BERLIN

Cost-effective rehabilitation of public buildings into smart and resilient nano-grids using storage

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Priority: B.4.3 - Support cost-effective and innovative energy rehabilitations relevant to building types and climatic zones, with a focus on public buildings
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3. Copyright

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4. Contents

1 Project summary

In an effort to address high energy consumption in the building sector that is mainly fossil–fuelled, support rural areas and areas powered by weak grids, which are common in the MENA region, and achieve higher grid penetration of renewable energy sources (RES) while maintaining grid stability and power quality, this project aims at the implementation of cross border pilots that will support innovative and cost–effective energy rehabilitation in public buildings based on the nanogrid concept. Thus, the BERLIN project focuses on the increase of photovoltaics (PV) penetration, which, coupled with energy storage and demand–side management (DSM), will increase the energy efficiency (EE) of the buildings. Implementing these technologies cost–effectively will result in a high level of self–resilient public buildings that are green, smart, innovative, and sustainable. A total of 6 pilot buildings will be implemented: 1 in Cyprus, 2 in Greece, 2 in Israel, and 1 in Italy.

The project has started in September 2019 and is expected to be completed within 48 months.

2 Introduction

This report includes information on the country specific procedures/roadmaps detailing the steps in order to reach higher resilience based on PV+ESS+DSM utilization. These steps include conducting a building energy audit, designing the BESS system, incorporating DSM strategies, integrating the PV+BESS+DSM hybrid system, etc. Each step will be implemented to have the required adaptations of regulations and technical guidelines and proposals to use specific financing instruments (including dynamic tariffs). A cost-benefit analysis was conducted following a hybrid solution in each partner country. This report includes country-specific insights from a cost-benefit analysis of the solution.

Finally, recommendations are presented for securing the necessary funding to rehabilitate existing public building stock.

3 Cyprus

3.1 Policy and market framework toward higher self-sufficiency

The current state of energy storage and grid integration policies in Cyprus highlights the need for further development and improvement to promote the deployment of Energy Storage Systems (ESS) and Demand-Side Management (DSM) solutions. While there are no specific laws or regulations in Cyprus that officially allow or prohibit the storage of electricity, the absence of storage-related regulations emphasizes the importance of new policies to facilitate the integration of ESS into photovoltaic (PV) systems.

Technical requirements for Energy Storage Systems

Despite a lack of specific regulations, a technical guide exists for installing energy systems in residential and non-residential buildings in Cyprus. This guide includes efficiency requirements and best practices for battery ESS, providing guidelines for their safe and efficient installation, operation, charging, discharging, and maintenance. These guidelines ensure that storage installations are deployed to maximize their effectiveness and minimize potential risks.

The current regulations in Cyprus do not explicitly address electricity discharging from ESS to the grid. However, net billing and net metering schemes suggest that discharging electricity to the grid is prohibited. To provide clarity and certainty for stakeholders in the energy sector, it would be beneficial to have explicit regulations regarding the discharging of electricity from storage systems.

While the current technical guidelines for ESS installations in Cyprus are considered straightforward and easy to implement, the absence of specific regulations suggests the need for future updates to align the guidelines with new policies. These updates would provide more explicit guidance for stakeholders involved in integrating storage systems and ensure that the procedures remain up to date with the evolving energy landscape.

Several licensed private companies in Cyprus collect and recycle end-of-life batteries. These companies are vital in promoting sustainable practices and preventing environmental pollution. To ensure that the recycling process adheres to stringent standards, it is essential to enforce regulations and monitor the activities of these companies. By doing so, Cyprus can minimize potential adverse environmental impacts and promote responsible battery recycling practices.

Deployment of smart meters

Cyprus has gradually deployed smart meters in public buildings to enhance energy efficiency and promote energy savings. These smart meters play a crucial role in facilitating the adoption of new energy policies and enable the coupling of solar PV systems with energy storage units. By accurately measuring and monitoring energy consumption, smart meters enable more effective DSM strategies and empower consumers to optimize their energy usage. However, for the effective deployment of smart meters, it is vital to support improved communication protocols and data acquisition capabilities to ensure the reliable and timely exchange of information between the meters and the relevant stakeholders.

Implementation of ESS-DSM solutions

The technical workforce in Cyprus is currently not adequately trained to propose and implement ESS-DSM solutions. Developing and implementing training programs that equip professionals with the necessary skills and knowledge to address the complexities of ESS and DSM is crucial. By fostering expertise in this field, Cyprus can build a well-prepared workforce to contribute to the successful deployment and operation of ESS and DSM solutions.

By addressing the identified gaps and implementing the recommended measures, Cyprus can promote the integration of ESS and DSM solutions. This will contribute to a greener and more sustainable energy future by increasing the share of renewable energy, enhancing grid stability, and optimizing energy consumption. Policymakers, regulators, industry stakeholders, and the technical workforce must collaborate to create a supportive regulatory environment and develop the necessary infrastructure and expertise to drive the adoption of ESS and DSM solutions in Cyprus. By doing so, Cyprus can position itself as a leader in sustainable energy practices and reap the environmental, economic, and social benefits of a clean and resilient energy system.

Autonomous (islanded) operation

The islanded operation, which allows buildings to operate independently from the main grid, is permitted for private buildings in Cyprus. However, it is considered infeasible for public buildings. Further research and evaluation are necessary to explore the potential for islanded operation in public buildings and identify the associated challenges and opportunities. By understanding the feasibility and implications of islanded operation, Cyprus can determine the best approach to achieve greater energy independence and resilience in both private and public sectors.

3.2 Cost-benefit analysis of the solution

The study case in Cyprus presents the profitability of PV and battery ESS considering the examined building's annual consumption of 36000 kWh and an electricity tariff of 0.36€/kWh. The economically viable combinations of PV and ESS sizes are outlined below. The most profitable solution identified is a system with a capacity of 29kWp–48kWh, resulting in a NPV of 112,000 €. This configuration achieves a self-sufficiency rate of 87% for the building. Interestingly, it is observed that for each PV size presented, a range of battery capacities between 44–48kWh maximizes investment profitability.

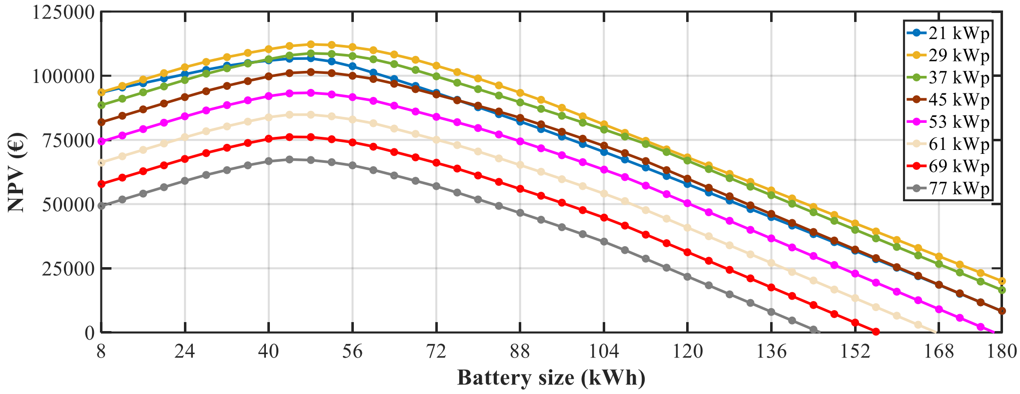

Figure 1. Cyprus: NPV analysis for 0% flexibility.

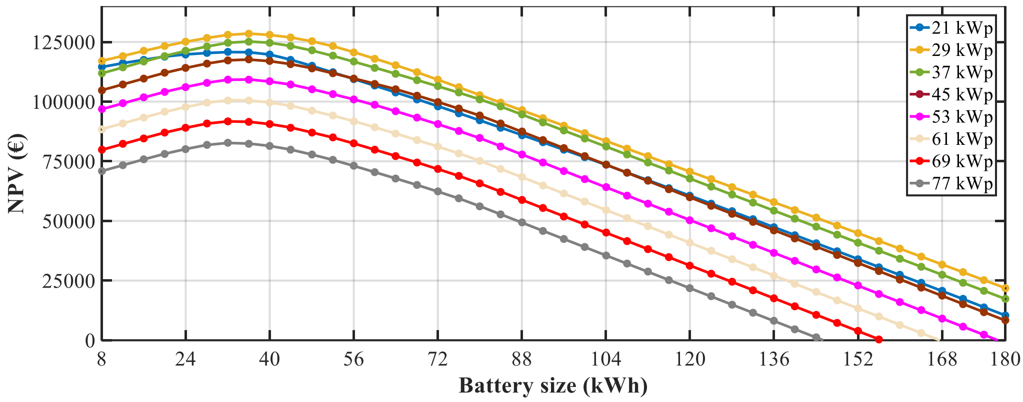

Figure 2. Cyprus: NPV analysis for 25% flexibility.

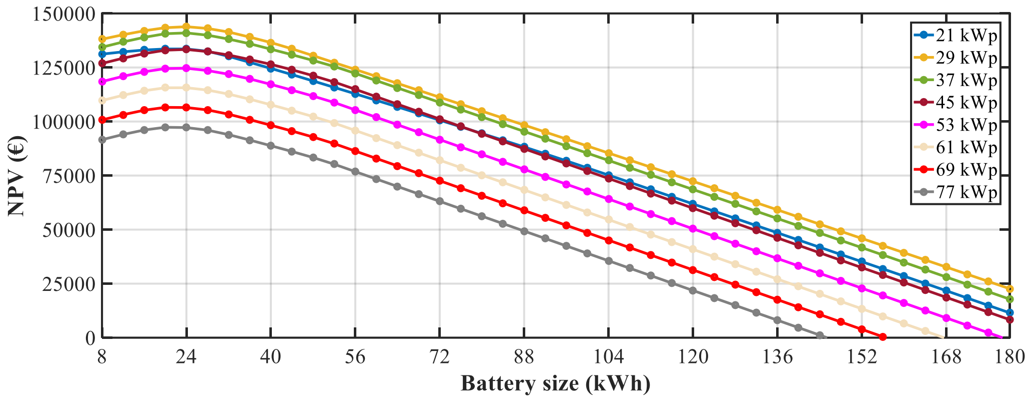

Figure 3. Cyprus: NPV analysis for 50% flexibility.

The battery capacity remains relatively consistent across the various PV sizes, primarily covering the load energy that does not align with the PV production period. This characteristic battery size decreases as the level of load flexibility increases, as a larger proportion of the demand energy is shifted and directly supplied by the generated energy. Specifically, for 25% load flexibility, this characteristic capacity ranges from 32–36kWh, while for 50% flexibility, it ranges from 20–24kWh. However, it is important to note that the investment cost of the ESS also influences this characteristic battery capacity. Different ESS costs would result in smaller or larger characteristic capacities for all the PV sizes shown in the illustrations above.

Examining the PV-battery solution that provides the maximum NPV, it is evident that 29kWp is the optimal size for all flexibility levels, while the ideal battery sizes are 48 kWh, 36 kWh, and 24 kWh for 0%, 25%, and 50% load flexibility, respectively. The self-sufficiency rate increases as the battery size increases for the 29kWp system and stabilizes around 96%. The saturation point, where the SSR reaches and remains almost constant at 96%, varies depending on the flexibility level: the higher the flexibility, the smaller the battery size above which the SSR saturation occurs. It can also be inferred that the SSR achieved by the ideal system size with 0% flexibility can be attained with smaller battery sizes if flexibility is introduced to the load consumption (as indicated by the dashed line). Therefore, to achieve an SSR of approximately 87%, the building owner could install a smaller battery with a lower investment cost, resulting in a higher NPV, by incorporating more flexible loads, as highlighted in Table 1.

Table 1. Cyprus. System Performance for SSR of 87%

Load Flexibility Level	0%	25%	50%
PV	29kWp	29kWp	29kWp
ESS	48kWh	32kWh	16kWh
Investment cost	57.3k€	46.9k€	36.5k€
NPV	112k€	128k€	142k€

3.3 Recommendations for securing the necessary funding for the rehabilitation of existing public building stock

This section examines the regulatory and financial aspects related to ESS and DSM solutions in Cyprus. It introduces the measures to secure the financial resources necessary to rehabilitate existing public buildings. It provides insights into policy schemes, tariff structures, demand response programs, monetary incentives, storage costs, DSM solutions, electricity pricing for public buildings, and controllable loads in public buildings, focusing on electric vehicles (EVs).

Regarding policy schemes, net metering in Cyprus does not favor electricity storage as it only includes flat tariff schemes. This discourages the use of local ESS, as prosumers can rely on the central power grid as a virtual and unlimited storage asset.

Regarding tariff structures, Cyprus currently has a simple two-rate Time-of-Use (ToU) tariff that remains constant throughout the year without variations between seasons. Implementing flexible ToU tariffs could encourage end-users to reduce electricity consumption during peak periods and shift it to off-peak hours, promoting the adoption of ESS and DSM solutions. Even without dynamic pricing, flat tariff schemes can still benefit prosumers through ESS and DSM practices, as they can minimize electricity imports from the grid and increase their self-consumption rate.

In Cyprus, no demand response programs are available for public buildings. Introducing such programs would enable public buildings to participate in managing electricity demand and optimizing energy usage actively. Public buildings could benefit from financial incentives by participating in load curtailment during peak periods or critical grid situations. The islanded operation, which allows buildings to operate independently from the main grid, is generally not favored or encouraged in Cyprus. Instead, demand response capabilities are a more viable solution during critical grid periods or high-demand situations.

Regarding controllable loads in public buildings, the Cyprus pilot program includes various controllable loads such as air-conditioning units, refrigerators, EVs, domestic water heaters, and lighting. The future projection for controllable loads involves implementing demand response for air-conditioning units, refrigerators, and water heaters. Moreover, controlling EV charging and battery ESS can optimize performance by maintaining state-of-charge levels within optimum ranges.

Public buildings in Cyprus do not currently participate as load aggregators in electricity markets. However, allowing them to form load aggregators would enhance their involvement and contribute to the development of the energy market. Additionally, the participation of public buildings in energy communities that benefit from ESS and DSM practices could optimize energy usage by sharing large battery ESS among community members.

Regarding economic and market aspects, the currently available information does not provide specific details about the current and projected future storage costs, DSM solutions, and PV installations in Cyprus. More comprehensive analysis and data are required to assess these aspects accurately. The current electricity pricing for public buildings in Cyprus is approximately 0.30€/kWh, including taxes and other charges. This pricing information reflects the cost incurred by public buildings for their electricity consumption.

Cyprus has no financial incentives for installing ESS and implementing DSM, such as subsidies, loans, or tax reductions. However, introducing subsidies for ESS, similar to those available for RES and solar PV systems, could incentivize the adoption of storage and DSM solutions and promote self-sufficiency.

In summary, Cyprus faces gaps and challenges in terms of regulatory frameworks and financial incentives for ESS and DSM solutions. The current policy schemes and flat tariff structures do not strongly encourage storage integration. However, implementing dynamic tariffs, demand response programs, financial incentives, and participation of public buildings in energy communities and load aggregation could enhance ESS and DSM solutions adoption in Cyprus. Additionally, addressing the financial aspects, including subsidies and cost projections, would contribute to developing a sustainable and efficient energy system in the country.

3.4 Roadmap to self-sufficient buildings based on PV+ESS+DSM utilization

From the above analysis, a roadmap can be formulated, aiming to propose the actions needed to promote buildings with high self-sufficiency through the PV+ESS+DSM nanogrid concept, which will be implemented with the rehabilitation of public buildings. This proposed roadmap includes the following steps:

1. Policy aspects

Step 1.1: Update energy-related policies

Existing policies must be revised and updated to promote and increase the self-sufficiency of public buildings. Specifically, a comprehensive policy framework must be developed to promote self-sufficiency with the utilization of solar photovoltaic, energy storage, and information-and-communication technologies.

2. Regulatory aspects

Step 2.1: Implement ESS-related regulations

Develop a regulatory framework that promotes RES-ESS combined energy systems, and specifically combined solar Photovoltaic-Battery ESS. Such regulations will remove existing barriers, and therefore can help promote integration of battery ESS with new or existing solar PV systems.

Step 2.2: Abolish the current net-metering scheme

The current net-metering scheme allows end-users to use the power network as a virtual and unlimited storage asset. The use of a new scheme (e.g., net-billing) can help create more active participation of prosumers, with more dynamic electricity tariffs that can help accelerate the sustainable energy transition with a higher RES share.

Step 2.3: Implement energy community-related regulations

A dedicated regulation on energy communities will help generate synergies in new decentralized energy systems such as microgrids. It will also help provide clear guidelines, and incentives for the establishment and development of such energy communities, with active citizen participation and promotion of RES-ESS systems. The regulation should clearly define how energy is generated, stored, and traded within the energy community. The participation of public buildings in energy communities that benefit from ESS and DSM capabilities could optimize energy usage by sharing the large ESS capacity among community prosumers.

3. Market aspects

Step 3.1: Transition to Time-of-Use (ToU) tariffs

Currently only a simple two-rate ToU tariff exists, and therefore the transition to more advanced ToU tariffs could encourage end-users to reduce their electricity consumption during peak hours and/or shift loads to off-peak hours. This is due to the fact that ToU tariffs are designed to reflect cost of the structure of the utility, which means that rates are high during peak hours, and low during off-peak hours.

Step 3.2: Deployment of demand response schemes

Demand response schemes should be deployed and become available to end-users. These schemes can help manage congestion, reduce peak demand, and provide balancing. Such schemes will enable public buildings to participate electricity demand management and actively optimize energy usage. Demand response could have a tremendous impact in public buildings, since such buildings have many controllable (deferrable) loads such A/C units, refrigerators, EVs, domestic water heaters, and lighting. Such capabilities could help provide effective solutions during critical grid periods or high-demand situations.

4. Network aspects

Step 4.1: Use of smart meters

The deployment of smart meters should be accelerated to enable end-users to access ToU tariff schemes, while actively managing their consumption. Additionally, smart meters integrated with BESS will allow end-users to reduce costs through optimum, flexible energy management. This is because the necessary information provided by the smart meters can help the end-users to optimally operate their ESS in combination to relevant communication protocols and modern data acquisition capabilities.

Step 4.2: Use of smart plugs/appliances

The deployment of smart plugs/appliances in combination with ToU tariffs can maximize energy management in building and help reduce consumption-related costs. These devices have wireless communication capabilities, which allows end-users to schedule operation.

Step 4.3: Optimize the grid infrastructure

The grid infrastructure must be upgraded to allow its smooth and optimum integration with decentralized PV-ESS systems. To achieve this, the grid reliability and stability must be enhanced, while verifying that the conditions and limitations under which end-users are allowed to own and operate a PV-ESS system are clearly defined.

5. Incentive aspects

Step 5.1: Subsidies for ESS

Since commercially available ESS are currently expensive, but simultaneously necessary for the increase of self-sufficiency rates, it is important to allow relevant subsidies, when utilized in integrated RES-ESS systems. Such subsidy schemes should ensure minimum bureaucratic procedures and provide relevant financing opportunities to end-users.

6. Marketing aspects

Step 6.1: Improve end-users' awareness

Take the necessary actions to improve the awareness of end-users on decentralized energy systems and system efficiency, by using the PV-ESS systems as a case study of increasing self-consumption and self-sufficiency, while reducing carbon emissions and operational costs. Illustrate how such systems can have a positive impact on the central power grid in comparison to using only grid-connected PV systems which create grid stability issues and enforce curtailment of RES-generated electricity. Also, communities and businesses should be encouraged to adopt such systems.

Step 6.2: Provide training on PV-ESS systems

Develop and provide (possibly through public funding) training programs for various professionals (engineers, technicians, and installers). The training programmes should provide the necessary skills and knowledge to design, install, and maintain RES-ESS systems.

The flowchart below (Figure 4) shows a schematic representation of the aforementioned roadmap steps for achieving self-sufficiency in Cyprus.

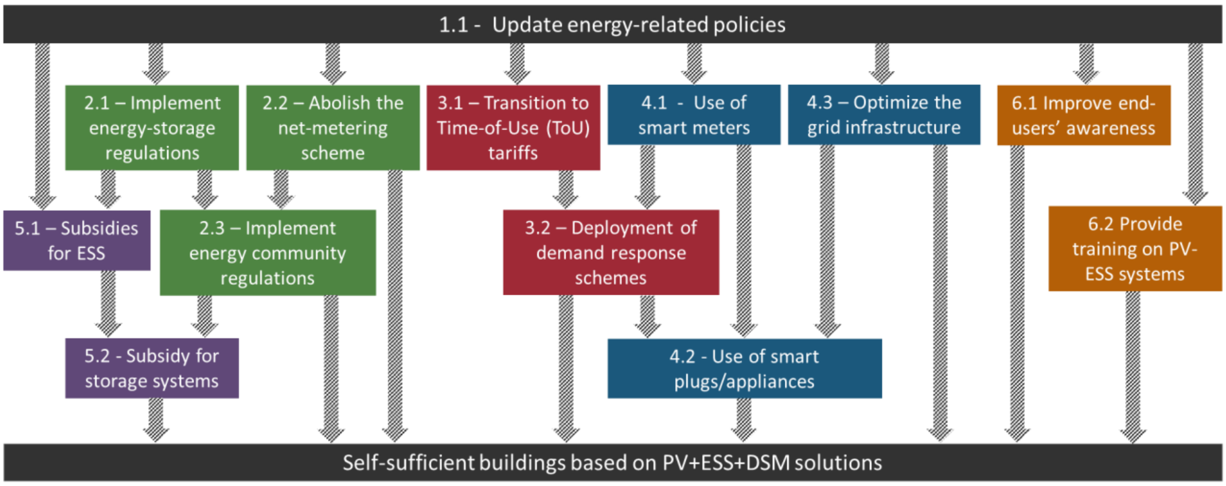

Figure 4. Roadmap to Self-sufficiency in Cyprus

4 Greece

4.1 Policy and market framework toward higher self-sufficiency

The penetration of Renewable Energy Sources (RES) in the Greek distribution network is constantly increasing, and especially after the energy crisis, there is a high demand for RES installations, with the dominant technology being the PV systems at household installations and small and medium-sized business installations.

Many parts of the Greek distribution network are already congested, according to HEDNO (the Greek DSO), due to limits on the network's installed power and short-circuit current. Also, the intermittent nature of RES production raises concerns regarding their further penetration. It sets the need for significant reserves in thermal plants that can cope with sudden changes in RES production.

Net-metering scheme and storage systems

In 2014, the net-metering scheme was introduced in the Greek electricity market, i.e., the netting of produced and consumed energy initially for systems with power up to 20 kW or up to 50% of the rated power of the installation and not more than 500 kW and with energy netting on an annual basis. In 2017, virtual net metering was introduced, extending the netting period to 3 years. In 2019, the power limit was increased to 1 MW, and the possibility of small storage plants was added. In 2021, the power limits were increased to 100% of the rated power of the installation, with the maximum power to be up to 3 MW.

Until 2019, electricity storage was prohibited in producer installations connected to the distribution network. Starting in 2019 this limitation was lifted, and storage systems have been allowed for net-metering prosumers with a maximum limit of the storage converter equal to the power of the production plant and not more than 30 kVA. From 2021, the power of the storage converter in stations of public enterprises is allowed to be up to the PV installed rated power. However, it is not allowed to install storage stations in prosumers with virtual net metering.

The exchange of energy between the storage systems with the grid is not allowed, i.e., the batteries must only charge from the RES production power and discharge to supply the local consumption of the prosumer.

Islanding operation in systems connected to the distribution network is not allowed. All class A inverters (< 1.0 MW) are required to be protected against islanding in accordance with VDE 0126 or an equivalent method.

Technical requirements for storage stations

HEDNO has published a brochure with technical instructions on connecting storage systems to the network. Furthermore, European standards apply to storage systems consisting of batteries and inverters. HEDNO technical requirements describe only the connection of the storage systems to the grid and the position and connection of the energy metering equipment. Usually, the equipment supplier defines further technical requirements and supports the installer in installing and commissioning the storage system.

The technical workforce is unfamiliar with storage systems because such systems have not been widely utilized. As in classic photovoltaic systems, electrical installers will quickly acquire the necessary knowledge and skills when storage systems are extended.

Energy Communities

Energy communities (EC) in Greece constitute a new model of self-generation, self-consumption and independence of the electricity consumer through their advancement to producers. ECs entered the Greek energy market with the publication of Law 4513 in January 2018. Yet, the legal framework gaps and bureaucracy delays have caused obstacles to developing this new way of self-generating electricity.

Until June 2022, with the most recent data according to the General Commercial Register (GEMI in Greek), the Energy Communities registered in Greece 1,217, with another 133 Energy Communities in pre-registration status. The previous publication with similar data was in November 2021, counting 1,036 Energy Communities. It means that during these six (6) months (November 2021-June 2022), there is an important increase of 21%. Most energy communities (around 75%) have 10 – 20 members. From 2018 until 2022, the interest in new RES installations in Low Voltage (LV) and Medium Voltage (MV) has increased significantly. The first applications for RES installations in Energy Communities were submitted in 2019 (344 applications), while the next year, 2021, there was a tremendous increase in new applications (by 731%). The first RES installations were electrified during 2020 (43 installations) with aggregated nominal power of 35.36MW. In November 2021, the applications for new RES installations continued to increase (88%), and it is noticed a larger increase in the electrified RES (677 installations, 466.5 MW aggregated nominal power). From November 2021 to May 2022, the increase in new applications from Energy Communities was not large (only 5%). However, this trend coincides with the total RES applications in the country.

Members of ECs can be citizens and legal entities, as well as regional and local authorities. At the same time, the purpose of each EC can be profitable (i.e., economic benefits through the sale of the electricity produced) or not (self-consumption). The ECs could engage in actions to help vulnerable consumers or even support those living below the poverty line within the area of responsibility.

A key point of law 4513/2018 lies in the locality element for shaping synergies on energy projects to address local needs and take advantage of the local renewable energy sources, returning the benefits to the community’s members. There is the obligation that 50% +1 of the members of an energy community be related to the place where the project’s base will be registered.

The Law introduces technological tools, such as net metering, virtual or not, aiming to protect vulnerable consumers. The Law also includes incentives for projects of up to 6 MW for wind power plants and of up to 1 MW for solar (PVs) to be excluded from bidding procedures, as well as other exemptions regarding, for instance, the payment of an annual fee covering the right to hold a power generation license.

The most recent Law (Law 5037/2023) introduces the terms “Renewable Energy Community (REC)” and “Citizen Energy Community (CEC),” which are in line with the European Directive 2018/2001 and 2019/944, as a replacement of the previous Law 4516/2018. These Directives emphasize the importance of citizen participation in energy transition as part of the “Clean Energy for All” European legislative package. Both new energy community types should contain 30 members as a minimum, a significant increase from the five members of the previous law. The new Law (Law 5037/2023) also provides additional provisions regarding the funding of energy communities. The Energy Communities can use public funds for financial support, while they are also included in the Development Law as a cooperative organization. This Law also deals with issues of self-production for apartment buildings, prohibits the transfer of producer certificates and other licenses, and permits the management of microgrids.

Smart meters and telemetering

Telemetering of Medium Voltage Customers

HEDNO implemented in 2009 the installation of Medium Voltage Telemetering and Processing equipment in the Greek Distribution Network. All MV customer installations are equipped with smart meters and telemetering modules. The collection and processing of metering data are performed in accordance with the “Meter Data Management and Network Suppliers Periodical Statistical Reports Manual” (Off. Journal B2612/31.12.2009), as amended and in force.

The MV telemetering project:

- Brought better conditions in the electricity market and facilitated market liberalization.
- It improved Medium Voltage User services.
- Allowed users to check their electricity consumption (or/and generation) through a web application that enables access to their metering data on the following page: https://meteringnet.deddie.gr. Active and reactive energy consumption in 15 min timestep is available.
- Encourages better electricity consumption behavior.
- Enables users to track the quality of their energy supply online (via web app), improving the quality and reliability of Medium Voltage supply services.

Metering of Low Voltage Customers

Today the Greek Low Voltage customers are equipped with old analog energy meters, with readings taken every four months under in situ reading by HEDNO personnel. Newer installations use digital energy meters with advanced functions without a central telemetering system.

While other countries have been enjoying the benefits of smart meters for years, in Greece, the bureaucracy, the lack of resources and objections among stakeholders created obstacles for a project that has been under discussion by HEDNO and the Ministry of Energy since 2014.

A tender procedure was launched in 2021 to install 7.3 million smart meters. After an initial expression of interest, a shortlist has been drawn up with the companies that meet the specifications of the tender and the submission of technical offers will follow. From this process, three joint ventures will be selected as the tender winners in a project estimated to exceed 850 million euros. All the sector's major players participated in the tender, and currently, HEDNO has shortlisted four out of seven first-round participants. A company that participated in the first round filed an appeal after failing to make it to the second round. The verdict is expected within the next few months.

According to the HEDNO plan, replacing analog or industrial meters with smart meters will be implemented over eight years and completed by 2030. The new smart meters will provide consumers with real-time information on the kilowatt-hours they use; consumption records via home devices or web applications; and varying supplier tariff levels, all of which will help consumers become more energy-efficient for lower energy costs. In addition, smart meters will help HEDNO identify technical problems in the grid, enabling swifter repair of damages.

<u>“PV on the Roof” subsidy program</u>

From April 2023, a new €200 million subsidy program called “rooftop PV” has been launched for solar projects and small storage systems in the residential and agricultural segments. The program is funded by the Recovery and Resilience Facility (RRF) and is managed by the Ministry of Environment and Energy.

According to the program rules, Greek households and farmers can apply for a subsidy to purchase and install small PV arrays and energy storage systems. The applicant can install up to 10.8 kW of PV power and 10.8 kWh of battery storage. For residential users, battery installations will be considered mandatory and must not have less kWh capacity than the kW PV power. However, farmers applying for subsidies will be free to decide whether to install batteries.

Rooftop and ground-mounted systems will be eligible for the subsidies. The program will also cover country houses, but applicants can claim funds for just one residential installation.

Households can obtain up to €16,000 each, while farmers can request up to €10,000 to cover such costs. The incentives will vary according to considerations such as the capacity and the income levels of applicants. The subsidy scheme can cover between 20% to 65% of PV system costs, while for batteries, the cover is 90% to 100% of battery purchase and installation cost.

4.2 Cost-benefit analysis of the solution

The findings regarding the NPV of the investment in the examined building in Greece for various PV and battery sizes are presented below, assuming no load shifting is available. As the PV size increases up to 9kWp, the NPV rises, but for larger PV capacities, it decreases. The most profitable option identified is to combine a 9kWp PV system with a 4kWh battery, resulting in NPV of 7710€. However, for larger batteries, the NPV decreases due to the higher overall cost of the battery system. Notably, the NPV of the 9kWp–4kWh PV-battery configuration differs only by 402€ from the choice of installing a 9kWp PV system without a battery, indicating that integrating battery systems into buildings in Greece remains expensive.

The subsequent section also depicts the self-sufficiency of the various PV and battery sizes examined. As expected, the self-sufficiency ratio (SSR) increases as the PV size rises because a higher percentage of the energy demand is covered by locally generated energy. Similarly, self-sufficiency also improves as the battery size increases. For instance, in the case of the 9kWp–4kWh configuration, the SSR is 38%, while it reaches 32% for the 9kWp–0kWh configuration.

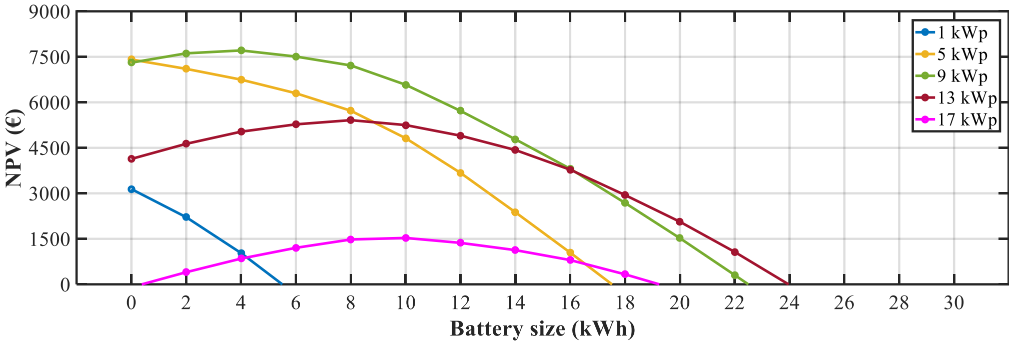

Figure 5. Greece: NPV analysis for 0% flexibility.

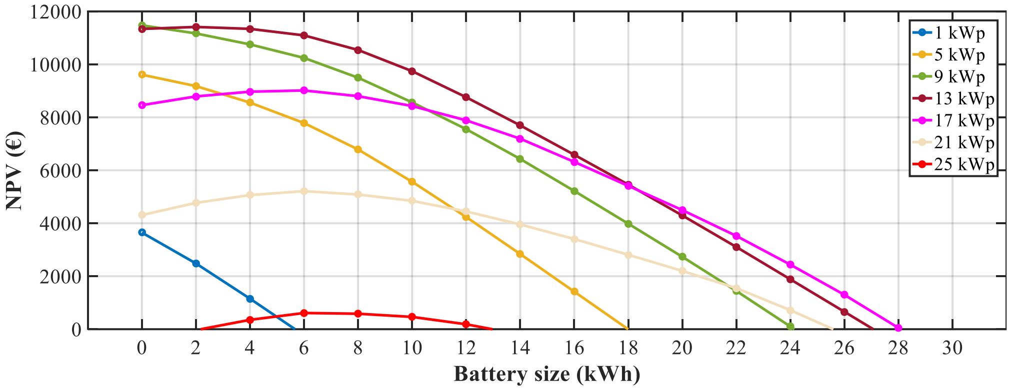

Figure 6. Greece: NPV analysis for 25% flexibility.

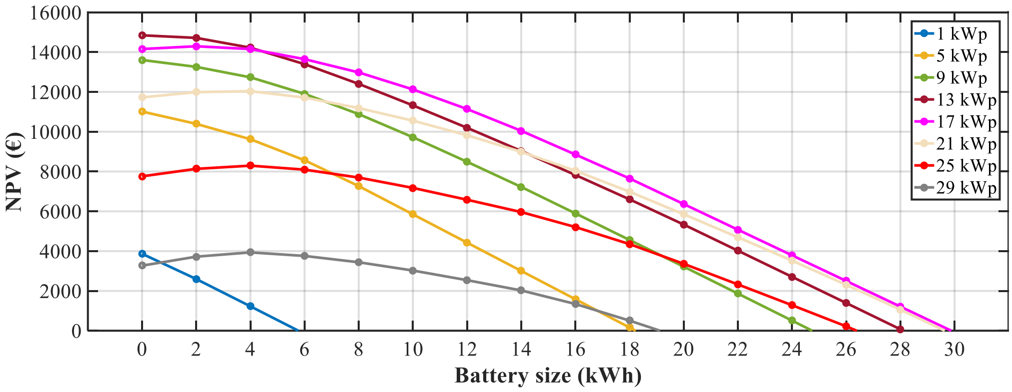

Figure 7. Greece: NPV analysis for 50% flexibility

By implementing load shifting, a portion of the total energy demand can be shifted to coincide with energy production hours, utilizing the building's own energy generation. Consequently, higher PV capacity and/or lower Energy Storage System (ESS) capacity may be necessary compared to scenarios without flexibility. This is demonstrated in the top figure above, where a flexibility level of 25% is examined. It is observed that the most profitable system capacity is 9kWp–0kWh, providing a NPV of 11473€. The ideal PV capacity remains unchanged, while the battery component is no longer financially viable. This configuration achieves a self-sufficiency ratio (SSR) of 40%.

With even higher load flexibility, such as 50%, more PV and battery sizes combinations become cost-effective, as illustrated in the bottom figure below. Additionally, the NPV of PV-battery solutions generally increases compared to lower flexibility levels. In this case, the most profitable solution is a 13kWp–0kWh system, with a NPV of 14844€ and an SSR of 54%. It is important to note that achieving the same level of self-sufficiency without load shifting would require a 13kWp PV system with a 16kWh battery, resulting in a reduced NPV of 3780€.

4.3 Recommendations for securing the necessary funding for the rehabilitation of existing public building stock

Rehabilitating the existing building stock to a zero-carbon-ready level is a key priority for achieving the building sector's decarbonization targets for 2030 and 2050. However, retrofitting buildings is a significant challenge since at least 45% of the buildings in Greece were built before 1980 when the first thermal regulations came into force. Retrofitting 20% of the existing building stock to zero-carbon-ready by 2030 is an ambitious yet necessary milestone toward the Net Zero Emissions by 2050 Scenario. An annual deep renovation rate of over 2% is needed to achieve this goal from now to 2030.

Retrofitting rates for existing buildings in Greece are currently around 1%, with most of these supported by the financial incentives of the “Exoikonomo” programs. However, awareness of the importance of deep building renovation is rising quickly. At the end 2021, the European Union (EU) proposed a major recast to its key Energy Performance of Buildings Directive (EPBD). The recast EPBD aims to accelerate building renovation rates, promote the uptake of renewable energy in buildings, and introduce a new EU definition of a ‘zero emissions building,’ which would apply to all new buildings from 2027 and all renovated buildings from 2030. The European Parliament approved its stance on the EPBD recast on March 2023; the EU Council's final approval is expected later in 2023.

Under the Recovery and Resilience Facility, Greece has requested €30.5bn. Energy renovation of buildings features throughout the Plan, both as an individual sub-component and part of wider investment across the public sector, with total funding amounting to €4.1bn. Notably, nearly €1.3bn is earmarked for investing in energy savings in homes, with a further €350m allocated to adaptation and further energy efficiency as part of regeneration plans. Also, initiatives such as the Renovation Wave for Europe and the Fit for 55 Programme aim to double the renovation rates by 2030, prioritizing the worst-performing buildings.

Finding the optimal cost-effective combinations of building envelope renovation solutions with high-efficient technical systems and using renewable energy sources are the main challenges for the new rehabilitation incentive programs. One of the most significant factors influencing the decision-making process is the required initial investment, which can be high and often have long payback periods.

Using new technology opportunities and construction practices, cost-effective renovation solutions that combine energy efficiency and renewable sources are being explored at the building level. However, for this to happen swiftly and effectively, a strong political will is required, and policy, legal, regulatory, and administrative support frameworks must be developed.

A hybrid PV+BESS+DSM installation has a high initial investment cost and must be supported with appropriate financial incentives, like the "rooftop PV" subsidy program. The building energy renovation actions have significant financial support from the EU and the state. Thus, adding PV+BESS+DSM installation to the list of supported actions will significantly improve the introduction of the above systems in the prosumers energy market.

4.4 Roadmap to self-sufficient buildings based on PV+ESS+DSM utilization

From the above analysis, we can formulate and propose a roadmap of the actions to promote buildings with high self-sufficiency based on PV+ESS+DSM utilization and facilitate the rehabilitation of existing public building stock. The roadmap includes the following steps:

1. Policy Issues

Step 1.1: Authorities and government commitment.

Policy and regulatory responsible authorities should express their will and strongly commit to promoting customers' energy self-sufficiency. The government must commit to allocating the necessary financial resources to implement the measures recommended by the authorities.

2. Regulatory Issues

Step 2.1: Removal of restrictions on storage systems.

All restrictions on the installation of storage systems must be removed. Storage systems must be allowed in all facilities (normal and virtual net-metering) without power limitations. Restrictions of charging from the gid or discharging to the grid must be abolished, to enable further market opportunities for ESS, such as energy arbitrage. The above will make ESS more attractive for building owners.

Step 2.2: Changes to the net-metering scheme.

The net-metering scheme uses the network as a large storage system. The scheme should be changed to consider the state of the energy market at the time of storage or consumption from the grid and become a net-billing scheme where netting is at the level of energy costs and not at the energy level. At a later stage, even the net-billing scheme should be abolished, and prosumers' export of energy to the grid will not be compensated.

Step 2.3: Virtual storage system from energy-communities.

Introducing the virtual storage system must strengthen the institution of energy communities. Specifically, installing a storage system in power production facilities (new and existing) of energy communities will be allowed. An energy storage system will lead to a smoother power curve from the production facility and exploit energy production from the facility during the night. This will have positive consequences in the calculation of energy remuneration of the facility and the profits of the energy community members.

3. Market issues

Step 3.1: Introduction of hourly rate tariffs.

The introduction of hourly rate tariffs and the differentiation of the energy cost depends on the consumption time and the current conditions of the energy market. The possibility of hourly billing is currently possible for medium voltage consumers who have telemetering infrastructure.

4. Network Issues

Step 4.1: Installation of smart meters in low voltage customers.

The tender procedure for replacing analog or industrial meters with smart meters in the Low Voltage network should be finalized. HEDNO should start installing the 7.3 million smart meters as soon as possible. The smart meters will allow extending the hourly rate tariffs to all Low Voltage consumers.

Step 4.2: Use of smart devices in buildings.

The use of smart devices can significantly improve the management of building loads. Many appliances already have wireless communication capability, allowing users to schedule their use time. Combined with hourly tariffs, they can generate significant changes in the load curve of consumers.

5. Incentive Issues

Step 5.1: Incentives through administrative procedures.

The Greek RES market is saturated, and there is a long waiting time for the issuance of connection terms for new RES units. Prosumers' power systems that include a storage system must precede all other power units and be connected to the grid as soon as possible.

Step 5.2: Subsidy for storage systems.

Energy storage using lithium batteries is still expensive, and their utilization should be accompanied by a market subsidy, such as the recent "rooftop PV" program. Other incentives, such as faster grid connection for new PV installations combined with batteries, may help to spread the introduction of storage systems further.

Step 5.3: Building renovation subsidies.

As described in section 4.3, the building energy renovation actions have significant financial support from the EU and the state. Adding PV+BESS+DSM installation to the list of supported actions will significantly improve the introduction of the above systems in the prosumers energy market.

6. Awareness Issues

Step 6.1: Actions aiming at raising consumers' awareness.

Actions explicitly aiming at raising consumers' awareness, like informing them about the benefits of improving self-consumption and its impact on grid operation and environmental issues, should be highly promoted. The user must be aware of the risks of power grid instability created by the high penetration of RES production and the need to help with their energy behavior to increase penetration further.

Figure 8 shows the relationship between the above steps formulating the road-map to self-sufficient buildings in Greece.

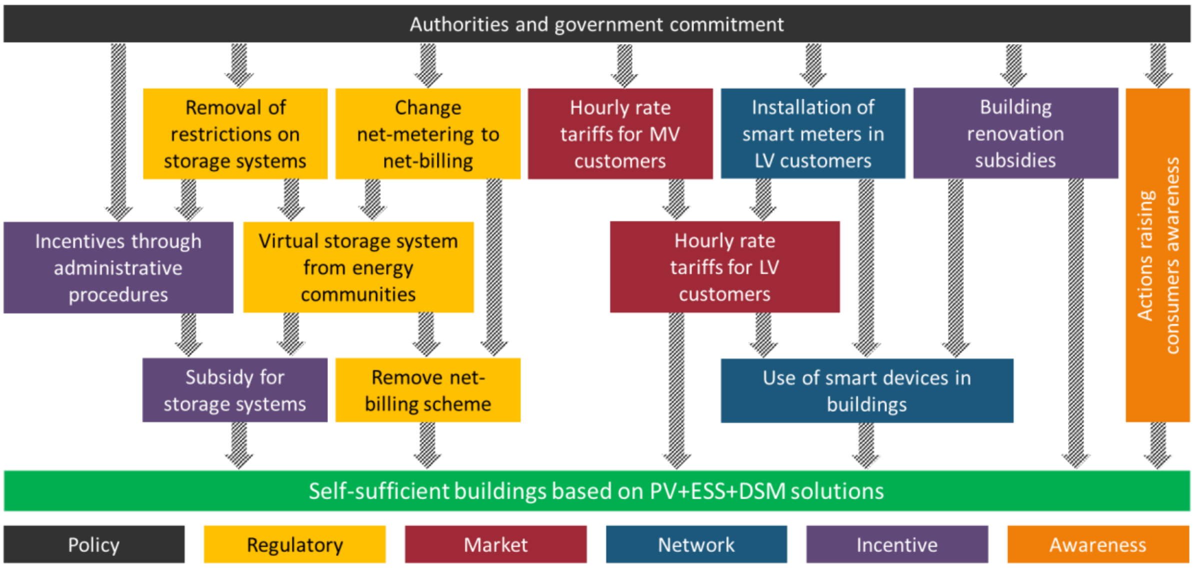

Figure 8. Roadmap to Self-sufficiency in Greece

5 Israel

Despite the extensive policy changes in Israel in recent years, the national target of achieving 30% of the production mix from renewable energy sources by 2030 requires additional complementary policy measures. To address this, the Israeli Ministry of Energy initiated two parallel work processes in the past year.

The first process involved an inter-ministerial collaboration led by various parties. This approach aimed to bring together stakeholders from different ministries to formulate policies and strategies for achieving renewable energy targets. The government intended to ensure a comprehensive and integrated approach to renewable energy development by involving multiple ministries.

The second process, "Down-Top," involved 25 government agencies working together to formulate a government plan to achieve renewable energy targets. This approach aimed to leverage the expertise and resources of government agencies to develop effective policies and initiatives. The involvement of multiple agencies ensured a multidimensional approach and increased the chances of successful implementation.

A customer journey approach, "Up-Bottom", involved entrepreneurs and industry representatives in policy formulation. By engaging with stakeholders from the actual establishment of renewable energy projects, this approach aimed to understand the challenges and barriers they face. The goal was to address these obstacles and prioritize the necessary steps to promote renewable energies in the energy sector.

Public participation meetings were held as part of both processes, providing a platform for stakeholders to voice their concerns, provide input, and offer suggestions. These meetings were crucial in identifying and addressing entrepreneurs' barriers and determining the prioritized actions required to advance renewable energy in the sector.

Through these parallel work processes, the government aimed to ensure a holistic approach to policy formulation, considering various stakeholders' perspectives. By addressing barriers, prioritizing actions, and involving entrepreneurs and industry representatives, the government intended to accelerate the adoption and integration of renewable energy sources into the national production mix, ultimately working towards achieving the 30% target by 2030.

5.1 Policy and market framework toward higher self-sufficiency

<u>Existing Barriers:</u>

Several steps and actions need to be taken in terms of policy and regulation to promote renewable energy and overcome barriers to self-sufficiency in Israel. Currently, the complex relationship between electricity regulation, planning regulations, and real estate regulations poses challenges for entrepreneurs. Obtaining permits from multiple regulators and navigating uncoordinated regulatory requirements can cause delays and complications. The existing regulatory framework is not fully supporting the development of nanogrids or microgrids. Grid connection requirements, energy pricing structures, and regulatory approvals can hinder the implementation of independent energy systems. Grid interconnection and achieving grid independence are also complex issues. Integrating nanogrids or microgrids with the main grid requires technological synchronization and managing energy supply and demand to maintain grid stability.

The scalability and cost of implementing self-sufficient systems can be perceived as barriers. Large-scale deployments often involve significant upfront costs, and achieving economies of scale is essential. Technical complexity is another barrier, as developing and operating self-sufficient buildings or communities requires expertise in multiple technologies.

Securing funding for initial investments and ongoing operation is a barrier as well. The high upfront costs, return on investment periods, and uncertainties around revenue streams can deter investors.

Sustainable Synergy Initiatives:

Addressing all the specified above issues requires coordinated efforts from policymakers, regulators, industry stakeholders, and the public to create an enabling environment for self-sufficient buildings and communities powered by renewable energy. Initiatives promoting self-sufficient buildings or communities include the Eco-Building Program by the Ministry of Environmental Protection, the Israel Smart Energy Association (ISEA) promoting smart energy systems, a microgrid system implemented by Kibbutz Sde Eliyahu, the "Ecological Village" project in Kfar Saba, and a nanogrid system at Ben-Gurion University. These positive yet insufficient initiatives encourage energy-efficient construction, renewable energy technologies, collaboration among stakeholders, and integration of solar panels, biogas generators, energy storage, and advanced control systems to achieve self-sufficiency in electricity and heating.

Economic Incentives and Reforms

Traditionally, economic incentives were provided through feed-in electricity tariffs, which the Israeli Electricity Authority determined. These tariffs were designed to ensure adequate profit for entrepreneurs, create business certainty through long-term agreements, and apply uniform rates based on various parameters.

The Electricity Authority is gradually transitioning towards tariff payments based on benefits rather than costs, reflecting the increasing use of renewable energy.

On the consumer side, dynamic tariffs, also known as time-of-use tariffs, are being explored to incentivize energy efficiency and load shifting. These tariffs involve varying electricity prices based on the time of day or grid demand, encouraging consumers to shift their energy usage to off-peak hours and reduce strain on the grid.

Israel's electricity sector is undergoing significant reforms, including introducing smart meters and advanced metering infrastructure (AMI), laying the foundation for the potential future implementation of dynamic tariffs or other demand-response mechanisms. The recently introduced selective time-of-use (ToU) tariff allows customers to align their tariffs with their specific consumption patterns, providing flexibility and control over electricity expenses. This option encourages customers to be mindful of their electricity consumption and potentially initiate a shifting of usage to off-peak hours, promoting grid efficiency and optimal resource utilization.

By combining economic incentives with technological advancements and demand-side management initiatives, Israel aims to create a sustainable and efficient energy sector that encourages renewable energy adoption and responsible consumption practices.

Promoting the Hybrid PV+BESS+DSM solutions:

In Israel, financial incentives are available to encourage the installation of ESS and the implementation of DSM strategies in buildings with on-site PV generation. These incentives promote energy self-consumption, grid stability, and overall energy efficiency. Feed-in Tariffs (FiTs) are offered by Israel's Electricity Authority, providing a fixed payment for every kilowatt-hour of electricity generated by the PV system. Net metering allows building owners to receive credit for excess electricity fed back into the grid, offsetting future electricity bills. Self-consumption incentives encourage on-site energy consumption and storage, with grants and subsidies available to support the installation of ESS and DSM strategies. Energy efficiency funds provide financial support for energy-saving initiatives, including integrating ESS and DSM solutions in buildings.

Israel has also implemented energy efficiency and DSM incentives across various sectors. The "Better Home" program offers grants and loans for residential energy retrofits, while the "Green Government Buildings" initiative focuses on reducing energy consumption in public buildings. The "Industrial Energy Efficiency" program supports industrial companies in optimizing energy usage, and the "Smart Electricity" program incentivizes demand response initiatives in the commercial sector. The Energy Efficiency and Conservation Authority (EECA) provides technical expertise and financial support for energy efficiency measures.

Controllable loads are being implemented in public buildings in Israel through lighting controls, advanced HVAC systems, building automation systems (BAS), and energy management systems. These measures optimize energy usage, reduce unnecessary consumption, and improve operational efficiency. Public buildings also integrate renewable energy sources and participate in demand response programs, contributing to grid stability and peak demand reduction.

Battery recycling in Israel offers potential financial profit by recovering valuable materials from ESS batteries. Growing market demand, government support and regulations, extended producer responsibility, and circular economy opportunities contribute to the financial profitability of battery recycling operations. Proper planning, efficient processes, and market positioning are crucial for maximizing returns.

Israel promotes using solar power for EV charging to support sustainable transportation. Policies and incentives, such as tax exemptions and grants, encourage the adoption of electric vehicles. Solar facilities for charging EVs, including PV carports and solar-powered charging stations, utilize renewable energy sources and contribute to a greener transportation system. Incentives are provided to businesses and organizations that install solar-powered charging stations.

These government incentives in Israel aim to accelerate the adoption of hybrid PV+ESS+DSM solutions, promote energy efficiency, and drive the transition to a more sustainable and resilient energy system.

Green construction:

Green construction is vital for promoting self-sufficiency, encompassing energy efficiency, renewable energy integration, water conservation, waste reduction, and environmental sustainability. While

Israel has made progress in adopting green construction practices, barriers hinder widespread adoption. The primary barriers include a lack of awareness and knowledge among stakeholders, cost considerations, regulatory constraints, limited availability of “green” materials, fragmented collaboration and coordination, perception and aesthetic concerns, limited expertise, skilled workforce, financial and economic factors, and scaling up and replicability challenges.

Limited land availability:

In Israel, where land availability is limited, proactive measures are being taken to overcome the land deficit for large-scale photovoltaic (PV) plants. Agrovoltaics, which involve growing agricultural produce under solar panels, are being explored to maximize land utilization. The building sector also offers significant potential for solar energy production by utilizing underutilized roofs and integrating solar systems near consumption centers.

To encourage solar energy adoption, the Ministry of Energy recommends mandating the installation of renewable energy systems in existing and new constructions, particularly in public structures and large educational institutions. Alongside awareness campaigns and incentives, these measures can accelerate the deployment of solar systems and leverage Israel's abundant sunshine.

PV and storage at educational buildings:

A special focus in Israel is given to promoting the installation of photovoltaic (PV) and storage systems in educational buildings, particularly schools. Many authorities and companies actively seek suitable school roof areas for installing solar systems and generating electricity. In 2020, the Ministry of Education published regulations and guidelines for installing solar panels on school roofs.

Private entities in Israel have been contacting local authorities to identify suitable areas, especially large roof spaces, for installing solar systems and generating electricity. School roofs are often preferred locations within urban areas due to their accessibility and potential for solar energy generation. However, installing a solar panel system in schools carries potential risks that need to be addressed, leading to establishing an installation policy.

The risks associated with setting up a solar system in schools include radiation hazards, electrification dangers, fire hazards, and the possibility of objects from the schoolyard hitting and damaging the solar panels on the roof.

5.2 Cost-benefit analysis of the solution

In Israel, the cost-benefit analysis focuses on a building that serves as a school. For this reason, the building exhibits higher energy requirements than other cases. Specifically, the annual consumption of energy amount to 303,010 kWh, meaning that it is almost nine times higher than building in Cyprus and 20 times higher than the Greek counterpart. Furthermore, the expected annual production energy for each installed kWp of PV is determined to be 1,909 kWh.

According to financial data in the case of Israel, the total electricity price, including the VAT, is determined to be 0.15239 €/kWh. In contrast to the other countries, the national provider does not impose additional taxes on electricity, making it the lowest cost. In addition, the installation and procurement costs of PV and Battery systems are defined as 1000€/kWp and 550€/kWh, respectively.

The building's high energy consumption necessitates installing high-capacity PV battery systems to enhance self-sufficiency and reduce reliance on grid energy. However, the low electricity price diminishes the need for such high-capacity systems to make a profitable investment.

To examine the potential profitability of PV and BESS projects in Israel, we conducted a Net Present Value (NPV) dependence analysis, considering different levels of load flexibility 0%, 25%, and 50%. Our analysis focused on identifying the most profitable combinations of PV and battery capacities.

Israel's relatively low electricity price of 0.15€ presents a promising environment for profitable high-cost-benefit photovoltaic (PV) and battery energy storage system (BESS) projects. With abundant sunshine throughout the year, Israel has excellent potential for solar generation. Additionally, implementing BESS technology allows for efficient energy storage, mitigating the intermittent nature of solar power. A benefit from PV + BESS projects is expected to rise as the battery size increase. So is the case for higher load flexibility levels, which reduce the on-site energy deficit when the production is low, and consumption prevails over it. Thus, load flexibility increases benefits with no impact on the cost, thus presenting a potential for higher NPV. In addition, high battery installation prices for larger BESS capacity contribute to the higher cost of the system, raising concerns about the cost-effectiveness of these solutions. A presented optimization problem was analyzed, and the insights are depicted below.

To this end, the NPV of the most profitable combinations of PVs' and batteries' capacities under flexibility levels of 0%, 25%, and 50% are presented in Figures 7-9, respectively. When flexibility is unavailable, the NPV rises as the PV size increases to 104kWp, while it decreases for larger PV capacities. In this way, the most profitable choice is the combination of a 104kWp PV with no battery system, providing an NPV of 162k€. For a flexibility level of 25%, the building could further exploit PV production. In this way, the NPV rises as the PV size increases up to 128kWp.

Consequently, the most profitable system capacity is selected at 128kWp-0kWh, providing an NPV of 232k€. In case the load flexibility is even higher, i.e., 50%, larger PV capacity systems could improve the NPV. In this case, the NPV rises as the PV size increases up to 164kWp, and the optimal NPV is calculated at 300k€ and is provided by installing 164kWp PV without a battery system. Finally, it is worth noting that although integrating battery systems could increase the NPV, whether the load shifting is available, the battery systems are expensive to incorporate into buildings in Israel.

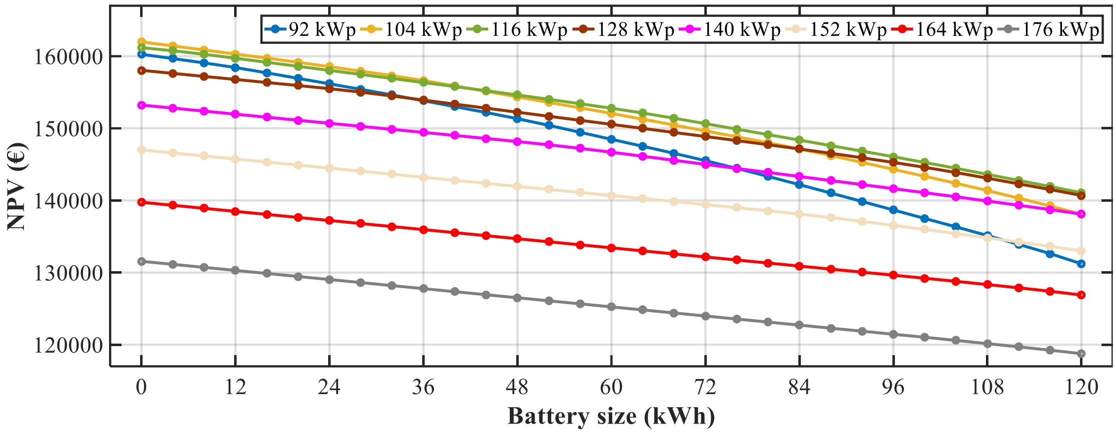

Figure 9. Israel: NPV analysis for 0% flexibility.

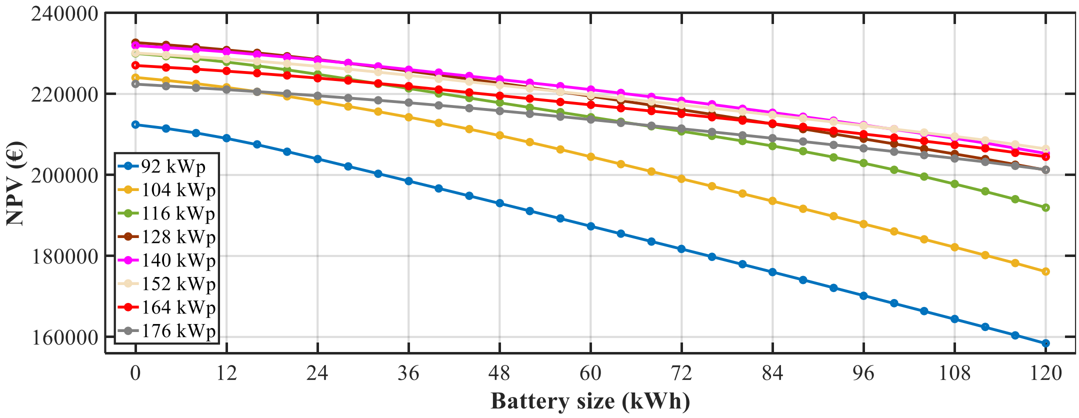

Figure 10. Israel: NPV analysis for 25% flexibility.

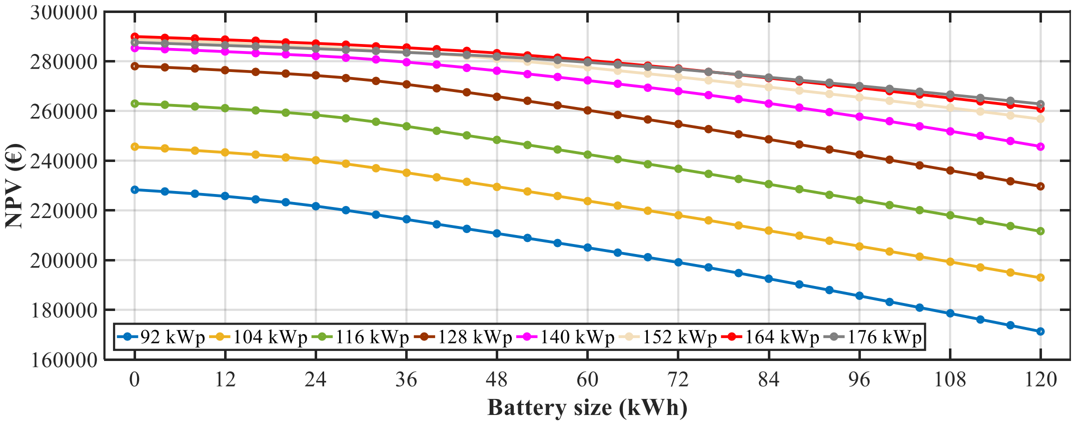

Figure 11. Israel: NPV analysis for 50% flexibility.

As stated above, none of the optimal solutions propose integrating a battery system due to high installation costs. Suppose the electricity prices in Israel will rise. In that case, as in 2022 in some EU countries, it will significantly increase the profitability of PV+BESS+DSM hybrid systems in Israel, probably motivating policymakers and private investors to promote such projects.

5.3 Recommendations for securing the necessary funding for the rehabilitation of existing public building stock

Rehabilitating public buildings in Israel is critical in improving energy efficiency, reducing greenhouse gas emissions, and creating sustainable infrastructure. However, securing the necessary funding for large-scale rehabilitation projects poses a significant challenge. To address these challenges, several recommendations have been proposed.

Dedicated funding for public buildings

One effective approach is establishing dedicated funding mechanisms tailored for public building rehabilitation, such as creating green building funds, revolving loan funds, or grant programs. These mechanisms can be capitalized through government budgets, international funding sources, carbon credit trading, and public-private partnerships. Israel has already established the "Green Building Fund," administered by the Israel Energy Ministry, which provides financial support for energy efficiency and sustainability projects in public buildings.

Public-private partnerships

Engaging the private sector through public-private partnerships (PPPs) can unlock additional funding sources and expertise. Public authorities can enter into long-term agreements with private entities, enabling them to finance, design, build, operate, and maintain public buildings. The Israeli government has embraced PPPs for infrastructure projects, such as the Haifa Port, where a partnership between the government, private consortium, and international investors facilitated the rehabilitation and upgrade of facilities.

International funding and grants

Accessing international funding and grants is another avenue for securing financing. International organizations, development banks, and climate funds offer financial and technical support for energy efficiency projects. Israel has received support from entities like the European Union (EU) and the United Nations Development Programme (UNDP) for research and innovation projects on energy efficiency and sustainable building practices.

Energy performance contracting

Implementing energy performance contracting (EPC) allows rehabilitation projects to proceed with minimal upfront costs. Under an EPC model, an energy service company (ESCO) finances, designs, and implements energy efficiency measures and is reimbursed through achieved energy savings. Israel has introduced the "Megurim Plus" EPC program to encourage energy efficiency projects in public buildings.

Crowdfunding platforms

Creating green bonds and utilizing crowdfunding platforms provide additional financing options. Public entities can issue green bonds to raise funds for environmentally sustainable projects, while crowdfunding allows individuals and communities to contribute towards specific rehabilitation initiatives. Green bonds have gained traction in Israel, with examples like the Israel Electric Corporation issuing a green bond to finance renewable energy projects.

Carbon credit mechanisms

Lastly, exploring carbon finance mechanisms and carbon credits can help secure funding. Carbon credits generated through energy efficiency improvements can be sold in carbon markets, providing a revenue stream for rehabilitation projects. Israel has actively participated in carbon credit projects under the Clean Development Mechanism (CDM) to reduce greenhouse gas emissions and promote sustainable development.

5.4 Roadmap to self-sufficient buildings based on PV+ESS+DSM utilization

By implementing these recommendations and leveraging diverse funding sources, Israel can overcome the funding challenge and accelerate the rehabilitation of public buildings, leading to improved energy efficiency and sustainable infrastructure. The roadmap is divided into several categories defining the most important paths to achieve higher building self-sufficiency.

1. Policy

Step 1.1: Ensure Long-Term Policy Stability for RES Growth

Establish and maintain long-term policy stability at national and municipal levels. Provide clarity on support mechanisms, feed-in tariffs, and incentive programs to build investor confidence in the renewable energy sector. Long-term policy stability is essential for attracting investment and fostering the growth of RES systems.

2. Regulations

Step 2.1: Enhance Regulatory Framework and Utility Structures for DSM Implementation

The regulatory framework in Israel should be revised to address barriers hindering DSM programs, such as inflexible rate structures, inadequate pricing mechanisms, and discouraging regulations. Promote regulatory flexibility by designing rate structures incentivizing demand response and dynamic pricing models. Encourage innovation in DSM approaches and ensure regulations support the implementation of demand response programs and dynamic pricing, which are vital for effective DSM. Foster collaboration among regulators, utilities, and consumers to develop regulatory reforms that create a favorable environment for DSM implementation while protecting consumer interests.

Step 2.2: Optimize Land Utilization and Collaboration for Renewable Energy

Efficiently allocate existing land resources, balancing renewable energy goals with other land uses. Engage local authorities in decision-making, establish planning regulations for agro-voltaic projects, collaborate with the Ministry of Defence for land use opportunities, and develop regulations and pricing mechanisms. Encourage local authorities to create climate change action plans and allocate standardized budgets. Explore solar installations above or alongside roads for widespread solar production.

Step 2.3: Streamline Permitting and Siting Processes for Energy Storage

Simplify and expedite the permitting process for energy storage facilities by establishing clear rules and guidelines for grid-scale projects. Address regulatory ambiguities to reduce uncertainty and attract investors. Improve coordination among regulatory authorities and streamline environmental impact assessments to minimize project delays and costs.

Step 2.4: Establish and Enforce Energy Efficiency Standards

Develop and enforce robust energy efficiency standards for buildings, appliances, and industrial processes. Clear and consistent standards will ensure accountability and promote energy-saving practices. Strengthen enforcement mechanisms to drive compliance and achieve energy efficiency goals effectively.

Step 2.5: Enhance Regulatory Support for Energy Efficiency

Revise and strengthen regulatory frameworks to prioritize energy efficiency initiatives. Implement building codes that require minimum energy performance standards and ensure effective enforcement of energy efficiency regulations. Provide incentives for builders and developers to prioritize energy-saving measures, fostering a culture of energy efficiency in construction and development practices.

3. Market

Step 3.1: Stimulate Market Availability and Competition for Energy Efficiency

Promote a diverse and competitive market for energy-efficient products by encouraging suppliers to offer a wider range of options. Facilitate the availability of energy-efficient appliances and products, empowering consumers to make informed decisions and fostering competition among suppliers to drive innovation and improve energy efficiency options in the market.

Step 3.2: Develop Favorable Market Structures for Energy Storage

Create well-designed market structures and mechanisms to enhance the economic viability of energy storage. Establish favorable tariff structures and enable participation in grid ancillary services markets. By providing adequate market incentives, potential investors will be encouraged, leading to increased deployment of energy storage systems.

4. Network

Step 4.1: Strengthen Grid Infrastructure and Integration for RES and Energy Storage

Upgrade and expand the existing grid infrastructure to accommodate the integration of energy storage and intermittent renewable energy sources. Enhance grid capacity, transmission, and distribution networks to handle bidirectional power flows and fluctuating power output. Prioritize infrastructure upgrades in remote regions with limited transmission capacity to enable efficient renewable energy transmission. Implement smart grid technologies, energy storage, and demand response systems to enhance grid flexibility and optimize RES integration.

Step 4.2: Streamline Interconnection Processes for RES Systems

Simplify administrative procedures and paperwork involved in interconnecting RES systems to the grid. Establish clear technical standards and regulations for grid interconnection, ensuring compliance with voltage stability and power quality requirements. Streamlining interconnection processes will reduce delays, lower costs, and facilitate the timely implementation of RES projects.

Step 4.3: Gradual Deployment of Smart Meters in LV and MV Infrastructure

Continuously deploy smart meters in the low voltage (LV) infrastructure across different regions in Israel. Conduct pilot projects to test the integration of smart meters in the medium voltage (MV) infrastructure. Focus on improving energy efficiency, enabling demand response programs, and enhancing grid management through the widespread adoption of smart meter technology.

5. Financing and Incentives

Step 5.1: Improve Financial Support and Accessibility for Energy Efficiency and RES Systems

Enhance financial incentives such as tax credits, subsidies, and favorable financing options to encourage investment in energy-efficient technologies and RES systems. Develop clear revenue streams and robust business models to mitigate perceived risks associated with energy storage projects. Foster innovation and cost reduction through research and development to make energy storage technologies more affordable. Increase accessibility to financing options for RES systems, addressing upfront costs and investment risks to promote widespread adoption.

Step 5.2: Align Incentives for Energy Efficiency in Rental Properties

Introduce policies and incentives to address split incentives in rental properties. Encourage property owners to invest in energy-efficient upgrades by offering financial incentives, tax credits, or subsidies. Empower tenants to participate by providing information, education, and incentives for energy-saving measures, fostering a collaborative approach to energy efficiency.

Step 5.3: Enhance Financial Incentives and Access to Financing for DSM and Energy Efficiency

Develop robust incentive programs and tariffs that reward energy efficiency and demand response actions, motivating consumers to invest in energy-saving measures. Establish specialized financing options, such as low-interest loans and energy efficiency grants, to overcome upfront costs and facilitate the adoption of energy-saving technologies.

6. Technology and Green Construction

Step 6.1: Develop Domestic Manufacturing Capabilities for RES Technologies

Investment in developing a strong domestic manufacturing base for RES components like solar panels reduces reliance on imports, shortens lead times, lowers transportation costs, and minimizes supply chain vulnerabilities. Improve accessibility and availability of energy-efficient technologies in the local market by supporting domestic manufacturing initiatives.

Step 6.2: Facilitate the Adoption of Advanced DSM Technologies

Address technical challenges by promoting the development and production of green building materials. Raise awareness through campaigns to enhance the availability of advanced energy management systems, smart meters, and IoT infrastructure. Encourage architectural and design innovations that prioritize sustainability and energy-efficient technologies. Provide training and support to improve technical knowledge and skills required to install and maintain energy-efficient technologies.

Step 6.3: Upgrade Aging Infrastructure for Energy Efficiency

Develop comprehensive retrofitting programs to address energy inefficiencies in older buildings. Prioritize upgrades such as insulation, HVAC systems, and lighting fixtures. Implement financial incentives and technical assistance to alleviate the cost burden and facilitate the transition to energy-efficient infrastructure. Foster partnerships between stakeholders to expedite the retrofitting process

7. Awareness and Marketing

Step 7.1: Ensure Data Accessibility and Privacy for Effective DSM

Establish mechanisms for data accessibility while safeguarding consumer privacy and data protection. Develop frameworks that allow secure and controlled access to accurate and real-time energy consumption data for DSM implementation. Implement robust data privacy regulations to build trust and address data ownership and privacy concerns.

Step 7.2: Engage Collaborative Stakeholder Engagement for DSM Success

Facilitate stronger collaboration among utilities, regulators, consumers, and stakeholders. Enhance coordination between utilities and end-users to develop effective demand response programs. Promote engagement of consumers in energy efficiency initiatives through targeted outreach and education. Encourage regular communication and collaboration among all stakeholders to ensure the successful implementation of DSM measures.

Step 7.3: Overcome Cultural and Behavioral Barriers, Enhance Data Availability, and Promote Awareness

Implement targeted education and awareness campaigns to shift consumer attitudes and behaviors towards energy efficiency, addressing cultural norms and lack of awareness. Enhance data collection and dissemination to provide information on energy consumption patterns, potential savings, and best practices. Energy efficiency promotion can be effectively supported by overcoming cultural barriers and increasing awareness while ensuring access to reliable data and information.

Step 7.4: Encourage Demonstration Projects and Knowledge Sharing

Initiate and support demonstration projects that showcase energy storage systems' technical and economic feasibility in real-world applications. Establish knowledge-sharing platforms to disseminate information and best practices. By demonstrating the benefits and building stakeholders' confidence, wider adoption of energy storage technologies can be encouraged, overcoming uncertainties and enhancing awareness of their potential benefits.

Step 7.5: Foster Research and Development for Energy Efficiency

Increase investment in research and development to drive innovation in energy-efficient solutions and technologies. Promote collaborations between academia, industry, and government agencies to support the development of cutting-edge energy-efficient products, materials, and systems. Continuous advancements will accelerate progress in promoting energy efficiency and facilitate the adoption of innovative solutions.

Step 7.6: Promote Accessible and Affordable Energy Audits

Facilitate the availability and affordability of energy audit services. Establish programs to train and certify auditors, ensuring a qualified workforce. Provide financial incentives or subsidies to encourage individuals and businesses to undergo energy audits. By increasing access to comprehensive audits, stakeholders can make informed decisions and prioritize energy-saving investments.

The diagram below (Figure 12) summarizes the mentioned roadmap steps presenting a flowchart for achieving self-sufficiency in Israel.

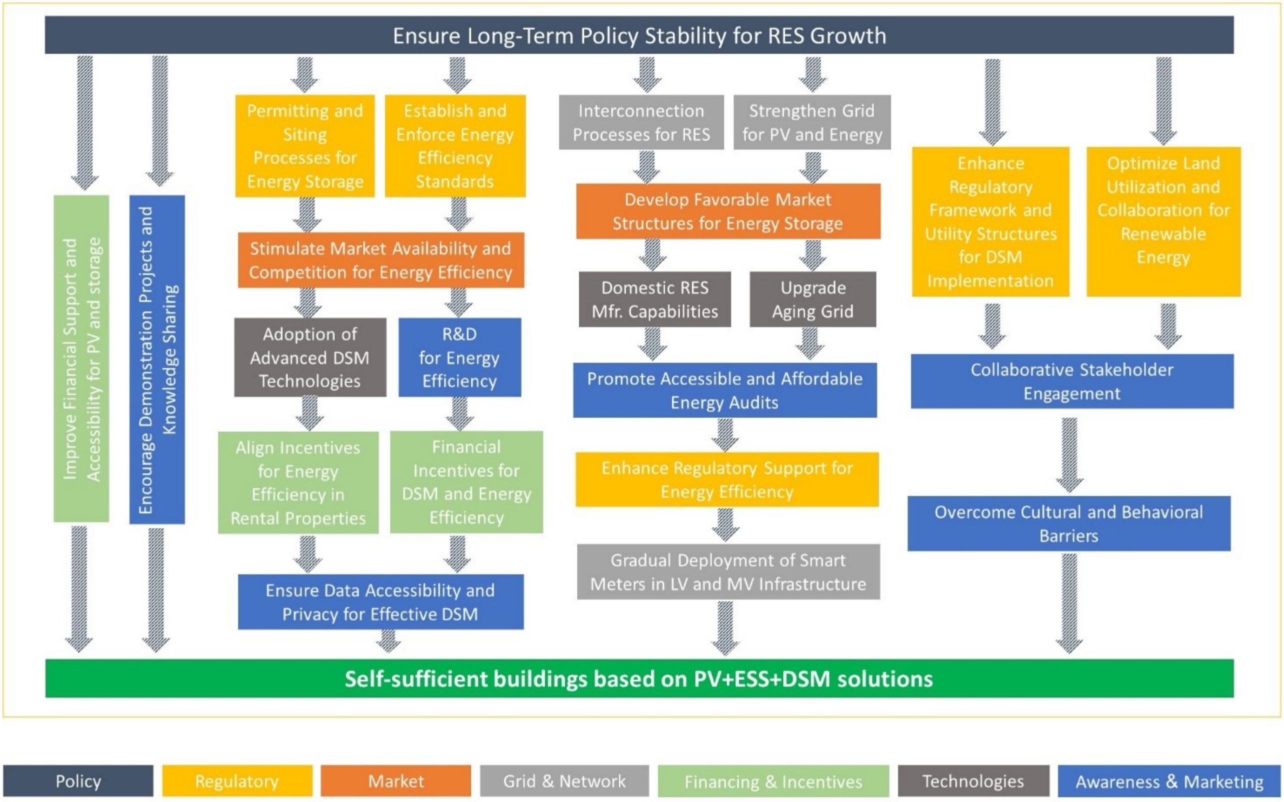

Figure 12. Roadmap to Self-Sufficiency in Israel

6 Italy

6.1 Policy and market framework toward higher self-sufficiency

Current Renewable Energy Sources (RES) and ESS regulation:

Italy has implemented different instruments to support renewable electricity generation, including support for produced electricity, grant aid, and fiscal incentives. GSE (*Gestore dei Servizi Energetici*) is in charge of managing and paying the incentives. The current incentive policy for newly built RES plants is based on competitive tender for awarding incentives, adopting a neutral approach among groups of technologies with similar structures and cost levels. The incentives are paid based on contracts for differences executed with the GSE (i.e., the incentive amount equals the difference between the awarded tariff and the market price). This mechanism enables predefined power levels to be programmed, providing certainty to operators. At the same time, it controls the costs of the support scheme. It avoids overcompensation with benefits for consumers who bear the costs of a support scheme passed on the electricity bill when the market price exceeds the recognized tariffs.

The main current support regimes in place for renewables are the following:

Offtake regime

Regulated under Annex A to ARERA Resolution No. 280/2007, the GSE manages the offtake regime and applies to plants below 10MVA. Under agreements with the GSE, producers sell the electricity generated to be injected into the grid to the GSE instead of selling it through bilateral contracts or directly on the power exchange market. The GSE purchases and resells the electricity to be fed into the grid at the zonal price or a minimum guaranteed price (for plants below 100kW only).

Net metering service

Under this service, regulated by the Consolidated Text on the Net Metering Service, the electricity generated by a consumer or producer in an eligible on-site plant and injected into the grid can offset the electricity withdrawn from the grid. The GSE pays a contribution to the customer based on injections and withdrawals of electricity in a given calendar year and on their applicable market values. Net metering is incompatible with the offtake regime or the all-inclusive feed-in tariff. The service applies to:

a. owners of RES electricity generation plants with a capacity of up to 20kW;

b. RES electricity generation plants with a total of up to 200kW;

c. high-efficiency combined heat and power plants with a capacity of up to 200kW.

Following the changes introduced under the RED II Decree, the **Net metering regime** ended to apply in June 2022. Plants entering operation after this date could access the new incentives provided, if eligible, or opt for the **offtake regime**, while the net metering service would be precluded. Existing plants currently benefiting from the net metering service will move to the incentive regime that will be in place at that time for small-scale plants.

In particular, using PV in residential applications can greatly reduce household consumption's environmental impact. Despite the huge availability of solar resources, the intermittence of PV production may reduce its exploitation. The introduction of storage systems can solve this problem. ESS stores electricity when PV overproduction occurs and acts as a source when PV generation is unavailable. So far, an unfavorable legal and regulatory framework has contributed to the low diffusion of ESS.

The decrees implementing the Renewables Directive (leg. Decree 199/2021, the so-called "RED II Decree") and the Markets Directive (leg. Decree 210/2021, the so-called "Markets Decree"), however, guarantee a gradual path over time for overcoming such criticalities. Approving the new decree-law on NRRP-related reforms (National Recovery and Resilience Plan), which also deals with simplifications regarding ESS, is an opportunity to review the status of the current regulations in Italy.

RED II Decree provides the main principles for implementing a new support regime for large-scale (1 MW or more) and small-scale (lower than 1 MW) renewable energy plants and communities. The incentive favors the coupling of renewable energy plants with storage facilities.

Italian NRRP includes adopting several legislative measures to ensure the effective deployment of renewable energy sources. Under the NRRP, the government is working on streamlining the authorization procedures and timing to provide the full expansion of plant installation. In this respect, changes have been made to the existing authorization framework focusing on ESS and PV plants.

Energy communities and self-consumption

The Directive on Common Rules for the Internal Electricity Market ((EU) 2019/944) introduced rules to enable active consumer participation, individually or through citizen energy communities, in all markets, either by generating, consuming, sharing, or selling electricity or by providing flexibility services through demand response and storage. Energy communities can help increase public acceptance of renewable energy projects and make it easier to attract private investments. Self-consumption and energy communities encourage energy efficiency and can help citizens lower their electricity bills.

Italy regulated energy communities' rules and incentives in 2019 and updated their 2021 regulation to foster their development. The legislation defines energy communities and collective self-consumption as final consumers/renewables producers that foregather to share electricity locally produced by new renewables plants with a capacity of up to 200 kilowatts. Energy communities and prosumers benefit from a targeted incentive mechanism for shared electricity (EUR 100-110/MWh) for 20 years. The RED II Decree raised the capacity limit to 1 MW and adjusted the incentive mechanism. Renewable energy communities represent a further element capable of increasing the renewable energy generation presence across territories and making consumers participants in the electricity system. In this respect, with the RED II Decree and the full implementation of the RED II Directive, large-scale energy communities are now a real possibility, including public buildings and municipalities. The NRRP provides EUR 2.2 billion to public administrations, households, and micro-enterprises in small municipalities (up to 5 000 inhabitants) to build energy communities and install 2 GW of renewable power capacity. However, the necessary implementation regulations are not in place yet. The implementing decree is still being published, even if the public consultations on the issue ended in mid-December 2022. The uncertainty about the regulations and the incentives has discouraged potential investors so far.

Authorization of BESS:

The Markets Decree contains provisions for developing national storage capacity and systems. Future technology development would see an increasing role for storage systems that, combined with renewable energy plants, could stabilize plant production and then play an active role in balancing the system. Moreover, the Installations will be favored by decreasing technology costs (down 80 percent from 2013 to 2020).

The authorization rules for ESS are included in Article 1 of Law 7/2002, amended by Article 9 of Law Decree 17/2022, converted into law on April 27th, 2022. The installation of ESS with a capacity of up to 10 MW is allowed under the "*free building*" regime (i.e., upon previous communication to the municipality), without prejudice to the authorizations for the protection of the landscape and cultural heritage, for the safety and fire prevention, and the need, in addition to obtaining the connection estimate, for prior consultation with Terna, which may send observations to the entities involved.

If the ESS is installed in areas where industrial plants, quarry areas, or power generation plants (P<=300 MW_t) are located and does not require an increase in height or occupation of new areas or a variation to the local town-planning regulation, the simplified enabling procedure (*Procedura Abilitativa Semplificata* – PAS) will be applied. This procedure also 40authorizes the connection line and implies compliance with the approved and adopted urban planning instruments. Prior verification of conformity with the urban planning instruments will be required.

Suppose the ESS is operated with renewable energy production plants (i.e., behind the same meter). In that case, such BESS will be authorized in the same way as production plants in case the plants are newly built.

If the ESS is added to existing or already authorized PV plants:

a) if new areas are occupied, a variant of the single authorization will be necessary;

b) if no new areas are occupied, a simplified enabling procedure will be sufficient.

In other cases, the installation and operation of ESS require a single ministerial/regional authorization. Finally, article 20, legislative decree 199/2021, provides simplified procedures for repowering or revamping existing PV plants in case of installation of new BESS with power up to 8 MW for each MW of the existing plant, without occupation of new areas.

In stand-alone installations (i.e., with a connection point separate from the production plant), the plants will not be subject to environmental assessments except for infrastructures connecting to the public grid where the lines require an environmental assessment.

ESS incentives:

Currently, the main possible sources of revenue for BESS in Italy are the following:

- Valorization of "physical" self-consumption;
- valorization of "virtual" self-consumption (i.e., simultaneously with the production of energy, there is a consumption of power from the grid by the parties participating in such system and

who are in the same substation: it is considered as "incentivized shared energy" such energy which is produced at the same moment in which the subjects that are part of the system are consuming energy);

- arbitrage between the withdrawal value and the energy input value (i.e., BESS either in stand-alone mode or combined with generation plants or consumption units can be used to exploit price differentials at various times of the day);
- grid services (i.e., in the context of calls for tenders for the selection of plants that will be obliged, if called upon, to assist Terna at certain times of the day, with penalties in the event of non-compliance and with the setting of maximum prices at which may be submitted to the GME);
- specific auctions and the capacity market (BESS facilities participated in 2022, 2023, and 2024 capacity market auctions. Plants participating in the capacity market accept to offer a certain amount of energy on the need for a definite number of hours/year at a maximum price. In return, they receive a remuneration, which for the 2024 auction for new plants was found to be €70,000/MWh for already authorized plants and a sum varying between €33,000 and €51,000/MWh for unauthorized plants, depending on the market zones. It is undefined whether capacity auctions will also be held in 2025. However, a new capacity mechanism specifically dedicated to BESS is provided for in Article 18 of Legislative Decree 210/2021).

The most suitable ESS to install to benefit from state incentives changes depends on the type of production plant and its use.

1. Small Plants
2. Large Plants
3. Renewable Energy communities (CERs) and Collective Self Consumption

For small plants, suppressing the 'on-site exchange' system ("Scambio sul posto") will lead to new domestic users and prosumers being equipped with BESS combined with plants, individually or collectively. According to the RED II decree, new incentives for small plants promote the combination with ESS, thereby encouraging the programmability of energy sources. The combination of ESS and RES production is to be favored, so the current two-way incentive system should be abolished for small plants to allow them to enjoy the possible higher energy value than the incentive tariff. The result mentioned above could be achieved in the following way for energy fed into the grid during the most profitable hours: the sum of the value of the energy plus the value of the feed-in tariffs (or plus premiums if the dual tariff is maintained).

The RED II Decree allows two-way incentives for large plants to be retained. Consequently, installing ESS with large plants will be profitable only for negative prices or plants in self-consumption. The structure of stand-alone plants without increasing the original plant area is recommended to obtain profitability from installing self-consumption ESS. On one side, the production plant will benefit from the specific incentives; on the other hand, the producer will benefit from the higher prices resulting from the energy input during peak hours from the ESS. It should be noticed that although stand-alone ESS will be immediately adjacent to renewable energy plants (preferably in the same area), the energy fed into the grid by stand-alone ESS will not benefit from guarantees of the origin or be considered green.

For CERs and Collective Self Consumption, the RED II Decree provides an incentive for shared energy only, which adds to the value of the power. The incentive mechanism is only granted for energy produced and consumed simultaneously within the perimeter of the substation. Therefore, installing ESS on both the production and consumption sides is useful. In this case, installing ESS in combination with production and consumption units seems advantageous. According to the previous regulatory framework, stand-alone ESS was not cost-effective for energy communities. Energy input from stand-alone ESS is not considered renewable, and consumption was not considered withdrawal but negative input. However, Arera's new "Integrated Text on Widespread Self-consumption" (TIAD) stipulates that the product of the absolute value of the electricity withdrawn from ESS for subsequent feed-in to the grid and the average efficiency of the BESS's charge/discharge cycle is also considered as withdrawn electricity for sharing. Including the energy withdrawn from the ESS within the shared withdrawn energy could make installing a stand-alone BESS at the consumption units cost-effective.

Supporting measures

Smart meters. In 2016, ARERA set requirements for second-generation (2G) smart meters. 2G smart meters have improved functionalities, such as increased efficiency of readings and the possibility of switching at any time (instead of the first day of the month with 1G). Also, 2G smart meters allow consumers to access 15-minute frequency readings directly from other devices (e.g., smartphones), with the potential to increase their consumption awareness and access dynamic electricity offers. In addition, 2G smart meters are ready to manage demand-side response with the possibility to control the load remotely and, in perspective, provide ancillary services to the network. Starting from January 2022, only 2G smart meters can be installed. By 2025, at least 90% of delivery points should be equipped with 2G meters and 96% by 2026. Following the Markets Decree, end-customers may request the network distributor to immediately install smart meters with all necessary interface and interoperability functions at their own cost and on fair terms. The distributor must install these meters within four months of the request. Smart meters bring benefits to owners of BESS. They can install smart meters to participate in dynamically priced electricity offers. Thanks to the flexible management provided by BESS, owners of BESS will be able to withdraw energy at times when the zonal price is lower and save significant energy costs.

The transition from the single zonal price (PUN) to the zonal price. According to Article 13 of the Markets Decree, the transition from the PUN to the zonal price will also occur for energy withdrawals. Compared to the PUN, the zonal price allows the producer to have dynamic prices. Consequently, thanks to the dynamic pricing system, customers will be assured that the renewable energy produced by them (or by third parties with whom they have PPAs) will have a value that offsets the market value of the energy purchased. For the benefit of BESS and renewable energy, consumers will be encouraged to consume energy from BESS during the hours of renewable energy production and install their plants. In addition, consumers will be prompted to enter long-term agreements to purchase renewable energy.

Demand Response Program in Italy

Italian regulation defines "virtual units" and "mixed enabled virtual units" as allowed to participate in the electricity market. A "virtual unit" aggregates different distributed resources acting as a single entity when engaging in power system markets or selling dispatching services to the system operator. "Mixed enabled virtual units" (UVAM) is an aggregation of consumption and production units and storage systems (including e-mobility charging stations).

Currently, UVAMs can provide services such as congestion management, balancing service, and replacement reserve, but the government aims to start experiments for using them for frequency restoration reserve. The regulation foresees a maximum number of four reliability tests per UVAM per year. In the event of failure of three tests in one year, the ancillary services market disables the UVAM, and the contract is terminated. Indeed, UVAMs are still in an experimental phase and should reach full implementation in the next few years.

In UVAMs, the user must define a baseline; if incorrect, it entails an implicit penalty for verifying the service realized. The program provides asymmetric penalties (only in case of underperformance) if the quantities requested are not correctly recognized. In the current Italian electricity market, the mechanism is configured as a tool to encourage Demand Response explicitly.

The market mechanism reorganization.

Of course, greater modification/structure market design and grid regulations in a way that supports energy storage are needed. Nevertheless, given the above, the new legislative and regulatory framework will lead to a positive trend for the BESS plants. Italy encourages substantial investment and great opportunities for more effective and profitable use of BESS. The indicative timeframe for significant positive effects is no more than 1/2 years. Consequently, residential end users can expect increased self-sufficiency and self-consumption, paving the way for more sustainable energy systems.

6.2 Cost-benefit analysis of the solution

The building chosen as the study case in Italy exhibits significantly high consumption, nearly ten times that of Cyprus and 22 times that of Greece. Therefore, a system with a considerably large PV battery capacity is expected to be profitable. Without load flexibility, the most cost-effective solution is a 300kWp–400kWh system, as depicted in Figure 13. The substantial PV and ESS capacities are influenced by the high electricity cost in Italy, which is 0.58€. Notably, each PV size above 270kWp offers a maximum NPV of around 1690 k€ (refer to the focused area in the figure). In such cases, opting for the PV-battery system that provides the highest self-sufficiency ratio (SSR) is advisable. A higher SSR indicates a lower reliance on grid-imported energy to meet the electricity demand not covered by the PV or the battery. This ensures a relatively low electricity bill even in future tariff increases. The 360kWp–390kWh system offers an NPV slightly lower than the most profitable solution by only 0.8% for the examined building.

Furthermore, considering a flexibility level of 25% enhances the economic benefits, as illustrated in the figure below, where the most cost-effective solution is a system with 315kWp–300kWh. A higher NPV can be achieved with the same PV size but a smaller ESS capacity by doubling the flexibility level. Generally, it is observed that as the flexibility level increases, the most profitable solutions necessitate a smaller battery size.

The value of SSR for a building rises until it reaches a maximum and then saturates as the PV and battery sizes increase. This saturation point may be attained by PV-battery solutions that are not economically viable. Hence, exploring a solution that offers the highest possible energy self-sufficiency while still being cost-effective is crucial.

Financial incentives such as subsidies for purchasing battery systems or the implementation of time-of-use tariffs could be introduced to promote the adoption of battery systems and enhance their profitability. These measures would encourage building owners to invest in PV battery systems with high self-sufficiency levels.

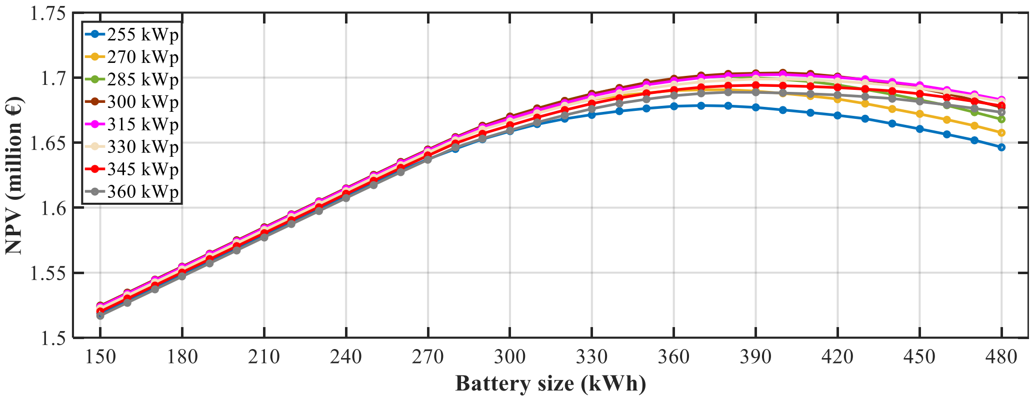

Figure 13. Italy: NPV analysis for 0% flexibility.

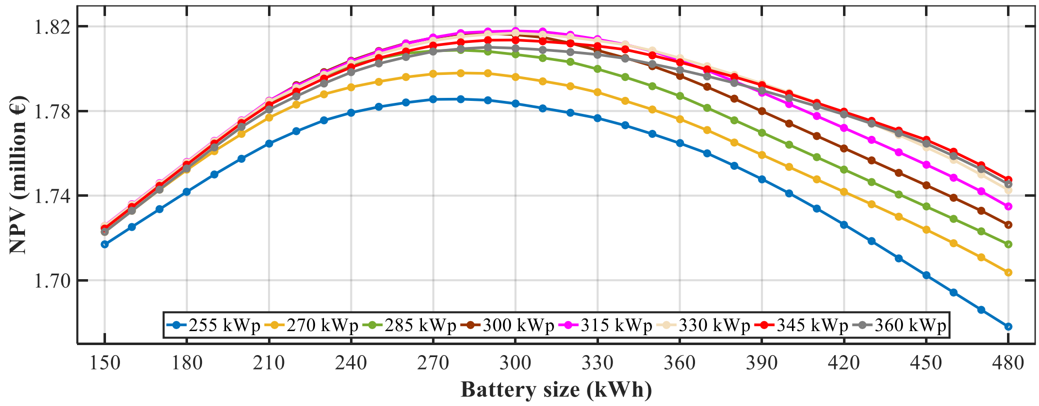

Figure 14. Italy: NPV analysis for 25% flexibility

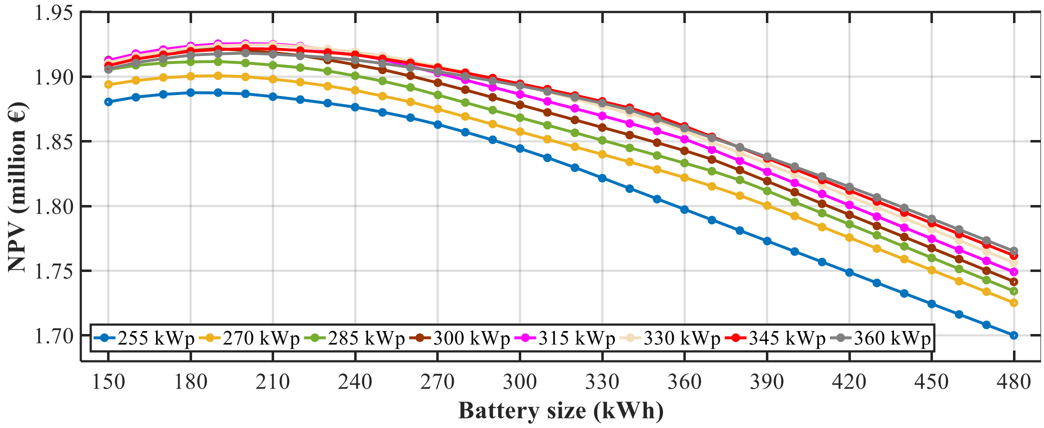

Figure 15. Italy: NPV analysis for 50% flexibility

6.3 Recommendations for securing the necessary funding for the rehabilitation of existing public building stock

Energy efficiency in buildings

The building sector is crucial in all the possible net zero scenarios suggested for the European Union.

The importance of improving energy efficiency in the Italian building stock is recognized by the National Energy and Climate Plan (NECP) and the Italian Long-Term Renovation Strategy (LTRS), which have set national targets and guidelines to achieve the 2030 and 2050 European objectives. Italy suffers from an aging and low-performance building stock and needs to increase its annual rate of energy retrofits to achieve these targets. Even though since at least 2007, several different incentive schemes intended to stimulate energy-efficiency interventions have been in place, Italy has not been sufficiently able to promote deep retrofits. According to Italian law (Italian Legislative Decree 192/05, as amended), an Energy Performance Certificate (EPC) is required for almost all categories of buildings. The EPC (EPC) is defined as "a document, drawn up in accordance with the rules contained in this decree and issued by qualified independent experts, which certifies the energy performance of a building through specific descriptors and provides energy efficiency improvement recommendations". In 2020, to help the economy recover after the lockdowns introduced to face the first phase of the COVID-19 pandemic, the existing incentives were increased to up to 110% of investments for interventions that improved the energy class by at least two grades. This so-called "Superbonus" was also extended to the public social housing sector thanks to a credit assignment scheme. Given the results of this provisional phase, a possible policy roadmap for the energy renovation of the residential and educational building stock in Italy is possible through an analysis of data related to the implementation of current instruments in terms of the number of interventions, the investment needed, energy savings and evaluation of potential benefits and costs that can derive from an increase in the current deep-renovation rate.

To tackle existing buildings, it is necessary to develop a mix of technical, fiscal, and regulatory measures that promote the spread of interventions and increase deep renovations: in particular, those that achieve the NZEB standard Italy issued a ministerial decree in 2015 for nearly zero energy buildings (nZEB). 'Nearly zero-energy building' means a very high-energy performance building. The nearly zero or very low amount of energy required should be covered significantly by energy from renewable sources, including energy from renewable sources produced on-site or nearby. As of December 31st, 2019, new buildings occupied and owned by public authorities should be nZEB. Moreover, since the beginning of 2021, all new buildings and buildings undergoing major renovation should align with nZEB standards. At the end of 2020, Italy's total nZEB stock was 7 831, 96% residential and 4% non-residential use. At the end of 2021, the estimated number of buildings with nZEB standards was 15 000 (Italy, MiTE, 2021).

Italy issued a Strategy for Energy Retrofitting of the National Building Stock in March 2021 (Italy, MiTE, 2021). Buildings are expected to contribute around 60% of the annual final energy savings target in 2030, and the strategy sets out the technical, financial, and regulatory measures to achieve it. In 2018, Italy had 12.4 million residential buildings, with a total surface of over 3 billion m^2. More than 65% of buildings were built before the first law on energy efficiency (1976), and 22% of the total residential building stock is not occupied. In addition, close to 1.6 million buildings are being used for non-residential purposes.

The NRRP Mission 2 – *Green revolution and ecological transition* 3rd component, "*Energy efficiency and redevelopment of buildings,*" aims at achieving energy efficiency in the public and private building stock while rendering structures safe and digitizing them. Priority is given to schools, hospitals, and social housing.

The component intercepts a very important dimension for reducing CO_2 emissions: the reduction in energy consumption of buildings that generate more than a third of total consumption in Italy and the adjustment of buildings to make them earthquake-resistant. Most of the country's 14.5 million buildings have been built in eras before current energy efficiency regulations. Italy is also exposed to seismic risks, which require widespread diffusion of preventive interventions.

The component consists of two design lines. The first regards the implementation of a program for greater efficiency and security of the heritage of public buildings, with particular reference to schools, public housing, municipalities, and judicial towns. The second relates to a temporary incentive for energy requalification and anti-seismic measures introduced with regard to private property through a tax deduction equal to 110 % of the costs incurred for the related interventions.

Two main objectives of the Component M2.C3:

- Energy efficiency of public and private building assets, with contextual securing and digitization of structures.
- Relaunch of the construction sector in terms of environmental sustainability and seismic performance.

NRRP M2.C3 - Energy efficiency and requalification of public buildings in metropolitan areas: Projects are under development with the ANCI (National Association of Italian Municipalities) regarding the requalification of municipal buildings for social use.

6.4 Roadmap to self-sufficient buildings based on PV+ESS+DSM utilization

1. Policy

Step 1.1: The Italian government should develop a comprehensive policy framework to promote energy self-sufficiency through renewable energy sources. The policy framework should prioritize integrating energy communities and encourage active consumer participation.

2. Regulatory

Step 2.1: Implement the RED II Decree:

Ensure the full implementation of the Renewable Energy Directive II (RED II) Decree provides the main principles for a new support regime for large-scale and small-scale renewable energy plants and communities. Create a framework that promotes combining renewable energy plants with storage facilities, including BESS.

Step 2.2: Publish the implementing decree for energy communities:

Finalize and publish the implementing decree for energy communities, providing clear guidelines, regulations, and incentives for establishing and operating energy communities. Ensure the decree supports the deployment of renewable power capacity and encourages citizen participation.

Step 2.3: Enable simplified procedures for BESS and PV plants:

Establish simplified enabling procedures for installing and operating BESS with existing or newly authorized PV plants. Streamline the authorization process to facilitate the integration of BESS into the energy system and encourage the use of storage technologies.

3. Market

Step 3.1: Promote market mechanisms for BESS:

Develop market designs and regulations that support BESS's effective integration and utilization. Enable BESS participation in grid services, such as demand response, ancillary services, and capacity markets. Create mechanisms for price arbitrage, incentivizing BESS operation during periods of low electricity prices and high demand.

Step 3.2: Transition to zonal pricing:

The transition from the single zonal price (PUN) to zonal pricing for energy withdrawals allows producers and consumers to benefit from dynamic pricing. Align the pricing system with renewable energy production and consumption patterns, encouraging the use of BESS and the adoption of renewable energy sources.

Step 3.3: Implement demand response programs:

Expand demand response programs in the electricity market, including virtual and mixed-enabled virtual units (UVAMs). Enable these programs for congestion management, balancing, and frequency restoration reserves. Develop regulations and penalties that ensure the reliability and effectiveness of demand response services.

4. Network

Step 4.1. Install smart meters:

Accelerate the deployment of 2G smart meters, ensuring that at least 90% of delivery points are equipped with 2G meters by 2025 and 96% by 2026. Enable customers with smart meters to access dynamic electricity offers and actively manage their energy consumption. Facilitate the integration of BESS with smart meters, allowing owners to take advantage of flexible energy management and cost-saving opportunities.

Step 4.2: Enhance grid infrastructure:

Upgrade the grid infrastructure to accommodate the integration of renewable energy sources and BESS. Assess and plan for the necessary grid reinforcements to support the increased penetration of decentralized generation and storage technologies. Ensure grid reliability and stability while optimizing the utilization of renewable energy.

Step 4.3: Develop storage-specific grid regulations:

Develop specific grid regulations that address energy storage systems' unique characteristics and requirements. Consider grid connection, power quality, system stability, and code compliance. Adapt grid regulations to facilitate the smooth integration and operation of BESS.

5. Marketing and Education

Step 5.1: Raise awareness about RES and BESS benefits:

Conduct public awareness campaigns and educational programs to inform citizens about the benefits of renewable energy sources and BESS. Highlight the environmental and economic advantages of using RES and BESS technologies. Encourage individuals, communities, and businesses to adopt renewable energy and storage solutions.

Step 5.2. Provide training on RES and BESS:

Develop training programs and educational resources to equip professionals, technicians, and installers with the necessary skills and knowledge to design, install, and maintain RES and BESS systems. Promote vocational training and certification programs to support the growth of the renewable energy and storage industry.

Step 5.3. Foster research and development:

Invest in research and development initiatives to advance renewable energy and storage technologies. Support universities, research institutions, and industry collaborations to drive innovation, improve efficiency, and reduce the costs of RES and BESS. Encourage the development of new technologies and solutions to address the challenges and maximize the potential of renewable energy and storage.

6. Financial Incentives:

Step 6.1: Introduce Subsidies and Grants for Residential Renewable Energy Systems

Implement subsidies and grants for residential renewable energy systems like solar panels. Offer financial incentives to encourage homeowners to invest in renewable energy, reducing grid dependence and promoting self-sufficiency. Establish clear eligibility criteria and streamlined application processes to ensure broad adoption of residential renewables.

Step 6.2: Implement Net Metering Programs with Favorable Terms

Implement net metering policies with fair compensation rates, longer contracts, and favorable terms to enable residential energy producers to offset consumption. Promote the integration of energy storage systems for enhanced self-sufficiency.

Step 6.3: Establish Feed-in Tariffs for Energy Communities and Collective Self-Consumption

Introduce community-specific feed-in tariffs, incentivizing local renewable energy production and consumption. Provide financial rewards to energy communities for their sustainable practices. Establish attractive tariff rates to enhance economic viability and attract investments, fostering community-level energy self-sufficiency.

The flowchart below (Figure 16) visually represents the roadmap steps for achieving self-sufficiency in Italy. These steps aim to support the growth of renewable energy sources and enable active consumer participation in the electricity system.

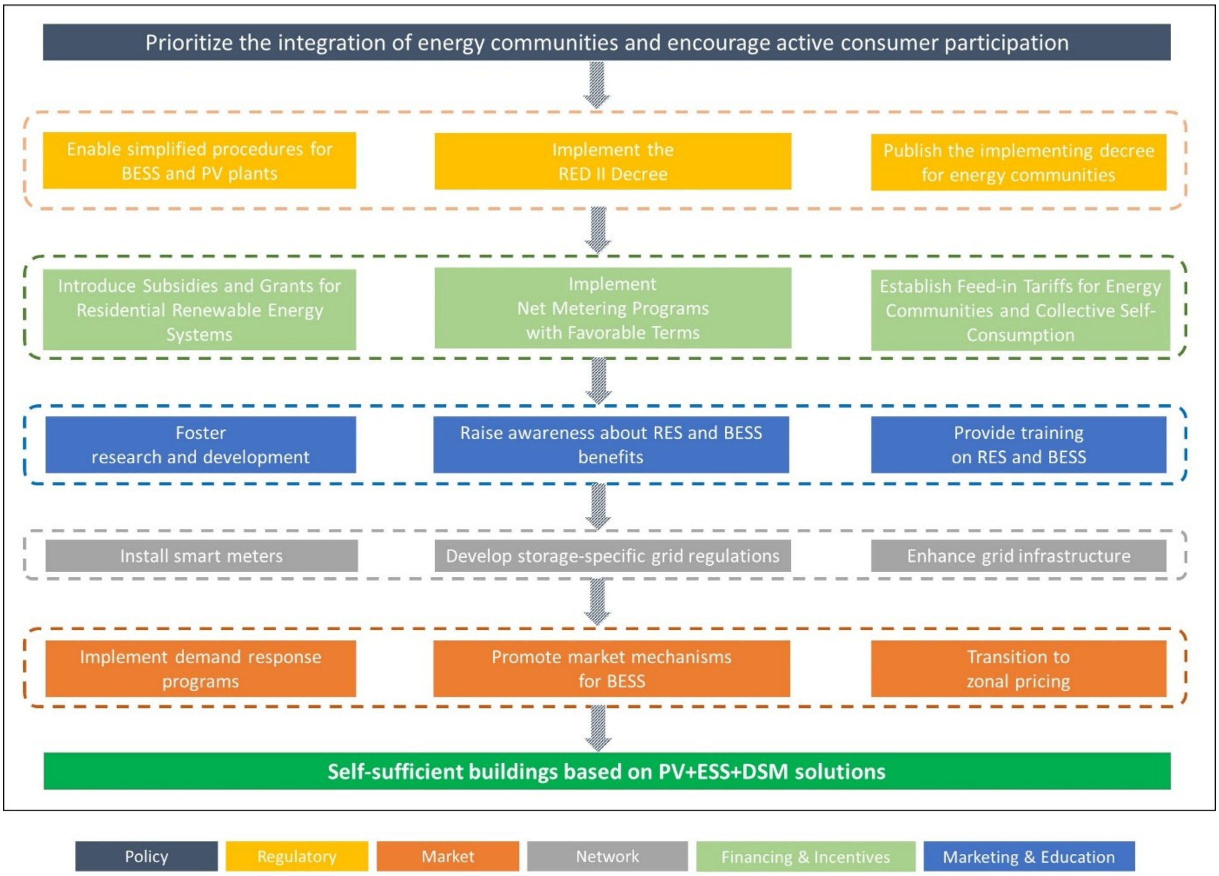

Figure 16. Roadmap for Self-Sufficiency in Italy

7 Generic Technical guidelines to reach higher resilience

The Mediterranean region faces an increasing demand for energy and a growing need for resilience in public buildings, particularly in climate change and natural disasters. The use of renewable energy sources, such as photovoltaic (PV) systems, battery energy storage systems (BESS), and demand-side management (DSM) strategies, can help to address these challenges and improve the resilience of public buildings.

Below, a generic roadmap to reach higher resilience is presented.

Step 1: Conducting a building energy audit

Conducting a building energy audit is important in improving energy efficiency and reducing carbon footprints. The audit involves assessing energy use, running a walkthrough, analyzing consumption data, identifying efficiency opportunities, developing an action plan, and implementing recommendations. Building owners can save money and contribute to a sustainable future by reducing energy waste.

Determining the optimal size of a photovoltaic (PV) system to meet a building's energy demands can be challenging, but online tools are making it more accessible. An online tool developed in the Berlin project considers factors such as energy usage patterns, location, and financial constraints to recommend an optimal PV system size. The user enters their location, building size, and average monthly energy usage, and the tool calculates the optimal PV system size and estimates energy and cost savings. This tool allows customers to make informed decisions about the optimal PV system size and save time and money.

In conclusion, building owners can increase energy efficiency by conducting a building energy audit and implementing recommendations. Determining the optimal PV system size can be challenging, but online tools make it more accessible and user-friendly. The Berlin project's online tool considers various factors to provide a customized recommendation for the optimal PV system size, allowing customers to make informed decisions and save time and money.

Step 2: Designing the BESS system

After determining the appropriate size of the PV system, the next step is to design the BESS system. The BESS system should be prepared to store excess energy generated by the PV system during periods of low energy demand and discharge the stored energy during periods of high energy demand or when the PV system is not generating energy due to low solar irradiance. The BESS system should be sized to meet the building's energy needs during low solar irradiance or power outages.

Designing a Battery Energy Storage System (BESS) requires careful consideration of various factors to ensure its effectiveness and efficiency. BESS systems are designed to store excess energy generated by renewable energy sources for use during periods of high demand or low renewable energy production. Here are some key considerations when designing a BESS system:

- System Capacity: The capacity of the BESS system should be determined based on the amount of energy generated by the renewable source and the expected demand. The system capacity should be large enough to store excess energy but not too large that it becomes uneconomical.
- Battery Type: The type of battery used in the BESS system is also an important consideration. Lithium-ion batteries are the most commonly used battery for BESS systems due to their high energy density and long cycle life.

- Control System: The control system of the BESS system is responsible for managing the flow of energy to and from the battery. The control system should be designed to ensure that energy is stored and discharged efficiently and reliably.
- Safety Features: Safety features should be incorporated into the design of the BESS system to prevent accidents and ensure the safety of people and property. This includes protection against overcharging, overheating, and short circuits.
- Monitoring and Maintenance: A monitoring and maintenance system should be implemented to ensure that the BESS system operates optimally. Regular maintenance and monitoring can prevent system failure and increase the lifespan of the BESS system.
- Integration with Grid: The BESS system should be designed to integrate with the power grid. This involves ensuring that the BESS system can connect to the grid and effectively manage the energy flow between the grid and the battery.

Designing a BESS system requires careful planning and consideration of various factors to ensure the system is reliable, efficient, and safe. By considering these factors, the BESS system can effectively store and discharge energy to meet the needs of the grid and the consumers.

Step 3: Incorporating DSM strategies

The final step is to incorporate DSM strategies into the overall system design. DSM strategies should be designed to manage the building's energy demand by controlling energy consumption during peak demand periods or when the PV system is not generating energy. DSM strategies include load shedding, demand response, and energy-efficient lighting and HVAC systems.

DSM (Demand Side Management) strategies effectively manage energy consumption and reduce peak energy demands. Implementing DSM strategies can reduce energy costs, improve energy efficiency, and reduce environmental impacts. Below are some ways to incorporate DSM strategies into your energy management plan:

- Energy Audits: Energy audits help identify areas in your facility where energy efficiency can be improved. Energy audits involve evaluating the building's energy use, identifying waste areas, and determining ways to reduce energy consumption. This can be done in-house or with the help of a professional energy auditor.
- Energy Efficiency Upgrades: Upgrading to more energy-efficient equipment can significantly reduce energy consumption. This includes upgrading to LED lighting, more efficient HVAC systems, and Energy Star-rated appliances. This can also include upgrading insulation and sealing air leaks in the building envelope.
- Load Shedding: Load shedding is a strategy that temporarily reduces energy consumption during peak demand periods. This can be achieved by turning off non-essential equipment or implementing demand response programs.
- Time-of-Use Pricing: Time-of-use pricing involves charging higher prices for energy during peak demand periods and lower prices during off-peak periods. This strategy incentivizes consumers

to reduce energy consumption during peak periods, reducing energy costs and improving energy efficiency.

- Habitants Education: Employee and residents' education programs can help raise awareness about the importance of energy conservation and how each employee can reduce energy consumption. This can include training on energy-efficient practices, providing feedback on energy consumption, and incentivizing energy-efficient behavior.

Incorporating DSM strategies into your energy management plan can result in significant cost savings, improved energy efficiency, and reduced environmental impacts. It is important to evaluate your facility's energy use and identify opportunities for improvement, implement energy efficiency upgrades, and educate employees about energy conservation practices.

Step 4: Integrating the PV+BESS+DSM hybrid system

The final step in achieving higher resilience in public buildings is integrating the PV+BESS+DSM hybrid system into the building's electrical infrastructure. This integration should be done in accordance with local regulations and standards and should take into consideration the building's existing electrical infrastructure and load profiles. The system should be designed to operate in parallel with the grid and should include appropriate protection and control systems to ensure the safety and reliability of the overall system.

The integration of Photovoltaic (PV), Battery Energy Storage Systems (BESS), and Demand Side Management (DSM) has become increasingly popular in recent years, intending to improve the reliability and efficiency of power supply. The integration of these systems creates a hybrid system that can improve the stability and resiliency of the grid by providing ancillary services and reducing peak demand.

The PV system generates electricity from solar radiation, and the BESS stores this energy for later use. DSM refers to managing energy consumption to balance the demand and supply of energy. Integrating these systems can help achieve a sustainable energy supply by maximizing renewable energy sources while reducing the carbon footprint.

Integrating PV, BESS, and DSM can be challenging, as these systems have different operating characteristics and objectives. One of the key challenges is managing the power flow between the different components of the system. For example, during periods of low demand, excess energy generated by the PV system can be stored in the BESS, and during peak demand, the BESS can discharge the stored energy to meet the load. However, the coordination of the system requires sophisticated control algorithms to optimize the use of the available resources.

Another challenge in integrating these systems is the communication and data management required for effective DSM. Real-time data on energy consumption, grid conditions, and weather forecasts are essential for effective energy management. Thus, advanced communication networks and data management systems are crucial for successfully integrating PV, BESS, and DSM.

Despite the challenges, PV, BESS, and DSM integration significantly benefit the grid and energy consumers. Maximizing renewable energy sources, reducing peak demand, and providing ancillary services, the hybrid system can improve grid reliability, reduce greenhouse gas emissions, and lower consumer energy costs. Therefore, investing in research and development is essential to improve further the integration of PV, BESS, and DSM and accelerate the transition towards a sustainable energy future.

The Mediterranean region is facing an increasing demand for energy and a growing need for resilience in public buildings. Using renewable energy sources, such as PV systems, BESS, and DSM strategies, can help address these challenges and improve the resilience of public buildings. The procedures outlined in this deliverable provide a roadmap for achieving higher resilience in public buildings across the Mediterranean region with a PV BESS DSM hybrid strategy. By following these procedures, public building owners and operators can improve energy efficiency, reduce their reliance on the grid, and enhance their resilience in natural disasters and climate change.

8 Conclusions

In conclusion, this report has presented a comprehensive analysis of the policy and market framework for achieving higher self-sufficiency through the integration of PV, ESS and DSM strategies in buildings. Additionally, a thorough cost-benefit analysis and a roadmap to self-sufficient buildings have been outlined for four countries: Cyprus, Greece, Israel, and Italy, along with six pilot projects located within these nations.

The findings of this report underscore the significance of adopting a robust policy and market framework to promote the widespread implementation of PV+ESS+DSM technologies in the building sector. Through various incentive mechanisms, feed-in tariffs, and tax credits, these countries can encourage investments in renewable energy systems, making them economically viable for both the private and public sectors. Moreover, regulatory reforms aimed at streamlining the permitting and approval processes for such installations will further expedite the transition towards self-sufficiency.

The cost-benefit analysis presented in this report has demonstrated that while the initial investment required for the deployment of PV+ESS+DSM technologies may be substantial, the long-term benefits far outweigh the costs. Not only do these systems reduce reliance on conventional energy sources and mitigate greenhouse gas emissions, but they also offer considerable financial savings to building owners and occupants through reduced utility bills and potential revenue generation from surplus energy exports.

The roadmap to achieving self-sufficient buildings has outlined a clear path towards integrating PV+ESS+DSM technologies at different scales, from individual residential units to commercial and public infrastructure. The establishment of pilot projects within Cyprus, Greece, Israel, and Italy has proven to be instrumental in identifying specific challenges and opportunities unique to each region. By leveraging the insights gained from these pilot projects, these countries can fine-tune their strategies and create tailored action plans to accelerate the adoption of self-sufficient building practices nationwide.

In summary, achieving higher self-sufficiency in the building sector is a complex yet achievable goal, and the integration of PV+ESS+DSM technologies plays a pivotal role in realizing this vision. By implementing the proposed policy and market framework and following the roadmap set forth in this report, Cyprus, Greece, Israel, and Italy can lead the way in sustainable development, reducing their carbon footprint, and ensuring a cleaner and more resilient future for generations to come. As global awareness of environmental issues continues to grow, the lessons learned from these countries' experiences can serve as a beacon of inspiration for other nations to follow suit, fostering a collective effort towards a greener and more sustainable world.