D2.4 - Final S4G Business Models

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Executive Summary

This deliverable summarizes the Final Business Modelling work in a subset of the three S4G test sites. This deliverable represents an incremental development of the previous use cases described in D2.3 – "Initial S4G Business Models" [D2.3], and it uses the S4G vision from D2.2 – "Final storage scenarios and use cases" [D2.2] and D6.2 – "Phase 2 Test Site Plans". This deliverable gives also an overview of the energy storage market, a deeper stakeholders and policy framework analysis, followed by a description of a subset of the most relevant business cases and the associated business models from the literature. The selection of the business cases has been done by the Partners of the Consortium as a whole. Relevant high-level business analyses were done for each High-Level Use-Case (HLUC), such as GAP analysis, Political Economic Social Environmental Legal (PESTEL) analysis, Service Technology Organization Finance (STOF) analysis and Strengthens Weakness Opportunity Threat (SWOT) analysis from the Distribution System Operator (DSO), prosumers and suppliers of Electric Vehicles (EV) and Energy Storage System (ESS) perspective. A final value proposition canvas and business model canvas has been realised too. Finally, the present deliverable describes a first draft proposal for a quantitative economic model to be applied to some Fur/Skive use cases. A more detailed explanation of the model will be done in WP5 and it will be tested and implemented in real scenarios through the Decision Support Framework Economic Engine (DSF-EE) and Professional Graphical User Interface (GUI) tools.

1 Introduction

This document describes the final business analysis of ESS. The goal of this deliverable is twofold: on one side, to analyse real business cases already described inD2.2 [S4G-D2,2] and D2.3 [S4G-D2.3] and, on the other side, to provide a first release of a quantitative economic modelling approach to analyse the benefits/costs for DSO and prosumers. While a number of technical capabilities and features of S4G control solutions can be operated by single business entities (e.g. private prosumers), the real value of such solutions lies in the use of S4G solutions as an enabler of complex business and market configurations where services of different stakeholders and partnerships are dynamically involved and integrated with the energy market.

This document represents the final analysis of deployment and operation of storage systems. Such initial activity includes references to current market configurations and regulations in Europe. In particular, a description of the European market ecosystem has been introduced with a focus on the main stakeholders involved in the deployment of storage system at substation and residential level.

After this initial analysis, the core of the work is performed by tackling the Business Modelling problem from a multi-partner, eco-system perspective, projecting technical and market condition in the target period 2020-2030. This activity includes the exploration of new business models to stimulate discovery of new opportunities introduced by S4G outcomes. A PEST(EL), GAP and SWOT analysis aims to deep the generic landscape of the main drivers and barriers to develop a new business ecosystem and to earn for stakeholders interested to invest in the storage market. New regulations and / or standardization will not be addressed at this moment. This makes the business models proposal an iterative process, as the evolving regulatory environment will dramatically influence the cost benefit analysis (CBA) results for each of the stakeholders. The stakeholders' business cases are being explored in business conditions, investments and cost, market perspective and regulatory issues. The focus in business modelling is business framework and cases definition. Focus in the target groups are on residential customers, a commercial fleet and grid site placement of storage. The business model view is in most cases analysed from the DSO perspective, the assumption is to avoid or postpone grid reinforcement and being able to control storages.

This deliverable represents a contribution to support the strategic decision-making process leading actors in the storage system market to understand how to best manage and find future opportunities, generated benefit or limiting costs, based on their respective markets. More specifically, the deliverable is organised in eight sections including these introductory comments. Section two looks at the market in which the project operates analysing it from an economic perspective in terms of trends and the related opportunities associated with them. Section three propose a description of the main tools used for the economic analysis. Section four looks at the definition of the economic model with logic structure and the variables description. Section five, six and seven, instead, focuses on the deep description of the three HLUC use cases and the results coming from the economic model. Finally, section eight concludes the deliverable by singling out some preliminary takeaway messages.

1.1 Scope

This deliverable presents the results generated by Work Package 2 "Business Models and Requirements Engineering", and more specifically by task T2.2. "Business Models and Eco-systems". It describes the methodology and the final business models for each use case at M30 of the project.

1.2 Related documents

ID	Title	Reference	Version	Date
D2.2	Final Storage Scenarios and Use Cases	[S4G-D2.2]	1.0	2018-07-31
D2.3	Initial S4G Business Models	[S4G-D2.3]	1.0	2018-03-20
D6.2	Phase 2 Test Site Plans	[S4G-D6.2]	1.0	2018-11-28

2 The distributed energy storage market

Electrical power generation is changing drastically in the last decades across the world because of the need to reduce greenhouse gas emissions and to introduce mixed energy sources. The power network faces great challenges in transmission and distribution to meet demand with unpredictable daily and seasonal variations and the electrical energy storage (EES) is recognized as underpinning technology to have great potential in meeting these challenges.

The European Energy Union highlights several inter-related priorities where there is growing evidence that energy storage (ES) can play a critical role in supporting at least three of these priorities: energy supply security, a fully integrated internal energy market, and decarbonisation of the EU's energy system. Technological development and related viable business models together with supportive regulatory instruments are some of the key factors required to enhance the full potential of ES. The current development of electric energy storage (EES) should be studied in terms of both technological progress and legislative support that include the need for a common definition of storage, valuing storage, ownership issues, and legislative barriers. Indeed, for instance, legal access to storage asset construction and operation by system operators in European unbundled electricity markets could be difficult both for DSO and prosumers.

The ESS can be defined as a set of equipment and devices for the management and control of power energy that can be deployed both in-front-to-the meter (FtM) and in behind-to-the-meter (BtM). In Italy, for instance, who installs a storage system should communicate to the network manager and the systems could be installed according to three different configurations as[i]:

- Monodirectional production side;
- Bidirectional production side;
- Bidirectional postproduction.

The economic and social value of ESS can depend on many aspects, as the services that storage can provide to the electricity generation system. Moreover, the value of ESS should be identified for each level of energy phase (i.e., generation, transmission e distribution) in order to capture the value associated with each location through, for instance, transmission and distribution (T&D) investment deferrals. ESS can provide a cost-effective alternative to expensive T&D investments by supporting peak load capacity in locations where they are most needed, even if storage may not be enough for covering the cost of an asset.

The range of benefits that can be provided by ESS falls into the following categories[ii]:

- **Energy market arbitrage** is the ability for electricity storage to absorb electric energy during low priced periods and discharge to produce energy during high priced hours;
- **Providing ancillary services** is the ability of electricity storage to support the real-time operations of the electricity grid by charging and discharging in granular time intervals or maintaining readiness to respond to the need of the system to maintain reliability. ES participate in ancillary services' markets (i.e., frequency control, reserve settlement), whereby system operators procure critical services related to the physical balancing and security of the grid. In these cases, additional forms of revenue, although still low in relative terms, can complement energy arbitrage;
- **Reducing ancillary services needs** is the ability of fast-acting storage technologies to reduce the quantity of operating reserves that system operators' need to hold aside to balance loads and generation on the power system;
- **Reducing production costs** is the ability of storage to reduce system-wide fuel and variable operating costs by charging during periods with low-cost generation costs and discharging during periods with high generation costs;
- **Avoiding generation investments** is the ability for storage to reduce the need for conventional resources, such as additional generating plants or demand response resources, to meet system-wide peak load with a reserve margin;
- **Deferring of T&D investments** is the ability for storage to defer T&D system investments by discharging energy to reduce load on constrained transmission and distribution components;
- **Increasing customer reliability**, the ability of storage devices to provide backup energy to reduce the frequency and duration of power outages faced by electricity customers;

- **Increasing power quality** is the ability of storage devices to improve the quality of power delivered to customers, such as by injecting real or reactive power to reduce voltage drops and stabilize local system conditions;
- **Integrating intermittent renewable resources** is the ability of storage to smooth out the generating pattern of intermittent resources and thereby enable the grid to accommodate more intermittent resources while maintaining system reliability and increasing the capacity value of the intermittent resources;
- **Reducing cycling of conventional generation** is the ability of storage to reduce the frequency by which conventional resources need to shut down and start up to manage low-load conditions on the power grid;
- **Reducing emissions** is the ability for storage to reduce the operation of certain fossil fuel-based generation and thereby reduce air emissions and other pollutants from power plants;
- **Reducing line losses** is the ability of storage devices located close to load to reduce the energy lost in transmitting power from generating resources to load by charging during off peak conditions (with low system losses) and discharging energy during on-peak periods (with high system losses).

Another relevant issue regarding ESS is the ownership models that are closely linked to the local regulation. The legal framework for storage assets is not clearly established in the EU and will need to rapidly evolve due to growing development of requirements such as grid support.

In the transmission sector, that in S4G will not analysed, there are different ownership models where the Ownership Unbundling: It is the most popular model in the EU, which states that the transmission system operator (TSO) must be unbundled from any integrated company. The TSO owns the grid assets and is paid by energy suppliers to use the grid. Under current European regulation, they are not allowed to own any producing assets, including storage assets. The unbundling principle present in the EU and in some other countries (Australia, etc.), hinders the acquisition of storage assets by system operators at the FtM level. Mitigating this prohibition, the Italian TSO Terna, for example, has deployed 40.9 megawatts (MW) of battery storage since 2013 for grid stability. This attests to the fact that no clear legal statement exists for storage ownership and operation by TSO respecting the unbundled principle. One way to remedy this precarious regulatory situation is to contract third parties to install, own and run storage assets and to access, as an energy producer, to additional revenue streams on unregulated markets[iii].

Today, there is also a strong need to reduce required grid investment. Distributed generation (DG) causes the grid to become more complex, increasing the required grid capacity and, simultaneously, the potential for more complex system management. Congestion management using flexibility services can save costs compared to applying the 'fit-and-forget' approach. Furthermore, DG increases the capacity of DSOs to respond to emergency situation and realise damage control. Investments for increasing the number of kilometres and for bidirectional flows requires huge economic resources for investors and those resources should guarantee an adequate return on investment and a 'stable' regulation that favours a long run investment.

Furthermore, DSO and end-users can have asymmetric information that needs to have a coordination system and stability on the regulation. Indeed, regulation should be clear and predictable in order to avoid investment that will not bring enough earnings. DSO (and TSO) should receive from end-users the needed information in order to monitor the efficiency of their own network, complying with privacy of end-users. The asymmetric information is a key issue concerning to the information about technical systems, the measurement of real time power consumption (e.g., through smart meter) for collecting data and transmit data to other operators. All these benefits coming from this strategy should be available as a source of economic savings, higher quality services, reduction of power losses. The grid stability and balancing issue is relevant because it is much difficult for distributors to exactly predict the energy that will be put in the grid from local sources of power generation. Finally, the management of data is another relevant issue since it dangerous to manage a huge amount of information and guarantee the privacy and security.

The overcapacity due to the excess of energy generated by renewable energy sources (RES) creates difficulties of return on investment (ROI). From economic point of view, the sustainability of high RES penetration should be computed taking into account the consequent grid instability generated by their intermittent generation and, in the long run, the market parity. Incentives and subsidies should be overtaken so that the growth of RES will be reached in competition conditions with other technologies and without charging the weight of further incentives on the customers. In other word, the parity with other technological solutions should be reached in operational way, where RES sources can provide services of energy supply to contribute to the functioning of the overall electricity systems. The generation from RES tends to decrease the wholesale price of electricity because they have zero cost of raw material, however, the intermittency makes the need to guarantee the availability of fossil plants. This situation will not change until the flexibility of the ESS become more economically viable.

2.1 The energy storage classification

ES is an instrument for balancing supply and demand, even if storage can be is expensive. When there is low demand and/or high supply, energy is fed into storage, from which it is released at times of high demand and/or low supply. At the same time, ES can be an alternative solution to traditional sources of ancillary services, for voltage regulation and other types of grid supports.

The ESS is often seen as a driver for future electricity systems changes. The high penetration of intermittent renewables also in international markets such as US (where California is the leader in the sector), Denmark, Germany and China, has been a strong driver for the ongoing changes in the electricity system that points toward rising opportunity for ES at the residential, commercial and utility levels. Nevertheless, there is still considerable uncertainty with regards to which market design and regulation may actually provide the necessary framework so that ES can be adequately developed and thus contribute to increase the necessary flexibility and move towards a low-carbon electricity system as a main target for EU communities.

The evidence indicates that policy interventions could affect renewables adoption in two separated but connected ways:

- One is to provide subsidies for research and development (R&D) in ES, whose progress would involve making renewable generation more profitable and eventually, as soon as possible, sustainable without subsidies;
- Another is to tackle regulatory and infrastructural issues: indeed, with larger and better functioning wholesale markets and smarter electricity grids, installing storage capacity should come closer to commercial profitability on its own. But how the changes in the regulation of electricity systems is required to adapt to the presence of ES is an open issue to be discussed in the future.

In this section it is proposed a set of possible classification of the ESS. A first attempt is based on two relevant “arenas” for storage services:

- **Time shift:** buy and sell energy in different periods of time (including energy related to ancillary services);
- **Location shift**: avoid the need to transport energy from one point to another, i.e. the need to use transmission and/or distribution networks.

Consequently, this first classification involves regulatory challenges, because storage competes with different types of services. A regulatory challenge is related to wholesale market design, because flexibility services can be sold in “competitive” wholesale markets (e.g., energy, ancillary services, etc.).

Another taxonomy of storage services and technologies is needed since different are the services can be provided by ESS according to their fundamental economic features and different are the regulatory and market design challenges that hat need to be tackled in order to coordinate these services. ESS can be classified based on the technology as follows:

- Mechanical;
- Electrochemical (batteries);
- Chemical.

Among different ES technologies, batteries seem to be the most promising ones, also because of its application to EVs and thus to the possibility of decarbonizing the transport sector as well. Moreover, the prices of batteries have been high until now, but they are decreasing in the past years since also an increasing number of companies start to sell ESS, mainly in US and Germany. Moreover, although still expensive, this technology is

developing rapidly, and costs are falling as companies like Tesla scale up production. S4G will focus mainly on battery storage system (i.e., Lithium, etc.).
A classification given by European Association for Storage of Energy[iv] is based on the division in traditional segments according to the core question about which kind of services ESS can provide to the network in the generation, transmission, distribution and customer services, respectively (Figure 1).

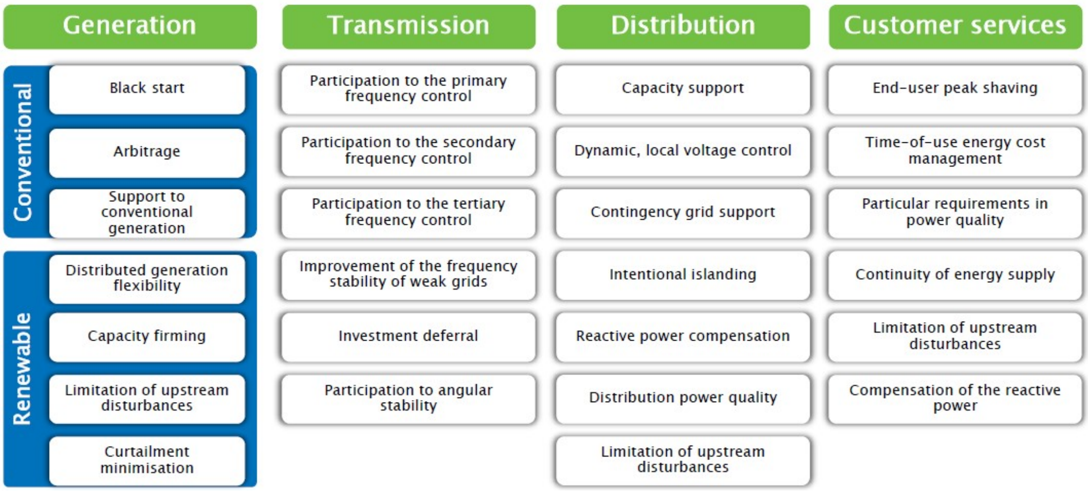


Figure 1 – Classification of storage based on the to the services for the network[iv]

Storage can be also associated to different uses, for centralized operation of the system, for decentralized operation, and end-users' applications (Table 1).

Table 1 – Classification of storage by end-user application[iv]

Storage application	Centralised	Decentralised	End-use
Balancing demand and supply	• Seasonal/weekly fluctuation • Geographical imbalance • Variability of wind/solar	• Daily/hourly fluctuations • Peak shaving • Integrate with heat/cold storage	• Daily/hourly fluctuations • Integrate with heat/cold storage
Grid management	• Voltage & frequency regulation • Participate in balancing markets	• Voltage & frequency regulation • Defer grid reinforcement • Substitute existing ancillary services	• Aggregate to provide grid services
Energy efficiency	• Time shifting: off-peak to peak	• Demand side management • Integrate with district heating & CHP	• Increase value of PV and micro grid • Facilitate behaviour change

Academy and think tanks provide a classification that concerns the technical aspects of energy storage[v] (Figure 2).

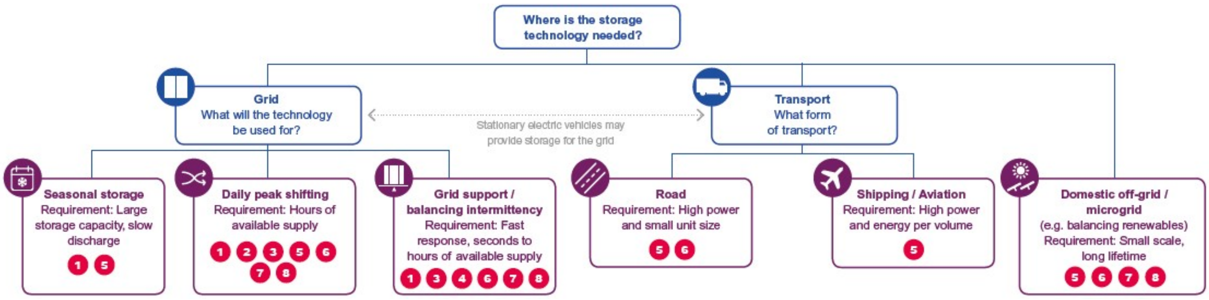


Figure 2 – Classification of storage by technical aspects[v]

Finally, a classification based on technical characteristics and the players in charge of coordinating the services provided by batteries has been provided by Fitzgerald[vi] (Figure 3).

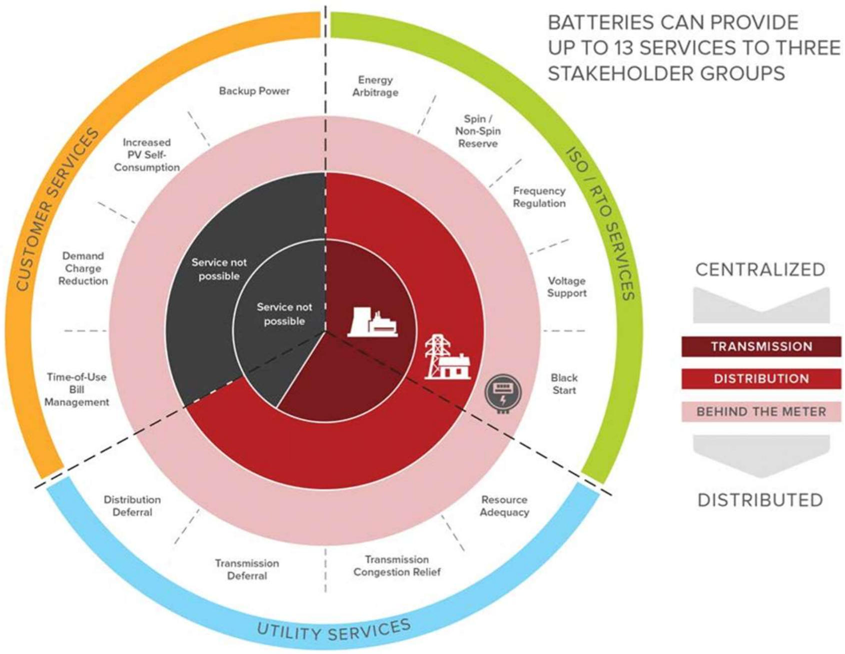


Figure 3 – Classification of storage by players and services[vi]

2.2 The creation of value for ESS

Basically, one possible added value of ESS to the grid is to provide flexible services as:

- Energy services (day-ahead markets), short and long term, commodity trading between two market players
- Adjustment services (intraday markets), trading services to deal with imbalances (trading among market players);
- Ancillary services (re-dispatching), trading between system operators (SOs) and market players in order to guarantee system integrity.

However, contractual agreements result to be fundamental to create flexibility in an environment where the trend of photovoltaic (PV) and storage penetration are going to increase in the medium and long run. And the main way also to coordinate incentives among all players in the markets is the long-term contract.

Real case studies where ESS have been applied are in Germany and in California, since in the global market they represent the most advanced markets of ES. With respect to the developments of storage regulation and market design, the German electricity market represents an interesting case study due to the high penetration of wind, solar and ES.
Indeed, Germany has the largest amount of PV capacity in the world, both in absolute (around 38 GW) and relative terms (around 58% of peak demand). Moreover, this is the first electricity market to have introduced support mechanisms specifically targeting storage equipment when combined with PV: it has been estimated that 13,000 residential battery systems were installed in 2015 across Germany and it has going towards significant changes in market design and regulation. Finally, the German wholesale electricity market is widely considered as one of the most competitive ones in Europe where the investments are very high as it is demonstrated by a state owned bank that gave low interest rate loans for 10,000 energy storage projects combined with PV plants with a power up to 30 kW (around EUR 163 million) with around 13,000 residential battery systems installed in 2015 across Germany[iv].
Also California is a relevant market of reference since it has a specific policy for utility-scale ES: in 2010 California's Public Utility Commission adopted a new ES mandate that required California's investor-owned utilities to develop 1.3 GW of additional ES by 2020 expand their ES capacity (from 4GW of grid connected ES capacity over a wide variety of technologies). There are no official financial incentives for ES projects, although California is the largest residential market in the US for the installation of PV. Table 2 highlights some variables of comparison between Germany and California[iv]. All these facts show how much is increasing the need to design a new power market with the introduction of storage systems.

Table 2 – Comparison of storage and renewable in Germany and California[iv]

Key indicators	Germany	California
Intermittent RES capacity	13%	15%
Wind installed capacity	1st in Europe, 3rd in the World (45 GW)	3rd in US, 11th in the World (6 GW)
PV installed capacity	1st in Europe, 2nd in the World (40 GW)	1st in US, 6th in the World (15 GW)
Low carbon policy	Wide and ambitious 55% RES by 2035	Wide and ambitious 50% RES by 2030
Energy storage policy	Only for residential	For utilities and DSO
Energy storage association	BVES	CESA
Economy size	1st in Europe, 4th in the World	1st in US, 6th in the World

The value of ESS is also linked to the self-consumption management for prosumers. The development of self-consumption should be built in a fair regulatory system for decentralized storage and a market improvement. In EU, an increasing number of manufacturers offer inverter and PV storage solutions for the market. Incentives are the driver for a deployment of self-consumption as, for example, the incentives and investments in ESS provided in different worldwide context[vii]:

- **US**: self-consumption has been promoted by the State of California through policies encouraging ES through the Self-Generation Incentive Program that issues incentives between 0.32 and 0.45 USS/Wh according to the size of the deployment;
- **Japan**: Distributed energy storage with batteries was included in the subsidies for installations of net zero energy houses and demonstration projects of net zero energy building. Some local governments also support storage batteries. for example, the Tokyo Metropolitan Government has been conducting the "Project to expand introduction of renewable energy for local production and local consumption";

- **Austria**: since 2016, more and more provinces provide an investment subsidy to support the installation of decentralized electricity storage systems in combination with PV. For example, Vienna provides a limited incentive of EUR 500 /kWh, while Burgenland has a non-refundable rebate of EUR 275 /kWh for storages up to 5 kWh. The highest incentive reached up to EUR 600 /kWh with a limit at 7.5 kWh;
- **Germany**: a program of incentives for storage units was introduced 2013, which aims at increasing self-consumption and developing PV with battery storage in Germany. A EUR 25 million market stimulation program has been introduced to boost the installation of local stationary storage systems in conjunction with small PV systems (< 30 kWp). Within the framework of this storage support program around 20,000 decentralized local storage systems were funded by the end of 2016. During 2017, 6,954 storage systems were funded, of which 6,390 were part of a new PV system and 564 being an upgrade for existing systems. The total funding within those two measures amounted to EUR 223 million. However, the number of installed battery storage system is higher: it is estimated that 20,000 have been installed in 2017 and the 100,000 mark has been reached in august 2018;
- **Italy**: after the end of the feed.in-tariff (FiT) law in 2013, tax credit (available for small size plants up to 20 kw and for storage devices), together with a net-billing scheme (so-called Scambio Sul Posto - SSP), are the measures to support the PV market that exists now. Italy switched from the net-metering mechanism to a net-billing scheme for systems below 500 kW in 2009, in which electricity fed into the grid is remunerated through an "energy quota" based on electricity market prices and a "service quota" depending on grid services costs (transport, distribution, metering and other extra charges). The net-billing scheme is valid for one year and automatically renewed once granted. Market prices are applied for the electricity injected into the grid as an alternative to SSP. Self-consumption is allowed for all PV system sizes.

2.3 Stakeholders

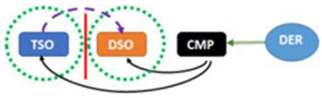
Different actors can cover a crucial role in the ES market: the TSO, DSO and management of ancillary services (that could coincide with the DSO and TSO or can be an independent market operator (IMO)), the aggregators (commercial market parity (CMP)), suppliers of electricity-related technology, suppliers of storage technology and prosumers. Hereafter, it is analysed some of these actors that could be relevant for the S4G project.

2.3.1 The role of DSO

The Distribution System Operators (DSO) has the obligation to be compliant in grid stability namely the voltage level. When private house owners invest in PV-systems, the voltage will locally increase and if the voltage reach its limits, the DSO needs to grid strengthen or do other actions to overcome the problem. Future actions may be investing in local storage or buying ancillary services from locally placed and owned storage. The storage may defer the grid strengthening, but that is also interesting for the DSO if the business-case is positive.
Possible schemes for interaction among DSO and other actors in a market context where they have different roles (Table 3):

Table 3 – DSO interaction schemes[viii]

Coordination mechanism	Description	Scheme
Centralised market	TSO and DSO can make direct agreement with all the DERs to get ancillary services for the management of balancing and or local congestion issues, with different logics w.r.t. the market for ancillary services.	

Local market	DSO acquires the use of DER to solve local issues of congestions management and becomes aggregator for other not locally used resources	
Sharing responsibility between TSO and DSO	TSO and DSO are both responsible for balancing issues for their own area of reference.	
Common market between TSO and DSO	TSO and DSO participate to the common market managed by an independent subject to collect the needed resources in real time.	
Integrated flexible market	The resources for transmission and distribution participate to a common market among, on one side, TSO and DSO purchasing resources for balancing issues, on the other side, commercial actors or aggregators.	

The DSO has a strategic role in the monitoring and planning the grid power flows in order to provide a stable energy flow to customers. The management of grid congestion, reverse flow and other criticalities requires huge investments and a good planning activity. The asymmetric information among different actors and a not stable and clear regulation about storage are criticalities that makes difficult the long run planning activity for DSO. This deliverable would propose also a first evaluation tool useful for DSO to analyse the cost structure of her possible future investments.

2.3.2 The role of aggregators

The management of the ESS requires to have an optimal allocation of storage in a territory in order to guarantee the security of the power supply and reduce the management costs. Other relevant actors that could be involved in the future storage market, and in the ES value chain may be the aggregators or service providers, also called commercial market parity (CMP). Aggregators make contracts with private house owners about ancillary services and bundle a community (a feeder-line or transformer station), to make the business case sustainable. The aggregator can offer ancillary services to the local DSO with a bigger volume and the aggregator collect all the details and take care of local control.
The regulation today highlights also the position of the aggregator that permits to favour the demand and supply market clearing. The aggregator makes contract with end-users to participate to the electric market on behalf of single operators and she can manage the generation in order to satisfy the contractual commitments. A first definition of aggregator is "the supplier of services that, on demand, aggregates several consumption units to sell to the market". Since many years, in some countries there is trial about the impacts of the aggregator in the market on the consumers[ix].
Another definition of aggregator is provided by Energynet[x]: "Aggregator has entered into an agreement with an electricity customer on access to disposing of the electricity customer's flexible consumption and/or generation in the electricity market. The aggregator pools flexibility from customers and converts it into electricity market services, for example for use by the TSO, DSO and/or balance responsible parties (BRP)".
The role of the aggregator is to favour the meeting among different actors (Figure 4) eventually by using also the storage system as a means of facilitate the providing of electricity (Figure 5).

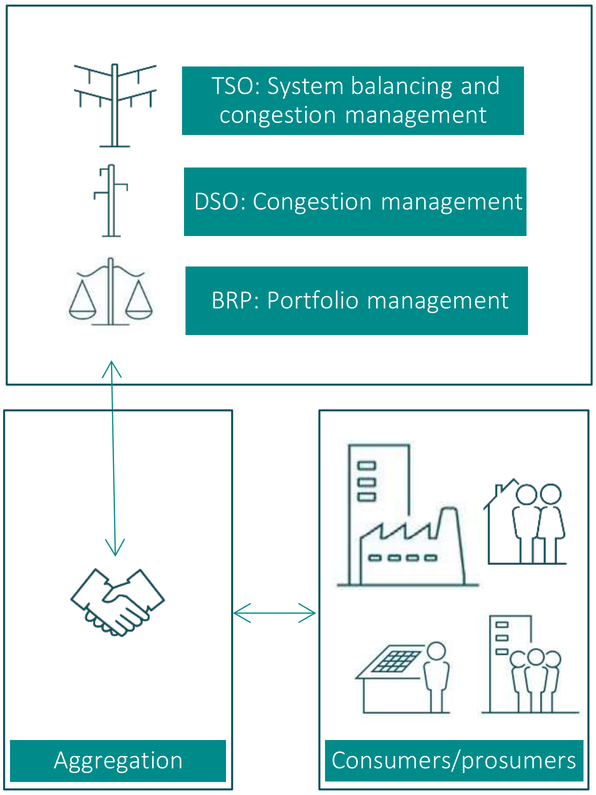


Figure 4 – The role of the aggregator[x]

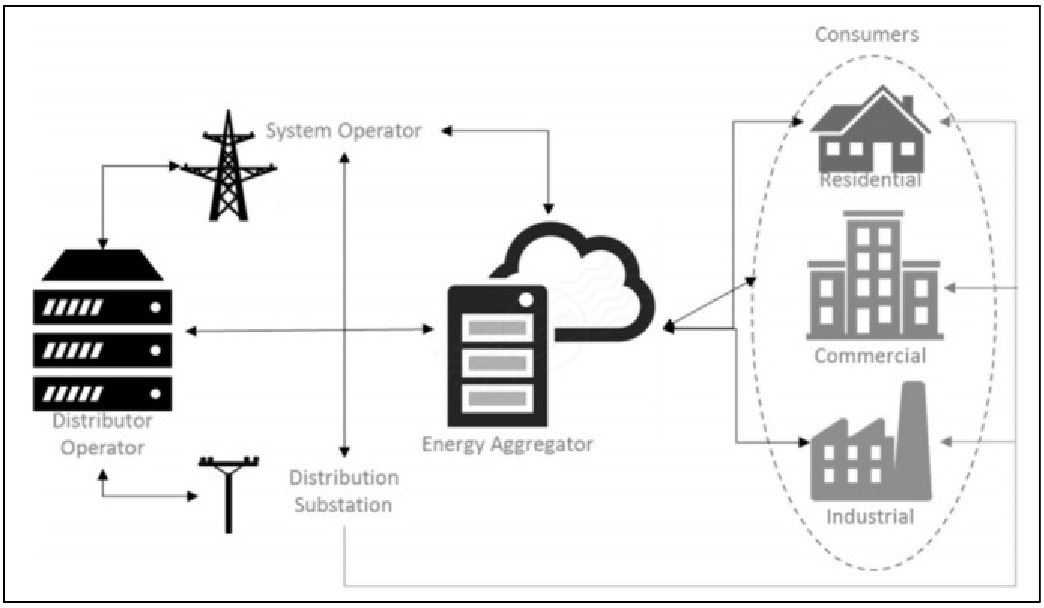


Figure 5 – The role of the aggregator in the electricity market[ix]

Flexibility services can be provided by different actors as electricity generators, industrial (SMEs or LEs) and household consumers but often there is not profitability in these kind of business models. The added value to have aggregators is that they can build a flexible portfolio as part of its business model which can be utilised by the electricity market players, thereby also representing a value.

However, the introduction of an aggregator as a market player can generate a set of complexities that concerns the difficulties to distinguish implicit flexibility (i.e., when costumer reacts to the hourly price and is rewarded with an overall lower electricity bill) and explicit flexibility (i.e., when customer is rewarded by adapting its consumption to the products in the electricity market), to measure the flexible consumption and to exchange information with the players with which aggregators make an agreement.
Examples of potential business model for the aggregators are related to the agreements among balance responsible party (e.g., DSO), electricity suppliers (e.g., prosumers) and end-user (consumers)[x] (Figure 6):

- The first business model is when an existing electricity supplier/balance responsible party takes the role of aggregator and where both implicit and explicit flexibility are handled by the same player, which settles this with the customer on a combined basis;
- A second model is when the implicit and explicit flexibility are handled by the same player, which settles this with the customer on a combined basis. Frequency stabilisation contains such small amounts of energy that the imbalance is negligible. As a result, the aggregator is able to activate and sell the customer's flexibility without exposing the balance responsible party to considerable imbalance costs;
- The third business model is when the aggregator works with one balance responsible party without being responsible for the actual electricity supply which is handled by the customer's existing electricity supplier and its balance responsible party. This means that electricity metering and settlement of the customer account remain unchanged, resulting in no additional costs in this respect. Through its own balance responsible party, the aggregator is able to deliver flexibility to all electricity markets, without this giving rise to any accountability on the part of the customer's original electricity supplier/balance responsible party. Balance responsibility is thus transferred to the aggregator's own balance responsible party during the activation period. In other words, imbalance costs are carried directly by the aggregator and its balance responsible party;
- Finally, the fourth business model is when the customer demands a single service such as a heat service (heat pump) or transport service (electric vehicle). Electricity supply and flexibility management are integrated into the single service received by the customer from the aggregator. The aggregator can activate flexibility in all electricity markets, and the aggregator is also responsible for the supply of electricity to the end-user. In the model, the aggregator works with its own electricity supplier/balance responsible party across its entire portfolio of customers and flexible units. The customer's total consumption is divided into classic (existing) and flexible electricity consumption through the establishment of a serial metering point. This allows the customer's classic and flexible consumption to be settled separately. As a result, the model particularly favours the aggregator's role as a service supplier that can combine electricity and flexibility into a single service to the customer. Imbalances resulting from the aggregator's activation of flexibility are handled as part of the current balance settlement.

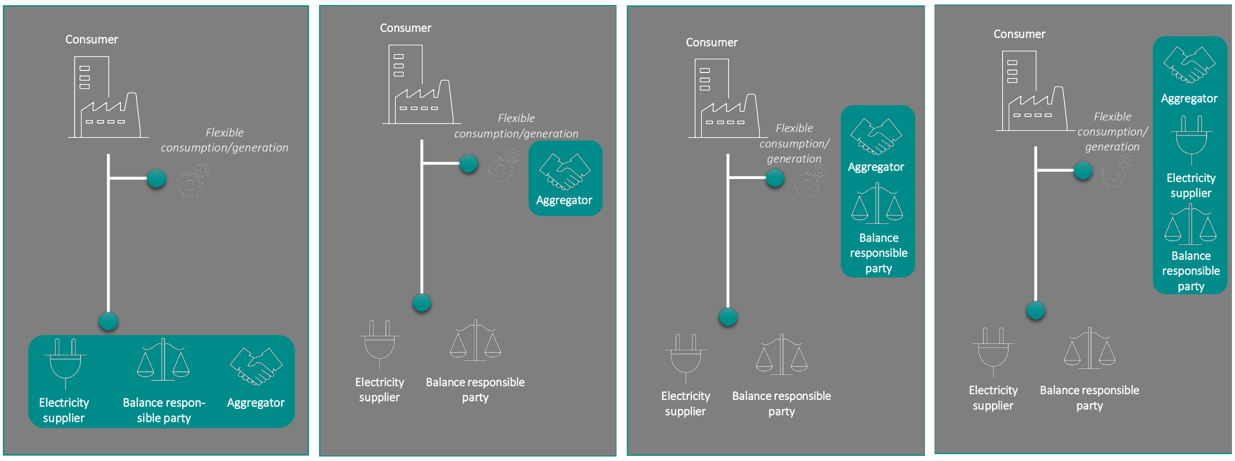


Figure 6 – Business models for aggregators[x]

2.3.3 Prosumers and storage owners

The electricity supply must be equal to the electricity demand at all times, otherwise the system risks breaking down. Non-flexible generators are used for serving the base load (the normal level of electricity use), while flexible generators are used for meeting peaks in demand. The increased share of variable capacity, such as wind and solar, means that more flexible generation capacity is needed to satisfy demand when production from variable generators is low. To ensure security of electricity supply, enough generation capacity must be available to meet demand at all times. Balancing supply and demand in the short term is done with the use of primary reserves (activated within seconds), secondary reserves (activated within a few minutes) and tertiary reserves (activated within 15 minutes)[xi].

Private house owners are investing in PV system to be self-sufficient to a certain point and/or as a feasible investment in their houses. When both consumption and production are present, they are called prosumers. A minor but increasing part of these house owners is beginning to install batteries in connection to the local PV production to increase their self-sufficiency and be more resilient. The ESS are autonomous and should optimize the business opportunity for the house owner. Investment in batteries at prosumer level becomes more attractive when the incentives in injecting PV energy in the grid decrease or disappear, then maximisation of self-consumption is more effective.

The future prosumer with battery have the possibility to offer also services to the DSO, such as ancillary services, whereby the prosumer gets more income out of their investment in the PV and storage system and increase their private business case further, while the DSO may avoid (or defer) grid strengthening due to the PV-system or increased local consumption.

Prosumers are the actors that generate energy from RES (e.g., solar, wind, etc.) and, they could have also ESS to store energy for self-consumption and/or for cooperative use, in other terms, they store the surplus for future use or send it to the grid for sharing and redistributing excess energy to other users in the grid.

Prosumers use smart meters (SM) during energy production and integrate these devices with household energy management systems, ESS and EV (or also vehicle to grid (V2G)) systems that, in turns, they have to be efficiently integrated into the smart grid.

Prosumers improve efficiency in the energy system through various means. They can enhance the household activities through smart devices and communication technologies, they can offer storage capacity to help manage power fluctuations, and they can support the balance of local demand and supply. Different factors affect this evolution such as new technologies (e.g., SM and advanced metering infrastructure (AMI), energy displays, and smart appliances), implementation of cost-efficient energy saving measures and government incentive schemes to encourage participation in the energy system[xii].

The number of prosumers is growing since many years and the expectation for the future is to have an exponential growth. Increased self-consumption also means that less electricity is consumed from the grid,

resulting in decreased revenues for grid operators, which makes it difficult for them to finance investments. As a consequence, consumers who do not generate their own electricity may face higher network charges.
The way to integrate an increasing share of RES and prosumers into the electricity markets, but also to improve the demand response and ESS, requires a combination of liquid short-term markets and long-term price signals, time-varying prices that reflect the scarcity or surplus of supply and provide incentives for storage and demand response, complemented by instruments aimed at mitigating revenue risk over 20-30 years, such as a market for long-term contracts and a regulatory framework for prosumers. This system highlights the role of DSOs.
The new energy-market design should provide technical and market conditions for ES. RES should be integrated into the market and should participate in balancing services, while support for mature renewables should be phased out[xi].
Cooperative prosumers are a way to sell energy to the market. It is shown that a 'group' of prosumers (i.e., cooperative prosumers) collectively selling energy to the grid is more efficient and reliable in providing sustainable energy supply compared to a prosumer acting as an individual entity, since individual prosumer's energy supply is unpredictable due to dependency on climatic conditions. Optimal prosumer communities offer a range of socio-economic benefits namely enhancing prosumers bargaining power, achieving higher sustainability, facilitating efficient energy transfer, reducing energy transfer cost, reducing energy loss, and promoting active involvement of the energy user into the supply chain. One research study proposed an algorithm that outputs coalitions of prosumers designed for aggregators who seek to maximize their offer of energy production while minimizing the risk of financial penalty if production falls below contracted amount[xii]. Generated coalitions provide more energy to the grid with lower variability, hence use less storage and waste less energy compared to unstable coalitions. The formed coalitions are also more resilient to random prosumer failures. Other solutions for improving efficiency of the system is the different forms such as peer-to-peer (P2P), virtual power plants (VPP), and microgrid.
The prosumer market can be characterized by consumers providing services to the grid and transforming into active prosumers. The grid enables consumers to engage and integrate with other entities in the energy value network using market-based energy prosumption strategies. Prosumers could potentially integrate into the energy markets through three engagement models:

- **P2P model**: a decentralized, autonomous, and flexible P2P network where prosumers interconnect directly with each other;
- **Prosumer-to-grid model**: prosumers providing services to either an independent microgrid or a microgrid connected to the main grid;
- **Organized prosumer group model**: composed of multiple groups of prosumers. The groups work together and pool resources for community benefit or can become large enough to form a prosumer VPP.

VPP and P2P platform can be combined to attain the advantages of each model. Also, two possible approaches for prosumers management can be:

- Individual integration method;
- Simple-group integration forming a VPP or microgrid.

Collective motivation can play an important role in a cooperative energy system. Prosumers that show the same energy sharing patterns can virtually connect each other to form a community and achieve a common goal such as providing a fixed amount of energy every week. Based on this approach, having similar behaviours and interests lead to stronger ties and reduced disagreements among members. Furthermore, sharing a common goal motivates the members to fulfil this goal and guarantees the quantity of energy supply to the grid, which consequently reinforces their bargaining power and enables long-term sustainability. Understanding their energy behaviour profiles, activities, and processes is critical (i.e., examining prosumer behaviour profiles is crucial during energy system planning). The prosumer profile is the set of characteristics of the user that may influence their energy demand.
The main characteristics in order to have a good management system can be identified in the following points:

- **Organization**: prosumer organization requires a comprehensive analysis of prosumers' behaviours and preferences and their behaviour profiles help in selecting the appropriate prosumers to participate in the energy sharing program;

- **Motivation**: prosumer motivation aims to positively influence the prosumers' attitude to enable consistent energy sharing behaviour within the smart grid and it encourages active prosumers to improve their contribution attracting also passive prosumers (i.e., prosumers who do not share energy) to participate in the energy sharing. Motivation can be triggered using economic incentives or penalties;
- **Overall control of prosumers** consists of five aspects:
    - Communication/negotiation to build trust and develop mutual understanding among the prosumers;
    - Standard/ethics definition to ensure compliance when joining the energy sharing process;
    - Prosumer assessment to identify influential prosumers and members who do not meet expectations;
    - Incentive/penalty distribution to motivate positive contribution from prosumers;
    - Risk assessment to identify negative prosumer behaviours, evaluate vulnerability and prevent long term negative effects to the energy sharing process.

The impact of smart grid and prosumers can be shown on the social (i.e., in terms of social interactions and mutual energy exchange or sharing), economic (i.e., the investment costs, maintenance costs, life cycle cost of energy (LCOE), savings from self-consumption, load profile and revenues from selling energy, incentives, payback period, etc.) and technological aspects.
An example of the technical and economic feasibility of both Household Energy Storage and Community Energy Storage technologies is investigated using real data of 39 households in a pilot project in the Netherlands[xii]. Results reveal that PV self-consumption significantly contributes to savings achieved by storage and influences the payback period, reducing costs by 22–30% while increases PV self-consumption by 23–29%.

2.3.4 Investors

In the future, new actors in this field may be discovered, for instance commercial partners who want to invest in the green transition and secure their investment. A future concept could be storage-as-a-service (SaaS), where the investor places storage at local houses or e.g. in communities/industry sector.

2.4 Criticalities of RES and contractual agreements

As mentioned before, in the context of an increasing trend of RES, by considering also the EV sector will become even more competitive, the issue of lack of management and lack of flexible generation will occur in the future. For this reason, DSO and TSO have the issue of guarantee the supply and the quality of the service, in other terms, the certainty of the energy provision.
Some indicators for the lack of flexible generation have been elaborated in the literature as the need of electricity flexibility beyond which the risk to not satisfy the demand is high and the RES curtailment risk (RCR) that measures the likelihood the curtailment occurs in some seasons as in Spring (Figure 7). The curtailment PV installed capacity has grown at an average rate of 49% for the last decade. Reduction of FiT and PV deployment can introduce more additional economic risk in the future and ESS integration of the renewable energy is becoming an interesting option for the future. The possible contribution to total curtailment in renewable energy source can be divided into involuntary and voluntary curtailment and storage can help to avoid curtailment[xiii] (Figure 8).

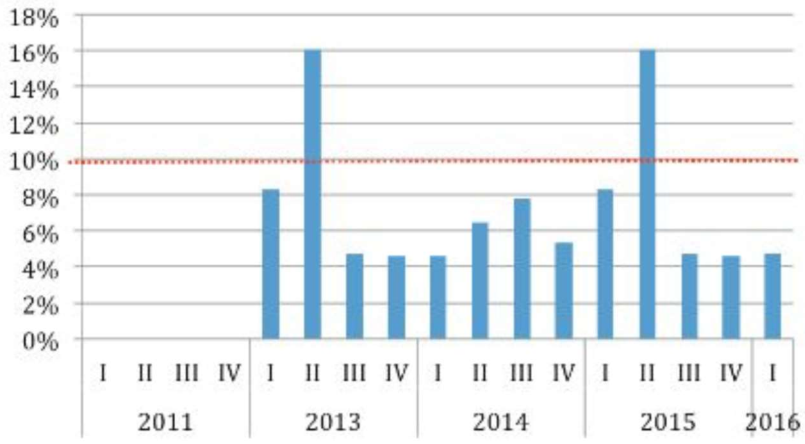


Figure 7 – Index of the risk of curtailment of the production from not programmable renewable sources

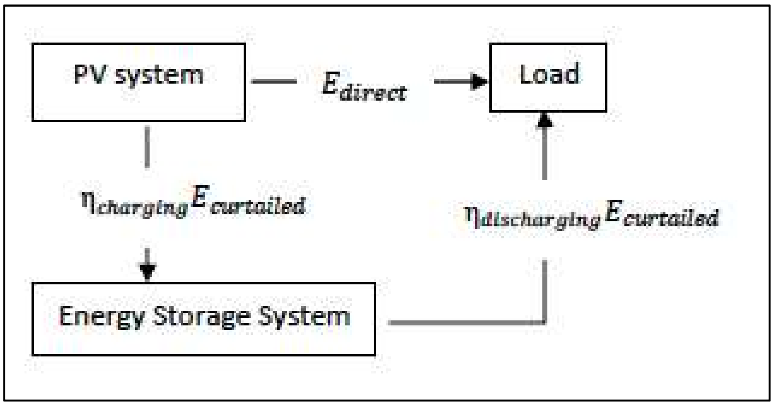


Figure 8 – Energy Flow Diagram PV system integrated with ESS[xiii]

Usually there is required maintenance work for improving the infrastructures that are not bidirectional since they were built to guarantee only one direction (from energy plant to the customer) and this requires high investment for the DSO. Furthermore, the household PV usually are connected to low voltage (LV) distribution network. Investment decisions should be guaranteed by an adequate ROI and it is due also to the regulation that guarantee a shorter payback period (PBP). The regulation should be, indeed, foreseeable and stable in order to guarantee clear expected returns, the coordination of the resources access between TSO and DSO, the DSO should receive data and information needed to monitor the efficiency of the network, also with respect to the privacy, in order to avoid asymmetric information[ix].

The regulatory reforms are needed to monitor and manage the optimal mix of electricity generation, since the market alone can bring to failure without a centralised approach and guarantee an appropriate margin of reserve. This logic should be implemented also for the developing of the right level of RES in order to reduce the risk of congestion and over production. Some typologies of policies can be developed are the FiT for stimulating the creation of pants (price-driven), quality-driven policies for sellers, decentralised coordinated public auctions for long run plants[ix]. The usage of ESS can affect the overall electric system characterised by RES that cannot be planned (e.g., PV, wind, etc.). A clear regulation should guide investors towards optimal choices in terms of efficiency in the long term.

Concerning to the modalities of selling energy in the grid, today the main typologies of contracts are the following[xiv]:

- Bilateral contracts, for producers of electrical energy finalised to selling;

- Direct energy exchange market, for producers of electrical energy finalised to selling;
- '*Ritiro dedicato*' (in Italy), for consumers and prosumers that would benefit from the energy produced and not consumed (this is the selling of energy to the electric distribution network management that will pay for it an established price per collected kWh as an intermediate (the price will be based on the average hourly price and there also are minimum guaranteed prices). The energy will be paid at the hourly average national price (the monthly average price). This can be paid with an encompassing tariff (*tariffa onnicomprensiva*). There is also a remuneration for the first 2 Million of kWh put in the grid with minimum prices;
- Net metering (e.g., '*scambio sul posto*' in Italy), for consumers and prosumers that would benefit from the energy produced and not consumed. Respect to the *ritiro dedicato*, the producer can deliver the energy that he/she does not self-consume and she/he can collect this quantity in a future moment gaining a compensation for the difference between energy produced and delivered in the gird and the economic value of the energy collected and consumed in a different moment of time;
- Purchasing power agreement (PPA) between electricity consumers and PV system operators (Figure 9).

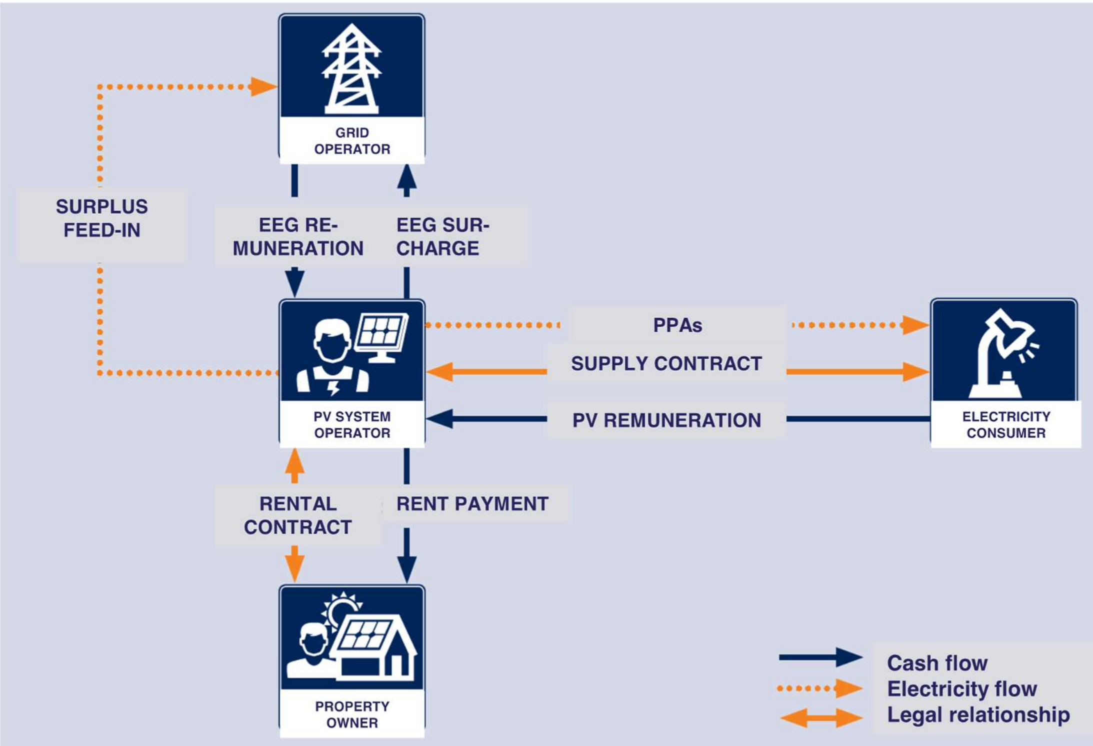


Figure 9 – Stakeholder structure for PPAs to individual customers[xiv]

2.5 The EV and charging station market

The market of EV is increasing a lot in European countries and this can be a driver to consider different models of management for the ESS and for grid preservation and stability.

EVs have been seen as the future of transportation since electric mobility has become an essential part of the energy transition, and will imply significant changes for vehicle manufacturers, governments, companies and individuals. Some governments announced that there will be no more new petrol or diesel cars for sale after the year 2040. Therefore, in near future, EV will become a commonplace thanks to certain financial advantages, including government grants. In June 2017, around 28,000 new electric cars were registered in Europe with a 54% growth compared to 2016[xv].

The most often considered issue related to the economy of EVs is the fuel savings. In Italy, EVs charged in the tariff can cover 100 km for about EUR 8.7 (indeed, the price of energy is EUR 0.2080 /kWh and for a typical car

with 40 kWh of battery capacity), which is the amount close to the price of a litre of fuel (currently (2019), the fuel price is around EUR 1.744 per litre, and supposing a car makes 16-20 km with 1 litre, it will cost from EUR 8 to 10 to make 100 km). Sceptics point out that EVs are much more expensive to buy. For example, an electric Smart Fortwo costs about EUR 22,600. The price of electricity is not the only factor generating savings; indeed, EVs are definitely easier to build due to less moving parts.
The current major battery technology used in EVs is lithium-ion (Li-ion) batteries because of its mature technology. Due to the potential of obtaining higher specific energy and energy density, the adoption of Li-ion batteries is growing fast in EVs, particularly in plug-in hybrid EV (PHEV) and battery EV (BEV)[xv].
In north Europe, the market of EVs has been characterised by a relevant growth in the last years. In Finland, electromobility is at an early stage of development, but it is dynamic development. In 2016 there were 1,500 electric cars in the whole country (compared to 2015, this is a jump of 117.5%). The Finnish Ministry of Transport prioritizes the development of electric buses. A model example of the development of electromobility in the Nordic countries is Norway. Over 120,000 PHEVs are already on the Norwegian roads. The Norwegian rise of electromobility was caused by huge number of subsidies but also access to cheap energy[xvi]. A substantial charging infrastructure may be a prerequisite for a continued growth of EVs. A recent survey showed that EV owners would like to use their cars for longer trips, but that the charging network is not yet viewed as sufficient. It is needed a launch of a national or local strategic and financial plan for developing charging infrastructure[xvii].
EVs are changing the face of the global automotive sector. The global stock of electric cars rose to over 3 million in 2017, up from 14,260 in 2010 (Figure 10). The International Energy Agency (IEA) has estimated that the number of electric passenger cars and light commercial vehicles could reach 125 million by 2030, on the basis of existing and announced policies, and there is potential to reach 228 million if governments increase their ambitions in line with international climate change goals. The sales of EVs show the China at the first place with France and Norway as the first EU countries in terms of market share[xviii] (Figure 11).

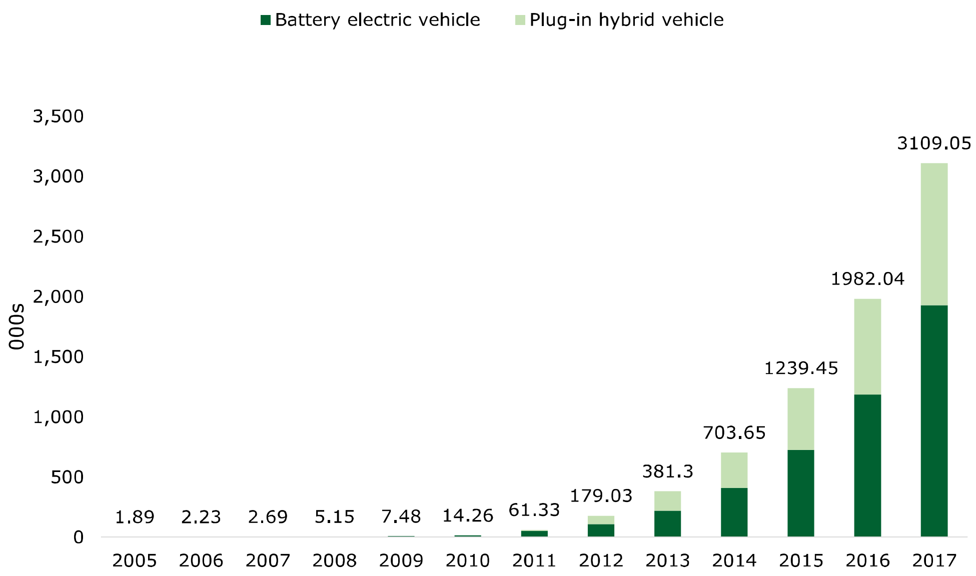


Figure 10 – Global EV stock by year and engine type[xviii]

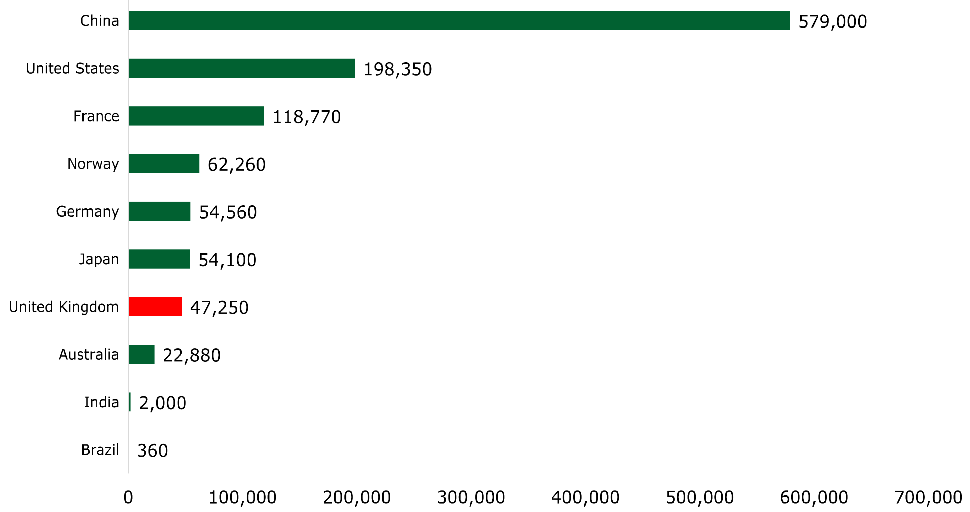


Figure 11 – Sales of EVs (battery EVs and plug-in hybrid EVs by country in 2017)[xviii]

The adoption of EVs have significant impacts on the electricity markets. First of all, moving from fossil fuels to electricity will increase electricity demand. If many users charge their EVs at the same time, more peaks in demand can be expected. On the other hand, 'smart' EV infrastructures can be seen as storage systems and EVs may provide storage services to the electricity grid by charging up when electricity is abundant and feeding electricity back into the grid when it is scarce and expensive[xi].

In combination with smart grids, EVs provide potential for the so-called 'valley filling', which refers to energy consumption during off-peak hours. Furthermore, if EVs are connected to the grid and do not require immediate charging, the energy stored in the batteries can be used during peak hours. Therefore, EVs provide a potential storage for variable renewable energy production and can potentially lower grid management costs through decreasing the investments required for handling peak capacity.

DSO can provide EV charging infrastructure (i.e., charging points) and sells electricity through the charging points. From the DSOs perspective, EV service providers (i.e., charging stations) are similar to other retailers and power consumers. However, EV service providers have different consumption patterns requiring tailored algorithms. As a consequence, the role for DSOs is to encourage beneficial recharging patterns. Without smart grids, this can be done through varying tariffs, based on patterns in electricity demand. With smart grids, dynamic pricing can be used to further match supply and demand. Communications between DSOs and EV service providers regarding the pricing, which should enable consumers to adjust their behaviour, should also be taken up by DSOs[xix].

The DSO can be in charge of installing and operating the publicly accessible charging points or DSOs can only technically operate the charging stations and leave the commercial provision of services fully to e-mobility service providers thus establishing a multi-vendor platform[xx]. The DSO disposes of an ICT back-end system to link the customer to an e-mobility service provider. Several are the market models for a rollout of EV charging infrastructure where the role of the DSO varies between an ownership role, a leading role or a facilitating role[xxi].

An important factor for the business potential of the EV are consumer preferences, for which a public charging network is crucial. However, it depends if exploitation of public charging stations is currently commercially feasible or not[xxii].

A business opportunity for DSO is to utilize electricity storage capacity of EV. Batteries of EV can be used for balancing of the grid. This is a specific example of potential for congestion management. Through peak-charging, EVs can also negatively affect demand volatility, posing an additional opportunity to efficiently handle the development of EVs charging infrastructure[xix].

Expanding the use of EVs requires a sufficient availability of charging points for EVs to become attractive. A distinction can be made between two types of charging[xxiii]:

- **Recharging points that are accessible to the public:** this first category is defined as recharging points that offer non-discriminatory access to users. Those can be located either in public or private areas;
- **Recharging points that are not accessible to the public:** the second category concerns recharging points with restricted access to the public, one might think of recharging points in private areas with private access.

Charging infrastructure also differs in the charging velocity, either normal or fast charging, and whether charging is performed in either an uncontrolled (dumb) manner or in a controlled (smart) way. The latter has implications for the degree of flexibility which EV may be able to provide. In case of uncontrolled, dumb charging, opportunities for flexibility such as storage or discharging cannot (easily) be deployed, while in case of smart charging flexibility can be harnessed.

A potential further business model concerning to EV distribution that affect the electricity grid management is given by the V2G mechanism that indicates the charging system for EVs and is able to transform all plug-in vehicles into on-demand batteries for the grid. This system permits to store energy when the costs are lower and sell during the peaks or sell the surplus during the black out. To do this, the charging EV stations (also called electric vehicles supply equipment (EVSE)) should be equipped with these technologies. The technological rationale is to provide services for balancing the grid during the pick and the economic rationale permits the prosumer to charge battery when the price is lower and sell energy to the grid when there are advantageous conditions. In Italy, regulation is trying to favour this opportunity and there is already a pilot to test (in Genova) for this kind of solution with bidirectional charging stations with companies as Enel, Nissan and IIT. This solution has been already tested in other countries as in Denmark where they launched the first V2G commercial hub. Also, in UK there has been a test at Cranfield and Newcastle of the first 10 V2G charging stations and with around 100 EVs with bidirectional battery[xxiv].

In UK, the potential impacts of EVs on the electricity grid have received considerable attention in media and policy circles, with a particular focus on the increase in generation capacity that will be needed to meet demand from EVs. For example, the Times and the Daily Mail reported last year that the UK would need 20 new nuclear power stations, whilst a Financial Times article claimed that the UK's generation capacity would need to increase by 70%. A sufficient new generation capacity, as well as necessary grid reinforcements and demand management technologies, can be brought online, on time to meet the increase in demand. In UK, EV could increase peak demand by 18 GW by 2050 in the worst case scenario but more realistically, the increase in peak demand from EVs is likely to be in the region of 8 to 11 GW, with the lower range being achievable if smart charging technologies, V2G technology and incentives to charge vehicles at off-peak times are used to shift and lower electricity demand.

Rather than increases to peak demand, the most problematic impacts of EVs on the electricity grid are likely to be experienced on distribution networks, where the majority of charge points are expected to be connected. If clusters of EV charge points emerge without sufficient planning and mitigation measures, then charging could overload local, low voltage networks, leading to power outages or 'brown-outs'. analysis by the Green Alliance has found that "as few as 6–8 cars charging in a small cluster, at peak time through dumb chargers, could result in significant disruptions to the local electricity distribution system. Rural networks may be particularly at risk, since they typically have lower resilience (being connected to fewer neighbouring networks). Mitigation of these impacts is expected to be achieved through a combination of physical grid reinforcements and 'smart charging' (which allows charging loads to be adjusted throughout the day), with innovative 'vehicle-to-grid' technologies potentially playing a role in the future. Recently, the UK government's invested £30 million in V2G R&D to explore the potential of this technology.

Local authorities are pivotal to the development of EV charging infrastructure: they have been the promoters and coordinators of exemplar EV cities and regions using competitively awarded central Government funds such as the Go Ultra Low Cities, Ultra Low Emission Taxis and Low Emission Buses schemes; they are responsible for setting local planning policy requirements, which can include provision for charge points in new developments and car parks; and most recently they have been targeted by central Government to deliver on-street charge points, albeit with financial support[xxv].

In a more innovative way, EV fleets could be managed to provide decentralized storage of electricity, benefiting management of the electric system and offering another revenue stream to EV drivers.
Finally, potential economic advantages arise also from charging EV at home. Usually, EVs have batteries around 16 and 24 kWh with 110-160 km autonomy with a full charge. The cost of kWh is around EUR 0.25. The PV owner will have more benefits if it has a PV at home[xxvi].

2.6 The ESS market and the batteries market

As mentioned before, growing demand for EVs, hybrid EVs, and PHEVs are creating a tremendous growth opportunity for the battery industry. Rise in need for security of energy supply, technological development, increasing disposable income of customers, development of a new application for batteries and decreasing prices of raw materials for manufacturing latest battery products further aided the battery industry.
Moreover, to meet the power demand during peak periods, utilities are expected to continue implementing ES solutions, of which, most of the energy is generated from renewable energy sources, during off-peak periods. Evolving business models and involvement of utilities in the ES space are expected to further enhance the adoption of ESSs in the future. Also, the growing need for increased self-consumption of PV electricity on a household level leads to increased demand for household storage systems.
The market of ESS had a high growth in the past years even if in 2016 and 2017 the increasing trends was more relevant. The cause of this lower growth could be identified in the fact that few incentives exist and the number of markets where ES could be competitive remains small. Today, only Germany had high incentives for battery storage in PV systems, while some cantons in Switzerland have subsidy schemes. In Germany, for instance, a regulation provides parameters for connection of inverter with and without storage and defines the requirements for introducing power in the grid.
The trend of PV installation in Germany, that is the leader for the per capita installed solar power capacity generating around 41 MW of capacity (representing the 6.4% of gross electricity consumption), is also associated to the increasing of ESS combined with PV installation. Indeed, around 40% of new PV systems are combined with batteries with around 20,000 new battery storage systems in 2017 (Figure 12)[xiv]. However, more systems have been also installed without incentives. In August 2018, the 100,000 installations threshold was reached.

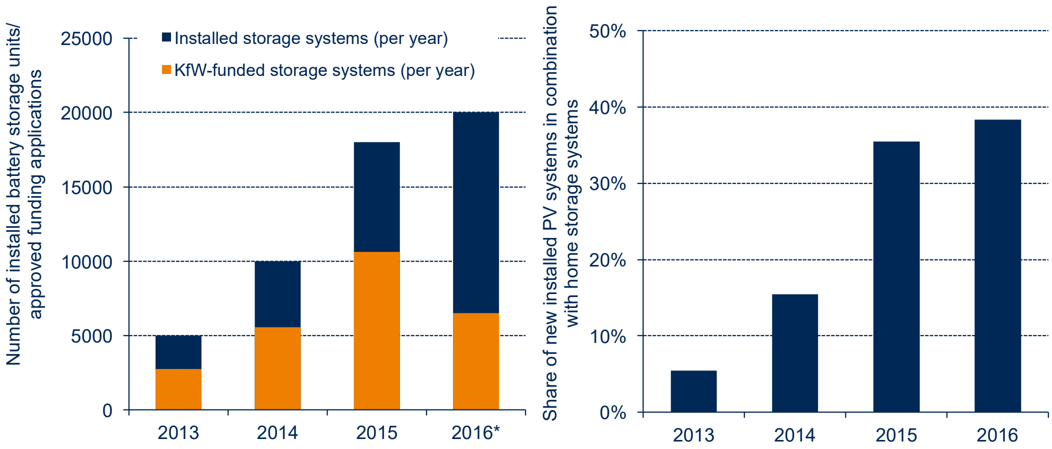


Figure 12 – Installed storage systems per year in Germany[xiv]

The trend for storage market in the future scenarios in Germany seems to go in this direction because of many reasons as increasing attractiveness of self-consumption, new business models for tenant solar, falling prices of solar batteries, trend towards E-mobility, openness the market to new actors such as real estate companies and municipalities (Figure 13).

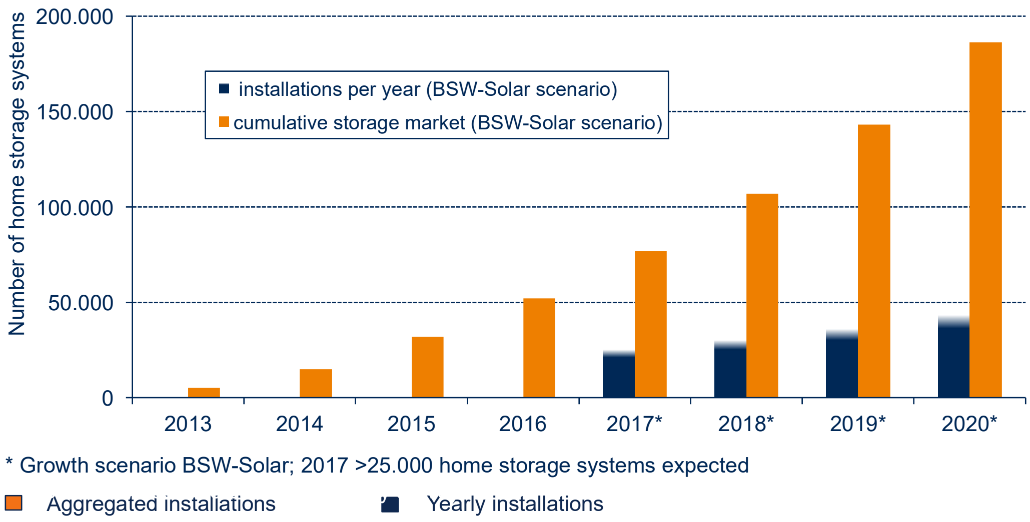


Figure 13 – Cumulative installation of storage per year[xiv]

Concerning to the incentives, in Italy for instance the Authority of electricity and gas (EEL) published a regulation about the access to the incentives for already installed plants or new plants with a storage system. There were extended incentives for storage and PV. In particular: who owns a PV plant and benefits from incentives of the feed-in-tariff can install an ESS with a fiscal deduction of 50% (i.e., Ecobonus) and who does not own a PV and would install a PV with ESS can also benefit from a fiscal deduction of 50%, even if not of the feed-in-tariff. The Authority is not able to monitor the right measure of power production. For this reason, it requires to communicate the installation and activation of a bidirectional meter device for power generation and storage and it is mandatory to communicate to the Authority about the installation of the storage system by 30 days from the grid integration. However, it is still uncertain how to regulate the ESS connection with the grid network and the inverter[xxvii].

Concerning to battery market, before the evolution of Li-ion battery, lead acid batteries were the dominant form of rechargeable batteries regarding growth rate, whereas the lead-acid batteries market share are still dominant. Lead-acid battery is expected to be the market with majority share in 2023 in volume, but Li-ion market is likely to be higher than Lead-acid from 2020. Li-ion battery market is driven by Automotive & Industrial applications. The market for Li-ion batteries has registered a Compound Annual Growth Rate (CAGR) of 25% during the period of 2000-2016. At present, lead acid batteries occupy the clear majority of the automobile market[xxviii].

Asia-Pacific is expected to be the fastest growing region during the forecast period, followed by North America and Europe. Growing demand for electric, hybrid electric, and PHEVs are creating an excellent opportunity for the battery industry. About 140 million EVs are expected to be on roads by 2030. Japan is another country where battery industry is proliferating. Japan has ambitious targets to produce half of the world's batteries by 2020. Japan also has a subsidy program for 66% of the cost for homes and business that install Li-ion batteries. In 2015, EV registrations witnessed a 70% increase from the previous year with 550,000 vehicles sold across the globe[xxviii].

Several are the sources that highlight the growth of battery market:

- The size of the global Li-ion battery market will exceed $60 billion by 2024, according to a study by Global Market Insight[xxix];
- Global Li-ion battery market was valued at $30,186.8 million in 2017, and is projected to reach $100,433.7 million by 2025, growing at a CAGR of 17.1% from 2018 to 2025[xxx];
- The overall Li-ion battery market is expected to grow from USD 37.4 billion in 2018 to USD 92.2 billion by 2024, at a CAGR of 16.2%[xxxi];

- According to data provided by Technavio, the global Li-ion battery market is expected to reach USD 81.65 billion by 2021 and growing at a CAGR of over 11%[xxxii].

Since many years, most of the producers of plants and equipment for RES, as Bosch, Tesla, Panasonic, Fiamm and SMA started a competition for decreasing price of selling and improving the technological development. In this scenario, the prices for ESS seems to follow a decreasing trend mainly in the production of ESS for the self-consumption[xxxiii].

A relevant issue concerns the cost of battery for households and for DSOs. The installation of a PV with storage can cover up to around 80% of the daily needs. In Italy, the price of installation of a PV plant is around EUR 3,000 /kW (hence, the CapEx for a 3 kW plant is around EUR 9,000 and the OpEx is EUR 150/200 per year for a length of 15/20 years and by considering that, after 10 years, the inverter should be substituted with a new one with a cost of EUR 1,000)[xxxiv].

The storage systems are becoming more and more efficient and cheap. The storage for PV systems is still expensive due to the fact they are a new technology, and they can be amortized in several years. On the other side, ESS have low maintenance costs.

It is difficult to provide a homogenous estimation about the costs for all kind of batteries since there is a continuous change in prices and prices are related to the market and the demand, and there is increasing number of new models. Moreover, the price obviously depends on the size of the ESS and if storage is installed or not with PV system. In general, prices are from EUR 2,500 to 4,000 for lead-acid batteries, from EUR 4,000 to 6,000 for Li-ion batteries. And for other batteries like Nickel, prices range from EUR 3,000 to 5,000.

The extra expenditure for a storage system is around EUR 4,000 and this can be amortized in 20 years, but the issue is that today a battery has a lifetime of 10-12 years. Hence, it seems to be not still convenient to invest in storage systems now for small size plants. Incentives and future technological improvement of efficiency can play a crucial role in favouring the future positive trend of ESS.

The impact of PV and ESS installation costs is clear if it is considered, for instance, the cost of energy is EUR 0.25 per kWh and the price to sell energy is around EUR 0.14 per kWh, hence, a saving of 40%. Indeed, if is supposed that the investment for a 20-years PV plant of 3 kWp with storage of 5.5 kWh is around EUR 13,000 (including maintenance costs and the expected substitution of batteries and inverter at least two times), the savings in terms of electricity could be around EUR 17.

A recent study concerning to the savings of PV with a storage system has been realized analysing around 25,000 households and 5 million of PV with ESS. This research finds out that, in North Italy, savings were around EUR 500,000 million per year that corresponds to EUR 166.7 for PV systems without incentive, or EUR 146.8 for PV systems with incentive. While for Centre Italy saving is EUR 171 for a new PV plant and 150 for existing one. Finally, for South Italy, savings are around EUR 169 per new PV and EUR 155.1 per existing one.

Another factor that should be considered to evaluate the benefit of storage installation is the modification of the old PV system already installed in the house, hence, increasing the initial cost[xxxv].

Cost reduction of batteries is one of the keyways of increasing the competitiveness of battery storage against other technology options. Driven primarily by increased manufacturing in the EVs and consumer sectors, the manufacturing cost of Li-ion batteries has fallen dramatically over the last few years. Costs of $273/kWh are now being reported by some manufacturers, which represent a 73% price reduction since 2010. BNEF predicts that prices for Li-ion batteries may fall as low as $73/kWh in 2030, which could open up the market to other revenue streams[xxxvi].

Hereafter, a list of examples of research in cost trends are provided[xxxvii]:

- The costs of storage (expressed as $/kWh) in US are showed in Figure 14[xxxviii]

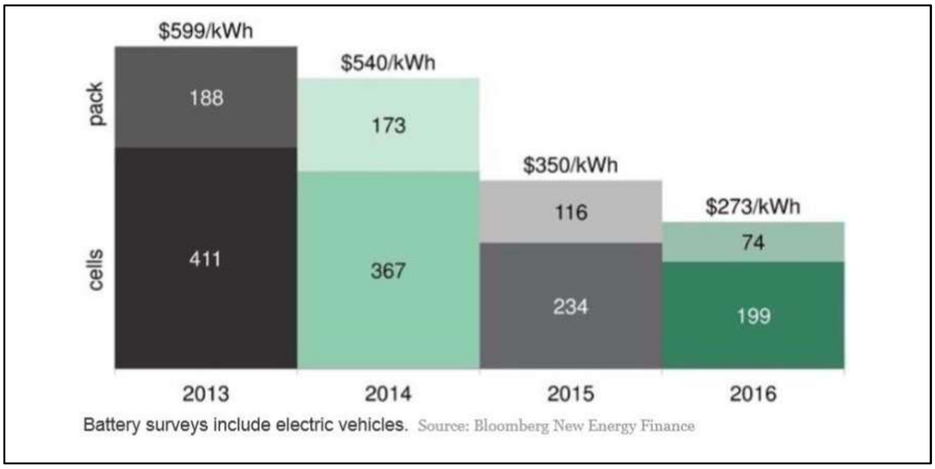


Figure 14 – Battery price trend in US[xxxviii]

- The forecasts of the expected battery cost development indicate that the battery costs are expected to decrease significantly towards 2030 (Figure 15, Figure 16, Figure 17, Figure 18 and Figure 19). Manufacturing costs are reducing due to innovation and economies of scale. The recent cost reduction is significant, with a drop of 70% from 2007 to 2014. Another reduction of 70% is forecasted towards 2030[xxxix]

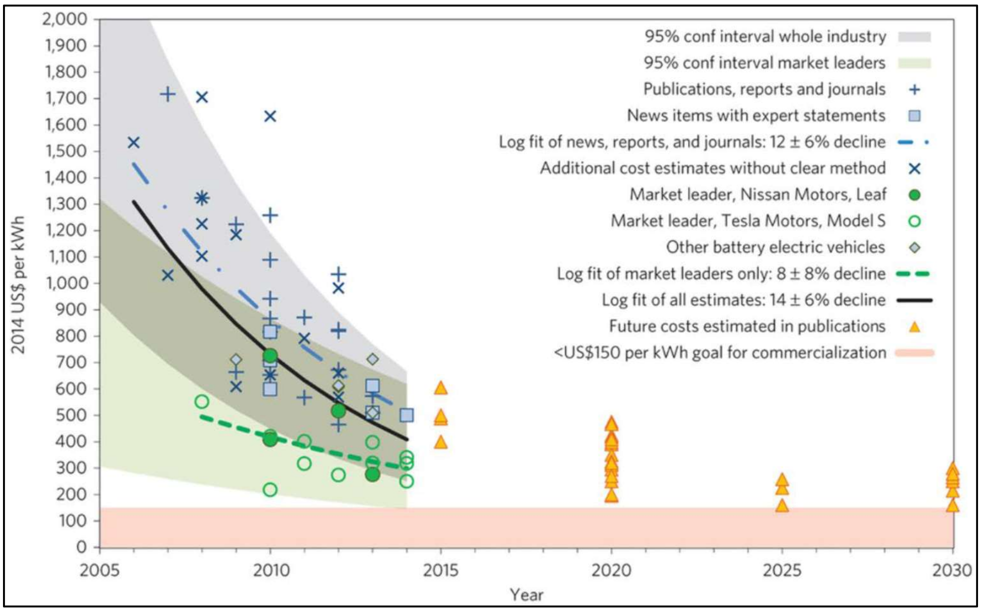


Figure 15 – Cost evolution of vehicle batteries[xxxix]

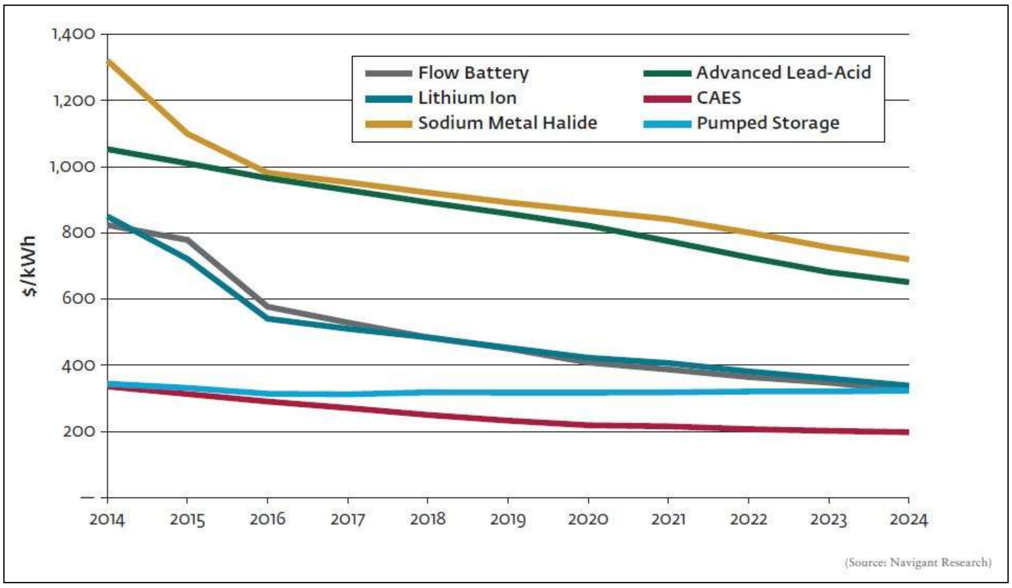


Figure 16 – Utility-scale ESS Cost Trends: global average 2014-2024[xl]

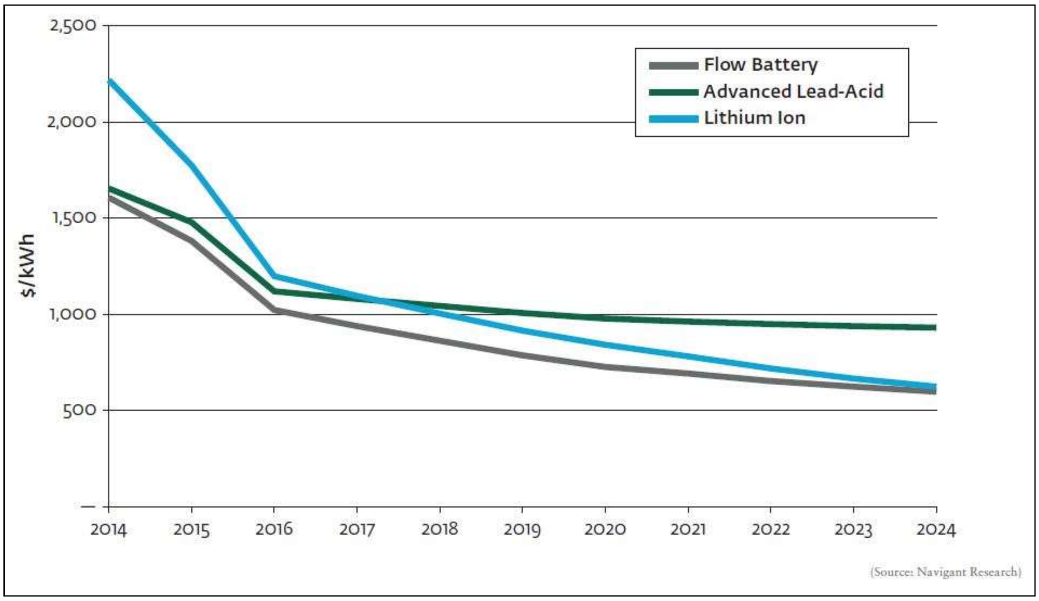


Figure 17 – BTM ESS Cost Trends by technology: global average 2014-2024[xl]

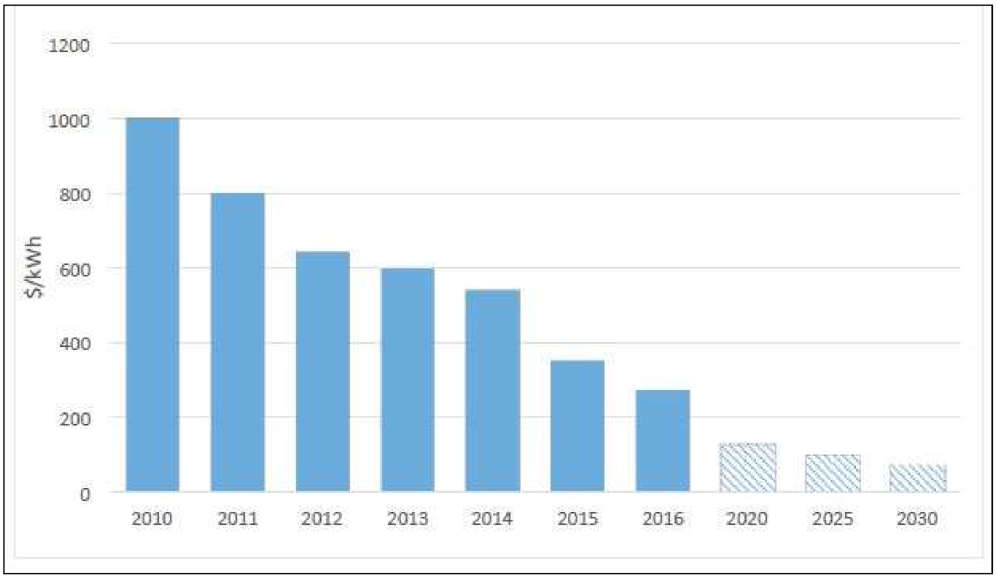


Figure 18 – Past and estimated Li-ion battery manufacturing cost[xli]

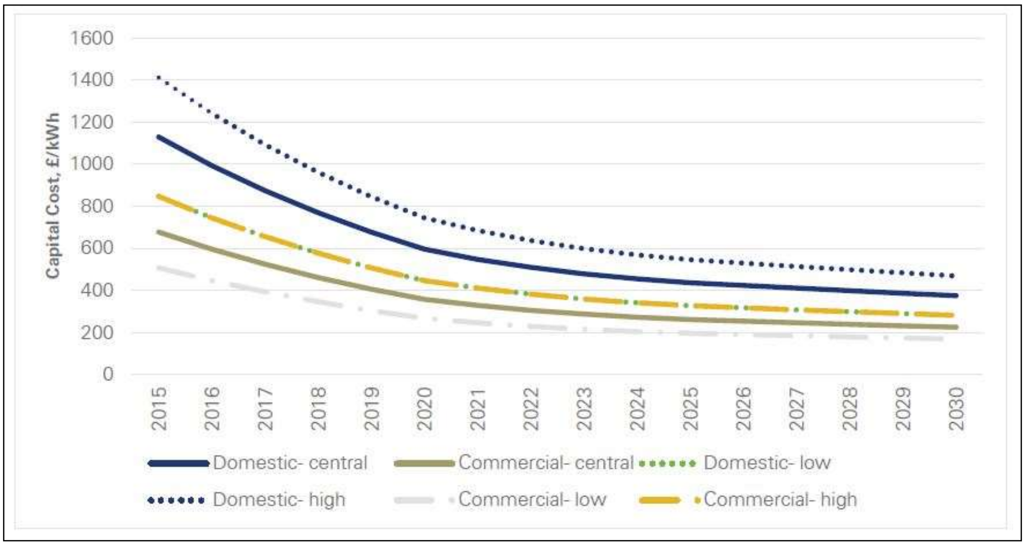


Figure 19 – Li-ion battery CapEx reduction profile[xlii]

- A declining in storage prices are tangible (Figure 20) where prices for Li-ion storage systems have fallen by more than 42% since 2013 in Germany[xiv].

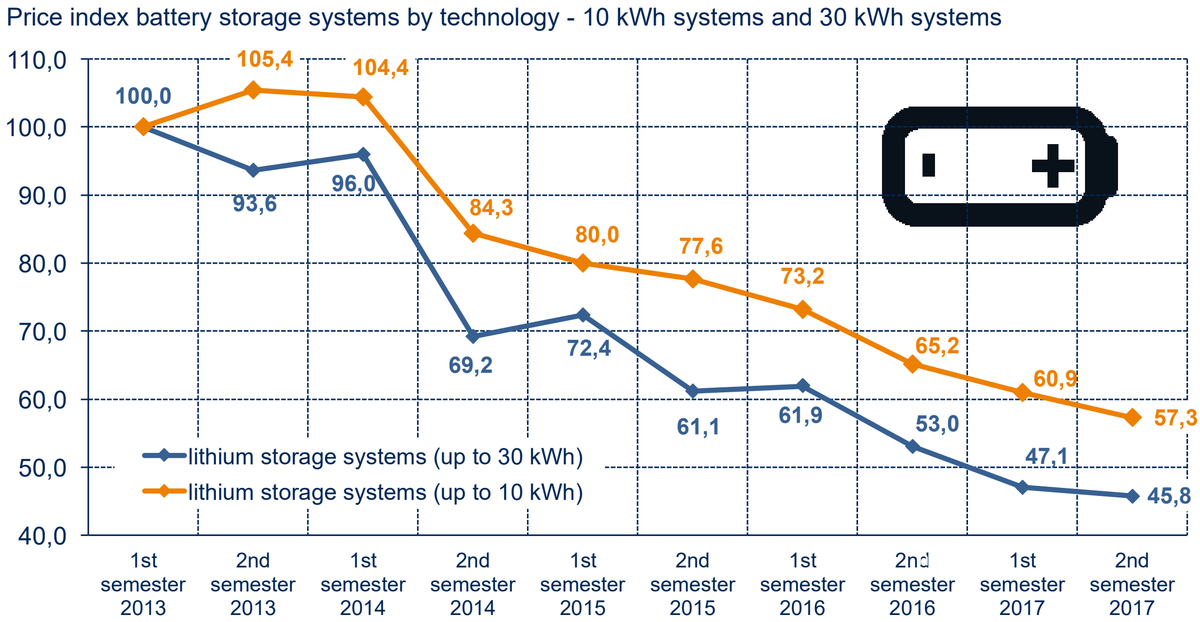


Figure 20 – Price index for battery storage[xiv]

The investment for battery storage requires high initial cost and a long run payback period (around 17 years), indeed, the upfront cost represents high barrier to entry. However, the expected decreasing prices for battery will grow the customers using battery storage solution with PV (Figure 21).

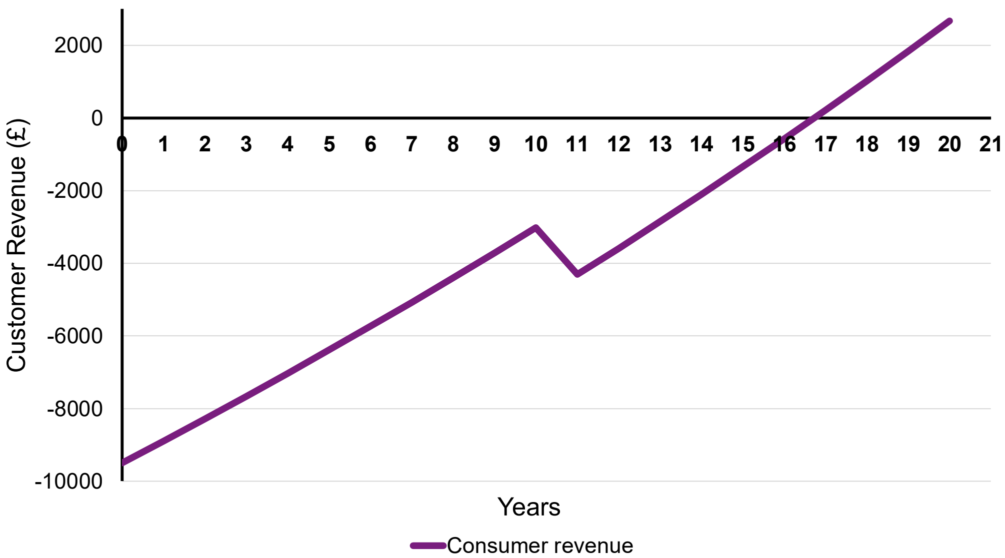


Figure 21 – Investment payback period for PV + storage[xliii]

2.7 Drivers and barriers for ESS

This chapter synthetizes the main drivers and barriers for the implementation of an ESS. A number of common profitability drivers and barriers to financing and deployment ESS across the EU. The common drivers can be described as follows:

- **Electricity prices**: High retail or wholesale prices are the main driver when building a business case for ESS with or without PV system. If the LCOE for ESS is lower than the retail or wholesale electricity price, then storage can be competitive. It is important to also have a reliable forecast of future prices over the 20 years of the project, in addition to data on current prices. A main driver for storage projects is how it can insure or hedge against future price increases. Storage systems can be sold as a way of reducing the risk of rising costs in the future.

- **Price for excess and storage electricity (fed into the grid)**: This is the amount paid, if at all, for electricity fed into the grid for a small or medium scale solar PV with storage. In some countries this is not remunerated at all and therefore has a price of zero. In other countries it is given a price similar to the wholesale price of electricity or higher. In Austria there is a settlement centre for renewable energy which has to by law purchase excess electricity at a pre-set (low) price. Other Austrian utilities can offer slightly higher prices for export electricity, as a way of enticing the power consumer to buy their residual electricity from them. In Spain if a solar array is self-owned, the consumer does not receive anything for the excess electricity injected into the grid.
- **Cost of capital**: This varies enormously across the EU depending on the country, application segment and financing scheme. It is broadly speaking a measure of the risk involved in the project – and often reflects the political risk of future changes in the regulatory framework. As said in the introduction, capital costs account for between a quarter and third of solar LCOEs. The cost of financing is an absolutely critical driver to whether or not a project is economic.
- **Self-consumption rate**: For self-consumption business models, the level and pattern of power demand of the power consumer and the extent to which that matches the pattern of power storage together with PV system is a key profitability driver.
- **Solar irradiation**: The solar irradiation, or level of sunlight, makes a significant difference to the output and therefore rate of return of a solar PV system, hence also for storage system with the opportunity to reduce the power loss.
- **Regulation.** The regulation is a crucial driver if we consider several aspects as the possibility to invest for DSO in a storage system that it is still not harmonized in Europe and to regulate the relationships among all the actors involved in the storage deployment and usage (prosumers, DSO, aggregators, storage suppliers, etc.).
- **System costs**: This is the cost of the storage modules and installation. The bigger the local market size and experience the greater the economies of scale that can be achieved on e.g. shipping costs which bring down the system costs of an installation.
- **Support schemes**: Incentives and subsidies. EU countries should have some form of a renewable support scheme in place (as for PV in the form of feed-in tariffs, feed-in premiums, quotas, tradeable green certificates, net metering, tax incentives or investment grants). However, as the cost of solar storage modules falls the level of these support schemes are generally being reduced.
- **Grid services revenues**: Storage can provide and be compensated for participating in the balancing market and ancillary services to the grid such as reactive power, frequency response and voltage control. Additionally, storage can help consumers to avoid peak and locational grid charges.
- **Green behaviour (environmental propension)**: This is a significant motivation especially in the domestic market, where investment decisions are not as "rational" as in the commercial market.
- **Risk of curtailment**: In markets where there are high levels of grid congestion and a lack of flexibility, the risk of a solar generating asset being curtailed and what kind of compensation the asset owner will receive if curtailment does take place can have a major impact on the bankability of a project. Storage can be an opportunity to avoid this and to stimulate consumers to invest in ESS as a system flexibility to allow for better integration of solar electricity.

The common barriers for ESS financing, can be described as follows:[xliv]:

- **Regulatory change and policy risk**: The regulatory change alters or abolishes the revenue stream of a project. The worst-case scenario in this case is retroactive regulatory change.
- **System and battery costs (for EU equipment).**
- **Standard requirements (for EU equipment).**
- **Taxes and charges:** Significant taxes and charges on self-consumed or exported solar electricity can act as a major barrier to investment. Taxing self-consumed electricity acts as a major barrier to the

transition to a more flexible, smarter and more decentralized energy system, and should therefore be avoided or kept to a minimum.

- **Grid charge**: Grid charges should be designed in such a way to be friendly to prosumer customers, as disproportionately high capacity-based grid charges can disincentivise self-consumption. Energy consumers should be incentivized to invest in technology that will increase system flexibility such as storage, aggregation, remotely controlled distributed assets and smart home energy management.
- **Quality risks**: Investors have to be very careful of low-quality modules that do not perform to standard. Poor quality products provide lower electricity output which leads to lower revenues.
- **Minimum investment limits**: Large-scale solar projects can often benefit from project finance. However, low cost of capital funding providers such as project finance banks, yield, pension funds and insurance funds have minimum investment limits which even larger solar projects cannot meet.

2.8 Overview of the RES context in some EU countries: Denmark, Italy and Germany

Europe has led PV development for almost a decade and represented more than 70% of the global cumulative PV market until 2012. Since 2013, European PV installations decreased while there has been rapid growth in the rest of the world. Europe accounted for only 7% of the global PV market with 6.1 GW in 2017. European countries had 110 GW of cumulative PV capacity by the end of 2017, the second largest capacity globally after having been on the top for years. It is important to distinguish the EU and its countries, which benefit from a common regulatory framework from part of the energy market, and other European countries which have their own energy regulations and are not part of the EU.

In addition to all measures existing in Member States, the EU has set up various legislative measures that aim at supporting the development of RES in Europe. The most well-known measure is the renewable energy directive that imposes all countries to achieve a given share of renewable energy in their mixes so as to reach an overall 20% share of renewable energy in the energy mix at the European level. Directive 2009/28/EC set mandatory targets for the Member States but let them decide about the way to achieve their binding 2020 targets, PV targets were set up in various ways. In October 2014, the European Council adopted an EU targets until 2030 for renewable energy development in the framework of its climate change policies. It set a new target of at least 27% of RES in the energy mix, together with energy savings targets and greenhouse emissions. however, different to the 2009 directive, no mandatory targets have been proposed for the individual Member States and it is unlikely that the new directive under preparation will do so, even if the target could be revised upwards, possible to 35% in 2018.

Besides the renewable energy directive, the so-called energy Performance of Building directive defines a regulatory framework for energy performance in buildings and paves the way for near zero and positive energy buildings. The grid development is not forgotten. dedicated funding schemes have been created to facilitate investments in specific interconnections, while several network codes (e.g. grid connection codes) are currently being prepared. This will have a clear impact on PV systems generators when finally approved and adopted[vii]. Currently, a global distribution of PV is depicted in Figure 22.

COUNTRY	2017 ANNUAL CAPACITY (MW)			2017 CUMULATIVE CAPACITY (MW)		
	GRID-CONNECTED		TOTAL	GRID-CONNECTED		TOTAL
	DECENTRALIZED	CENTRALIZED		DECENTRALIZED	CENTRALIZED	
AUSTRALIA	1 186	124	1 309	6 789	473	7 261
AUSTRIA	172	0	172	1 262	2	1 264
BELGIUM	289	0	289	3 877	0	3 877
CANADA	114	135	249	907	2 006	2 913
CHILE	9	883	892	14	2 023	2 037
CHINA	19 440	33 620	53 060	29 730	101 042	130 772
DENMARK	24	36	60	690	217	907
FINLAND	43	0	43	69	1	70
FRANCE	413	462	875	4 986	3 060	8 046
GERMANY	1 299	477	1 776	31 677	10 815	42 492
ISRAEL	68	35	103	430	548	978
ITALY	297	117	414	8 106	11 577	19 682
JAPAN	3 962	3 488	7 450	33 205	16 123	49 329
KOREA	90	1 281	1 371	641	5 231	5 873
MALAYSIA	49	0	49	391	0	391
MEXICO	95	190	285	272	377	649
NETHERLANDS	853	0	853	2 895	43	2 938
NORWAY	17	0	17	31	0	31
PORTUGAL	32	12	44	234	319	553
SOUTH AFRICA	69	0	69	285	1 474	1 759
SPAIN	144	4	148	92	5 192	5 284
SWEDEN	113	3	115	294	14	307
SWITZERLAND	241	1	242	1 898	4	1 902
THAILAND	0	251	251	0	2 667	2 667
TURKEY	0	2 588	2 588	2	3 425	3 427
USA	4 451	6 231	10 682	20 596	31 042	51 638
TOTAL IEA PVPS COUNTRIES	**33 470**	**49 938**	**83 407**	**149 371**	**197 674**	**347 045**
NON IEA PVPS COUNTRIES			**13 401**			**48 470**
REST OF THE WORLD ESTIMATES			**1 633**			**4 906**
GRID CONNECTED			**98 441**			**400 421**
ESTIMATED OFF GRID			**506**			**2 873**
TOTAL GRID + OFF GRID			**98 947**			**403 294**

Figure 22 – PV market statistics in 2017 worldwide[vii]

2.8.1 Denmark market

Around 60.7 MW of PV systems were installed in Denmark in 2017, with 24.2 MW in the distributed segment and 36 MW of utility-scale plants. The development of PV in Denmark has experienced difficulties, following a rapid start: by the end of 2011, only 17 MW were installed in Denmark. Grid-connected installations represented the majority, and some off-grid installations were found, for instance, in Greenland for stand-alone systems in the telecommunication network and remote signalling. Net metering system set by law for private households and institutions led to a rapid market expansion in 2012 that continued partially in 2013 before the market collapsed to 42 MW in 2014. The PV market represents, in total, 910 MW of PV were producing electricity in the country at the end of 2017.

Self-consumption replaced FiT system as the main driver for distributed PV applications, especially in the residential and commercial segments, but again at a lower level. at the end of 2015, Denmark launched a one-off pilot tender scheme of 20 MW for utility-scale ground-mounted PV systems up to 2.3 MW. A particularity from this tendering system is that it is open to German bids, which implies that PV installations in Germany could compete in the tender and the other way around. The utility-scale development that was seen in 2015 was the consequence of an interpretation of the existing EU legislation: five utility-scale PV farms ranging from 9 to 70 MW were registered in December 2015. All were built in subunits of 400 kW driven by the 2015 FiT regulations. The national energy committee that set it up has recommended renewable energy to be deployed based on market conditions (technology neutral auction schemes instead of politically defined technology targets), an effective international energy markets to be promoted and an integrated and flexible energy system including all technologies to be developed. The new energy plan was decided in mid-2018[vii].

2.8.2 Italian market

At the end of 2017, more than 774,000 plants were installed in Italy for a total capacity of 19,682 MW. The Italian market was quite stable with a new capacity of 414 MW and about 44,000 PV plants installed in 2017. PV electricity production reached 24.4 TWh in 2017, a growth of 10% compared to the previous year. Around 80% of the all PV systems installed in 2017 were residential, while half of the total capacity were related to industrial applications, with several plants with capacity between 200 kW and 1 MW. The public administration owns 16,073 PV plants for a capacity of 748 MW (3.8% of the installed capacity in Italy). As a matter of fact, around 66% of the Italian municipalities have at least one PV plant owned by the public administration.
Electricity produced by PV and self-consumed amounted to 4. 9 TWh in 2017, around 20% of total PV systems production, with a slight increase compared to 2016. The cumulative installed capacity is mostly due to past incentive mechanisms, from the so-called "10,000 PV roofs" of early 2000 to the five decrees of 2005 – 2013 (from feed-in premium (FiP) to FiT, all named "Conto energia"). The cost of the incentives is covered by a component of the electricity tariff paid by all final electricity consumers; for high energy intensive industry there are reductions or exemptions. The financial cap set by the FiP/FiT law was EUR 6.7 billion in terms of yearly payments. after the end of the FiT law in 2013, tax credit (available for small size plants up to 20 kW and for storage devices), together with a net-billing scheme (so-called Scambio Sul Posto - SSP), are the measures to support the PV market that exists now. Italy switched from the net-metering mechanism to a net-billing scheme for systems below 500 kW in 2009, in which electricity fed into the grid is remunerated through an "energy quota" based on electricity market prices and a "service quota" depending on grid services costs (transport, distribution, metering and other extra charges). The net-billing scheme is valid for one year and automatically renewed once granted. Self-consumption is allowed for all PV system sizes[vii].

2.8.3 Germany market

With installations close to 1.8 GW in 2017, Germany was ranked sixth of the largest global PV markets. Since 2014, yearly installations are constantly increasing from 1.2 GW (2014) to 1.8 GW (2017) with an ongoing positive trend in 2018. The German PV market is a GW market since more than 10 years having installed a total cumulative capacity of 42.5 GW by the end of 2017. Given the average yield and the capacity of the PV systems installed by the end of 2017, a share of 7.6% of the electricity demand could be covered by PV, while with respect to the overall electricity production in 2017, the contribution of PV reached 6.8% of the electricity mix. This was achieved thanks to a combination of several elements, especially a long-term stability of support schemes, the confidence of investors, and the appetite of residential, commercial and industrial building owners for PV.
A self-consumption premium that was paid above the retail electricity price was the main incentive to self-consume electricity rather than injecting it into the grid. In 2012, the premium was cancelled when FiT levels went below the retail electricity prices. with the same idea, for systems between 10 kW and 1 MW, the grid injection is capped to 70% of the maximum system power in order to force self-consumption. If the remaining 30% has to be injected anyway, a low market price is paid instead of the FiT. Prosumers pay 40% of the surcharge for renewable electricity for the self-consumed electricity for systems above 10 kW.
In 2017 this surcharge amounted to EUR 0.0688 /kWh consumed from the grid (in 2018: EUR 0.06792). a program of incentives for storage units was introduced 2013, which aims at increasing self-consumption and developing PV with battery storage in Germany. A EUR 25 million market stimulation program has been introduced to boost the installation of local stationary storage systems in conjunction with small PV systems (<30 kWp). within the framework of this storage support program around 20,000 decentralized local storage systems were funded by the end of 2016. In 2017, 6,954 storage systems were funded, of which 6,390 were part of a new PV system and 564 being an upgrade for existing systems. The total funding within those two measures amounted to EUR 223 million. A continuation of those programs is planned. However, the number of installed battery storage system is higher: it is estimated that 20,000 have been installed in 2017 and the 100,000 mark has been reached in august 2018[vii].

2.9 Example of business models

As today there is a lack of business models about ESS, this chapter refers to the business models for PV management for two reasons: first, PV management can be used as examples for the implementation of ESS business models since ES can improve what already is in place for PV management, second, ES plants can be frequently installed together with PV plants.

Until now, a large part of the PV market was based on traditional business models based on the ownership of the PV plant. For rooftop applications, it was rather obvious that the PV system owner was the owner of the building.

PV as-a-service is another business model that contributes significantly with the idea that PV could be sold as a service contract, not implying the ownership or the financing of the installation. Similar solution can be implemented for the storage systems. These business models could deeply transform the PV sector in the coming years, with their ability to include PV in long term contracts, reducing the uncertainty for the contractor. For instance, such business models represent already more than 50% of the residential market in the USA, and also, in a lower percentage, German, Austrian or Swiss utilities are starting to propose them. However, the US case is innovative by the existence of pure players proposing PV (such as SolarCity, Vivint, etc.) as their main product. Since it solves many questions related to the financing, the operations and reduces the uncertainty on the long term for the prosumer, it is possible that such services will develop in a near future, as the necessary developments that will push the distributed PV market up.

Incentives remain the first step to build a business model for pushing the investment in storage systems both for residential and for utility side. In the current stage of development, ES remains to be incentivized. The ES market remains more complex and largely uncompetitive without financial support. In 2017 few countries provided specific subsidies for storage system development. In Germany, since 2013, the Kreditanstalt für Wiederaufbau (KfW) is running a market stimulation program to boost the installation of local stationary storage systems in conjunction with small PV systems below 30 kWp. In Spain, the Catalan Government opened a line of financial support for the purchase of batteries for solar photovoltaic self-consumption in domestic and communities' installations. Also, in Sweden subsidies were allocated for promoting energy storage owned by private households. Canada has established several innovation funds that have given rise to solar projects with electricity storage. In the USA, several states including California has set up an energy storage mandate. In May 2018, new Jersey became the seventh state with an energy storage mandate, requiring 2 GW of storage by 2030. In 2017, the national development and reform Commission of China published the "Guidance opinion on promotion of energy storage technological and industrial development". The document called for development of power storage to promote pilot renewable energy applications, support the grid, and allow the participation of power storage in the auxiliary service market (China is a key global manufacturer of Li-ion batteries and its EVs markets is the largest in the world). In France (including Corsica), a second call for tenders for 50 MW of PV systems above 100 kW with storage has been initiated in 2016, aiming at increasing the grid stability. Japan is as well trying to increase the numbers of projects to install storage batteries but with still limited subsidies and high costs. In the past years storage batteries for residential applications were part of a subsidy program to accelerate the development of net zero energy houses. This subsidy program was distributed in ten different rounds of public invitation which received 7,747 applications in total (7,693 projects were selected). Installation of storage batteries was not subsidized within the Japanese's budget for fiscal year 2017[vii].

Self-consumption business models with FiT and net metering are the most common in the PV management. This is usually applied to a household, business or non-residential building. Figure 23 represents a typical business model structure for a self-consumption business model in the EU with a PV system.

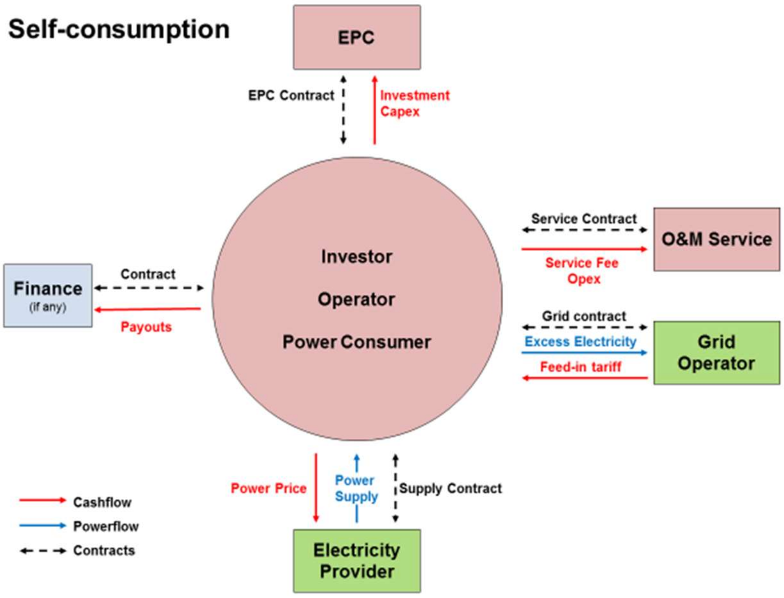


Figure 23 – Self-consumption business model[vii]

The power consumer or building occupier aims to consume as much solar power itself as possible as in so doing it displaces the electricity it would usually have to buy in from the grid at high retail electricity prices. The model assumes that the retail price of electricity is higher than the export price for excess electricity fed back into the grid, and that therefore there is a financial incentive to self-consumption.

The power consumer contracts with an engineering, procurement and construction firm to build the system. If the system is self-funded there is no need to contract with a finance provider but if the system is being financed by debt, equity or one of the other financing schemes (but usually debt or leasing scheme) then a contract needs to be signed and the capital repaid in the pre-defined instalments.

Excess electricity is sold to the grid operator (or electricity supplier) for a price (referred to as the FiT). The Power Consumer then gets its residual electricity from an electricity provider and contracts with an Operations and Maintenance (O&M) provider for maintenance.

There are major variations in the regulatory framework for self-consumption across Europe, with some countries heavily incentivizing it and others doing the opposite. Retail electricity bills are made up of the wholesale electricity price, grid charges and taxes and levies. The first key factor is which of these three components can be saved by self-consuming electricity. But there is uncertain framework in terms of its treatment with regards grid charges and taxes. The second key factor is what price the excess electricity can get for being exported to the grid where the goal should be to guarantee of a minimum price for exported electricity and the remuneration of ancillary services in order to avoid the risk of the dynamic pricing where the export price could then vary depending on the time of day and supply and demand.

For instance, in Austria self-consumed electricity is taxed when a single entity consumes more than 25,000 kWh/year. France was up until recently a special case as far as self-consumption was concerned. The export price for feeding electricity into the grid from small building integrated PV systems was set at EUR 0.24 /kWh. The retail price of electricity was just EUR 0.15 /kWh. This meant that households had no economic incentive to self-consume at all, and designed systems to export everything to the grid.

A Power Purchase Agreement (PPA) is a contract between an electricity generator and an offtaker (a consumer or reseller) which sets a price for a kWh for a relatively long period of time e.g. 5-20 years. The contract usually states a defined minimum amount of electricity to be supplied per year.

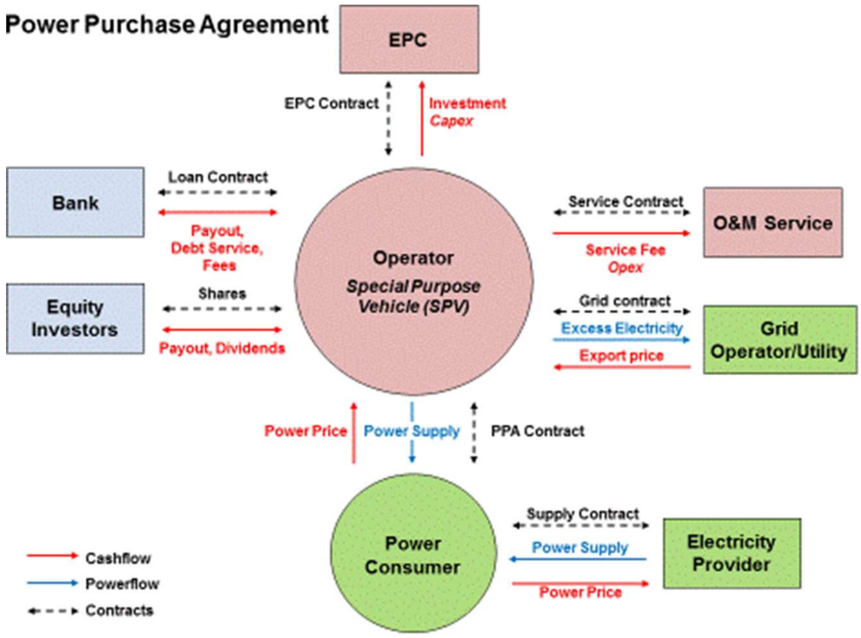


Figure 24 – Power Purchase Agreement (PPA) business model[vii]

The operator is a self-contained entity called a Special Purpose Vehicle (SPV). See Section 3 for more details on SPVs. The Power Consumer then contracts with an electricity provider for the residual electricity. The operator SPV contracts with the O&M service provider, the grid operator/utility to sell excess electricity, the Engineering Procurement and Construction (EPC) for construction and the bank and equity providers for financing. The price of PPA can be set through a fixed price for the duration of the contract, a discount on the wholesale/retail electricity price, or a dynamic discount in the retail electricity price where the higher is the increase in the price the greater the discount.

The regulatory framework for PPAs varies a lot across the EU and Europe as a whole. It is important to distinguish between corporate and wholesale PPAs. Corporate PPAs are with a building or business whereas wholesale PPAs inject electricity into the grid and sell it on wholesale markets. There are many countries such as the UK, Germany, Italy, the Netherlands and across Scandinavia where corporate PPAs are very common. However, in every market, PPAs required to be authorized. But for onsite direct wire PPAs it should be possible to build a private wire and the competition authorities must allow SPVs to sign long-term PPAs with customers as ultimately this is a way of creating more not less choice in the market[vii].

Finally, a cooperative business model represents a form of equity crowdfunding, with a separate legal status to other projects and can therefore be considered as business models. The benefit of cooperative schemes is that an experienced investor or actor can act as an intermediary and aggregator for a large number of smaller private and non-professional investors. They also facilitate and promote social acceptance of renewable energy projects. However, a certain number of regulatory basics have to be in place to implement a cooperative model, as there has to be a level playing field for new entrants such as cooperatives and incumbents. In France a new provision has recently been brought in for collective self-consumption, where electricity can be sold between a number of producers and consumers within a single low-voltage branch of the grid. This opens the way for community and cooperative business models[vii].

3 Economic modelling framework for S4G use cases

This chapter describes the preliminary economic modelling framework to be used in S4G project that has been carried out as a number of steps. In this description, we are going to define the tools for the business analysis of each use case already defined and described in D2.3 [S4G-D2.3]. This deliverable D2.4, indeed, represents an 'incremental' description of the business models depicted in D2.3 [S4G-D2.3] and for some of them we have built a deeper business analysis. However, some business models were modified and updated in D2.2 [S4G-D2.2] after a more in-depth analysis of the initial use cases previously defined. Therefore, D2.4 is based on the final use cases and business models defined in D2.2 [S4G-D2.2] and on the previous business models analysis of D2.3 [S4G-D2.3].

Our tools and steps are divided in two main parts: the first three steps define a high-level analysis of the HLUC-#, while the other steps will go in deep in each Primary Use-Case, PUC-#. The steps are divided as follows:

- **Step 1** is a stakeholder analysis, how to identify stakeholders, their roles and impact on the business model
- **Step 2** is the value network analysis (VNA)
- **Step 3** is a Gap analysis
- **Step 4** has its focus on the business environment, the so-called PESTLE analysis[xlv,xlvi] and STOF analysis
- **Step 5** is the value proposition canvas that will be the basis for the business model canvas
- **Step 6** is the SWOT analysis with input from the PESTLE analysis. The SWOT analysis is developed with focus key stakeholders. The External part of the SWOT analysis further investigates opportunities and threats as inputs to the risk analysis
- **Step 7** is profitability calculations, the economic business model.
- **Step 8** is the business model canvas.

3.1 Stakeholders analysis

Stakeholder analysis[xlvii] is where it is identified the most important stakeholders. The first stage of this is to brainstorm who the stakeholders are, the people who are affected by S4G business models, the ones that have influence or power over it, or have an interest in its successful or unsuccessful conclusion. This is being reported in Table 4.

Table 4 – Stakeholders analysis

Stakeholder	Role	The stakeholders' contribution and position	Possibility to affect the project	Actions toward the stakeholder

3.2 Value network analysis

Value network analysis (VNA) is a business modelling methodology that visualizes business activities and sets of relationships from a dynamic whole systems perspective[xlviii]. The network analysis derives from the identification of the main actors involved in the scenarios for ES deployment. Actors participate in the network playing specific roles in which they "convert tangible assets into negotiable offerings and fulfil different functions"[xlix,xlviii].

To develop the most valuable strategy for stakeholders, it is important to define and map the exchange of values across the network according to three main variables: roles (definition of stakeholders and their role to engage interaction and provide added value), deliverables (the 'things' to be moved from one role to another that can be physical, tangible[l] or intangible[li]) and transactions (activities that originate from one side and end in another side)[xlviii], as show in Figure 25.

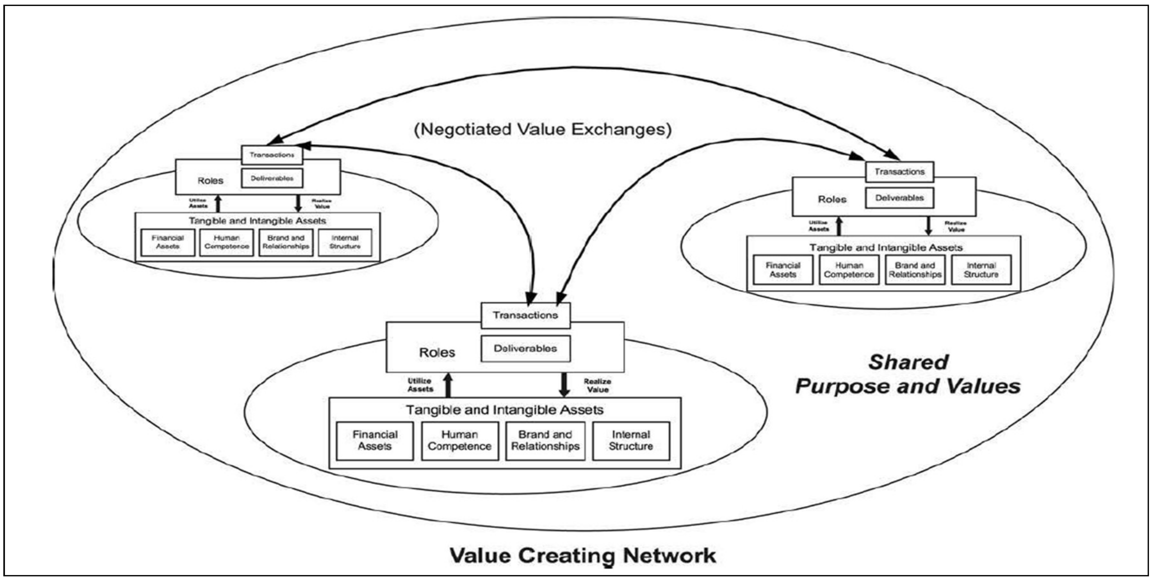


Figure 25 – VNA Diagram[xlviii]

We will elaborate a value network for each HLUC-# and PUC-# with the graphical scheme shown in Figure 26.

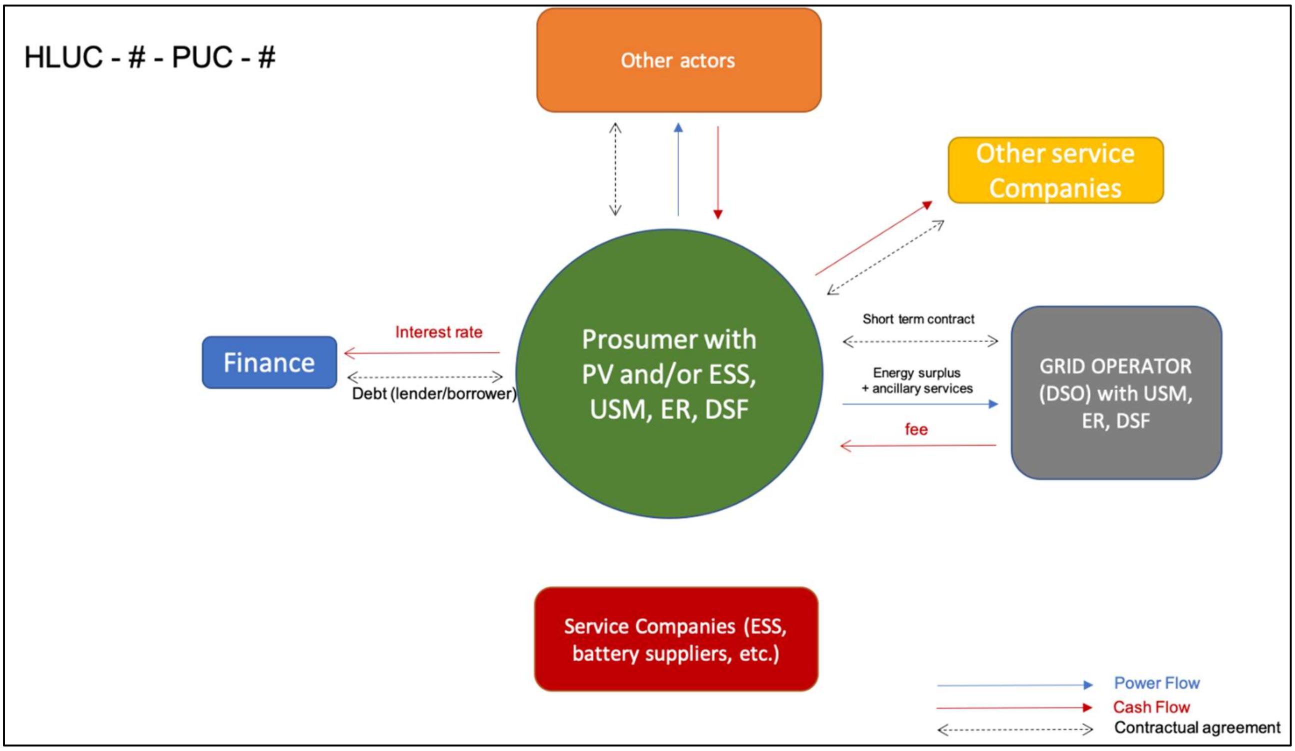


Figure 26 – Example of VNA and contractual relationship from different stakeholders

3.3 GAP analysis

Taking a helicopter view, S4G gap analysis is meant to single out issues and blind spots that are faced nowadays – hence in the AS-IS setting – by relevant stakeholders situated in the European energy and storage ecosystem. The gap analysis presented by S4G draws on the latest studies on the electrical grid system to pinpoint gaps between the current situation with PV penetration and future storage system deployment as, besides being under the spotlight in the sectoral grey literature, have been extracted by D2.2[S4G-D2.2] and D2.3 [S4G-D2.3] story telling.
The severity of these gaps has been evaluated in the present deliverable by means of an ordinary scale from A (high severity) to D (least important).
The classification of such gaps has been elaborated by making reference to the notion of 'ambidexterity'[lii] popularized by the management literature: in this context, ambidexterity refers to the ability to simultaneously manage today's business and also adaptably cope with tomorrow's changing demand. By the same token, S4G partners intends to frame the gap analysis around this dual focus on today's market (static perspective) and tomorrow's market (dynamic perspective), thus decoupling barriers that are seen as severe in the current state of play from the ones that are seen as hurdles in approaching years to come (Table 5).

Table 5 – Gap analysis

Perspective	Gap	Severity for Prosumers	Severity for DSO
Static	…		
	…		
Dynamic	…		
	…		

3.4 PEST(EL) and STOF analysis

The gap analysis previously outlined is complemented by the exogenous forces analysis, which aims to scan possible external forces – that neither stakeholders internal the ES context can control (i.e., DSO and prosumers) – which affect the transition to ESS scenario with resilient prosumers and cooperative storage system. While the PEST-based methodologies abound[liii], the PEST(EL) formalism bring to the fore macro changing factors[liv] – political, economic, social, technological, environmental, and legal – that are in place in the European energy storage sector. The column of Table 6 on the right is meant to specify to what extent (High, Medium, Low) an exogenous force determines a pressure – either of enabling or inhibiting nature – on the deployment of each scenario.
PESTLE Analysis is a simple and widely used tool that helps to analyse the Political, Economic, Socio-Cultural, Technological, Legal and Environmental (PESTLE) changes in a business environment. This helps to understand the "big picture" forces of change that something is exposed to, and, from this, take advantage of the opportunities that they present. The PESTLE analysis is carried out with special focus on S4G elements and business areas.
It is very critical for one to understand the complete depth of each **PESTEL** letters, as follows:

- **Political:** These factors determine the extent to which a government may influence the economy or a certain industry. For example, a government may impose a new tax or duty due to which entire revenue generating structures of organizations might change. Political factors include tax policies, fiscal policy, trade tariffs etc. that a government may levy around the fiscal year and it may affect the business environment (economic environment) in a great extent.

- **Economic:** These factors are determinants of an economy's performance that directly impacts a company and have resonating long term effects. For example, a rise in the inflation rate of any economy would affect the way companies price their products and services. Adding to that, it would affect the purchasing power of a consumer and change demand/supply models for that economy. Economic factors include inflation rate, interest rates, foreign exchange rates, economic growth patterns etc. It also accounts for the Foreign Direct Investment (FDI) depending on certain specific industries which are undergoing this analysis.
- **Socio-Cultural:** These factors scrutinize the social environment of the market, and gauge determinants like cultural trends, demographics, population analytics etc. An example for this can be buying trends for Western countries like the US where there is high demand during the Holiday season.
- **Technological:** These factors pertain to innovations in technology that may affect the operations of the industry and the market favourably or unfavourably. This refers to automation, research and development and the amount of technological awareness that a market possesses.
- **Legal:** These factors have both external and internal sides. There are certain laws that affect the business environment in a certain country while there are certain policies that companies maintain for themselves. Legal analysis takes into account both of these angles and then charts out the strategies in light of these legislations. For example, consumer laws, safety standards, labour laws etc.
- **Environmental:** These factors include all those that influence or are determined by the surrounding environment. This aspect of the PESTLE is crucial for certain industries particularly for example tourism, farming, agriculture etc. Factors of an environmental analysis include but are not limited to climate, weather, geographical location, global changes in climate, environmental offsets etc.

The following steps can be used to analyse the business environment, and the opportunities and threats that it presents.

1. Brainstorming the changes happening around us.
2. Brainstorm opportunities arising from each of these changes.
3. Brainstorm threats or issues that could be caused by them.
4. Take appropriate action – input to SWOT analysis.

Table 6 – PESTLE analysis

	Factor	Opportunity	Threat
Political			
Economical			
Socio-Cultural			
Technological			
Legal			
Environmental			

Driving forces – seen as a combination of reactions to gap identified and external pressure exerted by the surrounding environment – are the ultimate changing factors which could be harnessed by relevant stakeholders with the purpose of attaining results that are beneficial for them.
Plenty of tools meant to capture such variables are available, including – inter alia – the Business Model Design Space[lv] and the Context Map Canvas[lvi]. The present document resorts to the STOF[lvii] formalism to collect and systematize endogenous forces (i.e., levers that stakeholders internal the ES context can control, i.e., DSO and prosumers) that are driving the HLUC-# transition investigated by S4G project. The repertoire of endogenous driving forces is expounded in Table 7. Given that a wealth of driving forces can be identified at this juncture,

this table reports only a short-list of them filtered in view of 'golden principles' such as plausibility, consistency and decision-making utility.

Table 7 – STOF analysis

Domain	Perspective(s)	Possible driving forces	Explanation
Service	Description of value proposition (added value of the service offering) and target segments		
Technology	Description of functional and non-functional requirements		
Organization	Description of the structure of the multi-actor value network required to create and provide the service offering		
Finance	Description of the revenue generation logic and cost structure		

3.5 Value proposition canvas

The ultimate aim of the value proposition design is to ascertain that the commercial offering solves problems and satisfies needs expressed by target customers. As part of the problem-solution fit analysis, the Value Proposition Canvas[lv] allows observing and codifying a set of customers' characteristics for designing a value proposition that meets needs and wants of target segments.

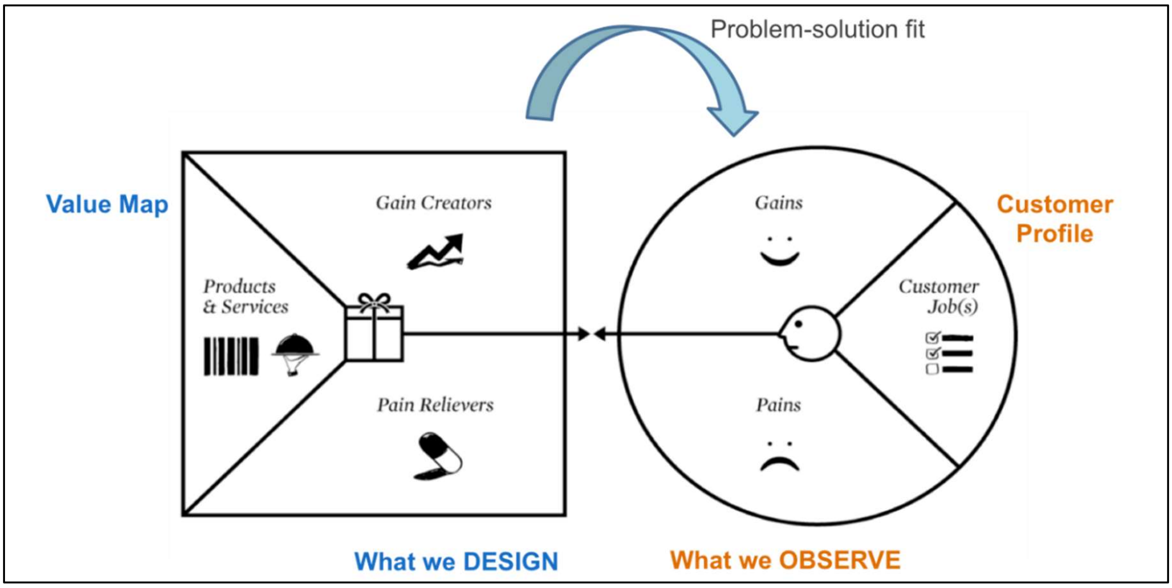


Figure 27 – Value Proposition Canvas[lv]

This process can require to identify and rank pains (i.e., risks and bad outcomes), gains (i.e., benefits and good outcomes) and jobs (i.e., needs and problems to be solved) of the potential end-users and to put a set of preferences and priorities for end-users.

3.6 SWOT analysis

Strength, Weaknesses, Opportunities and Threats (SWOT) analysis[lviii] is a useful technique for understanding Strengths and Weaknesses in business models, and for identifying both the Opportunities open and the Threats faced. Strengths and weaknesses are often internal to the organization, while opportunities and threats generally relate to external factors (Table 8).

Table 8 – SWOT analysis

Strength **What do you do well?** **What unique resources can you draw on?** **What do others see as your strength?**	**Weaknesses** **What could you improve?** **Where do you have fever resources than others?** **What are others likely to see as weaknesses?**
Opportunities **What opportunities are open to you?** **What trends could you take advantage of?** **How can you turn your strengths into opportunities?**	**Threats** **What threats could harm you?** **What is your competition doing?** **What threats do your weaknesses expose you to?**

SWOT helps to focus on strengths, minimize threats, and take the greatest possible advantage of opportunities available to the business model.

3.7 Profitability analysis

The profitability analysis will be a quantitative analysis for some use cases where we can collect data and information from test sites.

3.8 Business model canvas

The Business Model Canvas, developed in the context of the Business Model Generation Framework offers a tool to visualise the framework of the business model, mapping the different building blocks and making the model easier to communicate and understand.
In order to have a visual framework of the business model the different building blocks have been made into a map, which helps the company communicate the business model and which makes it easy for partners and employees to understand it within that specific area. This tool is called the Business Model Canvas (Figure 28). It is a central part of the framework as it should help the company visualise the final business model, making it easy to communicate to other employees or to external partners.
Therefore, the Business Model Canvas can be perceived as a communication instrument and a dynamic paper which can be updated and adapted to the business model so that it matches the current challenges and meets always the customer demands. This will help the company prepare for the future and reduce also risk and uncertainty by being one step ahead of the development, making fast updates and changes to existing business models, as the business model environment changes.
It is important to note that the Business Model Canvas is the result of the Business Model Generation process and is used for documenting and communicating this result.

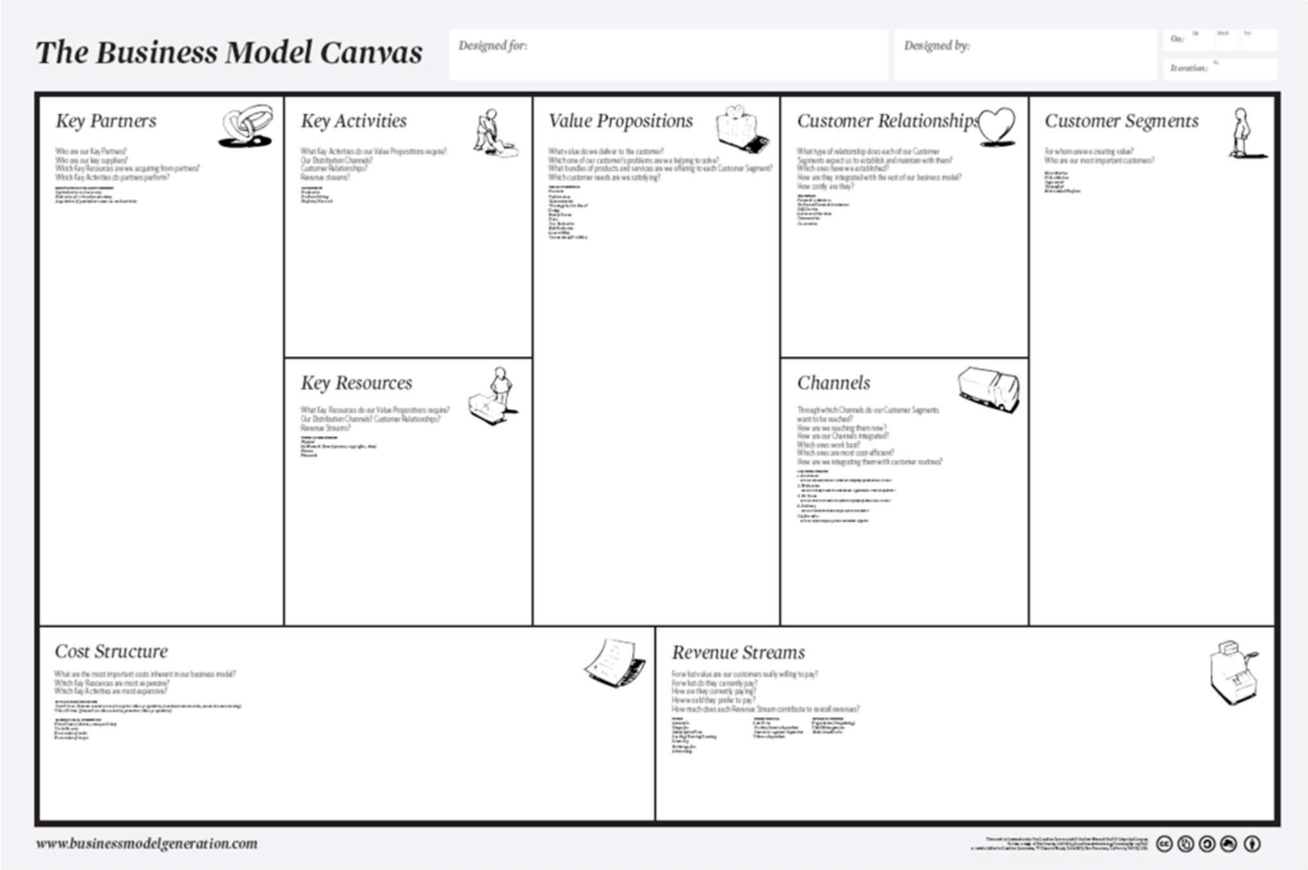


Figure 28 - The Business Model Canvas[lv]

In S4G, business model canvases have been created to map out the different models and document the result of the business model generation process.

4 Economic Model

This chapter describes the approach followed for the implementation of the economic model to be deployed for some of the use cases of the project, as a result of internal workshops and conference calls with the Partners of the S4G Consortium. This model is introduced here because it represents a quantitative evaluation for the business analysis for business analysis and it can enrich the stakeholders' evaluation. The deployment of this model will be done through the DSF-SE and the Professional GUI where the professional users can insert some information and get as a result outputs and insights useful for the investment evaluation. This model is based only on the side of the costs, in particular, on the total cost of ownership (TCO) for DSO investment point of view. The model represented in this chapter represents a theoretical definition of a generic model that will be adapted to the need of the DSF tool during the last stage of the project.

The model will provide more robust results in the DSF-SE since in this deliverable we will do only a numerical computation to provide a first preliminary set of figures based on assumptions that do not come from the grid network really deployed in the S4G use cases.

This chapter is divided in three sections. The first section provides a high-level methodological approach to be used for the implementation of the economic model. The second section describes in more details each step of the methodological approach for the economic model (e.g., the main scenarios we selected to deploy the economic model, the algorithm, etc.). In this context, we provide also a description of the main variables to be selected and used for the final computation and the requirements (input/output) Professional GUI platform.

4.1 Methodological approach

Based on what has been written in the DoA, the main terms related to the economic evaluation are TCO, ROI, cost evaluation, sustainability, and RES exploitation. Based on these and on the DSF-SE technical inputs, our approach has been to design an economic model that will be implemented through an algorithm tool called DSF-EE, that will collect information both from Professional GUI and technical (electrical) results from DSF-SE. Our work has been also to fix a set of requirements for the Professional GUI so that the end-users/planners (e.g., DSO, prosumer, etc.) can insert some values, based on their own information and needs, and check the results of economic model. These requirements will be deeply discussed in the D2.7 – "Final Lessons Learned and Requirements Report" and in the Jira tool.

The economic model focus on the comparison among at least three scenarios: the first is the scenario without any storage systems and the other two with ESS deployed at different levels of the grid (i.e., at substation and residential level). A discussion about which decision-maker should use the quantitative economic insight from this model has been done and it will be discussed in the next sections of this document.

The Table 6 of the DoA (in particular, in the output side) has been our first reference to build the basic model where some concepts have been introduced, as:

1. **Economic Sustainability**: long run evaluation of an investment from investor(s) point of view (e.g., DSO, prosumers, etc.);
2. **Cost Evaluation:** a cost analysis based on the life cycle cost (LCC) or, in this case, on the TCO of the investor(s);
3. **Policies impact estimation**: a (qualitative/quantitative) evaluation of the socio-economic impact (also with a welfare analysis) of different scenarios for different stakeholders as DSO, prosumers, aggregators, suppliers of batteries (also the outcome from 'expected effect on RES exploitation' will be used to explain the policies impact;
4. **Lifetime estimation:** based on the usage/duty/destination use of the ESS where DSF provides an estimation of the lifetime of the battery that for the economic model will be an input to be used to evaluate some scenarios with ESS;
5. **ROI**: cited in some part of the DoA, and it should be considered in the evaluation of the profitability of the investment for some scenarios. However, the information about revenues and income are not simple to be collected and the break-even analysis should be much difficult to be implemented in our economic model without going into a more detailed financial statement analysis, that it could be not

the goal of the DoA (mainly in the case of DSOs). A possible solution could be to analyse the prosumer profitability for some scenarios, as it will be explained in the next chapters.

From a methodological point of view, we identified the following five steps to build a first simplified economic analysis:

1. The first step is to define the actors, that is, to whom is addressed the results of DSF-SE and of the economic model;
2. The second step is to define the scenarios to be covered with the DSF;
3. The third step needs to define the (geographical) area of reference where economic simulation could be implemented;
4. The fourth step is to define the main variables and to identify clearly which kind of monetary flows (inflows or outflows) are exchanged among the actors, the correlation among variables and how they do affect the technical DSF-SE;
5. Finally, the fifth step is the construction of the functional form (i.e., the algorithm) and the tools to be used to get results of the computation.

All these steps will be discussed in the next sections and, more in deep, in D5.2 – "Final DSF Hybrid Simulation Engine". It is important to underline that the economic model will be based on the technical considerations developed by all the Partners. The relationship with the technical simulation of DSF-SE will be discussed until the end of the project and it will be reported in the WP5, D5.2 (M33), but the economic model will dependent on some results of technical simulations, even if some of them. The algorithm to be used for the financial evaluation will be inserted in the DSF-EE. To summarize, the logic flow for economic modelling approach should be represented by Figure 29.

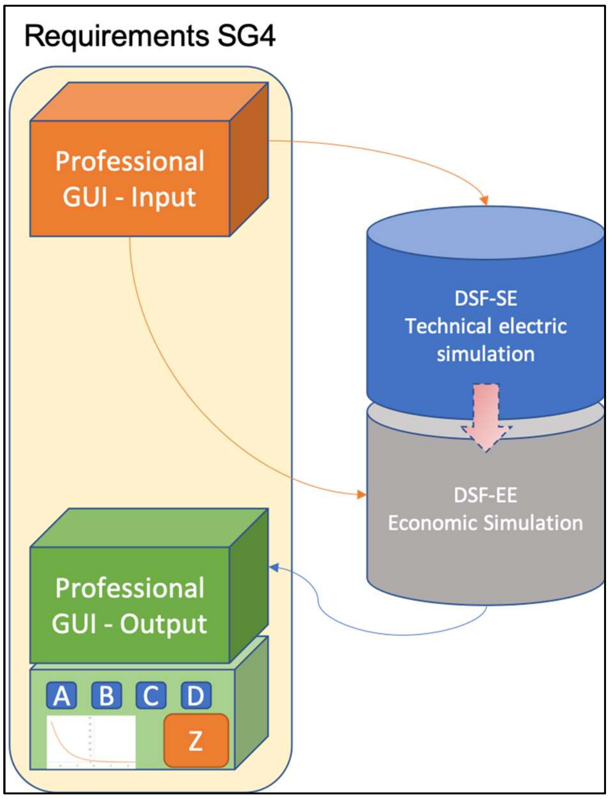


Figure 29 – Links between HLUC, Professional GUI, DSF-SE and DSF-EE

4.2 Description the model

In order to define the techno-economic model, it is important to define some hypothesis based on the steps identified in the Section 4.1.

4.2.1 Step 1: Stakeholders identification

The first step is to define the actors to whom is addressed the DSF-SE. The main actors that should be considered are DSO, prosumers, suppliers of storage systems, TSO, aggregators, storage owners, service companies etc. However, it could be difficult to find information about costs, revenues and commercial relationship for all these actors and it is out of the scope to consider all of them. Initially it was proposed to focus only on DSOs. However, after some discussion about the opportunity to consider also the prosumers in the economic evaluation for some scenarios, we decide that the final economic evaluation should be done for the social planner, hence, we will consider also prosumers and the community point of view. It has been a common decision to start with implementing the DSO point of view and, in a second stage, to add the prosumer evaluation (in terms of ROI or PBP). The results of DSF-EE should provide also some intuition for other stakeholders (e.g., enterprises suppliers of batteries, EV suppliers, utilities as EV services suppliers, RES plants, etc.).

4.2.2 Step 2: Scenario identification

The second step is to define the scenarios to be covered with the economic model. To do this, we should consider all the scenarios already developed in the DSF-SE simulation and the three scenarios described in the economic model will be transversal to all the HLUCs described both in D2.2 [S4G-D2.2] and in this deliverable. The reference use case for the baseline scenario is represented by HLUC-3-PUC-1-BM-1.

4.2.2.1 Scenario 0 (HLUC-3-PUC-1-BM-1) – Support for analyzing storage dimensioning and positioning in the low-voltage grid

This scenario simulates different way to have grid strengthening based on different levels of PV penetration (this is a static model), as it already has been described in the Fur/Skive grid (see Figure 30 and Figure 31).

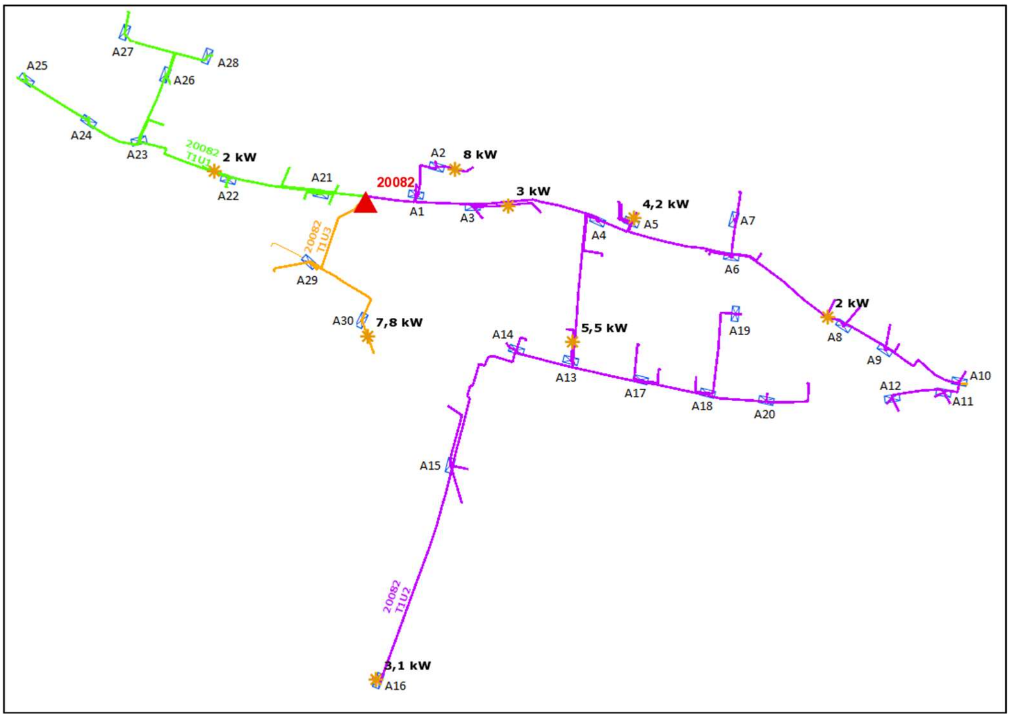


Figure 30 - Topology for grid network in HLUC-3-PUC-1 (Scenario 0)

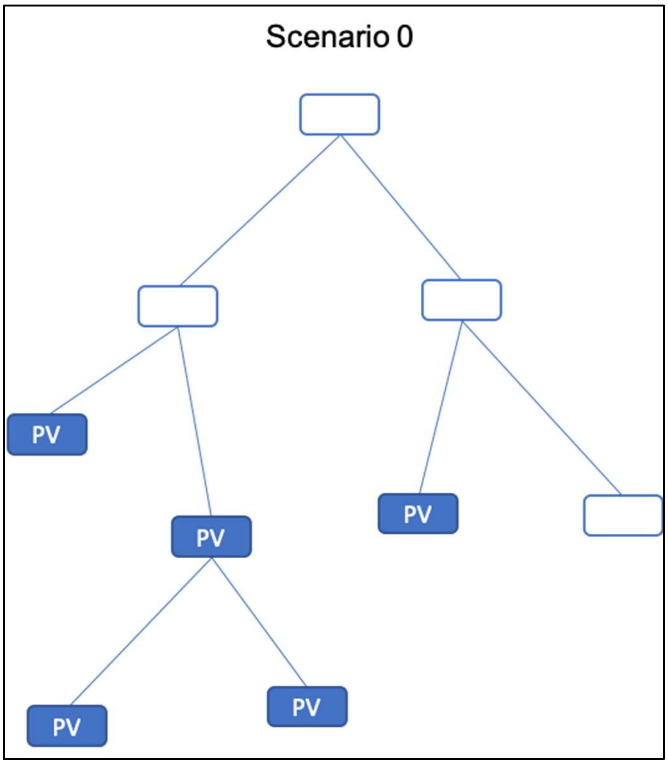


Figure 31 – HLUC-3-PUC-1 (Scenario 0) – Support for analysing storage dimensioning and positioning in the low-voltage grid

The choice of PV penetration can be done by the DSO or based on Table 9 or Table 10 that will be discussed in the next scenario.

4.2.2.2 Scenario 1 – Household Distributed Storage Systems

We can assume a number of prosumers investing in house storage system (ESS) in a network where different PV systems have been already installed. The storage system could be installed separately or integrated with PV. In other terms, we consider PV and storage (ESS) penetration in different percentages, respectively. This scenario is similar to the previous one, but we will consider also the storage penetration and how it can affect the grid strengthening costs (see Figure 32).

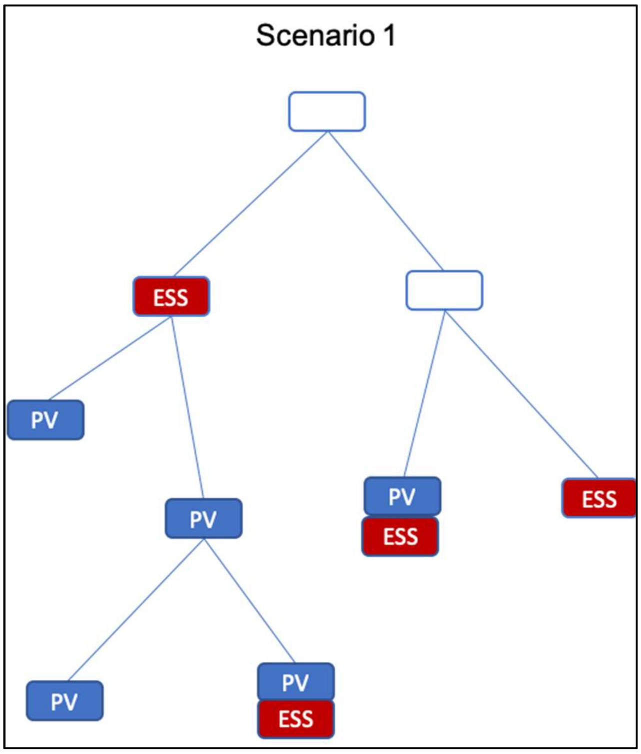


Figure 32 - Scenario 1 – Grid strengthening with ESS penetration

For instance, if DSO knows to have a PV penetration[lix] of 64% is different than to have a PV penetration of 64% together with an ESS penetration (suppose around 15%): in latter case, we can expect the cost for grid strengthening should be lower than the first case.
In order to compute the cost for grid strengthening of this scenario, the DSF-SE simulator should compute the total kWp for different level of PV and ESS penetration and we can build a new variable, called Equivalent PV penetration computed as the correspondent total value of kWp of PV that requires a grid strengthening after the introduction of ESS (see Table 11).
The PV penetration is assumed to start from the value of zero, today and all the values of the Table 9 are computed by considering a zero current PV deployment.

Table 9 - PV penetration, kWp and associated CapEx for grid strengthening

PV penetration	kWp	Grid strengthening cost (EUR)
24% flicker	36	27,300

64%	96	9,850
74%	111	21,000
84%	126	41,600
94%	141	43,100
100%	150	47,500

The DSOs will simulate different degree of ESS allocation in the grid by dragging the batteries in different nodes as they prefer, and they will see the final results of technical feasibility and final economic results. With a simple polynomial regression model, we can compute the other missing values, to get a more complete table (Table 10 and Table 11):

Regression model: $Cost = \alpha_0 + \alpha_1 x + \alpha_2 x^2 + \alpha_3 x^3 + \alpha_4 x^4$

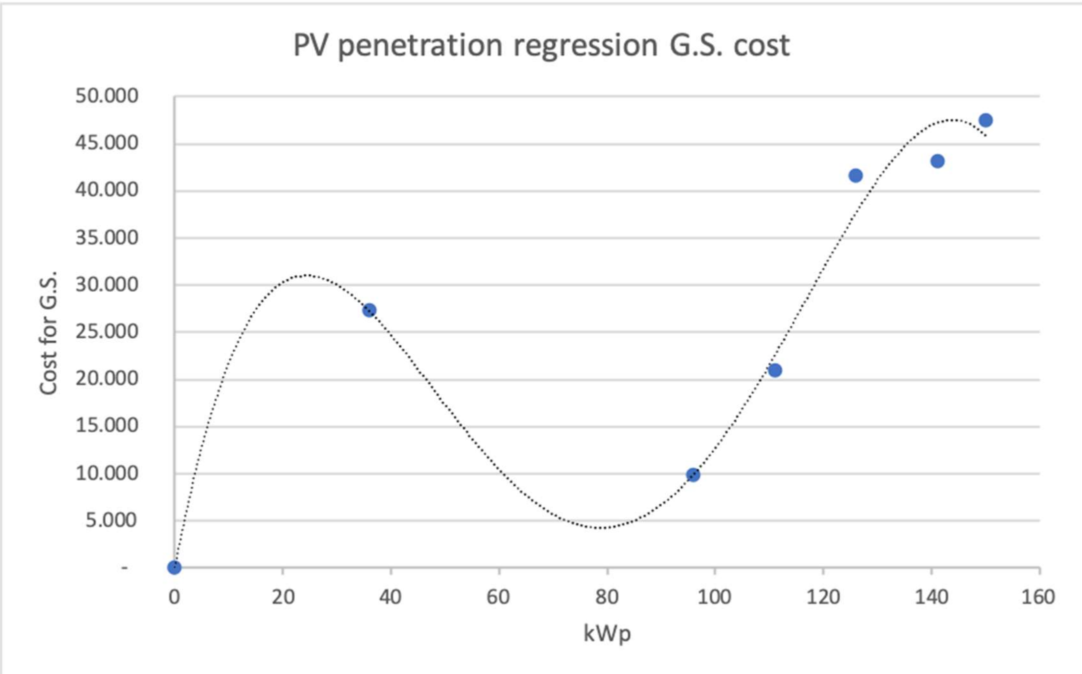


Figure 33 – PV penetration and grid strengthening cost (GS) – regression curve

Table 10 - PV penetration, kWp and associated CapEx for grid strengthening after the regression model

PV penetration	kWp	Grid strengthening cost (EUR)
0	0	0

…	…	…
24% flicker	36	27,300
…	…	…
40%	60	15,930
64%	96	9,850
74%	111	21,000
…	…	…
100%	150	47,500

After introducing ESS at sub-station or residential level, the DSF-SE will compute new value of kWp for the overall grid. This new value corresponds a new figure of PV penetration and CapEx of the Table 10 that it will be called Equivalent PV penetration. For instance, if we assume a PV penetration of 64% and ESS penetration of 15%, the DSF-SE simulator should provide the final value of power in kWp (let suppose 60 kWp). As a results of the previous Table 10, the Equivalent PV corresponds to the value of 40% of PV penetration, hence, in turn, it corresponds to the value of grid strengthening cost of EUR 15,930 (see Table 11).

Table 11 - PV penetration, ESS penetration, kWp, CapEx for grid strengthening and associated Equivalent PV

PV penetration	kWp	Grid strengthening cost (EUR)	ESS penetration	kWp after introducing ESS	Equivalent PV penetration	New Grid strengthening cost (EUR)
…	…	…	…	…	…	…
50%	63	7,320	…	…	…	…
64%	96	9,850	15%	60	40%	15,930
…	…	…	…	…	…	…
100%	150	…	15%	…	…	…

Storage penetration can be assumed by our hypothesis, in this deliverable, but in D5.2 and the Professional GUI where the end-user will inserts the number of storage systems they prefer, hence, for our economic model the ES penetration will be considered as an exogenous variable. DSF-SE provides simulation to compute the

kWp in case of PV+ESS (i.e., to compute the PV equivalent) in order to have the final power and compute the grid strengthening.
The added value of this scenario is to support DSO decision in a future realistic scenario where storage deployment can increase and how to stimulate the household ESS deployment. On the other side, also for enterprises suppliers of batteries can be useful to understand the potential market for storage where it can be viable for other actors in the market. Finally, for policy maker it can be useful tool to push to increase the level of storage to make more convenient the investment for all the actors. Indeed, for instance, if policy maker makes incentives for storage systems, this can affect the grid strengthening and the market of batteries.
A further not explored issue is to define how the household storage can affect the grid strengthening and if there is a correlation between PV penetration and Storage penetration.

4.2.2.3 Scenario 2 – Voltage control at grid side battery.

This is the case at the new place in Skive, Spøttrup Kulturhal (Denmark). Intuitively the capacity of the battery, in this case, should be different (higher) with respect to the batteries in Scenario 1. This scenario is related to the possibility for DSO to invest in storage at sub-station level, hence, to decrease the level of grid strengthening (Figure 34).

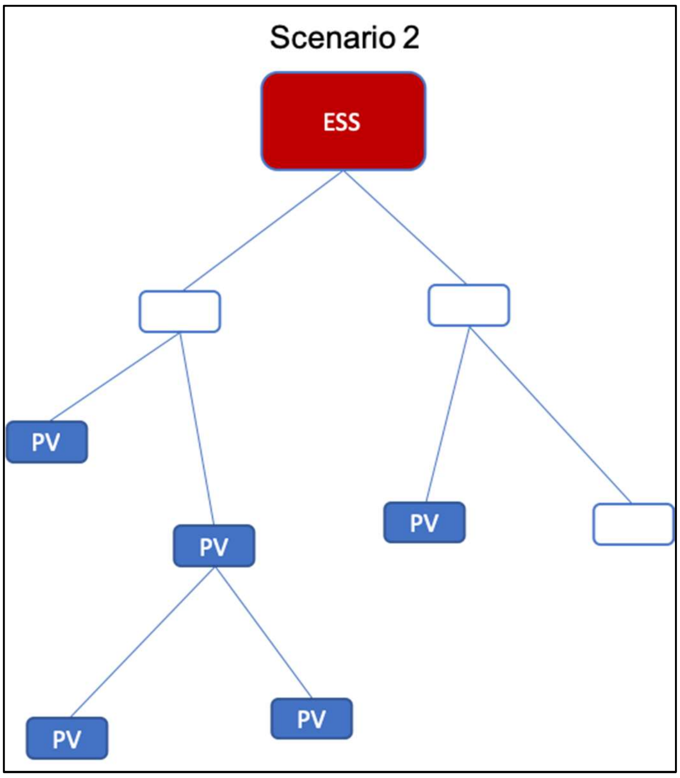


Figure 34 – Grid network with ESS at substation level

Figure 35 synthetize the three different scenarios (e.g., with 9 nodes).

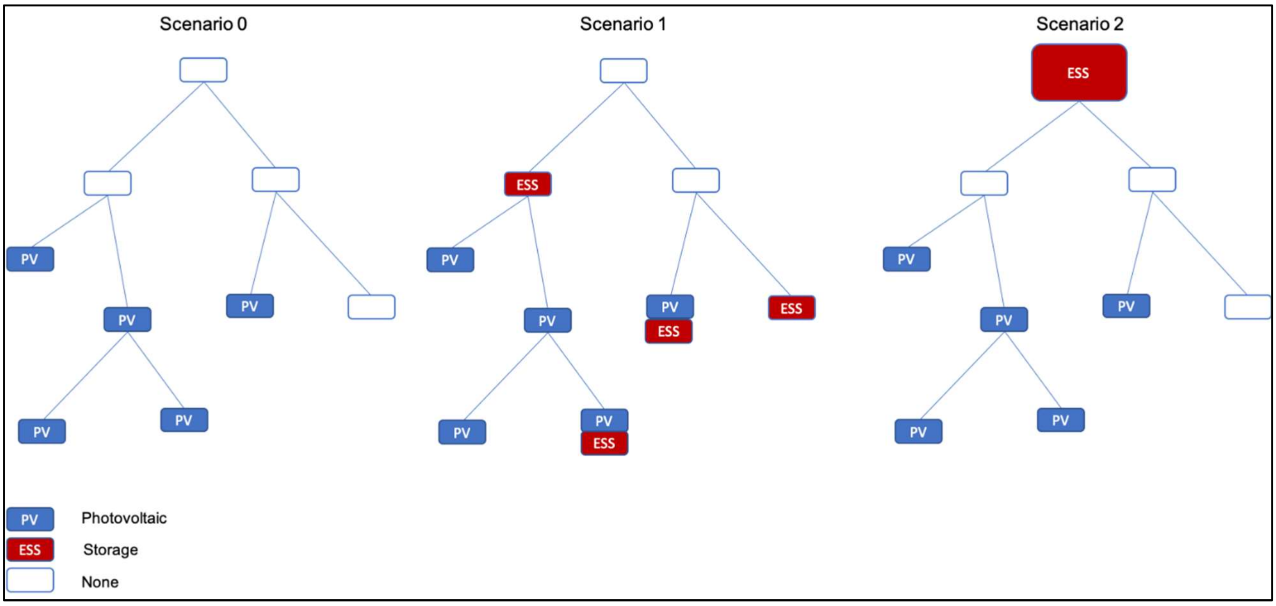


Figure 35 – Examples of PV and ESS distribution

4.2.3 Step 3: Geographical area identification

The third step needs to define the area of reference where the model can be simulated with real data. There has been defined the areas of Fur/Skive and Bolzano test sites for monitoring also the EV impact on the grid.

4.2.4 Step 4: Variable selection

Once defined the scenarios and the area, the fourth step was to define the variables of the model and to identify clearly which kind of monetary flows (inflows or outflows) are exchanged among the actors, the correlation among variables and how they do affect the technical DSF-SE simulation tool (see Section 4.2.6). If we consider the economic analysis from DSO point of view, we can focus on the cost side because we do not have sufficient indication about the financial statement for DSO in order to find the break-even point.

4.2.5 Step 5: Functional form

Finally, the fifth step is the construction of algorithm, i.e. the functional form and describe which tools to be used to get results of the computation (see Section 4.2.6).
If we consider the DSO, the outcome of the model will be to provide an indication about economic sustainability and cost evaluation, in other terms, the evaluation of two TCO function with a comparison between the baseline scenario (grid strengthening without any storage systems but with different level of PV and/or EV penetration) and the scenarios with storage system both at substation level and at household side. The simplest algorithm will be developed inside the DSF-SE and the Professional GUI will collect inputs and will show the final results based on what each DSO would provide as inputs of the model.

4.2.6 Variables selection

This section provides a preliminary list of variables to be used for the DSF-EE. Each variable will be described in the following way:

- Description;
- Variable name;

- Variable acronym;
- Link with Professional GUI, Input or Output (I/O).

4.2.6.1 Time horizon for the investment

- Description: We should define a generic time horizon for all the selected scenarios in order to compare the final results in a logic of sustainability of the investment for DSO in the long run. The basic assumption is to consider the maximum length for the grid strengthening duration from 10 to 20 years. The time horizon will be selected in the same way independently on the scenario. For our initial numerical computation, we can assume a length at least of 15 or 20 years of investment. A sensitivity analysis will be done in order to extend the results to different time horizon.
- Variable Name: Time of investment both for grid strengthening and battery deployment
- Variable acronym: T_{Inv}
- Professional GUI (I/O): it will be defined in D2.7 and D5.2.

4.2.6.2 PV penetration in a selected area (e.g., Fur, Skive, Bolzano)

- Description: Table 12 fixed a set of discrete values for PV penetration (i.e., 24%, 64%, 74%, 84%, 92% and 100%) based on the PV power distribution (kWp). Based on these data, we can also build a simple quadratic regression model in order to generate a continuous function (see explanation of Section 4.2.2.2). The PV penetration is assumed to start from the value of zero today (i.e., PV = 0% at time = 0). Indeed, all the values of the table are computed considering to start from zero current PV deployment. The PV penetration will be computed in the same way independently on the scenario.

Table 12 – PV penetration figures from D2.3 [S4G-D2.3]

PV penetration	PV power	PV power/ consumer	Strengthening cost
24 % - flicker	36 kWp	1.24 kWp	27.300 €
64 %	96 kWp	3.31 kWp	9.850 €
74 %	111 kWp	3.83 kWp	21.000 €
84 %	126 kWp	4.34 kWp	41.600 €
94 %	141 kWp	4.86 kWp	43.100 €
100 %	150 kWp	5.17 kWp	47.500 €

- Variable Name: PV penetration
- Variable acronym: PV_{pen}
- Professional GUI (I/O): it will be defined in D2.7 and D5.2.

4.2.6.3 Estimation of the CapEx for grid strengthening

- Description: We need to estimate how the deployment of grid strengthening affects costs and, as much as possible, with the indication of the main items included in this cost (e.g., components, equipment, labour cost, etc.). We are assuming that the cost for grid strengthening is an 'overnight cost', in other word, the deployment of grid strengthening can occur in a very short period of time so that it is not relevant for our economic analysis. Table 10 and Table 11 provides these values.
- Variable Name: CapEx for grid strengthening
- Variable acronym: $CapEx_{grid} = f(PV_{pen})_i$
- Professional GUI (I/O): it will be defined in D2.7 and D5.2.

4.2.6.4 The cost of maintenance (OpEx) for grid strengthening

- Description: We need to evaluate the yearly (or monthly) maintenance costs for grid strengthening based on different level of PV penetration, with the indication of the list of maintenance activities are needed along the years (e.g., workers, equipment maintenance, equipment failure cost, etc.).
- Variable Name: Operating Expenditure for grid strengthening
- Variable acronym: $OpEx(GS)_t = f(PV_{pen})_{i,t}$
- Professional GUI (I/O): it will be defined in D2.7 and D5.2.

4.2.6.5 Power Losses in energy production

- Description: the network losses in the distribution of electricity are defined as the difference between the amount of energy that is fed into the grid and the amount of energy that is consumed or exported, i.e. taken out of the grid. Network losses as an indicator for an efficient utilization of the power grid since network losses have a direct impact on network costs and energy consumption. Network losses can be computed using historical data as the share of network losses for each DSO during the regulatory period (e.g., 2016-2019) and it is computed to the price per MWh for network losses calculated as an average price of energy during the regulatory period (2016-2019) = EUR/MWh[lx]. Power losses can be paid with a high percentage from prosumers and a lower percentage from DSO. In some countries, regulation gives incentives to DSO such as requirement that no outages should be above 24 hours and individual customer compensation for outages above 12 hours, since outages >12/24 hours are not tolerated[lxi]. Furthermore, EI has specified that no customer should have more than 11 outages per year.
  In case of short outages (0.05–12 h), the upcoming tariff regulation will be based on reported SAIDI and SAIFI. The possible consequence for the DSO is decreased income limit, i.e., all customers collectively obtain revised tariff levels. To avoid "double penalization", outages from other categories are excluded. If customers are given sufficient notice of outages, the economic impact will be lower.
  In case of long outages (>12 h), the Table 13 summarizes the model for determining customer outage compensation to affected customers (example in Sweden).

Table 13 – Example of customer outage compensation

CONSEQUENCES OF OUTAGES >12 h

Length of the outage	Compensation to customer	Minimum compensation[1]
12-24 hours	12.5 % of α	2 % of β
24-48 hours[2]	+ 25 % of α	4 % of β
Following 24 hour periods[2]	+ 25 % of α	+ 2 % of β
⋮	⋮	
Max[2]	300 % of α	-

α = Individual customer's annual network tariff; this value depends on both the main fuse (power allowed) and annual energy consumption.
β = Yearly set base amount (42 400 SEK 2010, ~4700 €, ~6100$))
[1]Is always set to even 100 SEK values, rounded up → 2 % β is rounded up to 900 SEK (~100 €, ~140$)
[2]Additional consequences are likely , since >24 hours outages not are tolerated by the law from 2011

A more detailed explanation about network losses and compensation mechanism is provided by Wallnerström[lxi]. For our computation DSF-SE will provide the value of power losses per day and per year.

- Variable Name: Power Loss, expressed in MWh
- Variable acronym: $PwLoss_t$
- Professional GUI (I/O): it will be defined in D2.7 and D5.2.

4.2.6.6 *Battery exploitation (drop/down) and lifetime*

- Description: This represents the average load profile that an end-user would follow during the investment period. We supposed to have three kinds of load profiles: high, medium, low level of exploitation. Concerning the lifetime, the model should know the duration of different kind of batteries (i.e., power, kWh). Based on the usage/duty/destination use of the ESS, technical DSF-SE provides an estimation of the lifetime of the battery. Lifetime does not depend much on the size of the battery but on the exploitation profile. ESS can be deployed both by households (with a range of size from 3/5 kWh to around 12 kWh) and by DSO (with 50-100 kWh). DSO can deploy one ESS at substation level or more ESS in different points of the grid. S4G will define examples of battery for different usages and different cycles to simulate the final lifetime.
- Variable Name: Battery lifetime
- Variable acronym: $ES_{time} = f(Expl_e)$, where e = (high, medium, low)
- Professional GUI (I/O): it will be defined in D2.7 and D5.2.

4.2.6.7 *Type and Cost of battery for different type of exploitation*

- Description: This is the price for batteries that can be computed for different level of installation. Indeed, the batteries used in our model can be at substation level (scenario 2) or at residential level (scenario 1). We propose to select a restricted number of batteries and to make a simple quadratic regression model to compute the cost for different types of batteries.

Finally, we consider also the trend of the future prices along the years that it will be computed by LINKS by using an expected values for those prices (starting from LiBAL values at time 0), since we expect that the prices for batteries will decrease in the short run period. LINKS will use the literature of battery price costs to simulate those values. Currently, we have computed the following estimation of expected cost of storage per kWh (Table 14) for the next 10 years, based on the results from the literature cited in the Section 2.6. We also estimate an average rate of decreasing for batteries price around – 7% per year (Figure 36).

Table 14 – Estimation of prices for batteries from different sources

Source: IFC 2017[lxii]		Source: REA 2016[lxiii]		Source: BSW 2017[xiii]	
Year	**$**	**Year**	**$**	**Year**	**$**
2014	1,100	2014	1,493	2014	1,400
2015	1,037	2015	1,400	2015	1,222
2016	978	2016	1,307	2016	1,066
2017	922	2017	1,220	2017	930
2018	869	2018	1,139	2018	812
2019	819	2019	1,064	n.a.	n.a.
2020	772	2020	993	n.a.	n.a.
2021	728	2021	927	n.a.	n.a.
2022	686	2022	866	n.a.	n.a.
2023	647	2023	808	n.a.	n.a.
2024	610	2024	755	n.a.	n.a.
n.a.	n.a.	2025	705	n.a.	n.a.
n.a.	n.a.	2026	658	n.a.	n.a.
n.a.	n.a.	2027	614	n.a.	n.a.
n.a.	n.a.	2028	574	n.a.	n.a.
n.a.	n.a.	2029	536	n.a.	n.a.
n.a.	n.a.	2030	500	n.a.	n.a.
Rate of discount	**Yearly rate**	**Rate of discount**	**Yearly rate**	**Rate of discount**	**Yearly rate**
-44,55%	**-5,73%**	**-64,29%**	**-6,63%**	**-42,00%**	**-12,73%**

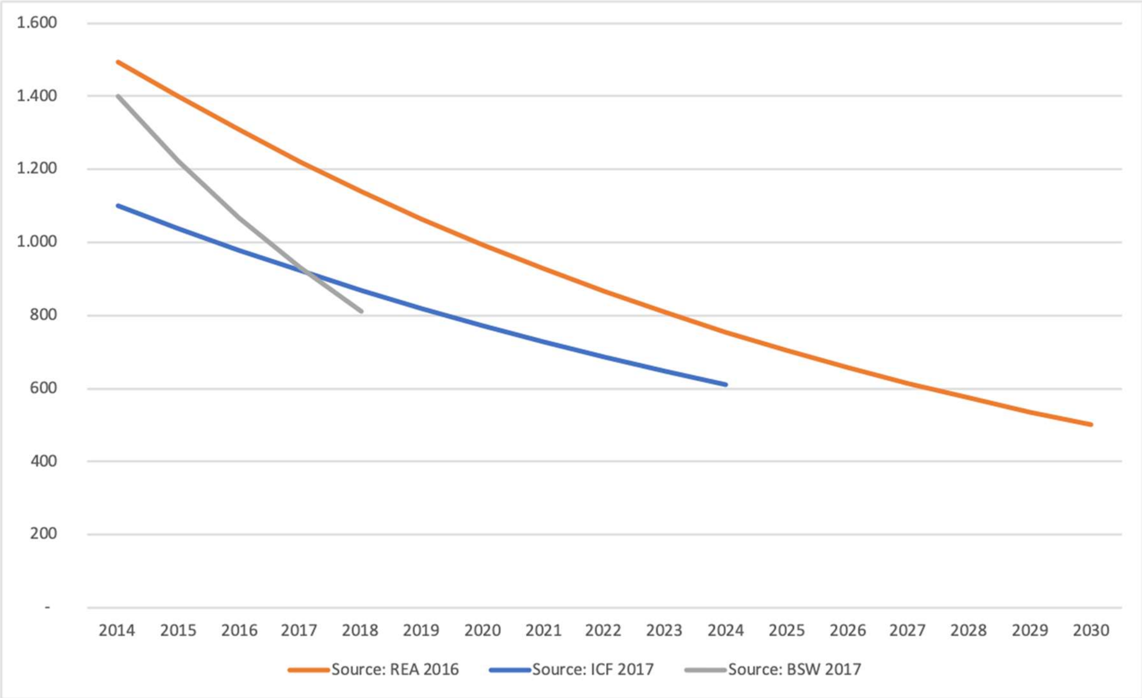


Figure 36 – Price of batteries dollar per kWh

- Variable Name: Battery cost
- Variable acronym: $C(ESS)_{type}$
- Professional GUI (I/O): it will be defined in D2.7 and D5.2.

4.2.6.8 Storage penetration

- Description: This is the level of ESS installed along the line by household prosumers. This value should be provided by the DSO of the Consortium. We collect the information from DSO (since DSO should know how many storage systems are installed in the area, since they must be registered at the DSO). In the DSF-SE, the DSO could choose how and where to insert ESS in the network. For this indicator we do not compute a percentage because it is difficult to estimate it, but we will use a KPIs that is number of batteries installed.
- Variable Name: Storage penetration
- Variable acronym: ES_{pen}
- Professional GUI (I/O): it will be defined in D2.7 and D5.2.

4.2.6.9 Equivalent PV penetration

- Description: See description in Section 4.2.2.2.
- Variable Name: PV equivalent
- Variable acronym: PV_{eq}
- Professional GUI (I/O): it will be defined in D2.7 and D5.2.

4.2.6.10 Total Cost of Ownership

- Description: The TCO is an approach under the Life-Cycle Costing methodology that allows entities to carry out an economic evaluation of the possible direct costs involved during the life cycle of a good, service or work, bringing out the "hidden" costs of the next-to-be-purchased items, along with the acquisition price (Figure 37).

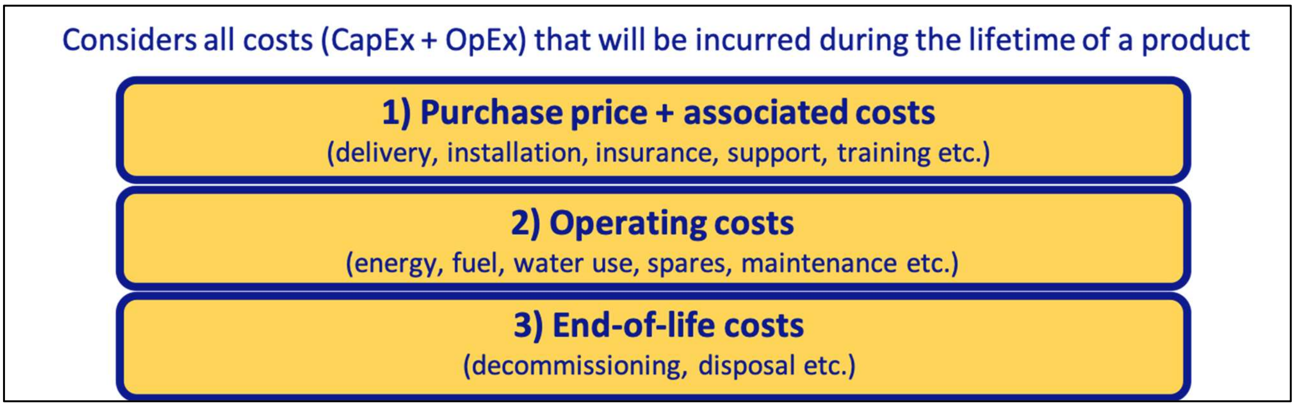


Figure 37 – Total Cost of Ownership

In the S4G context, the TCO should be defined for each scenario in order to be compared through a monetary point of view. We can summarize the three TCOs in the following ways:

- Scenario 0: TCO = $f(T_{Inv}, CapEx_{grid} ; OpEx_{grid,t} ; PwLoss_t)$
- Scenario 1: TCO = $f(T_{Inv}, CapEx_{grid} ; OpEx_{grid,t} ; PwLoss_t ; ESS_{pen} ; ESS_{exploit} ; C(ESS))$
- Scenario 2: TCO = $f(T_{Inv}, CapEx_{grid} ; OpEx_{grid,t} ; PwLoss_t ; ESS_{exploit} ; C(ESS))$

- Variable Name: Total Cost of Ownership
- Variable acronym: TCO_i where i = (0, 1, 2) is the scenario
- Professional GUI (I/O): it will be defined in D2.7 and D5.2.

4.2.6.11 [OPTIONAL] Penalisation cost.

- Description: the penalization represents the cost for decreasing the quality power or the losses of energy due to the grid inefficiencies. The idea is to compute a sort of cost of failure per year (e.g., 1 cent per second of interruption) without making grid strengthening. This variable is optional because it is difficult to be computed. In order to collect this information, we see two possible streets/options. Grid losses usually consist of physical losses and administrative losses (mainly fraud). The grid losses are expressed as a certain value of energy (kWh) per 15, 30 or 60 minutes. Usually the profile of the grid losses is closely linked to the profile of the distributed energy. However, the grid losses are an estimation as - by nature - they cannot be measured. In many Member States the DSO is responsible for the grid losses at the distribution level[lxiv].
  - *Option 1*: A first possible way is described by the following formula:

$$\text{Failure cost per year} = a \cdot SAIDI + b \cdot SAIFI$$

where *a* and *b* are given by energy contracts with end-users (also a generic average or estimated value should be sufficient for our analysis) and where SAIFI is the average number of interruptions per year affecting each customer:

$$SAIFI = \frac{\sum_i N_{LPi} \cdot \lambda_{LPi}}{\sum_i N_{LPi}}$$

and SAIDI is the average number of hours per year without electricity for each customer:

$$SAIDI = \frac{\sum_i N_{LPi} \cdot U_{LPi}}{\sum_i N_{LPi}}$$

LP_i = Load point number i of the analysed system
NLP_i = Number of customers at LP_i
λ LP_i = Total average failure frequency [failures/year] at LP_i
U LP_i = Total average down time [h/year] at LP_i
8,760 = Approximate number of hours per year (24*365).
Other similar indicators are: CAIDI, AENS, ASAI.

- *Option 2*: We need to know from the DSOs of the Project if there is some contract that can define figures/numbers of cost in case of failure of the system. ENIIG said that they have no direct failure cost per year, and they monitor the up-time (99.997%) but for the entire grid, not for a specific feeder line. They not sure about it but it might affect our income-frame-regulation/benchmarking.

- Variable Name: Penalization cost per year
- Variable acronym: $C(\text{failure})_{t,i}$ (only for scenario 0 and 1)
- Professional GUI (I/O): it will be defined in D2.7 and D5.2.

4.2.6.12 Other variables of interest

- *EV penetration*. As for PV penetration, we can assume some values and tested in the field or take some value from the literature and, based on these, we need to have costs for each value.
- *Incentive/subsidies*. The level of incentive from government could be one of the outputs of the model. The level of subsidies could be seen as the level of investment needed to make one scenario (e.g., scenario 2) more profitable with respect to another one (scenario 0).
- *Δ cost for grid strengthening* (from ΔPV penetration). Our additional idea is to define how the grid strengthening changes with expectation of increasing of PV penetration overtime. For instance, the investments will be done in different tranches (e.g., in year 1 to support 64% of PV, then, in year 6 to support 74% of PV, etc.). To do this, we need to compute the delta change of grid strengthening costs over years. Is it possible to compute the value of change in grid strengthening cost from one value to another one (e.g. from 64% to 74%, instead of from 0% to 64% and or to 74%)?

$$\Delta\,\textbf{cost}\text{ for grid strengthening} = \frac{\Delta CapEx}{\Delta PV\ penetration}$$

- *EU regulation*. How much external regulation on RES (i.e., PV and hydric, in this case) can affect this scenario, in particular, how regulation can affect the behaviour of the household? EU Target for PV penetration are important and they are a reference for future grid implementation, $Reg(GS)_{PV}$.
- Bureaucracy costs. This is the cost for mounting, documentation and network connection cost that it will be computed in the last phase of the project.

4.3 Preliminary results of Economic Model (HLUC-3)

The economic model described in this section has been realised to provide a quantitative computation for DSF-SE tool. This section provides only a numerical example for the three scenarios considered. Next steps will be to develop a more advanced version of the model in the DSF-SE, using the Professional GUI, and in order to simulate different combination of scenarios and PV, ESS deployment based on the grid topology. Hereafter, it is described the assumption for the model and the results. The assumptions for the model are represented in Table 15:

Table 15 – Economic model inputs

Inputs/Variables	Values	Source
PV penetration (%)	15%	LINKS assumption (but in the Professional GUI, the professional user will decide the actual percentage of the chosen topology)
PV penetration (kWp)	22	Economic regression model
Battery at substation level info:		
Type size	70 kWh	LINKS assumption (but in the DSF-SE S4G Partners will provide these information)
Number	1	LINKS assumption
Price (EUR)	57,186	LINKS assumption computed as price of batteries per kWh (but in the DSF-SE S4G Partners will provide these information)
Lifetime (years)	18	LINKS assumption (but in the DSF-SE S4G Partners will provide these information)
Operational mode	Support voltage regulation (sub-station)	LINKS assumption (but in the DSF-SE S4G Partners will provide these information)
Battery at substation level Info:		
Type size	12 kWh	LINKS assumption (but in the DSF-SE S4G Partners will provide these information)
Number	3	LINKS assumption

Price (EUR)	9,803	LINKS assumption computed as price of batteries per kWh (but in the DSF-SE S4G Partners will provide these information)
Lifetime (years)	15	LINKS assumption (but in the DSF-SE S4G Partners will provide these information)
Operational mode	Self-consumption (residential)	LINKS assumption (but in the DSF-SE S4G Partners will provide these information)
OpEx (percentage of CapEx), including grid repairs, etc.	2-5%	LINKS assumption
Losses – Scenario 0 (kWh per year)	19,600	LINKS assumption
Losses – Scenario 1 and 2 (kWh per year)	19,000	LINKS assumption (but DSF-SE will provide this figure)
Timeline (years)	20	LINKS assumption
Cost of capital	7%	LINKS assumption
Rate of decreasing storage prices/costs	-7.16%	LINKS assumption based on literature
Price of energy (EUR)	0.31	LINKS assumption (based on the current price in Denmark)
Number of houses with PV	21	LINKS assumption (based on the Denmark grid)

The numerical results of the investment costs are provided in the Figure 38 where it is compared the three scenarios and the TCO for the DSO and the TCO for the overall community (i.e., DSO and prosumers) point of view.

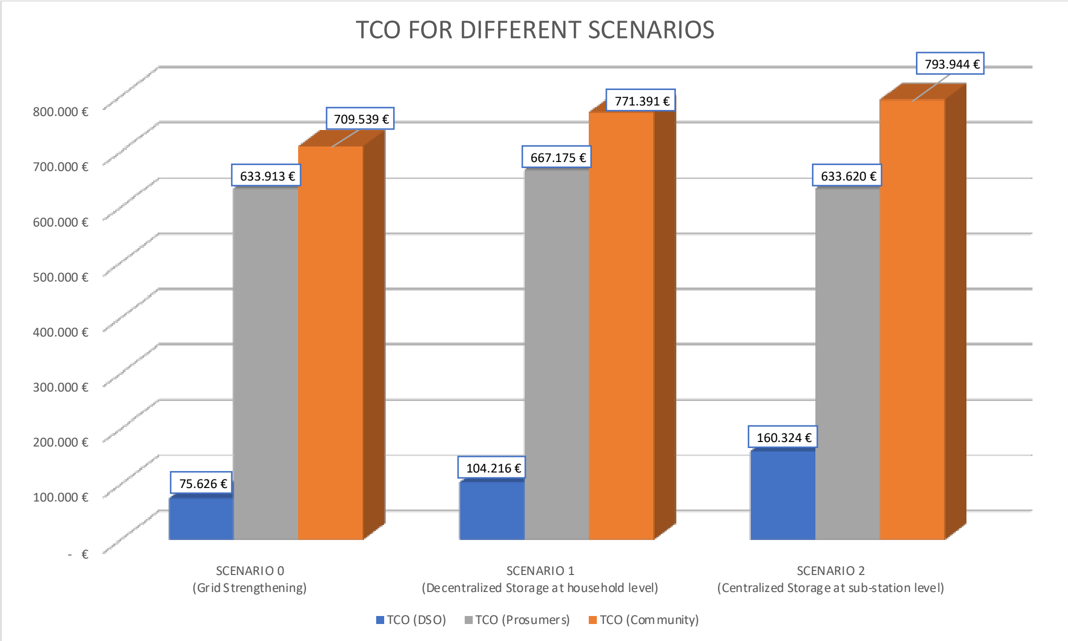


Figure 38 – TCO for different scenarios

The results from this very preliminary numerical simulation highlight how the TCO for the DSO is lower in the baseline scenario 0 and from the community point of view (prosumers plus DSO) it seems the more costly is the third scenario. Without incentives it could be difficult to invest in storage from all the stakeholders' point of view. Further numerical simulation and a refinement of the model are necessary to validate these figures. Future deliverable D5.2 will provide a more detailed description of the economic model with some numerical results and the implementation of the model with the Professional GUI and the DSF-SE.

5 Final Business models in the Bucharest test site

This use case already described in D2.2 [S4G-D2.2] and D2.3 [S4G-D2.3] is related to the deployment of an advanced cooperative storage system in order to connect neighbourhood prosumers and consumers. The generic goals of this use case are:

- Increasing prosumer's energy resilience
- Increasing energy transfer efficiency
- Empowering citizen through more flexible options in purchasing energy from the AC network and, as a consequence, increasing savings
- Increasing resilience of a local smart community by enabling a hybrid neighbour energy ecosystem.
-

The associated business models concern the goal of minimizing losses, i.e. to use surplus energy production as close as possible to the production site, in order to avoid grid losses, especially by using local storage technologies, to avoid curtailment orders from DSO, to prevent grid congestion and to reduce the grid strengthening costs for DSO. From a welfare point of view, these mean to avoid economic losses and/or gain from providing energy surplus to other consumers.

The business rationale is that it is possible to make a business out of using all the electricity generated from locally available resources (in our case, renewables). Private house owners or other investors are encouraged to install batteries in connection to local PV production (i.e. cost for household). Using the entire amount of locally available RES-based electricity (i.e. no curtailment), the customer can pay off the initial amount he/she invested (i.e. payback period can be shorter) and reduces the green gas emission (i.e. increased environmental benefit), offering also an independency from the grid availability (i.e. trade-off between lowest revenues for DSO and lowest power losses due to congestion of the grid).

The PV and battery owner can pay a connection fee to the DSO (i.e. costs), taking into account that the owner will use less energy from the grid (i.e. savings for household), and only when they need it (i.e. energy from RES are not available).

Due to the low TRL nature of HLUC-1 and the small-scale of the test site in Bucharest, a complete validation of business models is out of scope for S4G.

The Bucharest use cases for the test site in Bucharest (low TRL) to which he business models can be associated are summarized as follows:

- **High-Level Use-Case-1-Primary Use-Case -1- Situation-1 (HLUC-1-PUC-1-S-1)** (Avoid curtailment with/without storage capacity) is about testing SaaS between two entities (the one who owns the storage system and the one who generates electricity surplus), from which at least one has available storage on site, connected to the same low-voltage network. If one prosumer has spare storage capacity, it can absorb surplus energy from another prosumer, which otherwise will be curtailed by the DSO due to grid constraints reasons. The storage system can be installed and owned at substation level (DSO) and/or at microgrid level owned by various clients (e.g. prosumers). This corresponds to the Advanced Prosumer (AP) functionality that provides surplus energy coordination services during the peak production periods.
  The DSO should also install new technologies as:
  - USM to communicate with local DSO and forward demands and storage requests to the energy router
  - Energy router that, in turns, regulates electricity flow inside the prosumers micro-grid's (DC) and provide on request ancillary services to the DSO 's grid (revenues for the storage owner)
  - DSF software.
- **HLUC-1-PUC-1-S-2** (Serving peak demand on DSO level) is about testing SaaS between the grid operator and prosumers connected to the [legacy] low-voltage network. If there is a high consumption which may ask for consumption reduction, due to network constraints, the prosumer can use its stored energy in the local ESS to inject energy in the local LV network, thus being able to reduce the power requested on the upstream MV/LV transformer. This is a service for enhancing network capacity without investing in copper (additional wiring) and can be also seen as a transaction between two actors (the energy provider from

storage and the utility) connected on the same LV grid. In fact, it can be a stacked business case, combining peer-to-peer energy transaction and also network capacity enhancement.

- **HLUC-1-PUC-1-S-3** (Provide ancillary services, black-start) is about testing a grid service, seen as an ancillary service in case of a microgrid operating in isolated mode. The prosumer, which is able to deliver such black-start and grid-former service, is expected to be paid for the system service. The tests will be simulated by a small grid with consumption only and this load will be supplied from the microgrid with black-start capability based on frequency provision and necessary power needed to preserve a certain voltage level at the Point of Common Coupling (PCC).
- **HLUC-1-PUC-2** (Advanced self-resilient prosumer) is about testing resilient prosumers, with hybrid solution in the prosumer area, having a DC bus to which all sensitive loads are directly connected. It is a resilience by design service.
- **HLUC-1-PUC-3** (Resilient hybrid cooperative eco-system) is about testing more advanced resilient prosumers, with hybrid solution in the prosumer area, having a DC bus for all sensitive loads and with a DC exchange line with the neighbourhood. It is a cooperative resilience by design service.

5.1 Stakeholders Analysis

The main actors involved in this business case are the DSO, prosumers, storage owners, suppliers of technologies (e.g., USM, batteries, etc.), service companies, investors. Hereafter, we provide a description of the main characteristics (Table 16).

Table 16 – Stakeholder analysis for HLUC-1

Stakeholder	Role	The stakeholders' contribution and position	Possibility to affect the project	Actions toward the stakeholder
Prosumer	Investor, storage owner, seller of energy surplus	Avoids curtailment due to over generation at DSO level (wide area), avoid dispersion of power energy, distribute and collect energy surplus among consumers	Invests in own storage or in energy router/ communication with other entities (DSO, storage owners, other prosumers). Generates energy and store BtM	Incentives included in the connection agreement and contract with DSO
DSO	Balance Compliance, storage owner	Grid-owner, committed to ensure maximum RES-based energy (sustainability), has the means to dispatch energy and power among the controlled entities, distribute and collect energy surplus among consumers	Invest in communication and accepts different contractual agreements with prosumers and storage owners	Regulator accepts/ incentivizes the local energy flows

Storage owner	Investor storage owner, seller of energy surplus	Essential contributor to local balance compliance and contributes to sustainability by enabling higher RES-based production and avoids curtailment of another entity	Invest in communication and accepts different contractual agreements with prosumers	Incentives included in the connection agreement and contract with DSO
Suppliers of technology	Service and technology provider	Seller of batteries, energy router, USM, etc.	Invest in technology development	Favour storage deployment when prices go down
Service company	Service provider - Mediator	Mediator between prosumer and storage owner, in order to maximize income of prosumer and storage owner, while respecting DSO constraints	Invest in ICT platform to mediate and operate the service	Agreement and contract with other stakeholders (Prosumer, DSO, storage owner)

5.2 Value Proposition

Figure 39 gives a generic overview of the value proposition for the HLUC-1.

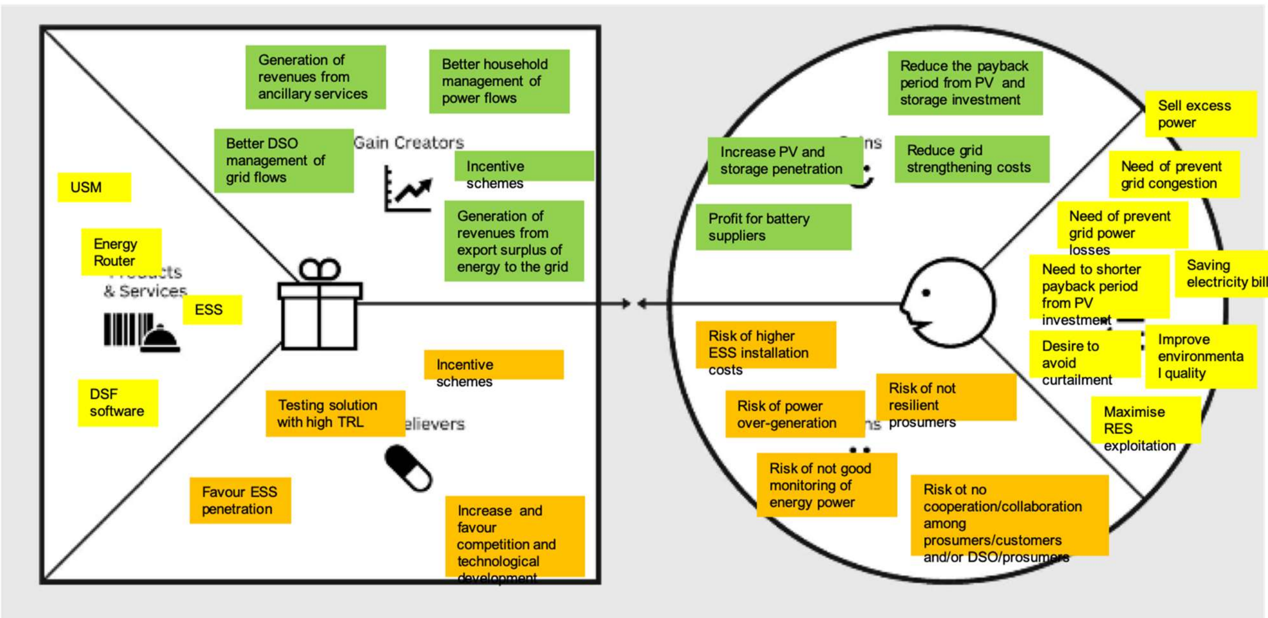


Figure 39 – Value proposition for HLUC-1 from Prosumer and DSO point of view

5.3 Value Network

The value network deals with the distribution of the Bucharest business case ideas. Thus, the main values of the HLUC, meaning providing storage as a service, obtaining a smooth impact on the grid (business as usual, reduced impact of an active distribution network drawbacks) while having high PV penetration and enhanced resilience for the end-user, need to be distributed among the interested stakeholders.
Since the Bucharest test site is part of a teaching institution, the outcome of the HLUC-1 solution and its business case will be promoted through university channels, meaning to teach the concepts to students, to promote the solution to end-users wanting to become prosumers, to energy communities, to energy services companies which see as an opportunity to become solution providers of resilient prosumers and communities.

5.4 GAP analysis

The gap analysis presented in Table 17 aims to pinpoint gaps between the current situation with PV penetration and low coordinate storage systems and future resilient storage system and APs.

Table 17 – Gap analysis related to the Bucharest scenario

Perspective	Gap	Severity for Prosumers	Severity for DSO
Static	Difficulty to manage the surplus of energy in a coordinate way	A	B
	Lack of efficient peak energy management	B	B
	Increase of grid strengthening maintenance costs due to PV penetration (high OpEx)	D	A
	Difficulty of grid management and planning due to the energy surplus during peak period	B	B
Dynamic	High investment costs for storage systems	A	A
	Difficulty to avoid curtailment (missed revenues or savings)	C	C
	Difficulty to coordinate PV and storage management in a local context	B	B
	Difficulty to reach the EU environmental target	D	B

5.5 PESTLE and STOF analysis

Table 18 leverages the PEST(EL) formalism to bring to the fore macro changing factors that are in place in the energy storage sector.

Table 18 – PEST(EL) analysis for HLUC-1

Area	Factor	Relevance for HLUC-1 deployment
Political	Incentive/subsidies schemes	Low
	Regulation stability	Medium
	Taxes and charges	High
Economic	Cost of capital	Medium
	Cost/price for storage	High
	System costs (energy routers, etc.)	Low
	GDP increasing	Medium
	Ease of access to credit (debt, equity, etc.)	Medium
	Venture capital	Low
Social	Marketing for increasing environmental awareness and desire for reliability and resiliency	Medium
	Penalties to incentive the prosumer motivation and behaviour and self-consumption	High
	Ease to have contractual systems that favour P2P or agreement between prosumers and power consumers or grid managers	Medium/High
	EV market development	High
Technological	Technological improvement of storage systems	High
	S4G technical solution	High
	Increasing of ESS patent	Medium
Environmental	Solar irradiation	Medium
	European RES target	High
Legal	No restriction to manage and own an ESS	High
	Quality assurance	High
	Legal framework to ESS	High

The STOF formalism collects and systematizes endogenous forces (i.e., levers that stakeholders internal the ES context can control, i.e., DSO and prosumers) that are driving the HLUC-1 transition investigated by S4G project. The repertoire of endogenous driving forces is expounded in Table 19.

Table 19 – STOF analysis for HLUC-1

Domain	Perspective(s)	Possible driving forces
Service		New service deployment (ancillary, flexibility, balancing services, etc.)

	Description of value proposition (added value of the service offering) and target segments	Self-consumption rate
Technology	Description of functional and non-functional requirements	Curtailment risk
		Quality risk
		Grid balance needs
		High penetration of intermittent renewables (endogenous)
Organization	Description of the structure of the multi-actor value network required to create and provide the service offering	Possibility to have aggregators or contract for exchange energy power
		Increased environmental awareness and desire for reliability and resiliency from customer point of view
		Increased environmental awareness and desire for reliability and resiliency from customer point of view
		SaaS
Finance	Description of the revenue generation logic and cost structure	Declining the costs for storage
		Likelihood to generate revenue streaming form ancillary services, flexibility services, EV, V2G power, sell excess of power (grid services revenues)
		Electricity prices
		Battery cost
		Minimum investment limit
		Grid strengthening costs

5.6 SWOT analysis

The SWOT analysis from the prosumer and DSO perspectives are shown in Table 20.

Table 20 – SWOT analysis for prosumer (HLUC-1)

Strength	Weaknesses
• Investment in ESS and PV already exists, investment in energy router is cheap, and the service is an "extra" • Payment for SaaS can be low (?) • Maximizing the RES-based electricity generation (due to network	• Needs communication to DSO/control entity • Needs "declared availability" of storage • Storage is depreciated by extra-cycles to serve the prosumer (who is not the owner of storage)

constraints, part of this available energy will not be wasted)	
Opportunities	**Threats**
• Avoid curtailment • Most benefits directed to the prosumer which in this way is maximizing initial investment in (for example) PV • Lower loss of energy for the community • Incentive for other prosumer to invest in a cooperative storage system in order to get opportunities for revenues or savings	• Storage owner is not incentivized to cover depreciation of storage life • Does this local system work in lager community with higher number of prosumers and more complex grid?

Table 21 – SWOT analysis for DSO (HLUC-1)

Strength	**Weaknesses**
• The solution can support the early adoption of new technologies • The solution enables a better use of the planet resources • Can benefit from ancillary services	• The need to invest in new devices (USM, ER, LESSAg and DSF software); • It is not BaU, needs several years to build confidence in the strengths
Opportunities	**Threats**
• The chance to support the RES production while maximizing its transformation and use in electricity • Having advanced software on the field it can be possible to discover unpredicted anomalies in the grid functionality • High reporting rate USM facilitates advanced knowledge on typical load curves • Dc link proposal and direct use of electricity in DC form enables further advancement of LV DC microgrids as a universal solution	• Low TRL might not gain momentum for fostering large uptake of the solution; • Potential decrease of benefits (monetary) of DSO (due to lower figures in the invoices) might block voluntarily the deployment of proposed solution; • Regulatory barriers might hinder deployment (for example, storage status as both load and generator, non-acceptance of prosumer's operational conditions in PCC etc.)

5.7 Business model canvas

In this paragraph we would propose a Business Model Canvas of HLUC-1 for the sellers of ESS is shown in Table 22.

Table 22 – The Bucharest Business Model Canvas for ESS suppliers

<table>
<tr><td colspan="6">

- **PUC-1: Grid strengthening and ancillary services simulation (providing services for the DSO)**
- **PUC-2: Advanced self-resilient prosumers (ASRP)**
- **PUC-3: Resilient hybrid cooperative ecosystem**

</td></tr>
<tr>
<td rowspan="2">Key Partners
• Installers
• Mediator
• ICT

<u>Value chain network:</u>
• DSO
• Prosumers
• Storage owners</td>
<td colspan="2">Key Activities
• Selling batteries
• Setting set-points at local owned batteries
• R&D and design
• Innovation development
• Software development
• Manufacturing and assembling software
• Marketing
• Building and maintenance chargers</td>
<td rowspan="2">Value Proposition
• Cost reduction and savings from grid power consumption for the prosumers
• Reducing grid congestion and costs for DSO
• Avoid curtailment
• Permit the integration of energy from prosumers into the grid, controlled by the service provider (can be DSO)</td>
<td>Customer Relationship
• Customers are encouraged to become "partners" (PUC-1), cooperative prosumers (PUC-2) and create an ecosystem (PUC-3);
• Provide technical assistance to customers along the years (installation, maintenance, etc.)
• Brand and reputation
• Self-service</td>
<td rowspan="2">Customer Segments
• Prosumers
• PV owners
• Green community: new potential PV owners in a cooperative environment
• Middle and higher class</td>
</tr>
<tr>
<td colspan="2">Key Resources
• Salespeople
• Manufacturing facilities
• Intellectual resources (engineers)</td>
<td>Channels
• Personal sale
• Advertising
• DSO partnership</td>
</tr>
<tr>
<td colspan="3">Cost Structure
• Components
• Manufacturing
• Technology development
• Engineering salaries
• Support
• Marketing
• Operation cost</td>
<td colspan="3">Revenue Streams
• Asset (battery integrated or not with PV system) sale (PUC-2 and PUC-3)
• Installation fee (PUC-2 and PUC-3)
• Supporting activity fee</td>
</tr>
</table>

The Bucharest Business Model Canvas for DSO and prosumers is show in Table 23.

Table 23 – The Business Model Canvas HLUC-1 for DSO and prosumers

<table>
<tr><td colspan="5">

- **PUC-1: Handle over-generation from RES into the grid (avoid curtailment orders from DSO)**
- **PUC-2: Advanced self-resilient prosumers (APRS) – Prosumer will act always as a consumer from the grid side and has internal DC network for high resilience**
- **PUC-3: Resilient hybrid cooperative ecosystem - Enabling energy services to connected neighbourhood prosumers and consumers**

</td></tr>
<tr>
<td rowspan="2">Key Partners
• Energy Storage suppliers
• Installers
• Mediator
• ICT

<u>Value chain network:</u>
• DSO</td>
<td>Key Activities
• Curtailment activities
• Building and maintenance chargers</td>
<td rowspan="2">Value Proposition
• Cost reduction and savings from grid power consumption for the prosumers
• Reducing grid congestion and costs for DSO
• Avoid curtailment</td>
<td>Customer Relationship
• Customers are encouraged to become "partners" (PUC-1), cooperative prosumers (PUC-2) and create an ecosystem (PUC-3);</td>
<td rowspan="2">Customer Segments
• Prosumers
• PV owners
• Green community: new potential PV owners in a cooperative environment</td>
</tr>
<tr>
<td>Key Resources</td>
<td>Channels</td>
</tr>
</table>

• Prosumers • Storage owners	• Grid-Planning people • Grid-operation people	• Permit the integration of energy from prosumers into the grid, controlled by the service provider (can be DSO)	• Internal network	
Cost Structure • Payment for ancillary services • Operation costs • Support			**Revenue Streams** • Postpones or avoid reinforcement • Savings from grid strengthening	

5.8 Conclusion

Due to the low TRL nature of HLUC-1 and the small-scale of the Bucharest test site, a complete validation of business models is out of scope of S4G.

In the business case of avoid curtailment with/without storage capacity a threat is represented by the fact that storage owner is not incentivized to cover depreciation of storage life and this can block the business case.

For the business case of advanced self-resilient prosumer the resulting solution is ensuring a load-only pattern on distribution grid side for an existing prosumer, by adding the storage unit and an intelligent ER, is superior to classic net-metering, with or without storage BtM, with two main advantages: savings attractiveness and in resilience, including resilience against regulatory changes and market variability for the locally (prosumer) generated electricity.

In the PUC-3 the business case will be relevant by enabling energy services (based on new technology) to connected neighbourhood prosumers and consumers. An important opportunity consists in the reduction of the energy/electricity consumption cost on the long term.

6 Final Business Models in the Bolzano test site

This chapter elaborates an improvement of the Italian business cases respect what has been already depicted in D2.2 [S4G-D2.2] and D2.3 [S4G-D2.3]. This business case is based on the deployment of cooperative EV charging in a place, Bolzano, where the growth of intermittent power generation from RES and the diffusion of EVs are very high, generating the strong need of efficient management and grid stability. This scenario, called "Cooperative EV charging" is tested in a residential case and a commercial case.

6.1 Overview of use cases and related business cases for the Bolzano test site

Table 24 and Figure 40 gives an overview of use cases and related business cases for the Bolzano test site.

Table 24 – Overview of the business models for the Bolzano test site

Business Model ID	Title	Target market	Time horizon
HLCU-2-PUC-1-BM-1	Residential Prosumer with ESS "stand alone" (base line)	Private houses with PV and EV	Short
HLCU-2-PUC-1-BM-2	Prosumer with grid integration	Private houses with PV and EV + DSO	Medium
HLCU-2-PUC-2-BM-1	Cooperative charging at commercial or fleet level	Commercial sites with EVs fleet	Medium

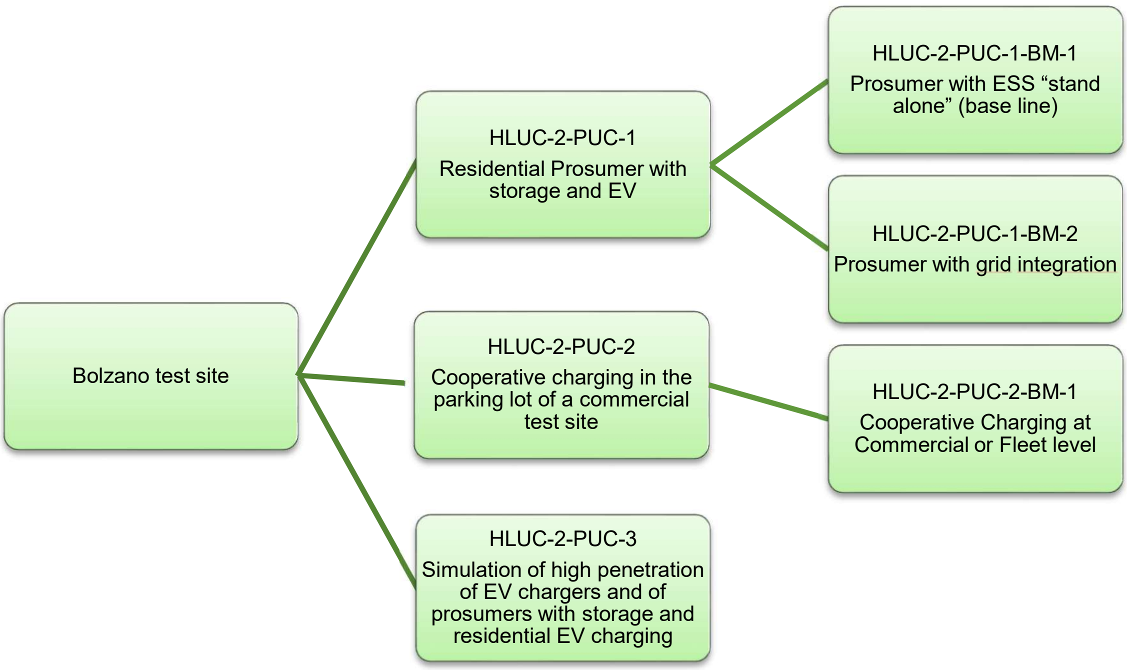


Figure 40 – Overview of use cases and related business case for the Bolzano test site

6.2 Background and expected impact for HLUC-2

Bolzano is a city of Alto Adige – Südtirol – an alpine region in northern Italy, characterized by a high share of RES, mainly hydropower. During the last decade the region showed a large increase in the amount of small, distributed PV plants connected to the low voltage grid. In 2016, the number of PV in Alto Adige was around 415 plants (240 in Bolzano and 174 in Trento) with an installed power of 415 MW and a constant increasing across the years (GSE, 2016). Edyna, the main DSO of the area, connects to its MV and LV grid more than 4.5 thousand PV plants with an overall installed power of 146 MW. On the other hand, large predictable loads (e.g. from high-consuming, heavy industry) are quickly decreasing in the area. Distributed, less predictable loads (e.g. EV fast-charging stations) are taking their place. Alto Adige is the region with the highest number of registered EVs in Italy, around 1,369 EVs[lxv]. As of today, in Alto Adige around 250 EVs are already active using a network of 35 public charging stations operated by the local utility Alperia, but the diffusion of EVs is currently growing significantly.

In order to allow European utilities, such as Alperia, to pursue their deployment plan regarding the EV charging infrastructure, while avoiding heavy investments in strengthening the grid, methodologies for planning, evaluating and controlling storage installations communicating and cooperating with EV charging systems are studied within the S4G project.

We can identify a set of different typologies of business model for EV charging station[lxvi]:

- DSO management, where the deployment of the infrastructure can be done by DSO (concession) in the area where DSO operates
- Service provider in a monopoly market, where only one industrial enterprise can operate after a tendering process or in concession in a specific area decided by region or municipality
- Service provider in a competitive market, where more enterprises can compete to build charging stations in a specific area regulated by region or municipality (similar to the current gasoil distributors business models)
- Commercial EV charging, where Retailers, shopping centres, hotels, fast food outlets, car parking providers and all kinds of business with off street parking can now offer EV charging with low effort. Commercial EV charging can also be a more strategic move from a larger chain, such as a hotel group or fast food chain.

6.3 Stakeholders Analysis

The main actors involved in this business case are the DSO, prosumers, storage owners, suppliers of technologies, service companies, investors, EV owners and suppliers. Hereafter, Table 25provides a description of their main characteristics.

Table 25 – Stakeholder analysis for HLUC-2

Stakeholder	Role	The stakeholders' contribution and position	Possibility to affect the project	Actions toward the stakeholder
Prosumers	Investor, storage owner, seller of energy surplus connected to the PV system and the grid	Increase self-consumption and maximise the investment in ESS and PV	Can offer ancillary services with storage, being able to control voltage and autonomous peak shaving	Information about the advantage of the storage
EV owners	Investor in EV and sellers of energy surplus with EV	Increase self-consumption and maximise the investment in ESS and	Can offer ancillary services with storage	Information about the advantage of the storage

	charging station (e.g., V2G)	EV. The vehicle owner or fleet manager becomes both a consumer and seller of electrical energy and capacity. V2G could be an additional opportunity that may present additional revenue for fleets by providing ancillary services, analog to individual EV owner.		
EV fleet owners	Investor in EV vehicles and sellers of energy surplus with EV charging station	A fleet owner could consider V2G as an additional revenue source, but would need to understand the risk of the investment and how it would affect the core business. The fleet vehicles are in use mostly during the day and are parked after working hours[lxvii]. V2G opportunities may present additional revenue for fleets by providing ancillary services, analog to individual EV owner. A fleet owner could consider V2G as an additional revenue source, but would need to understand the risk of the investment and how it would affect the core business. The fleet vehicles are in use mostly during the day and are parked after working hours	Can offer charging station and ancillary services with storage	Information about the advantage of the storage

DSO (around 135 in Italy and 2 in South Tyrol)	Balance Compliance, storage owner, compliance with technical (Italian Energy Authority) and voltage quality, balance dispatching (in the future?)	Grid-owner, committed to ensure maximum RES-based energy (sustainability), has the means to dispatch energy and power among the controlled entities, distribute and collect energy surplus among consumers. Decrease the maintenance costs and reduce or defer reinforcement	Demand local voltage regulation Demand local balancing aggregates	None
Suppliers of technology	Service and technology provider	Seller of batteries, ER, USM, etc.	Invest in technology development	Favour storage deployment when prices decrease
Aggregators	Balancing service provider	Utilities and DSOs may not wish to do business with thousands of small providers of battery storage. In this case, it will be the task of an independent third party with expertise in communication networks and customer application deployment to aggregate small storage capacities into MW blocks and steer the charging process of each ESS and EV within this virtual power plant.		Favour information about storage deployment
Vehicle manufacturers	Provider of EV and V2G	Vehicle manufacturers participate in a highly competitive market. The electrification of the automobile has begun to negatively affect the after sales revenues of automobile manufacturers. Entering the energy	Invest in technology development	None

		industry could be a way to compensate for lost revenue. A bidirectional port enabling V2G services can become an attractive quality of an EV contributing to the value of the car. On the contrary, additional charge and discharge cycles caused by V2G reduce the battery lifetime and could increase automotive warranty costs, conflicting with the interest of a vehicle manufacturer[lxviii].		

6.4 Value Proposition

Figure 41 gives an overview of the value proposition for the HLUC-2.

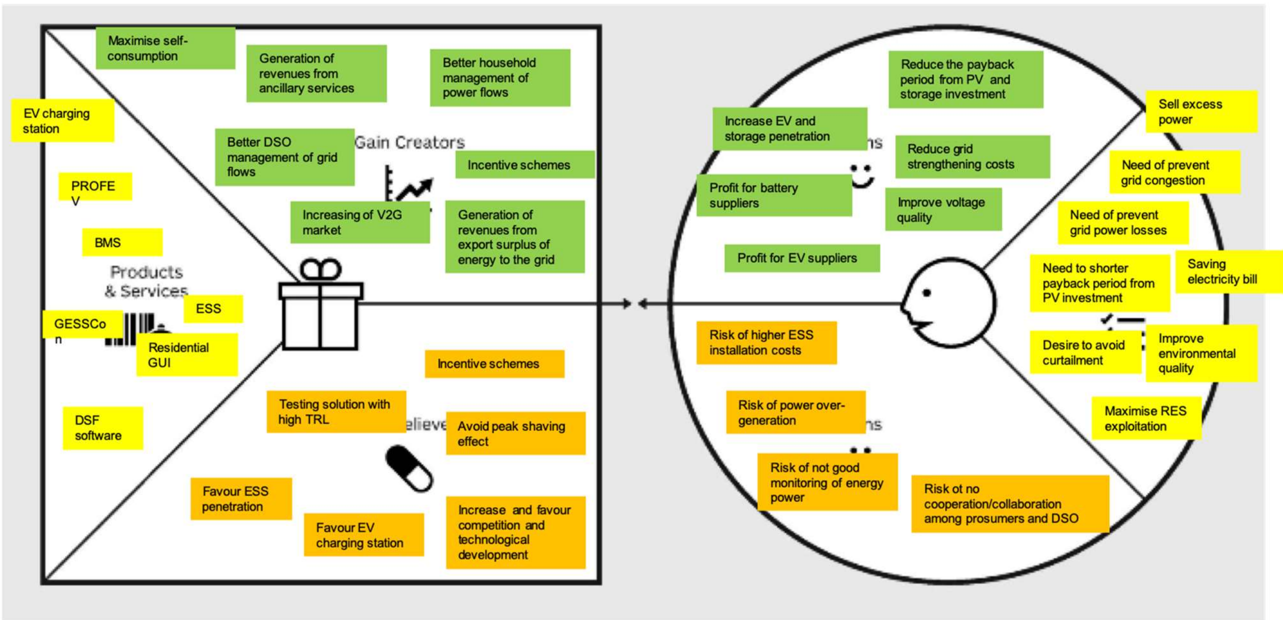


Figure 41 – Value proposition for HLUC-2 from Prosumer and DSO point of view

6.5 GAP analysis

As for HLUC-2, now we propose a gap analysis meant to pinpoint gaps between the current situation with PV and EV penetration and future resilient storage system that, besides being under the spotlight in the sectoral grey literature, have been extracted by D2.2 [S4G-D2.2] story-telling and D2.3 [S4G-D2.3] business models (Table 26).

Table 26 – Gap analysis related to the scenario HLUC-2

Perspective	Gap	Severity for Prosumers	Severity for DSO
Static	Difficulty to manage the surplus of energy due to PV and EV penetration	B	A
	Lack of efficient peak energy management	A	B
	Increase of grid strengthening maintenance costs due to PV and EV penetration (high OpEx)	D	A
	Difficulty of grid management and planning due to the energy surplus during peak period	B	A
	Peak shaving effect	A	C
Dynamic	High investment costs for ESS and/or PV+ESS	A	D
	Difficulty to avoid curtailment (missed revenues or savings)	B	C
	Difficulty to coordinate PV, EV and storage management in a local context	C	B
	Difficulty to reach the EU environmental target	D	B

6.6 PESTLE and STOF analysis

The gap analysis previously outlined is complemented by the exogenous forces analysis, which aims to scan possible external forces – that neither stakeholders internal the ES context can control (i.e., DSO and prosumers) – which affect the transition to ESS scenario with resilient prosumers and cooperative storage system. Table 27 and Table 28 show the PEST(EL) and STOF analysis for HLUC-2, respectively.

Table 27 – PEST(EL) analysis for HLUC-2

Area	Factor	Relevance for HLUC-2 deployment
Political	Economic incentives by local and state government for EVs	High

	Stability of a long run regulation	High
	Reducing asymmetric information and information about best solution for customers and DSO	Medium
	Taxes and charges (most of energy bill is taxes and fixed prices)	High
	Change in energy policy	
Economic	Cost of capital	High
	Cost/price for storage (decreasing)	High
	System costs (energy routers, etc.)	Low
	GDP increasing	Medium
	Ease of access to credit (debt, equity, etc.)	Medium
	Venture capital	Medium
Social	Marketing for increasing environmental awareness and desire for reliability and resiliency	Medium
	Penalties to incentive the prosumer motivation and behaviour and self-consumption	High
	Ease to have contractual systems that favour P2P or agreement between prosumers and power consumers or grid managers	Medium/High
	EV market development	High
	Increasing quality and life	High
	Buying EV can be depicted as a status symbol, people are becoming more environmental conscious. Increasing popularity of low-carbon lifestyles.	High
Technological	Technological improvement and effectiveness of storage and EV systems	High
	S4G technical solution	High
	Increasing of ESS patent	Medium
	More effective storage and PV systems may cause an increasing market in the future	Medium
	Likelihood to have V2G	High
Environmental	Solar irradiation	Medium
	European RES target and climate change and carbon reduction. Government aims to achieve carbon reduction as every other nation	High
Legal	No restriction to manage and own an ESS	High
	Quality assurance	Medium
	Legal framework to ESS	High

	The energy market is very hard regulated in Italy: most of the energy bill is taxes and fixed prices	High

Table 28 – STOF analysis for HLUC-2

Domain	Perspective(s)	Possible driving forces
Service	Description of value proposition (added value of the service offering) and target segments	New service deployment (ancillary, flexibility, balancing services, etc.)
		Self-consumption rate
Technology	Description of functional and non-functional requirements	Curtailment risk
		Quality risk
		Grid balance needs
		Depreciation rate for ESS
		High penetration of intermittent renewables (endogenous) and of EVs or V2G solution
Organization	Description of the structure of the multi-actor value network required to create and provide the service offering	Increased environmental awareness and desire for reliability and resiliency from customer point of view
		Increasing number of EV chargers
Finance	Description of the revenue generation logic and cost structure	Declining the costs for storage, EV and V2G
		Likelihood to generate revenue streaming form ancillary services, flexibility services, EV, V2G power, sell excess of power (grid services revenues)
		Electricity prices
		Battery cost
		Minimum investment limit
		Grid strengthening costs
		Bureaucracy costs

6.7 Business rationale

As the cost of batteries, fuel cells, and renewable energy decreases, it is becoming clear that energy storage will be a big business in the future. It can smooth out the variability inherent with wind and solar, provide valuable services to the grid, and shift cheap renewable energy produced during the daytime hours, to when it is most needed, as for example in the evening.

In Bolzano, the business rationales are various, according to the different business models, and they will be described in the following sections. In general, the business rational for the Cooperative EV charging scenario is that it is possible to make business by installing and controlling batteries for maximizing the consumption of self-produced PV energy and for minimizing the maximal power of the grid connection (peak shaving).

6.8 Residential prosumer with storage and EV: HLUC-2- PUC-1

This use case focuses on the residential installation of individual charging systems for EVs where the prosumers has already installed also a PV system. The residential case is tested in a private house provided with a PV roof plant of 9.6 kW, and 1 plug for classical charging of the EV. During the first year of the project the house was provided by Alperia with an ESS of 12 kWh.
This use case has been divided in two different subset of business models:

- BM-1: that considers the prosumers with a "stand alone" ESS
- BM-2: that integrates the BM-1 in order to have prosumers with grid integration.

6.8.1 Prosumers with ESS "stand alone" (baseline): HLUC-2- PUC-1-BM-1

This business model is the baseline for the other business models concerning the residential prosumer in the Italian context and in the Bolzano test site, and it will investigate if it is profitable for a residential prosumer with an EV charging station to invest money in a residential ESS. The prosumer has the following advantages, by adopting an ESS:

- Can store the surplus of local energy and use it during the evening, thus maximizing the self-consumption of the PV production;
- Avoids the upgrade of the contractual maximum power at the Point of Delivery (POD), thanks to the "peak shaving" effect of the ESS;
- Can obtain a shorter payback period and a short run return on investment (if price of battery will decrease in next years).

Private costumers have invested in RES such as PV systems, which in certain circumstances increase the voltage level and affect the flux and creates reverse energy flow in the feeder lines of the local DSO. The same private customers have EV with a charging station at home, which requests a higher contractual power with the DSO. A high number of EV charging stations is a potential threat for the distribution network because of the relative high request on power. The preconditions for this business model are:

- Investment in storage solutions must be more economically beneficial for the prosumer than to inject the overproduction of electricity into the grid;
- The ESS can be controlled in such a way that peaks of injected or withdrawn power are avoided (peak shaving).

6.8.1.1 Business rationale

The business rationale of this business model is that it is possible to make a business for prosumers by installing ESS for maximizing the consumption of self-produced energy and for minimizing the maximal power of the grid connection (peak shaving). If this statement is confirmed, private house owners, or other investors, are encouraged to install ESS in connection to local PV production and/or EV charging.
This way the prosumer can offer a sustainable solution to the DSO, whereby the prosumer gets as much out of his investment in the PV-system and increase his private business case, and the DSO avoids or postpones grid strengthening.
This business model does not take in account the possibility to offer ancillary services to the DSO (that will be considered in the HLUC-2-PUC-1-BM-1, but the DSOs can indirectly benefit from the installation of ESS in terms of enhanced voltage quality and defer investments in traditional grid reinforcements. The whole electrical system can benefit of ESS in terms of production – load balancing.

Furthermore, final consideration about suppliers of batteries should be considered since their economic benefit from high storage penetration could be relevant. Following an endogenous path, high penetration means the increasing of the demand of ESS and, consequently, increasing investment for suppliers in technology development and innovation and, in turns, decreasing of price batteries in the long run.

6.8.1.2 Value Network Analysis

Figure 42 gives an overview of the VNA.

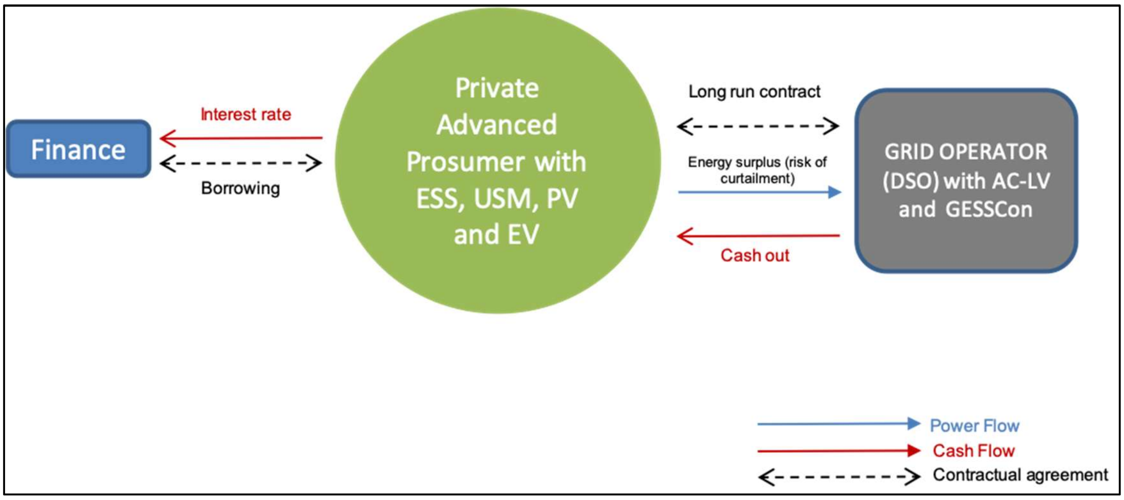


Figure 42 - Value Network Analysis – HLUC-2-PUC-1-BM-1

6.8.1.3 SWOT analysis

SWOT analysis for this business model from the prosumer and DSO perspective is show in Table 29 and Table 30.

Table 29 – SWOT analysis for PROSUMER perspective (HLUC-2-PUC-1-BM-1)

Strength	**Weaknesses**
• Ease of storage deployment • Autonomous management of ESS and PV • In the future, maybe economically interesting to increase self-consumption and reduce costs • Possibility to find new business opportunities	• At the moment in Italy is not very convenient due the possibility to use the grid as storage with the exchange on site • Still too expensive at the moment (even if in some regions in Italy there are public incentives)
Opportunities	**Threats**
• If the EV market expands, it will be necessary to have peak shaving of power needed for charging EVs	• Time for return of investment is very long and, in the meantime, external conditions (legal, economical…) could change

• If the PV market expands, it will be necessary to avoid load peaks in the evening hours • Increasing the solar penetration can lead the system operator to curtail solar to balance the grid during peak hours	

Table 30 – SWOT analysis for DSO perspective (HLUC-2-PUC-1-BM-1)

Strength	**Weaknesses**
• No further investment for the DSO • Possibility to find new business opportunities	• At the moment in Italy is not very convenient due the possibility to use the grid as storage with the exchange on site • DSO has no possibility to control and rely on the prosumer • Reliability of the DSO is not guaranteed
Opportunities	**Threats**
• If the EV market expands, it will be necessary to have peak shaving of power needed for charging EVs • If the PV market expands, it will be necessary to avoid load peaks in the evening hours • Increasing the solar penetration can lead the system operator to curtail solar to balance the grid during peak hours	• There is no possibility to control from the DSO point of view

6.8.1.4 Profitability analysis

This section provide a quantitative analysis of the BM-1. The supply and demand of power on the electricity grid must be in balance 24 hours a day, 7 days a week. Wind and solar energy are growing very fast and this is making it more challenging than ever to absorb peaks and troughs.
The new paradigm of the electricity market is linked to the growing use of distributed generation, both in terms of supply capacity to the market and in terms of flexibility offered to network operators for its continuous balancing.
It is in this context that the so-called "virtual" configurations arise, consisting in the aggregation of consumption units and / or production units, not necessarily located in the same site.
New electricity market players such as "aggregators" or "balancing service providers (BSPs)" emerge as protagonists in the most recent business models to which the competitive frontier is moving.
Recently, also Italy, through the introduction of Resolution 300/2017 by the Italian Authority for Energy (ARERA), has launched a series of pilot projects to allow also distributed generation to participate to the

Dispatching Services Market (MSD). Also aggregated storage system will be allowed to participate to this market.
At the same time, end-users or prosumers with PV would like to increase their self-consumption by installing a storage system. Now in Italy these systems are still not convenient from an economic point of view.
For the context of S4G project, a set of different economic simulation with the technique of the Discounted Cash Flow (DCF) and Net Present Value (NPV) theory have been carried out from Alperia by considering the point of view of the prosumer, who has invested in an ESS. The goal was to assess the convenience for a private prosumer equipped with a photovoltaic system to install a storage system. The purpose of the simulations was to answer the question: with current battery prices and taking into account the incentives available, is it currently convenient in Italy to install a small photovoltaic system equipped with a storage system?
The simulation was conducted in two situations. First, the discounted cash flow of the investment for a new ESS added to an existing PV system was calculated. Second, a new investment of a PV system plus an ESS was simulated. In both cases the prosumer had the possibility to do a Net Energy Metering contract with the DSO, this is the real actual case in Italy.
The input data have been taken from the residential test site. The cost of the ESS, the FiT, and the cost of the energy are taken from the real case. Regarding the total cost for ESS (with a battery size around 12 kWh), we consider the cost for battery (around 60% of the total cost), the installation and transport cost (around 22% of the total cost), inverter (16% of the total cost) and SM cost (2% of the total cost). As revenue, only the maximization of the self-consumption has been considered but not the peak shaving effect, because presently the regulation of the inverter does not allow peak shaving. Finally, we consider also an expected decreasing of battery price of around 7% per year, based on the current literature.
Respect D2.3 [S4G-D2.3], we consider four different sub-scenarios for the economic computation based on different hypothesis of the model.

- **BM-1a**: In the first scenario, we fix as main strong hypothesis to have a 20-years lifetime for ESS (i.e., the entire length, timeline, of the investment for prosumers) and the price of batteries to be constant.
- **BM-1b**: In the second scenario, we relax the previous hypothesis since we consider a 7-years lifetime for battery and the price of batteries to be constant.
- **BM-1c**: The third scenario is based on considering a 7-years lifetime for battery, as before, but the price of batteries decreases along the time of the investment with a rate of decreasing around 7% per year (assumption based on many references of the literature we find).
- **BM-1d**: The fourth scenario considers the same assumptions of the third scenario but with a deferral investment of different years. Through a numerical simulation and based on the current market hypothesis, we compute how many years the investment should be postponed in order to be feasible.

In the first simulation, BM-1a, we have a comparison between two situations: one with ex-post installation of ESS since prosumers already invested in PV system, the other with ex-ante installation of ESS+PV. In the former, the discounted cash flow is always negative (Figure 43). This is because the net energy metering contract, which the prosumer already has, is very convenient, and allows him to “store” the overproduction in the distribution grid, while being paid for it, and also to withdraw it when needed. This policy creates a lack of incentive to self-consumption.
In the second case, the initial investment of PV and ESS is higher, but the final Internal Rate of Return (IRR) is positive, because the revenues of the self-consumption compared with the situation before the investment are much higher (Figure 44).
This, of course, looking only to the economic side, while consumers are often driven to adopt a battery also for "ethical-political" reasons, such as being more independent and using the clean energy produced with the sun as much as possible. This is demonstrated by data on the domestic storage market in Italy, which has grown strongly in the last year with 10 thousand installed batteries and + 71% on 2016 (according to the European Market Monitor on Energy Storage commissioned by EUASE to Delta Energy).

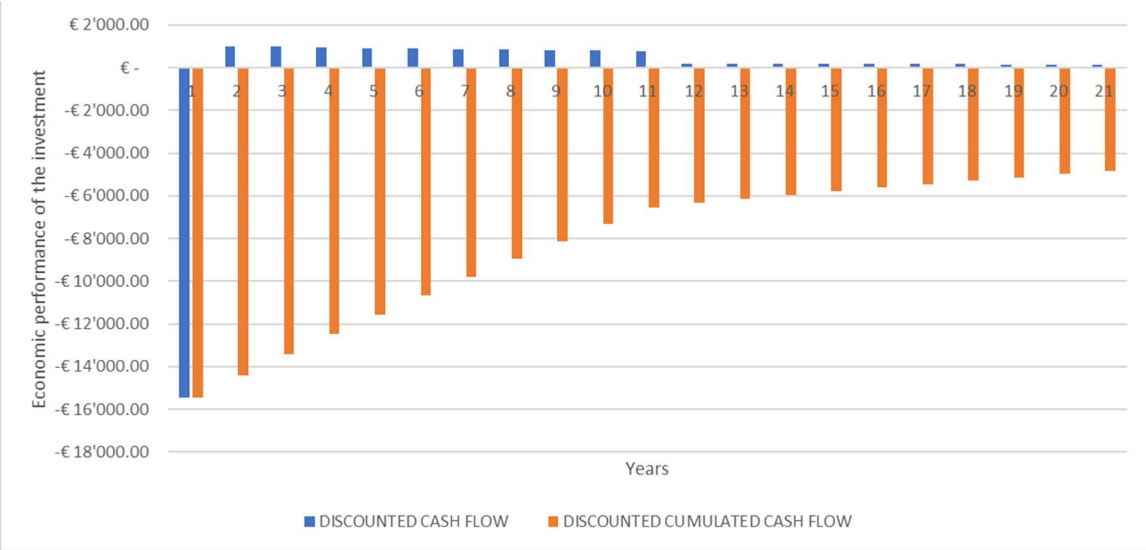


Figure 43 – Discounted cash flow of a new ESS in the presence of an existing PV system (BM-1a)

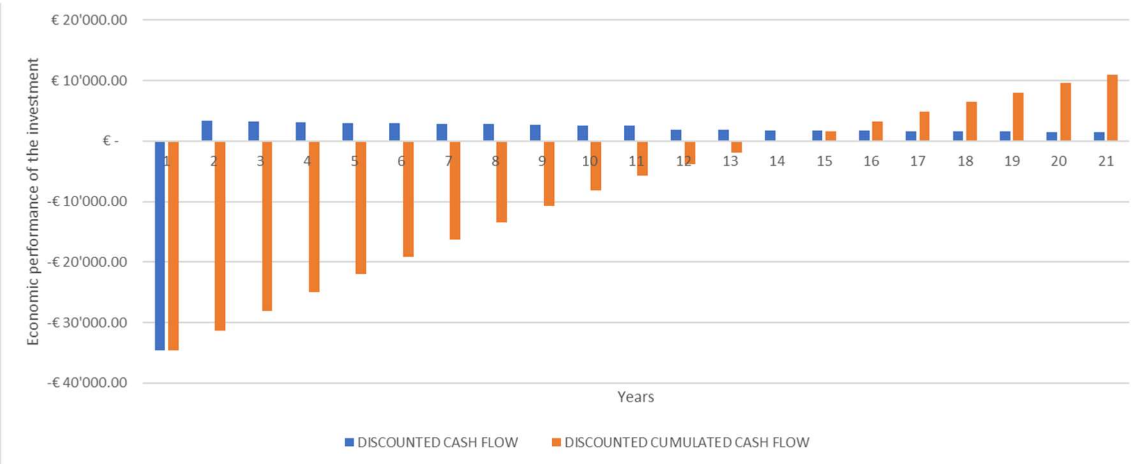


Figure 44 - Discounted cash flow of a new ESS and PV system (BM-1a)

In this context, it could be interesting both for a utility like Alperia, and for a prosumer to investigate the possibility to join the MSDby aggregating and managing a certain number of distributed ESS. In Italy, this market has a high potential and is exceeding EUR 1.5 billion. In this scenario, the principal outputs of the simulation are:

- The Pay Back Time is 13 years
- The Internal Rate of Return is 4.13 %
- The Net Present Value is 2,800 €

In the second scenario, BM-1b, the payback period is over 20 years (Figure 45).

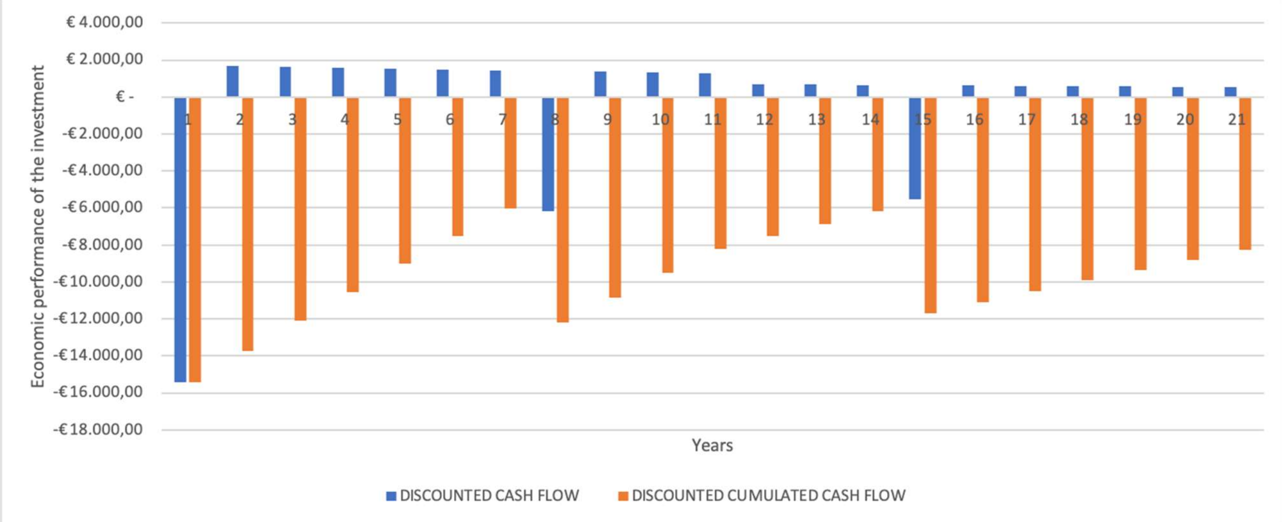


Figure 45 – Discounted cash flow of a new ESS and PV system (BM-1b)

In BM-1c, the payback period is also over 20 years, even if the payback seems to be shorter (Figure 46).

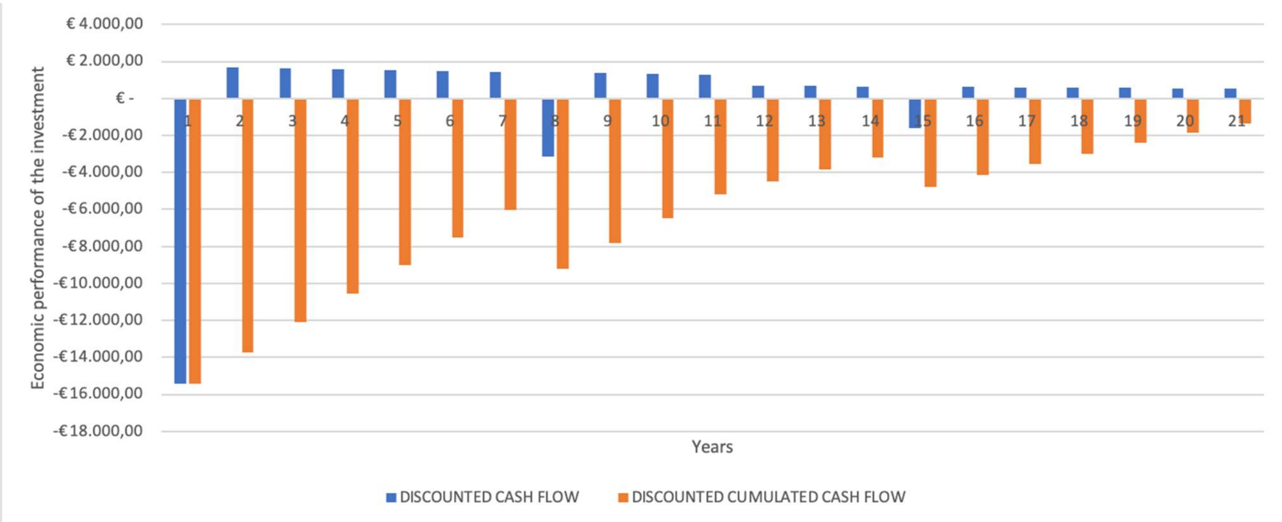


Figure 46 – Discounted cash flow of a new ESS and PV system (BM-1c)

Finally, in BM-1d, we make numerical simulation for a deferral investment and we find the optimal investment should be postponed at least of 5 years (Figure 47).

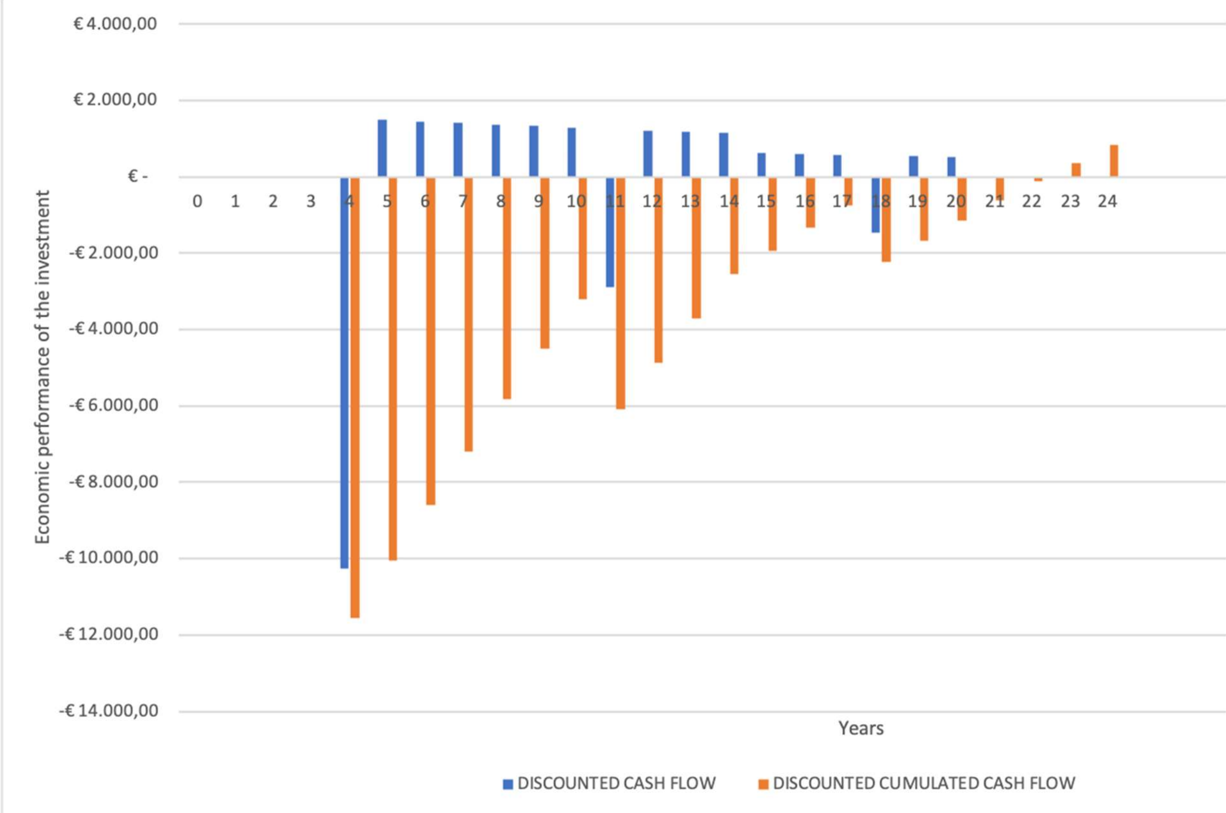


Figure 47 – Discounted cash flow of a new ESS and PV system (BM-1d)

Looking at the outputs of the previous scenarios, it is clear that the use of ESS in the residential sector is still far from being profitable with the actual conditions, namely costs and storage system lifetime, and the Italian regulatory framework.

6.8.1.5 Business model canvas

In this section, we propose different Business Model Canvas of HLUC-2-PUC-1-BM-1 for the sellers of ESS and EV, and for DSO and prosumers, as shown in Table 31.

Table 31 – Business Model Canvas for ESS and EV suppliers (HLUC-2-PUC-1-BM-1)

Key Partners • Installers • ICT <u>Value chain network:</u> • DSO • Prosumers • Storage owners • EV charging station owner • EV suppliers	**Key Activities** • Selling batteries • Setting set-points at local owned batteries • R&D and design • Innovation development • Software development • Manufacturing and assembling software • Marketing • Building and maintenance chargers	**Value Proposition** • Cost reduction and savings from grid power consumption for the prosumers • Reducing grid congestion and costs for DSO • Avoid curtailment • Permit the integration of	**Customer Relationship** • Customers are encouraged to become "partners" (PUC-1), cooperative prosumers (PUC-2) and create an ecosystem (PUC-3); • Provide technical assistance to customers along the years	**Customer Segments** • Prosumers • PV owners • Green community: new potential PV owners in a cooperative environment • Middle and higher class

		energy from prosumers into the grid, controlled by the service provider (can be DSO)	(installation, maintenance, etc.) • Brand and reputation • Self-service	
	Key Resources • Salespeople • Manufacturing facilities • Intellectual resources (engineers)		**Channels** • Personal sale • Advertising • DSO partnership	
Cost Structure • Components • Manufacturing • Technology development • Engineering salaries • Support • Marketing • Operation cost			**Revenue Streams** • Asset (battery integrated or not with PV system) sales • Installation fee • Supporting activity fee	

The Business Model Canvas of HLUC-1-PUC-1 for DSO and prosumers is show in Table 32.

Table 32 – The Business Model Canvas for DSO and prosumers (HLUC-2-PUC-1-BM-1)

Key Partners • Energy Storage suppliers • Installers • ICT <u>Value chain network:</u> • DSO • Prosumers • Storage owners • EV charging station owner • EV suppliers	**Key Activities** • Curtailment activities • Building and maintenance chargers • Investigating claims from prosumers with voltage issues • Setting set-points at local owned batteries to control charge/discharge on demand **Key Resources** • Grid-Planning people • Grid-operation people	**Value Proposition** • Cost reduction and savings from grid power consumption for the prosumers • Reducing grid congestion and costs for DSO • Avoid curtailment • Provide ancillary services • Avoid the upgrade of the contractual maximum power at the POD thanks to the peak shaving effect of (Decision Support System (DSS) • Maximise the self-consumption • Avoid grid strengthening costs and, at the same time, guarantee stable grid	**Customer Relationship** • Customers are encouraged to install ESS • **Channels** • Internal network	**Customer Segments** • Prosumers • Small SME

Cost Structure	**Revenue Streams**
• Payment for ancillary services • Operation costs • Support	• Postpones or avoid reinforcement • Savings from grid strengthening

6.8.1.6 Conclusion

Looking at the outputs of the previous sections, it is clear that the use of ESS in the residential sector is still far from being profitable with the actual conditions (costs and storage system lifetime, Italian regulatory framework). A deferral investment in the next 5 years could push towards a more viable investment if some conditions about future trends of ES costs will be verified. Bureaucracy costs currently have a high percentage (one third of the overall costs) for investing in a residential storage system.

6.8.2 Prosumers with grid integration: HLUC-2- PUC-1-BM-2

This second business model concerns the possibility for prosumers to make business by providing ancillary services to DSO by installing batteries in addition to the benefits obtained by the BM-1. In this case, private house owners or other investors are encouraged to install batteries in connection to local PV production and EV charging. This way, the prosumer can offer a sustainable solution to the DSO, whereby the prosumer gets as much out of his investment and increase his private business case and the DSO avoids or postpones grid strengthening. In this scenario, it is considered that the DSO has the possibility to control the battery management system (BMS) of the prosumer and to coordinate ESS and EV charging. The DSO's business model (i.e., savings) is:

- To avoid or defer investments in traditional grid strengthening;
- To enhance the voltage quality without other investments;
- To keep the system balanced – without curtailment of RES.

Private costumers have invested in RES such as PV systems, which in certain circumstances increase the voltage level and affect the flux creating reverse energy flow in local feeder lines.

The same private customers use one or more EVs, with a charging station at home, which requests a higher contractual power with the DSO. Investment in storage solutions must be more economically beneficial for the prosumer than to inject the overproduction of electricity into the grid. In addition to this benefit, it is possible for the prosumer to sell ancillary services to the DSO. The prosumer gives the possibility to the DSO to control the BMS and receives for this an economical benefit. The ESS must be controlled in such a way that the DSO needs have priority over the prosumer needs.

6.8.2.1 Value Network Analysis

Figure 48 gives an overview of the VNA.

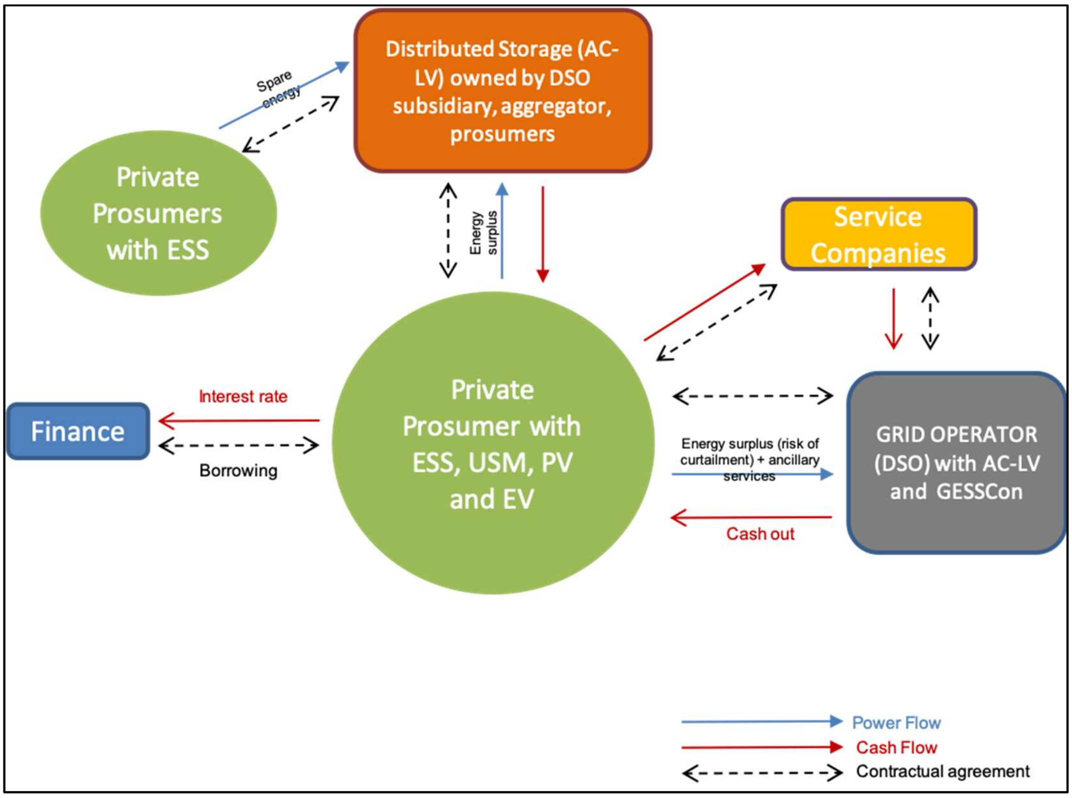


Figure 48 - Value Network Analysis – HLUC-2-PUC-1-BM-2

6.8.2.2 *SWOT analysis*

SWOT analysis for this business model from the prosumer and DSO perspective is show in Table 33 and Table 34.

Table 33 – SWOT analysis for PROSUMER perspective (HLUC-2-PUC-1-BM-2)

Strength	**Weaknesses**
• Ease of storage deployment • Autonomous management of ESS and PV • Revenues from ancillary services (new business models)	• Still too expensive at the moment (even if in some regions in Italy there are public incentives) • Prosumers make investment in ESS's BMS, but it is controlled by an external entity (i.e., DSO)
Opportunities	**Threats**
• If the PV market expands, it will be necessary to avoid load peaks in the evening hours • Increasing the solar penetration can lead the system operator to curtail solar to balance the grid during peak hours	• Time for return of investment is very long and, in the meantime, external conditions (legal, economical…) could change

Table 34 – SWOT analysis for DSO perspective (HLUC-2-PUC-1-BM-2)

Strength	**Weaknesses**
• Easy to establish • No further investment for the DSO • Autonomous • Possibility to find new business opportunities	• At the moment in Italy is not very convenient due the possibility to use the grid as storage with the exchange on site • Reliability of the DSO is not guaranteed • Complexity to control several (high number) of little storage
Opportunities	**Threats**
• If the PV market will expand, it will be necessary to avoid load peaks in the evening hours • Possibility for DSO to have new business models and opportunities • There is possibility to control BMS from the DSO	• Necessity to use external signal • Need of communication infrastructure Data security

6.8.3 Business model canvas

In this section, we propose different Business Model Canvas of HLUC-2-PUC-1-BM-2 for the sellers of ESS and EV, and for DSO and prosumers, as shown in Table 35.

Table 35 – Business Model Canvas for ESS and EV suppliers (HLUC-2-PUC-1-BM-2)

<table>
<tr><td colspan="5"></td></tr>
<tr>
<td rowspan="2">Key Partners
• EV suppliers
• ESS suppliers
• Installers
• ICT

<u>Value chain network:</u>
• DSO
• Prosumers
• Storage owners
• EV charging station owner
• EV suppliers</td>
<td>Key Activities
• Investigating claims from prosumers (or other customers with voltage issues)
• Selling batteries
• Setting set-points at local owned batteries
• R&D and design
• Innovation development
• Software development
• Manufacturing and assembling software
• Marketing
• Building and maintenance chargers</td>
<td rowspan="2">Value Proposition
• Cost reduction and savings from grid power consumption for the prosumers
• Reducing grid congestion and costs for DSO
• Avoid curtailment
• Permit the integration of energy from prosumers into the grid, controlled by the service provider (can be DSO)</td>
<td>Customer Relationship
• Customers are encouraged to become cooperative prosumers with the DSO;
• Provide technical assistance to customers along the years (installation, maintenance, etc.)
• Brand and reputation
• Self-service</td>
<td rowspan="2">Customer Segments
• Prosumers
• PV and EV owners
• Green community: new potential PV owners in a cooperative environment with the grid
• Middle and higher class</td>
</tr>
<tr>
<td>Key Resources
• Salespeople
• Manufacturing facilities
• Intellectual resources (engineers)</td>
<td>Channels
• Personal sale
• Advertising
• DSO partnership</td>
</tr>
</table>

Cost Structure	**Revenue Streams**
• Components • Manufacturing • Technology development • Engineering salaries • Support • Marketing • Operation cost	• Asset (battery integrated or not with PV system; EV) sales • Installation fee • Supporting activity fee

The Business Model Canvas of HLUC-2 for DSO and prosumers is show in Table 36.

Table 36 – The Business Model Canvas for DSO and prosumers (HLUC-2-PUC-1-BM-2)

Key Partners • Energy Storage suppliers • Installers • ICT <u>Value chain network:</u> • DSO • Prosumers • Storage owners • EV charging station owner • EV suppliers	**Key Activities** • Curtailment activities • Building and maintenance chargers • Investigating claims from prosumers with voltage issues • Setting set-points at local owned batteries to control charge/discharge on demand **Key Resources** • Grid-Planning people • Grid-operation people	**Value Proposition** • Cost reduction and savings from grid power consumption for the prosumers • Reducing grid congestion and costs for DSO • Avoid curtailment • Provide ancillary services • Avoid the upgrade of the contractual maximum power at the POD thanks to the peak shaving effect of DSS • Maximise the self-consumption • Avoid grid strengthening costs and, at the same time, guarantee stable grid	**Customer Relationship** • Customers are encouraged to install ESS and connect to the grid (become partners, cooperative prosumers) **Channels** • Internal network	**Customer Segments** • Other prosumers • Small SME • DSO

Cost Structure	**Revenue Streams**
• Payment for ancillary services (for DSO) • Operational costs • Support	• Postpone and avoid reinforcement • Savings from grid strengthening • Revenue streams (for prosumers)

6.8.4 Conclusion

This business model appears to be more economically attractive from the point of view of the prosumer, because it allows a multiple use of the batteries, that in addition to maximizing the self-consumption and reducing the contractual power can provide ancillary grid services and thus have an additional revenue.

This business case will be relevant to defer reinforcement for the DSO, but it is foreseen a big risk in having third party owned storage to secure grid stability.

6.9 Cooperative charging in the parking lot of a commercial test site (HLUC-2-PUC-2)

This use case to which we associated the related business model is about testing cooperative charging in the parking lot of a commercial test site.

6.9.1 Cooperative charging at Commercial or Fleet level: HLUC-2-PUC-2-BM-1

This business model will investigate if it is profitable for a commercial site (or a Company Fleet site) with some EV charging stations to invest money in an ESS with or without a PV plant. The commercial site has the following advantages by adopting an ESS:

- Can store the surplus of local energy (eventually produced by the PV plant) and use it for charging EVs in the evening or in other high load moments, thus maximizing the self-consumption of the PV production
- Avoids the upgrade of the contractual maximum power at the POD, due to the peak shaving effect of the ESS
- The commercial site avoids important modification of internal electrical plant (installation of transformer cabin)
- The DSO avoids strengthening the grid.

Only this business model is analysed, where no active role of DSO is considered, which leads to general conclusions valid for commercial sites willing to do the investment itself internally or for provider aiming to offer a new service to customers (commercial sites or companies having fleet of EVs).

6.9.1.1 Business rationale

The commercial site has invested in RES such as PV systems, which in certain circumstances increase the voltage level and affect the flux and creates reverse energy flow in the feeder lines of the local DSO. The same commercial site has or accept many EVs with charging stations, which requests a higher contractual power with the DSO. A high number of EV charging stations is a potential threat for the distribution network because of the relative high request on power. The preconditions for this business model are:

- Investment in storage solutions (higher respect to residential ones) must be more economically beneficial for the commercial site than to inject the overproduction of electricity into the grid;
- The ESS can be controlled in such a way, that peaks of requested power over contractual conditions with DSO for EV charging can be managed.

The business rationale is that it is possible to make a business for the commercial site by installing ESS for maximizing the consumption of self-produced energy and for minimizing the maximal power of the grid connection (peak shaving). If this statement is confirmed, private commercial sites owners or other investors are encouraged to install batteries in connection to local PV production and/or EV charging.
This way the commercial site can offer a sustainable solution to the DSO, whereby the commercial site gets as much out of his investment in the PV system and increase his private business case, and the DSO avoids or postpones grid strengthening.
The DSOs can indirectly benefit from the installation of ESS in terms of enhanced voltage quality and defer investments in traditional grid reinforcements. The whole electrical system can benefit of ESS in terms of production and load balancing.

6.9.1.2 Value Network Analysis

Figure 49 gives an overview of the VNA.

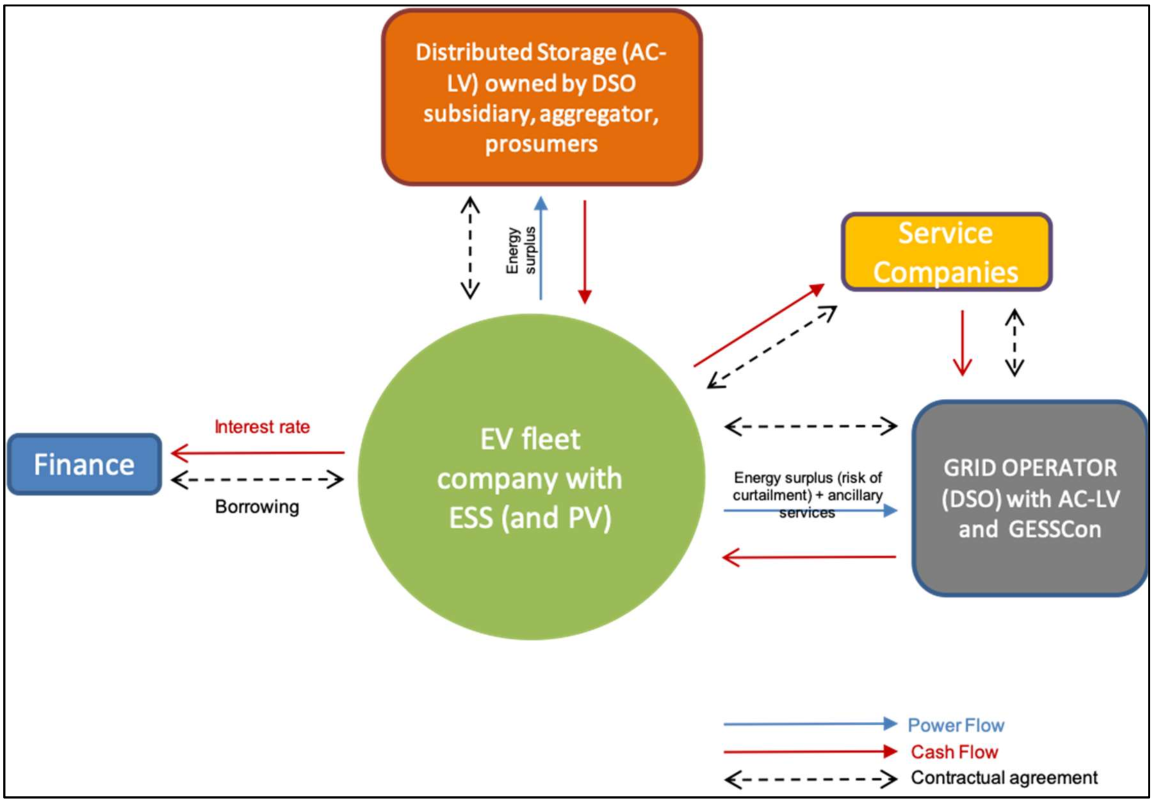


Figure 49 - Value Network Analysis – HLUC-2-PUC-2-BM-1

6.9.1.3 SWOT analysis

SWOT analysis for this business model from the prosumer and DSO perspective is show in Table 37 and Table 38.

Table 37 – SWOT analysis for EV fleet company perspective (HLUC-2-PUC-2-BM-1)

Strength	**Weaknesses**
• Ease of storage deployment • Autonomous management of ESS and PV • Revenues from ancillary services and balancing systems (new business models) • Reducing peak shaving effect	• Still too expensive at the moment (even if in some regions in Italy there could be public incentives) • Need to have a clear contractual agreement with DSO • Avoid modification of internal electrical plants
Opportunities	**Threats**
• Possibility to open new business opportunity from the deployment of V2G business scenarios	• Time for return of investment is very long and, in the meantime, external conditions (legal, economical…) could change

• If the EV market will expand, it will be necessary to avoid load peaks in the evening hours	

Table 38 – SWOT analysis for DSO perspective (HLUC-2-PUC-2-BM-1)

Strength	**Weaknesses**
• Easy to establish • No investment for the DSO • Autonomous	• At the moment in Italy is not very convenient due the possibility to use the grid as storage with the exchange on site • To find trade off with the alternative of reinforcing internal electrical distribution (change transformer, increase power)
Opportunities	**Threats**
• If the PV market will expand, it will be necessary to avoid load peaks in the evening hours • If the EV market will expand, it will be necessary to peak shaving of power needed for charging EVs • It does not require electrical and civil modifications • Likelihood to have incentives	• No possibility to control from DSO point of view

6.9.1.4 Business model canvas

In this paragraph, we propose different Business Model Canvas of HLUC-2-PUC-2-BM-1 for the sellers of ESS and EV, and for DSO, as shown in Table 39.

Table 39 – Business Model Canvas for EV fleet companies (HLUC-2-PUC-2-BM-1)

Key Partners	**Key Activities**	**Value Proposition**	**Customer Relationship**	**Customer Segments**
• EV suppliers • ESS suppliers • Installers • ICT <u>Value chain network:</u> • DSO • Fleet companies • EV charging station owner • EV suppliers	• Purchasing batteries • Increasing supply for EVs • Innovation development • Marketing • Building and maintenance chargers **Key Resources** • Intellectual (engineers) and operational resources (workers)	• Cost reduction and savings from grid power consumption • Reducing grid congestion and costs for DSO • Avoid curtailment • Permit the integration of energy from prosumers into	• EV fleet companies are encouraged to become cooperative prosumers with the DSO • Brand and reputation **Channels** • Personal sale • Advertising • DSO partnership	• EV customers • DSO • Green community: new potential EV owners in a cooperative environment with the grid • Middle and higher class

		the grid, controlled by the service provider (can be DSO)		

Cost Structure	Revenue Streams
• Components • Engineering salaries • Support • Marketing • Operational cost	• Asset (battery integrated or not with PV system; EV) sales • Installation fee (PUC-2 and PUC-3) • Supporting activity fee • Revenues from ancillary services

The Business Model Canvas of HLUC-2-PUC-2 for DSO and prosumers is show in Table 40.

Table 40 – The Business Model Canvas for DSO (HLUC-2-PUC-2-BM-1)

Key Partners	Key Activities / Key Resources	Value Proposition	Customer Relationship / Channels	Customer Segments
• Energy storage suppliers • EV fleet companies • Installers • ICT <u>Value chain network:</u> • DSO • EV owners • ESS owners • EV charging station owner • EV suppliers	**Key Activities** • Curtailment activities • Building and maintenance chargers • Investigating claims from prosumers with voltage issues • Setting set-points at local owned batteries to control charge/discharge on demand **Key Resources** • Grid-Planning people • Grid-operation people	• Cost reduction and savings from grid power consumption for the prosumers • Reducing grid congestion and costs for DSO • Avoid curtailment • Provide ancillary services • Avoid the upgrade of the contractual maximum power at the POD thanks to the peak shaving effect of DSS • Maximise the self-consumption • Avoid grid strengthening costs and, at the same time, guarantee stable grid • Increase quality power	**Customer Relationship** • EV fleet companies are encouraged to install ESS and connect to the grid (become partners) **Channels** • Internal network	• Other EV owners • Small SME • DSO

Cost Structure	Revenue Streams
• Payment for ancillary services • Operational costs	• Postpone and avoid reinforcement • Savings from grid strengthening

6.9.1.5 Conclusion

This business model appears to be more economically attractive from the point of view of the commercial site, because it allows multiple use of the ESS, that in addition to maximizing the self-consumption and reducing the contractual power can provide grid services and thus have an additional revenue.
This business case will be relevant to defer reinforcement for the DSO.
The rentability analysis is general, so it can be both used by commercial sites willing to invest internally or by an external provider aiming to offer the complete service to third parts.

6.10 Simulation of high penetration of EV chargers and of prosumers with storage and residential EV charging: HLUC-2-PUC-3

With respect to a future scenario with higher EV penetration, the DSF-SE will simulate the maximum possible amount of EVs and charging stations which can be supported by the existing grid (without additional grid strengthening). The outcomes will show the potential and limits of storage and cooperative charging in today's grid topology. Part of the model for simulation in the DSF-SE for the optimal EVs deployment and economic results will be described in the next chapters related to the HLUC-3 where a deep description of the DSF-SE for the use cases of Fur/Skive is presented.

6.11 Conclusion

Three business models have been developed both for the residential and the commercial test sites. HLUC-2-PUC-1-BM-1 is the baseline for all other business calculations and shows that the use of ESS in the residential sector is still far from being profitable with the actual conditions (costs and lifetime of the storage system, Italian regulatory framework). With a deferral investment of 5 years and with the current trends for decreasing price batteries, we find some economic viability for prosumers. Incentives and subsidies play, as usual, a crucial role for a more pervasive storage penetration, as was for the PV penetration in the past years. However, a regulatory challenge related to wholesale market design can stimulate the flexibility services to be sold in "competitive" wholesale markets (e.g., energy, ancillary services, etc.) and to become the ES implementation more economically viable.
Looking at the outputs of this study on possible business models for Bolzano, it is clear that to be economically attractive from the point of view of the commercial and residential sites, a multiple use of the ESS is required, that in addition to maximizing the self-consumption and reducing the contractual power can provide grid services and thus have an additional revenue.

7 Final Business Models in the Fur/Skive test site

This chapter concerns the Danish business cases related to use cases presented in D2.2 [S4G-D2.2] and D2.3 [S4G-D2.3]. Business models have been already elaborated in D2.3 [S4G-D2.3] at different levels depending on how close they are estimated to be to the market and the possibility to implement them in the test site. In this deliverable we add further business analysis to each business case and we develop a first draft of an economic model where to simulate, in particular, the use cases HLUC-3-PUC-1, HLUC-3-PUC-2, HLUC-3-PUC-3 and HLUC-3-PUC-4-BM-1.

7.1 Overview of use cases and related business cases for the Fur/Skive test site

Table 41 provides a detailed overview of the different business models and some key notes.

Table 41 – Overview of key notes for business models related to HLUC-3.

Business Model ID	Title	Key Pains targeted	Value Proposition	Target market	Time horizon
HLUC-3-PUC-1-BM-1	Baseline	State of the art	-	-	-
HLUC-3-PUC-2-BM-1	Autonomous voltage control at household battery	Grid Stability, security in supply, where is the optimal place to place storage	Stable grid at lowest cost	Private houses	Short
HLUC-3-PUC-3-BM-1	Voltage control at grid side battery	High voltage levels due to PV penetration	The DSO can easily be compliant in voltage	DSOs	Medium
HLUC-3-PUC-4-BM-2	Voltage control at both household and grid side battery	Grid stability, security in supply. Much more production than consumption in local feeder lines	Stable grid at lowest cost	Private house owners and DSO	Medium
HLUC-3-PUC-4-BM-3	Flux control and load shaving at households with PV and battery	Grid stability, security in supply	Stable grid at lowest cost	Private houses with batteries	Medium
HLUC-3-PUC-4-BM-4	Flux control at household battery by introducing network-controlled demand side management	Grid stability, security in supply	Stable grid at lowest cost	Private houses with RES	Long
HLUC-3-PUC-4-BM-5	Private owned virtual storage plant	Grid stability, security in supply Self sufficiency	Stable grid at lowest cost	Private houses with RES	Long

Figure 50 gives an overview of use cases and related business models.

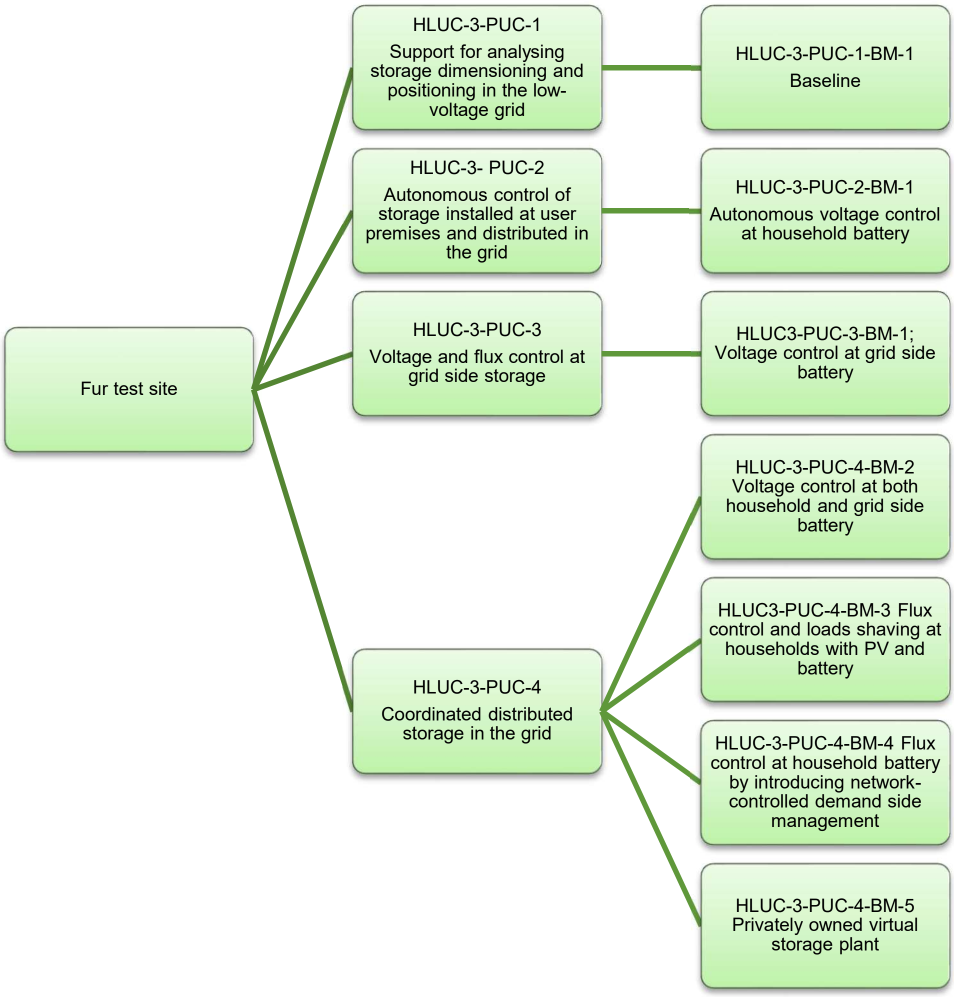


Figure 50 – Overview of use cases and related business case for the Fur/Skive test site

7.2 Background and expected impact for HLUC-3

As society is focusing on becoming more environmentally friendly and zero CO_2 emitting, the DSOs will experience an added pressure on their grid both on MV and LV grid. Basically, there are two topics that will influence the DSOs in the future: more DER production from RES installed and added consumption of electric energy as heating and transport are shifted from fossil fuels towards electricity.

Decentralized production in the LV grid in the form of PV and small wind generators gives a new energy flow. In the past, the energy flow was always top down as the energy was generated in big power plants in the HV grid and then distributed to the consumers at the LV grid. This was easier to analyse and plan. With the decentralized production, the energy flow is now shifting according to the production from DER and the consumption. With high production and low consumption, the energy will flow from the LV grid towards the higher voltage levels, causing grid loss. Besides the necessary transformation from DC produced by the RES to AC used in the HV grid, which also causes grid loss. The increasing use of RES also contributes to problems caused by unstable voltage levels in the grid. In grid planning, the transformers and the tap changers are usually designed according to the voltage drops in the cables related to the consumption, but with decentralized production the grid now experiences two situations.

1) During high production and low consumption, the voltage rises
2) During high consumption and low production, the voltage drops.

This leads to the necessity to trim the transformers in different settings during different situations. In low voltage areas, there is no monitoring and no remote control, thereby trimming is a manual task as one person must go to the transformer.
The added amount of consumption of electric energy will naturally give an added stress on the grid as this is planned according to the historical electricity consumption. With the added focus on EVs, as well as electric heating, the amount of consumed energy will experience a sudden rise for which the grid is not designed. This will ultimately increase the lower voltage in the grid, less reliable supply of electricity and more grid loss.
Same situation, but reversed, will be present when DER are producing more than the consumption is in the local grid and an unintended rise in voltage occurs, leading to grid loss and low electricity quality for the consumer, besides lower prices on selling former stored energy.
The normal way of coping with the above two problems from the DSO side will be grid strengthening by installing more and bigger cables and transformers. However, installing some kind of remote-controlled storage in the grid might help avoiding these situations and thereby avoid grid strengthening. Expected impact by installing storage is a more economical and technical business.

7.3 Stakeholders analysis

The main actors involved in this business case are the DSO, prosumers, aggregators, storage owners, suppliers of technologies, service companies, investors and ESS suppliers. Hereafter, Table 42 provide a description of the main characteristics.

Table 42 – Stakeholder analysis for HLUC-3

Stakeholder	Role	The stakeholders' contribution and position	Possibility to affect the project
DSO (around 50 in Denmark)	Balance Compliance, storage owner, compliance with technical (Danish Energy Authority) and voltage quality, balance dispatching (in the future?)	Grid-owner, committed to ensure maximum RES-based energy (sustainability) due to the issues with voltage level at local feeder line, has the power to dispatch energy and power among the controlled entities, distribute and collect energy surplus among consumers. Decrease the maintenance costs of the grid and defer reinforcement	Demand local voltage regulation Demand local balancing aggregates
Prosumers	Investor, storage owner, seller of energy surplus connected to the PV system and the grid	Increase self-consumption and maximise the investment in ESS and PV. Offer ancillary services as demand side management and/or curtailment in power injection (regulatory)	Can offer ancillary services with storage, being able to control voltage and autonomous peak shaving

Suppliers of technology	Service and technology provider	Seller of energy router, USM, etc.	Invest in technology development
Suppliers of storage	Service and technology provider	Seller of batteries and services for installation and maintenance	Invest in technology development
Aggregators or commercial market parity (CMP)	Balancing service provider	Utilities and DSOs may not wish to do business with thousands of small providers of battery storage. In this case, it will be the task of an independent third party with expertise in communication networks and customer application deployment to aggregate small storage capacities into MW blocks and steer the charging process of each ESS and EV within this virtual power plant.	Can offer ancillary services with storage, being able to control voltage and autonomous peak shaving, network-controlled demand side management

7.4 Value Proposition

Figure 51 gives an overview of the value proposition for the HLUC-3.

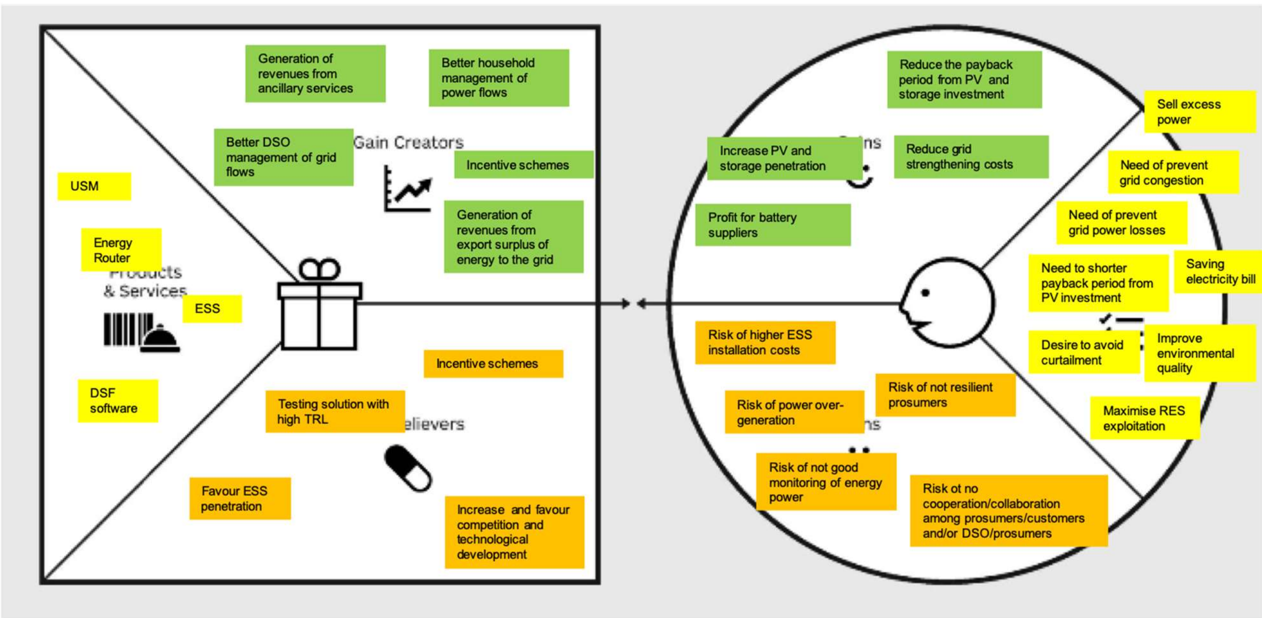


Figure 51 – Value proposition for HLUC-3 from Prosumer and DSO point of view

7.5 GAP analysis

As for HLUC-1 and HLUC-2, hereafter we design a gap analysis meant to pinpoint gaps between the current situation with PV penetration and future resilient storage system that, besides being under the spotlight in the sectoral grey literature, have been extracted by D2.2 [S4G-D2.2] story-telling and D2.3 [S4G-D2.3] business models (Table 43).

Table 43 – Gap analysis related to the scenario HLUC-3

Perspective	Gap	Severity for Prosumers	Severity for DSO
Static	Difficulty to manage the surplus of energy due to the growth of PV and EV penetration	A	A
	Lack of efficient peak energy management	A	B
	Increase of grid strengthening maintenance costs due to PV penetration (high OpEx)	D	A
	Difficulty of grid management and planning due to the energy surplus during peak period	B	A
	Peak shaving effect	A	C
Dynamic	High investment costs for ESS and/or PV+ESS for prosumers	A	B
	Difficulty to avoid curtailment (missed revenues or missed savings)	B	C
	Difficulty to coordinate PV and storage management in a local context	B	B
	Difficulty to reach the EU environmental target	D	B

7.6 PESTLE and STOF analysis

The gap analysis previously outlined is complemented by the exogenous forces analysis, which aims to scan possible external forces – that neither stakeholders internal the ES context can control (i.e., DSO and prosumers) – which affect the transition to ESS scenario with resilient prosumers and cooperative storage system. Table 44 and Table 45 show the PEST(EL) and STOF analysis for HLUC-3, respectively.

Table 44 – PEST(EL) analysis for HLUC-3

Area	Factor	Relevance for HLUC-3 deployment
Political	Economic incentives by local and state government for buying PV systems and storage	High
	Regulatory stability	High
	Reducing asymmetric information and information about best solution for customers and DSO	Medium
	Taxes and charges (most of energy bill is taxes and fixed prices)	High
	Change in energy policy	Medium
Economic	Cost of capital	Medium
	Cost/price for storage (decreasing)	High
	System costs (energy routers, etc.)	Low
	GDP increasing	Medium
	Ease of access to credit (debt, equity, etc.)	Medium
	Venture capital	Medium
Social	Marketing for increasing environmental awareness and desire for reliability and resiliency	Medium
	Penalties to incentive the prosumer motivation and behaviour and self-consumption	High
	Ease to have contractual systems that favour P2P or agreement between prosumers and power consumers or grid managers	Medium/High
	Increasing quality and life	High
	Buying PV can be depicted as a status symbol, people are becoming more environmental conscious. Increasing popularity of low carbon lifestyle	High
Technological	Technological improvement and effectiveness of storage systems	High
	S4G technical solution	High
	Increasing of ESS patent	Medium
	More effective storage and PV systems may cause an increasing market in the future	Medium
Environmental	Solar irradiation	Medium
	European RES target and climate change and carbon reduction. Government aims to achieve carbon reduction as every other nation	High
Legal	Restriction to manage and own an ESS for DSO	High

	Quality assurance	Medium
	Legal framework to ESS	High
	The energy market is very hard regulated in Denmark: most of the energy bill is taxes and fixed prices	High

Table 45 – STOF analysis for HLUC-3

Domain	Perspective(s)	Possible driving forces
Service	Description of value proposition (added value of the service offering) and target segments	New service deployment (ancillary, flexibility, balancing services, etc.)
		Self-consumption rate
Technology	Description of functional and non-functional requirements	Curtailment risk
		Quality risk
		Grid balance needs
		High penetration of intermittent renewables (endogenous)
Organization	Description of the structure of the multi-actor value network required to create and provide the service offering	Increased environmental awareness and desire for reliability and resiliency from customer point of view
		Increasing number of EV chargers
Finance	Description of the revenue generation logic and cost structure	Declining the costs for storage
		Likelihood to generate revenue streaming form ancillary services, flexibility services, sell excess of power (grid services revenues)
		Electricity prices
		Battery cost
		Minimum investment limit
		Grid strengthening costs

7.7 Business rationale

The business rationale is that it is possible to make a business out of controlling batteries both for the owner and the DSO. Private house owners or other investors are encouraged to install batteries in connection to local PV production. The storage system may be controlled by an external aggregator, who makes contracts with the DSO and the PV owner, and/or an investor. This way the battery owner can offer a sustainable solution to the DSO, whereby the PV owner gets more out of their investment in the PV-system and increase their private business case and the DSO avoids grid strengthening. The PV owner thereby get the possibility to offer ancillary services to the DSO as a solution to:

- Overcome voltage problems by managing household load and PV production with storage system
- Increase shortcut capacity in the grid with storage system (increasing robustness of grid)

- Increase both own-production and self-consumption and thereby lowering the grid losses
- And/or at grid side instead of reinforcing the local feeder lines to decrease maintenance cost or defer reinforcement.

7.8 Support for analysing storage dimensioning and positioning in the low-voltage grid: HLUC-3-PUC-1

This use case elaborates the daily operation, when grid strengthening is needed. This use case is the baseline traditional grid strengthening simulation for the other use cases in the Danish context and the Fur/Skive test site. Simulation of the baseline will run and interactions with customers are only necessary if there is the need to rent more land for transformers or if the cables need to be replaced.

7.8.1 Baseline: HLUC-3-PUC-1-BM-1

This business model calculates the cost of traditional strengthening of the grid, when more PV-systems are installed in local feeder lines.

7.8.1.1 Preconditions for the business model

Private house owners have invested in local PV production, this causes increasing voltage in local feeder lines. Which also can cause capacity issues, due to higher production compared to local consumption, this means export of electricity through the transformer representing additional grid loss. Traditionally cables are dimensioned for consumption and not for production.
The baseline is very dependent on the current topology of the grid. An overlooked of all transformer stations and feeder lines at the island of Fur were made to find feeder lines with a large penetration of PV-systems. The selected feeder line (purple) is shown in Figure 52, where the penetration is 23.73% (kWp of PV divided by size of transformer). This is a pretty high penetration for a feeder line in Denmark.

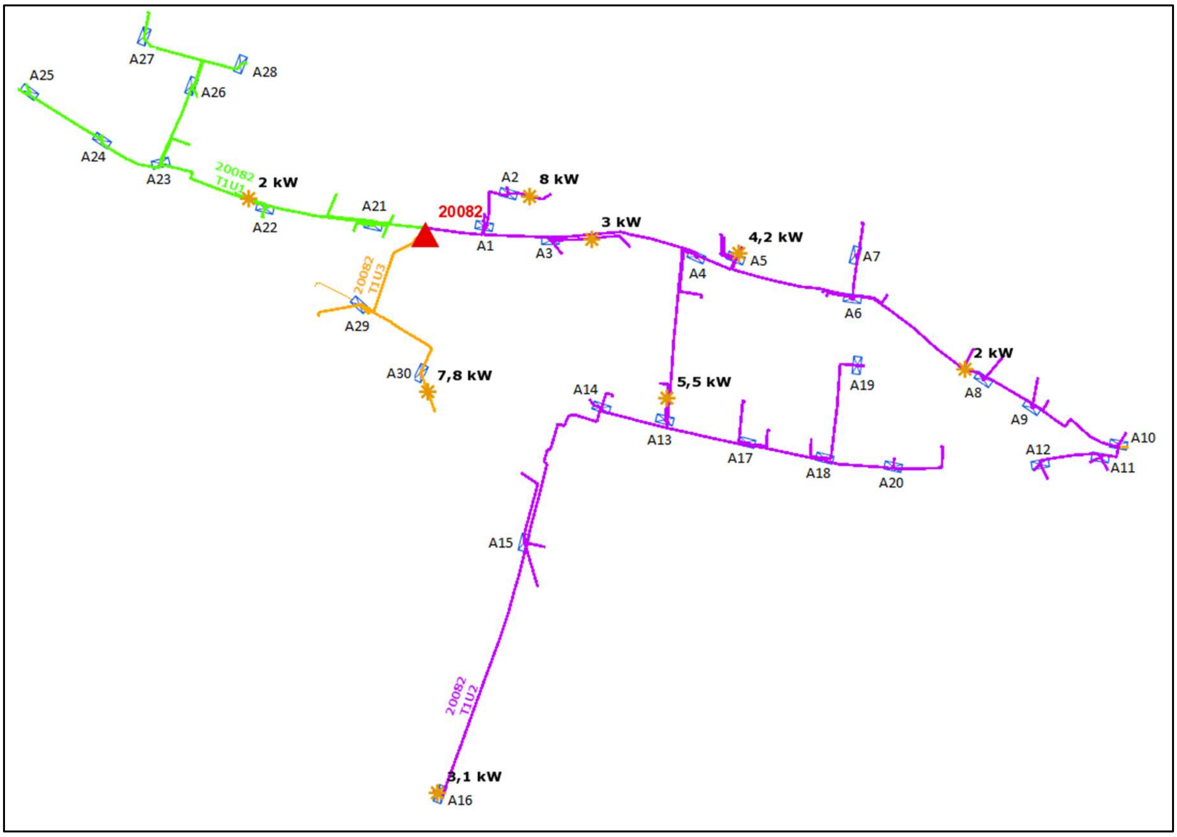


Figure 52 - Current topology in the Fur island.

This feeder line was stressed until grid strengthening is needed to create a feasible case for this baseline scenario. PV penetration is 23.73% today (35.6 kWp/150 kVA), this increasing more and more, see the results in Table 46.

Table 46 – Different scenarios of HLUC-3-PUC-1-BM-1

PV penetration	PV power	PV power/consumer	Problems
24%	36 kWp	1.24 kWp	
64%	96 kWp	3.31 kWp	ΔU
74%	111 kWp	3.83 kWp	ΔU
84%	126 kWp	4.34 kWp	ΔU
94%	141 kWp	4.86 kWp	ΔU
100%	150 kWp	5.17 kWp	ΔU

Note! U = ΔVoltage rises caused by PV production is too high. The dimension case will be on a sunny day with typical consumption in private houses. In the selected case, it was discovered that there must be flicker problems at the end of the feeder line, but no claims were received from customers. To dimension the new cases, it was chosen to use the feeder line as-is and have not strengthened it to today demands. The assumption is, that the DSO might have more feeder lines as this one, which needs to be evaluated in the future.

In each test case, it was calculated the necessary grid strengthening and related cost. These calculations are a static calculation with predesigned consumption and PV profiles. The calculations are made in the program NETPRO[lxix], developed by Danish Energy Association.

7.8.1.2 Value Network Analysis

In Figure 53 we give an overview of the VNA.

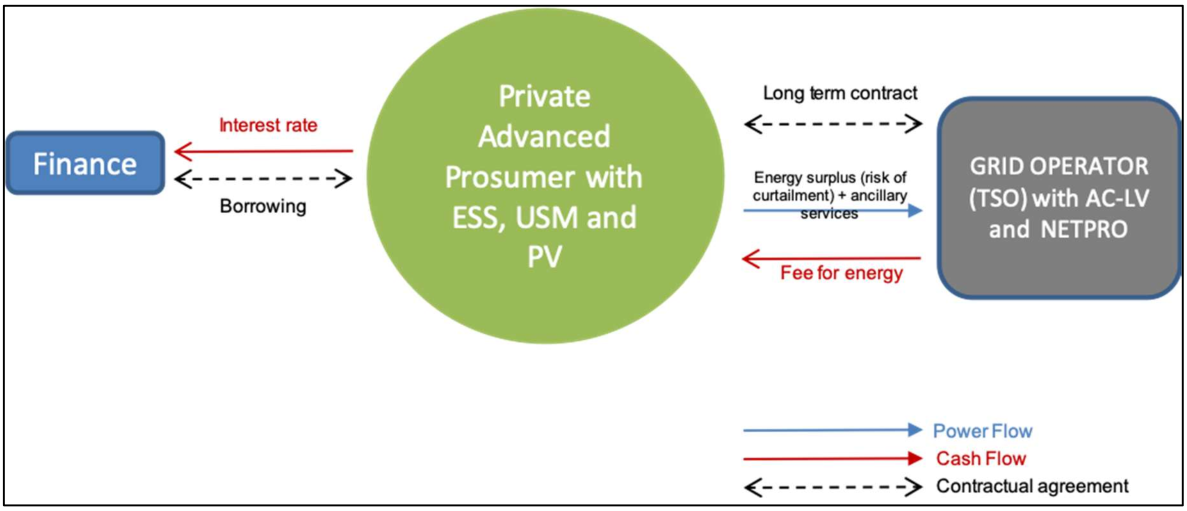


Figure 53 – VNA for HLUC-3-PUC-1-BM-1

7.8.1.3 Profitability calculations

When the grid strengthening is necessary, it is calculated the necessary cost for traditional grid strengthening in the low voltage grid (CapEx). The calculation includes (percentage of CapEx):

- Cables (37%);
- Digging (31%);
- Connection equipment, such as cable boxes (32%).

The calculation is excluding project design, management and documentation, since this will be similar as with battery calculations. The results are indicated in Table 47. In this table the maximum of kWp is 150 and it depends on the size of transformer. The main assumption is to consider each PV penetration value as a value reached starting from 0% of PV penetration at time zero (today). The table highlights also an approximate (annual) value for the maintenance cost of grid strengthening (OpEx) as a percentage of CapEx (i.e. we can suppose a 2-5% of CapEx, since it can be the price per km of cable in the low voltage grid, even if the cost for maintenance seems to be not relevant for the final computation).

Table 47 – Profitability calculations of HLUC-3-PUC-1-BM-1

PV penetration	PV power	PV power/consumer	Strengthening cost (CapEx)
24 % - flicker	36 kWp	1.24 kWp	27,300 €

64 %	96 kWp	3.31 kWp	9,850 €
74 %	111 kWp	3.83 kWp	21,000 €
84 %	126 kWp	4.34 kWp	41,600 €
94 %	141 kWp	4.86 kWp	43,100 €
100 %	150 kWp	5.17 kWp	47,500 €

In the very high penetration cases, the DSO might install a new transformer instead of traditional grid strengthening, but this has not been taken in account at this stage.

7.8.1.4 SWOT analysis

The SWOT analysis from the DSO and prosumer perspectives are shown in Table 48.

Table 48 – SWOT analysis of HLUC-3-PUC-1-BM-1 (DSO perspective)

Strength	**Weaknesses**
• For lower PV penetration DSO can limit the investment costs	• High maintenance costs for the grid in case of high PV penetration • High risk of power loss • High risk for lower power quality
Opportunities	**Threats**
• Flexible service, which can be moved around in the grid depending on the need	• More units to be controlled in the grid

7.8.1.5 Conclusions

Interesting findings are that if the grid was strengthened up till todays standard (24% flicker), the grid would be capable of consuming around 74% PV penetration without additional cost (places to strengthen the grid are almost the same for both flicker and PV penetration).
Another finding is that it is not very costly to strengthen the grid until is reached 84% of PV penetration, when more cables needs to be strengthened, which includes more cable boxes and other equipment.
In 2016 the average size of PV systems at households in Denmark was 4.33 kWp. The average is that 3.5% of all houses have PV systems (not the same as penetration according to transformer size).

Based on these indications, the economic model is going to provide a simulation results of the generic Total Cost of Ownership (TCO) function for DSO. The DSF-SE will provide a more accurate computation and description.

7.9 Autonomous control of storage installed at user premises and distributed in the grid: HLUC-3-PUC-2

This use case involves private households investing in residential storage to increase their self-sufficiency; local storage allows them to obtain more use of their own produced electricity from PV panels. These prosumers do not report the installation to ENIIG and the DSO has no access or knowledge about these installations. The BMS for these storages are autonomous and run independent of the grid. The DSO cannot remotely access the different storage systems, the local settings of the consumers are regulating the energy flow. On days where the energy production of RES is higher than the local consumption, the produced overhead is first directed to the residential storage. If the storage is fully charged, the prosumer's energy is fed back into the LV grid. On the other hand, the prosumer will first use his residential storage if the energy production from the RES is lower than the actual consumption. If the storage is empty, the prosumer will consume energy from the grid. This positively affects the costs for the prosumer, since his demand is lower compared to households without storage and RES. These local storages and BMSs run independent of the grid.

7.9.1 Autonomous voltage control at household battery: HLUC-3- PUC-2-BM-1

This business model will investigate how the DSO manages the voltage issues along the grid in order to setup voltage levels for the real-time power flow control at user premises, see Figure 54. The case is that one feeder is filled with PV penetration and that one (some) customer experiences instability electricity in their house. After investigating the problem, the DSO offers the prosumer to buy a battery and have automatic voltage control within defined limits controlled by the DSO. For this service, the DSO offers a limited payment to the prosumer. The DSO avoid reinforcing the grid or defer the reinforcement. The autonomous business model is to be understood as there is no necessity for external control. The battery controls the voltage level itself within some defined limits, with no external signals exchanged with the BMS The BMS monitors the local voltage level and regulates the level inside the demands. The BMS system does not interact with any external systems or cloud solutions.
The Prosumer gets access to a local GUI (Extended Solarweb[lxx]), where they can be informed about state of battery, state of charge, consumption, production etc.
The business case for the house owner must balance revenue from ancillary services and feed-in tariffs. In the other hand the business case must balance the DSO reinforcing cost, and expenses on ancillary services and related operational cost.
For the business model to be sustainable, the following preconditions have been identified:

- The DSO receives more claims from customers at specific feeder lines because of increased voltage levels from time to time. Specific feeders are filled with PV systems, which in specific hours increases the voltage, especially in hours with low local consumption.
- The DSO role is extended in the model by offering storage to prosumers. This is counter to legislation in some Member States, where the DSOs are facing a diminishing role in which the relation to customers is limited; the DSO being only responsible for the meter readings and distribution. This model, however, suggests a DSO role with new opportunities for smart grid engagement with customers.
- PV production sold to the grid is not in every country favourable: tariffs for selling energy to the grid are low and schemes restrict your usage (i.e. it has to be consumed what it was produced within the hour /real-time, the rest is sold (or given for free) to the grid) and a general high cost of electricity (especially distribution costs and taxes) thereby incentivising the prosumer to invest in storage.

- If the DSO shall choose this solution they must be able to trust the solution at any time, else the DSO cannot rely on this solution, therefore the prosumer has no rights to overrule DSO set-points. If the DSO cannot rely on the prosumers, they may still have voltage issues and the need of reinforcing the grid.
- Ancillary services have become common in the DSO grid

The DSO has the possibility to limit PV injection due to high voltage issues in the grid.

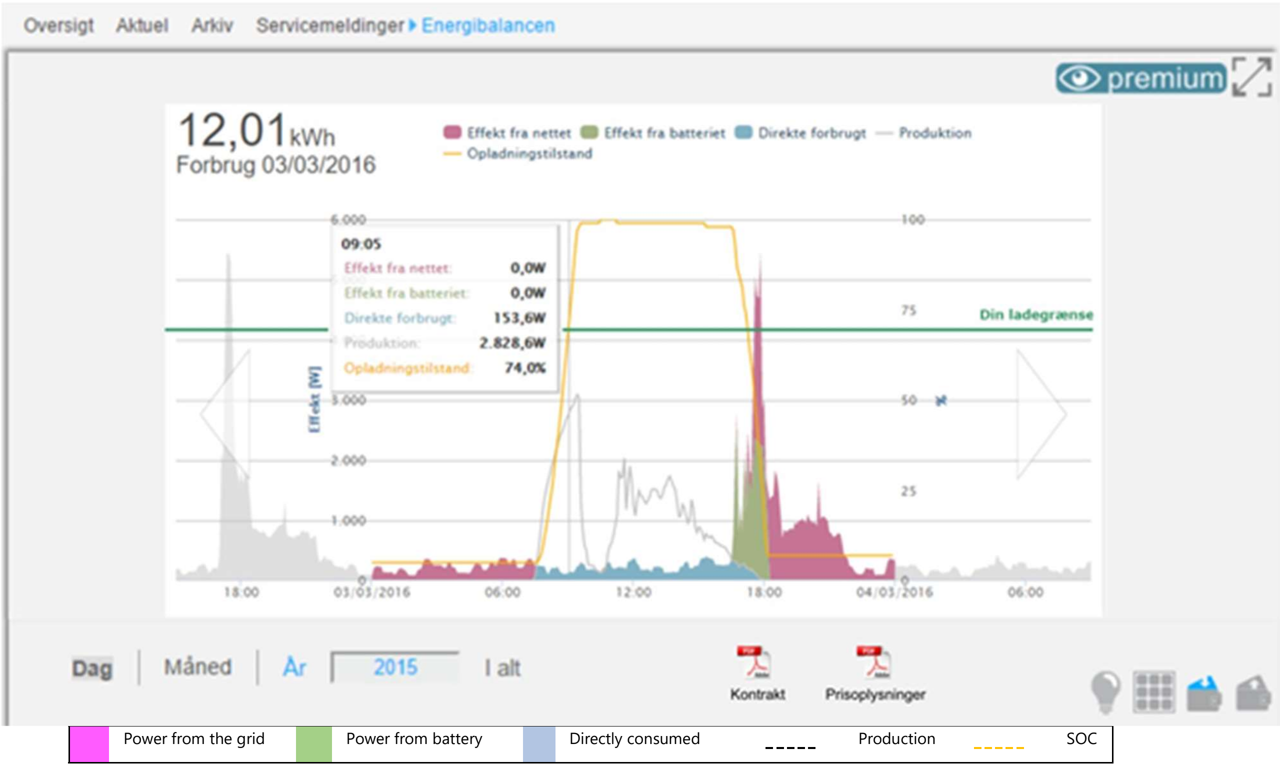


Figure 54 - Typical PV battery house consumption/production/SOC curve.

7.9.1.1 Preconditions for the business model

For the business model to be sustainable, the following preconditions have been identified:

- The DSO receives more claims from customers at specific feeder lines because of increased voltage levels from time to time. Specific feeders are filled with PV systems, which in specific hours increases the voltage, especially in hours with low local consumption.
- The DSO role is extended in the model by offering storage to prosumers. This is counter to legislation in some Member States, where the DSOs are facing a diminishing role in which the relation to customers is limited; the DSO being only responsible for the meter readings and distribution. This model, however, suggests a DSO role with new opportunities for smart grid engagement with customers.
- PV production sold to the grid is not in every country favourable: tariffs for selling energy to the grid are low and schemes restrict your usage (i.e. it has to be consumed what it was produced within the hour /real-time, the rest is sold (or given for free) to the grid) and a general high cost of electricity (especially distribution costs and taxes) thereby incentivising the prosumer to invest in storage.
- If the DSO shall choose this solution they must be able to trust the solution at any time, else the DSO cannot rely on this solution, therefore the prosumer has no rights to overrule DSO set-points. If the

DSO cannot rely on the prosumers, they may still have voltage issues and the need of reinforcing the grid.

- Ancillary services have become common in the DSO grid
- The DSO has the possibility to limit PV injection due to high voltage issues in the grid.

7.9.1.2 Stakeholder analysis

The Stakeholder analysis is show in Table 49.

Table 49 – Stakeholder analysis of HLUC-3-PUC-2-BM-1

Stakeholder	Role	The stakeholders' contribution and position	Possibility to affect the project	Actions toward the stakeholder
DSO	Compliance and grid stability	Local demand and regulation	Taking new business models into account and buying ancillary services in the distribution grid Offering storage to residential	None
Residential	Causing the voltage problem by owning local production	Investing in storage and be part of balancing the grid locally	By owning storage and allow the DSO to control it, the residential is part of the solution	Information about the need for the DSO Presenting a positive business model for the residential
ESS suppliers	Provide optimal size and quality of storage system both for substation level and residential sites	Batteries suppliers (competition)	Increase self-consumption on critical days e.g. Storage, heat-pumps or EVs	None

7.9.1.3 SWOT analysis

The SWOT analysis from the DSO and prosumer perspectives are shown in Table 50 and Table 51.

Table 50 – SWOT analysis of HLUC-3-PUC-2-BM-1 (DSO perspective)

Strength	Weaknesses
• Easy to establish • No daily operation • Automatic • Cheap	• Is the impact high enough? • Will people buy storage systems?

Opportunities	Threats
• Easy to test impact	• Can the DSO rely on this solution in the long term? • The DSO will not have the possibility to limit PV-injection (as-is) • Third party owned equipment to secure grid stability and be compliant.

Table 51 – SWOT analysis of HLUC-3-PUC-2-BM-1 (prosumers perspective)

Strength	Weaknesses
• Easy to establish • Higher likelihood to optimize the power consumption • Efficient optimization of self-consumption • Increase savings from electricity bill • Possibility to sell ancillary services	• Lifetime of battery is still too expensive now
Opportunities	**Threats**
• Possibility to defer the investment in residential storage system • Flexible service, which can be moved around in the grid depending on the need • Likelihood to sell flexible services	• Data security • The lack of incentives does not favour the ESS deployment for prosumers

7.9.1.4 Business model canvas

In this paragraph, we propose different Business Model Canvas of HLUC-3-PUC-2 for ESS suppliers, as shown in Table 52.

Table 52 – Business Model Canvas for ESS suppliers (HLUC-3-PUC-2-BM-1)

Key Partners • Installers • ICT Value chain network: • DSO • Prosumers	**Key Activities** • Investigating claims from prosumers and DSO (or other customers with voltage issues) • Selling batteries • Setting set-points at local owned batteries	**Value Proposition** Why: Stable grid at lowest cost What: Using private storage to manage demands	**Customer Relationship** • Customer assistance • Customers are encouraged to become a community (cooperative prosumers)	**Customer Segments** • DSO • Prosumers • Small SME (PV owners)

		in voltage without reinforcing the grid <u>How:</u> Charge/discharge on demand controlled by the DSO	• Self-service	
	Key Resources • Salespeople		**Channels** • On demand • Personal sale • Long term contractual agreement	
Cost Structure • Manufacturing costs • Operational cost • Assistance costs			**Revenue Streams** • Asset sales	

Hereafter, we propose different Business Model Canvas of HLUC-3-PUC-2 for DSO, as shown in Table 53.

Table 53 – The Business Model Canvas for DSO (HLUC-3-PUC-2-BM-1)

Key Partners	**Key Activities**	**Value Proposition**	**Customer Relationship**	**Customer Segments**
• Energy Storage Suppliers • Installers • ICT <u>Value chain network:</u> • Service providers • Prosumers	• Investigating claims from prosumers (or other customers with voltage issues) • Setting set-points at local owned batteries • Planning grid optimization from a technical and economic point of view	<u>Why:</u> Stable grid at lowest cost <u>What:</u> Using private storage to manage demands in voltage without reinforcing the grid <u>How:</u> Charge/discharge on demand controlled by the DSO	• Customers are encouraged to become "partners", cooperative prosumers • Long term contractual agreement with ESS producers	• Prosumers or small SME
	Key Resources • Grid-Planning people • Grid-operation people		**Channels** • Contractual power agreements	
Cost Structure • Payment for ancillary services			**Revenue Streams** • Postponed reinforcement costs (savings)	

7.10 Voltage and flux control at grid side storage: HLUC-3-PUC-3

This use case investigates if the battery systems can be placed in the LV grid and its ideal location. Due to either high local consumption or production it may be feasible to place storage at local feeder lines to overcome increasing or decreasing voltage levels and/or to control the flux, especially upwards flow in the grid. The optimal position of where to place the storage to gain the most positive effect will be addressed in this use case, taking consumption and production into account, as well as lifetime and operational cost. The owner and operator of the battery will be ENIIG (as a preliminary assumption) which allows for enhanced storage coordination all over the grid with respect to the current grid situation, generation, and consumption.

7.10.1 Voltage control at grid side battery: HLUC-3-PUC-3-BM-1

High local production may cause higher voltage levels locally, which can be eliminated by increasing consumption from grid side batteries or other consecutive consumption.

7.10.1.1 Preconditions for the business model

For the business model to be sustainable, the following preconditions have been identified:

- Private costumers have invested in RES such as PV systems, which increase the voltage level and affects the flux and create reverse energy flow in local feeder lines.
- Investment in storage solutions must be more economically beneficial than traditional investments (i.e. capacity reinforcement of the distribution grid and cable installations).
- It is allowed for the DSO to own and use the battery as a technical solution for grid stability.

7.10.1.2 Stakeholder analysis

The Stakeholder analysis is show in Table 54.

Table 54 – Stakeholder analysis of HLUC-3-PUC-3-BM-1

Stakeholder	Role	The stakeholders' contribution and position	Possibility to affect the project	Actions toward the stakeholder
DSO	Balance Compliance	Grid-owner, monopoly	Raises the demand Invests in storage	None
Private house owner	Creates the voltage problem	Delivers high voltage into the grid	Higher self-consumption on critical days e.g. Storage, heat-pumps	None / Information about behaviour change
ESS suppliers	Provide optimal size and quality of storage system for substation level	Batteries suppliers (competition)	Increase self-consumption on critical days e.g. Storage, heat-pumps	None
Aggregator/service provider	Coordinate/trade between DSO needs and prosumers services	Trade ancillary services to the DSO	Secure grid stability and the DSO to be compliant	None (this marked does not exist at the moment)

7.10.1.3 Value Network Analysis

In Figure 55 gives an overview of the VNA.

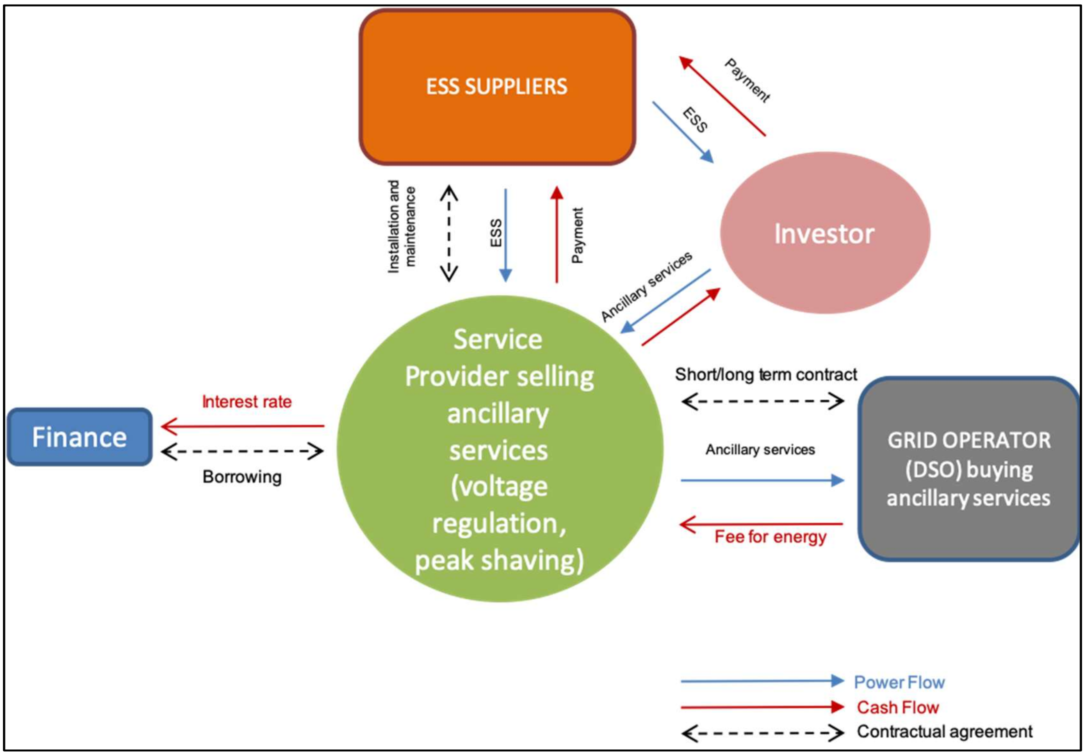


Figure 55 – VNA for HLUC-3-PUC-3-BM-1

7.10.1.4 SWOT analysis

The SWOT analysis from the DSO perspective is show in Table 55.

Table 55 – SWOT analysis of HLUC-3-PUC-3-BM-1 (DSO perspective)

Strength	**Weaknesses**
• DSO control of the storage system	• Lifetime of battery is shorter than traditional grid strengthening (need to substitute batteries, several times, at the end of lifetime) • Price of battery is too high
Opportunities	**Threats**
• Flexible service, which can be moved around in the grid depending on the need • Defer reinforcement of the grid • Alternative solution with economic benefit if price of batteries decreases	• More units to be controlled in the grid • Data security • Disincentive for prosumers to invest in storage system and to optimize consumption management

Table 56 – SWOT analysis of HLUC-3-PUC-3-BM-1 (prosumer perspective)

Strength	**Weaknesses**
• No further investment for prosumers	• Lower likelihood to sell excess of power to the grid
Opportunities	**Threats**
• Possibility to defer the investment in residential storage system	• Data security

A huge advantage of the DSO owned storage is that the DSO is independent of third party owned storage, which causes a big risk. The DSO must be able to rely on the storage 24/7/365. Threats is that implementing storage creates more units to control in the SCADA centre, even if it is expected that the storage is self-controlled. Another threat is data security. When creating more data communication lines, the risk for hacking or breaking down will increase.

7.10.1.5 Conclusions

It seems as a feasible solution for the DSO to invest and control grid side storage, in this way the DSO still have control of the grid state. The baseline calculation (HLUC-3-PUC-1) shows that storage must be cheap before the business case is positive, since grid strengthening is not that costly.
The former project GreenCom and participating islanders from Fur also participates in the ERA-Net Smart Grids Plus project MATCH[lxxi] (Markets – Actors – Technologies: A comparative study of smart grid solutions). The MATCH project analyses among others small consumers' involvement in smart island energy systems with a focus on technical feasibility of PV systems in combination with batteries.
Results indicate a tendency towards aggregated batteries being more favourable from a systems perspective, while on the other hand, individual batteries are more motivating and involving the consumers. The importance of minimizing flows to and from the grid as a result from fluctuating energy sources are addressed in both approaches. While individual batteries improve the individual household electricity supply, an aggregated battery would further regulate other inputs and demands[lxxii].

7.11 Coordinated distributed storage in the grid: HLUC-3-PUC-4

Installation of storage systems at different levels in the grid are considered by the DSO as a potentially interesting solution to help improving self-consumption, increase grid flexibility and deferring grid reinforcement. Such systems must be controlled externally to achieve adaptation to current grid conditions; achieving coordinated behaviour e.g. to exploit synergies arising between houses connected to the same radial and/or with storage at substation level; devising evaluation techniques to properly evaluate and dimension storage investments given specific user settings or load patterns. This use case gives information and control facilities to the house-owner about state of privately-owned battery.
The DSF-SE is used to model the situation of the grid when private storage and the storage on grid level is jointly operated and coordinated. In this situation, also ancillary services will be taken into consideration, depending on the regulatory environment.

7.11.1 Voltage control at both household and grid side battery: HLUC-3-PUC-4-BM-2

The case is that one feeder is filled with PV penetration, more than 60% of the houses have PV systems and that many customers experience instability electricity in their house. The DSO monitors too high voltage in many hours during a week. Some of the houses have storage and the DSO estimates that more houses may need storage and also a grid side storage is needed. The DSO offers the prosumer to buy a battery and have automatic voltage control within defined limits and set-points from the DSO. For this service, the DSO offers a limited payment to the prosumer.

The DSO estimated further that the grid side storage should both have voltage and flux control, because the production is much higher than consumption in many hours in this feeder line. This means that excess electricity is transformed through the 10/04 transformer to other feeder lines and this creates grid losses and is costly to the DSO.

The DSO avoids reinforcing the grid or defer the reinforcement. The business model is to be understood as there is automatic voltage control at both household and grid side level. The battery controls the voltage level itself within some defined limits, and there are no external signals exchanged with the BMS. The BMS monitors the local voltage level and regulates the level inside the demands.

The prosumer gets access to a local GUI (Extended Solarweb), where they can be informed about state of battery; state of charge, consumption, production etc.

The business case for the house owner must balance between revenue from ancillary services and feed-in tariffs. At the other hand the business case must balance between the cost of reinforcing for the DSO and expenses on ancillary services and related operational cost, besides grid loss and effectiveness of storage.

7.11.1.1 Preconditions for the business model

For the business model to be sustainable, the following preconditions have been identified:

- The same preconditions as for HLUC-3-PUC-4-BM-1
- Currently more production than consumption in many hours as well as yearly balance.
- More than 60% have PV systems
- More loss in transformer station than in storage.
- The profitable calculations are made with standard consumption, PV production and storage profiles for one house and aggregated.

7.11.1.2 Stakeholder analysis

The Stakeholder analysis is show in Table 57.

Table 57 – Stakeholder analysis of HLUC-3-PUC-4-BM-2

Stakeholder	Role	The stakeholders' contribution and position	Possibility to affect the project	Actions toward the stakeholder
DSO	Compliance and grid stability	Facilitator of local innovative solution	Taking new business models into account and buying ancillary services in the distribution grid Offering storage to residents	None

Residents with PV systems and perhaps storage	Causing the voltage problem by owning local production	Investing in storage and be part of balancing the grid locally	By owning storage and allow the DSO to control it, the resident is part of the solution	Information about the need for the DSO Presenting a positive business model for the residents
ESS suppliers	Provide optimal size and quality of storage system both for substation level and residential sites	Batteries suppliers (competition)	Increase self-consumption on critical days e.g. Storage, heat-pumps or EVs	None
Residents without PV systems and storage	May be influenced by voltage issues	Consume more electricity by investing in e.g. Heat pumps	Could be part of the solution	Information about the need for the DSO

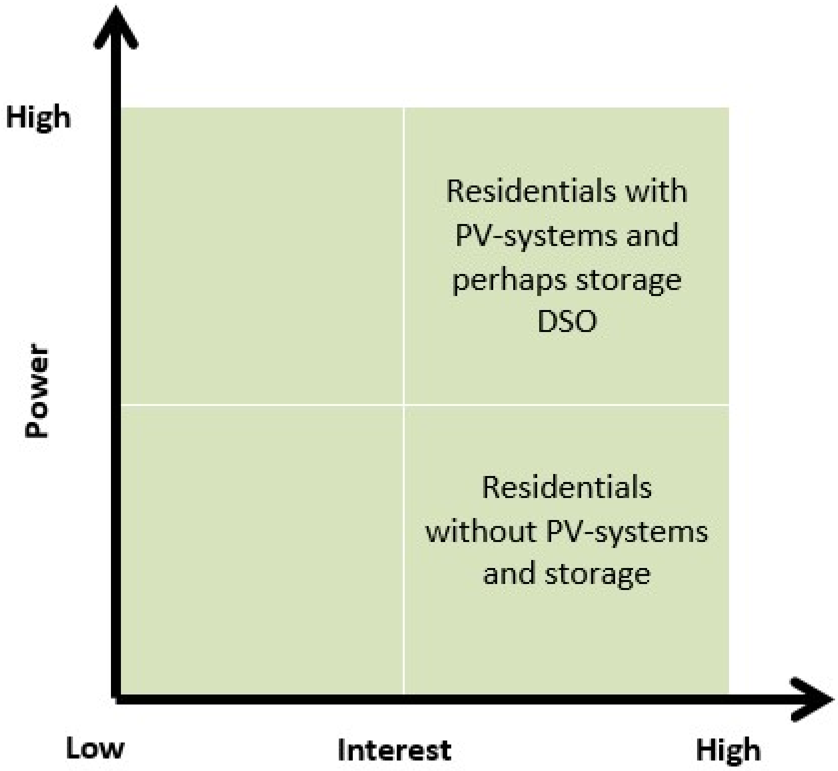


Figure 56 – Stakeholder interests

The DSO is the business model driver and the main stakeholder.

7.11.1.3 SWOT analysis

The SWOT analysis from the DSO perspective is show in Table 58.

Table 58 – SWOT analysis of HLUC-3-PUC-4-BM-2 (DSO perspective)

Strength	**Weaknesses**
• DSO has control of flux • Shared business model is cheaper	• Will people buy storage systems? • Voltage control is partly at third party
Opportunities	**Threats**
• High flexibility	• Can the DSO rely on this solution in the long term? • Some storage owned by third party • Rely on third party owned equipment to secure grid stability and be compliant.

Table 59 – SWOT analysis of HLUC-3-PUC-4-BM-2 (prosumer perspective)

Strength	**Weaknesses**
• SaaS is a mean to reduce, considerably, investment costs in ESS • Optimization of self-consumption • Increase savings from electricity bill • Possibility to sell ancillary services	• Long term contractual agreement with DSO can discourage the prosumers • Contractual agreement and fee with DSO are crucial
Opportunities	**Threats**
• Possibility to defer the investment in residential storage system • Flexible service, which can be moved around in the grid depending on the need • Likelihood to sell flexible services	• Data security

7.11.1.4 The Business Model Canvas

The Business Model Canvas of HLUC-3-PUC-4-BM-2 for DSO and ESS suppliers are shown in Table 60 and Table 61.

Table 60 – The Business Model Canvas for DSO (HLUC-3-PUC-4-BM-2)

Key Partners	**Key Activities** • Investigating claims from prosumers (or other	**Value Proposition** Why: Stable grid at lowest cost	**Customer Relationship** • Customers are encouraged to	**Customer Segments** • Prosumers or small SME

<table>
<tr>
<td rowspan="2">• Energy Storage suppliers
• Installers
• ICT

<u>Value chain network:</u>
• Prosumers</td>
<td>customers with voltage issues)
• Setting set-points at local owned batteries
• Setting set-points at grid side battery
• Interact with SCADA system
• Invest in energy storage (SaaS)/service provider contract</td>
<td rowspan="2"><u>What:</u>
Using private and grid side storage to manage demands in voltage and grid side storage to manage flux without reinforcing the grid

<u>How:</u>
Charge/discharge on demands controlled by the DSO</td>
<td>become “partners”, cooperative prosumers
• Long term contractual agreement with prosumers/ service provider contract</td>
<td rowspan="2"></td>
</tr>
<tr>
<td>Key Resources
• Grid-Planning people
• Grid-operation people</td>
<td>Channels
• On demand
• BtC</td>
</tr>
<tr>
<td colspan="2">Cost Structure
• Payment for ancillary services
• Operational cost</td>
<td colspan="3">Revenue Streams
• Postponed reinforcement costs (savings)
• Fee from batteries rental</td>
</tr>
</table>

Table 61 – The Business Model Canvas for ESS suppliers (HLUC-3-PUC-4-BM-2)

<table>
<tr><td colspan="5"></td></tr>
<tr>
<td rowspan="2">Key Partners
• Energy Storage suppliers
• Installers
• ICT

<u>Value chain network:</u>
• Prosumers</td>
<td>Key Activities
• Investigating claims from prosumers (or other customers with voltage issues)
• Selling batteries
• Setting set-points at local owned batteries
• Setting set-points at grid side battery
• Interact with SCADA system</td>
<td rowspan="2">Value Proposition
<u>Why:</u> Stable grid at lowest cost

<u>What:</u>
Using private and grid side storage to manage demands in voltage and grid side storage to manage flux without reinforcing the grid

<u>How:</u>
Charge/discharge on demands controlled by the DSO</td>
<td>Customer Relationship
Customers are encouraged to become “partners”, cooperative prosumers</td>
<td rowspan="2">Customer Segments
• Prosumers or small SME
• DSO</td>
</tr>
<tr>
<td>Key Resources
Salespeople
Grid-Planning people
Grid-operation people</td>
<td>Channels
• On demand
• Personal sale
• BtC</td>
</tr>
<tr>
<td colspan="2">Cost Structure
• Manufacturing costs
• Operational cost
• Assistance costs</td>
<td colspan="3">Revenue Streams
• Asset sales</td>
</tr>
</table>

7.11.1.5 Conclusions

This business model is very flexible and if you can rely on privately owned batteries capable of handling most problems in local feeder lines. There is a high risk in having third party owned storages and rely compliance and grid stability on them. Data security and communication lines are also a risk.

7.11.2 Flux control and loads shaving at households with PV and battery (HLUC-3-PUC-4-BM-3)

This business model is about controlling when to charge and discharge the battery depending on grid state. The sun peak and the consumption peak does not coincide which gives imbalances in the local grid. This case is about postponing storage until sun peak (during noon) and to discharge during cooking peak (during late afternoon time 5-8 pm). This is the ideal case, mostly only during summertime. Part of the use case is also to have weather forecasts to be able to charge/discharge depending on sunshine (during spring and fall). Another case is being able to charge from the grid during night-time to consume from storage in the morning or on days without sunshine (mainly during wintertime). See details in Figure 57 and Figure 58.

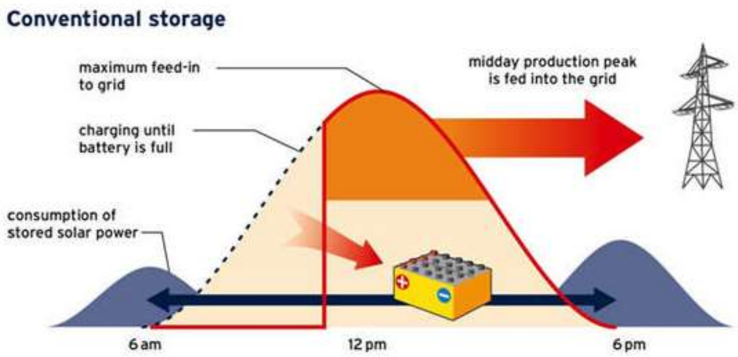


Figure 57 - Self-managed battery system

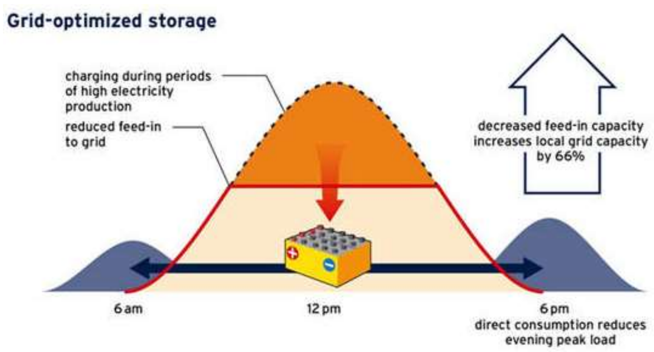


Figure 58 - Grid optimization storage

The case is a feeder line with many customers, mostly prosumers, and some prosumers with storage. The house owner gets the possibility to invest in storage to be more self-sufficient.

7.11.2.1 Preconditions for the business model

For the business model to be sustainable, the following preconditions have been identified:

- The DSO receives more claims from customers at specific feeders because of increased voltage levels from time to time. Specific feeders are filled with PV systems, which in specific hours increases the voltage, especially in hours with low local consumption.
- The DSO role is extended in this model by offering storage to prosumers. This is counter to legislation in some Member States, where the DSOs are facing a diminishing role in which the relation to customers is limited, with the DSO being only responsible for the meter readings and distribution. However, this model suggests a DSO role with new opportunities for smart grid engagement with customers.
- PV production sold to the grid is not in every country favourable: tariffs for selling energy to the grid are low and schemes restrict your usage (i.e. you have to consume what you produce within the hour /real-time, the rest is sold (or given for free) to the grid) and a general high cost of electricity (especially distribution costs and taxes) thereby incentivising the prosumer to invest in storage.
- If the DSO shall choose this solution, they must be able to trust the solution at any time, else the DSO cannot rely on this solution, therefore the prosumer has no rights to overrule the DSO set-points. If

the DSO cannot rely on the prosumers, they may still have imbalances and the need of reinforcing the grid.

- Ancillary services have become common in the DSO-grid.

7.11.2.2 Stakeholder analysis

The Stakeholder analysis show in Table 62.

Table 62 – Stakeholder analysis of HLUC-3-PUC-4-BM-3

Stakeholder	Role	The stakeholders' contribution and position	Possibility to affect the project	Actions toward the stakeholder
DSO	Compliance and grid stability	Local demand and regulation	Taking new business models into account and buying ancillary services in the distribution grid Offering storage to residents	None
Residents	Causing imbalances by owning local production	Investing in storage and be part of balancing the grid locally	By owning storage and allow the DSO to control it, the resident is part of the solution	Information about the need for the DSO Presenting a positive business model for the residents

7.11.2.3 SWOT analysis

The SWOT analysis from the DSO perspective is show in Table 63.

Table 63 – SWOT analysis of HLUC-3-PUC-4-BM-3 (DSO perspective)

Strength	Weaknesses
• Easy to establish • Automatic operation • Cheap	• Is the impact high enough? • Will people by storage systems?
Opportunities	**Threats**
• Easy to test impact	• Can the DSO rely on this solution in the long term? • Rely on third party owned equipment to secure grid stability and be compliant.

The SWOT analysis from the resident perspective is show in Table 64.

Table 64 – SWOT analysis of HLUC-3-PUC-4-BM-3 (resident perspectival)

Strength	Weaknesses
• Easy to establish • Automatic operation • Cheap	• Is there a positive business case? • No possibility to optimize the investment more
Opportunities	**Threats**
• Load-shaving to secure more self-consumption	• This solution turns out not to be sufficient for the DSO and break the contract.

This business case could be a big opportunity for residents to be more self-sufficient and, at the same time, offer ancillary services to the DSO, which improve their business model. Besides taking part of being more responsible according to grid services.

7.11.2.4 The Business Model Canvas

The Business Model Canvas of HLUC-3-PUC-4-BM-3 is show in Table 65.

Table 65 – The Business Model Canvas for DSO (HLUC-3-PUC-4-BM-3)

Key Partners	Key Activities	Value Proposition	Customer Relationship	Customer Segments
• Energy Storage suppliers • Installers • ICT Value chain network: • Prosumers	• Investigating claims from prosumers (or other customers with voltage issues) • Setting set-points at local owned batteries **Key Resources** • Grid-Planning people • Grid-operation people	Why: Stable grid at lowest cost What: Using private storage to manage imbalances in flux without reinforcing the grid How: Charge/discharge on demand controlled by the DSO	• Customers are encouraged to become "partners", cooperative prosumers **Channels** • BtC agreement	• Prosumers or small SME
Cost Structure • Payment for ancillary services • Minor operational cost		**Revenue Streams** • Postponed reinforcement		

7.11.2.5 Conclusion

This business case will be relevant to defer reinforcement for the DSO, but there is foreseen at big risk in having third party owned storage to secure grid stability and be compliant.

The business case is probably popular for residents, since it also raises their self-supply, and thereby give residents more credits for investing in PV systems and storage (with low or none feed-in tariffs).

7.12 Conclusion

Seven business models have been developed and some of them with a quantitative computation. Not all of them are realistic to test in the project. HLUC-3-PUC-1-BM-1 is the baseline for all other business calculations. The results from the baseline calculation are:

- If the DSO is compliant in flicker the grid becomes very strong and the PV-penetration must be very high before the DSO discovers voltage issues caused by PV-systems.
- Grid strengthening is not very costly until a certain point, which means that batteries must be inexpensive in investment and maintenance.

Results from this analysis are:

- The DSO may invest in batteries as a technical feature in the grid to avoid third party owned equipment, which the DSO may not trust (HLUC-3-PUC-3-BM-1). However, new EU-regulation denies DSO's to own storage;
- It is expected to be easier to establish storage in the grid compared to grid strengthening, but more complex to control in the SCADA system;
- There are a lot of possibilities for residential to offer ancillary services to the DSO and to increase their own business case (HLUC-3-PUC-2-BM-1, HLUC-3-PUC-4-BM-2 to 5).

8 Conclusions

This deliverable presents the final description of the business models analysed for the use cases selected in the S4G project and it has been realised as an incremental work starting from the D2.3 [S4G-D2.3]. The validation of the HLUCs has been done by the S4G consortium and a more detailed business analysis of some of them has been described. The sequence of the topics touched in the deliverable follows three main steps.

1. First, we outline an initial literature review where we find a description of the main trends and results from storage deployment currently in EU countries. We collect information about the creation of value from ESS, the battery price trends, how the EV market has been developed, which are the main stakeholders and their relationships in the PV and storage market and what are the main drivers and barriers that affect ESS in EU countries. Based on this information, on the one side, we described the HLUC from different points of view as DSO, prosumers, suppliers of technology and ESS, on the other side, we collect inputs from the economic model.
2. Second, a preliminary draft of an economic model has been described with the goal to provide some indication for some HLUCs where the model can be implemented.
3. Finally, a well detailed business analysis will complete the business opportunities for some actors in different HLUCs integrating some inputs from the previous two steps.

Storage opportunity comes both from the need for DSO to face and solve grid issues, for instance, when the PV penetration is increasing in local feeder lines, and from the need of prosumers to find how to reduce the charge for PV investment and opportunities to generate revenues or manage better EV systems. Issues for DSO may be both voltage problems and increasing losses besides local imbalances. Business cases related to minimizing losses and ensuring voltage levels are therefore interesting, i.e. how to use (including by charging the local storage) surplus production as close as possible to the production site in order to avoid grid losses and secure voltage control.

Concerning to the use case analysis, in the laboratory in Bucharest it has being studied more innovative business models on a low TRL-level. For instance, for the HLUC-1-PUC-2, the resulting solution is to ensure a

load-only pattern on distribution grid side for an existing prosumer, by adding the storage unit and an intelligent ER. This approach is superior to classic net-metering, with or without storage BtM, in both aspects: savings attractiveness and in resilience, including resilience against regulatory changes and market variability for the locally (prosumer) generated electricity.
HLUC-1-PUC-3 will be relevant by enabling energy services (based on new technology) to connected neighbourhood prosumers and consumers. An important opportunity consists in the reduction of the energy/electricity consumption cost on the long term.

Business models have been developed both for residential, commercial and grid test sites. For the Bolzano and Fur/Skive test sites, the baseline has been calculated, showing that the use of ESS is still far from being profitable with the actual conditions (costs and lifetime of the storage system, besides regulatory framework limits for DSO, lack of profitability for prosumers). The incentives for the storage owner are not at the moment financial attractive and we compute that it could be more viable to wait for a deferral investment of some years before investing in ES solution. Interesting calculations also shows, if the DSO is compliant in flicker, the grid becomes stronger and the PV penetration must be very high before the DSO discovers voltage issues caused by PV systems. Grid strengthening is not very costly to a certain point, which means that batteries must be inexpensive in investment and maintenance. This is confirmed also from the total cost of ownership calculation. However, our economic computation shows that, both from DSO and welfare point of view, a higher is the scenario with deployment of ESS both at sub-station and residential level. We find similar insights also if we compare the community as a whole (DSO and prosumers). From an approximative simple sensitivity analysis, we see that battery price can highly affect the scenarios results.

A deeper and refined computations are needed to validate these results and find for which parameters and level there is the threshold beside which it will be more convenient to invest in storage systems, certainly, they depend on the grid topology and PV penetration.
Looking at the outputs of this study on the business models, it is clear that to be economically attractive from the point of view of the grid, commercial and residential sites, a multiple use of the batteries and a decreasing of batteries prices are necessary condition. Maximising self-consumption and reducing the contractual power input can provide grid services, such as peak-shaving, and thus have an additional revenue.

Acronyms

Acronym	Explanation
AMI	Advanced Metering Infrastructure
AP	Advanced Prosumer
ARERA	Italian Authority for Energy
ASRP	Advanced Self-Resilient Prosumer
BaU	Business as Usual
BEV	Battery Electric Vehicles
BMS	Battery Management System
BRP	Balance Responsible Parties
BSP	Balancing Service Providers
BtM	Behind to the Meter
CAGR	Compound Annual Growth Rate
CapEx	Capital Expenditure
CBA	Cost Benefit Analysis
CMP	Commercial Market Parity
DCF	Discounted Cash Flow
DG	Distributed Generation
DoA	Description of Action
DSF	Decision Support Framework
DSF-EE	Decision Support Framework Economic Engine
DSF-SE	Decision Support Framework Simulation Engine
DSO	Distribution System Operator
DSS	Decision Support System
EEL	Authority of Electricity and Gas
EES	Electricity Energy Storage
EPC	Engineering Procurement and Construction
ER	Energy Router
ES	Energy Storage
ESS	Energy Storage System
EU	European Union
EV	Electric Vehicles

EVSA	Electric Vehicles Supply Equipment
FDI	Foreign Direct Investment
FiP	Feed-in Premium
FiT	Feed-in Tariff
FtM	In front to the Meter
GDP	Gross Domestic Product
GUI	Graphical User Interface
GW	Gigawatt
HLUC	High-Level Use-Case
ICT	Information and Communications Technology
IRR	Internal Rate of Return
kWh	Kilowatt per Hour
kWp	Kilowatt Peak
IMO	Independent Market Operator
LCOE	Life Cycle Cost of Energy
LE	Large Enterprise
Li-ion	Lithium-ion
LV	Low Voltage
MSD	Dispatching Services Market
MW	Megawatts
NPV	Net Present Value
O&M	Operations and Maintenance
OpEx	Operating Cost
PBP	Payback Period
PCC	Point of Common Coupling
PESTEL	Political, Economic, Social, Technological, Environmental and Legal
PHEV	Plug-in Hybrid Electric Vehicles
POD	Point of Delivery
PPA	Power Purchasing Agreement
PUC	Primary Use-Case
PV	Photovoltaic
P2P	Peer to Peer

R&D	Research and Development
RCR	Renewable Energy Resources Curtailment Risk
RES	Renewable Energy Sources
ROI	Return on Investment
SaaS	Storage-as-a-Service
SCADA	Supervisory Control and Data Acquisition
SM	Smart Meter
SME	Small Medium Enterprises
SO	System Operator
SPV	Special Purpose Vehicle
STOF	Service Technology Organization Finance
SWOT	Strengths, Weaknesses, Opportunities and Threats
S4G	Storage 4 Grid
T&D	Transmission and Distribution
TCO	Total Cost of Ownership
TRL	Technology Readiness Levels
TSO	Transmission System Operator
TWh	Terawatt-hour
USM	Unbundled Smart Meter
VNA	Value Network Analysis
VPP	Virtual Power Plants
V2G	Vehicle to Grid
KfW	Kreditanstalt für Wiederaufbau

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