Affidamento in «Concessione mediante project financing del servizio di assistenza passeggeri e di Stazione Marittima nel porto di Ravenna, nonché delle aree per la realizzazione e gestione della nuova Stazione Marittima e degli altri beni strumentali e/o complementari alla prestazione del suddetto servizio da realizzare sulla banchina crociere di Porto Corsini (RA) e aree demaniali adiacenti»
CUP: C61B21002130003 - CIG: 8709330E77 – CUI L92033190395202100009

RAV PE-H1-Energy Strategy Report

Client

RCCP
RAVENNA CIVITAS CRUISE PORT

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Rev	Date	Verified	Approved	Object
0	12/09/2022	ANTDE	ALODA	First emission

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

AHU	Ari Handling Units
AMP	Alternative Maritime Power
CAM	Criteri Ambientali Minimi
HDD	Heating Degree Days
HV	High Voltage
HVAC	Heating, Ventilation and Air Conditioning
LCOE	Levelized Cost of Energy
LEED BD+C	LEED Building Design and Construction
LV	Low Voltage
MV	Medium Voltage
nZEB	Nearly Zero Energy Building
PV	Photovoltaic

1 INTRODUCTION

Ravenna Civitas Cruise Port (RCCP) is a public and private shared company having being granted a concession to build and operate the new Cruise Terminal facility located in the port of Ravenna.
The facility will comprise:

- Roads and parking for the accessibility of cruise client and citizens wishing to visit the accessible areas of the port
- Terminal building, aimed for check in and drop off of cruise clients
- Gangway ("passerella"), aimed to connect the Terminal to the Passenger PBB
- PBB, connecting the Gangway to the Cruise Ships calling at the port of Ravenna.

This document aims to assess the final design of the building ("Progetto definitivo"), establishing a comprehensive model of the **building's energy performance in order to assess all achievable energy-efficiency opportunities**.

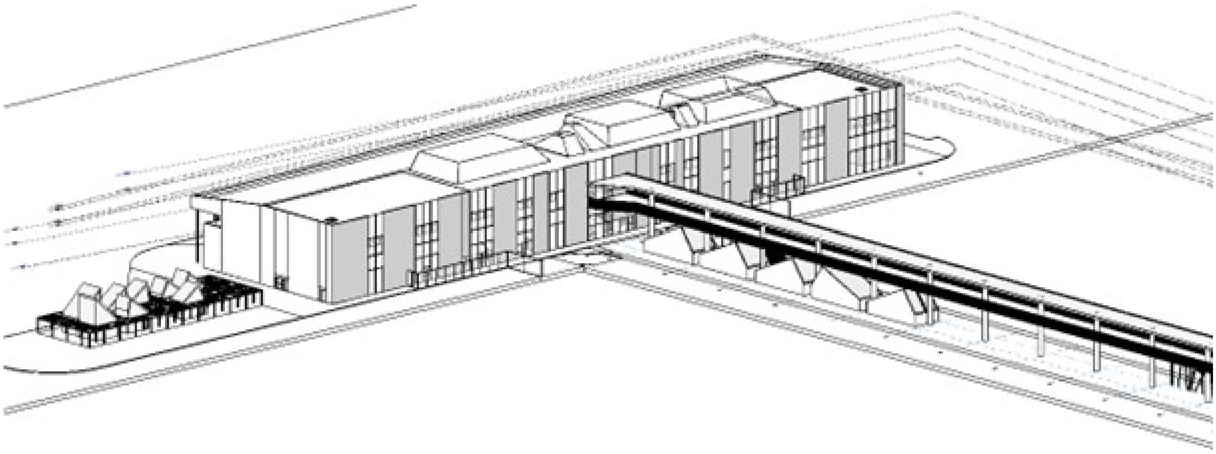


Figure 1.1: Terminal and Gangway

Figure 1.2: Aerial view

The energy efficiency strategy has been conceived as a preliminary activity to set the basis for the design and has been carried out during the review of the Final Design and in the early stages of the Detailed Design.

More specifically the purpose of this document is to provide guidelines for the detailed design phase so as not to distort the previously approved design, but to reasonably optimize it, improving the building's energy efficiency, facilitating the achievement of a higher score in LEED certification (to have a greater margin of safety on achieving the LEED Silver target), proposing some improvement scenarios, and ensuring compliance with national and local requirements.

All the energy performance assessments have been completed through dynamic energy modellings and as results different design scenarios have been proposed to the design team.

2 GENERAL INFORMATION

This section clarifies the scope of work and the process adopted, provides general information about the building and the climate context and presents an overview of the main regulatory framework for energy efficiency, systems, health and well-being, environment.

2.1 SCOPE OF WORK

The activity consists in checking the approved Final Design establishing a comprehensive picture of the building's energy performance and defining solutions aimed at further improving the energy efficiency of the building.

The solutions proposed have been defined evaluating:

- ✓ The building envelope, the heating, cooling and ventilation strategy, the lighting strategy both for the buildings and the external areas, the monitoring and sub metering of energy uses;
- ✓ Renewable energy strategy at site level;

2.2 PROCESS ADOPTED

The activity was developed as following:

- ✓ Review of the previous stage of design (Final Design) in order to identify the most promising opportunities to improve the energy performances and sustainability of the Terminal and surrounding area;
- ✓ Preliminary energy analysis: an energy simulation will be developed in order to establish a baseline (Proposed Final Design);
- ✓ Technology scouting: RINA is on the edge of the most advanced technologies related to energy efficiency for envelope, MEP and on-site renewable energy. A series of technology packages/solutions will be identified to enhance the energy performance of the project (Proposed Final Design);
- ✓ Scenarios definition: various energy simulations will be developed in order to assess the different technology packages/solutions identified during the technology scouting phase;
- ✓ Best Option identification: at the end of the process the best option to be implemented in the Detailed Design will be identified and proposed to the design team.

2.2.1 Modelling assumption

All the energy performance assessments have been completed through dynamic energy modellings. Following table summarizes the modellings general data.

Table 2.1: Modelling general data

General data	
Software used	IES Virtual Environment 2022
Weather data	ITA_Marina.di.Ravenna._IGDG.epw
ASHRAE 169-2006 standard	Climate type "4A" Mixed-Humid
Winter design day	Dry-Bulb Temperature (99.6%) = -3.20°C
Summer design day	Dry-Bulb Temperature (1%) = 34.80°C Wet-Bulb Temperature = 23.80°C

Conditioned floors	2
Conditioned floor area	8048 m^2

See below the energy modelling assumptions that were considered for this project.

Building Geometry

The surrounding topography was excluded from the modelling since it does not affect the solar analysis on the terminal building with shadows and the building geometry has been simplified for computing purposes (Figure 17).

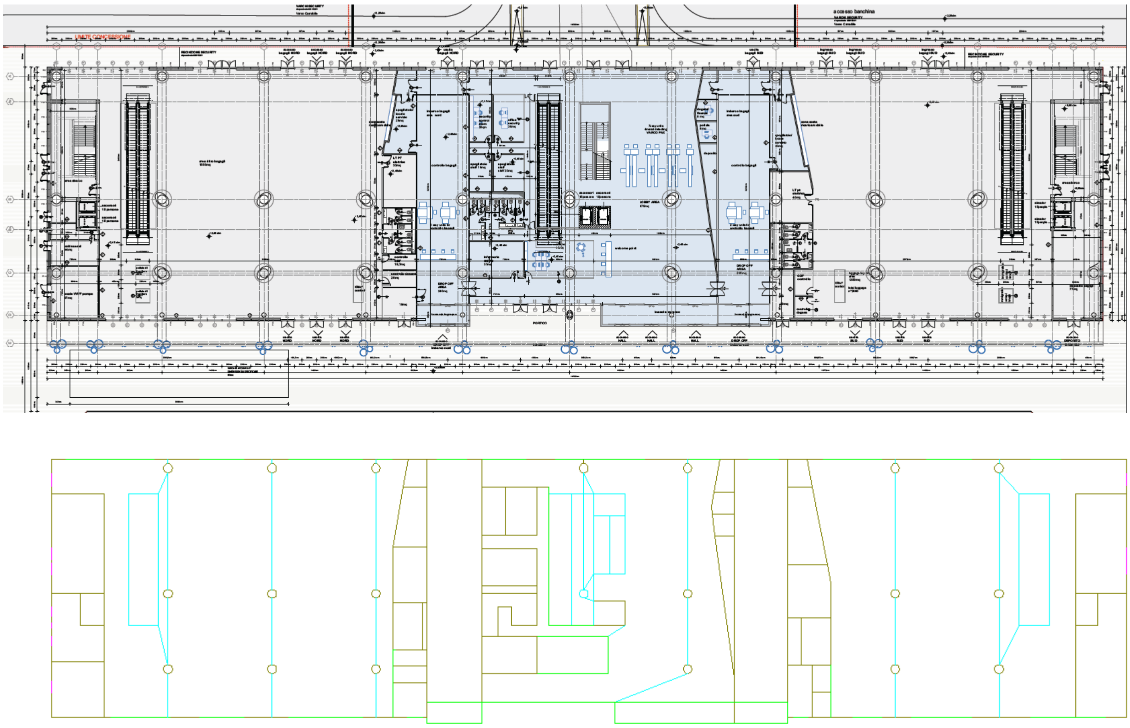


Figure 2.1: Comparison between GF floor plan as designed and as modelled for the energy assessment

Building Envelope

The thermal properties of the envelope (specific heat, density and thermal resistance for each material), when not directly available from the design details, were integrated into the energy model based on the experience of the energy modeler, using software defaults (when available), equivalent materials or derived from statistical data.

HVAC system

The energy modelling software does not have a specific component that represent a roof-top unit that combines ventilation and generation, even though it allows to model each element alone.

To evaluate the building performance, the cooling generation is modelled as a direct exchange cooling coil, while heating generation is modelled as an air-source heat pump (Figure 2.2). The efficiency and nominal capacity of the mentioned components is kept as indicated in the product cutsheet (roof-top unit). The technical properties of exhaust fans provided to restrooms were autosized because no information is available at this stage of design.

The main characteristics of interior VRF units were based on verbal discussions with the design team because no datasheets are available at this stage of design.

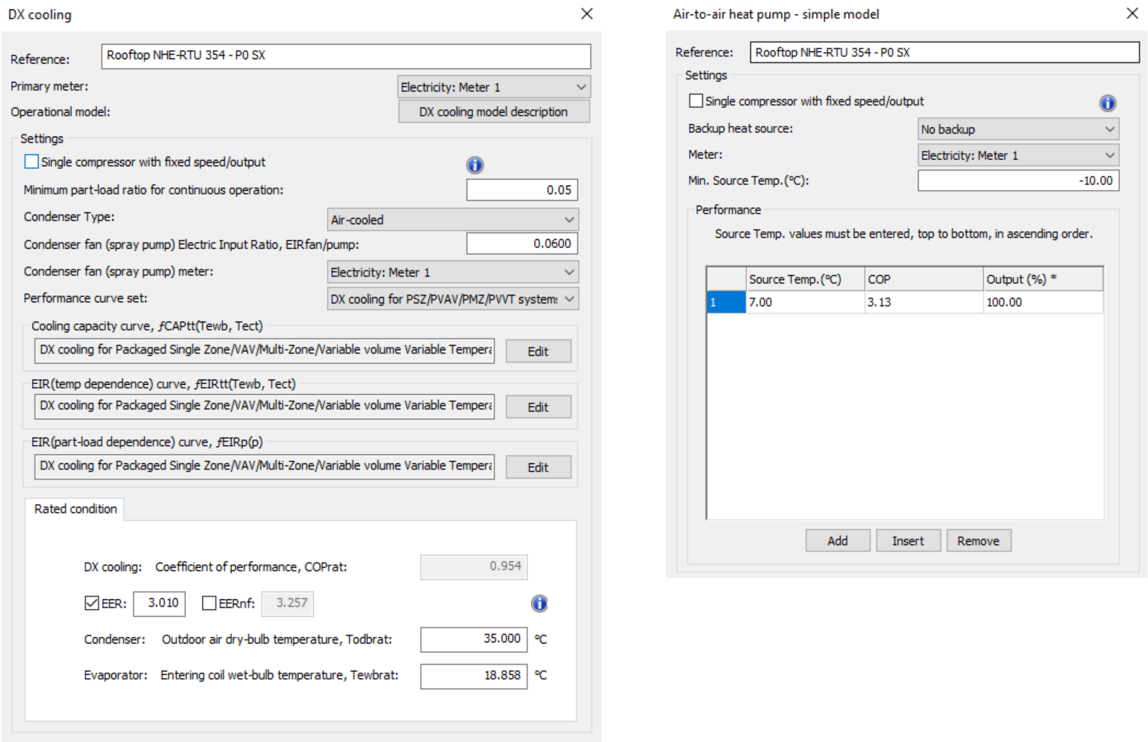


Figure 2.2: Equivalent components used to model the roof-top units

Schedules and profiles

Although actual opening and operating hours are not available at this stage, all models share the same schedules and profiles based on the following assumptions:

- ✓ Terminal Building operating from April 15th to November 15th, just a few office areas are operating all year (from 8:30 to 18:30 for 5/6 days a week);
- ✓ Average of 2/3 ships on weekdays, which has been modeled assuming the building is operating 3 times during weekdays from 8:00 AM to 3:00 PM;
- ✓ Terminal Building operating from 8:00 AM to 8:00 PM during weekends.

With no specific data available, the utilization schedules for lighting consumption, equipment consumption and occupation of thermal zones are based on default ASHRAE profiles (the same used for building performance analysis as per ASHRAE 90.1-2010 App.G).

Commercial volumes

The small group of kiosks located near the terminal building were excluded from this assessment since they are fully independent from an energy generation and consumption point of view.

Internal physical arrangement in the Terminal

The New Ravenna Cruise Terminal consists in a 2-storey building where three main parts can be identified: north area, south area and central part (Figures 2.3, 2.4 and 2.5).

Mechanical equipment and photovoltaics will be installed on the roof level, which will be covered in vegetation for more than 50% of its total surface (Figure 2.6). Following figures show the building configuration according to the Final Design stage.

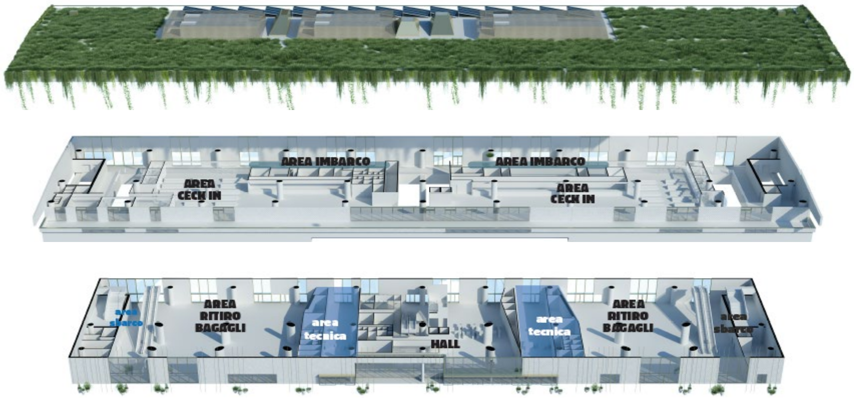


Figure 2.3: Exploded view of the building

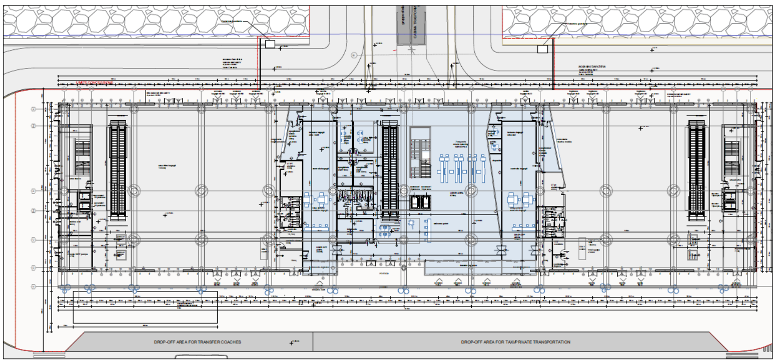


Figure 2.4: Ground floor plan view

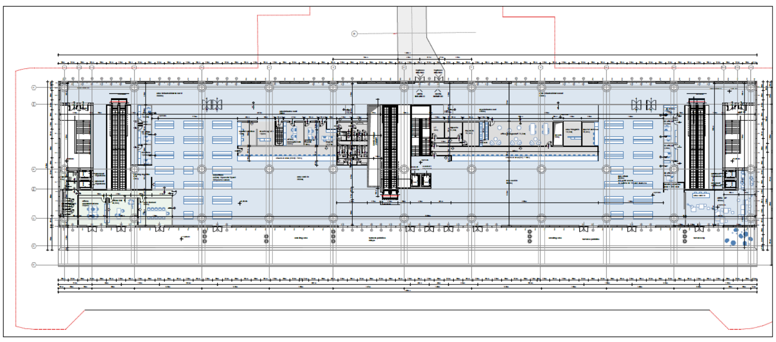


Figure 2.5: First floor plan view

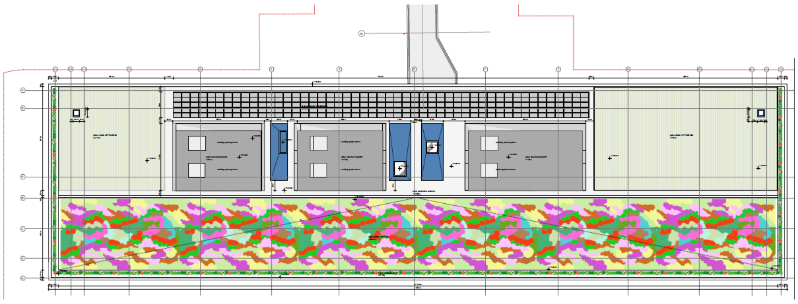


Figure 2.6: Roof floor plan view

2.3 CLIMATE ANALYSIS

The analysis carried out provides the data needed to make choices in terms of optimizing building envelopes and allows for an assessment of the benefits achievable using renewable energy sources.

Ravenna is located along the east Italian coastline (on the Adriatic Sea) and according to Italian law, it is classified in climate zone E. It is characterized by 2227 HDD (Heating Degree Days) with a typical Po Valley climate influenced by the Adriatic Sea, marked by moderately cold winters and muggy summers. The air has, in general, consistent degree of humidity with rates peaks in winter.

Figure 2.7: Site location

The following table summarises the average, maximum and minimum temperatures for each month (period 1991-2021) as well as the average rainfalls (period 1999-2019).

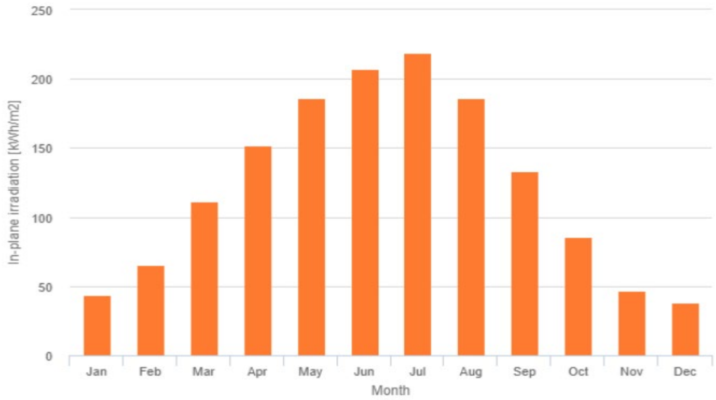
Table 2.2: Climate data

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Average Temperature (°C)	5	5.9	9.6	13.5	18.3	23.1	25.6	25.1	20.4	15.9	10.9	6.2
Minimum Temperature (°C)	1.8	2.1	5.3	8.9	13.4	18	20.6	20.3	16.3	12.4	7.8	3.2
Maximum Temperature (°C)	8.6	10	13.9	17.7	22.5	27.4	29.8	29.4	24.4	19.7	14.2	9.6
Humidity (%)	81%	77%	73%	71%	66%	60%	57%	61%	67%	76%	80%	81%
Precipitations (mm)	49	61	56	68	61	54	51	54	77	80	87	69

Note: source: https://it.climate-data.org/europa/italia/emilia-romagna/ravenna-1174/

July is the hottest month with an average temperature of 25.6 °C, while January is the coldest with an average temperature of 5 °C. During the year, average temperatures vary by 20.6 °C, which confirms that the climate is moderately mild. Additionally, November sorts to be the rainiest month, while July the driest with a minimum precipitation of 51 mm.

The analysis of the sun radiation is a key aspect to evaluate the solar gains of the buildings and to estimate the production of PV modules. In the table below it is reported the monthly in-plane irradiation on the horizontal plane.

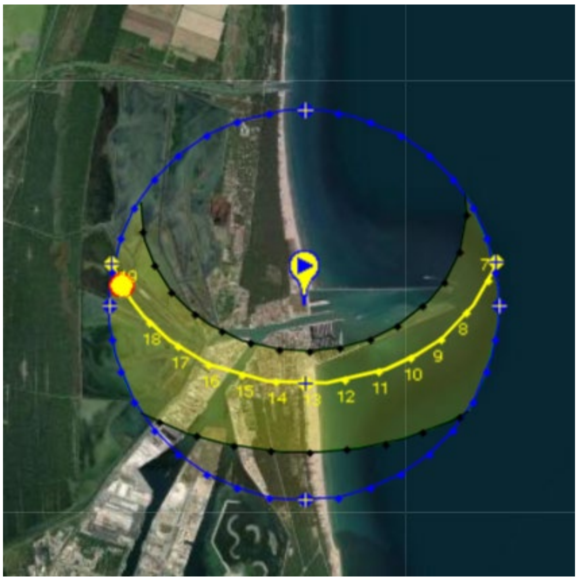


Note: source: https://re.jrc.ec.europa.eu/pvg_tools/en/)

Figure 2.8: Monthly in-plane irradiation for fixed angle

Figure 2.9 shows the orientation of the site, with the curved lines representing the sun's trajectory in the sky during the solstices (in black) and equinoxes (in yellow). The solar path is a function of both time of day and season. For the Ravenna Terminal Cruise, where the building's orientation was already defined and guided by other constraints and project requirements, the study of this path is useful to:

- ✓ analyze the hours of natural illuminance.
- ✓ prepare an analysis of the producibility of the PV system.
- ✓ identify the optimal placement of the PV panels.



Note: source: https://www.sunearthtools.com/

Figure 2.9: Sun path for the area

The following figures show the intensity of solar radiation on the facades and roof of the building.

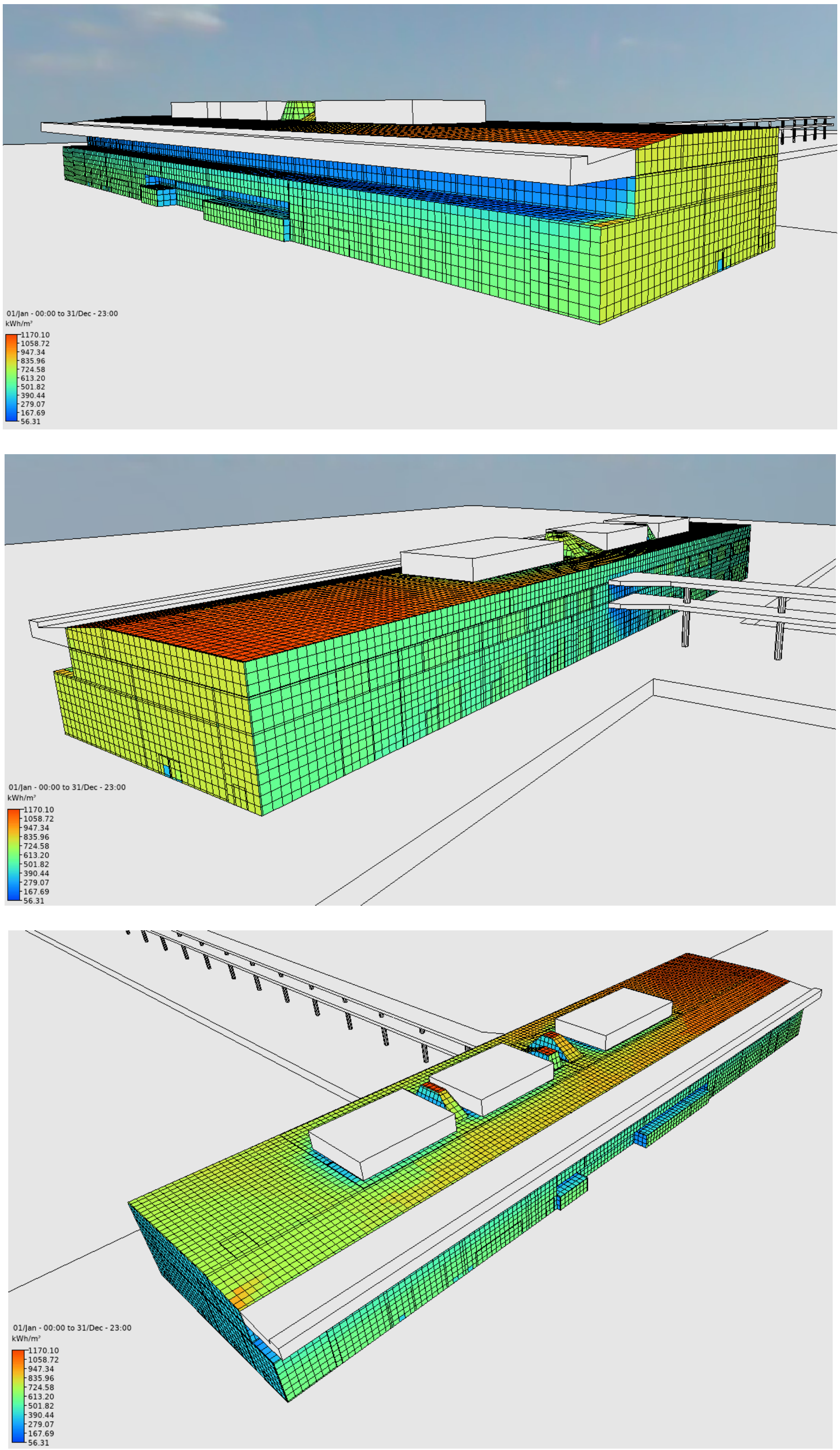


Figure 2.10: Solar radiation intensity on the facades and roof of the building

In particular, as shown in the following figure, the Porto Corsini Area is characterized by photovoltaic power output potential that ranges between 1300 and 1400 kWh/kWp (referred to ideal and optimized conditions of tilt and azimuth angle).

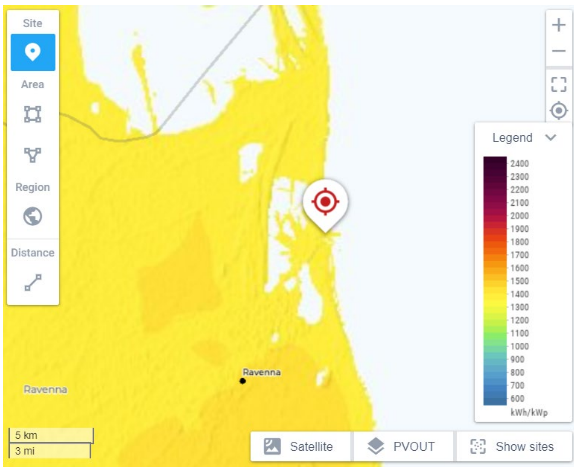


Figure 2.11: Photovoltaic power output potential

The analysis of the wind speed and direction is a key aspect in the study of the installation of a wind turbine for generating renewable energy on site. For most of the time during the year, the wind blows with a speed between 5km/h and 19km/h.

- ✓ 85.8 days/year wind speed > 5km/h;
- ✓ 139 days/year wind speed > 12 km/h;
- ✓ 98.3 days/year wind speed > 19 km/h.

The following figure shows that the main direction of the wind are E and ENE.

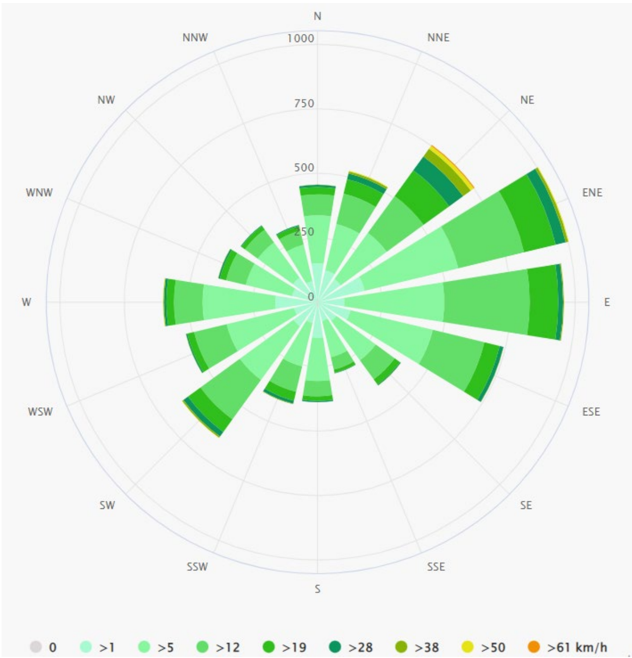


Figure 2.12: Photovoltaic power output potential

2.4 REGULATORY FRAMEWORK

2.4.1 Main regulatory framework for energy efficiency, systems, health and well-being, environment

- ✓ D.Lgs 199/2021 ”Attuazione della direttiva 2018/2001 del Parlamento europeo e del Consiglio, dell’11 dicembre 2018, sulla promozione dell’uso dell’energia da fonti rinnovabili.
- ✓ D.M. Requisiti Minimi del 26 giugno 2015 - “Requisiti minimi e Linee Guida per la Certificazione Energetica”
- ✓ D.P.R. 412 del 26 agosto 1993 “Regolamento recante norma per la progettazione, l’installazione, l’esercizio e la manutenzione degli impianti termici degli edifici ai fini del contenimento dei consumi di energia, in attuazione dell’art. 4, comma 4, della L. 9 gennaio 1991, n. 10”
- ✓ UNI 10349:2016 Riscaldamento e raffrescamento degli edifici - Dati climatici
- ✓ UNI EN 16798-3:2018 Prestazione energetica degli edifici – Ventilazione degli edifici – Parte 3: Per gli edifici non residenziali – Requisiti prestazionali per i sistemi di ventilazione e condizionamento degli ambienti
- ✓ UNI EN 15232-1:2017 Prestazione energetica degli edifici – Parte 1: Impatto dell'automazione, del controllo e della gestione tecnica degli edifici
- ✓ STANDARD ASHRAE 90.1.2016 Energy Standard for Buildings Except Low-Rise Residential Buildings
- ✓ UNI EN ISO 7730:2006 Ergonomia degli ambienti termici – Determinazione analitica e interpretazione del benessere termico mediante il calcolo degli indici PMV e PPD e dei criteri di benessere termico locale
- ✓ UNI EN ISO 16000 Aria in ambienti confinati
- ✓ EN 12464-1:2011 Luce e illuminazione - Illuminazione di spazi di lavoro – Parte 1: Posti di lavoro in interni
- ✓ EN 12464-2:2014 Luce e illuminazione - Illuminazione di spazi di lavoro – Parte 2: Posti di lavoro in esterno
- ✓ EN 13201:2016 Illuminazione stradale
- ✓ D.P.C.M. 5 dicembre 1997 Requisiti acustici passivi degli edifici
- ✓ UNI 11367:2010 Classificazione acustica delle unità immobiliari
- ✓ D.Lgs 152 del 3 aprile 2006 Norme in materia di ambiente
- ✓ UNI EN ISO 14040:2006 Gestione ambientale – Valutazione del ciclo di vita – Principi e quadro di riferimento
- ✓ UNI EN ISO 14044:2018 Gestione ambientale - Valutazione del ciclo di vita - Requisiti e linee guida
- ✓ UNI/TS 11300-1:2008 Prestazioni energetiche degli edifici Parte 1: Determinazione del fabbisogno di energia termica dell’edificio per la climatizzazione estiva ed invernale
- ✓ UNI/TS 11300-2:2019 Prestazioni energetiche degli edifici Parte 2: Determinazione del fabbisogno di energia primaria e dei rendimenti per la climatizzazione invernale, per la produzione di acqua calda sanitaria, per la ventilazione e per l'illuminazione in edifici non residenziali
- ✓ UNI/TS 11300-3:2010 Prestazioni energetiche degli edifici Parte 3: Determinazione del fabbisogno di energia primaria e dei rendimenti per la climatizzazione estiva
- ✓ UNI/TS 11300-4:2012 Prestazioni energetiche degli edifici Parte 4: Utilizzo di energie rinnovabili e di altri metodi di generazione per la climatizzazione invernale e per la produzione di acqua calda sanitaria
- ✓ UNI/TS 11300-5:2016 Prestazioni energetiche degli edifici Parte 5: Calcolo dell’energia primaria e dalla quota di energia da fonti rinnovabili
- ✓ UNI/TS 11300-6:2016 Prestazioni energetiche degli edifici Parte 6: Determinazione del fabbisogno di energia per ascensori e scale mobili

2.4.2 Best practices

- ✓ CAM - Criteri ambientali minimi per l'affidamento di servizi di progettazione e lavori per la nuova costruzione, ristrutturazione e manutenzione di edifici pubblici
- ✓ LEED BD+C v4 (and v4.1) for new construction or major renovation

3 BUILDING ENERGY PERFORMANCE - BASELINE

For the purpose of this work, the building baseline has been identified with the building at the Final Design stage.

In the following paragraph the relevant building features for the energy aspects are summarised. For a comprehensive description of all the features of the project, please refer to the Final Design documentation.

Below a few images of the building energy model geometrical representation.

Figure 3.1: Building energy model – geometrical representation

3.1 CONSTRUCTION

The building envelope, compliant with the national requirements, is already a high-performance envelope that consists in prefabricated concrete walls, curtain walls and green roof.

All the vertical opaque elements (external walls) are characterized by a thermal transmittance lower than 0.28 kWh/mq (Figure 3.2) while the slab on grade by a thermal transmittance lower than 0.29 kWh/mq (Figure 3.3) and the roof by a thermal transmittance lower than 0.24 kWh/mq (Figures 3.4 and 3.5).

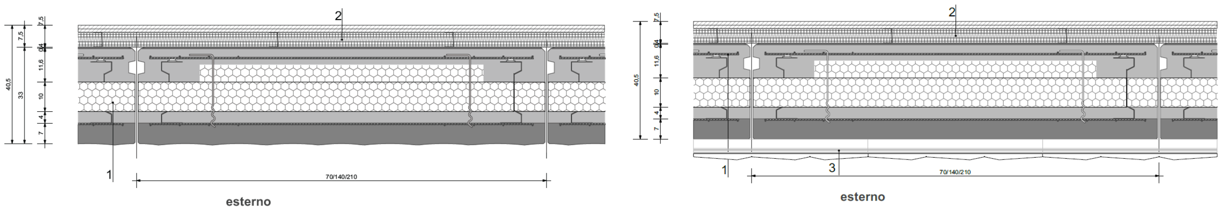


Figure 3.2: Prefabricated exterior walls

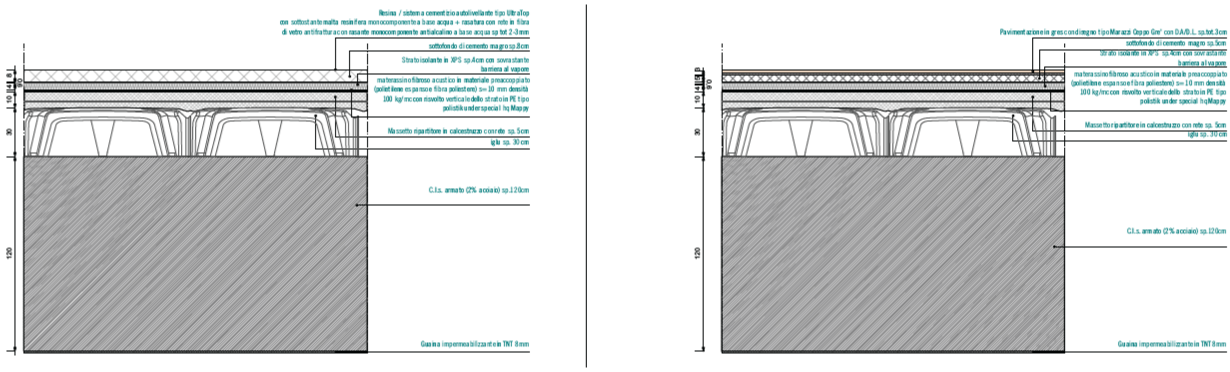


Figure 3.3: Slab on grade

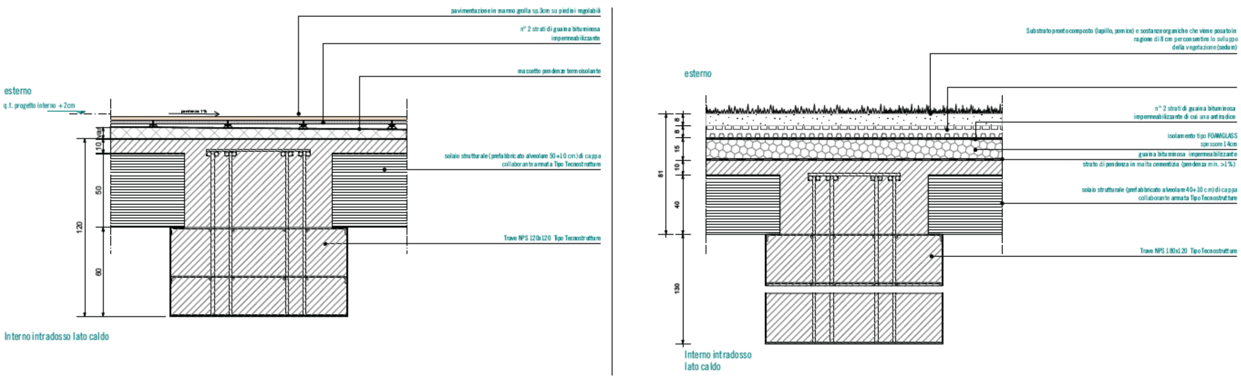


Figure 3.4: Roof assemblies (1): terrace floor on the left, extensive green roof on the right

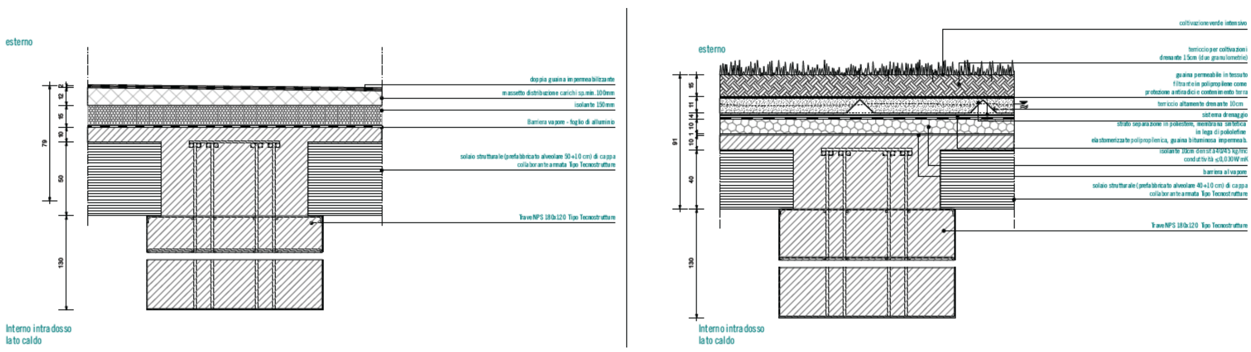
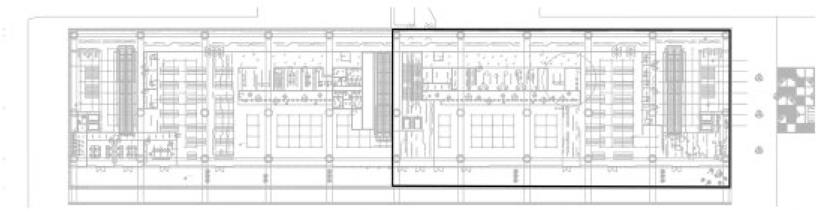


Figure 3.5: Roof assemblies (2): technical areas on the left, intensive green roof on the right

Regarding lighting, there is a low lighting power density installed (Figure 3.6) thanks the adoption of LED lamps.



Building 1 · Storey 1

Room List (Energy evaluation)

P_{total}	A_{Room}	Lighting power density	$\bar{E}_{perpendicular\ (Workplane)}$
10710.3 W	2540.05 m²	4.22 W/m² = 27.46 W/m²/100 lx (Room)	15.4 lx

Figure 3.6: Extract from illuminance evaluation report

Regarding the HVAC systems, the building is characterized by efficient HVAC equipment consisting in six roof-top units that provide both ventilation and conditioning to all terminal-related spaces, while smaller rooms (offices, break rooms, etc…) are provided with VRF units for local air conditioning (Figures 3.7 and 3.8);

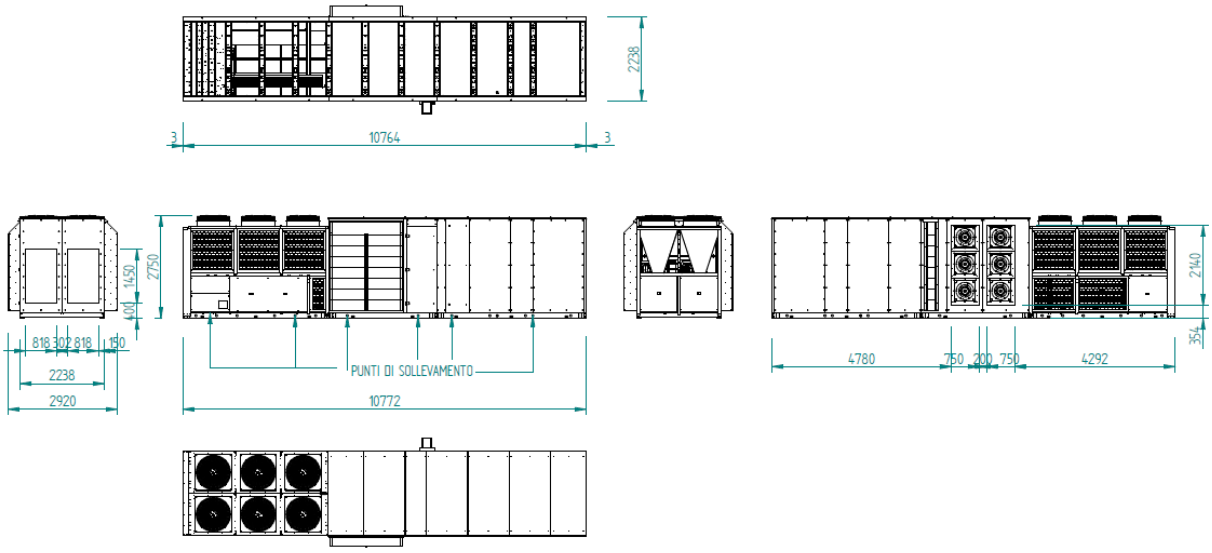


Figure 3.7: Rooftop unit representation

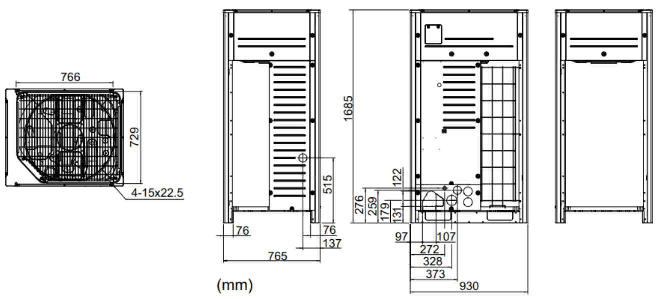


Figure 3.8: VRF outdoor unit representation

In office-related areas, outdoor ventilation is delivered by the roof-top units and air-conditioning is provided with a VRF system. Minimum outdoor ventilation airflow rates are based on ASHRAE 62.1-2010.

Domestic hot water is produced through a high-performance heat pump that will feed a thermal storage to guarantee service during peak times (Figure 3.9);

Figure 3.9: Service water reference heating equipment (left) and thermal storage (right)

Regarding the renewable energy production, the Cruise Terminal is equipped by photovoltaic panels installed on the roof level with a total peak power of 120 kW.

No product cutsheet was defined at the Final Design stage, hence standard and common module properties were assumed as below:

- ✓ Rated power – 370 W
- ✓ Efficiency – 20.30 %
- ✓ NOCT – 45°C
- ✓ Power temperature coefficient - 0.390 %/K

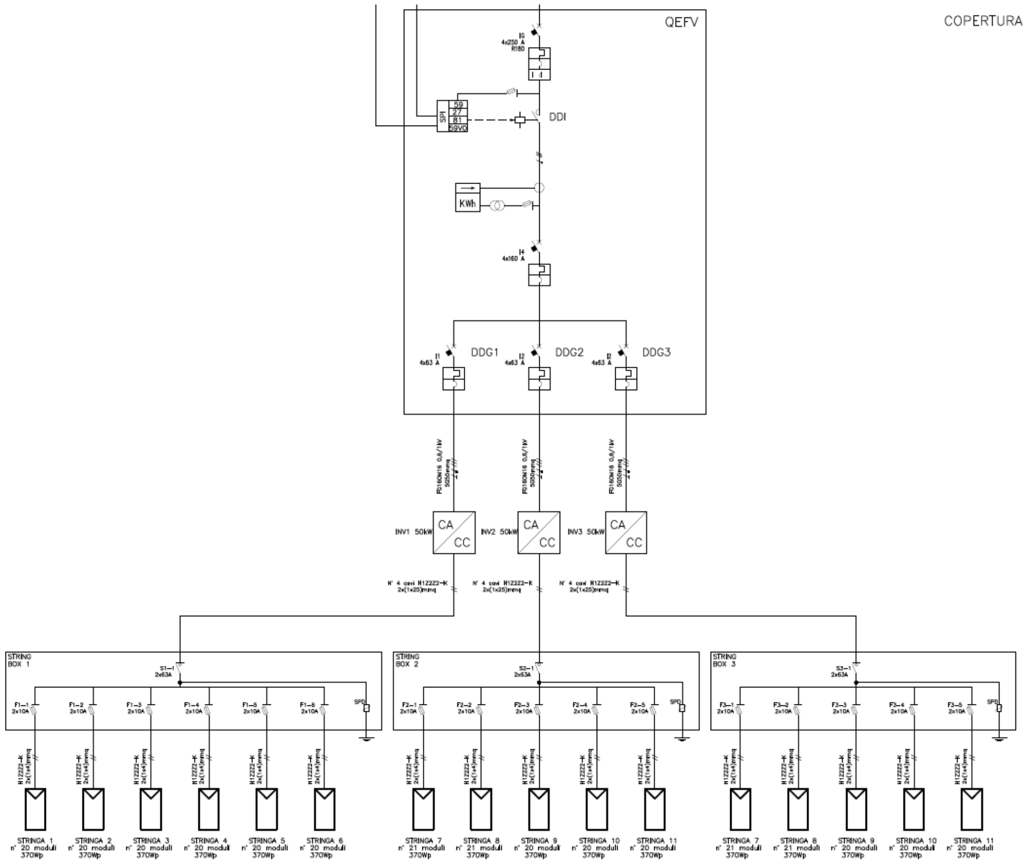
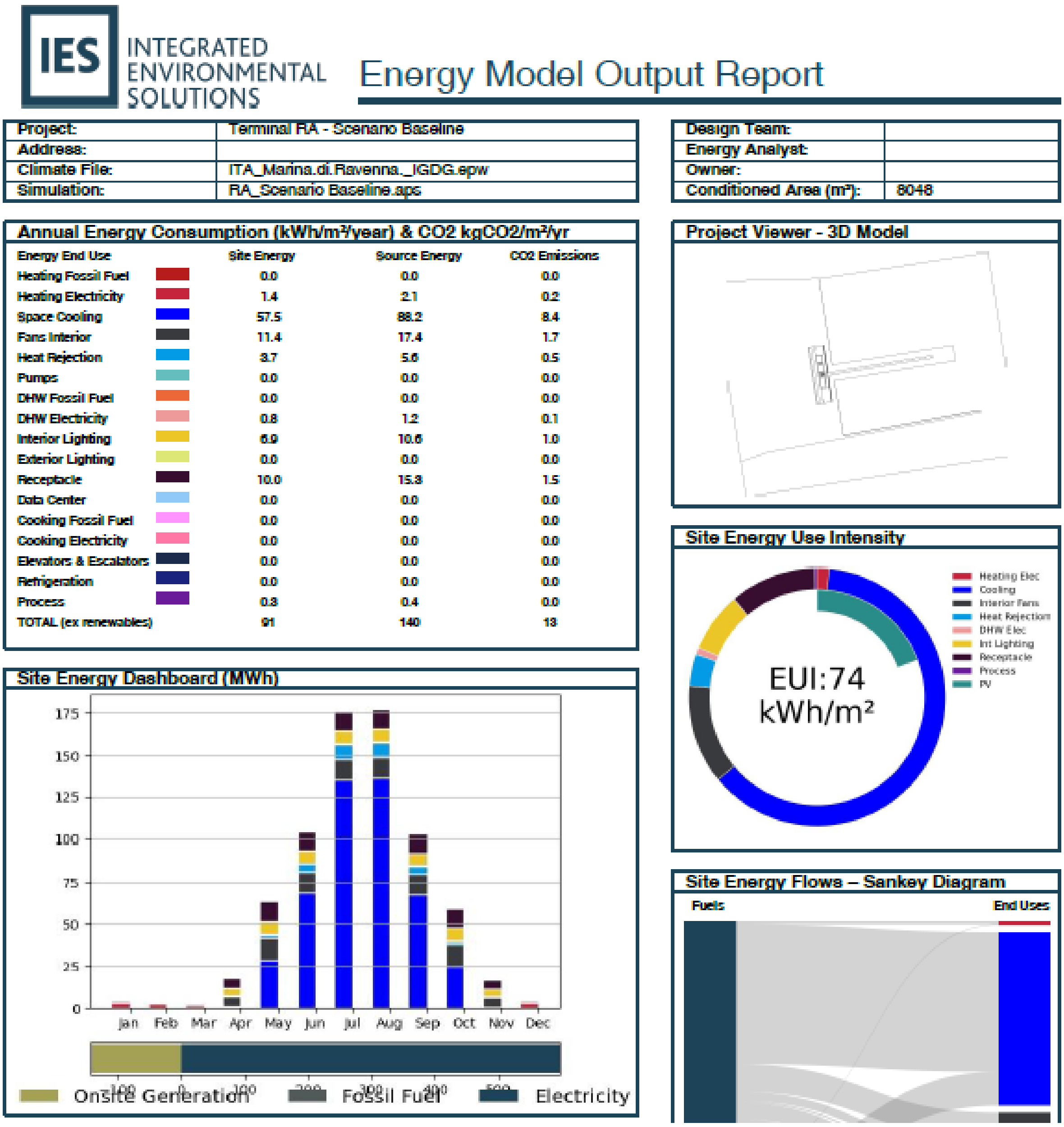


Figure 3.10: Photovoltaics scheme

3.2 ENERGY MODELLING OUTPUTS

Following figure summarises the energy results for the building at the Final Design stage (baseline).



IES INTEGRATED ENVIRONMENTAL SOLUTIONS

Energy Model Output Report

Project:	Terminal RA - Scenario Baseline
Address:	
Climate File:	ITA_Marina.di.Ravenna._IGDG.epw
Simulation:	RA_Scenario Baseline.aps

Design Team:	
Energy Analyst:	
Owner:	
Conditioned Area (m²):	8048

Annual Energy Consumption (kWh/m²/year) & CO2 kgCO2/m²/yr

Energy End Use	Site Energy	Source Energy	CO2 Emissions
Heating Fossil Fuel	0.0	0.0	0.0
Heating Electricity	1.4	2.1	0.2
Space Cooling	57.5	88.2	8.4
Fans Interior	11.4	17.4	1.7
Heat Rejection	3.7	5.6	0.5
Pumps	0.0	0.0	0.0
DHW Fossil Fuel	0.0	0.0	0.0
DHW Electricity	0.8	1.2	0.1
Interior Lighting	6.9	10.6	1.0
Exterior Lighting	0.0	0.0	0.0
Receptacle	10.0	15.3	1.5
Data Center	0.0	0.0	0.0
Cooking Fossil Fuel	0.0	0.0	0.0
Cooking Electricity	0.0	0.0	0.0
Elevators & Escalators	0.0	0.0	0.0
Refrigeration	0.0	0.0	0.0
Process	0.3	0.4	0.0
TOTAL (ex renewables)	91	140	13

Figure 3.11: Energy Simulation Results for the baseline

From the simulation performed, the Site Energy Use Intensity (EUI) that represents the total, annual building energy use normalized by its gross square footage corresponds to 74 kWh/m^2. Site energy is the amount of energy consumed by a building or development on site, usually reflected on utility bills, but including heat and power generated and used on site.

4 ENERGY EFFICIENCY FOR THE BUILDING

This section provides guidelines for the energy efficiency of the Ravenna Cruise Terminal. In particular, the following aspects were analyzed:

- ✓ the optimization of the building envelope;
- ✓ the optimization of the HVAC systems;
- ✓ the additional exploitation of renewable sources for the energy production;
- ✓ the optimization of the lighting and the building automation systems.

At the end 4 different scenarios have been deeply analysed and modelled using the same energy tool (IES software) and starting from the building energy model (baseline) representing the Final Design. Expected savings have been provided based on comparison between the energy simulations results.

4.1 PERFORMANCE TARGETS FOR ENERGY EFFICIENCY

The design of the building and the systems have to be carried out in accordance with the Minimum Requirements given by the D.M. 26.06.2015, the requirements provided by the CAM (Criteri Ambientali Minimi) decree and D.lgs 199/2021 for the minimum renewable energy production levels.

All the new buildings, according to Directive 2010/31/EU, should reach the target of nearly zero energy buildings (nZEB) as defined at national level from January 2021. A nZEB is a building with high energy performance, for which the nearly zero/very low amount of energy required (for heating, cooling mechanical ventilation, domestic hot water production and lighting) must be covered by renewable sources (produced on-site or nearby).

Additionally, the level of building automation required for each building will be BACS level 3.

4.2 AREA FOR IMPROVEMENTS

In general, to enhance the energy efficiency of a building it is essential:

- ✓ to increase the energy efficiency of the building envelopes, both for the winter and summer conditions, managing heat losses and solar radiation, and eventually use passive cooling strategies for the coolest hours;
- ✓ to increase the energy efficiency of the systems (HVAC, lighting) and of the equipment;
- ✓ to maximize renewable resources, especially through photovoltaic and solar panels, wind power and heat pumps.

4.2.1 Optimization of the building envelope

Building envelopes play a key role in reducing energy demand and creating comfortable indoor environments.

High envelope performance is already guaranteed by compliance with Italian standards that require insulation of opaque structures in order to meet the following thermal transmittance limits.

Table 4.1: Thermal transmittance limits (D.M. 25.06.2015)

Element type	Maximum thermal transmittance U (W/m^2K)
External Vertical walls	0.28
Roofs	0.24
External floors	0.29
Internal structures vs non conditioned areas	0.80

Transparent elements are also characterized by high performance with thermal transmittance below 1.40 W/m2K.

Additionally, the adoption of materials with high SRI (solar reflectance index) for the roof and the green roof areas allow to reduce both energy needs for summer air conditioning and the effect of island casting at the urban scale.

Reducing the thermal transmittance further would not bring significant improvements even in view of the fact that the prevailing use of the Cruise Terminal spans from mid-April to mid-November with the exclusion of the winter period.

For the summer conditions, appropriate shading systems for glazed surfaces might be implemented to reduce overheating of the rooms and allow proper daylight regulation, without creating conditions of visual discomfort or the use of artificial lighting.

4.2.2 Optimization the HVAC systems

Regarding the HVAC systems, the Final Design involves the adoption of six efficient roof-top units both for ventilation and conditioning to all terminal-related spaces, while smaller rooms (offices, break rooms, etc…) are provided with VRF units for local air conditioning. All the HVAC system are already compliant with the Italian standards.

Below, the minimum efficiency required by the Italian standards.

Tabella 6 – Requisiti e condizioni di prova per pompe di calore elettriche servizio riscaldamento (macchine reversibili e non)

Tipo di pompa di calore Ambiente esterno/interno	Ambiente esterno [°C]	Ambiente interno [°C]	COP
aria/aria	Bulbo secco all'entrata : 7 Bulbo umido all'entrata : 6	Bulbo secco all'entrata: 20 Bulbo umido all'entr.: 15	3,5

Tabella 7 – Requisiti e condizioni di prova per pompe di calore elettriche servizio raffrescamento (macchine reversibili e non)

Tipo di pompa di calore Ambiente esterno/interno	Ambiente esterno [°C]	Ambiente interno [°C]	EER
aria/aria	Bulbo secco all'entrata : 35 Bulbo umido all'entr.: 24	Bulbo secco all'entrata: 27 Bulbo umido all'entr.: 19	3,0

Figure 4.1: Minimum efficiency required by the Italian standard

The roof-top units already included in the Final Design are high-efficiency units, designed to be installed outdoors (typically on the roof) and use heat pump technology enabling the units to be compact and highly efficient.

Other aspects **already implemented** within the Final Design to enhance the energy performance are:

- ✓ variable-speed pumping systems (required by regulations) implemented to provide high efficiency to the whole system and match the building's indoor conditions;
- ✓ CO_2 sensors in ambient, to modulate the amount of air to be treated according to crowding;
- ✓ high-efficiency air filters to reduce machine pressure drops and increase efficiency.

However, to optimize further the efficiency of the HVAC system the following new measures have been prescribed:

- ✓ **free mechanical cooling** selecting appropriate equipment;
- ✓ provide not-too-high redundancy for heat pumps, to enable the management of any failures, without increasing the initial capital costs. A **reduction of the power installed and/or the numbers of the RTU units is possible and can be done in detail design**. More detailed datasheets will be delivered at the end of the detailed design phase;
- ✓ **optimize air distribution reducing pressure losses** by limiting air speed in the ducts and reducing bends

4.2.3 Additional exploitation of renewable sources for the energy production

Considering the availability of solar radiation, the large electricity needs of the Cruise Terminal, and the global increase in energy prices, the **increase of the photovoltaic system** included in the Final Design (120 kW PV system) is the most attractive area of improvement for the building (Ref. to SCENARIO 01 section).

Beyond the self prescriptions of this study it is important to be aware that the most recent national regulation (Legislative Decree 199/21, in force from June 2022), the PV system are to be increased anyway in order to meet the following requirement:

Peak Power Installed = Building footprint [sqm] x 0,055 (considering the 10% of increase for public buildings)

4.2.4 Optimization of the lighting and building automation systems

The Final Design already includes a few of the energy efficiency solutions for lighting as the use of high-efficiency LED lamps and the implementation of smart lighting system controls able to automatically manage and control the real need of users, reducing both waste and endogenous heat loads produced by light sources and ensuring indoor visual comfort.

Lighting systems are already designed in order to ensure an appropriate level of illuminance in relation to the different activities carried out and the characteristics of the rooms to be lit, optimizing natural light sources and illuminance uniformity. Daylight sensors, timed controls, and presence and transit sensors can be used to achieve maximum energy savings without removing flexibility. External light pollution will be limited through the use of totally shielding luminaires so that they do not emit light above a horizontal plane passing through the center of the lamp.

The Detail Design should include however a **Building Management Systems** to support energy and systems management, increase the energy efficiency by enabling consumption monitoring and set points refinement.

Thanks to the adoption of a Building Management System, the user has all the elements to:

- ✓ analyze load profiles and take actions to improve the situation and verify the effects of the actions taken;
- ✓ optimize the energy costs, prevent costly downtime and avoid waste.
- ✓ Improve reliability, availability and optimize maintenance.

4.3 SCENARIO 01

The first proposed improvement involves the **expansion of the photovoltaic system from a peak power capacity of 120 kW to a system with a peak power capacity of 310 kW** in order to meet the new regulatory requirement and significantly increase the on-site electrical production.

The PV system, consisting of horizonal monocrystalline panels and connected to the public network, will be installed partly on the Terminal’s roof and partly on the roof of the walkway.

Ravenna benefits of a good sun irradiation but, being dependent on the sun irradiance, the energy output has a high monthly variability. The yearly energy output for horizontal panels is expected to be about 340 MWh, corresponding to a yearly yield of around 1000-1100 kWh/kWp. The maximum energy output is expected to be reached in June and July, while the minimum from November to January. The monthly trend is presented in the figure below (source: PVGIS).

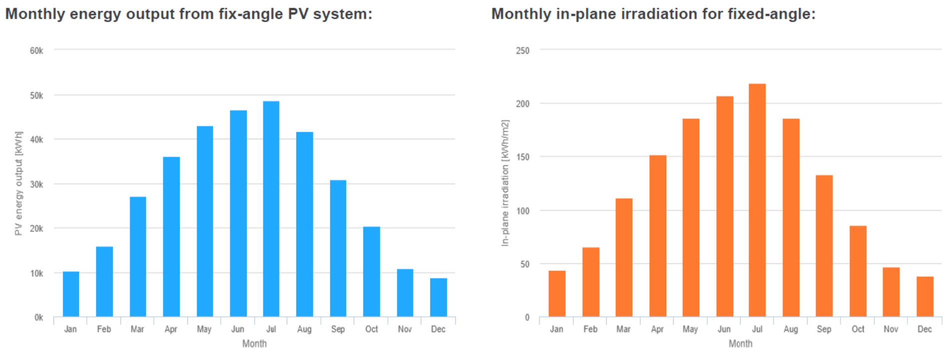
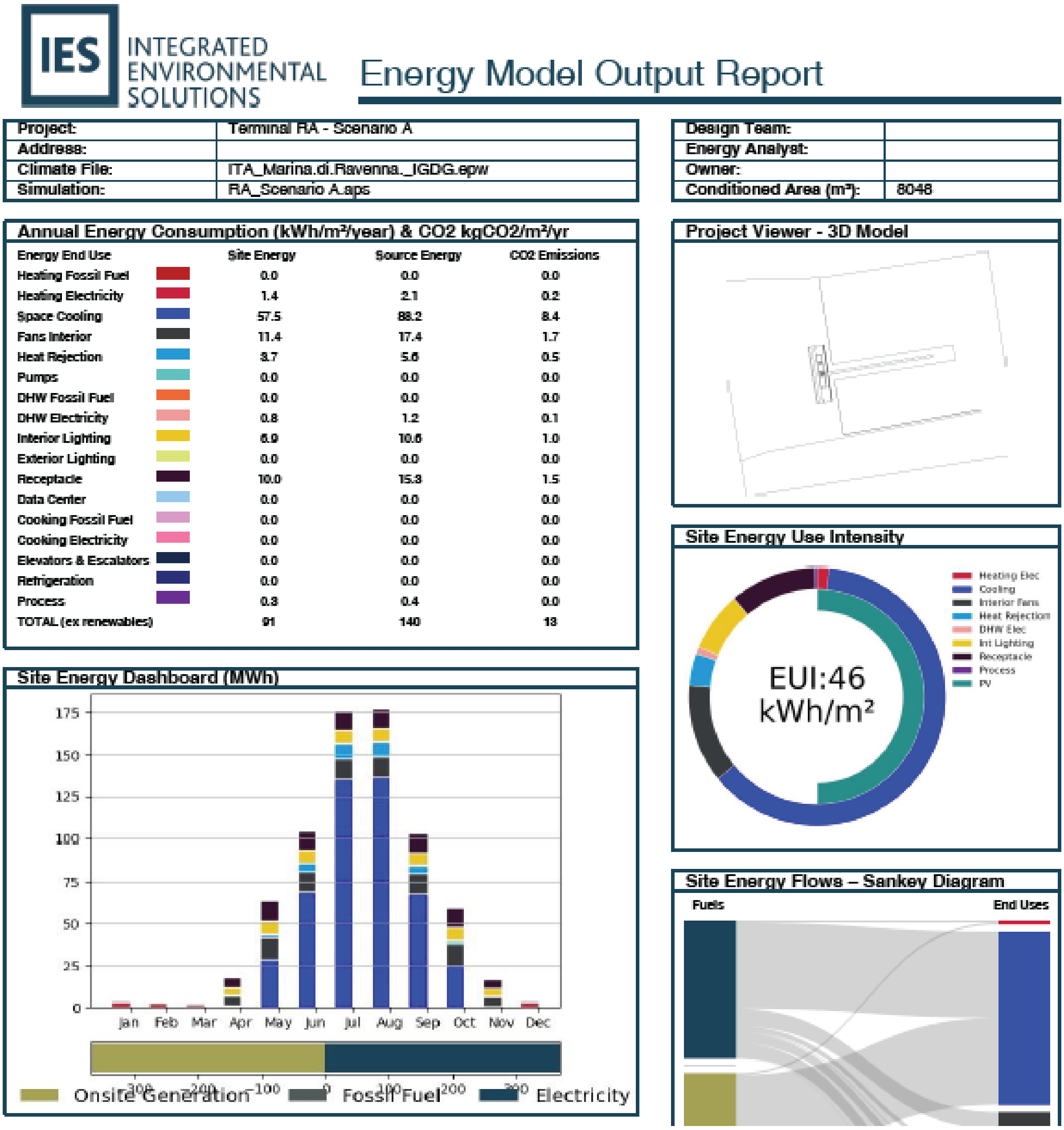


Figure 4.2: Monthly energy output

Following figure summarises the energy results for the Scenario 01.



Project:	Terminal RA - Scenario A
Address:	
Climate File:	ITA_Marina.di.Ravenna._IGDG.epw
Simulation:	RA_Scenario A.aps

Design Team:	
Energy Analyst:	
Owner:	
Conditioned Area (m²):	8048

Annual Energy Consumption (kWh/m²/year) & CO2 kgCO2/m²/yr

Energy End Use	Site Energy	Source Energy	CO2 Emissions
Heating Fossil Fuel	0.0	0.0	0.0
Heating Electricity	1.4	2.1	0.2
Space Cooling	57.5	88.2	8.4
Fans Interior	11.4	17.4	1.7
Heat Rejection	3.7	5.6	0.5
Pumps	0.0	0.0	0.0
DHW Fossil Fuel	0.0	0.0	0.0
DHW Electricity	0.8	1.2	0.1
Interior Lighting	6.9	10.6	1.0
Exterior Lighting	0.0	0.0	0.0
Receptacle	10.0	15.3	1.5
Data Center	0.0	0.0	0.0
Cooking Fossil Fuel	0.0	0.0	0.0
Cooking Electricity	0.0	0.0	0.0
Elevators & Escalators	0.0	0.0	0.0
Refrigeration	0.0	0.0	0.0
Process	0.3	0.4	0.0
TOTAL (ex renewables)	91	140	13

Figure 4.3: Energy Simulation Results for the scenario 01

From the simulation performed, the Site Energy Use Intensity (EUI) corresponds to 46 kWh/m^2. Therefore, the amount of energy consumed by the building on site, including heat and power generated by the PV system, decreased by 28 kWh/m^2.

In order to have a first idea of the simple payback of the PV extension investment a preliminary analysis have been done and results are presented in the table below (supposing a revenue derived by the saving of energy withdrawn from the grid at a cost of 0.25€/kWh).

Table 4.2: Preliminary analysis on the PV investment

Parameters (referred only to the increased size)	
PV cost	2,500 €/kWp
Increased size of PV	190 kW
CAPEX	475,000 €
Energy Savings	225,344 kWh (28 kWh/mq)
Lifetime of the system	25 / 30 years
Cost savings	56,336 €
sPBT	8.4 years

The table below shows how the LCOE is affected by the size of the PV installed. Looking at the table it is possible to see how the increase in the size of the PV system, rather than being mandatory by the Italian law, it also represent a good investment, and allows you to be protected from sudden increases in electricity price (Figure 4.4).

Table 4.3: Preliminary analysis on the PV investment

PV size [kWp]	LCOE [€7kWh]
120	0.2197
310	0.1687

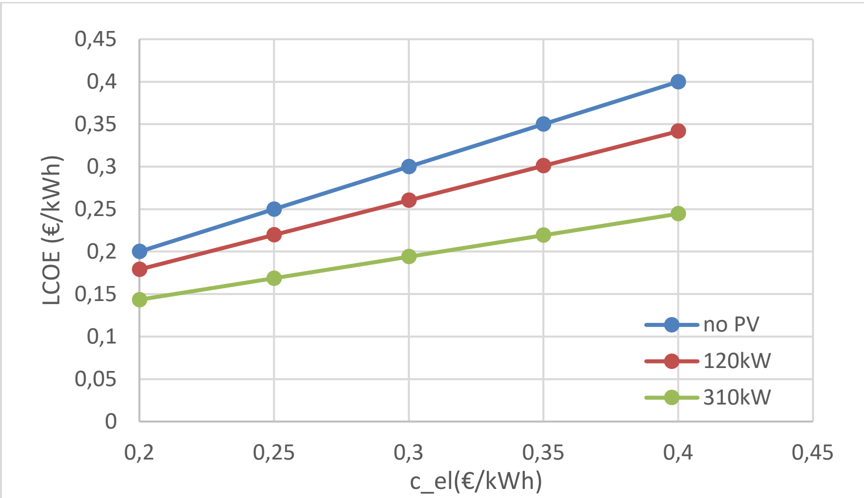


Figure 4.4: LCOE of different solution given different electricity prices

The terminal building is characterized by a very discontinuous load profile because it is used at his maximum potential only when the cruise ship is at the berth. In particular the terminal is expected to be used only two or three days per week and only in the period from Mid-April to Mid-November. In the remaining period the terminal is either closed or partly used. For this reason, there will be several days during the year when it will be necessary to manage a surplus of energy produced. For this reason, selling the surplus to the national grid through an agreement with the GSE (national renewable energy management service company) like "Ritiro dedicato" or other types of incentives shall be investigated.

4.4 SCENARIO 02

The second proposed improvement involves an optimization in the choice of the version of roof-top units to be installed so that **free cooling** can be realized and the performance of the HVAC system can be improved during the summer season.

High efficiency roof-top units equipped with free cooling controls, as the Roccheggiani NHE-RTU, are able to exploit free cooling (also available for 100% of the treated air flow) and heat recovery through two separate technologies: active thermodynamic recovery and sensitive and latent heat recovery through a high-efficiency enthalpy wheel.

Thanks to these solutions, a high seasonal energy efficiency (also at partial loads) is feasible, with performances that contribute to energy saving.

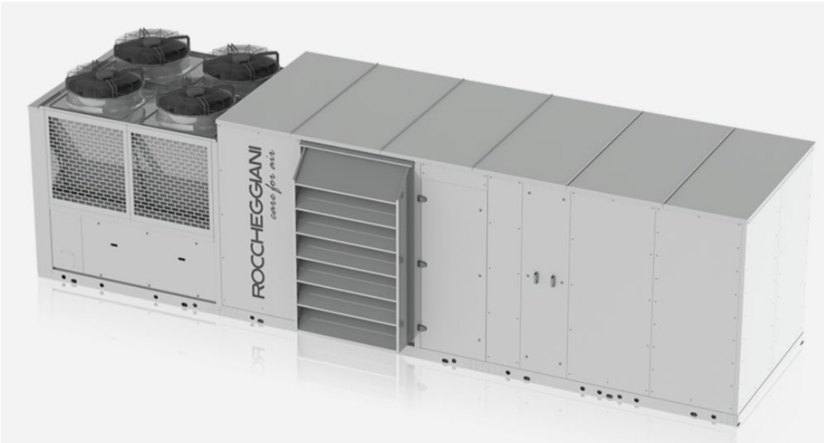


Figure 4.5: Roccheggiani Roof-top units equipped with free-cooling controls

Following figures show the general schemes as modeled in the baseline model and in the scenario 02, to simulate the presence of the free-cooling controls.

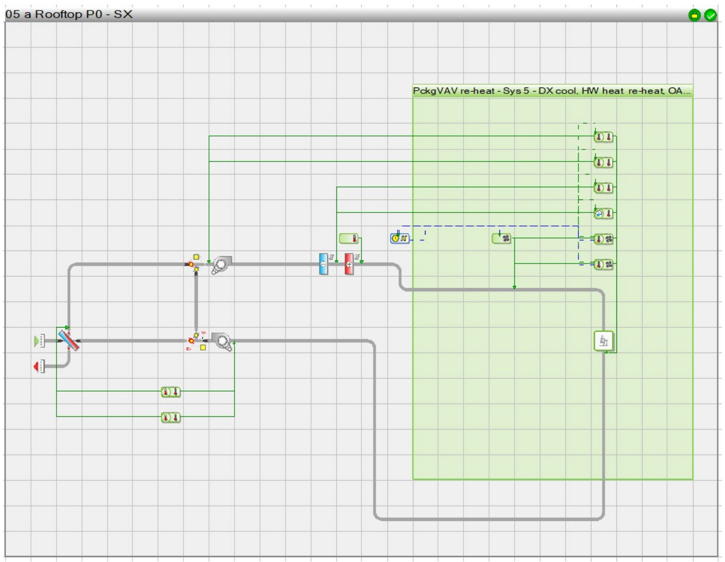


Figure 4.6: General scheme of the roof-top units

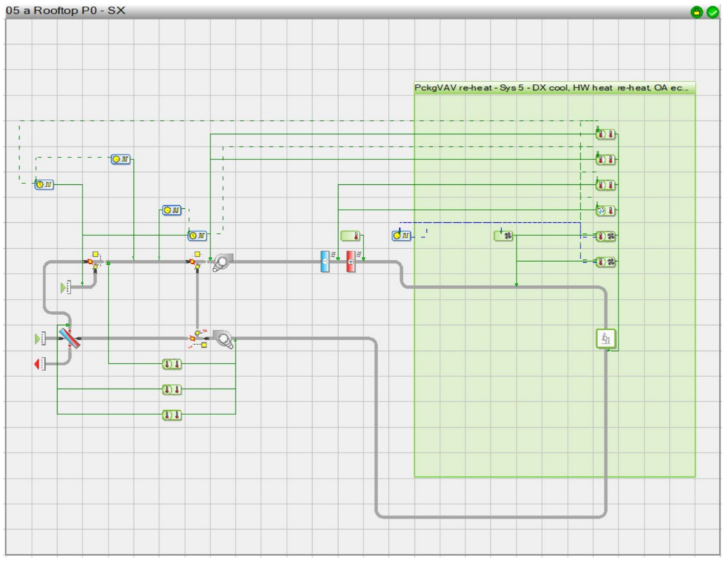
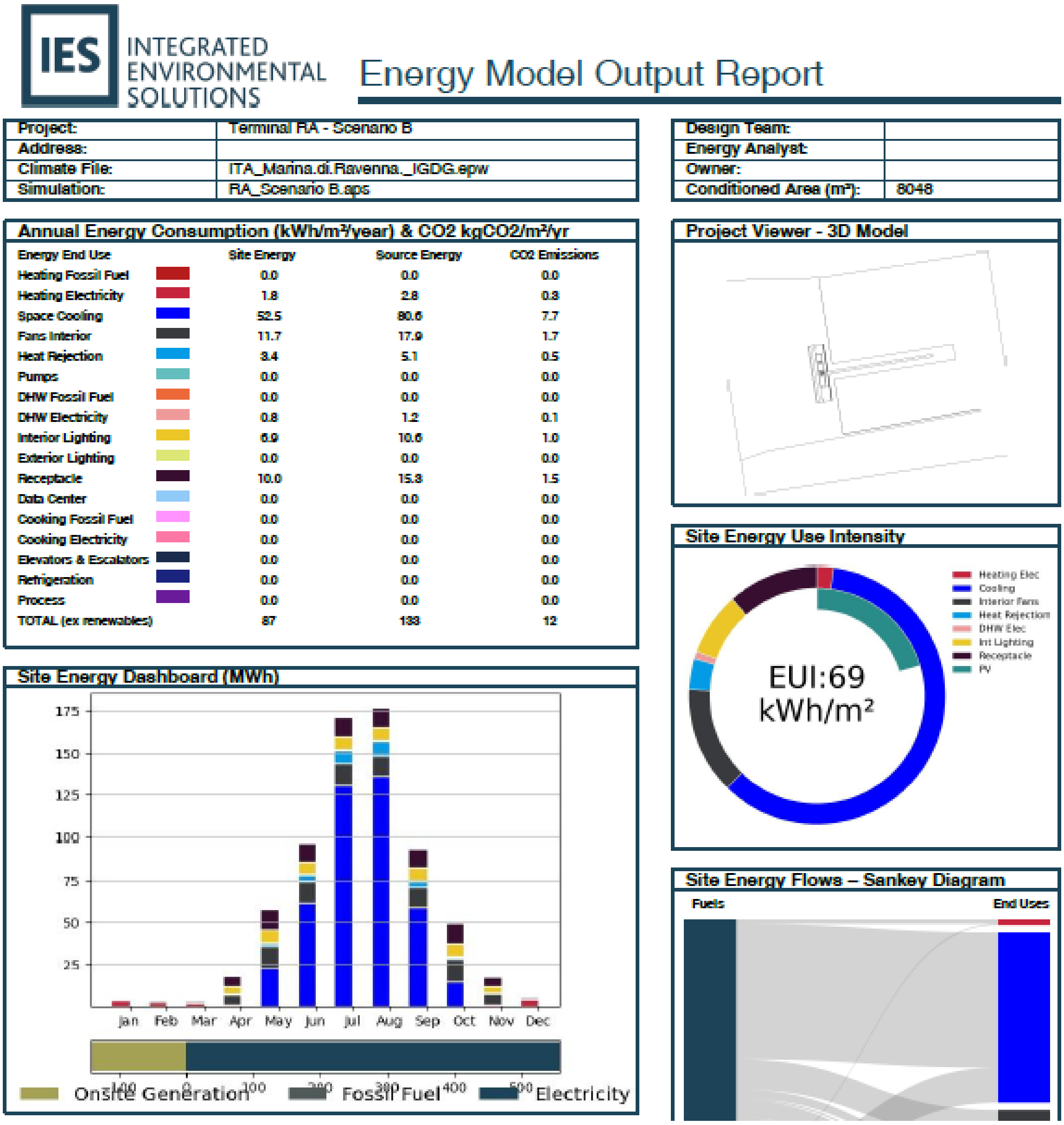


Figure 4.7: General scheme of the roof-top units

The figure below summarizes the energy results for Scenario 02. As expected, even considering the high performance of the HVAC system included in the Final Design, the energy savings are quite low. However, it should be considered that the improvement intervention does not involve significant increases in equipment cost.

From the simulation performed, the Site Energy Use Intensity (EUI) corresponds to 69 kWh/m^2. Therefore, the amount of energy consumed by the building on site, including heat and power generated by the PV system, decreased by 5 kWh/m^2.



Energy End Use	Site Energy	Source Energy	CO2 Emissions
Heating Fossil Fuel	0.0	0.0	0.0
Heating Electricity	1.8	2.8	0.3
Space Cooling	52.5	80.6	7.7
Fans Interior	11.7	17.9	1.7
Heat Rejection	3.4	5.1	0.5
Pumps	0.0	0.0	0.0
DHW Fossil Fuel	0.0	0.0	0.0
DHW Electricity	0.8	1.2	0.1
Interior Lighting	6.9	10.6	1.0
Exterior Lighting	0.0	0.0	0.0
Receptacle	10.0	15.3	1.5
Data Center	0.0	0.0	0.0
Cooking Fossil Fuel	0.0	0.0	0.0
Cooking Electricity	0.0	0.0	0.0
Elevators & Escalators	0.0	0.0	0.0
Refrigeration	0.0	0.0	0.0
Process	0.0	0.0	0.0
TOTAL (ex renewables)	87	133	12

Figure 4.8: Energy Simulation Results for the scenario 02

4.5 SCENARIO 03

Scenario 03 simply combines scenario 02 and 03 in order to evaluates the combined effects of improved photovoltaics generation and roof-top units equipped with free cooling controls.

The figure below summarizes the energy results. The Site Energy Use Intensity (EUI) corresponds to 41 kWh/m^2. Therefore, the amount of energy consumed by the building on site, including heat and power generated by the PV system, decreased by 33 kWh/m^2.

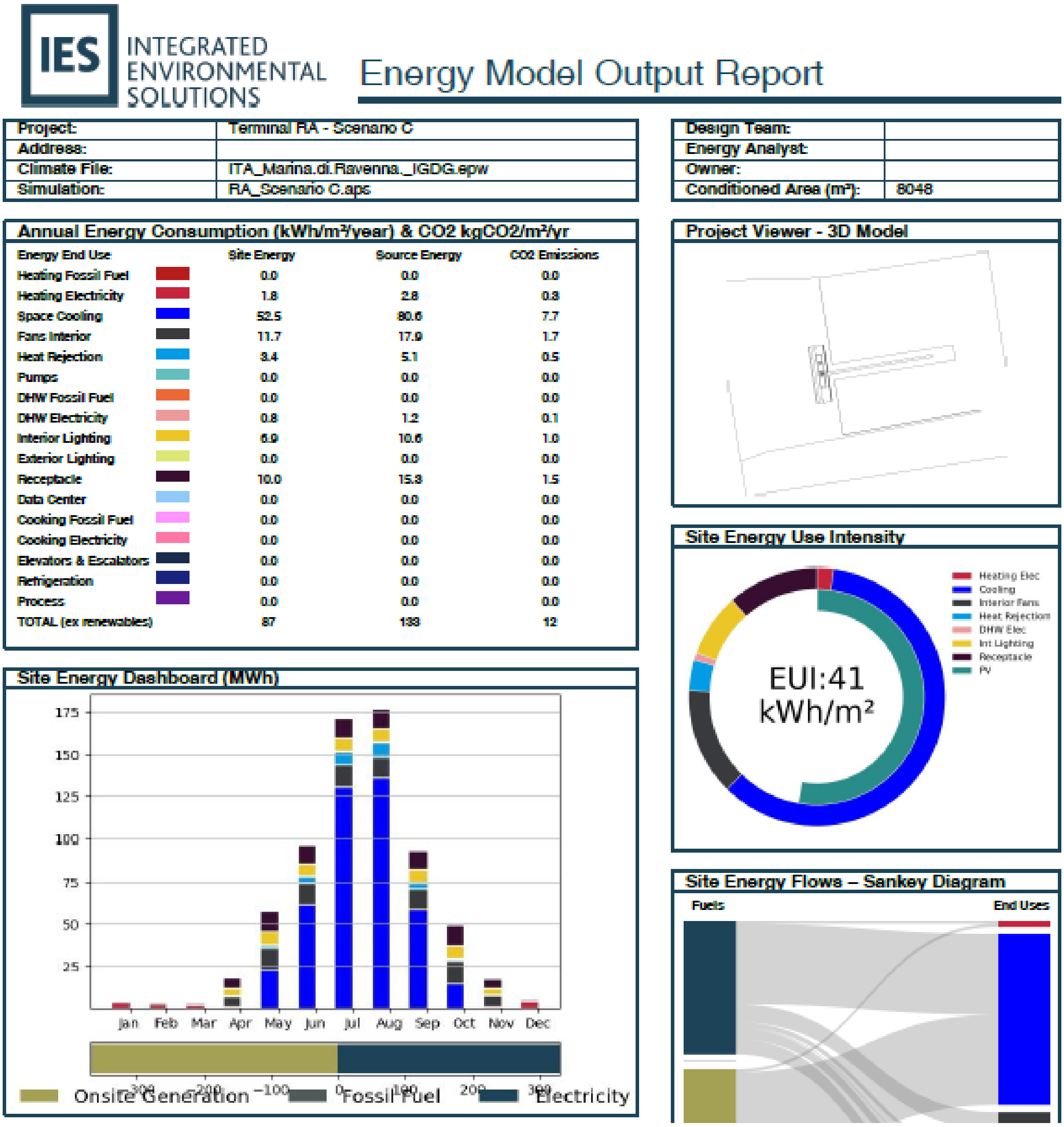


Figure 4.9: Energy Simulation Results for the scenario 03

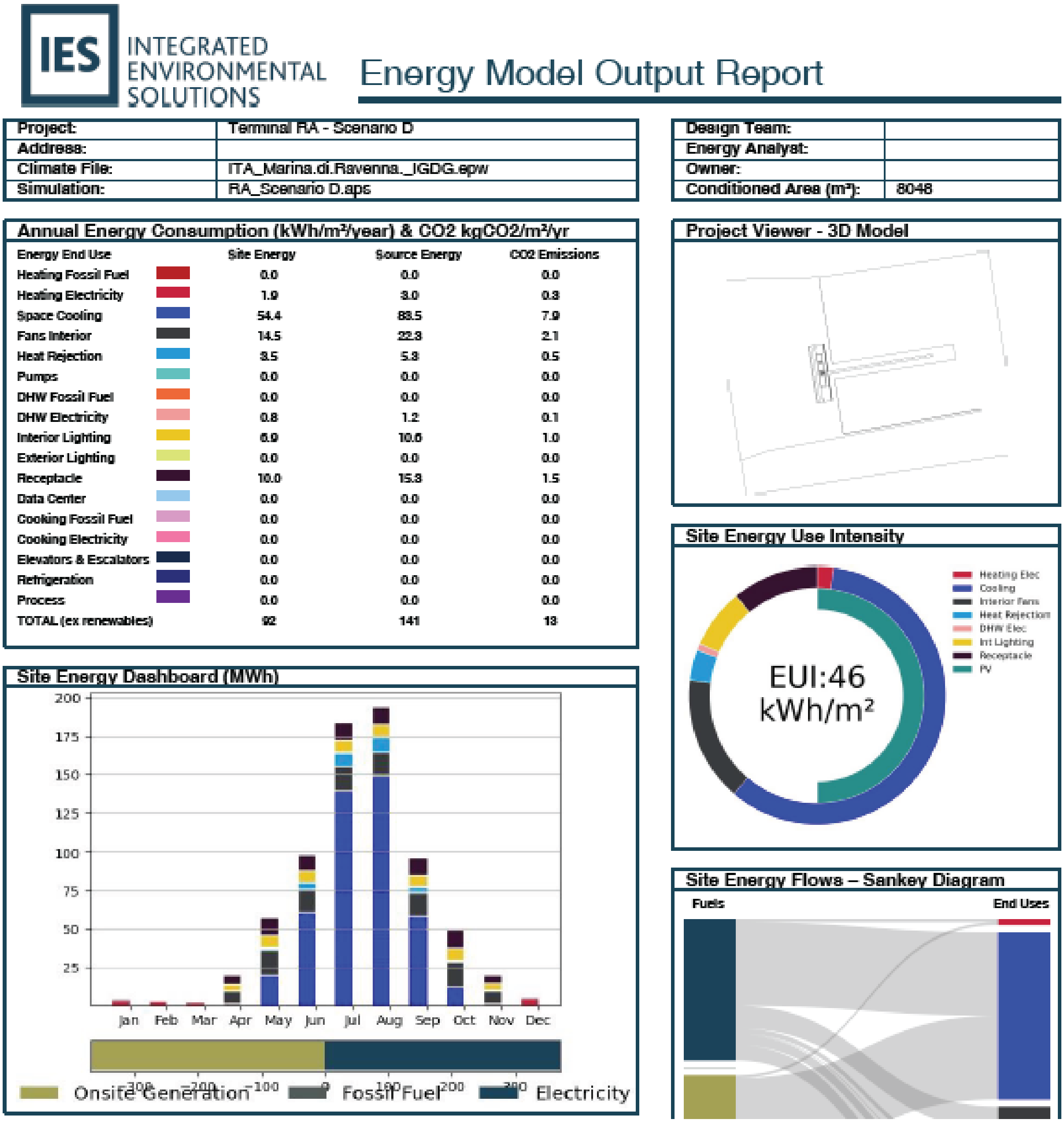
4.6 SCENARIO 04

With the perspective of pursuing the LEED certification, the last scenario evaluated started from the scenario 03 (the best scenario proposed) and considers a 30% increase of **minimum outdoor air ventilation flow rates**, which is associated to the “Enhanced Indoor Air Quality Strategies” credit (1 points).

Of course increasing the air ventilation rates lower the energy performance but increase the indoor air quality and allow to earn 1 point for the LEED certification.

The figure below summarizes the energy results. The Site Energy Use Intensity (EUI) corresponds to 46 kWh/m2.

The amount of energy consumed by the building on site, including heat and power generated by the PV system, increased by 5 kWh/m^2 with reference to the scenario 03 (best scenario) and decreased by 46 kWh/m^2.



Energy End Use	Site Energy	Source Energy	CO2 Emissions
Heating Fossil Fuel	0.0	0.0	0.0
Heating Electricity	1.9	3.0	0.3
Space Cooling	54.4	83.5	7.9
Fans Interior	14.5	22.3	2.1
Heat Rejection	3.5	5.3	0.5
Pumps	0.0	0.0	0.0
DHW Fossil Fuel	0.0	0.0	0.0
DHW Electricity	0.8	1.2	0.1
Interior Lighting	6.9	10.6	1.0
Exterior Lighting	0.0	0.0	0.0
Receptacle	10.0	15.3	1.5
Data Center	0.0	0.0	0.0
Cooking Fossil Fuel	0.0	0.0	0.0
Cooking Electricity	0.0	0.0	0.0
Elevators & Escalators	0.0	0.0	0.0
Refrigeration	0.0	0.0	0.0
Process	0.0	0.0	0.0
TOTAL (ex renewables)	92	141	13

Figure 4.10: Energy Simulation Results for the scenario 04

This scenario seems the least promising since increasing by 30% the ventilation rate above current national regulations (based on occupancy) would require an overall absolute ventilation ranging 40%-50%, which is relevant.

4.7 OPTIONS DISCARDER WITHOUT MODELING

A few technical solutions for the renewable energy production exploitation (the most promising area of improvement for the building) were excluded in advance such as:

- ✓ **Micro-wind turbines** can be generally used for the electricity production. However, one of the main barriers at the installation of micro-wind turbines is linked to the environmental aspects and to the substantial modification of public spaces. In the context of Ravenna and the Parco delle Dune the installation of wind turbines appears not to be a good choice firstly for environmental reasons and for noise and turbulence issues;

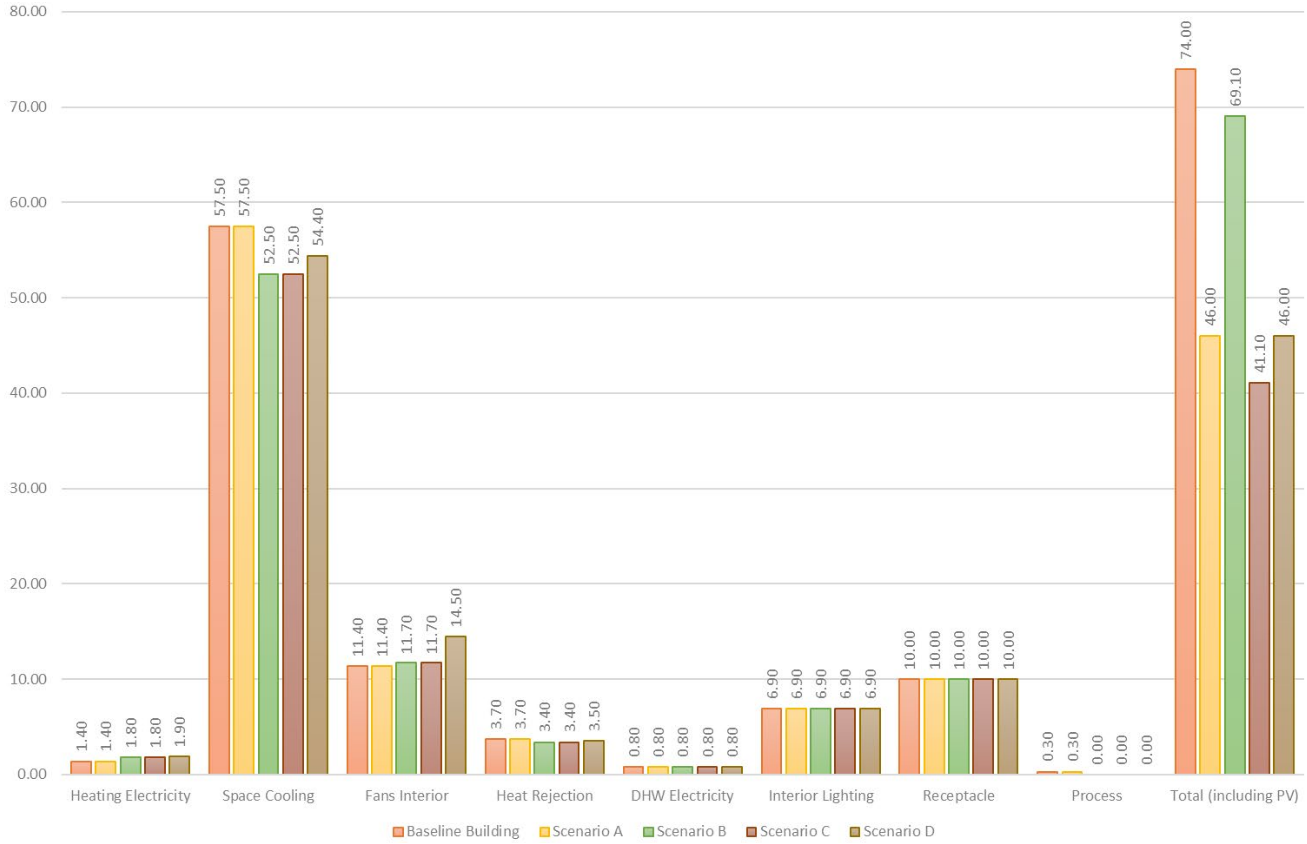
- ✓ **solar thermal systems** to produce domestic water. Based on the low domestic hot water demand of the building, the technology is not significant for the building.

5 CONCLUSIONS

The report provides an impact assesment of the **possible energy efficiency strategies optimizing the Final Design** of Ravenna Terminal without disrupting design, construction schedule and costs. Implementaiton will be done by the design team during the finalization of the Detailed Design and based on the Client's feedbacks.

Four scenarios of improvements have been assessed by setting the corresponding energy models and comparing the performance from previous final design ("progetto definitivo"):

Figure 5.1: Simulation outputs grouped by Energy End Use (kWh/m^2.yr) and Scenarios



Scenario 01 confirm that the greatest impact on the final energy performance is given by the increase of **photovoltaic from a peak power of 120 kW to 310 kW**, while the adoption of **reduced number of roof-top units equipped with free-cooling** (Scenario 02) has a quite good impact on the overall performance since it helps reducing energy use to cover cooling loads during the mid-seasons.

The best scenario is summarized within Scenario 03 which combines the increase of PV system and the adoption of free cooling controls.

The final scenario (Scenario 04) sees a 30% increase of **outdoor airflow rates** provided to Scenario 03 (Scenario 01 and 02): as expected, this has an impact on the final energy performance due to the higher work required to central fans for air movement. Such impact can be addressed in the measure of +12% energy use compared to the same model with outdoor air flow rates not increased (Scenario 03).

Other generic recommendations are listed below. They are already under integration in detail design after discussion with the design team:

- ✓ Enlargement of the zones governed by **DALI light control** (or equivalent). Extra cost is not relevant;
- ✓ Adoption of **Building Management System** (its use was not certain in final design) with calendar functions, monitoring and remote adjustment of set points from mobile. Extra cost is relevant but for this type of builfdings the system is strongly advised and may give interesting energy saving opportunities;

- ✓ Reduction of the **numbers of the RTU** units was already performed following a better understanding of the energy performance at design conditions. More detailed calculations will be delivered at the end of the detailed design phase;
- ✓ **Optimization of air distribution** reducing pressure losses by limiting air speed in air ducts and reducing bends. No extra cost since bigger air ducts are compensated by less complexity in distribution.

Due to the already high performance requested by the most recent legislation no significant improvements can be recommended for the **envelope**.

Client

Design Team