European Commission

Review on Policy framework for introducing Energy Storage technologies

Task 4 Final Report

S. Afxentis[2]
V. Venizelou[2]
G. Makrides[2]
G. E. Georghiou[1,2]
V. Efthymiou[1,2]

[1]FOSS RESEARCH CENTRE FOR SUSTAINABLE ENERGY – UNIVERSITY OF CYPRUS
[2]PV TECHNOLOGY LABORATORY – UNIVERSITY OF CYPRUS

Release date	March 2019
Status	Final
Version	7

This project has been funded and managed by:

EUROPEAN COMMISSION

Joint Research Centre
Directorate C — Energy, Transport and Climate
Unit C.3 — Energy Security, Distribution and Markets

Contact: Stamatios Chondrogiannis

E-mail: Stamatios.CHONDROGIANNIS@ec.europa.eu

Table of Contents

List of Tables

List of Figures

Executive Summary

For many years, energy storage was not considered a priority for the energy system development, because the technologies were not yet economically viable and also because the benefits of storage were valued less in centralized fossil fuel-based power systems. However, the need for energy system decarbonization is rapidly improving the cost-performance of energy storage technology, leading to a significant increase of RES share in electricity generation. This report outlines the developing energy and climate policy framework of the European Union (EU) and how this is a driver for promoting energy storage in combination with Renewable Energy Sources (RES) and the transition to a low-carbon energy system. Best practices from EU policy frameworks will be identified and their applicability will be examined for adoption to the Cypriot energy market. In addition to the above, the role of energy storage is also changing and is gradually penetrating the modernized energy market to support even further RES penetration. The utilization of energy storage is no longer to store base-load overcapacity, but to handle an increasing amount of intermittent renewable generation. Different technologies of energy storage exist and differentiate for "behind-the-meter" and "in-front-of-the meter" topologies that can play a role to accommodate intermittency and to balance electricity demand and supply. In order EU members to reach the national targets, different frameworks have been introduced to promote storage deployment. A summary of the policies currently applied in the EU level is presented and their applicability to the existing energy system in Cyprus is examined.

1. Introduction

The EU's energy and climate policies have become increasingly ambitious over the years. Since the Climate and Energy Package, with its '20-20-20' targets [1], was agreed back in 2007, the EU has issued a host of strategies and policies to support the development of a low-carbon energy system. Furthermore, EU Member States agreed on even more aspiring EU-wide climate and energy targets for 2030 which have been revised through the trialogue and finally approved at the level of 32% for RES energy consumption and 32.5% for energy efficiency. More explicitly through the adapted Regulation 2018/1999 of the EC has agreed the following:
The Union's 2030 targets for energy and climate: means the Union-wide binding target of at least 40 % domestic reduction in economy-wide greenhouse gas emissions as compared to 1990 to be achieved by 2030, the Union- level binding target of at least 32 % for the share of renewable energy consumed in the Union in 2030, the Union-level headline target of at least 32,5 % for improving energy efficiency in 2030, and the 15 % electricity interconnection target for 2030 or any subsequent targets in this regard agreed by the European Council or by the European Parliament and by the Council for 2030.

As far as environmental concerns and climatic changes are concerned, this is closely linked with the energy sector which is why EU policy makers closely relate climate and energy policies. However, substantial energy system decarbonisation requires increased RES deployment and at the same time maintain energy security, energy efficiency and research, innovation and competitiveness. Responding to the above challenges and as part of the climate and energy framework, Europe has put forward the long-anticipated "Clean Energy For All Europeans" package (Winter Package) [2] . In particular, the Winter Package paves the way towards achieving a clean energy transition and provides measures to promote the industrial competitiveness in the EU. As a consequence, various key stakeholders will benefit from the renewable directive. A good example is the renewable energy industry, since the various uncertainties for investors will be minimised. In light of this, the aspects of the package specifically touching on energy storage, as well as other barriers affecting the energy storage business case, were addressed by the Commission in a Staff Working Document issued in February 2017 [3]. One pillar of the Energy Union targets is the Strategic Energy Technology Plan (SETPlan), which focuses on accelerating the development and deployment of technologies with the greatest impact on the decarbonisation of the energy system. The communication on Accelerating Clean Energy Innovation identifies "developing affordable and integrated energy storage solutions" as one of four priority R&I areas [4]. Furthermore, the new proposal for a Directive on common rules for the internal market in electricity proposes the active engagement of the consumers, which constitutes an important objective of the SETPlan. The deployment of new and innovative technologies such as smart energy management systems and battery storage solutions to support further RES share into the new energy system will be established. In light of this, there will be a fundamental shift from a centralised fossil fuel energy system to a distributed generation system supported by a range of flexibility options. Developing such system with a high share of distributed RES generation will be challenging to ensure that electricity supply and demand are maintained.

Driven by the above policies, significant changes are expected in the European energy system within the next decades. According to the International Energy Agency (IEA), the increasing electrification in many sectors, such as transport and heating and cooling, means that the globally installed RES capacity would have to be more than double by 2040. On the other hand, electricity demand is expected to rise by more than a third by 2050 compared to 2000 levels. Meanwhile, in the EU, the RES share in the electricity generation is expected to reach 24% in 2030 and 56% by 2050 [5]. In accordance with "The Energy Roadmap 2050 of the European Commission *"The share of renewable energy (RES) rises substantially in all scenarios, achieving at least 55% in gross final energy consumption in 2050, up 45 percentage points from today's level at around 10%. The share of RES in electricity consumption reaches 64% in a High Energy Efficiency scenario and 97% in a High Renewables Scenario that includes significant electricity storage to accommodate varying RES supply even at times of low demand."* [6]. Actually, for the expected levels of RES penetration in Europe until 2050, the operation of the bulk transmission system will face major challenges [7]. These include keeping the system stable in the presence of intermittent generation mix with much lower mechanical inertia, which needs to remain unaffected from abrupt and fluctuating ramps. With the introduction further RES penetration, more drastic and frequent changes in power flow patterns will take place due to the uncertainty of renewables, thus compromising the energy system operation with system operators to face unprecedented difficulties including more flexible sources for ancillary services. In light of this, the significant RES deployment that is expected for the next couple of decades, calls for the existing energy system modernization including the development and deployment of infrastructure, capable of tackling the aforementioned stability issues. Energy Storage Systems (ESS) is a versatile and reliable option for the projected energy system transition, offering services that can support the operation of the existing energy network. Energy storage is considered as a reliable solution capable of providing the desirable resilience to the energy system. Storage can be either centralized or distributed, and can be connected either "in-front-of-the-meter" or "behind-the-meter", with different business models to implement in each category. Storage technology offers numerous services including the grid operation support under higher RES penetration circumstances. In addition to this, it can dynamically supply demand response and other services depending on the allocation level such as transmission, distribution or local. A number of services can be offered from the deployment of storage technology as depicted in Figure 1. In this potential scenario, sufficiently flexible ES systems particularly those connected through fast-response electronic interfaces, would ideally complement to generation portfolio that will possibly include both low carbon thermal resources (e.g. nuclear and fossil fuel generators equipped with carbon capture and storage technologies) as well as variable and partly unpredictable RES (primary energy supply).

At the power distribution network level, fast response Energy Storage technologies (i.e. electrochemical storage such as secondary battery systems) [8] can support integration of RES, such as wind and photovoltaic (PV), in conjunction with or replacing other active network management schemes by storing electricity, in constrained networks for later reutilization. This applies particularly at the medium voltage (MV) level, in the case of long rural feeders where a generation from concentrated wind and PV farms can cause voltage rise issues. The same may occur in the case of PV connected to the low voltage (LV) network (i.e. dense residential areas), especially in the presence of high concentration within a feeder and at times of low local demand. The concept for "behind the meter" storage can offer important services to benefit the prosumer, such as the flexibility to self-consume, to optimally manage energy based on user behaviour and PV generation or even adhere to Time-of-Use or real-time tariff management to minimize electricity bill. Finally, by balancing the variable RES nature, the stability of the electricity grid can be maintained. More importantly, grid voltage and frequency levels should remain within the allowable ranges as defined by the national grid code of each country. The implementation of these changes necessitates significant investments for the development and large-scale deployment of low-carbon energy technologies. These investments do not only refer to RES but also to the technologies that can support an increased share of RES in the system, including energy storage, interconnections, and smart grids.

Different storage technologies have shown considerable development over the past years. Technologies of interest include pumped hydro, electrochemical batteries (conventional and flow-based cells) and thermal storage (mainly coupled with concentrated solar power). Pumped hydro storage (PHS) is a mature and well-established technology, however, the deployment of PHS facilities is strictly limited by geographical as well as environmental constraints. New storage technologies typically include various types of electrochemical batteries and/or super capacitors, being connected to the network through fast-response AC/DC power converter systems. These systems are operated using sophisticated control strategies, e.g. taking into account voltage levels or fluctuations and/or price signals. They can contribute to maintain grid voltage levels within the accepted boundaries, increase network capacity, and reduce losses. Therefore, their deployment might defer investments in traditional grid assets, regardless of other regulatory or economic considerations. Utilities are also considering the use of flywheels at primary or secondary substations as a means of improving the quality of service.

A good example is the evolution of electrochemical storage technology and especially secondary (rechargeable) technology. It is considered as an emerging and competitive energy storage solution, however an expensive option at the moment especially for residential deployment. This stems from the absence of a profitable policy framework that will incentivise users to use batteries behind the meter. The new European legislation that is coming through the adaption of the so called "Clean Package" is introducing the right market environment that will facilitate the evolution of cost reflective dynamic tariffs that will enhance investment decisions in utilising storage systems behind the meter.

Energy storage is a technology suitable for coupling with fast response renewables such as PV systems in order to balance the generation intermittency and support the growing need for an innovative and resilient energy system with even higher RES shares in the energy mix. Nevertheless, more R&D is required to achieve further technological progress and increase its cost competitiveness.

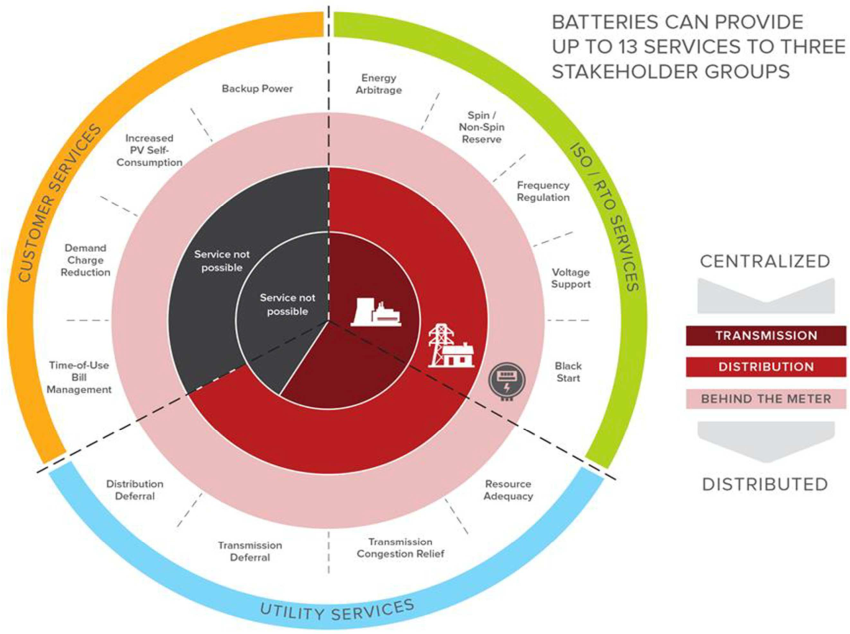

Figure 1. Potential services of battery storage systems [9].

Alongside other flexibility options, energy storage will play a crucial role in the transition to a low-carbon energy system. The IEA estimates that limiting global warming to below 2 ^{o}C will necessitate globally installed energy storage capacity to increase from 140 GW in 2014 to 450 GW in 2050 [10]. Such increase is necessary because, as the European Commission underlines, "energy storage can support the EU's plans for Energy Union by helping to ensure energy security, a well-functioning internal market and helping to bring more carbon-cutting renewables online. By using more energy storage, the EU can decrease its energy imports, improve the efficiency of the energy system and keep prices low by better integrating variable renewable energy sources" [11]. Although the importance of energy storage is widely recognized, the current regulatory framework needs to be evolved to support a cost-efficient deployment. For instance, the lack of financial support and user remuneration schemes in most of the EU countries is an important issue to tackle. This, however, stems from the uncertainty of energy storage utilization and how energy storage devices should be treated through regulation, underpinning two pillars that reveal the lack of energy storage definition within EU.

2. Storage Integration Practices

As the deployment of RES is growing considerably quick, new challenges will arise to the existing energy system with system stability issues and production and consumption mismatches to become more frequent. The integration of energy storage can alleviate such issues as state-of-art energy storage systems come with adaptive energy management strategies according to the end-user behaviour [7]. A very common strategy is charging the storage unit during valleys of "net demand" from PV produced electricity and discharging during peak hours. Therefore, energy storage systems can make a profit from the differences in energy prices while at the same time reducing the need for expensive peak generators and preventing congestion due to the injection of renewable energy to the grid. The energy management strategy is usually accompanied with a forecasting tool and system control unit to give added value to the storage system operation, being fully coordinated with demand-side needs. Additional markets that could enhance the business case for storage might also emerge in the near future; for example, providing ancillary grid services (voltage and frequency regulation) through the power converter advanced features to further support grid stability.

In general, the use of energy storage offers a great promise. However, most European countries are short of specific commercial (as opposed to technical and safety) regulation of energy storage. In the absence of storage-specific regulation, storage is treated as a combination of power consumption and generation and has to conform to relevant rules for both operating modes. While examples of cost reflective regulation exist both among EU countries and outside of Europe, but in general national legislation only addresses a section of the emerging capabilities.

2.1 Best Practices

Within Europe, Germany has currently the most developed, although not necessarily most favourable, policy framework for energy storage. For residential users, the framework is mainly based on renewable generation (i.e. Solar Photovoltaics) offering time-shifting to achieve increased self-consumption. Financial incentives for storing surplus electricity from PV systems initiated in 2013 with the introduction of the Feed-in Tariff (FiT). By 2015 it had decreased to about 12.8 c€/kWh, compared to the retail electricity price that has grown to an average of 29.7 c€/kWh[12]. To increase the potential of residential energy storage systems, the government developed a market incentive scheme for small PV systems (<30 kWp) aiming at achieving increased self-consumption and at the same contribute to grid stabilization. The incentive program offers low-interest loans and a repayment bonus. Regulations set the total maximum power output of the PV system to the grid to be limited to 50% of the installed peak capacity, leaving self-consumption limit to another 50% [13][14]. Under this framework, the coupling of PV and ESS can be suitable for end-users, however remuneration conditions are not suitable yet for the financial compensation of such a system. However, it is a prerequisite for the further deployment of RES, to provide cost reflective tariffs that consider the use of energy storage and the benefits they provide in order to aid the adoption of such systems at the end-user / behind-the meter level.

In response to the Climate Change Act 2008 [15], the UK has set a carbon emissions reduction by at least 80% of 1990 emissions by 2050, and the UK energy market is rapidly transitioning to support this target. From a system primarily based on large and centralized fossil fuel generation, the UK energy system is under transformation to deliver increased flexibility with low carbon power generation. National Grid, as the Transmission System Operator (TSO), recognises the extreme energy transition that is required and responds with a very challenging call for tenders. In particular, the tender procures services for very fast frequency response to provision the sporadic and dense deployment of renewable generation [16]. The so-called Enhanced Frequency Response (EFR), is explicitly designed to be delivered by energy storage systems, allowing for state-of-charge (SoC) management between service windows, which was not possible in the existing frequency response services. However, extremely strict requirements have been specified, such as the very short response time-window (<1 sec) and narrow frequency thresholds, which leave battery energy storage systems as a very suitable competitor for the tender.

Worldwide, the USA is the front-runner, with energy storage applications specifically for residential use to double compared to previous year capacity. In particular, for the second quarter of 2018 the total energy storage deployment was 61.8 MW / 156.5 megawatt-hours (MWh), growing at a 200% rate compared to 2017 capacity measure [17]. At the same time, California has a fast growing energy storage market including the mandate adopted in 2010 to deploy 1,325 GW of storage technologies across the power value chain by 2020 [18]. This is driven by the significantly high target set in 2008 to establish a 33% of energy consumption from RES by 2020. The California Energy Commission (CEC) developed specific regulations on energy storage, which includes the mitigation of RES generation intermittency. In addition to the above, the "Energy Storage Systems" act (AB 2514) which adopted in 2010, requires set of targets for the procurement of viable and cost-effective energy storage systems. The California Public Utilities Commission (CPUC) established the energy storage target of 1.325 GW for three Investor-owned electricity Utilities (IoUs) to be installed by the end of 2024. The target includes the integration of storage in all three pillars, transmission, distribution and "behind-the-meter" use. Targets are only defined in system power capacity without any clear indication regarding the system, energy capacity or technology as this is left open to the market and the IoUs to determine the kind of technology and sizing based on the most cost-effective solution. This urges for integrating a mixture of new energy storage technologies to the energy system.

Based on the storage promoting policies described above for the European level and worldwide, an extensive analysis follows to examine the current regulations in the following pillars: access to market, remuneration of energy storage, frequency reserve and finally T&D deferral. The following section investigates the regulation governing the participation of energy storage technologies in large energy markets in the EU (Germany, the UK, France, Italy, Spain). It is noticeable that none of the countries has comprehensive regulation for electricity storage technologies, and most of the countries do not have a specific regulation for energy storage besides pumped hydro plants which have been historically regulated thanks to the maturity of the particular storage technology. The main concern related to storage integration is the absence of a specific definition, which leaves energy storage to be treated either as a power consumption or a power generation, and it has to conform to the relevant rules. Further to this, best practices for energy storage integration in the worldwide are also examined. Finally, there are recommendations for removing regulatory obstacles to enable further development of storage and further research suggestions to comprehensively assess the new regulatory options.

2.2 Market Access

The market developed in Germany for promoting energy storage integration with small PV systems (<30 KWp) allows for the increase of self-consumption and contribute to grid stabilization. The incentive program offers low-interest loans and a repayment bonus [12].Under the current support scheme, a storage unit in combination with a PV system can be attractive for end-consumers, although not necessarily the most beneficial from an economic point of view. This remains the primary goal of these programs, such as the adoption of ESS to help further RES deployment where at the same time eliminate distribution grid issues related to increased RES penetration. This has led storing solar PV energy for self-consumption to be the main business for ESSs in Germany for the moment. In the future, one could identify additional returns for the ESS by operating many behind-the-meter ESSs and aggregating them to a virtual power plant which participates in the wholesale and balancing market.

Further to this, the framework availability for Time-Shift market access[19] is another important market possibility. Allowing storage technologies to access the wholesale market for time-shift application. Such market is generally allowed in the main energy players across Europe such as Germany, France, Great Britain, Italy and Spain. However, in some countries (e.g., France, Spain, Italy), only pumped hydro is explicitly considered by regulation for this application (

Table **1**).

- Frequency reserve: Storage technologies eligible for participation in frequency reserve markets in Germany and the Great Britain as per the current regulations via combined offerings ("pooling") with other providers. In the rest of the countries reviewed (France, Italy and Spain), frequency regulation is applicable only with pumped hydro facilities. In Cyprus, the existing Trading and Settlement rules do not permit energy pooling, while it is not included in the upcoming CERA regulatory framework.

- T&D deferral: use of storage for T&D deferral is currently possible only in Italy and the UK. Generally, in Europe, TSOs and DSOs are not allowed to have control over an electricity generating facility due to the unbundling requirement of Article 9 (1) of the Electricity Directive (Directive 2009/72/EC). Thus, in the absence of storage-specific regulation and also due to the fact that storage system is treated by regulation as generation, TSOs and DSOs cannot operate storage assets [20]. The UK enables small generating facilities, including energy storage, to obtain exemption from the obligation to hold a generation licence on a case-by-case basis, which enables TSOs and DSOs to deploy smaller-scale energy storage for T&D deferral.

Table 1. Breakdown of ES market participation in reviewed EU countries [19].

	Germany	France	Great Britain	Italy	Spain
Wholesale Market (Time-shift)	YES	YES	YES	YES	YES
Frequency Reserve Market	YES	YES only PHS	YES	YES only PHS	YES only PHS
TSO/DSO Ownership	NO	NO	YES small storage facilities	YES if the most effective option	NO

2.3 Remuneration

• Time shift: from the remuneration perspective, there is even less storage-specific regulation than for the access of storage to the above-mentioned applications. Operating in consumption and generation modes, storage may be subject to fees relevant to both operating modes in the absence of storage-specific regulation.

- Presence of double network charges in certain countries is an example of treatment where storage technologies both in charging (i.e., consumption mode) and discharging (i.e., generating mode), which has negative impact on storage profitability.
- Germany has the most advanced regulation also regarding the remuneration of storage technologies across EU. The urgently needed support for further RES penetration accompanied with grid stability and safety provisions, imposed for amendments to the existing framework and also new self-consumption policy regulations which enable the integration of energy storage systems to the energy system. In particular, financial motivation for the storage of excess PV generated electricity is paid either with a defined FiT or through the new Feed in Premium (FiP) model on top of the electricity market prices. Electricity charged to storage is exempted from the consumption tax, but only if it is 100% renewable; otherwise the consumption tax would apply. New storage and refurbished pumped hydro are also exempted from network usage fees for 20 years of operation. Furthermore, German regulation preserves to storage the remuneration payable to renewables for power directly fed into the grid. Thus, storage will receive the FIT according to used technology when discharging interim-stored power to the grid. To receive the FIT, electricity stored must be 100% renewable.

• Frequency reserve: if possible, participation of storage technologies in frequency reserve markets is remunerated identically as in the case of all other providers: no allowance is made for faster ramping resources as seen in California. Because the ancillary services provision differs between EU and the US, the solution may not be applicable. A recent development is the tender of the UK TSO for Enhanced Frequency Regulation (EFR) that creates a great market opportunity for storage providers whose services may otherwise be inaccessible. The successful bidders (offering battery facilities mostly) were awarded a contract to provide this service for 4 years

continuously (24/7) on their bidding price. The EFR service gives a degree of stability against price uncertainty under the mandatory service arrangements as it requires both dynamic and non-dynamic response to changes in frequency. The payment for the EFR service consists of an availability per hour fee (£/MW/h) that is paid for the hours a provider has tendered to make the service available to us.
At the same time, a record-breaking battery energy storage system, the largest in Europe, was installed in Jardelund, Germany. The battery system was built in about eight months and was put in operation on 31st May 2018, designed to participate at the country's primary reserve market [21]. After the project had been under consideration for a couple of years, lithium-ion battery costs finally hit the right price point and with 48 MW and more than 50 MWh capacity, the system is expected to compete against the gas and coal generation plants. The NEC based battery system will be used for the Balancing Capacity market to replace conventional power plants which previously supported frequency regulation activities. Further system utilization is also considered through the connection of wind farms located close to the area. In times of high-power generation, network congestion should be prevented.

• T&D deferral: there is no storage-specific remuneration scheme and respective regulation. TSOs and DSOs benefit from capex savings from avoiding or substituting conventional grid upgrades. As already mentioned before, the UK allows TSOs and DSOs to own and operate small-scale storage for T&D deferral, but caps the turnover from non-distribution activities at 2.5% of distribution business revenues [22]. However, T&D deferral remuneration is not applicable at the moment across the EU region.

2.4 Best Practices outside Europe

The US has recently made the most considerable changes to power market regulation. They focused particularly on allowing storage technologies to access the ancillary service market and introducing performance-based remuneration for the provision of ancillary services. Specifically:

- The Federal Energy Regulatory Commission (FERC) order No. 719 of 2008 directed independent system operators (ISOs) and regional transmission organisations (RTOs) to open markets for new technologies that can provide ancillary services. This provision opened a door also to storage to provide the frequency regulation service.

- In 2011, FERC order No. 755 required ISOs and RTOs to compensate providers of frequency regulation based on their performance. Following this order, a two-tier remuneration system was introduced for the provision of regulating power. The first payment remunerates the provider for the capacity dedicated to ancillary services, and the second, additional payment– also known as "mileage" – compensates the provider for the regulation actually supplied to the grid. Because fast-ramping resources, including storage, are able to follow the frequency signal more accurately and provide more specific regulation to the grid, they get paid more for the service.

- The current energy storage market in the US is constantly growing. Within the US, but also worldwide, California has created the most storage-supportive environment by passing the 'Energy Storage Systems' Law (AB 2514). Adopted in 2010, the regulation makes a distinction between publicly-owned electric utilities (POUs) and Investor-owned electric utilities (IOUs). The law enforces POUs utilities to purchase a targeted energy storage capacity equivalent to 1% of peak load by 2020. Hence, California became a pioneer in mandating deployment of storage for the purpose of renewable integration and ancillary services. California's largest investor-owned utilities (Southern California Edison, Pacific Gas and Electric as well as San Diego Gas and Electric) need to jointly invest in and deploy 1,325 GW of energy storage by 2020 into the transmission, distribution and consumption being part of the power value chain. Procurement targets were set by the California Public Utilities Commission (CPUC) as a compromise between what was deemed cost-effective and technically achievable with the aim to set realistic targets and allow for proper planning and safeguards.

- Apart from the California market, the PJM interconnection introduces market rules for frequency response. The PJM interconnection is a regional transmission organization (RTO) in the US, primarily based on the provision of frequency regulation according to Federal Energy Regulatory Commission Order 755, which requires compensation for capability and performance of frequency regulation. Due to the high performance of ESSs in providing frequency regulation, PJM is a profitable market for ESSs. An increase in ESS deployment and thus more efficient frequency regulation could even lead to a decrease in market size and lower compensation prices.

3. Current Status and Integration Barriers

In order to determine the storage potential in the energy market of Cyprus, it is of particular importance to outline and assess the current market and policy situation and identify the barriers that prevent further RES penetration as well as energy storage integration. In light of this, this chapter makes a clear review of the existing situation in the renewable market of Cyprus and describes the currently available regulatory frameworks and T&D provisions in relation to RES growth. Finally, the primary obstacles for storage integration and participation in the energy market in Cyprus are explained.

3.1 Existing Situation

Renewable sources have been introduced to the Cypriot energy mix over the last decade due to the generous subsidies offered and more recently as a result of the significant system price reduction. Considering the ambitious target of 20% of the total gross energy consumption set by the EU, Cyprus has an individual mandatory target to reach a RES share of 13% in the gross national consumption of energy in 2020. On the electricity sector this target rises to 16% which is again ambitious. Until now, the electricity generation mix in Cyprus relies heavily on imported fuels, mainly crude oil. The bulk of the electricity generation is provided by three main power stations with 1478 MW of total installed capacity. According to the statistics published by the Cyprus Transmission System Operator (TSO) [23], an enormous share of 91.6% of the country's total electricity demand by the end of 2017 is covered from fossil fuel generating units, with the remaining 8.4% coming from RES. More specifically, wind parks constitute the primary renewable source of the island, reaching a share of 4.2% into the Cyprus electrical system by the end of 2017. Additionally, the contribution of PV systems is of paramount importance considering the island's solar energy potential, having 2000 kWh/m^2 of annual solar irradiation. PV penetration accounted for a share of 3.4% whilst biomass accounted for the remaining 0.7% of the total electricity consumption.

Based on data published by the Cyprus Energy Regulatory Authority (CERA), the total installed capacity from RES has amounted to 279.3 MW by the end of 2016. The installed capacity for different RES is depicted in Figure 2. In particular, wind parks amounted to 56,4% of the total installed capacity or 157.5 MW. Additionally, the significant increase of PV installations over the last few years is reflected on the PV deployment growth, having a share of 40.14% in the total installed capacity which amounts to 112.1 MW. Finally, the total installed capacity for biomass reached 3.46%, having a total installed capacity of 9.7 MW by the end of 2017.
In response to the EU energy framework, Cyprus has put forward very ambitious national targets to be met by 2020. According to the projections provided by the Ministry of Energy, Commerce, Industry and Tourism (MECIT), RES contribution to the annual gross electricity demand is expected to double by 2020, reaching as high as 16% [24]. This of course, is a positive step towards energy sustainability, however concerns related to grid operation are getting more attention due to the fact that Cyprus has a small isolated network. Issues related with system stability will arise if no mitigation actions are taken.

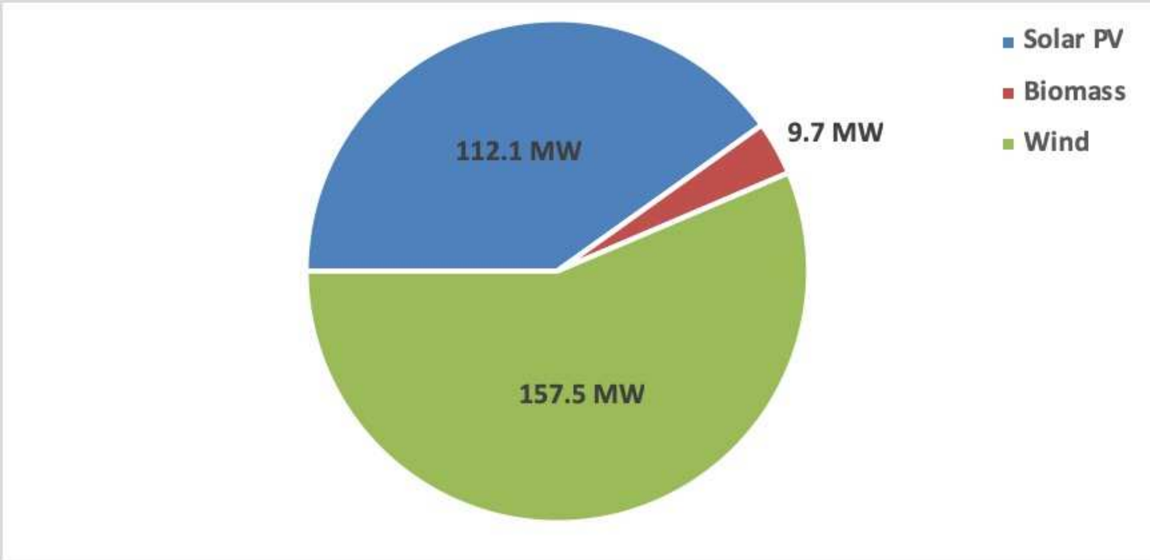

Figure 2. Total installed capacity of different types of RES in Cyprus by 2017.

3.2 Current Policy Framework

The establishment of support schemes is an important part of the energy strategic plan of the government towards promoting RES penetration and in particular through the active engagement of consumers in achieving high shares of PV in the energy. Owing to the high solar energy potential in Cyprus, solar PV technology is the most favourable option for RES deployment in the island. Grid parity conditions combined with the implementation of favourable policies such as net-metering have contributed to increasing PV system installations on the island. Overall, there have been several financial schemes announced over the last years in Cyprus to encourage the further deployment of PV systems. The PV market initiated with the FiT incentives firstly launched in 2010 by the Ministry of Energy, Commerce, Industry and Tourism (MECIT) to promote PV penetration. The particular plan included for the first time incentives for stand-alone and grid-connected PV systems up to 20 kWp. For stand-alone systems which were used for grid-isolated households, prosumers could benefit a 55% subsidy of the total PV system, whereas for grid-connected systems owners could benefit a 55% subsidy and a 22,5c€/kWh FiT for the electricity fed back to the grid. Under this framework, a total capacity of 43 MWp has been achieved by the end of 2013. A similar scheme was announced in the same year, supporting large-scale PV projects (>150 kWp) by means of a competitive bidding process in return of a FiT remuneration price. Concurrently, the total PV capacity for installations under FiT incentives by the end of 2016 amounted to a total installed capacity of 53.0 MWp.

With the intension to integrate PV systems at the end-user level, the Net-Metering support scheme was administrated by the MECIT and established in 2013 allowing the installation of residential PV systems with maximum capacity up to 3 kWp. According to the framework amendment released by the year 2015 [26], the upper limit for net-metered systems has been increased to 5 kWp. This comprises the only available policy framework for residential PV installation in Cyprus. In order to further promote and push for the utilization of PV systems, governmental subsidies were offered for vulnerable prosumers (i.e. low-income families) for a benefit up to €2700 of the total system price. The aforementioned conditions awarded Net-Metering scheme as a very favourable framework and fueled the deployment of small-scale PV systems across the island.

Apart from that, the same policy framework encourages self-consumption to encourage the integration of ESS along with PV systems to enable the transition of passive consumers to active "prosumers". The scheme however, is only applicable for large PV systems (10-500 kWp) offering no incentive-based tariffs for any surplus power fed back to the grid. A first amendment of self-consumption policy was released in 2015 where the upper limit of the permitted capacity was increased to 10 MWp and an 80% capacity limit was set. In fact, considering the need to encourage self-consumption through storage and increase the system flexibility, the 80% cap can be lifted to maximum peak (i.e. 100% of the maximum user consumption) in case there is an energy storage system installed or a limitation controller to reduce surplus electricity injected to the grid.
A call for more RES installation was issued by the government in 2017 that included 120 MWp of PV installations. The Cyprus DSO who has issued the terms for all the 120 MWp systems has not included any terms for storage. Storage is left on the developer and how best he sees it in responding to the market needs. Until the opening of the market they will be receiving the avoidance cost and after that, they should operate freely in the market. How they will operate is their responsibility.
In parallel the government has introduced the net billing tariff for commercial and industrial customers enabling them to combine local generation with storage but limited to the maximum energy they consume. This consists the first attempt for integrating energy storage systems with grid-connected renewable generation system, however it is only limited mainly for industrial/commercial use where demand side management is applicable (i.e. Time-of-Use tariffs for industrial users), but with no incentive offered for the energy spilled to the grid.

Despite the governmental attempt to pave the way for energy storage and promote self-consumption for all user levels, the absence of incentive frameworks coupled with the high cost of storage units has not yet resulted in any storage uptake. At the same time, allowing Net-metering to become a very popular option for PV deployment in residential level in the previous years, it now consists the main obstacle towards integrating energy storage in residential level. As per the current framework, end-users can use the grid as a "virtual storage" to store excess PV generation. In opposite to this, the new EU directive introduces a new, more active role for customers. The strategic plan proposes the transition of passive consumers to active prosumers, being able to participate in DR and energy efficiency schemes and operate directly or through aggregation on the new market, where non- discriminatory network charges will apply. Practically, the active engagement of prosumers comes together with balance responsibility and that can be illustrated only when current not market based schemes (i.e. Net-Metering) are abolished. This is also confirmed in Article 15.1c of

[25], which clearly states that existing schemes that do not account separately the electricity from and to the grid, shall not be in effect beyond 2025.

3.3 Current T&D Provisions for Generators Using RES

The national framework for Transmission and Distribution Rules (TDR) specify all mandatory procedures that should be followed for the connection to the network. Of particular emphasis is the latest TDR release as it contains additional provisions for power stations using RES (Task T16 of [26]). More specifically, the task includes provisions applicable for Wind Parks and PV Parks that are connected or request a connection to the Transmission or the Distribution Network with the objective of ensuring the safe and reliable operation of the Power System, and to set out certain provisions for favourable treatment during Generation Dispatching for Generators using RES. Apart from several operating capabilities such as voltage frequency (i.e. nominal voltage limits, over/under–voltage, voltage dips, operating frequency range, synchronization), reactive power control (generation/absorption of reactive/active power, power factor control) and LV ride-through capability, the rule includes the capability of the facility to control active power generation in terms of Ramp-Rate (RR) limitation in order to conform with the requirements in Table 2. It is highlighted that the RR limitation shall be met to all stages, including start-up, normal operation, operation with limited generation, stand-by and shut-down. It is important to note the RR limitation provision is restricted to RES facilities with capacity above 8 MW.

Table 2. Ramp Rate Limit to generated Active Power (T16.4.6.2 of [26]).

RES Capacity (P)	Mean RR (per minute) for a 10-min interval	Mean RR (per minute) for a 10-min interval
8 MW < P ≤ 20 MW	7.5% of capacity	15% of capacity
P> 20 MW	3.5% of capacity	7% of capacity

In addition to this, the TDR contains the obligation to submit a generation forecast, The most important provisions are described below.

1. First, the Generator using RES shall submit a Generation Forecast to the TSO on 24-hour basis and at least 12 hours before Dispatch Day. The Generation Forecast shall state the per half hour forecast of Active Power generation of the Power Station using RES for the period starting 72 hours after the start of Dispatch Day. The Generation Forecast shall be submitted in the manner and format required by the TSO and it shall take into consideration the availability of the Generation Units of the Power Station using RES (e.g. reduced availability due to unit/equipment maintenance).

2. Next, The Generation Forecast must be extremely precise since it affects significantly the Generation Schedule of the TSO. It is clarified that the methodology described below does not apply in the case of a revised Generation Forecast, submitted during the course of Dispatch Day. Below, the methodology for calculating the Daily Forecast Error and the Monthly Forecast Error in relation to the Generation Forecast.

3. The <u>mean Daily Forecast Error for Dispatch Day</u> is determined thus:

(a) Normalized Mean Absolut Error (NMAE)

$$NMAE = \frac{1}{n}\sum_{i=1}^{n}\frac{|X_i - Y_i|}{P_{inst}}$$

where:
X_i : Value of Half-hourly Wind Power Forecast
Y_i : Value of Half-hourly Wind Power Measurement
P_{inst} : Installed Power
n : Forecast Time Horizon (48)

(b) Normalised Root Mean Square Error (NRMSE)

$$NRMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{|X_i - Y_i|}{P_{inst}}\right)^2}$$

where:
X_i : Value of Half-hourly Wind Power Forecast
Y_i : Value of Half-hourly Wind Power Measurement
P_{inst} : Installed Power
n : Number of Forecast Periods for Dispatch Day (48)

where the mean Monthly Forecast Error is determined as:

(c) Monthly Average of NMAE ($NMAE_{month}$)

$$NMAE_{month} = \frac{1}{m}\sum_{j=1}^{m} NMAE$$

where:
m : Number of days in the month

(d) Monthly Average of NRMSE ($NRMSE_{month}$)

$$NRMSE_{month} = \frac{1}{m}\sum_{j=1}^{m} NRMSE$$

where:
m : Number of days in the month

The Daily Forecast Error and the Monthly Forecast Error shall be assessed on a regular basis by the TSO. In the case where the Monthly Forecast Error (NMAE and NRSME) is greater than 10%, the TSO will take those measures he considers necessary to improve the Generation Forecast. In the case where, during the Control Phase, a significant deviation is observed from the forecast wind generation, which will be determined by the TSO based on the System conditions at the time, the TSO reserves the right to limit the generation using RES for the purpose of maintaining the safe operation of the Power System.

3.4 Current Tariff Methodology

The design of a proper tariff structure is necessary for the promotion of new technologies in the existing energy system. Furthermore, tariffs should be designed in a non-discriminatory way, meaning that network costs should be regulated among users by taking into consideration the network impact in terms of energy and capacity. The tariff regulation in Cyprus was administrated by CERA (Regulatory Decision No 02/2015) which provides a transparent, and consistent with EU legislation methodology [27]. In principle, the network charges in Cyprus are defined by the voltage level connection, divided in Low Voltage – LV for connections below 1kV, Medium Voltage - MV for connections between 1kV and 36kV and High Voltage – HV for connections beyond 36kV. Based on the aforementioned regulatory decision, the tariff categories applicable to all end-users are set in accordance to Table 3 [28]. More information on the electricity tariffs is provided in APPENDIX I. It is important to note that the current pricing for distribution network tariffs (T-NM and T-NL), there is a target for adopting both capacity and volumetric components, rather than volumetric component only.

Table 3. Tariff Categories applied by CERA's Decision No 02/2015.

Tariff Category	Description
T-W	Wholesale electricity tariff applied to the sale of electricity by the dominant generator (i.e. EAC) to supply
T-NH	Use of Transmission System Tariff (beyond 36kV)
T-NM	Use of Distribution System Tariff (MV) which includes a charge component related to the DSO
T-NL	Use of Distribution System Tariff (LV) which includes a charge component related to the DSO
T-BM	Tariff for Business Management Services provided to customers (invoicing, etc)
T-AS	Tariff for the provision of Ancillary Services and long term reserve
T-PRC	Tariff for the recovery of expenses of the provision of PSOs and promotion of RES and co-generation systems
T-TSO	Tariff for the recovery of expenses of the TSO
T-MET	Tariff for the recovery of expenses of metering incurred by the DSO (for users connected to the distribution network)

The transition from "passive" end-users to "active" prosumers being able to produce renewable generation as well, requires substantial changes in the existing framework and especially to the network charging methodology. In light of the network tariff methodology explained previously, this section performs an analysis of the network charges envisaged to end-users for the two currently available support schemes that support PV promotion in Cyprus, namely the Net-Metering (NM) and the Self-Consumption (SC) schemes.

The only available policy for PV deployment in residential section in Cyprus is the NM scheme and was administrated by CERA in 2013. According to the relevant decision (Decision 908/2013), the prosumers will be charged for both consumption and PV generation [29]. Typical charges for consumption include the tariff for Business Management Services (T-BM), the tariff for the provision of ancillary services and long-term reserve (T-AS), the tariff for the recovery of expenses of the provision of PSOs and promotion of RES (T-PSO) and the tariff for the recovery of expenses of metering incurred by the DSO. Charges for the Use of Transmission and Distribution Network (e.g. T-NH, T-NM, T-NL) are applied to the gross consumption of the end-user; metering data are used to determine the user gross consumption. Additional volumetric charge is added according to the system net consumption. On top of that, the user is charged for the on-site generation as well. According to CERA Decision 909/2013, a capacity charge is applied for each installed system kW (€/kWp) for the categories shown in Table 4, scaled by a factor in relation to the approved tariff [30]. Similar to NM scheme, SC scheme brings consumption and RES generation to the forefront. The volumetric consumption charges includes a tariff according to the net consumption. In comparison to NM scheme, charges for the use of the Transmission and Distribution Network (T-NH, T-NM, T-NL and T-PRC) are adjusted for average annual network losses at the voltage level to which the user is connected to and at, and for all voltage levels above that level. For the generation charges, the categories remain the same as in NM scheme and are shown in Table 4, scaled by a factor in relation to the approved tariff. According to CERA Decision 919/2013, the volumetric charge for generation is charged per kWh (€/kWh) on the electricity generated by the PV or bio-system that is self-consumed (using the metering data from the two metering devices - one at the PCC and another one on the generation side) [31]. Finally, the network charges of SC scheme are reduced by a factor that represents the contribution of self-generation to the reduction of network losses and a 10% reduction on the T-AS charge.

Table 4. Network Charges for NM and SC schemes [30].

Description	NM factor	SC factor
TSO operating expenses (Decision 03/2010 and 04/2010)	100%	100%
Provision for the Ancillary Services charges	100%	100%
Provision for long term reserves charges	20%	20%
Use of Transmission System charges	25%	25%
Use of the Medium Voltage Distribution System charges	50%	25%
Use of the Low Voltage Distribution System charges	75%	25%
Recovery of expenses of the PSO provision and promoting RES	100%	100%

3.5 Storage Integration Barriers

3.5.1 Regulatory Barriers

To achieve integration of energy storage systems in the existing energy system, it is a prerequisite to introduce new regulations. Efficient deployment of storage, as well as other new technologies, requires that grid tariffs shall reflect to a cost, such that it will motivate end-users to participate. This can be achieved in a few different ways, such as the avoidance of RES electricity that is spilled to the grid. In this way, the end-user shall investigate for the potential of storing or better managing the on-site renewable generation. With the current legislation in Cyprus, residential prosumers are under Net-Metering framework, that allows them to use the electricity network as a virtual and at the same time unlimited storage unit, limited only to the surplus renewable energy spilled to the grid. This situation made Net-Metering as a very favourable policy in Cyprus, with the integration of new frameworks to be very difficult from the market perspective. Although the combination of Time of Use (ToU) tariffs along with self-consumption scheme is available in Cyprus, this is applicable only for industrial and commercial users in an attempt to reduce energy consumption from high-consumption users. A possible policy improvement could be the adoption of Time-of Use tariffs for residential users as well. This could definitely be another significant incentive for promoting energy storage technology and its integration to the distribution grid. High electricity tariffs during peak hours and low electricity tariffs on valleys of the total electricity demand profile, is a commonly used strategy that could force prosumers to adapt their energy consumption needs and utilize energy storage properly to achieve reduced electricity bills. Moreover, the coupling of energy storage units can offer renewables energy time-shifting and at the same time maximize self-consumed PV electricity. Towards this direction, several technical barriers stem from the implementation of the aforementioned recommendations including the modernization of the existing network and will be discussed next.

Another significant obstacle that new energy storage has to tackle is the absence of a clear ownership regulation as this has a significant impact on the viability of the storage business model and on competition. According to the new EU Directive, Network Operators cannot own, develop, operate or manage energy storage facilities unless specific derogation is taken [32]. Exceptions are made only with the regulatory authority grant and such facilities must be fully integrated network components. Otherwise, exceptions can apply only when the storage facilities are necessary for the DSO to fulfil their obligations for the efficiency, reliability and security of the distribution system and they are not used for any other purpose (i.e. buying or selling electricity to the market). For taking it, the DSO should open a tendering procedure. At the same time, the regulatory authority is responsible for assessing the necessity of such derogation, evaluate the tendering procedure and approve the derogation. In fact, it is within the regulatory authority responsibility to perform a public consultation at a regular basis in order to assess and approve the potential availability and interest of market parties to invest in storage facilities.

3.5.2 Market Barriers

Energy storage has not yet developed its full potential in the energy markets. This is because some of the storage technologies were not widely developed, or due to the absence of a suitable regulatory framework to accommodate new flexible solutions [3]. At the same time, the continuous support for increased electricity generation, regulated prices and green fees have impacted on the development of energy storage. At the same time, energy storage faced critical regulatory frameworks across Europe, with market inefficiency to be the most important one due to the high capital cost. There is no clear definition amongst the Member States on how storage can be treated in the energy system. For instance, in several countries storage facilities pay grid fees both as consumer and producer, in other countries only as producer, or they have other special regimes. In general, the reduction of administrative fees and the enabling of non-discriminatory grid access for energy storage, would reduce the overall storage payback period. The new legislative proposals for market design in the context of the Clean energy for all Europeans package support the cost-efficient use of energy storage solutions, covering energy markets aspects, the regulatory framework, system planning and specific technical aspects [2].

By studying the current legislation in Cyprus, the behaviour and point of connection of energy storage in the energy system is not defined since there is no supportive regulation. Until recent publication from CERA (Preliminary Regulatory Decision 03/2018) regarding the future plans for energy system expansions [33], the storage levels are clearly divided in "in-front-of-the meter" and "behind-the-meter" storage with particular focus on the former topology, as this can offer added flexibility to the existing energy system including the enhanced system flexibility, decarbonization of the existing energy network, grid stabilization and increased RES penetration. The preliminary decision proposes the participation of "in-front-of-the meter" storage (without any on-site RES production) to the new energy market of Cyprus and even more allowing storage to operate either as a generation unit (discharging mode) or a load (charging mode). Although the decision provisions the integration of "in-front-of-the meter" storage in both distribution and transmission system with a window for adjusted network charges, the storage ownership restriction is not lifted off, with TSO and DSO to be prohibited to own energy storage units. As far as "behind the meter" storage is concerned, no clear definition is included in the proposed regulation, leaving numerous uncertainties in relation to the value assessment of that kind of technology. Taking into account the possible abolition of Net-metering schemes by the end of 2025, net billing in combination with time of use tariffs might prevail as the preferred policy for domestic and small commercial consumers. This, however, requires further refinement to remove current taxes and levies that are charged to current users of net billing in Cyprus. Otherwise, there is no other framework currently under discussion for the support of "behind the meter" storage and also the further penetration of RES (in particular solar PV) in the distribution grid. Therefore, a clear and transparent policy framework is urgently needed to support the integration of "behind-the-meter" storage and promote incentivized mechanisms such as ToU tariffs or Real Time Pricing (RTP) which will drive to further facilitating Demand Response - DR on the consumer level. On the other hand, the active participation of end-users to the energy market as proposed in Article 15 of the Directive [25], provisions the consumer flexibility to easily switch role between energy producers and prosumers (i.e. to produce, consume and sell energy simultaneously). This comes together with the opening of completely new business opportunities and increased responsibilities for consumers where appropriate know-how on the new regulatory and business environment are required for the efficient prosumer participation to the energy market.

In fact, the integration of "behind-the-meter" storage is becoming viable only with the abolition of the currently favourable frameworks including Net-Metering scheme. Several ways exist for lifting off certain concerns related to storage integration including the introduction of incentive frameworks for end-users. Examples include the adoption of ToU tariffs mechanism (similar to what is applied already in net-billing scheme for commercial and industrial users), or even to take advantage the technology and IT development to generate real time price signals for different consumer categories. This will bring DR mechanisms on end-users since there will be a flexibility on adjusting electricity usage in periods with low or high demand. However, the implementation of the latter poses significant technical barriers which are described next in Section 3.5.3. Another example is the reduction of existing grid consumption tariffs or removal of unnecessary storage contributions (i.e. green tax, public service obligation levy). A case study analysis of Net-Billing scheme for the combination of PV and BESS residential systems is presented in Section 3.6.

3.5.3 Technical Barriers

The integration of variable distributed generation sources in weak and isolated power networks such as the distribution grid in Cyprus comes with numerous technical issues. Even though there are market and regulatory issues related to the creation of an appropriate market to incentivize the growth of storage capacity and provision of storage services, there are important technical challenges that need to be addressed. It should be taken into consideration that to facilitate the increasing of RES capacity and improve energy system efficiency requires substantial restructuring of the existing infrastructure. In order to optimally do that, new technologies such as local (domestic), decentralized or community storage applications should be developed.

Transmission and Distribution grid upgrades are drivers for flexible sources and allow sharing flexibility over a larger geographic area, including interconnections and interoperability of different smart energy networks (heat and electricity, demand side management and demand response). Taking it one step further, the creation of energy communities will allow different units to communicate with each other and behave according to the grid measurements or local consumption measurements. This requires the modernization of the existing infrastructure and in particular of the metering devices and power converters to be compatible with communication standards. For instance, the replacement of traditional metering devices in residential premises with smart meters will pave the way towards administrating new policy frameworks that can incentivise storage technology (i.e. ToU tariffs, dynamic pricing). Regarding the metering devices topology, two meters are required only in the cases that generated data is required for other services such as forecasting. Otherwise, one is adequate at the point of common coupling with two independent registers to measure import and export parameters that are useful for the implementation of dynamic tariffs. If curtailment is a need for the operators, then additional operational means should be erected. Curtailment should not be a standard feature but instead utilise the advance features of inverters to offer system services in support of frequency and voltage profiles. At the same time, synchronous data acquisition features are necessary for communicating with a central TSO/DSO platform for energy management purposes and also be able to receive real-time pricing schemes. Even though this is an ongoing task, the long-anticipated roll-out plan for smart-metering devices in Cyprus is to have a potential for dynamic pricing on the 80% of the consumers by 2027. Further to the above, another important issue is the overall system cost. One single solution will probably not be the most cost-optimal solution. A mix of all solutions is needed, tailored for each region and system architecture. Another issue which present challenges to storage development are the future of the CO_2 emissions framework, public acceptance of cables, grid access and investment priorities. If they are adequately addressed, the situation for energy storage could be considerably improved.

Another significant obstacle can be the selection of a suitable location to install. The core of the distribution system was designed many decades ago and no provision was taken for additional equipment inside or close to the substations. Also, taking into account the large space requirements for battery units' installation along with a proper ventilation and cooling system, a large number of distribution system substations will be unsuitable to accommodate large-scale storage systems. This leaves the installation to an open area with additional material for housing (i.e. insulating container), as a possible solution with equipment security and communication connectivity to be even more difficult to tackle. The same stands for distribution level storage units as well. Taking into example residential system, the choice of installing PV systems on rooftop is a commonly used approach. This, however is not optimal for housing a battery storage system. In particular, the environmental conditions on rooftop environment such as high temperature and humidity levels, are not favourable for the battery storage operation, leading to system efficiency and life-time reduction. Also, the DC cable length between the battery unit and the power converter should be short enough to reduce ohmic losses (typically less than 10 meters) as well as to avoid loose or exposed wiring for protection from electrical hazards [37]. Taking the above points into account, the selection of the installation location is a critical decision for battery system design, with many residential buildings to have insufficient or improper space to accommodate such systems.

Taking into account the recent evolution of electric vehicles, electromobility will certainly be built around battery technology. Possible benefits are manifold, but current regulations have generally been laid on the assumption of stationary loads. That should change, both regarding the possibility of trading energy and other system services in several locations as the EV moves around, as well as offering access tariffs that take mobility into account. Proper regulation for parties offering charging and intermediation services (e.g. aggregating all EVs in a parking lot in order to sell reserves to the system) must be developed.

In order to boost the development and maturity of different ES technologies, suitable incentives might have to be considered for ES as a sustainable energy system enabler, in line with what is done with several RES. Further, in consideration of the strategic importance of developing, implementing and integrating ES technologies both to maintain the competitive advantage of our economy and to preserve the welfare of European citizens, the EU should develop a long-standing and ambitious framework specifically aimed at promoting and stimulating the joint cooperation of European partners on energy storage systems.

3.6 Economic assessment of installing BESS under Net-Billing scheme in Cyprus

Since there is no depreciation scenario for "behind-the-meter" residential storage under Net-Metering scheme, an economic analysis is presented in this section based on the currently applied net-billing tariffs (as of March 2019) [34]. The analysis was performed for an existing 5 kWp residential PV system which is AC-Coupled (definition in APPENDIX II) with a 3 KW and 94% round-trip efficiency battery inverter [35]. The assessment includes a pay off period evaluation of the battery system by assuming two different battery system costs of 450 €/kWh and 200 €/kWh, where a constant annual maintenance cost of 0.5% is applied. In addition, the effect of the interest rate on the depreciation period was investigated by considering an annual interest rate of 4.5% through a personal bank loan equal to the total system cost (PV and Battery facilities). More information regarding the parameters used for the economic assessment is included in Table 5 below. The battery capacity was selected based on an analysis performed by the authors of this report [36]. In that analysis, a methodology for determining the optimal sizing of BESS was developed based on a clustering method by considering energy profiles of residential prosumers in Cyprus. The clustering procedure was carried out based on the daily import electricity profiles recorded for domestic prosumers (3 KWp rooftop PV systems) over the period of one year which revealed the daily energy needs of each cluster targeting to maximize self-consumption. The results highlighted that the optimal battery size ranges between 5.8 to 8 kWh. The size was upscaled to 10 kWh in order to match the 5 KWp PV system capacity size used in this study. Since the round-trip efficiency and energy availability of the BESS was assumed to be 94% with an annual usage of the capacity of the battery equalling 90% of the available usable capacity (taking into consideration cloudy days etc), therefore the average usable battery capacity is equal to 8.46 kWh for the selected 10 kWh BESS.

The economic assessment aims to reveal the main barriers for storage remuneration in Cyprus by comparing different Case Studies (CS) as shown in

Table 6. Description of the Case Studies (CS) examined in the assessment for Category A prosumers.

Parameters	CS-A1	CS-A2	CS-A3	CS-A4
PV Power (pre-installed) / Storage Capacity	5 kW / 10 kWh	5 kW / 10 kWh	5 kW / 10 kWh	5 kW / 10 kWh
Storage Price	€450/kWh	€450/kWh	€450/kWh	€200/kWh
Current Regulatory framework regarding charges on self-consumption	✓			
Without network charges but with taxes and levies on self-consumption		✓		
Without nor network charges nor taxes and levies on self-consumption			✓	✓

Table 7. Description of the Case Studies (CS) examined in the assessment for Category B prosumers.

Parameters	CS-B1	CS-B2	CS-B3	CS-B4	CS-B5	CS-B6	CS-B7
PV Power / Storage Capacity	5 kW / 0 kWh	5 kW / 10 kWh	5 kW / 0 kWh	5 kW / 10 kWh	5 kW / 0 kWh	5 kW / 10 kWh	5 kW / 10 kWh
Storage Price	€450/kWh	€450/kWh	€450/kWh	€450/kWh	€450/kWh	€450/kWh	€200/kWh
Current Regulatory framework regarding charges on self-consumption	✓	✓					
Without network charges but with taxes and levies on self-consumption			✓	✓			
Without nor network charges nor taxes and levies on self-consumption					✓	✓	✓

. The main objective of this study is to make a clear and transparent separation between prosumers with already installed PV systems and considering to invest in storage (Category A) and future prosumers that want to invest in PV systems and at the same time they are considering the combination of PV and storage (Category B).

The currently applied network charges and tariff structure are included in Appendix III-1 along with the detailed analysis results. Daily energy consumption and PV production profiles that were considered in the economic assessment are also available as in the third section of Appendix III-2. Under Net-billing scheme, remuneration of local generated energy is allowed with an appropriate cost reflective amount for all energy that is exported to the grid. This provided that the selling price contains the following elements:
Average or (better) time of use wholesale price of generated energy mix of the incumbent generator that includes fuel, CO_2 emissions, fuel storage, capital, personnel and maintenance. The only tax to be included is VAT as with all other generated electricity. Currently it is not the whole sale price but the avoidance cost that does not include capital and personnel costs (only maintenance cost for generating the replaced energy) and this is not a true reflection of the cost that needs to be corrected once the market becomes operational in 2020+. As long as the price difference between retail price and wholesale price does not pay back investments in storage, prosumers will not invest in storage on their own investment decision. Hence, any policy taken by the government for prudent investments in storage (due to system needs) should take this reality into account and base policies on repayment possibilities. This could mean partial incentives for specific periods of time since current calculations reveal that repayment with current prices is not possible with the savings made over the useful lifetime of batteries.

Table 5. Parameters used for the economic analysis of the energy storage.

Description	Value
Technical Parameters	
Annual Load Consumption	8427.63 kWh
Peak PV Power	5 kWp
Annual Energy Yield	8100 kWh (1620 kWh/kWp)
Battery Inverter Rated Power	3 kW
Battery Unit Usable Capacity	10 kWh
Battery Lifetime[1]	6000 cycles @ 90% DoD (approximately 15 years)
Battery Round-Trip Efficiency	94%
PV-Battery Coupling	AC-Coupled
Economic Parameters	
Battery System Cost	450 €/kWh and 200 €/kWh
PV System Cost	€1000 / kW
Loan Interest Rate	4.5% per annum
Maintenance Cost	0.5% of the total system cost per annum

1 BESS vendors/manufacturers typically warrant that the product retains at least 60% of the nominal energy for either 10 years after the initial installation date or when battery reaches a specific energy throughput. [LG Chem Lithium-ion Battery Limited Warranty, Web link: https://d3g1qce46u5dao.cloudfront.net/warranty/resu10h_lg_chem_lithium_ion_battery_limited_warranty_rev.pdf]

Table 6. Description of the Case Studies (CS) examined in the assessment for Category A prosumers.

Parameters	CS-A1	CS-A2	CS-A3	CS-A4
PV Power (pre-installed) / Storage Capacity	5 kW / 10 kWh	5 kW / 10 kWh	5 kW / 10 kWh	5 kW / 10 kWh
Storage Price	€450/kWh	€450/kWh	€450/kWh	€200/kWh
Current Regulatory framework regarding charges on self-consumption	✓			
Without network charges but with taxes and levies on self-consumption		✓		
Without nor network charges nor taxes and levies on self-consumption			✓	✓

Table 7. Description of the Case Studies (CS) examined in the assessment for Category B prosumers.

Parameters	CS-B1	CS-B2	CS-B3	CS-B4	CS-B5	CS-B6	CS-B7
PV Power / Storage Capacity	5 kW / 0 kWh	5 kW / 10 kWh	5 kW / 0 kWh	5 kW / 10 kWh	5 kW / 0 kWh	5 kW / 10 kWh	5 kW / 10 kWh
Storage Price	€450/kWh	€450/kWh	€450/kWh	€450/kWh	€450/kWh	€450/kWh	€200/kWh
Current Regulatory framework regarding charges on self-consumption	✓	✓					
Without network charges but with taxes and levies on self-consumption			✓	✓			
Without nor network charges nor taxes and levies on self-consumption					✓	✓	✓

It must be first noted that the annual electricity cost for a typical residential consumer is approximately €1,743.6 for electricity demand above 8.000 kWh per annum (average domestic load in Cyprus for three-phase residential facilities is in the range of 8,000 kWh, meaning an annual bill of around €1,750 with the current prices of fuel). This cost is estimated based on the Time-of Use tariff considered in this economic evaluation. The installation of a PV system or a combination of PV and BESS change the energy profile of the typical consumer (now prosumer). The following table summarizes the annual energy metrics for both cases, with and without battery inclusion.

Table 8. Comparison of annual energy metrics without/with BESS.

	Annual Gross Consumption (kWh)	Annual Self-Consumption (kWh)	Annual Import Energy (kWh)	Annual Export Energy (kWh)	Annual PV Production (kWh)
Without BESS	8,486.4	2,681.22	5,805.2	5,723.2	8,404.39
With BESS	8,486.4	5,769.12	2717.3	2635.3	8,404.39

In this analysis it is also important to identify the various cost elements which will provide valuable evidence for formulating suitable policies for achieving the required capacities of storage behind the meter. More specifically, the following energy costs were calculated within the scope of this analysis:

- Cost of imported energy
- Revenue from exported energy
- Cost of self-consumed energy
- Total cost

The revenue is calculated as follows:

$$Total\ Cost = (Import\ Cost + Self\ Consumption\ Cost) - Revenue\ from\ exported\ energy$$

3.6.1 Case Study A: Prosumers with existing PV systems

The results of case study A, where prosumers have already installed PV systems at their premises and are considering investing into BESS systems, are presented in this section. The following tables illustrate the annual savings as well as the annual costs for imported, self-consumed energy and the revenue from the exported energy. The cases where payback period exceeds battery lifetime are considered not applicable. The annual savings are defined as the difference between the annual cost of energy that would have resulted under the ToU tariff scheme and the respective annual cost of each investigated case resulting under the net-billing scheme.

Table 9. Annual savings and pay-off period of each case study in Category A (preinstalled PV system).

Regulatory Framework	Case Study	Total Capital Cost	Annual Savings without storage	Annual Savings with storage	Payback Period
Current regulatory framework	CS-A1	€4,500.00	€1,220.5	€1,381.1	Not Applicable
Without network charges but with taxes and levies on self-consumption	CS-A2	€4,500.00	€1,385.2	€1,545.7	Not Applicable
Without nor network charges nor taxes and levies on self-consumption	CS-A3	€4,500.00	€1,414.6	€1,609.1	Not Applicable
	CS-A4	€4,500.00	€1,414.6	€1,609.1	Not Applicable

Table 10. Annual energy costs of each case study in Category A (pre-installed PV system).

	Cost of Imported Energy	Revenue from Exported Energy	Cost of Self-Consumption	Total Cost
CS-A1	€583.60	€396.39	€175.29	€362.51
CS-A2	€530.89	€396.39	€63.39	€197.89
CS-A3	€530.89	€396.39	€0.00	€134.51
CS-A4	€530.89	€396.39	€0.00	€134.51

3.6.2 Case Study B: Prosumers with existing PV systems

The results of case study B, where consumers are considering investing into PV-BESS systems are presented in this section. The following tables illustrate the annual savings as well as the annual costs for imported, self-consumed energy and the revenue from the exported energy.

Table 11. Annual savings and pay-off period of each case study in Category B (investing in both PV and BESS).

Regulatory Framework	Case Study	Total Capital Cost	Annual Savings	Payback Period
Current regulatory framework	CS-B1	€5,000.0	€1,220.5	Between 5th and 6th year
	CS-B2	€9,500.0	€1,381.1	Between 9th and 10th year
Without network charges but with taxes and levies on self-consumption	CS-B3	€5,000.0	€1,385.2	Between 5th and 6th year
	CS-B4	€9,500.0	€1,545.7	Between 8th and 9th year
Without nor network charges nor taxes and levies on self-consumption	CS-B5	€5,000.0	€1,414.6	Between 5th and 6th year
	CS-B6	€9,500.0	€1,609.1	Between 8th and 9th year
	CS-B7	€9,500.0	€1,609.1	Between 6th and 7th year

Table 12. Annual energy costs of each case study in Category B (investing in both PV and BESS).

	Cost of Imported Energy	Revenue from Exported Energy	Cost of Self-Consumption	Total Cost
CS-B1	€1,302.47	€860.86	€81.47	€523.08
CS-B2	€583.60	€396.39	€175.29	€362.51
CS-B3	€1,189.87	€860.86	€29.46	€358.47
CS-B4	€530.89	€396.39	€63.39	€197.89
CS-B5	€1,189.87	€860.86	€0.00	€329.01
CS-B6	€530.89	€396.39	€0.00	€134.51
CS-B7	€530.89	€396.39	€0.00	€134.51

The following figure shows the cash flow analysis of the aforementioned case studies.

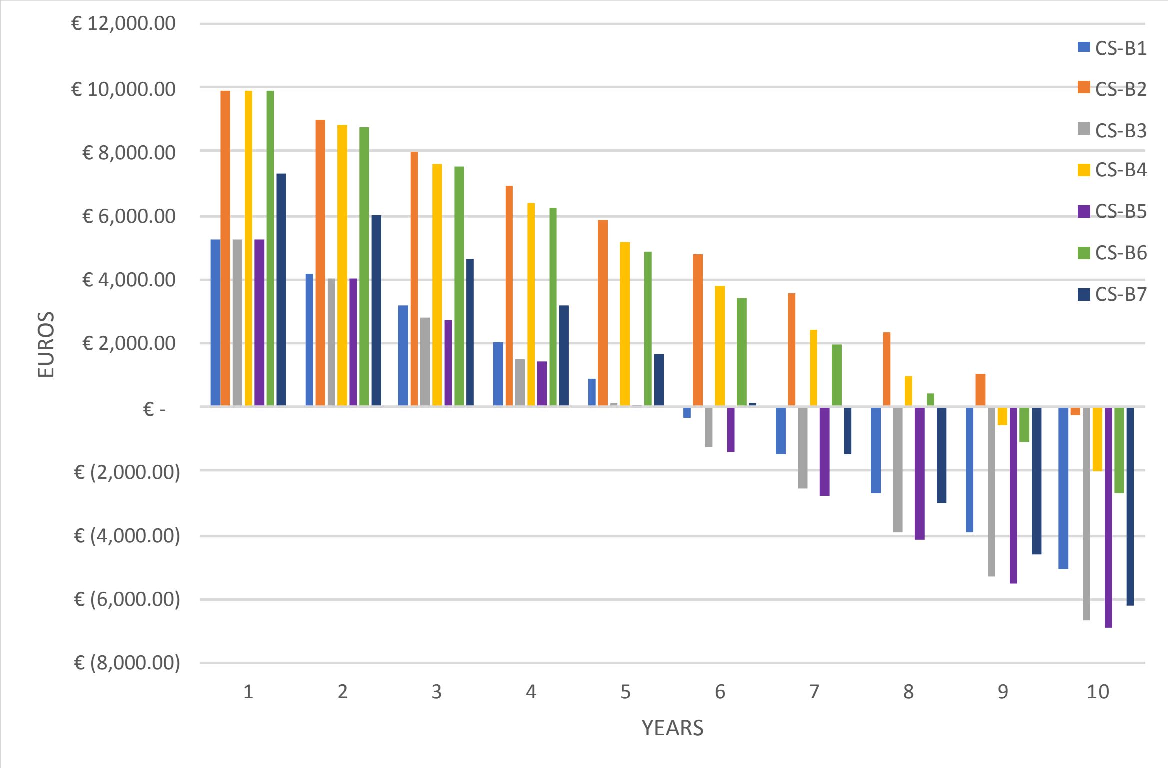

Figure 3. Capital cost payoff breakdown for all cases.

The obtained results highlight that investing in the installation of a BESS while having an already installed PV system (Category A) is not profitable. Neither the current regulatory framework, nor the exclusion of Net-Billing or levy charges promote the investment of storage as the annual savings do not surpass the annual loan payment including the interest rate of 4.5% within the considered battery lifetime period.

For the case where a consumer wants to invest in both PV and BESS systems (Category B), the results demonstrate that the removal of Net-Billing charges for self-consumed energy reduces the payback period from nine to eight years. The same applies for the removal of levy charges on self-consumed energy. Moreover, the analysis revealed that a lower battery unit cost (€200/kWh), can potentially reduce the payback period to six years. It is worth noting that investing only in PV system without BESS is the best option as the payback period is equal to five years regardless the regulatory framework for self-consumed energy.

In light of the above, the introduction of a different Tariff structure is important to promote BESS utilization and even more make their investment more profitable. In general, the value of storage will increase with a more explicit time valuation of energy both withdrawn from and injected into the Grid. For the former (energy withdrawn from the grid) this means pricing structures reflecting closer to wholesale electricity prices (more sophisticated ToUs or dynamic pricing). For the latter (energy injected into the grid), this means economic compensation according to the half-hourly wholesale spot price when the new market arrangements become operational.

By revisiting the retail tariffs in Cyprus (**Table III- 2** of Appendix III), they follow the same route as rest of Europe in separating the contributing costs. To start with, energy cost for central generation does not include any additional costs apart from VAT where for carbon-based generation, electricity cost includes fuel, capital/personnel, maintenance, fuel storage and CO_2 cost. For distributed generation, non-coherent policies are introduced across the different schemes. More specifically additional retail related costs such as grid losses, network, ancillary services, supply, metering, PSO and RES are included in energy selling cost under net-metering scheme. For net-billing, the selling cost is the RES tariff/avoidance cost that is approved by CERA and it does not include any capital/personnel cost for every energy unit sold to the grid.

From the above, it can be said that a coherent policy is needed on what is charged on generated electricity regardless the voltage connection level as long as the energy enters the grid. In a similar way, the energy supplied from the grid should contain all costs that are passed on to end users. What is clearly fair and justifiable is the losses that are 100% charged at supply side and not at generation side. In this respect energy that is self-consumed directly or through storage should not bare any losses element (this reflects the current policy of Cyprus). It is also equitable to say that prosumers who have introduced storage in their systems can partially improve the quality of supply at the point of common coupling as storage can assist in balancing PV intermittency as well as network congestion reduction. Hence, a careful evaluation of the cost implications is needed and shall be correctly adjusted to reflect effectively storage presence. Finally, the current remuneration price for the electricity injected from the prosumer back to the grid is based on the avoided cost tariff approved by the Regulator instead of the wholesale price that will prevail when the market rules go into operation. This flat regulated price for the energy injected into the grid does not reflect fully its true temporal value.

4. Investigation of the Applicability in Cyprus

The integration of energy storage technologies in Cyprus depends to a large extent on the R&D efforts and relevant policy framework across the entire EU level to support their deployment. However, an enabling regulatory environment that allows energy storage to compete on an equal basis with other flexibility providers will be essential to sustain growth in the energy storage industry. As mentioned before, the regulatory framework at EU and Member State level has partially evolved only and does not enable to support a cost-efficient deployment of energy storage in a full scale. At the moment, the demonstration of storage technologies face serious regulatory and technical barriers described in previous chapters. In addition, a fair market design is lacking for energy storage systems. Following the above, the aim of this section is to first of all perform a critical review of the upcoming CERA regulatory framework in Cyprus proposed in March 2018 that is anticipated to assist in identifying the barriers towards storage deployment in the island. Next, the applicability of best practices for energy storage applications in the existing energy network and framework in Cyprus are examined. Policy recommendations are provided such that barriers for storage integration in the energy system of Cyprus can be lifted up towards achieving the targets of the upcoming energy transition.

4.1 Review of CERA's proposed Regulatory Decision

According to the latest draft of CERA's Regulatory Decision 03/2018 [33], substantial changes will be expected to the regulatory framework around RES and energy storage by 2019 in Cyprus. For the first time, the proposed regulation makes reference to grid-connected storage technologies and is divided into "in-front-of-the-meter" and "behind-the-meter" electrical energy storage facilities. According to the draft decision, the former storage facility is not combined with local electrical energy consumption, where the latter as facilities where consumption and storage coexist with or without local electricity production. Even though it makes a clear definition for two levels of storage, the proposal develops a framework only for "in-front-of-the-meter" storage, under which the participation in the Electricity Market is allowed as long as services to the Transmission and Distribution (T&D) System. Regarding storage ownership, the draft proposal clearly states in Article B.2, that regulated services of Transmission System (i.e. Cyprus TSO) and Distribution System (i.e. Cyprus DSO) cannot own "in-front-of-the-meter" storage.

For the participation of the Electricity Market, "in-front-of-the-meter" storage facilities should be licenced, comply with the T&D rules and be able to interact with the grid bidirectionally (charging from the grid and energy spilling to the grid) for the needs of RES energy storage for a 24-hour time window. Following the above, the Cyprus TSO acting as the Electricity Market Operator as well, is called to review the Electricity Market and T&D rules such that "in-front-of-the-meter" storage are able to:

Participate in the Producers Registry, Dispatchable Load Registry and Balancing Services Providers Registry,

Offer all technically possible services and products

Fully participate in the electricity market (non-discriminatory market rules) as producers by injecting energy to the system as well as loads by absorbing energy from the system.

Contract with renewable generation producers for the provision of observance of energy injections forecasts.

Moreover, for the preparation of the 10-year Transmission System Development Plan (TSDP) the TSO in collaboration with the DSO, is called to take into consideration the services that will be available from the "in-front-of-the-meter" storage along with the system needs and define the following measures to include it in the 10-year TSDP:
The minimum, maximum and total power capacity of electrical storage units that can be integrated to the system for the provision of T&D services.
The identification of "in-front-of-the-meter" storage installation location for purposes of provision of services to T&D System.

Additionally, the Cyprus TSO is called to review and amend the Energy Market and T&D rules by taking into to account the technical characteristics of the daily charging cycle of "in-front-of-the-meter" storage facilities in order to propose a non-discriminatory participation of storage in the Electricity Market (Article B.4). Furthermore, network charges are also included in the new settlement. In particular, Cyprus TSO is called to review and propose the use of network charges (i.e. T-NH, T-NM, T-NL) that will be imposed when "in-front-of-the-meter" storage facilities offer services to the system and operate under the operator instructions (Article B.5). Finally, the working document proposes the development of "in-front-of-the-meter" storage for T&D system services provision, to be carried out (upon CERA's approval) from TSO/DSO through a capacity based, technology-neutral tendering procedure (Article B.7). The electrical storage services procured through the tendering procedure will remain to the TSO/DSO responsibility and will operate in a way that they will offer by priority the agreed services to the TSO/DSO. From the proposed regulatory decision, there is a clear intention from CERA to introduce, for the first time, grid-connected storage facilities to the transmission and distribution system. Storage facilities are clearly divided in two main topologies, the "in-front-of-the-meter" and "behind-the-meter" storage. Based on the proposal, the former topology is well specified in terms of operation and market levels. Its application however is limited only to grid-connected storage facilities and cannot be combined neither with local electrical energy consumption nor production. At the same time, the definition for the latter is unclear in terms of the storage technology, operation and services. Therefore, it is highly recommended that CERA provides a better definition for "behind-the-meter" in terms of market participation as well as operation provisions.

Moving on, the draft CERA decision proposes a set of operational requirements for "in-front-of-the-meter" participation in the Electricity Market. One of them is the provision for RES energy absorption from the power system. This definition is contradicting with other storage services set in the same proposal such us the provision of services for T&D system and reduction of losses. Therefore, "in-front-of-the-meter" units should not be limited to operate only in charging mode for energy absorption from the grid, but for energy injection to the grid as well, if this is required for the optimal market or system operation. Furthermore, the draft decision sets as a prerequisite for "in-front-of-the-meter" storage facilities to participate in the Producers as well as in the in Dispatchable Load Registry since bidirectional interaction with the grid is required for selling/buying electrical energy. This denotes that storage facilities must comply with the latest T&S rules published by CERA in 2017 [38]. For the prosumers participation in the Day-Ahead Market, the rules state that they are obliged to submit an Energy Offer per Generating Unit for the Available Capacity of the unit for each Trading Period of the Trading Day. Similar to this, producers participating in the Integrated Scheduling Process for Balancing and Reserve Offers, must submit a separate fully Energy Offer for each Generating Unit, for each Trading Period of each Trading Day and for the whole technical capability of each Generating Unit. Regarding storage participation to the Dispatchable Load Registry, the T&S rules require that Transmission System Use of System (TUOS) and Distribution System Use of System (DUOS) are applicable charges for all Offtakes. At the same time, additional charges including the levy for the Promotion of RES and Energy Savings, PSO and Cyprus TSO administrative expenses are applicable for all Load participants.

4.2 Recommendations for further improvement

The efforts for decarbonizing the existing energy network has begun across the entire European level and member states have put pressure on meeting their national energy targets. As part of this energy transition, regulatory measures become an important element towards the establishment of a sustainable energy policy. The active engagement of consumers to a competitive Internal Energy Market can lift off the financial concerns that render storage technology. In this section, a critical review of the proposed CERA's draft Regulatory Decision 03/2018 is provided and recommendations for further improvement are included in accordance to the Regulation of the European Parliament and of the Council on the Internal Market for Electricity (recast) COM(2016)861 [39].

4.2.1 Critical review of storage participation to the Electricity Market

By studying the obligations described in Section 4.1 regarding the provisions for the participation of storage to the T&D system, it can be concluded that storage is treated both as a production and load unit with negative impact on its commercial integration to the grid. Storage is a capacity-restricted technology and in order to meet the imposed Prosumer Registry obligations, significant development barriers may arise. For instance, facility owners and potential investors would be forced to oversize the system capacity to meet the Day-Ahead Market rules. At the same time, storage participation to Dispatchable Load Registry brings additional network charges, such as TOUS and DUOS to the forefront which are exclusively imposed for load facilities. This situation significantly increases electricity price which becomes larger than the wholesale price, thus bringing an unfair treatment of storage with serious concerns regarding the imposed network connection charges and technology deployment to arise. In light of this, an appropriate declaration from CERA is recommended to specify whether storage facilities will follow network charges provisions for generators, loads or both.

Stemming from the above, it is highly recommended to remove additional network charges and provisions for storage facilities such that network charges for connection and access to networks shall not discriminate against storage (Recast Article 16). This can also be illustrated in the economic analysis performed in previous section proving that discrimination of storage in network connection and access charges acts ineffectively to the energy market penetration. One practice is the inclusion of storage in RES producers and aggregators as an energy constrained unit. In such scenario, storage will be exempted from additional network charges imposed by Dispatchable Load Registry provisions and in addition, be more flexible with *Energy and Reserve Offers.* Since it is rather clear that storage inclusion from Producers Registry should be avoided, another solution would be the creation of an additional Registry for storage facilities to differentiate between generation and load units. Another recommendation is to treat storage the same way as RES producers and RES aggregators are treated in the latest T&S rules. In such case, storage will also be considered as a capacity restricted entity, eligible (not binded) to submit *Energy and Reserve Offers up to their Available or Technical capability.*

4.2.2 Critical review of storage participation to the T&D System

Another pillar of storage services included in the proposed CERA draft decision includes several requirements of "in-front-of-the-meter" storage facilities for the provision of services to the T&D system. More specifically, "in-front-of-the-meter" storage should be able to offer the following services, with the same criteria at both Transmission and Distribution levels:

- Ancillary Services to the T&D System
- Dispatching in the Transmission System
- Flexibility Services in the Distribution System

In order to achieve the aforementioned services, CERA proposes the collaboration between TSO and DSO to take into consideration the participation of "in-front-of-the-meter" storage in the 10-year TSDP for the provision of services in both T&D system. According to the proposal for a Directive on common rules for the internal market in electricity (recast), it is recommended that potential services offered to the Distribution System to be included in the respective 10-year development plan prepared by the DSO.

Article B.4 refers to the technical characteristics of the daily charging cycle of "in-front-of-the-meter" storage. According to the draft CERA's decision, this shall be taken into consideration by the Cyprus TSO in order to amend the T&D and Energy Market rules for the provision of "in-front-of-the-meter" storage services. The specific reference to the technical characteristics is rather unclear and unnecessary since storage participation into the market should stem to a large extend from price signals.

Moving on to Article B.5 of the proposed Decision, the Cyprus TSO is called to refine Use-of-Network charges that will be imposed on "in-front-of-the-meter" storage facilities during their operation under TSO/DSO instructions as well as T&D System services provision. Regarding the participation in the Electricity Market, it was previously mentioned that storage will be included in Dispatchable Load Registry and load facilities Use-of Network charges will be incurred. On the other hand, Article B.5 proposes the possibility for different Use-of-Network charges for storage acts for the provision of services (benefit of T&D system). This proposes different network charges based on storage operation and services, which is not in favour as there will be discrimination between the storage operation levels and can bring solemn instabilities to the entire market structure. Based on the above, it is recommended that a coherent treatment of storage should be applied where the same Use-of Network charges are imposed to storage regardless the operation and service (either provision of services or Energy Market participation). A revised framework is recommended under which storage will receive fair and equal network charges.

Finally, another critical concern that has significant impact on storage investment development is the right to own storage facilities. According to Article 36 (Ownership of storage facilities) and Article 54 (Ownership of storage and provision of ancillary services by TSOs) of the proposal for a Directive on Common Rules for the Internal Market in Electricity (recast), it is well specified that distribution system operators shall not be allowed to own, develop, manage or operate energy storage facilities. By way of derogation, storage ownership is permitted to distribution system operators under the fulfilment of the following conditions:

- such facilities are necessary for DSOs to fulfil their obligations for the efficient, reliable and secure operation of the distribution system;
- such facilities are not used to buy or sell electricity to the wholesale market, including balancing markets;
- other parties, following an open, transparent and non-discriminatory tendering procedure, subject to review and approval by the regulatory authority have not been awarded with a right to own, develop, manage or operate such facilities.

At the same time, CERA's draft proposal complies with the Directive on Common Rules for the Internal Market in Electricity (recast) and makes specific reference (Article A.2) to storage ownership and more specifically that TSO and DSO cannot own storage facilities. In addition to this, there is a specific provision for TSO/DSO to call for a tendering procedure in case "in-front-of-the-meter" storage services are required for the provision of services in the T&D system (Article B.6). In addition to this, storage management and operation of in-front-of-the-meter storage should be prohibited for the TSO and DSO, even for facilities that occur from the tendering process as well. On the contrary, there is a specific statement in Article B.7 of the proposed draft decision that daily scheduling of in-front-of-the-meter storage facilities integrated into the system through a tendering procedure will remain to the TSO/DSO jurisdiction. This statement is opposed to the previous rule since TSO/DSO are not allowed to own, manage or operate storage facilities apart from exception cases.

4.2.3 Other Recommendations

A correctly regulated framework is important for bringing new technologies to the forefront and support RES generation in the energy system. This remains, to a large extend, a liability to Member States to develop their own framework by considering the local particularities of national energy systems. In Cyprus, the draft CERA's Regulatory Decision 03/2018 proposed two different storage levels, the "in-front-of-the-meter" storage technology and a framework for participation to the energy market and T&D, and makes reference for "behind-the-meter" technology as well. However, the lack of a clear definition and the exclusion from market participation does not offer a transparent environment for decentralized energy storage growth. This could stem from the uncertainty for safety and reliable operation that rendered older energy storage technologies along with certain concerns regarding the load demand drop that will impact the network operator revenue model negatively.

On the other hand, serious measures should be taken to embed "behind-the-meter" storage provisions to the existing network. Considering the global deployment of storage, batteries and thermal storage facilities in conjunction with solar power systems are quickly becoming economically attractive for end-users. At the same time in Germany, installation of decentralized storage facilities reveals a significant increase for self-production and local storage of energy. This is expected to bring a significant reduction of energy demand as well as serious framework adjustments to increase network operator revenue from fossil fuel generation. At this point, facilities with coupled storage and solar technologies would become attractive to end-users to reduce electricity bills [20]. From the above, it is clear that combining energy storage with renewable generation is an important contribution in grid balancing and necessary measures need to be taken to allow the deployment of "behind-the-meter" storage. For instance, the exemption of energy storage facilities in Germany from grid tariffs is a strong motivation towards deploying storage to the current network infrastructure. More specifically, new energy storage facilities that feed electricity back to the grid are exempt from network tariffs for a period of twenty years [40]. Another recommendation includes the acceptance and promotion of demand side flexibility, including demand response and energy efficiency provisions. While the following can offer incentivised conditions for end-users through dynamic pricing and variable tariffs, it is strongly advised to perform an impact assessment to investigate the implications of the network during the modernization phase, especially with the integration of new technology (grid monitoring, "in-front-of-the-meter" storage, "behind-the-meter" storage, smart metering infrastructure etc.). Taking the above into consideration, it is essential that regulatory authority and network operators examine the affordability and grid economic viability when it comes to introduce the coupling of renewables and storage technologies. The assessment includes the adjustment of tariffs and grid fees in order to incentivise end-users where at the same time keep the grid affordable and well-functioning.

The regulatory barriers rendering decentralized storage in Cyprus mainly stem from the existing policy framework. Lifting off those constrains and applying the aforementioned points to pilot systems is a first step towards assessing the practical usage and operation of storage whilst supporting the technical innovation and practicability of storage projects. Demonstration projects are suitable for gathering valuable information and knowledge about the market applications for energy storage systems and are very effective route to pull technologies into commercialization.

A final point to review is the current obligation for Ramp Rate (RR) limitation and forecasting provisions for RES plants above 8MWp. The existing T&D rules drives investors and interested parties to go selectively below the threshold capacity value to avoid such obligations. The practice of putting a capacity-based RR obligation as a mandatory grid rule is rather inefficient as it is achieved by limiting inverter output by applying specific mechanisms (i.e. in PV systems, inverter operates outside MPPT). Following this, energy storage is obliquely proposed as it can be accommodated in conjunction with RES plants for storing temporal surplus renewable generation. In light of this, storage along with smart inverter mechanisms could be used to meet RR limitation requirements as well as minimizing the mean daily forecast error to make generation dispatch even more precise [41]. Following the above, it is highly recommended that RR limitation and forecast obligations shall be removed from grid rules. Additionally, a good practice could be the integration of RR limitation and forecasting in market rules since the energy market itself should be able to motivate participants to invest on future technologies such as storage. For instance, profitable mechanisms (i.e. lower network tariffs or reduced network charges) can be offered when storage facilities are accommodated. Therefore, the provision of RR limitation and day-ahead forecasting shall be encouraged by the new framework and not treated as a mandatory grid rule.

5. Conclusions

The unobstructed penetration of RES technologies in the energy system can cause significant issues to the energy system when new technologies are not coupled to assist in grid operation. The upcoming of storage technology growth can assist in alleviating obstacles for further renewable deployment, however a suitable regulatory framework is necessary for the deployment of such facilities in the Power System and Electricity Market of Cyprus. In this report, the current regulatory framework for storage technology integration has been analysed and regulatory shortcomings, market, technical and economic barriers have been analysed in detail. In addition to this, a critical review on policy framework for introducing energy storage technologies has been conducted. More particularly, the latest draft of CERA's Regulatory Decision 03/2018 gives a very positive perspective for fair storage treatment and brings substantial framework changes including storage technology participation in the T&D system and Energy Market. The most important elements include CERA's intention to develop a non-discriminatory framework for "in-front-of-the-meter" storage facilities participation into the Electricity Market and the provision of services to the T&D network. Also, the inclusion of "in-front-of-the-meter" storage facilities into the 10-year TSDP as a possible service provider for T&D system and the provision for a tendering procedure for storage facilities procurement (subject to CERA's review and approval) are some key elements that highlight the future of storage utilization in the energy system of Cyprus.

In addition to this, this report has also presented critical comments on CERA's Draft Decision and suggested policy recommendations for a transparent utilization of energy storage technologies. One point is the inclusion of "behind-the-meter" storage definition without limiting storage framework explicitly for "in-front-of-the-meter" storage. Another element for improvement could be the eligibility criteria set for "in-front-of-the-meter" storage participation to the Energy Market and for ancillary services provision to the T&D system. Such criteria stem from storage inclusion in both Producers and Dispatchable load registry and shall be revised as they limit storage operational flexibility as well as market opportunities for storage investment. Instead of treating storage both as a load and generation unit, it is recommended to introduce a specific registry that will underpin "in-front-of-the-meter" storage participation in different segments of the Energy Market such as flexibility services, ancillary services provision and wholesale energy market. Furthermore, network charges should be revised for "in-front-of-the-meter" storage facilities. A coherent framework shall be deployed where network connection charges shall be equal for all facilities connected to the grid, regardless the connection level. Last, storage ownership is clearly described in the draft proposal where TSOC and the DSO prohibited not only to own, but to develop, manage and operate "in-front-of-the-meter" storage, even for facilities that are developed through a tendering process in accordance to the Directive on Common Rules for the Internal Market in Electricity (recast). To conclude, storage inclusion in CERA's draft Regulatory proposal is undeniably a big step towards the modernization of the existing energy network in Cyprus. However, significant regulatory changes are needed in order to have a consolidated and transparent framework that is capable of accommodating storage technology for different services and at different levels.

6. References

[1] EASE-EERA, “Energy Storage Technology Development Roadmap 2017,” 2017.
[2] European_Commission, “Commission proposes new rules for consumer centred clean energy transition,” 2016. .
[3] European_Commission, “Energy storage – the role of electricity,” Brussels, 2017.
[4] European_Commission, “Communication on Accelerating Clean Energy Innovation,” 2016.
[5] European_Commission, “Energy Roadmap 2050 - Impact assessment and scenario analysis.”
[6] European_Commission, “The Commission’s Energy Roadmap 2050,” 2011. [Online]. Available: http://europa.eu/rapid/press-release_MEMO-11-914_en.htm.
[7] IEEE, “Energy Storage for Renewables Integration in the European Union,” 2018.
[8] “IEC 62619:2017 - Safety requirements for secondary lithium cells and batteries, for use in industrial applications.” .
[9] RMI, “THE ECONOMICS OF BATTERY ENERGY STORAGE,” 2015.
[10] IEA, “International Energy Agency: Technology Roadmap Energy Storage,” 2014.
[11] “European Commission: Energy Storage, 2016.”
[12] K.-P. Kairies, D. Magnor, and D. U. Sauer, “Scientific Measuring and Evaluation Program for Photovoltaic Battery Systems(WMEP PV-Speicher),” *Energy Procedia*, vol. 73, pp. 200–207, Jun. 2015.
[13] “PV battery systems in Germany to benefit from €30 million investment - Renewable Energy Focus.” [Online]. Available: http://www.renewableenergyfocus.com/view/43823/pv-battery-systems-in-germany-to-benefit-from-30-million-investment/.
[14] T. Tsanova, “Germany announces solar-plus-storage incentives for 2016-2018 - SeeNews Renewables.” .
[15] “Climate Change Act 2008 (c.27),” 2008.
[16] EnergyUK, “Ancillary services report 2017,” 2017.
[17] “GTM Research and Energy Storage Association, U.S. Energy Storage Monitor Q3 2018.”
[18] “State of California - Assembly Bill No. 2514,” 2010.
[19] European_Commission, “Fuel Cell and Hydrogen joint undertaking - commercialisation of energy storage in Europe,” 2015.
[20] S. Ugarte *et al.*, “Energy Storage: Which Market Designs and Regulatory Incentives Are Needed?,” 2015.
[21] “Eneco, Mitsubishi put into operation 48-MW battery in Germany,” 2018. [Online]. Available: https://renewablesnow.com/news/eneco-mitsubishi-put-into-operation-48-mw-battery-in-germany-614753/.
[22] “Smarter Network Storage: Electricity Storage in GB,” 2013.
[23] Cyprus-TSO, “Penetration of Renewable Energy Sources (RES) into the Cyprus electrical system,” Nicosia, 2018.
[24] Cyprus-MECIT, “National Renewable Energy Action Plan 2010-2020,” Nicosia, 2010.
[25] European_Commission, “Proposal for a Directive of the European Parliament and of the council on common rules for the internal market in electricity (recast),” 2017.
[26] Cyprus-TSO, “TRANSMISSION AND DISTRIBUTION RULES Issue 4.0.0,” 2013.
[27] European_Commission, “Study on tariff design for distribution systems,” 2015.
[28] CERA, “Statement on Regulatory Practice and Methodology of Electricity Tariffs,”

2015.
[29] CERA, "Decision 908/2013," 2013. [Online]. Available: https://www.cera.org.cy/en-gb/apofasis/details/apofasi-908-2013.
[30] CERA, "Decision 909/2013." [Online]. Available: https://www.cera.org.cy/Templates/00001/data/apofaseis/2013_07-Apofasi_909_2013.pdf.
[31] CERA, "Decision 919/2013." [Online]. Available: https://www.cera.org.cy/Templates/00001/data/apofaseis/2013_07-Apofasi_919_2013.pdf.
[32] European_Commission, "Article 36 Ownership of storage facilities - Proposal for a directive of the European Parliament and the Council on common rules for the internal market in electricity (recast) - COM(2016) 864 final."
[33] CERA, "Preliminary Regulatory Decision 03/2018," Nicosia, 2018.
[34] "Electricity Authority of Cyprus - Commercial and Industrial Use Tariffs," 2018.
[35] SMA Solar Technology AG, "Energy Efficiency of PV Storage Systems."
[36] S. Afxentis, M. Florides, S. Theocharides, V. Venizelou, and G. E. Georghiou, "Residential Battery Storage Sizing Based on Daily PV Production and Consumption Load Profile Characterization," *35th Eur. Photovolt. Sol. Energy Conf. Exhib.*, no. Lv, pp. 1744–1749, 2018.
[37] SMA Solar Technology AG, "Operating Manual SUNNY BOY STORAGE 2.5."
[38] "Cyprus TSO - Trading and Settlement Rules V2.0.0," 2017.
[39] European_Commission, "Regulation of the European Parliament and of the Council on the Internal Market for Electricity (recast) COM(2016)861," 2016.
[40] DIWBerlin, "Policy Efforts for the Development of Storage Technologies in the U.S. and Germany."
[41] E. Oh and S.-Y. Son, "Energy-storage system sizing and operation strategies based on discrete Fourier transform for reliable wind-power generation," *Renew. Energy*, vol. 116, pp. 786–794, Feb. 2018.

APPENDIX I

Further information on the tariff categories is provided below in accordance with CERA Regulatory Decision No 02/2015.

T-W: Wholesale Electricity Tariff

T-W shall apply to all sales of power by dominant generators with the exception of their power sold through the pool, the balancing mechanism and imbalance settlement, the ancillary services contracts with the Cyprus TSO and the long run reserve contracts with the transmission system operator (TSO). The T-W tariff shall form the basis for the regulated contracts between a generator with a dominant position and other generators/suppliers.

T-NH: Use of Transmission Network Tariff

T-NH is applied to all loads on the Cyprus electricity network. T-NH shall be set so as to recover the allowed total revenues of the transmission owner, excluding connection revenues, other customer contributions and costs related to Cyprus TSO, as well as the cost of ancillary services relating to the Transmission Network such as voltage regulation. T-NH shall be applied to a supplier as a charge related to each of the supplier's end consumers. Towards the adoption of a hybrid tariff mechanism, both a capacity and volumetric charge will be introduced but at the moment only a volumetric charge is applied.

T-NM/T-NL: Use of Distribution System Tariff at Medium/Low Voltage

T-NM and T-NL are the tariffs for the use of distribution system at the medium and low voltage levels respectively and are applied to all loads connected to the Cyprus electricity distribution network.

T-NM and T-NL are non-discriminatory capacity charges and are applied equally to all suppliers as a charge related to each of the supplier's end-user customer connected to the distribution network. It includes the charges which are applied to the suppliers uplifted to cover distribution network losses depending on the voltage level of connection. Both T-NM and T-NL capacity tariffs are calculated by dividing the allowed revenues to be recovered through energy charges in a year to the forecast energy load for the year of all customers connected to the respective distribution level (MV or LV).

T-BM: Tariffs for Business Management Services
T-BM includes the costs incurred by a supplier in managing its customers such as managing contracts and billing, complaints service and retail offices. The tariff applied by the dominant supplier shall be regulated in the form of an allowance for reasonable business management cost plus an allowed margin on such costs.

T-AS: Tariff for the Provision of Ancillary Services and long-term reserve
T-AS is applied to procure the ancillary grid services from the Cyprus TSO such as voltage and frequency control and operating reserves to maintain system balance, quality and restoration from black start.

T-PRC: Tariffs for the Levies PSO, RES-E, High-Efficiency Cogeneration
The T-PRC is related to the recovery of the costs incurred by the Cyprus TSO for promoting renewable electricity generation and promoting high-efficiency co-generation. The T-PRC is a fixed volumetric tariff imposed to consumers.

T-TSO: Tariff for Cyprus TSO Expenses
The T-TSO tariff recovers the allowed costs that the TSO incurs to manage the Cyprus electricity system. The allowed cost includes the cost of metering in the transmission network, which is applied as a fixed charge per customer and varies according to the type of the meter installed at the location of the supplier's customer or will correspond to meter type for high-voltage connections. In the course of the operation of the Electricity Market, especially with regard to the Balancing Mechanism, the Cyprus TSO (as Market Operator) may incur costs or gain financial benefit. In such cases, the T-TSO shall be readjusted accordingly at the end of the year so that the differences are carried over into the following year. T-TSO shall be recovered through a charge levied on gross consumption and gross demand in the same way as T-NH.

T-MET: Tariff for Metering Expenses
The T-MET tariff shall recover the cost of reading the meters of all end-consumers that are connected to the distribution network. It is levied in the form of a fixed charge per customer. In the future regulation, T-MET will vary according to the meter type installed at the supplier's customer site.

APPENDIX II

Definition of the AC-Coupled PV-Battery Storage System Topology

The topology name comes from the utilization of a common AC-bus between the PV and Battery units. The topology consists of a unidirectional PV inverter and a bidirectional Battery inverter which are both connected to the grid and the load via the common AC-bus. The PV inverter consists of a DC/DC converter which operates as the Maximum Power Point Tracking system (MPPT) and an on-grid inverter. The Battery inverter consists of a DC/DC converter which serves as the Battery Charge Controller (CC) and an on/off-grid inverter. The connection to the grid is made via a bidirectional electricity meter and an optional grid switch. The meter should be able to communicate with the Battery inverter, which serves as the central controller of the system, and regulates the power flow from/to the battery and hence to/from the grid in order to achieve the desired service. The grid switch is used to isolate the system from the grid in case of a grid outage and potentially allow backup power to the load from the PV and/or the battery provided the local Grid Rules are adhered to.
An operational drawback of this system is that in backup mode the PV inverter is able to provide power only if the Battery inverter is operating, i.e. if the Battery inverter shuts down unexpectedly the PV inverter will automatically shut down as well (due to its automatic shutdown function in cases of grid outage, so-called "anti-islanding" feature). Even if the automatic shutdown is disabled, a PV inverter cannot provide AC voltage on its output by itself due to its design. Another implication of this is that if the grid is off, the PV inverter cannot provide power for charging the battery. It is worth mentioning that if PV power curtailment is required, the Battery inverter should be able to communicate and control the PV inverter.

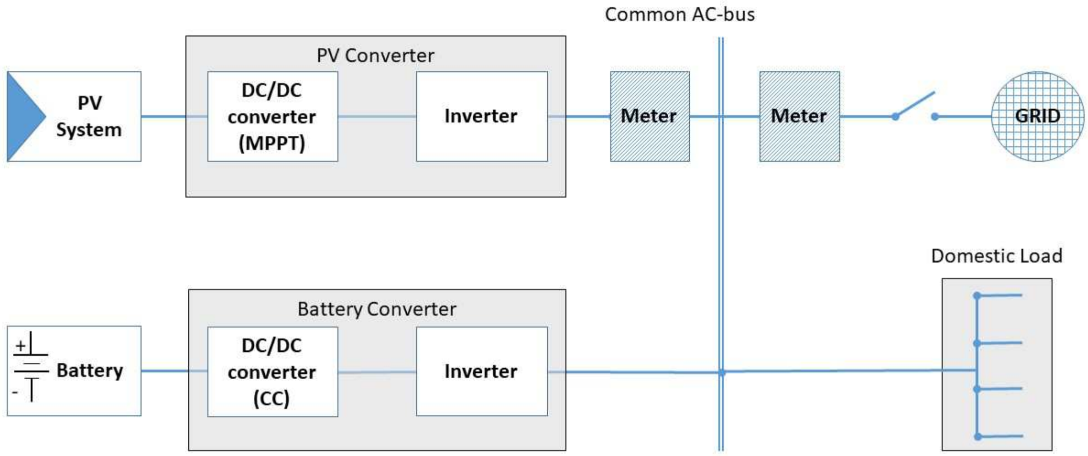

Figure II- 1. Schematic Diagram of an AC-Coupled PV-Battery Storage system.

APPENDIX III

III-1 Network tariffs and energy cost used for the economic analysis.

In Table III-1 below, the tariff structure and the wholesale price under Net-billing scheme are outlined. The final retail electricity price is calculated after including additional taxes and network charges as shown in Table III-2.

Table III- 1. Current tariff structure and wholesale energy price under Net-Billing scheme.

	Tariff Period 1 (October – May)		Tariff Period 2 (June – September)	
	Week Days	Weekends and Public Holidays	Week Days	Weekends and Public Holidays
On-Peak Period	16:00 – 23:00		09:00 – 23:00	
Off-Peak Period	23:00 – 16:00		23:00 – 09:00	
Wholesale energy cost during on-peak period	8.72 c€/kWh	8.38 c€/kWh	13.83 c€/kWh	8.45 c€/kWh
Wholesale energy cost during off-peak period	7.49 c€/kWh	7.12 c€/kWh	8.34 c€/kWh	8.15 c€/kWh

Table III- 2. Additional taxes and network charges imposed to wholesale energy price.

Description	Value[2]
PSO Levy	0,083 c€/kWh + VAT
Ancillary Service Cost	0.67 c€/kWh + VAT
Fuel Adjustment Clause	4.407 c€/kWh + VAT
LV Network Charge	3.210 c€/kWh + VAT
Meter Reading Charge	49 c€ (Monthly Charge) + VAT
Supply Charge	234 c€ (Monthly Charge) + VAT
Green Tax Contribution	1.00 c€/kWh

The per unit (kWh) charges are automatically adjusted by the fuel adjustment charge, to cover any increase or decrease in the cost of fuel per metric ton (M.T.). The Fuel Adjustment Charge is calculated on the basis of the current and basic fuel price. The price of unit (KWh) charged shall be increased or decreased by the value of the

2 Standard VAT rate in Cyprus by the end of Dec 2018 is 19%

coefficient of fuel adjustment currently in force for every 1 cent increase or decrease in the basic price of €300 per Metric Ton (M.T.) of fuel cost.

The Fuel Adjustment Charge is equal to:

$$\text{Fuel Adjustment Charge} = \frac{(\text{Current Fuel Price} - \text{Basic Fuel Price})\ \text{X Coefficient of Fuel Adjustment}}{1\ €c}$$

Basic Fuel Price: €300 / M.T
Coefficient of Fuel Adjustment used: for consumers connected to the low voltage is 0,00025557 €c/kWh/M.T

The Fuel Adjustment Charge which is calculated every month is used for:

- Monthly customers whose meter reading is recorded the month following the calculation of the Fuel Adjustment Charge.
- Bi-monthly customers whose meter reading is recorded two months after the calculation of the Fuel Adjustment Charge.

The current fuel price is the Weighted Average Fuel Price of the Month (WAFP) which is calculated every month on the basis of the fuel consumption and cost of fuel as shown below (in simplified form):

$$\text{WAFP} = \frac{\text{Cost of fuel consumption of the month} + \text{COSMOS charge}}{\text{Amount of fuel consumed during the month}}$$

Where COSMOS (Cyprus Organisation for Storage and Management of Oil Stocks) charge is the amount of euros that EAC pays for every metric ton (M.T.) it receives.

The following Tables summarize the fuel Adjustment charge as well as the Coefficient of Fuel Adjustment for the year 2018.

Table III- 3. Fuel Adjustment charge for 2018.

Monthly Consumers	Bi-Monthly Consumers	Weighted Average Monthly Cost of Fuel	Fuel Adjustment charge per unit (cent)	
		2018		
	January	332,95	HIGH VOLTAGE	0,7249
			MEDIUM VOLTAGE	0,7381
			LOW VOLTAGE	0,7579
January	**February**	347,75	HIGH VOLTAGE	1,0505
			MEDIUM VOLTAGE	1,0696
			LOW VOLTAGE	1,0983
February	**March**	347,88	HIGH VOLTAGE	1,1253
			MEDIUM VOLTAGE	1,1459

			LOW VOLTAGE	1,1701
March	**April**	356,29	HIGH VOLTAGE	1,323
			MEDIUM VOLTAGE	1,3472
			LOW VOLTAGE	1,3756
April	**May**	363,31	HIGH VOLTAGE	1,488
			MEDIUM VOLTAGE	1,5152
			LOW VOLTAGE	1,5472
May	**June**	391,92	HIGH VOLTAGE	2,1604
			MEDIUM VOLTAGE	2,1999
			LOW VOLTAGE	2,2463
June	**July**	394,42	HIGH VOLTAGE	2,2192
			MEDIUM VOLTAGE	2,2598
			LOW VOLTAGE	2,3074
July	**August**	409,36	HIGH VOLTAGE	2,6149
			MEDIUM VOLTAGE	2,7308
			LOW VOLTAGE	2,7949
August	**September**	460,37	HIGH VOLTAGE	3,8346
			MEDIUM VOLTAGE	4,0046
			LOW VOLTAGE	4,0986
September	**October**	455,47	HIGH VOLTAGE	3,7174
			MEDIUM VOLTAGE	3,8822
			LOW VOLTAGE	3,9733
October	**November**	484,29	HIGH VOLTAGE	4,4066
			MEDIUM VOLTAGE	4,6019
			LOW VOLTAGE	4,7099
November	**December**	505,47	HIGH VOLTAGE	4,913
			MEDIUM VOLTAGE	5,1308
			LOW VOLTAGE	5,2512
December		496,81	HIGH VOLTAGE	4,7059
			MEDIUM VOLTAGE	4,9145
			LOW VOLTAGE	5,0299

Table III- 4. Coefficient of Fuel Adjustment for the year 2018.

<table>
<tr><td rowspan="3">from 1/2/18</td><td>HIGH VOLTAGE</td><td>0,00023503</td><td rowspan="3">for monthly February</td></tr>
<tr><td>MEDIUM VOLTAGE</td><td>0,00023933</td></tr>
<tr><td>LOW VOLTAGE</td><td>0,00024438</td></tr>
<tr><td>from 1/3/18</td><td colspan="2">0,00024438</td><td>for bi-monthly March</td></tr>
<tr><td rowspan="3">from 1/7/18</td><td>HIGH VOLTAGE</td><td>0,00023911</td><td rowspan="3">for monthly July</td></tr>
<tr><td>MEDIUM VOLTAGE</td><td>0,00024971</td></tr>
<tr><td>LOW VOLTAGE</td><td>0,00025557</td></tr>
<tr><td>from 1/8/18</td><td colspan="2">0,00025557</td><td>for bi-monthly August</td></tr>
</table>

In light of the above, the retail cost of import energy is calculated using the following equation:

$$
\begin{aligned}
&Import\ Retail\ Cost \\
&\quad = [Wholesale\ Energy\ Price + Network\ Charge + Ancillary\ Services\ Cost \\
&\quad + PSO\ Levy + Fuel\ Adjustment\ Charge] * (1 + VAT\ Rate) \\
&\quad + Green\ Tax\ Contribution
\end{aligned}
$$

Where Wholesale Energy Price is based on the temporal consumption as determined in Table III-1 and the rest of the variables to be as in Table III-2. To conclude to the final electricity price, it is important to consider the Net-Billing charge, that is equal to 1,63 c€ per imported energy unit from the grid (kWh). The final imported energy cost is then calculated using the formula below:

$$
\begin{aligned}
&Final\ Import\ Energy\ Cost \\
&\quad = (Import\ Retail\ Cost * Energy\ Conumption) \\
&\quad + (Energy\ Consumed * Net\ Billing\ Charge) * (1 + VAT\ Rate)
\end{aligned}
$$

To continue with, exporting RES energy to the grid, the exported energy is remunerated in the applied Net-Billing scheme with a rate calculated in equation below. The *RES price* is the EAC's approved purchase price for RES energy and is equal to 12.64 c€/kWh in December 2018. The cost paid by the EAC for energy produced from RES is published on the EAC website each month. The cost of purchasing electricity from RES is calculated using the current EAC Fuel Cost of the month. In order to calculate the purchase price of the kilowatt-hour, the fuel price readjustment is considered in the basic purchase price of RES. The basic purchase price is equal to the fuel cost of EAC, plus a variable maintenance cost for the EAC. This price also includes the avoided CO_2 emissions cost. Further details regarding the annual RES price for year 2018 are available in Table III-6 below.

$$
Export\ Energy\ Cost = [Export\ Energy\ * RES\ price * (1 + VAT\ Rate)\ ]
$$

Finally, the charging price for self-consumed energy under the current regulatory framework is calculated using the following equation:

$$
\begin{aligned}
&Self\ Consumed\ Energy\ Cost \\
&\qquad = [Energy\ Self\ Consumed * (Net\ Billing\ Charge + PSO\ Levy) \\
&\qquad * \ (1 + VAT\ Rate)\ ] + Green\ Tax\ Contribution
\end{aligned}
$$

Table III- 5. Current tariff structure and final energy prices under Net-Billing scheme.

	Tariff Period 1 (October – May)		Tariff Period 2 (June – September)	
	Week Days	**Weekends and Public Holidays**	**Week Days**	**Weekends and Public Holidays**
Retail energy cost injected from the Grid (including wholesale price, network charges, taxes and levies) on-peak period	21.95 c€/kWh	21.54 c€/kWh	28.03 c€/kWh	21.63 c€/kWh
Retail energy cost injected from the Grid (including wholesale price, network charges, taxes and levies) off-peak period	20.48 c€/kWh	20.04 c€/kWh	21.49 c€/kWh	21.27 c€/kWh
Net-billing charge	1,63 c€/kWh			
RES price (selling price)	12.64 c€/kWh (December 2018, Table III-6)			

In addition to the aforementioned energy costs, a supply and metering cost are charged on a monthly basis.

Table III- 6. Purchase Price by EAC for energy produced from Renewable Energy Sources (€cent/kWh) for the year 2018.

Monthly Producers	Bi-Monthly Producers	Monthly Weighted Average Fuel Price (€)	Fuel Adjustment on Basic Purchase Price (increase) cent			Total Purchase Price (Basic Price+Fuel Adjustment) cent		
			132/ 66 kV	11 kV	LV	132/ 66 kV	11 kV	LV
-	**January**	332,95	0,712	0,725	0,738	7,435	7,554	7,712
January	**February**	347,75	1,031	1,051	1,070	7,754	7,880	8,044
February	**March**	347,88	1,105	1,125	1,146	8,240	8,389	8,539
March	**April**	356,29	1,299	1,323	1,347	8,434	8,587	8,740
April	**May**	363,31	1,461	1,488	1,515	8,596	8,752	8,908
May	**June**	391,92	2,121	2,160	2,200	9,256	9,424	9,593
June	**July**	394,42	2,179	2,219	2,260	9,314	9,483	9,653
July	**August**	409,36	2,566	2,615	2,731	9,839	10,022	10,456
August	**September**	460,37	3,763	3,835	4,005	11,036	11,242	11,730
September	**October**	455,47	3,648	3,717	3,882	10,921	11,124	11,607
October	**November**	484,29	4,324	4,407	4,602	11,597	11,814	12,327
November	**December**	505,47	4,821	4,913	5,131	12,094	12,320	12,856
December	-	496,81	4,618	4,706	4,915	11,891	12,113	12,640

III-2 Energy production and consumption profiles used for the economic analysis.

The following figures represent the daily average load consumption and PV production profiles that were considered in the economic analysis. It can be clearly observed that load consumption pattern changes over the year and is seasonally affected. The energy production was considered for a residential 5 KWp PV system.

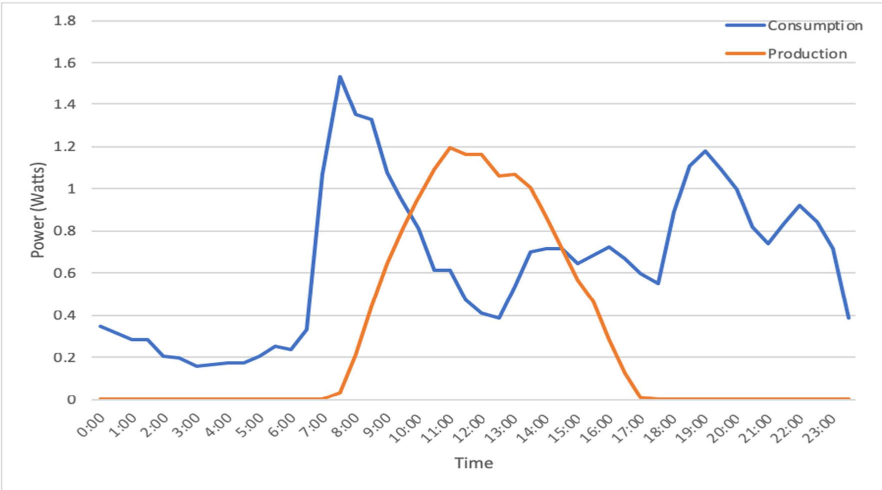

Figure III- 1. Daily average PV production and load consumption in January.

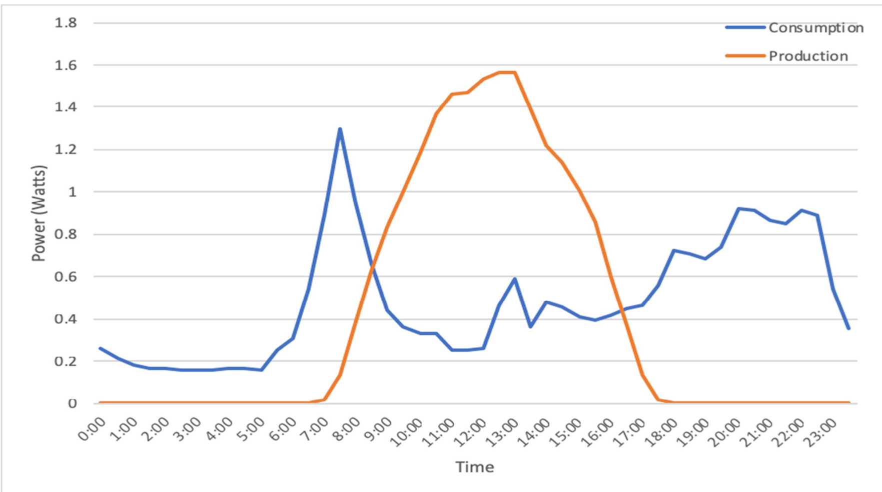

Figure III- 2. Daily average PV production and load consumption in February.

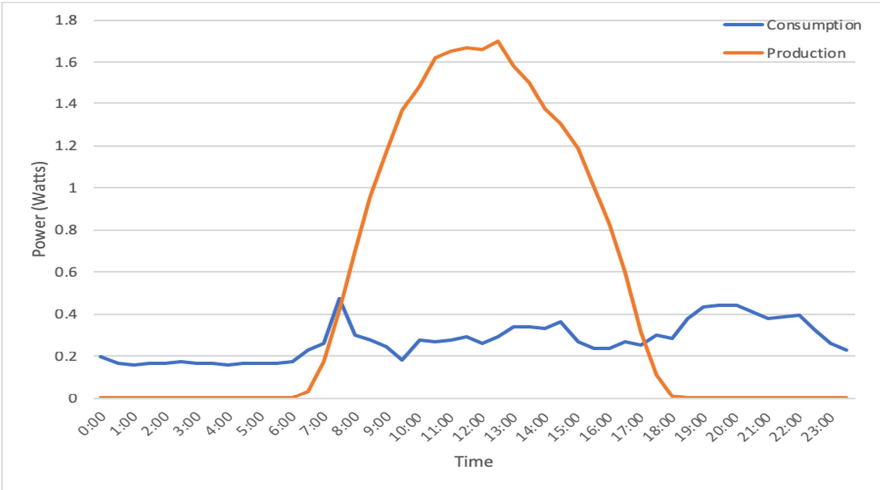

Figure III- 3. Daily average PV production and load consumption in March.

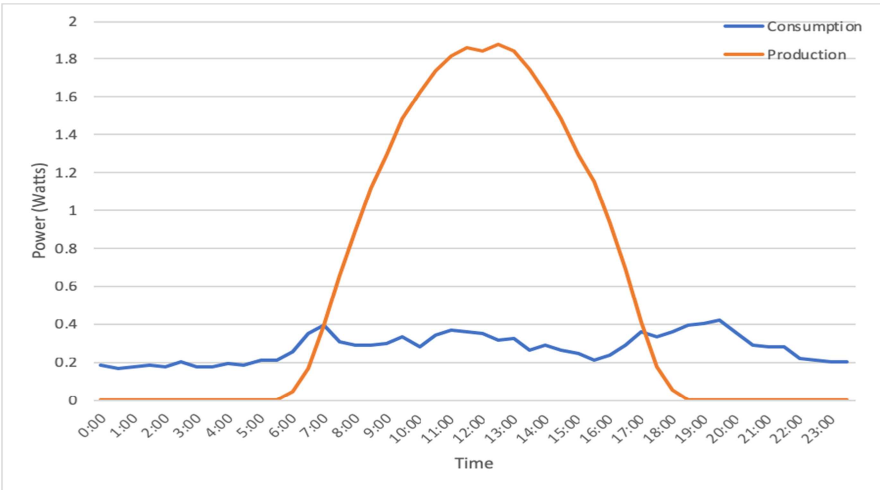

Figure III- 4. Daily average PV production and load consumption in April.

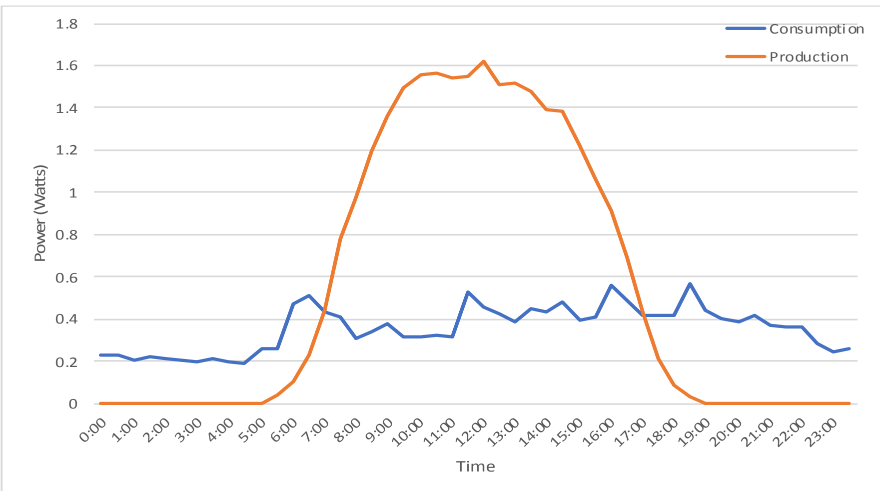

Figure III- 5. Daily average PV production and load consumption in May.

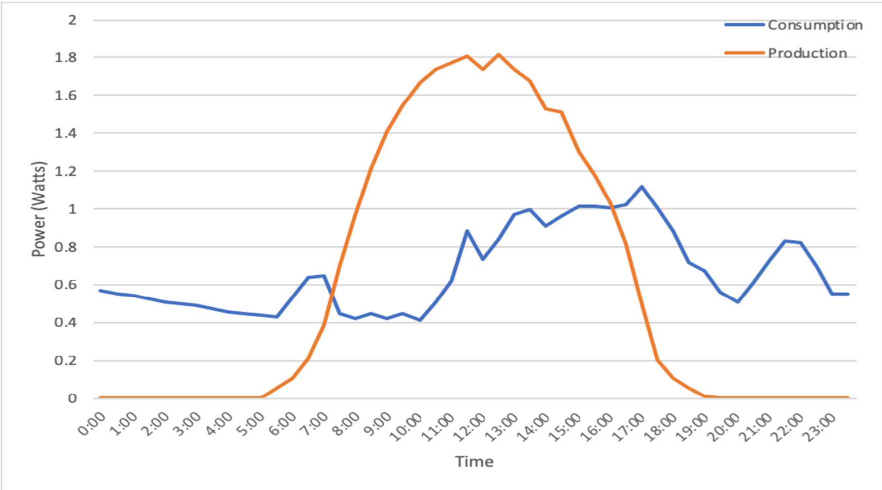

Figure III- 6. Daily average PV production and load consumption in June.

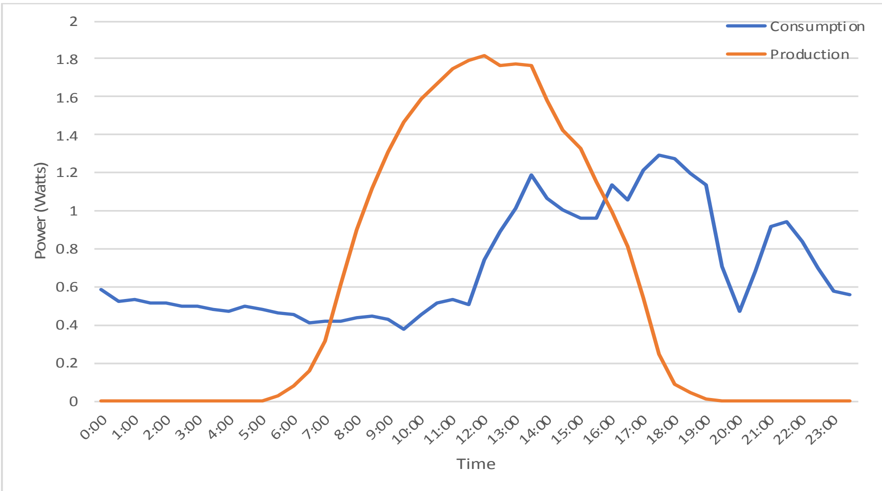

Figure III- 7. Daily average PV production and load consumption in July.

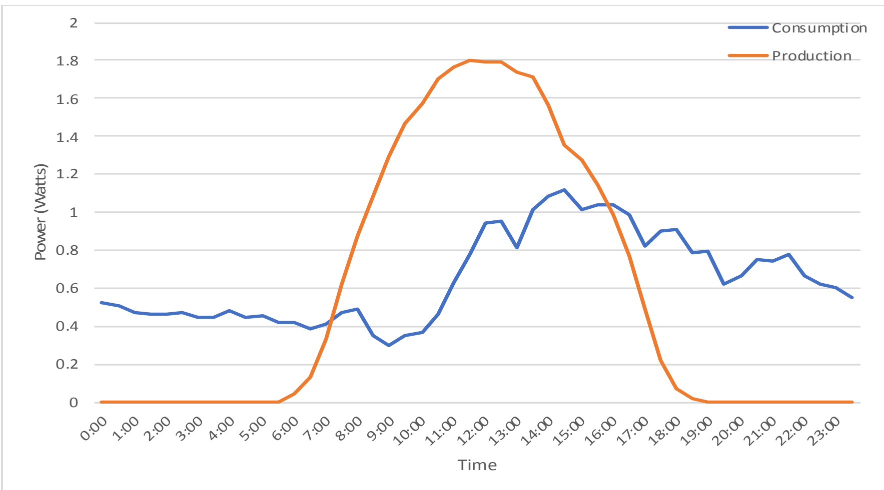

Figure III- 8. Daily average PV production and load consumption in August.

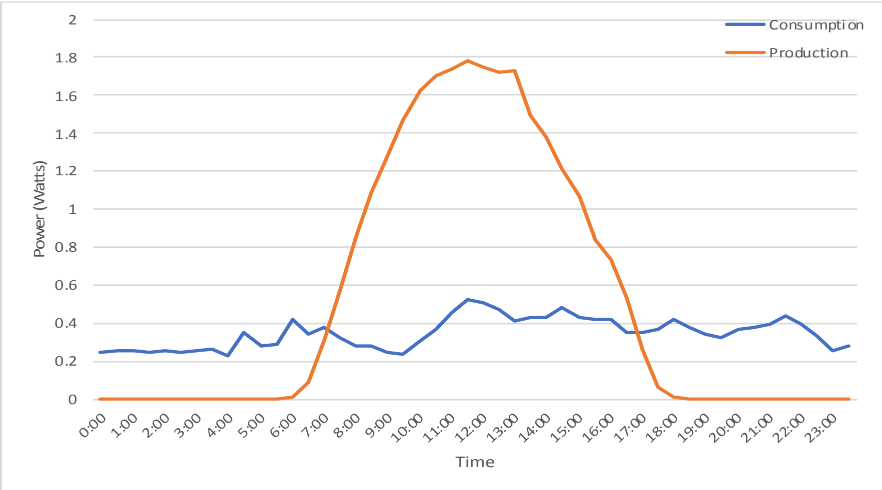

Figure III- 9. Daily average PV production and load consumption in September.

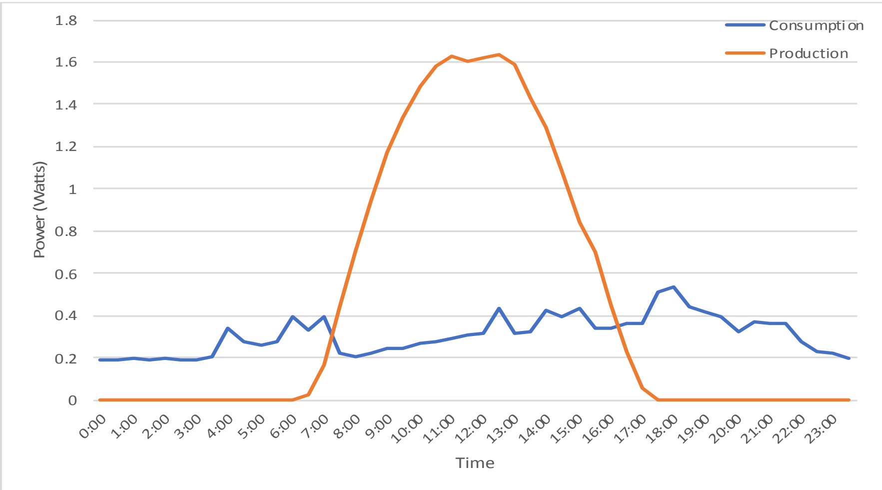

Figure III- 10. Daily average PV production and load consumption in October.

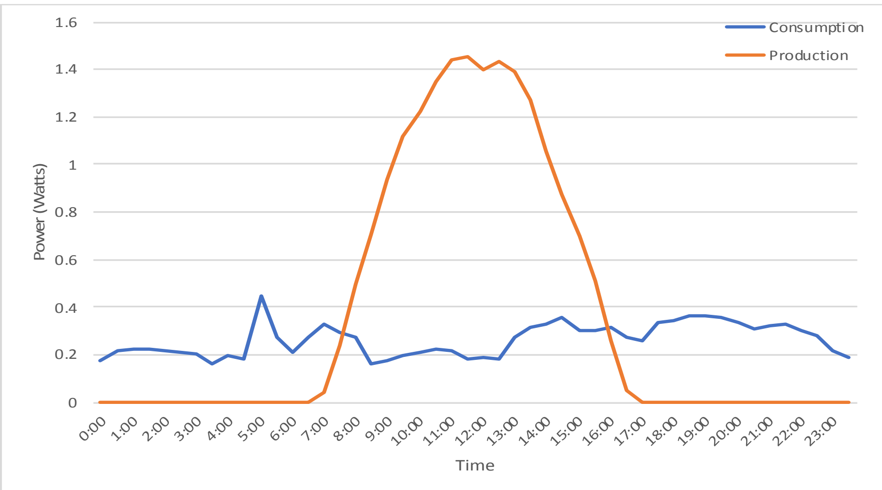

Figure III- 11. Daily average PV production and load consumption in November.

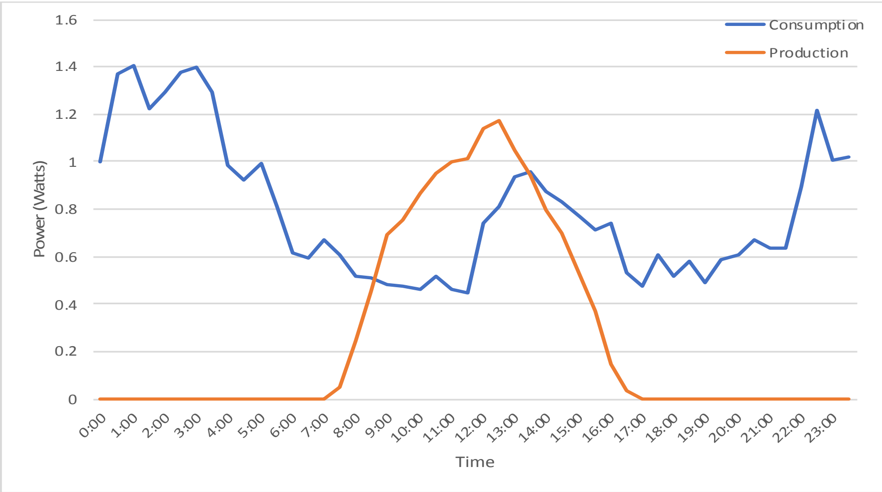

Figure III- 12. Daily average PV production and load consumption in December.