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RENEWPORT RES Toolkit for MED ports testing report

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Content

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1. INTRODUCTION

1.1 Presentation of the Interreg Euro-Med programme

Interreg is a European Union (EU) instrument to improve cooperation between regions within the EU. It promotes regional development, cohesion, and reducing economic disparities. It takes part of the EU's Cohesion Policy and participate of the European Regional Development Fund (ERDF).

For the period 2021-2027, the fund will enable investments to make Europe and its regions:

- More competitive and smarter
- Greener, low-carbon and resilient
- More connected by enhancing mobility
- More social, supporting effective and inclusive employment, education, skills, social inclusion and equal access to healthcare
- Closer to citizens.

Interreg includes 86 programmes divided in three types:

- Cross border programmes (64 programmes)
- Transnational (13 programmes)
- Interregional (4 programmes)
- Outermost Regions (5 regions)

The transnational programmes, grouped as Interreg B, make reference to big areas of Europe. They support a wide range of project investment related to innovation, environment, accessibility, telecommunications, urban development and governance. Interreg Euro-Med makes part of this kind of programmes. It aims to make the Mediterranean region smarter and greener and improve the governance between its stakeholders. The programme includes 69 regions of 14 countries from Northern shore of the Mediterranean, from Lisbon to Cyprus. It includes 10 EU Member States and 4 countries from the Instrument for Pre-accession Assistance (IPA). Around 140 million people live in this area.

The programme has embedded the objectives into missions for a more comprehensive approach. The four missions are:

1. Innovative sustainable economy Mission, to strength an innovative sustainable economy, to boost a fair transition to a circular economy
2. Natural heritage Mission focused on protecting, restoring and valorising the natural environment and heritage
3. Green living areas Mission, to improve the lives of Mediterranean citizens by promoting the development of green living areas
4. Sustainable tourism Mission focused on fostering a circular tourism considering the sustainability of ecosystem services.

The programme provides funds for projects developed and managed by public administrations, universities, private and civil society organisations. The total programme budget amounts to almost € 300 millions for the 2021-2027 period. Six kinds of projects are foreseen in the programme:

- Thematic Community projects that aim at establishing conditions for the reuse of results, the development of synergies and the increase of coordination between thematic projects working towards the same mission by articulating a community of Interreg Euro-MED projects partners and implementing transfer and mainstreaming strategies of Euro-MED thematic projects results.
- Institutional Dialogue projects contributing to the implementation of transfer and mainstreaming strategies by engaging with local, regional and national authorities and to the implementation of transfer and mainstreaming strategies and setting up long-lasting conditions for a permanent institutional and social dialogue to bridge the transnational dimension with the local solutions.
- Study projects that perform analyses to better address a thematic issue and open the door to the development of new instruments, policies, strategies, and action plans.
- Test projects that experiment common instruments, policies, strategies and action plans already developed to validate concrete solutions to be transferred.
- Transfer projects that optimise and share validated common instruments, policies, strategies and actions plans to have the stakeholders adopt them.
- Strategic territorial projects that conduct studies, test solutions and transfer results addressing the strategic topics of a specific type of territory.

1.2 Presentation of the project

The project "Harnessing RENEWable energy potential for clean energy transition of MED PORTs – RENEWPORT" is a Test project approved under the second all of the Interreg Euro-Med programme. The main objective is to tackle the negative contribution to climate change of ports by supporting the clean energy transition of MED ports, turning them from emitters of pollutants and greenhouse gases to clean energy hubs by exploiting the untapped potential of renewable energy sources (RES). Through RENEWPORT, policy makers will be endowed with new solutions supporting them to fight climate change reaching energy goals and carbon neutrality and citizens will benefit from cleaner air, MED territories becoming greener living areas.

The project is divided in three main activities:

- The first one is the development of a toolkit that will guide MED ports in the adoption of the most suitable renewable energy source in each location, based on their own current and future energy needs. The toolkit will be freely available on the project's website and will be replicable in other geographical contexts, even beyond the MED Area.
- The second one will consist of the testing of renewable energy options in MED ports. Each port participating in the project will implement concrete pilot activities and investments testing the use of RES in different scenarios and contexts. For the evaluation of these pilot actions, the partners jointly elaborate a set of processes, techniques models, tools, methods and services, deriving a solution answering the need of transforming ports in renewable energy hubs to be replicated in the MED area and beyond.
- At the end, the partners will upscale and transfer the project's solutions. By one side, an e-learning platform will be created containing the technical knowledge gathered in the development of the RENEWPORT RES toolkit and pilot activities and investments. By other hand, some networking activities will be organised with target groups at local, transnational and macro-regional level to inform them about the overall project's results.

The project is led by the Port Network Authority of the Eastern Adriatic Sea (Italy) and the partnership is composed of:

- Port Network Authority of the Northern Tyrrhenian Sea (Italy)
- Var Chamber of commerce and industry (France)
- Valenciaport Foundation (Spain)
- Valencia Port Authority (Spain)
- Luka Koper, port and logistic system, public limited company (Slovenia)
- Port of Rijeka Authority (Croatia)
- Port of Bar (Montenegro)
- Durres Port Authority (Albania)
- Piraeus Port Authority (Greece)

1.3 The Toolkit

The RENEWPORT project has developed a Renewable Energy Sources (RES) Toolkit as a strategic and technical solution **to accelerate the clean energy transition in Mediterranean ports**. This toolkit directly supports the project's objective of transforming ports from fossil-fuel energy users into clean energy hubs by harnessing their untapped solar and wind potential. It is conceived as a **practical, user-friendly resource for port authorities, energy technicians, and other stakeholders to identify how much electricity can be generated on-site from renewable sources**, given each port's local characteristics and energy needs. By providing tailored guidance and calculations, the toolkit serves as a powerful planning aide for ports to map out renewable installations and meet sustainability targets in line with regional and EU climate goals.

Accessible and Replicable Solution: A key advantage of the RENEWPORT toolkit is its accessibility. The tool is available as **a free web application on the project's website**, designed with an intuitive interface that lowers the barrier for non-experts. This means any Mediterranean port, can easily use it to explore their renewable energy options. Importantly, the toolkit is fully replicable, offering a solution that can be adopted and customized by other ports beyond the project's own pilots.

In practice, this replicability ensures that **lessons and benefits from RENEWPORT extend across the port industry, making the toolkit a model that can be scaled up to drive clean energy transitions in various geographical contexts**. Port planners and decision-makers can thus rely on the toolkit as a common framework to evaluate renewable projects, compare scenarios, and share best practices, fostering a collaborative approach to green energy in ports.

Basic Functionality: The toolkit combines **geospatial data, advanced simulations, and easy reporting features to deliver actionable insights**. Its core functionalities can be summarized as follows:

- **Geographic Data & Site Selection**: Users begin by selecting their port area and specific sites for potential installations via an interactive map interface. The toolkit leverages mapping technology **to obtain precise geographic coordinates** (latitude, longitude, elevation) **of the chosen location**. This geospatial approach allows port stakeholders to virtually mark rooftops, open yards, or waterfront areas where solar panels or wind turbines could be installed, taking into account the exact local conditions of each site.
- **Solar or Wind Option Selection**: After pinpointing a location, the user specifies the type of renewable installation – solar photovoltaic (PV) panels or wind turbines – for that site. The toolkit then prompts for basic parameters relevant to the chosen technology. For a solar PV analysis, the user can input details such as the available surface area (or number of panels) and panel characteristics (e.g. technology type or tilt angle). For a wind energy analysis, the user may select

a turbine model or capacity and the hub height. This flexible input step ensures that the calculations are customized to the port's actual scenario and plans (for example, considering a large warehouse roof for PV or a particular dock location for a wind turbine).

- **External Data Integration**: Once the site and technology are selected, the toolkit automatically retrieves high-quality solar and wind resource data for that location by connecting to external databases. For solar assessments, it uses the European Commission's Photovoltaic Geographical Information System (PVGIS) API to fetch site-specific solar irradiation and climate data. For wind assessments, it taps into the Global Wind Atlas dataset (via its API) to obtain local wind speed distributions or capacity factor information. By integrating these trusted external sources, the toolkit ensures that its calculations reflect real-world environmental conditions at the port – for instance, accounting for the region's sunshine levels and wind patterns throughout the year. This connection to validated external APIs adds technical rigor to the tool, as it builds upon the same data sources used by experts for renewable energy feasibility studies.
- **Energy Output Estimation**: With the input parameters and resource data in hand, the toolkit computes the expected energy generation for the proposed installation. The result is an hour-by-hour generation profile for an entire typical year, which the toolkit then aggregates into monthly totals. This means users can see both the fine-grained details and the big picture. The output is presented in clear graphs and tables: for example, a chart might display the estimated electricity (in kWh) produced each month from a selected rooftop solar installation. Users can run multiple scenarios (e.g. trying different locations or combining solar and wind setups) – the toolkit will calculate each scenario separately and can also aggregate results to show the combined impact. This functionality gives a general yet informative view of the benefits and performance one could expect by installing renewable energy systems in various configurations at the port.

In essence, the RENEWPORT RES Toolkit is both an **innovative and practical instrument for advancing clean energy in ports**. Strategically, it empowers port authorities and operators to make informed decisions on renewable investments by clearly showing the potential solar and wind gains on their premises. Technically, it streamlines complex calculations and data gathering into a straightforward application, ensuring that even those without specialized expertise can engage in energy planning. The toolkit's emphasis on accessibility, accuracy, and replicability positions it as a catalyst for green transition in the Mediterranean port sector and beyond.

2. COMPARISON

This section presents the results obtained by each project partner during the testing phase of the RENEWPORT Toolkit. The main objective of this analysis was to validate the accuracy and applicability of the tool in estimating renewable energy generation under real operating conditions in Mediterranean ports. For each partner, real data or previous studies were compared with the Toolkit's estimations, and the resulting differences were analysed to assess the level of deviation and identify possible causes.

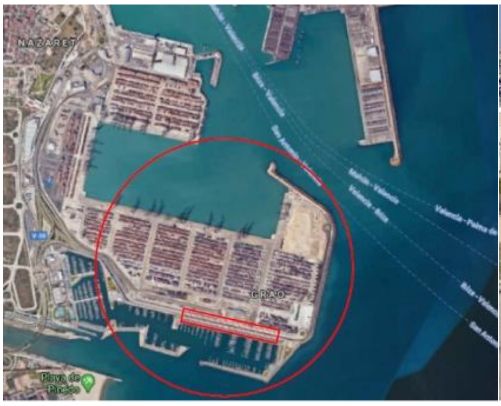
2.1 Valencia Port Authority

To evaluate the accuracy of the RENEWPORT Toolkit, two real photovoltaic (PV) installations managed by the Valencia Port Authority were analysed. These systems were selected because they represent two different scales and contexts within the Valencian port network: one large installation at the Port of Valencia and a smaller one in the Port of Gandía. Both are fully operational and equipped with advanced monitoring systems, which provided reliable data for comparison.

2.1.1 Real Values or Previous Studies

Príncipe Felipe Dock – Port of Valencia

The first PV installation is situated at the Príncipe Felipe dock in the Port of Valencia. This large-scale solar array features the following characteristics:



- **Panel Power:** 465 Wp
- **Panel Brand:** Jinko
- **Model:** JA Solar JAM72S20-465/MR
- **Number of Panels:** 2,990 units

- **Total Installed Capacity:** 1.390,35 kWp
- **Mounting Structure:** Inclined at 30°
- **Surface Area Used:** 6,420 m²
- **Inverters:** 8 units of Huawei iSUN 2000-185KTL-H1 (185 kW, 800 Vac output)

This installation is monitored for its actual energy production, allowing a detailed comparison between expected and real generation. For the period from January 17, 2024, to January 16, 2025, the **expected total energy output** was **2,204.64 MWh**, while the **actual energy generated** reached **2,416.17 MWh**.

2024	Jan (17-31)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan (1-16)	TOTAL (MWh)
Energy (MWh)	54.7	168.4	190.3	245.6	273.7	242.1	265.2	239.8	201.8	171.0	133.7	148.0	82.1	**2,416.17**

Port of Gandía

The second real installation is located in the Port of Gandía, with the following technical specifications:

- **Panel Power:** 460 Wp
- **Panel Type:** ZNSHINE Solar ZXMS-NHLD144
- **Number of Panels:** 1,620 units
- **Total Installed Capacity:** 745.20 kWp
- **Tilt Angle:** 10°

- **Surface Area Used:** 4,500 m²
- **Inverters:** 6 units of Ingeteam Ingecon Sun 3Play 100TL
- **Storage System:** 1,000 kW power, 1,020 kWh energy capacity

This installation is also equipped with a monitoring system that records real-time energy generation. From January 17, 2024, to January 16, 2025, the **expected energy production** was **548.57 MWh**, while the **actual energy generated** was **572.57 MWh**.

2024	Jan (17-31)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan (1-16)	TOTAL (MWh)
Energy (MWh)	16.9	41.3	49.8	56.5	53.7	53.4	60.6	69.8	56.5	44.5	30.0	30.6	9.0	**572.57**

These real values serve as essential benchmarks for assessing the accuracy of the toolkit's estimations. The data from both installations, with their specific technical setups and environmental conditions, provide a solid basis for evaluating how well the toolkit can replicate real-world results and support decision-making in renewable energy planning for ports.

2.1.2 Toolkit Results

The following section presents the estimated energy generation data as calculated by the Toolkit for the renewable installations previously defined by the partners. These results reflect the Toolkit's simulation outputs based on the input parameters and local conditions of each installation.

Príncipe Felipe Dock – Port of Valencia

id	month	E_d	E_m	H(i)_d	H(i)_m	SD_m
66	1	5053,1	156676	4,42	136,96	24159,2
66	2	5621,2	157244,1	4,99	139,7	21557,9
66	3	6189,3	191748,7	5,61	173,83	20062,9
66	4	6518,2	195605,8	6,03	180,75	12707,5
66	5	6817,2	211452,8	6,44	199,64	16833,7
66	6	6966,7	209329,9	6,73	201,76	5382
66	7	7056,4	218778,3	6,87	213,11	7355,4
66	8	6847,1	212260,1	6,62	205,25	9059,7
66	9	6219,2	186665,7	5,93	177,85	10465
66	10	5561,4	172762,2	5,17	160,26	19554,6
66	11	4903,6	147018,3	4,39	131,59	19704,1
66	12	4694,3	145134,6	4,09	126,85	13484,9

- **E_d:** Average daily energy produced by the system in kilowatt-hours per day (kWh/d).
- **E_m:** Total monthly energy produced by the system in kilowatt-hours per month (kWh/mo).
- **H(i)_d:** Average daily solar irradiation received by the panel (kWh/m²/d).
- **H(i)_m:** Total monthly solar irradiation received (kWh/m²/mo).
- **SD_m**: Monthly standard deviation of production due to annual variability.

2024	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL (MWh)
Energy (MWh)	156.6	157.2	191.7	195.6	211.9	209.3	218.7	212.2	186.6	172.7	147.0	145.1	**2,204.64**

Port of Gandía

id	month	E_d	E_m	H(i)_d	H(i)_m	SD_m
68	1	972	30156,3	3,21	99,62	4098,6
68	2	1182,6	33193,8	3,96	110,89	4187,7
68	3	1474,2	45619,2	4,97	154,07	5119,2
68	4	1725,3	51767,1	5,9	176,98	4455
68	5	1976,4	61276,5	6,87	212,92	5540,4
68	6	2114,1	63512,1	7,49	224,57	2357,1
68	7	2114,1	65415,6	7,55	233,93	2721,6
68	8	1863	57777,3	6,67	206,68	2600,1
68	9	1539	46089	5,43	162,91	3717,9
68	10	1223,1	38005,2	4,27	132,23	3782,7
68	11	972	29111,4	3,26	97,81	3515,4
68	12	858,6	26649	2,91	90,17	2324,7

2024	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL (MWh)
Energy (MWh)	30,15	33,1	45,61	51,76	61,27	63,51	65,41	57,77	46,0	38,00	29,11	26,6	**548,57**

2.1.3 Results

The table below displays a comparative summary of the real installation reports alongside the Toolkit's estimated values. Additionally, the estimation errors are calculated to assess the Toolkit's performance and reliability in replicating actual renewable energy generation in port environments.

$$\text{Error Margin} = \frac{|\text{Real Value} - \text{Estimated Value}|}{\text{Real Value}} \times 100$$

Port of Valencia	Real Value (MWh)	Toolkit Value (MWh)	Error (%)
Port of Valencia - Príncipe Felipe Dock	2,416.17	2,204.64	8.75
Port of Gandia	572.57	548.57	4.19

2.2 PNANTS

2.2.1 Real Values or Previous Studies

Port of Piombino solar panel system

The Project of the intervention is complementary to the preliminary design of environmental mitigation of the Waterfront and landscape mitigation of the area for the Port of Piombino. The intervention consists in the construction, on state-owned areas, of photovoltaic systems with a power of 685 kWp on car shelters to be installed on the parking lots serving the port located in the Poggio Batteria area.

The installation features the following characteristics:

- **Panel Power:** 400 Wp
- **Number of Panels:** 1,700
- **Total Installed Capacity:** 680 kWp
- **Mounting Structure:** Inclined at 30°
- **Azimuth:** 15°

Expected Energy generated in one year:

2024	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL (MWh)
Energy (MWh)	31.8	53.0	89.8	117.4	150.4	154.7	154.7	138.7	100.9	72.4	45.4	33.6	**1,152.8**

Port of Livorno Wind energy system

Description: The project involves the construction of a system of wind farms for a total power of approximately 200 kW to be installed in a port area exposed to the prevailing winds and not obstructed by buildings and cranes. It is planned to install two turbines with a power of 100 kW each.

The installation features the following characteristics:

- **Turbine:** VICTORY 24-100
- **Power Control System:** Pitch
- **Hub Height:** 30m
- **N° of turbines:** 2

2024	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL (MWh)
Energy (MWh)	24	22	23.5	20	18	17	15.5	16	18.5	20	22.5	25.5	**242.5**

2.2.2 Toolkit Results

Solar Energy Estimation

2024	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL (MWh)
Energy (MWh)	51.5	63.5	86.4	98.7	110.1	113.6	121.7	114.4	94.2	76.2	51.2	48.3	**1,029.89**

Wind Energy Estimation:

2024	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL (MWh)
Energy (MWh)	13.04	13.11	23.76	12.82	15.36	6.73	8.50	4.16	9.08	14.59	39.00	32.58	**192.73**

2.2.3 Results

The table below displays a comparative summary of the real installation reports alongside the Toolkit's estimated values. Additionally, the estimation errors are calculated to assess the Toolkit's performance and reliability in replicating actual renewable energy generation in port environments.

$$\text{Error Margin} = \frac{|\text{Real Value} - \text{Estimated Value}|}{\text{Real Value}} \times 100$$

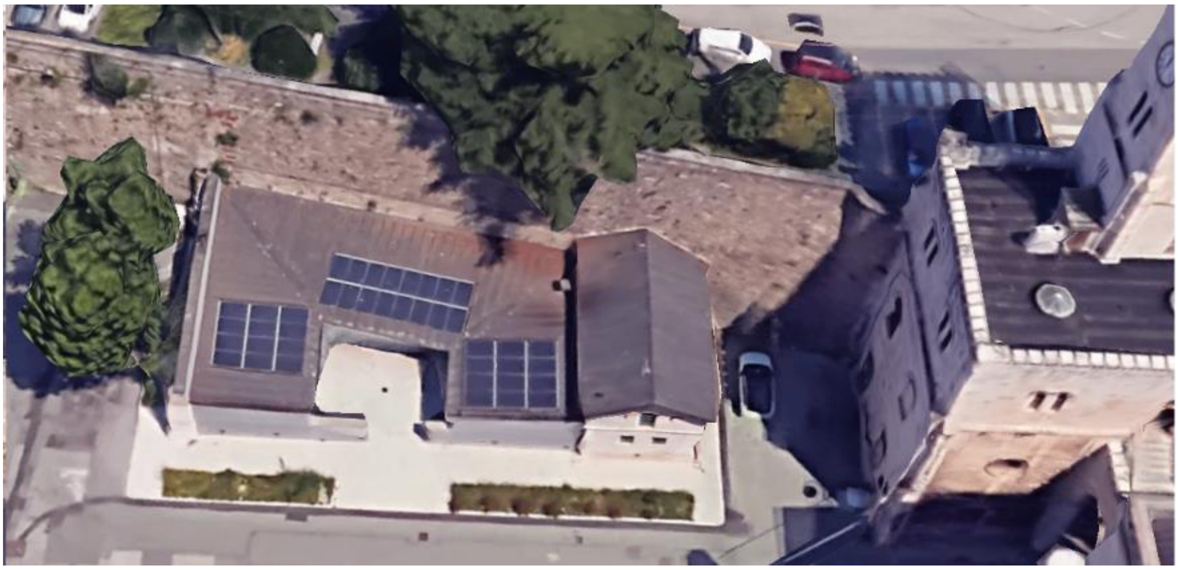
PNANTS	Real Value (MWh)	Toolkit Value (MWh)	Error (%)
Port of Piombino solar panel system	1,152.80	1,029.89	10.66
Port of Livorno Wind energy	242.5	192.73	20.52

2.3 PNAEAS

2.3.1 Real Values or Previous Studies

Port of Trieste "UPS" PV

The photovoltaic system is installed on the roofs of the Port Network Authority of the Eastern Adriatic Sea headquarters, located in Trieste.



The installation features the following characteristics:

- **Panel Power:** 300 Wp
- **Number of Panels:** 40 units
- **Total Installed Capacity:** 12 kWp
- **Mounting Structure:** n.a.
- **Azimuth:** n.a.

Energy generated in 2023 (In 2024, a technical problem caused an incorrect reading of the energy produced):

2024	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL (MWh)
Energy (MWh)	0,17	0,39	0,72	0,86	0,93	1,11	1,11	1,14	0,71	0,52	0,24	0,12	**8,01**

Port of Trieste "MERIDIAN" PV

The photovoltaic system is installed, in concession, on the roofs of the following buildings owned by the Port Network Authority of the Eastern Adriatic Sea, located in the New Free Port area located in Trieste, with a total area of 89,212 square meters.

The installation features the following characteristics:

- **Panel Power:** 200 Wp
- **Number of Panels:** 40,204 units
- **Total Installed Capacity:** 8,040.80 kWp
- **Mounting Structure:** n.a.
- **Azimuth:** n.a.

Energy generated in 2018 (After 2018, some portions of the plant were removed for the construction of various infrastructure works in the Port of Trieste, so energy data from more recent years would not be consistent with the scope of this calculation.):

2024	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL (MWh)
Energy (MWh)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	**9.262**

2.3.2 Toolkit Results

Port of Trieste "UPS" PV

id	month	E_d	E_m	H(i)_d	H(i)_m	SD_m
326	1	27,2	844,4	2,64	81,86	244,4
326	2	37,2	1044	3,68	103,14	227,6
326	3	45,6	1418	4,63	143,65	246,4
326	4	52	1555,2	5,46	163,7	236,8
326	5	52,8	1640,8	5,69	176,25	204,4
326	6	56,8	1702	6,26	187,77	138,8
326	7	59,6	1852,4	6,67	206,79	109,2
326	8	56,4	1752	6,27	194,35	160,8
326	9	49,2	1481,6	5,29	158,65	144
326	10	38	1175,6	3,9	120,85	150,4
326	11	26	780,4	2,6	77,92	197,6
326	12	25,2	775,6	2,44	75,68	152

2024	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL (MWh)
Energy (MWh)	0.84	1.04	1.42	1.56	1.64	1.70	1.85	1.75	1.48	1.18	0.78	0.78	**16.02**

Port of Trieste "MERIDIAN" PV

id	month	E_d	E_m	H(i)_d	H(i)_m	SD_m
328	1	19297,92	596627,36	2,79	86,37	173681,3
328	2	24926,48	701559,8	3,7	103,46	153177,2
328	3	30555,04	951226,64	4,64	143,82	165238,4
328	4	34575,44	1041283,6	5,45	163,6	158403,8
328	5	35379,52	1097569,2	5,68	175,99	137095,6
328	6	37791,76	1137773,2	6,24	187,25	92871,24
328	7	39801,96	1238283,2	6,65	206,25	73171,28
328	8	37791,76	1172348,64	6,26	194,09	107746,7
328	9	32967,28	993038,8	5,29	158,68	96891,64
328	10	25328,52	790812,68	3,91	121,33	101716,1
328	11	17689,76	531094,84	2,64	79,2	135085,4
328	12	17287,72	537929,52	2,53	78,31	106138,6

2024	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL (MWh)
Energy (MWh)	596.6	701.5	951.2	1,041.2	1,097.5	1,137.7	1,238.2	1,172.3	993.0	790.8	531.0	537.9	**10,789**

2.3.3 Results

The table below displays a comparative summary of the real installation reports alongside the Toolkit's estimated values. Additionally, the estimation errors are calculated to assess the Toolkit's performance and reliability in replicating actual renewable energy generation in port environments.

$$\text{Error Margin} = \frac{|\text{Real Value} - \text{Estimated Value}|}{\text{Real Value}} \times 100$$

Port of Trieste	Real Value (MWh)	Toolkit Value (MWh)	Error (%)
1 – Port of Trieste "UPS" PV	8.01	16.02	-100.0
2 – Port of Trieste "MERIDIAN" PV	9,262	10,789	-16.49

The results confirm some characteristics of the considered PV system that cannot be calculated by the tool as no specific PV panel model data, installation angle or azimuth were provided nor detail about the site conditions:

1. Concerning the "UPS" photovoltaic system, its placement is a compromise due to site conditions: as can be seen from its photo, it is built in adhesion with the roof of a building that has 3 different angles. In addition, the "UPS" building is adjacent to other structures that obstruct the full irradiation of the PV system. The toolkit shows that the efficiency of the system is not maximised due to installation constraints, and the efficiency reduction is estimated to be 100 percent of the generated power.

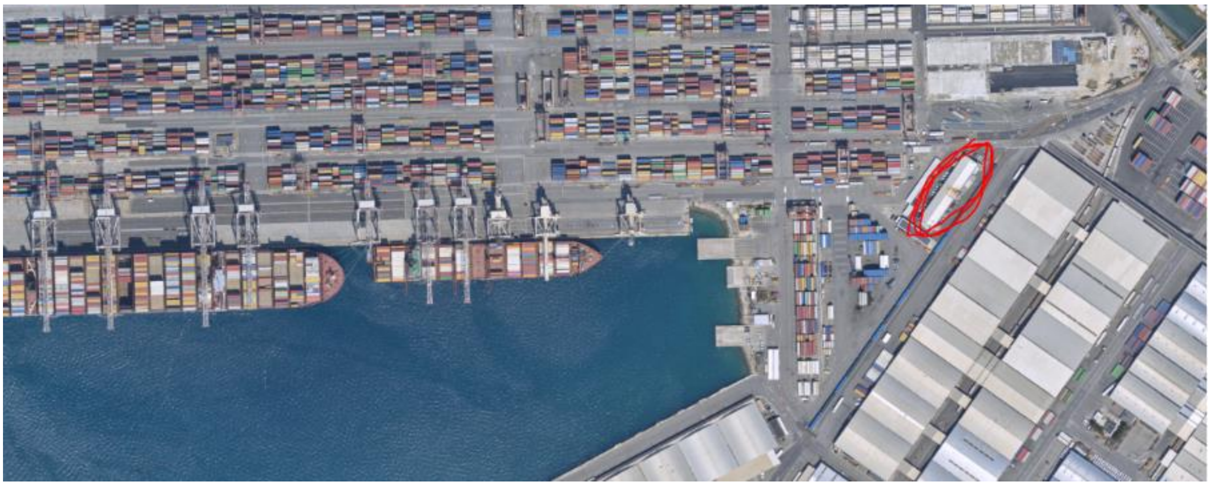
2. The toolkit generated a fairly good estimate of the PV system, considering that no specific PV panel model data, installation angle or azimuth were provided. The measured delta could be related to reduced panel efficiency due to panel deterioration or less than perfect cleaning condition.

2.4 Luka Koper

2.4.1 Real Values or Previous Studies

Luka Koper PV

The PV system is located at the Container Terminal in the Port of Koper. This large-scale solar array, mounted on the rooftop of the administrative building of the Container Terminal, features the following characteristics:



- **Panel Power:** 460 Wp
- **Number of Panels:** 321 units
- **Total Installed Capacity:** 147.66 kWp
- **Mounting Structure:** 321 panels Inclined at 6°
- **Azimuth:** 153 panels at 125° and 168 panels at 305°

Energy forecasted per month (source SolarEdge). Real data will be provided from now, until the end of the year or until the end of the project. The solar plant was installed few months ago and it's not useful to include few data at this stage:

2024	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL (MWh)
Energy (MWh)	7.85	10.33	15.74	17.00	22.64	25.69	25.80	22.91	17.23	12.53	9.88	6.82	**171**

2.4.2 Toolkit Results

Solar Energy Estimation

2024	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL (MWh)
Energy (MWh)	5.150	7.763	13.331	17.439	20.719	22.668	23.930	20.398	14.775	9.688	5.318	4.296	**165.48**

2.4.3 Results

The table below displays a comparative summary of the real installation reports alongside the Toolkit's estimated values. Additionally, the estimation errors are calculated to assess the Toolkit's performance and reliability in replicating actual renewable energy generation in port environments.

$$\text{Error Margin} = \frac{|\text{Real Value} - \text{Estimated Value}|}{\text{Real Value}} \times 100$$

	Real Value (MWh)	Toolkit Value (MWh)	Error (%)
Port of Koper PV	171	165.48	3.22

2.5 Durres Port Authority

2.5.1 Real Values or Previous Studies

Ministry of Finance

Description: The PV installation is situated at the Ministry of Finance in Tirana. This large-scale solar array features the following characteristics:

- **Panel Power:** 455 Wp
- **Number of Panels:** 276 units
- **Total Installed Capacity:** 125.58 kWp
- **Mounting Structure:** Inclined at 10°
- **Azimiuth:** 168°

2.5.2 Toolkit Results

Solar Energy Estimation

In this section, we provide the **solar energy estimates** generated by the Toolkit for the installation:

2024	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL (MWh)
Energy (MWh)	10.00	12.00	28.00	32.00	41.00	46.00	47.00	42.00	31.00	23.00	11.00	9.00	**342**

2.5.3 Results

The table below displays a comparative summary of the real installation reports alongside the Toolkit's estimated values. Additionally, the estimation errors are calculated to assess the Toolkit's performance and reliability in replicating actual renewable energy generation in port environments.

$$\text{Error Margin} = \frac{|\text{Real Value} - \text{Estimated Value}|}{\text{Real Value}} \times 100$$

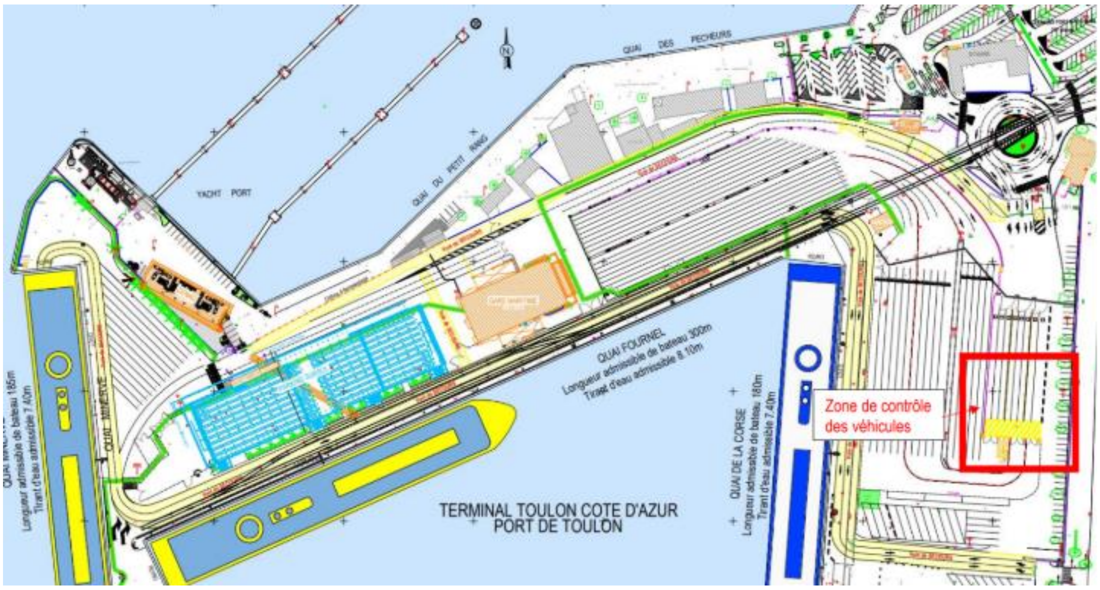
DPA	Real Value (MWh)	Toolkit Value (MWh)	Error (%)
Ministry of Finance Tirana	310	342	-9.81

2.6 CCI du Var

2.6.1 Real Values or Previous Studies

Port of Toulon PV PIF VL

The future photovoltaic installation will be located on the TCA terminal at the vehicle control station.



This solar installation has the following characteristics:

- **Panel Power:** 425 Wc
- **Number of Panels:** 108 units
- **Total Installed Capacity:** 45.9 kWc
- **Mounting Structure:** Inclined at 30°
- **Performance:** 22%

Assumption of solar production over one year:

2024	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL (MWh)
Energy (MWh)	2.500	3.269	5.188	6.233	7.628	8.119	8.378	7.346	5.533	4.273	2.562	2.137	**63.166**

Port of Toulon PV CENAQ

A 5,000 m2 shaded area is available in the port of Toulon to supply the CENAQ (Shore Connection) facilities. It has been in service since February 2025.

The installation features the following characteristics:

- **Panel Power:** 410 Wc
- **Number of Panels:** 2,484 units
- **Total Installed Capacity:** 1,006 kWc
- **Mounting Structure:** Inclined at 30°
- **Performance:** 22%

The preliminary study predicted the following production: 1.300 MWh / year

Total example 1 + example 2 = 1.363 MWh / year

2.6.2 Toolkit Results

Solar Energy Estimation for PV PIF VL

This data is read from the curve, taking the low value.

2024	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL (MWh)
Energy (MWh)	3.597	4.133	5.729	6.332	6.557	7.092	7.632	7.340	6.154	4.774	3.459	3.518	**66.317**

Solar Energy Estimation for PV CENAQ

This data is read from the curve, taking the low value.

2024	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL (MWh)
Energy (MWh)	79.8	91.7	127.2	140.5	145.5	157.4	169.3	162.9	136.5	105.9	76.8	78.0	**1,471.52**

Total Solar Energy Estimation

Total of simulation 1 + simulation 2, with low values = 1.538 MWh / year
Total estimation on the report toolkit, this data is read from the monthly solar energy production table:

2024	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL (MWh)
Energy (MWh)	97.7	110.6	146.5	157.1	165.2	170.1	181.0	173.9	150.8	123.0	94.7	94.7	**1,665.26**

2.6.3 Results

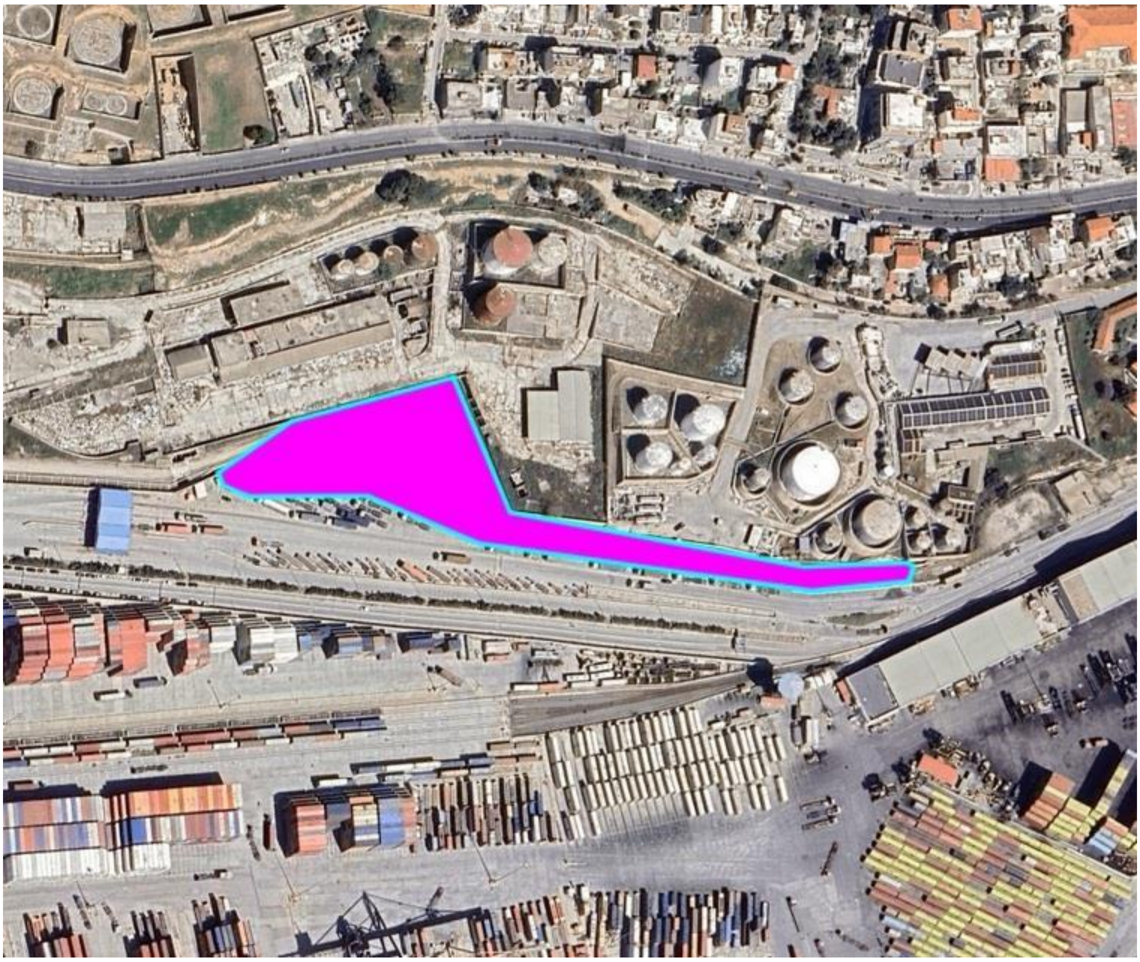
The table below displays a comparative summary of the real installation reports alongside the Toolkit's estimated values. Additionally, the estimation errors are calculated to assess the Toolkit's performance and reliability in replicating actual renewable energy generation in port environments.

$$\text{Error Margin} = \frac{|\text{Real Value} - \text{Estimated Value}|}{\text{Real Value}} \times 100$$

Port of Toulon	Real Value (MWh)	Toolkit Value (MWh)	Error (%)
Example 1 – Port of Toulon PIF VL PV	63,166	66,317	4.99
Example 2 – Port of Toulon CENAQ PV	1.300	1.471,52	13.19

2.7 Port of Piraeus

2.7.1 Real Values or Previous Studies



The real installation is a grid-connected photovoltaic (PV) power plant, located at the "Neo Ikonio" zone of the commercial port of Piraeus, Municipality of Perama. The system comprises two sections:

- **Wall-mounted system** (3,835 m²): 904 PV panels
- **Ground-mounted system** (3,263 m²): 532 PV panels

  Total surface: 7,098 m²

  Key Technical Data:

- **Installed capacity**: 430.80 kWp
- **Technology**: Polycrystalline silicon panels (Yingli Solar YL300P-35b, 300 W each)
- **Total number of panels**: 1,436

- **Mounting structure**: Fixed-tilt at 30°
- **Orientation**: Varied (0°, 23°, -22° depending on inverter)
- **Inverters**: 19 x SMA STP 20000TL-EE-10
- **Commissioning date**: Connected to the grid on **27/07/2016**
- **Transformer**: 500 kVA MV substation

The data of the installation: Energy generated in 2025:

2025	Jan	Feb	Mar	Apr	May	Jun	Jul	TOTAL (MWh)
Energy (MWh)	41.35	34.29	59.59	55.78	61.68	62.32	57.8	**372.8**

2.7.2 Toolkit Results

Solar Energy Estimation

id	month	E_d	E_m	H(i)_d	H(i)_m	SD_m
113	1	1335,48	41241,92	3,72	115,42	5126,52
113	2	1536,52	43180,52	4,38	122,66	5069,08
113	3	1881,16	58129,28	5,45	169,01	4480,32
113	4	2110,92	63456,84	6,32	189,63	4523,4
113	5	2168,36	67018,12	6,64	205,83	3475,12
113	6	2283,24	68324,88	7,15	214,65	2943,8
113	7	2369,4	78236	7,46	231,29	1952,96
113	8	2340,68	72474,92	7,34	227,45	1637,04
113	9	2053,48	61791,08	6,33	189,82	3073,04
113	10	1680,12	51997,56	4,99	154,68	5097,8
113	11	1392,92	41758,88	3,99	119,73	4882,4
113	12	1234,96	38211,96	3,43	106,31	4595,2

2025	Jan	Feb	Mar	Apr	May	Jun	Jul	TOTAL (MWh)
Energy (MWh)	41.24	43.18	58.13	63.46	67.02	68.32	73.24	**414.59**

2.7.3 Results

The table below displays a comparative summary of the real installation reports alongside the Toolkit's estimated values. Additionally, the estimation errors are calculated to assess the Toolkit's performance and reliability in replicating actual renewable energy generation in port environments.

$$\text{Error Margin} = \frac{|\text{Real Value} - \text{Estimated Value}|}{\text{Real Value}} \times 100$$

Port of Piraeus	Real Value (MWh)	Toolkit Value (MWh)	Error (%)
Port of Piraeus PV	372.80	414.59	**-11.21**

2.8 Port of Rijeka

2.8.1 Real Values or Previous Studies

Within Interreg MED – RENEWPORT-Pilot project Port of Rijeka Authority prepared detail design and construction of a photovoltaic power plant on the roof of the administrative building and signed the contract for installation.

The photovoltaic power plant will be 50 to 60 kw and will covered around 50 % of energy cost from green sources. The signed contract for installation of photovoltaic power plant is within the framework of the budget.

- **Panel Power:** 440 Wp
- **Number of Panels:** 195 units
- **Total Installed Capacity:** 85,8 kWp
- **Mounting Structure:** Inclined at 3°
- **Azimuth:** 26°

Estimated monthly PV energy production

The data of the installation: Energy generated in 2025

2025	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	TOTAL (MWh)
Energy (MWh)	3.1	4.4	7.4	9.5	11.2	12.5	13	11.4	8.3	5.7	3.1	2.55	**92.15**

2.8.2 Toolkit Results

Solar Energy Estimation

id	month	E_d	E_m	H(i)_d	H(i)_m	SD_m
132	1	183,3	5653,05	2,46	76,2	1606,8
132	2	237,9	6649,5	3,25	90,98	1515,15
132	3	296,4	9163,05	4,15	128,52	1815,45
132	4	352,95	10602,15	5,15	154,48	1536,6
132	5	364,65	11321,7	5,43	168,24	1612,65
132	6	403,65	12136,8	6,17	185,14	729,3
132	7	421,2	13065	6,5	201,45	856,05
132	8	403,65	12493,65	6,16	190,91	1339,65
132	9	333,45	10007,4	4,94	148,08	1131
132	10	255,45	7948,2	3,66	113,35	1029,6
132	11	169,65	5081,7	2,35	70,64	1466,4
132	12	165,75	5140,2	2,22	68,81	1185,6

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	TOTAL (MWh)
Energy (MWh)	5.65	6.65	9.16	10.6	11.3	12.1	13.1	12.5	10.0	7.95	5.08	5.14	**109.23**

2.8.3 Results

The table below displays a comparative summary of the real installation reports alongside the Toolkit's estimated values. Additionally, the estimation errors are calculated to assess the Toolkit's performance and reliability in replicating actual renewable energy generation in port environments.

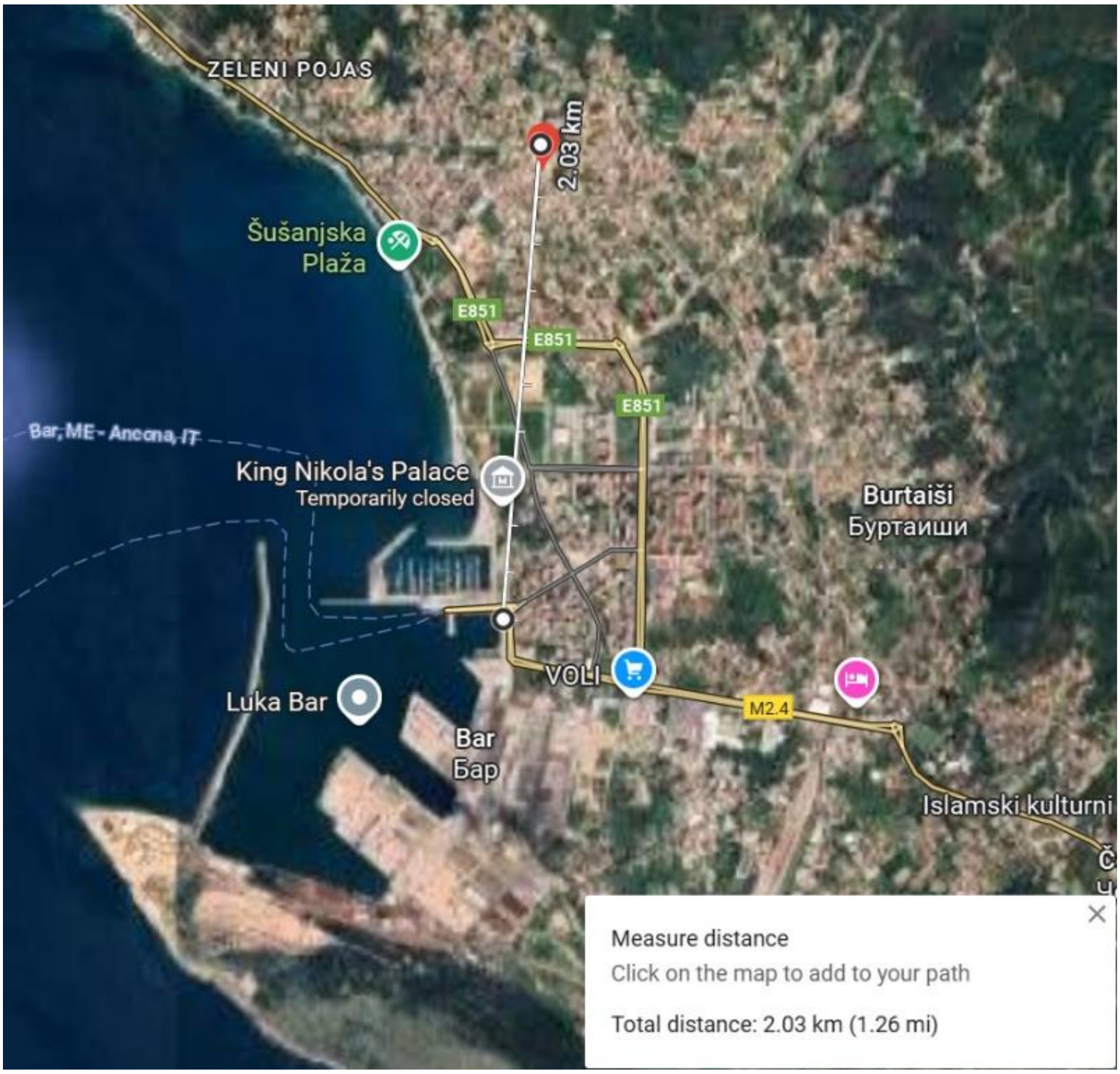
$$\text{Error Margin} = \frac{|\text{Real Value} - \text{Estimated Value}|}{\text{Real Value}} \times 100$$

Port of Rijeka	Real Value (MWh)	Toolkit Value (MWh)	Error (%)
Port of Rijeka PPS	92.15	109.23	-18.53

2.9 Port of Bar

2.9.1 Real Values or Previous Studies

Within the Port of Bar area, there are currently no existing solar panel installations that could serve as a benchmark for comparison. To address this limitation, the analysis will reference performance data from a 5kWp solar power plant (private owners) located 2.03 km from the designated site for the solar canopies. At the moment, we only have data on the plant's installed capacity and electricity production. Since the installed capacity of the reference plant is 5 kWp, we will scale its production data by a factor of 10 to reflect the planned 50 kWp capacity of our solar power plant.

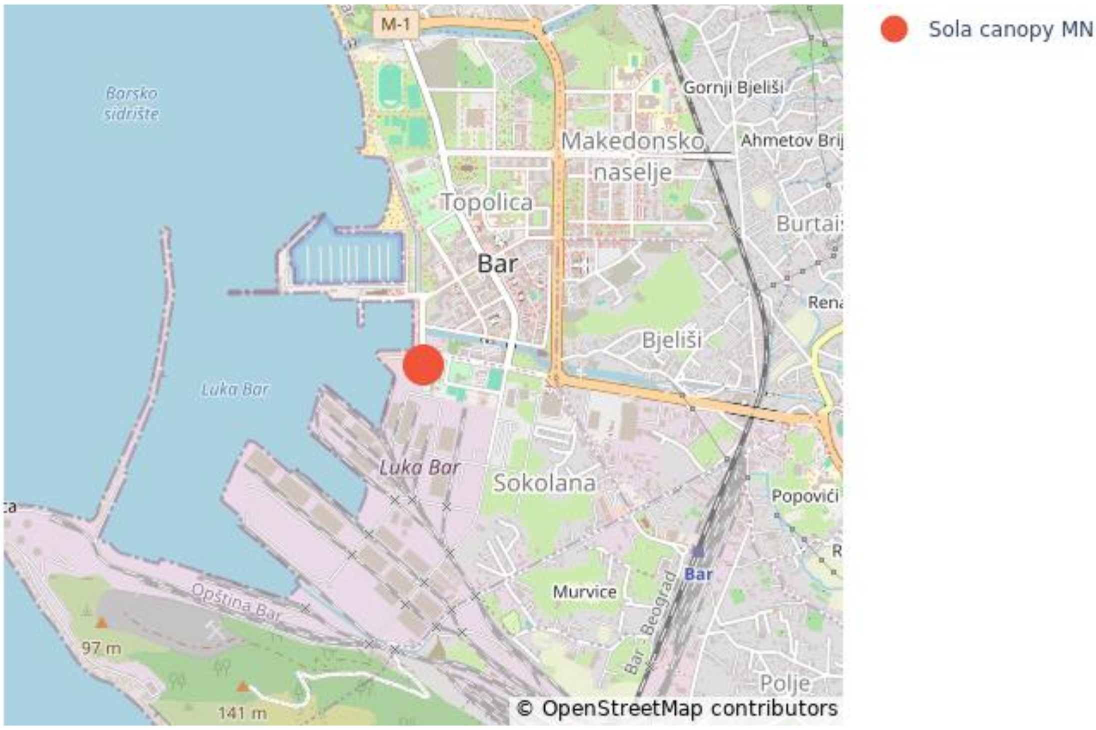


- **Total Installed Capacity:** 5 kWp

The data of the installation: Energy generated in 2024:

2024	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL (MWh)
Energy (KWh) 5kWp	0.45	0.57	0.73	0.95	0.96	1.02	1.18	1.06	0.80	0.67	0.48	0.35	**9.22**
50 kWp production	4.47	5.70	7.26	9.49	9.61	10.21	11.80	10.60	7.97	6.73	4.85	3.54	**92.2**

2.9.2 Toolkit Results



Solar Energy Estimation

In this section, please provide the **solar energy estimates** generated by the Toolkit for the installation or study you are analysing.

id	month	E_d	E_m	H(i)_d	H(i)_m	SD_m
134	1	131,04	4064,97	3,1	95,99	768,95
134	2	149,24	4175,99	3,57	100,05	891,8
134	3	186,55	5792,15	4,59	142,32	964,6
134	4	222,95	6685,77	5,62	168,74	745,29
134	5	236,6	7337,33	6,08	188,51	576,03
134	6	256,62	7688,59	6,73	201,9	433,16
134	7	270,27	8373,82	7,17	222,37	290,29
134	8	262,99	8160,88	6,98	216,29	378,56
134	9	222,95	6681,22	5,78	173,42	466,83

134	10	183,82	5689,32	4,62	143,07	693,42
134	11	133,77	4007,64	3,26	97,72	761,67
134	12	123,76	3830,19	2,91	90,31	1052,87

2024	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL (MWh)
Energy (MWh)	4.06	4.18	5.79	6.69	7.34	7.69	8.37	8.16	6.68	5.69	4.01	3.83	72.49

2.9.3 Results

The table below displays a comparative summary of the real installation reports alongside the Toolkit's estimated values. Additionally, the estimation errors are calculated to assess the Toolkit's performance and reliability in replicating actual renewable energy generation in port environments.

$$\text{Error Margin} = \frac{|\text{Real Value} - \text{Estimated Value}|}{\text{Real Value}} \times 100$$

Port of Bar	Real Value (MWh)	Toolkit Value (MWh)	Error (%)
Solar canopy	92.2	72.49	21.3%

The high margin may be due to the limited knowledge of all characteristics of the private solar plant used for comparison, given the absence of a similar solar system within the Port of Bar area.

3. Results

The validation of the RENEWPORT Toolkit across the consortium provided a comprehensive overview of its performance under real and projected operating conditions in different Mediterranean ports. Each partner contributed either actual energy production data or figures from previous feasibility studies, which were compared with the Toolkit's estimations. This benchmarking exercise is crucial for assessing the accuracy of the tool and identifying potential limitations associated with its use.

Overall, the Toolkit demonstrated a strong ability to approximate real-world performance, with most deviations falling within a range that is considered acceptable for renewable energy simulation studies. Photovoltaic (PV) installations generally showed errors between 4% and 11%, reflecting the inherent variability in solar resource conditions and system-specific parameters, such as panel orientation, shading, and maintenance conditions. Wind installations exhibited higher discrepancies, which aligns with the fact that wind power generation is more sensitive to microclimatic variations and modelling assumptions.

It is important to note that **a certain margin of error is normal** in any renewable energy generation estimate. Specifically, the **PVGIS and Windatlas** estimation (used by the Toolkit for calculations) is based on the average solar radiation and wind speed data from recent years, which may not fully account for seasonal or yearly variations. Additionally, in renewable energy generation, there is always a considerable degree of **uncertainty** due to factors such as panel orientation, local climate conditions, and even shading or system efficiency losses.

Partner	Location	Real Value (MWh)	Toolkit Value (MWh)	Error (%)
APV	Príncipe Felipe Dock	2,416.17	2,204.64	8.75
APV	Port of Gandía	572.57	548.57	4.19
PNANTS	Port of Piombino PV	1,152.80	1,029.89	10.66
PNANTS	Port of Livorno Wind	242.50	192.73	20.52
PNAEAS	Trieste "UPS" PV	8.01	16.02	-100.0
PNAEAS	Trieste "MERIDIAN" PV	9,262.00	10,789.00	-16.49
Luka Koper	Container Terminal PV	171.00	165.48	3.23
DPA	Tirana PV (Ministry of Finance)	310.00	340.42	-9.81
CCI du Var	Toulon PIF VL PV	63.17	66.32	-4.99
CCI du Var	Toulon CENAQ PV	1,300.00	1,471.52	-13.19

PPA	Piraeus – Neo Ikonio	372.80	414.59	-11.21
PRA	Port of Rijeka	92.15	109.23	-18.53
POB	Port of Bar	92.2	72.49	21.38
Average Error	–	–	–	**18.69**
Average Error Excluding Extreme Outlier	–	–	–	**11.91**

The validation process of the RENEWPORT Toolkit across different Mediterranean ports demonstrates that the tool is a reliable instrument for supporting renewable energy planning in port environments. When applied to real-world or previously studied installations, the Toolkit showed an overall ability to reproduce energy generation values with a reasonable level of accuracy.

For photovoltaic (PV) systems, which represented the majority of the analysed cases, the Toolkit's performance was consistently strong, with deviations typically falling between **4% and 12%**. These values are well within the accepted range for feasibility studies and confirm that the tool can serve as a robust decision-support system for early-stage project development. In contrast, wind energy simulations presented a higher deviation, which is not unexpected given the greater sensitivity of wind energy production to localized weather variations and the assumptions embedded in the simulation model.

The initial dataset included an extreme outlier (Trieste UPS PV, with a deviation of 100%), which was excluded from the global analysis as it resulted from incomplete input data and unique site constraints. Once this anomaly was removed, the **average absolute error across all remaining cases decreased to approximately 11,9%**, a figure that reflects the Toolkit's true predictive capability under normal operating conditions.

These findings underscore the importance of providing accurate and detailed input parameters to achieve reliable results. Cases where azimuth, tilt, or environmental conditions were missing or approximate exhibited larger discrepancies, reinforcing that the tool's effectiveness is closely tied to the quality of the data entered by the user.

In summary, the RENEWPORT Toolkit proves to be an effective and practical solution for guiding Mediterranean ports toward the integration of renewable energy systems. While some refinements, particularly for wind energy modelling, could further improve its precision, the current performance levels are adequate for supporting informed investment decisions and advancing the clean energy transition in the maritime sector.

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RENEWPORT

HARNESSING RENEWABLE ENERGY POTENTIAL FOR CLEAN ENERGY TRANSITION OF MED PORTS