Interreg Mediterranean

RENEWABLE ENERGY

Project co-financed by the European Regional Development Fund

Energy Storage Systems for a major diffusion of PV in the MED area

Synthesis report on the StoRES Project

Interreg Mediterranean StoRES

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This document has been realised by

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Introduction

The StoRES project aimed at increasing the photovoltaic (PV) diffusion in the energy mix in Mediterranean islands and rural areas, by integrating Energy Storage Systems (ESS) to PV plants, under an optimal market policy. To do that, the project team implemented and tested several smart solutions integrating ESS, PV and smart data providing systems in 6 MED islands and rural areas: Cyprus, Sardinia, Thessaloniki, Algarve, Slovenska Bistrica and Zaragoza. Subsequently, among others, they developed policy recommendations and a sizing tool for integrated ESS and PV systems.

The present document has been elaborated by the Interreg MED Renewable Energy Community, in collaboration with the StoRES project partnership, to give an overview of the main results and outcomes obtained by the project in terms of technical results and also contribution to the model developed by the Community of *Ecosystemic Transition Unit (ETU)*. This model has been built on the basis of the activities and results of the 6 modular projects belonging to the Interreg MED RES Community and dealing with:

> **StoRES**: Promotion of higher penetration of distributed PV through storage for all
> **PRISMI**: Promoting RES integration for smart Mediterranean islands
> **COMPOSE**: Rural Communities engaged with positive energy
> **ForBioEnergy**: Forest Bioenergy in the protected Mediterranean areas
> **LOCAL4GREEN**: Local fiscal policies for Green Energy
> **PEGASUS**: Promoting effective generation and sustainable Use of electricity through microgrids

An *Ecosystemic Transition Unit* is a territory implementing its energy transition taking into account an ecosystemic approach, based on the following main pillars: technological (energy facilities), social (energy community), legal (energy governance) and territorial (energy planning). As a conclusion of these 3 years of work, both for the project and for the Interreg MED RES Community, but also as a starting point for the implementation of the *ETU* at territorial level and consequently the transferring and capitalisation of the results of the projects of the community, it was important to underline better the different contribution each project gave to the *Ecosystemic transition Unit* Concept.

The present document is composed by the following main sections:

1. a general section, with the main features of the project and its general outcomes
2. a technical section dedicated to the results of the project pilot activities
3. a policy section, synthetizing the main lessons learnt and policy recommendations of the project
4. a section dedicated to specify the contribution of the project to the “Ecosystemic Transition Unit” model

ENJOY THE READING!

Title of the project: StoRES - Promotion of higher penetration of Distributed PV through storage for all

Partners and associated partners:

Active partners:

1. University of Cyprus (CY) – Project coordinator
2. Aristotle University of Thessaloniki (GR)
3. AREAL – Regional Energy and Environment Agency of Algarve (PT)
4. SARGA - Government of Aragon (SP)
5. Municipality of Slovenska Bistrica (SI)
6. Regional Energy and Environment Agency in Rhône-Alpes (FR)
7. Ministry of Energy, Commerce, Industry and Tourism of Cyprus (CY)
8. Electricity Authority of Cyprus/Distribution System Operator (CY)
9. Municipality of Ussaramanna (IT)

Associated partners:

1. University of Cagliari (IT)
2. Cyprus Energy Regulatory Authority (CY)
3. Mediterranean Technology Platform for Smart Grids
4. Autonomous Region of Sardinia – Regional Planning Centre (IT)
5. Federacion Aragonesa de Municipios Comarcas y Provincias (SP)
6. Ministry of Environment and Energy of Greece/General Secretariat of Energy and Mineral Raw Materials/General Directorate of Energy/Directorate of Renewable Energy Sources and Electricity (GR)
7. Municipality of Kozani (GR)
8. EDP Distribuicao Energia (PT)
9. Hellenic Electricity Distribution Network Operator S.A. (GR)
10. SODO Electricity Distribution System Operator (SI)

Budget and duration:

> Total budget: €2 m
> ERDF Budget: €1,7 m
> Duration: 36 months

Testimony of lead partner

StoRES foresees the development of an optimal policy for the effective integration of Photovoltaics and Energy Storage Systems via testing smart solutions in 6 Mediterranean islands and rural areas. It aims to increase PV penetration in the energy mix of islands and rural areas in the Mediterranean by integrating PV and ESS under an optimal market policy.

Project outcomes

Main outcomes

- Development and validation of an improved self-consumption policy.
- Pilot demonstration of integrated PV and ESS systems into the energy mix of rural areas and islands.
- Identification and addressing all technical and regulatory requirements for the introduction of ESS into the energy mix.
- Evaluation of ESS contributions to solve intermittent RES shortcomings & increase the level of possible RES penetration into the energy mix.
- Integration of ESS in the energy mix of participating regions.
- Enhancement of Demand Side Management (DSM) possibilities.
- Major engagement of the key stakeholders in the development, implementation and monitoring of sustainable energy policies and plans.
- Creation of an online storage solution (namely StoRES Online PV and Storage Optimisation Tool available at the following link: www.storestool.eu).
- Creation of an online web platform (namely StoRES Living Lab available at the following link: https://www.archelios.com/AURAEE/chart.html).
- Summary of policy recommendations for the deployment of ESS in the countries involved, as well as the rest of Europe.
- Recommendations issued from the conducted Cost & Benefit Analysis
- Rollout of integrated PV + Storage solution to a broader MED region and beyond.

Capacity of replication in other territories

The StoRES project has a significant capacity of replication as its main outcomes (i.e. the lessons learnt from the project, the StoRES Online PV and Storage Optimisation Tool for hybrid PV+Storage systems, etc.) can be easily replicated in nearby countries of the broader region and even beyond. Specifically, countries aiming at the promotion of PV through residential storage solutions, with similar environmental conditions (i.e. solar irradiance) and status of PV in their energy mix can benefit from the main outcomes of the project. Furthermore, the main outcomes can also be utilised by other European countries beyond the MED region.

Contribution to know how and added value

In most of the participating countries, the implemented pilots are the first grid connected ESS in buildings. The StoRES project was a great opportunity to implement and validate different solutions available in the market in the MED region. The project's pilots include a wide range of system manufacturers, system sizes, technologies (e.g. lithium-ion, lead-acid etc.) and configurations (AC-coupled/DC-coupled). In addition, the pilots have been integrated in territories with a high solar potential, which are suitable for increased PV self-consumption of the end-users. The project's ESS assisted the households towards significant increases in self-consumption and self-sufficiency.

StoRES Pilots in Cyprus – Installation of 4 residential and 1 social storage pilots in Nicosia

Budget: 591,868.75€

The University of Cyprus is responsible for the installation and operation of five pilots, specifically four 2.5 kW / 9.8 kWh residential storage systems installed in residences and a 30 kW / 50 kWh social storage system installed at the Low-Voltage feeder which powers the four abovementioned households.

The installation of the ESS in Cyprus has brought numerous benefits to all the partners involved in the project. **As these are the first grid-connected storage systems in Cyprus**, the project allowed increasing the know-how on different features related to ESS, starting from the stakeholders directly involved (household owners, University of Cyprus, Electricity Authority of Cyprus, Ministry of Energy, Commerce and Industry of Cyprus) through to the designers, the installers, local authorities and the wider public. Indeed, during the project several aspects have been faced, like the design phase, the installation process, the data monitoring and analysis, and the dialogue with the local stakeholders.

With regards to main results, **the buildings' self-consumption of on-site PV generation has been increased significantly** due to the storage operation (40% increase on average). In addition, **the self-sufficiency of the households** (the contribution of PV generation over the total household demand) **has also been increased notably** (>30% increase on average), while the storage systems have contributed to the reduction of PV export to the grid (>20% decrease on average). Furthermore, **the household energy consumption is currently mostly covered (>50%) by PV and storage in each one of the pilot households**.

The lithium-ion batteries are effectively operated on a daily basis. Due to the low maintenance requirements of this technology and mostly due to its characteristics, no major issues have been faced since the integration of the battery systems in the households. **For the first year of operation, approximately 3.8 tons of CO_2 per annum per pilot location have been avoided.** Table 1 provides a summary of the implemented pilots, while Figures 1 to 5 demonstrate the implemented residential and social BESS.

Cost	Battery inverter	Battery power	Battery capacity	PV peak power	Self-consumption	Self-sufficiency
1,266 €/kWh (residential) + VAT 1,350 €/kWh (social) + VAT	1-ph (residential) 3-ph (social)	2.5 kW - 30 kW	9.8 kWh Lithium-ion (residential) 50 kWh Lithium-ion (social)	3 kWp (residential) No direct PV (social)	From 45% to 95% (residential)	From 25% to 49% (residential)

Table 1 - Synthesis of the main characteristics and results of the pilot installations in Cyprus

Figure 1 - First BESS residential pilot in Cyprus

Figure 2 - Second BESS residential pilot in Cyprus

Figure 3 - Third BESS residential pilot in Cyprus

Figure 4 - Fourth BESS residential pilot in Cyprus

Figure 5 - Social BESS pilot in Cyprus

StoRES Pilots in Italy – Installation of 13 residential pilots in the Municipality of Ussaramanna

Budget: 198,850€

The University of Cagliari and the Municipality of Ussaramanna are responsible for the installation and operation of thirteen residential pilots, with an energy storage capacity range of 4-8 kWh.

The installation of the residential ESS in Municipality of Ussaramanna has brought numerous benefits to all the Sardinian partners involved in the project.

First of all, the project starts showing the advantages of the use of ESS in the reduction of the energy consumption (and thus the electricity cost), by increasing the PV self-consumption. Moreover, the project, thanks to the set objectives, the challenges faced, the first results obtained and the interaction with the other partners, allowed increasing the know-how on different features related to ESS starting from the stakeholders directly involved (citizens, University, Municipality) through to the designers, the installers, local authorities and public. Indeed, during the project several aspects have been faced, like the design phase, the installation process, the data monitoring and analysis, and the dialogue with the local stakeholders.

Finally, the project raised the awareness related to **the positive effects of battery storage** and allowed identifying the main aspects to be reported to Distribution System Operators (DSOs), national energy authorities and local and national politicians **to foster and facilitate the use of such technology**. Table 2 provides a summary of the implemented pilots.

Cost	Battery inverter	Battery power	Battery capacity	PV peak power	Self-consumption	Self-sufficiency
1,260 €/kWh (13 residential)	Twelve 1-ph Sonnen One 3-ph VARTA	2.5 – 3.3 kW	2 x 8 kWh Li-Ion 5 x 6 kWh Li-Ion 6 x 4 kWh Li-Ion	3 -12 kWp	From 28% to 63%	From 33% to 64%

Table 2 - Synthesis of the main characteristics and results of the pilot installations in Italy

StoRES pilots in Greece – 3 installations in public buildings, 1 residential installation and 1 installation in commercial warehouse and offices in Thessaloniki

Budget: 81,000€

The Aristotle University of Thessaloniki has installed five pilot sites at buildings with an existing PV system used for self-consumption, as it can be seen in Table 3.

Pilot	Kind of building	PV system capacity	Inverter	Storage system
1	Public building	10 kWp	3x1 ph-6.9 kW	20 kWh-OPzV
2	Public building	10 kWp	3x1 ph-6.9 kW	20 kWh-OPzV
3	Public building	10 kWp	3 ph-5 kW	7.5 kWh-Li-Ion
4	Residential	5 kWp	3 ph-5 kW	7.5 kWh-Li-Ion
5	Commercial-office	20 kWp	3x1 ph-6.9 kW	20 kWh-OPzV

Table 3 - Storages' technical data implemented in Greece

The different installed systems have the characteristic shown in the table above. Self-consumption of on-site produced energy has been increased due to the ESS operation, as it can be seen in Table 4. OPzV and Li-Ion batteries are effectively exploited on a daily basis. Due to maintenance requirements of OPzV batteries, operating limits (State-of-Charge upper and lower limits) should be carefully selected, considering seasonal reconfiguration.

Cost	Battery inverter	Battery capacity	PV peak power	Self-consumption	Self-sufficiency
1,140 €/ kWh	2 x 3-ph (residential + public) 3 x 1-ph (commercial + two public)	2 x 7.5 kWh Li-Ion (residential + public) 3 x 20.16 kWh OPzV (community + two public)	5 kWp (residential) 20 kWp (commercial) 3 x 10 kWp (public)	From 51% to 68%	From 28% to 37%

Table 4 - Synthesis of the main characteristics and results of the pilot installations in Greece

PILOT 1: Municipality Office Building

The pilot installation is a public building, with a 10 kWp PV system. Three 1-ph storage inverters, operating as a 3-ph inverter with total capacity of 6.9 kW, have been installed along with 20 kWh OPzV batteries and three energy meters, equipped with data storage capabilities and Ethernet connection to a local hub, as it can be seen in Figure 6.

Self-consumption of on-site produced energy has been increased due to storage operation. OPzV batteries are effectively exploited on a daily basis. Due to maintenance requirements of OPzV batteries, operating limits (state of charge upper and lower limits) should be carefully selected, considering seasonal reconfiguration.

Figure 6 - Storage system of the first Greek pilot (public building)

PILOT 2: Former Town-Hall of Ellispontos

The pilot installation is a public building, with a 10 kWp PV system. Three single-phase storage inverters, operating as a 3-ph inverter with total capacity of 6.9 kW, have been installed along with 20 kWh OPzV batteries and three energy meters, equipped with data storage capabilities and Ethernet connection to a local hub, as it can be seen in Figure 7.

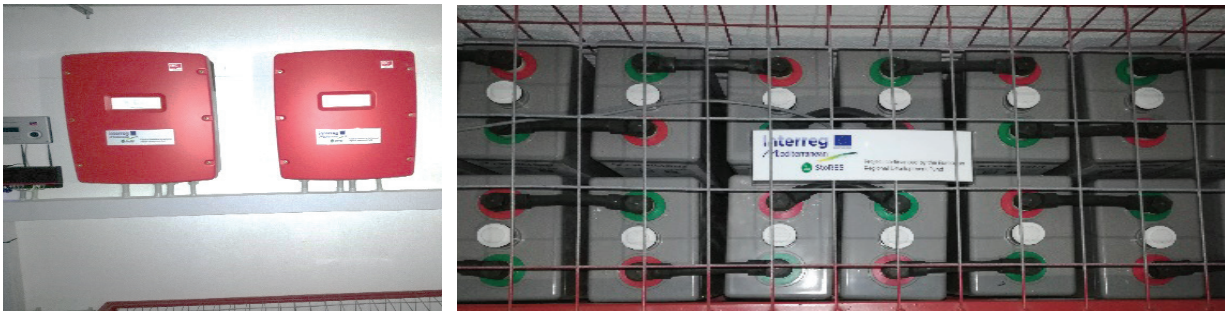

Figure 7 - Storage system of the second Greek pilot (public building)

Self-consumption of on-site produced energy has been increased due to storage operation. OPzV batteries are effectively exploited on a daily basis. Due to maintenance requirements of OpzV batteries, operating limits (state of charge upper and lower limits) should be carefully selected, considering seasonal reconfiguration.

PILOT 3: Town-Hall

The pilot installation is a public building, with a 10 kWp PV system. A 3-ph storage inverter of 5 kW has been installed along with a 7.5 kWh Li-ion battery storage system, as it can be seen in Figure 8. Additionally, three energy meters with Ethernet communication and data storage have been installed.

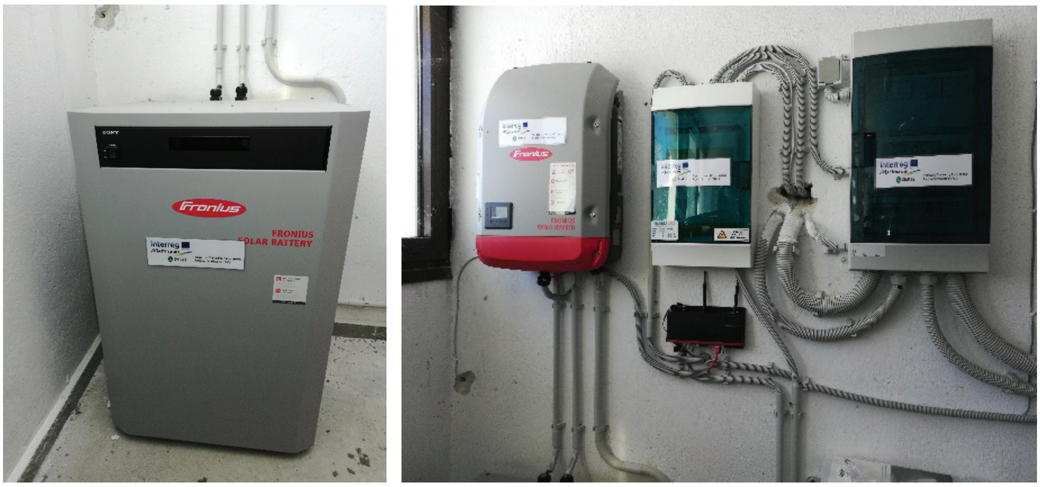

Figure 8 - Storage system of the third Greek pilot (public building)

Self-consumption of on-site produced energy has been increased due to storage operation. Li-Ion batteries are effectively exploited on a daily basis.

PILOT 4: Residential Installation

The pilot installation combines a residence and a fitness center, with a 5 kWp PV system. A 3-ph storage inverter of 5 kW has been installed along with a 7.5 kWh Li-Ion battery storage system, as it can be seen in Figure 9. Additionally, three energy meters with data capabilities and Ethernet communication have been installed.

Figure 9 - Storage system of the fourth Greek pilot (residential building)

Self-consumption of on-site produced energy has been increased due to storage operation. Li-Ion batteries are effectively exploited on a daily basis.

PILOT 5: Commercial warehouse and offices

The pilot installation is a public building, with a 10 kWp PV system. Three single-phase storage inverters, operating as a 3-ph inverter with total capacity of 6.9 kW, have been installed along with 20 kWh OPzV batteries and three energy meters, equipped with data storage capabilities and Ethernet connection to a local hub, as it can be seen in Figure 10.

Figure 10 - Storage system of the fifth Greek pilot (commercial – office building)

PV produced energy rarely supplies the warehouse daily energy demand. Therefore, PV surplus energy is insufficient to properly charge the batteries on a daily basis. An alternative charge/discharge control strategy or electrical configuration may be considered in such installations, to effectively exploit the installed storage capacity.

StoRES pilots in Portugal – Installation of 5 residential pilots in the region of Algarve

Budget: 30,000€

In Portugal 5 similar pilot sites were installed at households with an existing self-consumption PV system, as it can be seen in Table 5.

The AREAL – Regional Energy and Environment Agency of Algarve, had prepared the process of recruiting participants, namely through the publication in two regional newspapers of the invitation addressed to the owners of residential self-consumption facilities.

The selection of participants was made taking into account the installed power and the amount of energy injected into the network.

	Premise type	PV system capacity	Supply	Tariff
1	Typical household	1.5 kWp	1-PH	Dual rate
2	Typical household	1.5 kWp	1-PH	Dual rate
3	Typical household	1.0 kWp	1-PH	Single rate
4	Typical household	1.5 kWp	1-PH	Single rate
5	Typical household	1.5 kWp	1-PH	Single rate

Table 5 - Storages' technical data located in Portugal

In the general context, the pilots in Algarve have the following energy flows: **22% from PV, 6% from the storage system and 72% from the mains (grid)**.

All the installed systems have contributed to **the increase of self-consumption and self-sufficiency** (Table 6). However, **the savings of the battery system are lower than expected**, mainly due to the following aspects:

- > **Battery capacity over dimensioning** (increase of PV power would be necessary to increase viability). Notice that the current PV power demonstrates a low economic viability mainly due to the installed PV power;
- > **Low "round-trip" efficiency** (≈60%), **compared to the one indicated by Sonnen supplier** (92%). According to the supplier the latest batteries (eco 9.x) have higher "round-trip" efficiency values;
- > **Low potential of arbitrage of charge**, in systems of this dimension.

Furthermore, the storage system has contributed the **reduction of PV export to the grid**.

Cost	Battery inverter	Battery power	Battery capacity	PV peak power	Self-consumption	Self-sufficiency
3,000 €/kWh + VAT	1-ph Sonnen	4 x 2 kW 1 x 1.5 kW	2 kWh	4 x 1.5 kWp 1 x 1 kWp	From 66% to 95%	From 22% to 27%

Table 6 - Synthesis of the main characteristics and results of the pilot installations in Portugal

PILOT 1: Sitio dos Agostos

The pilot installation is a household located in Santa Bárbara de Nexe – Faro, in the Algarve region. The capacity of the PV plant already existent was 1.5 kWp (6 modules of 250 Wp). A storage system with 1ph 1-2.5 kVA Battery Inverter, AC power at 45°C continuously with grid-tie functionality for home applications under 6 kWh for AC-coupled systems was integrated in this pilot, as it can be seen in Figure 11.


Figure 11 - Storage system of the first Portuguese pilot (residential building)

Since the start of the installation of the ESS, pilot 1 has carried out a total consumption of 4,628 kWh (April 2018 to January 2019). Of this total, the PV represents 19%, the battery system 8% and 73% from the mains (grid).

In addition, 10% of PV production is injected into the grid, indicating a potential to optimize battery capacity. For the same period, **589 kgCO_2/year of emissions were avoided**.

PILOT 2: Albufeira

The pilot installation is a household located in Albufeira, district of Faro, in the Algarve region. The capacity of the PV plant already existent was 1.5 kWp (6 modules of 250 Wp). A storage system with 1ph 1-2.5 kVA Battery Inverter, AC power at 45°C continuously with grid-tie functionality for home applications under 6 kWh for AC-coupled systems was integrated in this pilot, as it can be seen in Figure 12.


Figure 12 - Storage system the second Portuguese pilot (Residential building)

Since the start of the installation of the ESS, pilot 2 has carried out a total consumption of 5,261 kWh (April 2018 to January 2019). Of this total, the PV represents 30%, the battery system 7% and 63% from the mains (grid). In addition, 2% of PV production is injected into the grid. For the same period, **830 kgCO_2/year of emissions were avoided**.

PILOT 3: Gambelas

The pilot installation is a household located in Montenegro – Faro, in the Algarve region. The capacity of the PV plant already existent was 1.0 kWp (4 modules of 250 Wp). A storage system with 1ph 1-2.5 kVA Battery Inverter, AC power at 45°C continuously with grid-tie functionality for home applications under 6 kWh for AC-coupled systems was integrated in this pilot, as it can be seen in Figure 13.

Since the start of the installation of the ESS, pilot 3 has carried out a total consumption of 4,252 kWh (April 2018 to January 2019). Of this total, the PV represents 15%, the battery system 3% and 82% from the mains (grid). In addition, 1% of PV production is injected into the grid. For the same period, **342 kgCO_2/year of emissions were avoided**.

Figure 13 - Storage system of the third Portuguese pilot (residential building)

PILOT 4: S. Romao

The pilot installation is a household located São Brás de Alportel, district of Faro, in the Algarve region. The capacity of the PV plant already existent was 1.5 kWp (6 modules of 250 Wp). A storage system with 1ph 1-2.5 kVA Battery Inverter, AC power at 45°C continuously with grid-tie functionality for home applications under 6 kWh for AC-coupled systems was integrated in this pilot, as it can be seen in Figure 14.

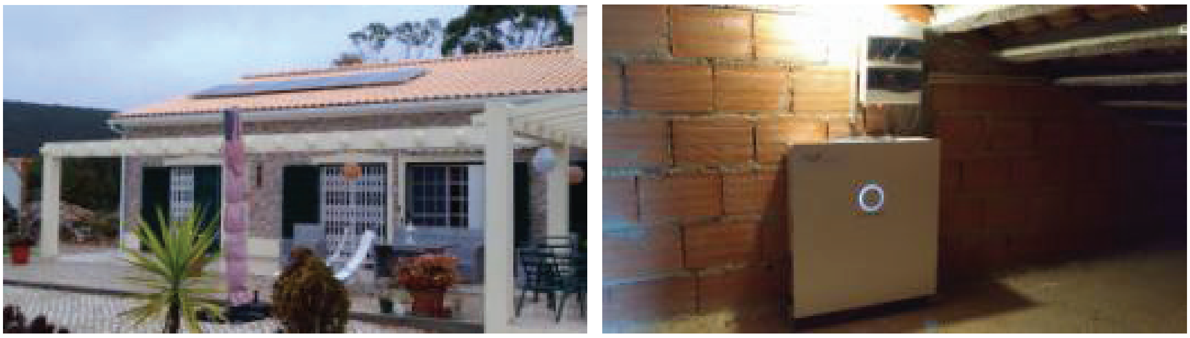

Figure 14 - Storage system of the fourth Portuguese pilot (residential building)

Since the start of the installation of the ESS, pilot 4 has carried out a total consumption of 5,331 kWh (April 2018 to January 2019). Of this total, the PV represents 23%, the battery system 4% and 73% from the mains (grid). In addition, 1% of PV production is injected into the grid. For the same period, **626 kgCO_2/year of emissions were avoided**.

PILOT 5: Benafim

The pilot installation is a household located in Benafim – Loulé, district of Faro, in the Algarve region. The capacity of the Photovoltaic power plant already existent was 1.5 kWp (6 modules of 250 Wp). A storage system with 1ph 1-2.5 kVA Battery Inverter, AC power at 45°C continuously with grid-tie functionality for home applications under 6 kWh for AC-coupled systems was integrated in this pilot, as it can be seen in Figure 15.

Figure 15 - Storage system of the fifth Portuguese pilot (residential building)

Since the start of the installation of the ESS, pilot 5 has carried out a total consumption of 5,260 kWh (April 2018 to January 2019). Of this total, the PV represents 18%, the battery system 5% and 77% from the mains (grid). In addition, 1% of PV production is injected into the grid. For the same period, **509 kgCO_2/year of emissions were avoided**.

StoRES Pilot Slovenia – 1 residential installation in the Municipality of Slovenska Bistrica

Budget: 161,250€

The Municipality of Slovenska Bistrica, although initially not a pilot country, has implemented one pilot location in order to get a better basis for transferring the results to the local stakeholders, interest groups and general public. The residential building chosen for being a pilot is in the net-metering scheme. A 7 kWh LG battery with a 1-ph inverter was installed (Table 7), as it can be seen in Figure 16.

Figure 16 - Storage system of Pilot in Slovenia

The PV system cannot operate in island mode, but only with the connection to the grid. Therefore, it is not possible for the ESS to operate as a backup.

The 1-phase battery storage system directly provides energy to the 3-phase building consumption system in one phase directly and in other two phases indirectly through the grid.

Monitoring system enables insight into voltage profiles.

Pilot system is a testing polygon for:

- planning future support schemes for PV with storage systems,
- optimum energy operation and investments in residential buildings for maximum self-sufficiency and self-consumption.

Cost	Battery inverter	Battery power	Battery capacity	Self-consumption	Self-sufficiency
1,255 €/kWh +VAT	1-ph	3 kW	7 kWh LG	From 46% to 69%	From 21% to 28%

Table 7 - Synthesis of the main characteristics and results of the pilot installations in Slovenia

StoRES pilots in Spain – 5 households installation in Zaragoza

Budget: 60,000€

The results of the installation of battery-based ESS together with PV systems in the five pilots (Tables 8 and 9) distributed by Aragón have been very promising.

The installation process has been arduous due to administrative issues, but technically it has not presented any difficulties.

The users of the installation are happy with it, it is a low impact installation, with no maintenance and works correctly from day one.

They have also seen how this energy storage facility actively contributes to lowering their electricity bill.

	Pilot 1	Pilot 2	Pilot 3	Pilot 4	Pilot 5
Municipality	Sadaba	Zaragoza	Zaragoza	Langa de Castillo	Zaragoza
Installed power (kWp)	5.55	3.18	4.24	4.16	4.32
Annual consumption (kWh)	6,958	3,139	7,370	4,200	21,200
Nb of Solar panels	30	12	16	16	16
Power (each panel) (Wp)	185	265	265	260	270

Table 8 - Storage systems' technical data located in Spain

Cost	Battery inverter	Battery capacity	PV peak power	Self-consumption	Self-sufficiency
1,162 €/kWh	Solarwatt	4 x 8.8 kWh 1 x 4.4 kWh	3.2 kWp - 5.6 kWp	From 54% to 82%	From 47% to 70%

Table 9 - Synthesis of the main characteristics and results of the pilot installations in Spain

PILOT 1: Sabada

It is a detached house located in the town of Sádaba within the province of Zaragoza. Since the start of the installation of the ESS, as it can be seen in Figure 17, pilot 1 has carried out a total consumption of 4,256 kWh (August 2018 to April 2019). Of this total, the PV share represents 63%. Thanks to the use of the ESS the use of energy produced was increased up to 84%. The use of batteries increases the photovoltaic performance of the installation by 33%.

Figure 17 - Storage system of the first Spanish pilot (residential building)

PILOT 2: Calle Biel

It is a detached house located in the town of Zaragoza. The assumption of this installation is minor because it had part of the pre-installation made. Since the start of the installation of the ESS, as it can be seen in Figure 18, pilot 2 has carried out a total consumption of 2,904 kWh (August 2018 to April 2019). Of this total, the PV share represents 64%. Thanks to the use of the ESS the use of energy produced was increased up to 92%. The use of batteries increases the photovoltaic performance of the installation by 44%.

Figure 18 - Storage system of the second Spanish pilot (residential building)

PILOT 3: Reyes de Aragon

It is a detached house located in the town of Zaragoza. Since the start of the installation of the ESS, as it can be seen in Figure 19, pilot 3 has carried out a total consumption of 3,992 kWh (August 2018 to April 2019). Of this total, the PV share represents 63%. Thanks to the use of the ESS the use of energy produced was increased up to 96%. The use of batteries increases the photovoltaic performance of the installation by 52%.

Figure 19 - Storage system of the third Spanish pilot (residential building)

PILOT 4: Langa del Castilo

It is a detached house with a small cheese farm attached to it. It´s located in the town of Langa del Castillo within the province of Zaragoza. Since the start of the installation the ESS, as it can be seen in Figure 20, pilot 4 has carried out a total consumption of 2,876 kWh (August 2018 to April 2019). Of this total, the PV share represents 19%. Thanks to the use of the ESS the use of energy produced was increased up to 24%. The use of batteries increases the photovoltaic performance of the installation by 27%.

Figure 20 - Storage system of the fourth Spanish pilot (residential building)

PILOT 5: Avda Ilustracion

It is a detached house located in the town of Zaragoza. Since the start of the installation the ESS, as it can be seen in Figure 21, pilot 5 has carried out a total consumption of 3,782 kWh (August 2018 to April 2019). Of this total, the PV share represents 62%. Thanks to the use of the ESS the use of energy produced was increased up to 95%. The use of batteries increases the photovoltaic performance of the installation by 53%.

Figure 21 - Storage system of the fifth Spanish pilot (residential building)

Lessons learnt

The StoRES *Lessons Learnt* is the learning gained from the process of performing the project activities. It captures the challenges faced throughout the project's lifecycle as well as the solutions found to ensure a better execution in the future. Understanding and sharing the lessons learnt is an integral part of the StoRES project and acts as a foundation for transferring the project results to the relevant stakeholders.

The lessons learnt for systems with PV+Storage as per the results of the StoRES project are outlined below:

- With the **prices of storage still relatively high**, **a PV system without storage is more profitable to an investor under most circumstances** in the studied MED countries. Currently the **MED countries do not have policies that favour the installation of storage alongside PV systems**. Even in the cases where higher self-consumption is encouraged (e.g. the Net-Billing of Cyprus or the partial Net-Metering scheme in Greece), **the resulting incentive is not adequate to make a hybrid PV + storage system more profitable** (with the current storage system prices).
- The profitability of a PV + storage system depends upon **several parameters** and, hence, requires **careful planning**. The parameters include:
    - a) Consumption profile;
    - b) Electricity costs;
    - c) Existing policy/scheme;
    - d) Solar irradiance and temperature profile of the installation location; and
    - e) Technical related data of PV and storage.
- The **optimal sizing of the hybrid system** should take into account all the above parameters.
- Policy makers that want to encourage the use of storage systems alongside PV's, should consider the **adaptation of existing schemes** to make systems with storage more profitable than those without. Small tweaks upon existing schemes in the MED region may be enough to achieve that.
- **The inclusion of storage systems should not be considered in cases where the load consumption is very high compared to PV installed capacity**. In that case, the storage system will rarely be charged by the PV excess energy and this will lead to either its fast degradation, or to charging from the grid for maintenance reasons (keep SoC within operational limits).
- **The technology of the battery system should be carefully chosen**. Lead-acid batteries may be economically preferable than Lithium-ion ones, but one should consider that they exploit a lower level of their nominal capacity (lower usable kWh/nominal kWh rate) and they present higher self-discharge rates.
- **The choice of AC-coupled systems is the most preferable one for existing PV installation**s, since it can be sized independently and with more technical available choices. **The choice of DC-coupled systems may be preferable for new systems**, as the cost is kept low compared to AC-coupled ones, while losses may be limited.
- Finally, **the distribution system operators in MED region should adapt their regulations** to facilitate the widespread of PV + storage hybrid systems as soon as possible. **Clear guidelines** should be given to prospective investors in concise and simple way.

Policy recommendations

A summary of the proposals concerning practises suitable for the promotion of ESS at the consumption-side is provided in the Table 10.

Recommendation	Description
Net-Billing and other Self-Consumption policies/schemes	> Abolition of other active supportive schemes, i.e. Net-Metering, FiTs. > Introduction to the regulatory framework (if absent). > Clear and transparent framework definition regarding self-consumption, storage ownership and service provision. > Simplified procedures for registering new systems. > Avoidance of discriminatory charges (no added charges/levies applied, avoidance of double taxation as consumers and producers). > Ensure inclusive eligibility (i.e. ESS participating along PV systems as coupled solutions). > Avoidance of taxation on self-consumed energy.
Market access	> Abolition of other active supportive schemes, i.e. Net-Metering, FiTs. > Clear and transparent framework enabling participation and access to all organised markets, i.e. flexibility market etc. > Active participation of end-users in all markets through aggregation/synergies formation.
Cost-reflective pricing	> Abolition of flat pricing. > Time-varying pricing (i.e. Tou Tariffs, Real-time Pricing) for all types of consumers. > Support enablers, such as Smart Meters, storage subsidies, etc.
Energy Communities	> Introduction to the regulatory framework (if absent). > Clear and transparent framework definition regarding access to all organised markets, i.e. flexibility market etc. > Simplified procedures for registering new systems. > Avoidance of discriminatory charges (no added charges/levies applied, avoidance of double taxation as consumers and producers). > Avoidance of taxation on self-consumed energy.

Table 10 - Summary of proposals regarding Energy Storage exploitation practises

All the identified barriers related to ESS exploitation, identified in the framework of the StoRES project are described in the "*Deliverable 3.7.3 – Tariff, policy and market rules recommendations*". The recommendations synthesised above are more detailed in the same document.

Contributions to the Ecosystemic Transition Unit model

The Ecosystemic Transition Unit model has been defined by the Interreg MED Renewable Energy Community during on the basis of the activities and results of the projects belonging to the community, as a capitalisation methodology of the latests. An Ecosystemic Transition Unit **is a territory implementing its energy transition taking into account an ecosystemic approach**, based on the following main aspects/pillars: **technological** (energy facilities), **social** (energy community), **legal** (energy governance) and **territorial** (energy planning).

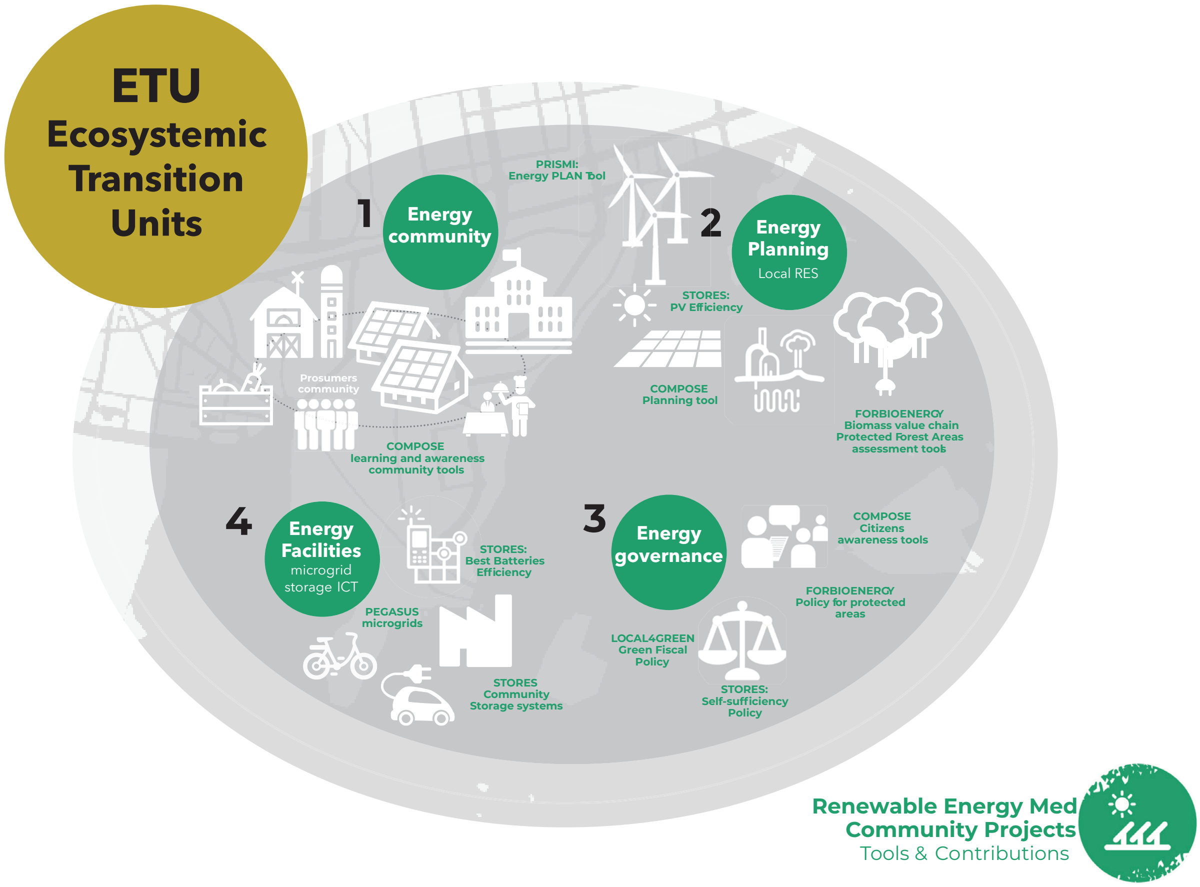

Figure 22 – Scheme representing the 4 components of the *Ecosystemic Transition Unit* model

In that conclusion phase of the project of the community, it is important to understand more precisely the **contribution of each project to the general ETU model**. Regarding the StoRES project, it is possible to underline the following impacts on the 4 main characteristics of an ETU:

Energy Community

The implementation of pilot activities as demonstrators participate to increase the awareness of the citizens of the area and the diffusion of their results in a major way. Several pilot energy storage systems have been installed in private houses, allowing to giving an idea of convenience and benefit for a single citizen or a group of citizens. Moreover, the key local stakeholders became more engaged in the development, implementation and monitoring of sustainable energy policies and plans, as they have been involved in trainings and pilot results presentation.

Energy planning

The creation of the online tool dedicated to size ESS and related PV systems (namely StoRES PV and Online Optimization Tool available at the following link: www.storestool.eu) could allow both private citizens and local authorities to plan the distribution of PV+ESS coupled systems at local level. The Optimization Tool aims at calculating the optimal size of a hybrid PV + Storage system in terms of the net present value of the investment. The tool requires as inputs: electricity consumption; solar irradiation; PV and battery size; electricity costs. A financial analysis is undertaken for a period of 20 years, taking into consideration technical and financial parameters as well as various options of energy policies. The tool's predictions are based on the actual data obtained from the 14 PV + Storage pilots implemented across the Mediterranean and described in the previous pages.

Energy facilities

The StoRES project was a great opportunity to implement and validate different solutions available in the market in the MED region. The project's pilots include a wide range of system manufacturers, system sizes, technologies (e.g. lithium-ion, lead-acid etc.) and configurations (AC-coupled/DC-coupled), at both residential and community levels. This panel of tested batteries give an overview of the efficiency and yields of different systems nowadays available on the market.

Moreover, the StoRES PV and Online Optimization Tool allows to obtain an optimal size for PV system and battery in a given situation, in terms of consumption, geographical location and other parameters. This sizing can address the citizens/local authorities to a limited range of Energy Storage Systems and PV plants, facilitating the choice of the technological plants. In addition, the development and integration of the proposed solution and the application of different policy scenarios consents to lift the barriers related to the grid integration of ESS and to extend the practical knowledge about this technology.

Energy Governance

The StoRES project team developed and validated an improved self-consumption policy and identified and addressed all technical and regulatory requirements for the introduction of ESS into the energy mix. The individuation of barriers for the major development of the ESS and all the policy recommendations have been transmitted and presented to key stakeholders at national and local levels in the MED area, and more precisely to responsible authorities directly involved in designing and implementing policies, government bodies in the MED area, Distribution and Transmission System Operators and Regulatory Authorities.

Conclusion

The StoRES project addressed the development of an optimal policy for the effective integration of Renewable Energy Sources and Energy Storage System. The primary challenge is to achieve an increased penetration of RES and predominantly PV, in the energy mix of islands and rural areas in the 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, allows to decrease the current barriers concerning grid reliability with higher RES deployment. 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 consents to lift the barriers related to the grid integration of ESS and to extend the practical knowledge about this technology.

As part of the Interreg MED RES Community, the StoRES project participates mainly and in a very relevant way to the “Energy planning”, “Energy Governance” and “Energy Facilities” as *Ecosystemic Transition Unit* components. The model of *Ecosystemic Transition Unit* has been thought to be used by the territorial/energy planners of the local authorities of remoted and isolated territories in the MED areas. As a community, our main work now is to diffuse these results, policy recommendations and tools already available and tested and to support local authorities to applied it on their own territory.

This report describes very briefly the *modus operandi* of the StoRES project and more precisely the pilot activities implemented in the MED area, in order to make the conclusions, at technical and policy levels, and tools created, easily understandable and applicable for the national and local authorities potentially interested in applied it in their process of energy transition. For more details, it is possible to refer to the StoRES project website (https://stores.interreg-med.eu/) and particularly its deliverable library (https://stores.interreg-med.eu/what-we-achieve/deliverable-library/) and to the Interreg MED RES Community website (https://renewable-energies.interreg-med.eu/) and its deliverable library (https://renewable-energies.interreg-med.eu/what-we-achieve/deliverable-library/).

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