Extensive use of net-metering in Crete's region public buildings

Marini Markaki[1*], *Emmanuel* Karapidakis[1], *Yiannis* Katsigiannis[1], *Maria* Apostolaki[2], *Giannis* Kornilakis[1], and *Panagiotis* Floyris[1]

[1]HMU, Electrical and Computer Engineering Department, 71410 Crete, Greece
[2]Region of Crete, Environment & Spatial Planning Directorate, Crete, Greece

Abstract. Net metering and zero feed-in are two different methods used in photovoltaic (PV) installations to manage the excess energy locally produced by consumers. Net metering allows the energy generated by the PV system to be fed back into the grid, and the excess energy is credited to the owner's account. Zero feed-in, on the other hand, involves the use of an inverter that reduces the amount of energy exported to the grid to zero, while still allowing the PV system to generate power for self-sufficiency use. This paper examines the advantages and disadvantages of both net metering and zero feed-in systems, whereas proposes an algorithm for optimal dimensioning of PV considering the relevant load profiles of each examined load demand. The analysis considers factors such as self-sufficiency and rejection of PV production. The results of this study can help stakeholders to make informed decisions when they are obliged to use a zero feed-in scheme for their PV installations.

1 Introduction

Buildings are responsible for about a third of global energy consumption and a quarter of CO_2 emissions [1]. In particular, the building sector is responsible for approximately 40% of primary energy consumption and 36% of CO_2 emissions in the European Union (EU) [2], where about 35% of the buildings are over 50 years old and 75% of the overall stock is energy inefficient [3]. Consequently, the required energy demand, either in the form of thermal energy (mainly oil) or in the form of electricity, results in significant emissions, mainly CO_2 and in addition a significant financial burden due to the high cost of energy [4].

A recent assessment by the International Energy Agency (IEA) regarding the status of the global building sector according to the Sustainable Development Goals (SDGs) identifies that "emissions from buildings appear to have risen again in 2018 for the second year in a row" due to "several factors, including extreme weather that raised energy demand for heating and cooling" and that "enormous potential remains untapped due to the widespread use of less-efficient technologies, a lack of effective policies and insufficient investment in sustainable buildings" [5],[6].

* Corresponding author: marinimarkaki@hmu.gr

To handle this demanding issue, the EU has set binding climate and energy targets for 2030: reducing greenhouse gas emissions by at least 40%, increasing energy efficiency by at least 32.5%, and increasing the share of renewable energy to at least 32% of EU energy use [7]. In the EU, since 2020 all new buildings are obliged to follow in all the aspects to achieve nearly zero energy consumption [8], [9].

Considering the complex framework and the large variety of buildings, a careful planning of interventions is required to pursue the energy performance objectives of public buildings promoted by the EU, accelerating renovation of the existing stock, and moving towards nearly zero energy and net zero carbon emissions buildings [10], in accordance with the National Energy Efficiency Action Plans (NEEAPs) and the NECPs.

A range of suitable energy saving measures which are already available and have applied to existing buildings, aiming to reduce energy, can be grouped into three categories:

- building envelopes (e.g., thermal insulation, suitable opening systems, passive solar systems, green roofs);
- heating and electricity loads (HVAC, electric lighting and appliances) efficiency upgrade;
- the rational use of the building (e.g., energy management);
- exploitation of RES Technologies.

A main difference between an energy-efficient building and a self-sufficient building is that in the first case a reduced energy has been succeeded, using the first three measures of the previous list. Consequently, a self-sufficient building covers the remaining energy (after the energy saving interventions) with utilization of available renewable energy sources. The most common technologies are the following:

- Photovoltaics;
- Wind turbines;
- Solar thermal heaters;
- Geothermal heat pumps.

Therefore, in order to satisfy the remaining energy demand and to maximize energy production in buildings by means of renewable sources, the extensive use of net-metering method is proposed [11]. In this paper, an analysis of extensive utilization of net metering policy instrument in all the public buildings of Crete regions is carried out. It has to be noticed that according to the current version of the Greek Legislative Framework that is related to PV net-metering, which has been updated a few months ago, batteries can also be included in PV net-metering installations, and the maximum rated power of their inverter (in kVA) cannot exceed the installed power of the PVs (in kW_p). Because our analysis is limited at the end of year 2023, we have not considered the impact of batteries in our study.

2 Case study analysis

In this section, an analysis based on measured electricity consumption data for the years 2019, 2020 and 2021 has been carried out for all the municipalities on the island of Crete.

The electrical load of the examined public buildings and premises of Region of Crete (RoC) can be categorized in, water supply (WP), street lighting (SL), technical & maintenance (TN), small offices (SO), and large premises (PR). Figure 1 depicts the annual energy demand from 2017 till 2021 of the above-mentioned types.

In 2020, consumption in all cases were less than in 2019, obviously due to COVID pandemic. It must be mentioned that energy demand has been restored in 2021, with the exception of SO and SL. The first is due to further installation of LED lights and the second due to reduced attendance in this kind of offices, even after lockdowns.

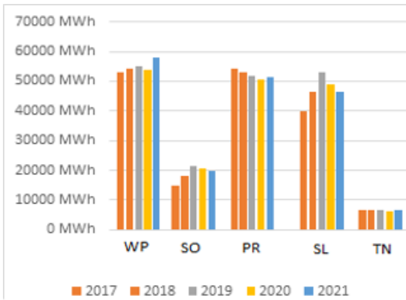

Fig. 1. Annual electric energy consumption per type.

Following, Table 1 presents the data of all the public energy meters, which count 11,636 in total for the 24 municipalities of the island. It shows the differences between demand types, the significant consumption of specific types, such as PR, and the variation of electricity prices per kWh that is equal to 95.45 €/MWh. Concluding, public buildings in RoC have the biggest share of energy (38.9%) and have the highest share in cost (50.3%), as it is shown in Figure 2.

Table 1. Consumption (in MWh) per Area and per Type of Provision for the year 2021.

Type of Service	Number of Meters	Consumption (MWh)	Total Cost (€)	Price (€/MWh)
Technical	23	7,881.94	1,234,215	156.59
Pumps	715	57,922.56	7,160,765	123.63
Small Offices	3626	20,005.98	3,071,254	148.61
Premises	982	51,358.38	11,251,547	219.08
Street Lighting	6290	46,469.76	5,791,571	124.63

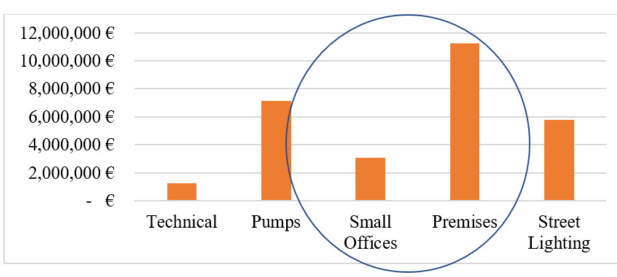

Fig. 2. Annual electricity cost per demand type in 2021.

Furthermore, Figure 3 shows that the examined large office premises of Crete's region are preferable to propose and assess any energy saving intervention, due to relatively higher cost of energy, in addition to their high demand share.

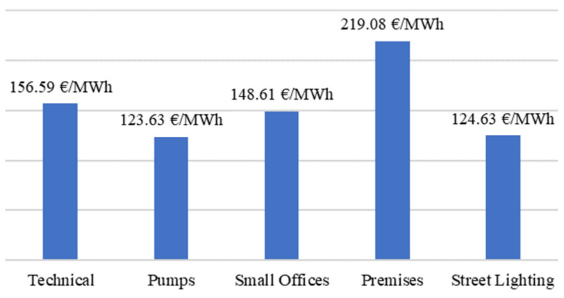

Fig. 3. Descending order for normalized types of provisions.

Additionally, two more features of the examined load profiles that can be extracted are:

- TN is the most demanding type per meter, although they represent a small percentage of them, due to its literally high electricity load demand, which is supplied through medium voltage (MV).
- The 6.290 street lightings meters represent the 54% of totally 11.636 meters, although they require less than 25% of the total annual energy demand, classifying them as the most cost-effective public services in region of Crete. This performance will be improved to its maximum, by replacing all the streetlights with LED technology.

Therefore, the high electricity demand of public buildings should be confronted, in order to improve future energy security and energy sustainability of this sector. Solar energy has been proven as the most appealing source, which can contribute to enhance buildings' sufficiency, resilience and financial completeness, targeting to the required Energy Trilemma.

3 Methodology

In this section, the potential margins for extensive use of net-metering are calculated and evaluated to cover all the corresponding electrical consumptions. Figure 4 presents the trendline of the estimated demand, which is stated as a reference, based on the years under review, for the year 2023. Considering an annual consumption of 194.93GWh in 2023, the main objective is the coverage of this demand by solar energy utilization.

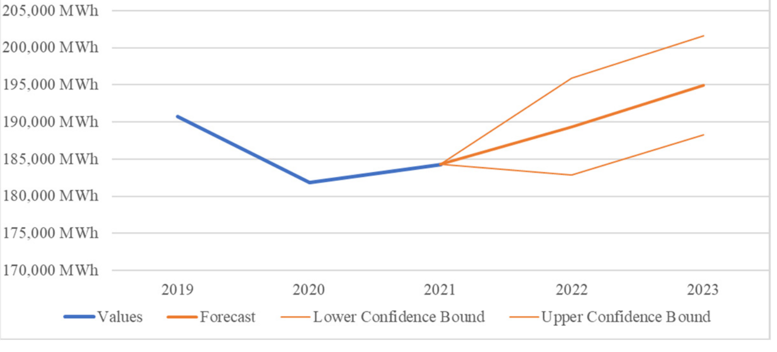

Fig. 4. Consumption forecasting.

The legislation for the installation of PV in the context of net-metering measure is taken into account. The Licensed Power Limit (LPL) of each supply is an important feature for any study of this kind.

Therefore, in order LPL of all the examined meters to be calculated, this study had used data from the corresponding payments. This was necessary to evaluate the limit of the maximum possible installed PV. The method uses the following two functions. One for the transmission systems charges:

$$LPL = \frac{TN - (C*E)}{P*Y}, \quad (1)$$

where: *TN*, is Transmission Network charge, , is the Consumption, , is the Energy Cost Factor, *P*, is the Power Cost Factor, *Y*, is the Billing Days/365.

One for distribution grid charges:

$$LPL = \frac{DN - (C*E)}{P*Y}, \quad (2)$$

where: *DN*, is Distribution Grid charge, *C*, is the Consumption, *E*, is the Energy Cost Factor, *P*, is the Power Cost Factor, *Y*, is the Billing Days/365.

It should be mentioned that the calculation of LPL for AGROT is not attainable, because the energy and power cost factors values are zero. The first assessment of the above calculation leads to the fact that PV with a total capacity of 176.93GW could be installed in the Region of Crete as max in the context of net-metering. At this point it is not examined whether the power of 176,94GW covers the energy consumption of Crete. The allocation of supplies by meter's type and level of LPL is presented in Table 2.

Additionally, Table 3 shows in parallel both the maximum required installed capacity of PV systems in order to cover all electrical load demands throughout the Region of Crete, and the calculated LPL. Particularly, the required PV power to cover all electricity consumption in 2023, is 125.76MW.

At this point it should be mentioned that it was considered a capacity factor equal to 17.7% (i.e. 1550 kWh/kW), being adjusted by the European GIS [12]. In addition, it should be noted that these PV are subjected to the limitation of each substation available capacity of each local distribution grid.

Table 2. Allocation of Supplies per type and capability.

Tariffs	Agreed Power (kVA)	No Supllies	PV Power Limit (kW)	Total (kW)
G1	8	9	72	127
	15	2	30	
	25	1	25	
G21	8	2,174	17,392	45,697
	15	672	10,080	
	25	729	18,225	
G22	35	368	12,880	75,055
	55	273	15,015	
	85	142	12,070	
	135	134	18,090	
	250	68	17,000	
G23	8	1	8	1,033
	15	1	15	
	25	15	375	
	35	11	385	
	250	1	250	
FOP	8	5,923	47,384	55,024
	15	226	3,390	
	25	143	3,575	
	35	13	455	
	55	4	220	
Totals:		**10,910**	**176,936**	**176,936**

Table 3. Consumption (kWh) and PV Power Limits per Regional Unit for the year 2023.

Regional Unit	Consumption (kWh) 2021	Predicted Consumption (kWh) 2023	PV POWER (kW)	Agreed Power (A.P.)(kVA)	PV Power Limit (kW)
Heraklion	84,778,777	88,030,185	56,793.667	67,060.000	67,060.000
Chania	47,909,722	48,310,735	31,168.216	49,008.000	49,008.000
Rethymno	23,127,555	25,030,990	16,149.026	32,213.000	32,213.000
Lasithi	28,484,157	31,587,414	20,378.976	28,655.000	28,655.000
Total:	**184,300,211**	**192,959,323**	**124,489.886**	**176,936.000**	**176,936.000**

Figure 5 shows the geographical dispersion of the proposed installed capacity per regional units of Crete Island. In the rest of the paper Heraklion will be referred to as Area 1, Chania as Area 2, Rethymno as Area 3 and Lasithi as Area 4.

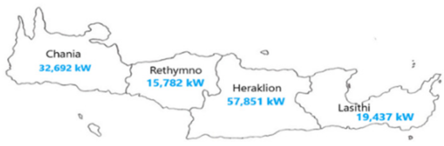

Fig. 5. Geographical dispersion of the proposed PV per area.

The same methodology is carried out for the calculation and evaluation of the installation margins potential, in the geographical subunits of each Area separately. In this way, a more accurate and detailed analysis is achieved for the determination of the maximum installed capacity limits of PV for the energy coverage of the respective consumptions, in accordance with the specific energy demands. According to the provided data, four forecasts were made, as shown in the following figures (Figure 6 to Figure 9)

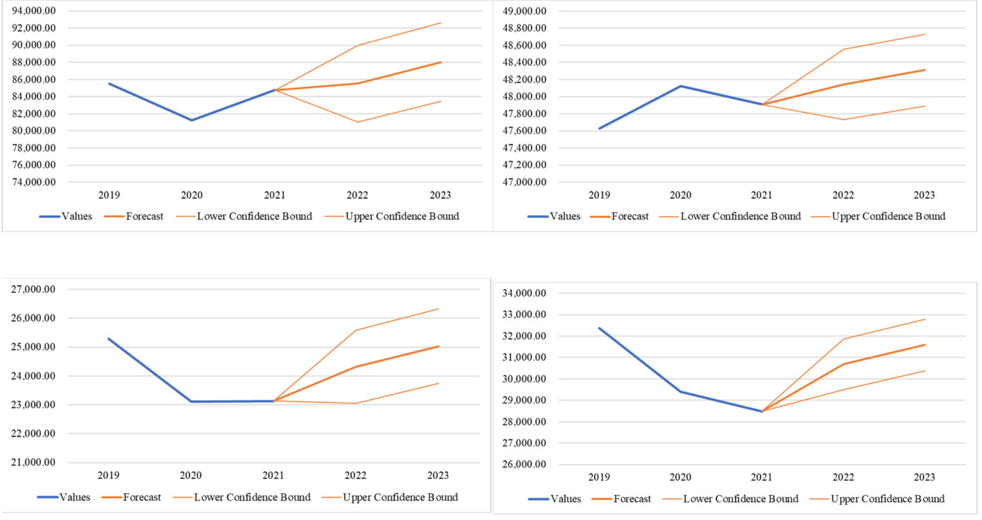

Fig. 6. Demand forecast for (a) Area 1, (b) Area 2, (c) Area 3 and (d) Area 4.

At this point, it is noted that the predicted consumption of the year 2023 according to the first analysis (made for the whole of Crete) was 194.93GWh while the current analysis (per Regional Unit of Crete) it results to 192.96GWh. There is a difference of 1.97GWh, concluding that the more accurate a study is, the more approximate and realistic our results will be.

Subsequently, according to the carried-out calculations, four estimated values are derived as the total maximum power of PV systems needed in the context of net-metering. More specifically, about Areas 1, 2, 3 and 4, the total power of PV systems that could be installed are 67.06MW, 49.01MW, 32.21MW and 28.65MW, respectively. Cumulatively, the total power of PV adds to 176.93MW. The following Tables 4 to 7 present the aforementioned results.

Table 4. Allocation of Supplies per A.P. and Capability for Area 1.

Tariffs	Agreed Power (kVA)	No Supplies	PV Power Limit (kW)	Total (kW)
G1	8	5	40	40
G21	8	842	6,736	19,976
	15	331	4,965	
	25	331	8,275	
G22	35	155	5,425	30,855
	55	138	7,590	
	85	59	5,015	
	135	45	6,075	
	250	27	6,750	
G23	15	1	15	160
	25	3	75	
	35	2	70	
FOP	8	1,793	14,344	16,029
	15	29	435	
	25	43	1,075	
	35	5	175	
Totals:		3,809	67,060	67,060

Table 5. Allocation of Supplies per A.P. and Capability for Area 2.

Tariffs	Agreed Power (kVA)	No Supplies	PV Power Limit (kW)	Total (kW)
G1	8	4	32	57
G21	25	1	25	
	8	506	4,048	9,223
	15	80	1,200	
G22	25	159	3,975	
	35	102	3,570	20,425
	55	63	3,465	
	85	44	3,740	
	135	40	5,400	
G23	250	17	4,250	
	25	2	50	50
	8	2,071	16,568	19,253
FOP	15	88	1,320	
	25	41	1,025	
	35	5	175	
	55	3	165	
Totals:		3,223	49,008	49,008

Table 6. Allocation of Supplies per A.P. and Capability for Area 3.

Tariffs	Agreed Power (kVA)	No Supplies	PV Power Limit (kW)	Total (kW)
G1	15	2	30	30
G21	8	551	4,408	10,108
	15	150	2,250	
	25	138	3,450	
G22	35	60	2,100	13,350
	55	40	2,200	
	85	24	2,040	
	135	26	3,510	
	250	14	3,500	
G23	25	9	225	790
	35	9	315	
	250	1	250	
FOP	8	915	7,320	7,935
	15	8	120	
	25	17	425	
	35	2	70	
Totals:		1,966	32,213	32,213

Table 7. Allocation of Supplies per A.P. and Capability for Area 4.

Tariffs	Agreed Power (kVA)	No Supplies	PV Power Limit (kW)	Total (kW)
G21	8	275	2,200	6,390
	15	111	1,665	
	25	101	2,525	
G22	35	51	1,785	10,425
	55	32	1,760	
	85	15	1,275	
	135	23	3,105	
	250	10	2,500	
G23	8	1	8	33
	25	1	25	
FOP	8	1,144	9,152	11,807
	15	101	1,515	
	25	42	1,050	
	35	1	35	
	55	1	55	
Totals:		1,909	28,655	28,655

Table 8 shows in parallel both the maximum required capacity of PV systems in order to cover all the electrical demands, and the limits due to LPL. In total, the required PV capacity, which is necessary to cover all energy consumption amounts to 124.49MW.

Table 8. Consumption and PV Power per Area in 2023.

Regional Unit	Consumption (kWh) 2021	Predicted Consumption (kWh) 2023	PV POWER (kW)	Agreed Power (A.P.)(kVA)	PV Power Limit (kW)
Heraklion	84,778,777	88,030,185	56,793.667	67,060.000	67,060.000
Chania	47,909,722	48,310,735	31,168.216	49,008.000	49,008.000
Rethymno	23,127,555	25,030,990	16,149.026	32,213.000	32,213.000
Lasithi	28,484,157	31,587,414	20,378.976	28,655.000	28,655.000
Total:	**184,300,211**	**192,959,323**	**124,489.886**	**176,936.000**	**176,936.000**

At this point similarly mentioned above, it should be mentioned that it was considered a capacity factor equal to 17.7% (i.e. 1550 kWh/kW). In addition, it should be noted that these PV installations are subject to the limitation of each substation of the local distribution grids.

4 Results

Generally, to evaluate an investment, various indices must be considered that determine whether it is profitable or not over a predetermined period of time. Such indices are Net Present Value (NPV), Internal Rate of Return (IRR) and Payback Period (PBP).

The CAPEX of PV is considered equal to 1,000€ per kWp. For project A, an investment for the total coverage of the predicted consumption in 2023 (i.e. 192,9GWh), a total of 124,5MWp in PV is required, which amounts to a total CAPEX equal to 124,490,000€. At the same time, for project B, an investment for the total coverage of the projected consumptions in 2023 for each category of tariffs, the total costs for each investment are presented based on demand type in Table 9.

Table 9. Investment Cost per public service type.

Category	Consumption 2023 (kWh)	kWp 2023	Investment Cost (€)
Agricultural	60,643,974.98	39,125	39,125,000.00
Industrial	8,252,273.44	5,324	5,324,000.00
Residential	45,036.01	29	29,000.00
Commercial	75,364,752.64	48,623	48,623,000.00
Street Lighting	48,653,285.94	31,389	31,389,000.00
Total	**192,959,323.00**	**124,490**	**124,490,000.00**

Mainly, an investment is a capital commitment that is expected to bring additional capital to the investor in a predetermined period of time. More specifically, the investment consists of a sequence of Free Cash Flow (FCF). Cash flows are divided into cash inflows and outflows, the difference between them constitutes the Free Cash Flow (FCF).

$$FCF_i = Cash\ inflows_i - Cash\ outflows_i. \quad (3)$$

Also, in order to calculate the FCF, an average Degradation Rate of photovoltaics has been applied and the lifetime of the panels are considered to be twenty years. The degradation rate is the annual decrease of a photovoltaic panel's efficiency, due to overheating of photovoltaic cells, resulting to the alteration of the structure of their materials. Depending on the environment's temperature or the area of installation of the panels, the degradation rate ranges from 0.5% and above [13]. In the current application, the degradation rate has been set at 0.5%.

Project A:

This investment project, as mentioned initially, involves the coverage of public energy consumptions of the entire Region of Crete for 2023. In addition, in order to calculate the cash flows, a single cost price of MWh has been set at 157,56 €/MWh, which is the average of the normalized prices of the tariffs. As mentioned before, for an investment to be considered profitable, some rating indicators should be taken into account, as it is shown in Table 10.

Table 10. Financial assessment of Project A.

Year	Production (MWh) with Degradation Rate applied	Cash Flows	Annual Present Values (PV)
		-124,490,000.00 €	-124,490,000.00 €
2023	192,959.50 MWh	30,401,841.22 €	30,100,832.89 €
2024	191,994.70 MWh	30,249,832.02 €	29,653,790.82 €
2025	191,034.73 MWh	30,098,582.86 €	29,213,387.99 €
2026	190,079.56 MWh	29,948,089.94 €	28,779,525.79 €
2027	189,129.16 MWh	29,798,349.49 €	28,352,107.09 €
2028	188,183.51 MWh	29,649,357.74 €	27,931,036.19 €
2029	187,242.59 MWh	29,501,110.96 €	27,516,218.82 €
2030	186,306.38 MWh	29,353,605.40 €	27,107,562.11 €
2031	185,374.85 MWh	29,206,837.37 €	26,704,974.55 €
2032	184,447.98 MWh	29,060,803.19 €	26,308,366.02 €
2033	183,525.74 MWh	28,915,499.17 €	25,917,647.71 €
2034	182,608.11 MWh	28,770,921.68 €	25,532,732.15 €
2035	181,695.07 MWh	28,627,067.07 €	25,153,533.16 €
2036	180,786.59 MWh	28,483,931.73 €	24,779,965.83 €
2037	179,882.66 MWh	28,341,512.07 €	24,411,946.54 €
2038	178,983.24 MWh	28,199,804.51 €	24,049,392.88 €
2039	178,088.33 MWh	28,058,805.49 €	23,692,223.68 €
2040	177,197.89 MWh	27,918,511.46 €	23,340,358.97 €
2041	176,311.90 MWh	27,778,918.91 €	22,993,719.97 €
2042	175,430.34 MWh	27,640,024.31 €	22,652,229.08 €
Opportunity Cost (i) :		**1.00%**	
Net Present Value (NPV) :		**399,701,552.25 €**	
Iternal Rate of Return (IRR) :		**23.60%**	
Payback Period (PBP) :		**4.24 years**	

Project B:

As already mentioned, this investment project targets the coverage of the projected consumptions in 2023 for each demand type separately. Therefore, in this project there is one investment per type, thus giving the investor the choice. In addition, in order to calculate the cash flows, an average normalized price of €/MWh has been determined for each demand type (category of tariffs). Concluding, Tables 11 to 14 below, present the assessment of each investment of project B.

Table 11. Indicators of Project B for TN.

Year	Production (MWh) with Degradation Rate applied	Cash Flows	Annual Present Values (PV)
		-48,623,000.00 €	-48,623,000.00 €
2023	75,365.65 MWh	12,547,153.78 €	12,422,924.54 €
2024	74,988.82 MWh	12,484,418.01 €	12,238,425.66 €
2025	74,613.88 MWh	12,421,995.92 €	12,056,666.86 €
2026	74,240.81 MWh	12,359,885.94 €	11,877,607.45 €
2027	73,869.60 MWh	12,298,086.51 €	11,701,207.34 €
2028	73,500.26 MWh	12,236,596.08 €	11,527,427.03 €
2029	73,132.75 MWh	12,175,413.10 €	11,356,227.62 €
2030	72,767.09 MWh	12,114,536.03 €	11,187,570.78 €
2031	72,403.26 MWh	12,053,963.35 €	11,021,418.73 €
2032	72,041.24 MWh	11,993,693.54 €	10,857,734.30 €
2033	71,681.03 MWh	11,933,725.07 €	10,696,480.82 €
2034	71,322.63 MWh	11,874,056.44 €	10,537,622.19 €
2035	70,966.01 MWh	11,814,686.16 €	10,381,122.85 €
2036	70,611.18 MWh	11,755,612.73 €	10,226,947.76 €
2037	70,258.13 MWh	11,696,834.67 €	10,075,062.40 €
2038	69,906.84 MWh	11,638,350.49 €	9,925,432.76 €
2039	69,557.30 MWh	11,580,158.74 €	9,778,025.34 €
2040	69,209.52 MWh	11,522,257.95 €	9,632,807.14 €
2041	68,863.47 MWh	11,464,646.66 €	9,489,745.65 €
2042	68,519.15 MWh	11,407,323.42 €	9,348,808.83 €
Opportunity Cost (i) :		**1.00%**	
Net Present Value (NPV) :		**167,716,266.05 €**	
Iternal Rate of Return (IRR) :		**25.04%**	
Payback Period (PBP) :		**4.00 years**	

Table 12. Investment indices of Project B for SP and LP.

Year	Production (MWh) with Degradation Rate applied	Cash Flows	Annual Present Values (PV)
		-29,000.00 €	-29,000.00 €
2023	44.95 MWh	7,663.91 €	7,588.03 €
2024	44.73 MWh	7,625.60 €	7,475.34 €
2025	44.50 MWh	7,587.47 €	7,364.32 €
2026	44.28 MWh	7,549.53 €	7,254.95 €
2027	44.06 MWh	7,511.78 €	7,147.20 €
2028	43.84 MWh	7,474.22 €	7,041.06 €
2029	43.62 MWh	7,436.85 €	6,936.49 €
2030	43.40 MWh	7,399.67 €	6,833.47 €
2031	43.18 MWh	7,362.67 €	6,731.98 €
2032	42.97 MWh	7,325.86 €	6,632.00 €
2033	42.75 MWh	7,289.23 €	6,533.51 €
2034	42.54 MWh	7,252.78 €	6,436.47 €
2035	42.33 MWh	7,216.52 €	6,340.88 €
2036	42.11 MWh	7,180.43 €	6,246.71 €
2037	41.90 MWh	7,144.53 €	6,153.94 €
2038	41.69 MWh	7,108.81 €	6,062.54 €
2039	41.49 MWh	7,073.27 €	5,972.51 €
2040	41.28 MWh	7,037.90 €	5,883.81 €
2041	41.07 MWh	7,002.71 €	5,796.42 €
2042	40.87 MWh	6,967.70 €	5,710.34 €
Opportunity Cost (i) :		**1.00%**	
Net Present Value (NPV) :		**103,141.98 €**	
Iternal Rate of Return (IRR) :		**25.68%**	
Payback Period (PBP) :		**3.91 years**	

Table 13. Investment indices of Project B for WP.

Year	Production (MWh) with Degradation Rate applied	Cash Flows	Annual Present Values (PV)
		-5,324,000.00 €	-5,324,000.00 €
2023	8,252.20 MWh	1,376,143.20 €	1,362,518.02 €
2024	8,210.94 MWh	1,369,262.49 €	1,342,282.61 €
2025	8,169.88 MWh	1,362,416.17 €	1,322,347.72 €
2026	8,129.03 MWh	1,355,604.09 €	1,302,708.89 €
2027	8,088.39 MWh	1,348,826.07 €	1,283,361.73 €
2028	8,047.95 MWh	1,342,081.94 €	1,264,301.90 €
2029	8,007.71 MWh	1,335,371.53 €	1,245,525.14 €
2030	7,967.67 MWh	1,328,694.67 €	1,227,027.24 €
2031	7,927.83 MWh	1,322,051.20 €	1,208,804.06 €
2032	7,888.19 MWh	1,315,440.95 €	1,190,851.53 €
2033	7,848.75 MWh	1,308,863.74 €	1,173,165.61 €
2034	7,809.51 MWh	1,302,319.42 €	1,155,742.36 €
2035	7,770.46 MWh	1,295,807.82 €	1,138,577.87 €
2036	7,731.61 MWh	1,289,328.79 €	1,121,668.30 €
2037	7,692.95 MWh	1,282,882.14 €	1,105,009.86 €
2038	7,654.48 MWh	1,276,467.73 €	1,088,598.82 €
2039	7,616.21 MWh	1,270,085.39 €	1,072,431.51 €
2040	7,578.13 MWh	1,263,734.97 €	1,056,504.31 €
2041	7,540.24 MWh	1,257,416.29 €	1,040,813.65 €
2042	7,502.54 MWh	1,251,129.21 €	1,025,356.03 €
Opportunity Cost (i) :		**1.00%**	
Net Present Value (NPV) :		**18,403,597.16 €**	
Iternal Rate of Return (IRR) :		**25.08%**	
Payback Period (PBP) :		**4.00 years**	

Table 14. Investment Indices of Project B for SL.

Year	Production (MWh) with Degradation Rate applied	Cash Flows	Annual Present Values (PV)
		-31,389,000.00 €	-31,389,000.00 €
2023	48,652.95 MWh	6,063,673.57 €	6,003,637.20 €
2024	48,409.69 MWh	6,033,355.20 €	5,914,474.27 €
2025	48,167.64 MWh	6,003,188.43 €	5,826,635.55 €
2026	47,926.80 MWh	5,973,172.49 €	5,740,101.35 €
2027	47,687.16 MWh	5,943,306.62 €	5,654,852.32 €
2028	47,448.73 MWh	5,913,590.09 €	5,570,869.37 €
2029	47,211.49 MWh	5,884,022.14 €	5,488,133.68 €
2030	46,975.43 MWh	5,854,602.03 €	5,406,626.75 €
2031	46,740.55 MWh	5,825,329.02 €	5,326,330.31 €
2032	46,506.85 MWh	5,796,202.37 €	5,247,226.40 €
2033	46,274.31 MWh	5,767,221.36 €	5,169,297.29 €
2034	46,042.94 MWh	5,738,385.26 €	5,092,525.55 €
2035	45,812.73 MWh	5,709,693.33 €	5,016,893.98 €
2036	45,583.66 MWh	5,681,144.86 €	4,942,385.66 €
2037	45,355.75 MWh	5,652,739.14 €	4,868,983.89 €
2038	45,128.97 MWh	5,624,475.44 €	4,796,672.25 €
2039	44,903.32 MWh	5,596,353.07 €	4,725,434.54 €
2040	44,678.81 MWh	5,568,371.30 €	4,655,254.82 €
2041	44,455.41 MWh	5,540,529.44 €	4,586,117.37 €
2042	44,233.13 MWh	5,512,826.80 €	4,518,006.72 €
Opportunity Cost (i) :		**1.00%**	
Net Present Value (NPV) :		**73,161,459.27 €**	
Iternal Rate of Return (IRR) :		**18.20%**	
Payback Period (PBP) :		**5.40 years**	

The investments with the highest IRR, are the most profitable and the most likely to be chosen. So, the most profitable investment is the demand type of public buildings (both SP and LP) of project B.

5 Conclusions

Extensive use of net-metering method in public buildings is a promising solution towards the energy transition and additionally an attractive investment.

In the examined public facilities of Crete's region, LP and SP are the most preferable to introduce electricity saving and/or production measures, due to comparatively high electricity cost. Considering a specific demand forecasting for 2023 which is 194.93GWh, required PV capacity to cover it all should be 125MW, approximately.

Future research will focus on evaluating the total impact of more specific types of public buildings (schools, sport facilities, campuses) towards the energy transition of the island, as well as on studying the impact of batteries in net-metering installations.

This work received financial support from the project "Enhancing resilience of Cretan power system using distributed energy resources (CResDER)" (Proposal ID: 03698) financed by the Hellenic Foundation for Research and Innovation (H.F.R.I.) under the Action "2nd Call for H.F.R.I. Research Projects to support Faculty Members and Researchers".

References

1. Y. Xing, N. Hewitt, P. Griffiths, Ren. Sust. En. Rev. **15,** 3229-3236 (2011)
2. M.González-Torres, L.Pérez-Lombard, J. F. Coronel, I. R. Maestre, D. Yanc, En. Rep. **8**, 626-637 (2022)
3. European Commission, Clean energy for all Europeans package (2019), available athttps://ec.europa.eu/energy/topics/energy-strategy/clean-energy-all-europeans_en (accessed on 13 Feb 2023)
4. European Commission, Energy Performance of Buildings Directive (2018), available at https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en (accessed on 13 Feb 2023)

5. Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (2010), available at https://eur-lex.europa.eu/eli/dir/2010/31/oj (2010) (accessed on 13 Feb 2023)
6. A. Kumar, H. C. Borah, U. Goswami, (2021). Grid Connected Rooftop Solar Photo-Voltaic Power Plants Programme in India: *A Review of State Solar Rooftop Policies, Net Metering Regulations, Challenges and Way Forward*, advances in Smart Communication Technology and Information Processing, OPTRONIX, India (2021)
7. International Energy Agency, Tracking buildings 2019 (2019).
8. European Commission, Official Journal of European Union 13-35 (2010)
9. R. Dufo-López, J. L. Bernal-Agustín, En. **84**, 684-694 (2015)
10. C. Cooremans, A. Schönenberger, J. Cl. Prod. **230**, 264-275 (2019)
11. W. U. Rehman, A. R. Bhatti, A. B. Awan, I. A. Sajjad, A. A. Khan, R. Bo, S. S. Haroon, S. Amin, I. Tlili, O. Oboreh-Snapps, IEEE Access **8**, 170364-170388 (2020)
12. Photovoltaic Geographical Information System, avalable online: https://re.jrc.ec.europa.eu/pvg_tools/en/ (accessed on 13 Feb 2023)
13. NREL Transforming ENERGY, available online: https://www.nrel.gov/state-local-tribal/blog/posts/stat-faqs-part2-lifetime-of-pv-panels.html (accessed on 13 Feb 2023)