BERLIN

Cost-effective rehabilitation of public buildings into smart and resilient nano-grids using storage

Thematic Objectives: B.4 - Environmental protection, climate change adaptation and mitigation (Address common challenges in environment)
Priority: B.4.3 - Support cost-effective and innovative energy rehabilitations relevant to building types and climatic zones, with a focus on public buildings
Countries: Cyprus, Greece, Israel, Italy

Output nº: 3.1
Output Title: Pilot actions in buildings in 4 countries
Activity nº: 3.1.3
Activity title: Joint development and design of pilot demonstration and solution

September 2020

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Consisting of

Coordinator:	FOSS Research Centre for Sustainable Energy, University of Cyprus (UCY)	Cyprus
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	The municipality of Eilat	Israel
	University of Cagliari	Italy
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4 Contents

1 Project summary

In an effort to address high energy consumption in the building sector that is mainly fossil – fuelled, support rural areas and areas powered by weak grids, which are common in the MENA region, and achieve higher grid penetration of renewable energy sources (RES) while maintaining grid stability and power quality, this project aims at the implementation of cross border pilots that will support innovative and cost – effective energy rehabilitation in public buildings based on the nanogrid concept. Thus, BERLIN project focuses on the increase of photovoltaics (PV) penetration, which coupled with energy storage and demand – side management (DSM) will increase the energy efficiency (EE) of the buildings. The implementation of these technologies in a cost – effective way will result in high level of self – resilient public buildings that are green, smart, innovative and sustainable. A total of 6 pilot buildings will be implemented: 1 in Cyprus, 2 in Greece, 2 in Israel and 1 in Italy.

The project has started in September 2019 and is expected to be completed within 36 months.

2 Introduction

In this report, the technical solution for each pilot building is presented. All pilots have followed the same methodology and are based on PVs for generating and a battery energy storage system (BESS) for storing electrical power, as well as a controller for managing the interaction between the aforementioned technologies with the building loads and external power entities, such as the utility grid. As each pilot is unique and has its own particularities with respect to the size of the building, the required energy to fulfil its needs, the available space for housing the equipment and infrastructure and the equipment that is already installed and available at the premises, each solution has been adapted to the specific needs of every pilot.

This report forms the basis for the preparation of the tender procedure and the procurement for the equipment and infrastructure purchase, as well as for the installation of the complete solution in each participating country.

3 Cyprus

The main objective of the nanogrid implemented at the facilities of FOSS Research Centre for Sustainable Energy is to transform the PV Laboratory into a living lab, where the energy consumption will be fulfilled by the energy production from the PVs and the stored energy from the battery energy storage system. The target is to reduce to the minimum the energy consumption costs and nullify the CO_2 footprint of the laboratory. Thus, this project aims to develop and implement a pilot nanogrid consisting of a renewable energy source (photovoltaics), an energy storage system (battery) and DSM. To achieve that, a turnkey solution consisting of 40 kWp of building – integrated photovoltaics (BIPVs) has been designed, in combination with a BESS of 50 kWh usable capacity and the existing energy management system (EMS).

The installation location will be at the premises of FOSS Research Centre for Sustainable Energy of the University of Cyprus (UCY). The site is located at 35°08'45.69"N 33°25'0.43"E and has an altitude of 133 m above sea level.

3.1 FOSS nanogrid overview

A list of the main equipment required for the FOSS nanogrid is:

- 40 kWp photovoltaic panels
- 50 kWh (100 kW) batteries
- Inverters
- Low Voltage AC (LVAC) panels
- System protection and metering
- Programmable electronic load
- Supporting structure – metal frames for PV mounting

Drawing number TD_A1 in Figure 1 shows the schematic diagram of FOSS nanogrid, including the connection of the LVAC distribution board to the energy centre and the existing laboratory infrastructure.

Figure 2 illustrates the structure that will be used for the installation of the BIPV modules, thus creating a canopy at the outdoor area of the PV Technology Laboratory that covers approximately 300 m^2.

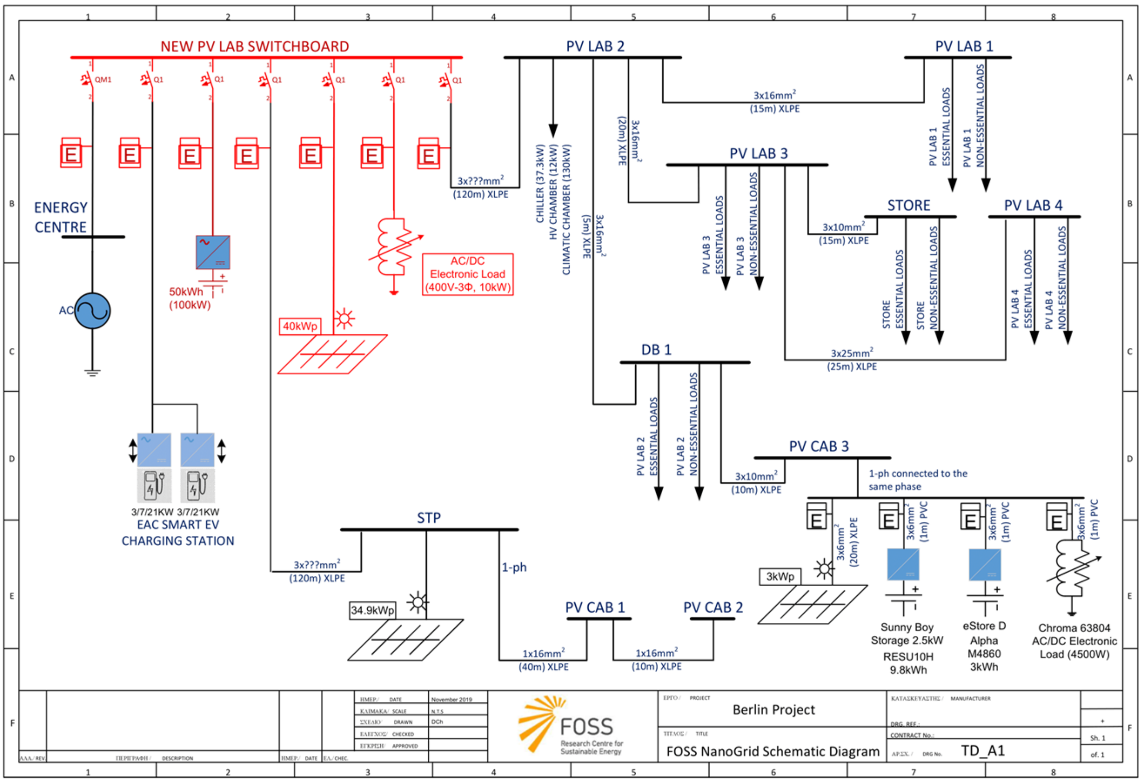

Figure 1 Schematic diagram of FOSS nanogrid

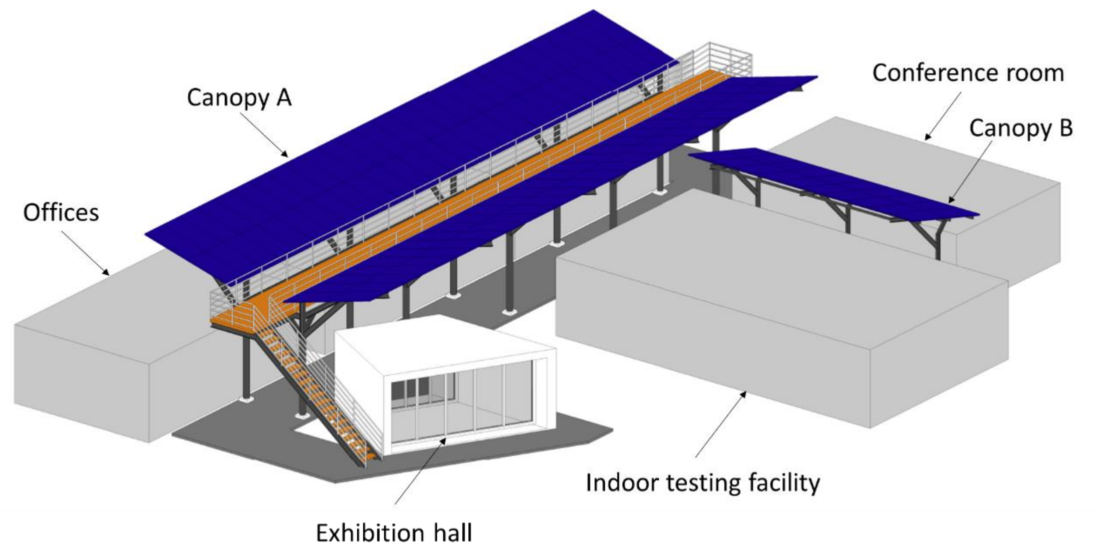

Figure 2 Initial design of BIPV canopy at PV Technology Laboratory.

3.2 Technical specifications

The following technical specifications have been selected for the implementation of FOSS nanogrid for the main components, including PV modules, BESS, inverters, nanogrid controller and monitoring system, power quality meters, LVAC distribution board, electronic programmable load and power plugs.

Table I: Technical specifications for photovoltaic modules

Parameter	**Requirement**
General	
Mono-crystalline	Yes
Bifacial	Yes
Has a level of transparency	Yes
Junction box position	Side mounted
Electrical Characteristics at Standard Test Conditions (STC)	
Maximum Power (Pmax)	> 330 W
Tolerance of Pmax	+5/-0 %
Voltage and Current	Chosen to match the inverter
Temperature Characteristics	
Normal Module Operating Temperature	45 °C（±2 °C)
Maximum Temperature Coefficient of Pm	-0.45 %/°C
Maximum Temperature Coefficient of Voc	-0.35%/°C
Maximum Temperature Coefficient of Isc	+0.05%/°C
General Electrical Characteristics	
Junction Box Rated Current	≧ 15 A
Bypass diodes	At least 3
Mechanical Characteristics	
Frame Material	Anodized aluminum profile
Front Cover	tempered glass with high light transmission and anti-reflective properties

Parameter	Requirement
Typical Size (LxWxH)	200x100x4 cm
Junction Box	IP67
Electrical Terminals	Compatible with MC4
Electrical Terminals Wire	4 mm^2 (cross-section), 1.2m long each
Typical Weight	20 kg
Maximum Ratings	
Maximum System Voltage	1000 or 1500 VDC (IEC) as specified in the drawings
Minimum Series Fuse Rating	15 A
Minimum Front Surface Load Capacity	5400 Pa
Minimum Back Surface Load Capacity	2400 Pa
Ambient Temperature Range	–40 to +60 °C
Impact Resistance	25 mm diameter hail at an impact speed of 23 $m \cdot s^{-1}$
Warranty	
Product Warranty	10 years
Output Warranty of Pmax	First year: 98%, After 1st year: <0.4% annual degradation, 25 years output: > 88.4%
Certifications and Tests	
General certifications	EN 50380 IEC 62941 IEC 61215:2016 IEC 61730:2016 CE
UV test	IEC 61345
Salt Mist Corrosion test	IEC 61701
Systems above 600 Vdc – certified for potential induced degradation	IEC 62804
Intensive farming sheds - certified for ammonia	IEC 62716

Parameter	Requirement
corrosion	
Desert regions – certified for wind-blown dust and sand	IEC 60068-2-68

Table II: Technical specifications for PV modules' inverters.

Parameter	Requirement
General Characteristics	
Inverter design	Transformer-less
Peak Efficiency	>= 95%
AC Port	
Direction	Output
Connection	3-Phase
Nominal Voltage	400 VAC ±10%
Nominal Power at 45 °C, continuous	> 40 kVA
Nominal Frequency	50 Hz ±10%
Power factor (cos ϕ)	0.85 – 1 inductive / capacitive
Total harmonic distortion	<= 5%
DC Port	
Direction	Input
Nominal Voltage	1000 or 1500 VDC
Nominal Power at 45 °C, continuous	Depending on system design – Total 40 kW
MPPT	Yes
Mechanical	
Ingress protection	>= IP65
Cooling	Passive or regulated air cooling
Installation	Indoor and outdoor installation

Parameter	Requirement
Permitted humidity	5 - 100 %
Ambient temperature range	-10 to +50 °C
Communication	
Internet Connection	Ethernet
Communication with EMS or external controller	Ethernet and/or FO
Communication with BESS	Ethernet and/or FO
Warranty	
Product	>= 20 years
Certifications	
EMC	EN 61000-6-1 or EN61000-6-2 (immunity) EN 61000-6-3 or EN61000-6-4 (emissions)
Electrical Safety	EN 62477-1 (power electronic converters and equipment) EN 61010-1 (safety requirements) EN 62040-1 (UPS) EN 62109 (PV converters)
Operation	IEC 62116 VDE AR-N 4105:2011-8

Table III: Technical specifications for battery and battery inverter.

Parameter	Requirement
Functional Requirements	
Battery Technology	Lithium Ion
Nominal Discharge rating	100 kVA
Nominal usable capacity	50 kWh
Operational capability	Full 4-Quadrant
Rated discharge duration	30 minutes
Charge rating	Greater than or equal to 100 kVA

Parameter	Requirement
Nominal Operating Voltage	400 Vac 3 ph
Operating frequency	50 Hz
Chronological life	Minimum 25-year chronological life with no replacement of any major component technologies.
Minimum Cycle Life	Ten thousand (10000) complete charge/discharge cycles
Transient response characteristics	Discharge: From stand-by (idle) to rated output in less than 1 minute (100% per minute); Charge: From stand-by (idle) to full rated charge rating, in less than 3 minutes; Reverse time: (from full power input (charging) to full power output (discharging) in less than 4 minutes and vice-versa.
Acceptable Performance Degradation - Charge/Discharge Ratings	Less than 10%, over required chronological/cycle lifetime
Acceptable Performance Degradation –Energy Storage Capacity	Less than 10%, over required chronological/cycle lifetime
Availability	Greater than or equal to 90% over full 25-year life
External ambient temperature	-10ºC to +50ºC
External ambient relative humidity	0% to 100%
Installation	Indoor
DC to DC Round trip cycle efficiency at nominal 2-hour rating	95% or greater
Acceptable Performance Degradation at nominal 2-hour rating – Round trip cycle efficiency	Less than 5%, over required chronological/cycle lifetime
Number of inverter units	1 (single 100 kW inverter)
Certifications	
Battery safety	IEC62281 or UN/DOT 38.3 (transportation testing for lithium batteries) IEC62133 or UL1642 (safety test for lithium batteries) EN62619 (safety requirements for secondary lithium cells and batteries)

Parameter	Requirement
EMC	EN61000-6-1 or EN61000-6-2 (immunity) and EN61000-6-3 or EN61000-6-4 (emissions)
Electrical safety	EN62477-1 (power electronic converters and equipment)

Table IV: Existing system control and monitoring system.

Parameter	
Communication protocol	IEC 61850
Telecontrol interface to the DSO's upstream network control/process control centre	Communication protocol IEC 60870-5-104
Interface to power converters	Available
Interface to IEDs	Available
Control of switchgear devices	Available
Interface to Smart Plugs	Available
Alarm and status monitoring	Available
Alarm and status display	Available
Acquisition, pre-processing and display of measured values	Available
Operational metering	Available
Power Converter Functions	
Control function INV1	Connect / disconnect from grid
Control function INV2	Adjust maximum generation level up/down
Control function INV3	Adjust power factor
Control function INV4	Request active power (charge or discharge storage)
Control function INV5	Pricing signal for charge/discharge action
Volt-var mode VV11	Available vars support mode with no impact on watts
Volt-var mode VV12	Maximum var support mode based on Wmax
Volt-var mode VV13	Static power converter mode based on settings

Parameter	
Volt-var mode VV14	Passive mode with no var support
Frequency-watt mode FW21	High frequency reduces active power
Frequency-watt mode FW22	Constraining generating/charging by frequency
Dynamic reactive current support TV31	Support during abnormally high or low voltage levels
“Must disconnect” MD curve	Available
“Must remain connected” MRC curve	Available
Watt-power factor WP41	Feed-in power controls power factor
Alternative Watt-power factor WP42	Feed-in power controls power factor
Voltage-watt mode VW51	Volt-watt management: generating by voltage
Voltage-watt mode VW52	Volt-watt management: charging by voltage
Temperature-function mode TMP	Ambient temperature indicates function
Pricing signal-function mode PS	Pricing signal indicates function to execute
Function DS91	Modify power converter-based DER settings
Function DS92	Event/history logging
Function DS93	Status reporting
Function DS94	GPS time synchronization
Week-day schedule for volt-var actions	Available
Weekly schedule for frequency-watt actions	Available
Monitoring system	
Sequence of event recording (SOE)	Available
Archiving of data comprising of measured values, event and alarm data, including those obtained from the intelligent electronic devices	Available
Feeder protection	Available
Automatic Control Sequences	Available
Synchrocheck	Available

Parameter	
Monitoring of generation elements (inverters, strings, batteries, transformers)	Available
Monitoring of LV AC control panel, fire alarm control panel, firefighting equipment, security system, weather station and other auxiliary systems of the PV system.	Available
Tools (engineering PC with 21-inch screen and software both locally and remotely) for analysing engineering data and interrogating intelligent electronic devices and generation elements including updating of parameters and settings	Available

Table V: Technical specifications for power quality meter.

Parameter	Requirement
Rated Inputs	
Power	3ph
Number of Wires	4
Nominal Voltage	3x230/400 Vac or 3x110 Vac see relevant drawings
Voltage Range	57.5 - 240V
Current measurement	CT Connected
Reference basic current Ib	1A
Reference maximum current Imax	1.2A
Frequency	50Hz
Power Supply	230Vac +/-10%, 50Hz or 24 Vdc see relevant drawings
Measurements	True RMS 4–quadrant metering up to the 63rd harmonic on three-phase systems, 256 samples per cycle. IEC 62053-22 class 0,5 S
kWh	total import/export
kvarh	Q1, Q2, Q3, Q4
Class Index (Active Energy)	Class 0.2
Class Index (Reactive Energy)	Class 0.5S

Parameter	Requirement
Type of measurement	Apparent power total, Active power per phase, Reactive power total, Reactive power per phase, Voltage, Current, Frequency, Power factor total, Power factor per phase
Power quality analysis	Waveform capture, Harmonic distortion, Voltage sag and swell detection, IEC 61000-4-30: class S power quality measurement up to the 63rd harmonic, Transient capture EN 50160 compliance report
Data recording	Historical logs, Transient logs, Data logs, Time stamping, Harmonics logs, Time synchronisation, Alarms, Sag and swell logs, Event logs
Display	LCD or TFT
DI, DO	2, 2 (Programmable)
Communication	
Communication Ports	2 Ethernet
Communication Protocol for Ethernet Port	IEC 61850
Time synchronisation protocol	NTP
Installation	Flush Mounted
Environmental	
Operating temperature	-10°C to +50°C
Humidity	5 to 95 % relative humidity (without condensation) at +35°C
Operating Altitude	2000m
Resistance to water and dust	IP20 on terminal block without protective enclosure and IP50 in protective enclosure, according to IEC
EMC compatibility	
Surge voltage test	4 kV 1.2/50 µs (IEC 61000-4-5)
Fast transient burst test	4 kV (IEC 61000-4-4)
Immunity to electromagnetic HF-fields	80 MHz - 2 GHz at 10 V/m (IEC 61000-4-3)
Immunity to conducted disturbance	150 kHz - 80 MHz, (IEC 61000-4-6)
Immunity to disturbance with harmonics	2kHz - 150kHz
Radio frequency emission	EN 55022, class B (CISPR22)

Parameter	Requirement
Electrostatic discharge	15 kV (IEC 61000-4-2)
Standards	Latest version of the above standards applies

Table VI: Technical specifications for LVAC switchboard.

Parameter	Requirement
Enclosure/Complete Switchboard	
Area per incoming cable	300 mm x 300 mm
Thickness	2 mm (14 SGW)
Degree of protection	IP 31
Certifications	EN 60439 – 1 EN 60529 (IP 31) EN ISO 12944
Busbars	
Current rating:	
• Phase busbar	1000A
• Neutral Busbar	1000A
Cross sectional area	
• Phase & Neutral Busbars	264 mm^2
• Earth bar	95 mm^2
Certifications	EN 60439 – 1
Short circuit current rating for 1 seconds	50 kA
Incoming Circuit Breakers – Motorized MCCBs	
Certifications	EN 60898 EN 60947 – 2
Current rating/No. of poles	800A, 4P
Rated Service Short-Circuit Breaking Capacity (Ics)	50kA
Rated Short-time Withstand Current (Icw) for 1s	20 kA

Parameter	Requirement
Operating Mechanism Details:	
• Type	
• Electrical release coil	24 or 48 V_{DC}
Outgoing Circuit Breakers - MCCBs	
Certifications	EN 60898 EN 60947 – 2
Current rating/No. of poles	According to drawing no. TD_A4
Short circuit current rating for 1 seconds	25 kA
Current Transformer for Metering	
Amperes Ratio	1000/5A
Burden	15 VA
Accuracy Class	0.1

Table VII: Technical specifications for electronic programmable load.

Parameter	Requirement
Supply voltage	400 VAC 3-PH
Input voltage	400 VAC 3-PH
Input current	>30 A
Input rated power	>10 kW
Operating frequency	40 – 70 Hz
Power factor	0 – 1
Crest factor	1.4 – 4
Ambient temperature	0 – 40 °C
Relative humidity	5 – 95%
Communication	Ethernet
Features	

Parameter	Requirement
AC mode	Constant current (CC), Constant resistance (CR), Constant power (CP)
DC mode	Constant current (CC), Constant voltage (CV), Constant resistance (CR), Constant power (CP)
Programmable	Yes
Rectified load mode	Optional
Analog outputs for monitoring emulated voltage and current	Optional

Table VIII: Technical specifications for power smart plugs.

Parameter	Requirement
Operating voltage	240 V
Operating frequency	50 Hz
Maximum current	>=12 A
Maximum load	>=3 kW
Ambient temperature	0 – 40 °C
Relative humidity	5 – 95%
Amount	10

4 Greece

The main objective of the nanogrids implemented at the two pilot sites in Greece, i.e., a building of student dormitories and a town hall, is to increase the self-sufficiency of the buildings by reducing the energy demand from the utility grid. Specifically, in the case of the town hall, a full coverage of electric needs will be attempted. In both cases, the existing PV installation will be expanded, while a new BESS will be added. Demand side management capabilities of the buildings will be enabled by installing controllable loads (controlled by smart plugs). In both cases the main target will be to increase the self-consumption rate (SCR) (more than 85%) and the self-sufficiency rate (SSR).

The installation locations will be at the student dormitories of University of Western Macedonia (UOWM) and at the town hall building of Koilada. Both sites are located near Kozani at 40°18'01.85"N 21°47'21.81"E and have an altitude of 700 m above the sea level.

4.1 UOWM dormitories nanogrid overview

In the dormitories building, a PV system of 22.86 kWp is already installed along with a BESS system of 20.4 kWh. Two 10 kW hybrid inverters are currently used to control PV production and battery operation. The inverters work independently, while the battery control strategy aims at SCR maximization. The priority of the PV energy flow is load-battery-grid, and battery discharges only to the load. The main LVAC switchboard metering system, consisted of 14 power analyzers (Janitza UMG604), monitors almost all the electrical lines.

The main equipment needed for the dormitories nanogrid is listed below:

- 12 kWp PV panels
- 11 kWh BESS
- 10 kW hybrid inverter
- Main controller
- Meteorological station
- Energy meters (compatible to the existing ones)
- Electric car charger
- Monitoring and controlling system of corridor lights
- Thermo- and humidity meters
- Smart plugs
- DC and LVAC switchboards

Figure 3 shows the schematic diagram of UOWM dormitories nanogrid, including the existing infrastructure.

Figure 4 shows floor plans and section of the site of installation.

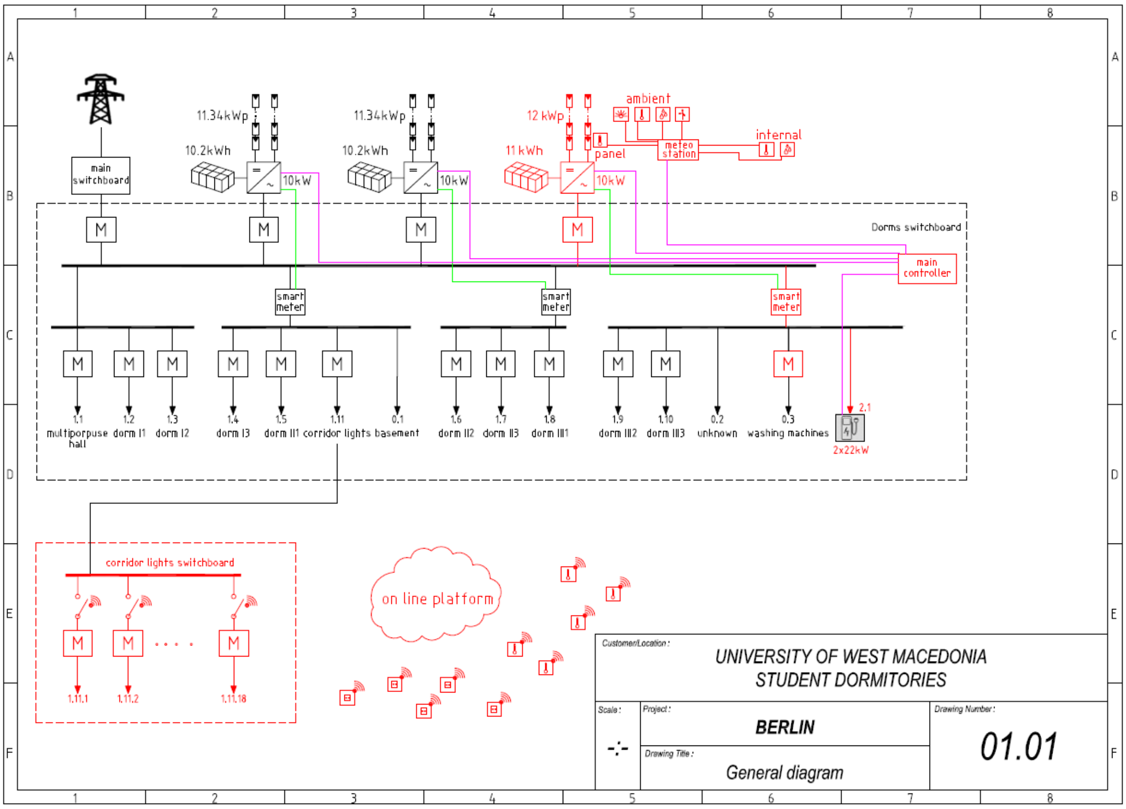

Figure 3 Schematic diagram of UOWM dormitories nanogrid

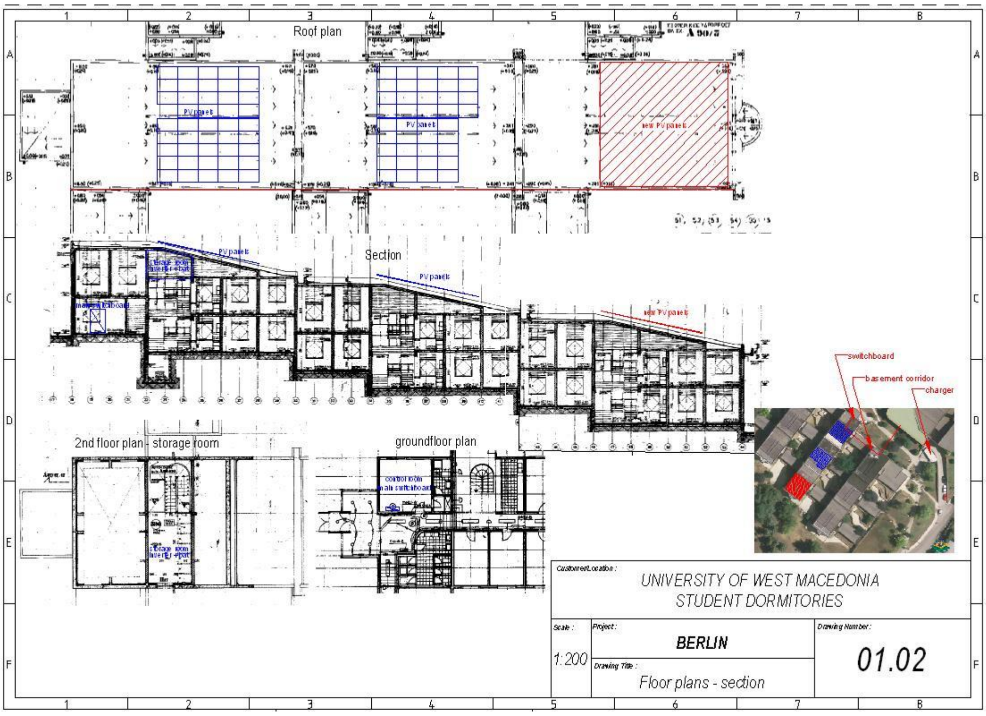

Figure 4 Floor Plans & sections of UOWM dormitories

4.2 Town hall building of Koilada nanogrid overview

A 10 kWp PV system with KACO string-inverters and a BESS consisted of 20kWh Sunlight OPzV batteries and three single-phase SMA Sunny Island inverters, are already installed and operating at the town hall building. PV and BESS systems are AC-coupled.

The main equipment required for the town hall nanogrid is listed below:

- 10 kWp PV panel
- 12 kWh BESS
- 10 kW hybrid inverter
- Main controller
- Meteorological station
- Energy meters (compatible to the existing ones)
- Smart plugs
- Monitoring and controlling system of building lights
- DC and LVAC switchboards

4.3 Technical specifications

Table IX: PV panels specifications

Parameter	**Requirement**
General	
Poly-crystalline	Yes
Electrical Characteristics at Standard Test Conditions (STC)	
Maximum Power (Pmax)	≥ 270 W
Tolerance of Pmax	+5/-0 %
Voltage and Current	Chosen to match the inverter
General Electrical Characteristics	
Bypass diodes	At least 3
Mechanical Characteristics	
Frame Material	Anodized aluminum profile
Front Cover	tempered glass with high light transmission and anti-reflective properties
Junction Box	IP67
Electrical Terminals	Compatible with MC4
Maximum Ratings	
Maximum System Voltage	1000 VDC (IEC)
Minimum Front Surface Load Capacity	5 kPa
Minimum Back Surface Load Capacity	2 kPa
Ambient Temperature Range	–40 to +85 °C
Impact Resistance	20 mm diameter hail at an impact speed of 80 kmk/h
Warranty	
Product Warranty	5 years
Output Warranty of Pmax	10 years output: > 90% 25 years output: > 80%
Certifications and Tests	

Parameter	Requirement
General certifications	IEC 61215:2016 IEC 61730:2016 CE

Table X: Battery specifications

Parameter	Requirement
Functional Requirements	
Battery Technology	lithium iron phosphate
Nominal Discharge rating	11 kVA
Nominal usable capacity	11 kWh
Minimum Cycle Life	Five thousand (5000) complete charge/discharge cycles
Acceptable Performance Degradation - Charge/Discharge Ratings	Less than 10%, over required chronological/cycle lifetime
External ambient temperature	5°C to +35°C
External ambient relative humidity	0% to 100%
Installation	Indoor
Certifications	
Battery safety	VDE 2510-50 EN62619 (safety requirements for secondary lithium cells and batteries)

Table XI: Hybrid inverter specifications

Parameter	Requirement
General Characteristics	
Inverter design	Transformer-less
Peak Efficiency	>= 90%
AC Port	
Direction	Output
Connection	3-Phase

Parameter	Requirement
Nominal Voltage	400 VAC ±10%
Nominal Power at 45 °C, continuous	>= 10 kVA
Nominal Frequency	50 Hz ±10%
Power factor (cos ϕ)	0.85 – 1 inductive / capacitive
Total harmonic distortion	<= 3%
DC Port	
Direction	Input
Nominal Voltage	1000 VDC
Nominal Power at 45 °C, continuous	Depending on system design – Total 10 kW
MPPT	≥3
Mechanical	
Ingress protection	>= IP55
Cooling	Passive or regulated air cooling
Installation	Indoor and outdoor installation
Ambient temperature range	-10 to +50 °C
Communication	
Internet Connection	Ethernet, wifi
Communication with EMS or external controller	Ethernet, Modbus
Communication with BESS	Modbus
Warranty	
Product	>= 5 years
Certifications	
	CE, ISO9001, EN62109, EN61000-6-2, EN61000-6-3, EN61000-3-2, EN61000-3-3, IEC 61683:1999, VDE 0126-1-1

Table XII: Power analyser specifications

Parameter	Requirement
Rated Inputs	
Power	3ph
Nominal Voltage	3x230/400 Vac
Voltage Range	100 - 270V
Current measurement	CT Connected
Reference basic current Ib	1A -5A
Frequency	50Hz
Power Supply	230Vac +/-10%, 50Hz
Measurements	True RMS 4–quadrant metering up to the 25th harmonic on three-phase systems, 256 samples per cycle. IEC 62053-22 class 0,5 S
Measuring parameters	P, Q, S, PF, V, I, f, THDV, THDI
Sampling frequency	5.4kHz
Class Index V/I	Class 0.2%
Class Index (Energy)	Class 0.5S
Type of measurement	Apparent power total, Active power per phase, Reactive power total, Reactive power per phase, Voltage, Current, Frequency, Power factor total, Power factor per phase
Power quality analysis	Harmonic distortion
Data recording	Historical logs, Data logs, Time stamping, Harmonics logs, Time synchronisation, Alarms
Display	LCD or TFT
Communication	
Compatibility	Compatible as slave to Janitza UMG PRO 604
Installation	Rail Mounted

Table XIII: Electric car charger specifications

Parameter	Requirement
Supply voltage	400 VAC 3ph - 50Hz

Parameter	Requirement
Maximum power	22 kW
Number of simultaneously charging cars	2
Number of plugs	2 x T2S 2 x schuko
Protection	IP55 IK10
Communication	Ethernet, wifi, Modbus RS485

Table XIV: Smart plugs specifications

Parameter	Requirement
Operating voltage	230 V
Operating frequency	50 Hz
Maximum current	>=16 A
Maximum load	>=3 kW
Ambient temperature	0 – 40 °C
Relative humidity	5 – 95%
Communication	Wifi
Other	Monitor & control from online platform with time scheduling and programming with if-then-else commands

Table XV: UOWM dormitories controller specifications

Parameter	Requirement
Mounting	Rail
Voltage Supply	230 VAC
Monitor	No
Memory	Flash memory 2GB RAM 512 MB SD card 2GB
Communication Ports	2x Ethernet, 1x RS-232, 1x RS-485, expandable to more 10 ports
Communication protocols	Simultaneous use of 8 protocols

Parameter	Requirement
	TCP-IP IEC 60870-5-1XX IEC 61850 Modbus RTU/TCP DNP3
I/O	8x Digital outputs (DC 24/60/110/220V, AC 110/230V) 16x Digital Inputs (DC 24V) 4x Analog Inputs (Pt100/Ni100) 4x Analog Inputs (-20/20mA, -10/10V) Expandable to 2048 I/O
Software	Included for full use of capabilities of controller

Table XVI: Town hall building of Koilada controller specifications

Parameter	Requirement
Mounting	Rail
Voltage Supply	230 VAC
Monitor	No
Memory	Flash memory 16MB RAM 32 MB SD card 2GB
Communication Ports	2x Ethernet, 1x RS-232, 1x RS-485
Communication protocols	Simultaneous use of 4 protocols TCP-IP IEC 60870-5-1XX IEC 61850 Modbus RTU/TCP DNP3
I/O	8x Digital outputs (DC 24/60/110/220V, AC 110/230V) 16x Digital Inputs (DC 24V) 4x Analog Inputs (-20/20mA, -10/10V) Expandable to 128 I/O
Software	Included for full use of capabilities of controller

Table XVII: Meteorological station specifications

Parameter	Requirement
Sensors	Pyranometer, PV thermometer, thermo-humidity meter (indoor-outdoor), anemometer
Data logger	
Memory	Flash memory 4MB SD card 2GB
Monitor	Yes
Communication Ports	Ethernet, RS-232
Inputs	8x Analog 10x Digital Bus SDI-12, Modbus RTU
Sampling	1Hz, variable mean recording 1sec-1h
Software	Included for full use of capabilities of data logger
Pyranometer	
Spectral range	360nm-1120nm
Field of view	180°
Output	0-250 mV
Sensitivity	0.20 mV/W/m2
Calibration uncertainty	±5%
Measurement repeatability	<1%
Long term drift	< 2%/year
Response time	< 1msec
Operating environment	-40 to 70°C 0 to 100% RH
Thermo humidity sensor	
Operating environment	-40 to 90°C 0 to 100% RH
Output	0-1V, 0-2.5V, 0-5V Modbus RTU
Sensitivity	0,2°C (0-60°C) 1.8% RH (0-80% RH)
Measurement repeatability	<0.3%RH <0.15°C

Parameter	Requirement
Long term drift	<0.5%RH/y <0.05°C/y
Response time	<12sec
Other	The outdoor sensor comes with protection cage
PV panels surface thermometer	
Type	Pt100, 3wires
Operating environment	-50 – 150°C
Measurement range	-50 – 150°C
Sensitivity	0.15°C
Cover	Aluminium with adhesive tape
Protection	IP66
Anemometer	
Type	Wind speed
Operating environment	-40 – 60°C 0-100%RH 0-95 m/sec
Measurement range	0-45 m/sec
Sensitivity	0.75 m/sec

Table XVIII: Indoor thermometers system specifications

Parameter	Requirement
Number of sensors	18
Type of sensors	Thermo-humidity sensors
Measurement range	0 – 50°C 20-90%RH
Sensitivity	2°C 5% RH
Response time	<5sec
Communication	Wifi, compatible to NodeRed platform
Other	Wifi extenders included, single band 2.4GHz-300Mbps

Table XIX: Specifications of the system for lighting monitoring & control

Parameter	Requirement
General	Monitors (energy meter) & controls each line of the corridor lighting switchboard. Wifi real time connection to the online platform.
Power-energy meter	
Mounting	Rail
Type	230VAC 1ph
Operating conditions	161-300 VAC 50Hz ±10% 20mA – 25A
Operating environment	-10°C - +40°C
Measuring parameters	Power, Energy
Maximum sampling	60sec
Sensitivity	<1.5% Class 1
Monitor	Yes
Certifications	IEC 62053-21
Control module (on/off)	
Mounting	Rail
Type	230VAC 1ph
Operating conditions	196-253 VAC 50Hz ±10% I_{max} 25A
Operating environment	-10°C - +40°C
Certifications	IEC 61905
Communication module	
Mounting	Rail
Operating conditions	230 VAC, 50Hz
Operating environment	-10°C - +40°C
Communication protocol	Wifi IEEE 802.11
Communication security	TLS/SSL
Other specifications	The system comes with an online platform able to monitor and control at real time. The platform should allow the scheduling of the control units and the programming with if-then-else commands.

5 Israel

5.1 Eilot regional council

Eilot is facing increased energy demand in the forms of electricity, cooling and thermal energy. In order to face the increased demand while lowering energy prices, the Municipality needs to find alternative renewable energy sources, in the case of the Eilat-Eilot region, solar PV is an attractive alternative. The cost of solar energy sources is dropping and will soon be lower than that of fossil fuels, becoming a viable alternative for cities. Since the energy production from renewable sources is based on natural resources outside human control, there is a need for smart energy management that can decide when and how to use renewable energy sources alongside existing proven and controllable fossil fuel resources. As part of the national and municipal efforts to make Eilot carbon neutral (Net-Zero), numerous R&D projects and pilots are taking place in the areas of renewable energy, smart transport, energy efficiency and sustainable development. Through the Eilat-Eilot Renewable Energy Initiative, Eilat and Eilot have become a leader in energy efficiency, as 75% of the city's and region's daytime electricity is supplied by renewable energy.

5.1.1 Eilot nanogrid overview

The Eilot nanogrid is comprised of solar PV systems, battery storage and a Load Management System (LMS). Both Building Applied PV (BAPV), for maximum energy production and BIPVs, serving also as shading for the public areas, are to be installed.

The school was designed and built using modern energy efficient building techniques including a Building Management System (BMS) that controls all lighting and HVAC elements in the school. The circuits controlled by the existing BMS are listed in Table XX together with the installed power of the consumers as a controlled entity. Figure 5 portrays a typical field in a local electrical distribution board showing the entities controlled by the BMS. The proposed EMS will control the existing BMS. The sum total of the table is 322 kW. This is not the total installed capacity, but can be assumed to represent 90% of the load. There are 52 air conditioners along with 4 exhaust fans and 6 fresh air intake fans that will be controlled by the proposed EMS.

The EMS will manage the solar PV production, battery storage and school consumption towards zero consumption from the public grid.

Table XX: HVAC system of the school

Electric panel name	Hall lighting [kW]	Restroom lighting [kW]	Classroom lighting [kW]	Outdoor lighting [kW]	Exhaust fan [kW]	Fresh air fan [kW]	A/C [kW]	Water heaters etc. [kW]
Com							2	2
DP0	1.04	0.68	0.32	1.14			2	5
DP1	1.4	0.68	3.92	0.88		5	42.6	3
DP2	1.04	0.68	2.28	0.72		5	26	4
DP3	1.2	0.76	1.68	0.24	4	5	20.8	4

Electric panel name	Hall lighting [kW]	Restroom lighting [kW]	Classroom lighting [kW]	Outdoor lighting [kW]	Exhaust fan [kW]	Fresh air fan [kW]	A/C [kW]	Water heaters etc. [kW]
DP4	1.2	0.76	1.68	0.2	4	5.2	20.8	3
DP5	1.52	0.8	3.32	0.68	4	10	26.2	6
DP6	2.52	0.8	2.72	0.88	4	10	35.4	4
M1	0	0	0.72	0			4	
M2	0	0	0.6	0			5	
M3	0	0	0.76	0			3.2	
M4	0	0	0.72	0			4.6	
M6	0	0	0.96	0			6.6	
Sports field				5				
Total [kW]	9.92	5.16	19.68	4.74	16	40.2	199.2	31

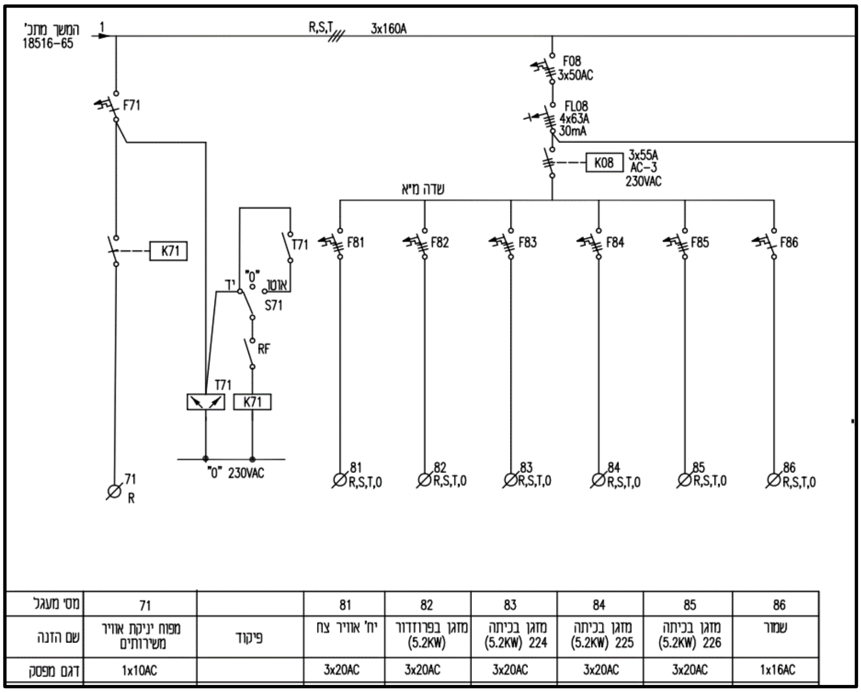

Figure 5: Typical HVAC control circuit in the electric panel.

A list of the main equipment required for the Eilot nanogrid includes:

- 350 kWp photovoltaics

- 600 kWh (200 kW) batteries
- PV solar Inverters
- Battery inverters and accompanying BESS
- System protection and monitoring
- Programmable logic controllers for load management
- Support structure of metal frames for PV mounting

5.1.2 Site description

The elementary school has only recently been commissioned and is comprised of two buildings, as can be seen in Figure 6. The northern building consists of a single floor with 10 classrooms and 7 administrational rooms and offices with 3 sets of restrooms. The southern building consists of two levels with 14 classrooms and 2 sets of restrooms on the ground floor and 11 classrooms and 2 sets of restrooms on the second level.

Figure 6: The new school with PV placement.

Figure 7 displays a possible layout of the BAPV and BIPV on the campus taken from initial feasibility studies performed for the project.

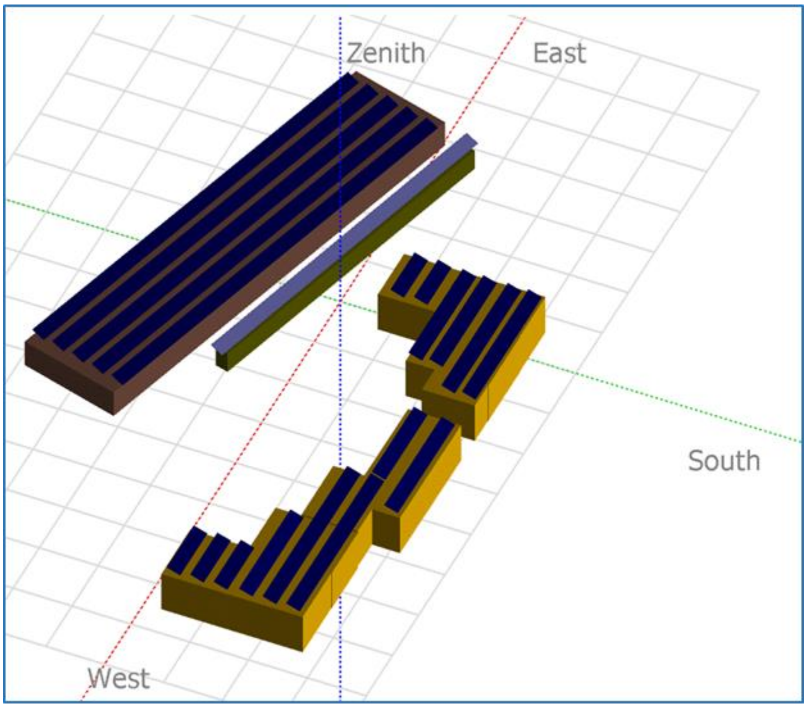

Figure 7: Initial design of BIPV and BAPV at the Nof Edom school in Eilot R.C.

5.2 Eilat city

Eilat city is on a continuous work towards energy transition to 100% renewable sources. Besides the goal to reduce greenhouse gas (GHG) emissions, because of its location on the African-Syrian rift valley, it is crucial to develop resilient centres that can operate under extreme conditions such as earthquakes, extreme hot weather conditions and during blackouts. The Berlin project in Eilat is planned to be installed in the Yeelim school, shown in Figure 8, and community centre. The project will support the local community by creating a local energy resilient centre in the school and community centre.

Figure 8: Aerial photo of Yeelim school.

The monthly consumption for 2019 is shown in Figure 9. As shown, the summer (June-October) is the season with the highest consumption. August is relatively low because the schools are closed and in September the school is being prepared for the opening of the year.

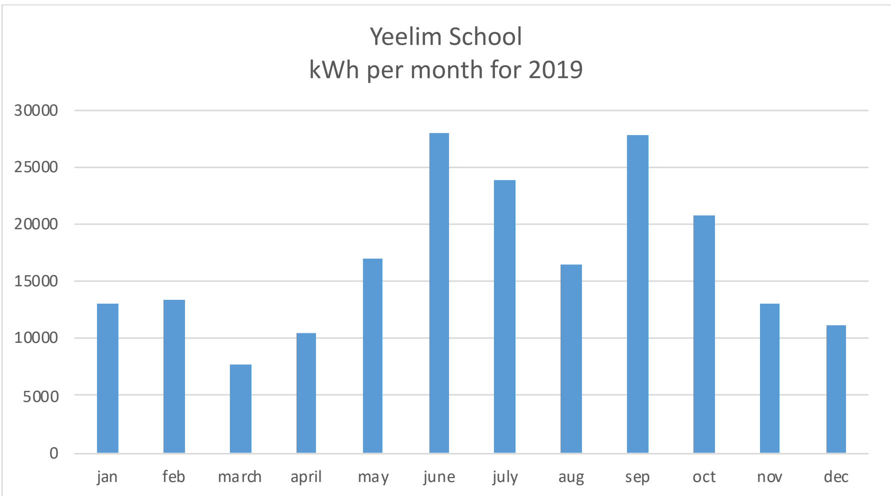

Figure 9: Monthly consumption of Yeelim school for 2019.

5.2.1 Eilat nanogrid overview

The school is not new, and does not have the same BMS that is available in the newly build Eilot school. This requires direct control of the significant loads by the EMS as opposed to controlling the existing BMS.

The overall system will function in a similar fashion to that to be installed at the school in Eilot, requiring additional hardware in the local electrical distribution panels.

A list of the main equipment required for the Eilot nanogrid includes:

- 350 kWp photovoltaics
- 600 kWh (200kW) batteries
- PV solar Inverters
- Battery inverters and accompanying BESS
- Retrofitting LVAC electrical distribution panels
- System protection and monitoring
- Programmable logic controllers for load management
- Support structure of metal frames for PV mounting

5.3 Technical specifications

Table XXI: PV panel specifications.

Parameter	Requirement
General	
Mono-crystalline	Yes
Bifacial	Yes (only on canopy)
Has a level of transparency	Yes (only on canopy)
Junction box position	Side mounted
Electrical Characteristics at Standard Test Conditions (STC)	
Maximum Power (Pmax)	> 500 Wp
Tolerance of Pmax	+5/-0 %
Voltage and Current	Chosen to match the inverter
Temperature Characteristics	
Normal Module Operating Temperature	45 °C（±2 °C)
Maximum Temperature Coefficient of Pm	-0.38 %/°C
General Electrical Characteristics	
Junction Box Rated Current	≧ 15 A
Bypass diodes	At least 3
Mechanical Characteristics	

Parameter	Requirement
Frame Material	Anodized aluminum profile
Front Cover	tempered glass with high light transmission and anti-reflective properties
Typical Size (LxWxH)	200x100x4 cm
Junction Box	IP67
Electrical Terminals	Compatible with Solar MC4 DC connector
Maximum Ratings	
Maximum System Voltage	1000 or 1500 VDC (IEC)
Minimum Series Fuse Rating	15 A
Minimum Front Surface Load Capacity	5400 Pa
Minimum Back Surface Load Capacity	2400 Pa
Ambient Temperature Range	–40 to +85 °C
Impact Resistance	25 mm diameter hail at an impact speed of 23 $m \cdot s^{-1}$
Warranty	
Product Warranty	10 years
Output Warranty of Pmax	First year: 98%, After 1st year: <0.45% annual degradation
Certifications and Tests	
General certifications	EN 50380 IEC 62941 IEC 61215:2016 IEC 61730:2016 CE
UV test	IEC 61345
Salt Mist Corrosion test	IEC 61701
Systems above 600 Vdc – certified for potential induced degradation	IEC 62804
Intensive farming sheds - certified for ammonia corrosion	IEC 62716

Parameter	Requirement
Desert regions – certified for wind-blown dust and sand	IEC 60068-2-68

Table XXII: Inverter specifications.

Parameter	Requirement
General Characteristics	
Inverter design	Transformer-less
Peak Efficiency	>= 97%
AC Port	
Direction	Output
Connection	3-Phase
Nominal Voltage	400 VAC ±10%
Nominal Power at 45 °C, continuous	> 470 kVA
Nominal Frequency	50 Hz
Power factor (cos ϕ)	0.85 – 1 inductive / capacitive
Total harmonic distortion	As per national standard requirements for inverters
DC Port	
Direction	Input
Nominal Voltage	1000 or 1500 VDC
Nominal Power at 45 °C, continuous	>350 kWp
MPPT	Multi
Mechanical	
Ingress protection	>= IP65
Cooling	Passive or regulated air cooling
Installation	Indoor and outdoor installation
Permitted humidity	5 - 100 %

Parameter	Requirement
Ambient temperature range	-10 to +50 °C
Communication	
Internet Connection	Ethernet
Communication with EMS or external controller	As per system design requirements
Communication with BESS	As per system design requirements
Warranty	
Product	>= 20 years
Certifications	
EMC	EN 61000-6-1 or EN61000-6-2 (immunity) EN 61000-6-3 or EN61000-6-4 (emissions)
Electrical Safety	EN 62477-1 (power electronic converters and equipment) EN 61010-1 (safety requirements) EN 62040-1 (UPS) EN 62109 (PV converters)
Operation	IEC 62116 VDE AR-N 4105:2011-8

Table XXIII: Battery and inverter specifications.

Parameter	Requirement
Functional Requirements	
Battery Technology	Lithium Ion
Nominal Discharge rating	200 kVA
Nominal usable capacity	600 kWh
Rated discharge duration	30 minutes
Charge rating	Greater than or equal to 100 kVA
Nominal Operating Voltage	400 Vac 3 ph
Operating frequency	50 Hz

Parameter	Requirement
Chronological life	Minimum 25-year chronological life with no replacement of any major component technologies.
Minimum Cycle Life	Ten thousand (10000) complete charge/discharge cycles
Transient response characteristics	Discharge: From stand-by (idle) to rated output in less than 1 minute (100% per minute); Charge: From stand-by (idle) to full rated charge rating, in less than 3 minutes; Reverse time: (from full power input (charging) to full power output (discharging) in less than 4 minutes and vice-versa.
Acceptable Performance Degradation - Charge/Discharge Ratings	Less than 10%, over required chronological/cycle lifetime
Acceptable Performance Degradation –Energy Storage Capacity	Less than 10%, over required chronological/cycle lifetime
Availability	Greater than or equal to 90% over full 25-year life
External ambient temperature	-10ºC to +50ºC
External ambient relative humidity	0% to 100%
Installation	Indoor or outdoor
DC to DC Round trip cycle efficiency at nominal 2-hour rating	95% or greater
Acceptable Performance Degradation at nominal 2-hour rating – Round trip cycle efficiency	Less than 5%, over required chronological/cycle lifetime
Certifications	
Battery safety	IEC62281 or UN/DOT 38.3 (transportation testing for lithium batteries) IEC62133 or UL1642 (safety test for lithium batteries) EN62619 (safety requirements for secondary lithium cells and batteries)
EMC	EN61000-6-1 or EN61000-6-2 (immunity) and EN61000-6-3 or EN61000-6-4 (emissions)
Electrical safety	EN62477-1 (power electronic converters and equipment)

Table XXIV: Power meter specifications.

Parameter	Requirement
Rated Inputs	
Power	3ph
Number of Wires	4
Nominal Voltage	3x230/400 Vac or 3x110 Vac
Voltage Range	57.5 - 240V
Current measurement	CT Connected
Reference basic current Ib	1A
Reference maximum current Imax	1.2A
Frequency	50Hz
Power Supply	230Vac +/-10%, 50Hz or 24 Vdc see relevant drawings
Measurements	True RMS 4–quadrant metering up to the 63rd harmonic on three-phase systems, 256 samples per cycle. IEC 62053-22 class 0,5 S
kWh	total import/export
kvarh	Q1, Q2, Q3, Q4
Class Index (Active Energy)	Class 0.2
Class Index (Reactive Energy)	Class 0.5S
Type of measurement	Apparent power total, Active power per phase, Reactive power total, Reactive power per phase, Voltage, Current, Frequency, Power factor total, Power factor per phase
Power quality analysis	Waveform capture, Harmonic distortion, Voltage sag and swell detection, IEC 61000-4-30: class S power quality measurement up to the 63rd harmonic, Transient capture EN 50160 compliance report
Data recording	Historical logs, Transient logs, Data logs, Time stamping, Harmonics logs, Time synchronisation, Alarms, Sag and swell logs, Event logs
Display	LCD or TFT
DI, DO	2, 2 (Programmable)
Communication	
Communication Ports	2 Ethernet and GPRS

Parameter	Requirement
Communication Protocol for Ethernet Port	IEC 61850
Time synchronisation protocol	NTP
Installation	Flush Mounted
Environmental	
Operating temperature	-10°C to +50°C
Humidity	5 to 95 % relative humidity (without condensation) at +35°C
Operating Altitude	2000m
Resistance to water and dust	IP20 on terminal block without protective enclosure and IP50 in protective enclosure, according to IEC
EMC compatibility	
Surge voltage test	4 kV 1.2/50 µs (IEC 61000-4-5)
Fast transient burst test	4 kV (IEC 61000-4-4)
Immunity to electromagnetic HF-fields	80 MHz - 2 GHz at 10 V/m (IEC 61000-4-3)
Immunity to conducted disturbance	150 kHz - 80 MHz, (IEC 61000-4-6)
Immunity to disturbance with harmonics	2kHz - 150kHz
Radio frequency emission	EN 55022, class B (CISPR22)
Electrostatic discharge	15 kV (IEC 61000-4-2)
Standards	Latest version of the above standards applies

Table XXV: Power smart plugs specifications.

Parameter	Requirement
Operating voltage	230 V
Operating frequency	50 Hz
Maximum current	>=16 A
Maximum load	>=3.7 kW

Parameter	Requirement
Ambient temperature	0 – 40 °C
Relative humidity	5 – 95%
Amount	10

6 Italy

The main goal of the Italian pilot project is to create a demonstrative installation (and living lab) of nanogrid for existing buildings to show the feasibility of a greener, ecologically sustainable and economically profitable future scenario. In particular, the nanogrid will allow reducing the building energy consumption, for minimising the electricity bill, and providing flexibility services if required. Three technologies, namely PV, BESS and DSM, will be implemented and tested, under the concept of nanogrid, within the "Building F" of the Unica Campus. By evaluating the meteorological information, the energy consumption and the PV energy production, the EMS of the nanogrid will handle the controllable loads and the BESS in order to maximise self-consumption and minimise the CO_2 building production.

The chosen building, which includes a university library, several classrooms and some offices, is part of a large campus of the University of Cagliari that is already interested by a bigger automation project for the realization of a Smart Grid. Therefore, the new nanogrid will have to interact also with the EMS of the whole campus.

6.1 Unica campus Nanogrid overview

The following equipment will be purchased and installed in the "Building F" to form the nanogrid:

- A 40 kWp rooftop PV system
- A 30 kW - 71 kWh BESS
- An EMS for the effective operation of the nanogrid (main controller and software tools)
- Smart power meters and data logger for the remote monitoring of building generation, consumption and storage of electrical energy
- Sensors for the measurement of the main indoor and outdoor ambient parameters (temperature, relative humidity, air quality, presence/occupancy, brightness, solar irradiation, wind speed), in order to monitor and store ambient operating conditions, improve the effectiveness of load and generation forecasting, enable the building automation, and facilitate nanogrid management
- Local controllers and actuators for the remote control of loads (smart plugs, lighting, HVAC)

All this equipment will form the nanogrid pilot with the goals of managing and controlling the energy demand of "Building F", the electric storage capability and photovoltaic generation as a small microgrid (nanogrid), normally operated on-grid to improve its energy efficiency and provide potential services by participating to Demand Response programs, but able to automatically work islanded from the grid in case of outages. A schematic representation of the pilot is depicted in Figure 10.

The Photovoltaic plant will be installed on the rooftop of “Building F”, formed by 112 panels that covers approximately 240 m^2. Figure 11 shows the PV plant layout, while Figure 12 depicts some details of modules installation, whose inclination on the plan rooftop has been chosen of 7° in order to avoid the visibility of the plant and reduce the shadowing among modules, allowing a tighter installation of the string. The whole PV plant will be realized in two sections of about 27 kW and 13 kW, both supplied by dedicated inverters. The estimated production of the whole PV plant has been estimated in 54.78 MWh/year.

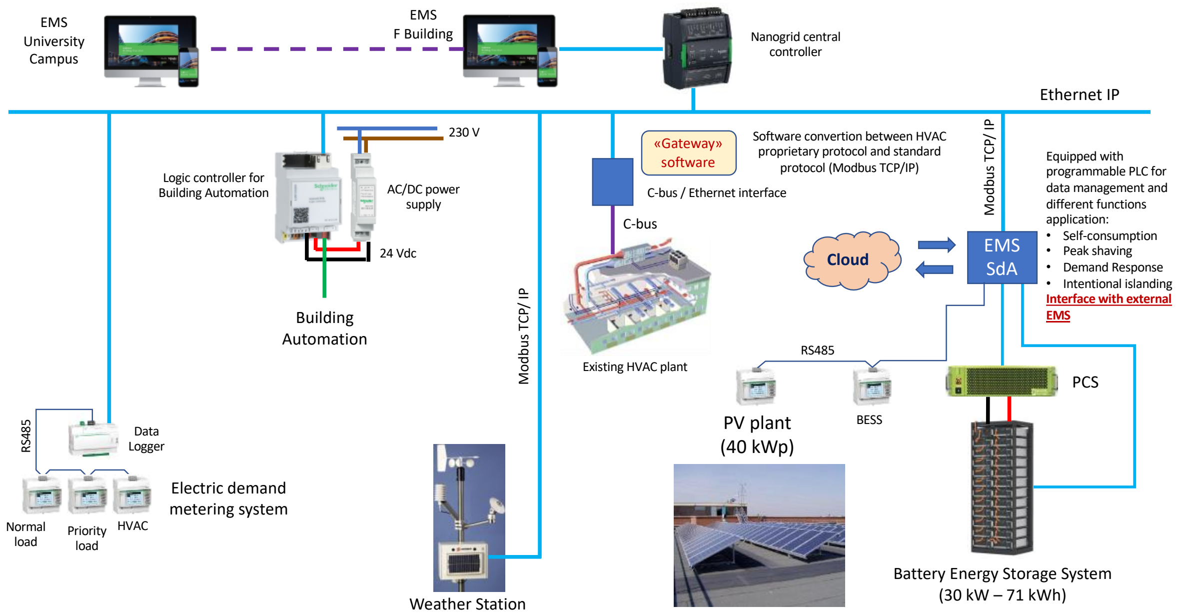

Figure 10 Schematic representation of the Unica nanogrid pilot project

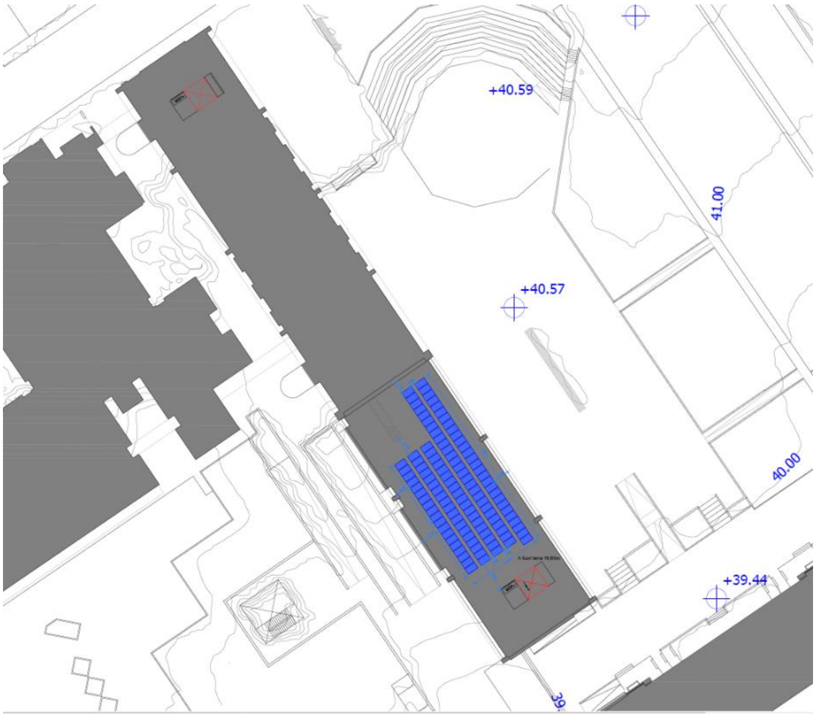

Figure 11 PV layout

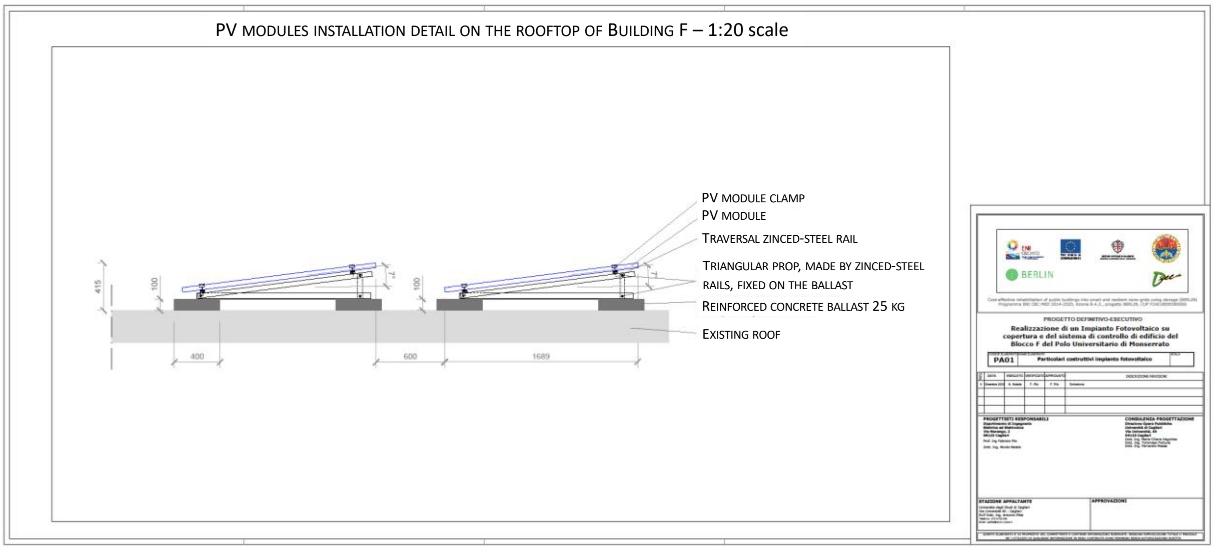

Figure 12 Details of the PV modules installation on the rooftop of Building F

Figure 13 illustrates the schematic diagram of the electric connections and protections for the PV plant and storage installations in the Nanogrid pilot project, in respect of the Italian standards and grid connection regulation.

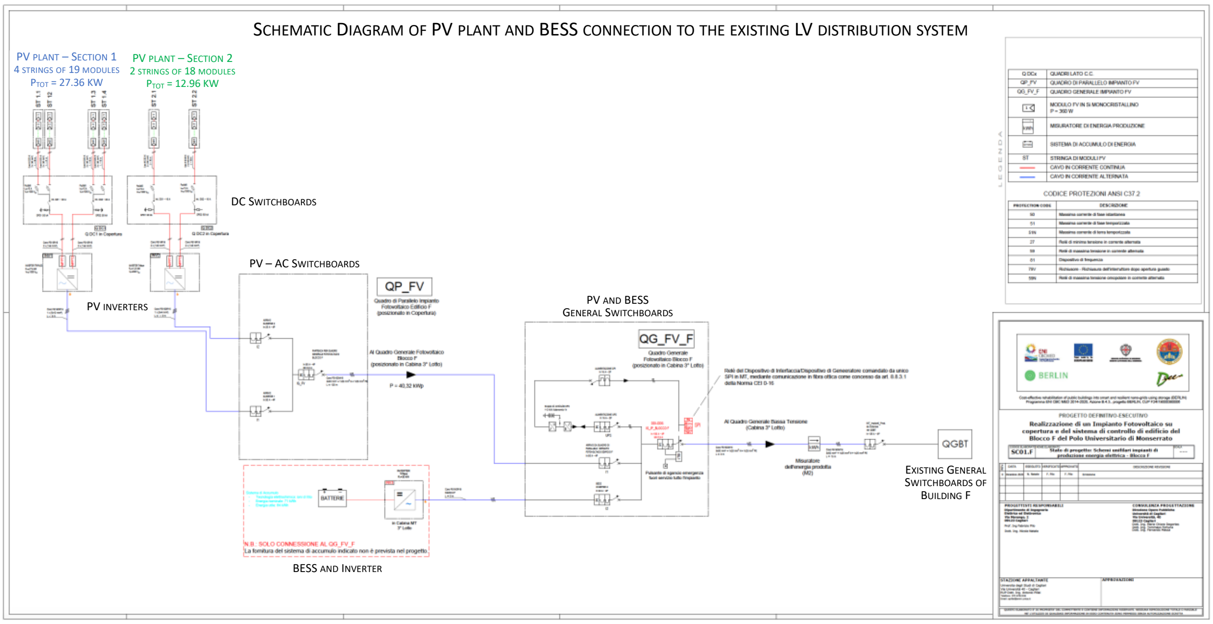

Figure 13 Nanogrid schematic diagram

6.2 Unica campus - Technical specifications

In this section the requirements of the rooftop PV plant, the battery, the inverters and all the smart plugs inside nanogrid in the “Building F” will be described.

Table XXVI Unica PV requirements

General characteristics PV plant	
Parameter	**Requirement**
Electrical Characteristics at Standard Test Conditions (STC)	
Maximum Power (Pmax)	360 W
MPP Voltage (V_{mpp})	36,5 V
MPP current (I_{mpp})	9,87 A
Open circuit Voltage (V_{oc})	42,7 V
Short circuit Current (I_{sc})	10,79 A
Tolerance of Pmax	+3/-0 %
Efficiency	21,4 %
Electrical Characteristics at NOCT Conditions	
Maximum Power (Pmax)	271 W

General characteristics PV plant	
Parameter	**Requirement**
MPP Voltage (V_{mpp})	36,4 V
MPP current (I_{mpp})	7,45 A
Open circuit Voltage (V_{oc})	40,2 V
Short circuit Current (I_{sc})	8,69 A
Temperature Characteristics	
Normal Module Operating Temperature	44 °C（±3 °C)
Maximum Temperature Coefficient of Pm	-0.30 %/°C
Maximum Temperature Coefficient of Voc	-0.24%/°C
Maximum Temperature Coefficient of Isc	+0.04%/°C
General Electrical Characteristics	
Junction box characteristics	IP68
Bypass diodes	3
Mechanical Characteristics	
Frame Material	Anodized aluminum profile
Front Cover	tempered glass with high light transmission and anti-reflective properties
Cells dimensions	161,7x161,7 mm
Electrical Terminals	MC4, 05-8
Electrical Terminals Wire	4 mm^2 (cross-section), 2m long each
Typical Weight	18,5 kg
Typical dimensions	1.700x1.016x40 mm
Maximum Ratings	
Maximum System Voltage	1000 V
Minimum Series Fuse Rating	20 A

General characteristics PV plant	
Parameter	**Requirement**
Minimum Front Surface Load Capacity	6000 Pa
Minimum Back Surface Load Capacity	5400 Pa
Ambient Temperature Range	–40 to +90 °C
Impact Resistance	25 mm diameter hail at an impact speed of 23 $m \cdot s^{-1}$
Warranty	
Product Warranty	>10 years
Output Warranty of Pmax	First year: 98%, After 1st year: <0.4% annual degradation, 25 years output: > 88.4%
Certifications and Tests	
General certifications	EN 50380: 2018 IEC 62941 IEC 61215: 2016 IEC 61730 -1/-2: 2016 ISO 9001 CE
UV test	IEC 61345
Salt Mist Corrosion test	IEC 61701
Systems above 600 Vdc – certified for potential induced degradation	IEC TS 62804-1 (PID)
Intensive farming sheds - certified for ammonia corrosion	IEC 62716
Module Fire reaction	Class C

Table XXVII Unica PV Inverter 1

General characteristics Inverter 1	
Parameter	**Requirement**
Inverter design	Transformer-less

General characteristics Inverter 1	
Parameter	**Requirement**
Peak Efficiency	>= 98%
AC Port	
Connection	3-Phase
Nominal Voltage	400 VAC ±10%
Nominal Power at 45 °C, continuous	27,6 kVA
Nominal Frequency	50 Hz ±10%
Power factor (cos ϕ)	0.90 - 1 inductive / capacitive
Total harmonic distortion	<= 4%
DC Port	
Nominal Voltage	620 VDC
Nominal Power at 45 °C, continuous	28.6 kW
Number of MPPT	2
Mechanical	
Ingress protection	>= IP65
Cooling	Passive or regulated air cooling
Installation	Outdoor installation
Permitted humidity	5 - 100 %
Ambient temperature range	-15 to +55 °C
Communication	
Internet Connection	Ethernet
Communication with EMS or external controller	Ethernet and/or FO
Communication with BESS	Ethernet and/or FO
Warranty	
Product	>= 20 years

General characteristics Inverter 1	
Parameter	**Requirement**
Certifications	
EMC	EN 61000-6-1 or EN61000-6-2 (immunity) EN 61000-6-3 or EN61000-6-4 (emissions)
Electrical Safety	EN 62477-1 (power electronic converters and equipment) EN 61010-1 (safety requirements) EN 62040-1 (UPS) EN 62109 (PV converters)
Operation	IEC 62116
Grid connection	CEI 0-21, CEI 0-16

Table XXVIII Unica PV Inverter 2

General characteristics Inverter 2	
Parameter	**Requirement**
Inverter design	Transformer-less
Peak Efficiency	>= 97%
AC Port	
Connection	3-Phase
Nominal Voltage	400 VAC ±10%
Nominal Power at 45 °C, continuous	12,5 kVA
Nominal Frequency	50 Hz ±10%
Power factor (cos ϕ)	0.90 - 1 inductive / capacitive
Total harmonic distortion	<= 4%
DC Port	
Nominal Voltage	580 VDC
Nominal Power at 45 °C, continuous	12.8 kW

General characteristics Inverter 2	
Parameter	**Requirement**
Number of MPPT	2
Mechanical	
Ingress protection	>= IP65
Cooling	Passive or regulated air cooling
Installation	Outdoor installation
Permitted humidity	5 - 100 %
Ambient temperature range	-15 to +55 °C
Communication	
Internet Connection	Ethernet
Communication with EMS or external controller	Ethernet and/or FO
Communication with BESS	Ethernet and/or FO
Warranty	
Product	>= 20 years
Certifications	
EMC	EN 61000-6-1 or EN61000-6-2 (immunity) EN 61000-6-3 or EN61000-6-4 (emissions)
Electrical Safety	EN 62477-1 (power electronic converters and equipment) EN 61010-1 (safety requirements) EN 62040-1 (UPS) EN 62109 (PV converters)
Operation	IEC 62116
Grid connection	CEI 0-21, CEI 0-16

Table XXIX Unica BESS Requirements

General characteristics BESS	
Parameter	**Requirement**

General characteristics BESS	
Parameter	**Requirement**
Functional Requirements	
Battery Technology	Lithium Ion
Nominal Discharge rating	30 kVA
Capacity	71 kWh with 64 kWh usable capacity
Modules number	15
Operational capability	Full 4-Quadrant
Charge rating	Greater than or equal to 30 kVA
Nominal Operating Voltage	400 Vac 3 ph
Operating frequency	50 Hz
Chronological life	>10 years
Minimum Cycle Life	Five thousand (5000) complete charge/discharge cycles
External ambient temperature	-20°C to +50°C
External ambient relative humidity	0% to 100%
Installation	Indoor
Number of inverter units	1 (single 30 kW inverter)
Certifications	
Battery safety	IEC62281 or UN/DOT 38.3 (transportation testing for lithium batteries) IEC62133 or UL1642 (safety test for lithium batteries) EN62619 (safety requirements for secondary lithium cells and batteries) CE
EMC	EN61000-6-1 or EN61000-6-2 (immunity) and EN61000-6-3 or EN61000-6-4 (emissions)
Electrical safety	EN62477-1 (power electronic converters and equipment)

Table XXX Unica Weather station

General characteristic Weather Station	
Data logger Parameters	
Communication protocols	Modbus RTU
Number inputs	12
Voltage supply	12 VDC
Data transmission	ASCII format through LAN for connection to remote PC
Data logger protection	IP66
Power supply device	230 Vac with emergency battery(2Ah)
Software	CommNET (LSI LASTEM BSZ306.2)
Pyranometer	
Name	LSI LASTEM DPA252
Class	A
Response time (95%)	3s
Irradiance range	0 – 4000 W/m2
Certifications	IEC 61724-1: 2017
Thermohygrometer	
Name	LSI LASTEM DMA672.1
Temperature Uncertainty	0,1°C (0°C)
Temperature Resolution	0,01°C (M/R/E-Log)
Humidity Uncertainty	±1,5% RH (5-95%)
Humidity Measuring range	0÷100%
Anemometer	
Name	LSI LASTEM DNA202.1
Measuring range	0÷75 m/s
Uncertainty	2,5% (calibration tested to 63 m/s)
Threshold	0,5 m/s

General characteristic Weather Station	
Data logger Parameters	
Output	2,65 Hz x m/s

Table XXXI Unica Power metering system

Power Metering System	
Type of measurement	True rms up to the 15th harmonic on three-phase (3P, 3P+N) and single-phase AC systems. 32 samples per cycle.
Communication	RS485 port, Ethernet port
Instantaneous rms values	
Current	Per phase and average
Voltage	Per phase and average
Active, reactive, apparent power	Total and per phase
Power factor	Total and per phase
Active, reactive and apparent energy	Import and export
Power Quality measurements	
THD (Total Harmonic Distortion)	Current and Voltage
Measurement accuracy	
Current with x/5 A CTs	0.3 % from 0.5 A to 6 A
Voltage	0.3 % from 50 V to 330 V (P-N), from 80 V to 570 V (P-P)
Power factor	±0.005 (0.5-6 A with TA x/5 A, 0.1-1.2 A with TA x/1 A, from 0.5L to 0.8C)
Active/Apparent Power with x/5 A CTs	Class 0.5
Active/Apparent Power with x/1 A CTs	Class 1
Reactive Power	Class 2
Frequency	0.05 % from 45 to 65 Hz
Active Energy with x/5 A CTs	IEC62053-22 Class 0.5
Reactive Energy	IEC62053-23 Class 2

Power Metering System	
Input-Voltage characteristic	
Measured Voltage	from 50 V to 330 V AC (direct/VT secondary Ph-N) from 80 V to 570 V AC (direct/VT secondary Ph-Ph) up to 1 MV AC (with external VT)
Frequency range	from 45 Hz to 65 Hz
Input-current characteristic	
Measurement input range with x/5 A CTs	0.05 – 6 A
Permissible overload	10 A continuous, 20 A for 10 s/hour
Mechanical characteristics	
IP degree of protection (IEC60529)	IP40 front panel, IP20 meter body
Environmental conditions	
Operating temperature	from –25 to +55 °C
Humidity rating	5-95 % RH at 50 °C (non-condensing)
Pollution degree	2
Metering category	III, for distribution system up to 277/480 V AC
Dielectric withstand	As per IEC 61010-1, doubled insulated front panel display
Certifications	
General	IEC 61557-12, EN 61557-12, IEC 61010-1, UL 61010-1, IEC 62052-11, IEC 62053-21, IEC 62053-22, IEC 62053-23, EN 50470-1, EN 50470-3
EMC	IEC 61000-4, Class B (EN 55022)
Safety	CE as per IEC 61010-1
Data Logger	
Main supply	24 V DC
Maximum Power consumption	26 W 24 V DC

Power Metering System	
Communication gateway	Ethernet TCP/IP to Modbus
Memory capacity	128 MB RAM, 256 MB flash, 4 GB SDRAM
Current transformer for Power Meter	
Current transformer ratio	800/5
Accuracy class	Class 0.5 at 2,5 VA
Permissible cur	48000 A during 1 s

Table XXXII Unica Sensors requirements

Sensors Characteristics	
CO2 Sensor	
Type	Non-dispersive Infrared (NDIR), diffusion sampling
Output range	0 to 2000 ppm
Accuracy	±30 ppm ±2% of measured value
Repeatability	±20 ppm ±1% of measured value
Time response	<60 s for the 90% of variation
Humidity Sensor	
Accuracy	±2% from 10% to 80% UR 25 °C (77 °F)
hysteresis	1,5%
Linearity	Inside accuracy requirement
Stability	±1% 20 °C (68 °F)
Output range	0 to 100 % of UR
Temperature coefficient	±0,1% UR/°C if different from 25 °C (77 °F)
Temperature sensor	
Type	Thermistor 10K type 3
Accuracy	±0,2 °C (±0.4 °F)
Resolution	0.1 °C (0.2 °F)

Sensors Characteristics	
Output range	0 to 50 °C
Light sensor	
Range	0-400 lux, 0-20k lux
Precision	±5%
Supply	24V AC, 15-36 V DC
Movement sensor	
Installation	1.8-3.6 From the target
Optimal temperature	from –20 °C to +50 °C
Supply	24V AC/DC ±2V AC/DC

The PV plant, the inverters, the sensors, the power meter, the BESS and the weather station will be managed and coordinated from the EMS. By exploiting the communication protocol Modbus TCP/IP over the existing Ethernet network of the building, the EMS will be able to collect data from metering system and sensors, elaborate them and identify the system status. Automatic functions will be implemented to manage some loads of the building F (lighting of the library rooms, stairs and corridors). The building automation system will be realized with a KNS network (Figure 14).

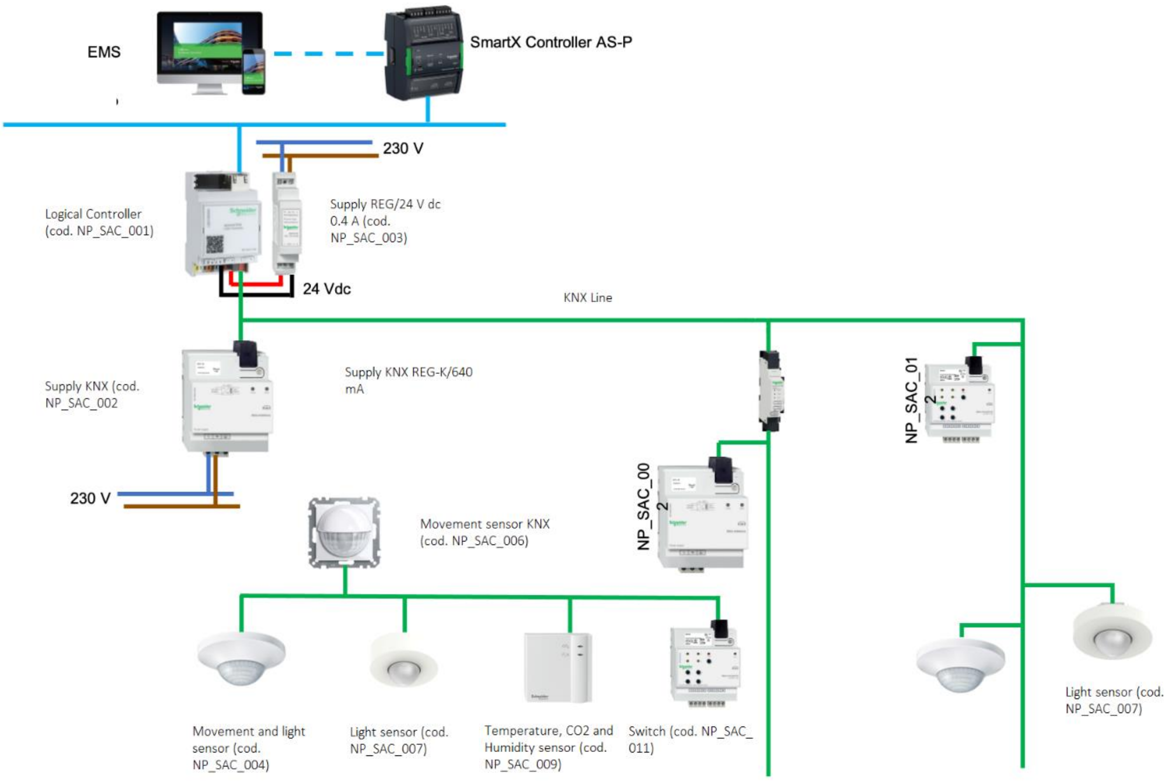

Figure 14 Building automation system scheme

With the same protocol (Modbus TCP/IP) the EMS gets data from the PV Inverter and from the battery BMS in order to apply some functions as:

- forecast the energy production from the PV plant and the energy consumption of the building by means of suitable algorithms that exploit weather forecast information, historical DER energy data, site specific operating constraints;
- provide schedules of all involved DER (particularly of the storage system), frequently updated;
- manage the exchange of active and reactive power at the nanogrid point of common coupling (PCC);
- manage the Air conditioning system and lighting systems for maximizing the exploitation of the building thermal inertia and of the natural light without compromise the comfort of the building's users;
- Coordinated operation with the Smart Grid campus EMS;
- Capability of automatically islanding the nanogrid from the grid in case of outages.

It must be observed that for the air conditioning system, a software gateway will be installed that will be developed by the original manufacturer, in order to allow the conversion of the proprietary protocol to a standard open protocol (ModBus). The EMS and the main controller of the nanogrid are potentially able to control the air-conditioning system, but the effective capability will be tested on field since not all the existing devices are ready to be remotely controlled.

7 Conclusions

The technical solution for each pilot building has been presented in this report. A common solution based on the PV/ESS/DSM hybrid has been selected for all the buildings. However, as each building has its own attributes, the specifications have been tailored to their specific needs, thus, each solution is unique. This report constitutes the foundation for the tender process that is required for the purchase of the equipment and the installation of the components required for the proposed nanogrids.