StoRES

Promotion of higher penetration of Distributed PV through storage for all

Priority Axis 2: Fostering low-carbon strategies and energy efficiency in specific MED territories: cities, islands and remote areas

2.2: To increase the share of renewable local energy sources in energy mix strategies and plans in specific MED territories

Deliverable n°: **4.4.1**

Deliverable Name: **Design and Circulation of a PV+Storage Monitor**

Project co-financed by the European Regional Development Fund

1. Document Info

Project Name	Promotion of higher penetration of Distributed PV through storage for all (StoRES)
Funding Scheme	ERDF
Work Package Number	WP4
Name of Work Package	Transferring
Number	D4.4.1
Title	Design and Circulation of a PV+Storage Monitor
Dissemination Level	PU
Date	23.10.2019
Authors	UCY
Contributors / Reviewers	All partners have reviewed the document before finalised
Status	Final

2. Document History

Date	Author	Action	Status
17.01.2019	UCY/AUTH	Document creation	Draft
21.01.2019	UCY/AUTH	Document update	Draft
11.02.2019	UCY/AUTH	Document update	Draft
06.03.2019	UCY/AUTH	Document update	Draft
22.04.2019	UCY/AUTH	Document update	Draft
09.05.2019	UCY/AUTH	Document update	Draft
16.07.2019	UCY/AUTH	Document update	Draft
29.07.2019	UCY/AUTH	Document update	Draft
22.08.2019	UCY/AUTH	Document update	Draft
02.09.2019	UCY/AUTH	Document update	Draft
11.09.2019	UCY/AUTH	Document update	Draft
18.10.2019	UCY/AUTH	Document update	Draft
21.10.2019	AURA-EE	Official review	Draft
21.10.2019	UNICA	Official review	Draft
23.10.2019	UCY/AUTH	Document finalisation	Final

3. Contents

4. List of Figures

5. List of Tables

6. Project Summary

The project addresses the development of an optimal policy for the effective integration of Renewable Energy Sources (RES) and Energy Storage Systems (ESS). The primary challenge is to achieve increased penetration of RES and predominantly Photovoltaics (PV), in the energy mix of islands and rural areas in the Mediterranean (MED) region without compromising grid stability. The main objective of StoRES is to boost self-consumption in the MED region with the integration of optimal storage solutions. Testing coupled PV-ESS solutions in different pilot sites and taking into account local particularities for optimization, current barriers concerning grid reliability with higher RES deployment will be eliminated. In addition to this, the development and integration of the proposed solution at both residential and community levels and the application of different policy scenarios will lift the barriers related to the grid integration of ESS and will extend the practical knowledge about this technology. It is expected that all the shortcomings regarding the intermittent nature of PV energy for increased penetration into the energy mix will be addressed whilst maintaining smooth operation of the grid.

The project started on the 1st of November 2016 and is expected to be completed within 36 months.

7. Introduction to Deliverable 4.4.1

In this deliverable, the design and circulation of a report that consists of an analysis of the proposed ESS solution and results from the implementation of the developed Tool in Work Package (WP) 3 is presented. In Deliverable 3.8.1, an Online Storage Optimisation Tool was developed providing information to stakeholders regarding optimal self-consumption and ESS sizing for a given location. It was made with replicability in mind for broader geographical use.

The PV+Storage Monitor is designed based on the PV Grid Parity Monitor issued by CREARA Energy Experts [1]. It consists of an economic evaluation of the storage integration in the different MED countries participating in the project, utilising the Levelized Cost of Use (LCOU) indicator with a direct focus on residential systems. LCOU coefficients regarding hybrid PV+Storage systems have been calculated within this report for six participating project countries with the use of the abovementioned tool [2]. The calculation results were then used to evaluate the viability of a hybrid PV+Storage system in the energy market under a future pure self-consumption policy and finally, to assess the proximity of a PV+Storage installation to Grid Parity. This work was also submitted as a paper at a peer-reviewed academic journal [2], aiming at the further dissemination of the PV+Storage Monitor.

8. Methodology

8.1 Description of the methods used

The Levelized Cost of Electricity (LCOE) term is a method commonly used to evaluate the economic viability of Distributed Generation (DG) projects and specifically, the cost of a generating asset on the power system [3, 4]. Its main aim is the comparison of different technologies with different features such as installation capacity, capital cost, lifetime, payback period and risk [3, 4]. The LCOE is a way to economically assess the total cost of a power generation system (from the installation to its full operation) through its lifetime, divided by the total generated energy over that period. It can also be considered as the minimum cost at which generated electricity must be sold in order to achieve break-even pricing over the lifetime of a system [3].

With regards to solar PV systems, the LCOE is generally considered as an indicator of the competitiveness of the PV technology in the energy market [3]. Although the capital cost of an investment in a power-generating project is of significant importance and usually holds the highest share of the system's total cost, the most important parameter in order to assess the competitiveness of the project is the LCOE indicator. Thus, the main aim of an investment in DG projects and especially in solar PV systems is to reduce the LCOE indicator, rather than just aiming at the reduction of the capital costs [5].

Relating to the exploitation of energy storage in the power network, the LCOE can be used by policy makers and other interested entities to consider the type and sizing of a storage technology, its discount rate etc. [3]. As mentioned above, similarly to the case of power-generating projects, although the capital cost of storage is of significant importance, the most important parameter is the LCOE and it should be assessed with great attention. The LCOE of hybrid PV+Storage systems has not been given a proper treatment and has not been clearly justified [3], as most efforts until now were focused on the LCOE analysis only for the storage component, without taking into consideration the cost at a system level and especially without considering the energy exchange between the storage asset and the generation unit. Thus, this report aims to provide an indicator on the definition of PV+Storage Grid Parity. This is done by providing an estimation of the corresponding LCOU term for six participating project countries, namely Cyprus, France, Greece, Italy, Portugal and Spain [2]. As the LCOE constitutes a generalized term, it should be modified on each occasion, depending on the policy scheme considered. The term LCOU is further justified in subsection 8.3. The comparison results provide an insight into the difference of the cost of a hybrid PV+Storage system when compared to the current electricity price in the countries under study.

8.2 Definition of PV+Storage Grid Parity

The classic PV Grid Parity is reached when the PV LCOE is lower than the retail electricity price. Similarly, the PV+Storage Grid Parity is reached when the PV+Storage LCOE is lower than the retail electricity price. However, the PV+Storage LCOE indicator is not intended to show the actual economic viability of an investment, since other parameters must be also considered for the case of a PV+Storage system, such as the Self-Consumption Rate (SCR), which indicates the on-site consumption of PV generation. Thus, the PV+Storage LCOU term is used for the purposes of this report as it is considered more appropriate. The PV+Storage LCOU can be an indicator that fewer incentives are required for a specific country towards a pure self-consumption policy that includes no compensation for the surplus of produced energy [2]. In this context, the report aims to provide a comparison between the LCOU price of a PV+Storage system and the retail price when purchasing electricity directly from the grid.

Furthermore, an illustration of the PV+Storage Grid Parity in the participating countries is included in this report. This is presented with the use of quantitative and qualitative scales to assess the viability of the PV+Storage LCOU to the current retail electricity price and the national support for PV self-consumption, as it can be seen in Figures 1 and 2 respectively.

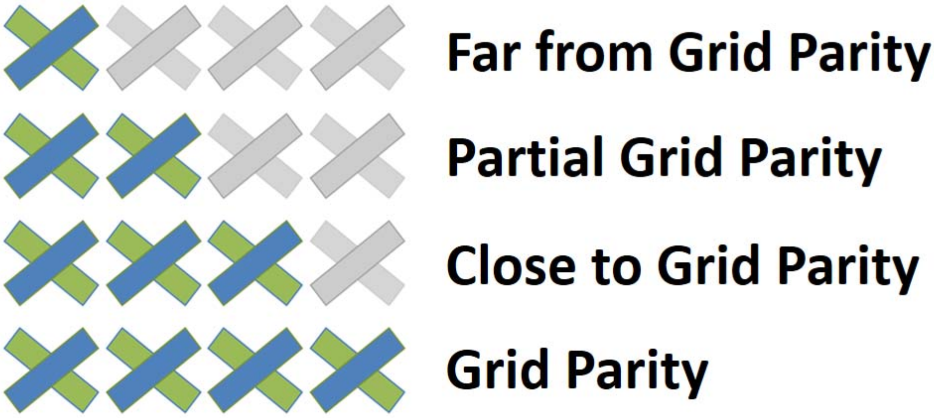

Figure 1: Quantitative scale for the assessment of the PV+Storage Grid Parity proximity.

Where:

- **Far from Grid Parity:**
  For up to 20% of the examined cases, the corresponding LCOU indicator is lower than the current retail electricity price.
- **Partial Grid Parity:**
  For 21-70% of the examined cases, the corresponding LCOU indicator is lower than the current retail electricity price.
- **Close to Grid Parity:**
  For 71-85% of the examined cases, the corresponding LCOU indicator is lower than the current retail electricity price.

- **Grid Parity:**
  For more than 85% of the examined cases, the corresponding LCOU indicator is lower than the current retail electricity price.

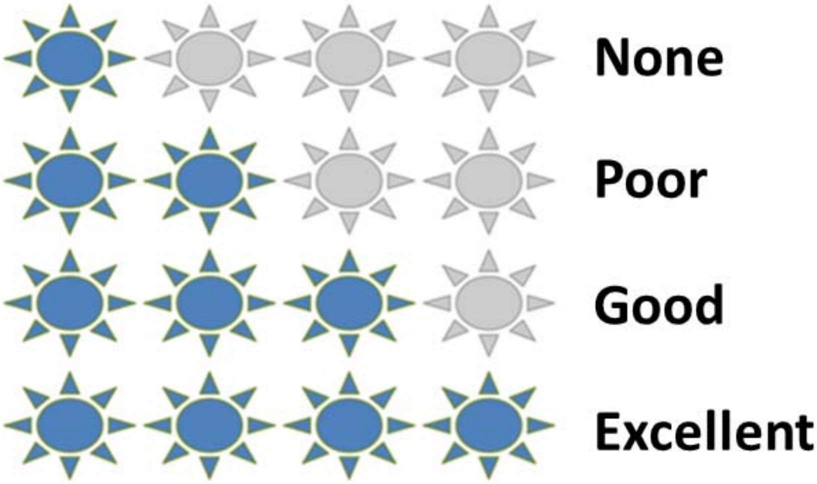

Figure 2: Qualitative scale for the assessment of the national support for PV+Storage systems.

Where:

- **None:**
  A compensation for the excess energy fed into the grid which is higher than or equal to the retail electricity price or a full Net-Metering scheme exists. Self-consumption and thus the use of hybrid PV+Storage systems are not incentivised at all.
- **Poor:**
  A compensation for the excess energy fed into the grid which is lower than the retail electricity price through a Feed-in Tariffs (FiT) scheme exists.
- **Good:**
  No scheme that compensates excess energy exists. Energy exported to the grid is not valued. PV+Storage systems are attractive as the only way to enhance self-consumption and decrease the energy purchased from the grid.
- **Excellent:**
  No scheme that compensates excess energy (Net-Metering, FiTs, etc.) exists, while other incentives are given for the use of PV+Storage systems, such as tax credit, subsidy for investment, etc or a Net-Billing/Time-of-Use (ToU) tariffs scheme exists.

8.3 Determination of PV+Storage LCOU

Classic calculation of LCOE of PV system:

Equation (1) below introduces the classic calculation of the LCOE of a PV system. This equation is best suited for full Net-Metering or FiT schemes, since it does not take into account the grid parameter (i.e. grid interaction).

$$LCOE_{PV} = \frac{CAPEX_{PV} + \sum_{n=1}^{N} \frac{C_n}{(1+r)^n}}{\sum_{n=1}^{N} \frac{E_n^{produced}}{(1+r)^n}} \qquad (1)$$

The above equation regards the case of only a PV system, where:

$CAPEX_{PV}$ = Capital Expenditure of PV system,
C = system maintenance costs,
$E^{produced}$ = total PV generation,
n = end of year,
N = last year of analysis,
r = discount factor.

Introduction of LCOU of PV+Storage system:

The modified equation (2) below is better suited for schemes/policies that encourage a higher self-consumption rate of PV generation, where the exported energy to the grid is not valued [2]. Thus, the use of the self-consumed energy in the denominator can be noticed, resulting to a more representative indicator for the case of PV+Storage systems. LCOU is the LCOE for the combined assets, PV and ESS, with a specific "use", i.e. mode of operation. The main purpose of the LCOU term is to provide the understanding of the cost implications to the renewable and storage assets [2]. It must be noted that the lifetime of the system (i.e. PV system and ESS) affects significantly the LCOU [3].

$$LCOU = \frac{CAPEX_{PV+Battery} + \sum_{n=1}^{N} \frac{C_n}{(1+r)^n}}{\sum_{n=1}^{N} \frac{E_n^{produced} \cdot SCR_n}{(1+r)^n}} \qquad (2)$$

The above equation regards the case of a PV+Storage system with pure self-consumption, i.e. no sale of PV energy to the grid, taking into consideration the energy self-consumption, where:

$CAPEX_{PV+Battery}$ = Capital Expenditure of both PV system and ESS,
C = system maintenance costs,
$E^{produced}$ = total PV generation,
SCR = Self-Consumption Rate,
n = end of year,
N = last year of analysis,
r = discount factor.

It must be noted that the above equation directly depends on the SCR of each system. Thus, in order to result to a more generic case (country specific and not system specific), different levels of consumption were investigated (i.e. 4,500-10,500 kWh). As a result, different SCRs were acquired, affecting thus the value of the LCOU. The SCR is an indicator of the on-site consumption of PV generation and for the scope of this work, it is calculated by simulating both the electricity consumption and the PV generation of a PV+Storage system in each country at a 15-minute resolution over a yearly period. It has to be noted that the consumption level of a household affects the power capacity selection of the PV system installation, which then affects the battery's rated power and energy capacity selection. A PV system installation range (i.e. 1-10 kWp) is also taken into consideration when performing the simulations. Thus, for a more generic case, different rates of installed battery capacity over installed PV power (e.g. 1 kWh/kWp, 2 kWh/kWp etc.) were adopted. The above are explicitly presented in subsection 9.1.

Summarising, in this report, equation (2) is used to implement the necessary simulations and estimate the corresponding LCOU values in each country, which are then compared with the retail price when purchasing electricity from the grid, in order to evaluate the PV+Storage Grid Parity proximity.

8.4 Assumptions

Since energy storage can have many applications such as power balancing and frequency regulation of the power network, the LCOE of a hybrid PV+Storage system will differ significantly given the operating conditions of the ESS and mostly, any possible monetary reimbursement of this operation [3]. As a result, the term LCOU is introduced in subsection 8.3. Regarding equation (2), the operation mode (i.e. "use") of the ESS asset is targeting to maximise the self-consumption of the PV generation and does not benefit financially from energy trading with the grid, as there are no PV sales. In particular, PV generation is stored to the ESS rather than injected to the grid and at times that this generation is not adequate to meet the household's demand, energy already stored to the ESS is used.

Moreover, due to this operation mode, only the surplus PV energy can be stored in the ESS.

As due to battery efficiency there are storage losses of generated power, the energy delivered by the ESS is reduced due to the asset's round-trip efficiency [3]. Given equation (2) above, such losses are taken into consideration through the use of the SCR. This ratio is defined as the portion of the PV produced energy, that is finally used for own needs. The SCR is enhanced by the use of storage, compared to the case of ESS absence.

Furthermore, it has to be noted that the proposed term is applicable only for newly installed hybrid PV+Storage systems, as it incorporates all relevant costs of both PV and ESS in the capital and maintenance expenses of the hybrid system, as seen in equation (2). Finally, a future pure self-consumption policy that provides no reimbursement for excess PV energy injected to the grid was assumed in this work. This was decided given the prospective abolition of FiTs and Net-Metering schemes in the European Union (EU) by 2023, leading to an on-going transition to more cost-oriented approaches, such as self-consumption policies [6].

8.5 Limitations

The SCR of different systems imposes restrictions to the use of equation (2) as mentioned above, as this will result to more system-specific LCOU values. This is resolved by investigating different levels of consumption as aforementioned, in order to conclude to a more generic case, as it is presented in the next section.

Furthermore, the LCOU values are highly dependent on the system location, due to variation of solar irradiance which has a direct effect to the energy output and the regional cost differences of the systems [7]. Additionally, the application case varies widely and is directly dependent on the type of service provided as mentioned above, posing a relative arbitrariness on the resulted values. The LCOU results are given in a range of values, mainly because of the uncertainty in the annual energy production from the PV system. Finally, regarding the assessment of the LCOU indicator, the comparison is done with the current electricity prices in each country (under a flat pricing scheme) and no increase in future electricity prices is taken into consideration.

9. Country Analysis

9.1 Case studies

As already mentioned, six participating project countries, namely Cyprus, France, Greece, Italy, Portugal and Spain, were analysed for the purposes of this Deliverable. Typical PV generation and consumption profiles for residential premises the abovementioned countries were used.

The consumption profile of the end-users/prosumers was divided in three different categories according to their annual consumption:

- Type A: **4,500 kWh/year** (low consumption)
- Type B: **7,500 kWh/year** (medium consumption)
- Type C: **10,500 kWh/year** (high consumption)

The PV systems considered had an installed capacity of **1 to 10 kWp**. The ESS for each case was connected to the PV power in the following ratios:

- **0.5 kWh/kWp**
- **1 kWh/kWp**
- **2 kWh/kWp**

For all countries, a common PV system (PV array and hybrid inverter) cost of **1,300 €/kWp + VAT (per country)** [8] was considered (with no subsidy provided), while for the battery cost, two different cases were taken into account (one current with a low value and an expected future one with an extremely low value respectively):

- **500 €/kWh + VAT (per country)**
- **150 €/kWh + VAT (per country)**

With regards to the PV system cost, prices in the countries studied can be different to the benchmark used in [8]. A common price for all countries was taken into consideration for ease of comparison. In addition, the prices noted for each country vary from each other and mostly, they are not considered as a benchmark.

Specifically, the country analysis breakdown is as follows:

A) **Prosumer Type A:** Consumption 4,500 kWh/year & 1-5 kWp PV
- 0.5 kWh/kWp ESS
- 1 kWh/kWp ESS
- 2 kWh/kWp ESS

B) **Prosumer Type B:** Consumption 7,500 kWh/year & 3-8 kWp PV
- 0.5 kWh/kWp ESS
- 1 kWh/kWp ESS
- 2 kWh/kWp ESS

C) **Prosumer Type C:** Consumption of 10,500 kWh/year & 5-10 kWp PV
- 0.5 kWh/kWp ESS
- 1 kWh/kWp ESS
- 2 kWh/kWp ESS

For each country, typical residential PV generation and consumption profiles were used. Regarding consumption, data sets of typical load profiles are utilized, whereas differences between working and non-working days are also taken into consideration. With regards to PV generation profiles, typical monthly curves are calculated for the capital city of each country [2].

Table 1 presents the breakdown of the residential electricity charges per country.

Table 1: Residential electricity charges breakdown per country.

		Cyprus	**France**	**Greece**	**Italy**	**Portugal**	**Spain**	**Description**	**Comments**
Charges breakdown	Generation Charge (€/kWh)	0.09230	0.05950	0.10252[1]	0.09050	0.12000	0.13500	Charge for generation of electrical energy	[1]For a specific case of having >2,000 kWh per 4 month period.
	Network Charge (€/kWh)	0.03210	0.04797	0.02657	0.08128	0.04500	0.04500	Charge for electrical networks	
	Taxes (€/kWh)	0.03753	0.03512	0.02494	0.02783	-	-	Taxes calculated on electrical energy	
	Total Before VAT (€/kWh)	0.16193	0.14258	0.15403	0.19961	0.16500	0.18000		
	VAT (%)	19.00%	17.924%	13.00%	10.00%	23.00%	21.00%	VAT applying to electricity prices	
	TOTAL (€/kWh)	0.19270	0.16814	0.17405	0.21957	0.20295	0.21780		
	Fixed charges before VAT (€/year)	33.96	-	31.15	48.00	-	35.00	Standing fees, power component of transmission and distribution charges etc.	

9.2 PV+Storage Grid Parity Proximity

The analysis results display the performance of the introduced LCOU term, while they are also used to assess the proximity of PV+Storage systems to Grid Parity for the countries under study. The sensitivity analysis implemented indicates that the PV+Storage LCOU depends significantly on the system sizing, regarding both the PV and ESS components.

With regards to prosumers of low consumption levels (i.e. Type A), an ascending trend of the LCOU term can be observed, given an increase in the system size (assuming an ESS of 1 kWh/kWp), as shown in Figure 3a. In addition, by comparing the LCOU results and the prices seen in Table 1, it was revealed that the operation of a hybrid PV+Storage system leads to an LCOU below the retail electricity price for lower PV sizes. Specifically, this is observed for PV systems up to 2 kWp for Cyprus, Portugal and Spain, 1 kWp for Greece and Italy, while in France the LCOU is higher than the current electricity price for residential premises for all examined cases. A reduction of ESS costs diminishes the resulted LCOU values, as expected, as it can be seen in Figure 3b.

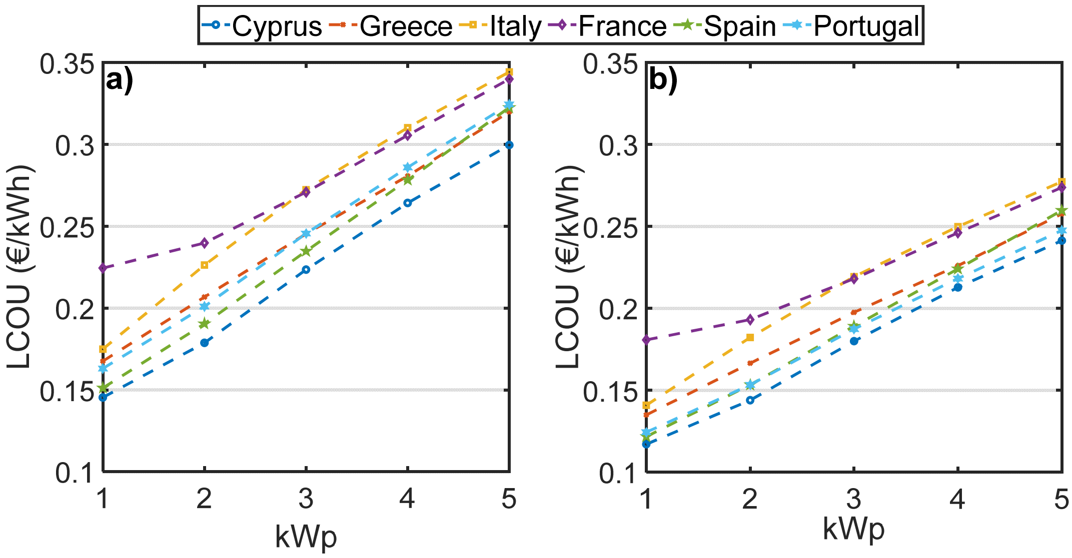

Figure 3: LCOU analysis for prosumer Type A (1 kWh/kWp ESS considered). Battery unit costs: a) 500 €/kWh; b) 150 €/kWh [2].

Concerning prosumers of higher consumption levels, i.e. Types B and C, the analysis revealed that the LCOU rises proportionally to the PV and ESS size. Yet, this trend converses for systems exceeding 7 kWp and 9 kWp installed PV capacity for Type B (Figure 4a) and Type C (Figure 5a) respectively. It has to be noted that in most cases the LCOU exceeds the current retail electricity price. However, hybrid PV+Storage systems are profitable for all examined countries except France, when reduced ESS costs (i.e. 150 €/kWh + VAT) are assumed, as illustrated in Figures 4b and 5b for prosumers Type B and Type C, respectively.

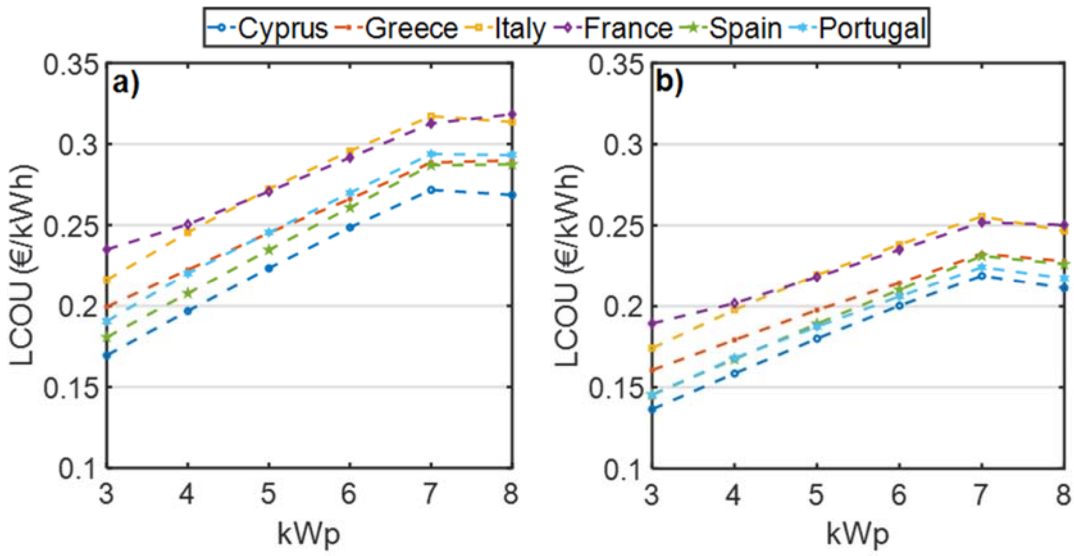

Figure 4: LCOU analysis for prosumer Type B (1 kWh/kWp ESS considered). Battery unit costs: a) 500 €/kWh; b) 150 €/kWh [2].

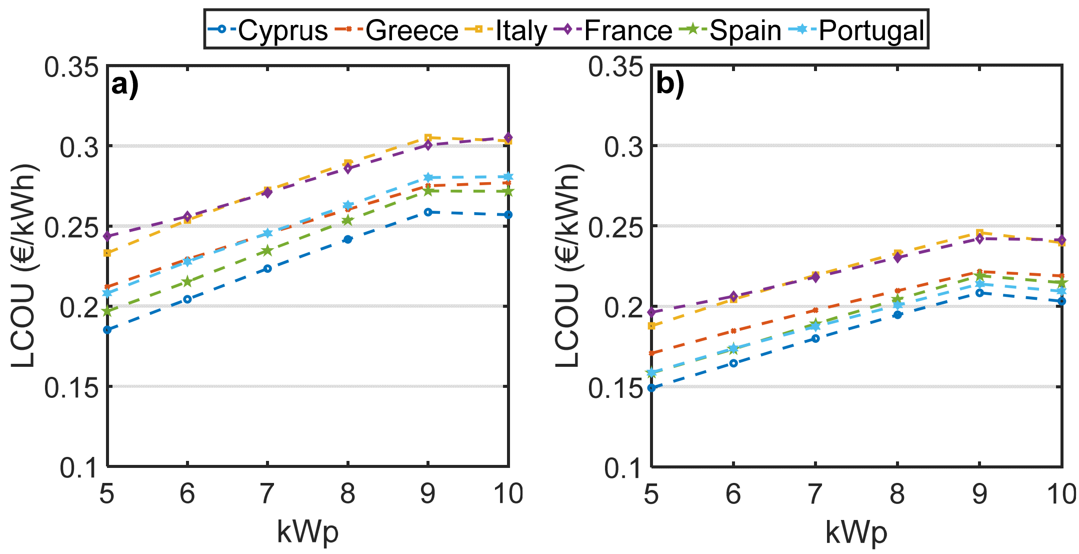

Figure 5: LCOU analysis for prosumer Type C (1 kWh/kWp ESS considered). Battery unit costs: a) 500 €/kWh; b) 150 €/kWh [2].

The analysis also demonstrated that when the PV+Storage Grid Parity is reached, i.e. the PV+Storage LCOU is lower than the retail electricity price, the Net Present Value (NPV) of the investment is always positive, thus denoting a viable investment. The NPV value for each examined case was also calculated with the developed tool mentioned above. The results are explicitly presented in [2]. In addition, it has to be noted that the analysis showed that the SCR and Self-Sufficiency Rate (SSR) are generally increased by the ESS use, especially for premises that present a medium or high consumption level, i.e. prosumers Type B and C respectively. Yet, the utilisation of storage in Type A prosumers slightly improves the performance of the installation, especially for lower PV installed capacities. Similarly, the results are demonstrated in [2].

The assessment of PV+Storage Grid Parity under a pure self-consumption scheme is conducted, utilising the LCOU results for all countries under study. The results are summarised in Figure 6. Notably, the allocation of all examined cases per country in terms of LCOU is illustrated. It can be seen that given the current ESS market prices (500 €/kWh + VAT), the PV+Storage Grid Parity is rarely reached. On the other hand, when the future reduced ESS costs (150 €/kWh + VAT) are considered, the LCOU of all systems under study is decreased in general. Mostly, PV+Storage Grid Parity is reached in most cases for Cyprus, Italy, Portugal and Spain. Specifically, for all the examined PV and ESS sizes and prosumer types, PV+Storage Grid Parity is reached in 61%, 59%, 63% and 73% of all cases for the abovementioned countries, respectively. In Greece, this only covers 22% of all cases, while in France PV+Storage grid parity is not reached in any case.

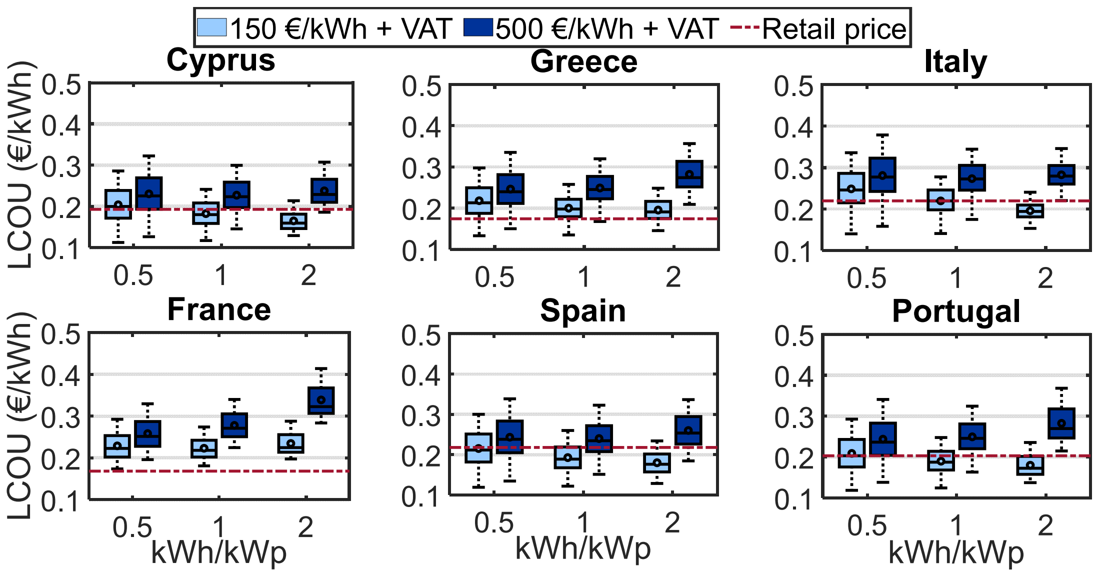

Figure 6: Statistical analysis of LCOU in each country considering all three types of prosumers using boxplots [2].

9.2.1. Cyprus

Figure 7 illustrates the percentage of the cases that PV+Storage Grid Parity is reached in Cyprus. It can be seen that PV+Storage Grid Parity is reached only in 18% of all the examined cases (PV and ESS sizes and prosumer types) for the current ESS costs. However, this value surges to 61% given the future ESS costs.

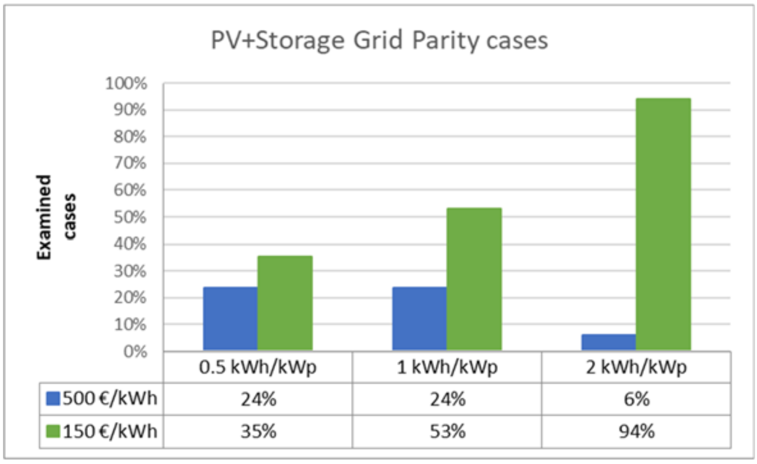

Figure 7: PV+Storage Grid Parity for all examined cases in Cyprus.

Figure 8 demonstrates the PV+Storage Grid Parity proximity in Cyprus, based on the maximum percentage of PV+Storage Grid Parity among all examined cases, i.e. 24%. This evaluation considers the current retail electricity price in the country and the current ESS costs.

Figure 8: Cyprus PV+Storage Grid Parity proximity.

9.2.2. France

As previously mentioned, in France, PV+Storage Grid Parity is never reached for all the examined cases (PV and ESS sizes and prosumer types) for the current ESS costs. Similarly, given the future ESS costs PV+Storage Grid Parity is also never reached. Two are the main reasons behind these observations. The first one is the reduced PV generation considered for the analysis (the lowest among the countries under study), affecting significantly the calculated LCOU values. The other one is the relatively low current retail electricity price of the country (the lowest among the countries under study).

Figure 9 demonstrates the PV+Storage Grid Parity proximity in France given the current retail electricity price and the current ESS costs.

Figure 9: France PV+Storage Grid Parity proximity.

9.2.3. Greece

Figure 10 illustrates the percentage of the cases that PV+Storage Grid Parity is reached in Greece. It can be seen that PV+Storage Grid Parity is reached only in 4% of all the examined cases (PV and ESS sizes and prosumer types) for the current ESS costs. However, this value increases to 22% given the future ESS costs. The relatively low value of the current retail electricity price (the second lowest among the countries under study) must be noted.

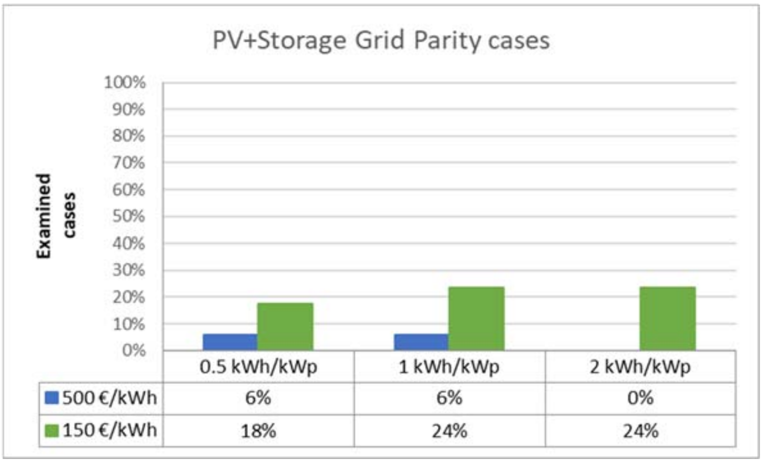

Figure 10: PV+Storage Grid Parity for all examined cases in Greece.

Figure 11 demonstrates the PV+Storage Grid Parity proximity in Greece, based on the maximum percentage of PV+Storage Grid Parity among all examined cases, i.e. 6%. This evaluation considers the current retail electricity price in the country and the current ESS costs.

Figure 11: Greece PV+Storage Grid Parity proximity.

9.2.4. Italy

Figure 12 illustrates the percentage of the cases that PV+Storage Grid Parity is reached in Italy. It can be seen that PV+Storage Grid Parity is reached only in 10% of all the examined cases (PV and ESS sizes and prosumer types) for the current ESS costs. However, this value surges to 59% given the future ESS costs.

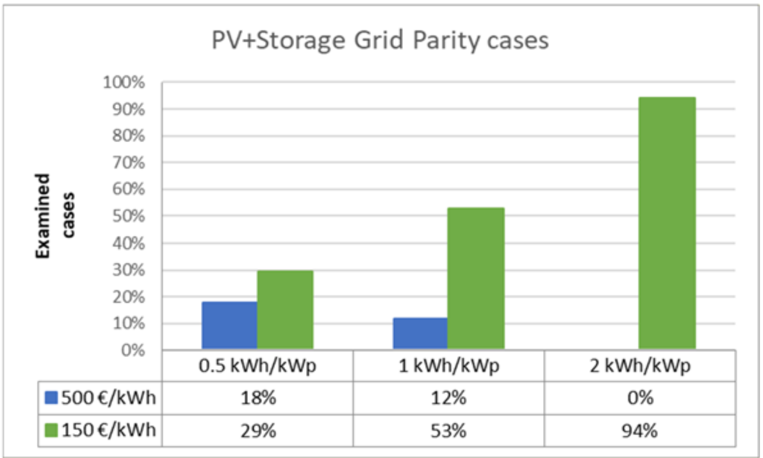

Figure 12: PV+Storage Grid Parity for all examined cases in Italy.

Figure 13 demonstrates the PV+Storage Grid Parity proximity in Italy, based on the maximum percentage of PV+Storage Grid Parity among all examined cases, i.e. 18%. This evaluation considers the current retail electricity price in the country and the current ESS costs.

Figure 13: Italy PV+Storage Grid Parity proximity.

9.2.5. Portugal

Figure 14 illustrates the percentage of the cases that PV+Storage Grid Parity is reached in Portugal. It can be seen that PV+Storage Grid Parity is reached only in 14% of all the examined cases (PV-ESS sizes and prosumer types) for the current ESS costs. However, this value surges to 63% given the future ESS costs.

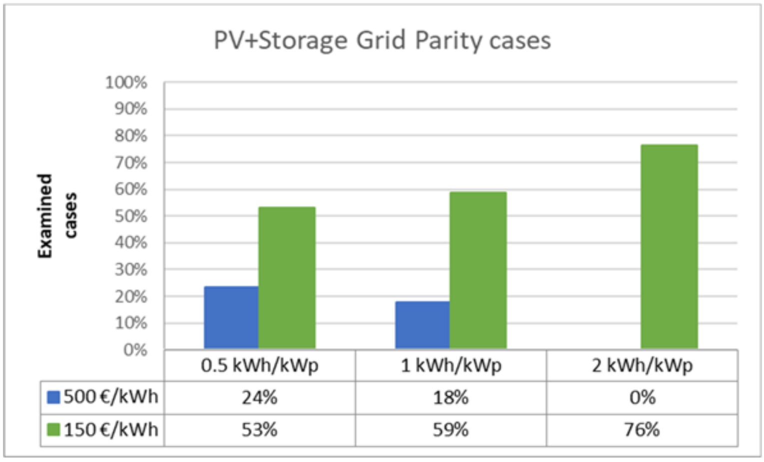

Figure 14: PV+Storage Grid Parity for all examined cases in Portugal.

Figure 15 demonstrates the PV+Storage Grid Parity proximity in Portugal, based on the maximum percentage of PV+Storage Grid Parity among all examined cases, i.e. 24%. This evaluation considers the current retail electricity price in the country and the current ESS costs.

Figure 15: Portugal PV+Storage Grid Parity proximity.

9.2.6. Spain

Figure 16 illustrates the percentage of the cases that PV+Storage Grid Parity is reached in Spain. It can be seen that PV+Storage Grid Parity is reached in 31% of all the examined cases (PV and ESS sizes and prosumer types) for the current ESS costs. However, this value increases significantly to 73% given the future ESS costs. The increased PV generation considered for the analysis (the highest among the countries under study), affecting significantly the calculated LCOU values, must be noted.

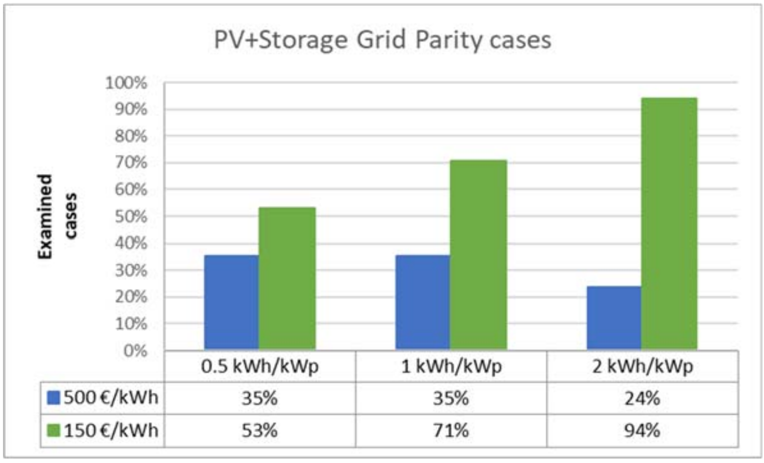

Figure 16: PV+Storage Grid Parity for all examined cases in Spain.

Figure 17 demonstrates the PV+Storage Grid Parity proximity in Spain, based on the maximum percentage of PV+Storage Grid Parity among all examined cases, i.e. 35%. This evaluation considers the current retail electricity price in the country and the current ESS costs.

Figure 17: Spain PV+Storage Grid Parity proximity.

9.3 Regulatory support to PV+Storage systems

9.3.1. Cyprus

In Cyprus, there is no legislative framework regarding energy storage and especially ESS in domestic premises yet. Currently, only the Net-Metering scheme, which is based on energy credits, is applicable for residential PV systems. The Net-Metering scheme is not regarded as a cost-wise approach that can fully utilise the operation of an ESS, as it does not incentivise self-consumption and the limitation of the household's grid interaction. Specifically, any excess PV generation injected to the power system is not remunerated, but credited to the next billing period. In addition, the absence of Dynamic (Real-time) Pricing and of ToU tariffs at the domestic level currently in Cyprus is also a barrier that prevents the full utilization of the features of an ESS and thus the exploitation of energy storage.

Figure 18 introduces the assessment of the regulatory support to PV+Storage in Cyprus.

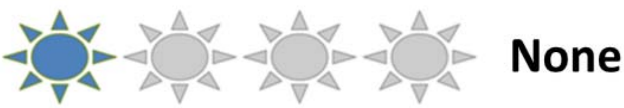

Figure 18: Assessment of regulatory support to PV+Storage systems in Cyprus.

9.3.2. France

In France, there is currently a legislative framework regarding energy storage and specifically for ESS in domestic premises. The integration of ESS is possible but only if connected with PV systems. Most importantly, the storage system can only be charged by the PV system on-site, as charging from the grid is restricted. Furthermore, there is no specific support or incentives dedicated to energy storage, as PV systems integrated with storage assets are considered like PV systems without storage. The only options which are possible in a residential self-consumption scheme are:

1) consuming all the electricity produced without injecting anything to the grid (pure self-consumption),
2) selling the excess electricity to the grid. In this case, the national framework proposes a specific FiT (10 c€/ kWh for plants ≤36 kWp, 6 c€/kWh for plants 36-100 kWp) and a subsidy (different levels from 390 €/kWp for plants ≤3 kWp to 90 €/kWp for plants ≤100 kWp).

It has to be noted that for both cases, the legal framework also includes some partial tax reduction and that there is no Net-Metering possibility in France.

Figure 19 introduces the assessment of the regulatory support to PV+Storage in France.

Figure 19: Assessment of regulatory support to PV+Storage systems in France.

9.3.3. Greece

In Greece, the current legislative framework for PV systems in residential buildings includes two distinct incentive schemes: a FiT for rooftop PVs and a partial Net-Metering scheme with rolling energy credits. Additionally, a Virtual Net-Metering scheme may be applied to public legal entities, private legal entities providing services of public interest and Energy Communities.

Considering the current legislation about ESS, a new law (759B/2019) launched in 2019 describes that ESS may be installed alongside PV installations operating under the Net-Metering scheme. Storage systems will exploit only the excess of PV produced energy and are restricted from absorbing or injecting energy to the grid. However, such systems may be installed after the technical specifications are released by the distribution system operator.

In the partial Net-Metering scheme that is currently valid in Greece, electricity charges are divided in the netted cost and the grid demand cost and taxes. Grid demand cost and taxes are calculated based on the absorbed energy from the grid, whereas netted cost is calculated based on the netted energy. If there is a surplus of netted energy (produced energy is greater than consumed energy) over a billing period, the surplus energy is credited to the next billing period. Energy rolling credits are reset once every three years. Through this scheme, a prosumer may install an ESS to rise self-consumption and thus reduce the grid demand cost and the taxes at the electricity bill. On the other side, the netted cost is not affected by a rise in self-consumption through the use of ESS. Therefore, the profit to the prosumer from an ESS is rather limited under the current partial Net-Metering scheme. In addition, the absence of ToU tariffs at the domestic level currently in Greece is also a barrier that prevents the full utilization of the features of an ESS and thus the exploitation of energy storage.

Figure 20 introduces the assessment of the regulatory support to PV+Storage in Greece.

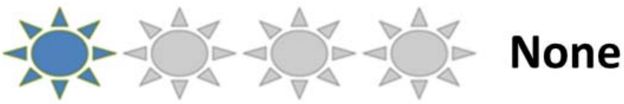

Figure 20: Assessment of regulatory support to PV+Storage systems in Greece.

9.3.4. Italy

In Italy, there is no legislative framework regarding energy storage and specifically ESS in domestic premises yet. Currently, only the Net-Metering scheme, which is based on energy credits, is applicable for residential PV systems. Nevertheless, the Italian government has recognised the importance of energy storage (both centralised and distributed) to achieve the objectives set in the Clean Energy Package. In the draft of the Integrated National Energy and Climate Plan (INECP), Italy sees in storage a resource not only for increasing the presence of RES in the electricity network (the target set is equal to 30%) but also, coupled with demand response actions, a tool that allows improving the flexibility and security of the system [9].

The intent of the Italian Government is to provide economic support for installing distributed storage systems. Moreover, regulatory support for the aggregation of generating plants, in association with storage systems, and consumption units in order to access the services markets is foreseen. Actually, only few regions are promoting incentives for the use of storage coupled with PV systems. Veneto region, following the example of Lombardy, in 2019 proceeded a call for tender for the assignment of a grant, with a maximum amount of €3,000, variable up to 50% of the expenditures incurred for the purchase and the installation of ESS for residential prosumers.

Figure 21 introduces the assessment of the regulatory support to PV+Storage in Italy.

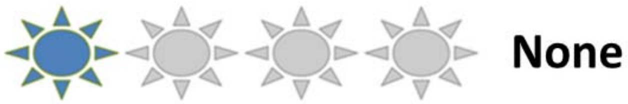

Figure 21: Assessment of regulatory support to PV+Storage systems in Italy.

9.3.5. Portugal

In Portugal, it became possible to produce electricity from RES for self-consumption purposes or to sell to the grid through small production units, after the launch of the Decree-Law 153/2014. The market has been adjusting to this legislation, making available Self-Consumption Production Units (UPAC), based mainly on PV systems with powers adapted to the needs of families and companies.

The UPAC's mode of operation is to inject the energy produced preferentially in the consumption facility. Any surplus of instantaneous production can be injected into the Public Electricity Grid (RESP). A bidirectional counter on-site counts the energy that is directly consumed from the network, but also the surplus of energy production that is injected into the public network. In this case, the surplus injected into the public network is currently paid about 4 c€/kWh.

At this moment in Portugal there is no specific legislation regarding energy storage, especially in domestic installations. However, safeguarding the technical and safety conditions, it is possible to integrate ESS. On the other side, the lack of financial incentives associated with the still high cost has contributed to the contraction of the use of ESS.

In the case of collective self-consumption, there is neither a legislative framework nor a legal definition allowing the creation of Energy Communities. However, in this case, considering the European context and Portugal's decarbonisation objectives, it has led the government to announce that a new legislative framework for Collective Self-Consumption and Renewable Energy Communities is coming soon. This announcement unveiled the promise of positive impacts on tariffs, which now consider not only the costs but also the benefits of this mode for the system.

Figure 22 introduces the assessment of the regulatory support to PV+Storage in Portugal.

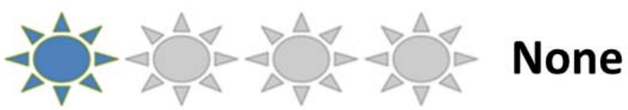

Figure 22: Assessment of regulatory support to PV+Storage systems in Portugal.

9.3.6. Spain

Recently, a new PV self-consumption regulation has been approved in Spain. The regulations do not contemplate how the net balance is accounted in other countries. Specifically, in the Net-Metering scheme the excess energy of generated by the PV system is accounted for and compensate per Watt. Thus, for each Watt injected to the grid, a Watt can be recovered when needed. In the system proposed in this new Spanish regulation, this compensation is not going to be per Watt, but it is going to be an economic compensation for discharged Watt that will be deducted from the electric bill. The price will depend on the electric distributor.

In the new regulation different schemes are contemplated but there is no mention of energy storage and specifically of battery storage. In addition, the current compensation system reduces significantly the profitability that can be obtained by battery energy storage, since the sale price of electric energy is not attractive to make the corresponding investment. There is no specific regulation related to battery-based storage in the current legislation except those related exclusively to technical issues of electrical installation and safety.

Figure 23 introduces the assessment of the regulatory support to PV+Storage in Spain.

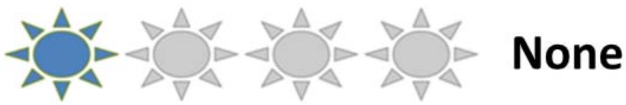

Figure 23: Assessment of regulatory support to PV+Storage systems in Spain.

10. Conclusions

In this deliverable, the proximity of PV+Storage systems to Grid Parity in six participating project countries was assessed. The developed StoRES Online Storage Optimisation Tool (http://www.storestool.eu/) was used to perform all the necessary calculations, which were then employed to assess the viability of PV+Storage systems in the current energy market. The report also provides a description of the national support of the countries under study to energy storage.

This deliverable utilises the abovementioned LCOU indicator with a direct focus on residential systems for the participating countries. The calculation results were used to evaluate the viability of a hybrid PV+Storage system in the energy market under a future pure self-consumption policy and finally, to assess the proximity of a PV+Storage installation to Grid Parity by comparing the derived values with the current retail electricity price in each country.

The results provide an insight into the difference of the cost of a residential PV+Storage system when compared to the retail electricity price. Thus, the PV+Storage LCOU term can be an indicator that fewer incentives are required for a specific country towards a pure self-consumption policy that includes no compensation for the surplus of produced energy [2].

It was observed that for half of the countries under study, PV+Storage Grid Parity has been partially reached. For the rest of the countries, PV+Storage systems are still far from Grid Parity. Generally, in most cases, the PV+Storage Grid Parity cannot be reached under the current market prices, unless the cost of BESS is further decreased. This applies for all countries under study. Given future reduced ESS costs, PV+Storage Grid Parity has been observed in some cases. It is also derived that the system sizing plays an important role in the viability of such systems. In addition, the SCR should be considered when evaluating the PV+Storage proximity to Grid Parity under self-consumption policies with no reimbursement for surplus energy.

The assessment of the national support to energy storage and especially ESS integrated with PVs at the residential level revealed that further actions are needed, especially when considering the low viability level of residential PV+Storage systems under the current market conditions, as derived from the analysis. This regards both the absence of policies and schemes that are considered suitable for the promotion of ESS, the absence of any subsidies provided and finally, the current active status of schemes that do not promote the increase of self-consumption in the countries under study.

The conducted work was also circulated as a paper at a peer-reviewed academic journal [2], aiming at the further dissemination of the proposed PV+Storage Monitor.

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