Eindhoven University of Technology

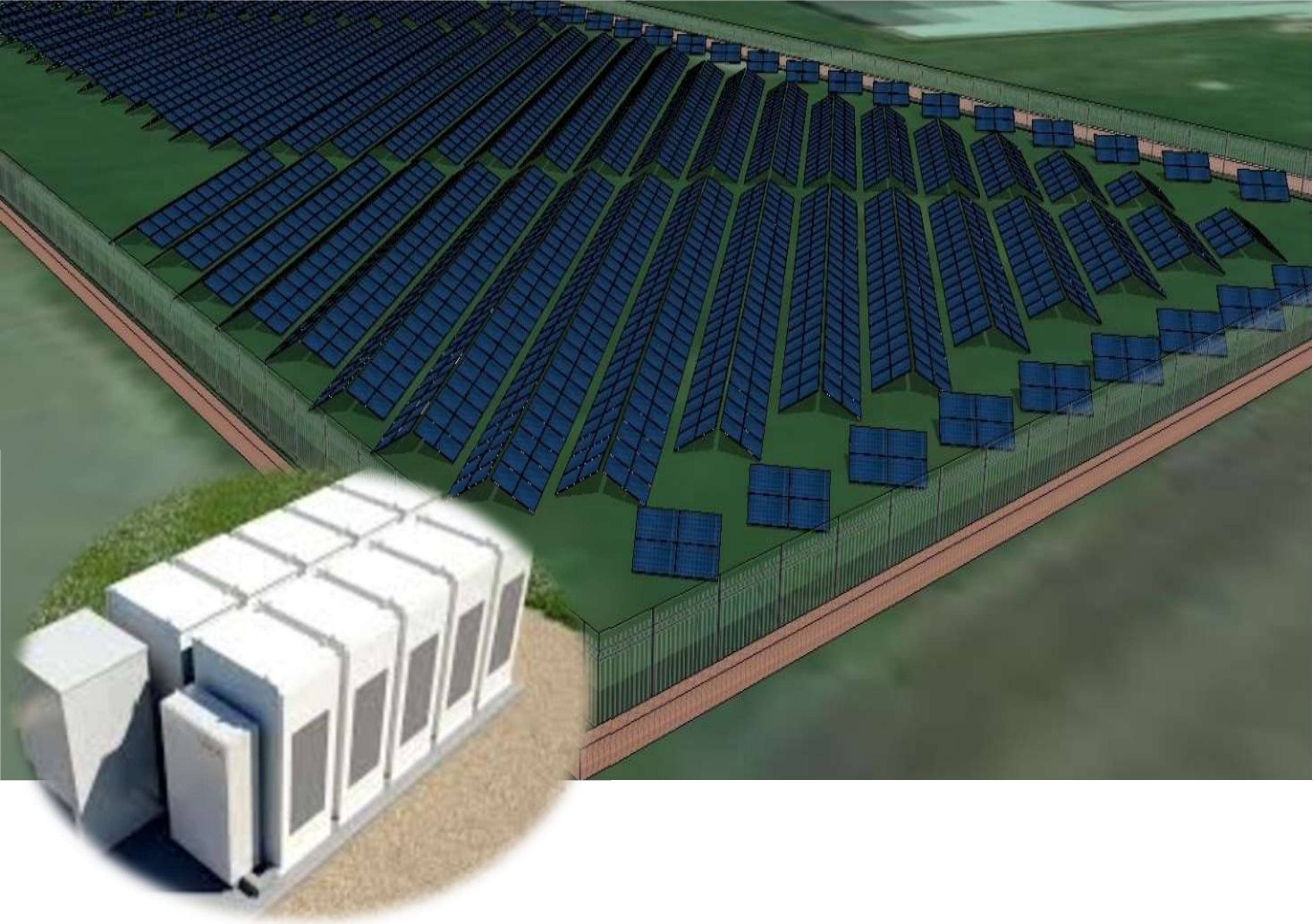
MASTER

Solar and Storage simply go together?

Boosting community-owned solar PV and battery storage systems by exploring multiple value creation

Leghissa, Giulia

Award date:
2018



Solar and Storage simply go together?

Boosting community-owned solar PV and battery storage systems by exploring multiple value creation

Master thesis

Sustainable Energy Tehcnology

G. Leghissa
1035868

Date: 24-09-2018

Technische Universiteit Eindhoven
University of Technology

TU/e Technische Universiteit
Eindhoven
University of Technology

Declaration concerning the TU/e Code of Scientific Conduct for the Master's thesis

I have read the TU/e Code of Scientific Conduct[i].

I hereby declare that my Master's thesis has been carried out in accordance with the rules of the TU/e Code of Scientific Conduct

Date

………………………………05-09-2018……………………………..

Name

……………………………Giulia Leghissa…………………………..

ID-number

………………………………1035868……………………………..

Signature

……………………Giulia Leghissa……………………..

Submit the signed declaration to the student administration of your department.

---

[i] See: http://www.tue.nl/en/university/about-the-university/integrity/scientific-integrity/
The Netherlands Code of Conduct for Academic Practice of the VSNU can be found here also.
More information about scientific integrity is published on the websites of TU/e and VSNU

January 15 2016

Eindhoven, 24-09-2018

Solar and Storage simply go together?

Boosting community-owned solar PV and battery storage systems by exploring multiple value creation

By Giulia Leghissa BSc

Student identification number: 1035868

In partial fulfillment of the requirements for the degree of

Master of Science
In Sustainable Energy Technology

Department: Industrial Engineering and Innovation Sciences
Research group: Technology, Innovation and Society

Supervisors:

Prof. dr. ir. G.P.J. Verbong	Faculty of Industrial Engineering & Innovation Sciences
Dr. ir. M.N. van den Donker	Solar Energy Application Centre (SEAC)

ACKNOWLEDGMENTS

This past year has been a period of intense learning for me, not only in terms of academic knowledge and skills but also on the personal level. Looking back over this time, there are several people whom I feel I would like to thank for their support and help.

Firstly, my supervisors Geert Verbong and Menno van den Donker: thank you for giving me the opportunity to be part of the SEAC group and to work on an interesting project in the field of renewable energy. I feel proud of having been able to contribute with my research towards a greener, brighter future (as the Latin saying states, *de minimis granis magnus acervus* – in other words, even the smallest step counts). I am grateful for the guidance throughout this research and for the advices and ideas that added value to my study. Thank you for making my graduation project a challenging, educative and gratifying experience.

Secondly, I would like to thank the people at SEAC for this past year. It was a privilege for me to conduct both my internship and graduation project in such a stimulating working environment.

Thanks to all my friends who have seen less of me during these past months. A special thanks to Cristina, Daniel, Lea, Mateja, Matia and Sara for the time spent together – these moments are the true confirmation that quality is by far more important that quantity.

I want to thank my family for the unconditional love and sympathetic ear. Thank you for always being there for me, supporting every decision I make and encouraging me even during the hardest moments. A particular thanks to my brother Mattia, for his support and care: I know this has been a difficult time for you, but I promise I will make it up to you.

Finally, I would like to thank my boyfriend Alberto for his endless patience during these months and for his constant faith in me. I owe you more than an infinite number of Sacher cakes can ever repay.

ABSTRACT

The energy sector is facing significant changes, especially towards a more sustainable and secure energy system, based on renewable sources that reduce greenhouse gas emissions and enhance energy independence and security. In this regard, the addition of battery storage systems to large-scale renewable projects (such as solar parks) can play a vital role in the overall energy transition.

This research focuses on the conjunction of district battery storage systems with a community solar park, giving the rising importance of energy cooperatives and the increasing number of community projects. In particular, the feasibility of community Solar-Plus storage projects is investigated with a multi-perspective study, from business modelling and comprehensive business case calculations via a techno-financial analysis to the identification of barriers and opportunities for this technological development using the theoretical framework of transition studies.

Battery storage co-located with a solar park can provide several benefits and can be used for a variety of applications, such as reserve capacity, energy arbitrage, increased self-consumption, backup power, peak shaving or grid reinforcement deferral. The different type of service tackled by the battery system has an influence on the business model, in particular in terms of ownership and operation, as pointed out by the results of the benchmark study of current large-scale Solar-Plus-Storage projects worldwide.

By considering the wishes of a community regarding the values that batteries added to solar PV system should provide, three different business model scenarios are developed and analysed. In all scenarios, the community, through an energy cooperative, is the owner of the Solar-Plus-Storage installation, with the battery storage applied for more than one service (i.e. benefit stacking). In this way, multiple values can be created and captured: as such, not only monetary benefits can be achieved, but also other types of values can be reached (for example increased energy independence). The three scenarios differ in terms of applications that the battery storage provides and organizational settings (in particular regarding the operator of the asset), which in turn have an impact on the complexity of the overall business model and its financial feasibility. The latter is assessed with a techno-financial analysis, both for the present year (2018) as well as for the near future (2025); thus, the effect of future developments in costs and revenues is checked.

Overall, the main conclusion that can be drawn is that the choice of the business model scenario depends on both the desires of a community (i.e. the legal owner of the installation) and the experience of the asset operator. However, from a monetary perspective, in order for a Solar-Plus-Storage project to be financially feasible, primary reserve capacity should be included among the tackled applications, both for the 2018 case as well as for the 2025 case: the higher the amount of time that the battery is used for this service, the higher the profitability of a project. In addition, grid reinforcement deferral might play a big role in the profitability of a project, provided that it can be legally possible to tackle this service and that high revenue streams are associated with it.

Despite the several benefits and opportunities that the addition of a battery storage to a solar park can offer, there are also challenges faced by this technology, ranging from technological, regulative, market and cultural factors. Attention to these barriers and their subsequent elimination has the potential to reconfigure energy systems by boosting Solar-Plus-Storage projects. Making solar and storage simply go together can in turn provide a significant contribution to a sustainable energy future.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1 INTRODUCTORY REMARKS

Over the last decades, the energy sector has been subject to substantial changes in terms of generation and distribution mechanisms, in particular towards a more sustainable and renewable energy system. This transition has been primarily fostered by the need to limit and mitigate the effects of climate change, fossil fuels' depletion and the uneven distribution of resources (Bull, 2001; Droege, 2011; Leach, 1992).

In this regard, one of the technologies that can contribute to a greener and more sustainable energy production is solar photovoltaics (usually abbreviated with PV), which absorbs solar radiation by means of solar panels and converts it into usable electricity. Worldwide solar PV market has seen an exponential growth in the last period; the global cumulative installed capacity in 2016 was about 300 GW, while in 2010 it was only 40 GW (IRENA, 2017a). Some of the most important factors that catalysed this growth are costs reductions of solar cells and modules, economies of scale and technical improvements (such as higher efficiency of PV panels), but also favourable governmental subsidy schemes and incentives (for example Feed-in-Tariffs, i.e. fixed electricity prices for energy from renewable sources injected into the grid).

The increase of the so-called PV penetration level is consistent with the EU renewable energy portfolio, who has established several goals in relation to energy generation, CO_2 emissions and energy efficiency measures. Within these targets, the Netherlands has committed itself to increase the share of energy production from renewable sources to 14 % by 2020 and at least to 27% by 2030 (Rijksoverheid, n.d.-b). Nonetheless, at the moment renewable energy sources represent only 6% of the total Dutch energy production (CBS, 2017). It is therefore clear that a boost in installed capacity is still needed in order to meet the goals that were agreed upon. In this regard, it is interesting to notice that in the period 2015-2017, the amount of solar PV capacity in the Netherlands has increased from a cumulative capacity of 1,3 GW at the end of 2015 to over 2,1 GW in 2017 (EurObserv'ER, 2017).

1.2 PROBLEM DEFINITION

With the spread of solar PV systems (especially grid-tied ones) within the energy mix, problems can start to arise. Due to the intermittency of the solar resource, fluctuations in power flow pose issues for both power reliability and quality (Hill, Such, Chen, Gonzalez, & Grady, 2012; Idlbi, Von Appen, Kneiske, & Braun, 2016). Furthermore, an additional problem with this renewable energy source is the partial mismatch between PV production and load demand profiles, due to the intrinsic nature of the technology itself; one clear example is during evenings or at night, when the output from the solar panels is zero, but electricity is still required by private and business properties. On the other hand, excess production from the PV panels during low consumption periods can start to cause congestion in the electricity grid (van Blijswijk & de Vries, 2012). These issues can represent a big problem especially for large-scale solar parks because of their significant production of power; in addition, they can be particularly important for installations located in sparsely populated areas (where there is ample space for larger solar parks, but the maximum load of the local grid may not be always enough to handle the excess peak power from the PV panels).

One of the ways to address these problems is to implement an energy storage system. Among others, in the last years Lithium-ion Battery Energy Storage Systems (BESSs, also simply called batteries) have gained momentum as the most common storage solution to be implemented in combination with solar PV installations (IRENA, 2015). Nowadays, they are regarded as one of the most promising technology to help to accommodate further solar PV systems in the energy mix, which in turn plays an important role in reaching the national goals for renewable energy generation. In fact, in recent years the number of Solar-Plus-Storage projects is rising, not only on the residential level but also on a larger scale. Some of the reasons behind this result are the following. Firstly, the prices for battery storages have seen a rapid decrease (BNEF, 2017; IRENA, 2017b), therefore making this solution more financially attractive; secondly, increasing penetration levels of renewables have already started to cause grid stability problems (Denholm, Eichman, & Margolis, 2017; Idlbi et al., 2016; Rönnberg & Bollen, 2013), thus further stimulating the research on possible alternatives to expensive grid reinforcement measures; lastly, some governments (for example Germany) have decided to decrease FiT (Feed-in-Tariff) incentives below retail prices or cancel them and switch to alternative subsidy schemes, hence providing a financial stimulus to increase the self-consumption of renewable-generated energy by directly consuming it or storing it with batteries.

Nevertheless, one of the down-points of adding a storage solution to a solar PV installation (especially in case of larger systems) are the high upfront investments needed to implement batteries, despite the rapid price reduction of this technology in the last years. However, several analyses show that if the battery storage is used to provide one service only, it does not operate 100% of the time. Thus, the rest of the time the battery is in idle mode, and it could be therefore used for other purposes as well; in this way, its economic viability can be increased. In fact, the increasing number of large-scale Solar-Plus-Storage projects clearly suggest that when several benefits are included in the economic analysis, the conjunction of batteries with PV systems can be financially feasible and profitable. However, despite this, only a limited number of studies exists on the economic assessment in case of benefit stacking of such systems, due to the novelty of the topic. Furthermore, it should be remembered that the interplay of different stakeholders involved in a large-scale Solar-Plus-Storage project should not be neglected, especially when multiple values are addressed at the same time.

In addition, Roland Berger (2017) suggest that when several revenue streams are targeted, this can also give rise to "*new business models on the ownership and management of batteries*" (Roland Berger, 2017). As a matter of fact, recent years have already seen a rise in new types of business models for solar PV, among others of community-shared business models, where the collective participation of citizens is central. Takata (2017) argues that community-driven PV projects (for example by energy cooperatives interested in boosting the local sustainable energy generation) have two major advantages. Firstly, these projects provide the opportunity to expand the adoption of solar power to consumers that have financial or structural constraints (such as no available space on their own rooftop or not enough capital to invest in a private home system). Secondly, they are usually seen as bottom-up initiatives, which allow higher social support for the project. This is especially important to mitigate the Not In My Back Yard (or better, Not In My Neighbourhood) phenomenon, which is characterized by the opposition of residents to the implementation of an installation nearby their residential area. One clear example of this is the suspension of the permit for the construction of a 100MWp solar park in Sappemeer, in the Dutch province of Groningen. Local residents opposed to the large-scale solar park due to the big impact of the project itself (approximately 117 hectares of solar panels, located in proximity of an agricultural area and a park used by the resident for recreation) (RTV Noord, n.d.). The importance of energy cooperatives has been stressed also by the Dutch government, which has included them in the new coalition agreement (regeerakkoord 2017). The coalition agreement states that there is a separate regulation for energy cooperatives which enables local residents to participate more easily in sustainable energy projects (HIER Opgewekt, n.d.).

Despite all this, community-oriented business models for the conjunction of solar PV and battery storage have not been yet investigated in deep. The goal of this study is therefore to assess the feasibility of a community-owned large-scale Solar-Plus-Storage system by considering multiple value creation, in particular in case of benefit stacking. In the end, the results are meant to shed light on how to boost the number of community Solar-Plus-Storage projects in the Netherlands as well as abroad, which can be in turn a valid and economically viable solution to help reaching fossil fuels reduction targets and allowing further integration of renewables in the energy mix, especially if the battery storage is designed to provide different service uses.

1.3 CASE STUDY DESCRIPTION

In order to assess how to boost community-shared Solar-Plus-Storage project by looking at various applications for the battery system as well as at multiple values that are created with the addition of a battery storage to a PV installation, this research will take as geographical focus the Netherlands, and in particular larger-scale PV systems.

Throughout the research, a case study will be selected as basis for the analysis: the case study is linked to a specific project, namely the COOP-Store project - a collaboration, amongst others, between Solar Energy Application Centre (SEAC), Weert Energie (a local energy cooperative), Soltronergy and Scholt Energy Service. The main goal of this project is to investigate the benefits of a central energy storage and create a platform that enables the development of a business case for it that would benefit all the involved stakeholders.

This project thus focuses on the various services that battery storage can provide, and that can make it economically viable and interesting for the diverse stakeholders involved (which are part of both the regulated and free market): peak shaving (storing electricity at times of peak solar energy generation and low demand, and using it later during times of higher electricity demand), relief of the local grid (by reducing the peak load) and energy trading. For this purpose, the COOP-Store project takes as a “living lab” the implementation of a cooperatively-owned storage facility of approximately 500 kWh in combination with the realization of a 1,1 - 1,2 MWp solar park in the neighbourhood of Altweerterheide, in the municipality of Weert (see Figure 1.1). A schematic view of how this solar park would look can be found in Figure 1.2.

Figure 1.1: Left: Location of Altweerterheide, near Weert (Limburg). Right: The red area corresponds to the location of the “living lab” for the COOP-Store project in Altweerterheide

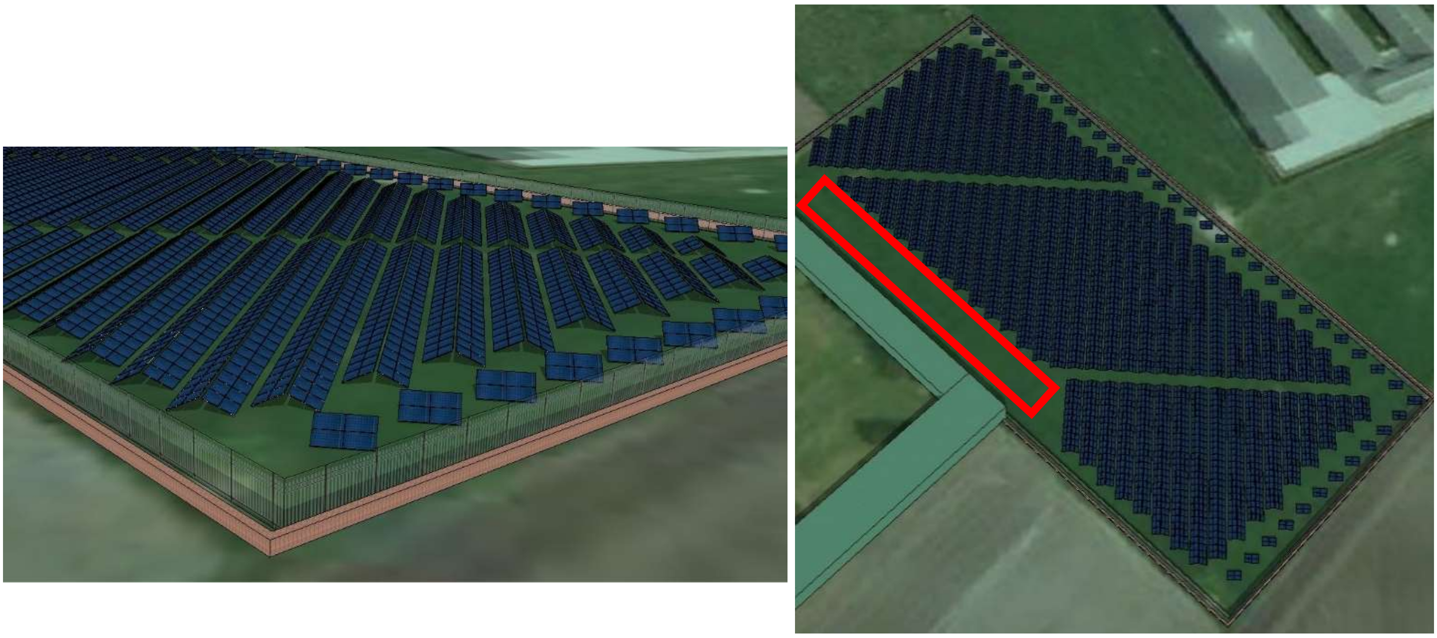


Figure 1.2: The design of the solar park in Altweerterheide (source Soltronergy, 2017)*; the red rectangle represents the area where the battery storage will be located*

1.4 RESEARCH QUESTIONS

Following the conclusions from the previous section, the main aim of this research is to understand what multiple values can be created by the conjunction of a cooperative district battery storage with a local solar park, in order to make this combination more cost-effective. In addition, this research focuses on how these values can be captured by the different actors involved in such a project and what barriers as well as opportunities lie there.

Thus, the main research question can be formulated as:

How can multiple values be created and captured by combining a community-owned battery storage system with a solar park?

The above research question can be in turn divided into the following sub-questions, which will help to answer the main question:

1) *Who are the most important actors in a community-driven large-scale Solar-Plus-Storage project?*
2) *What values do these actors perceive in the addition of a storage system to a solar park?*
3) *What organizational settings are possible within a community-owned large-scale Solar-Plus-Storage project that exploit several advantages of battery storage?*
4) *What is the value capturing strategy of the actors involved, and how do they interact with each other?*
5) *What representative scenarios can be constructed to assess the techno-economic feasibility of the combination of Solar-Plus-Storage?*
6) *What are the costs and the benefits in the different scenarios, now and in the near future?*

7) *What barriers and opportunities lie in the multiple value creation and capture for a community-owned district battery storage system, implemented in combination with a solar park?*

1.5 STRUCTURE OF THE REPORT

This report is organized in 11 chapters. Firstly, Chapter 1 introduces the topic of this research, together with the main goal and research questions.

Then, Chapter 2 describes the theoretical framework applied in this study to answer the above main research question (and with that also the sub-questions).

After that, Chapter 3 gives an overview of the methodology used throughout the research.

Chapter 4 provides additional background information about the main battery storage applications, current business models for large Solar-Plus-Storage installations and energy cooperatives in the Netherlands; all this serve as a base for the research presented in this study.

Next, Chapter 5 starts with a stakeholder mapping and analysis of the actors' main values in the addition of a battery storage to a PV installation. Thus, the first two research sub-questions are answered. Later in Chapter 5, three business model scenarios for a community grid-tied Solar-Plus-Storage system are developed and discussed, answering the third and fourth research sub-questions.

Subsequently, Chapter 6 presents the business case calculations that help assessing the financial feasibility of the Solar-Plus-Storage combination, for different applications of the battery system. This techno-financial analysis thus answers the fifth and sixth research sub-questions.

The last research sub-question regarding the barriers and opportunities of battery storage systems is answered in Chapter 7.

Following that, further reflections and discussions about the research presented in Chapter 8.

Lastly, Chapter 9 provides the conclusions of this report, including explicit answers to the main research question and sub-questions and suggestions for future research.

Chapter 10 consists of the list of references used in this research, while Chapter 11 contains the appendices to this report.

2 THEORETICAL FRAMEWORK

This chapter presents the theories which are relevant to this research, namely business modelling theory and Strategic Niche Management. In fact, the combination of these two theories represents a useful tool to assess technological developments and innovations by allowing a comprehensive study on a particular topic (such as Solar-Plus-Storage, as it is in this research): from what are the opportunities that can be exploited and what are the barriers that may hinder the project, to how to create and capture value in business terms and gain competitive advantage.

2.1 BUSINESS MODELS

The theory that is central to this research is the business modelling theory (which is regarded as a way to describe businesses, especially in an entrepreneurial setting), given the fact that Solar-Plus-Storage project can be considered as an entrepreneurial activity. In addition, as stated by Richter (2013), any type of value (economic, environmental or social value) of a technological innovation is "*latent until it is successfully commercialized through a business model*". Firstly, a general overview of this theoretical framework is presented, followed by a broader perspective on new business models' possibilities.

2.1.1 General definition and framework

Business models can be defined as "*a concise representation of how an interrelated set of decision variables in the areas of venture strategy, architecture, and economics are addressed to create sustainable competitive advantage in defined markets*" (Morris, Schindehutte, & Allen, 2005).

However, this is not the only accepted definition, but several different definitions exist for business models. One of the main reasons for this diversification is that business models are a relatively young topic: the interest in this concept only became prominent in the mid-1990s, in a period associated with the advent of the Internet and the "new economy" – from a manufacturing- to a service-based economy (Morris et al., 2005; Zott, Amit, & Massa, 2011). Nevertheless, it can be stated that in general they represent the core aspects of a business, including purpose, business process, target customers, strategies, organizational structures and operational processes. In other words, they aim to describe and classify how a firm or an organization can create, deliver and capture value (Osterwalder & Pigneur, 2010).

As a result of the difference on how to properly define business models, there is also a lack of consensus over the main elements, or key components, that should be included in a model. Furthermore, differences in business models' components may arise depending on the specific case for which a business model is analysed or developed. As an example, according to Richter (2013), a conceptualization based on four elements is favoured by several authors; these elements are value proposition, customer interface, infrastructure and revenue model. On the other hand, Osterwalder (2004) describes nine building blocks in a business model, which are value proposition, target customer, distribution channel, relationship, value configuration, capability, partnership, cost structure and revenue model. Moreover, Chesbrough (2007) presents instead six key elements, namely value proposition, target market, value chain, revenue mechanism, value network or ecosystem and competitive strategy. As can be therefore seen by comparing these examples, there are in fact similarities among the main features that should be included in business models (since similar aspects of business are emphasized in all of these examples), even if some proposed frameworks are more detailed than others.

Building on this, Morris, Schindehutte, & Allen (2005) propose an integrative, six-component framework for characterizing business models, which can be used regardless of the venture type. They present the following key elements:

1) **Value proposition** – Firstly, it is important to understand how a firm can create value; therefore, decisions must be made in terms of what is the nature of the product or service offered, what is the firm's role in all this and how can the value offering be made available to customers. In fact, as pointed out by Morris et al. (2005), "*there is no business without a defined value proposition*".
2) **The customer** – The next important question to ask is for whom the firm will create value. Customer can differ per type, location/geographical dispersion or interactions.
3) **Internal competences** – Another key element is to identify the internal source of advantage within the firm. Building advantage around the internal capabilities and skills (which the firm performs relatively better than others) enhances and solidifies the firm's role in the value chain.
4) **Competitive strategy** – Business models should also include how will the firm position itself in the market; in other words, how can it achieve competitive advantage over competitors, based on the particular internal competences (from the previous point). Typically, a firm wants to identify key points of difference between itself and the competitors that can be maintained over time (especially given the ability firms to quickly imitate one another).
5) **Profit mechanism –** In addition to the elements described above, a core component of a business model is how can a firm make money and what is the logic for earning profits. In this regard, it is not only important to look at the revenue model, including pricing and revenue sources, but also to consider other economic factors, such as the firm's ability to achieve higher or lower margins and the typical cost structure.
6) **Growth and time objectives** – Lastly, the entrepreneur's time, scope and ambitions play a role in the overall business model. In fact, different types of ventures influence the economic performance, the creation and management of internal competences and of the competitive strategy.

A general conclusion that can be drawn for the definition and framework description described above is that typical business models are designed around one firm or organization. However, innovations are usually characterized by high degree of complexity, involving several actors and interactions among them; thus, a single-firm approach tend to be less appropriate in those cases. In order to provide a wider-lens perspective and expand the focus of business models beyond one focal company, the concept of business model ecosystem is considered.

The term "business ecosystem" was introduced by Moore (1993) to describe "*an economic community supported by a foundation of interacting organizations and individuals –the organisms of the business world. The economic community produces goods and services of value to customers, who are themselves members of the ecosystem. The member organisms also include suppliers, lead producers, competitors, and other stakeholders*." In other words, the main idea behind this is that companies do not work alone, but rather within a whole ecosystem. The term ecosystem comes from biology, where it describes a natural system made up of different parts (plants, animals, microorganisms, minerals, etc.), interacting with one another to create a stable unit (Biology Online, n.d.) and interconnected with each other for mutual survival. In the business analogy, different interrelated and interdependent actors cooperate together to deliver a specific product or service that wouldn't be possible in case of an isolated firm. Each actor contributes with its own resources, competences and specializations, making the overall value proposition feasible. Therefore, it can be stated that the focus is more on the customer and the value created within a network of companies, instead of on one firm's capabilities and strategies.

2.1.2 Broader perspective on business models

Apart from broadening the perspective on business models by looking at a whole business ecosystem instead of a single company, it is also possible to look beyond the traditional way of doing business in general terms.

In this respect, the theory of Shared Value Creation and the concept of New Business Models will be analysed in this section.

First of all, the idea of creating shared values was originally proposed by Porter & Kramer in 2006 as a way to redefine the purpose of business as "*creating economic value in a way that also creates value for society by addressing its needs and challenges*" (Porter & Kramer, 2011, p.64). This approach thus serves as a bridge between the self-interest of a firm and social well-being, which results from redefining markets, revising the process of value creation and renewing the relationship between the company and the society or community in which the company operates. In other words, Shared Value Creation forms an integral part of the company's business strategy and represents a way to achieve economic success through operating practices that "*enhance the competitiveness of a company while simultaneously advancing the economic and social conditions*" of the society (Porter & Kramer, 2011, p.66).

Among the criticisms to the theory of Shared Value Creation, one of the main points of debate is the fact that the theory assumes there is no tension between the social and economic value. According to (Dyllick, 2014), Shared Value Creation leads companies to focus on easy win-win solutions and individual problems, while not resolving deeper social issues and not regarding in a proper way the negative impacts of corporate activities.

A theoretical framework that builds on this, but goes beyond the concept introduced by Porter and Kramer, is the approach proposed by Jonker (2012), which focuses on new business models that create and capture multiple values. A key element of this theory is that within a business ecosystem, economic value is not the only important feature; other values, such as environment benefits and social cohesion, also play an important role. Nevertheless, traditional business models focus merely on the individual performance of a company, considering purely monetary values. Instead, New Business Models (NBMs) consider three types of value: economic, social (for example trust, autonomy, social cohesion) and ecological (such as climate change, resources, waste, biodiversity). In other words, this approach goes beyond the consideration of costs and benefits in terms of money, but applies instead a broader perspective where all these three types of values are integrated within the business model. In this regard, the theory of NBMs presents some similarities to the approach of Shared Value Creation. However, the differences lie in the relation between the economic value and the other two. In particular, the strategic intention of addressing social needs to enhance the success of a business is here replaced by true sharing and fundamental principles of collaboration, as stated by Lüdeke-Freund, Massa, Bocken, Brent, & Musango (2016). Value creation should be understood as a collaborative effort (including not only different companies, but also governments and active community members), in order to lead to a positive contribution on multiple dimensions, as previously described.

According to Jonker, the design of NBMs should follow three principles in creating the value proposition:

1. **Collective value creation** (the idea that value should be created together, not only by one firm)
2. **Shared value creation** (when the value is created in a collaboratively way, it is then also shared among the actors creating the value)
3. **Multiple value creation** (providing at the same time ecological, social and economic value)

In conclusion, there are in total five key elements that together offer the possibility to generate a New Business Model: principles (collective, shared and multiple), design (who and what is needed), value proposition, value creation (not only monetary values are created, and thus also different types of transactions are present) and community (the main idea behind it is that you cannot create shared and collective value if you don't have a community of people). This is graphically represented in the Clover Business Model Canvas below.

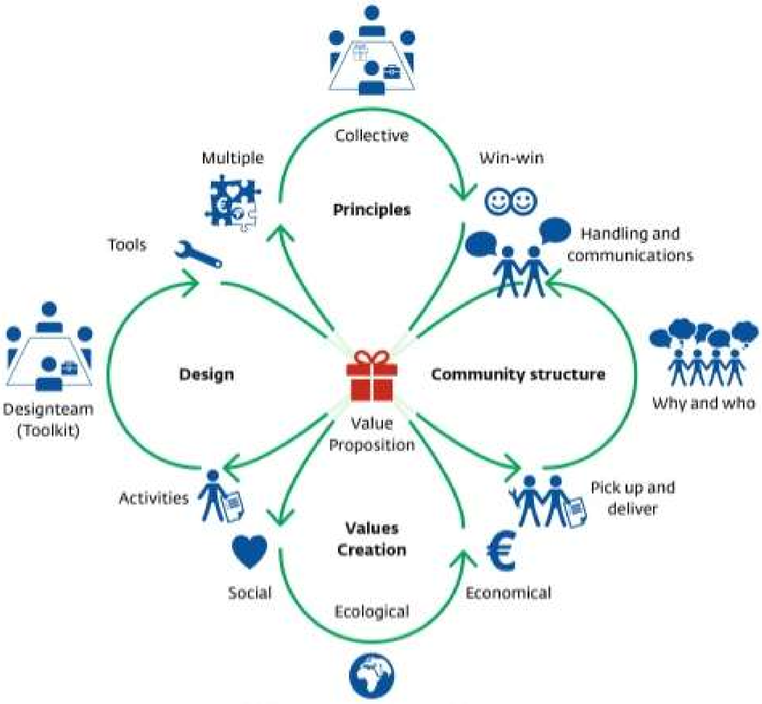


Figure 2.1: The Clover Business Model Canvas (source Jonker, 2014)

2.1.3 Visualizing a business model

In order to represent and describe a business model in a clear and consistent way, several mapping tools can be used. In particular, in terms of visual toolkits, different possibilities exist.

Among the most famous ones is the Business Model Canvas, typically used because of its easy-to-grasp layout. Consisting of nine blocks, it builds around three central aspects: creation of value, delivery of value and capturing of value. However, the Business Model Canvas mostly focuses around a focal firm, rather than taking an ecosystem perspective. In addition, it represents the business model in a rather static way, without emphasizing the different value streams and interactions between the actors involved. Lastly, the Business Model Canvas fits with conventional business models, giving its focus on profit and money values; however, it offers little space for visualizing non-monetary values.

For this reason, this research focuses instead on the Value Flow Model as a tool for designing and analysing business models. This method is selected because of its suitability to understand and design business models for complex value networks, where multiple actors (not just businesses, but also governmental bodies, non-profit organizations or even individuals) are involved, each with its own interests and wishes, but also capabilities and core activities. In fact, den Ouden (2012) describes it as a method of identifying relevant stakeholders who play a role in the ecosystem and their interactions (which do not come only in monetary form or goods and services, but also intangible values). In other words, it provides a "*perspective for understanding value-creating roles and relationships, and offers a dynamic view of how both financial and non-financial assets are converted into value*" (den Ouden & Brankaert, 2013).

Therefore, the Value Flow Model builds upon two main elements: the actors and the flows of value between them. The actors are indicated with their roles (such as consumers, provider of goods, regulators) and they can be individuals or groups. The different roles are presented below; further information about the roles can be found in Appendix A.1.

Figure 2.2: Roles of actors in the Value Flow Model (source den Ouden, 2012)

The second element in the Value Flow Model consists of transactions, i.e. flows between the actors. They are divided into goods and services, money and credits, information, and intangible values (such as for example experience or reputation). These transactions are represented with arrows using different colours, showing also the direction of the flow and the content of the transaction.

For a better clarity, the Value Flow Model puts at the centre of system the core value proposition, in order to highlight it in comparison with potential complementary offerings and the supplying network. Without the elements of the core value proposition, there is no value created for the customers. Secondly, complementary offerings are positioned within the Value Flow Model, surrounding the core value proposition. The actors involved in this part of the model still have a direct contact with the customers, but the value proposition can still work without them; they provide complementary offerings to enrich the value and make it more attractive for the customer. Next to complementary offerings there is the supplying and enabling network, which consists of actors that supplies components (such as hardware) for integration into the value proposition, or that enable the value proposition in a certain way (an example here can be the regulatory bodies). Lastly, at the periphery of the Value Flow Model there are other stakeholders who are affected by the value proposition, but without being directly involved in it. Although it may be difficult to draw a limit here (i.e. in determining the actors who should be included in this last element), a good practice is to consider those actors that are impacted by the value proposition, experiencing direct or indirect consequences. Figure 2.3 provides a simplified example of the Value Flow Model, with some actors and flows depicted as part of the core value proposition, complementary offerings and the supplying and enabling network.

Overall, the Value Flow Model as a visualization tool represents a good fit with the theory of New Business Models. Firstly, it is in line with the broader perspective on business models and actors involved, thus building on the concept of business ecosystems (rather than focusing solely on one firm) and shared value creation. Secondly, the mapping of interactions between the actors follows the idea of NBM regarding multiple values: not only goods and money are included among the interactions, but also intangible values are considered.

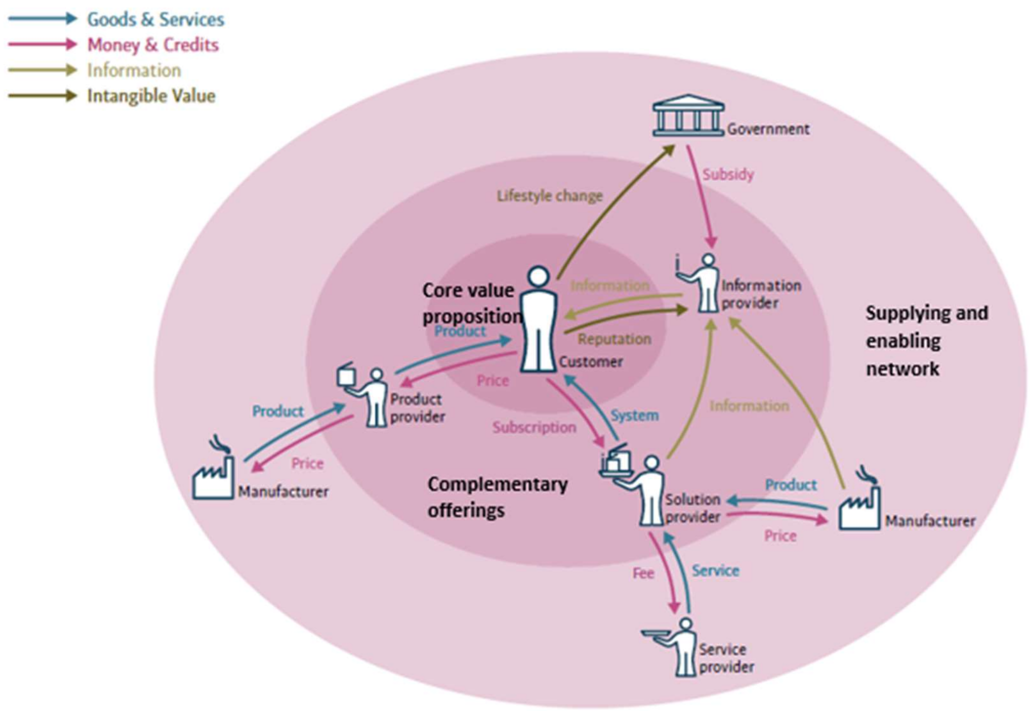


Figure 2.3:Example of a Value Flow Model (source den Ouden & Brankaert, 2013)

2.2 STRATEGIC NICHE MANAGEMENT

The theory of Strategic Niche Management (SNM) was firstly introduced by Kemp, Schot, & Hoogma (1998) as a way to explain how socio-technological transitions come about. In particular, SNM was developed for a specific type of innovations: socially desirable innovations (serving long-term goals, for example sustainability) and radical novelties (which are not in line with the existing practices, regulations or infrastructure) (Schot & Geels, 2008). By creating protected spaces (i.e. niches) where experimentation with new technologies, practices or regulations is allowed, innovation can be facilitated. Therefore, SNM is not only about mere experimentation, but it also emphasises the importance of learning processes (which are necessary for further development of the new technology), institutional changes and network building. In fact, Kemp et al. (1998) present four aims of SNM:

1. Articulation of changes in the technology and in the institutional framework, necessary for the economic success of the innovation
2. Learning about technical, economic and environmental feasibility of different technological alternatives
3. Stimulation of further research (to achieve for example cost efficiencies, complementary technologies, skills or new societal organizational settings)
4. Creation of constituency for a product (reports, researchers, companies, etc.) to allow its future introduction into the market, for which a coordinated action is key

All of this is required in order for a new technology to develop from a mere concept and idea into a real, used product.

The key idea, according to Kemp, Schot, & Hoogma (1998), is that new technologies and practices cannot compete immediately against already established ones on the market: they experience opposition and resistance from both inside and outside the innovation organization. In this regard, SNM aims to assess and explain these barriers that exists in the introduction and diffusion of new technologies. Typically, a technology does not experience only one barrier, but rather a combination of different opposing factors, ranging from technological factors (including the technology itself and its infrastructure), market factors, the regulatory framework and governmental policies, social factors and additional undesirable effects. In many cases, these different types of barriers are interconnected and may be feeding upon each other.

Taking into consideration this theoretical framework, this analysis will study the barriers and opportunities that arise when a battery storage is installed together with a community solar park, in particular in case that multiple values are created and captured.

2.3 CONCLUSION THEORETICAL FRAMEWORK

In this chapter, two main theoretical frameworks have been described: business modelling theory and Strategic Niche Management. Firstly, the theory of business models was explained. Although there exists a wide range of definitions for this concept, it can be stated to represent the core aspects of a business and aim to describe how can a company (or an organization) create, deliver and capture value. Following that, an integrative framework for the characterization of business models has been presented, consisting of six key components: value proposition, customers, internal competences, competitive strategy, profit mechanism and growth & time objectives.

Nevertheless, typical business models focus around one firm only, whereas innovations usually involve a higher degree of complexity in terms of actors, interactions and organization – this is also the case for community Solar-Plus-Storage projects. For this reason, the notion of business ecosystem will be considered in this analysis, which focuses on the value proposition created within a network of actors (rather than looking on business models from the point of view of a single company's capabilities and strategies). Building on that, this research will mostly focus on the theory of New Business Models (NBM) presented by Jonker. According to Jonker, values should not be measured only in terms of money, but also from a social and environmental perspective. In this regard, the value proposition should be created together, in a collaborative way; then, it is also shared among the actors (therefore, a business ecosystem approach is essential). Lastly, value should not be intended only in monetary form, but also from the perspective of environmental benefits and social value. This theory thus fits well with the whole idea of community projects that emphasize the creation and capturing of multiple and shared values, which is the central focus of this research. Overall, this research will use the Value Flow Model as a visualization tool, given its suitability to represent business models (and in particular NBMs) from an ecosystem perspective, with flows of both tangible and intangible values between the actors (thus considering multiple values created and shared among different stakeholders).

The second theory presented in this chapter (and that will be later used in this research) corresponds to the SNM theory, which aims to explain how socio-technological transitions come about and to analyse what barriers (ranging from technological and market factors to regulations and cultural aspects) have to be overcome for a successful introduction and diffusion of sustainable technologies in the existing market.

Both business models and SNM offer a distinct perspective on how technological sustainable transition can be achieved: SNM focuses on the opportunities that can be exploited and on the barriers that should be avoided or overcome, while business models describe how to translate this knowledge in business terms by creating, delivering and capturing value. Thus, these two theories can be stated to complement each other and for this reason they represent a suitable theoretical framework for assessing the spread of new technological developments, such as the combination of solar PV installation and battery storage in case of community projects throughout the Netherlands.

3 METHODOLOGY

To investigate and assess the feasibility of a community-owned large-scale Solar-Plus-Storage system by considering multiple value creation and capturing, a multi-perspective analysis is selected. In this regard, two main themes were developed in the course of this research to answer the main research question, namely business models and business cases. In the end, not only technical and economic feasibilities have been studied, but also regulative, operational and organization viewpoints have been considered in this research. In order to do so, a combination of different methodologies has been used.

The following chapter presents an overview of the general methodology followed in this research. However, it should be mentioned that further details about the methods used in the different sections to obtain specific results will be explained later in the corresponding parts of the report.

3.1 GENERAL METHODOLOGY

To determine and assess the possible business models in case of community Solar-Plus-Storage installations, firstly a desk study was performed on the typical values that battery storage (and in particular the addition of this technology to a solar PV system) bring. After that, currently deployed business models were studied by considering the results of the literature research and the benchmark study of larger Solar-Plus-Storage projects worldwide. Secondly, an actor analysis has been carried out by taking the COOP-Store project as a reference case, in order to gain insights about the important stakeholders in a cooperatively-owned Solar-Plus-Storage project; this was done by means of a combination of literature study and personal communication with the relevant actors from the COOP-Store. Furthermore, these actors were also interviewed (though semi-structured interviews) to determine the values that the stakeholders find more important in the addition of a battery storage to a community-shared solar park. In conclusion, this section therefore answers the first two research sub-questions.

The results from these two sections (namely the desk study of already established business models on one hand and the actor analysis, together with the stakeholder values' study, on the other) have been then combined to develop three business model scenarios for community Solar-Plus-Storage projects that were further analysed in this research, thus answering the third research question. The scenarios are chosen to target different types of values mentioned by the relevant stakeholders and to represent different degrees of complexity (in terms of number of key stakeholders, organizational settings and number of service uses that the battery provides); at the same time, they are also selected by keeping in mind the theoretical framework of New Business Models by Jonker, so that multiple values are created and captured. In addition, the interaction among the actors and their value capturing mechanism in the different scenarios were assessed in a business modelling workshop (further explanations can be found in the following section) and subsequently by considering the results of the desk study and interviews. In this way, the fourth sub-question is answered.

The techno-financial feasibility of the business model scenarios was assessed with a business cases' analysis. In this regard, inputs have been gathered by an extensive literature research, personal communication with professionals and relevant parties, and part of the results from the business modelling workshop; in addition, the COOP-Store project was also taken as the reference for some inputs. The techno-financial analysis was performed for the present year (2018) and for the future (in specific, the year 2025 was arbitrarily selected for this purpose). In this way, not only price developments have been considered, but also the impact of assumed regulatory changes has been taken into account in the calculation of possible future revenues. In the end, this analysis provides the answers for the fifth and sixth research sub-questions.

Lastly, to answer the last research sub-question, the barriers and opportunities that arise within a community-owned large-scale Solar-Plus-Storage project have been assessed by applying the theoretical framework of Strategic Niche Management. The approach used here includes a combination of desk study and results from both the semi-structured interviews as well as the workshop that focus on the factors opposing the wider spread of community Solar-Plus-Storage, including market factors but also technological and regulatory barriers. Instead, the opportunities that lie in the addition of battery systems to solar PV installations follow from the previous parts of the research.

3.2 INTERVIEWS

In this research, interviews were held with relevant stakeholders and professionals in order to assess the opportunities and values that battery storage can provide (in particular when it is added in combination with a larger source of renewable generation, such as a solar park), and the barriers that this technology currently faces.

The interviews were semi-structured and held in person (apart from one, which was a telephone communication); a list of all the interviewees is shown in Table 3.1. It should be noted that the interviewees, though representing a specific company or stakeholder, do not speak for the organization as a whole, but rather from the point of view of their specific department and personal experience with the topic. Moreover, the results should not be considered static, since they can change in time.

Stakeholder/Organization	**Interviewee(s)**	**Function**
WeertEnergie – Energy cooperative	Peter Ramaekers	Cooperative member, responsible for the COOP-Store project
Scholt Energy Services – Energy service company	Frits Maas; Joël Nolten	Business Development Analyst; Product Manager Energy Storage
Soltronergy – EPC company	Bert ten Haaf	Owner, project manager and consultant
Enexis – DSO	Karl Langeveld	Environment Management Consultant (Adviseur Omgevingsmanagement)
Enpuls – part of Enexis group (DSO)	Alexander Savelkoul	Flexibility Manager (Manager Flexibiliteit)
DNV GL – quality assurance and risk management company	Melvin van Melzen	Consultant New Energy Technologies & Energy Storage
Netwerk Energietransitie Nederland; Stichring Walk of Wisdom – foundation	Martijn Messing	Member of Netwerk Energietransitie Nederland; co-founder and broad member of Walk of Wisdom Foundation

Table 3.1: List of interviewees

3.3 BUSINESS MODELLING WORKSHOP

The workshop session was carried out with two goals in mind: determining the interactions among relevant stakeholders in the proposed business model scenarios and gaining insights for the techno-financial analysis as well as for the determination of barriers and opportunities of Solar-Plus-Storage installations.

Therefore, the workshop was divided into two interactive parts. In the first one, the participants (divided into groups) were asked to fill in a mind maps for each separate service that battery storage can provide, reflecting in particular on the following questions:

- When is the battery used (for the particular application)?
- How much money can be made with this service?
- Which customer pays for this service?
- Which (legal or other) barriers exist for this service?

The second interactive part focused on the interactions and relationships between different actors. Here, the selected method was the Value Flow Model – a visualization tool for business models especially used to design business models for complex networks, where multiple actors and values are involved, as previously described in Chapter 2. This method was selected due to its applicability and relevance for the considered scenarios, consisting of different flows of tangible and intangible values between multiple stakeholders. After a short presentation of the Value Flow Model's methodology, the participants were divided into groups, each focusing on a different business model scenario. The scenarios differed in terms of owner and operator of the Solar-Plus-Storage asset and the service uses that the battery storage is designed to provide, and reflected the scenarios developed in this research. For each scenario, the participants were asked to construct the Value Flow Model by determining the following:

- Who are the core actors needed in each scenario? Who are the complementary actors and who are the enabling actors?
- What is the flow of tangible and intangible values between these actors?

For the actors, the participants were provided with the names of some stakeholders on post-it notes, which had to be positioned within the Value Flow Model (in the appropriate circle). In addition, blank post-it notes were available to be filled in, in case that relevant stakeholders were missing. Lastly, each group determined the flow of goods and services, money, information and intangible values between the actors using differently coloured arrows.

3.4 SIMULATION MODELLING

As part of the techno-financial analysis, simulations were performed in order to calculate the percentage of time that the battery storage would be needed to provide specific servicess (in specific, for peak shaving, as will be later discussed in the report).

To do so, production profiles for a solar park with the location and orientation as in the COOP-Store project were developed. In particular, as will be later presented in the Chapter 6, a 2,3 MWp solar park is chosen, located in the area of Weert and with the following orientation: 48,5% East, 48,5% West and 3% South. The hourly-based production profiles were obtained with the software PVSyst, using the meteorological data from the Meteonorm software for a typical meteorological year for the location of Weert.

From these profiles of the solar output, the amount of time for which a battery would be needed for peak shaving has been calculated. As will be later explained, a threshold of 1750 kVA was selected for the maximum output possible; from that, the number of occurances for which the hourly PV production was greater than 1750 kW was counted. This in turn gave the number of days for which peak shaving would be needed (to deliver power into the grid that is lower than the selected threshold), as well as the total number of hours in that day. An example of this simulation can be found in Appendix A.2.

The simulation was performed both in case of a solar park installed in 2018 as well as 2025 (the only difference being the efficiency of the solar panels). In addition, the results of this simulations were used also to compute the overall yearly electrical output produced by the solar park, which has been used for the business case calculations.

4 BACKGROUND

4.1 APPLICATIONS OF BATTERY STORAGE

Battery storage is by nature quite versatile in terms of the range of applications it can be used for. In fact, as stated by Hoium (2016), there is value from battery energy storage systems (BESSs) *"for the entire grid, from utility to customer*". Some of the most important advantages of BESSs are the following: they can be placed in every level of the grid (from generation, transmission, distribution or end-user -level), they usually don't require complex infrastructure projects for their installation, they provide mobile and scalable solutions and have a relatively high speed of deployment compared to some other alternatives (i.e. can be operative in a couple of months, whereas for example grid expansion projects usually take more time) (EUROBAT, 2016).

The following section presents an overview of the primary applications where battery storage is currently used to provide value, in particular also when it is combined with a renewable source generation system such as a solar PV installation (even if it should be remembered that some of the applications described here can be provided even by the battery system alone, for example reserve capacity, demand peak shaving and imbalance trading).

4.1.1 Increased self-consumption

Self-consumption is defined as the share of the total output (for example from solar panels) that is directly consumed by the end-users. In fact, the production and consumption of electricity from renewable sources such as PV systems often do not coincide in time, causing periods of surplus or shortage of electricity. In this regard, battery storage can be used to increase the self-consumption by storing the surplus electricity from the PV panels and use it later when there is a shortage of production (which can be for example during cloudy periods or at night). In this way, the surplus electricity (which is not directly used) is not lost or injected into the grid but used later when needed. This in turn reduces the amount of energy that needs to be taken from the grid, which has the potential of lowering the electricity bill for the end-users. In addition, increasing self-consumption is becoming nowadays even more attractive giving the fact that in some countries the compensations from "exporting" the surplus electricity into the grid are decreasing below electricity retail prices. This provides an additional financial stimulus to directly consume the produced electricity or store it in a battery storage for later use.

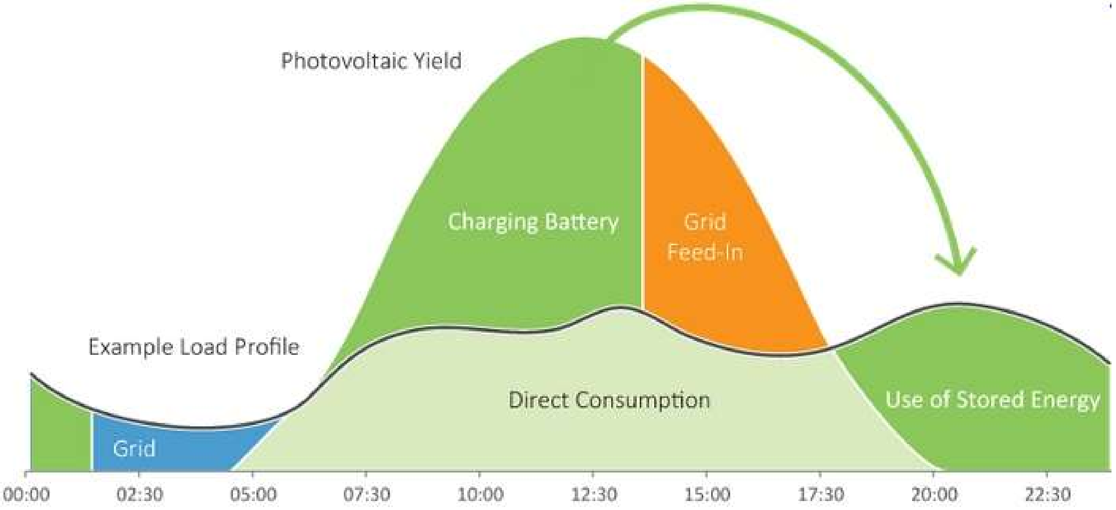


Figure 4.1: Example of how can a battery storage be used to increase self-consumption (source PowerTech Systems (n.d.)*)*

4.1.2 Increased self-sufficiency

Self-sufficiency is defined as the fraction of a customer's consumption that is supplied by the solar PV panels; in other words, a customer can become self-sufficient with a solar installation if the system provides all the necessary electricity. In this case, the customer can become independent from the grid and covers all the demand with the electricity produced by the solar system. Total self-sufficiency (or an increase in self-sufficiency) can be achieved with the addition of a battery storage, which stores the surplus production (such as for example at noon, when the demand is lower than the electricity generated by the solar panels) and delivers it when there is less output from the PV system than what is needed. Typically, increased self-sufficiency for larger Solar-Plus-Storage systems is currently targeted in remote areas, where the connection to the existing grid can be very expensive. In addition, it is also used for the systems located in areas where the grid is not entirely reliable; batteries can therefore allow a continuous and reliable supply of electricity even in a grid-disconnected mode.

4.1.3 Peak shaving

Battery storage can be used for peak shaving of electricity. In this regard, two separate cases can be considered: demand peak shaving or supply peak shaving.

Demand peak shaving can be interesting to those customers that are typically charged for their peak demand (kW) in addition to the amount of energy they consume. During times of low demand, the storage can be charged, and is then discharged during peak demand times, in order to reduce the peak load and thus demand charges faced by the consumer. For example, in the Netherlands, part of the grid fees that industrial consumers pay with their monthly energy bill are represented by two variable tariff components: the contracted power (the maximum number of kW that the connection has ever taken from the grid) and the monthly maximum power (maximum consumption in kW taken from the grid in a given month, considered on a 15-minute basis) (Enexis, 2018; Nolten, 2017). If a battery storage is used for demand peak shaving, the monthly energy bill can be lowered due to the reduction of the contracted and maximum power.

Instead, supply peak shaving is usually applied when a battery storage is co-located with a new renewable energy source system, for example a solar park. By storing the peak power produced during times of high renewable resource availability (such as at midday during sunny summer days), the battery storage can contribute to the reduction of the connection capacity needed to connect the solar PV installation to the electricity grid. This in turn lowers the connection costs for the generator and at the same time limits investments in the grid for the grid operator.

4.1.4 Backup power

In case of an unexpected outage or a failure in the electricity grid, battery storage can supply emergency power to specific customers for whom a continuous flow is essential, such as hospitals where an uninterrupted supply is vital for the operation of life-saving equipment. Another example of end-users that require backup power are server rooms, data centres and other industrial customers where a loss of power (or other power supply issues) can be harmful for the sensitive devices used.

4.1.5 Reserve capacity

In case of a supply-demand imbalance, changes in the frequency of the electricity grid occur. When supply exceeds demand, the grid frequency increases above the standard 50 Hz (for Europe). On the contrary, if there is a generation deficit, the frequency decreases below nominal values. In order to restore the original frequency, three grid balancing services are usually defined: primary, secondary and tertiary reserve, which operate on different timeframes. These balancing services can be traded on the electricity market in the form of reserve capacity and are settled by the TSOs (transmission system operators) (Emissions-EUETS, 2018).

Primary reserve, also known as Frequency Containment Reserve or FCR, consist of fast-acting active power reserves, which are the first activated reserves to reconcile fluctuations in frequency when an imbalance occurs. The operating reserves in this category need to have an activation time up to 30 seconds and have to be able to deliver their rated power for a period of at least 30 minutes(Emissions-EUETS, 2018; Nolten, 2017). In the Netherlands, the primary reserve market is tendered on a weekly basis, with a tender process of 1MW or higher, in blocks of 1MW; this may change in the near future to 4-hours tender blocks (Scholt Energy Service, 2017). The secondary reserve, or automatic Frequency Restoration Reserve (aFRR) is the second set of reserve capacity that is activated; it is used to restore the system frequency within a synchronous area and to allow primary reserve to be available to react in case of a new disturbance. This category usually includes reserves with an activation time between 30 seconds and 15 minutes. The market for secondary reserve is tendered quarterly and yearly with a minimum bid size of 5 MW (Nolten, 2017). Lastly, tertiary reserve (manual Frequency Restoration Reserve - mFRR) is used in case of very large disturbances and, unlike primary and secondary reserve which are activated automatically, is manually activated by the TSOs. The activation time of units providing tertiary reserve capacity is within 15 minutes, for a period of at least 60 minutes. The minimum amount of contracted power is 20 MW, tendered on a quarterly basis (Nolten, 2017).

Conventionally, reserve capacity is provided by spinning reserves that are delivered by traditional rotating generation units. However, battery storage can also be used to provide reserve capacities used for containment of frequency deviations from nominal values, in order to ensure power balance (for example in the whole synchronously interconnected system in the European electricity grid). This is essential to guarantee the stability of the grid and prevent problems such as damage of equipment, grid failures or blackouts. At the moment, battery storage is most commonly used for primary reserve capacity, due to a high financial reward for this sector but also because the design of primary reserve matches the characteristics of the battery storage technology.

4.1.6 Grid reinforcement deferral

In cases where the electricity network is nearing its peak capacity, grid congestion can start to arise; this can follow from a peak demand of electricity (by end-users, companies or industries) or from a peak supply (for example when the electricity output from a renewable energy generation system is not directly consumed by the local loads). In both circumstances, the current Business-As-Usual procedure is to reinforce the existing infrastructure by introducing new grid lines, cables or transformers. However, battery storage can be installed to delay costly upgrades by limiting the amount of energy flowing and moving it instead to off-peak times (in other words, by using the battery storage for peak shaving, grid reinforcement deferral can also be targeted as a service).

In addition to that, studies (for example Idlbi et al. (2016); Tant et al. (2013)) show that electricity grids, especially on the lower voltage distribution level, can suffer from voltage violations due to the increasing distributed generation of renewable energies on one hand and the increasing electricity demand on the other. To mitigate voltage violation problems, system operators usually undertake grid reinforcement measures. Nevertheless, battery storage can be used as a remedy for voltage control and in this way defer grid reinforcements. In specific, voltage control usually refers to the supply of reactive power to maintain the grid voltage within it nominal range of operation; in this case, distributed storage can be attractive since reactive power cannot be transmitted efficiently over longer distances (ESA, n.d.).

In fact, battery storage can be used both as a long term solution or as short term application: apart from the immediate cost savings of delaying grid reinforcement, a more flexible planning of grid reinforcement provides planners the opportunity for better clarity regarding (future) loads' needs, "*which reduces risk and enhances the effectiveness of the grid investments*" (ACORE, 2016).

4.1.7 Energy arbitrage

The generation of electricity by means of a renewable energy source depends on the resource availability (for example, solar panels produce electricity output during the day, when the sun is shining). However, the prices of electricity usually do not follow the same trend (fluctuations in prices derive from the fact that demand and supply must at all time be match; however, electricity cannot be stored on a large scale at the moment, and both demand and supply become less elastic the closer is the time of delivery (Nolten, 2017)). By means of a battery storage, it is possible to store the generated electricity during periods when the electricity prices on the energy market are low and sell it later during high-price periods. This time shift of electricity thus creates arbitrage opportunities that can maximize revenues for energy generators.

In the Netherlands, electricity is traded in several markets, operating on different time scales: the future market, day-ahead market, intraday market and imbalance (real-time) market. Following the results presented by Nolten (2017), battery storage is most commonly used on the day-ahead market and on the imbalance market. For this reason, a short description of these two markets is provided. Detailed information about the other markets is placed out of scope of this research; for further specifications a reference is made to the literature (Frontier Economics, 2015).

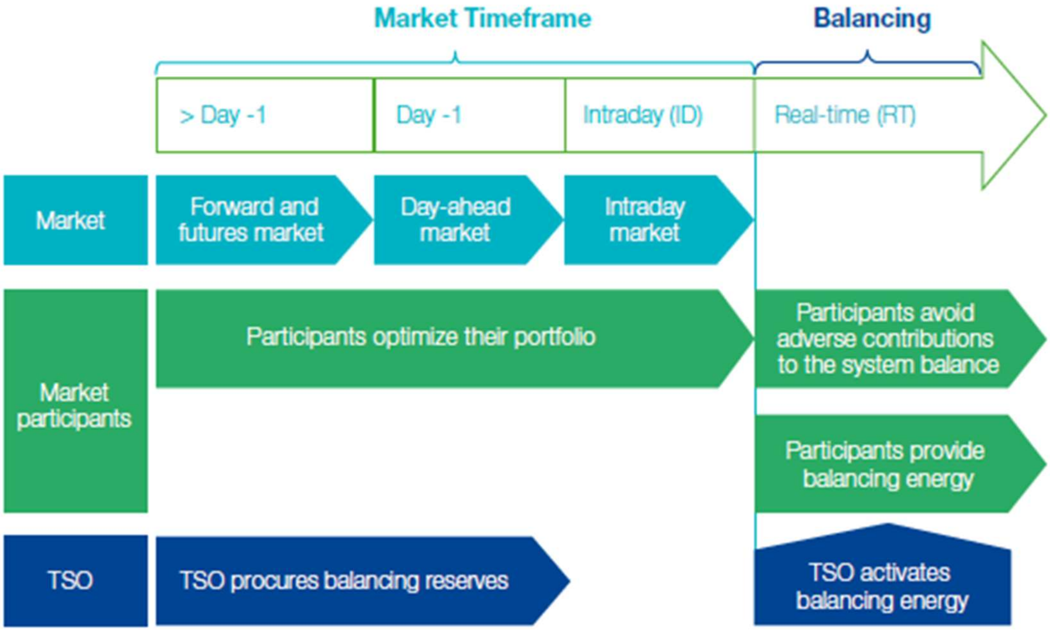


Figure 4.2: Design of the Dutch electricity market (source TenneT (2018))

Day-ahead market

In the day ahead market, the trading of electricity happens on the day before the actual delivery (typically bids can be submitted until 12 a.m.). In the Netherlands, this market is organized by the APX power exchange, thus it is also known as the APX spot market. It is the market with the highest trading volumes and number of participants; because of that, the price of the electricity from this market is usually called simply “electricity price” (TenneT, 2018).

Imbalance trading

As previously said, there must always be a balance between the amount of supplied and demanded electricity. However, this is even more complicated for generators which use renewable energy sources, given the variability and unpredictability of power production by resources such as wind or solar. In this regard, battery storage can be used for portfolio optimization, in order to reduce the difference between the predicted and actual output from sustainable energy sources. This in turn is important since the party responsible for this imbalance has typically to pay a penalty for the imbalance created.

In many countries, the costs for the imbalance is proportional to the costs associated with the activation of reserve power (the TSO is typically tasked with the activation of these reserves, in order to maintain grid balance); however, market designs can be different per country (Nobel, 2016). For example, in the Netherlands the TSO provides live updates on reserve activation volumes and prices, thus allowing parties to profit from fluctuating imbalance prices – this practice is called imbalance trading.

Table 4.1 presents a summary of the battery storage service uses described above, together with the central value proposition of each application.

Name of application	**Type of service**	**Core value proposition**
Increased self-consumption	Customer service	Higher return on investment, lower electricity bill for end-users
Increased self-sufficiency	Customer service	Increased energy independence, reliable supply of electricity even for off-grid systems
Peak shaving	Customer service and grid service	Savings on the energy bill (in case of demand peak shaving); lower connection capacity and therefore lower connection costs (in case of supply peak shaving). In both cases, it also avoids grid upgrades
Backup power	Customer service (specific customers such as hospitals, data centres)	Uninterrupted availability of power for essential equipment
Reserve capacity	Grid service with market access	Ensure stability of the grid by providing grid balancing through fast reaction to frequency changes
Grid reinforcement deferral	Grid service	Deferral (or sometimes even avoidance) of investments in grid updates; multi-purpose flexibility in the grid
Energy arbitrage	Market-related (profit)	Increased revenues by storing electricity when the prices are low or negative, selling when the prices are high

Table 4.1: Summary of battery storage applications

4.2 CURRENT BUSINESS MODELS FOR SOLAR-PLUS-STORAGE

Currently, the combination of solar and battery energy storage is deployed on multiple scales, from small households' systems to bigger installations directly connected to the transmission or distribution grid. This variety of location and sizes has a consequence also on the stakeholders involved in each project, particularly from the point of view of who owns the system and who is responsible for its management and maintenance. Furthermore, there are also different applications for which the storage can be used in these projects.

Because of all this, various business models can be identified from existing Solar-Plus-Storage systems. To capture these differences in a consistent manner, the following distinctions will be used in this analysis to create a business model description framework (the framework is based on the methodology used in Pöyry Management Consulting, 2014):

- **Location of the system**: Firstly, Solar-Plus-Storage business models can be grouped into two large markets, depending if the system is installed Behind the Meter (BTM) or in Front of the Meter (FTM). BTM systems are typically installed on the customer side and are meant for on-site consumption, for example in private households, commercial buildings or industrial facilities (thus literally "behind the meter"). On the other hand, FTM systems are utility-sided, connected to the distribution or transmission grid, from where the electricity is then transported to the consumers.

In most cases, the location is linked to the scale of the installation: for BTM systems, the installations have usually a smaller scale, while larger-scale systems are generally located in front of the meter and directly connected to the electricity grid.

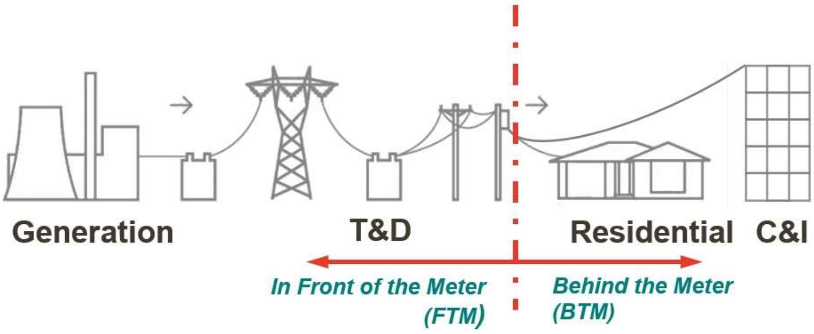


Figure 4.3: Difference between the location of Front of the Meter (FTM) and Behind the Meter (BTM) systems. T&D stands for transmission and distribution grid, while C&I represents commercial and industrial buildings

- **Owner:** Business models vary also on the ownership of the assets. The owner can be the end-user, a system operator (distribution-DSO or transmission-TSO), a community or a third party. The owner is typically responsible for the investments for the system and its provision, and for the operating expenses needed.
- **Operator:** There are also different possibilities in terms of who is responsible for the operation, management and maintenance of the system, among the same set of actors (i.e. end-users, community, network operators or third parties).
- **Application:** As already mentioned, adding a battery storage to a solar PV system provides different benefits. The possible applications have been described in the previous section.

The following section presents an overview of the most used business models in current worldwide Solar-Plus-Storage projects, considering the four criteria mentioned above (location, owner, operator and application). For this analysis, the geographical area of the research has been extended outside the Netherlands due to the limited number of Dutch Solar-Plus-Storage projects (especially in case of larger-scale projects). The outcomes have been obtained from a benchmark study of larger Solar-Plus-Storage installations, consisting of solar systems above 500 kWp and battery storage capacities above 250 kWh (these thresholds have been set arbitrarily; see Appendix A.5 for an overview of the benchmark study's results). In addition to that, the outcomes of the benchmark study were later integrated with further literature review on current business models for the combination of battery storage and solar systems (ACORE, 2016; EUROBAT, 2016; Pöyry Management Consulting, 2014; Roland Berger, 2017; Takata, 2017).

From this desk study it can be concluded that there are several business models which are currently applied for battery energy storage co-located with a solar PV generation system. However, the results also show that from the point of view of the type of service that the battery storage provides (if these are divided into three categories, i.e. supporting the electricity grid, providing benefits to the end-users and contributing to market purposes), three business models are mostly deployed.

1. End-user -related benefits

Typically, these systems are positioned behind the meter, they are smaller in size (up to 1 MWp of solar panels) and located on residential sites (private households) or in industrial and commercial buildings (some examples here include wineries, breweries, farms, hotels or resorts). The end-users are therefore the producers of energy by means of the solar panels as well as the consumers (on-site generation and consumption); therefore, in these cases end-users can be referred to as prosumers. Besides owning the Solar-Plus-Storage installation, they also operate it themselves in most cases.

The applications of the battery storage in these projects is mainly related to increasing the share of the own-produced energy and to keep as much electricity as possible on-site, without exporting it to the grid. This implies that less electricity is needed from the grid, which in turn increases energy independence and at the same time facilitates the return on investments for the installation itself. Therefore, the two primary targeted service uses are increased self-consumption or increased self-sufficiency by means of the battery storage. It should be noted that systems addressing self-sufficiency are mainly located in remote areas or in off-grid projects (for example hotels on tropical islands or lodges in African national parks). In this regard, one clear example is the Kruger National Park in South Africa: the resort owns the Solar-Plus-Storage installation (corresponding to 1 MWp of solar park installed in 2016 and 3 MWh battery storage added in 2017), but also operates it for increasing the resort's self-sufficiency and providing an off-grid solution.

In some commercial and industrial properties (for example large farms, breweries, etc.), batteries are also used for demand peak shaving. By shifting the electricity demand from on-peak to off-peak periods, end users can save on peak demand charges and therefore on their overall electricity bills.

Lastly, storage is sometimes used to provide backup power and ensure a continuous supply of electricity even in case of outages or disruption. This feature is extremely important for vital or critical equipment, for example in hospitals or software centres. It should be noted that this service use is typically targeted for small-scale installations, especially when it is the only application of the battery storage; in case of larger-scale systems, it is usually combined with other service uses. However, in both cases the number of projects that apply the combination Solar-Plus-Storage for backup power is limited.

In addition, it should be noted that in some cases it is also possible for the end-user to be the owner of the installation, but the operation is left to another party, typically an energy service provider with experience in these systems and their management procedures. One example in this case is the Redstone Arsenal Army post in Alabama, US; the army, representing the end-user of the 100MWp solar park and 2 MWh battery storage, owns the system, but a commercial party (SunPower) is responsible for its operation and maintenance, in particular in terms of delivering a secure supply of solar energy and reducing electricity costs via peak shaving.

Figure 4.4 below presents a schematic view of the "End-user -related benefits" business models in terms of the description framework previously defined. It should be kept in mind that in the figure all the applications mentioned in within the "End-user -related benefits" business models are depicted with a coloured background. However, this does not signify that all these benefits are generally targeted by the same systems; in fact, usually only one service use (or a combination of two services) of the battery storage is addresses in most of the projects considered in this analysis. Similarly, the both Third party and End-user operator are depicted in the figure, indicating that both possibilities are used in current business models (although not for the same system).

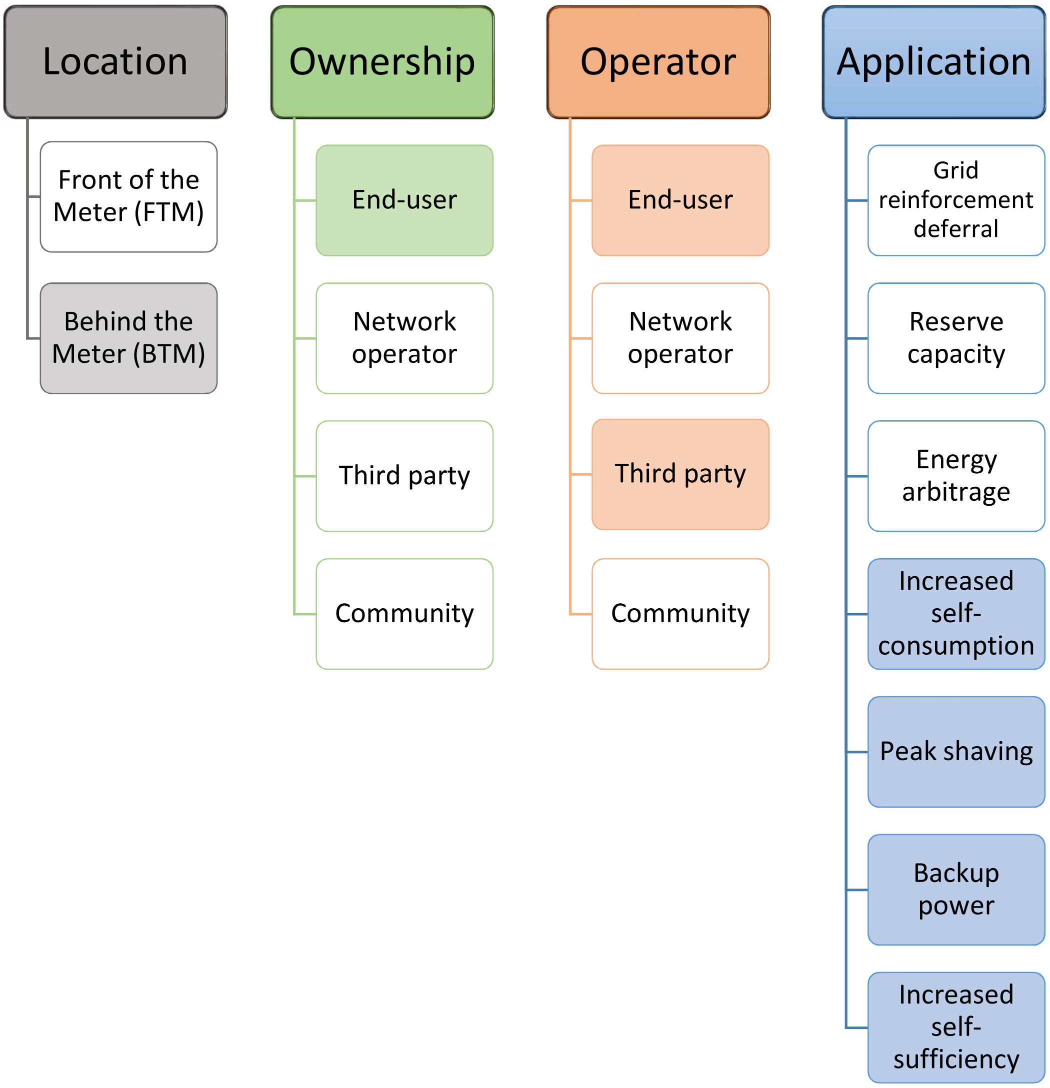


Figure 4.4: "End-user -related benefits" business model (obtained from the literature study)

2. Grid-related benefits

In the cases when the battery storage is designed to support the electricity grid, the system is located in front of the meter. For Solar-Plus-Storage projects, the batteries are co-located with the solar park. The main applications of the storage are typically grid reinforcement deferral (mostly with peak shaving of supplied electricity, which allows a lower connection capacity for the solar installation) and provision of ancillary services (such as voltage control) to keep the electricity network stable, which also avoids grid updates.

Firstly, it is important to mention that this business model is currently not very common in large Solar-Plus-Storage projects. In fact, when the batteries are used for grid-related benefits, they are typically deployed as a separate asset, not in combination with a solar park or other types of power plants. In this way, they are not bound to a specific place, but can be instead positioned at critical nodes or in those locations where they are mostly needed to support the electricity grid. In addition, the separation of the battery system from the solar units allows the network operators in some cases to both own and operate the storage, if only network values are captured by it.

However, considering instead Solar-Plus-Storage projects (thus the implementation of battery storage in combination with solar panels, which is the focus of this analysis), the "Grid-related benefits" business model is mainly deployed in pilot projects that specifically study the role of battery systems for the management of electricity grids; two examples are a pilot project in Finland between an energy generator and the local network operator, and a pilot project developed by the Ecole Polytechnique Federale de Lausanne in Switzerland.

Typically, the owner of the Solar-Plus-Storage system is a third party (in some cases this can also be a research institute or a university), which furthermore acts as the operator of the asset. In addition, the network operator is also involved in the project. This participation is typically not in the form of active management of the battery system, but rather in the form of a contract agreement with the asset owner and operator. In other words, the network operator contracts with the Solar-Plus-Storage system operator for the provision of local network services, but overall the third party has direct operational control of the asset. For example, in Finland the energy company Helen Ltd. Energy Solutions has built a 1,2 MWp solar park and 0,6 MWh battery storage in order to study how can batteries contribute to voltage control and frequency regulation when combined with a renewable energy source; the local network operator is directly involved in the project by providing information about the status of the electricity grid, but it does not have a direct operational control over the asset.

In Figure 4.5, as far as operators are concerned, both the 'third party' as well as 'network operator' boxes are marked, in order to emphasize the active involvement of both parties in this scenario.

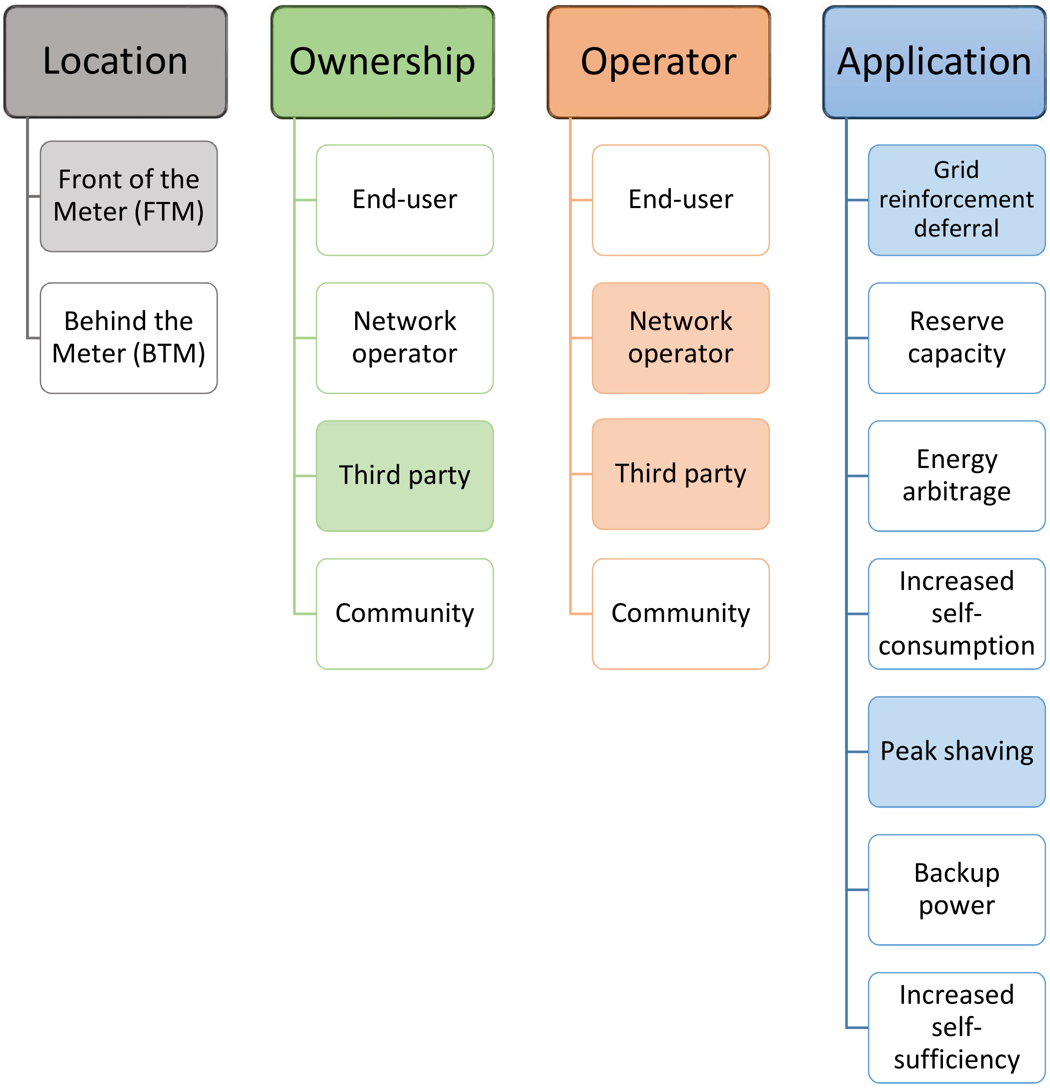


Figure 4.5: "Grid-related benefits" business model (obtained from the literature study)

3. Market purposes and grid services

In most situations when a battery storage is coupled with a larger renewable source generation unit (such as for example a solar park), the two most used applications of batteries are energy arbitrage on the electricity market (typically on the day-ahead market) and the provision of primary reserve capacity, which is used by the network operator for grid balancing.

The battery storage, together with the solar PV system, is located in front of the meter. Both assets are either owned and operated by the same third party (usually a generator company), or by two different companies who have a contract agreement between them. In the latter case, the most common organizational setting is that one third party is the owner and operator of the solar installation, while another company oversees the ownership and management of the battery storage. This latter business model is for example used by Anesco in the UK: this commercial company owns and manages the batteries installed in different locations within the UK in combination with a solar PV installation (such as Northampton, Chesterfied or Dorset), while a different third party is the owner and operator of the solar park.

Overall, in this business model there is a clear emphasis on battery storage being used by electricity producers for additional revenues. Firstly, one of the main applications of the batteries is energy arbitrage, i.e. managing the solar output to improve the economic return, that is for example shifting the delivery of electricity produced by the solar panels from periods when the prices of electricity are lower to times with higher prices, thus higher revenues can obtained. In fact, due to the increasing number of systems based on intermitted renewable sources, major fluctuations in output lead to larger price differences. However, storage represents an opportunity to take advantage of these differences by energy arbitrage.

In many cases, the batteries are also used for grid stabilization services. In this regard, market parties that own and operate battery storage systems provide ancillary services to the grid operator. In general, the most targeted service use of batteries in this aspect is the delivery of primary reserve capacity, since it is usually the most viable application for storage systems. It should be noted that in these business models, grid services are typically not targeted with the final aim to support the electricity grid and provide benefits to the network operators, but rather because of their profitability and possibility of additional revenues.

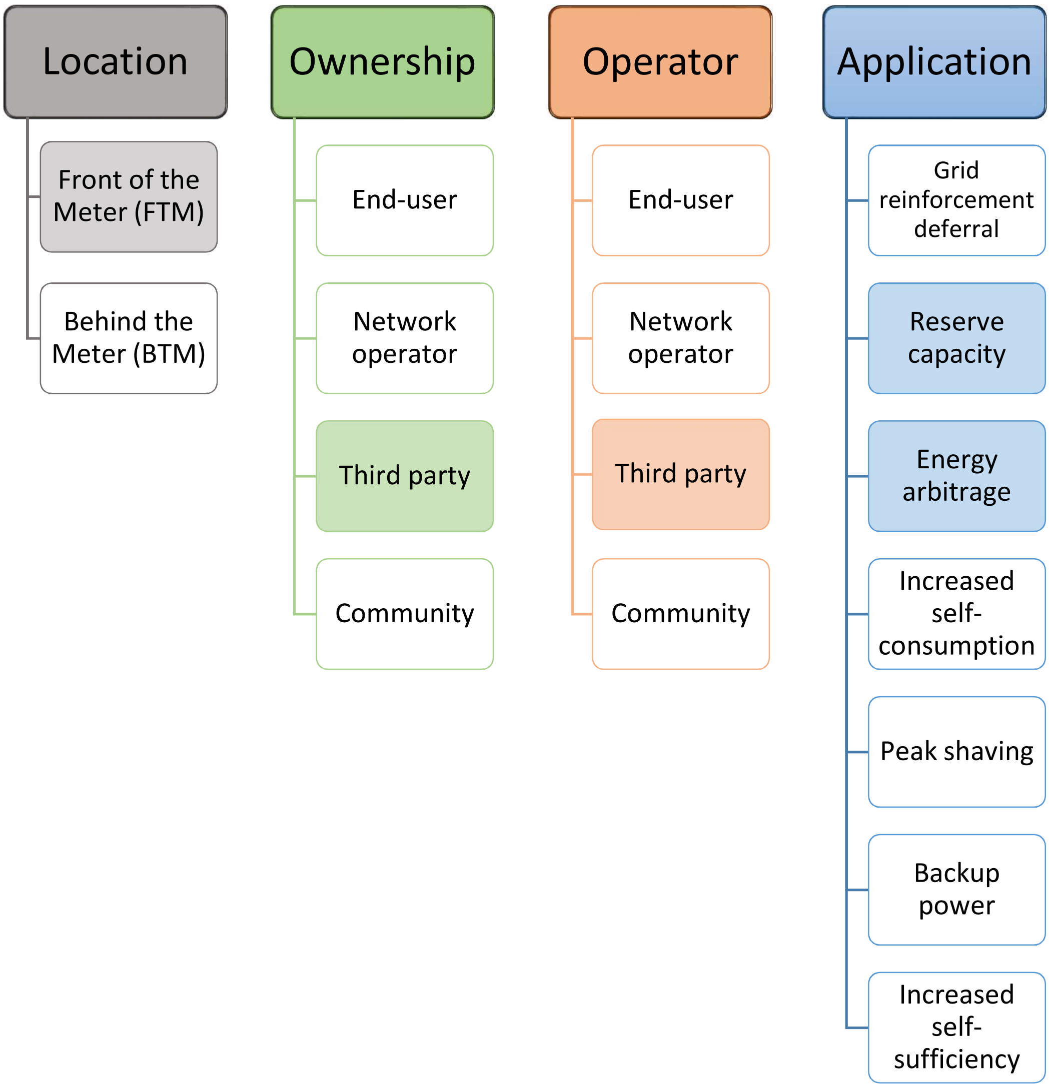


Figure 4.6: "Market purposes and grid services" business model (obtained from the literature study)

4.3 ENERGY COOPERATIVES IN THE NETHERLANDS

4.3.1 Definition

A cooperative is usually defined as a group of people acting together to meet common needs and aspirations of its members; it is also characterised by sharing ownership and making decisions democratically. The vast majority of local cooperatives are small-scale voluntary organizations, where the main goal is not primarily about making big profits for the shareholders, but rather providing benefits for its members and also for the broader community.

Following this, an energy cooperative is a type of cooperative that is typically engaged in power generation (mostly from renewable energy sources such as wind and solar), collective purchasing of electricity or energy saving measures. Overall, there is generally a strong emphasis on environmental protection, contribution to climate change mitigation and CO_2 emission reduction, and social cohesion. Because of that, it can be stated that energy cooperatives "*stand at the crossroad of two important changes in society*" (Hans & Schwencke, 2014) : the energy transition on one hand (with the promotion of renewable energy as well as towards a more decentralised, local energy production) and social decentralisation (i.e. the transfer of tasks from a central government to local entities, the market and society at large).

4.3.2 General information

Recent years have seen a significant growth in the number of energy cooperatives in the Netherlands, from around 50 in 2012 to more than 280 by the end of 2017 (HIER Opgewekt, 2017). Currently, they are spread throughout the country and present in almost every Dutch municipality. In most regions, local energy cooperatives work in close relation with each other, usually via an umbrella organization which acts as a facilitator through the support of new projects by creating contacts and partnerships between local cooperatives, organizing workshops and contributing to the overall awareness of the broader population on the impact of the energy cooperatives in the energy transition.

Of all the energy cooperatives in the Netherlands, about 70% are active in projects concerning energy saving measures, 60% of the cooperatives are engaged in local generation of energy from renewable sources (mostly wind and solar PV) and 60% organize collective purchase of electricity (HIER Opgewekt, 2017). This means that energy cooperatives are typically involved in more projects that focus on different aspects of the energy transition. Hereafter, due to the scope of this research, the focus will be only on projects involving local generation of green electricity via solar PV installations.

The cumulative power coming from collective solar projects from local energy cooperatives in the Netherlands was 36,6 MWp in 2017. Giving the fact that the total installed solar PV capacity in the country in the same year was 2,1 GWp, it means that energy cooperatives contributed only by 1,7% of the total Dutch solar capacity. However, according to HIER Opgewekt (2017), there are more than 200 new cooperative solar projects in the pipeline for the year 2018, which will help to boost the total installed capacity with an additional cumulative capacity of approximately 66MWp.

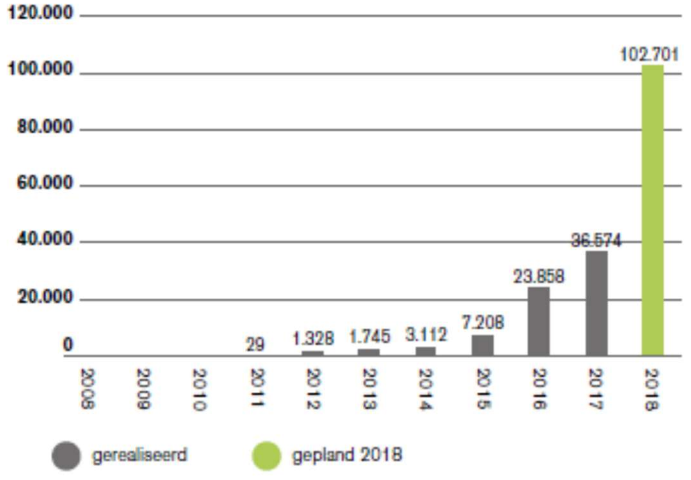


Figure 4.7: Cumulative solar PV capacity from cooperative projects from 2008 till 2017; the green column represents the expected cumulative capacity at the end of 2018 (if all the projects in the pipeline will be realised) (source HIER Opgewekt, 2017)

Considering the total 36,6 MWp installed capacity in 2017, around 16 MWp comes from ground mounted, larger-scale solar parks, while the rest of the cumulative capacity is from rooftop installation (with the majority of these being small systems, below 100 kWp).

Further information about the cumulative installed capacity of cooperative solar projects per province and additional details about the total number of solar projects per year can be found in Appendix A.3.

4.3.3 Financing the projects: investments and subsidy schemes

Typically, the investments for collective solar projects in the Netherlands come from citizens and small entrepreneurs via the cooperative (according to HIER Opgewekt (2017), there are presumably about 15 thousand people that have invested in one of the 269 cooperative solar projects since 2008), or through a crowdfunding platform. In some projects however there are also other investors involved, usually a third party (who is later also the owner of the installation) or a bank (by providing a loan to the energy cooperative). The type of investment mostly depends on the scale of the project: the majority of small projects are 100% financed by the citizens and small entrepreneurs, while for large projects the participants bring an equity between 10% and 30% while the rest is financed via a third party or a loan from a bank. Usually, the participants are also members of the energy cooperative, but this does not always have to be the case, since it entirely depends on the role of the cooperative, its structure and the financing construction of the project itself.

In order to stimulate the production of sustainable energy, the Dutch government has established several fiscal incentives which can be applied for by companies involved in the generation of green energy, private citizens or energy cooperatives. There are three types of subsidy schemes important for energy cooperative solar projects: net metering (“salderingsregeling”), the ‘postcoderoos’ (“Regeling verlaagd tarief”, or RVT) and the sustainable energy production incentive (“Stimuleringsregeling Duurzame Energieproductie”, usually abbreviated with SDE+). The first fiscal incentive settles the amount of generated electricity and the own consumption behind the meter, thus it is typically used for rooftop installations. The postcoderoos, or RVT, is a subsidy in the form of discount on the energy tax, meant for private individuals or companies that invest in solar panels for a rooftop or ground installation; the recipients of this subsidy need to be the legal owners of the solar installation and are required to live in the same (4-digits) postal code or in the adjacent postal code regions (known as postcoderoos area). Lastly, the SDE+ is a fiscal incentive intended for larger projects of renewable energy production; in specifics, it is an operating subsidy that generators get for every kWh of produced energy, in order to compensate for the difference between the cost price of renewable energy and conventionally generated energy. Further details about the postcoderoos and the SDE+ can be found in Appendix A.4.

Out of the cumulative cooperative solar capacity (36,6 MWp) in 2017, almost 70% (more or less 25,4 MWp) make use of the SDE+ subsidy scheme; this incentive is usually applied in case of larger projects (above 500 solar panels). On the other hand, if the number of panels (and thus, the capacity of the solar installation) is lower, the postcoderoos is applied. In fact, the number of projects with the postcoderoos in 2017 was higher than the number of projects with SDE+ (114 RVT projects against 81 for the SDE+); however, since these projects are typically smaller-scale, the cumulative capacity in 2017 that made use of the postcoderoos was only 8,7 MWp. These results can be also seen in the figure below. Only a small fraction of the total installed capacity (which nevertheless represents a quite significant number all the projects) uses net metering as fiscal incentive.

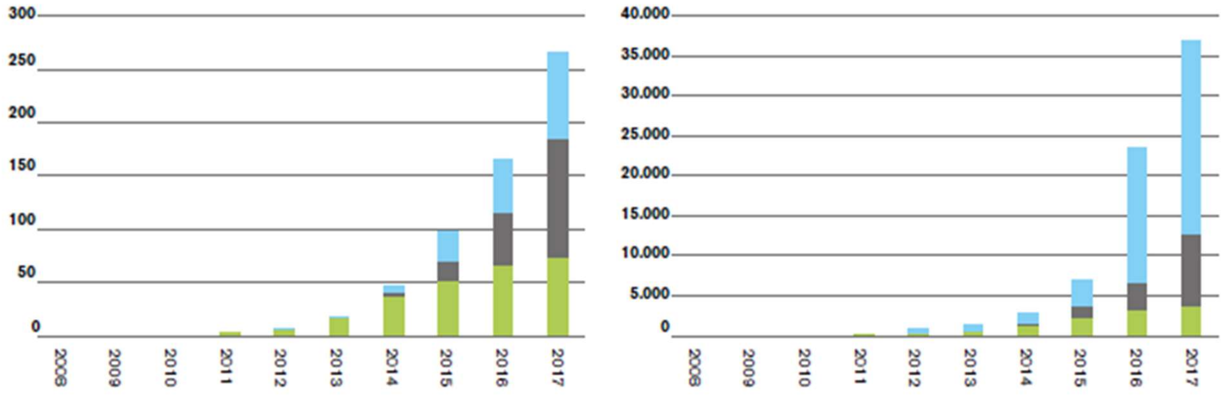


Figure 4.8: Left: number of projects per type of fiscal incentive – green corresponds to net metering projects, grey to the postcoderoos ones and blue to the projects that make use of the SDE+ subsidy scheme. Right: cumulative capacity of projects per type of fiscal incentive – same colours as in the left figure.

It is not always known who the legal owner of the solar installation is. Usually it is the energy cooperative itself (especially since this is a condition to be allowed to apply for the postcoderoos regulation). However, in some cases a third party can be the owner of the asset (in the case where the SDE+ scheme is applied to the project), while the role of energy cooperative is to develop the project, apply for the subsidy scheme and recruit participants.

4.4 CONCLUSION BACKGROUND

This chapter presented some background information that is useful for this research regarding community Solar-Plus-Storage projects.

First of all, the most common service uses of battery storage systems have been listed and explained. These include increased self-consumption, increased self-sufficiency, peak shaving (both in case of demand or supply), provision of backup power, reserve capacity, grid reinforcement deferral and energy arbitrage (in particular imbalance trading and arbitrage on the day-ahead market).

Following that, current business models used in large scale Solar-Plus-Storage projects worldwide have been assessed using the description framework that focuses on four key aspects: the location of the system, the owner, the operator and the application of the battery storage. Although several different possibilities exist, three business models can be found when considering the type of services that the battery system provides: these are the “End-user – related benefits” business model, the “Grid – related benefits” business model and the “Market purposes and grid services” business model. In each of those, the ownership and actors responsible for the operation of the asset change, and at the same time the battery storage is used for a different application (or in some cases also set of applications. In this regard, it is interesting to notice that in most projects the battery storage is not used for providing benefits stacking; instead, it targets one type of service uses, typically depending on who is the owner of the installation (in most cases it is either a commercial party such as an energy generation company, or the end-users).

Another conclusion that can be drawn from the literature study of current business models for Solar-Plus-Storage projects is that in some cases there is not a clear link between the solar park and the battery system. In other words, sometimes the two assets are deployed separately (which is emphasized even more by the fact that in some projects there are two different operators, one responsible for the solar park and another for the management of the battery storage). Therefore, this may point to the fact that under the current legislative framework, there are limited advantages in co-locating a battery storage with a solar park when the battery system provides certain service uses, for example reserve capacity or other grid services such as grid reinforcement deferral.

Lastly, it is interesting to notice that for current large Solar-Plus-Storage projects the owner is typically the end-user of the installation or an energy generator; it is thus not common to talk about community storage, although community solar is nowadays an established concept. In fact, the latter is also true for the Netherlands, where the number of energy cooperatives has surpassed 280 in 2017, as discussed in the last section of the chapter which provides some information about Dutch cooperatives, in particular looking at their activities with regard to solar projects. Even if the majority of solar installations are small scale (and the cumulative capacity of 36,6 MWp is not significant if compared to the national solar capacity of 2,1 GWp), the total number (and thus, the cumulative capacity) of community solar projects is rising. This suggests a growing importance of cooperatives and of community projects.

Therefore, a logical next step seems to be to start talking not only about community solar, but about community solar and storage. This will be further researched in the next chapters, which will focus on the possible business model scenarios for large-scale community-owned Solar-Plus-Storage projects and on their financial feasibility by means of a techno-financial analysis.

5 INNOVATIVE BUSINESS MODELS FOR COOPERATIVE SOLAR-PLUS-STORAGE PROJECTS

In this chapter, new business models for cooperative Solar-Plus-Storage projects will be developed and studied. To do so, firstly it is important to assess who are the key actors needed for such a project to take place; in this regard, the COOP-Store project will be considered as a case study for the stakeholder analysis. In addition to that, the COOP-Store project will also serve as a base to determine the main value proposition that the relevant stakeholders see in joining the project, and in particular in having a battery storage added to a solar PV installation. Combining then these results with the outcomes from the desk study about current business models for worldwide Solar-Plus-Storage projects, three business model scenarios are developed. Lastly, this chapter presents also a description of each scenario and a schematic representation by means of the Value Flow Model.

5.1 STAKEHOLDER ANALYSIS

To study the actors involved in a Solar-Plus-Storage business model, firstly a Stakeholder Analysis is performed by taking the COOP-Store project as a reference. In fact, several actors are involved in such a project, including the owner, the end-consumers, the utility, governmental bodies, EPC (Engineering, Procurement and Construction) companies, the financier/investor and suppliers of components (such as PV panels, inverters and storage). In particular, since this analysis focuses on the COOP-Store project, the above-mentioned actor groups can be translated into specific stakeholders.

First of all, the central actor in the COOP-Store project is the local energy cooperative, WeertEnergie. It is an independent cooperative association of residents of the Weert region, who promotes and realizes projects related to sustainability and affordable energy generation from renewable energy sources. Founded in mid-2013, its vision is to make the municipality of Weert energy neutral in the near future. At the moment, it has around 150 members (over approximately 50.000 inhabitants of the Weert region). One of the goals of the cooperative is to realize different solar parks in the Weert area; Altweerterheide will be a pilot Solar-Plus-Storage project with the main aim of learning the best-practice for enabling residents to "*actively contribute to the self-production of green energy and to profit from such installations*" (WeertEnergie, n.d.). Moreover, part of the cooperative's strategy is also to offer energy product and services that create social and environmental benefits; therefore, multiple values are targeted within the same community. Regarding the COOP-Store project, besides being the owner and manager of the solar installation, WeertEnergie is also responsible for being in contact with local residents, target interested prosumers and to provide knowledge dissemination to local educational institutions.

Another important actor in the COOP-Store project is Scholt Energy Services, a company mainly involved in providing energy services and assistance for their clients. Its core strategies involve solutions for energy consumption, generation of energy and energy storage. It supplies services and products to the commercial energy market in the Netherlands, Belgium and Germany. Within the COOP-Store project, its role is to take care of the management of the battery storage, together with the development of the software for its control strategies.

The engineering and consultancy for the project is done by Soltronergy. As a specialist in technical, financial and fiscal aspects related to projects, its tasks typically vary from the design of the energy system to management, maintenance and quality check of the installations (Soltronergy, n.d.). Soltronogy has also experience in giving complete business case advice and project guidance for both developing plans as well as already-submitted plans. Its focus spans from smaller scale installation (from 15kWp) to larger-scale plants (up to 5 MWp). In the COOP-Store project, it takes care of the design and development of the PV park in combination with the storage solution, as well as of the integration of the system with the local electricity grid.

A further actor in the COOP-Store project is the Solar Energy Application Centre (SEAC). SEAC was founded in 2012 as a cooperation between ECN, TNO and Holland Solar; it is a party involved in the application-oriented solar energy research and aims to stimulate the research and business activities in the field of innovative solar energy projects by giving advice to companies by means of field testing, benchmarking and techno-financial modelling in projects; it also provides linkages and cooperation between knowledge institutes and firms. SEAC thus acts as a knowledge institute with a strong focus on R&D regarding PV systems and their applications.

These actors mentioned above form together a consortium for the COOP-Store project, communicating and consulting closely with each other, sharing findings and knowledge. Outside the consortium, there are also other actors which are important for the business model, starting from the end-users who consume the electricity generated by the solar park. They can be either private households as well as companies. Furthermore, in the case of a community project such as the COOP-Store, the end-users can also be (partially) the investors and thus can be regarded as active energy consumers (or prosumers). This can be done by purchasing one or more solar panels and contributing with a fee for the battery storage system. Typically, the end-users who take part in such projects are interested in a sustainable lifestyle and in green energy creation and consumption. Possibly, they also do not have the possibility (or don't want to) to install solar panels and battery units on their own roof and in their own household.

The end-users buy electricity from an energy supplier, who in turn buys the electricity generated by the solar park by the owner of the asset. However, at this stage of the COOP-Store project, it is not known yet who will be the selected energy supplier.

Because the solar park and the battery storage will be connected to the local medium voltage grid, the local distribution system operator (DSO) is another actor that has to be taken into account. The medium voltage grid in Weert and its surrounding area is operated by the Dutch DSO Enexis since July 1st, 2017. Before that, the local network operator was Stedin (which is the regional grid operator of Zuid-Holland and Utrecht). The takeover is in line with the policy of the Ministry of Economic Affairs that seeks to organize the network operators along provincial borders (Stedin, 2017). With this, Enexis is the regulated network administrator of the entire province of Limburg (together with the provinces of Groningen, Drenthe, Overijssel and North Brabant). As the local DSO, Enexis is responsible for the electricity connections and transport, for infrastructure investments and for the overall maintenance of the distribution grid.

In the COOP-Store project, the governmental bodies also play a role and are thus considered in this stakeholder analysis. Firstly, the municipality of Weert represents the local governmental body. Its main role is to provide all necessary permits and licences for the project. In addition, the municipality of Weert has also a reviewing role in the COOP-Store project by checking for conformity with local laws and regulations. Secondly, other governmental bodies are important, especially the national government, since it helps to finance sustainable energy generation projects with subsidy schemes, in particular via the Netherlands Enterprise Agency (RVO), which is part of the Ministry of Economic Affairs. Further on, the national government checks for compliance of the project with national regulations and helps to convert governmental policies into action.

In order to construct the solar park in combination with a battery storage, the providers of upstream components and the costruction companies also play a role by supplying materials and hardware components (such as PV panels, inverters, battery pack and cabinets for the storage fitting), and by constructing the solar park. In some cases, these actors can also provide services such as maintenance of the supplied components. At the current stage of the COOP-Store project, it is not yet decided who will be the specific companies linked to these actors' groups.

Giving the fact that one of the targetet service uses of the battery storage in the COOP-Store project is also the provision of frequency control for the electricity grid (through the tendering of primary reserve capacity), the transmission system operator (TSO) is included in this analysis. TenneT is the only TSO in the Dutch electricity network; it is thus the administrator of the national high voltage grid (110 kV or higher). Its tasks are to manage and maintain the transmission grid, invest in the infrastructure and resolve large-scale interruptions. In addition to that, TenneT is responsible for monitoring the supply of electricity in the Netherlands and maintaining a balance between demand and supply (TenneT, n.d.). As such, it operates the balancing market and settles the reserve capacity offered.

It is not sure yet if the energy cooperative will be able to fully pay the required sum for the investment in the solar park and battery storage; therefore, it is not excluded that an external investor, such as a bank, finances (even partially) the project.

Lastly, many Dutch energy cooperatives are united under a common umbrella organization. As for the COOP-Store project, the umbrella organization of cooperatives is the REScoopNL, which is responsible for supporting the dissemination of knowledge about this project and to help other energy cooperatives in the Netherlands to follow the example of WeertEnergie, in particular due to its national-level involvement. The primary contact point for REScoopNL will be its regional department, REScoopLimburg.

5.2 VISUAL REPRESENTATION OF STAKEHOLDERS

In order to provide a graphical overview of the actors described above, this section provides a simplified version of the Onion Diagram, as presented by Jonker (2014); he calls it the Involvement Circle. This mapping tool is particularly useful when a broader view is aimed within a project (for example, a whole ecosystem is considered and not only one company), which is in line with the concept of sustainable business models. It presents the relevant stakeholders in a three layers' analysis using concentric circles. The innermost circle represents the stakeholders who are central to the project, the next layer corresponds to stakeholders who are re-enforcing or strengthening the main value proposition, while the last layer includes additional actors who are "nice to have" members or, in general, who are also important for the project, but are not central to the value proposition.

It should be noted that this method is also appropriate given the selected visualisation tool for the business models. In fact, the Value Flow Model also relies on an Onion Diagram-like representation, starting from a core value proposition and the key stakeholders that are central to achieve it, up to stakeholders who represent the enabling network and other possible actors involved. In this way, the results from this section can serve as a base further on during the business model mapping.

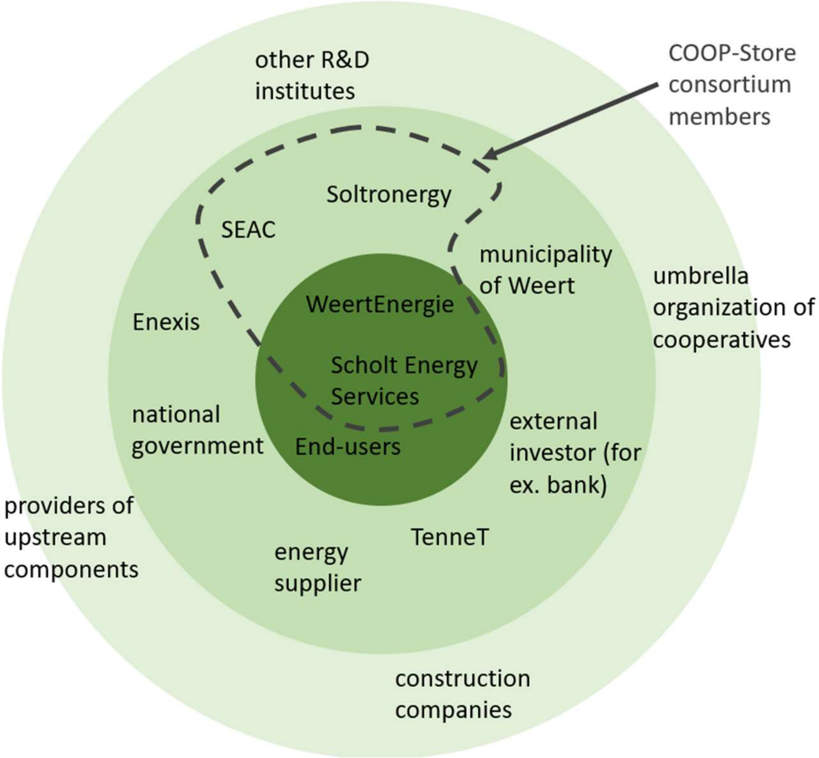


Figure 5.1: Involvement Circle for the COOP-Store project

In the case of the COOP-Store project, the inner circle includes the energy cooperative WeertEnergie, Scholt Energy Services and the end-users. The end-users are included as central actors because part of them are people who, unified in the cooperative, are responsible for the project (in fact, it is good to remember that not all the end-users are members of the cooperative, given the ratio between the number of inhabitants of the Weert area and the members of the cooperative, as described previously) and for its (partial) financing. Furthermore, they are also the targeted customer for the installed system. The second circle with the strengtning actos includes the local DSO (Enexis), governmental bodies (municipality of Weert and national government), SEAC as the research institute within the consortium, the engineering company Soltronergy, the energy supplier, TenneT as the TSO and the external investor. Lastly, the outer circle corresponds to the actors who are still important to include in the project, but are not central; these are other R&D and knowledge dissemination institutes, construction companies, the providers of upstream components and the umbrella orgnization of cooperatives.

It should be noted that the Involvement Circle in Figure 5.1 is case-specific, and in particular it derives from the Stakeholder Analysis of the COOP-Store project, which is a pilot project in terms of cooperative Solar-Plus-Storage project in the Netherlands. Therefore, it is not excluded that changes are possible in the position of each actor in the various circles, if the same analysis is applied to a different project.

5.3 STAKEHOLDERS' VALUE PROPOSITIONS

In order to structure new business models' scenarios in case of a community Solar-Plus-Storage project, it is essential to understand what are the values that the most important stakeholders see in such projects (in particular in the addition of a battery storage system to a solar installation). To do so, the COOP-Store project is again taken as the base for the research. In this regard, interviews were held with the central actors of the project (as defined in the previous section about visualizing the stakeholders by means of the Involvement Circle) regarding the values that each actor sees in the addition of the battery system to the solar park. However, besides the end-users, the energy cooperative and Scholt Energy Services, the local distribution system operator (Enexis) is also considered in this analysis, given the results of the previous chapters where the potential of battery storage to provide several grid services has been discussed.

It should be noted that in case of end-users, no direct contacts with the local residents (via interviews or surveys) have been part of this research due to time constrains. The results presented here were obtained by combining the outcomes from the interviews of the representative from the energy cooperative (by specifically asking for the point of view of the end-users within the community, in addition to the one of the cooperative itself) and the results from other personal communications.

Stakeholder	**Main value(s)**	**Secondary goals**
End-users	Increased consumption of locally-generated electricity and increased energy autonomy	Better return on equity
Energy cooperative (WeertEnergie)	Better return on equity	Increased energy autonomy (vision of energy neutral village)
Scholt Energy Services	Profit	Increased customer base (experience with similar projects and publicity)
DSO (Enexis)	Better and cheaper service delivery (cheaper and quicker connection to the grid, also by means of grid upgrade deferral)	Congestion management and grid stability (voltage control)

Table 5.1: Values per stakeholder for the addition of a battery storage to a solar PV installation

As can be seen in Table 5.1, the main values that end-users see in case that a battery storage system is installed in combination with a solar park, as it is the case of the COOP-Store project, are an increase in energy autonomy (within the village/community where the Solar-Plus-Storage project is located) and an increase in the amount of (renewable) energy which is not only locally produced, but also consumed (put plainly, batteries can contribute to boost the idea of "*what is generated in the neighbourhood, stays in the neighbourhood*"). In fact, these two values are interconnected, since the more electricity is consumed locally, the higher the energy autonomy (and less electricity, which is not produced in the neighbourhood, needs to be supplied). However, in all this it should be remembered that these results follow from interviews with members of the energy cooperative, therefore it can be questionable how representative they are with respect to all the end users in the area (given the ratio 50.000 inhabitants and 150 members of WeertEnergie)[1]. In fact, it can be argued that these results may also represent the wishes of the energy cooperative and of its members regarding the main values and goals that end-users see in such projects (to put it simply, what the cooperative would like the end-users to say, rather than what the end-users actually prefer).

Another critical issue is that the added battery storage could also contribute to a better return on equity: this feature is especially important for those end-users who have a share in the project (i.e. those people that invest in the Solar-Plus-Storage installation), and are therefore interested in a better gain from their investment.

---

[1] It is interesting to mention that according to HIER Opgewekt (2017), there are around 285 energy cooperatives in the Netherlands, with approximately 63.000 members in total. This means that on average, there are roughly 220 members per cooperative. In fact, a medium-sized cooperative has around 300 members, according to HIER Opgewekt (2017). This means that WeertEnergie correspond to a rather small energy cooperative, considering the standard of other cooperatives in the Netherlands.

Similar goals can also be found for the energy cooperative, given the fact that, as previously defined, a cooperative is a collective of local people (i.e. end-users) who share similar interests and desires. The values of the cooperative should therefore reflect the values of its members. It is however interesting to see that in the former case, return on equity is selected as a primary goal, while in the latter case it is a secondary goal. The reason for this is that return on equity in case of a cooperative is usually directly used for the realisation of other projects, which together contribute to the main idea of the cooperative of increasing energy autonomy (and eventually establishing an energy neutral village).

As a commercial, for-profit company, the core values mentioned by Scholt Energy Services are profit and customer base enhancement. The latter value is not strictly related with the COOP-Store project, since this is a pilot project. However, it allows the company to obtain experience in these kinds of Solar-Plus-Storage projects, which can be useful for future customer base enhancement. In addition to that, the COOP-Store project provides a good opportunity for publicity, which also plays a role in gaining new customers.

Finally, for the local DSO Enexis, the addition of a battery storage to a solar park represent the opportunity to deliver grid connection services (for the customer) quicker. In addition, if the battery system is used to reduce the amount of power supplied to the grid during peak periods (i.e. peak shaving of supplied electricity), this can also limit the investments the DSO needs to make in terms of grid updates for establishing the connection between the Solar-Plus-Storage installation and the local grid. Moreover, if battery storage is used to increase energy autonomy within a community, this can in turn also limit congestions in the grid (less electricity needs to be supplied from other places). Lastly, an additional important feature for battery systems is the provision of ancillary services for the local grid (such as voltage control and grid stability); however, this service is location-specific, thus a case-to-case analysis is required. Furthermore, at the moment most of the problems with voltage violations are within the low voltage grid, while larger solar installations are typically connected to the medium voltage grid (Enexis, 2018), therefore limiting the possibility of batteries to provide this value.

5.4 NEW BUSINESS MODELS DESCRIPTION

In order to assess what are the possible business models for a larger-scale community Solar-Plus-Storage project, three different scenarios are developed and discussed within this research. As previously described, they are constructed by combining both the results from the desk study about current typical business models for large scale Solar-Plus-Storage installations, as well as the results from the stakeholder analysis regarding the values that actors see in the addition of the battery storage to a solar park (as derived from the COOP-Store project). Because of that, each scenario targets a different set of applications for the battery system, with a different degree of complexity in terms of number of key stakeholders (relevant for the core value proposition) and organizational setting.

Considering the framework presented in Section 4.2 all three scenarios are about a Solar-Plus-Storage system located in front of the meter (as it is the case for larger PV installations), with the cooperative being the owner of the system. In fact, the ownership is kept the same in all the developed scenarios because of the goal and scope of this research, namely focusing on community projects (with the energy cooperative representing the entity where people within a community are unified to develop a specific Solar-Plus-Storage project). On the other hand, the operator as well as the service uses that the battery system provides is varied.

The three scenarios are:

1. **“Idealistic” scenario** – In this case, the battery storage is used to increase the autonomy of a community, making it more energy independent. In particular, the battery system is used for increasing the self-consumption, as backup power (for a company or entity such as a hospital within

the community) and for peak shaving; the latter is included among the service uses since it provides additional benefits for the cooperative in terms of lower connection costs, as discussed before. Therefore, the focus in this scenario is on multiple values (economic, social and environmental) that the battery storage can provide, as presented by Jonker regarding New Business Models. The economic benefits are targeted with peak shaving, while increased self-consumption and backup power are important for a higher energy independence. Lastly, using the battery to increase the self-consumption of a community means that end-users require less energy to come from the grid (which can be produced with fossil fuels) and instead increase their usage of local green energy; this in turn can be seen as an environmental value that the battery provides for the community.

Because of the nature of the application for the battery storage, the Idealistic scenario considers the cooperative as both the owner as well as the operator of the Solar-Plus-Storage installation. In this way, the idea of autonomy is further emphasized in this scenario.

2. **“Money Maker” scenario** – As the name of the scenario itself implies, this business model focuses primarily on making profit. In this regard, it can be said to target the value of “better return on equity” expressed by both the energy cooperative as well as the end-users (i.e. members of a community). However, in order to do so, the cooperative itself cannot be the operator of the battery storage given the limited knowledge and experience with the exploitation of the Solar-Plus-Storage system, in particular in case of market related benefits (as primary reserve capacity and energy arbitrage). In fact, looking at the results from the desk study, it can be argued that these two service uses are potentially the most profitable, since they are the most common applications for commercial Solar-Plus-Storage projects (where the main goal of the owner, typically an energy utility, is usually to make as much profit as possible). For this reason, these two applications are targeted in this scenario. In addition, the Money Maker scenario includes also peak shaving as another service use for the battery storage: in this way, a lower investment is needed for the cooperative to build the project because of lower connection costs, resulting in a better return on equity.

   From the theoretical point of view, this scenario reflects the design and structure of conventional business models (in terms of the broader perspective of business ecosystems, not single firms), which focus mostly on monetary values instead of including also societal benefits in the core value proposition, although it can be argued that maximizing the profit for the energy cooperative can translate into the fact that the cooperative quickly recovers enough money to establish more similar projects which boost sustainable energy within communities.

3. **“Multi-Actor” scenario –** The last scenario builds on the Idealistic scenario, while combining also some features of the Money Maker scenario. In other words, a trade-off between the goal of better return on equity and increased energy autonomy is addressed here. Therefore, in this scenario the battery storage is used for a variety of different purposes: increased self-consumption, peak shaving, energy arbitrage and reserve capacity, as well as grid reinforcement deferral. The latter is added in this scenario because of its importance if the end goal of energy autonomy and neutrality of a community is kept in mind. In other words, in order to reach those end goals in the future, grid reinforcement will be eventually needed due to an increase in renewable energy installations (either larger-scale or home systems[2]). Nonetheless, battery storage can help to mitigate these problems (in particular when they are not extreme and present only for a small fraction of time) and can also contribute for a better planning of future grid upgrades by delaying the need of reinforcing the electricity grid.

---

[2] As an example, some low voltage grids already experience voltage violations due to an increasing number of distributed renewable energy generation systems, especially rooftop PV panels in private households.

However, in order to tackle all of these service uses, multiple actors are needed: the cooperative is again the owner of the Solar-Plus-Storage system, while a third party with more capabilities and experience is the operator (similarly as in the Money Maker scenario). In addition, the DSO also plays a key role in the Multi-Actor scenario by informing the operator of the asset if it is needed for the battery to provide services for the grid (i.e. using it for grid reinforcement deferral). It should be noted that in the other two scenarios the DSO is also an important actor since it allows the Solar-Plus-Storage park to be connected to the grid and thus to deliver energy and services to the end-users or other stakeholders; nevertheless, this scenario presents instead a direct involvement of the DSO also in terms of shaping the core value proposition.

Looking at it from a theoretical point of view, similarly to the Idealistic scenario, also here multiple values are addressed (not only economic, but also environmental and social). In particular, the economic aspect is further enhanced if compared to the Idealistic scenario since the battery provides also market-related benefits (namely reserve capacity and energy arbitrage). Moreover, this scenario emphasises also the other two principles mentioned by Jonker regarding New Business Models (shared and collective value creation), given its structure and the nature of battery storage applications.

In the next section, the above presented scenarios are further described, including also a graphical representation of the actors and flow of tangible and intangible values between them using the Value Flow Model. The following figure represents instead a short schematic overview of the three scenarios.

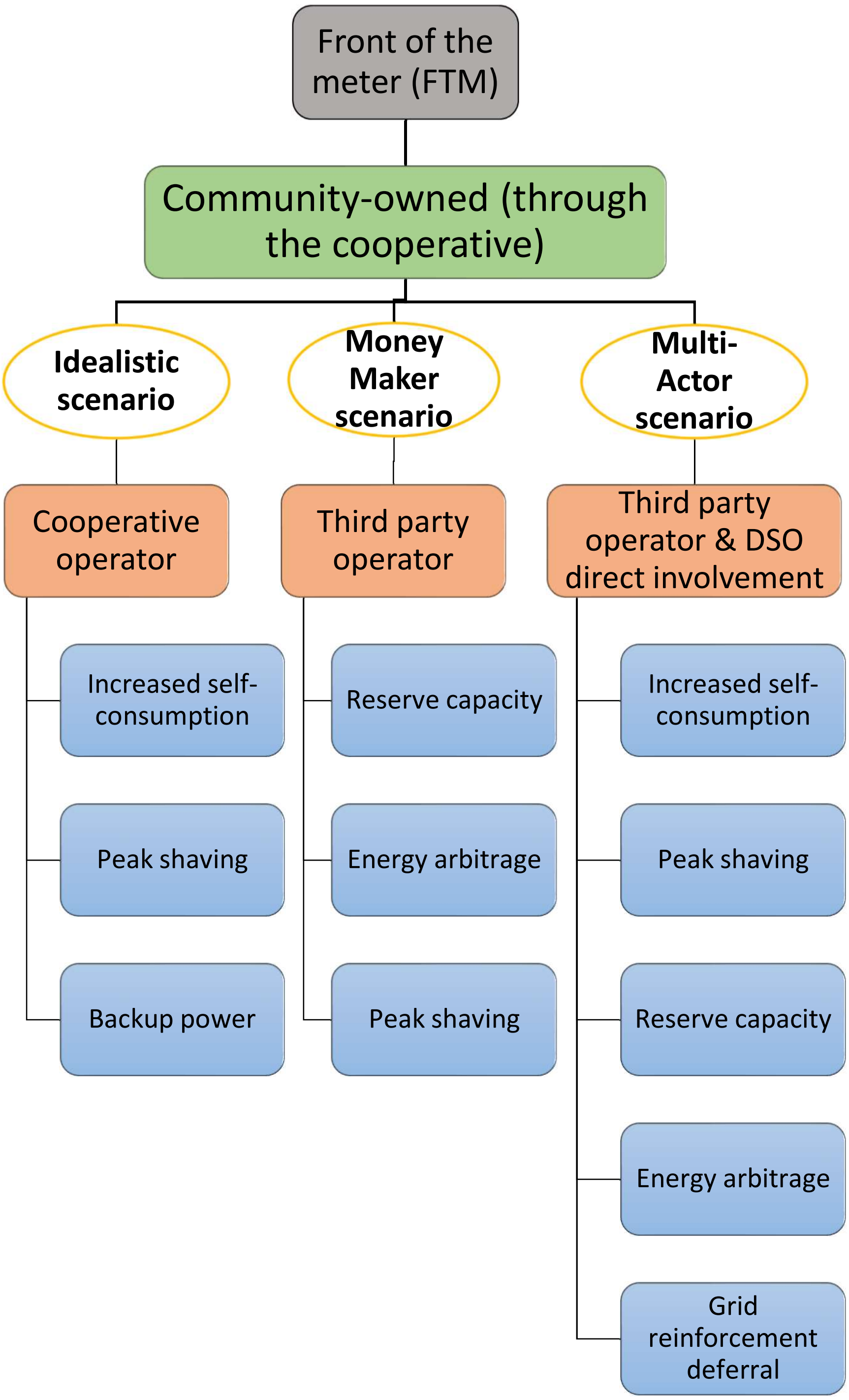


Figure 5.2: Schematic overview of the three business model scenarios. The green box represents the ownership of the asset, the orange ones the operator and the blue boxes correspond to the different services that the battery is designed to provide in each scenario; this framework is the same as previously used in Chapter 4.2 when analysing current business models for worldwide Solar-Plus-Storage projects, thus also the same colours as before are applied in the above figure. The name of each scenario is instead presented in the yellow circle, before the operator of the installation.

5.4.1 Idealistic scenario

In the first scenario, part of the end-users from a community are unified in an energy cooperative and decide to build a Solar-Plus-Storage installation; they are the owners of the solar park and of the battery storage. As such, they are also responsible for financing the project. In addition, the energy cooperative is also the operator of the asset and uses it for its own purposes, or better to provide services for the community.

In this regard, the service uses of the battery storage associated with this scenario follow from the results of the interviews: as previously seen, the main values that the community and the cooperative see in the addition of a battery storage to a solar park is the possibility to increase the actual self-consumption of the energy output from a renewable source and to have a bigger energy independence (with a long term aim of establishing an energy neutral village). For this reason, the main applications of the battery storage in this scenario are the increased self-consumption of the electricity from the solar panels and the provision of backup power (i.e. provision of emergency power in the event of a power failure, which can be particularly important in some locations where the continuous flow of electricity is essential, for example data centres or hospitals). In addition, the combination of a battery storage with a larger solar park can be also used for peak shaving of the electricity output. In this way, the grid connection capacity required is reduced, which in turn reduces the capital costs for the connection of the system that the cooperative has to pay to the local distribution system operator (DSO), which is usually based on the maximum amount of power that the solar park produces[3]. In fact, it can be argued that peak shaving is beneficial also to the DSO, since it can provide congestion relief and grid upgrade deferral; however, this service is not directly addressed in this scenario but can be instead merely considered as a side effect of peak shaving of the PV output. In order words, the DSO is not directly involved in the operation of the battery storage, nor does it rent services from the battery asset; however, peak shaving can be beneficial also for the grid operator (since it is not required to build new cables and reinforce the grid in order to allow all the electricity to be transported from the solar park to the end-users even during peak production times). In addition, it can be argued that peak shaving produces also societal benefits: since the DSO does not need to recover the costs for grid updates by use-of-system charges for the network customers, the end-users do not see an increase of network tariffs in their energy bills.

At a first glance, this scenario can be interpreted as similar to the End-user – related benefits business model from the literature study, where the end-users are both the owners and the operators of the installation (for example home systems or installations located on a company's roof). By confronting the two figures (Figure 4.4 and Figure 5.2), it is possible to notice that also the service uses of the battery storage match. The novelty of this scenario is that it is applied for a large installation, located in front of the meter, where multiple people from a community are the end-users of the electricity. Another difference with the business model from the desk study is that the individual end-users are not directly the operators of the asset, but instead the cooperative takes this role as a unified actor. However, due to limited knowledge and experience by the local energy cooperative to exploit the installation and for a better mitigation of risks, this scenario can become more feasible if the cooperative establishes a venture or company, specialized in proper operation of the Solar-Plus-Storage system. The company is thus in charge of the monitoring and management of the installation, bearing both the responsibility and risks. Another option can be that the operating company is in fact a cooperatively-established operator which works with different local energy cooperatives; in this way, it is easier to establish an entity that has enough capabilities, resources and knowledge needed for the purpose. In other words, this operating company is organized in a cooperative way, so that the member cooperatives have control over its operations and in the way it conducts business (a similar structure can be

---

[3] It should be noted that throughout the analysis it is asumed that the community Solar-Plus-Storage installation is connected to the distribution grid and not on the high-voltage grid. Therefore, the DSO is the central actor responsible for the smooth flow of electricity from the solar park to the end-users. The reason behind this it that the majority of community projects are not considerably large-scale systems, located within the community and typically connected to the medium-voltage grid.

already found in case of the cooperative energy retailers Om and NLD operating in the Netherlands). At the same time, this still ensures that the risks are transferred from the single local energy cooperative to the more experienced cooperatively-established operator.

One advantage of the Idealistic scenario is its rather simple organizational setting: the emphasis here is on the cooperative, since it is both the owner as well as the operator of the assets. In can be argued that the community (in particular those people who are directly participating in the project by being members of the cooperative) has a direct saying on the management of the Solar-Plus-Storage system. On the other hand, one of the main bottlenecks of this scenario is the fact that cooperatives have usually limited knowledge and experience with the operation of these kind of systems, especially concerning battery storage. In addition to that, the nature of the applications that the storage provide may hinder the financial sustainability of the project (for example due to the fact that no market-related benefits are tackled in this scenario, and also because at the moment there is no fiscal incentive to stimulate self-consumption increase, which is among the primary service uses of the battery in this scenario).

As stated in the previous chapters, in order to get a visual representation of the business model scenario in terms of actors and interactions among them, a Value Flow Model is constructed. This allows a dynamic overview of the flows of both tangible and intangible values among the stakeholders. Figure 5.3 presents the Value Flow Model in case of the Idealistic scenario.

Firstly, the figure shows that the energy cooperative can be said to act as a central actor: it is the owner of the Solar-Plus-Storage installation, responsible for its financing and implementation, as well as for its management and allocation of services to the end-users (some of which are members of the cooperative itself). In this regard, it should be noted that for simplicity only the local energy cooperative is depicted as the actor in the Value Flow Model responsible for the ownership and operation of the assets, although it is not excluded that in reality the cooperative establishes a venture for this latter purpose, as previously discussed.

The energy cooperative sells the electricity on the energy market (from which it gets revenues per kWh of sold electricity), where it is bought by an energy retailer and then sold to the end-users. The end-users pay their energy bill to the energy retailer: this includes the actual costs for the electricity, supply costs, grid fees, the energy tax and the VAT (Waleson, 2017). The energy retailer then passes the energy tax to the government, while the grid operator collects the grid fees (which cover the costs for both a smooth flow of electricity from the solar park to the individual households, as well as for other grid services). However, this represents the flow of the contracts for the energy delivery and the corresponding payments; the physical flow of electricity is instead from the solar park (owned and operated by the energy cooperative) through the DSO (in charge of the distribution electricity grid) to the end-users. The latter is depicted in the figure by the green dotted arrows.

By using the battery storage as a way to increase the self-consumption, the energy cooperative provides an increased energy autonomy for the community. In addition to that, in this scenario the battery system is used also for backup power for particular customers (such as for example a hospital within the community or a specific company who requires a continuous power supply), for which they pay a fee to the operator of the battery (in other words, they rent this service instead of buying a personal UPS system). Lastly, the battery storage is used for peak shaving of the produced electricity from the solar park, which reduces the required connection capacity that the DSO has to provide to the owner of the solar park. In return, the energy cooperative has to pay a lower amount for this connection to the DSO.

In order to build the solar park and to install the battery storage, the energy cooperative has to have enough capital for the investment. Typically, part of the budget is already available within the cooperative (from external contributors, membership fees etc.), while the rest comes from a financial institution such as a bank, who provides a loan which needs to be repaid throughout a certain period of time. The energy cooperative establishes also a contract with an EPC company, who in return for a fee provides the engineering and construction of the solar park, as well as procurement for the materials and components needed (among others the PV panels, inverters and the battery system). Lastly, before building the Solar-Plus-Storage system, the energy cooperative needs to have all the required permits, which can be obtained from the local government (usually the municipality where the installation will be located). In addition, the local government may also be responsible for providing the land where the solar park will be constructed, although this is not the only possibility (for example, the land might be rented or bought from a private citizen or a company).

Another actor included in the Value Flow Model is the umbrella organization of cooperatives, who offers support and shares experience & knowledge (from other projects) with the local energy cooperative for a successful project development. Further on, research institutes can also play a part by providing knowledge dissemination and know-how on best practices (concerning for example the management for the battery storage), contributing also with inputs regarding policy making (and potential regulatory changes) to the national government. Moreover, both the local as well as the national government have an interest in assisting and encouraging community projects, since in this way they can get support from the citizens.

Finally, the national government is also responsible for the fiscal incentives that stimulate the production of renewable energy. As mentioned before in the report, there are two kinds of subsidies available in the Netherlands for larger PV installations: the postcoderoos (or RVT) and the SDE+ (see Appendix A.4 for further information). Figure 5.3 shows the case when the SDE+ is applied to the project: the government grants the subsidy, for which the energy cooperative must deliver a business case.

However, it can also be that the energy cooperative decides to apply for the postcoderoos fiscal incentive. In this case, the members of the community, living in the adjacent postal code areas from where the installation is located) and unified in the energy cooperative, invest in the project by buying shares of the solar park (i.e. they are the legal owners of some PV panels). In fact, this can be interpreted as a way to finance the project and obtain the initial investments required (therefore, in this case it is not required to have an external financial institution). Depending on the share that each participant has in the project, a contribution in the form of a reduction of the energy tax is guaranteed. This is arranged through the energy retailer. In other words, the end-users who have a share in the solar park (and are thus also its legal owners) get a reduced tariff per kWh, which corresponds to the reduction of the energy tax that the energy retailer needs to pass to the government. In order to apply the reduced rate for every participant, the energy retailer must have access to the information about the share of each member in the project - this is usually obtained from the energy cooperative via a member statement. The Value Flow Model for the Idealistic scenario in case of the postcoderoos incentive can be found in Figure 5.4; here, only the flows that are different with respect to the SDE+ case from Figure 5.3 are highlighted.

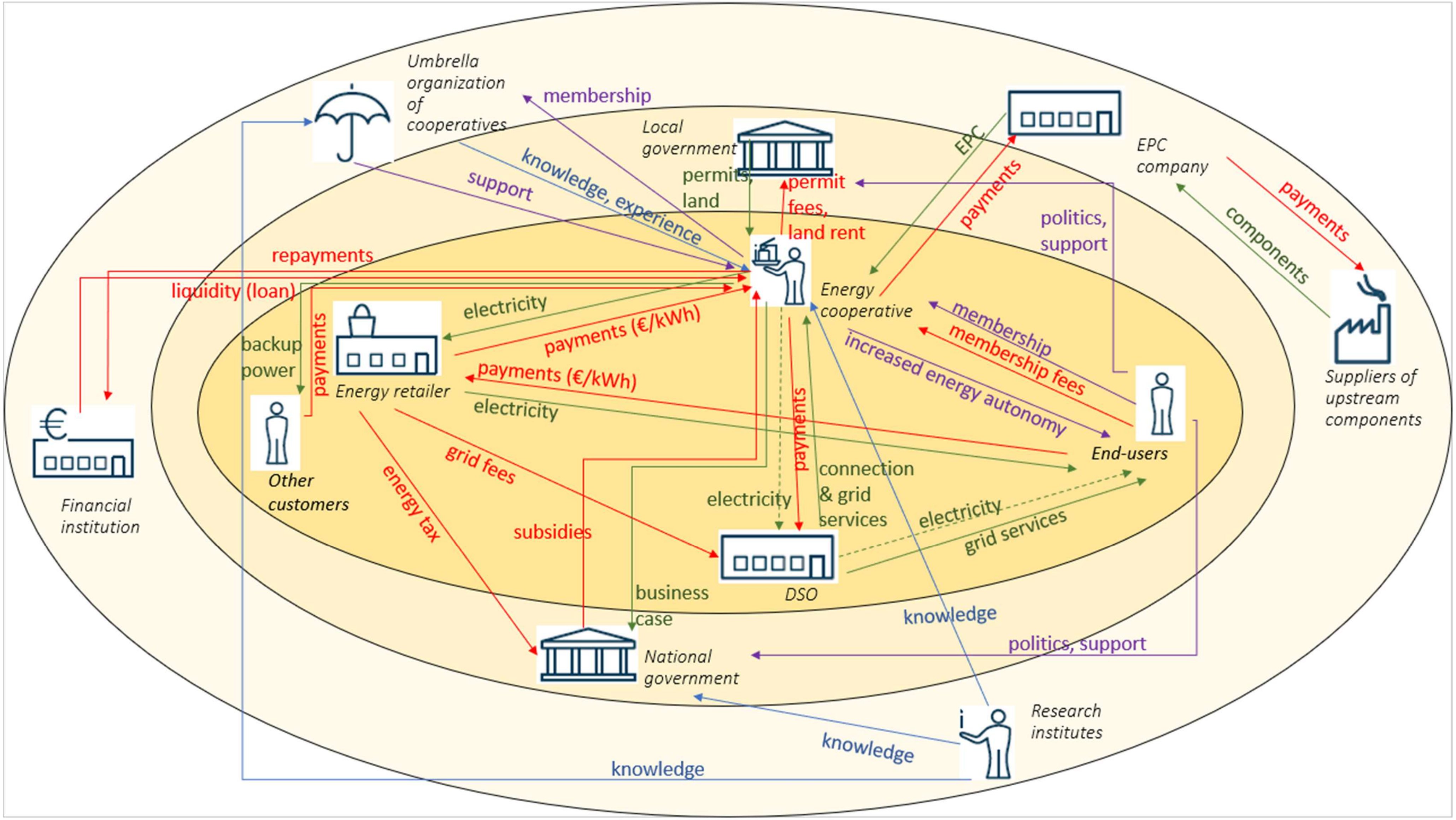


Figure 5.3: Value Flow Model for the Idealistic business model scenario (if the SDE+ subsidy is considered). The green arrows represent the flow of goods and services, the red is for money and credits, the blue is for information and the purple ones correspond to the flow of intangible values.

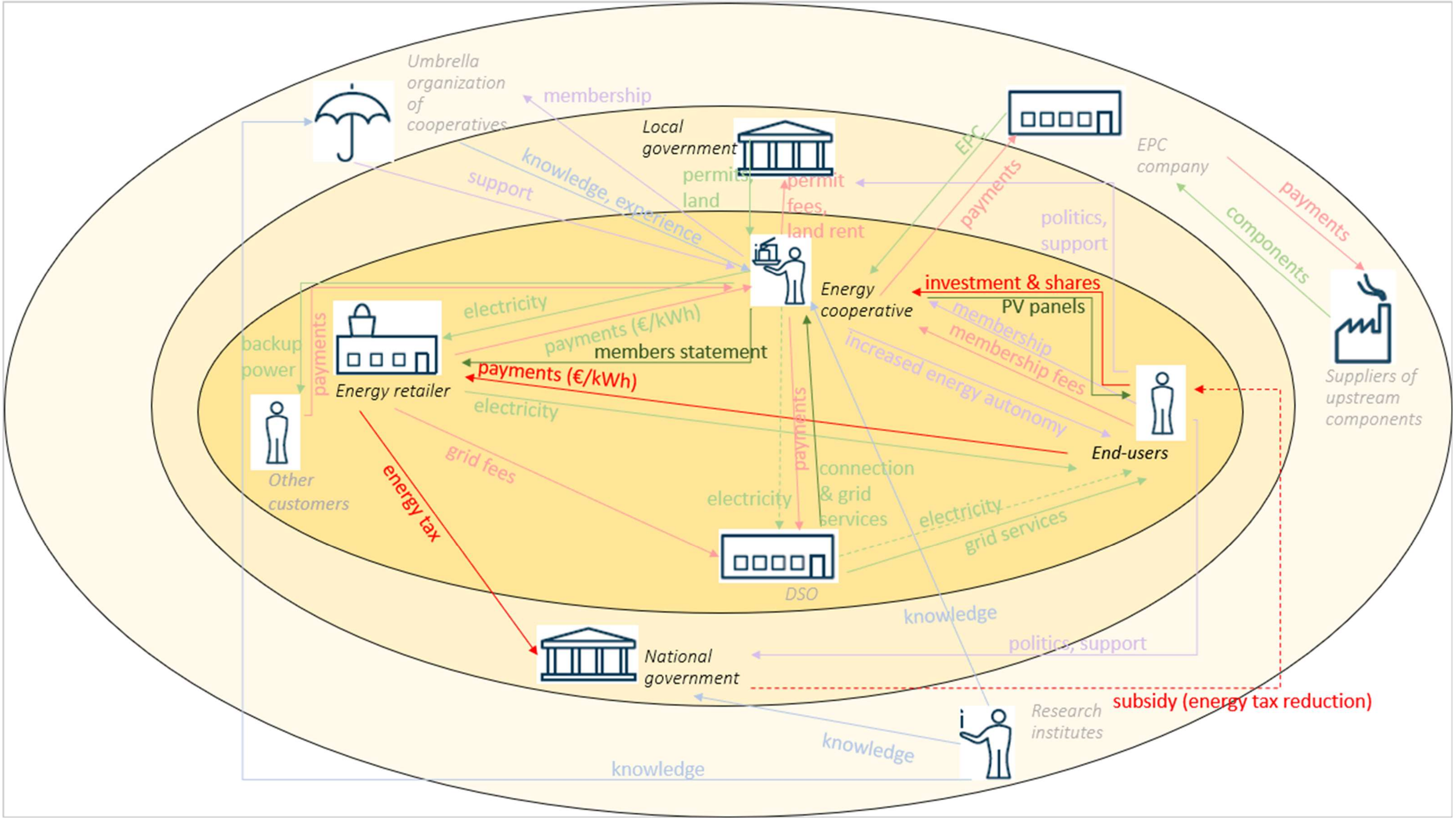


Figure 5.4: Value Flow Model for the Idealistic business model scenario, in case that the postcoderoos fiscal incentive is applied

5.4.2 Money Maker scenario

As previously mentioned, in this scenario the Solar-Plus-Storage system is owned by the community, which is unified in an energy cooperative. However, in this case the operation of the assets is not central to the cooperative; instead, a third party (commercial company) holds the responsibility over the management and maintenance of the installation. In this way, the cooperative is not required to establish a venture, but instead contracts an already-existing third party that has enough experience and knowledge as an operator. The difference in this case is that the third-party operator is a commercial company (usually with a primary aim of profit maximization) and not part of the cooperative itself.

From the name of the scenario itself, the central goal is to make money. This is reflected also in the service uses that the battery storage provides in this scenario. The central applications of the battery system are therefore for energy arbitrage (i.e. storing electricity when the prices on the market are low, or even negative, and selling it when the prices are high) and for primary reserve (also known as Frequency Containment Reserve or FCR, which consists in reserves capacities necessary restore power balance in the electricity grid in case of a frequency deviation from nominal values). As previously mentioned, both services are market accessible and can thus provide revenues for the operator of the battery storage system or for the owner (depending on the contract between these two parties). In addition, since the cooperative is the owner of the system, it requires from the operator to use the battery also for peak shaving, thus limiting the connection capacity needed, which in turn lowers the connection costs that should be paid to the DSO.

As for the Idealistic scenario, also here it is possible to find a parallel with the business models of current Solar-Plus-Storage projects worldwide, which have been presented before (see Chapter 4.2). In particular, this scenario can be correlated with the Market purposes and grid services business model, where the battery storage system provides similar services as described in the above paragraph. However, in the Market-purpose business model the third party is usually both the owner as well as the operator of the asset, while in this scenario community ownership is applied. This means that the community, through the cooperative, has a certain degree of influence on the operation of the system it owns. This mostly depends on the contract that the third-party operator and the cooperative stipulate with each other, determining among others the degree of freedom of the commercial company in the operation of the asset, the services that should be provided by the battery storage and additional specific requirements needed in order to balance the goals that both the commercial party and the community want to achieve with the project.

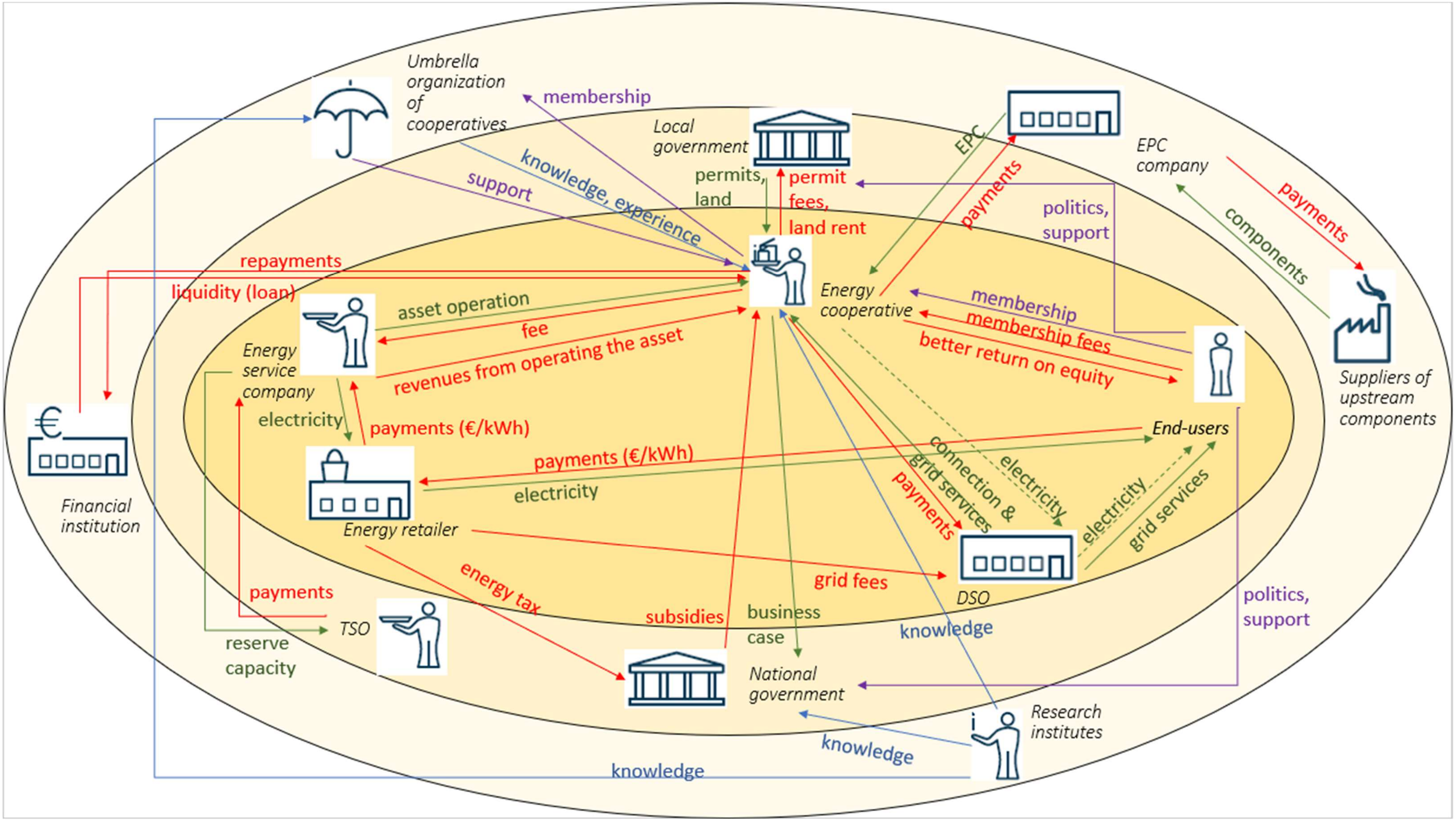


Figure 5.5: Value Flow Model for the Money Maker business model scenario in case that the SDE+ subsidy is considered

As can be seen in Figure 5.5, there are two actors in this scenario which were not present in case of the Idealistic scenario, namely the energy service company and the TSO (TenneT, in the Netherlands). The former corresponds to the operator of the Solar-Plus-Storage installation, who provides the management and operation of the asset owned by the energy cooperative in exchange for a fee. The Value Flow Model presented above assumes that all the revenues from selling the electricity on the energy market and from the market-related applications of the battery storage (i.e. energy arbitrage and provision of primary reserve capacity) are collected by the asset operator, who then passes them to the legal owner of the installation, the energy cooperative. It should be noted that this is not the only possible organizational setting, but it can vary depending on the contract between the owner and the operator of the Solar-Plus-Storage asset. However, this particular interaction is chosen here for straightforwardness reasons, since in this way the operator acts as the only responsible figure for all the energy market-related services and renumerations.

Similarly to the Idealistic scenario, the energy cooperative (as the owner of the solar park and of the battery storage) is responsible for financing the project and for contracting an EPC company who is in charge of building the installation. In addition, being the responsible actor for the project development, the energy cooperative has to pay the connection costs to the local DSO. In this regard, since peak shaving is also tackled as a service use for the battery storage, a lower connection fee can be achieved. As has been mentioned before, the cooperative can require from the operator of the battery system to tackle this application, given the fact that it is the owner of the asset and thus has a say in its management.

In this scenario, the battery storage is also used for frequency control, or better to provide reserve capacity when an imbalance occurs between demand and supply of electricity. As previously mentioned, reserve capacities are traded on the electricity market and are settled by the TSO, which is the actor responsible for maintaining the balance in the grid. Therefore, the TSO is included among the stakeholders who provide complementary offerings, since the renumerations from bidding on the capacity market enrich the value proposition, allowing a better return on investment for the energy cooperative.

Comparing the Value Flow Models in Figure 5.3 and Figure 5.5, it can be seen that the other interactions among the actors, as well as the different flows of tangible and intangible values are the same. The only difference in this regard is that for the Money Maker scenario, there are no other customers who get backup power, since this application is not included in this scenario. Furthermore, in case of the Idealistic scenario there is a flow of intangible values from the energy cooperative to the end-users corresponding to an increased energy independence. Nevertheless, the Money Maker scenario does not tackle this goal, given the fact that the primary aim here is to make money and provide a better return on equity for the cooperative (and, in return, for its members). For this reason, it can be in fact questionable what are the benefits for the entire community in this scenario, apart from not having to pay a higher grid fees due to the installation of the solar park because of peak shaving. However, it can be argued that if the cooperative passes the revenues to its members who have invested in the project, the value from the energy cooperative to the end-users (although only part of them) can be stated as “better return on equity”. On the other hand, if the revenues collected by the energy cooperative are used to establish new project, this can potentially provide social and environmental benefits for the entire community; this means anyway that the benefits are achieved indirectly via this scenario and do not come in specific directly from the service uses tackled in the Money Maker business model scenario.

Lastly, the Value Flow Model in Figure 5.5 represents the case when the SDE+ subsidy is applied as a fiscal incentive. Nevertheless, the postoceroos is also possible for this scenario. In this case, the differences between the interactions among the actors are the same as in Figure 5.4, only applied to the Money Maker scenario: those end-users who invest in the solar park and have a share in it receive a reduction on the energy tax from the government, which is passed through the energy retailer depending on their shares (specified in the member statement provided by the energy cooperative).

5.4.3 Multi-Actor scenario

Lastly, the Multi-Actor scenario represents a sort of mixture between the other two scenarios, both in terms of applications that the battery storage delivers as well as organizational settings in the overall business model. Furthermore, in this scenario the DSO is directly involved in the main value proposition by determining when is the battery storage needed for grid congestion deferral. On the other hand, in the other two scenarios presented above the DSO does not have a share in the operation of the battery storage; in other words, its role is only to connect the solar park to the electricity grid and to take care that the flow of electricity from the solar park to the end-users is as smooth as possible, without interruptions or major disturbances in power quality. The only gain that the DSO sees in the addition of a battery storage to a solar PV installation in this way is the reduction of grid reinforcement needed when the solar park has to be connected to the electricity network, since the storage system is designed to provide also peak shaving of the electricity output.

As already said, also in the Multi-Actor scenario a commercial third party operates the solar park and the battery storage, while the community (through the cooperative) owns the system. However, in addition to these actors, a DSO is included among the relevant stakeholders, thus the name of the scenario itself. This DSO has a contract with the operating company to rent services from it when needed. For this reason, grid reinforcement deferral has been added among the application of the battery storage in Figure 5.2. In other words, when required by the DSO, the battery storage should be available for this service use, for which the operating company or the cooperative (depending on the contract between those two actors) might get a monetary compensation from the network operator. Taking into consideration that the peak shaving of the PV output is also considered among the applications of the battery storage in this scenario, the additional storage capacity required for grid reinforcement deferral might not be significant; as a result, this partially limits the probability of concurrent services.

It can be said that a major advantage of this scenario is that multiple benefits are provided and shared among various stakeholders with the same Solar-Plus-Storage system. However, on the other hand this can also create additional complexity from an operational as well as organizational point of view, since a trade-off between the different applications and values must be established. This might implicate that the actors should be willing to compromise their primary goals in order to work together (due to the fact that maximizing individual goals and interests may hinder the collaboration). Therefore, a well stipulated contracts between the owner, operator and DSO are essential for the success of the scenario. Another bottleneck of the Multi-Actor scenario is that at the moment, the DSO is not allowed in the current regulatory framework to rent or buy services from a commercial party; therefore, legal changes are actually required to fully exploit the potential of this scenario.

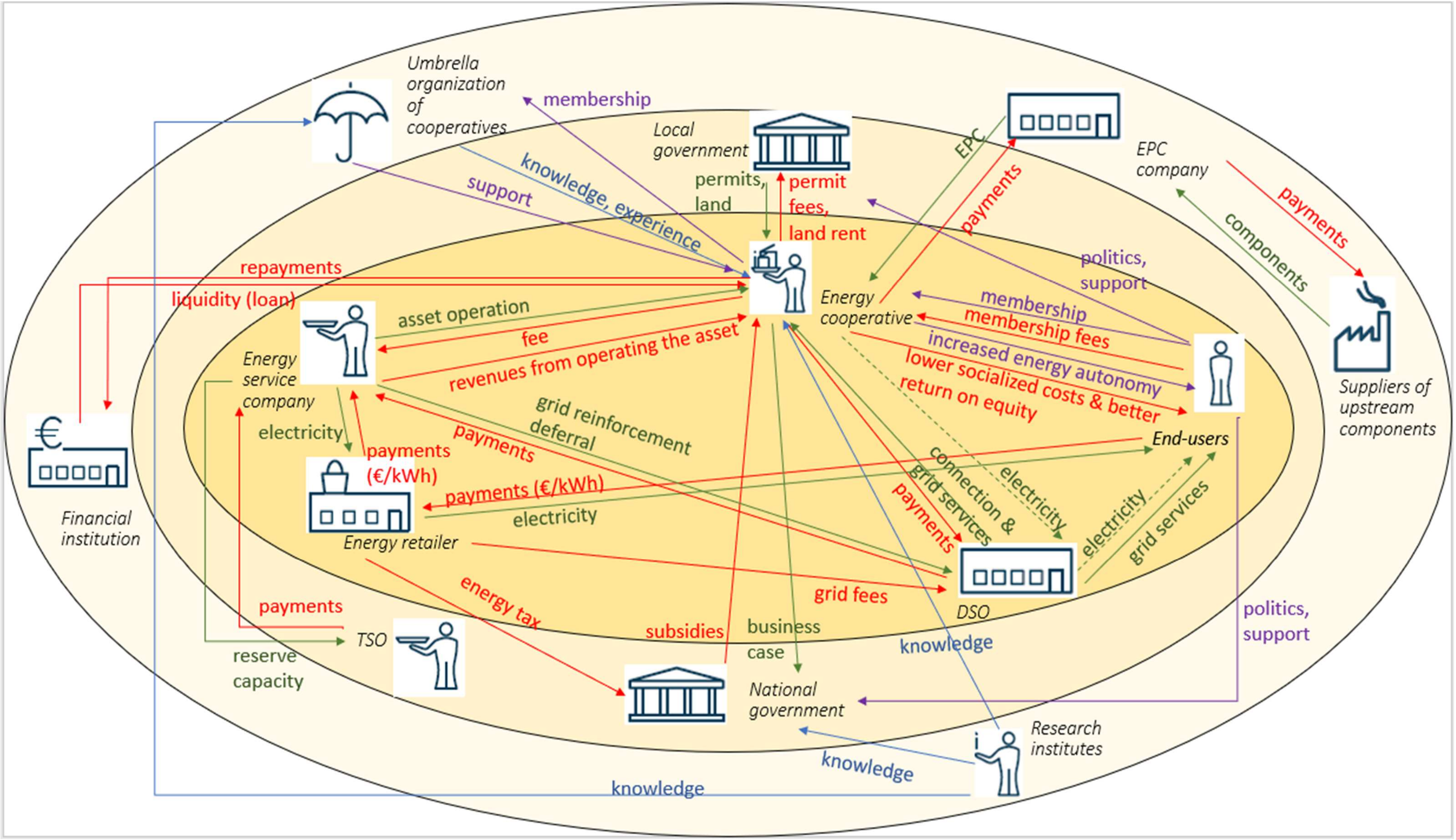


Figure 5.6: Value Flow Model for the Multi-Actor business model scenario (in case that the SDE+ subsidy is applied)

In terms of actors involved in the business model as well as flows among them, the Value Flow Models for the Money Maker scenario and the one for the Multi-Actor scenario are very similar. The first reason for this is that the owner and operator of the Solar-Plus-Storage installation are the same in the two scenarios, the energy cooperative being the owner of the asset, whereas the energy service company is responsible for its management. The second reason come from the applications of the battery storage: in the Multi-Actor scenario, part of the services that the battery provides are the same as in the Money Maker scenario (i.e. reserve capacity, peak shaving and energy arbitrage).

Nevertheless, there are two differences between the two Value Flow Models. The first difference concerns the role of the DSO in the overall scenario. As previously discussed, both in the Idealistic and Money Maker scenario the DSO is responsible for connecting the Solar-Plus-Storage installation to the electricity grid and to provide grid services in order to keep a smooth flow of electricity. However, in the Multi-Actor scenario, the battery storage is also used for grid reinforcement deferral when this is needed in the local electricity grid, for example due to an increased energy demand or new energy generation systems (such as rooftop PV systems). In practice, the DSO informs the energy service company if the battery storage should be used to avoid grid updates, for which the operator of the battery asset may get a compensation.

It should be noted that in practice, under the current legislative framework the DSO is not allow to rent services from a commercial party. Therefore, if there are no regulative changes, there is no monetary compensation possible from the DSO to the energy service company. Nevertheless, this does not mean that grid reinforcement deferral is not tackled in the Multi-Actor scenario. As a matter of fact, it is possible that the community through the cooperative (who is the legal owner of the Solar-Plus-Storage installation), wishes to use the battery system to provide grid reinforcement deferral for the local DSO, in order improve power quality and system efficiency.

Following that, the second difference between the Money Maker and the Multi-Actor Value Flow Models regards the flow between the energy cooperative and end-users. Because of the applications that the battery storage offers (for which the energy cooperative has a say, being the owner of the asset), the energy cooperative provides an increased energy autonomy for the community since increased self-consumption is also tackled (as in the Idealistic scenario), as well as lower socialized costs due to the grid reinforcement deferral. In addition, similarly as to the Money Maker scenario, also a better return on equity can be achieved for the members investing in the Solar-Plus-Storage project, given the fact that also market-related applications are included in the Multi-Actor scenario. Therefore, it can be concluded that scenario allows more flows from the energy cooperative to the end-users in the community than the other two scenarios, as can be seen in the Value Flow Model above.

Finally, also Figure 5.6 depicts the case when the SDE+ subsidy scheme is applied to the project; if the postcoderoos regulation is instead chosen as the fiscal incentive, the same interactions as in Figure 5.4 should be considered.

5.5 CONCLUSION BUSINESS MODELS

This chapter presented a business model analysis for community Solar-Plus-Storage projects. In this regard, firstly an actor analysis was performed in order to study the main actors involved in such projects and influencing the business models. Further on, the Involvement Circle was selected as the visualisation tool for the graphical overview of the stakeholder analysis. Lastly, the most important values that the key actors see in the addition of a battery storage to a solar PV installation were assessed, which in turn helped to structure the different business model scenarios described and studied in this section. Throughout these steps, the COOP-Store project was taken as a case study.

Following that, three business model scenarios for larger-scale community Solar-Plus-Storage projects were developed by combining the results from the main benefits and values that the key stakeholders see in the co-location of a battery system with a solar park and the typical business models for current Solar-Plus-Storage projects worldwide. These business model scenarios are: the Idealistic scenario, the Money Maker scenario and the Multi-Actor scenario. In all of them, the system is located in front of the meter, connected to the electricity grid. Another key aspect that is kept constant throughout the scenarios is the ownership of the system: due to the focus of this research, the owner is the community, through the energy cooperative. The difference between the scenarios cover the operator of the installation (i.e. actor responsible for its management) and the applications that the battery storage provides.

Considering the theoretical framework presented previously, it is possible to draw a parallel between the conventional business models or the theory of New Business Models with the three scenarios developed. First of all, the Money Maker scenario is the one that mostly reflects conventional business models, due to the strong focus on monetary values in the value proposition. On the other hand, the Idealistic scenario emphasises also environmental and social benefits, thus considering the principle of multiple value creation proposed by Jonker (2014) for designing New Business Models. Building on that, the Multi-Actor scenario also covers multiple values; however, in addition to that there is also a stronger focus on shared and collective value creation. Therefore, it can be stated that this scenario combines all three principles which need to be present in a New Business Model, according to Jonker (2014).

The three scenarios were analysed from the point of view of business ecosystems (thus not focusing on one stakeholder only, but instead assessing the business model considering multiple actors). Furthermore, to visualize the business model in a schematic manner, three Value Flow Models were designed (one for each scenario). In this way, not only the actors involved in the business model were studied, but also the interactions among them (in terms of flows of good & services, money & credit, information and intangible values).

Table 5.2 below presents a summary of the scenarios considering the owner and operator of the asset, the role of the network operator, advantages and bottlenecks of each scenario, as well as existence of market incentives legal barriers for the different applications of the battery storage.

	Business model scenario		
Key features	**Idealistic**	**Money Maker**	**Multi-Actor**
Ownership	community (through cooperative)	community (through cooperative)	community (through cooperative)
Operator	cooperative	third party (commercial company)	Third party (commercial company)
Role DSO	connection to the grid and stable flow of electricity	connection to the grid and stable flow of electricity	connection to the grid, stable flow of electricity and rent of services from battery storage operator (for grid reinforcement deferal)
Advantages	own control; simple organizational setting	experience, resources and knowledge; higher revenue streams	benefit stacking, multiple values created for different actors
Bottlenecks	limited knowledge and experience of cooperative; possible low financial return	increased complexity; need for good stipulated contracts	Complexity (good-stipulated contracts required); willingness of stakeholders to compromise their primary goals; presence of legal barriers

Market incentives for the different battery storage applications	yes, but none existing for increased self-consumption	yes	limited (not available for increased self-consumption and grid reinforcement deferral)
Legal barrier	no	no	Yes (DSO not able to rent services from a market party)

Table 5.2: Summary of the three business model scenarios

In conclusion, it can be said that an energy cooperative can decide to choose whether it operates the Solar-Plus-Storage installation by itself depending on the capabilities and knowledge it has. When this is not possible, it might be preferred to appoint a commercial company for this role, thus reducing the risks of improper management.

Secondly, the applications that the battery storage provide have an impact on the actors that are important in the business model, as we as on the flows between them. Some clear examples in this regard are: the presence of additional customers for backup power in the Idealistic scenario (whereas these stakeholders are not considered in the other two scenarios) and for reserve capacity (in the Money Maker and Multi-Actor scenarios), or the additional flows between the DSO and the system operator when grid reinforcement deferral is included among the service uses. In addition, depending on the scenario (and therefore on the application of the battery), there is a different flow of values between the energy cooperative and the end-users in the community, as can be seen by comparing Figure 5.3, Figure 5.5 and Figure 5.6.

Another consideration about the interactions presented in the various Value Flow Models regards the nature of the flows. As can be concluded from the figures above, the majority of arrows are either green or red, thus corresponding to the flow of goods & services or money. On the other hand, the flow of information concerns almost exclusively the research institutes, whereas flows of intangible values can be found for the cooperative entities, end-users and governmental bodies. Therefore, the result suggests that these are the actors who are primarily responsible for enabling or strengthening the concept of New Business Models (in specific the multiple value creation principle), since they value also additional benefits besides money.

Finally, the scenarios discussed in this chapter must not be interpreted as the only business model possibilities for larger community Solar-Plus-Storage project. As a matter of fact, a different combination of services provided by the battery storage might be tackled, as well as a different allocation of ownership and operation of the asset might be applied. This in turn influences the stakeholders that should be considered in the business model, their importance with regard to the core value proposition and the interactions between them.

6 BUSINESS CASE

In order to investigate the financial feasibility of a cooperative Solar-Plus-Storage project, a techno-financial analysis is performed. Thus, this chapter focuses on the business case calculations both in case that the battery system is designed to provide one service only as well as in case of benefit stacking.

6.1 OUTLINE

First of all, to assess the costs and benefits in a community Solar-Plus-Storage project and in particular in the addition of a battery storage to a solar park, the sizing of both the battery system as well as the PV installation had to be selected. This has been done by taking the COOP-Store as a reference: in this particular project, a 1,1 – 1,2 MWp solar park will be built in combination with a battery storage of approximately 500 kWh. However, given the fact that for certain applications of the battery storage there exists a minimal power to enter the market (for example, as explained earlier, primary reserve capacity is tendered with blocks of 1 MW, with a minimum of 1 MW to enter the market), a 2,3 MWp solar park and 1 MW/ 1MWh battery storage are taken as base for the calculations in this research. The selected values follow from the COOP-Store project, since the same ratio between the battery system's size and the solar park nominal capacity are applied; at the same time, a 1MW/1MWh battery storage does not have any entry barrier for accessing specific markets associated with the various service uses that can be storage asset can provide.

The techno-financial analysis is performed for a Solar-Plus-Storage project in case that the battery storage is used for one service only and in case that multiple services are tackled with the same system, to evaluate the advantages of benefit stacking in monetary terms. Furthermore, in all of the cases the business case calculation is performed both for the present year (2018) as well as for the near future - in specific, for the year 2025. The reason behind this is that in this way, it is not only possible to check the impact of future price developments (especially since lower costs are expected in the future both for PV systems as well as battery storage), but also to take into account the possible changes in regulations and how these may open up new revenue streams. The choice for the year 2025 is set arbitrarily.

Throughout the analysis, the perspective of the owner of the Solar-Plus-Storage installation is considered. Given the focus of this research, this means that all results will be presented from the point of view of the cooperative. In particular, the results of the business case calculations will be presented by two figures of merit, namely the payback period (PBP) and the net present value (usually abbreviated with NPV) for the cooperative. The payback period represents the time which is required to recover the costs of the initial investments for the project (thus, a shorter the payback period is preferred). In this analysis, the time value of money is included in the calculations for the PBP by discounting future cash flows. The primary reason for selecting this figure of merit is its simplicity: the payback period is an easy way to compare different scenarios and evaluate their financial feasibility. However, one of the limitations of the PBP is that does not give a clear indication of the profitability of the different scenarios (after they have reached the payback period). Therefore, the NPV is also calculated, which focuses on the present value of the cash inflows (revenues) and outflows (expenditures) over a specific period of time (in this analysis, the selected period for the calculation of the NPV is the whole lifetime of the solar park). For a profitable project, the NPV has to be positive over the selected period; on the other hand, a negative NPV signals that there will be a net loss. In specific, the formula used for the calculation of the Net Present Value is the following:

$$NPV = \sum_{j=1}^{T} \frac{C_j}{(1+r)^j} - C_0$$

with *j* representing the year (over the whole lifetime of the installation), C_j representing the net cash inflow in year *j*, C_0 the initial investment (in year 0) and *r* the discount rate.

6.2 SCENARIOS

As previously mentioned, this research aims to assess the financial feasibility of the addition of a battery storage to a cooperative solar PV installation (in particular when the battery system is designed to provide multiple benefits). To do so, the cost-benefit analysis described in this chapter studies both the case when the storage is used for one application only, and in case of benefit stacking.

In the former case, all the applications mentioned in the business model scenarios (Chapter 5.4 - see in particular Figure 5.2) are considered separately, namely increased self-consumption, peak shaving, backup power, energy arbitrage (on the day-ahead market and imbalance trading), reserve capacity (only primary reserve) and grid reinforcement deferral. In other words, it is assumed that the battery is used only for a particular service, regardless if the system is actually operating the whole time or only partially (and the rest of the time the battery is in an idle mode). Just to give an example, if the storage system is installed to allow a lower connection (and thus, a lower connection fee) by shaving the production peaks, the battery is used only a couple of hours per day, during sunny periods; nevertheless, it is assumed that the battery is not used for other purposed when it is not needed for peak shaving.

Instead, for the economic evaluation in case of benefit stacking, three different scenarios are considered, which follow from the business model scenarios presented previously in Section 5.4; in this way, their financial feasibility is studied and compared.

6.2.1 Idealistic scenario

As previously described, in this scenario the battery storage provides peak shaving of the electricity produced by the solar park (thus a lower connection is required) and increased self-consumption. In addition, the storage system is also used for backup power, when it is not needed for the other two services.

In order to calculate the amount of time that the battery is used for peak shaving, simulations are performed by considering a 2,3 MWp solar park (with the specifics provided in Appendix A.6). If the battery storage is used to allow a lower connection to the grid (taking 1750 kVA as threshold, as will be later explained), it is used about 1% of the days in one year. Considering charging and discharging, this means that the storage is used in total less than 0,2% of hours within one year in case of 2018. For 2025, the battery is needed approximately 35 days per year, or in total about 1% time (in hours); this difference is due to a higher yield of the solar panels in 2025.

Secondly, in order to target the increase in self-consumption, it is assumed that the battery is daily charged during midday and discharge during evening hours, operating in total 6-7 hours per day (this value comes from a combination of simulation results and from typical values from literature, see for example Luthander, Widén, Munkhammar, & Lingfors (2016) and Weniger, Tjaden, & Quaschning (2014). Therefore, the battery in 2018 is used in total 27% of the time in case of 2018. On the other hand, for 2025 it is assumed that the battery operates 6 hours per day (due to an increased yield, it can be charged faster), thus in total 25% of the time throughout a year.

In fact, given that peak shaving is usually also needed during midday, it can be stated that if the battery is used in a smart way, both peak shaving and increased self-consumption can be achieved at the same time: while charging the battery at midday to deliver the electricity later during evening hours, peak shaving is also targeted.

For the rest of time, when the battery is not used for self-consumption increase (together with peak shaving), the storage system is used for backup power. This results in 73% of the time within one year for 2018, and 75% of the time in 2025.

6.2.2 Money Maker scenario

This scenario focuses on making profit and as such it targets peak shaving, energy arbitrage and primary reserve capacity as service uses for the battery storage.

As previously seen, if the battery is used for peak shaving, it operates only a small fraction of time within one year. For the rest of the time, the storage system can be used for primary reserve capacity. However, since at the moment this market operates on weekly tenders, it is possible that peak shaving is not required every day within the same week, but on different weeks, thus lowering the amount of time for tendering the 1MW capacity on the primary reserve market.

In the worst case, assuming that each peak shaving-occurrence happens on a different week, the battery can be used for primary reserve capacity on all the other weeks, thus in total approximately 92% of the time over a year. During "peak shaving periods", since the battery is not used for the whole day for peak shaving but only for a couple of hours, it is assumed that the rest of the time (within that day and for the rest of the week) energy arbitrage is addressed to provide additional revenues. In conclusion, this means that energy arbitrage is targeted for about 7,8 % of the time, while peak shaving counts for only 0,2%.

For calculating the percentage of time for the various service uses in case of 2025, it has been assumed that the primary reserve capacity market switches to 4-hours tender blocks. This allows to tackle this application more often than in case of 2018, since even on those days when the battery storage is used for peak shaving, primary reserve capacity can be addressed, for example only for 4 bids (corresponding to 12-16 hours within a day). On the other hand, as the results from the simulations point out, there is more time with peak shaving needs in 2025 due to a higher efficiency of the solar panels (and thus, an increased energy yield). In total, 1% of the time is used for peak shaving; however, the battery for this service use is needed approximately 35 days per year, with an average of 3 hours per day. Assuming that in the worst case this happens in between two 4-hour bids, this means that for the rest hours energy arbitrage can be tackled. This corresponds to more or less to 2% of the total time. Lastly, the remaining 97% of the time is assumed to be reserved for bidding on the primary reserve market.

6.2.3 Multi-Actor scenario

As previously explained, this scenario can be interpreted as a trade-off between the previous two scenarios; thus, the battery storage is used to provide the following services: peak shaving, increased self-consumption grid reinforcement deferral, energy arbitrage and primary reserve capacity.

Given the fact that an increased energy autonomy is among the primary goals of both the energy cooperative as well as the end users within the community, this scenario gives a big focus on addressing increased self-consumption. As in the first scenario, also in this case peak shaving is addressed at the same time as increased self-consumption, thus providing additional revenues for the battery system. However, it is not possible to have a better return on equity if only these two services are considered. Therefore, this scenario includes also other applications for the battery storage. In order to allow benefit stacking, and in particular in order to have the possibility of tendering on the reserve capacity market during some weeks, it is assumed that self-consumption increase is only targeted 6 months (for example, excluding winter and autumn months when the electricity production from the solar park is reduced due to a lower irradiance whereas the electricity demand increases, thus a higher fraction of the electricity produced is directly met by the loads). Considering a 6-hours daily charging and discharging time (as previously discussed in the first scenario), this means that in total the battery storage operates for about 12% of the time to increase the self-consumption, while providing at the same time peak shaving (which typically happens on sunny spring or summer days). The rest of the time within the day (the other 18 hours), the battery can be used for energy arbitrage; considering 18 hours for 6 months, this leads to about 40% of the time being used for this application.

Furthermore, the battery in this scenario is also used for grid reinforcement deferral. Typical percentage of time when this service is currently needed are difficult to estimate due to case-to-case specific conditions within the grid. However, by combining the results from personal communication with professionals and from the workshop, an average of 5-10% of total time has been obtained; therefore, 7,5% is taken as reference number for in this analysis for the business model calculations in 2018. It should be noted that for simplicity, this analysis assumes that grid reinforcement deferral is not concurrent with the other service uses, meaning that it is not needed for example when self-consumption increase is targeted.

The rest of the time (amounting to approximately 40,5%), instead of being in idle mode the battery storage can be used to deliver primary reserve capacity, thus providing additional revenues.

It should be noted that the above division is used for the year 2018. On the other hand, for the calculations for 2025, also in this case it is assumed that the primary reserve capacity market works on 4-hourly tenders, thus allowing more time being used for this service use.

First of all, also in this case the battery storage is used for grid reinforcement deferral. According to the results from the workshop, a good estimation for the percentage of time that a battery is used for this application can be between 10-30%; therefore, the average value of 20% is selected in this analysis. Also in this case it is assumed that grid reinforcement deferral is not concurrent with the other service uses.

Secondly, the storage system is used to boost self-consumption. However, given the fact that the tendering process for primary reserve capacity in this case does not operates on weekly bid blocks, these two applications (namely increased self-consumption and primary reserve) do not exclude each other, meaning that both can be tackled within the same day. Therefore, it is assumed that the battery is used for increased self-consumption throughout the year, as presented in the first scenario; thus, following the results from the previous section, the battery operates approximately 6 hours per day, totalling 25% of the whole time. Also here, peak shaving of the produced electricity is provided at the same time as increased self-consumption (by charging the battery around noon and discharging it during evening hours).

Considering on one hand the periods when the battery is used for grid reinforcement deferral or increased self-consumption and the 4-hours tendering process for primary reserve capacity on the other, there is also some time when the battery would be in idle mode. During these periods, energy arbitrage can be tackled; considering an average of 2 hours per day (the difference between two 4-hour bids and the 6-hour period for increased self-consumption), this translates to around 8% of the time. Finally, the rest of the (approximately 47% of the time within a year), it can be used to provide primary reserve capacity.

The scenarios presented in this section are summarized in Figure 6.1 below. It should be noted that peak shaving is included also in the first and last scenario (namely Idealistic and Multi-Actor scenarios), both for the present year as well as for 2025. However, since this application is tackled in combination with increased self-consumption, it is not depicted in the figure. Furthermore, the Money Maker scenario uses the battery for peak shaving for 0,2% of the time: it is not possible to see the red area corresponding to this application in the figure merely because of the small percentage.

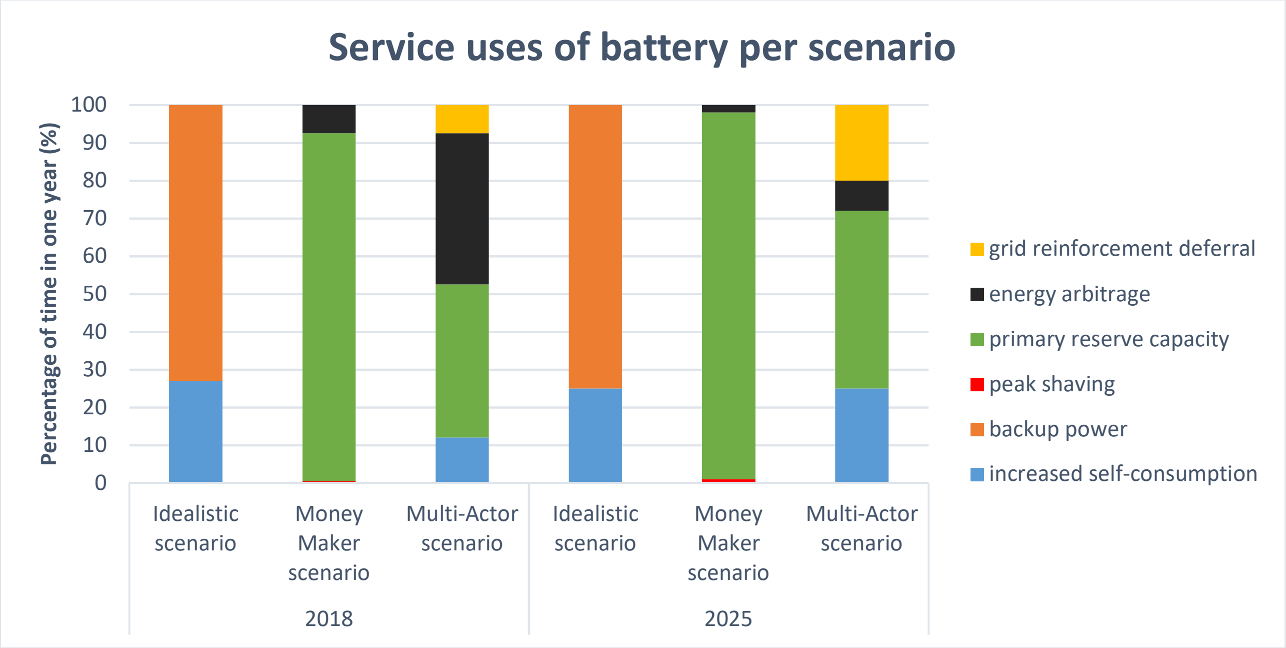


Figure 6.1: Percentage of time when the battery is designed to provide a particular service use, for each of the three scenarios in 2018 and in 2025

6.3 ASSUMPTIONS AND INPUTS

Several assumptions are needed in order to perform a business case calculation. The overall assumptions selected in this analysis are explained below. Detailed tables with values and inputs used for the business case calculations can be found in Appendix A.6.

6.3.1 General

Firstly, to cover the investment in a project, financing is needed. This can come in the form of personal resources of the owner of the asset, but also from an external financier such as a bank – the choice of the form of investment may play a significant role in the profitability of the project. When a larger investment is required for a Solar-Plus-Storage project, it is probable that the owner (in this analysis, the cooperative) does not have all the initial capital available. Therefore, a debt is made for the PV system and the battery storage; the assumed debt-to-equity ratio is 70/30 (based on typical ratios for sustainable project in the Netherlands, as presented in (ECN & DNV GL, 2017)), meaning that 70% of the total initial investment comes from a debt, while the rest is covered by the money already available by the cooperative. Furthermore, it is assumed that the debt is repaid annually within the first 15 years, since this is also the value taken for the lifetime of the inverters and of the battery storage system, as well as for the depreciation rate.

Another assumption that has been made in this analysis is that the lifespan of the Solar-Plus-Storage project equals the lifetime of the solar PV modules (which corresponds to 30 years, according to Stahley (2017)). Thus, the NPV is calculated over a 30-years period, assuming that the battery storage system is bought and installed in year 0, together with the solar park. Given the fact that the lifetime of both inverters as well as battery storage is 15 years, it is assumed that in year 16 new inverters are bought. However, no new storage is added to the solar park; instead, in the year 16, the batteries are sold at 10% of their original value. Therefore, from that period onwards, only the costs and revenues from the solar park are considered.

6.3.2 Solar park

In order to estimate the yield factor, which in turn allows to calculate the yearly electrical output produced by the solar panels, the COOP-Store project is again taken as reference for the location and orientation of the solar park. Once the amount of electricity generated has been determined, it is also possible to compute the revenues that can be gained from the solar park. In this regard, it is assumed that both electricity as well as guarantees of origin are sold. In case of electricity, it is assumed that the selling is done to the grid, on the APX market (the prices are estimated based on the average spot price in the Netherlands in 2018). In addition to that, this analysis assumes that guarantees of origins are also sold. A guarantee of origin (Garanties van Oorsprong or GvO in Dutch) is an energy certificate that proves that the electricity supplied comes from a renewable energy source, in other words that it has been generated sustainably. For every MWh of electricity generated, a guarantee of origin can be obtained and sold on the market; however, it should be noted that they are not tied to the physical delivery of electricity (TrackMyElectricity, n.d.). For the prices of the guarantees of origin in the business case for 2025, assumptions had to be made since no estimations or price projections have been found. In this regard, the assumption in based on the trends for biomass and wind guarantees of origin, as presented by CE Delft (2016).

As has been previously already described in this report, there exist several fiscal incentives from the Dutch government to stimulate the production of renewable energy. In this regard, this business case calculations take as an assumption that the Solar-Plus-Storage project applied for an SDE+ subsidy. As previously stated, this is an operating subsidy for every kWh of produced energy, in order to compensate for the difference between the cost price of renewable energy and conventionally generated energy. Even though there exists also another fiscal incentive which explicitly targets community projects, namely the postcoderoos regulation, this techno-financial analysis is based on the assumption that the SDE+ (and not the postcoderoos) is considered. The reason behind this comes from the desk study on current cooperative projects in the Netherlands: as discussed in Chapter 4.3, when larger solar parks are installed (approximately above 125 kWp), the SDE+ is the most used subsidy scheme (even in case of community projects). Since this analysis focuses on a 2,3 MWp solar park, the SDE+ is chosen. Nevertheless, it can be argued that the real reason why the postcoderoos is not used also for larger projects can be found in the difficulty to find enough citizens who are willing to invest and participate in a postcoderoos project, due to the intrinsic nature of the fiscal incentive itself (in other words, people find it difficult to understand the principles of how do this incentive work for them). In fact, this observation holds also for the COOP-Store project, where the initial plan of applying for the postcoderoos for the whole solar park’s capacity had to be reconsidered, due to difficulty to find enough participants for the project that could contribute to the initial investment.

Furthermore, another assumption in this analysis regarding the subsidies concerns the fiscal incentive for the business case calculations for the year 2025. In particular, it is assumed that the SDE+ runs for 15 years, which means the same as it is at the moment for solar PV.

6.3.3 Battery storage

Also regarding the battery storage system some assumptions have been made. First of all, as previously mentioned, it is assumed that the battery has a capacity of 1MWh and a rated power of 1MW; in this way, it is twice as big as the battery considered in the COOP-Store project, while having a rated power that allows to enter the primary reserve market (which is the market with the highest access barrier in terms of power, among the ones considered in this analysis).

Another important assumption concerns the yearly expenditures for the battery system. From personal communication with professionals, it has been found that typical O&M costs for batteries co-located with a solar park are in the range 20.000€-25.000€ per MWh, including grid fees. Because of that, a value of 22.000€/year seems a reasonable assumption and has been taken as the reference value for this research, given that grid fees vary depending on the application that the battery storage is used for. In particular, grid fees in case that electricity is only delivered into the grid are lower than in case when electricity is also taken from the grid to charge the battery; moreover, in the latter case, the fees depend on how much power is taken. Further details on grid fees are provided in Appendix A.7.

In addition, there are also yearly fees that the owner of the asset has to pay to the operator of the storage system, in case that the management is not done by the same actor. For the business case calculation when the storage is used only for one service use, only the O&M costs of 22.000€/year are considered for simplicity. On the other hand, for the techno-financial analysis in case of benefit stacking a division has been made in order to keep representability of a real business case. In the first scenario, again only the O&M costs of 22.000€/year are taken into account, given the fact that in this scenario the owner and the operator are the same actor. However, for the other two scenarios, a third company is responsible for the management of the battery, for which it receives a fee from the cooperative (i.e. owner of the asset). For this reason, the total O&M costs here include both the 22.000€/year as well as the management fee.

6.4 REVENUES FOR BATTERY STORAGE APPLICATIONS

This section describes what are the revenues that each service use of the battery storage provides, and how have these revenues been obtained.

6.4.1 Primary reserve capacity

As previously described, the market for primary reserve capacity in the Netherlands operates on a weekly basis, where power can be tendered in blocks of 1MW. From communication with professionals and the results from the workshop, it can be concluded that if the battery is used only for primary reserve capacity, it must be constantly maintained at 40-60% state of charge (since it has to be able either to provide extra power into the grid or to withdraw it, depending on the needs of the transmission system operator). Even if the battery system is not fully operational all the time, it is typically not used for other services during the week that it is reserved for primary reserve (failure to provide the requested capacity – in or out – at any specific moment results in a significant fine).

In 2018, the average revenues for primary reserve capacity in the Netherlands are approximately 2.800€/MW/week, as has been calculated from the data available on the ENTSOE Transparency Platform (see Appendix A.8 for the trends in the period 29/12/2014 – 04/06/2018).

Although it is difficult to say what will be the future revenues from primary reserve capacity, a 30% decrease from current values is assumed for the revenues in year 2025. This comes from combining the trends in this market since 2014 and the results presented by Fleer et al. (2017), as well as communication with professionals (Enpuls, 2018). At the same time, it should be noted that it is possible that in the near future, the market structure for primary reserve will change from weekly tenders to 4-hours bid blocks (Scholt Energy Service, 2017); this can be an important consideration for benefit stacking, as already discussed in the report.

6.4.2 Energy arbitrage

Regarding energy arbitrage, two markets have been assessed for the application of battery storage: the day-ahead market and the imbalance market.

On the day-ahead market, hourly prices of electricity typically fluctuate between 30€/MWh and 60€/MWh (APX-Group, n.d.). This means that, taking 30€/MWh/day as a price difference, the revenues for a 1MW/1MWh battery storage is on average 11.000 €/year. In this calculation, it is assumed that on the days when there is not enough solar radiation to fully charge the battery, cheap electricity is taken from the grid (at low prices) and sold later when the prices are higher. For the revenues in 2025, it is assumed that the price spread does not change, as several studies point out (CE Delft, 2017; DNV GL, 2015; Nolten, 2017); therefore, the same revenues are applied also for the future case (in 2025).

Usually, the benefits of a battery storage system used for imbalance trading vary depending on the imbalance prices and the trading strategy. In this regard, as stated by Nolten (2017), there exists a trade-off between the number of cycles that a battery storage conducts and the average revenue per cycle, which is needed to balance revenues and degradation of the battery. In 2017, the average yearly revenues for a 1MW/1MWh battery storage used for imbalance trading was approximately 50.000 €/year (Scholt Energy Service, 2017).

However, as has been pointed out during the workshop conducted during this research, in 2015 the benefits were around 65.000 €/year; some possible explanations for this trend could be better forecasting for the production of electricity or better balancing reserves' contracting. Following this trend, and supposing that in the future more storage systems will be deployed (thus lowering imbalance prices even further), this report takes as an assumption that the revenues in 2025 for imbalance trading will be 17.500 €/year. Although this value is significantly lower than the one for 2018, imbalance trading is still more attractive (from a monetary perspective) than arbitrage on the day-ahead market, both now as well as in the near future.

6.4.3 Peak shaving

In the Netherlands, there are two types of costs that should be paid to the network operator when a new connection is made: the connection costs, which are paid in year 0 (when the installation is commissioned), and the yearly grid fees (divided into a fixed and a variable part, as explained in Appendix A.7). All of these costs depend on which part of the electricity grid the installation is connected, which in turn depends on the size of the system. In particular, as far as the connection costs are concerned, for a connection above 1750 kVA, significantly higher costs are applied with respect to a connection below this threshold (Bruning & Rikze, 2016). The reason behind this is that above 1750 kVA, deep connection costs are applied when a new connection is made (meaning that all infrastructure-related costs, including possible grid extensions, are paid by the owner of the installation being connected); on the other hand, if a smaller connection is needed, shallow connection costs apply, i.e. the owner is responsible only for the cost of the connection, while the network operator bears the costs for enhancing the grid in order to allow a smooth flow of electricity (and recovers these costs by use-of-system charges for the network customers) (Cottier & Espa, 2017). Therefore, this is translated into higher costs in case of an installation which requires a connection above 1750 kVA.

Since the solar park considered in this analysis has a nominal capacity of 2,3 MWp, a connection above 1750 kVA is required. This results in upfront connection costs of around 170.000€ for 2018, and 180.000€ for 2025 (based on communication with professionals and price developments, as presented in Bruning & Rikze (2016); Liander (2018); Stedin (2018)). If the battery is used to shave the peaks produced by the solar park in order to allow a connection below 1750 kVA, the connection costs become approximately 41.000€ in 2018 and 43.500€ in 2025 (based on the same sources).

Furthermore, also yearly connection fees (i.e. fees for being connected to the grid) vary: without peak shaving, the costs are approximately 1.800 €/year in 2018 and 2.000€/year in 2025, while with peak shaving they are reduced to 670 €/year in 2018 and 760 €/year in 2025 (Enexis, 2018; Liander, 2018; Stedin, 2018).

Therefore, it can be concluded that the revenues associated with peak shaving can be divided in two parts: the first one consists of a lower connection costs in year 0 (given by the difference between the costs for a connection above or below 1750 kVA) and the second one is represented by lower yearly grid fees (again, given by the difference between fees for connections higher or lower than 1750 kVA).

6.4.4 Increased self-consumption

If the battery storage is used to increase the percentage of produced electricity that is also locally consumed by the community, by storing for example the excess electricity during midday and deliver it at evenings, no fiscal incentive or direct revenue streams are possible at the moment. Therefore, for the year 2018, there are no revenues associated with this service use of the battery storage.

However, given the large interest in this application not only by the cooperative and end-users, but also by other actors in the energy sector, this analysis assumes that in 2025 increased self-consumption of solar PV energy by the community will yield income (some proposed mechanisms on how this can be achieved are discussed later in the report, specifically in Chapter 8). In particular, the proposed tariff which can be applied to stimulate self-consumption is 0,03€/kWh. This value has been set arbitrarily, while keeping in mind the spread of the electricity prices on the day-ahead market, where a similar value can be found.

By simulations of the production patters for a 2,3 MWp solar park, with the location and orientation as specified in Appendix A.6 which follow from the COOP-Store project and the yield factor for 2025, it has been concluded that the solar park may not generate every day enough electricity to fully charge the battery storage (i.e. 1MWh); in fact, this happens approximately 6,5% of the time (with a charging that varies between 100 kWh and 800 kWh). For this reason, in order to come up with a yearly revenue for the battery in case of increased self-consumption, it is assumed that on these days the storage system reaches on average a state of charge of 50%. In conclusion, the total yearly income linked to this service use can be approximated to 9870 €/year.

6.4.5 Backup power

The provision of backup power depends on the specific location of the Solar-Plus-Storage installation. For example, if there is a company in the neighbourhood that operates with devices which are sensitive to power supply issues (such as data centres or server rooms), this company may rent services from the owner of the battery storage instead of buying for itself an uninterruptible power source (UPS). In turn, this creates additional revenue streams for the battery storage. However, the exact value of this benefit is extremely case-specific and should be instead calculated individually based on each particular project. Nonetheless, in order to provide an example of the possible revenues that this application provides, the value of 500 €/MW/month, as used in DNV GL (2018) and based on an estimate of current UPS services, is also adopted in this analysis, both for the present year as well as for 2025.

6.4.6 Grid reinforcement deferral

At the moment, using a battery storage, owned by a cooperative or a commercial party, to provide grid reinforcement deferral for the DSO is not possible. In other words, the network operator is legally not allowed to rent services for managing the grid (as discussed earlier, these services can be for example in the form of reactive power supply for voltage control or demand peak shaving to avoid grid congestion). For this reason, no revenues can be obtained in 2018 if the battery is used for grid reinforcement deferral. Nevertheless, this does not exclude that in order to avoid reinforcements in the electricity grids, the community decides to provide these services also if no direct revenue streams can be gained from the DSO.

On the other hand, several studies (ACORE, 2016; DNV GL, 2018; EDSO, 2016; EUROBAT, 2016; INSIGHT_E, 2015) have already started to suggest the need for a regulatory change, in order to allow DSOs and TSOs to either own battery storage or, possibly, rent grid services from a different actor. Building on that, this analysis assumes that due to changes in legislation, in 2025 the DSO will be able to rent services from the community storage asset, for which a certain fee can be asked. However, determining the revenues that a battery storage used for grid reinforcement deferral can provide is not easy, especially given the fact that it is extremely case specific. As an example, the report presented by DNV GL (2018) focuses on to case studies: for the first one, a revenue stream of 1.200€/MW/year can be associate with congestion backup and reinforcement deferral, while the second case has a revenue stream of 33.600€/MW/year (both values come from a rough estimation of network tariffs in consultation with local network operators). For this reason, the latter values are taken only as an indication of the potential minimum and maximum earnings, due to the limited information available about this revenue stream.

All the revenue streams described in this chapter are summarized in the table below.

Application of battery storage	Revenues in 2018	Revenues in 2025
Primary reserve capacity	2.800 €/week	1.960 €/week
Energy arbitrage (day-ahead market)	11.000 €/year	11.000 €/year
Imbalance trading	50.000 €/year	17.500 €/year
Peak shaving	129.000 €/connection (in year 0) AND 1.130 €/year	136.500 €/connection (in year 0) AND 1.240 €/year
Increased self-consumption	0	9.870 €/year
Backup power	500 €/month	500 €/month
Grid reinforcement deferral	0	1.200-33.600 €/year

Table 6.1: Revenues for different applications of the battery storage, in case of a 1MW/1MWh system, for the present year and for 2025

As previously discussed, in case of benefit stacking, three scenarios were considered in this analysis, which consisted in a combination of various service uses. In this regard, the same values from Table 6.1 are used, considering the % of time that the battery is used to provide a specific application (as described in Section 6.2). It should be noted that in all the scenarios where energy arbitrage is targeted, only imbalance trading (and not arbitrage on the day-ahead market) is considered. The reason for this is that imbalance trading is more profitable, both now and in the near future (year 2025).

6.5 RESULTS

After having explained in the above sections how the different scenarios are calculated and what are the assumptions and the inputs used throughout the techno-financial analysis, this section presents the results of the business case calculations. As previously mentioned, two figures of merit are considered, namely the payback period (PBP) and the Net Present Value (NPV), both for the present year (i.e. 2018) as well as for the near future (year 2025).

Firstly, the results for each application of the battery storage are presented separately; in other words, they represent the case when the battery system is used only for one single purpose (regardless if the battery storage is actually operating the whole time or if it's in an idle mode). In addition, the analysis includes also the case with "PV only", which corresponds to the situation when there is no battery storage added to the solar park. In other words, only the costs of the PV installation are considered, together with the revenues from selling the electricity and the guarantees of origins. In this way, it is possible to compare the results in case of a PV-only situation and a Solar-Plus-Storage situation, thus allowing a better understanding of the advantages (or disadvantages) of adding a battery storage to a solar PV system in financial terms.

Application of battery storage	PBP - 2018	PBP - 2025
Primary reserve capacity	10 years	11 years
Energy arbitrage (day-ahead market)	> 30 years	> 30 years
Imbalance trading	30 years	> 30 years
Peak shaving	> 30 years	> 30 years
Increased self-consumption	> 30 years	> 30 years

Backup power	> 30 years	> 30 years
Grid reinforcement deferral (minimum)[4]	> 30 years	> 30 years
Grid reinforcement deferral (maximum)[5]	> 30 years	27 years
PV only – no battery	12 years	14 years

Table 6.2: Payback period results per battery storage application and in case of solar park only (no battery storage added)

The first thing that can be noticed in the above table is that if the battery storage is used only for one service use, the time needed in most of the cases to earn back all the costs is more than 30 years (which corresponds to the lifetime of the PV panels). In other words, for most of the applications, all the financial outflows (for both the solar park as well as the battery storage, apart for the "PV only" situation) are not fully repaid by the inflows (revenues from the battery system application, selling of electricity and selling of the guarantees of origin) within the whole system's lifetime. It is interesting to notice that this holds not only for the 2018 case, but also for the 2025 one. The reason for this is that although for 2025 significant cost reductions are expected, most of the associated revenues are also still low (as can be seen from Table 6.1, thus limiting the profitability of a certain application.

The only two service uses of the battery storage for which a positive business case can be currently obtained within the lifetime of the solar park are primary reserve capacity and imbalance trading. This result is in line with the outcomes from the literature study, where it has been found that these two applications are currently tackled in large Solar-Plus-Storage systems that are owned (and operated) by commercial parties with the main interest in profit maximization. As a matter of fact, adding a battery storage and using it only for primary reserve capacity throughout the whole year makes a better business case than having only a solar park. On the other hand, if the battery storage is used for imbalance trading purposes, the system breaks even only after 30 years. This suggests that tacking only imbalance trading can be risky in financial terms: for example, if the solar panels do not have 30 years of lifetime (and must be replaced before that), there would not be a positive cash flow for the project.

For the 2025 case, primary reserve capacity is again the most profitable solution (even if compared with the PV-only situation). Here, the PBP is 11 years (instead of 10 years in 2018): this results from a lower revenue base per week that can be gained with this service use with respect to the current year (despite the costs of battery and PV systems). In addition, it is interesting to notice that the PBP in case of grid reinforcement deferral is 27 years. However, this is only true in case of the maximum revenue stream, while for lower revenues the project would not be profitable within 30 years.

Next, the results from the NPV are shown in the figure below (exact results can be found tabulated in Appendix A.9).

---

[4] The minimum coresponds to the case that 1.200 €/year is selected as the revenue stream associated with this service use for the battery storage.

[5] The maximum is when 33.600 €/year is chosen instead.

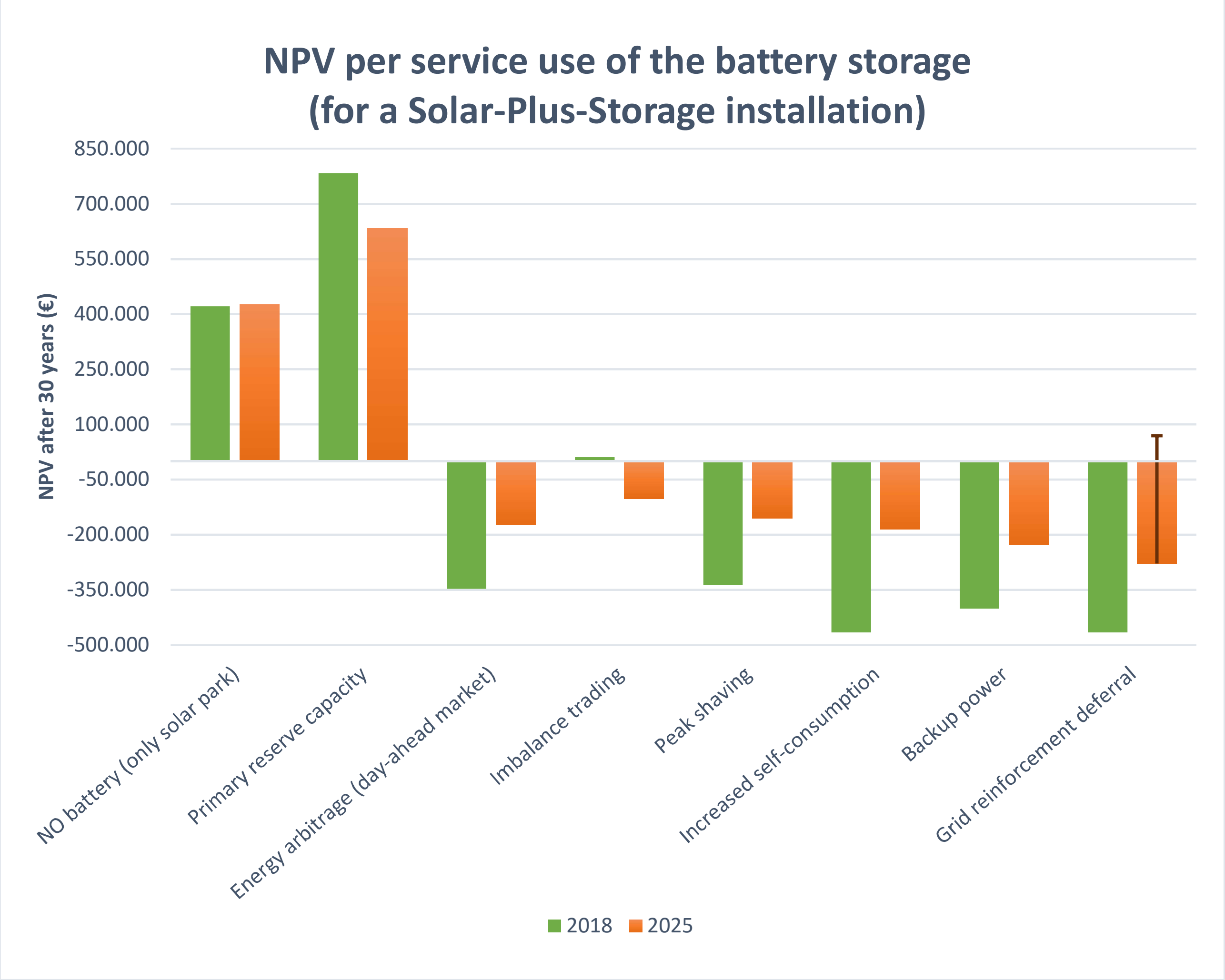


Figure 6.2: NPV results for each battery storage application and for the solar park-only case, both for 2018 as well as for 2025. The column for grid reinforcement deferral corresponds to the minimum case, while the error bar represents the result if the maximum revenue is applied.

Firstly, the NPV results show that using the battery storage for primary reserve capacity leads to the best business case, as has been previously discussed following the PBP results. The second-best option is instead to install a solar park without the addition of a battery system: this clearly indicates that the costs associated with it (both in terms of investments as well as yearly O&M costs) are higher than the profit that can be made with it, with the exception of the primary reserve capacity case. Thus, a first conclusion that can be drawn from these results is that adding a battery storage to a solar park is not financially attractive without benefit stacking, unless the battery is used for the whole time for reserve capacity. It is interesting to notice that this holds both for 2018 and for 2025, thus suggesting not only that primary reserve capacity will remain the most profitable application for battery storage, but also that benefit stacking is not only a short-term solution to overcome the barrier of current high initial costs of battery system. On the contrary, it appears to be a prerequisite for financial sustainability of a Solar-Plus-Storage project, both now and in the future.

Secondly, it is important to remember that a project is profitable within a specific period of time (in this case, 30 years) if the NPV is positive. Therefore, it can be concluded that only primary reserve capacity actually guarantees financial feasibility both in 2018 and in 2025 (if a Solar-Plus-Storage system is considered, and not a solar park-only situation). As such, in order to increase the return on investment of a project in case of benefit stacking, it may be required to use the battery for primary reserve capacity at least some % of the time. Furthermore, imbalance trading returns a positive (although very small) NPV only for 2018, indicating that the cost reductions of batteries in the future cannot compensate the lower revenues associated with this application. An opposite result can be found for grid reinforcement deferral, where depending on the location of the storage within the grid (and thus the associated cash inflows), this service use can be financially attractive in the future. For all the other battery storage applications, the NPV is negative both for 2018 as well as 2025.

Lastly, focusing on the difference between the green columns (representing the NPV for 2018) and the orange ones (representing the results for 2025), it can be seen that in 2025 the system performs better in terms of profitability for most of the applications, except for primary reserve capacity and imbalance trading. This results from a combination of lower investments and higher revenues for 2025 with respect to 2018 (in case of peak shaving, increased self-consumption and grid reinforcements deferral), which nevertheless do not guarantee the system to be profitable within the 30 years' lifetime. Backup power and energy arbitrage have a better NPV in 2025 than in 2018 only because of lower costs, since the revenues are the same for both periods. On the other hand, the trade-off between costs are revenues is better in 2018 than in 2025 for primary reserve capacity and imbalance trading, thus the decrease in profits for these two applications is more drastic than the cost reductions. Finally, it is also interesting to notice that for the solar park-only case, the NPV is higher for in 2025 than for the 2018. These results follow from a combination of the lower costs, higher solar panels efficiency (thus an increased energy yield) and higher revenues from selling the electricity on the energy market; the only two parameters which are lower in 2025 with respect to 2018 are the revenues from the guarantees of origin and the SDE+ contributions. However, the PBP for the PV-only case is better for 2018 than for 2025. This is a clear example why it is important to incorporate more than one figure of merit when assessing the financial feasibility of a project: although for the 2018 case it is possible to obtain a positive cash flow sooner than for the 2025 case, the overall profitability is better for the latter situation. The reason for this comes from the structure of the cash inflows. For the 2018 case, the SDE+ contributions in the first 15 years play an important role in making the project profitable within 12 years. On the other hand, for the 2025 case the SDE+ contributions are smaller (thus the project is less subsidy-dependent), but the overall costs are lower and the revenues from selling the electricity are higher, therefore a higher financial return is accumulated in the 30-years period.

The second part of this section focuses instead on the techno-financial analysis in the case of benefit stacking (in other words when the battery is used for more than one application, minimizing its idle time). In this regard, as previously discussed, three scenarios are considered, which follow from the business model scenarios. Also in this case the situation without the battery storage is included, to allow a better comparison between the solar park-only and the combination Solar-Plus-Storage.

Scenario	**PBP - 2018**	**PBP - 2025**
Idealistic	> 30 years	> 30 years
Money Maker	10 years	11 years
Multi-Actor (minimum)[6]	18 years	21 years
Multi-Actor (maximum)[7]	18 years	13 years
PV only – no battery	12 years	14 years

Table 6.3: Payback period results for each scenario and for the solar park-only situation

---

[6] Same as Footnote 4 (since this scenario includes also grid reinforcement deferral)

[7] Same as Footnote 5 (since this scenario includes also grid reinforcement deferral)

The first thing that can be seen in Table 6.3 is that the Idealistic scenario is not profitable within a 30-years period, both for the present year as well as for 2025. This is linked to the applications that are tackled in this scenario. To recap, the Idealistic scenario focuses on providing backup power, increased self-consumption and peak shaving of the produced electricity (from the solar park). Thus, none of the applications which have a positive NPV either in 2018 or 2025 (primary reserve capacity, imbalance trading or grid reinforcement deferral) are included.

The Money Maker scenario has the lowest payback period, not only in terms of the three scenarios considered in the analysis, but also compared with the PV-only case. It is interesting to notice that the PBP for the Money Maker scenario is the same as for the primary reserve capacity (thus, when the battery storage provides only that service use). This result follows from the % of time that the battery is used for this specific application. In fact, in the Money Maker scenario the battery is used most of the time for primary reserve capacity, while only for a small % is assigned to imbalance trading and peak shaving. However, one conclusion that can be drawn from this is that the PBP in this scenario is not hindered by the provision of additional services besides reserve capacity. In other words, while still having the same PBP as the primary reserve-only situation, the Money Maker scenario provides further benefits since two additional applications are tackled in this case.

Finally, the Multi-Actor scenario has a PBP that lies between the PBP of the Idealistic and of the Money Maker scenario. This reflects the intrinsic nature of the Multi-Actor scenario, which is somehow a combination of the other two in terms of applications that the battery storage provides. On one hand, with respect to the Idealistic scenario, also more profitable service uses are tackled here (namely primary reserve capacity and grid reinforcement deferral). On the other hand, the % of time for reserve capacity is smaller than in the Money Maker scenario, thus increasing the payback time for the Multi-Actor scenario. Furthermore, the PBP for the Multi-Actor scenario in 2025 strongly depends on the revenues associated with grid reinforcement deferral (given that the battery is used 20% of the time for this purpose): for high revenues, the PBP can be lower than in the solar park-only case (in 2025), whereas this does not hold for lower revenues (with a PBP up to 21 years in comparison with 14 years).

After that, the results for the NPV for the different scenarios are presented in Figure 6.3 (exact values are tabulated in Appendix A.9).

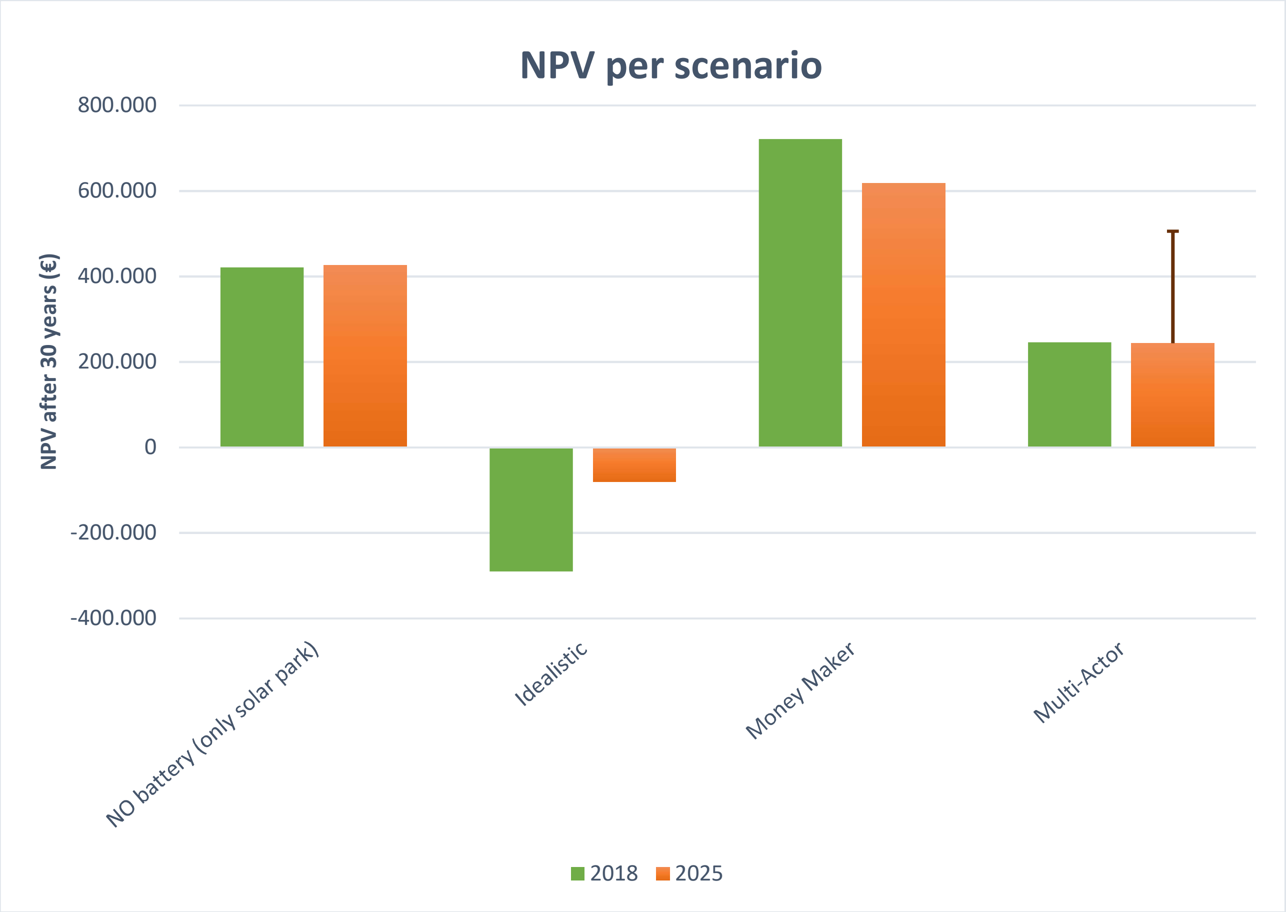


Figure 6.3: NPV results for the different scenarios, for the 2018 and the 2025 case. As before, also in here the orange column for the Multi-Actor scenario corresponds to the minimum case (i.e. when the minimum revenue stream for grid reinforcement deferral is applied), whereas the error bar represents the result for the maximum revenues.

As concluded from the PBP results, the Idealistic scenario is not profitable within 30 years (and has therefore a negative NPV), due to the low revenues from the applications tackled in this case. This is true both for 2018 as well as 2025, although the 2025 case performs better: the reason for this comes from the higher revenues, in particular for increased self-consumption (as a matter of fact, for the 2018 this revenue stream is 0€).

Next, the Money Maker scenario is the most profitable, mainly due to the large amount of time that the battery is used for primary reserve capacity. Although the PBP is the same for this scenario and for the case when the primary reserve is the only application for the battery system, the NPV in the Money Maker scenario is lower because the battery here is partially reserved for peak shaving and imbalance trading, which both provide lower revenues than reserve capacity. Furthermore, the Money Maker scenario has a higher NPV than the solar park-only solution: for the 2018 case, the NPV is approximately 75% higher than for the solar park-only situation, while for the 2025 case the increase is around 40%. Thus, despite the initial investments, adding a battery storage to a solar park and using it for benefit stacking increases the profitability of a project, under the condition that primary reserve capacity is mainly tackled.

Lastly, the Multi-Actor scenario (where the battery storage is used for peak shaving, increased self-consumption, primary reserve capacity, grid reinforcement deferral and imbalance trading) has a positive NPV both for the present year as well as in the 2025 case. Nevertheless, this scenario performs worse than the PV-only case when the revenues associated with the grid reinforcement deferral are low. Instead, for higher revenue streams this scenario becomes the second most profitable in 2025, after the Money Maker scenario. This clearly suggests the importance of understanding how much grid reinforcement is actually required in the electricity grid.

As a final remark, it must be noted that throughout this analysis it has been assumed that the battery is used for grid reinforcement deferral every year for the same % of time, providing the same revenue stream every year. However, this might not be always the case: for example, the battery can be used only to postpone major grid upgrades, resulting in different revenues pre- and post- upgrade.

6.6 CONCLUSION BUSINESS CASE

This chapter focused on the business case calculation for a Solar-Plus-Storage project. In particular, a techno-financial analysis was performed both in the case that the battery is used for one service use only as well as in the case of benefit stacking (i.e. if the battery storage is used for a combination of different applications). The analysis was conducted for the present year (2018) and for the year 2025, in order to understand the impact of cost and revenue developments.

Firstly, the outline of the analysis was presented, including the structure of the different scenarios in case of benefit stacking (which follow from the business model scenarios and differ in terms of applications and % of time that a specific service use is addressed), the inputs and assumptions used and how the revenues for the various applications were calculated. Following that, the results of the techno-financial analysis were presented; in this regard, two figures of merit were considered, namely the payback period (PBP) and the Net Present Value (NPV).

If the battery is used for one single application only, the most profitable case is for primary reserve capacity, both in 2018 as well as in 2025. Furthermore, this business case has a higher NPV than a solar park-only solution, thus indicating that the addition of a battery storage make sense in purely financial terms only when this service use is tackled. For all the other services, the Solar-Plus-Storage solution performs worse than the solar-only. In particular, for most of the applications the yearly revenues are too small to compensate for the yearly expenditures and the initial investments, leading to a negative NPV. In fact, in general terms a revenue stream of at least approximately 48.700 €/year is required in order to have an NPV > 0 for the 2018 case, and around 27.000 €/year for the 2025 case. This in turn can be translated into specific information for each application. For example, in order to have a positive NPV, increased self-consumption needs to deliver a revenue of about 0,082 €/kWh. A conclusion that can be drawn from this first part of the analysis is that benefit stacking is essential to ensure the financial feasibility of a Solar-Plus-Storage project if the battery system does not provide primary reserve capacity for most of the time; this holds for the 2018 as well as for the 2025 case. In addition, the results also suggest that primary reserve capacity should be tackled at least for some % of the time, in order to guarantee a positive business case within a 30-years period in case of benefit stacking.

On the other hand, when the battery storage is designed to provide more than one application (i.e. benefit stacking), three scenarios were considered for the techno-financial analysis: the Idealistic scenario, the Money Maker scenario and the Multi-Actor scenario. The Idealistic scenario, which does not include any application with a high revenue stream (in particular primary reserve capacity), is not profitable within 30 years, making this scenario financially unattractive. Next, the Money Maker scenario is instead the most profitable one, especially because most of the time the battery provides primary reserve capacity (which, as previously seen, is the application that provides the highest revenues). In fact, this scenario has a higher NPV than the solar park-only solution, both for the year 2018 as well as for 2025. In addition, although the actual values of the NPV are lower than for the only-primary reserve capacity case, this scenario provides additional benefits while still remaining more profitable than the PV-only solution; this can be therefore interpreted as a clear confirmation of the feasibility of benefit stacking. Lastly, the Multi-Actor scenario performs better than the Idealistic scenario (among others, it allows a positive NPV). In this regard, this scenario for 2025 can be more profitable than the solar park-only business case, but only for higher revenue streams for grid reinforcement deferral. Since the profits that can be made with this application are case-specific, a good analysis of the grid requirements and of the potential revenues for this service use are thus essential. As a general rule, this scenario becomes more financially attractive than the PV-only when the revenues for grid reinforcement are above approximately 23.500 €/year.

Overall, it should be remembered that this analysis assumes that grid reinforcement deferral and increased self-consumption, despite not providing revenues for the 2018 case, can lead to profit in the 2025 case. However, it is not certain if there will actually be a financial stimulus for increasing the self-consumption, or that legislative changes will take place leading to the DSO being able to rent grid services from a commercial party or a community. If this does not happen, the financial feasibility of the Idealistic and the Multi-Actor scenario is hindered, causing both scenarios to perform worse than what has been presented in this chapter.

Considering how the different scenarios have been constructed (namely they differ only in terms of type of application that is addressed and the % of time that the battery is used for that, while the rest of the inputs and parameters are kept the same), it can be stated that the business case results per application can be interpreted as a sort of sensitivity analysis with a single-variable test. In other words, the % of the time that battery is used for one application is set to 100, which is repeated for every service use. In this way, it is possible to check what is the main reason for a certain scenario to perform better than the other (note: the focus here is on the relative financial feasibility between the scenarios, not the actual values obtained for the NPV, which are influenced by the numerical inputs and assumptions). In general, the parameter that influences the most the financial feasibility of a scenario is primary reserve capacity. Since it is the most profitable application for the battery storage (both in 2018 as well as in 2025, despite the decrease in revenues), the more this service is tackled, the better a scenario performs in monetary terms. However, the revenue streams associated with it have the overall largest impact on the NPV: as can be seen in Figure 6.3, despite the lower costs for batteries and the increase in % of time that primary reserve capacity is addressed, the Money Maker scenario performs worse in 2025 than in 2018 due to lower revenues gained by tackling this application.

In conclusion, from a profitability point of view, it is possible to rank the three business model scenarios by considering the NPV results presented in this chapter: starting from the Money Maker scenario, the solar park-only and Multi-Actor scenario to the Idealistic scenario. However, this does not mean that it is possible to determine an overall best scenario that should be implemented for every Solar-Plus-Storage project. Each one provides also additional benefits (as well as challenges), which vary per scenario; therefore, the choice depends mostly on the specific interest and requirements of the owner of the installation who is responsible for the project.

7 BARRIERS AND OPPORTUNITIES

Besides assessing the values and benefits of battery storage (in particular in combination with a community-shared solar park), it is also relevant to study the barriers that can influence the development of a Solar-Plus-Storage project. This report focuses primarily with the barriers concerning battery systems, since the aim is to assess the factors that hinder the addition of a battery system to a solar PV installation. In this regard, the theory of Strategic Niche Management is applied, which provides information about the aspects that influence the spread of a sustainable technology into the market, ranging from technological, cultural and regulative factors to market barriers and other externalities. Identifying and addressing these barriers is an essential step for boosting energy storage adoption and thus for a successful development of this technology. Lastly, as stated by DNV GL (2018), it is important to acknowledge the fact that the removal of barriers is essential for business models to work not only in theory but also in practice and to have a stable and sustained duration.

Therefore, this chapter firstly presents the different barriers obtained by combining the results from the literature study with the results from the interviews with relevant stakeholders and professionals as well as the outcomes form the workshop. In addition to that, some possible solution on how to overcome these barriers are discussed.

7.1 TECHNOLOGICAL FACTORS

The most important technological barrier for a broader diffusion of battery storage concerns the safety of the asset, in particular in case of Lithium-ion battery systems. In the last years, Li-ion batteries were featured in the news because of different episodes of fire: from battery storage systems (such as in Flagstaff, Arizona in 2012 or in Drogenbos near Brussels in 2017), to electric vehicles and even in mobile phones (Samsung's Galaxy Note 7 smartphone was even withdrawn from the market because its batteries kept burning up) (Deign, 2017).

Typically, a Li-ion battery is constructed by a lithium-metal oxide cathode and a carbon anode, with a non-conductive foil designed to prevent a short circuit that separates the two; the electrical charge is transferred from the cathode to the anode through a conductive electrolyte solution. The contents of the battery are under pressure, thus if there is a small puncture (either in the partition that keeps the components separate or in the battery itself), short circuits can arise and cracks in the battery allow air to get in, where lithium can catch fire in contact with humid air (Schmidt, 2016). Another problem can be that the battery is charged or discharged too quickly, it can overheat. All this can lead to a chemical reaction between the cathode and anode in the electrolyte, which causes combustible gases to escape from the battery, such as methane, ethane and hydrogen (Helmenstine, 2018). Because of the intrinsic nature of the fire from battery systems, it cannot be extinguished with water, since this could potentially lead to a hydrogen gas explosion (Schmidt, 2016). For this reason, it is essential for firefighters and operators of battery storage systems to be trained on the best procedure how to deal in these circumstances.

Despite all this, the actual chance that a fire occurs in reality is quite small, and battery storage manufacturers and suppliers have started to equip the assets (especially large-scale ones) with a variety of prevention features, such as for example fire detection and extinguishing systems within the battery storage container. However, according to DNV GL (2018), there is still a lack of standards regarding safety and quality control in terms of larger-scale battery systems connected to the electricity grid (although organizations such as IEEE and IEC are working on that). For this reason, some recommended practices in the field of safety and operation are proposed by DNV GL (2018), including for example risk mapping, proper connection to the electricity network, important parameters to monitor and relevant control systems for an effective operation of the battery storage.

A solution to this barrier, apart from technological developments to reduce fire risks, involves a thorough guidance and information on how to deal with battery storage in case of fire (in particular for battery storage manufacturers, operator and firefighters). In addition, a common framework for safety and quality standards should be developed for both national and international applications.

7.2 REGULATIVE FACTORS

According to EUROBAT (2016), the biggest barrier to energy storage in the current legislative landscape is the lack of definition of what energy storage actually is. As a matter of fact, battery storage system (but also other types of energy storage in general) are seen as both generation as well as consumption assets. This in turn results in a series of barriers, for example in terms of network tariffs (which will be discussed later under the Market factors) and ownership possibilities. In fact, as stated by ACORE (2016), "*how a storage resource is classified affects how it is compensated and valued*". Due to the fact that it falls (also) in the category of generation components, battery storage is bound to network codes of other generation systems. Most importantly, this influences the ownership possibilities of these assets, since according to the unbundling principle, network operators (DSOs and TSOs) cannot own or control generation units. In addition, they are not allowed to rent services from a commercial party that operates a battery storage, which could limit benefit stacking opportunities in some projects and prevent an optimal application of the storage asset.

Therefore, in order to solve this problem, firstly a clear definition of battery storage is required. In this regard, several studies propose to consider storage as a separate entity, besides (and not part of) generation, transmission, distribution and consumption components (ACORE, 2016; DNV GL, 2018; EUROBAT, 2016). Due to its hybrid nature, battery storage does not fit entirely into one of these specific categories; thus, a new definition is required, considering the intrinsic characteristics, properties and services of this technology. EUROBAT (2016) also suggests including the new definition in the EU Electricity Directive, to avoid complications in legislations between different EU countries. Regarding instead the question of ownership, different researches point to the fact that TSOs and DSOs should be allowed to control battery storage to balance the grid and for grid reinforcement deferral. Overall, a "build-or-buy" choice should be made available, "*allowing operators to choose the most efficient solution depending on the specific situation*" (EUROBAT, 2016). This is currently done in some EU countries (EDSO, 2016): in Italy, network operators can operate batteries (if the investment is justified with a cost/benefit calculation and it is shown that battery storage is the most efficient solution), while in Belgium the network operator Elia can use batteries for grid balancing, provided that certain conditions are met (among others, commercial purposes are not tackled with the same asset and the stored electricity is the last resource to be called upon).

Another barrier is that the structure of current subsidy schemes for renewable energy generation in the Netherlands does not seem to stimulate battery energy storage systems. Taking as an example large-scale solar parks, the owner of the installation receives the same contribution per kWh, regardless on when the electricity is injected into the grid. The lack of fiscal incentive for time-shift of electricity can hinder some service uses for the battery storage, in particular in case of increased self-consumption of produced electricity. Instead, asset owners may prefer to choose to tackle other applications with a (higher) financial return. It should be noted that this barrier is even more important in case of solar and battery home systems, since in this case net metering is applied in the Netherlands (a billing mechanism that credits owners of PV panels for the electricity surplus added into the grid). Since the same tariff is applied when taking the electricity from the grid (to be used) and delivering it into the grid (from the PV panels, when it is not needed at the household level), there are no incentives in storing the surplus electricity in a battery system (while on the other hand a battery storage represents a substantial investment). However, this might change in 2020, and a new support mechanism will be developed, with a cap on how much surplus power can be injected into the grid (Bellini, 2018). According to Bellini (2018), the postcoderoos scheme might be subject to a similar change in the future.

7.3 MARKET FACTORS

A first economic-related barrier concerning battery storage is the current price of these systems. Although recent years have seen an exponential price reduction of this technology (from approximately 1.000$/kWh in 2010 to 300$/kWh in 2016 (BNEF (Bloomberg New Energy Finance), 2017; IRENA, 2015)), the upfront investments needed are still high. As a matter of fact, the values for the battery prices above correspond to the battery cell prices; however, if the entire system is considered (including inverters, air conditioning, storage containers and control systems), the price range in 2016 was around 750-1500 $/kWh (Greentech Media, 2015; Solar Choice, 2017). The main reason for these high costs is the relative novelty of the technology itself; therefore, optimizations in the production processes and exploitation of economies of scale are still required (Roland Berger, 2017). However, several studies predict that battery pack prices will follow a similar learning curve as solar PV, possibly reaching 100$/kWh by 2025 (BNEF (Bloomberg New Energy Finance), 2015; Cole, Marcy, Krishnan, & Margolis, 2016).

Another barrier related to battery systems is linked to the remuneration: more precisely, the market is not fully developed for all the benefits (i.e. applications that the battery storage can provide, as previously seen in this report), resulting in a lower revenue base. In addition, there are also barriers for currently market-accessible services; for example, the primary reserve capacity market operates with a tendering process consisting of 1MW blocks (therefore, a battery storage below this threshold cannot be used for this application or has to be aggregated together with other assets). This problem, in combination with the high costs of energy storage, increases the uncertainties of establishing a positive business case for a specific project (which however depends on different aspects such as the battery storage size, service uses and location within the grid).

Concerning the reserve capacity market, another barrier that was found in this analysis is the structure tendering process itself, in particular since this market operates on a weekly basis. This partially limits the possibility of benefit stacking, because the battery is reserved for a whole 7-days-period. However, it should be remembered that this will probably change to 4-hours bidding blocks in the near future (Scholt Energy Service, 2017), thus potentially increasing benefit stacking possibilities.

Lastly, as a consequence of the unclear definition of storage (described before among the Regulative barriers), the owners of battery storage systems have to pay double taxes when the technology is used both to charge and discharge electricity into the grid (since grid fees are imposed on both generation and consumption). This means that the same energy is charged twice, once when it is stored and once when it is delivered back into the grid (EDSO, 2016).

7.4 SOCIAL AND CULTURAL FACTORS

One of the most important social barriers regarding battery storage is connected to the technological factor described above (i.e. fire safety concerns). In particular, risks of fires and explosions pose a significant acceptability issue, since they contribute to a bad image of battery storage systems within the society and spread an overall negative public opinion about this technology. Building on that, the concerns around the safety of battery storage may hinder the spread of home battery systems. Therefore, if there is a choice to be made between smaller home batteries, installed in every household, or a larger-scale community or utility storage, the preference can fall on the latter, where experienced people are appointed to manage the battery and take responsibility over its proper and safe operation. It should be noted that this latter remark has to be interpreted merely as a barrier for home systems, not for the technology in general terms.

Furthermore, there is also a concern among citizens about the throughout environmental sustainability of a certain technology (in other words, if it is really greener compared to its alternative solution) (Soltronergy, 2017). This holds also in case of battery storage, in particular regarding its ecological footprint (since some technologies can include rare materials, such as lithium) and potentially harmful substances (in case of hazardous or toxic materials present) (INSIGHT_E, 2015). Firstly, as previously discussed, batteries can give off gasses when they are damaged, some of which can be hazardous or even toxic for the environment and for humans. Secondly, some of the core ingredients of battery storage systems (such as lithium or cobalt) are rare, and their extraction "*can lead to water pollution and depletion among other environmental consequences*" (Gardiner, 2017). Finally, there are also critical debates around the question of waste, i.e. what to do with the batteries after their lifetime. In this regard, both recycling as well as reusing the battery system are two viable options, although with recycling it is not possible to fully recover all of the materials (most importantly, lithium ends up in the mixed by-product, where it could be potentially reclaimed, but these extra processes increase the recycling costs (Gardiner, 2017)).

Moreover, another factor influencing large-scale battery storage, in particular when this system is located within a community (for example in proximity of a village and not in a more isolated area), is linked to the noise from the battery cabins and containers (which comes from the cooling system that prevents the overheating of batteries) (Soltronergy, 2017).

Overall, to mitigate social barriers it is crucial to manage public opinion by sharing information about this technology, with a particular focus on risk mitigation approaches, safety measures and waste disposal procedures. In addition, when applicable, a second life for battery storage is preferred to recycling: for example, batteries that are no longer good for electric vehicles (due to a lower capacity resulting from degradation) can be used as assets connected to the electricity grid.

7.5 OTHER FACTORS

Besides technological factors and social acceptance as well as economic and regulative issues, there are other externalities that should be considered when assessing the barriers of battery storage, especially concerning its adoption in combination with solar PV systems.

First of all, it should be remembered that although battery storage can provide a variety of different services, it is not the only technology for that. In fact, it competes with other solutions that are currently used for these applications; for example, gas-powered power plants are used for the provision of primary reserve capacities, and new cables and lines are installed in case of congestion in the electricity grid (instead of using a battery system for grid reinforcement deferral). The study conducted by Roland Berger (2017) indicates that existing solutions (such as new interconnections, grid upgrades, the capacity market for gas-fired power plants etc.) cause a lock-in for some battery storage services: several actors involved in the energy value chain, from system operators to policy makers and regulators, still focus most attention to these solutions rather than on battery storage. Therefore, battery energy systems have not received yet enough consideration and have not been thoroughly included in their agenda (EUROBAT, 2016).

In addition, as has been also pointed out in this research, benefit stacking (i.e. the provision of multiple services with the same battery storage system) can introduce complexity. Although it is desirable to use the battery storage for more than one purpose, especially to increase the financial profitability of a project when the less lucrative applications are tackled and to avoid keeping the battery in idle mode, benefit stacking means that additional players might be needed. This in turn increases the difficulties to find a trade-off between the wishes of a variety of different actors, as well as the overall complexity of the business model from an organizational and operational perspective (for example due to new interactions among the key stakeholders) (Pöyry Management Consulting, 2014). To solve this, good stipulate contracts can be required between stakeholders for the success of a project.

An important final remark about the different barriers presented in this chapter concerns the linkages between them. In other words, the factors discussed above should not be intended as separate entities, but rather a set of interrelated problems that reinforce each other. For example, the risk of fires (examined under the technological factors) influences public opinion regarding safety and sustainability of this technology (thus influencing social and cultural factors); the unclear definition of storage instead influences not only the ownership possibilities of these systems, but also the problem of double taxation (in case of both charging and discharging of electricity from and into the grid). However, this also means that solving one barrier can help overcoming or mitigating other problems as well.

8 DISCUSSION

After the results from the business models, business cases calculation and the analysis of barriers and opportunities for a community-owned Solar-Plus-Storage project, some of the aspects presented in this research are discussed in this chapter. First, a digression is made on the potential mechanisms that could stimulate the application of battery storage for increased self-consumption of the produced electricity (for example from a solar park). Afterwards, a general reflection on the results obtained in this study are presented, followed by a discussion on the methods used throughout this research.

8.1 MECHANISMS TO STIMULATE INCREASED SELF-CONSUMPTION

As has been previously discussed, in particular in the previous Chapter concerning the business case calculations, there are no fiscal incentives that stimulate the usage of a large battery storage, co-located with a solar park, for increasing the self-consumption of a community. Nevertheless, there is a growing interest in this application, especially from end-users and energy cooperatives who want to boost local production and consumption of green electricity. In the techno-financial analysis from the previous chapter, a revenue of 0,03 €/kWh is proposed for every kWh of electricity that is shifted from low consumption periods (which in case of households is typically midday, when the production from the PV panels is at its maximum) to evenings (when there is usually a peak consumption). But what can be a suitable mechanism for this? In other words, where can the 0,03 €/kWh come from? To answer this questions, two mechanism are proposed and discussed: flexible energy prices and flexible subsidy schemes.

The first option requires to sell the electricity on the spot market and not for example to an energy retailer through a Power Purchase Agreement (PPA) with constant prices (in other words, the prices for the electricity should be flexible and not constant). In addition, this option requires that the prices for electricity on the energy market are higher at evenings and lower during the day. In fact, this trend can be observed in the electricity spot market in some EU countries, such as Italy and Germany (Fraunhofer-ISE, n.d.; GME, n.d.), while it is not always observed at the moment on the Dutch day-ahead market (APX-Group, n.d.). Among the possible reasons for this difference is that the Netherlands has currently still a small share of renewables in its energy mix, in particular solar PV (renewables count for 6% of the total Dutch energy production (CBS, 2017), where solar PV represents only a small fraction) if compared with Germany (around 33% of renewables, with in total 6% solar (Appunn, Bieler, & Wettengel, 2018)) and Italy (39% renewables, with solar PV counting for 9% in the total energy mix (Statista, 2018)). Following this premise, it is not unreasonable to think that in the future (with more PV in the Dutch energy mix) it could be possible for an owner of a Solar-Plus-Storage installation (for example a local energy cooperative) to earn revenues by tackling increased self-consumption simply by storing the electricity into the battery and selling it via the electricity grid during evenings. As a matter of fact, it can be argued that in this way increased self-consumption is the same as energy arbitrage, since in both cases the battery is charged with electricity during low prices periods and discharged into the grid during high prices periods. In this regard, a revenue of 0,03 €/kWh is in line with the current spread of electricity prices on the Dutch day-ahead market, which according to several studies (CE Delft, 2017; DNV GL, 2015; Nolten, 2017) will not change in the future.

Another possibility for stimulating increased self-consumption in case of a large Solar-Plus-Storage installation is to shift from a fixed subsidy contribution to a flexible one, with higher contribution if the electricity is delivered into the grid during high consumption periods. In this regard, it could be possible either to consider standard consumption profiles for households in the Netherlands, or to monitor the individual patterns through smart meter measurements. The latter option allows a more specific match between the injection of stored electricity and actual needs of the local community and could be particularly favourable in case of the postcoderoos (thus linking the consumption and production of each end-user having a share in the solar PV installation). The low points are that it requires additional monitoring (which may encounter some barriers, in particular in terms of consumer opposition) and it increases the complexity of the regulation itself. Another generic problem of flexible subsidies is whether they can be regarded as a valuable long-term solution. Falling costs of solar PV in the last years have already induced a decrease in the SDE+ compensation values, and different studies suggest that by 2030 solar will become subsidy-free (Aurora Energy Research, n.d.; Solarplaza, 2017). Therefore, this option could be applied in practice mostly as a short-term solution for stimulating increased self-consumption within a community.

As a final remark, it is good to mention that in case of home Solar-Plus-Storage systems, the options are more straightforward. A first possibility is to follow the example of Germany and introduce Feed-in-Tariffs (FITs) below retail prices instead of net metering compensation mechanisms. In fact, according to Bellini (2018) the Dutch government is planning to switch from a net-metering scheme to Feed-in-Tariffs starting from 2020. Another solution can be to adopt flexible electricity tariffs for end-users and apply the net metering according to these changing tariffs. It should be noted however that this last option could be viable possibility in case of high prices during the evening and low prices during midday; however, as previously mentioned, this is not always the case in the current Dutch electricity market.

Further details related to this topic are not taken into account in this analysis and left instead for future studies, since they are considered out of scope for this research. However, they can be an interesting basis for additional insights on how to stimulate large-scale grid-connected battery storage, in particular in combination with a renewable energy generation plant.

8.2 GENERAL REFLECTION ON RESULTS AND THEORY

A first comment that should be drawn from the results presented in this analysis is that overall there tends to be a stronger focus on energy cooperatives than on communities in general. A clear example of this are the Value Flow Models of the different business model scenarios, where the energy cooperative (being the owner, and in one case also the operator of the Solar-Plus-Storage installation) is the core actor, with the majority of interactions with other stakeholders, exchanging both tangible as well as intangible values. Although it can be argued that a local energy cooperative should represent its community in terms of goals, wishes and concerns (and this research was built upon the assumption that this holds), it can happen that it is not always so. In particular, it can sometimes occur that a cooperative (despite still being an entity where members are volunteers rather than paid professionals) operates more like a commercial company than a group of citizens, unified under a common goal. The members and representatives of the energy cooperative may lose contact with the whole community, prioritizing instead only the requirements of members and shareholders (for example those investing in the solar park established by the cooperative itself). On the other hand, less focus is put towards the concerns and wishes of the other members of the community, who don't have a share in the project. Therefore, it can be concluded that when a community project is established through a local energy cooperative, it is important to assess if the entire community is actually included in the picture. In other words, does the term "community" represent merely members of the energy cooperative and shareholders, or the whole village, municipality or area?

A second remark concerns the business model scenarios developed and presented in this research. As seen in the various Value Flow Models, green (representing the flow of goods and services) and red lines (representing the flow of money) between the actors involved in a project are dominant, with respect to the other two types of interactions. In particular, the focus on flows of tangible values was predominant during the business modelling workshop, whereas intangible values were mostly neglected. This suggests that conventional business model thinking is still prevailing. In other words, it is difficult to go beyond the pure monetization of values and benefits; in fact, as stated by Jonker, Riordan, & Marsh (2015), although the meaning of "profit" is changing in some lines of business, "*the organisation of transaction value(s) other than money is not yet fully exploited*".

From this, a general reflection for the theory of New Business Models (NBMs) can be drawn. On one hand, they represent a theoretically solid and promising concept which can shape our perception not only of business but also society as a whole. However, on the other hand they are currently more difficult to put into practice. One reason for this comes from the fact that they are a relatively new topic, thus less known among both professionals and as well as researchers. Since conventional business models are instead already established and well-known, a wider spread of NBMs theory is required, which will then lead to a transition in people's mindset (for example, from looking at a project merely in terms of costs and revenues, but also on what other type of values are gained). Also from an academic perspective, there is still a stronger focus on conventional business models and their visualization tools, in particular the Business Model Canvas. The Value Flow Model, which fits well with the theory of NBMs, is instead less familiar, especially among professionals (as will be later discussed); moreover, the Clover Business Model Canvas developed by Jonker specifically for NBMs is also uncommon both in business practice as well as in academic literature. As an example, it is very difficult to find any real-life example where the Clover Canvas was used for a specific project; this is also the main reason why the Clover Canvas was not considered in this analysis. Another problem with NBMs can be found in the organizational complexity that comes with creating value in a collaborate way and sharing it among different actors. As has been already observed in this research, in specific in Chapter 5 regarding business model scenarios for community Solar-Plus-Storage projects, increasing the number of key stakeholders that deliver and/or capture values also increases the complexity of the scenario itself. A trade-off between the single interests of each actor and the throughout value proposition of a project built around multiple and shared values has not only to be established but also maintained, for a successful and sustained duration of the project.

However, at the moment there is still less focus on collaborative efforts and shared value creation; furthermore, in many cases money is still the most (if not the only) targeted value. Although firms and organizations are starting to become more aware and interested also in other types of value, most of the times this has to come with an explicit financial gain. In this regard, this conclusion can be also seen by the business case calculations, where all the battery storage's applications have been assessed in monetary terms (even for the service uses that do not provide any financial compensation at the moment, for example increased self-consumption). The main problem can be therefore found in the fact that it is difficult to determine the value of non-monetary benefits, particularly when a financial feasibility has to be assessed through a cost-benefit analysis. Thus, the most straightforward solution is to try to translate them all into revenues (in monetary form), although this diverges with the whole idea of New Business Models, as proposed by Jonker (2014), where economic value should not be the only central focus. However, it should be mentioned that Jonker himself, despite providing some instruments that can be integrated in a cost-benefit analysis to make non-monetary values more implicit, does not propose a definitive method to solve this problem. Nevertheless, it can be argued that finding a proper method for this might help NBMs to gain momentum and potentially replace conventional business modelling theory and mindset.

In the end, it can be said that although the results of the techno-financial analysis presented in this study provide a ranking (of the various applications of battery storage as well as of the business model scenarios selected in this research) in terms of financial feasibility, no definite conclusion can be drawn on what is the overall best scenario for a community Solar-Plus-Storage project. On one hand, it is true that revenues are important; as pointed out by Jonker, Riordan, & Marsh (2015), a sustainable financial performance is a key factor for a long term sustainability of New Business Models. All organization or ventures need to ensure an appropriate financial sustainability if they want to continue to exist and to operate, thus profit still remains a crucial component in a business model. However, also other types of value can play a significant role, especially in case of a community project (for example, end-users may not be interested in the maximization of profit as the ultimate goal but prefer a lower revenue base as long as the solution stimulates energy autonomy and provides additional environmental and social benefits).

8.3 FURTHER REFLECTIONS ON METHODOLOGY

A first comment that should be made regarding the methodology used in this research concerns the interviews held with professionals and other relevant stakeholders to assess both the values and barriers of adding a large-scale battery storage to a solar PV installation. In particular, the needs and issues of the end-users living in the community were mainly obtained through communications with the representative from the local energy cooperative. However, as previously discussed, it can be questionable whether the cooperative truly represents the wishes of the whole community, or rather only those of its shareholders. Thus, additional interviews with citizens from the local community (in case of the COOP-Store, the people living in the municipality of Weert and in particular in the village of Altweerterheide) could have been helpful to gain a deeper knowledge on what benefits and applications of battery storage they value the most. A viable and more pragmatic alternative would have been to set up a survey through an online platform; in this way, a broader sample of the population could have been reached, which would allow a better generalization of the outcomes. In the end, this approach would allow a better integration of end-users' preferences into the business model scenarios, as well as of their concerns in the analysis of barriers and opposing factors.

Secondly, the selection of the Value Flow Model as a tool to design and visualize the business model scenarios was an appropriate choice, given its emphasis on the business ecosystem (thus allowing to map all the important actors required for the delivery of the core value proposition) and its dynamic approach regarding flows of tangible and intangible values. In addition, it represents a useful way to check the distribution of benefits among the stakeholders and the specific type of interactions (using different colours for goods & services, money & credit, knowledge and intangible values). However, the major problem of this method which has been encountered during the business modelling workshop is linked to its familiarity. In other words, although participants already had a background on the business model theory, they were not familiar with Value Flow Models. Therefore, additional time was needed to present this tool before the hands-on session could start. Furthermore, in some cases the little experience resulted in difficulties and confusion, for example concerning the exact location of actors within the Value Flow Model (i.e. whether a certain actor should be put in the central circle, or among the complementary offerings or in the supplying network).

Finally, a general reflection can be drawn on the business modelling session. The first interactive part (where participants were required to fill a mind map for different battery storage applications) can be considered successful, since all relevant questions were addressed in detail, providing a solid base for the different analyses carried out during this research (business model scenarios, business case calculations and the analysis of barriers and opportunities). The second part of the workshop consisted in mapping the business model scenarios in terms of actors and interactions among them by using the Value Flow Model. Here, time constraints and lack of experience with this method led to the circumstance that the Value Flow Models were only partially filled. In particular, some participants decided to fill only the most important actors (i.e. central to the core value proposition) and the flows of values between them, while others focused more on allocating the actors in each particular circle within the Model, while putting less emphasis on the relationships among these stakeholders. To solve this problem, either more time should have been allocated to the second interactive part or the session itself should have been repeated in another occasion, thus providing an iterative process to the design of the business model scenarios (for example, focusing firstly on where to distribute the actors within the different layers of the Value Flow Model and then, during the second session, the flows of tangible and intangible values could have been mapped). Lastly, also in the case of the workshop, the direct involvement of end-users (i.e. members of the community who are not representing other stakeholders such as the energy cooperative) could have provided additional insights into their needs and wishes, in order to integrate those in the business model scenarios and in the identification of barriers and opportunities of community Solar-Plus-Storage projects.

9 CONCLUSIONS

This report presented the research done on the conjunction of a cooperative district battery storage with a local solar park, in particular when multiple values are created and captured by the battery system. The feasibility of these larger-scale, grid-tied Solar-Plus-Storage installation was studied from different perspectives, from a stakeholder analysis and business modelling theory to business case calculations (through techno-financial analyses) and scientific theories that aimed to identify the barriers and opposing factors to the diffusion of this technological development.

Together, all these analyses contributed to answering the main research question and the sub-question given in Chapter 1; the outcomes are presented below in Sections 9.1 and 9.2. In addition, this chapter includes also describes some future research possibilities, following the limitations in this study.

9.1 RESEARCH SUB-QUESTIONS

Who are the most important actors in a community-driven large-scale Solar-Plus-Storage project?

Typically, a broad range of actors is needed for a community Solar-Plus-Storage project. In this regard, the theoretical perspective of business ecosystems comes in handy: a firm or organization cannot act alone. On the contrary, different interrelated and interdependent stakeholders cooperate together to deliver a product or service, each contributing to the project with its own resources and competences.

Following a stakeholder analysis, where the COOP-Store is taken as the reference case study, several actors were identified. Firstly, the energy cooperative, whose members are part of the local community, plays a central role, together with the end-users (i.e. energy consumers) and energy service company (who, depending on the organizational settings, may be responsible for the management of the asset). Next, governmental bodies, both local as well as regional, are involved in the project by giving permits and fiscal incentives (subsidies). After that, network operators (DSO and TSO) provide the connection of the system to the electricity grid and additional grid services. Moreover, the energy supplier is responsible for selling the electricity from the solar park to the end-users, while EPC companies arrange the engineering and construction of the Solar-Plus-Storage installation, interacting directly with the providers of upstream components. Usually, when a larger-scale system is built, an external investor (such as a bank) is also needed to provide financing for the project. Furthermore, the umbrella organization of cooperatives supports the local energy cooperative, providing experience and sharing know-how. Lastly, research institutes can also play a role in the project by contributing with knowledge dissemination and provision of inputs on best practices.

What values do these actors see in the addition of a storage system to a solar park?

Due to the intrinsic nature of the technology, battery storage is quite versatile in terms of the range of applications it can be used for, providing services for end-users, grid operators or electricity generation companies. The typical applications where this technology is currently used to provide value are increased self-consumption and self-sufficiency, peak shaving (of demand and supply), backup power, reserve capacity, energy arbitrage and grid reinforcement deferral. In order to study the core values that the actors involved in a community Solar-Plus-Storage project see in the addition of a battery system to a solar PV installation, the key stakeholders identified from the COOP-Store project were considered.

The values differ per stakeholder: end-users are mostly interested in the idea of increased energy independence and of a better return of equity. Similarly, the energy cooperative sees the battery storage firstly as an opportunity to have a better return on the investment, and in broader terms also as a way to achieve its long-term goal of an energy neutral village. Energy service companies focus on the market services that the battery can provide, in order to maximize profit, whereas the DSO values a quicker and cheaper service delivery as well as congestion management opportunities.

What organizational settings are possible within a community-owned large-scale Solar-Plus-Storage project that exploit several advantages of battery storage?

In this research, three business model scenarios were developed and studied: these are the Idealistic scenario, the Money Maker scenario and the Multi-Actor scenario. They vary in terms of services that the battery storage is used for, which follow from the results of the main values that the central actors see in the co-location of a battery system with a solar park. This in turn requires a different organizational setting between the actors, in particular regarding the operation of the Solar-Plus-Storage installation. It should be noted that throughout the analysis, the ownership of the Solar-Plus-Storage installation is kept the same for all three scenarios, due to the focus of this research: in this regard, the community, through the cooperative, is the legal owner of the asset.

The Idealistic scenario emphases increasing the energy independence of a community, thus providing increased self-consumption and backup power; in this case, the ownership as well as the management of the asset are kept within the community through the energy cooperative. For one thing, this scenario allows a simpler organizational setting for the energy cooperative (and its members); nevertheless, it may be hindered by the limited knowledge and experience of the cooperative in the operation of the battery storage.

The Money Maker scenario focuses on market services and those applications that allow profit maximization and a better return on equity (energy arbitrage and reserve capacity). Despite higher revenue streams, this scenario also solves the problem of limited experience for the management of the battery storage, by transferring this task from the cooperative to a third party (such as an energy service provider). However, this creates new bottlenecks in terms of organizational settings, since the goals of both owner and operator of the asset should be balanced.

Lastly, the Multi-Actor scenario presents a combination of the other two scenarios, while adding also grid reinforcement deferral among the applications tackled by the battery storage. Overall, also in this case the cooperative is the owner of the Solar-Plus-Storage installation, while a commercial party is responsible for its operation. Because of the variety of services targeted, a mayor barrier in this scenario comes from its complexity in terms of actors and interactions. Firstly, a trade-off between the goals of each key stakeholder has to be determined, therefore good stipulated contracts might be required for a sustained and solid collaboration. Secondly, regulative changes are needed to fully exploit the potential of this scenario, given the fact that at the moment the DSO is not allow to rent services from a third party.

In addition to all this, all three scenarios also target peak shaving of the produced electricity from the solar park. Although this is primarily done to allow a lower connection (and thus lower connection fees to the grid operator), it also results in the mitigation of congestion problems in the local electricity grid which can arise due to the installation of the solar park.

In the end, it should be noted that these business model scenarios reflect the theoretical framework of business modelling from two different perspectives. On one hand, the Money Maker scenario puts more emphasis on monetary values, thus it is more in line with conventional business models. On the other, the Idealistic and Multi-Actor scenario reflect the theory of New Business Models, which emphasize also social and environmental benefits besides purely monetary ones, and call for collective and shared value creation.

What is the value capturing strategy of the actors involved, and how do they interact with each other?

The interactions among the various actors involved in a community Solar-Plus-Storage project have been presented with the Value Flow Model, a visualization tool for business models in case of complex value networks. For each business model scenario, a Value Flow Model has been constructed, depicting not only the stakeholders and their relevance for the core value proposition (starting from the inner circle with the key actors, to the complementary offerings and enabling network), but also the flow of tangible and intangible values among them. In this way, it is also possible to determine how each actor delivers and captures value. The complete Value Flow Model for each business model scenario is shown in Figures 5.3, Figure 5.5 and Figure 5.6, in Chapter 5.

Although both the actors as well as interactions between them can change depending on the scenario, some features are constant in all of them. Most importantly, the energy cooperative acts as the central actor, being the owner of the asset and responsible for financing the project (which can partially come from the contributions of those end-users who are members in the cooperative, but also from an external investor or financial institution). Furthermore, in the Idealistic scenario the cooperative is also the operator of the asset, thus in charge of selling the electricity on the energy market and providing services to the end-users by operating the battery storage. Instead, in the other two scenarios, a third party takes this role; this partially changes the flows of tangible and intangible values, in particular regarding the selling of electricity or other services (such as reserve capacity) and the associated revenue streams.

In general, the interactions can be in form of goods and services (such as provision of electricity, grid services and connections, reserve capacity, permits and hardware components), money and credit (for example subsidies, payments and fees), information (knowledge dissemination and experience) and intangible values (support, politics or increased energy autonomy).

Overall, it should be remembered that two subsidy schemes are possible in the Netherlands for large renewable energy projects. The Value Flow Models presented in Chapter 5 for each business model scenario consider the SDE+ subsidy. However, the postcoderoos is also possible, where the members of the community, unified in a cooperative, invest in the solar park, for which they receive a fiscal incentive from the government in the form of tax reductions. The interaction patterns slightly change if the postcoderoos is applied instead of the SDE+, as has been shown in Figure 5.4 in case of the Idealistic scenario; the changes can be then applied also to the other two scenarios accordingly.

What representative scenarios can be constructed to assess the techno-economic feasibility of the combination of Solar-Plus-Storage?

The financial feasibility of the addition of a battery storage to a solar PV installation has been evaluated by means of business case calculations. In this regard, different applications for the battery storage have been taken into account. Firstly, a techno-financial analysis has been conducted in case that the battery system provides only one application (increased self-consumption, peak shaving, backup power, energy arbitrage, primary reserve capacity or grid reinforcement deferral). In other words, each application for the battery storage is considered separately, regardless if the system actually operates continuously or only for a small fraction of time, the rest being in idle mode.

Secondly, the techno-financial analysis has been performed in case of benefit stacking, thus when the battery provides more than one benefit. In this case, three separate scenarios have been considered, which follow from the business model scenarios. The percentage of time that the battery storage is used for a specific application in each scenario follow from a combination of simulations, literature review and communication with professionals.

Overall, two separate calculations have been presented: one for the present year (2018) and one for the near future (2025); in this way, the impact of future developments of both costs as well as revenues (for example also due to regulatory changes) has been assessed. In addition, the results of these two analyses have been compared with the outcomes in the case of a solar park-only situation, in order to understand whether the addition of a battery storage to a solar PV installation make sense in purely financial terms.

What are the costs and the benefits in the different scenarios, now and in the near future?

The techno-financial analysis resulted in a complete overview of the costs associated with the solar park and the battery storage, as well as the revenues that can be obtained by selling the produced electricity, the guarantees of origin and by the additional services that the battery storage is designed to provide. In this regard, all the applications that can be tackled with the battery system has been translated into monetary terms. For those applications that do not have a financial compensation at the moment (for example increased self-consumption and grid reinforcement deferral), no revenues were assigned for the 2018 business case, but only for the 2025 case (assuming for example changes in legislation).

Overall, it can be concluded that the statement that the addition of a battery storage can only be positive if benefit stacking is addressed is not true, providing however that the battery system is used for primary reserve capacity. Otherwise, the Solar-Plus-Storage solution performs worse than the solar-only, meaning that the revenues are too small to compensate for the yearly expenditures and the initial investments. Therefore, if the battery storage is used for other applications, benefit stacking is a necessary condition to make a positive business case. However, this is not a sufficient condition, as shown by the results from the business case calculations for the different scenarios. In particular, in case of the Idealistic scenario, where primary reserve capacity is not among the tackled applications of the battery storage, the business case is still not profitable despite the benefit stacking. Thus, it can be concluded that primary reserve capacity (at least targeted for a certain amount of time throughout the year) is essential in order for a project to be financially feasible within 30 years. In addition, as seen from the results of the Multi-Actor scenario, grid reinforcement deferral can play a significant part in the profitability of a project, making this scenario more financially attractive than the solar park-only solution. However, this holds only is the situation that high revenue streams are associated with this service use.

As a last remark, it should be remembered the choice for the optimal scenario (and thus for the combination of applications that the battery should provide in a specific project, together with the percentage of time reserved for a particular application) depends on the main wishes and values of the asset owner.

What barriers and opportunities lie in the multiple value creation and capture for a community-owned district battery storage system, implemented in combination with a solar park?

The addition of a community battery storage to a solar park offers several opportunities. In particular, the different values and benefits that can be provided vary depending on the applications that are tackled. For example, the battery storage can be used to lower the connection capacity required, thus lowering both grid upgrades as well as grid costs; then, it can be used for energy arbitrage, by storing the electricity produced by the solar panels when the prices on the energy market are low and delivering it into the grid during high-price periods; additionally, it can be also used for increasing the self-consumption of a community or for the provision of primary reserve capacity to ensure the stability of the electricity grid in case of frequency deviations. Generally speaking, these different services can provide both monetary as well as not monetary values (such as increased energy autonomy or environmental benefits). Therefore, by using the battery storage for more than one application (i.e. benefit stacking), multiple values can be created and captured with the same project.

Nevertheless, there are also some barriers to the development of Solar-Plus-Storage projects. Identifying and subsequently eliminating these opposing factors is crucial for boosting the adoption of battery storage. The barriers found by applying the theory of Strategic Niche Management are summarized in Table 9.1.

Perspective	**Type of barrier**
Technological	Safety of material (in particular concerning the possibility of fires and explosions)
Regulatory and legislative	Unclear classification/definition of storage; ownership options for battery storage; current structure of subsidy schemes

Market and economic	Price of battery storage; market access; uncertainty of positive business case; double taxes
Social and cultural	Negative public opinion (concerning safety issues, ecological footprint of batteries, rare materials and harmful substances); resistance (noise disturbance)
Other factors	Lock-in of alternatives; complexity of business models for benefit stacking

Table 9.1: Summary of barriers and opposing factors concerning battery storage systems

9.2 MAIN RESEARCH QUESTION

How can multiple values be created and captured by combining a community-owned battery storage system with a solar park?

The concept of community solar is not new: for example, in the Netherlands there are currently more than 260 community solar projects installed, and their number is rising. However, little attention is put to the addition of battery storage to these solar PV installations, in particular in case of larger systems (with respect to home systems). Among others, a mayor barrier in this regard is linked to the high upfront investments required for these systems. Nevertheless, the growing number of large-scale Solar-Plus-Storage projects around the world is a clear indication that this combination is feasible, both from a financial as well as organizational perspective, and worth exploring.

As for the technology itself, the co-location of a district battery storage to a community solar park can provide a variety of different benefits, from services to the end-users and members of the community, market-related services or grid services. In this regard, a combination of different service uses can be also addressed, what is typically known as benefit stacking; in this way, multiple values can be created using the same battery storage system. The choice of which applications to tackle depends on the wishes of the community, who, through a local energy cooperative, is responsible for the project. The members are thus the ones who shape the value proposition and steer the operation of the battery system towards the benefits that their value the most. However, it is also possible to involve additional stakeholders in the project to enrich the core value proposition, such as energy service companies or grid operators. On one hand, this helps to increase the values created by the Solar-Plus-Storage system; on the other, it may add complexity from a practical and operational perspective, as actors might be required to compromise their own goals. Nevertheless, addressing multiple values in a collective and shared manner can be understood as way to make together the whole pie bigger, instead of thinking about how to get individually a larger portion of a smaller pie.

Concerning organizational settings, there are different ways how multiple values can be created and captured in case of a community Solar-Plus-Storage project. In this regard, this research focused on three separate business model scenarios. Overall, it can be concluded that in general the choice depends both on the applications that the battery is designed to provide as well as on the resources and experience of the key actors involved, in particular regarding the operation and management of the battery storage.

Although addressing multiple values means that profit is no longer the only important benefit, the financial performance of a project is still a crucial component in a business model for a sustainable operation. In this respect, the results of the techno-financial analysis suggest that certain battery storage applications (such as primary reserve capacity) are necessary to guarantee a positive business case, while some others (for example grid reinforcement deferral) might also play a significant role in the future.

Lastly, it is important to note that storage still faces various challenges, ranging from technical and regulative factors to social and market ones, in particular if multiple values are targeted. Recognising and addressing these barriers is essential to fully exploit the potential of community Solar-Plus-Storage systems and to help boosting these projects, making solar and storage simply go together.

9.3 FUTURE RESEARCH

In this research, a combination of different methodologies was used in order to obtain the percentage of time that the battery is needed to provide a specific service, ranging from simulations to literature review and interviews with professionals and relevant stakeholders. These results were then used for the business case calculations for the three business model scenarios. In this regard, a potential future research subject could be to consider more deeply the technical specifications of the battery storage, the local electricity grid and the solar park. In other words, extensive simulation modelling of the charging and discharging patterns of the battery system should be performed, taking into consideration the goal that wants to be achieved (i.e. the main value proposition), electricity prices (developments on the different markets, such as day-ahead market, imbalance market and reserve capacity market) and production profiles (from the solar PV panels). In addition, further information about the electricity grid may be necessary, especially if grid reinforcement deferral is included among the tackled services; in this way, it is possible to have a better understanding of the real revenue streams associated with this application.

Considering the business case calculations, this research focused on the SDE+ as the only subsidy. Nevertheless, the typical fiscal incentive for smaller cooperative projects is the postcoderoos. Therefore, it may also be wise to conduct a techno-financial analysis in this case, taking into account not only the cash inflows and outflows for the cooperative but also for each member participating in the project. In this way, the emphasis is not only on the Solar-Plus-Storage installation as a whole, but also on the gains that each participant gets by investing in the project.

Although this research does not elaborate on smaller home Solar-Plus-Storage systems, they can be another topic of future research. In particular, the advantages or disadvantages of larger installations against smaller ones should be considered not only in technical terms, but also from the economic and regulative points of view (for example concerning the applications that the battery storage can provide if it is located behind or in front of the meter, the associated revenue streams and value capturing mechanisms). In addition, the combination of larger neighbourhood installations and home systems can be also be studied, for example neighbourhood battery and distributed home PV systems or larger-scale solar park and small batteries located behind the meter, distributed among the end-users in a community.

Lastly, in this research all the different benefits provided by the addition of a community battery storage to a solar park were integrated into the business case calculations by translating them into monetary form. However, as previously stated in the report, this idea diverges with the concept of multiple value creation and New Business Models. Therefore, further studies can focus on determining a more suitable approach to integrate also non-monetary values in a cost-benefit analysis or to find a solution on how to make them more implicit in a business case.

10 REFERENCES

ACORE. (2016). *Beyond Renewable Integration - The Energy Storage Value Proposition*. Retrieved from http://www.ourenergypolicy.org/wp-content/uploads/2016/11/Beyond-Renewable-Integration-The-Energy-Storage-Value-Proposition-Final.pdf

Appunn, K., Bieler, F., & Wettengel, J. (2018). Germany's energy consumption and power mix in charts. Retrieved August 9, 2018, from https://www.cleanenergywire.org/factsheets/germanys-energy-consumption-and-power-mix-charts

APX-Group. (n.d.). EPEX SPOT prices Netherlands. Retrieved June 30, 2018, from https://www.apxgroup.com/market-results/apx-power-nl/dashboard/

Aurora Energy Research. (n.d.). Power market forecast. Retrieved August 9, 2018, from https://www.auroraer.com/expertise/renewables/

Bailey, J. (2018). Getting PV to 2ct a kWh: panel vs. balance of system costs. Retrieved May 10, 2018, from https://energynarrative.com/getting-pv-to-2-cents-per-kwh-panel-balance-of-system-costs/

Bellini, E. (2018). Netherlands to replace net metering with new scheme for residential, commercial PV. Retrieved August 7, 2018, from https://www.pv-magazine.com/2018/06/18/netherlands-to-replace-net-metering-with-new-scheme-for-residential-commercial-pv/

Biology Online. (n.d.). Ecosystem. Retrieved July 11, 2018, from https://www.biology-online.org/dictionary/Ecosystem

BNEF (Bloomberg New Energy Finance). (2015). *EV battery price outlook*.

BNEF (Bloomberg New Energy Finance). (2017). *New Energy Outlook 2017 - Executive summary*.

Bruning, F., & Rikze, H. (2016). *Beslisboom Zonneparken*.

Bull, S. R. (2001). Renewable Energy Today and Tomorrow. *Proceedings of the IEEE*, *89*(8), 1216–1226.

CBS. (2017). Share of renewable energy in 2016. Retrieved January 15, 2018, from https://www.cbs.nl/en-gb/news/2017/22/share-of-renewable-energy-at-5-9-in-2016

CE Delft. (2016). *Ontwikkeling prijzen garanties van oorsprong*.

CE Delft. (2017). *Energy and electricity price scenarios 2020-2023-2030*.

Chesbrough, H. (2007). Business model innovation: it's not just about technology anymore. *Strategy & Leadership*, *35*(6), 12–17.

Cole, W. J., Marcy, C., Krishnan, V. K., & Margolis, R. (2016). Utility-scale lithium-ion storage cost projections for use in capacity expansion models. *NAPS 2016 - 48th North American Power Symposium, Proceedings*. https://doi.org/10.1109/NAPS.2016.7747866

Cottier, T., & Espa, I. (2017). *International Trade in Sustainable Electricity: Regulatory Challenges in International Economic Law*. Cambridge University Press.

Deign, J. (2017). Engie Investigates Source of Belgian Battery Blaze. Retrieved August 1, 2018, from https://www.greentechmedia.com/articles/read/engie-investigates-source-of-belgian-battery-blaze#gs.dHL6nis

den Ouden, E. (2012). Designing Ecosystems. In *Innovation Design* (pp. 143–192). London: Springer.

den Ouden, E., & Brankaert, R. (2013). Designing New Ecosystems: The Value Flow Model. *Advanced Design Methods for Succesfull Innovation*, 189–209.

Denholm, P., Eichman, J., & Margolis, R. (2017). *NREL - Evaluating the Technical and Economic Performance of PV Plus Storage Power Plants*. Retrieved from https://www.nrel.gov/docs/fy17osti/68737.pdf

DNV GL. (2015). *Routekaart Energieopslag 2030*.

DNV GL. (2018). Haalbaarheid en schaalbaarheid van de buurtbatterij.

Droege, P. (2011). *Urban Energy Transition: From Fossil Fuels to Renewable Power*.

Dunbar, R. (2017). How efficient will solar PV be in the future. Retrieved May 4, 2018, from https://cleantechnica.com/2017/08/15/efficient-will-solar-pv-future-10-year-predictions-industry/

Dyllick, T. (2014). The opposing perspectives on creating shared value. Retrieved July 13, 2018, from https://www.ft.com/content/88013970-b34d-11e3-b09d-00144feabdc0

ECN, & DNV GL. (2017). *Final advice base rates SDE +*.

EDSO. (2016). *Integrating electricity storage in distribution grids*.

Emissions-EUETS. (2018). Imbalances (Electricity Balancing Market). Retrieved March 1, 2018, from https://www.emissions-euets.com/imbalances

EnergySage. (2018). What are the most efficient solar panels on the market? Retrieved June 20, 2018, from https://news.energysage.com/what-are-the-most-efficient-solar-panels-on-the-market/

Enexis. (2018). personal communication.

Enpuls. (2018). personal communication.

ESA. (n.d.). Grid Operations Benefits. Retrieved May 30, 2018, from http://energystorage.org/energy-storage/energy-storage-benefits/benefit-categories/grid-operations-benefits

EUROBAT. (2016). *Battery energy storage in the EU - barriers, opportunities, services and benefits*.

EurObserv'ER. (2017). Barometer. *Systemes Solaires. Le Journal Du Photovoltaique*, *46*(2), 61–80.

Fleer, J., Zurmühlen, S., Meyer, J., Badeda, J., Stenzel, P., Hake, J. F., & Uwe Sauer, D. (2017). Price development and bidding strategies for battery energy storage systems on the primary control reserve market. *Energy Procedia*, *135*, 143–157. https://doi.org/10.1016/j.egypro.2017.09.497

Fraunhofer-ISE. (n.d.). Electricity production and spot prices in Germany. Retrieved August 9, 2018, from https://www.energy-charts.de/price.htm

Fraunhofer-ISE. (2015). *Current and Future Cost of Photovoltaics*.

Frontier Economics. (2015). *Scenarios for the Dutch electricity supply system - Report for the Dutch Ministry of Economic Affairs*. Retrieved from https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/rapporten/2016/01/18/frontier-economics-2015-scenarios-for-the-dutch-electricity-supply-system/frontier-economics-2015-scenarios-for-the-dutch-electricity-supply-system.pdf

Gardiner, J. (2017). The rise of electric cars could leave us with a big battery waste problem. Retrieved August 2, 2018, from https://www.theguardian.com/sustainable-business/2017/aug/10/electric-cars-big-battery-waste-problem-lithium-recycling

GME. (n.d.). Esiti Mercato Elettrico - Italia. Retrieved August 9, 2018, from http://www.mercatoelettrico.org/It/default.aspx

Greentech Media. (2015). What's Included in the Price of Your Home Battery System? Retrieved January 16, 2018, from https://www.greentechmedia.com/articles/read/whats-included-in-the-price-of-your-home-battery-system#gs.yWMXEqs

Hans, E., & Schwencke, A. M. (2014). *Energy cooperatives: aims , operational perspective and interaction with municipalities - The energetic society in action*.

Helmenstine, A. M. (2018). Why Lithium Batteries Catch Fire. Retrieved August 1, 2018, from houghtco.com/why-lithium-batteries-catch-fire-606814

HIER Opgewekt. (n.d.). Energiecoöperaties krijgen positie in nieuw regeerakkoord. Retrieved January 30, 2018, from https://www.hieropgewekt.nl/nieuws/energiecooperaties-krijgen-positie-in-nieuw-regeerakkoord

HIER Opgewekt. (2017). *Lokale energie monitor 2017*.

HIER Opgewekt. (2018). Postcoderoosregeling: Hoe werkt de verrekening van de energiebelasting? Retrieved June 25, 2018, from https://www.hieropgewekt.nl/kennisdossiers/postcoderoosregeling-hoe-werkt-verrekening-van-energiebelasting

Hill, C. A., Such, M. C., Chen, D., Gonzalez, J., & Grady, W. M. K. (2012). Battery energy storage for enabling integration of distributed solar power generation. *IEEE Transactions on Smart Grid*, *3*(2), 850–857.

HilverZon. (n.d.). Energie-belasting voor elektriciteit omhoog voor 2018 – voordeel postcoderoos-projecten stijgt. Retrieved June 25, 2018, from https://www.hilverzon.nu/vooruitzichten-postcoderoos-2018/

Hoium, T. (2016). *What Business Model Will Succeed in Energy Storage?*

Idlbi, B., Von Appen, J., Kneiske, T., & Braun, M. (2016). Cost-Benefit Analysis of Battery Storage System for Voltage Compliance in Distribution Grids with High Distributed Generation. *Energy Procedia*, *99*(March), 215–228. https://doi.org/10.1016/j.egypro.2016.10.112

INSIGHT_E. (2015). *Business models for flexible production and storage - Policy report*.

IRENA. (2015). *Battery Storage for Renewables : Market Status and Technology Outlook*. *Irena*.

IRENA. (2016). *The power to change: solar and wind cost reduction potential to 2025*.

IRENA. (2017a). *Renewable capacity statistics 2017*. Abu Dhabi: International Renewable Energy Agency (IRENA).

IRENA. (2017b). *REthinking Energy*. *REthinking Energy 2017: Accelerating the global energy transformation* (Vol. 55).

Jonker, J. (2012). *New Business Models - An exploratory study of changing transactions creating multiple value(s)*. Working paper, Radboud University Nijmegen – The Netherlands. https://doi.org/10.1007/978-88-470-2838-8

Jonker, J. (2014). *New business models: Collaborating to create value*. The Hague: Academic Service.

Jonker, J., Riordan, L. O., & Marsh, N. (2015). The Art of Balancing: Enabling the Realisation of Multiple and Shared Values Through a New Generation of Business Models. In *New Perspectives on Corporate Social Responsibility* (pp. 229–246).

Kemp, R., Schot, J., & Hoogma, R. (1998). Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management. *Technology Analysis & Strategic Management*, *10*(2), 175–198.

Leach, G. (1992). The energy transition. *Energy Policy*, 116–123.

Liander. (2018). Grootverbruik. Retrieved April 17, 2018, from https://www.liander.nl/node/3011/?ref=5726

Lüdeke-Freund, F., Massa, L., Bocken, N., Brent, A., & Musango, J. (2016). *Business models for shared value*.

Luthander, R., Widén, J., Munkhammar, J., & Lingfors, D. (2016). Self-consumption enhancement and peak shaving of residential photovoltaics using storage and curtailment. *Energy*, *112*, 221–231.

Moore, J. F. (1993). Predators and Prey: A New Ecology of Competition. *Harvard Business Review*, (May-June issue).

Morris, M., Schindehutte, M., & Allen, J. (2005). The entrepreneur's business model: Toward a unified perspective. *Journal of Business Research*, *58*(6), 726–735. https://doi.org/10.1016/j.jbusres.2003.11.001

Netherlands Enterprise Agency. (2018). *SDE+ Spring 2018 - Instructions on how to apply for a subsidy for the production of renewable energy*. Retrieved from https://english.rvo.nl/sites/default/files/2018/02/Brochure-SDE-Spring-2018.pdf

Nobel, F. A. (2016). *On balancing market design*. PhD thesis, Technische Universiteit Eindhoven (TU/e).

Nolten, J. (2017). *Smart integration of battery storage*. Master thesis, Technische Universiteit Eindhoven (TU/e).

Nolten, J. (2018). Personal communication.

NREL. (n.d.). Photovoltaic Lifetime Project. Retrieved March 15, 2018, from https://www.nrel.gov/pv/lifetime.html

Osterwalder, A. (2004). *The business model ontology - A proposition in a design science approach*. Ecole des Hautes Etudes Commerciales de l'Université de Lausanne.

Osterwalder, A., & Pigneur, Y. (2010). *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*.

Porter, M. E., & Kramer, M. R. (2006). Strategy and Society: The Link between Competitive Advantage and Corporate Social Responsibility. *Harvard Business Review*, *84*(12), 78–92.

Porter, M. E., & Kramer, M. R. (2011). Creating Shared Value. *Harvard Business Review*, *89*(1–2), 62–77.

Postcoderoosregeling. (n.d.). Wat houdt de PCR-regeling precies in? Retrieved June 25, 2018, from http://www.postcoderoosregeling.nl/wat-houdt-de-pcr-regeling-precies-in/

PowerTech Systems. (n.d.). Self-consumption and self-sufficiency. Retrieved January 9, 2018, from https://www.powertechsystems.eu/home/applications/energy-storage/self-consumption/

Pöyry Management Consulting. (2014). *Storage business models in the GB market*.

PWC. (2017). Netherlands Taxes on corporate income. Retrieved June 5, 2018, from http://taxsummaries.pwc.com/ID/Netherlands-Corporate-Taxes-on-corporate-income

Reclamedienst verspreidingen. (n.d.). Reclameverspreiding. Retrieved June 25, 2018, from https://www.reclamedienstverspreidingen.nl/reclame-verspreiding/plaats:weert-altweerderheide-keent/postcode:6006/straal:10/formaat:-1

Richter, M. (2013). German utilities and distributed PV: How to overcome barriers to business model innovation. *Renewable Energy*, *55*, 456–466. https://doi.org/10.1016/j.renene.2012.12.052

Rijksoverheid. (n.d.-a). Corporation tax. Retrieved June 5, 2018, from https://www.government.nl/topics/taxation-and-businesses/corporation-tax

Rijksoverheid. (n.d.-b). Dutch goals within the EU. Retrieved September 5, 2017, from https://www.government.nl/topics/climate-change/eu-policy

Roland Berger. (2017). *Energy storage can bring utilities back into the game*. Retrieved from https://www.rolandberger.com/publications/publication_pdf/roland_berger_energy_storage_final.pdf

Rönnberg, S., & Bollen, M. (2013). Solar power in northern Scandinavia, its impact on the grid and methods to mitigate this impact. In *2013 4th IEEE/PES Innovative Smart Grid Technologies Europe, ISGT Europe 2013* (pp. 1–5).

RTV Noord. (n.d.). Nog voor Kerst uitspraak over "gigantisch" zonnepark Sappemeer. Retrieved January 30, 2018, from https://www.rtvnoord.nl/nieuws/187425/Nog-voor-Kerst-uitspraak-over-gigantisch-zonnepark-Sappemeer

Schmidt, F. (2016). How can a battery catch fire? Retrieved August 1, 2018, from https://www.dw.com/en/how-can-a-battery-catch-fire/a-36029578

Scholt Energy Service. (2017). personal communication.

Schot, J., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys : theory , findings , research agenda , and policy. *Technology Analysis & Strategic Management*, *20*(5), 537–554.

Solar Choice. (2017). Battery Storage Price Index. Retrieved January 16, 2018, from https://www.solarchoice.net.au/blog/battery-storage-prices-november-2017

Solarplaza. (2017). Dutch solar market can compete subsidy-free in 2020. Retrieved August 9, 2018, from https://thesolarfuture.nl/nieuws-source/2017/5/8/dutch-solar-market-can-compete-subsidy-free-in-2020

Soltronergy. (n.d.). Wij Zijn Soltronergy. Retrieved February 11, 2018, from https://www.soltronergy.eu/

Soltronergy. (2017). personal communication.

Stahley, B. (2017). Commercial solar panel degradation. Retrieved March 22, 2018, from http://businessfeed.sunpower.com/articles/what-to-know-about-commercial-solar-panel-degradation

Statista. (2018). Energy mix in Italy in 2017. Retrieved August 9, 2018, from https://www.statista.com/statistics/873552/energy-mix-in-italy/

Stedin. (2017). Enexis vanaf 1 juli netbeheerder van Weert. Retrieved October 18, 2017, from https://www.stedin.net/over-stedin/pers-en-media/persberichten/enexis-vanaf-1-juli-netbeheerder-van-weert

Stedin. (2018). Tarieven. Retrieved April 16, 2018, from https://www.stedin.net/zakelijk/betalingen-en-facturen/tarieven

Takata, E. (2017). *Analysis of Solar Community Energy Storage for Supporting Hawaii's 100% Renewable Energy Goals*. The University of San Francisco. Retrieved from http://repository.usfca.edu/capstone%0Ahttp://repository.usfca.edu/capstone

Tant, J., Geth, F., Six, D., Tant, P., & Driesen, J. (2013). Multiobjective battery storage to improve PV integration in residential distribution grids. *IEEE Transactions on Sustainable Energy*, *4*(1), 182–191.

TenneT. (n.d.). TenneT - Taking power further. Retrieved September 16, 2017, from https://www.tennet.eu/our-key-tasks/security-of-supply/services-in-the-netherlands/

TenneT. (2018). *Market Review 2017 - Electricity market insights*.

TrackMyElectricity. (n.d.). Guarantee of Origin system (Europe). Retrieved July 6, 2018, from http://www.trackmyelectricity.com/learn-more/certificate-system/

van Blijswijk, M. J., & de Vries, L. J. (2012). Evaluating congestion management in the Dutch electricity transmission grid. *Energy Policy*, *51*(September 2010), 916–926. https://doi.org/10.1016/j.enpol.2012.09.051

Waleson, T. (2017). *Who is going to pay? On the utility death spiral and grid defection in the Netherlands*. Master thesis, Utrecht University.

WeertEnergie. (n.d.). Betaalbare, eigen en duurzame energie. Retrieved April 15, 2018, from https://www.weertenergie.nl/

Weniger, J., Tjaden, T., & Quaschning, V. (2014). Sizing of residential PV battery systems. *Energy Procedia*, *46*, 78–87. Retrieved from http://dx.doi.org/10.1016/j.egypro.2014.01.160

WiseNederland. (2017). Prijzen GvO. Retrieved June 30, 2018, from https://www.wisenederland.nl/groene-stroom/prijslijst-garanties-van-oorsprong

Zon op Nederland. (n.d.). Postcoderoos. Retrieved June 25, 2018, from https://www.zonopnederland.nl/postcoderoos/

Zott, C., Amit, R., & Massa, L. (2011). The business model: Recent developments and future research. *Journal of Management*, *37*(4), 1019–1042. https://doi.org/10.1177/0149206311406265

11 APPENDICES

APPENDIX A.1

This description of the different roles of actors used in the Value Flow Model follows the explanation provided by den Ouden (2012).

Customers – they are the targeted users or buyers of the value proposition; in addition, they may also contribute by co-creating or delivering information

Providers of Systems – integrate goods and services into one system, and deliver them to the customers

Providers of Goods – provide physical goods (which constitute part of the core value proposition or complementary goods)

Providers of Services – provide specific or generic services, such as logistics, customer care, service management, billing or financial transaction management

Providers of Content – create content and provide it to the customers

Intermediary – actors who are in direct contact with the customers, selling them products or services; some examples are retailers or brokers

Supplier – this business actor delivers components to the Provider of Goods or Systems, but does not have a direct contact with the end-users/customers

Enabler – enables the delivery of the service by providing goods and services for the Providers, such as the infrastructure that helps the Providers (an example here can be an online platform)

Financier – investor who provides financial support for the development and implementation of the value proposition

Marketing & Communications – promotes the new value proposition

Godfather – has political influence and can protect the project from undesirable intervention

Competitor – can be important to create demand and supply of new technologies and in building legitimacy

Government – might be important for the approval before the market introduction of a good/service; in addition, it also plays a role in providing subsidies which may be important for the project

APPENDIX A.2

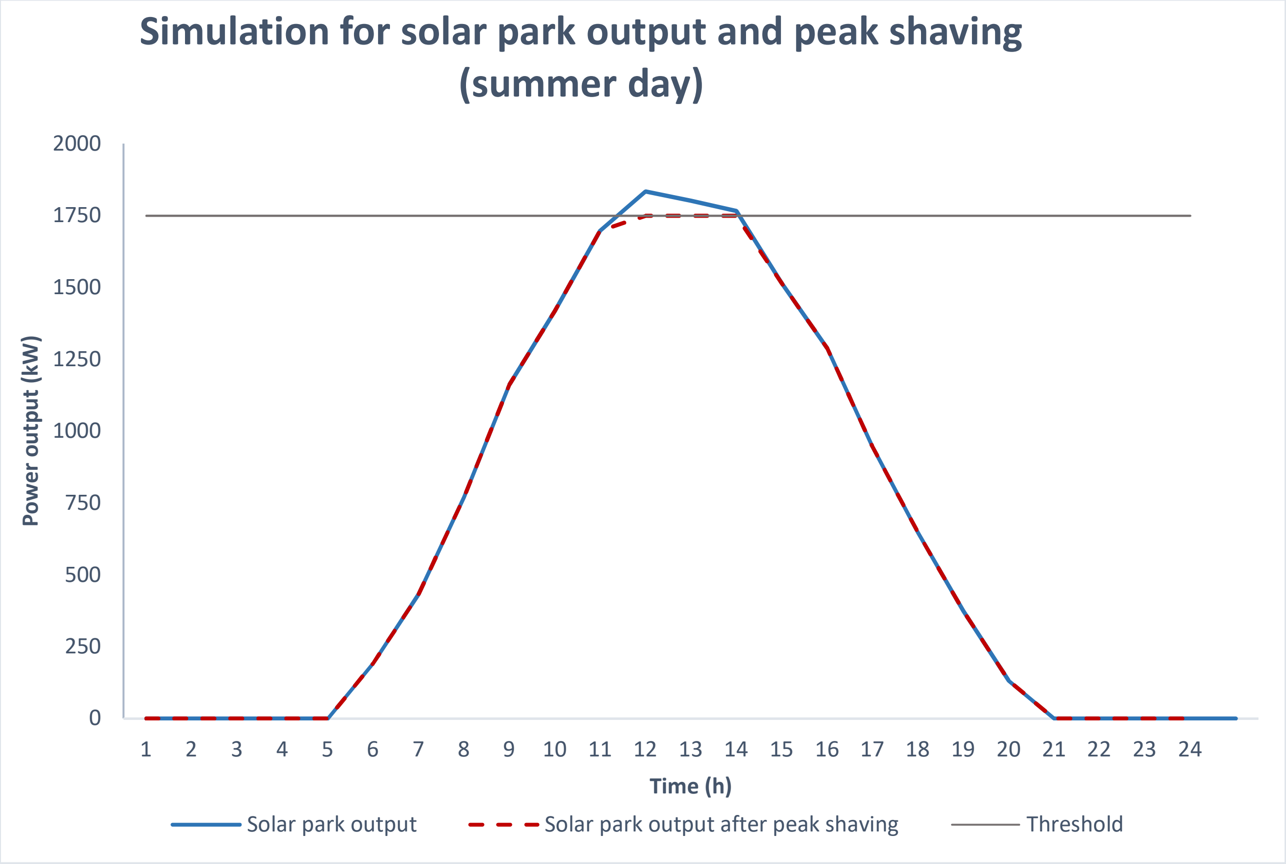


Figure 11.1: Production profiles during a summer day, for a 2,3 MWp solar park installed in 2025. The blue line represents the solar park outpus, while the grey line represents the threshold of 1750 kVA; the battery storage can provide peak shaving by storing everything above the threshold (and deliver it later, when the production is lower). Thus, the result of peak shaving is shown by the red dotted line, which represents the electricity delivered by the solar park after the peak production has been lowered.

APPENDIX A.3

In 2017, there were in total 269 cooperative solar projects in the Netherlands, with a cumulative installed capacity of 36,6 MWp (for a division of the installed capacity per province, see Figure 11.2: The cumulative capacity of all the cooperative solar projects in the Netherlands per province (source HIER Opgewekt, 2017)).

As can be seen from Figure 11.3: Total number of cooperative solar projects since 2008 (source HIER Opgewekt, 2017), the number of projects grew in the last years, and is expected to rise even further in the following years – almost doubling from 2017 to 2018 (if all the projects in the pipeline will be realised). Among the 229 new projects expected in 2018, half are small-scale installations (below 100 kWp), while the rest are larger-scale. Out of the total 229 projects, 158 have applied for the postcoderoos subsidy scheme, while 71 opted for the SDE+ regulation.

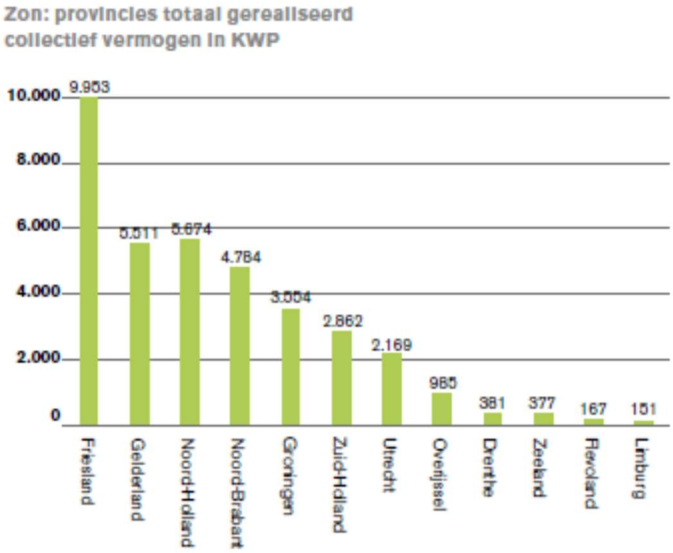


Figure 11.2: The cumulative capacity of all the cooperative solar projects in the Netherlands per province (source HIER Opgewekt, 2017)

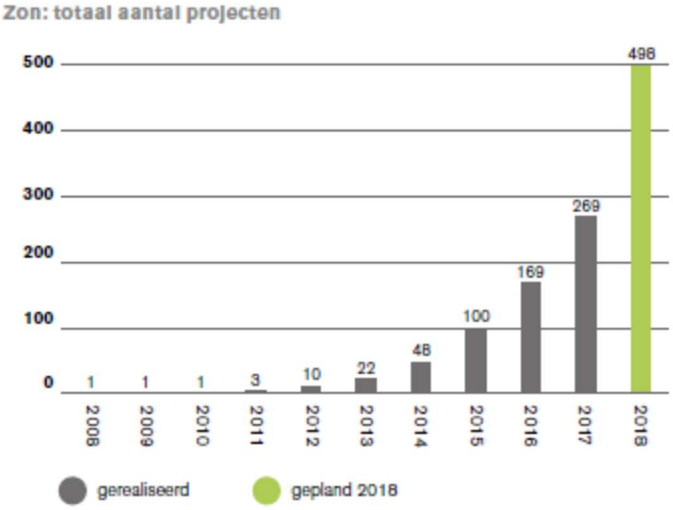


Figure 11.3: Total number of cooperative solar projects since 2008 (source HIER Opgewekt, 2017)

APPENDIX A.4

Postcoderoos (or RVT)

As previously described, the postcoderoos is a subsidy in the form of discount on the energy bill, in specifics on the energy tax. It is designed for citizens' initiatives that want to generate energy from renewable sources in a cooperative context. In particular, the recipients of the subsidy are private households or companies, typically unified in a cooperative, that invest in solar panels and are the legal owners of the asset. It should be noted that the solar installation does not have to be located on the owner's roof, but it can be also installed elsewhere, for example on a large agricultural rooftop or on an available land plot within a community.

Usually, if a cooperative builds a solar park in a certain postal code, it sells the generated electricity to an energy supplier, which in turn sells the electricity at a normal price to the end consumers. However, because of the postcoderoos scheme, the supplier applies a reduced rate on the individual energy bill, on the basis of the share that each individual has in the solar park. To do so, the supplier must have access to the data about the members' share in the solar installation, typically done through the member statement (or ledenverklaring), which the cooperative provides to the energy supplier (Postcoderoosregeling, n.d.). The postcoderoos incentive runs for 15 years from when it has been appointed, and in 2018 the compensation for each participant is 12,65 €ct/kWh (including VAT, or 10,458 €ct/kWh excluding VAT) (HilverZon, n.d.; Zon op Nederland, n.d.).

To be eligible for the subsidy, the first requirement is that each member doesn't have more than 20% of the share in the cooperative (HIER Opgewekt, 2018). In addition, all participants have to live either in the same postal code, or in the adjacent postal code regions, i.e. postcoderoos area. As a result, the postal code region for the solar installation (which will be the region of the postcoderoos appointment) can be chosen in a way that allows a larger number of adjacent postal codes, thus allowing more people to participate in the subsidy scheme. Taking the COOP-Store as a case study, the following map shows the postal code regions in the postcoderoos area. If the solar park is built in the postal code area of Weert (6006), citizens living in the 5 adjacent postal code regions (6001, 6002, 6004, 6005, 6039) are also eligible for the RVT fiscal incentive.

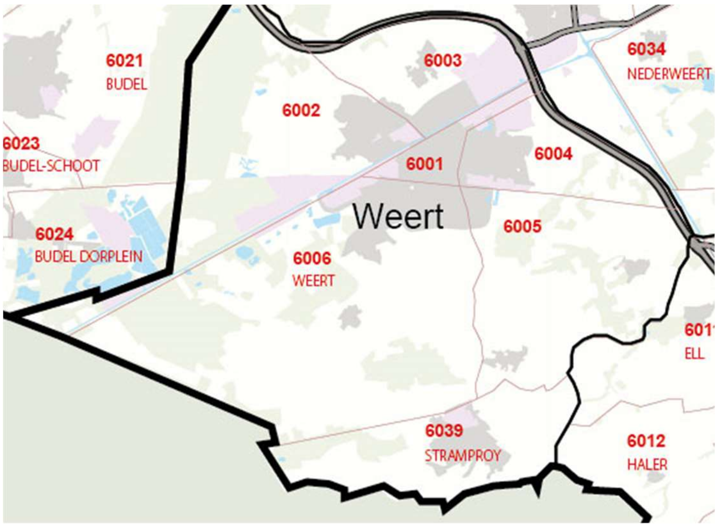


Figure 11.4: Postcoderoos area Weert (considering the COOP-Store project) - source Reclamedienst verspreidingen, n.d.

SDE +

The SDE+, or Stimuleringsregeling Duurzame Energieproductie, is an operating (feed-in-tariff) subsidy meant for larger projects of renewable energy generation (in case of solar PV, it is meant for projects with a capacity above 15kWp and a connection above 3*80A (Netherlands Enterprise Agency, 2018)). This means that the producers of renewable energy get compensated per generated kWh.

Most of the times the cost of production from renewable sources is higher than in the case of fossil fuels; therefore, the SDE+ aims to compensate this difference by guaranteeing a grant for a fixed period of time (in case of solar PV, the subsidy runs for 15 years). The cost price for the production of renewable energy is determined in the base sum, while the cost price for conventionally generated energy set in the correction sum. The maximum SDE+ compensation is thus calculated as the difference between the maximum base sum and the correction sum, as seen in the below figure.

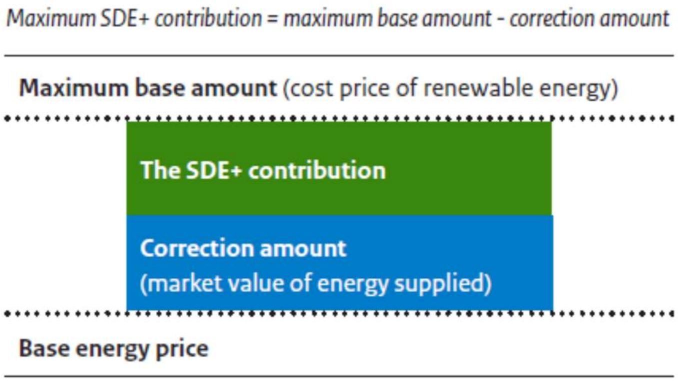
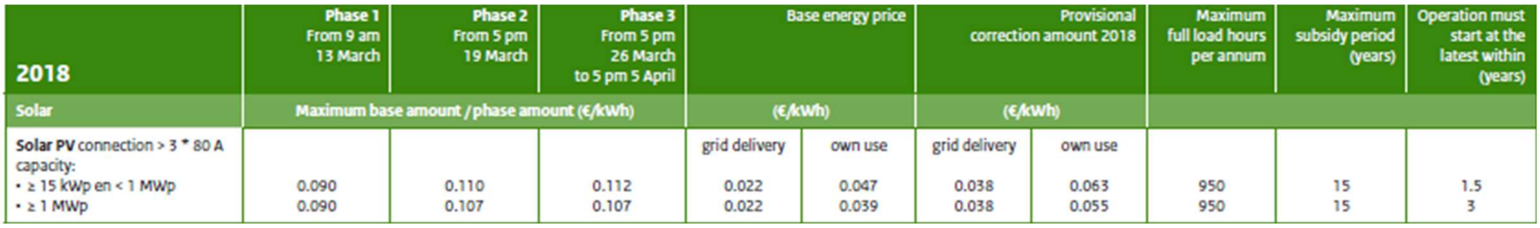


Figure 11.5: Structure of the SDE+ compensation (source Netherlands Enterprise Agency, 2018)

As can be seen in Figure 11.5: Structure of the SDE+ compensation (source Netherlands Enterprise Agency, 2018), the correction sum depends on the market value of the supplied energy. This means that the SDE+ compensation is dependent on the energy prices: when energy prices are higher, the producer of renewable energy gets more from the energy purchaser, but the SDE+ subsidy is lower; the opposite happens in case of lower energy prices. The base energy price is the lowest limit of the correction sum: in case that the correction sum equals the base energy price, the maximum SDE+ contribution is reached. Final payments for the SDE+ contribution are determined every year, depending on the energy price levels and the amount of generated electricity. Also the correction sum is re-established every year, on the basis of the evolution of energy prices.

In 2018, there are two rounds of the SDE+ subsidy, in spring and in autumn; each round is divided into three phases (each phase involves a higher base sum for the subsidy). As from 2018, there are some changes in the SDE+ regulation. For solar PV, the new feature is the distinction between the electricity fed into the grid and the one which is used directly (and thus not used for grid delivery). The rates and SDE+ compensations for the frist round of 2018 are depicted in the following figure.



2018	**Phase 1** From 9 am 13 March	**Phase 2** From 5 pm 19 March	**Phase 3** From 5 pm 26 March to 5 pm 5 April	**Base energy price**		**Provisional correction amount 2018**		**Maximum full load hours per annum**	**Maximum subsidy period (years)**	**Operation must start at the latest within (years)**
Solar	**Maximum base amount / phase amount (€/kWh)**			**(€/kWh)**		**(€/kWh)**				
Solar PV connection > 3 * 80 A capacity:				grid delivery	own use	grid delivery	own use			
• ≥ 15 kWp en < 1 MWp	0.090	0.110	0.112	0.022	0.047	0.038	0.063	950	15	1.5
• ≥ 1 MWp	0.090	0.107	0.107	0.022	0.039	0.038	0.055	950	15	3

Figure 11.6: SDE+ phases and rates for solar PV (source Netherlands Enterprise Agency, 2018)

APPENDIX A.5

Country	Location	PV size (MWp)	Battery capacity (MWh)	Year of commissioning	Storage main application /service use	Owner	Operator
Germany	Neuhardenberg, Brandenburg	145	5	solar park in 2012, batteries in 2016	frequency regulation	Enerparc AG (third party)	Upside Group (thidr party)
US	Arizona	100	120	under construction	renewable energy time shift, renewables capacity firming	NextEra Energy (third party, generator)	NextEra Energy (third party, generator)
Germany	Wittstock, Brandenburg	68	2	solar park in 2011, batteries in 2014	voltage control, grid stability	Vattenfall (third party)	Belectric (third company)
US	El Centro, California	50	20	solar park at beginning of 2016, batteries in late 2016	frequency regulation, voltage control	Community-owned utility company (Imperial Irrigation District)	Community-owned utility company (Imperial Irrigation District)
US	Loiza, Puerto Rico	26	0,4	2012	frequency regulation, ramp-rate control	Third party (URIEL Renewables Inc)	Third party (URIEL Renewables Inc)
Australia	Lakeland, Far North Queensland	13	5,3	under construction	fringe of grid - remote area	Conergy (thidr party, generator)	Conergy (thidr party, generator)
US	Kauai, Hawaii	13	52	2017	microgrid	Kauai Island Utility Cooperative	Kauai Island Utility Cooperative
China	Shuanghu County, Tibet	13	24	2016	microgrid	generator Power Construction Company of China	Third party (Clou Electronics)
US	Redstone Arsenal, Alabama	10	2	under construction	security of energy supply, future scaling up to off-grid project	End-user (army)	Third party
UK	Flitwick, Bedfordshire	10	6	2017	trading of electricity	third party (not known)	Anesco (third party, operates the battery)
US	Sonoma County, California	6,5	4,2	solar park in 2014, batteries in 2015	renewable energy time shift, increase self-consumption	End-user	Third party (EnerNOC company)
UK	Northampton	5	1,1	2017	grid stability, peak shaving	Third party (not known)	Third party (Anesco)
UK	Chesterfield	5	1,1	2017	grid stability, peak shaving	Third party (not known)	Third party (Anesco)
UK	Stratford-upon-Avon	5	1,1	2017	grid stability, peak shaving	Third party (not known)	Third party (Anesco)
US	Norwich, Connecticut	4,7	3	2016	renewable energy time shift, increase self-consumption	Connecticut Municipal Electric Energy Cooperative (CMEEC), generator	Connecticut Municipal Electric Energy Cooperative (CMEEC), generator

Rwanda	Kayenzi	3,3	2,7	solar park not given, batteries under construction	renewable energy time shift, fringe of grid - remote area	Third party (Tesvolt)	Third party (Tesvolt)
Australia	Gatton, Queensland	3,275	0,76	2016	grid stability, peak shaving	Third party (AGL company)	Third party (AGL company)
US	Galt, California	3	0,125	2013	grid stability, peak shaving	Utility (Sacramento Municipal Utility District)	Utility (Sacramento Municipal Utility District)
US	Chico, California	2	1	solar park not given, batteries in 2017	increased self-consumption	End user	End user
Switzerland	Lausanne , Canton of Vaud	2	0,5	2015	renewable capacity firming, grid stability	End-user (Ecole Polytechnique Federale de Lausanne)	End-user (Ecole Polytechnique Federale de Lausanne)
Japan	Fukuoka , Kyushu	2	1,2	solar park not given, batteries in 2016	renewable energy time shift, trading of electricity	Third party (Colon)	Third party (Colon)
UK	Butleigh, Somerset	1,5	0,64	solar park in 2011, batteries in 2016	renewable energy time shift	British Solar Renewables (third party)	British Solar Renewables (third party)
American Samoa	island of Ta'u	1,4	6	2016	microgrid	American Samoa Power Authority (public utility)	American Samoa Power Authority (public utility)
US	Porterville, California	1,4	0,72	2015	renewable energy time shift, trading of electricity	End-user (group of co-located schools)	End-user (group of co-located schools)
US	Denver, Colorado	1,3	2	under construction	microgrid	Third party (utility - generator and retailer) Xcel Energy	Third party (utility - generator and retailer) Xcel Energy
Finland	Kalasatama	1,2	0,6	solar park in 2015, batteries in 2016	frequency regulation, voltage control, peak shaving	Helen Ltd. Energy solutions (energy company, third party)	Helen Ltd. Energy solutions (energy company, third party)
US	Lanai, Hawaii	1,2	0,5	2012	increased self-consumption, renewable energy time shift	Castle&Cooke (third party)	Castle&Cooke (third party)
US	Twentynine Palms, California	1,2	0,48	2015	renewable energy time shift, trading of electricity	End-user (military installation)	End-user (military installation)
Fiji	Mamanuca Group island of Malolo	1	4	2017	microrid	End-user (resort owner)	End-user (resort owner)
South Africa	Kruger National Park	1	3	solar park in 2016, batteries in 2017	off-grid	End-user (resort owner)	End-user (resort owner)
Australia	Daly River , Northern Territories	1	2	2016	off-grid	End-user (cooperative)	Third party (utility)
US	Sherrills Ford , North Carolina	1	0,8	solar park in 2010, batteries in 2012	renewable energy time shift	Utility (Duke Energy)	Utility (Duke Energy)
US	New Orleans , Louisiana	1	0,5	2016	renewables capacity firming,	Utility (Entergy)	Utility (Entergy)

					increased self-consumption		
Haiti	Port-au-Prince	0,65	0,448	2015	microgrid	End-user (hospital)	End-user
UK	Dorset, England	0,5	0,25	solar park not given, batteries in 2014	renewable energy time shift	Third party (Farm Power Apollo)	third party (Anesco for the storage)
US	City of Commerce , California	0,5	0,25	2016	increased self-consumption, renewable energy time shift	End-user (institute)	End-user (institute)

Table 11.1: Results of the benchmark study on worldwide larger-scale Solar-Plus-Storage projects currently operatonal or under development

APPENDIX A.6

General input values

Parameter	Value	Units	Source
(Real) discount rate	4	%	Assumed, based on personal communication with professionals
Debt/equity fraction	70/30	fraction	Assumed, based on (ECN & DNV GL, 2017)
Loan interest rate	2	%	(ECN & DNV GL, 2017) – value with green funding
Loan repaiment structure	annuity	-	Assumption
Loan repayment term	15	years	Assumption
Taxes	25	%	(PWC, 2017; Rijksoverheid, n.d.-a)
Depreciation	15	years	(Bruning & Rikze, 2016)
Residual value	10	%	(Bruning & Rikze, 2016)
SDE+ subsidy contribution 2018	0,069[8]	€/kWh	(Netherlands Enterprise Agency, 2018)
SDE+ subsidy lenght 2018	15	years	(Netherlands Enterprise Agency, 2018)
SDE+ subsidy contribution 2025	0,008	€/kWh	Based on personal calculations[9]
SDE+ subsidy lenght 2025	15	years	Assumption

Solar park input values - 2018

Parameter	Value	Units	Source
Installed power	2.300	kWp	Assumption
Lifetime modules	30	years	(Stahley, 2017)
Degradation modules	0,5	%/year	(NREL, n.d.)
Orientation	3% South, 97% East-West		Based on COOP-Store project
Efficiency modules	17	%	(EnergySage, 2018)

---

[8] Which corresponds to the second and third application phase for 2018; this is selected because if the SDE+ contribution from the first phase is applied, the business case considering only costs and benefits from the solar park does not become positive within the first 15 years

[9] Calculated by considering only costs and benefits from the solar park in year 2025; by changing the value of the subsidy contribution, the minimum value for which the business case becomes positive before 15 years (0,008 €/kWh) is selected as the reference input value

Yield factor	881	kWh/kWp	Based on COOP-Store project – simulation results
Electrical yield first year	2.026.300	kWh	From simulations
Electrical yield (total lifetime)	56.580.702	kWh	From simulations
Inverter lifetime	15	years	(Fraunhofer-ISE, 2015)
Total PV costs	0,9	€/Wp	(Soltronergy, 2017)(Bruning & Rikze, 2016)
Inverters price (after 15 years)[10]	0,045	€/Wp	Based on learning curves and (Fraunhofer-ISE, 2015)
Grid connection costs	170.000	€	Based on personal communication with professionals
Total investments[11]	2.240.000	€	calculated
General operation&maintenance	0,0075	€/Wp/year	(Bruning & Rikze, 2016; ECN & DNV GL, 2017; Fraunhofer-ISE, 2015)
Yearly grid fees	2.240	€/year	Based on personal communication with professionals (Enexis, 2018)
Total O&M[12]	19.490	€/year	calculated
Revenue from selling electricity	0,045	€/kWh	Averaged EPEX SPOT NL price (APX-Group, n.d.)
Revenues from selling guarantees of origin	0,00275	€/kWh	(WiseNederland, 2017)

Solar park input values - 2025[13]

Parameter	Value	Units	Source
Efficiency modules	19,5	%	(Dunbar, 2017)
Yield factor	1.010	kWh/kWp	Based on calculations
Electrical yield first year	2.324.285	kWh	calculated
Electrical yield (total lifetime)	64.901.394	kWh	calculated
Inverter lifetime	15	years	(Fraunhofer-ISE, 2015)
Total PV costs	0,5	€/Wp	(Bailey, 2018; IRENA, 2016)
Inverters price (after 15 years)	0,036	€/Wp	Based on learning curves and (Fraunhofer-ISE, 2015)
Grid connection costs	180.000	€	Based on price developments in the past years and from personal communication with professionals
Total investments	1.330.000	€	calculated
General operation&maintenance	0,006	€/Wp	(IRENA, 2016)
Yearly grid fees	2.340	€/year	Assumed, based on price developments in the past years
Total O&M	16.140	€/year	calculated
Revenue from selling electricity	0,05	€/kWh	(CE Delft, 2017)
Revenues from selling guarantees of origin	0,0015	€/kWh	Assumption, based on (CE Delft, 2016)

---

[10] Assumed that after 15 years, they are replaced in order to have 30 years lifetime for the system.

[11] Total investments include the costs for PV panels, inverters, additional Balance of System (DC cabling, mounting, installaton, infrastructure, planning & documentation) and grid connection; they not include however possible costs for permits, security, communication & marketing

[12] Not included administration costs and rent for the area where the solar pakr is located

[13] The parameters not specified in this table are kept the same as for the 2018. In addition, also in the case of total investments and O&M costs for 2025, some features have been excluded – see footnotes 3 and 4.

Battery storage input values - 2018

Parameter	Value	Units	Source
Capacity	1.000	kWh	Assumption
Rated power	1.000	kW	Assumption
Degradation[14]	0,5	€/year	(DNV GL, 2018)
Lifetime	15	years	(Nolten, 2017)
Investment[15]	850.000	€	Based on COOP-Store project and (Nolten, 2017)
Commisioning[16]	90.000	€	Based on COOP-Store project
Total investments	940.000	€	calculated
O&M costs[17]	22.000	€/year	Based on communication with professionals (Nolten, 2018)
Fee for battery management (in case of third party operator)	12.000	€/year	Based on COOP-Store project and personal communication with professionals

Battery storage input values - 2025

Parameter	Value	Units	Source
Investment	600.000	€	Based on predictions from BNEF (Bloomberg New Energy Finance), 2015; Cole, Marcy, Krishnan, & Margolis, 2016
Commisioning	90.000	€	Assumed constant
Total investments	690.000	€	calculated
O&M costs	18.000	€/year	Assumption based on Cole, Marcy, Krishnan, & Margolis (2016)
Fee for battery management (in case of third party operator)	12.000	€/year	Assumed constant

APPENDIX A.7

Yearly grid fees for being connected to the electricity grid can be divided into a fixed part and a variable part. In case that the Solar-Plus-Storage system is connected to the medium voltage grid (> 173 kVA), the following fees apply (Enexis, 2018):

- yearly fees for being connected (keeping the connection up and running) – vastrecht aansluiting
- yearly transport fees (including costs for registration, processing of metering data, administration costs, customer support, etc.) – vastrecht transport
- contracted power tariff in €/kW (based on the expected maximum power in kW that will be even drawn from the grid, measured in 15-minutes intervals; the electricity grid must be able to deliver this at any time). A customer can request a lower contracted power, if it is not likely that the specific value in kW will be reached; on the other hand, if the power drawn in a certain month exceeds the

---

[14] Assuming degradation without the specific influence from different service uses (typically, degradation depends on the application that the battery storage provifes, which influence the charging and discharging cycles)

[15] Includes batteries, container, inverters, air conditioning system, system control and energy management system interface

[16] Includes transformer, transport of container, building of foundation and connection to the electricity grid

[17] Including grid fess, trading fees, insurance and maintenance

contracted power (i.e. if a higher peak power consumption occurs), the contracted power (and thus the tariff) increases to that value from that month onwards.

- maximum power per month in €/kW (corresponding to the maximum consumption on a 15-minute basis in a specific month)

The first two are fixed fees, since they do not depend on the amount of power flowing, while the other two fees correspond to the variable part. In addition, it is important to mention that the latter two tariffs do not apply in the case that a connection only delivers power into the grid (Enexis, 2018). Therefore, when a solar park is built without a battery storage, or if the storage (co-located with the solar park) is only charged with the electricity produced by the solar panels, only the fixed part of the grid fees has to be paid.

Furthermore, all the above-mentioned fees depend on the connection required; typically, for connections between 173 kVA and 1750 kVA the costs are lower, while they increase if a connection above 1750 kVA is required. In addition to that, a smaller connection allows lower investments for establishing a new connection (when the Solar-Plus-Storage system is built). All these advantages are discussed in the business case calculations by considering the battery storage for peak shaving purposes.

APPENDIX A.8

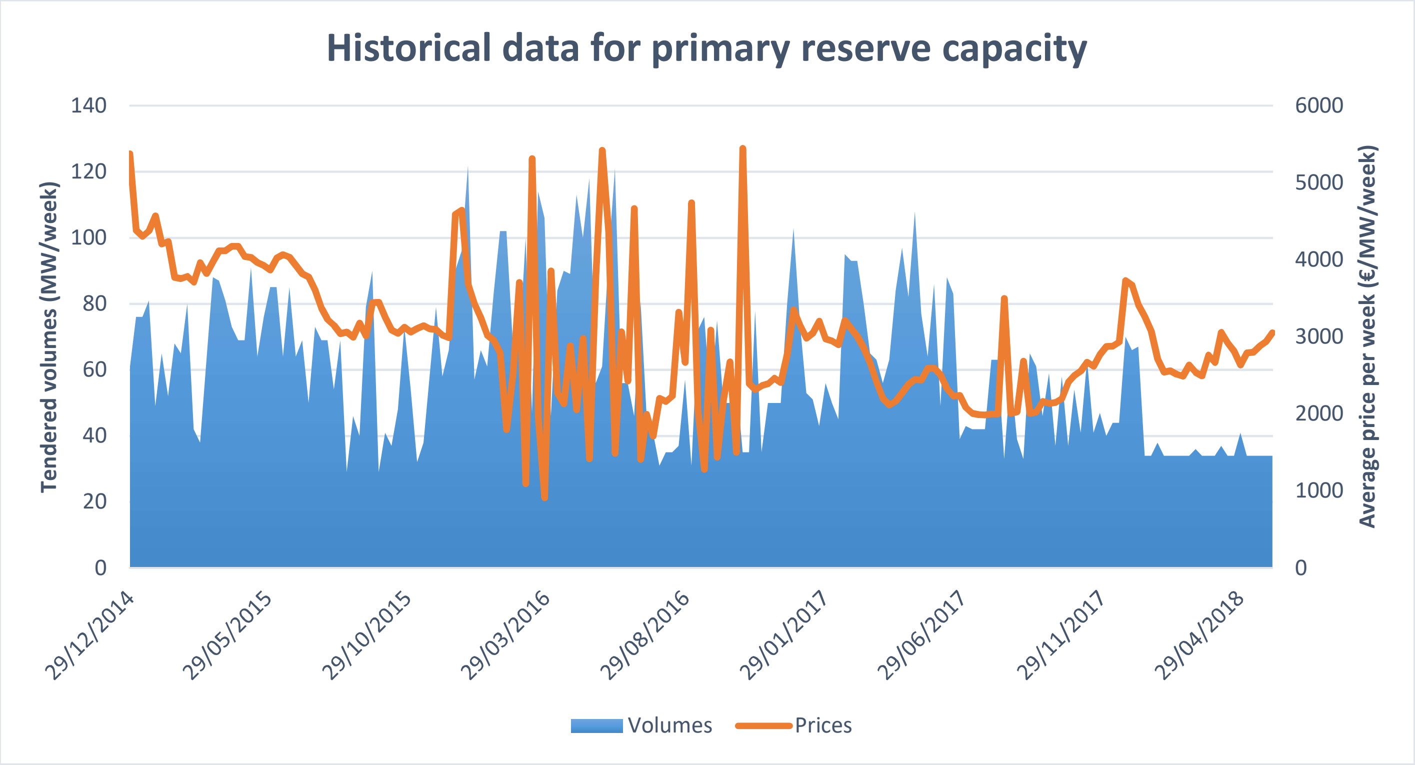


Figure 11.7: Average weekly tendered volumes and prices for primary reserve capacity in the Netherlands

APPENDIX A.9

Overview of the results from the business case calculations, for each application of the battery storage and for the three business model scenarios (Idealistic scenario, Money Maker scenario and Multi-Actor scenario). The results present both the payback period (PBP) as well as the net present value (NPV) for the business case in 2018 and in 2025.

Application of battery storage	PBP - 2018	NPV - 2018	PBP - 2025	NPV - 2025
Primary reserve capacity	10 years	783.191	11 years	632.606
Energy arbitrage (day-ahead market)	> 30 years	-347.147	> 30 years	-172.312
Imbalance trading	30 years	10.497	> 30 years	-102.263
Peak shaving	> 30 years	-337.536	> 30 years	-154.773
Increased self-consumption	> 30 years	-465.692	> 30 years	-184.490
Backup power	> 30 years	-401.031	> 30 years	-226.196
Grid reinforcement deferral (minimum)[18]	> 30 years	-465.692	> 30 years	-277.924
Grid reinforcement deferral (maximum)[19]	> 30 years	-465.692	27 years	69.235
PV only – no battery	12 years	420.843	14 years	426.341

Figure 11.8: Business case results per single application of battery storage

Scenario	PBP - 2018	NPV - 2018	PBP - 2025	NPV - 2025
Idealistic	> 30 years	-290.490	> 30 years	-79.686
Money Maker	10 years	721.512	11 years	617.898
Multi-Actor (minimum)[20]	18 years	245.578	19 years	244.140
Multi-Actor (maximum)[21]	18 years	245.578	12 years	560.602
PV only – no battery	12 years	420.843	14 years	426.341

Figure 11.9: Business case results per business model scenario

---

[18] The minimum coresponds to the case that 1.200 €/year is selected as the revenue stream associated with this service use for the battery storage.

[19] The maximum is when 33.600 €/year is chosen instead.

[20] Same as Footnote 2 (since this scenario includes also grid reinforcement deferral)

[21] Same as Footnote 3 (since this scenario includes also grid reinforcement deferral)