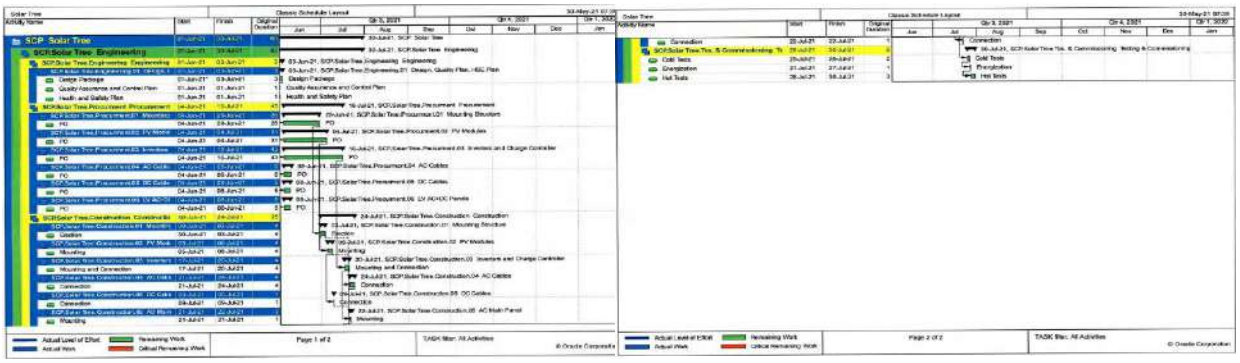


Fig.22 work plan

The design by AutoCADwhich include; distribution of array, connection with component, was provided as follow:

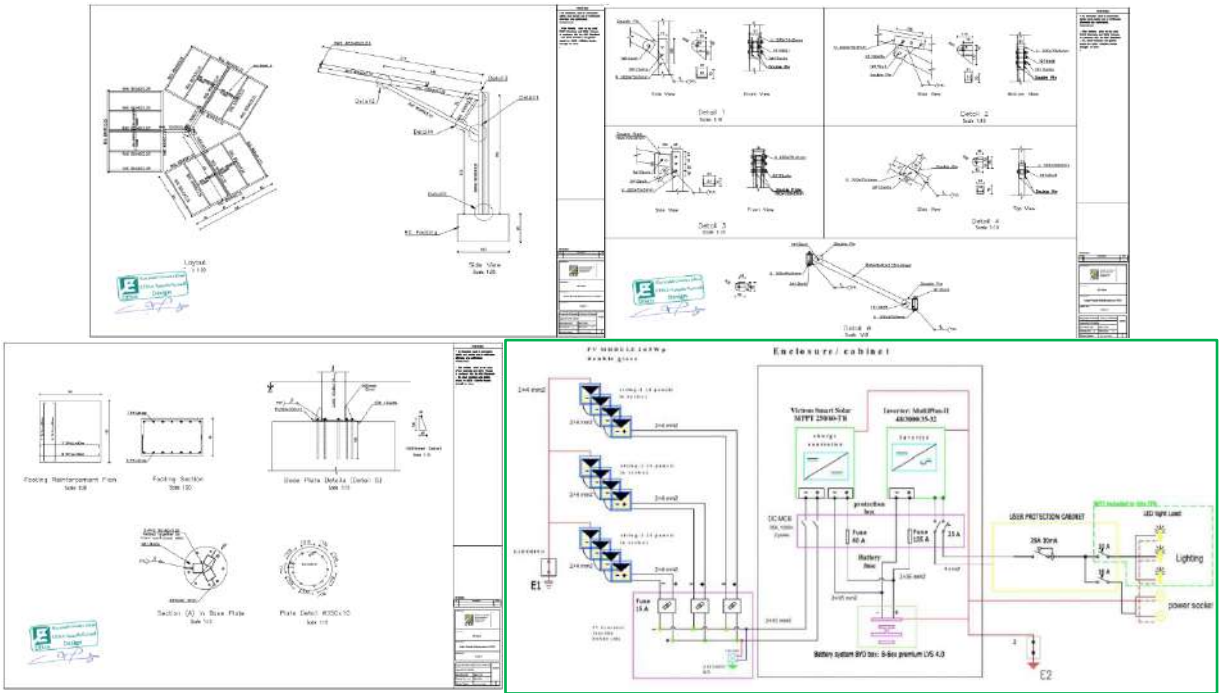


Fig.23 3k design & connection drawing

Civil & electrical Site Work

After taking the approval from ANNU, the contractor company start purchasing the components and manufacturing the steel structure and cement base, then they start implementing the project as follow:

13- Prepare the site

14- Implement the foundation




15- Install the steel structure




16- Install PV panels



17- Install inverter/charger and connect all components and all the cables were installed in tranches and trunks for aesthetic image of the project and facilitate the maintenance work in future

18- Then the DC/AC earthing was connected and lightning Pulsar

19- Then the energy meters was installed and configured with monitoring portal – victronEnergy Portal for performance monitoring, condition monitoring and data reporting

20- Finally, Automated Water Purification & Cleaning Technology, to clean PV system on frequence bases

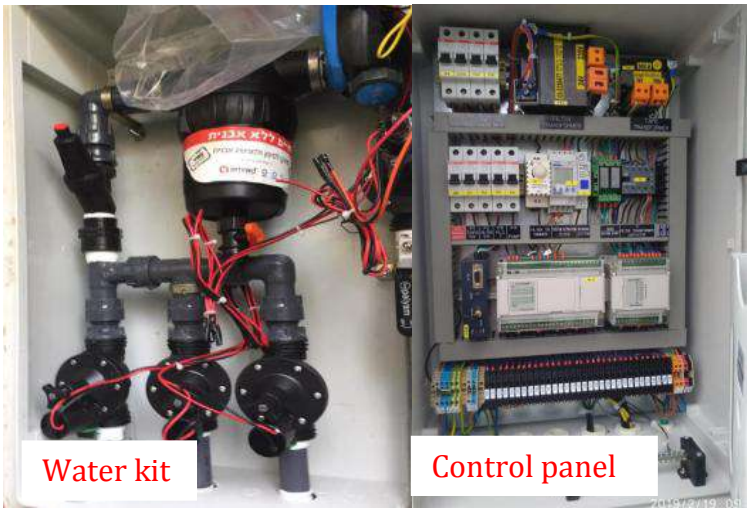


Fig.24 PV system implementation process

Validation stage

In order to operate the system successfully, the system components were checked and test by civil and electrical engineering in university during the implementation process to inspect the work and then a test was conduct before the system operation completely.

So three levels of commissioning and system testing was conduct as follow:

- **Level-1: site acceptance Inspection**

The acceptance of the site to install the equipment of the PV system is responsibility of the installing contractor (in our case 3k Company) and to start implementing the concrete base, galvanized steel structure.

- **Level-2: Pre-functional testing**

Characteristics and Visual Inspection test

- **Level-3: performing operational test**

In the last point of the project commissioning, the PV solar plant components during operation are checked and the successful operation of project is checked.
Operational test was done according to International Electro technical commission (IEC) recommendation [IEC 62446], to ensure that the system is properly installed and performing optimally.

The test has been carried out as follow:

- ✓ Tests to all DC circuit(s) forming the PV array, which include the following tests:
- ✓ Tests to all AC circuit(s)

The equipment's that have been used for testing are all calibrated by authorized utility as follow:


Digital Earth resistance test device


Power analyzer device


HT AC clamp meter

The result of test was as follow:

Project Name:	NNU Solar Tree
Form:	Testing Report
DC Side	
Test Before Operation	
Test	Measurements
DC Voltage for string input 1 (V)	152
DC Voltage for string input 2 (V)	151
DC Voltage for string input 3 (V)	151.5
DC Current for string input 1 (A)	8.92
DC Current for string input 1 (A)	8.93
DC Current for string input 1 (A)	8.92
DC Voltage for MPPT input	152
DC Current for MPPT input	26.79
Test After Operation	
Test	Measurements
DC Voltage for string input 1 (V)	128
DC Voltage for string input 2 (V)	128.1
DC Voltage for string input 3 (V)	127.9
DC Current for string input 1 (A)	8.39
DC Current for string input 1 (A)	8.38
DC Current for string input 1 (A)	8.39
DC Voltage for MPPT input	128
DC Current for MPPT input	25.17
AC Side	
Test	Measurements
AC Voltage	220
AC Current	3A
Earthing Resistance	
Test	Measurements
Earthing Resistance	3.9
Comments:	
The AC Current value was measuered hen we added a testing load.	

Fig.25 PV system test report

4. Faculty of Agriculture and Veterinary Medicine building

4.1. Introduction

ANNU through the project has carried out implementation of top-roof PV system in Faculty of Agriculture and Veterinary Medicine building in Tulkarem, in order to reduce the energy consumption annually of campus by 60% with available free shadow space on roof around 900 m2.

Table VIII. Geographical site of project

Location coordinate	32°18'52.2"N,35°01'20.0"E
available area	900

Table IX. Design parameters of the PV plant

Design parameters	Characteristics
Year of construction	2022
Type of plant	Top-roof mounted, fixed
Orientation and tilt	South, 22 degree
Installed nominal power	77.76kWp
Module type	Monocrystalline
The number of PV module	144 panel3540Wp
Inverter	13sungrow- 50 kWp + 13Sungrow 33Kw

4.2. Major methodology of retrofit technology implementation

Selection process & acquiring devices

After analyzing the site, and according the free shadow space on roof and considering the shadow distance between PV array, the initial design and PV array distribution was shown, in fig.26.

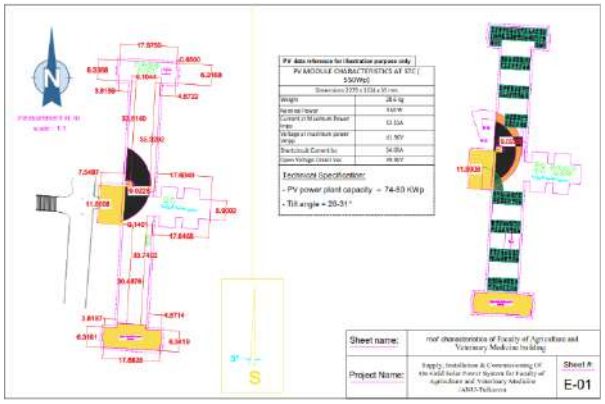


Fig.26PV system initiative design

After checking the system design, the budgetary estimation was done to analyze the project cost and its feasibility.

Therefore, in order to choose the best offers for devices and civil & electrical site work in terms of technical effectiveness and lowest offers, the tender dossier was prepared as follow:

Fig.27 tender dossier

The tender call was published on 26/12/2021, as follow:

https://www.najah.edu/ar/tenders/rfq-12519/

Fig.28 tender call

During the tenderer offers preparation, a tour visit was organized by ANNU on 10/1/2022 to inspect the site and replying their query. And then the tender call was closed on 16/1/2022, and the applicants were as follow:

1) Hybrid company
2) Abaad Contracting Company
3) triple R for trading and marketing
4) AGEC
5) MSADER
6) SATCO
7) trust energy
8) alawael

Then the offers were evaluated technically and financially, to select the best offer for supplying materials and implementing the project

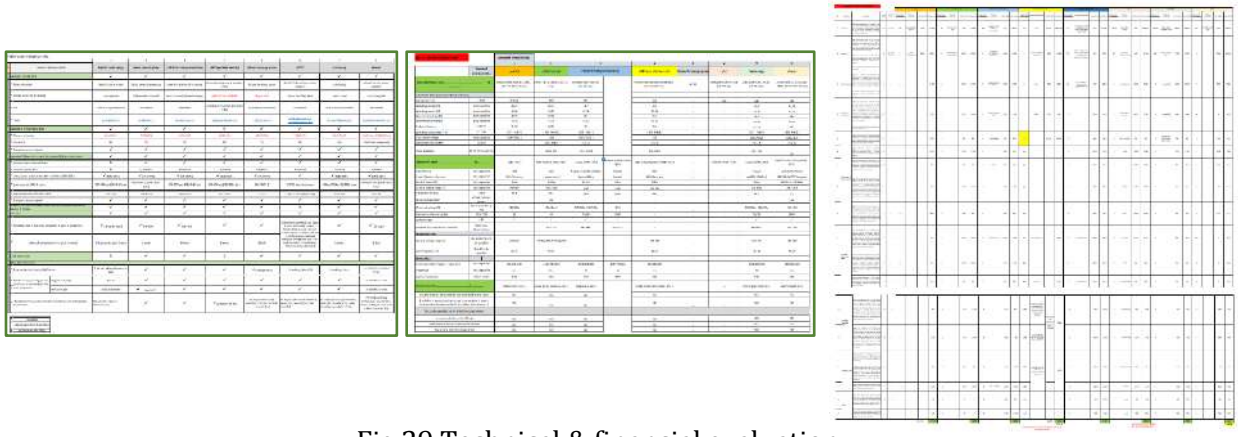


Fig.29 Technical & financial evaluation

Then according to the tender committee, the tender has been awarded to Alawael company, and the work agreement/POwas signed between ANU and Alawael to start the implementation activity and purchasing the project materials.

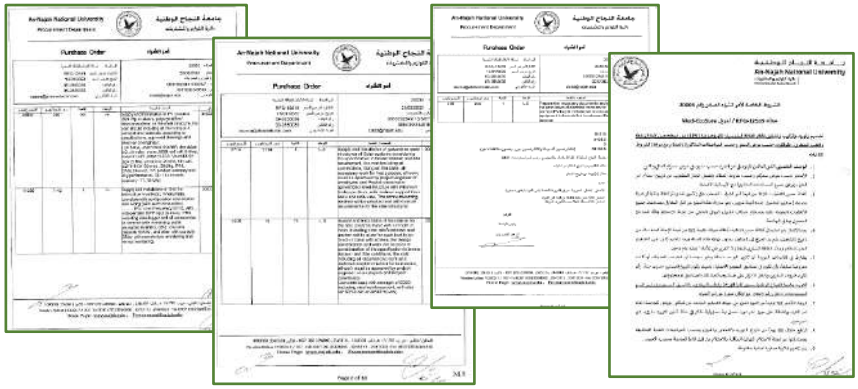


Fig.30 Purchasing order agreement

Implementation stage

Work plan and design approval

Before the contractor initiate the implementation process on the site, the work plan, designs and equipment information are sent by contractor in order to get ANNU approval of them and giving an order directly to work to contractor.

Fig.31 work plan

The design by AutoCADwhich include; distribution of array, connection with component, was provided as follow:

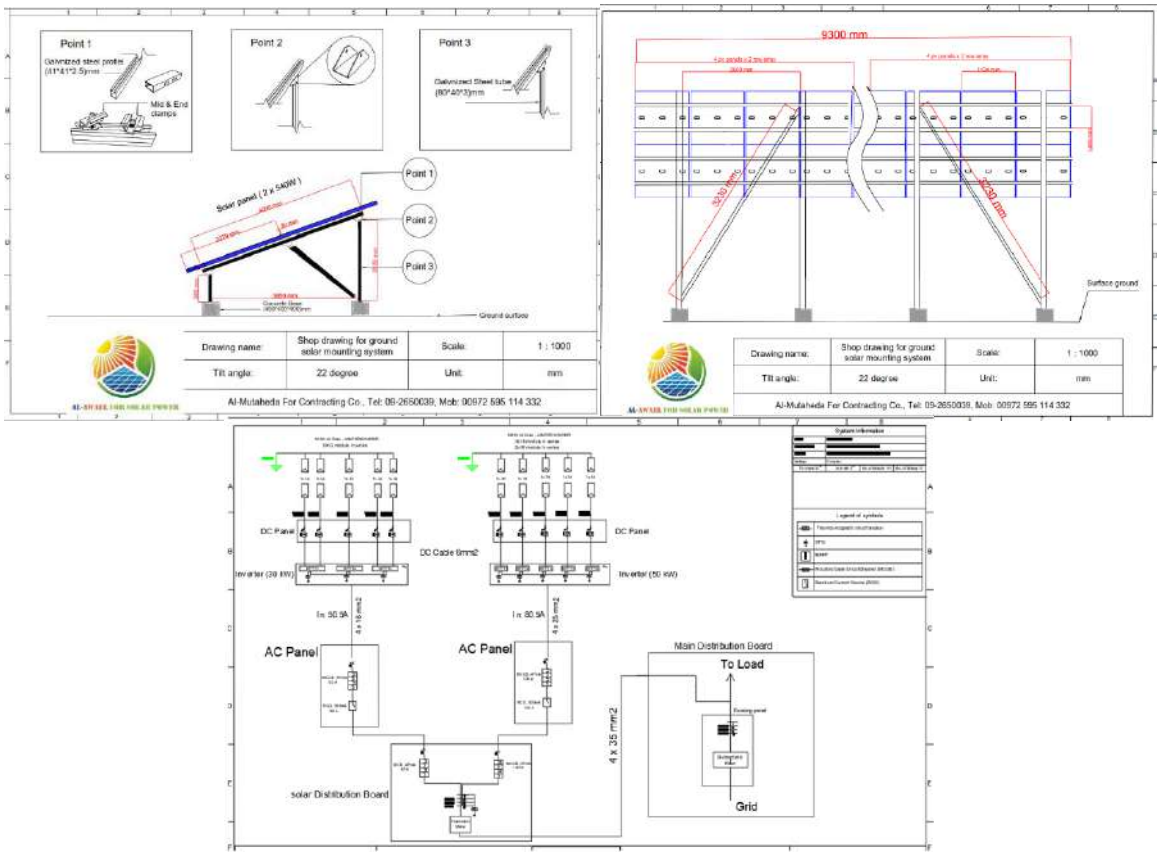
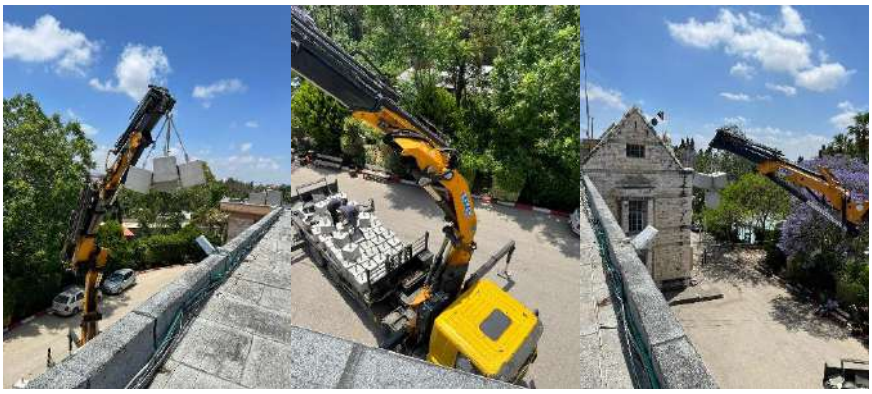


Fig.32 Alawael design & connection drawing

Civil & electrical Site Work

After taking the approval from ANNU, the contractor company start purchasing the components and manufacturing the steel structure and cement base, then they start implementing the project as follow:

21- Prepare the site and supply cement foundation



22-distribute the foundation

23-Install the steel structure

24-Install PV panels

25- Install inverter and connect all components and all the cables were installed in tranches and trunks for aesthetic image of the project and facilitate the maintenance work in future



26- Then the DC/AC earthing was connected and lightning Pulsar, Earth resistance measurement 2.8 ohm



27- Finally the energy meters was installed and configured with monitoring portal – **isolarcloud** for performance monitoring, condition monitoring and data reporting and weather sensor station was installed.

Fig.33PV system implementation process

Validation stage

In order to operate the system successfully, the system components were checked and test by civil and electrical engineering in university during the implementation process to inspect the work and then a test was conduct before the system operation completely.

So three levels of commissioning and system testing was conduct as follow:

- **Level-1: site acceptance Inspection**

The acceptance of the site to install the equipment of the PV system is responsibility of the installing contractor and to start implementing the concrete base, galvanized steel structure.

- **Level-2: Pre-functional testing**

Characteristics and Visual Inspection test

- **Level-3: performing operational test**

In the last point of the project commissioning, the PV solar plant components during operation are checked and the successful operation of project is checked.
Operational test was done according to International Electro technical commission (IEC) recommendation [IEC 62446], to ensure that the system is properly installed and performing optimally.

The test has been carried out as follow:

- ✓ Tests to all DC circuit(s) forming the PV array, which include the following tests:
- ✓ Tests to all AC circuit(s)

The equipment's that have been used for testing are all calibrated by authorized utility as follow:


Digital Earth resistance test device


Power analyzer device


HT AC clamp meter

The result of test was as follow:

Fig.34PV system test report

5. Improve Energy Efficiency-Lamp replacement

5.1. Introduction

Under framework of the Mediterranean University as Catalyst for Eco-Sustainable Renovation (Med-EcoSuRe), ANNU had conducted a comprehensive energy audit of all university buildings in order to determine the measures to improve the energy efficiency of university and achieve a reduction in cost operational and CO2 emissions, as a result which reflect on environment, create a comfortable and healthy atmosphere on campuses.

so, the university according to results of energy audit report and within strategy of university to reach zero energy bills, continuously conducting full scale experimentation of innovative retrofit technologies for example lamps replacement of old unit with high efficient LED lamp unit for 3 buildings of old campus in Nablus and One agriculture faculty building in Tulkarem as result of Energy audit process which was conducted for university`s facilities in order to achieve a meaningful decrease in energy usage.

5.2. Major methodology of high efficient lamps implementation

Selection process & acquiring devices

After determining the quantity, types and civil work (if needed), as figure-1.

literature lighting analysis-1:				existing	
Total no. of lamp	Total Unit	replace lamp	replace all unit	lamp type-unit	Lumen
564	282	0	282	FL. 2 Tube (150 cm)	5000
70	35	0	35	FL. 2 Tube (120 cm)	2500
7	7	0	7	FL. 1 Tube (120 cm)	2500
	324				

learning lighting analysis-2:				existing	
Total no. of lamp	Total Unit	lamp only	replace all unit	lamp type-unit	Lumen
116	58	0	58	FL. 2 Tube (120 cm)	2500
	58				

old library lighting analysis-3:				existing	
Total no. of lamp	Total Unit	replace lamp	replace all unit	lamp type-unit	Lumen
18	9	0	9	FL.2 Tube (120 cm)	2500
3	3	0	3	FL.1 Tube (120 cm)	2500
	12				

tulkarem campus lighting analysis-3:				existing	
Total no. of lamp	Total Unit	replace lamp	replace all unit	lamp type-unit	Lumen
12	6	0	6	FL.2 Tube (120 cm)	2500

Fig.35existing lamp quantity

and thus, the budgetary estimation was done to analyze the project cost and its feasibility.

Therefore, in order to choose the best offers for lamp unit in terms of technical effectiveness and lowest offers, the tender dossier was prepared as follow (see annex-1):

Fig.36 tender dossier

The tender call was published on 10/8/2023 as follow:

https://www.najah.edu/ar/tenders/rfq-12947/

جامعة النجاح الوطنية
طرح عطاء

تدعو جامعة النجاح الوطنية الشركات المتخصصة والراغبة بالمشاركة في العطاء المذكور أدناه:

رقم العطاء	RFQ-12947	
الموضوع	توريد وحدات انارة موفرة للطاقة بكفاءة عالية	
السعر	مجانا	
تم النشر في	2023-08-10	
الموعد النهائي	2023-08-17	الساعة 1:00 م

على الراغبين بالاشتراك في العطاء المذكور مراجعة دائرة اللوازم والمشتريات - قسم العطاءات - مكتب رقم -1120 في مبنى الإدارة العامة الحرم الجديد - نابلس، للحصول على نسخة مجانية من وثائق العطاء او من خلال مراسلة البريد الالكتروني procurement@najah.edu

للاستفسار يرجى الاتصال على:

دائرة اللوازم والمشتريات – هاتف 2345113-09-970+ - فاكس: 2345618-9-970+ البريد الالكتروني: procurement@najah.edu

Read 14 times

Fig.37 tender call-1

Then the tender call was closed on 22/8/2023, and the applicants were as follow:

13- Al-Takamul Engineering Company
14- Clean Energy Electrical Contracting Company
15- Sparkle Technology and Trade Company
16- Masdar Energy Systems Company

Then the offers were evaluated technically and financially for first time, to select the best offer for supplying high efficient lamp (see annex-2)

جـامـعـة النـجـاح الـوطـنـيـة
An-Najah National University
دائرة اللوازم والمشتريات
Procurement Department

محضر دراسة عطاء رقم RFQ-12947

رقم طلب الشراء: 35868 قيمة طلب الشراء: 20020 يورو الجهة الطالبة: عماد بريك Med-EcoSuRe									
	البند	العدد	سباركل		التكامل		الطاقة النظيفة		مصادر لأنظمة الطاقة
			UP €/	TP/ €	UP €/	TP/ €	UP €/	TP/ €	€TP/
1	توريد وحدات انارة موفرة للطاقة لاستبدال وحدات الانارة القديمة (من نوع فلورسنت ، ثيون مزدوج ، طول 150 سم، قدرة 58واط ، 5000 لومن (بوحدات موفرة مكافئة بقدرة 40 واط او اقل، متوسط العمر الافتراضي 30000 - 50000 ساعة ، 4400 لومن، اوروبية الصنع، Surface-mounted LED ceiling luminaire with translucent cover	110	43	43	167	1430	20	200	85	9350
	الصنف المقدم		FSL 1.2 OM 36 Watt صيني		Thorn 30x120 Surface Mounted Data) (96634509) With Frame (96634508) as attached		OSRAM 20Watts		Fosnova 120W 4200Lumens 60000 Hours

Fig.38 Technical & financial evaluation-1

The submitted offers were studied from a technical and financial standpoint, and it was found that all the submitted offers did not conform to the required specifications, which necessitated resubmitting the bid directly, with the specifications modified to suit what is available in the market and achieve the required benefit (see annex-2), as follow:

The tender was also re-invitedon 17/8/2023 as follow:

https://www.najah.edu/ar/tenders/0-550/

جامعة النجاح الوطنية
إعادة طرح عطاء

تدعو جامعة النجاح الوطنية الشركات المتخصصة والراغبة بالمشاركة في العطاء المذكور أدناه:

رقم العطاء	RFQ-12947
الموضوع	توريد وحدات انارة موفرة للطاقة بكفاءة عالية
السعر	مجانا
تم النشر في	2023-08-17
الموعد النهائي	2023-08-22 الساعة 1:00 م

على الراغبين بالاشتراك في العطاء المذكور مراجعة دائرة اللوازم والمشتريات - قسم العطاءات - مكتب رقم -1120 في مبنى الإدارة العامة الحرم القديم - نابلس، للحصول على نسخة مجانية من وثائق العطاء او من خلال مراسلة البريد الالكتروني procurement@najah.edu

للاستفسار يرجى الاتصال على:

دائرة اللوازم والمشتريات – هاتف 2345113-09-970+ - فاكس: 2345618-9-970+ البريد الالكتروني: procurement@najah.edu

Read 14 times

Fig.39 tender call-2

Then the tender call was closed on 22/8/2023, and the applicants were as follow:

1- Al-Takamul Engineering Company
2- A united company
3- Triple R
4- Clean Energy Electrical Contracting Company
5- Shaaban and Sons Company
6- Sparkle Technology and Trade Company
7- Masdar Energy Systems Company

Then the offers were evaluated technically and financially for second time, to select the best offer for supplying high efficient lamp (see annex-2)

جامعة النجاح الوطنية
An-Najah National University
دائرة اللوازم والمشتريات
Procurement Department

محضر دراسة اعادة طرح عطاء رقم RFQ-12947

رقم طلب الشراء: 35868
قيمة طلب الشراء: 20020 يورو
الجهة الطالبة: عماد بريك Med-EcoSure

أسماء الشركات المشاركة في العطاء
العروض باليورو و لا تشمل ض.ق.م

البند	العدد	مصادر لأنظمة الطاقة TP/€	مصادر لأنظمة الطاقة UP/€	سباركل TP/€	سباركل UP/€	شعبان TP/€	شعبان UP/€	تربيل ار TP/€	تربيل ار UP/€	الطاقة النظيفة TP/€	الطاقة النظيفة UP/€	A united TP/€	A united UP/€	التكامل TP/€	التكامل UP/€	
Led Light PANAL 48W Size Dimention (1200mm x 300mm) 6000K 4320 lm CRI: >80	400	38000	95	15360	38.4	14000	35	14000	35	7800	19.5	22000	55	70000 24800	175 62	1
الصنف المقدم		Dizano 4000K		Optima		60W Input أخيارا أبيض 6500K		40W OPPLE Size 1200x300mm Lumens 4000 6500K 30,000 Hours		sovi-T8-1tube 6500K CRI 84 4500 Lumens 30,000 Hours		NLED42045M		1. Thorn Beta 3 Part + Additional Frame 2. LEDvance Led value panel 36w + surface mount frame		
مدة التوريد		6-8 weeks		3 days		لم يوضح		4 Months		8 days		2 – 3 Months		90 – 120 Days		
الكفالة		5Y		لم يوضح		2 YEARS		5Y on opple		لم يوضح		5Y		لم يوضح		

Fig.40 Technical & financial evaluation-2

Then according to the tender committee, the tender has been awarded to Shaaban and Sons Company, and the work agreement /PO was signed between ANU and Shaaban to purchase the project materials and supply them immediately to ANNU. (see annex-3)

Fig.41 Purchasing order agreement

Implementation stage

The contractor supplies the lamps to university store immediately as agreement, and the technical teams in university start installing the lamps in four building immediately.

- remove the old lamp:

- Replace the old lamp with high efficient lamp unit

Fig.42 implementation process

Validation stage

In order to ensure the approach has achieved the expected goals, we will check the electrical consumption of each building using energy analyzer and electrical bills of campuses by end of year to inspect the variation of consumption and the results of installing high efficient lamp.

The equipment's that have been used for testing are all calibrated by authorized utility as follow:

Power analyzer device

HT AC clamp meter

6. Recommendation

1- We recommended other public buildings to benefit from these implemented pilot projects at ANNU, and to use the same methodology in order to reduce their independency from conventional supply.
2- We recommend that our partners continue working together on project proposals related to eco-sustainable renovation in public buildings, in order to bring the energy consumption in our public buildings to zero
3- The feasibility of the proposed and implemented approach should be tested and monitored for long-term to consider change/update on base data and conduct the required computational.

4- The approach followed in implementation, follow-up, monitoring and examination to ensure the effectiveness of the implemented projects in a positive and effective manner, as the projects have been completed, installed, operated successfully.

Innovative Retrofit Technology Report

Rooftop Solar Photovoltaic System (SPVs) for Faculty of Agriculture and Veterinary Medicine building – An-Najah National University

(Faculty of Agriculture and Veterinary Medicine building– An-Najah National University at Tulkarem)

Prepared by:
An-Najah national university (ANNU)

2023

Project Acronym	University building
Project Name	"Mediterranean University as Catalyst for Eco-Sustainable Renovation" (Med-EcoSuRe)
Project Duration	September 2019- August 2022
Website	www.enicbcmed.eu/projects/med-ecosure
Authors	An-Najah National University (ANNU)
Date	February 2023
File Name	Full scale experimentation of innovative retrofit technologies, validation and testing in real life report (**Rooftop Solar Photovoltaic System (SPVs) for Faculty of Agriculture and Veterinary Medicine building - An-Najah National University – Palestine**)

This project is part of the Mediterranean University as Catalyst for Eco-Sustainable Renovation (Med-EcoSuRe). The project aims to implement full scale experimentation of innovative retrofit technologies, validation and testing in real life in An-Najah university campuses, in order to allow a relevant energy demand reduction and mitigate greenhouse gas emission.

TABLE OF CONTENTS

1. Introduction

Low energy educational buildings are becoming the standard for new buildings in European and Mediterranean countries. Technical solutions are continuously developed by universities for eco-sustainable building renovation, but there is still a gap between designed models and their actual application. This is due to several barriers, such as the insufficient collaboration between key actors and the lack of efficient suitable tools from the public sector to develop solutions.

Under framework of the Mediterranean University as Catalyst for Eco-Sustainable Renovation (Med-EcoSuRe), the partnership universities of project have taken action that aims to find Technical solutions for eco-sustainable building renovation. The Med-EcoSuRe project offers an innovative approach to the definition and diffusion of cost-effective energy renovation within university buildings, with the perspective of extending results to the whole public buildings sector in the long term. A Mediterranean cross-border living lab - bringing together researchers, building managers, companies, public organisations and students - will be established to develop energy efficiency and renewable energy solutions as well as retrofitting schemes to be implemented in 9 university buildings. The final aim behind the project is to turn university managers into active players contributing to the co-creation and experimentation of emerging ideas, breakthrough scenarios and innovative concepts, where the Low energy educational buildings are becoming the standard for new buildings in European and Mediterranean countries.

The project aims to achieve the following: -

- Environmental protection, climate change adaptation and mitigation
- Improving energy efficiency in university building and installing On-grid PV solar system.
- Reduce the energy demand from local public electrical network, which reduce electricity bills and contribute in educational process positively.
- A sustainable, reliable, safety and cost-effective electrical energy supply
- PV power Plant is tested, evaluated and monitored using monitoring, sensor and data logging system which monitored remotely and at site for public demonstration & display

ANNU aims through its facilities and activities to achieve environmental sustainability as follow: -

- Promote and create a campus which supports academic, research and enterprise activities in a sustainable way
- Provide the education, advancement, dissemination and application of sustainable development

- Maximize the wider impact of ANU's environmental sustainability activities at local, regional, national and international level through collaboration, partnership and communications
- become a leader across the HE sector in terms of environmental sustainability

Accordingly, ANNU through Med-EcoSuRe project had conducted Full scale experimentation of innovative retrofit technologies for example Rooftop Solar system as a solution to conserve energy in old buildings where a deep retrofit approach is not possible in order to achieve a meaningful decrease in energy usage and GHG emissions and as a result, a comfortable and healthy atmosphere on campus.
Also contribute in providing visibility of the energy that is being used across campus to facilitate culture change within the ANNU community

2. What & Why Solar Rooftop On Grid?

Solar rooftop is a solar panel installed on the roofs of buildings that are either commercial, institutional, or residential. The roof top system consists of a series of solar panels which are mounted on roof and connected together to convert solar radiation to electrical energy. The electrical energy from the series of panels is fed into an inverter so that the energy can be converted in alternating current compatible with grid power. Hence, the system will only work when there is constant electricity supply from the power grid.

So, why solar Rooftop system?

- reliable, easy-to-install system with a lifespan of 25 years using existing roof space to generate clean energy
- reducing the electricity bills because of Net Metering mechanism which once the PV system synchronized with grid electricity can be used to transfer excess electricity back to the main grid
- Cuts Down on Carbon Footprint, installing the rooftop panel will generate clean energy, which mitigate global warming by lowering the emission of greenhouse gases
- Low Costs of Maintenance: there are no significant expenses, so it's an economical option, because the system needs periodic excellent cleaning and maintenance and the average solar rooftop has a 25-year life expectancy, making the investment worthwhile
- Installation doesn't require any additional room
- Adaptable to the Palestine Climate: Palestine is part of the eastern Mediterranean basin and geographically located in such a way that it receives a relatively high quality of solar energy all over the year where it has nearly 3000 sunny hours.
- Safe investment: The price of electricity is always changing. Therefore, it is challenging to estimate the cost of electricity over a specific time period. On the other

hand, it is simple to estimate the cost of power produced when it comes to electricity produced by solar rooftops. In reality, it is possible to estimate how much it will cost to produce electricity in another 10 years. This makes it a safe investment.

- widens the availability of energy source and achieve independency: Even though Palestine's power shortage is steadily improving, cities, institutions and many individuals still lack sufficient and dependable access to electricity all the time, in either urban and rural locations. which forced them to use alternative means such as diesel generators. These alternatives have detrimental consequences on one's health and have unstable running expenses. Solar energy can provide a cheap source of electricity in this situation.

3. Technology Description

In this pilot project, we proposed to use a solar photovoltaic (PV) system, mounted on the roof that converts solar energy into electricity to meet the building's own energy consumption requirements or, in certain situations, fed back into the electrical grid.

The size of the installation can vary dramatically, and is dependent on:

- ✓ available space on roof
- ✓ load bearing capacity of roof
- ✓ possibility to redistribution of existing objects on roof and shadow distance
- ✓ the amount of electricity required or coverage percentage of load
- ✓ the funding available for the project
- ✓ the grid operator's willingness to accept excess capacity.

the system components include PV modules, their accompanying mounting structure and an inverter.

Based on the data of the target building in the project, the building is old and the existing loads i.e. tanks, have been distributed to create a load balance and therefore it cannot be displacing. accordingly, the remaining available no-shadow space on the roof is what had determined the capacity of the system which determines the percentage of coverage for electricity consumption or savings in the electricity bill.

In addition, On-Grid PV system contributes in increasing the awareness of teacher, pupils, and community regarding the "green energy technology" and increase the positive environment in the Schools by reducing the CO2 emission.

4. Full scale experiment of Innovative Technologies

ANNU through the project has carried out implementation of top-roof PV system in Faculty of Agriculture and Veterinary Medicine building in Tulkarem, in order to reduce the energy consumption annually of campus by 60% with available free shadow space on roof around 900 m2.

Table I. Geographical site of project

Location coordinate	32°18'52.2"N, 35°01'20.0"E
available area	900

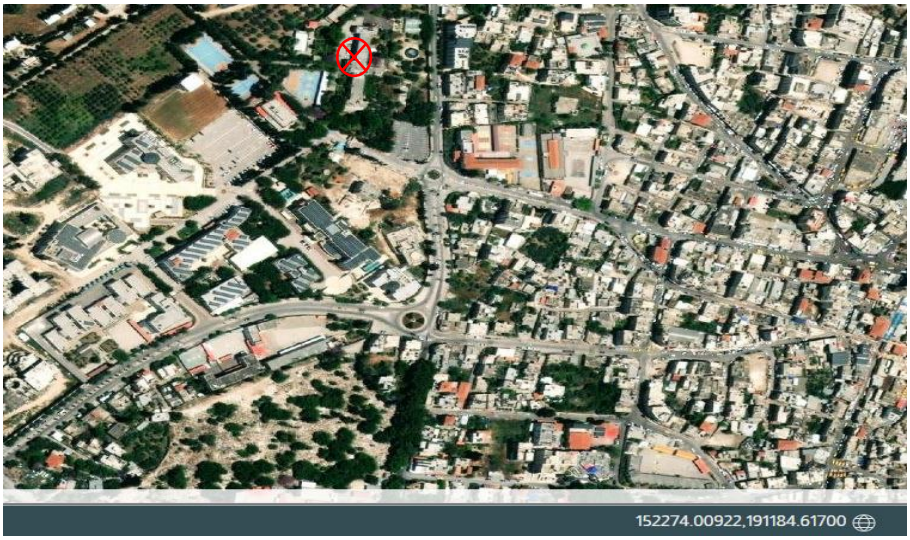


Fig.1 information location of PV system

Accordingly studying the roof type and space availability is so important because different roofs require different mounting solutions which reflect on capital cost of project, and while PV systems add relatively low additional load on a roof, it is still important to ensure that the overall system is in line with structural allowances, and that it does not compromise the building's roof insulation.

4.1 Project PV plant Summary

Table II. Design parameters of the PV plant

Design parameters	Characteristics
Year of construction	2022
Type of plant	Top-roof mounted, fixed
Orientation and tilt	South, 22 degree
Installed nominal power	77.76 kWp
Module type	Monocrystalline
The number of PV module	144 panel × 540Wp
Inverter	1 × sungrow- 50 kWp + 1 × Sungrow 33Kw

4.2 Contribution of the project activity to sustainable development

The project contributes to the general well-being of the region and is in line with the sustainable development policies of the host site.

Social well-being:

The project activity will lead to employment generation during installation as well as operation phase of the project activity.

Economic well-being:

The project implementation will provide a fillip to economic activity in the region. Direct & indirect employment will be generated in the plant for the project implementation & management. The success of this project will encourage more business to be developed in the local region thus bringing in economic prosperity in the region.

Environmental well-being:

The project being a renewable energy power project would contribute to mitigation of global warming. In addition, the project activity also would not lead to any air pollution unlike fossil fuel based power plants

5. Major methodology of retrofit technology implementation

5.1 Selection process & acquiring devices

After analyzing the site, and according the free shadow space on roof and considering the shadow distance between PV array, the initial design and PV array distribution was shown, in fig.2.

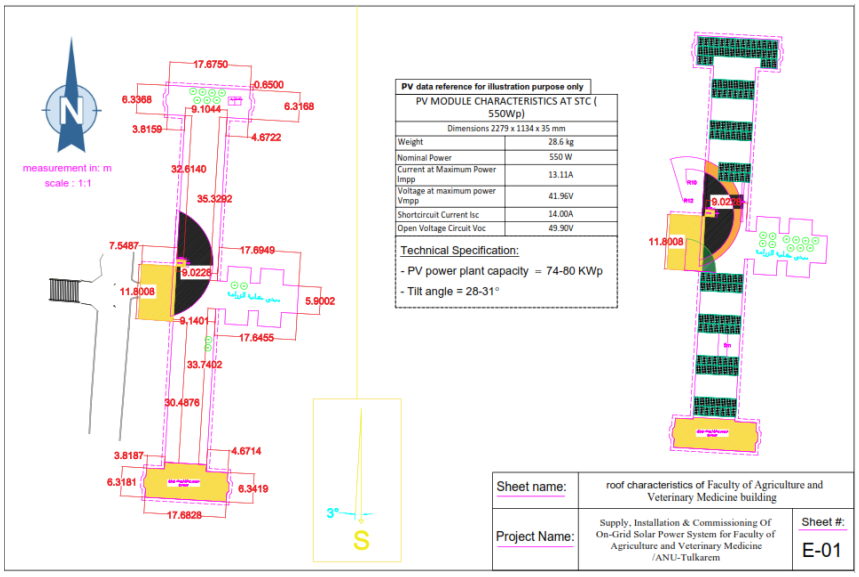


Fig.2 PV system initiative design

After checking the system design, the budgetary estimation was done to analyze the project cost and its feasibility.

Therefore, in order to choose the best offers for devices and civil & electrical site work in terms of technical effectiveness and lowest offers, the tender dossier was prepared (see annex-1) as follow:

Fig.3 tender dossier

The tender call was published on 26/12/2021, as follow:

https://www.najah.edu/ar/tenders/rfq-12519/

Fig.4 tender call

During the tenderer offers preparation, a tour visit was organized by ANNU on 10/1/2022 to inspect the site and replying their query. And then the tender call was closed on 16/1/2022, and the applicants were as follow:

1) Hybrid company
2) Abaad Contracting Company
3) triple R for trading and marketing
4) AGEC

5) MSADER
6) SATCO
7) trust energy
8) alawael

Then the offers were evaluated technically and financially, to select the best offer for supplying materials and implementing the project (see annex-2)

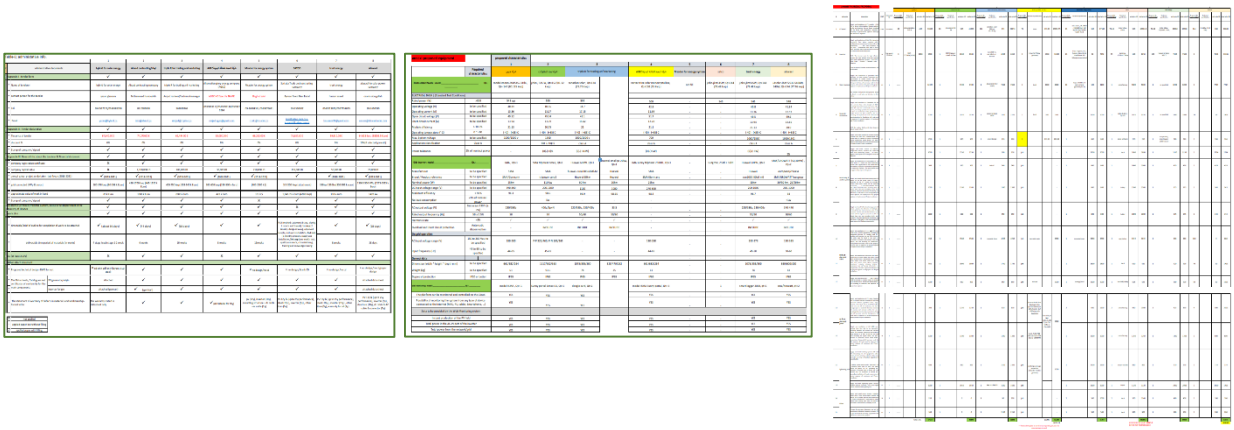


Fig.5 Technical & financial evaluation

Then according to the tender committee, the tender has been awarded to Alawael company, and the work agreement/PO was signed between ANNU and Alawael to start the implementation activity and purchasing the project materials. (see annex-3)

Fig.6 Purchasing order agreement

5.2 Implementation stage

Work plan and design approval

Before the contractor initiate the implementation process on the site, the work plan, designs and equipment information are sent by contractor in order to get ANNU approval of them and giving an order directly to work to contractor.

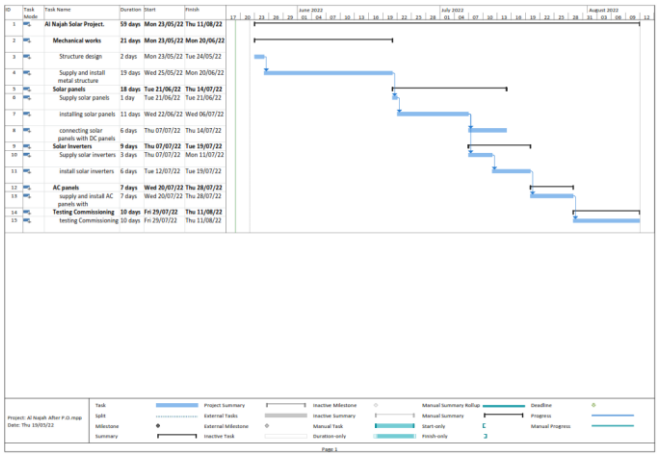


Fig.7 work plan

The design by AutoCAD which include; distribution of array, connection with component, was provided as follow:

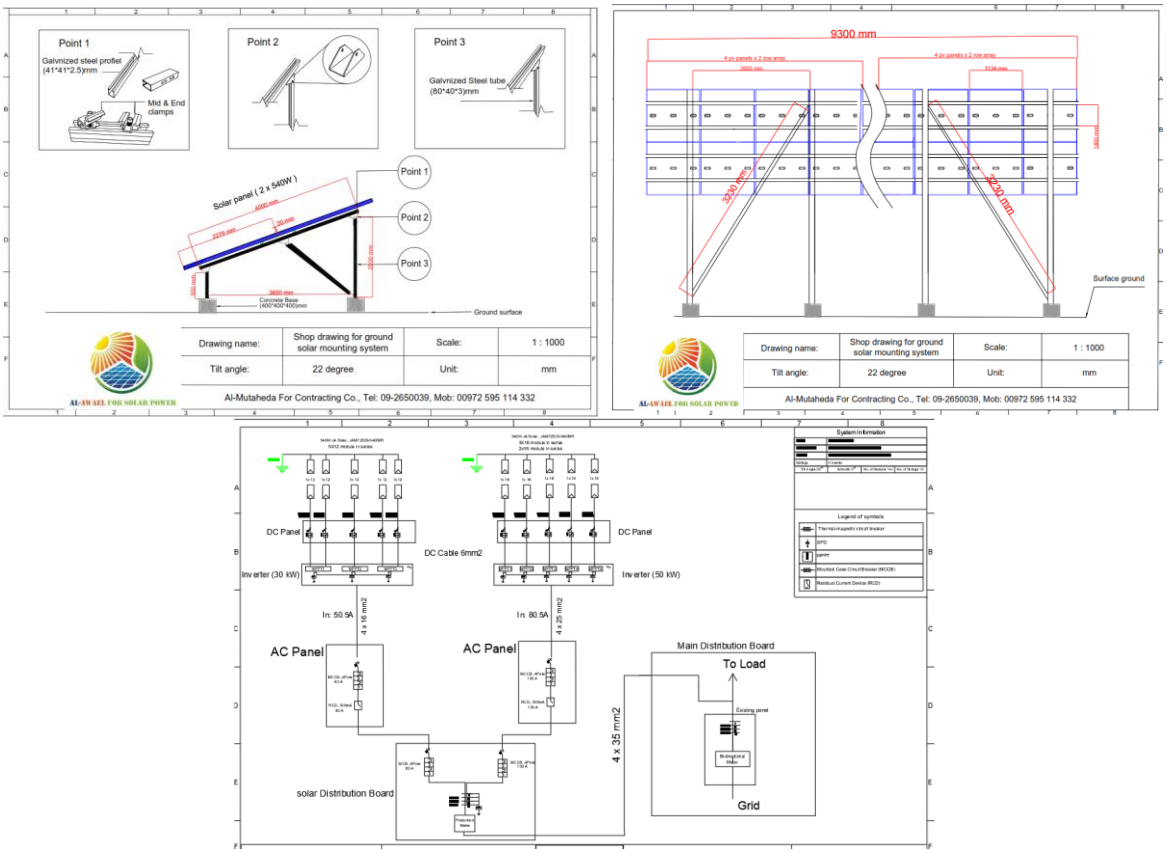
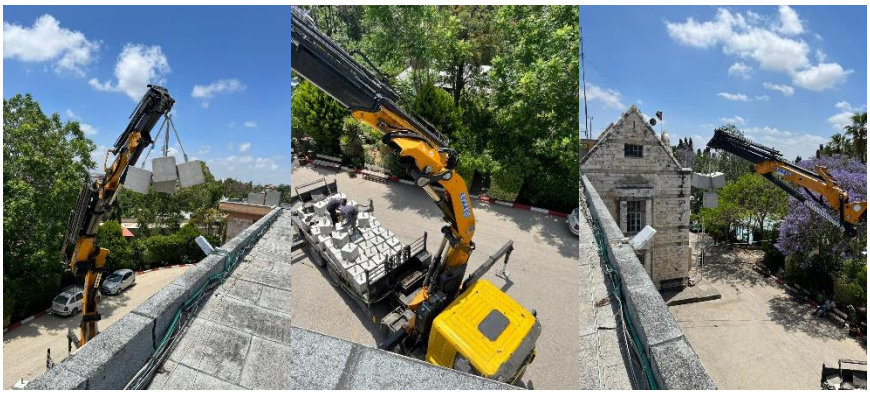


Fig.8 Alawael design & connection drawing

Civil & electrical Site Work

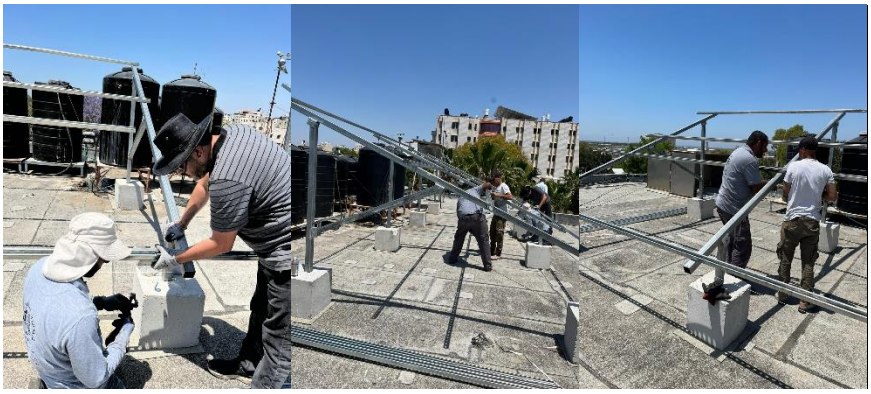
After taking the approval from ANNU, the contractor company start purchasing the components and manufacturing the steel structure and cement base, then they start implementing the project as follow:

1- Prepare the site and supply cement foundation



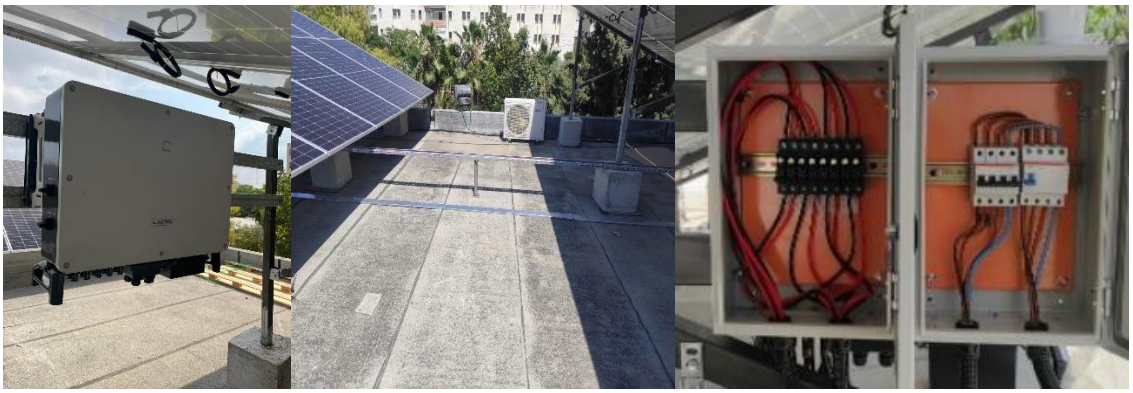
2- distribute the foundation

3- Install the steel structure



4- Install PV panels

5- Install inverter and connect all components and all the cables were installed in tranches and trunks for aesthetic image of the project and facilitate the maintenance work in future.



6- Then the DC/AC earthing was connected and lightning Pulsar, Earth resistance measurement 2.8 ohm

7- Finally the energy meters was installed and configured with monitoring portal – **isolarcloud** for performance monitoring, condition monitoring and data reporting and weather sensor station was installed.

Fig.9 PV system implementation process

5.3 Validation stage

In order to operate the system successfully, the system components were checked and test by civil and electrical engineering in university during the implementation process to inspect the work and then a test was conduct before the system operation completely.

So three levels of commissioning and system testing was conduct as follow:

- **Level-1: site acceptance Inspection**

The acceptance of the site to install the equipment of the PV system is responsibility of the installing contractor and to start implementing the concrete base, galvanized steel structure.

- **Level-2: Pre-functional testing**

Characteristics and Visual Inspection test

- **Level-3: performing operational test**

In the last point of the project commissioning, the PV solar plant components during operation are checked and the successful operation of project is checked.
Operational test was done according to International Electro technical commission (IEC) recommendation [IEC 62446], to ensure that the system is properly installed and performing optimally.

The test has been carried out as follow:

- ✓ Tests to all DC circuit(s) forming the PV array, which include the following tests:
- ✓ Tests to all AC circuit(s)

The equipment's that have been used for testing are all calibrated by authorized utility as follow:

Digital Earth resistance test device

Power analyzer device

HT AC clamp meter

The result of test was as follow:

Verification test draft

For PV generator:

PV generator		Reference Value	Remarks: Confirm	Remarks: non confirm
Modules	Unit STC capacity	540 Wp	✓	
	Technology	Monocrystalline	✓	
	Quantity	144	✓	
	Manufacturer	JAsolar	✓	
	Existence by-pass diodes	Yes-3 diodes	✓	
Assembly	Orientation	True South	✓	
	Tilt	22 degree	✓	
	Shades (if any)	Yes, in early morning/ late evening for the middle array	✓	
Structures	Type of structure	Hot deep strength	✓	
	Structure material	Steel	✓	
	Mechanical strength	Strong	✓	
	Bolts and nuts material	stainless steel	✓	
	Resistance to corrosion	Yes, it is galvanizes	✓	
	Quality of attachment fittings	Excellent	✓	
	Quality of anchors	Excellent	✓	
	Earthing	Yes, it is earthed with cable size 10 mm²	✓	

Cabling		Reference Value	Remarks: confirm	Remarks: non confirm
Interconnections of modules	Cable type	Solar cable	✓	
	Cross section	6 mm²	✓	
	Length	≥ 1200 mm	✓	
	Protection of junction	IP65	✓	
	Junction attachment	Yes	✓	
Modules-to-junction box	Cable type	Solar Type	✓	
	Cross section	6 mm²	✓	
	Length	According to each array	✓	
	Quantity	red & black	✓	
	Protection of junctions	IP65	✓	
Junction box	Quantity of boxes	2	✓	
	Number of strings per box	(1):4 , (2):5	✓	
	String fuses specifications	20 A	✓	
	Sealing efficiency	Very Good, IP65	✓	

cabling (cont'd)		Reference Value: Voc	Reference Value: Isc	Remarks: confirm	Remarks: non confirm
Strings	Voc and Isc per string				
	string 1.Inv1	866	13.5		
	string 2.Inv1	861.1	13.46		
	string 3.Inv1	671.4	13.12		
	string 4.Inv1	673.4	13.2		
	string 1.Inv2	763.6	13.21		
	string 2.Inv2	763.0	13.25		
	string 3.Inv2	763.5	13.27		
	string 4.Inv2	765.7	13.2		
	string 5.Inv2	764.3	13.24		
(Grid inverter)	Cable type	Kablo N2XY		✓	
	Cross section	4*35 mm²		✓	
	Number of AC panel	1		✓	
	Existing lighting arrestors	Yes		✓	
	Voltage drop at I max	Less than 1%		✓	

For inverter:

Inverter	Reference Value	Remarks: confirm	Remarks: non confirm
Manufacturer	Sungrow	✓	
Inverter #	2: 50kw & 33kw	✓	
MPP voltage range	200-1000 V	✓	
Nominal input voltage	585 v	✓	
DC reverse connection protection	yes	✓	
AC short circuit protection	yes	✓	
DC switch / AC switch	Yes/no	✓	
Nominal AC voltage	3/N/PE, 230/400 V	✓	
Rated output frequency	50 Hz	✓	
Inverter -1			
A.C. power	36.3 KVA	✓	
Max AC output current	55.2 A	✓	
Input voltage range	312 V to 528 V	✓	
No. of independent MPP input	3	✓	
Inverter -2			
A.C. power	55 KVA	✓	
Max AC output current	83.6 A	✓	
Input voltage range	312 V to 528 V	✓	
No. of independent MPP input	5	✓	

Fig.10 PV system test report

Monitoring & evaluation stage

The performance of system was analyzed using technical data downloaded from the data logger of isolar cloud portal.

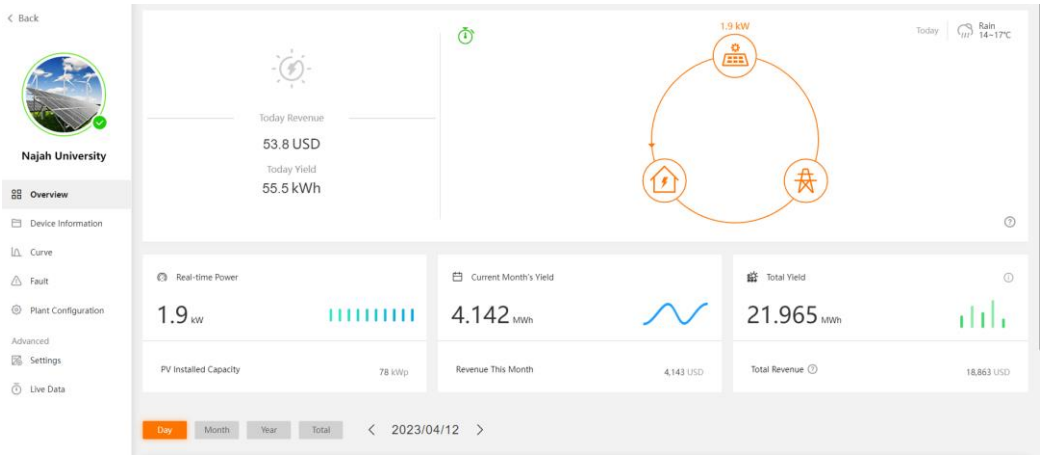


Fig.11 remote monitoring portal- iSolarCloud

The PV system operation was monitored from 18/9/2022-31/12/2022 & 12/2/2023-28/2/2023 , during the operation period a periodic maintenance of the system will be carried out and followed up to solve problems when they occur, such as changing a fuse or cleaning the panel, and the results were as follow:

Total production over operated period 2022/2023= 37.92 MWh

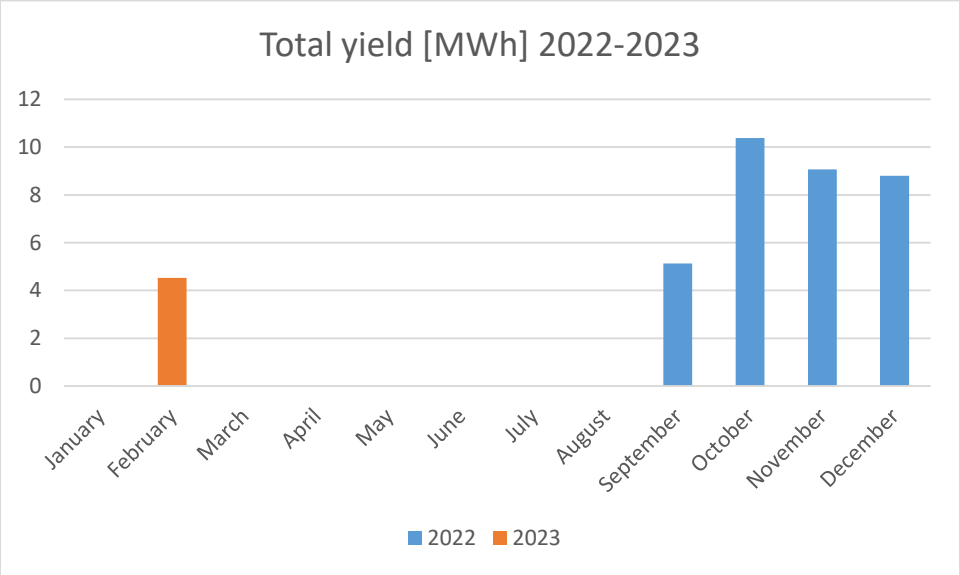


Fig.11 PV system yield (MWh) of year 2022-2023

According to data, the system was working properly, and thus is shown in the indicator below:

Technical evaluation:

- System Efficiency

The efficiency of PV system measures the ability of system to convert the sunlight into required energy for load consumption, the system efficiency is given by following form:

$$\eta \text{ (system efficiency)} = \frac{\text{Output energy of PV system (KWh)}}{\text{Global radiation energy received by PV array area (KWh)}}$$

The System efficiency for operation period (Sep-Dec/2022) is 17 %
The System efficiency for operation period (Feb-March/2023) is 14 %

- Performance Ratio

$$PR = \frac{\text{actual energy generated by PV system (KWh)}}{\text{Energy produced by system at STC (KWh)}}$$

The Performance Ratio for operation period (Sep-Dec/2022) is 78%

The Performance Ratio for operation period (Feb-March/2023) is 63%

- Final Yield (Yf)

$$Y_f = \frac{\text{actual energy generated by PV system (KWh)}}{\text{PV array maximum Capacity (KW)}}$$

The final yield will refer for how many hours the system is operated in year or day.

Accordingly,

Yf over operated period is 488.01 h and average solar hour per day is 3.83 h/day

- Capacity Factor (Cf)

The capacity factor varies quite a bit for solar photovoltaic systems depending on the location. Generally, it is in the range of 10-25%. One of the key reasons for this low ratio is the nature of renewable power.

$$C_f = \frac{\text{actual energy generated by PV system (KWh)}}{\text{PV array maximum Capacity (KW)} \times 8760\text{h/year}}$$

total hours over operated period is 2952 h, accordingly **the average capacity factor of system over this period is 16 %.**

Environmental and Economic evaluation:

The CO2 emission will be reduced according to how much energy produce from the PV solar system since the system operation, as follow:

It's expected that the reduction in CO2 emission will be 94.15 ton CO2/year

It's expected to reduce energy bills yearly by 27300 Euro

PV Investment cost (€) = 58153.5 Euro

S.P.B.P = Investment / saving cost per year

= 58153.5 Euro / 27300 Euro = 2.13 years ≈ **2 years & 2 month**

But according to the actual energy output, the average monthly energy saving was 9.4 MWh, around 1845 Euro/month which equivalent to 22148 Euro/year, and thus reflect in number of years of payback period.

Actual Saving cost in 1st year (€/year) = 22148 €/year

S.P.B.P = Investment / saving cost per year

= 58153.5 Euro / 22148 Euro = 2.63 years ≈ **2 years & 8 month**

6. Recommendations and future scale up of installing Rooftop PV system

In general, innovative technologies and processes should be conceived in order to seize low radiation energy and optimize its transformation into actual power. Based on what was previously mentioned so we recommended the following to install rooftop PV system:

- The optimum power output must be estimated before the installation of the photovoltaic plant, which was influenced by quantity and quality of the solar energy resource of the desired project location.
- Solar module efficiency: Modules in operation typically have an efficiency of between 9% and 22%; however, module performance typically deteriorates over time. This module degradation can occur at a rate of approximately 0.3% to 1%/year, depending on the module type and local conditions, so choosing high efficient module will reflect on solar energy production.

  Two types were available in Palestinian Market; Poly-crystalline and mono-crystalline which used in PV installations and those modules have different properties, which influence the suitability of their application:

  - Poly crystalline modules are widely used with many proven manufacturers around the world. They are typically less expensive to produce than mono-crystalline modules, but are not as efficient. Because of the way they are manufactured,
  - Mono crystalline modules have a higher efficiency than most other types of modules, but can be more expensive as a result.

  Typically, modules come with a 10-year mechanical warranty on the product, and a 25-year performance warranty.
- Appropriate design considerations: such modules layout and spacing, cable lengths and inverter sizing, to reduce the losses in individual components of the system, as the energy is converted from solar to electrical energy.
- Shading losses analyses play a crucial role before installation because they allow to predict and analyse the performance of the designed PV system, where Inter-row shading and the surrounding landscape influences how much exposure the system

has to the sun. Neighbouring buildings, trees or natural features can shade part or the whole of a system, affecting overall energy generation.

- The system's layout should consider local health and safety requirements, including whether or not access is required by emergency services in the event of a fire. This also affects accessibility for system maintenance, cleaning the modules, and carrying out maintenance on any of the components.
- In addition, structure of PV frameworks carefully identified, especially on the roofs of old buildings, to limit the heaviness of photovoltaic panels. A PV panel typically weighs 20–40 kg. Since a PV array clearly incorporates numerous panels, the all-out weight of the introduced array is much bigger. So reducing the basic load of the PV structure will solve this issue, make PV modules lighter and diminish transportation costs besides decreasing the cost of the materials used for the photovoltaic structure.
- To avoid penetrate the roof when fixing the mounting structure of PV systems to keep the building's waterproofing and roofing warranties
- The mounting system should be able to withstand applicable wind and/or snow loading
- It is important that the material selected (i.e. structure, welding Screws and clamps) is adequately treated and galvanized to prevent corrosion, as the mounting system will be exposed to the environment and external factors
- Installing Energy meters' measure electricity generated by the system, and this data is used in assessing facility performance and bidirectional meter with grid to measure the flow of electricity in two directions and thus monitor power usage in real time and save money.
- Installing weather station to measure and track temperature, insolation and wind speeds, so that the performance of the system can be compared to what should have been generated, given the conditions.

  The performance of a system is dependent on the environmental conditions
- Installing System remote monitoring to ensure the system operates efficiently

As is clear, getting accurate information on the actual behavior of the designed PV system will allow understanding how to optimize its efficiency, thus contributing to reduce the amount of energy generated from non-renewable sources and the emissions.

This system is a cost-effective energy solution, which permits to save a huge amount of money and time during the PV system installation, which can replicate on the roof of other new/old building through a robust design of the system, taking in to account the mentioned consideration to achieve the maximum energy efficiency of system and make use of the available spaces in order to enhances the autonomy of the national grid and reduce the cost of electrical energy.

This type of system encourages investors to increase in the uptake of solar PV installations due to:

- Lower costs of PV technology: Overall installation costs for PV technologies have decreased significantly in recent years, and it's expected to continue going forward and overall system costs are forecasted to decrease by between 40% and 75% by 2050;
- increasing grid supplied electricity prices;
- the availability of preferential feed-in-tariffs or other financial incentives for renewable energy technologies (including tax credits);
- carbon emission reduction;
- the availability of alternative financing options;
- air pollution concerns; and
- energy security concerns

Med-EcoSuRe

Innovative Retrofit Technology Report

Grid-Tied PV Power Plant at Top-Roof of Old-Campus Buildings – An-Najah National University

(Faculty of educational science and teachers' training building & faculty of humanity and economics building)

Prepared by:
An-Najah national university (ANNU)

2023

Project Acronym	University building
Project Name	"Mediterranean University as Catalyst for Eco-Sustainable Renovation" (Med-EcoSuRe)
Project Duration	September 2019- August 2022
Website	www.enicbcmed.eu/projects/med-ecosure
Authors	An-Najah National University (ANNU)
Date	February 2023
File Name	Full scale experimentation of innovative retrofit technologies, validation and testing in real life report (**Old-Campus PV system- An-Najah National University – Palestine**)

This project is part of the Mediterranean University as Catalyst for Eco-Sustainable Renovation (Med-EcoSuRe). The project aims to implement full scale experimentation of innovative retrofit technologies, validation and testing in real life in An-Najah university campuses, in order to allow a relevant energy demand reduction and mitigate greenhouse gas emission.

TABLE OF CONTENTS

1. Introduction

Low energy educational buildings are becoming the standard for new buildings in European and Mediterranean countries. Technical solutions are continuously developed by universities for eco-sustainable building renovation, but there is still a gap between designed models and their actual application. This is due to several barriers, such as the insufficient collaboration between key actors and the lack of efficient suitable tools from the public sector to develop solutions.

Under framework of the Mediterranean University as Catalyst for Eco-Sustainable Renovation (Med-EcoSuRe), the partnership universities of project have taken action that aims to find Technical solutions for eco-sustainable building renovation. The Med-EcoSuRe project offers an innovative approach to the definition and diffusion of cost-effective energy renovation within university buildings, with the perspective of extending results to the whole public buildings sector in the long term. A Mediterranean cross-border living lab - bringing together researchers, building managers, companies, public organisations and students - will be established to develop energy efficiency and renewable energy solutions as well as retrofitting schemes to be implemented in 9 university buildings. The final aim behind the project is to turn university managers into active players contributing to the co-creation and experimentation of emerging ideas, breakthrough scenarios and innovative concepts, where the Low energy educational buildings are becoming the standard for new buildings in European and Mediterranean countries.

The project aims to achieve the following: -

- Environmental protection, climate change adaptation and mitigation
- Improving energy efficiency in university building and installing On-grid PV solar system.
- Reduce the energy demand from local public electrical network, which reduce electricity bills and contribute in educational process positively.
- A sustainable, reliable, safety and cost-effective electrical energy supply
- PV power Plant is tested, evaluated and monitored using monitoring, sensor and data logging system which monitored remotely and at site for public demonstration & display

At the same pace, ANNU aims through its facilities and activities to achieve environmental sustainability as follow: -

- Promote and create a campus which supports academic, research and enterprise activities in a sustainable way
- Provide the education, advancement, dissemination and application of sustainable development

- Maximize the wider impact of ANU's environmental sustainability activities at local, regional, national and international level through collaboration, partnership and communications
- become a leader across the HE sector in terms of environmental sustainability

Accordingly, ANNU through Med-EcoSuRe project had conducted Full scale experimentation of innovative retrofit technologies for example Rooftop Solar system as a solution to conserve energy in old buildings where a deep retrofit approach is not possible in order to achieve a meaningful decrease in energy usage and GHG emissions and as a result, a comfortable and healthy atmosphere on campus.
Also contribute in providing visibility of the energy that is being used across campus to facilitate culture change within the ANNU community

2. What & Why On Grid Solar rooftop?

Solar rooftop is a solar panel installed on the roofs of buildings that are either commercial, institutional, or residential. The roof top system consists of a series of solar panels which are mounted on roof and connected together to convert solar radiation to electrical energy. The electrical energy from the series of panels is fed into an inverter so that the energy can be converted in alternating current compatible with grid power. Hence, the system will only work when there is constant electricity supply from the power grid.

So, why solar Rooftop system?

- reliable, easy-to-install system with a lifespan of 25 years using existing roof space to generate clean energy
- reducing the electricity bills because of Net Metering mechanism which once the PV system synchronized with grid electricity can be used to transfer excess electricity back to the main grid
- Cuts Down on Carbon Footprint, installing the rooftop panel will generate clean energy, which mitigate global warming by lowering the emission of greenhouse gases
- Low Costs of Maintenance: there are no significant expenses, so it's an economical option, because the system needs periodic excellent cleaning and maintenance and the average solar rooftop has a 25-year life expectancy, making the investment worthwhile
- Installation doesn't require any additional room
- Adaptable to the Palestine Climate: Palestine is part of the eastern Mediterranean basin and geographically located in such a way that it receives a relatively high quality of solar energy all over the year where it has nearly 3000 sunny hours.
- Safe investment: The price of electricity is always changing. Therefore, it is challenging to estimate the cost of electricity over a specific time period. On the other

hand, it is simple to estimate the cost of power produced when it comes to electricity produced by solar rooftops. In reality, it is possible to estimate how much it will cost to produce electricity in another 10 years. This makes it a safe investment.

- widens the availability of energy source and achieve independency: Even though Palestine's power shortage is steadily improving, cities, institutions and many individuals still lack sufficient and dependable access to electricity all the time, in either urban and rural locations. which forced them to use alternative means such as diesel generators. These alternatives have detrimental consequences on one's health and have unstable running expenses. Solar energy can provide a cheap source of electricity in this situation.

3. Technology Description

In this pilot project, we proposed to use a solar photovoltaic (PV) system, mounted on the roof that converts solar energy into electricity to meet the building's own energy consumption requirements or, in certain situations, fed back into the electrical grid.

The size of the installation can vary dramatically, and is dependent on:

- ✓ available space on roof
- ✓ load bearing capacity of roof
- ✓ possibility to redistribution of existing objects on roof and shadow distance
- ✓ the amount of electricity required or coverage percentage of load
- ✓ the funding available for the project
- ✓ the grid operator's willingness to accept excess capacity.

the system components include PV modules, their accompanying mounting structure and an inverter.

Based on the data of the target building in the project, the building is old and the existing loads i.e. tanks, have been distributed to create a load balance and therefore it cannot be displacing. accordingly, the remaining available no-shadow space on the roof is what had determined the capacity of the system which determines the percentage of coverage for electricity consumption or savings in the electricity bill.

In addition, On-Grid PV system contributes in increasing the awareness of teacher, pupils, and community regarding the "green energy technology" and increase the positive environment in the Schools by reducing the CO2 emission.

4. Full scale experiment of Innovative Technologies

ANNU through Med-EcoSuRe project has carried out implementation of **top-roof PV system** in old campus in Nablus, in order to reduce the energy consumption annually of old campus by 11% with available free shadow space on roof of both buildings around 1000 m2 in total.

1- Faculty of Humanities & Faculty of Economics and Social Studies Building

Table I. Geographical site and roof space- faculty of humanities

Location coordinate	32°13'12.69"N,35°14'37.56"E
Height from sea level	616.7 m
Building occupied area	2968.6 m2
Free shadow, available area	700 m2

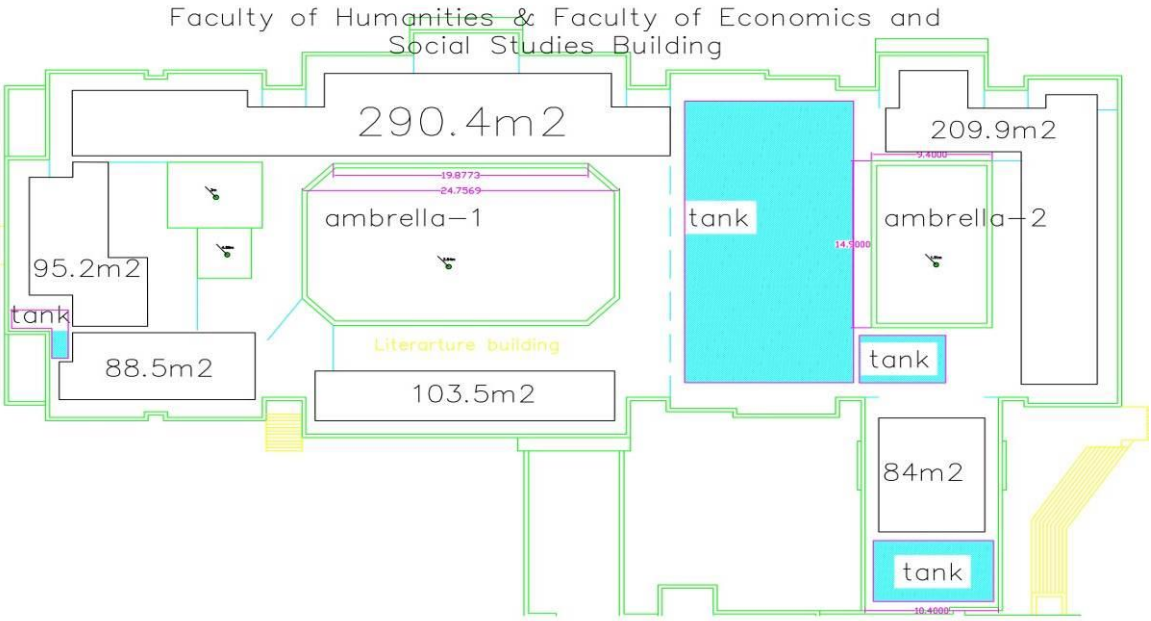


Fig.1 Faculty of Humanities & Faculty of Economics and Social Studies Building and roof space information

2- Faculty of Educational Sciences and Teachers' Training Building

Table II. Geographical site and roof space- faculty of Educational Sciences

Location coordinate	32°13'14.09"N,35°14'37.64"E
Height from sea level	612 m
Building occupied area	1719.4 m2
Free shadow, available area	300 m2

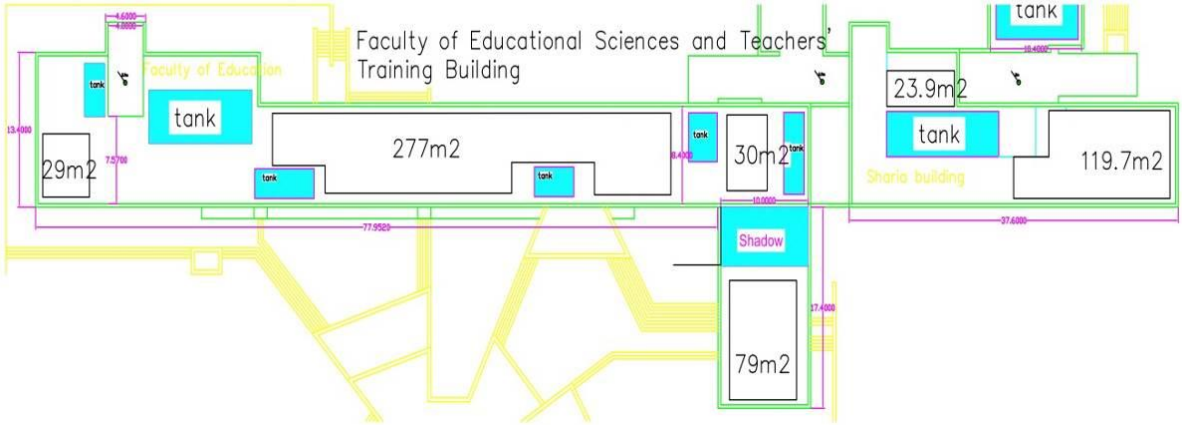


Fig.2 Faculty of Educational Sciences and Teachers' Training Building and roof space information

Accordingly studying the roof type and space availability is so important because different roofs require different mounting solutions which reflect on capital cost of project, and while PV systems add relatively low additional load on a roof, it is still important to ensure that the overall system is in line with structural allowances, and that it does not compromise the building's roof insulation.

4.1 Project PV plant Summary

Table III. Design parameters of the PV plant

Design parameters	Characteristics
Year of construction	2020/2021
Type of plant	roof-mounted, fixed
Orientation and tilt	South, 27 degree
Installed nominal power	145 kWp
Module type	Monocrystalline
The number of PV module	366 (140 panel × 390Wp & 226 panel × 400Wp)
Inverters	1 × ABB PVS-50-SX & 2 × ABB PVS-50-SX2

Fig.3 old Campus PV system

4.2 Contribution of the project activity to sustainable development

The project contributes to the general well-being of the region and is in line with the sustainable development policies of the host site.

Social well-being:

The project activity will lead to employment generation during installation as well as operation phase of the project activity.

Economic well-being:

The project implementation will provide a fillip to economic activity in the region. Direct & indirect employment will be generated in the plant for the project implementation & management. The success of this project will encourage more business to be developed in the local region thus bringing in economic prosperity in the region.

Environmental well-being:

The project being a renewable energy power project would contribute to mitigation of global warming. In addition, the project activity also would not lead to any air pollution unlike fossil fuel based power plants

5. Major methodology of retrofit technology implementation

5.1. Selection process & acquiring devices

After analyzing the site, and according the free shadow space on roof and considering the shadow distance between PV array, the initial design and PV array distribution was shown in fig.5.

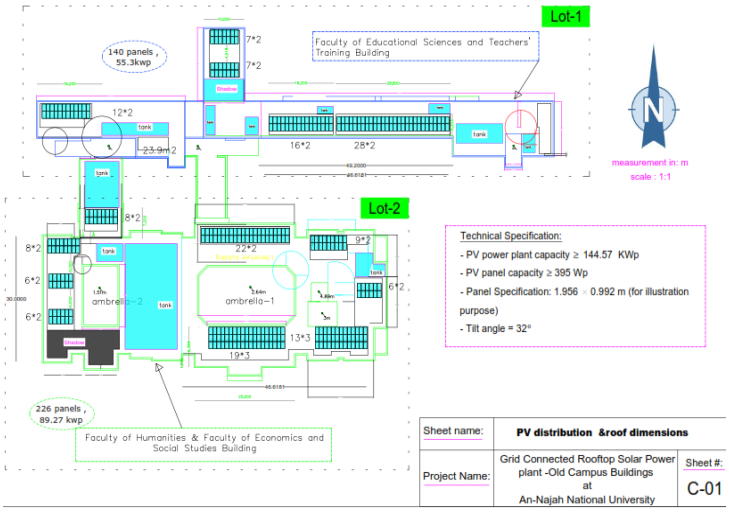


Fig.4 PV system initiative design

After checking the system design and yield using PVSol software, it was confirmed that the system distribution on roof has no object around may affect the PV performance negatively, and thus the budgetary estimation was done to analyze the project cost and its feasibility.

Therefore, in order to choose the best offers for devices and civil & electrical site work in terms of technical effectiveness and lowest offers, the tender dossier was prepared (see annex-1) as follow:

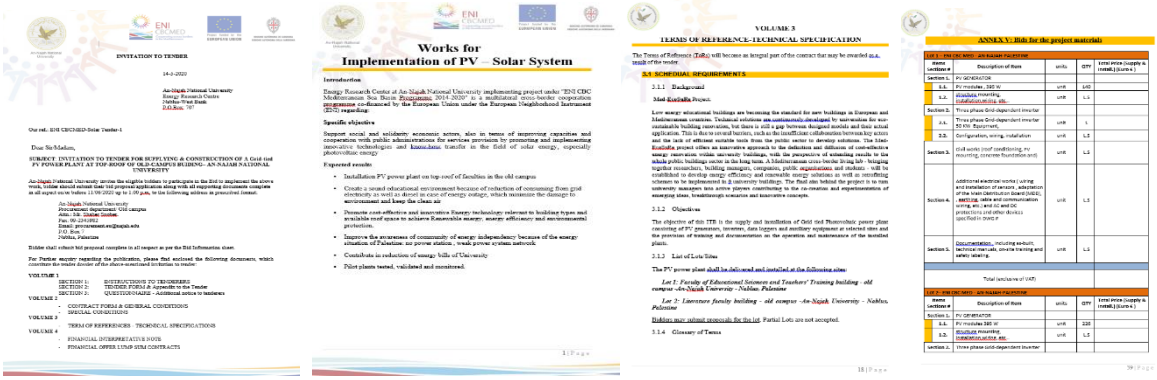


Fig.5 tender dossier

The tender call was published on 14/5/2020 as follow:

https://www.najah.edu/ar/tenders/rfq-12119/

Fig.6 tender call

During the tenderer offers preparation, a tour visit was organized by ANNU on 1/6/2020 to inspect the site and replying their query. And then the tender call was closed on 11/6/2020, and the applicants were as follow:

1- ITEC
2- Excellent Systems
3- Triple R
4- MTSC
5- SATCO
6- Alawael
7- 3K

Then the offers were evaluated technically and financially, to select the best offer for supplying materials and implementing the project (see annex-2)

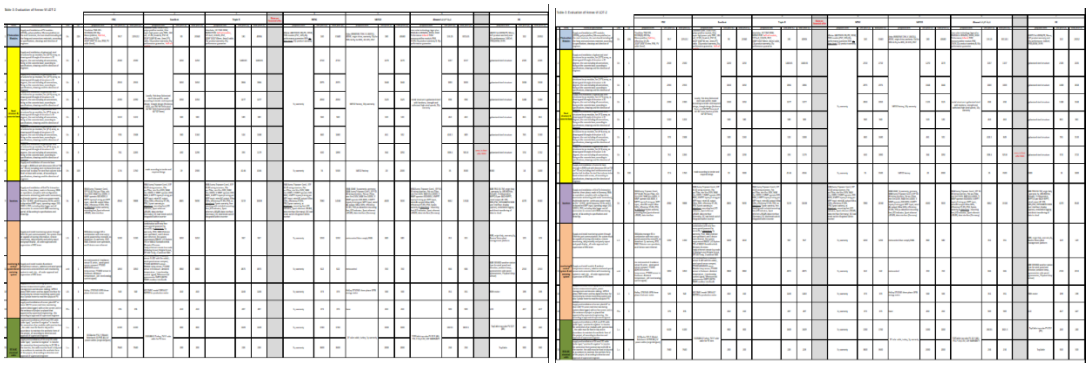


Fig.7 Technical & financial evaluation

Then according to the tender committee, the tender has been awarded to 3K company, and the work agreement /PO was signed between ANU and 3K to start the implementation activity and purchasing the project materials. (see annex-3)

Fig.8 Purchasing order agreement

5.2. Implementation stage

Work plan and design approval

Before the contractor initiate the implementation process on the site, the work plan, designs and equipment information are sent by contractor in order to get ANNU approval of them and giving an order directly to work to contractor.

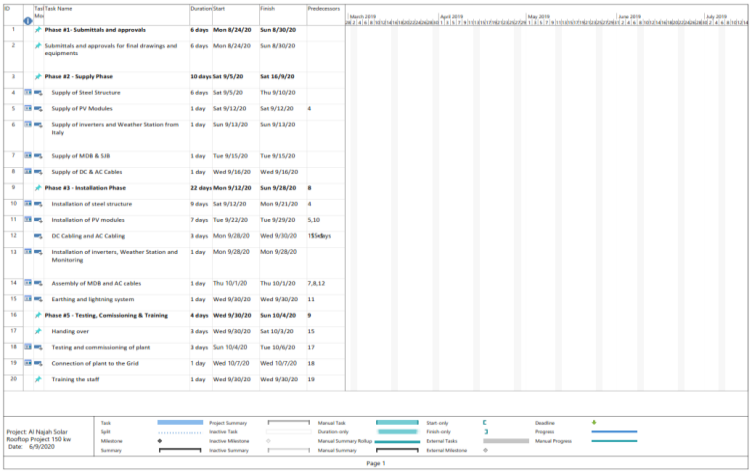


Fig.9 work plan

The design by 3k which include; distribution of array, connection with inverter and MDB of building, was provided as follow:

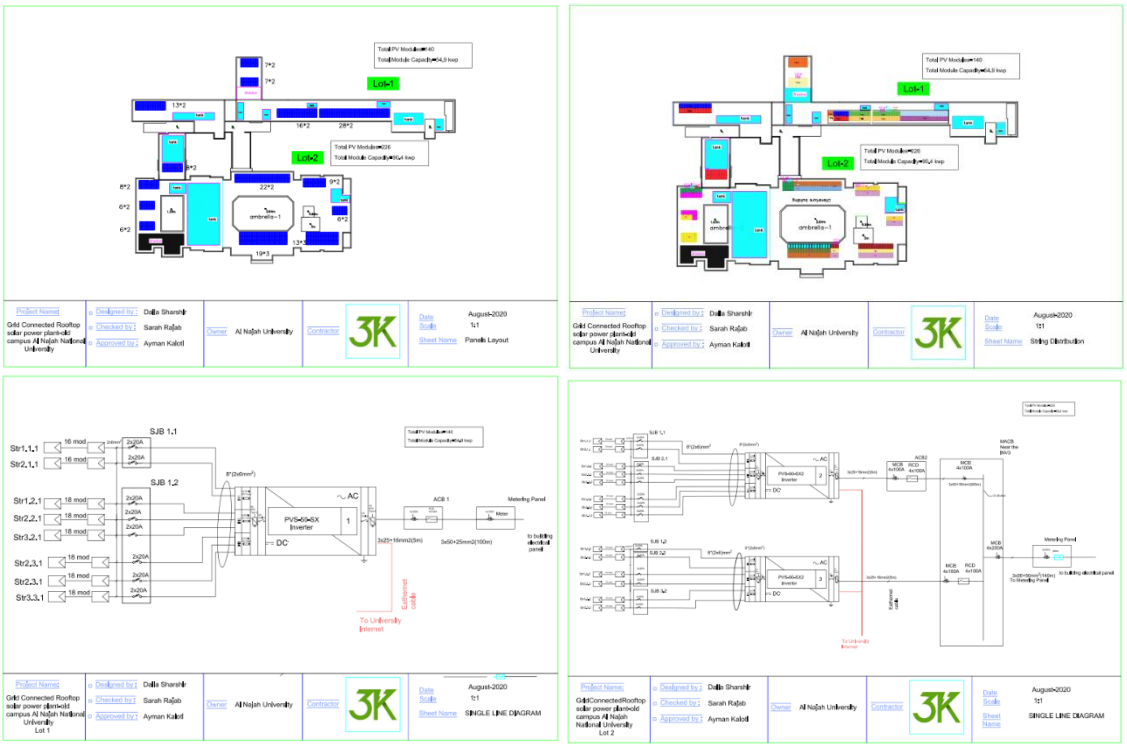


Fig.10 3k connection drawing

Civil & electrical Site Work

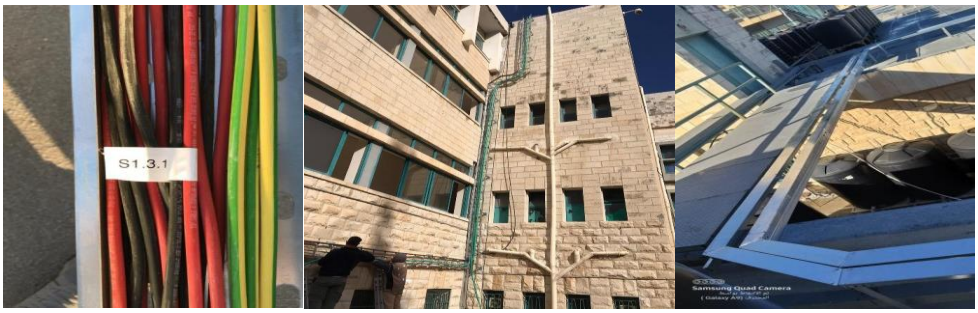
After taking the approval from ANNU, the contractor company start purchasing the components and manufacturing the steel structure and cement base, then they start implementing the project as follow:

1- Delivery of project materials to the site and distribute the cement foundation

2- Install the steel structure

3- Install PV panels, inverter and connected the main AC cables with university electrical board.

4- All the cables were installed in tranches and trunks for aaesthetic image of the project and facilitate the maintenance work in future



5- Then the DC/AC eacrthing was connected and lightning Pulsar

6- Finally the energy meters, weather stations sensors were installed and configured with monitoring portal - Aurora Vision® Plant Management Platform for performance monitoring, condition monitoring and data reporting

Fig.11 PV system implementation process

5.3. Validation stage

In order to operate the system successfully, the system components were checked and test by civil and electrical engineering in university during the implementation process to inspect the work and then a test was conduct before the system operation completely.

So three levels of commissioning and system testing was conduct as follow:

- **Level-1: site acceptance Inspection**

The acceptance of the site to install the equipment of the PV system is responsibility of the installing contractor (in our case 3k Company) and to start implementing the concrete base, galvanized steel structure.

- **Level-2: Pre-functional testing**

Characteristics and Visual Inspection test

- **Level-3: performing operational test**

In the last point of the project commissioning, the PV solar plant components during operation are checked and the successful operation of project is checked.
Operational test was done according to International Electro technical commission (IEC) recommendation [IEC 62446], to ensure that the system is properly installed and performing optimally.

The test has been carried out as follow:

- ✓ Tests to all DC circuit(s) forming the PV array, which include the following tests:
- ✓ Tests to all AC circuit(s)

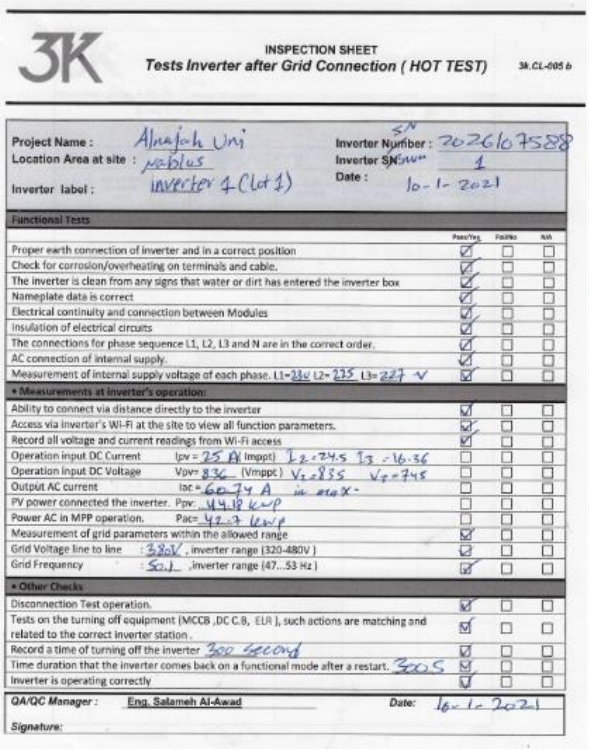
The equipment's that have been used for testing are all calibrated by authorized utility as follow:

Digital Earth resistance test device

Power analyzer device

HT AC clamp meter

The result of test was as follow:

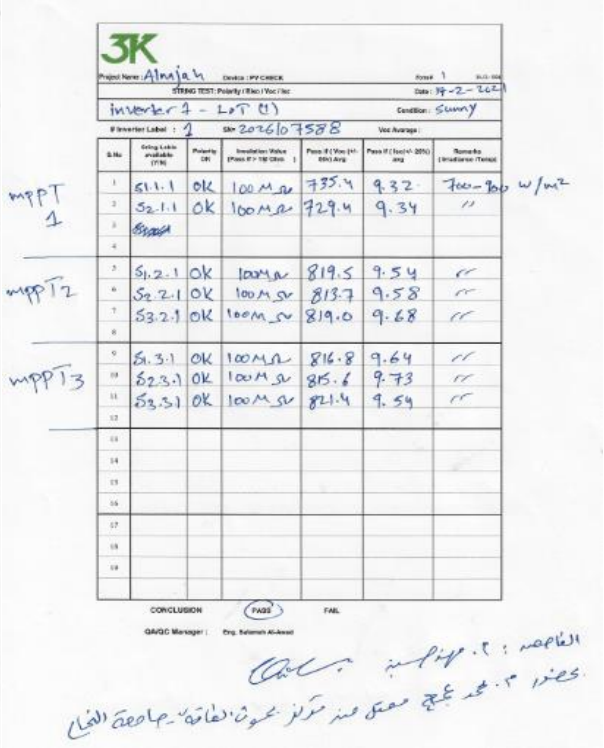


INSPECTION SHEET
Tests Inverter after Grid Connection (HOT TEST)
3K.CL-005.b

Project Name : Almajah Uni
Location Area at site : nablus
Inverter label : inverter 1 (Lot 1)
Inverter Number : 202607588
Inverter SN : 1
Date : 10-1-2021

Functional Tests	Pass/Yes	Fail/No	N/A
Proper earth connection of inverter and in a correct position	☑	☐	☐
Check for corrosion/overheating on terminals and cable.	☑	☐	☐
The inverter is clean from any signs that water or dirt has entered the inverter box	☑	☐	☐
Nameplate data is correct	☑	☐	☐
Electrical continuity and connection between Modules	☑	☐	☐
Insulation of electrical circuits	☑	☐	☐
The connections for phase sequence L1, L2, L3 and N are in the correct order.	☑	☐	☐
AC connection of internal supply.	☑	☐	☐
Measurement of internal supply voltage of each phase. L1=230 L2=235 L3=227 V	☑	☐	☐
• Measurements at inverter's operation:			
Ability to connect via distance directly to the inverter	☑	☐	☐
Access via inverter's WI-FI at the site to view all function parameters.	☑	☐	☐
Record all voltage and current readings from WI-Fi access	☑	☐	☐
Operation input DC Current Ipv = 25 A (Imppt) I2=24.5 I3=16.36	☐	☐	☐
Operation input DC Voltage Vpv= 836 (Vmppt) V1=835 V2=745	☐	☐	☐
Output AC current Iac = 60.74 A in max-	☐	☐	☐
PV power connected the inverter. Ppv: 44.18 kwp	☐	☐	☐
Power AC in MPP operation. Pac= 42.7 kwp	☐	☐	☐
Measurement of grid parameters within the allowed range	☑	☐	☐
Grid Voltage line to line : 380V , inverter range (320-480V)	☑	☐	☐
Grid Frequency : 50.1 ,inverter range (47...53 Hz)	☑	☐	☐
• Other Checks			
Disconnection Test operation.	☑	☐	☐
Tests on the turning off equipment (MCCB ,DC C.B, ELR), such actions are matching and related to the correct inverter station .	☑	☐	☐
Record a time of turning off the inverter 300 Second	☑	☐	☐
Time duration that the inverter comes back on a functional mode after a restart. 300 S	☑	☐	☐
Inverter is operating correctly	☑	☐	☐

QA/QC Manager : Eng. Salameh Al-Awad Date: 16-1-2021
Signature:



3K
Project Name : Almajah — Device : PV CHECK — Date : 17-2-2021
STRING TEST: Polarity / Rso / Voc / Isc
inverter 1 - Lot (1) — Condition : Sunny
Inverter Label : 1 — SN: 202607588 — Voc Average :

S.No	String Cable available (Y/N)	Polarity OK	Insulation Value (Pass if > 100 Ohm)	Pass if (Voc (+/- 05%) Avg	Pass if (Isc(+/- 20%) avg	Remarks (Irradiance / Temp)
1	S1.1.1	OK	100 MΩ	735.4	9.32	700-900 w/m²
2	S2.1.1	OK	100 MΩ	729.4	9.34	"
3	[illegible]					
4						
5	S1.2.1	OK	100 MΩ	819.5	9.54	"
6	S2.2.1	OK	100 MΩ	813.7	9.58	"
7	S3.2.1	OK	100 MΩ	819.0	9.68	"
8						
9	S1.3.1	OK	100 MΩ	816.8	9.64	"
10	S2.3.1	OK	100 MΩ	815.6	9.73	"
11	S3.3.1	OK	100 MΩ	821.4	9.54	"
12						
13						
14						
15						
16						
17						
18						
19						

MPPT 1
MPPT 2
MPPT 3

CONCLUSION PASS FAIL
QA/QC Manager : Eng. Salameh Al-Awad

INSPECTION SHEET
Tests Inverter after Grid Connection (HOT TEST)
3k.CL-005 b

Project Name : Almajah Uni	Inverter Number : # 1 LOT (2)
Location Area at site : Nablus	Inverter SN: 194411 2125
Inverter label : INV 1 (LOT2)	Date : 10-1-2021

Functional Tests	Pass/Yes	Fail/No	N/A
Proper earth connection of inverter and in a correct position	☑	☐	☐
Check for corrosion/overheating on terminals and cable.	☑	☐	☐
The inverter is clean from any signs that water or dirt has entered the inverter box	☑	☐	☐
Nameplate data is correct	☑	☐	☐
Electrical continuity and connection between Modules	☑	☐	☐
Insulation of electrical circuits	☑	☐	☐
The connections for phase sequence L1, L2, L3 and N are in the correct order.	☑	☐	☐
AC connection of internal supply.	☑	☐	☐
Measurement of internal supply voltage of each phase. L1= 230 L2= 225 L3= 229	☑	☐	☐
• Measurements at Inverter's operation:			
Ability to connect via distance directly to the inverter	☑	☐	☐
Access via inverter's Wi-Fi at the site to view all function parameters.	☑	☐	☐
Record all voltage and current readings from Wi-Fi access	☑	☐	☐
Operation input DC Current Ipv = [illegible] (Imppt) I1=16.62 I2=24.5 I3=25.3	☑	☐	☐
Operation input DC Voltage Vpv= ____ (Vmppt) V1=705 V2=751 V3=754	☑	☐	☐
Output AC current Iac = 56.21 A in max .	☑	☐	☐
PV power connected the inverter. Ppv: 41.49 kWp	☑	☐	☐
Power AC in MPP operation. Pac= 40.47 kWp	☑	☐	☐
Measurement of grid parameters within the allowed range	☑	☐	☐
Grid Voltage line to line : 380V , inverter range (320-480V)	☑	☐	☐
Grid Frequency : 50.2 ,inverter range (47...53 Hz)	☑	☐	☐
• Other Checks			
Disconnection Test operation.	☑	☐	☐
Tests on the turning off equipment (MCCB ,DC C.B, ELR), such actions are matching and related to the correct inverter station .	☑	☐	☐
Record a time of turning off the inverter 300 sec	☑	☐	☐
Time duration that the inverter comes back on a functional mode after a restart. 300 sec	☑	☐	☐
Inverter is operating correctly	☑	☐	☐

QA/QC Manager : Eng. Salameh Al-Awad *Date:* 10-1-2021

Signature:

3K

Project Name : Almajah Device : PV CHECK Form# 1

STRING TEST: Polarity / Riso / Voc / Isc Date : 14-2-2018

inverter 1 - LOT2 Condition : Sunny

Inverter Label : 1 SN: Voc Average :

	S.No	String Lable available (Y/N)	Polarity OK	Insulation Value (Pass if > 1M Ohm)	Pass if [Voc (+/- 5%)] Avg	Pass if [Isc(+/- 20%)] avg	Remarks (Irradiance /Temp)
MPPT 1	1	S1.1.1	OK	100MΩ	682.1	10.37	700-900 w/m2
	2	S2.1.1	OK	100MΩ	679.6	10.39	"
	3						
	4						
MPPT 2	5	S1.2.1	OK	100MΩ	721.1	10.34	"
	6	S2.2.1	OK	100MΩ	720.1	10.40	"
	7	S3.2.1	OK	100MΩ	718.7	10.42	"
	8						
MPPT 3	9	S1.3.1	OK	100MΩ	724	10.47	"
	10	S2.3.1	OK	100MΩ	740.2	10.44	"
	11	S3.3.1	OK	100MΩ	723.8	10.48	"
	12						
	13						
	14						
	15						
	16						
	17						
	18						
	19						

CONCLUSION (PASS) FAIL

QA/QC Manager : Eng. Salameh Al-Awad

الفاحص : م. [illegible]

بحضور م. محمد عجيج ممثل عن مركز تكوين الطاقة - جامعة النجاح.

INSPECTION SHEET
Tests Inverter after Grid Connection (HOT TEST)
3k.CL-005 b

Project Name : Almajah	Inverter Number : # 2
Location Area at site : Nablus	Inverter SN: 194511 4009
Inverter label : INV(2) LOT2	Date : 10-1-2021

Functional Tests	Pass/Yes	Fail/No	N/A
Proper earth connection of inverter and in a correct position	☑	☐	☐
Check for corrosion/overheating on terminals and cable.	☑	☐	☐
The inverter is clean from any signs that water or dirt has entered the inverter box	☑	☐	☐
Nameplate data is correct	☑	☐	☐
Electrical continuity and connection between Modules	☑	☐	☐
Insulation of electrical circuits	☑	☐	☐
The connections for phase sequence L1, L2, L3 and N are in the correct order.	☑	☐	☐
AC connection of internal supply.	☑	☐	☐
Measurement of internal supply voltage of each phase. L1= 230 L2= 225 L3= 227	☑	☐	☐
• Measurements at Inverter's operation:			
Ability to connect via distance directly to the inverter	☐	☐	☐
Access via inverter's Wi-Fi at the site to view all function parameters.	☐	☐	☐
Record all voltage and current readings from Wi-Fi access	☐	☐	☐
Operation input DC Current Ipv = ____ (Imppt) I1=16.61 I2=8.58 I3=16.9	☑	☐	☐
Operation input DC Voltage Vpv= ____ (Vmppt) V1=750 V2=758 V3=852	☑	☐	☐
Output AC current Iac = 38.6	☑	☐	☐
PV power connected the inverter. Ppv: 33.8 kWp	☑	☐	☐
Power AC in MPP operation. Pac= 30.8 kWp	☑	☐	☐
Measurement of grid parameters within the allowed range	☑	☐	☐
Grid Voltage line to line : 380 , inverter range (320-480V)	☑	☐	☐
Grid Frequency : 50 ,inverter range (47...53 Hz)	☑	☐	☐
• Other Checks			
Disconnection Test operation.	☑	☐	☐
Tests on the turning off equipment (MCCB ,DC C.B, ELR), such actions are matching and related to the correct inverter station .	☑	☐	☐
Record a time of turning off the inverter 300 sec	☑	☐	☐
Time duration that the inverter comes back on a functional mode after a restart. 300 sec	☑	☐	☐
Inverter is operating correctly	☑	☐	☐

QA/QC Manager : Eng. Salameh Al-Awad *Date:* 10-1-2020

Signature:

3K

Project Name : Almajah Device : PV CHECK Form# 1

STRING TEST: Polarity / Riso / Voc / Isc Date : 14-2-2021

Inverter 2 LOT2 Condition : Sunny

Inverter Label : 2 SN: 194511 4009 Voc Average :

	S.No	String Lable available (Y/N)	Polarity OK	Insulation Value (Pass if > 1M Ohm)	Pass if [Voc (+/- 5%)] Avg	Pass if [Isc(+/- 20%)] avg	Remarks (Irradiance /Temp)
MPPT 1	1	S1.1.2	OK	100MΩ	730.8	10.21	700-900 w/m2
	2	S2.1.2	OK	100MΩ	732.4	10.20	"
	3						
	4						
MPPT 2	5	S1.2.2	OK	100MΩ	728.4	10.10	"
	6	S2.2.2	OK	100MΩ	718.1	10.52	"
	7						
	8						
MPPT 3	9	S1.3.2	OK	100MΩ	814.0	10.23	"
	10	S2.3.2	OK	100MΩ	815.3	10.32	"
	11						
	12						
	13						
	14						
	15						
	16						
	17						
	18						
	19						

CONCLUSION (PASS) FAIL

QA/QC Manager : Eng. Salameh Al-Awad

الفاحص : م. [illegible]

بحضور م. محمد عجيج ممثل عن مركز تكوين الطاقة - جامعة النجاح

5.4. Monitoring & evaluation stage

The performance of system was analyzed using technical data downloaded from the data logger of Fimer Aurora Vision and digital meters.

The PV system operation was monitored from 1/1/2021 until 28/02/2023, during these period a periodic maintenance of the system was carried out and followed up to solve problems when they occur, such as changing a fuse or cleaning the panel, and the results were as follow:

For the 1st year of project operation-2021, the total energy yield was= 200.08 MWh/year:

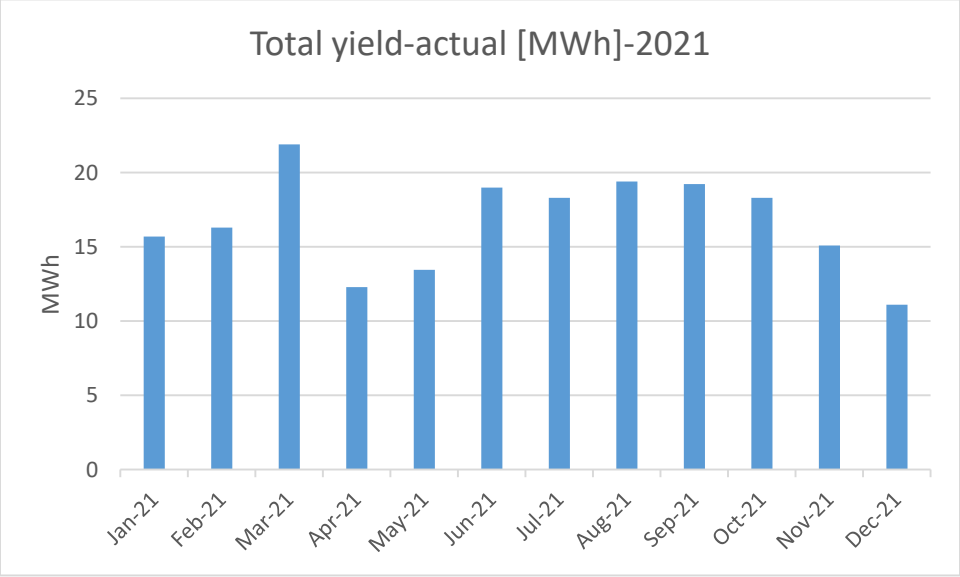


Fig.12 PV system yield of year 2021 -MWh

For the 2nd year of project operation-2022, the total energy yield was= 213.09 MWh/year,

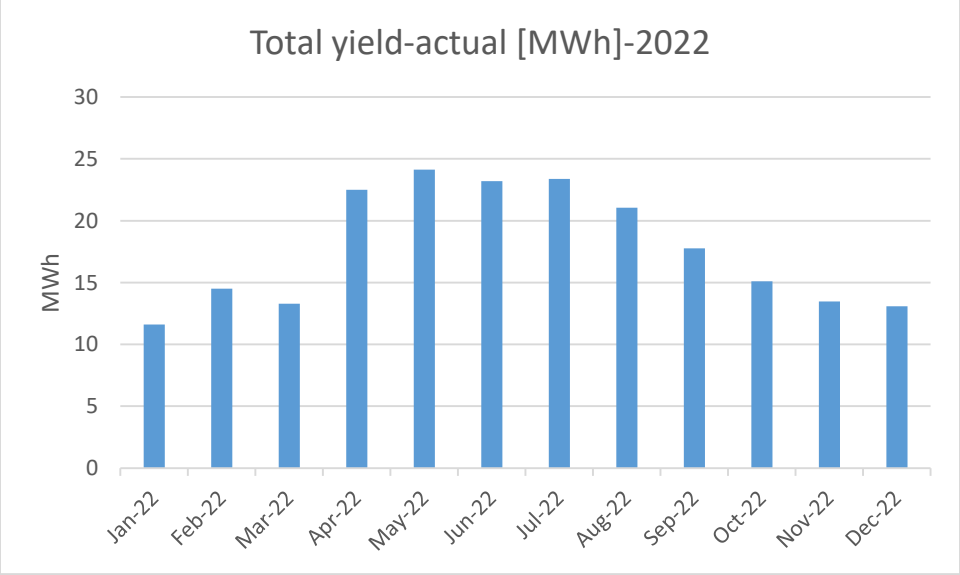


Fig.13 PV system yield of year 2022 -MWh

For the 3nd year of project operation-2023, the total energy yield was (until 28th February,2023) = 27.62 MWh/year,

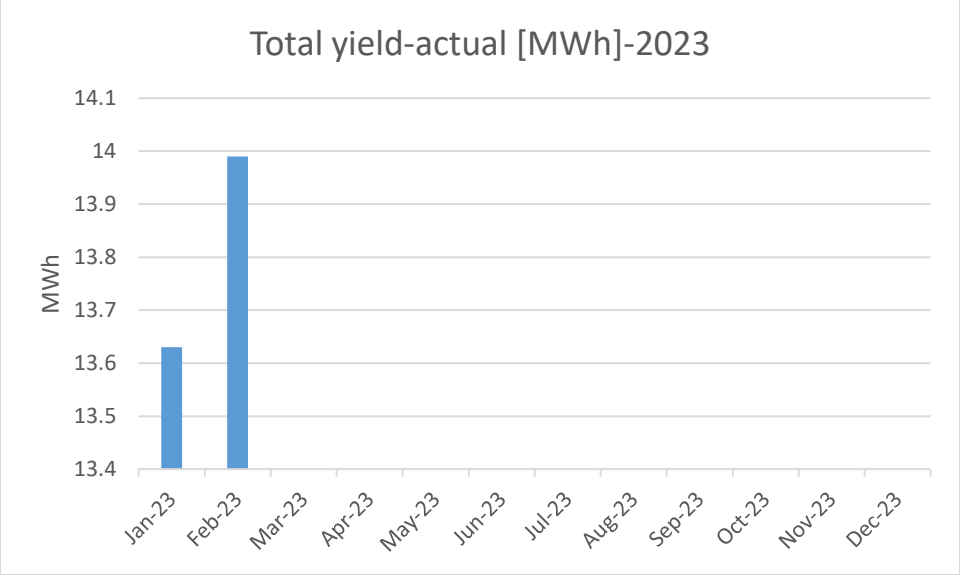


Fig.5 PV system yield of year 2023 –MWh

So, the total solar system yields 2021-2023, as follow:

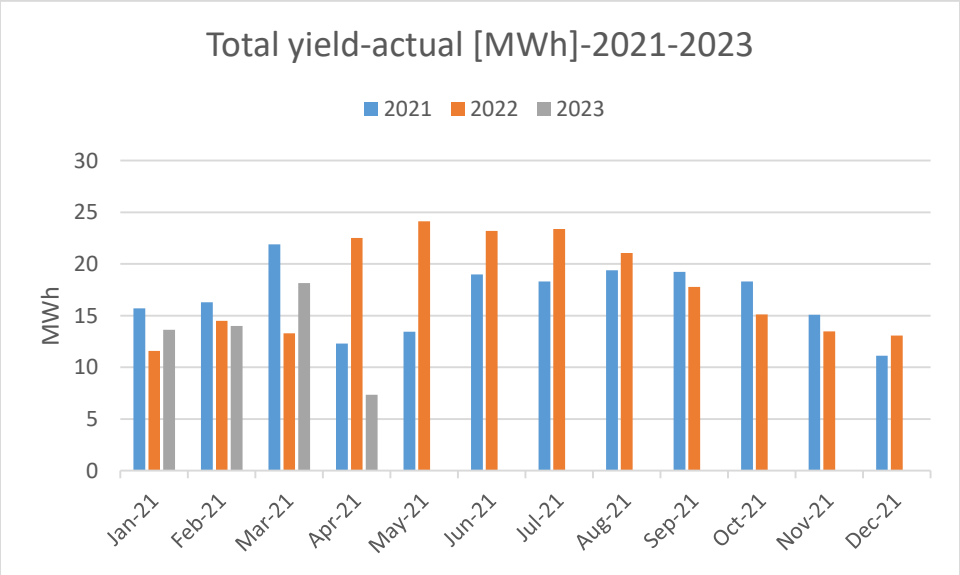


Fig.6 PV system yield (MWh) of year 2021-2023

According to previous data, the system was working properly, and thus is shown in the indicator below:

Technical evaluation:

- System Efficiency

The efficiency of PV system measures the ability of system to convert the sunlight into required energy for load consumption, the system efficiency is given by following form:

$$\eta \text{ (system efficiency)} = \frac{\text{Output energy of PV system (KWh)}}{\text{Global radiation energy received by PV array area (KWh)}}$$

The System efficiency for 1st year (2021) is 14%
The System efficiency for 2nd year (2022) is 15%
The System efficiency for 3rd year (March-2023) is 12%

- Performance Ratio

$$PR = \frac{\text{actual energy generated by PV system (KWh)}}{\text{Energy produced by system at STC (KWh)}}$$

The Performance Ratio for 1st year (2021) is 64.6%
The Performance Ratio for 2nd year (2022) is 75%
The Performance Ratio for 3rd year (March-2023) is 63%

- Final Yield (Yf)

$$Y_f = \frac{\text{actual energy generated by PV system (KWh)}}{\text{PV array maximum Capacity (KW)}}$$

The final yield will refer for how many hours the system is operated in year or day.

Accordingly,

Y_f over operated period is 3039.93 and average solar hour per day is 3.68 h/day

- Capacity Factor (Cf)

The capacity factor varies quite a bit for solar photovoltaic systems depending on the location. Generally, it is in the range of 10-25%. One of the key reasons for this low ratio is the nature of renewable power.

$$C_f = \frac{\text{actual energy generated by PV system (KWh)}}{\text{PV array maximum Capacity (KW)} \times 8760\text{h/year}}$$

the total hours over operation period is 18936h, accordingly **the average capacity factor of system over this period is 15%.**

Environmental and Economic evaluation:

The CO2 emission and electricity bills will be reduced annually according to how much energy produce from the PV solar system since the system operation, as follow:

- **The electricity bill will reduce over 2021-2022 = 63628.18 Euro**
- **CO2 emission will reduce by 268.3 ton CO2**

➢ Payback time

The previous estimation calculation was as follow:

Expected Saving cost (€/year) = 2158.16 €/month*12month=25897.92 €/year

PV Investment cost (€) = 92488 Euro

S.P.B.P = Investment / saving cost per year

= 92488 Euro / 25897.92 Euro = 3.57 years ≈ **3 years & 6 month**

But according to the actual energy output, the saving was higher which reflect in decreasing number of years of payback period.

Actual Saving cost in 1st year (€/year) = 30812.32 €/year

PV Investment cost (€) = 92488 Euro

S.P.B.P = Investment / saving cost per year

= 92488 Euro / 30812.32 Euro = **3 years**

6. Recommendations and future scale up of installing Rooftop PV system

In general, innovative technologies and processes should be conceived in order to seize low radiation energy and optimize its transformation into actual power. Based on what was previously mentioned so we recommended the following to install rooftop PV system:

- The optimum power output must be estimated before the installation of the photovoltaic plant, which was influenced by quantity and quality of the solar energy resource of the desired project location.
- Solar module efficiency: Modules in operation typically have an efficiency of between 9% and 22%; however, module performance typically deteriorates over time. This module degradation can occur at a rate of approximately 0.3% to 1%/year,

depending on the module type and local conditions, so choosing high efficient module will reflect on solar energy production.

Two types were available in Palestinian Market; Poly-crystalline and mono-crystalline which used in PV installations and those modules have different properties, which influence the suitability of their application:

- Poly crystalline modules are widely used with many proven manufacturers around the world. They are typically less expensive to produce than mono-crystalline modules, but are not as efficient. Because of the way they are manufactured,
- Mono crystalline modules have a higher efficiency than most other types of modules, but can be more expensive as a result.

Typically, modules come with a 10-year mechanical warranty on the product, and a 25-year performance warranty.

- Appropriate design considerations: such modules layout and spacing, cable lengths and inverter sizing, to reduce the losses in individual components of the system, as the energy is converted from solar to electrical energy.
- Shading losses analyses play a crucial role before installation because they allow to predict and analyse the performance of the designed PV system, where Inter-row shading and the surrounding landscape influences how much exposure the system has to the sun. Neighbouring buildings, trees or natural features can shade part or the whole of a system, affecting overall energy generation.
- The system's layout should consider local health and safety requirements, including whether or not access is required by emergency services in the event of a fire. This also affects accessibility for system maintenance, cleaning the modules, and carrying out maintenance on any of the components.
- In addition, structure of PV frameworks carefully identified, especially on the roofs of old buildings, to limit the heaviness of photovoltaic panels. A PV panel typically weighs 20–40 kg. Since a PV array clearly incorporates numerous panels, the all-out weight of the introduced array is much bigger. So reducing the basic load of the PV structure will solve this issue, make PV modules lighter and diminish transportation costs besides decreasing the cost of the materials used for the photovoltaic structure.
- To avoid penetrate the roof when fixing the mounting structure of PV systems to keep the building's waterproofing and roofing warranties
- The mounting system should be able to withstand applicable wind and/or snow loading
- It is important that the material selected (i.e. structure, welding Screws and clamps) is adequately treated and galvanized to prevent corrosion, as the mounting system will be exposed to the environment and external factors
- Installing Energy meters' measure electricity generated by the system, and this data is used in assessing facility performance.

- Installing System remote monitoring to ensure the system operates efficiently

As is clear, getting accurate information on the actual behavior of the designed PV system will allow understanding how to optimize its efficiency, thus contributing to reduce the amount of energy generated from non-renewable sources and the emissions.

This system is a cost-effective energy solution, which permits to save a huge amount of money and time during the PV system installation, which can replicate on the roof of other new/old building through a robust design of the system, taking in to account the mentioned consideration to achieve the maximum energy efficiency of system and make use of the available spaces in order to enhances the autonomy of the national grid and reduce the cost of electrical energy.

This type of system encourages investors to increase in the uptake of solar PV installations due to:

- Lower costs of PV technology: Overall installation costs for PV technologies have decreased significantly in recent years, and it's expected to continue going forward and overall system costs are forecasted to decrease by between 40% and 75% by 2050;
- increasing grid supplied electricity prices;
- the availability of preferential feed-in-tariffs or other financial incentives for renewable energy technologies (including tax credits);
- carbon emission reduction;
- the availability of alternative financing options;
- air pollution concerns; and
- energy security concerns

Med-EcoSuRe

Innovative Retrofit Technology Report

Solar Carport for Fine Arts Faculty in New-Campus Building– An-Najah National University

(The south garage of Fine Arts Faculty in New-Campus building)

Prepared by:
An-Najah national university (ANNU)

2023

Project Acronym	University building
Project Name	"Mediterranean University as Catalyst for Eco-Sustainable Renovation" (Med-EcoSuRe)
Project Duration	September 2019- August 2022
Website	www.enicbcmed.eu/projects/med-ecosure
Authors	An-Najah National University (ANNU)
Date	February 2023
File Name	Full scale experimentation of innovative retrofit technologies, validation and testing in real life report (**Solar Carport in New-Campus Building - An-Najah National University – Palestine**)

This project is part of the Mediterranean University as Catalyst for Eco-Sustainable Renovation (Med-EcoSuRe). The project aims to implement full scale experimentation of innovative retrofit technologies, validation and testing in real life in An-Najah university campuses, in order to allow a relevant energy demand reduction and mitigate greenhouse gas emission.

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1. Introduction

Low energy educational buildings are becoming the standard for new buildings in European and Mediterranean countries. Technical solutions are continuously developed by universities for eco-sustainable building renovation, but there is still a gap between designed models and their actual application. This is due to several barriers, such as the insufficient collaboration between key actors and the lack of efficient suitable tools from the public sector to develop solutions.

Under framework of the Mediterranean University as Catalyst for Eco-Sustainable Renovation (Med-EcoSuRe), the partnership universities of project have taken action that aims to find Technical solutions for eco-sustainable building renovation. The Med-EcoSuRe project offers an innovative approach to the definition and diffusion of cost-effective energy renovation within university buildings, with the perspective of extending results to the whole public buildings sector in the long term. A Mediterranean cross-border living lab - bringing together researchers, building managers, companies, public organisations and students - will be established to develop energy efficiency and renewable energy solutions as well as retrofitting schemes to be implemented in 9 university buildings. The final aim behind the project is to turn university managers into active players contributing to the co-creation and experimentation of emerging ideas, breakthrough scenarios and innovative concepts, where the Low energy educational buildings are becoming the standard for new buildings in European and Mediterranean countries.

The project aims to achieve the following: -

- Environmental protection, climate change adaptation and mitigation
- Improving energy efficiency in university building and installing On-grid PV solar system.
- Reduce the energy demand from local public electrical network, which reduce electricity bills and contribute in educational process positively.
- A sustainable, reliable, safety and cost-effective electrical energy supply
- PV power Plant is tested, evaluated and monitored using monitoring, sensor and data logging system which monitored remotely and at site for public demonstration & display

At the same pace, ANNU aims through its facilities and activities to achieve environmental sustainability as follow: -

- Promote and create a campus which supports academic, research and enterprise activities in a sustainable way
- Provide the education, advancement, dissemination and application of sustainable development

- Maximize the wider impact of ANU's environmental sustainability activities at local, regional, national and international level through collaboration, partnership and communications
- become a leader across the HE sector in terms of environmental sustainability

Accordingly, ANNU through Med-EcoSuRe project had conducted Full scale experimentation of innovative retrofit technologies for example solar carport as a solution to conserve energy in new buildings where the roof of the buildings does not have spaces for installing solar systems due to the presence of air conditioners devices, chillers and water tanks, so the Solar CarPort is a great alternative to roof mounted solar and ideal for electric vehicle charging, to achieve a meaningful decrease in energy usage and GHG emissions and as a result, a comfortable and healthy atmosphere on campus.

Also contribute in providing visibility of the energy that is being used across campus to facilitate culture change within the ANNU community.

2. What & Why On Grid Solar CarPort?

Solar carport is a roof supported by beams or posts to protect the vehicles in the parking from harsh weather and form shadow for them and includes solar panels that cover the carport's roof to capture solar energy and convert it into energy.

Solar carport systems include a number of key components that require considerable electrical and mechanical design. Solar car parks range in size from a single carport arrangement for one parking space to large multi-bay car parks.

Multifunctional solar carports can provide a flexible energy system designed to fulfil a number of functions. Function requirements of these carports are site specific and take into account:

- Onsite electrical loads (i.e. lighting, EV charging etc.) and storage capacity
- solar generation capacity (size and performance of solar array installed)
- local distribution network and weather conditions

So, why solar CarPort system?

- Efficient Space Usage: No additional space is required to construct a carport; instead, an already existing area can be used to increase productivity and visitor, customer, and employee comfort.
- Protection: the carport will shield the vehicle from the bad weather, such as snow or sweltering sun rays and also can help improve vehicle fuel economy by providing shade to keep cars from overheating in the sun

- Better Power Generation: the tilt angle is flexible and can be constructed to maximize energy output and exposure, which is different from conventional solar panel system which there is restrictions on how much the panels can be tilted or even how they can be fastened for roof installations.
- Single-source solution for canopy structure design and construction

So, it is an ideal way to add Solar PV to any property without altering it and at the same time provides a sheltered place with integrated charging point for electric vehicles. The solar panels can then provide an income from the feed-in tariff and free fuel for the electrical cars.

3. Technology Description

A solar carport is a taller version of a solar array attached to the ground. The solar panels will serve as the new structure's roof, eliminating the need for one.

Solar carports employ the same solar energy technology as a regular ground- or rooftop-mounted system. When exposed to sunlight, carports transform photons into energy, which is then used to produce voltage or electric current in a photovoltaic cell. It is frequently referred to as the photovoltaic effect.

Although most solar carports are grid-connected, some freestanding off-grid solutions are also available. These also go by the name of solar canopies. Parking lots and other paved areas are frequently used as the location for solar canopies. Bifacial solar panels, which catch the light reflected from the ground, are another option.

the system components include PV modules, their accompanying mounting structure, built in generation meter and switchgear for PV and an inverter.

4. Full scale experiment of Innovative Technologies

ANNU through the project has carried out implementation of solar PV carport system in new campus in Nablus, in order to reduce the energy consumption annually and As part of the university's constant endeavor towards increasing the coverage of solar cell systems for the university's total consumption by exploiting the spaces on the one hand, and on the other hand, the university's desire to spread new ideas for the implementation of solar energy projects, the idea of the solar garage was come up..

Table I. Geographical site of garage

Location coordinate	32°13'38.7"N, 35°13'17.1"E
garage occupied area	198 m2
available area for carport	432 m2

Fig.1 information location of south garage fine arts faculty

4.1 Project PV plant Summary

Table II. Design parameters of the PV plant

Design parameters	Characteristics
Year of construction	2022
Type of plant	Ground mounted, fixed
Orientation and tilt	South, 10 degree
Installed nominal power	50 kWp
Module type	Monocrystalline
The number of PV module	105 panel × 465Wp
Inverters	1 × SMA Sunny Tripower Core1- 50 kwp

Fig.2 PV carport-new Campus PV system

4.2 Contribution of the project activity to sustainable development

The project contributes to the general well-being of the region and is in line with the sustainable development policies of the host site.

Social well-being:

The project activity will lead to employment generation during installation as well as operation phase of the project activity.

Economic well-being:
The project implementation will provide a fillip to economic activity in the region. Direct & indirect employment will be generated in the plant for the project implementation & management. The success of this project will encourage more business to be developed in the local region thus bringing in economic prosperity in the region.

Environmental well-being:
The project being a renewable energy power project would contribute to mitigation of global warming. In addition, the project activity also would not lead to any air pollution unlike fossil fuel based power plants

5. Major methodology of retrofit technology implementation

5.1. Selection process & acquiring devices

After analyzing the site, and considering the shadow distance between PV rows, the initial design and PV array distribution was shown in fig.3.

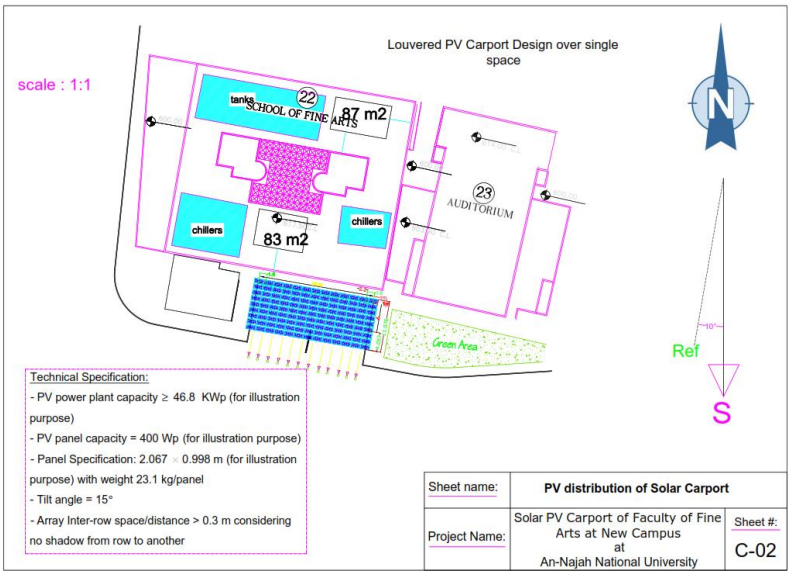


Fig.3 PV system initiative design

After checking the system design and yield using PVSol software, and the budgetary estimation was done to analyze the project cost and its feasibility.

Therefore, in order to choose the best offers for devices and civil & electrical site work in terms of technical effectiveness and lowest offers, the tender dossier was prepared (see annex-1) as follow:

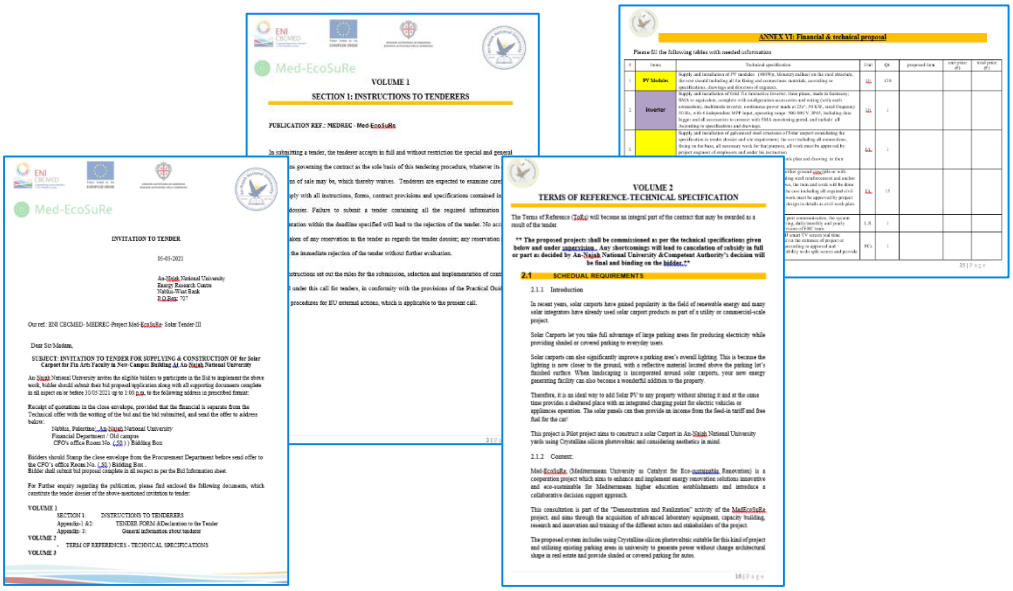


Fig.4 tender dossier

The tender call was published on 5/5/2021 as follow:

https://www.najah.edu/ar/tenders/rfq-12348/

Fig.5 tender call

During the tenderer offers preparation, a tour visit was organized by ANNU on 17/5/2021 to inspect the site and replying their query. And then the tender call was closed on 30/5/2021, and the applicants were as follow:

1- 3k Solar
2- SATCO
3- Sunergy

Then the offers were evaluated technically and financially, to select the best offer for supplying materials and implementing the project (see annex-2)

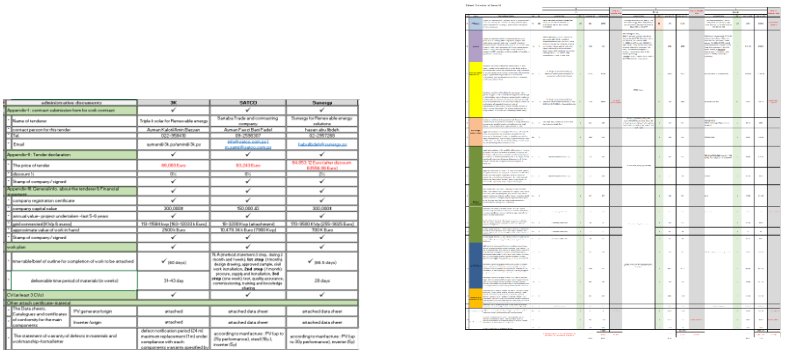


Fig.6 Technical & financial evaluation

Then according to the tender committee, the tender has been awarded to SATCO company, and the work agreement/PO was signed between ANU and SATCO to start the implementation activity and purchasing the project materials. (see annex-3)

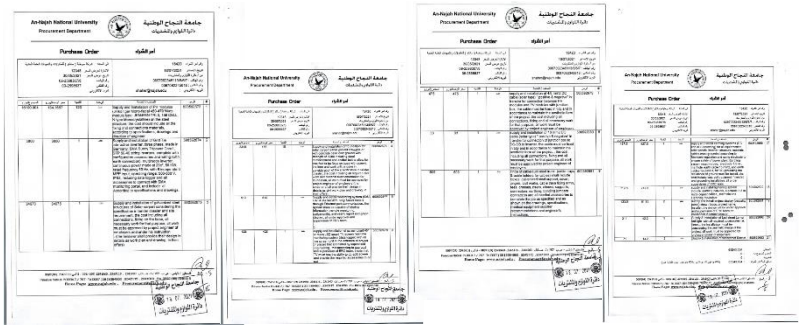


Fig.7 Purchasing order agreement

5.2. Implementation stage

Work plan and design approval

Before the contractor initiate the implementation process on the site, the work plan, designs and equipment information are sent by contractor in order to get ANNU approval of them and giving an order directly to work to contractor.

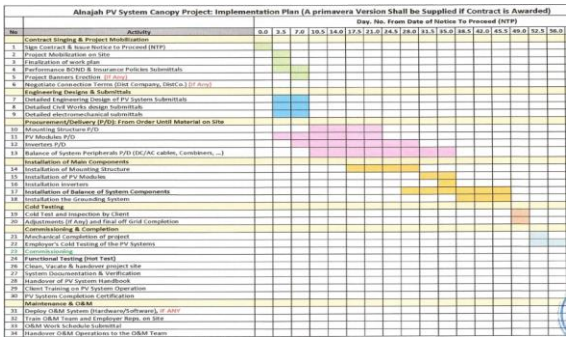


Fig.8 work plan

The design by AutoCAD which include; distribution of array, connection with inverter and MDB of building, was provided as follow:

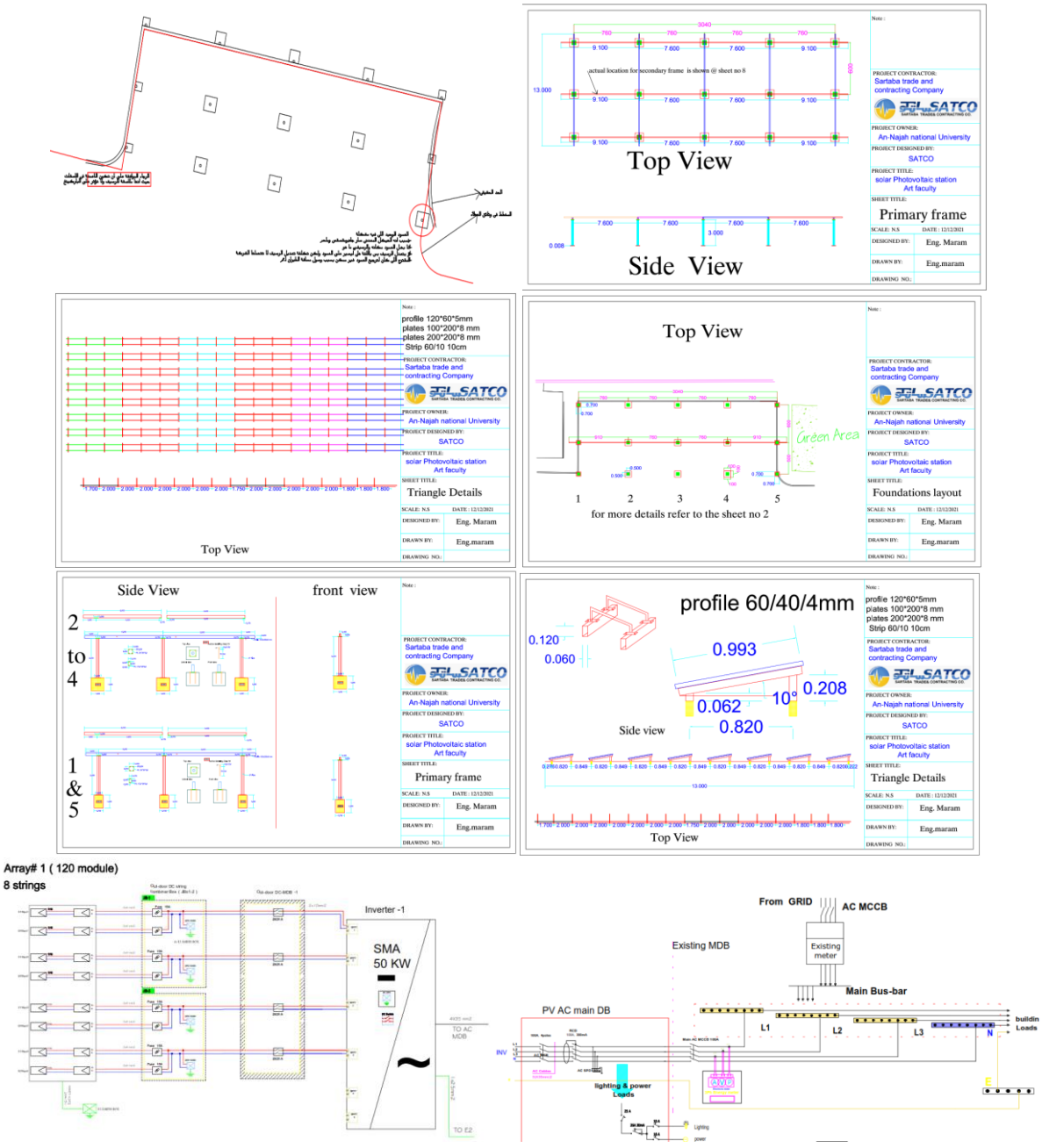


Fig.9 SATCO connection drawing

Civil & electrical Site Work

After taking the approval from ANNU, the contractor company start purchasing the components and manufacturing the steel structure and cement base, then they start implementing the project as follow:

1- Delivery of project materials to the site and prepare distribute the column for foundation preparation

2- Install the steel structure

3- Install PV panels, inverter and connected the main AC cables with university electrical board.

4- All the cables were installed in tranches and trunks for aesthetic image of the project and facilitate the maintenance work in future
5- Then the DC/AC eacrthing was connected and lightning Pulsar
6- Finally the energy meters was installed and configured with monitoring portal – SMA Sunny Portal powered by ennexOS for performance monitoring, condition monitoring and data reporting.

Fig.10 PV system implementation process

5.3. Validation stage

In order to operate the system successfully, the system components were checked and test by civil and electrical engineering in university during the implementation process to inspect the work and then a test was conduct before the system operation completely.

So three levels of commissioning and system testing was conduct as follow:

- **Level-1: site acceptance Inspection**

The acceptance of the site to install the equipment of the PV system is responsibility of the installing contractor (in our case 3k Company) and to start implementing the concrete base, galvanized steel structure.

- **Level-2: Pre-functional testing**

Characteristics and Visual Inspection test

- **Level-3: performing operational test**

In the last point of the project commissioning, the PV solar plant components during operation are checked and the successful operation of project is checked.
Operational test was done according to International Electro technical commission (IEC) recommendation [IEC 62446], to ensure that the system is properly installed and performing optimally.

The test has been carried out as follow:

- ✓ Tests to all DC circuit(s) forming the PV array, which include the following tests:
- ✓ Tests to all AC circuit(s)

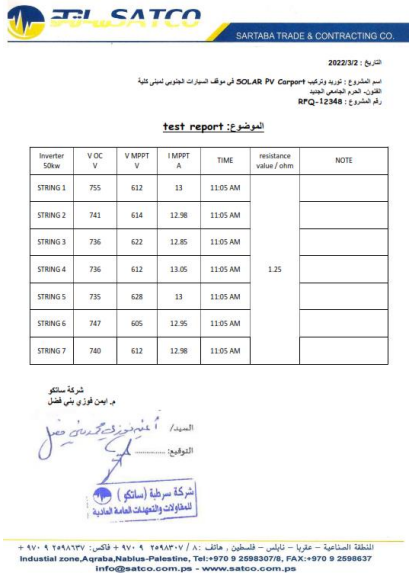
The equipment's that have been used for testing are all calibrated by authorized utility as follow:

Digital Earth resistance test device

Power analyzer device

HT AC clamp meter

The result of test was as follow:



SARTABA TRADE & CONTRACTING CO.

التاريخ : 2022/3/2

اسم المشروع : توريد وتركيب SOLAR PV Carport في موقف السيارات الجنوبي لمبنى كلية القرآن الكريم الجامعي الجديد
رقم المشروع : RFQ-12348

الموضوع: test report

Inverter 50kw	V OC V	V MPPT V	I MPPT A	TIME	resistance value / ohm	NOTE
STRING 1	755	612	13	11:05 AM		
STRING 2	741	614	12.98	11:05 AM		
STRING 3	736	622	12.85	11:05 AM		
STRING 4	736	612	13.05	11:05 AM	1.25	
STRING 5	735	628	13	11:05 AM		
STRING 6	747	605	12.95	11:05 AM		
STRING 7	740	612	12.98	11:05 AM		

شركة ساتكو
م. ايمن فوزي بني فضل

السيد/
التوقيع:

شركة سرطبة (ساتكو) للمقاولات والتجهيزات العامة العالمية

المنطقة الصناعية – عقربا – نابلس – فلسطين ، هاتف : ٨٠ / ٢٥٩٨٣٠٧ ٩ ٩٧٠ + فاكس: ٩٧٠ ٩ ٢٥٩٨٦٣٧ +
Industial zone,Aqraba,Nablus-Palestine, Tel:+970 9 2598307/8, FAX:+970 9 2598637
info@satco.com.ps - www.satco.com.ps

Fig.11 PV system test report

5.4. Monitoring & evaluation stage

The performance of system was analyzed using technical data downloaded from the data logger of SMA portal and digital meters.

The PV system operation was monitored from 1/2/2022 until 31/3/2023, during these period a periodic maintenance of the system was carried out and followed up to solve problems when they occur, such as changing a fuse or cleaning the panel, and the results were as follow:

In 2022, the Total energy production = 76.01 MWh.

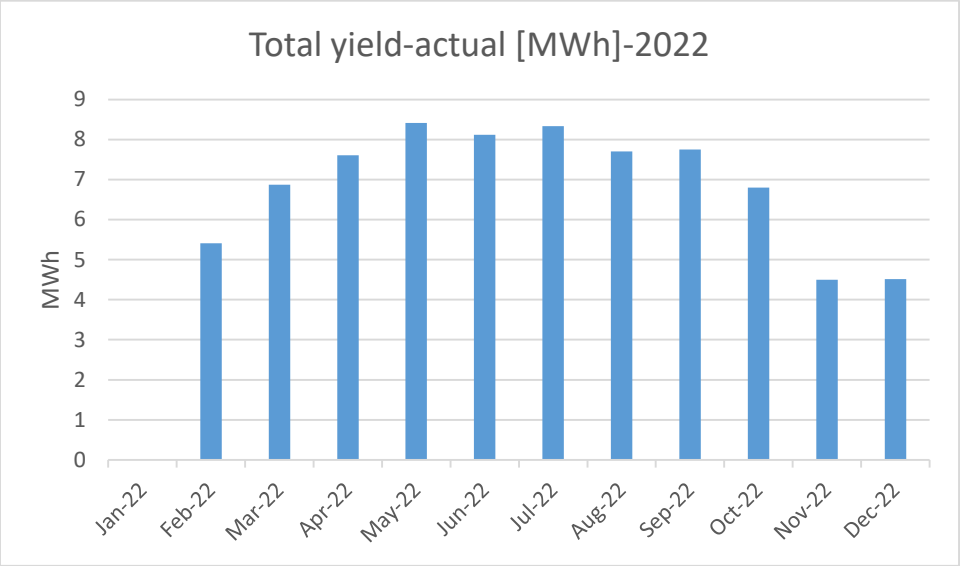


Fig.12 PV system yield of year 2022 -MWh

For the 2nd year of project operation-2023, the total energy yield until 28/2/2023 was 9.45 MWh.

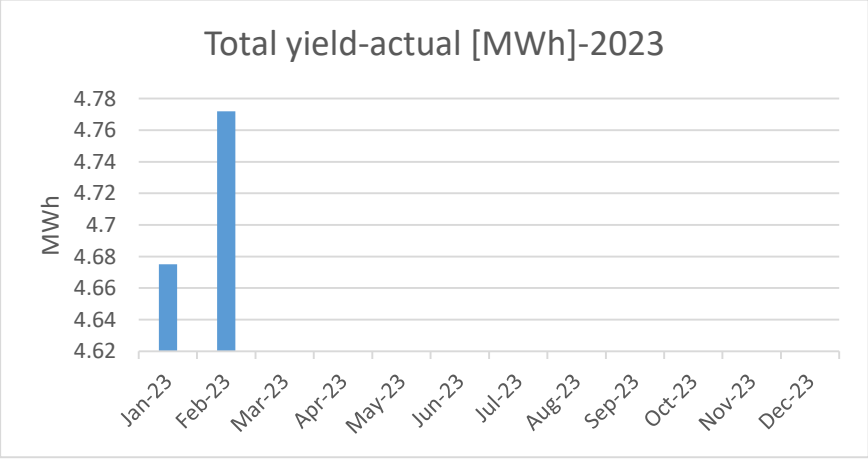


Fig.7 PV system yield of year 2023 -MWh

So, the total solar system yields 2022-2023, as follow:

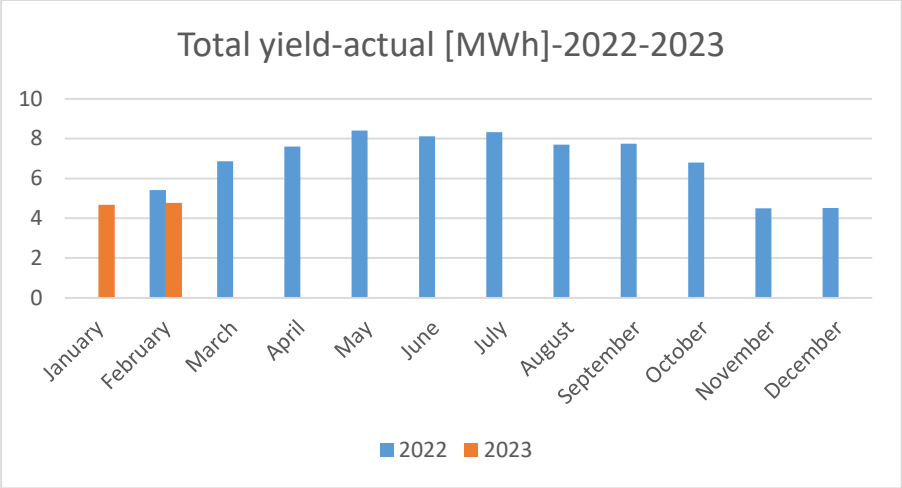


Fig.8 PV system yield (MWh) of year 2022-2023

According to previous data, the system was working properly, and thus is shown in the indicator below:

Technical evaluation:

- System Efficiency

The efficiency of PV system measures the ability of system to convert the sunlight into required energy for load consumption, the system efficiency is given by following form:

$$\eta \text{ (system efficiency)} = \frac{\text{Output energy of PV system (KWh)}}{\text{Global radiation energy received by PV array area (KWh)}}$$

The System efficiency for operation period (2022) is 20%
The System efficiency for operation period (3-2023) is 14%

- Performance Ratio

$$PR = \frac{\text{actual energy generated by PV system (KWh)}}{\text{Energy produced by system at STC (KWh)}}$$

The Performance Ratio for operation period (2022) is 86%
The Performance Ratio for operation period (3-2023) is 61%

- Final Yield (Yf)

$$Y_f = \frac{\text{actual energy generated by PV system (KWh)}}{\text{PV array maximum Capacity (KW)}}$$

The final yield will refer for how many hours the system is operated in year or day.

Accordingly,

Yf over operated period is 1750.48 h and average solar hour per day is 3.97 h/day

- Capacity Factor (Cf)

The capacity factor varies quite a bit for solar photovoltaic systems depending on the location. Generally, it is in the range of 10-25%. One of the key reasons for this low ratio is the nature of renewable power.

$$C_f = \frac{\text{actual energy generated by PV system (KWh)}}{\text{PV array maximum Capacity (KW)} \times 8760\text{h/year}}$$

total hours over operated period is 9432 h, accordingly the average capacity factor of system over this period is 16%.

Environmental and Economic evaluation:

The CO2 emission and electricity bills will be reduced according to how much energy produce from the PV solar system since the system operation, as follow:

The electricity bill is reduced until March/2023 = 14145.27 Euro

And CO2 emission will reduce by 54.11 ton CO2

- Payback time

Expected Saving cost (€/year) = 1258 €/month*12month=15096 €/year
PV Investment cost (€) = 63243 Euro
S.P.B.P = Investment / saving cost per year
= 63243 Euro / 15096 Euro = 4.19 years ≈ **4 years & 2 month**

But according to the actual energy output, the average energy saving was 7.5 MWh, around 1503 Euro/month which equivalent to 18036 Euro/year, and thus reflect in number of years of payback period.

Actual Saving cost in 1st year (€/year) = 18036 €/year
PV Investment cost (€) = 63243 Euro
S.P.B.P = Investment / saving cost per year
= 63243 Euro / 18036 Euro = **3.5 years ≈ 3 years & 6 month**

6. Recommendations and future scale up of installing Rooftop PV system

The most successful current approach to reducing emissions from the transport sector is to electrify transport systems, which is driving an increased reliance on decarburization of the electricity supply sector. Electric vehicles can lower GHG emissions, and also promise to lower the lifecycle costs of transportation.

With this in mind, it is not difficult to understand the need for integrating Solar Carports into transport network, so the project aims to encourage the Palestinian Universities, decision makers and investors to adopt this pilot project and replicated in other site, because this system can be applied wherever there is a requirement for, or an existing carpark, for example a park and ride hub, and also may install in combination with battery energy storage systems (BESS) and EV charging to the solar carport, which lead to realize even more climate benefits.

Electric vehicle charging using renewable energy provides sustainable transport for the future. In addition, there is potential to establish a network of publicly available solar powered charging stations at retail car-parks, tourist attractions, council properties, and bus stations etc.

In general, innovative technologies and processes should be conceived in order to seize low radiation energy and optimize its transformation into actual power. Based on what was previously mentioned so we recommended the following to install solar carport system:

- System size: When choosing the size of your carport, it is essential to strike a balance between installation costs, available space, and the amount of electricity you can produce so choosing the optimum configuration based on your parking lot and energy requirements.
- The Space/height under Solar Carport: the design must consider how much space/height there is beneath the panels and it must be high enough for equipment and cars to pass easily underneath but not too height to not unnecessarily drive up the price of project.
- Lighting: providing adequate lighting for anyone who parks in your lot is still critical. Lighting can be installed under the carport to keep the parking areas well-lit and secure. This is critical for a larger solar carport system that span two or more rows of parking spaces.

Solar carports stand out due to their versatility, which offers clean energy while protecting your car and freeing up space.

Med-EcoSuRe

Innovative Retrofit Technology Report

Solar Power Tree in in University's` Yard of New-Campus– An-Najah National University

(University's` Yard of entrance in New-Campus)

Prepared by:
An-Najah national university (ANNU)

2023

Project Acronym	University building
Project Name	“Mediterranean University as Catalyst for Eco-Sustainable Renovation” (Med-EcoSuRe)
Project Duration	September 2019- August 2022
Website	www.enicbcmed.eu/projects/med-ecosure
Authors	An-Najah National University (ANNU)
Date	February 2023
File Name	Full scale experimentation of innovative retrofit technologies, validation and testing in real life report (**solar power tree in University's` Yard of New-Campus Building - An-Najah National University – Palestine**)

This project is part of the Mediterranean University as Catalyst for Eco-Sustainable Renovation (Med-EcoSuRe). The project aims to implement full scale experimentation of innovative retrofit technologies, validation and testing in real life in An-Najah university campuses, in order to allow a relevant energy demand reduction and mitigate greenhouse gas emission.

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- A sustainable, reliable, safety and cost-effective electrical energy supply
- PV power Plant is tested, evaluated and monitored using monitoring, sensor and data logging system which monitored remotely and at site for public demonstration & display

These goals are in line with the desire of An-Najah University, which seeks to obtain and achieve environmental sustainability through its facilities and activities as follow: -

- Promote and create a campus which supports academic, research and enterprise activities in a sustainable way
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- Maximize the wider impact of ANU's environmental sustainability activities at local, regional, national and international level through collaboration, partnership and communications
- become a leader across the HE sector in terms of environmental sustainability

Accordingly, ANNU through Med-EcoSuRe project had conducted Full scale experimentation of innovative retrofit technologies for example **solar tree with technology of PV glass** which is an independent unit that produces green energy and provides a place of comfort and energy for a wide variety of services and thus contribute in:

- Providing visibility of the energy that is being used across campus to facilitate culture change within the ANNU community
- Allowing Academics and Students to use the Estate as a living lab for sustainability research by providing appropriate data

2. So…. What is Solar Tree?

Solar Tree is an environmental enterprise, an ecological sculpture, an artificial solar structure that looks like sculptural trees and exists from a small scale (size of a bonsai tree) to a large scale (about the size of a wind turbine) power plant. The structure is a ground-mounted solar system with a pole that supports many individual panels up in the air. The aesthetics of solar trees differ and they have been designed to provide different means of power to different urban and built environments.

It can be placed in residential areas and in urban areas, courtyards, schools and universities, parks, and along hiking trails. It can also be placed in cultural institutions as an icon and a symbol of community, environment, and green education.

3. Why Solar Tree?

solar trees offer a few surprising benefits over their ground-mounted counterparts, including:

- **Efficient design & preserve land**: In situations where space is a constraint, and the vertical integrated is required, solar trees provide an option for installing multiple layers of solar panels while maximizing the efficiency of the available area.

- **Beautiful & great scenery**: The solar tree design is efficient and strikingly appealing, compared to the way standard solar panels are laid out, solar trees look

a lot more aesthetically pleasing. The sight of a tree-shaped solar installation can be quite pleasing to the eyes.

- **Flexibility and compatibility**: Solar panel trees can serve as an excellent option where solar roofing is not available and also can be installed with automatic sun tracking and in-built cleaning mechanisms.

- **Perfect to increase awareness of clean energy**: it's a live experience which Individuals and businesses looking to showcase their support for sustainability can do so in style by installing solar trees, also its A great way to educate people about solar and build awareness about solar technology and are being used for this purpose in various schools and institutions around the world.

- **Potentially enhanced electricity output**: There are certain solar tree designs which claim to produce a substantially higher amount of electricity when compared to standard solar panels covering the same surface area.

Therefore, ANNU proposed to install solar tree using Crystalline silicon photovoltaic glass, which yield more power per sqm ((twice)-in comparison to amorphous silicon glass and also using storage unit of BYD Battery-box LV.

4. Technology Description

In this pilot project, we proposed to use a combination of Crystalline silicon PV glass and storage unit for domestic use of university students.

Crystalline silicon PV glass is the most suitable material to be used on canopy and skylight applications, spandrel glass, solid walls and guardrails. PV glass presents the same mechanical properties as conventional architectural glass used in construction for architectural purposes.

This type of panel can be easily customized especially in term of shape since trapezoids can be fabricated without difficulty, and its efficiency reached to 16%.

BYD battery-box is a lithium battery unit with battery control unit for usage with external inverter, batter box LV is 48 V battery with flexible and modular design with no cable inside, one box contains 1-4 battery unit that connected in parallel to generate (3.5-14 KWh) as required.

Also the proposed solar tree structure is Trestle, as follow:

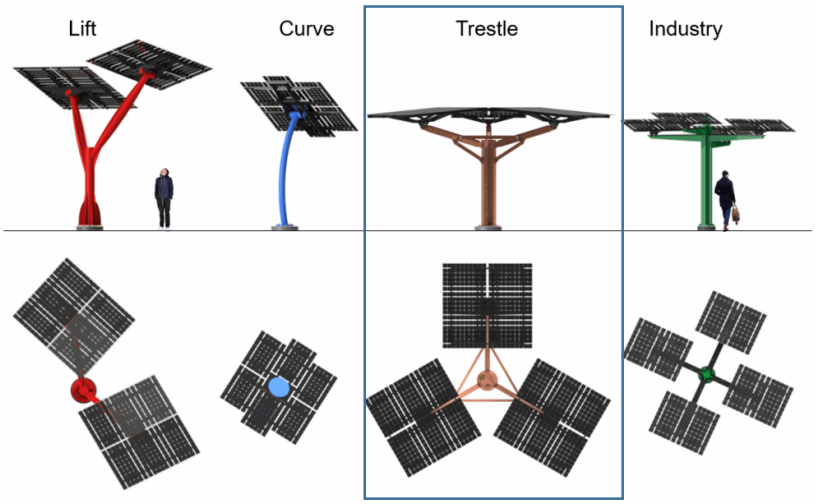


Fig.2 solar tree structure

5. Full scale experiment of Innovative Technologies

ANNU through Med-EcoSuRe project has carried out implementation of **solar tree with technology of PV glass** off-grid system in yards of new campus in Nablus, for domestic use of university students in order to charge the Mobile, laptops under the shade of the solar tree.

Solar tree generated energy form the solar panels and store the energy to the battery by a DC Charge controller. The controller is MPPT. During the daytime when the sunlight is sufficient to meet the loads, the generated solar energy directly feed to the loads. Any excess solar energy after meeting the loads should be stored in the battery.

This project is the first one in Palestine so it will stand out and be a part of university's plan to spread new ideas for the implementation of solar energy projects.

Table I. Geographical site of garage

Location coordinate	32°13'38.5"N, 35°13'21.2"E
available area	All yards of campus

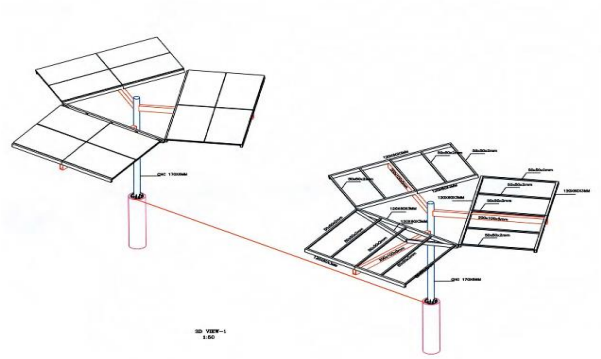


Fig.3 information location of solar tree

the An-Najah National University (ANNU) seeks to be to be the first in pioneering projects and provide the stimulus for other universities in Palestine to improve the energy efficiency and apply its measurement, which complies to some extent with Palestinian government action plan in public buildings - the national energy efficiency action plans (NEEAPs), which must be reinforced by the renovation strategies in university, and vice versa.

5.1 Project PV plant Summary

This innovative PV system will encourage the investor to invest in this kind of project because it is expected to produce 25% to 30% more power if all panels may be rotated by 180 in the afternoon and morning towards the east and the west by an easy mechanism and increasing the awareness of teacher, pupils, and community regarding the "green energy technology" and increase the positive environment in the Schools by reducing the CO2 emission.

Table II. Design parameters of the PV plant

Design parameters	Characteristics
Year of construction	2022
Type of plant	Ground mounted, fixed
Orientation and tilt	Azimuth angle 60, 0 , 30 degree, inclination angle 11 degree
Installed nominal power	3.18 kWp
Module type	Monocrystalline
The number of PV module	12 panel × 265Wp
Inverter/Charger	1 × Victron Energy- 48/3000 Wp, 1 × SmartSolar MPPT 250/60-TR
Battery	Lithium battery-BOX premium LVS 4.0

Fig.4 PV solar tree-new Campus

5.2 Contribution of the project activity to sustainable development

The project contributes to the general well-being of the region and is in line with the sustainable development policies of the host site.

Social well-being:

The project activity will lead to employment generation during installation as well as operation phase of the project activity.

Economic well-being:

The project implementation will provide a fillip to economic activity in the region. Direct & indirect employment will be generated in the plant for the project implementation & management. The success of this project will encourage more business to be developed in the local region thus bringing in economic prosperity in the region.

Environmental well-being:

The project being a renewable energy power project would contribute to mitigation of global warming. In addition, the project activity also would not lead to any air pollution unlike fossil fuel based power plants

6. Major methodology of retrofit technology implementation

6.1. Selection process & acquiring devices

After analyzing the site, and considering the shadow distance from surrounding tree and objects, the initial design and PV array distribution was shown in fig.2 &3.

After checking the system design, the budgetary estimation was done to analyze the project cost and its feasibility.

Therefore, in order to choose the best offers for devices and civil & electrical site work in terms of technical effectiveness and lowest offers, the tender dossier was prepared (see annex-1) as follow:

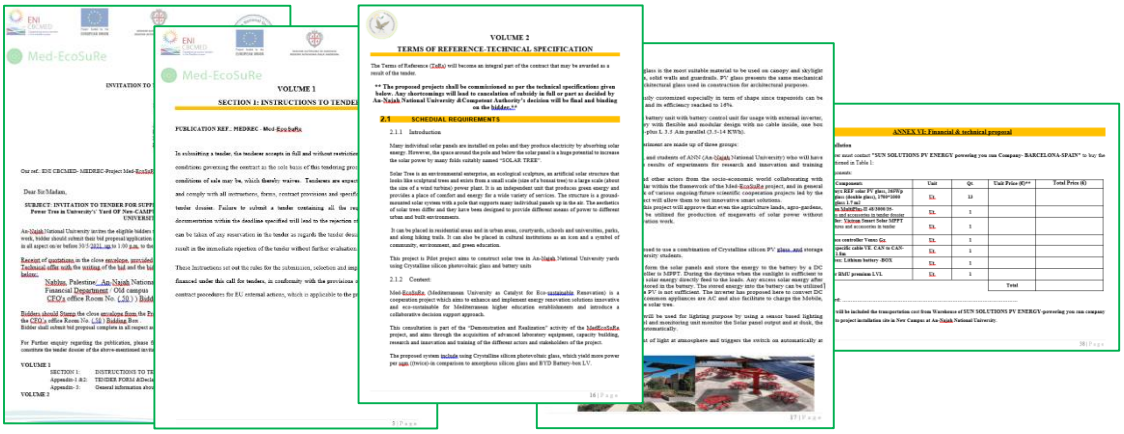


Fig.5 tender dossier

The tender call was published on 10/5/2021, And the bid was resubmitted on 31/5/2021 as follow:

https://www.najah.edu/ar/tenders/rfq-12353/

https://www.najah.edu/ar/tenders/0-23/

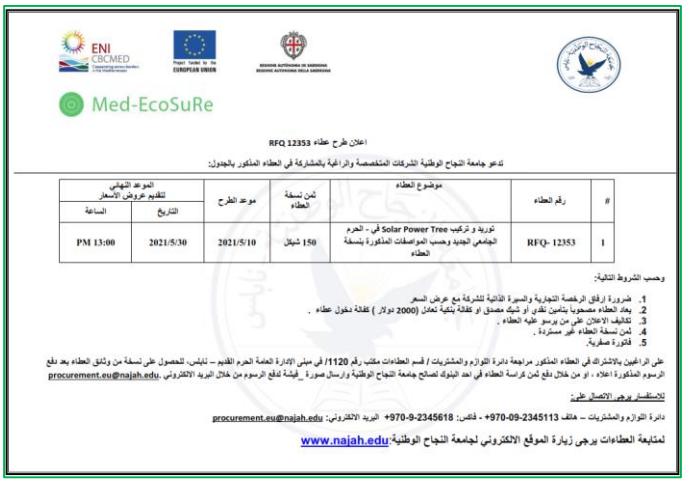


Fig.6 tender call

During the tenderer offers preparation, a tour visit was organized by ANNU on 17/5/2021 to inspect the site and replying their query. And then the tender call was closed on 10/6/2021, and the applicants were as follow:

1- 3k Solar
2- SATCO

Then the offers were evaluated technically and financially, to select the best offer for supplying materials and implementing the project (see annex-2)

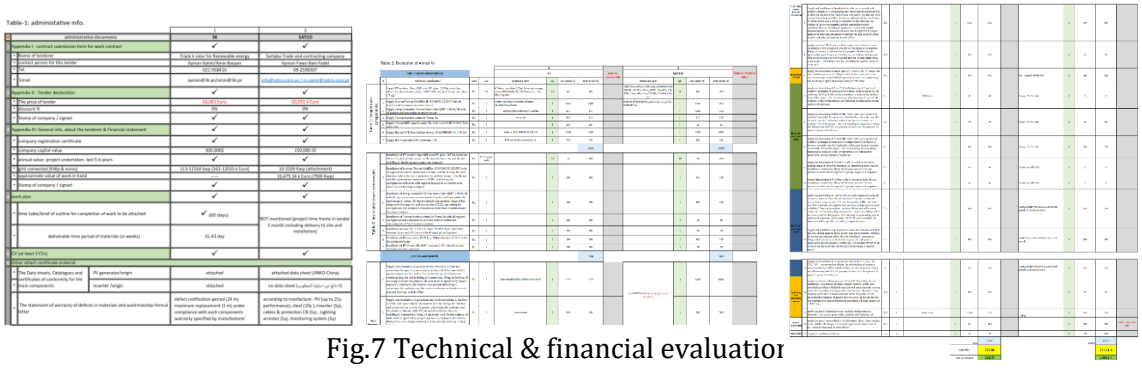


Fig.7 Technical & financial evaluation

Then according to the tender committee, the tender has been awarded to 3k company, and the work agreement/PO was signed between ANU and 3k to start the implementation activity and purchasing the project materials. (see annex-3)

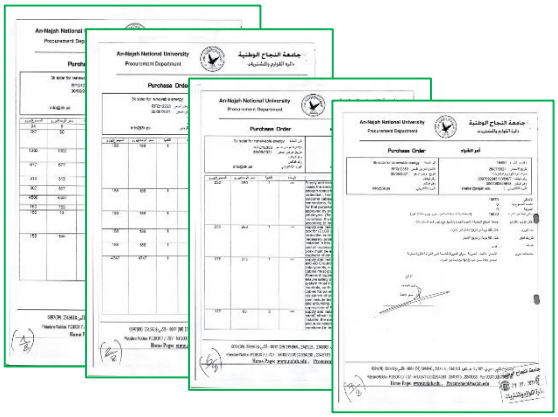


Fig.8 Purchasing order agreement

6.2. Implementation stage

Work plan and design approval

Before the contractor initiate the implementation process on the site, the work plan, designs and equipment information are sent by contractor in order to get ANNU approval of them and giving an order directly to work to contractor.

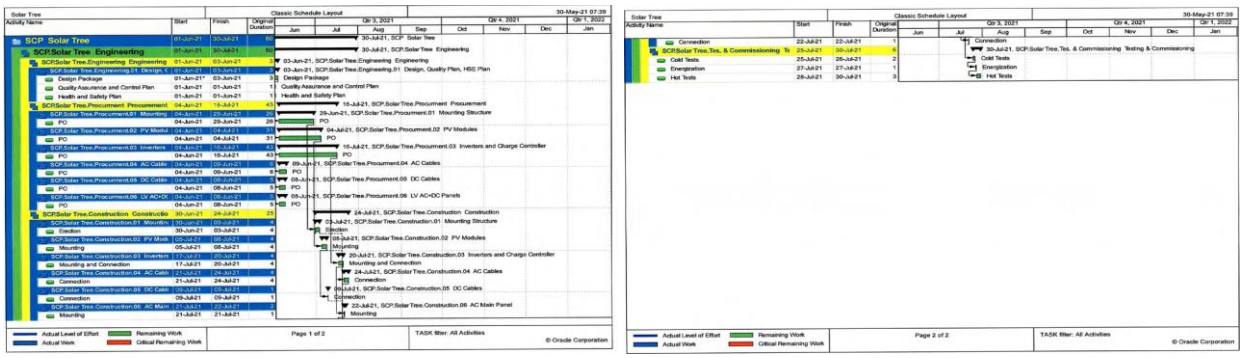


Fig.9 work plan

The design by AutoCAD which include; distribution of array, connection with component, was provided as follow:

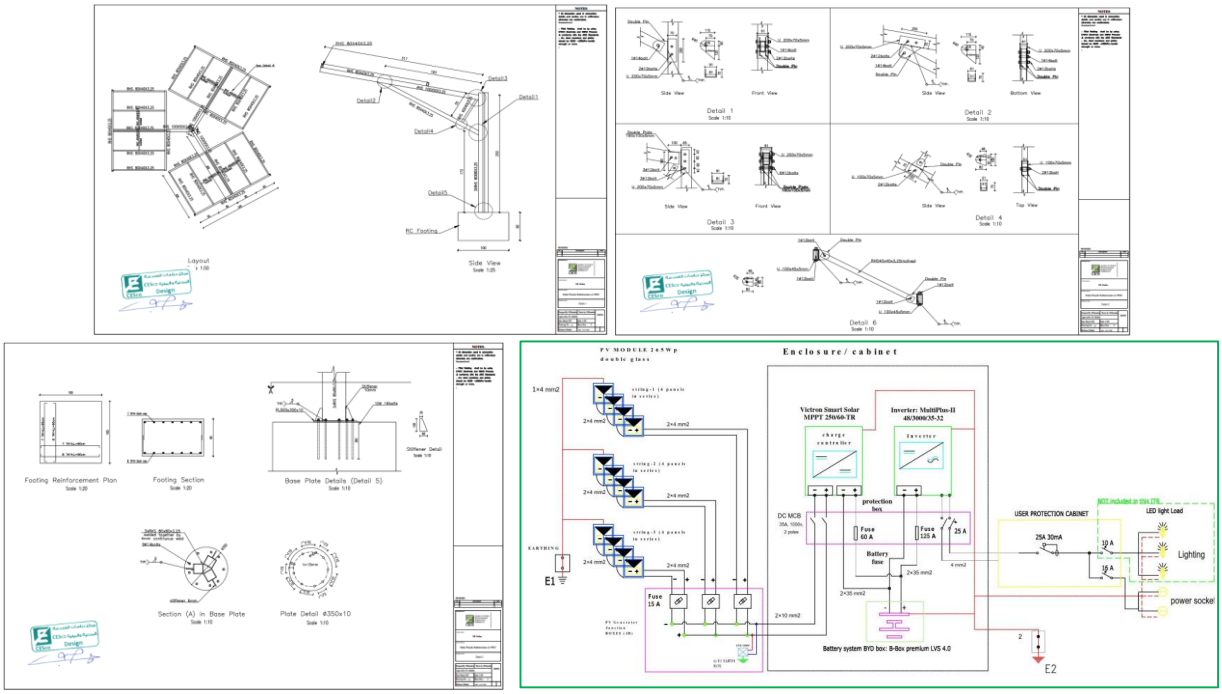


Fig.10 3k design & connection drawing

Civil & electrical Site Work

After taking the approval from ANNU, the contractor company start purchasing the components and manufacturing the steel structure and cement base, then they start implementing the project as follow:

1- Prepare the site

2- Implement the foundation




3- Install the steel structure




4- Install PV panels

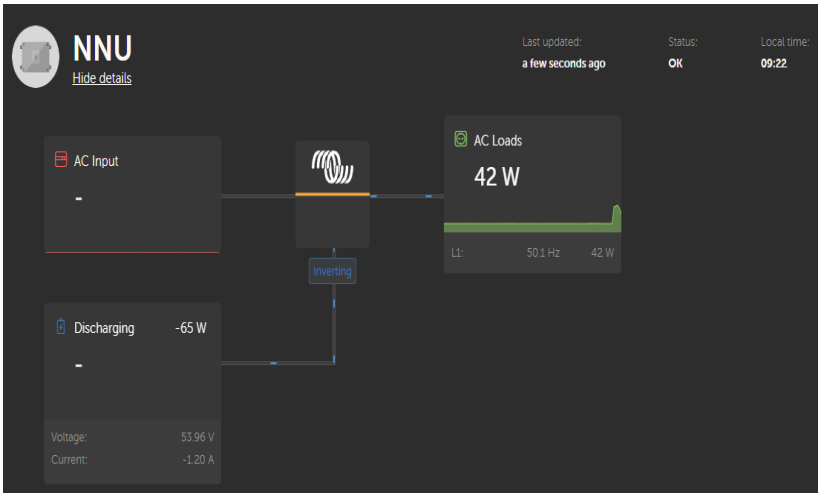


5- Install inverter/charger and connect all components and all the cables were installed in tranches and trunks for aesthetic image of the project and facilitate the maintenance work in future

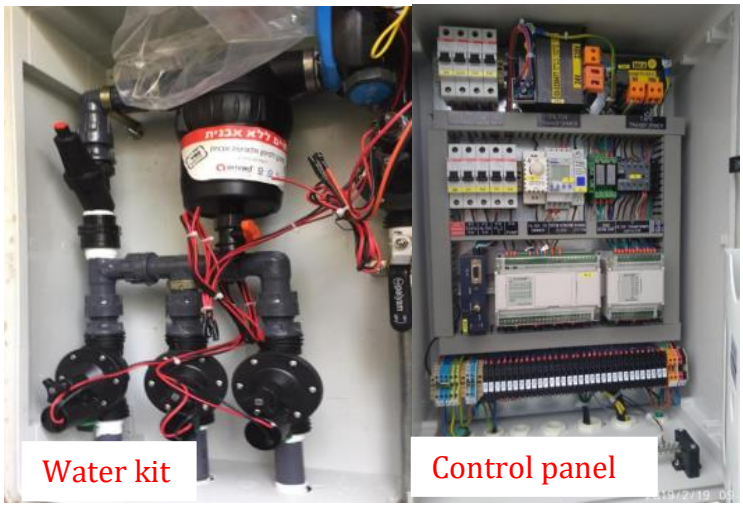


6- Then the DC/AC earthing was connected and lightning Pulsar

7- Then the energy meters was installed and configured with monitoring portal – victronEnergy Portal for performance monitoring, condition monitoring and data reporting



8- Finally, Automated Water Purification & Cleaning Technology, to clean PV system on frequence bases



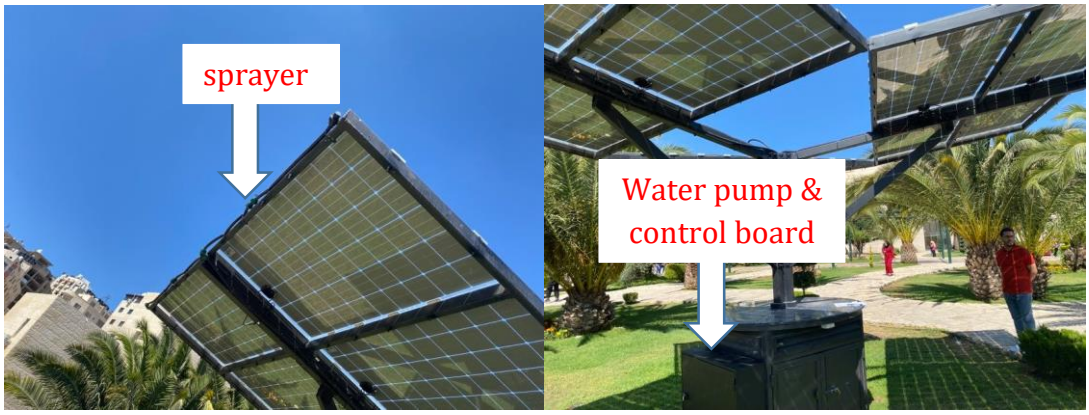


Fig.11 PV system implementation process

6.3. Validation stage

In order to operate the system successfully, the system components were checked and test by civil and electrical engineering in university during the implementation process to inspect the work and then a test was conduct before the system operation completely.

So three levels of commissioning and system testing was conduct as follow:

- **Level-1: site acceptance Inspection**

The acceptance of the site to install the equipment of the PV system is responsibility of the installing contractor (in our case 3k Company) and to start implementing the concrete base, galvanized steel structure.

- **Level-2: Pre-functional testing**

Characteristics and Visual Inspection test

- **Level-3: performing operational test**

In the last point of the project commissioning, the PV solar plant components during operation are checked and the successful operation of project is checked.
Operational test was done according to International Electro technical commission (IEC) recommendation [IEC 62446], to ensure that the system is properly installed and performing optimally.

The test has been carried out as follow:

- ✓ Tests to all DC circuit(s) forming the PV array, which include the following tests:
- ✓ Tests to all AC circuit(s)

The equipment's that have been used for testing are all calibrated by authorized utility as follow:

Digital Earth resistance test device

Power analyzer device

HT AC clamp meter

The result of test was as follow:

Project Name:	NNU Solar Tree
Form:	Testing Report
DC Side	
Test Before Operation	
Test	Measurements
DC Voltage for string Input 1 (V)	152
DC Voltage for string Input 2 (V)	151
DC Voltage for string Input 3 (V)	151.5
DC Current for string Input 1 (A)	8.92
DC Current for string Input 1 (A)	8.93
DC Current for string Input 1 (A)	8.92
DC Voltage for MPPT Input	152
DC Current for MPPT Input	26.79
Test After Operation	
Test	Measurements
DC Voltage for string Input 1 (V)	128
DC Voltage for string Input 2 (V)	128.1
DC Voltage for string Input 3 (V)	127.9
DC Current for string Input 1 (A)	8.39
DC Current for string Input 1 (A)	8.38
DC Current for string Input 1 (A)	8.39
DC Voltage for MPPT Input	128
DC Current for MPPT Input	25.17
AC Side	
Test	Measurements
AC Voltage	220
AC Current	3A
Earthing Resistance	
Test	Measurements
Earthing Resistance	3.9
Comments:	
The AC Current value was measuered hen we added a testing load.	

Fig.12 PV system test report

6.4. Monitoring & evaluation stage

The performance of system was analyzed using technical data downloaded from the data logger of Victron energy portal.

The PV system operation was monitored from 24/5/2022, during the operation period a periodic maintenance of the system will be carried out and followed up to solve problems when they occur, such as changing a fuse or cleaning the panel, and the results were as follow:

Total production from 24/5/2022 until 1/3/2023 = 3254.35 KWh.

For the 1st year of project operation-the system operated in period 24/5/2022 – 31/12/2022, the total energy yield was= 2.845 MWh/year:

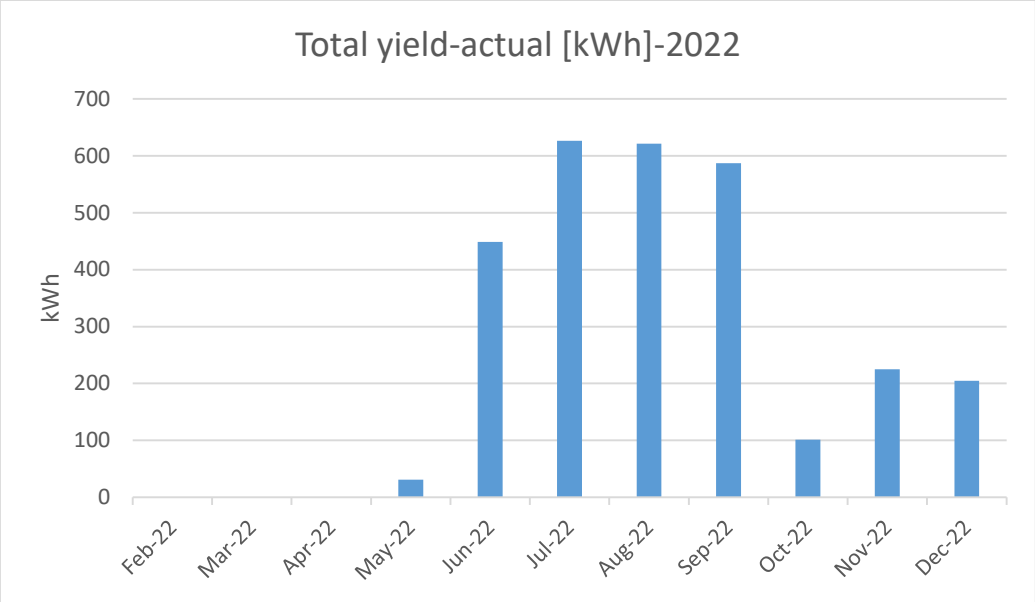


Fig.13 PV system yield of year 2022 –kWh

For the 2nd year of project operation-2023, the system operated in period 1/1/2023 – 28/2/2023, the total energy yield was= 0.41 MWh/year

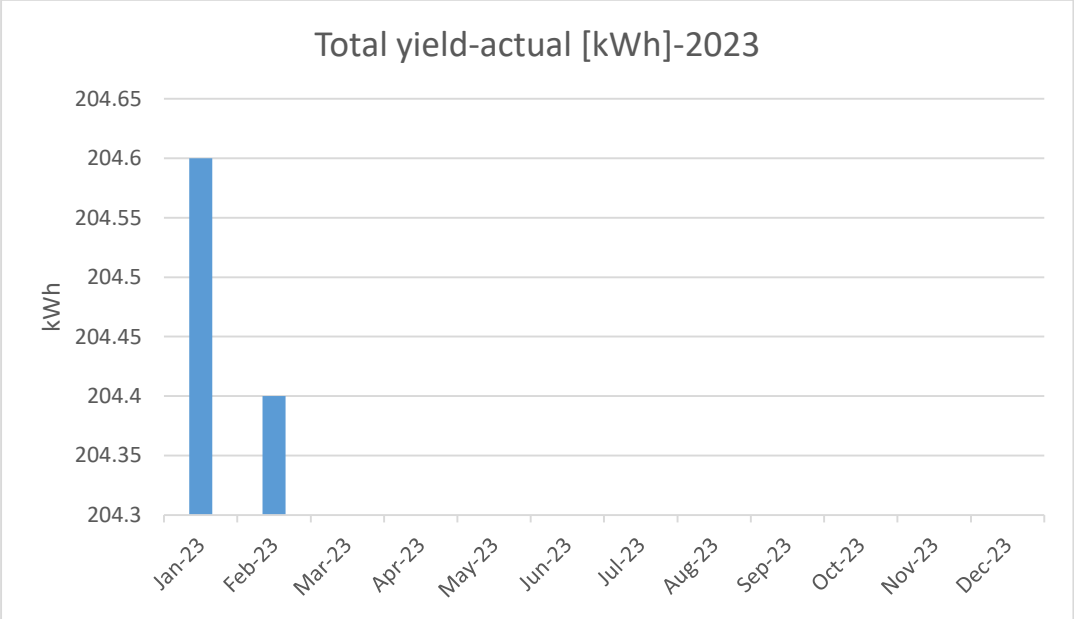


Fig.9 PV system yield of year 2023 –MWh

So, the total solar system yields 2022-2023, as follow:

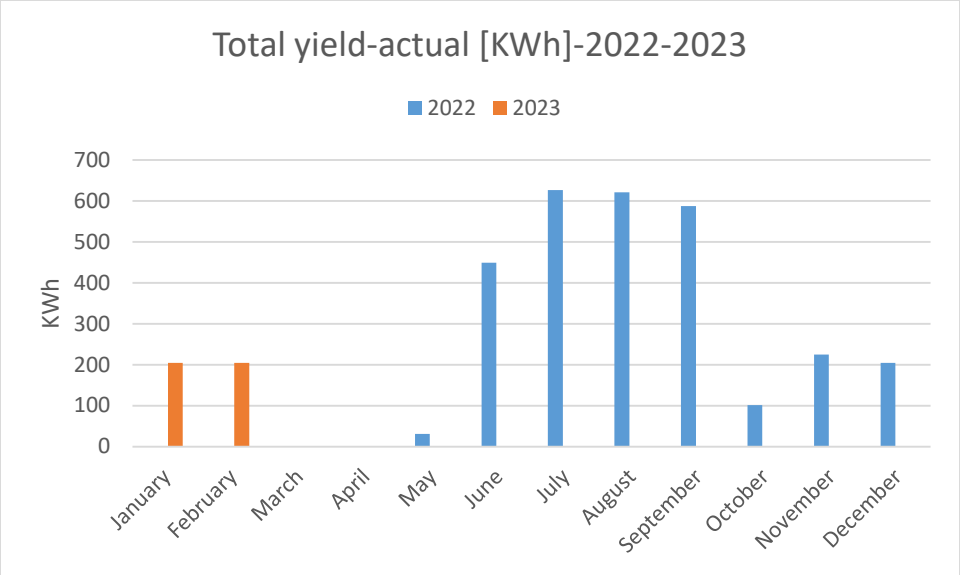


Fig.10 PV system yield (kWh)of year 2022-2023

According to previous data, the system was working properly, and thus is shown in the indicator below:

Technical evaluation:

According to data, the system was working properly, and thus is shown in the indicator below:

- System Efficiency

The efficiency of PV system measures the ability of system to convert the sunlight into required energy for load consumption, the system efficiency is given by following form:

$$\eta \text{ (system efficiency)} = \frac{\text{Output energy of PV system (KWh)}}{\text{Global radiation energy received by PV array area (KWh)}}$$

The System efficiency for 1st year (2022) is 19%
The System efficiency for 2nd year (March-2023) is 11%

- Performance Ratio

$$PR = \frac{\text{actual energy generated by PV system (KWh)}}{\text{Energy produced by system at STC (KWh)}}$$

The Performance Ratio for operation period (2022) is 70%
The Performance Ratio for operation period (March-2023) is 40%

- Final Yield (Yf)

$$Y_f = \frac{\text{actual energy generated by PV system (KWh)}}{\text{PV array maximum Capacity (KW)}}$$

The final yield will refer for how many hours the system is operated in year or day.

Accordingly,

Y_f over operated period is 1023.38 h and average solar hour per day is 2.98 h/day

- Capacity Factor (Cf)

The capacity factor varies quite a bit for solar photovoltaic systems depending on the location. Generally, it is in the range of 10-25%. One of the key reasons for this low ratio is the nature of renewable power.

$$C_f = \frac{\text{actual energy generated by PV system (KWh)}}{\text{PV array maximum Capacity (KW)} \times 8760\text{h/year}}$$

total hours over operated period is is 6744 h, accordingly **the average capacity factor of system over this period is 12 %**

Environmental and Economic evaluation:

The CO2 emission will be reduced according to how much energy produce from the PV solar system since the system operation, as follow:

According to actual data, the average energy that produced around 402 KWh/month, and in a year round 4.825 MWh, so It's expected that the reduction in CO2 emission will be 2.84 ton CO2/year

7. Solar Tree Technology future scale up

During the previous years, the ANNU university was keen to install solar panels of a type Monocrystalline in projects, although it's slightly has higher price in comparative with polycrystalline, but ANNU aims to get a PV system with acceptable appearance and decent technical architecture, without neglecting performance or durability.

plus, the high efficiency and power output which we get from monocrystalline panels can provide better saving over lifetime of system, where monocrystalline efficiency reach 17-22%.

also, we at ANNU care to install high quality solar panel and ensure that by checking the performance and efficiency ranking of solar panel brands list, for example; Suntech, Sun power, Canadian Solar, Jinko, Trina and JA solar, to choose the solar panels that work best in our university.

The Monocrystalline panel has two types; Monofacial panels and Bifacial solar panels/Glass Technology which was used for solar tree pilot project

The solar tree glass Technology has the same purpose of monofacial panels but there is significant difference must be analyzed for future scale-up technology possibilities of this type, as follow:

	bifacial	monofacial	comment
Energy Generated KWh per 1 KW	1516.98	1469.5	using bifacial panel, the energy generated was 3.2% higher than monfacial project
System Efficiency	19%	14-16%	
Occupancy Efficiency (m2/kw)	6.415	7.736	using bifacial panel, the occupancy space was 20.6% less than monfacial project
panel technology Capital Cost (Euro/watt)	0.2755	0.2565	the benefits of bifacial modules did outweigh the cost advantages of monofacial options

Accordingly, the glass technology which used in solar tree pilot project more power than monofacial solar panels, which mounted on rooftops or ground, but they provide shade while taking up minimal surface area. A creative mind could find endless uses for these trees: shade for city sidewalks, parking lots, playgrounds, backyards and more.

It is worth mentioning here the major advantage and disadvantage of glass solar panel technology and highlight some of its best features: -

- Advantage:
    - Up to 1% more efficiency than traditional solar panels.
    - Better usage of the available space.
    - Cost-effective technology.
    - Prices for new solar panels will get reduced as the technology becomes more popular
- Dis-advantage:
    - Relatively larger cost than traditional technologies

The use of this technology is quite convenient for the solar application in general, so with rise of PERC & bifacial solar panels, homeowners and utilities can benefit by using less space, fewer installation components, and using PV modules with higher performance and an infinity of applications.