WP6- Innovation Management, Exploitation, Market Uptake and Business Models

IDENTIFICATION, DESIGN AND EVALUATION OF BUSINESS MODELS

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Executive Summary

This report provides an in-depth analysis of the business models suitable for sustainable plus energy neighbourhoods (SPENs), focusing on long-term viability and potential revenue streams, especially concerning surplus energy production. The report encompasses various business model formulations, regulatory challenges, stakeholder perspectives, and optimization strategies within the context of the four syn.ikia demonstration sites in Austria, the Netherlands, Spain, and Norway. Through a detailed techno-economic analysis on the syn.ikia demonstrators, the report offers insights into the potential revenue sources, value capture opportunities, and financial strategies pertinent to SPENs business models.

The report presents a framework on developing business models around SPENs, highlighting the entities, technologies, markets, and business case integral to their function. It specifically identifies key stakeholders in the energy system – from utility companies to end-users – and other relevant actors by presenting them in a set of business model canvas. The main business models analysed within the context of syn.ikia are as follows:

1. **Local Market and P2P Energy Trading**: P2P trading empowers direct energy exchange within a community, bypassing traditional market intermediaries. It leverages technologies like smart meters and blockchain for efficient transaction management. Revenue streams primarily stem from transaction fees and software subscriptions. This model thrives on the community spirit, allowing neighbours to share excess solar power, thus painting a future of local energy independence.

2. **Power Purchase Agreements (PPAs)**: PPAs involve contracts where renewable energy producers (e.g., SPEN solar surplus) sell electricity directly to consumers. Key activities include managing production, demand forecasting, and balancing risks. This model guarantees a stable, long-term energy source at predetermined prices, offering predictability to both producers and consumers.

3. **SPEN as Retailer/Aggregator**: SPENs could act as energy retailers, purchasing wholesale electricity and vending it to customers. This model sees its strength in flexibility resources like batteries, optimizing profitability via arbitrage. A model that cleverly balances and optimizes the collective energy needs, acting as a bridge between the individual and the larger energy market.

4. **Community-Based Shared Assets**: Communities collectively invest in renewable energy generation and storage systems. Critical considerations include fair cost and benefit distribution among members, with various pricing models like flat or time-of-use rates. This model reduces total operational costs and maximizes resource utilization.

5. **Green Investor**: Private investors finance renewable energy installations (like solar panels on residential properties) in exchange for energy-related returns. This model addresses upfront capital costs and shares the risks of fluctuating energy prices between the investor and residents.

Evaluating the above business models across syn.ikia demonstrators showcases varying profitability and operational challenges. For example, Austria’s adoption of shared asset models led to decreased costs and a rise in PV system installations. The success of the green investor model also showed notable variations across regions, influenced by factors like local energy outputs, prevailing market rates, and specific tariff structures. Additionally, the report emphasizes how regulatory frameworks markedly impact the feasibility of SPENs. For example, incentives such as subsidies and tax reliefs, as seen in Austria, the Netherlands, and Norway, enhance the appeal of models like PPAs and P2P trading, by diminishing the burden of initial investments. Furthermore, insights gathered from a questionnaire distributed among stakeholders of the syn.ikia project shed light on the dynamics of adopting SPEN business models. It is discerned that the motivation behind embracing these models predominantly revolves around economic benefits and political backing. Stakeholders underscore the importance of collaboration and early-stage planning in the successful deployment of SPENs, emphasizing that these strategies are vital for their efficient and effective realization.
APPENDIX B. DATA USED ......................................................................................... 87
Business model 1 - Local Markets .......................................................................... 87
Business model 4 – Community-based shared assets ............................................... 89
Business model 5 - Green investor model ................................................................ 90

APPENDIX C. STAKEHOLDER QUESTIONNAIRE......................................................... 92

ACKNOWLEDGEMENT OF EU FUNDING ................................................................. 97
1 Introduction

In the syn.ikia project, Sustainable Plus Energy Neighborhoods (SPENs) envision the development of new approaches to urban development, energy consumption, and environmental sustainability. By design, these neighborhoods not only meet their own energy needs but also produce more energy than they consume, primarily through sufficiency and energy efficiency measures, as well as renewable sources. The positive energy balance offers a promising pathway towards reducing the overall carbon footprint, enhancing local energy security, and promoting socio-economic benefits through reduced utility costs\(^1\) and potential income from energy and flexibility services sales. Furthermore, SPENs embody a transformative concept in urban living, where communities are not just energy self-sufficient but also active participants in a wider sustainable ecosystem, contributing positively to both environmental and societal goals.

Business models for SPENs serve as enablers in realizing this transformative vision. They provide the structural framework necessary to efficiently operate, manage, and finance these energy-positive neighborhoods. Effective business models are essential for determining the viability and sustainability of SPENs, as they directly influence the capacity to generate revenue, attract investments, and achieve cost-effectiveness. Such models need to address the diverse aspects of energy production, distribution, and consumption, adapting to various regulatory environments and market dynamics across different regions. Critically, these business models facilitate the alignment of stakeholder interests, encompassing residents, energy providers, investors, and governmental bodies, ensuring that the economic, environmental, and social benefits of SPENs are optimized and shared among all participants. In essence, the development and implementation of robust, innovative business models are fundamental in shaping the practicality, profitability, and long-term success of SPENs.

Successful execution of these business models necessitates a comprehensive analysis of potential revenue sources and a strategic approach to capturing value for all involved parties—sellers and consumers alike within SPENs. This rigorous exploration involves considering a multitude of factors, including geographical variances, diverse stakeholder viewpoints, and the dynamics of market. Central to this exploration is the surplus energy production within SPENs—a factor that requires detailed scrutiny from both a technical and business perspective. This report provides a systematic assessment of the business models associated with surplus energy management in SPENs, aiming to delineate their intricacies, challenges, and opportunities.

The report is structured around several pivotal questions:

1. **Emerging Business Models for Local Energy Production**: Which business models are becoming increasingly relevant in the domain of local energy production for SPENs? (Chapter 2)
2. **Regional Applicability**: How do these business models align with the specific needs and characteristics of the four demonstration sites in Norway, the Netherlands, Spain, and Austria? (Chapter 3)
3. **Profitability Analysis**: How do the proposed business models fare in terms of profitability within the distinct economic landscapes of the four countries? (Chapter 4)
4. **Stakeholder Analysis**: Who comprises the central stakeholders within the SPENs ecosystem, and what are their perspectives and concerns regarding these business models? (Chapter 5)

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\(^1\) This might differ in cases with high electrification rates or other context specific situations where energy bills could increase
5. **Financial and Regulatory Considerations:** What are the viable financing strategies for these business models, and what regulatory challenges might arise during their implementation? (Chapter 6)

By addressing these questions, this report aims to offer a structured, analytical perspective on the business models associated with SPENs, facilitating informed decision-making for stakeholders and outlining ideas for their possible implementation and scalability across varying contexts.

The methodology to identify and develop the business models has been based on reviewing related literature and the ideas of the syn.ikia concept for SPEN (see chapter 2). Hence, the emerging business models in the literature as well as proposition from researcher partners set the scene for the business models analyzed in this report (see Chapter 3). These set of selected business models, then was followed up with interviews and join discussion with the syn.ikia partners in charge of the demo sites. Individual meetings and inputs were collected regarding on what demo partners deem as relevant to investigate and to assess (see chapter 2 and 5). These initial set of proposed business models were also discussed in an international workshop organized by syn.ikia in Brussels, where syn.ikia partners and other European projects provided further comments and ideas to the business models. The central methodology to analyze and quantify the potentials of the business models was through developing specific state-of-the art techno-economic models. These modes were developed by NTNU, the central underlying methodology of these models is based on mathematical programming commonly used in energy systems research. The models results and analysis provided extensive results that were studied in detail within this report (see chapter 4). These results were then discussed with syn.ikia partners in informative meetings followed up with a stakeholder survey (Chapter 5). Moreover, in light of the design and formulation of the business models, financial strategies were discussed (chapter 6).

### 1.1 SPEN Definition and Glossary

SPEN has been defined in the syn.ikia project is a highly energy efficient and energy flexible neighbourhood with a surplus of energy from renewable sources.

The syn.ikia definition of a SPEN follows a similar procedure as described for Positive Energy Buildings, but the geographical boundary is physically or digitally expanded to the entire site of the neighbourhood development, including local storage and energy supply units.

The SPEN framework includes a strong focus on cost efficiency, indoor environmental quality, spatial qualities, sustainable behaviour, occupant satisfaction, social factors (co-use, shared services and infrastructure, community engagement), power performance (peak shaving, flexibility, self-consumption), and greenhouse gas emissions (see Salom J. 2021).

Moreover, energy communities and collective self-consumption has been brough to the European policies through the recast of the Renewable Energy Directive (RED-II) and the Internal Electricity Market Directive and Regulations (IEM-R). The first introduced the term of “renewable energy communities” (RECs) while the

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2 SPEN concept and definition: [https://www.synikia.eu/about-syn-ikia/](https://www.synikia.eu/about-syn-ikia/)

3 Buildings that produce at least as much renewable energy as they use in a year.
second expanded its definition to “citizens energy communities” (CECs). Both definitions agreed upon the voluntary participation of its members. Nevertheless, they differ in (Reis et al. 2021):

- **Geographical scope**: CECs are not restricted by geographical boundaries while RECs are limited.
- **Activities**: CECs include a wider range of activities coming from renewable assets, electrical and thermal storage, energy efficiency measures etc. Contrarily, RECs focus mostly on energy projects related to renewable generation.
- **Membership**: RECs allow only small enterprises, households and public entities to be involved, while the CECs opens up to larger companies.

Based on these definitions, throughout the report, we use the terms “energy community” and SPEN interchangeably, considering they fit the regulatory approach of CECs.

This report uses various terms and definitions throughout the analyses and discussions. These are explained in the table below.

<table>
<thead>
<tr>
<th>Term or Stakeholder</th>
<th>Explanation</th>
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<tbody>
<tr>
<td><strong>SPEN</strong></td>
<td>Sustainable Plus Energy Neighbourhood</td>
</tr>
<tr>
<td>Prosumers</td>
<td>Individuals who both produce and consume energy</td>
</tr>
<tr>
<td>Collective self-consumption</td>
<td>Joint energy sharing between consumers/prosumers from jointly owned distribute energy assets</td>
</tr>
<tr>
<td>Distribution System Operator</td>
<td>Entity responsible for operating, maintaining, and developing the distribution network in a region.</td>
</tr>
<tr>
<td>Transmission System Operator</td>
<td>Entity responsible for the high-voltage transmission grid and for ensuring the balance between supply and demand in the power system.</td>
</tr>
<tr>
<td>Solar PV Panels</td>
<td>Photovoltaic panels that convert sunlight into electricity.</td>
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<td>BESS</td>
<td>Battery energy storage systems</td>
</tr>
<tr>
<td>Peers</td>
<td>Members within the SPEN who engage in energy sharing activities</td>
</tr>
<tr>
<td>Wholesale Market</td>
<td>A marketplace for buying and selling energy in large quantities, often involving various energy producers, retailers, and traders.</td>
</tr>
<tr>
<td>P2P Local Energy Markets</td>
<td>Referred here as collective self-consumption involving two or more buildings</td>
</tr>
<tr>
<td>End-user/Consumer</td>
<td>Individuals or entities that consume energy but do not produce it.</td>
</tr>
<tr>
<td>Community Members</td>
<td>Residents or entities that are part of a specific SPEN.</td>
</tr>
<tr>
<td>Neighbours</td>
<td>Individuals living in close proximity within a SPEN, often involved in energy sharing activities.</td>
</tr>
<tr>
<td>Retailer</td>
<td>Entities responsible of participating in the power market to purchase electricity to sell to end-users.</td>
</tr>
<tr>
<td>Aggregator</td>
<td>A company or entity that pools multiple customers or assets to participate as a single entity in the electricity market.</td>
</tr>
<tr>
<td>Financial Institutions</td>
<td>Banks or other financial organizations that may provide loans, grants, or investments for energy projects.</td>
</tr>
<tr>
<td>PPA</td>
<td>Power Purchase Agreement</td>
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<tr>
<td>Role</td>
<td>Description</td>
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<td>--------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Investors</strong></td>
<td>Individuals or groups investing capital in energy projects, potentially including third-party models like the &quot;Green Investor.&quot;</td>
</tr>
<tr>
<td><strong>Service Providers</strong></td>
<td>Companies or entities that provide the hardware and software needed for energy systems, including Solar PV, BESS, and management software.</td>
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2 Mapping Business Models (BM) for SPENs

2.1 Energy-related business modes for SPEN

At its core, "mapping business models" refers to the process of creating a detailed representation or blueprint of how a business (or, in this case, SPEN) operates and generates economic value. This includes various components such as assets, revenue streams, value propositions, customer segments, and partnerships.

The purpose of SPEN includes providing high-quality housing solutions by constructing, renovating and provision of dwellings for sell or rent. These dwellings provide multiple benefits for residents, such as enhanced comfort, access to shared services, a sense of community, among others. Moreover, SPENs also contribute to society by reducing GHG emissions, lowering pollution levels, and contributing to energy security. Unlike other advanced neighbourhoods, SPENs stand out by their positive net energy balance. They can produce more local electricity than they consume throughout a year. Based on this characteristic, SPENs can gain economic benefits by implementing business models around their excess electricity. The adoption of these BMs will impact the economic attractiveness of SPENs and, consequently, their market uptake and economic sustainable.

The business models considered in this report look at the excess energy motivated by developing smart energy systems that efficiently use and promote on-site renewable energy. Energy-related business models are centred on understanding how this produce, distribute, consume, and even trade or sell energy.

Therefore, the report’s prime focus is to present the intricacies of energy management, the financial architecture underneath these operations, the sources of revenue, and potential areas of inefficiency or vulnerability. By laying out all these aspects, stakeholders can get a clearer picture of how the entire system functions. Stakeholders can be anyone from community members and local governments to investors and energy providers.

From our detailed mapping, stakeholders can gain insights into:

**Dynamics:** This refers to the flow of energy, money, and information within/outside the community.
- How is energy distributed among members?
- Are there any bottlenecks?
- Is there an opportunity for trading energy with external entities?

**Potential:** This touches on the capacity of the SPEN to grow or evolve.
- Can they incorporate more renewable sources?
- Could they expand their infrastructure or form partnerships with neighbouring communities?
- Is there potential to attract more members or investors?

With a detailed map in hand, stakeholders can critically analyse the business model to pinpoint:

- **Strengths:** What is the SPEN doing right? This could be efficient energy production, a strong sense of communal responsibility, or even profitable energy trading mechanisms.
- **Opportunities:** What are the untapped possibilities? Maybe there’s potential for integrating newer technologies, forming strategic partnerships, or tapping into government grants and incentives.

Once these are clear, stakeholders can develop strategies to:
• Increase the efficiency of energy generation, possibly by upgrading technology or diversifying energy sources.
• Ensure energy consumption is sustainable and aligned with the community's goals, potentially through energy-saving measures or educational programs.
• Explore ways to maximize benefits from any surplus energy, be it through storage, sales, or community development initiatives.

2.2 Why business model matters?

The transition towards renewable energy solutions has many complexities that span multiple dimensions—financial, regulatory, technical, and social. These details make the exploration of versatile business models important. This study aims to delve into these multifaceted challenges by scrutinizing a range of business models tailored to address specific issues.

Tailoring Strategies to Geography

The availability of can vary significantly based on geographic locations, thereby necessitating different strategies tailored to each locality's specific conditions. This further underscores the need for a variety of business models that can adapt to diverse geographic and resource constraints. In this context, the advent of offers an avenue for increased local self-consumption of decentralized renewable energy generation. While these systems are not yet economically profitable for most private users, a growing interest in new technologies and a demand for local green electricity are driving investments in small storage systems. The costs are also on a downward trend, particularly for lithium-ion batteries. A study by the International Renewable Energy Agency in 2017 indicated a range of costs between USD 145 per kilowatt-hour (kWh) and USD 480/kWh depending on the battery chemistry (IRENA, 2017). However, by 2030, these costs are predicted to fall significantly, below USD 308 per kWh, making them an increasingly viable option (Wesley Cole and Akash Karmakar, 2023).

Financial Barriers and Investment Opportunities

Access to capital remains a significant barrier for both individual and collective investments in renewable energy assets. However, the "Community-based shared assets" model shows promise. In this approach, community members pool resources to invest in distributed energy resources like solar PV panels and energy storage devices. This collective effort offers several advantages:

Enhanced Investment Capacity: Collective contributions can meet minimum capital requirements, opening up investment opportunities that might be

Alongside, Power Purchase Agreements (PPAs) offer another avenue for overcoming financial barriers. In this setup, partnerships range from BESS suppliers to financial institutions, each playing a distinct role in bolstering the system's overall efficiency and resilience. For example, BESS suppliers ensure that energy storage is efficient and meets the demands of the network, while financial institutions provide the essential capital, thereby diversifying the risk and investment portfolio in the renewable energy sector.

Roof Renting: A Win-Win for Homeowners and Tenants

A different angle comes from the "Green Investor", targeting apartment buildings with non-habitable roofs in communities resistant to renewable investments. The inability to reach consensus for installing solar panels in residential communities often comes from diverse financial capabilities among homeowners and a lack of direct benefits for tenants. A third-party entity provides the capital and management for solar installations, offering either fixed or variable compensation based
Social Dynamics and Community Engagement

Community investment models can foster social inclusion by allowing even economically disadvantaged members to participate (addressed in BM: Community shared assets). They can also enhance community cohesion and responsibility towards sustainable energy use. However, these models bring their challenges, such as the equitable allocation of costs and benefits among members, an issue that has broad implications for the sustainability of such initiatives.

Another transformative approach under consideration is that of centralised energy management systems, which allows optimal management of distributed energy assets (addressed in BM: Self-consumption and BM: Local Markets). The adoption of collective energy sharing can serve multiple purposes, from incentivising local renewable energy production to enhancing grid stability and flexibility by receiving price signals from DSOs. In essence, it allows for a more democratised, efficient, and secure energy landscape. Usually, this is enabled by advanced smart grid infrastructure, incorporating IoT devices, smart meters, and automated demand-response systems. These technologies not only facilitate real-time monitoring but also enable more responsive and efficient energy flow management.

However, while energy-sharing offers numerous advantages, it is not without challenges. These include various regulatory, technical, and market design complexities that must be navigated carefully for successful operation and adoption.

Regulatory Complexities and Electricity Billing

The electricity billing adds further layers to the regulatory complexities. Retailers and end-users alike face financial implications through various charges. An interesting component is the electricity bill, which comprises costs for both electricity and grid rent. These can vary significantly between countries and are subject to taxation policies, often influenced by market conditions, such as the high wholesale prices observed in the second half of 2022. The distribution of these taxes can vary significantly from country to country, as illustrated in Figure 1 provided in the European Union Electricity Price Statistics (EUROSTAT, 2023.). Note that the prices in the figure are from the second half of 2022, which was a year with several countries subsidising electricity consumption due to very high wholesale prices (including Netherlands and Norway).
If sharing of PV production is allowed, this arrangement can lead to significant tax savings. The electricity that is produced by the shared PV system and is consumed within the community. Therefore, it doesn’t incur grid fees or energy taxes, which are generally calculated based on the amount of electricity drawn from the public grid. By generating and consuming electricity within the community, households and businesses can avoid paying VAT on that portion of their energy usage. If energy sharing is legally allowed, then ‘self-consumption’ is the most logical financial model which also reduces taxes. Consumers find the self-consumption model straightforward as they can easily see the reduction in taxes reflected in their energy bills.

Market Volatility and Financial Risks

The volatility of energy prices introduces another layer of complexity. Market prices can significantly fluctuate, creating financial risks for stakeholders involved, especially third-party investors. Business models that can adapt to these market conditions are crucial to mitigate such risks and ensure the feasibility of renewable energy projects. A specific benefit of SPENs is that, through self-consumption, reducing the dependency from the grid implies avoiding the risk of the market fluctuations. On the other hand, if SPENs are involved in selling energy to third parties (e.g., through PPA agreements), price volatility should be considered when analysing the risks of the business model.

Regulatory Complexities and Penalties in Energy Balancing Markets

The energy balancing market introduces another dimension to the regulatory complexities. Retailers can face financial penalties if their scheduled energy does not align with actual consumption. These imbalance charges, imposed by grid operators or regulatory bodies, are designed to ensure grid stability but can accumulate into significant expenses for retailers over time. This risk makes the need for adaptive business models that can navigate the balancing market’s intricate landscape of regulations and penalties.

The SPEN can offer solutions to retailers to manage such imbalances. SPEN's mix of solar PV systems, energy storage facilities, flexible household devices and energy management systems can help the retailer adjust to
unexpected changes in PV output, avoiding penalties. This flexibility, however, requires excellent communication and coordination between the retailer and the community, underscoring the need for sophisticated business models that can facilitate such interactions.

1. **Day-Ahead Market (DAM):** The Day-Ahead Market (DAM) is an electricity trading market where participants buy and sell energy for delivery on the next day. Transactions in this market occur 24 hours before the actual delivery of power. The goal of the DAM is to allow market participants to hedge their risks and plan their energy production or consumption based on predicted prices. Prices in this market are usually more stable because they’re based on anticipated supply and demand conditions.

2. **Intraday Market:** The intraday market allows market participants to adjust their positions in the hours leading up to real-time. This is after the day-ahead market has cleared and schedules have been set, but before the actual delivery of electricity. The intraday market is typically continuous, meaning that trades can be made at any time up until shortly before delivery. The purpose of the intraday market is to allow market participants to respond to changes in conditions (such as changes in demand or generation capacity) that occur after the day-ahead market has cleared.

3. **Balancing Market:** The balancing market operates in real-time, during the actual delivery of electricity. The purpose of the balancing market is to correct any imbalances between supply and demand that occur in real-time. This is done by the system operator, who can call on flexible resources to increase or decrease their output as needed to balance the system. The prices in the balancing market can be quite volatile, as they reflect the real-time cost of balancing supply and demand.

**How differences between day ahead and real time price can be converted into profitability?**

- Uncertain future markets: The future electricity market is expected to be increasingly uncertain due to factors like the proliferation of electric vehicles (number of EVs, charging capacity increase) which could lead to unpredictable load increases.
- Measures for uncertainty: In response to increasing uncertainty, energy storage and other flexibility measures can be crucial for managing imbalances. Energy storage systems can be used to store excess power during periods of low demand or high generation, and then discharge it during periods of high demand or low generation. This can help to smooth out price fluctuations and reduce the risk of imbalance costs.
- Arbitrage Opportunities: The difference between day-ahead and real-time prices in electricity markets can create opportunities for arbitrage. Market participants can buy electricity at a lower price in the day-ahead market and sell it at a higher price in the real-time market, or vice versa, depending on the price fluctuations. The difference between day-ahead and real-time prices can be leveraged for profitability by managing a portfolio of flexible resources such as demand response programs, energy storage systems, and controllable loads.

**2.3 Emerging BM and trends**

Within the framework of syn.ikia, the overarching objective is to develop SPENs, which necessitate localized energy production to achieve net-positive energy outcomes. The benefits of SPENs to society are manifold, including reduced carbon emissions, localized energy resilience, avoided costs in grid infrastructure upgrades,
and potential cost savings for community members. However, the successful implementation and long-term viability of SPENs hinge on the presence of a robust business model that ensures economic sustainability.

In the realm of SPEN, there is a wave of emerging business models that are transforming the way energy is generated, consumed, and managed. Additionally, there are notable trends within these emerging business models, including the integration of renewable energy sources, demand response programs, and advanced energy management technologies. The main identified business models that hold great potential for community-based initiatives (SPEN) in the project are Self-consumption, Local Energy Markets, Power Purchase Agreement (PPA), retailer/aggregator models, shared ownership of energy assets, and the inter-SPEN concept. By leveraging these emerging business models, SPEN aims to foster numerous benefits:

1. Lower Energy Costs: Once installed, solar PV panels and other renewable energy technologies often produce electricity at a lower cost than traditional energy sources. This can lead to significant savings on utility bills for the community members.

2. Energy Independence: By generating their own power, communities reduce their dependence on purchasing from retailers and the volatility of energy prices. This can provide a measure of financial stability.

3. Revenue Generation: Excess power generated may be sold back to the grid or to other third parties in certain jurisdictions, providing another source of revenue for the community.

4. Grants and Incentives: Governments and other entities often provide grants, tax credits, or other incentives for the installation of renewable energy systems, which can offset initial costs and increase the rate of return on these investments.

These business models are described briefly in the upcoming section, and comprehensive information on their implementation and benefits can be found in section 0.

2.4 Syn.ikia focus and implementation potential.

There is a need to assess the implementation potential of the various business models discussed in this chapter. To address this, an in-depth evaluation of the feasibility and adaptability of these models is undertaken in the following chapter.

The four demo sites of syn.ikia are located in Austria, Netherlands, Spain and Norway. The demo site in Austria (GEWIN Gneis) is a non-profit housing project. Similarly, the demo site of Netherlands is also a social housing project with 39 flats on the Loopkantstraat in Uden. In Norway, the private property developer Arca Nova, has properties for sale in the private housing market in pilot project Verksbyen. In Spain, the pilot consists of social housing apartments managed by INCASÒL. A detailed study of the pilot projects and their macro-analysis of their social, economic, and technological conditions are given in report (Kvellheim, Sandberg, & Cheng).

The feasibility of BMs within demo sites is explored in this section, aiming to determine their alignment with the goals and objectives of the demo sites. The feasibility study of business models within demo sites involves gathering feedback and insights from the individuals actively engaged in the project and stakeholders at different demo sites (Table 1). This feedback provides valuable input on the practicality, effectiveness, and alignment of the BMs with the goals and objectives of the demo sites. Moreover, regulatory compliance also puts perspective as to which BMs are applicable in a particular country. As an instance, collective self-consumption of local energy is viable for all demo sites as all considered countries allow it. As for the distinction between internal and external BMs, this refers to where the value of the BM lies. Models that focus on or
prioritize the sharing, sale, and purchase of energy within SPENs would be considered internal. Those that focus on the export of energy outside SPENs would be considered external.

Table 1 Feedback on implementation potential of the proposed business models in the syn.ikia’s demo sites.

<table>
<thead>
<tr>
<th>Business Model</th>
<th>Category</th>
<th>Demo Norway</th>
<th>Demo Netherlands</th>
<th>Demo Spain</th>
<th>Demo Austria</th>
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<tr>
<td>Collective Self-consumption</td>
<td>Internal</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>P2P Local Energy Market</td>
<td>Internal</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Community Based Shared Assets</td>
<td>Internal</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>SPEN as Retailer/Aggregator</td>
<td>External</td>
<td>Yes</td>
<td>No</td>
<td>Limited</td>
<td>Yes</td>
</tr>
<tr>
<td>PPA</td>
<td>External</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Inter-SPEN</td>
<td>External</td>
<td>No</td>
<td>No</td>
<td>Limited</td>
<td>Yes</td>
</tr>
<tr>
<td>Green Investors</td>
<td>Internal</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>SPEN Grid-flexibility services</td>
<td>External</td>
<td>Maybe</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

By combining feedback from project participants, country relevant policies and rigorous analysis through simulations and studies, the feasibility study provides an evaluation of the suitability of the BMs within the demo sites.
3 Business Models Overview

3.1 P2P Local Energy Markets

Energy sharing between buildings, referred to as P2P Local Energy Markets, presents a transformative approach to energy distribution by promoting an even more efficient energy usage than standard collective self-consumption, as more energy assets can be jointly operated. This enhances the self-sufficiency and resilience of the SPEN, reducing reliance on external energy suppliers. It also allows for greater energy equity as prosumers can set their own prices, usually leading to cheaper rates than traditional utilities.

This model relies on partnerships with Energy Suppliers for the provision of energy, Distribution System Operators (DSOs) for grid integration, and technical experts for system installation and maintenance. Third-party Service Providers offer crucial software solutions for transaction tracking.

The core activities in this model are interconnected, beginning with the installation of smart meters for real-time energy data. These meters inform community demand assessments and enable the development of a software platform for energy trading.

The value proposition of this model is robust, focusing on local energy independence, dynamic pricing, and empowerment of individual community members. It serves a diverse customer base, including households and small and medium enterprises (SMEs).

On the financial front, costs are primarily associated with technology and maintenance, while revenue is generated through transaction fees and software subscriptions.

The table below offers a comprehensive yet concise look at the key aspects of the P2P Energy Trading business model.

Table 2: Business Model Canvas for P2P local market. The perspective is from a software company that delivers services to SPENs.

<table>
<thead>
<tr>
<th>Key Partners</th>
<th>Key Activities</th>
<th>Value Proposition</th>
<th>Customer Segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy suppliers</td>
<td>Installation of Smart Meters</td>
<td>Local Energy Independence</td>
<td>Households</td>
</tr>
<tr>
<td>DSO and other network operators</td>
<td>Measuring the Demand of the Customers and Production Outcomes</td>
<td>Dynamic Pricing</td>
<td>Building Collectives</td>
</tr>
<tr>
<td>Technical Know-how (Engineers,</td>
<td>from Shared Assets</td>
<td>Empowerment of Individuals:</td>
<td>SMEs and Commercial Entities (e.g.,</td>
</tr>
<tr>
<td>Electricians)</td>
<td>Software Development of the Platform for the Energy Trade</td>
<td>Optimal Clearing of Energy Trade Within and Between Energy Communities</td>
<td>kindergarten)</td>
</tr>
<tr>
<td>Service Providers (Purchase of</td>
<td>Maintenance of Smart Meters and IT System</td>
<td>Bill Reduction by Allowing Sharing Resources</td>
<td></td>
</tr>
<tr>
<td>Software)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Key Resources</td>
<td>Generation and storage assets (BESS/PV), Smart meters, Software.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.2 Power Purchase Agreements (PPA)

A Power Purchase Agreement (PPA) is a contract between two parties, typically a prosumer and a consumer, where the purchaser agrees to buy electricity from the producer for a specified period (as in a couple of years etc.) at a predetermined price. PPAs are commonly used in the renewable energy sector, where a renewable energy project developer sells the energy generated from a renewable source, such as wind or solar, to a utility. The PPA sets the terms for the sale of electricity, including the price, payment terms, and other conditions such as the quantity and quality of electricity to be delivered. PPAs are important for renewable energy projects because they provide a stable revenue stream for the project, which helps attract financing and make the project economically viable. For purchasers, PPAs provide a reliable source of electricity at a predictable price over the term of the contract, as well as marketing value for buying ‘green energy’. Figure 2 gives the illustration of the fixed tariff PPA and the players involved.

The core activities in this model—from monitoring PV production to market analysis and risk management—are intricately interconnected. Real-time monitoring feeds data into demand forecasting algorithms, which in turn aids in energy balancing. This series of activities is instrumental in achieving the model’s primary value proposition: providing a reliable and stable source of renewable energy at a predictable cost.

By offering reliability and price stability, this model aims to attract a diverse customer base, from large corporations to educational institutions. The cost structure and revenue streams are designed to ensure long-term sustainability. Initial costs such as BESS installation are often offset by stable revenue streams like energy sales to buyers at predetermined prices.

After this comprehensive overview, the table below provides a quick-reference guide to the key components of the PPA business model:

<table>
<thead>
<tr>
<th>Cost Structure</th>
<th>Revenue Streams</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Technology and ICT cost (hardware and software)</td>
<td>• Transaction Fees</td>
</tr>
<tr>
<td>• Installation, repair, and maintenance expenses</td>
<td>• Remuneration for software subscription</td>
</tr>
<tr>
<td>for hardware and software</td>
<td>• Consultation Services</td>
</tr>
</tbody>
</table>

*Figure 2: Illustration of PPA concept, with SPEN selling PV generation to outside consumer.*
### Table 3: Business Model Canvas for Power Purchase Agreements.

<table>
<thead>
<tr>
<th>BUSINESS MODEL CANVAS: PPA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Key Partners</strong></td>
</tr>
<tr>
<td>• BESS Suppliers</td>
</tr>
<tr>
<td>• Energy Management</td>
</tr>
<tr>
<td>Software Developers</td>
</tr>
<tr>
<td>• Local Utilities/Grid</td>
</tr>
<tr>
<td>Operators</td>
</tr>
<tr>
<td>• Financial Institutions</td>
</tr>
<tr>
<td>• Maintenance and</td>
</tr>
<tr>
<td>Service Providers</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Cost Structure</strong></td>
</tr>
<tr>
<td>• PV and BESS Installation</td>
</tr>
<tr>
<td>• Operational &amp; Maintenance Costs of PV and BESS</td>
</tr>
<tr>
<td>• Balancing Charges</td>
</tr>
<tr>
<td>• Battery Degradation</td>
</tr>
</tbody>
</table>

### 3.3 SPEN as a Retailer/Aggregator

Market-based tariffs have proven their efficiency in several countries already (e.g., Spain, Norway), although posing a challenge to retailers’ forecast accuracy of demand as consumers’ reactions to price signals need to be accounted for. Additionally, the rise of distributed energy resources (DERs) entails difficulties estimating the net load of prosumers who generate and store energy. To tackle this conflict, prosumers and consumers form an citizen energy community (CEC) can also participate in wholesale markets without relying on an external retailer. To gain profits, and as a cooperative retailer, the individual supply-demand decisions of a SPEN can be pooled, and jointly optimized to be interfaced with the market. In particular, SPEN can help through market design allowing community household to trade with their peers or the wholesale market and thereby empower end-users aggregated in a local energy community to become their own retailer. The future market reforms, proposed within EU, would also allow increased consumer participation in ancillary market (Energy, 2022)

Balancing and flexibility services are integral to the modernization and reliability of energy grids, especially within the context of SPEN. Collaboration with Transmission System Operators (TSOs) and Distribution System Operators (DSOs) helps regulate the balancing markets, while Energy Market Aggregators pool flexibility resources. For instance, Software & Data Analytics Providers are crucial for real-time monitoring and PV forecasting, and Financial Institutions offer the necessary capital for BESS installations.

Core activities, such as Energy Forecasting and Real-time Monitoring, are interconnected and aim to predict and balance PV generation and demand efficiently. These activities ultimately support the value proposition of ensuring grid reliability, quick response times, and the integration of more renewables.
This model targets a broad customer base, from TSOs and DSOs to neighbouring communities that can benefit from enhanced grid stability. The cost structure is designed for long-term sustainability, including both infrastructure investments and operational expenditures. Revenue is generated not just from balancing services fees but also from participation in the balancing market and offering flexibility services to aggregators.

For a more detailed look into the various components of the balancing services business model, refer to the table below:

Table 4: Business Model Canvas for SPEN as a Retailer/Aggregator.

<table>
<thead>
<tr>
<th>BUSINESS MODEL CANVAS: SPEN as a Retailer/Aggregator</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Key Partners</strong></td>
</tr>
<tr>
<td>• Transmission System Operators (TSOs) &amp;</td>
</tr>
<tr>
<td>• Distribution System Operators (DSOs)</td>
</tr>
<tr>
<td>• Energy Market Aggregators</td>
</tr>
<tr>
<td>• Software &amp; Data Analytics Providers</td>
</tr>
<tr>
<td>• Financial Institutions</td>
</tr>
<tr>
<td>• Maintenance and Service Providers</td>
</tr>
<tr>
<td><strong>Cost Structure</strong></td>
</tr>
<tr>
<td>• Infrastructure Investment</td>
</tr>
<tr>
<td>• Operational Expenditure</td>
</tr>
<tr>
<td>• Market Transaction Expenses</td>
</tr>
</tbody>
</table>

3.4 Community-based shared assets in SPENs

New installations of heat pumps, solar PV or BESS are significant investments. By sharing the ownership, community members can distribute the initial costs and ongoing maintenance expenses. This makes the technology more accessible to individuals who might not have been able to afford it otherwise. Shared energy assets allow the community to generate a significant portion of their energy needs locally, reducing the reliance on external energy providers and the electricity markets.

Both the investment and operational costs should be distributed among owners. Similarly, if SPENs generate revenues by selling services or excess power to external actors, the asset owners must agree on sharing the benefits. To do so, the community members require the adoption of methods to allocate the profit fairly.
Ensuring a fair cost allocation is a critical element in fostering equitable energy sharing within SPEN. Thus, in this business model we propose a community to partner with a software company that guarantees the automatization of this process. Table 5 shows the business model canvas from the perspective of the software company.

The core activity of the company is to guarantee the appropriate allocation of the cost in each resident electricity bill by installing the required hardware such as smart meters, establishing a contractual agreement with the Energy Supplier and the DSO, as well as the design of the allocation method procedure. Hence, key partnerships include energy suppliers, DSOS, technical experts. The latter includes engineers and electricians which are indispensable for system integration and maintenance.

The value proposition for the SPEN is multi-faceted, focusing on stable customer engagement, and tariff optimization. It aims to serve a varied customer base, including individual community members and housing associations.

Financially, the cost structure is geared towards long-term sustainability and primarily involves smart meter installation and IT system maintenance. The revenue generated for the company would be through software subscriptions paid by the customers and consultancy services that help in the reduction of consumer electricity bill.

**Table 5: Business Model Canvas for the Community-based shared assets. The perspective is from a software company that delivers services to SPENs.**

<table>
<thead>
<tr>
<th>BUSINESS MODEL CANVAS: Community-based shared assets</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Key Partners</strong></td>
</tr>
<tr>
<td>• Energy suppliers (establish contracts)</td>
</tr>
<tr>
<td>• DSO and other network operators</td>
</tr>
<tr>
<td>• Technical Know-how (Engineers, Electricians)</td>
</tr>
<tr>
<td><strong>Key Activities</strong></td>
</tr>
<tr>
<td>• Installation of Smart Meters</td>
</tr>
<tr>
<td>• Measuring the Demand of the Customers and Production Outcomes from Shared Assets</td>
</tr>
<tr>
<td>• Software Development of the Cost Allocation Method</td>
</tr>
<tr>
<td><strong>Value Proposition</strong></td>
</tr>
<tr>
<td>• Billing Services to Customers that Ensure Fair Allocation of the Benefits</td>
</tr>
<tr>
<td>• Stable Coalitions Where Members are Ensured Fair Treatment</td>
</tr>
<tr>
<td><strong>Customer Segments</strong></td>
</tr>
<tr>
<td>• Energy community members</td>
</tr>
<tr>
<td>• Housing Associations</td>
</tr>
<tr>
<td>• Enterprises</td>
</tr>
</tbody>
</table>
• Maintenance of Smart Meters and IT System
• Billing

### Key Resources
Generation assets, Smart meters for community and each consumer, Software.

<table>
<thead>
<tr>
<th>Cost Structure</th>
<th>Revenue Streams</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Investment cost in smart meters</td>
<td></td>
</tr>
<tr>
<td>• Installation, repair, and maintenance expenses for hardware and software</td>
<td>• Remuneration for software and hardware subscription</td>
</tr>
<tr>
<td></td>
<td>• Payments for consultancy services</td>
</tr>
</tbody>
</table>

### 3.5 Inter-SPEN concept

In continuation of the Self-Consumption and Tax Exemption BM, within community members (households), the energy sharing between separate communities can also entail financial benefits. For instance, communities can trade energy to balance out their energy supply and demand, also reducing their dependence on the energy markets and its price volatility. If one community has an abundance of energy, it can sell this to others, which may also indirectly lower the electricity prices. Moreover, by sharing and trading energy, communities can potentially avoid the price spikes that can occur in traditional energy markets. Finally, inter-SPEN energy sharing can also stimulate local revenue generation to sustain long-term maintenance and operation of shared energy resources such as solar PV or BESS. It also keeps revenue within the local area (town, city etc.) rather than paying external entities.

### 3.6 Green Investor

The "Green Investor" business model focuses on investing in renewable energy production in apartment buildings. It addresses challenges like a lack of consensus and capital in the community. The model involves a third party installing and paying for smart meters and solar panels on the roofs. The smart meters are installed to measure energy consumption in each dwelling. The third party then play a role of an energy provider by selling electricity and purchasing electricity.
Green Investors serve as a catalyst for sustainable energy within SPEN communities by investing in rooftop solar installations. Their partnerships extend from community/building owners to energy markets and Distribution System Operators (DSOs). Each partner plays a critical role; for example, community owners provide the physical space for installations, while DSOs facilitate the permitting process and integration of these energy assets into the grid. Core activities encompass the entire energy value chain—from installation and maintenance of smart meters and PV systems to market participation for energy sales. These activities are supported by various resources, including generation assets like PV systems and BESS, as well as specialized software. The value proposition is designed to appeal to a broad range of stakeholders. For community members, the benefits include access to cheaper, clean energy and a simplified enrollment process. For building owners, the value lies in generating revenue from otherwise unused rooftop spaces. Financially, the model is built on a dual revenue stream: selling energy directly to SPEN members and participating as a producer in the broader energy market. Costs are primarily upfront and include investments in PV systems and technology. The Table 6 below provides a summary of the Green Investors business model.

Table 6: Business Model Canvas for Green Investor. The perspective is from a third-party investor that delivers services to SPENs.

<table>
<thead>
<tr>
<th>BUSINESS MODEL CANVAS: Green Investor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Key Partners</strong></td>
</tr>
<tr>
<td>SPEN Community/Building Owners/Housing Associations</td>
</tr>
<tr>
<td><strong>Key Activities</strong></td>
</tr>
<tr>
<td>Installation of smart meters and PV system</td>
</tr>
<tr>
<td><strong>Value Proposition</strong></td>
</tr>
<tr>
<td>Access to cheaper energy</td>
</tr>
<tr>
<td><strong>Customer Segments</strong></td>
</tr>
<tr>
<td>Households</td>
</tr>
</tbody>
</table>

| **Key Resources**                   |
| Generation assets (BESS/PV), Smart meters, Software. |

| **Cost Structure**                  |
| Upfront cost of PV system | Technology and ICT cost (hardware and software) | Cost of rooftop rent |

| **Revenue Streams**                 |
| Energy retailer role | Energy producer role |

3.7 Assumptions of the business models adjusted to syn.ikia demo projects

In developing BMs for syn.ikia demo sites, several assumptions are made to guide the planning and implementation processes effectively. These assumptions are based on a comprehensive understanding of the
demo site’s context, goals, and available resources. Some common assumptions that may be considered in the business models and demo sites include:

- **Renewable Energy Potential**: Assumptions are made about the availability and potential of renewable energy sources within the demo site, specifically pertaining to solar PV generation. The simulated PV generation profile assume the average solar irradiance for the region, considering seasonal and weather variations. In general, the simulations consider a higher capacity utilization factor (CUF) of PV generation for warmer climates such as of Spain and relatively lower CUF for Norway. Therefore, the studies are based on average yearly/daily solar irradiance of each area. Moreover, the efficiency of the PV panels can also vary greatly due to several factors such as the age and quality of the panels, and the angle and direction they are installed. A detailed study of the impact of such factors on the potential of the proposed business models is out of scope of this report.

- **Infrastructure Readiness**: Assumptions are made regarding the existing infrastructure and its readiness to support the implementation of the proposed BMs. This includes considering the availability of transmission lines, grid connectivity, grid generation capacity and BESS capabilities shared among all households.

- **Regulatory Environment**: Assumptions are made about the regulatory framework and policy support for renewable energy and community-based initiatives within the demo site.

- **Cost Factors**: Finally, the business models also require assumptions on the various costs, including the cost of installing and maintaining the PV panels and BESS, the varying electricity tariff, and the price at which energy can be traded within the community. These cost factors can also vary based on the procurement process through an energy systems provider, which would also impact the community-wise levelized cost of electricity (LCOE). Therefore, some general assumptions on the capital and O&M costs of PV, BESS systems are taken to make comparative case studies of different business models on different countries/demo sites.
4 Syn.ikia Business Models: Analysis and results

In this chapter, we present the analysis and results of our study on business models in the context of SPENs in syn.ikia. Through thorough data collection and analysis, we gained valuable insights into the strengths, weaknesses, and opportunities associated with different business models. Our findings reveal key factors that contribute to the success and effectiveness of these models, such as P2P energy trading, PPAs, retailer/aggregator models, and community-owned assets. By delving into the analysis and results, we aim to provide a comprehensive understanding of the business model landscape, enabling stakeholders to make informed decisions, optimize energy practices, and foster energy resilient SPENs.

Case studies scope in each BM

Before proceeding with the introduction of each BM, we provide an overview of the scope of case studies covered in the section.

- **BM 0** – Collective self-consumption: this is a reference business model where is look on how residents in SPENs can reduce their electricity bill by maximising from their own self consumption. In this energy shared inside the limits of the same building.
- **BM 1** – Local Market: The study on P2P energy trading is specialized for the Austrian market at section 4.2. We have presented a detailed mathematical formula to underpin the simulation studies conducted for this specific case.
- **BM 2** – Power Purchase Agreement: section 4.3 presents a comprehensive methodology and simulation studies applicable to general cases. Additionally, a cross-country comparative analysis has been carried out to understand how PPAs vary across different national landscapes.
- **BM 3** – SPEN as Retailer/Aggregator: The general method for balancing is presented in 4.3.1. A qualitative analysis has also been performed to compare balancing methods across different countries at section 0.
- **BM 4** – Community-based shared assets: For community storage/fair allocation/cost allocation methods are discussed at section 4.4. First, the exploration of cost allocation for one building is carried out in each four countries. Then, the Austrian demo in Gneis is used to empirically validate the discussed concepts.
- **BM 5** - Green investor: The BM is discussed at section 4.5. Results for all syn.ikia’s countries are presented, specifically focusing on designated demo sites for more granular insights.

4.1 Business model 0 — Collective self-consumption

4.1.1 Business model description

This initial section dives into the application of the collective self-consumption business model where residents in SPENs can reduce their electricity bill by maximising from their own self consumption of RE and selling the excess to the grid. This involves energy sharing inside the same building. Throughout this section, we explore the potential savings offered and examine the specific regulation at each country. A case study is developed to explain the benefit of adopting storage technologies for agents adopting this BM.

4.1.2 Background and methodology

When evaluating the potential savings from a collective self-consumption model, it is important to consider the diverse tax structures across different countries. Each nation levies unique taxes and fees on energy, which
can significantly impact the potential for savings. The collective self-consumption model allows consumers to save on grid fees, taxes, and VAT, which will directly lower their energy bills. However, the magnitude of these savings can vary considerably from one country to another due to differing tax rates and regulations. To accurately assess and compare these savings, we must delve into the specific energy tax structures of each country.

Moreover, this BM needs real time energy monitoring with good time resolution (e.g., 15 minutes, 30 minutes) at the location of each participating entity. It is imperative that both the real-time power consumption of participants and the contemporaneous PV power production are tracked. Furthermore, the PV system itself must have a dedicated metering point to record the energy it injects into the system. Billing procedures between the operator and the participants are conducted independently of the network operator and hinge on contractual agreements. The network operator provides the necessary billing data to the operator to facilitate this process.

**Norway**

Norway has three types of taxes on electricity consumption:

- **Excise tax:** A fixed fee per electricity volume consumed (approx. 15 EUR/MWh)
- **Enova tax:** A fixed fee per year independent on electricity consumption (approx. 80 EUR/yr)
- **Value Added Tax:** 25% of total electricity bill.

Note that the Enova tax does not increase incentives for self-consumption because it is independent on electricity consumption. In addition to the taxes, grid fees are partly based on the net electricity consumption within each hour in Norway. This means that self-consumption also yields cost savings on parts of the grid fees in Norway.

Norway has high taxes, but support from government in recent years (2021-2023) somewhat offsets the tax, thereby reducing the net electricity costs to end consumers. If there is no support from the government this could provide a significant disincentive for selling excess energy because the value of self-consumption is increased. It might encourage the community to consider investing in a BESS and PV production to store excess energy for later use, thereby avoiding the high energy tax.

For electricity surplus fed into the grid, Norwegian customers do not pay fixed grid fees if the surplus feed-in is below 100 kW ("Plusskundeordning"). The surplus feed-in is still subject to a marginal loss payment, however, this payment is usually small. Sometimes, the marginal loss payment is negative, meaning there is a feed-in payment to the customer. This is in situations where the alternative electricity supply would cause greater marginal losses than the surplus feed-in.

From October 1st 2023, it is allowed in Norway to self-consume local production between several customers if they are located on the same address (same gårds- og bruksnummer), typically within an apartment building. The same conditions apply as for self-consumption for single customers, and it is possible to share self-consumption from installations up to 1000 kW.

**Spain**

In Spain, self-consumption is defined in the Real Decreto 244/2019 as the consumption of electrical energy from production facilities that are close to and associated with the consumers' facilities and includes consumption by one or more consumers (collective self-consumption). The taxation system in Spain
distinguishes two types of collective self-consumption modalities subject to different tax obligations. The two modalities are:

- **Self-consumption without excess electricity**: the producer does not inject electricity to the distribution or transmission grid.
- **Self-consumption with excess electricity**: in this category excess generation from producers is injected to the grid. Within this category, the producer might be economically compensated or not.

Nowadays, there are three taxes applied to self-consumption: “Impuesto Especial sobre la Electricidad” (IEE) (Special Tax on Electricity), “Impuesto sobre el Valor de la Producción de la Energía Eléctrica” (IVPEE) (Tax on the Value of Electricity Production) and the Value Added Tax (VAT).

The IEE is regulated by the “Ley 38/1992, de 28 de diciembre” and applies to those generators which supply electricity to consumers or to themselves. In other words, they are under the Self-consumption with Excess Electricity modality. However, it does not apply to producers with capacities lower than 100 kW or any facilities using renewable technology, cogeneration and waste. The tax rate is 5.1127%.

Moreover, the IVPEE is regulated in “Ley 15/2012, de 27 de diciembre” which sets the taxation measures for sustainable energy. It applies to all producers who inject power to the grid, independently from the type of facilities. The tax base is constituted by the total benefit of the taxpayer for the production and injection to the electrical system. The tax rate is 7%.

The VAT in Spain is determined by “Ley 37/1992, de 28 de diciembre” and applies to all producers, including small-scale self-consumers. This tax applies as any excess producer is considered to obtain economic benefits. The tax rate in this case is 21%, although it can be reduced to 10% if the installation of renewable technologies is considered part of a refurbishment project, the production capacity of 10 kW or when the monthly average price in the spot market is above 45€/MWh. If the producer is subscribed to the modality of self-consumption without excess, the VAT is not applied.

Concerning grid tariffs, the Real Decreto 244/2019 de 5 de abril states that consumers satisfying their demand from electricity generated by self-consumer producers are exempted of paying grid tariffs (regulated in Real Decreto 1544/2011).

Moreover, the calculation of energy consumed for collective self-consumption included in the Spanish regulation involves a few steps:

- **Net Hourly Generated Energy**: First, calculate the total energy generated by the production facilities associated with your consumption group for each hour.
- **Net Hourly Consumption**: Determine the total energy consumed by all members of the collective self-consumption group for each hour.
- **Net Balance Calculation**: Subtract any excess energy (if the net generated energy exceeds the consumed energy) from the total generated energy to get the net energy consumed by the group.
- **Distribution Among Consumers**: The net energy consumed by the group is then distributed among the consumers based on their respective consumption patterns or any pre-agreed sharing mechanism.

The distance permitted between the production asset and the consumer associated for consideration of self-consumption is limited to a range of 2 km, as is the case in France and Portugal.
As of 2011, the Dutch renewable energy sector has been predominantly guided by the *Stimulering Duurzame Energieproductie* (SDE+) premium feed-in scheme. This policy was initially devised with yearly net metering and primarily catered to small-scale residential consumers with electrical installations rated at 3x80 Amp. One notable aspect of the policy was the direct financial benefit of renewable installations, as the revenues obtained from these energy sources directly reduce electricity bills.

In 2014, the policy underwent crucial modifications. One significant amendment eliminated the upper limit on prosumers' capability to counterbalance excessive photovoltaic (PV) generation against grid electricity consumption, a threshold previously set at 5 MWh per annum. Simultaneously, new regulations were instituted allowing third-party ownership of the energy generation assets and capping the allowable PV size to 15 kW. These changes aimed to create a more conducive and inclusive environment for the promotion and utilization of renewable energy sources.

However, the regulatory landscape underwent substantial alterations. The Dutch government decided to incrementally phase out the existing yearly net metering law from 2023 (now 2025). This approach decreases the surplus electricity eligible for net metering every year. This measure will ultimately culminate in a complete phase-out by 2031 towards a quarter-hourly imbalance settlement. The underlying rationale for this modification lies in the reduced tax revenue derived from electricity usage and the pressure on the grid. Notably, households without solar panels contribute Value Added Tax (VAT) for each kilowatt-hour consumed, while households equipped with solar panels can significantly minimize their VAT obligations due to the net metering law. A consequence of this political decision is the promotion of storage technologies, which will be the most direct mechanism to benefit from the excess power. A second option is demand-side flexibility to maximise self-consumption by installing smart and energy management systems. An alternative could be the proliferation of new BMs that allow for the generation of profit from surplus energy while ensuring tax compliance. Business models like Power Purchase Agreements (PPAs) and P2P local markets, as discussed in this report, could serve as viable solutions in this context.

Nevertheless, the residual percentage of excess power not subject to net metering holds value, as households will still receive compensation for this electricity, albeit at a rate inferior to the cost of the electricity they consume. The government has mandated a minimum remuneration for power returned to the grid, termed the 'reasonable compensation' (or 'redelijke vergoeding' in Dutch). Although the precise amount of this 'reasonable compensation' remains unspecified, it is suggested in policy proposals that it should not be less than 80% of the basic cost of electricity, exclusive of all taxes and surcharges.

**Austria**

In 2017, Austria introduced Collective Self-Consumption (CSC) through an amendment to the Green Electricity Act and the Electricity Act (ElWOG), thereby facilitating the sharing of electricity within multi-apartment buildings and other settings that were previously bounded by restrictions.

This amendment has led to the development of the Building-Based Generation Plant model for CSC, which distinguishes itself by relying solely on the building's internal electrical grid. This approach effectively eliminates the costs associated with distributing energy within the building. However, it is important to note that this scheme has a geographic constraint, as it does not permit the transmission of generated energy via the grid owned by the Distribution System Operator (DSO). The management of this alternative energy system can either be overseen by the building's residents themselves or delegated to a third-party entity. The operation of solar energy within this framework is guided by a formal framework agreement that is signed by both the owners of the photovoltaic (PV) system and the inhabitants of the building.
The variation in tax policies across different countries has a considerable impact on the potential value of a BESS. SPEN should conduct comprehensive studies, using historical data, to understand these impacts more accurately. Additionally, the years from 2020 to 2022 saw increased fluctuations in market clearing prices and day-ahead prices due to mismatches in energy supply and generation. To accommodate these price fluctuations, various tax incentives have been provided by countries. This emphasizes the importance of understanding the tax landscape and its influence on the value of energy storage systems like BESS.

We develop an optimisation model to study the benefits of BESS. The algorithm implements the practise of self-consumption by importing power \( p_t^{\text{import}} \) subject to spot price \( \text{Price}_t \) and taxes whereas by exporting power \( p_t^{\text{export}} \) the monetary benefits are subject to only spot prices. Then a constraint is set to make sure the agent is in balance at all times.

\[
\min \sum_{t \in T} p_t^{\text{import}} (\text{Price}_t + \text{taxes}) - p_t^{\text{export}} \text{Price}_t
\]

\[
p_t^{\text{import}} + p_t^{\text{PV}} + p_t^{\text{batt}} = p_t^{\text{export}} + p_t^{\text{batt}} + p_t^{\text{load}}
\]

### 4.1.3 Case studies and Results

A case study to exemplify the basics of self-consumption in SPENs is explained in the following section. Figure 5 shows a scenario where the SPEN generates its own electricity with PV production, reducing the amount of electricity imported from the grid, which is subject to taxes and other grid charges. Moreover, a BESS allows the community to store excess/surplus energy produced during peak PV production hours (10:00 – 14:00). This further decreases the operational costs as lower grid imports imply additional savings on taxes and charges.

![Figure 5: BESS charging and discharging dispatch based on varying spot prices, PV generation and loads.](image-url)
In the case where a BESS is available, but taxes are not included (With BESS, tax not included), power is exported to the grid during the day. This happens because exporting power is only subject to the hourly spot prices, and any excess power produced can be sold to the grid to reap financial benefits, i.e. energy arbitrage.

On the other hand, when taxes are also included (With BESS, tax included), both power import and export are reduced to zero. This is explained by the higher costs associated to importing power from the grid with the inclusion of taxes. Therefore, selling power to the grid is less financially beneficial than using excess power to reduce imports from the grid. This stored power can then be used when needed, effectively reducing the need to import power from the grid. Using a BESS to absorb excess PV production and increasing self-consumption proves to be a more beneficial and economical solution for an entire community, especially in the scenario where taxes are included in the power import cost.

When a BESS is not in place and grid imports are subject to taxes (Without BESS, tax included), the SPEN is somewhat restricted in its options for handling excess power production. Considering no storage option, any excess power generated by the community's PV system has to be sold to the grid. Therefore, the case of not having a BESS and the inclusion of taxes underscores the necessity for a BESS. By providing storage for excess PV production, a BESS allows for increased self-consumption, reducing reliance on grid power purchase, and thus mitigating the financial impact of taxes included in power import costs.

![Graphs showing grid power import and export in three case scenarios.](image)

*Figure 6: Grid power import & export in three case scenarios with/out inclusion of energy taxes and BESS.*

### 4.2 Business model 1 — P2P Local Energy Market

#### 4.2.1 Business model description

A P2P Local Energy Market is a democratised energy platform that allows transactional relationships between producers and consumers of energy within members of the energy community. Built on the principles of
digitization and decentralisation, P2P local energy markets leverage technologies that require data analytics to enable a transparent, efficient, and secure energy exchange. The difference with the collective self-consumption model, is that in this one the energy sharing can be done between buildings.

In this paradigm, prosumers who produce surplus energy, typically through renewable energy sources like solar or wind, can directly sell this excess energy to local consumers, bypassing traditional utility intermediaries. This architecture incentivizes local renewable energy production, facilitates energy independence and resilience, and can potentially lead to economic benefits for participants.

Such a market also promotes grid flexibility and stability, as localized generation and consumption patterns can reduce transmission losses and alleviate pressure on central grid infrastructure. The intricacies of price determination in these markets are often influenced by factors such as demand and supply dynamics, grid congestion levels, and the time of energy generation and consumption.

However, while P2P local energy markets offer numerous advantages, they also present challenges related to regulatory frameworks, technical implementation, market design, and participant behaviour that need to be considered for successful operation and adoption.

Implementation of P2P local energy markets can be realized via multiple avenues. Two prevalent methodologies include the deployment of blockchain technology and smart contracts, and the operation of a centralized platform overseeing the energy transactions amongst participants.

Alternatively, energy trading could be facilitated by a centralised platform, which manages the energy transactions among peers. This platform acts as an intermediary, streamlining energy trading by matching supply with demand and ensuring compliance with relevant regulations and standards. Such a model may offer scalability and simplicity, as the platform could provide robust management and oversight capabilities. However, it might not offer the same level of decentralisation as the blockchain-based model.

Regardless of the chosen path, both approaches aim to facilitate efficient, secure, and transparent energy transactions within the P2P local energy market, though they do so via different operational and infrastructural paradigms.

Figure 7: P2P energy sharing of surplus PV generation within community households.

4.2.2 Background and methodology

To examine the economic benefits of P2P, an optimization model was employed with the objective of minimising the operational costs of SPENs. Table 23 in Appendix B describe the variables utilized in conducting the work. The objective function is minimized as the goal is to find the operations that result in the lowest possible costs for the SPENs. The equation provided below defines the objective function.
The balance equation defines the balance between supply and demand. Hence, the sum of energy produced, discharged, imported from the grid, and imported from other peers must equal the demand, charging of batteries, export to the grid and export to other peers. This balance is ensured by the following equation.

\[ PV^{(t,i)} + D^{(t,i)} + Im^{(t,i)} + Imp^{(t,i)} = Dem^{(t,i)} + C^{(t,i)} + Ex^{(t,i)} + Exp^{(t,i)} \]
**P2P constraints**

Finally, the optimisation model also models the trading interactions between peers, such that it is guaranteed that the imported energy from the grid equals to exported energy to the grid for each building and the whole REC.

\[
\sum_{j=0}^{N_p} \text{Imp}(t,i,j) = \sum_{j=0}^{N_p} \text{Exp}(t,i,j)
\]

\[
\text{Im}(t,i,j) = \text{Ex}(t,i,j)
\]

### 4.2.3 Case Study and Results

The business model under examination has been implemented in the case studies of Wir inHAUSer, Berchtesgadener Straße, and GNICE, in compliance with 3 main alternatives of sharing the energy in Austria:

- **Building-Based Generation Plant:** This method allows for the distribution of energy across multi-party buildings. The unique aspect of this model is that it exclusively utilizes the building’s electrical grid, thereby circumventing grid costs for the volume of energy disseminated within the building. However, this scheme is geographically confined as it prevents the transmission of produced energy over the grid owned by the Distribution System Operator (DSO). The management of this alternative can be undertaken by the building inhabitants themselves or with the assistance of a third-party entity. The modus operandi for solar energy management is pursuant to a framework agreement signed by the PV system owners and the building inhabitants. This is equivalent to the collective self-consumption.

- **Renewable Energy Communities:** This system facilitates energy sharing among multiple buildings. There are several incentives to adopt this alternative, including an exemption from electricity tax (1.5 cents/kWh), exemption from Renewable Support Contribution (1.3 cents/kWh), and a third incentive that varies based on the building’s geographical location:
  1. **Local Renewable Energy Community:** Operates on a local network transformer. Any parties sharing a single local network transformer may potentially participate in this community. Participants stand to gain a grid reduction benefit of 57%.
  2. **Regional Renewable Energy Community:** Operates on the substation level. Participants in this community receive a grid reduction benefit of 28%.

- **Citizen Energy Communities:** These communities can operate without any network-level restrictions across Austria but do not receive any grid reduction benefits. These communities may span the concession areas of several DSOs.

The mention categories share several common principles, including environmental, economic, and social benefits. Participation in these energy distribution models is open and voluntary, and the primary objective must not be financial gain. In addition RECs and CECs compared to the first option are legal entities with governance requirements.

The regulatory framework has been deployed as follows:

1. **Building-Based Generation Plant:** This framework was utilized to emulate P2P energy exchanges within individual buildings. The transactional process, hence, took place at the instantaneous spot price, excluding any taxation or fee element, effectively bypassing the DSO meter.
2. Renewable Energy Communities: This framework was employed to emulate energy exchanges from one building to another. Consequently, a subsidy was applied as a discount at a rate of 2.8 cents/kWh to all transactions. The grid tariff subsidy was set at 57% for energy procurement among all buildings comprising the Wir inHAUsEr and Berchtesgadner Straße case studies, due to their shared local grid code (LocalID: 19826395). This principle was also extended to transactions conducted within the three buildings of the GNICE case study (LocalID: 21126471). Given that the case studies Wir inHAUsEr, Berchtesgadner Straße, and GNICE have different local grid codes but share the same regional code (RegionalID: 43854445), a subsidy of 28% was applied to the procurement of energy interchanged between these case studies.

3. Any surplus energy not purchased within the renewable energy community is sold to the retailer at the spot price in real-time.

4. The energy-associated taxation was derived from the spot price, accounting for 18.3% of the invoice, set by legislative authority, and 24.8% to the grid tariff, rendering the fraction associated with energy procurement at 56.9%. This data was extracted from a leading energy and infrastructure service provider in the state capital of Salzburg, Austria.

5. The spot prices employed were the mean prices for the past five years in Austria. An elaboration of the acquisition method can be found in the Green Investor business model section.

6. The dimensions of the simulated PV installations for each case study reflect projected sizes. The hourly demand data was simulated in WP2.

7. No losses in the grid were modelled as they were encompassed within the grid tariff.

8. No preferences were determined with respect to energy management (whom to purchase from or sell to, or battery management)

The case study considers that the three Austrian demos of syn.ikia can share energy to minimise their total operational costs. To reflect the economic benefits of this business model, we explore three scenarios:

1. **Reference Scenario: Measuring the Opportunity Cost**
   - **Methodology**: Omitted any investment in photovoltaic installations, considering it as the baseline for evaluating other options.
   - **Key Insight**: Establishes the "business as usual" metrics, serving as a control for assessing the effectiveness of other models.

2. **No Community Scenario: Collective self-consumption**
   - **Methodology**: Each builds would sell its surplus energy at the spot market price and buy additional energy at the total of the spot price, grid tax, and government tax.
   - **Key Insight**: While this option allows for the monetization of excess energy, it exposes the resident to fluctuating market prices and additional taxes.

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4 https://www.salzburg-ag.at/,
3. **P2P between builds Scenario: Realizing the Power of Community**

- **Methodology:** P2P energy trading among buildings.
- **Key Insight:** Enables a self-sufficient and sustainable community, optimizing the total community energy storage capacity.

**Results**

Figure 8 presents the total annual energy bill in the three scenarios considering different capacity of storage technologies. This computation includes all applicable taxes and profits accrued from selling community surpluses. In this figure, it is evident that the reference option maintains a consistent value of approximately 200,000 euros per year, regardless of the integration of batteries. This constancy is attributable to the absence of any energy input from the demonstrations into these batteries. Conversely, both the P2P Trade and No community renewable investment alternatives are influenced by the incorporation of batteries, particularly affecting the initial 630 Wh of batteries per household. This influence stems from the batteries’ capacity to enhance the flexibility of utilizing the generated renewable energy. The disparity between these latter two options can be attributed to the subsidies mentioned earlier.

![Figure 8: Annual energy bill for the local community from by all buildings in all 3 demos (300 households).](image)

In Figure 9a, the total net balance of the entire community in each year is depicted. This would be equivalent to the annual bill to be paid including investment costs and the final valance of the energy purchase and sale to the market. For this calculation, it is presupposed that the batteries will be replaced twice over the lifespan of the photovoltaic installation (30 years). A discount rate of 0% was applied in the annuity calculation, equivalent to possessing the capital outright as shown in Table 7. This would be similar to not taking out a loan, since the capital is available, or acquiring a loan at 0% interest. On the right can be seen the case for a loan interest rate of 5%. This is a more realistic case and the opportunity cost can be extrapolated from it.
The results show that the participation in a local community’s community provides about 11% higher profit compared to the collective self-consumption alternative (no community). It is also concluded that it can make the difference between profitability or non-profitability. The installation of batteries, specifically of a size around 1.5-2 kWh per apartment in the Austrian case, is economically compelling. However, beyond this capacity, additional installation would not be a cost-effective solution.

### 4.3 Business model 2 — Power Purchase Agreement (PPA)

#### 4.3.1 Business model description

The PPAs involve the supply of clean energy that matches every unit of demand, with measurements taken at frequent time intervals, such as hourly intervals. The new 24/7 clean PPA has been recently introduced and analysed in a recently published report (Diego Hernandez Diaz, Florian Kühn, Martin Linder, Esperanza Mata, 2022). The term "24/7" refers to the continuous and consistent supply of electricity that the buyer is committing to purchase simultaneously from production. This type of PPA has been shown to offer an improvement over traditional PPAs. Typically, PPAs use pay-as-produced renewable energy, which only balance supply and demand on an annual basis and achieve between 40% to 70% decarbonization of the off-taker’s actual electricity consumption. The 24/7 clean PPA addresses both problems by using a combination of renewables and flexible capacity to create a more precise match between renewable energy supply and demand. A more detailed description could be found in Section 3.2.
Motivation to adopt a PPA business model

One of the primary motivations for adopting PPAs is to mitigate the uncertainties and volatilities of the energy market. The market price for electricity, often referred to as the 'spot price', can fluctuate significantly over time. For instance, comparing the spot prices in 2019 and 2022, we observe increased variations in 2022.

In contrast, a PPA offers stability. The price in a PPA is fixed for the contract's duration, often in years. This allows both parties to plan their finances with greater certainty. For the seller, this means a guaranteed revenue stream, which can be particularly beneficial when investing in costly renewable energy infrastructure. For the buyer, this means predictability in energy costs, which can be a significant advantage for businesses seeking to manage their operational expenses.

Objective

The following section quantifies the potential economic benefits for SPENs by offering 24/7 PPAs to external consumers.

4.3.2 Background and Methodology

In the following section, we describe the steps followed to determine the optimal PPA price offered from SPENs to external customers as well as the operational decisions assuming the SPEN has balancing responsibilities.

Step 1) Decide the volume of energy to be traded between the seller and the buyer. This is done by using prediction and subsequent risk-assessment of PV generation at the seller's side.

In this study, we use LSTM (Long Short-Term Memory) on predicting amplitudes and trends instead of predicting absolute (exact) values. Trend prediction involves forecasting the general direction in which the data is moving. For example, if the annual PV production has been increasing over the past few years, a trend prediction would suggest that it will continue to increase in the future. Amplitude prediction, on the other hand, involves predicting the size of the fluctuations in the data. In the context of PV production, this could mean predicting the size of the seasonal variation in the production values.

When it comes to long-term forecasting of PV production, predicting trends and amplitudes can be more useful and accurate than trying to predict exact absolute values. This can be understood by an example. In Norway, which has distinct seasonal trends due to its high latitude, the sun sets very early in the winter, meaning that there's a significant drop-off in PV production during this time. This is a trend that an LSTM model could potentially learn and predict: as winter approaches, PV production will decrease, reaching its lowest point during the months with the shortest days.

Given the prediction of trends and amplitudes in photovoltaic (PV) production, SPENs are able to estimate a range of potential power generation volumes. This information can provide the foundation for negotiating Power Purchase Agreements (PPAs) with potential buyers. However, the uncertain nature of PV production introduces an element of risk to these agreements. To manage this risk, SPENs can adopt different strategic approaches, depending on its risk tolerance.

If SPENs are risk-averse, they may choose to contract a conservative volume that is less susceptible to variations in PV production. For example, it might decide to contract only 50% of the predicted volume. This approach minimizes the risk of underproduction but might also limit potential profits if the actual PV production exceeds the predictions. On the other hand, if SPEN is risk-seeking, it might be willing to contract
a larger proportion of the predicted volume, potentially leading to greater profits if PV production meets or exceeds expectations, but also introducing a higher risk of underproduction.

Figure 10: Risk assessment of 24-hour PV generation to be sold within a PPA contract.

In either case, SPENs can employ statistical tools to quantify the risk associated with different contract volumes. These tools can help determine the probability distribution of possible PV production volumes based on the predicted trends and amplitudes. By understanding this distribution, SPENs can make informed decisions about the volume to contract in its PPAs, balancing the potential profits against the risks of underproduction.

Step 2) The PPA strike price is decided for the set energy volume. This is done considering the levelized cost (LCOE) of the PV plant and the average wholesale market price (Jianzhong, Yue, & Wei, 2023).

In PPAs, the agreed-upon price between an SPEN and a buyer is a crucial aspect of the contract. This price, which remains fixed for the duration of the contract, provides certainty for both parties in the midst of constantly fluctuating market prices. Unlike the hourly or daily changes in the open market, the PPA price remains consistent for an extended period, often exceeding a year. When determining the PPA price, several key factors must be considered:

- **Seller’s Cost**: The seller (i.e., SPEN) should aim for a price that at least covers their levelized cost of electricity, which represents the marginal price they can accept without making a loss. Ideally, the seller would prefer a price closer to or higher than the average market price.

- **Buyer’s Price Comparison**: From the buyer’s perspective, if the PPA price is higher than the current market price, they may choose to buy directly from the market instead. Therefore, the buyer’s aim is to secure a price at or near the levelized cost of electricity of the seller.

- **PPA Price Determination**: Consequently, the PPA price is typically negotiated to fall between the levelized cost of electricity (the seller’s minimum acceptable price) and the average market price (the buyer’s maximum acceptable price).

- **Risk Consideration**: The risk tolerance of both parties can also influence the PPA price. If SPEN is risk-averse, they may be willing to sell at the levelized cost of electricity to ensure they are just be able to cover their costs. Conversely, if the buyer is risk-averse, they might be willing to pay the average market price.

- **Bargaining**: The bargaining process between the seller and buyer is a critical factor in determining the final PPA price. This negotiation will take into account the risks and preferences of both parties, as well as market conditions and projections of future price trends.

Moreover, the PPA strike price $\text{Price}_{\text{strike}}$ is decided based on bargaining between the buyer and the seller.
Where, utility/payoff of seller

\[ U_s = \text{Price}_{\text{strike}} \times \text{Volume} - \text{LCOE} \times \text{Volume} \]

and utility of buyer,

\[ U_b = \text{Price}_{\text{market}} \times \text{Volume} - \text{Price}_{\text{strike}} \times \text{Volume} \]

If \( \text{Price}_{\text{strike}} \) is high, seller utility \( U_s \) would be high, whereas, buyer utility \( U_b \) would be low. And, vice-versa. An optimal price can be calculated by maximizing the product of utility of buyer and seller i.e.,

\[ \max U_b \times U_s \]

![Diagram](image)

**Figure 11:** Bargaining solution for PPA strike price using utility function of the seller and buyer, considering a fixed volume of energy trade.

This would be the best price considering the utility of both buyer and seller. Notice that we have not considered taxes in this study, as buyers have to pay the taxes even in the case of PPA as it is using grid infrastructure to get the electricity from SPEN and SPEN is not responsible to deliver electricity to the buyer.

**Step 3)** For any imbalance between contracted generation and demand, the economic benefit of using battery storage systems is analysed under market price fluctuations.

After setting the volume and price of a PPA contract, we focus on balancing requirements considering there could still be times where PV generation would not match the buyers demand. Balancing of generation/demand is especially important for 24/7 PPA contracts where seller faces the risk of balancing costs in the wholesale market (see ref. (Diego Hernandez Diaz, Florian Kühn, Martin Linder, Esperanza Mata, 2022) for details)

**Need of balancing responsible party in PPA**

The Power Purchase Agreement (PPA) process, after accounting for risk preferences, involves finalizing a contract and agreeing on a price. However, due to the inherent uncertainty of PV power production, there can be instances when the total PV volume generated is less than what is stipulated in the PPA contract. This necessitates the role of a Balancing Responsible Party (BRP) to account for any surplus or deficit in electricity production.

A BRP, often a utility or retailer, is a standard component of every PPA. The BRP takes on the responsibility of balancing any deviations in generation or consumption, absorbing the costs associated with these imbalances. However, in our scenario, we assume that the SPEN itself acts as the BRP. In this way, the SPEN opts to take responsibility for balancing any deficits and surpluses, either through market purchases or the use of battery energy storage systems. This decision implies that the costs associated with imbalances fall on the SPEN.
Given this responsibility, it is crucial that they implement some form of short-term forecasting mechanism, allowing them to predict the necessary balancing measures based on the anticipated PV production. Shared assets, such as battery storage systems, can be used to manage these imbalances. For this purpose, the community requires a forecasting tool capable of predicting PV production for the next 24 hours. This short-term prediction, of next day’s PV generation, is likely to be more accurate than the long-term LSTM forecasts, providing valuable insights into the difference between contracted volumes and day-ahead forecasts.

To further support this process, we have developed an optimization model with the objective of achieving balance, reducing penalties, and improving the viability of the PPA. This model uses the spot price and the PPA price as inputs. The goal of this system is to minimize purchases from the market while fulfilling the commitments made in the long-term contract.

Some assumptions are taken in the model:

- The SPEN can invest on a battery energy storage system (BESS) for balancing if PV generation is lower than contracted to the buyer.
- The charging/discharging of battery energy storage would be based on varying market prices. The seller (local energy community in our case) would optimize its energy cost for balancing the generation and demand.

4.3.3 Case Study and Results

**Definition of the case study**

Three cases have been explored to quantify the benefits of PPA in SPENs:

1) **No PPA:** In this first case, the SPEN does not sell its electricity to a specific buyer at a predetermined price as it would under a PPA; instead, it sells through the wholesale market at the spot price.

2) **PPA w/o battery:** In the second case, the SPEN sells all its surplus electricity to a specific buyer and purchase from the wholesale market in case of not having enough production to meet the buyer’s demand. However, relying solely on the wholesale market for additional energy exposes both the buyer and seller to price risks. In this scenario, the buyer would purchase electricity from the wholesale market when there is a deficit in the supply from the seller, and seller can sell any excess electricity...
on the wholesale market in case of surplus. However, the prices of electricity in the wholesale market can fluctuate, depending on several factors such as supply and demand conditions, fuel prices, and weather conditions. For the buyer, purchasing electricity from the wholesale market during periods of high demand or low supply can lead to higher prices, increasing the overall cost of their electricity. Similarly, if the seller is unable to sell excess electricity at a favourable price on the wholesale market, it can reduce their revenue and profitability.

3) **PPA w/ battery:** The reason for exploring a PPA with battery storage is that renewable energy sources, such as wind and solar, are subject to weather conditions, resulting in fluctuations in the availability of electricity. Therefore, a 24/7 PPA that involves these sources of energy would require the integration of energy storage and backup power sources to ensure an uninterrupted and dependable supply of electricity.

**Forecasting of PV generation**

As previously mentioned, a machine learning algorithm is utilized for forecasting future PV generation. Nonetheless, the prediction may either overestimate or underestimate the PV plant's generation capacity, as illustrated in Figure 14. In the upcoming section, we will use two days (surplus and deficit) to demonstrate the advantages in the specified cases (no PPA, PPA without battery, PPA with battery).

![Forecasting of PV generation](image1)

**Figure 14:** LSTM based long-term prediction of amplitude, trend and cyclic variation in future PV generation based on historical data available with the supplier (SPEN).

![Forecasting of PV generation](image2)

**Figure 15:** Day Ahead Prediction of PV production using auto-regressive (AR) model (Deficit Day)

![Forecasting of PV generation](image3)

**Figure 16:** Day Ahead Prediction of PV production using auto-regressive (AR) model (Surplus Day)
Example day: Surplus

In this example day, the day-ahead PV generation predicted using auto regression surpasses the contracted PV generation under the PPA for most of the hours. For example, at the 15th hour, when there is an excess of 10 kW between the predicted generation and contracted generation, the surplus is utilized to charge the battery storage. Conversely, at the 9th hour, when the contracted PV generation exceeds the predicted generation, the battery compensates for the deficit by providing power to the buyer. By balancing the deficit and surplus, battery storage can play a significant role in reducing or eliminating the need for reliance on the electrical grid.

Figure 17: Visualization of prices, predicted and contracted generation, and optimal operational decisions obtained from the model for the case example of surplus.

Given that most hours have a surplus PV production, optimal battery storage size is found out to be 15 kWh.
Figure 18 provides an overview of the costs and benefits associated with a representative SPEN. The costs labelled as "Grid import costs" represent the expenses incurred when purchasing power from the grid in the event of a power deficit. "Revenue from the market" indicates the income generated by selling excess power to the open market. "Revenue from the Power Purchase Agreement (PPA)" represents the earnings obtained from selling power to a specific buyer with whom the community has a PPA contract. The "Overall revenue" refers to the profit obtained by subtracting the grid import costs from the revenue generated in the market.

As shown in the figure, having a battery storage system as it is extremely advantageous in the event of deficits. Given the ability to supply at these times, the battery increases overall profit by approximately 36% more profit compared to the case without it. In the absence of a battery, the SPEN must purchase more power from the grid even in expensive hours for balancing, thereby resulting in higher grid import costs. In this particular example, the grid import cost are 0.87€.

It is essential to acknowledge that in the absence of battery storage, having surplus power is advantageous for the SPEN. If the spot price exceeds the Power Purchase Agreement (PPA) price (as illustrated in Figure 17), the community can generate income by selling the excess power to the grid. Therefore, the revenue earned from selling to the market, without battery storage, surpasses the revenue earned with battery storage.

**Example day: Deficit**

In this example day, the day-ahead PV generation predicted using auto regression is less than the contracted PV generation under the PPA for most of the hours as depicted by Figure 19.
During hours 20 to 24, when the spot price falls below the PPA price, the battery system is effectively charged from the grid. PV to battery is zero as there not enough electricity to cover the contracted generation volume. However, the battery storage system plays a crucial role by discharging its stored energy to fulfil the contracted power requirements for the buyer with whom there is a PPA, assuming it had electricity stored from previous timesteps. This enables the delivery of the agreed-upon power despite the deficit in PV generation, ensuring contractual obligations are met. The optimal battery size in this case comes out to be 50 kWh, which signifies the need for larger storage systems when the PV generator of the SPEN produces power under its capacity.

PPA in demo countries of syn.ikia
This section explores the factors that contribute to the unique characteristics and circumstances of each demonstration country, which may result in different PPA arrangements. These differences in PPA arrangements among them can be attributed to several factors, including variations in PV size and cost, differences in renewable energy targets and investments, varying market prices, and variations in PV generation profiles.

Among these factors, variations in PV size and cost, renewable energy targets and investments, are particularly uncertain. The size and cost of PV installations can vary based on factors such as the availability of land, solar resource potential, and local manufacturing capabilities. Moreover, countries establish different renewable energy targets and allocate varying levels of investments, which can significantly influence the scale and development of PV projects. However, for PPAs, the most influential factors are PV generation, which depends on geographical characteristics like irradiation/weather, and country-specific wholesale market prices.

An effective analysis for different countries can be based on historical data, specifically looking at market price fluctuations and variations in PV generation patterns of a specific country. Let’s consider Norway as an example. Being a cold country, the PV generation profile in Norway may exhibit similar patterns due to weather conditions.

Historical data demonstrates that Norway experienced relatively stable market prices until 2019, primarily due to the substantial hydropower production, which offers a consistent and predictable energy source. Figure 21 provides an illustration by comparing the day-ahead market prices for two different years. In a scenario where the market price remains stable, such as in 2019, there is little incentive for communities to enter into a PPA with a buyer, as both parties would incur losses. However, if the market exhibits more dynamic behaviour, entering a PPA becomes advantageous.

\[ \text{Figure 21: Comparison of historical day ahead market price of Norway (ENTSO-E, Intraday market data, 2022)} \]

Figure 22 compares the dynamics of spot price, PV generation, and average spot price in both Spain and Norway. In Spain, a positive correlation of 0.2 exists between spot price and PV generation. This positive correlation signifies that when PV production increases, the spot price of electricity also tends to rise, and vice versa. Essentially, these variables are directly related, meaning that higher PV production is associated with higher spot prices, while lower PV production corresponds to lower spot prices. In the context of a PPA scenario, if the spot price exceeds the average price and sufficient PV production is available, selling electricity to the market becomes more advantageous than adhering to the PPA contract for the SPEN. Furthermore, PV production in Spain demonstrates relatively low variability throughout the year. Consequently, this correlation
and market price combination suggest the potential for reduced revenue when entering a PPA, as highlighted in Figure 23.

In contrast, Norway exhibits a negative correlation of -0.3 between PV generation and spot price. This can prove advantageous and result in higher revenues, as also shown in Figure 23. For instance, at the beginning of the year when the spot price is high and PV production is low, it becomes beneficial if the PPA price is lower than the spot price. However, during the peak of the year when irradiance is at its highest and PV production reaches its peak and the spot price is low (because Norway, being a cold country, experiences increased electricity consumption for heating purposes during winter, which becomes the driving factor behind price determination). Therefore, a PPA agreement becomes financially beneficial in the summer when irradiance is maximum, and the average price exceeds the spot price.

Figure 22: Correlation between normalized PV generation data and spot prices for the year 2019.

Figure 23: Market vs. PPA revenue considering data of year 2019.

Figure 24 presents the differences in photovoltaic (PV) production between two consecutive days. This comparison is vital as it provides insights into the daily variability of PV generation, which is a critical factor
influencing prediction accuracy and balancing needs. Ideally, the lower the day-to-day variation, the better the prediction performance, and consequently, the lower the need for balancing.

The implications of lower variation are significant. A smaller range of PV production changes results in a reduced need for market intervention to balance the electricity supply, thereby reducing associated penalties. Consequently, this leads to higher revenue.

This concept can be better understood through an example. Consider a threshold value for PV production differences between two consecutive days, let’s say 10 kW. If we compare Spain and Norway, Spain shows fewer instances where this difference exceeds 10 kW. This is attributable to Spain’s relatively consistent PV generation throughout the year. As a result, the cost of balancing in Spain is less than in Norway.

This factor is captured in Figure 25 A, which illustrates the costs associated with balancing deficits (purchasing from the market) and surpluses (selling to the market). Spain incurs lower costs compared to other countries, indicating a closer alignment with contracted PV production. However, the situation in Norway is different. Throughout the year, the cost of balancing deficits is consistently higher than the revenue generated from surplus power. This pattern indicates a significant challenge for Norwegian PV production. Figure 25 B displays the overall profit in different countries, calculated as PPA revenue plus surplus revenue minus costs. Excluding Norway, all countries demonstrate similar profit levels, assuming the same PV production capacity (50 kWp). This disparity underscores the unique challenges faced by Norway in achieving profitable PV production under a PPA.

Figure 24: Variation in PV generation in subsequent days, highlighting the need for balancing from BESS or market.
Figure 25: A) Cumulative market revenue of selling surplus PV generation, and balancing costs (in PPA) for deficit volume trading. B) Cumulative profit of being in a fixed tariff PPA, relative to the country dependent market dynamics and solar power generation capabilities

Business model 3 — SPEN as Retailer/Aggregator

4.3.4 SPEN as Retailer/Aggregator

The core function of an energy retailer is to buy electricity or gas wholesale from energy producers or the open market and then sell it to residential and commercial customers. Energy retailers also have the responsibility of balancing the energy they supply with the energy their customers consume. If there is an imbalance, the retailer might need to buy or sell energy on the balancing market to correct it.

Aggregators enable the aggregation of energy generation and consumption data from various sources within the SPEN, allowing for more efficient energy planning and optimization.
4.3.5 Case studies with SPEN as Retailer/Aggregator

Figure 28 illustrates the relationship between the imbalance price and the day ahead price. It is evident that the imbalance price is above the day ahead price particularly during certain hours. This indicates that there is a higher cost associated with additional demand in the market during those specific hours, that is, the overall market is facing a generation deficit pushing the imbalance prices higher. Furthermore, the community requires an additional load as indicated by the higher imbalance volume (red bar graph) compared to the day ahead volume. This signifies that there is a need to address the imbalances between generation and consumption within the community. If the SPEN assumes the role of a balancing responsible party, it implies that the imbalance prices are applicable on the SPEN. In this case, any additional demand bought by the SPEN in the balancing market is directly affected by the higher costs, as also seen in the cumulative imbalance penalty in Figure 25b. This highlights the significance of implementing effective strategies BESS, or flexibility in the SPEN, to use, which can potentially reduce the imbalance costs, as we will see in the next.
In Figure 29, the analysis focuses on the response of flexible loads to both day-ahead and imbalance prices. The aim is to understand how these loads adjust their consumption patterns based on the pricing signals from both markets. The flexible loads under consideration are assumed to be heat pumps and community BESS. Whenever imbalance prices are lower than day ahead price, flexibility can increase consumption. Conversely, when the imbalance prices are higher, such as during the 3rd hour, SPEN may reduce their consumption (can also be considered as providing generation) to gain profits. This strategy aligns with the core principles of aggregation and energy arbitrage, enabling SPEN to maximize their economic gains. Another important observation in the provided figure is that during the middle (daytime) hours, values are zero. This indicates that the PV generation from SPEN is sufficient to meet the local loads, eliminating the need to purchase additional electricity from either the day-ahead or imbalance market. This can be visually observed in the figure below, where the load-PV generation line is around zero during those hours.

Figure 29: Arbitrage possibility using flexibility (BESS + flexible loads) in the balancing markets.

Figure 30: Net loads in the community considering PV generation.
In Figure 31, the possible increase in expected (or average) economic profits is seen. Intuitively, the increase in flexibility of consumer loads (or BESS size capacity) would have a positive impact on the profits that a community can attain. This is because quick flexibility induces response to varying prices in the balancing markets, thereby allowing the SPEN to make decisions on increasing or decreasing their electricity consumption as per the market requirements. Moreover, the profits also rise sharply initially as the flexibility increases from zero. This indicates that even a small amount of flexibility in the SPEN can result in potential arbitrage profits through market participation. In Figure 32, the increase in profitability of SPEN is seen with variation in balancing market prices. If the imbalance prices do not vary far from the day ahead market prices, the chance of profitability acting as an aggregator would be low. This is because the SPEN responds to the time-based price variation between the two energy markets operating day-ahead and in real-time. However, if the electricity prices do not fall or rise in the real-time balancing markets, it would be ideal for the SPEN to remain fixated on its day-ahead energy consumption bids.

4.3.6 Results

The "single-price imbalance system" is a mechanism used by electricity markets to balance the deviations between supply and demand in real-time. In a single-price imbalance system, these deviations are settled at the balancing market price, regardless of whether the producer generates more (excess) or less (lack) than forecasted. The imbalance price can be higher or lower than the day-ahead market price depending on whether there’s a general lack of power production (upregulation) or excess of power production (downregulation) of power production in the system (Mazzi & Pinson, 2017).

This price difference creates arbitrage opportunities for power producers as described below.

| a producer generates excess power when there's a lack of power in the system. | Bonus | System imbalance (Negative) Producer imbalance (Positive) |
| both the producer and the system are producing excess power | Penalised | System imbalance (Positive) Producer imbalance (Positive) |
In essence, this system incentivizes power producers to manage their generation effectively and to help maintain overall balance in the electricity grid. By doing so, they can profit from price differences between the forecasted day-ahead market and the real-time imbalance market. Norway follows single price mechanism.

In double price imbalance system if a power producer’s deviation helps to reduce the overall system imbalance, the deviation is traded at the day-ahead market price. For instance, if the system has a power surplus (overproduction) and the producer underproduces (which helps to reduce the system’s overall imbalance), the producer’s underproduction is priced at the day-ahead market price. The producer doesn’t receive any bonuses for this, which is a significant difference from the single-price imbalance system where the producer would receive a bonus for helping to reduce the system's imbalance.

On the other hand, if a power producer’s deviation worsens the overall system imbalance, the deviation is priced at the balancing market price. For example, if the system already has a power deficit (underproduction), and the producer also underproduces (thus adding to the deficit), the producer's underproduction is priced at the balancing market price, which usually results in a penalty for the producer.

This dual-price system aims to discourage power producers from creating further imbalances in the power system. Importantly, it eliminates the arbitrage opportunity present in the single-price system, where power producers could potentially profit from creating imbalances that were opposite to the system's imbalance (Mazzi & Pinson, 2017).

In Fig. 34, the implications of varying flexibility resources within SPEN, or BESS size, on the balancing market penalty across Austria, Spain, Norway, and the Netherlands are shown. Austria has a distinctive energy pricing

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*Figure 33: A) Illustration of Arbitrage opportunities in balancing market compared to the day ahead market (Single price mechanism) B) Illustration of Arbitrage opportunities in balancing market compared to the day ahead market (Double price mechanism)*

*Figure 34: Country wise imbalance penalty as a Retailer*
landscape, where notable difference is present between day-ahead and imbalance prices. Sudden spikes in imbalance prices can be particularly challenging for SPEN-Retailer in Austria. These neighborhoods, which have high PV generation, can have unpredictable energy demands resulting in significant penalties when energy consumption aligns with these price spikes. However, as BESS size grows, the penalties in Austrian case drop drastically. This underlines the importance of having ample energy storage in regions with volatile energy prices. In contrast, Spain, Norway, and the Netherlands having a more predictable price difference show a more gradual penalty decline with increasing BESS size.

4.4 Business model 4 — Community-based shared assets

4.4.1 Business model description

Differently from other business models, this approach implies that each community member adopts the role of owner, investor, and user of the cooperative. Each of these roles has specific rights and responsibilities. Becoming an owner in a cooperative implies that each household holds voting rights for decision-making related to the control and operation of the asset. As investors, community participants might expect a financial return on investment. Nevertheless, community members might expect a lower rate of return than third parties who seek the profitability of their business model. Finally, as users of the community, participants have the right to use the assets and obtain operational benefits.

Overall, this business model offers considerable benefits for energy communities. However, it also comes together with some difficulties in its real-life implementation.

Communities might need help to reach an agreement in defining the cost/benefit allocation among members. How should the total cost/benefit of the community be split among community members?

Cost allocation problem in Community-based shared assets

The issue of cost allocation among users has been a persistent topic of discussion in several areas of the energy sector. A notable case involves the debate on defining grid tariffs that distribute transmission and distribution costs among end users. Generally, grid tariffs established by system operators aim to ensure capital cost recovery, efficiency, fairness, non-discrimination, cost-reflectivity, transparency and stability, following the directives prescribed by regulatory bodies.

Defining the cost allocation method within a community with shared assets requires reaching consensus on the most suitable method. This negotiation is a critical feature, as members need to perceive that their involvement in the SPEN delivers fair outcomes. Otherwise, there is a risk of members exiting the community, which potentially jeopardizes the longevity of SPENs.

Therefore, adopting a value allocation method that fosters fairness and promotes stability within the community is an essential design feature when adopting SPENs with joint investments. Here, an allocation method is considered “fair” when each community member earns/pays proportionally to their contribution. For instance, a user whose load matches with local generation, reducing the community’s total cost, should pay less than another user whose load requires the import from external sources.

Cost allocation methods in SPENs

Therefore, once the investment decisions are taken, the members of the SPEN face the task of determining how to distribute the financial earnings and expenses. There are several benefits associated with defining a fair cost and benefit allocation in SPENs (Li et al. 2021):
- It enhances and keeps cooperation between community members.
- It avoids free-rider behaviour where some members can benefit from others’ contributions.
- It provides economic signals that promote cost-efficient behaviours.
- A well-designed allocation method may ensure economic efficiency by ensuring price equals the marginal cost.
- Finally, it promotes social acceptance as people will perceive that members are treated fairly.

The energy system counts with several cost allocation methods that can be used. Table XX lists some of the cost allocation methods applicable for SPENs. Each of these methods has advantages and disadvantages that could lead to fairness issues. For a more detailed discussion about each methodology, we refer to Li et al. (2021).

Table 9. Cost allocation methods applicable to SPENs (based on Li et al. 2021)

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flat energy pricing method</strong></td>
<td>Fixed price according to the total electricity consumption. The time of energy consumption is irrelevant. Households are not encouraged to modify their consumption to match with the local renewable generation.</td>
</tr>
<tr>
<td><strong>Base and peak method or Time of Use</strong></td>
<td>There are two pricing periods: base and peak hours. It promotes consumers to move their consumption to lower priced times, reducing peaks.</td>
</tr>
<tr>
<td><strong>Average and excess method</strong></td>
<td>The method defines a first allocator based on the share of average consumption of a customer in relation to the system’s average consumption. Then, a second allocator calculates the share of excess consumption (difference between peak consumption and average consumption) compared to the whole system excess consumption. It basically sends the signal that the households should keep their consumption close to their own average consumption.</td>
</tr>
<tr>
<td><strong>Postage stamp method</strong></td>
<td>This method calculates the price by dividing the total costs by the maximum peak of the community (as a whole) throughout the whole year. It only considers the peak demand of households, irrespective of their volumetric consumption.</td>
</tr>
<tr>
<td><strong>Coincident peak method</strong></td>
<td>Similar to the postage stamp, but it calculates the price several for several seasons of the year.</td>
</tr>
<tr>
<td><strong>Non-coincident peak method</strong></td>
<td>Similar to the two previous methods, but instead of using the maximum peak of the community, it aggregates the maximum peak of each consumer throughout the whole year. The total costs are divided by this sum and the cost allocated to each household is proportional to its own highest peak.</td>
</tr>
<tr>
<td><strong>Cost allocation based on cost-causality principle method</strong></td>
<td>This is a cost-reflective method where usually imply three steps: functionalization, classification and allocation. The first consist on identifying the different expenses based on their operations (e.g., generation, transmission, distribution and supply). The second stage involves identifying the main cost drivers for each of the categories. The last one is the process of the allocating the costs for each of the categories for different consumer categories. It leads to detailed final tariff structures but it is a complex system.</td>
</tr>
</tbody>
</table>
**Objective**

In the rest of the chapter, how members of a community can benefit from this business model is discussed and exemplified. Also, the Shapley Values method is introduced as a potential cost allocation method to promote fairness within SPENs with shared assets.

### 4.4.2 Background and methodology

**Theoretical Background: Shapley Values**

In the context of cooperative game theory, Shapley Values have been a popular choice of cost allocation method in fields as diverse as economics, operations research and machine learning. This concept was first introduced by Lloyd Shapley in 1951 which led him to win the Nobel Memorial Prize in Economic Sciences in 2012.

The Shapley value method determines the unique share of the total surplus/expenses for each participant in a coalition, considering their individual contributions. Notably, the Shapley value is the only approach that satisfies:

- **Efficiency**: The total sum of the Shapley values of all agents equals the value generated by the coalition. None of the value or benefit created by the whole community gets lost.
- **Symmetry**: If two actors are equally beneficial or valuable for the group, they will get the same share of profit. People who contribute equally get rewarded equally.
- **Linearity**: This property indicates how the Shapley values work with separate sources of value. Imagine two separate sources of benefit. If you combine these two sources into a single one, the share that each person obtains out of the total benefit is the same as if you added up their shares from each separate source.
- **Null player**: If the contribution of a member is zero, its Shapley value is also zero. This principle avoids free-riding behaviours by ensuring that only those who contribute receive a share of the benefits. Also, it further reinforces the fairness aspect of the Shapley value.

Another important concept in cooperative game theory is the stability of a coalition. We say that a coalition is stable when any group of agents is incentivized to form a coalition by its own instead of belonging to the whole community. In the context of energy communities, this happens if some households obtain more benefits by grouping together instead of belonging to the whole community. Despite the multiple benefits of Shapley values, it does not guarantee the stability of the community. This has the practical implications that an energy community may not be stable throughout time as smaller communities can be formed. The stability of the different SPENs considered will be considered in our comparative study.

**Joint Investment model**

The business model of joint investments requires the determination of the capacity of generation and storage technologies. A SPEN can determine their investment decisions based on technical and economical assessments. Here, the methodology assumed is a techno-economic optimisation model.

The model used in this analysis is a linear programming algorithm that minimises the annualized investments and operational costs for a community of dwellings. The annualized investment costs include the capital cost of generation and energy storage systems. The operational costs reflect maintenance costs of the energy
assets invested and the cost incurred by withdrawing electricity from the main grid. The latter volumetric cost depends on the grid tariffs, taxes, and spot prices on the specific area of analysis (e.g., country, area).

Moreover, the model is designed specifically for multi-dwelling buildings with shared areas where energy assets can be placed. Figure 35 illustrates the set-up of the model. Each dwelling in the community may cover its electricity demand by importing from the main grid or the shared areas. The electricity imported from the main grid will be priced according to the grid tariff, spot price and taxes, while the electricity imported from the shared areas is not priced in the model. Similarly, the shared areas can import from the main grid under the same pricing to charge the batteries if necessary. Additionally, the model offers the possibility to inject excess energy into the main grid valued at the spot price.

Both the investments and operations are constrained by technical limitations. The amount of installed generation will be determined by the available roof-top area of the building, while the maximum capacity of batteries is function of the number of dwellings considered. Moreover, each household and common areas must be in energy balance in every timestep. In the case of each household, the load must always equal the energy imported from the grid or the common areas. Similarly, the electricity imported from the main grid, discharges from storage technologies and the locally produced electricity must equal the demand for charging the batteries and exporting electricity to each household in the common areas. The model also includes operational constraints for the batteries to ensure the state of charge is a function of charging and discharging decisions and the amount of power injection and withdrawal from batteries is in accordance with its model.

This type of investment model usually implies high computational effort and can be time-consuming to solve. Instead of considering the full operational time horizon, the model considers representative seasons which are scaled up. This reduces the computational time, which is particularly relevant for the calculation of Shapley values. Moreover, the model considers perfect information about renewable generation and consumer load demand. The model can be extended to assume uncertainty, although, for the purposes of this report, a deterministic version is used.

**Theoretical Background: Shapley Values Formulation**

Formally, a coalition is defined by a set of players \( N \) and a characteristic function \( \nu(S) \) that maps the value generated of subcoalition \( S \). A set of sub-coalitions is the set of possible combinations of the agents in \( N \). According to the formulation of the Shapley value, the amount of economic value that a player/resident receives is:
\[ \phi_i(v) = \sum_{S \subseteq N \setminus \{i\}} \frac{|S|! (|N| - |S| - 1)!}{|N|!} (v(S \cup \{i\}) - v(S)) \]

**Additional flexibility sources – effect on the business model**

In the case of the community-based share asset business model, the aggregation of other flexible technologies like heat pumps, heat storage technologies, and electric vehicles, might reduce the overall cost of each building. By increasing flexibility, the buildings can leverage the price differences when subscribed to dynamic pricing tariffs like time-of-use (ToU).

Nevertheless, the effect of these assets differs whether they are owned by the community or by individual members. In the case of EVs of flexible loads (demand response) are individually “owned”, thus the agents contributing with these types of assets should be rewarded. Shapley values allowed to consider the individual contributions and ensure fairness even with no-community owned assets.

**4.4.3 Case Study and Results**

**Definition of the case study**

The case study proposed for examining this business model assumes a multi-dwelling building with a rooftop area suitable for installing solar photovoltaic (PV) panels and connection to the main grid. For the purpose of the analysis, the considered roof-top area was not limited, such that the community can optimize its capacity without limitations. The local electricity is only used to cover the households’ load and no external feed-in is considered to be valuable. The goal is to optimize the investment and operations of the SPEN and determine the cost allocation among residents using the Shapley value method.

Four case studies have been defined based on the geographical location (i.e., Spain, Netherlands, Austria and Norway). Given that each climatic zone has varying irradiation levels, the generation profiles in each country varies. The generation profiles for three representative weeks in each country is plotted in

Figure 36 A). The total annual consumption in the case study is 46 MW. Moreover, the location also affects the capital cost of the technology, tax and grid costs, and wholesale electricity prices. Table 27 in “Appendix B. Data used” shows the input data considered per country for the investment model.
Moreover, investments costs are annualized using an annuity factor, assuming a 20-year lifespan and a 6% real interest rate. A high interest rate was selected to reflect uncertainties such as maintenance or degradation costs. Note that using annuities implies disregarding fluctuating factors such as electricity prices. Also, the model also presupposes that the entire investment in the solar panel is made up front.

The case study assumes end users belong to the same multi-dwelling building. Although this is the assumption made in this case study, the business model offers the possibility to expand to communities with end users not living in the same residential block.

Finally, the study does not consider possible subsidies or net metering policies applied in each country. A more depth analysis in this regard is provided in Section 4.6.7.

After comparing the four countries assuming a common building, we explore the application of this business model in the Gneis (Austria) demo site of syn.ikia.

**Results: Country Comparison**

Table 10 compares the annual costs and installed capacities for the building in Austria, the Netherlands, Norway and Spain, under both individual and community-based investments. Notably, there is an overall reduction in the total annual cost, ranging from 5 to 8%, when households engage in shared investments.

<table>
<thead>
<tr>
<th></th>
<th>Austria</th>
<th>Netherlands</th>
<th>Norway</th>
<th>Spain</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total annual cost</strong></td>
<td>Individual investments</td>
<td>7784</td>
<td>7821</td>
<td>5594</td>
</tr>
<tr>
<td></td>
<td>Shared investments</td>
<td>7385 (-5.1%)</td>
<td>7350 (-6.0%)</td>
<td>5593 (-0.02%)</td>
</tr>
<tr>
<td><strong>Operational cost</strong></td>
<td>Individual investments</td>
<td>6875</td>
<td>6787</td>
<td>5469</td>
</tr>
</tbody>
</table>
The extent of cost reduction varies considerably among countries due to differences in factors such as wholesale prices, the levelized cost of electricity (LCOE) of the solar technologies, and the alignment between electricity generation and load. Norway emerges as the country with the least attractive conditions for solar adoption, predominantly due to low electricity prices combined with high LCOE. The total investment in Norway is roughly half of that in Austria, the next less attractive country for solar generation. Consequently, there is lower economic incentives for households to invest in solar panels in Norway, whether individually or in a community-based setting. Interestingly, the adoption of communities based on sharing assets models does not yield substantial economic benefits.

In contrast, Spain shows a different scenario: under individual investments, its capacity is more than four times larger than community-shared assets in Norway. The building’s most significant cost reduction when transitioning to a community-based shared assets model is observed in Spain, largely due to decreased investments. This suggests that households investing individually are likely to over-dimension the installed solar capacity, even if this may result in significant curtailment of excess power. However, shared investments enable households to utilise excess production more effectively and consequently reduce total installed capacity.

For the remaining countries, a noticeable increment in installed PV capacity is observed when households adopt the Community-based shared assets business model. Under individual investments, households refrain from oversizing their investments as excess production do not yield economic advantages. Conversely, shared investments foster efficiency and lead to an increase in the number of installed PV panels.

In summary, sharing investments in the overall increase the efficiency of the assets. However, while in countries with high capital costs this model also increases the total installed capacity, in those with low investment costs it stops the over dimension of the installations.

Moreover, the Shapley values for the different households were computed. Table 11 provides insight into the electricity bills of households that adopt shared investments in the four countries. Notably, despite the considerable differences in the results from solar panel installations in Norway and Spain, these two countries deliver the lowest electricity bills. Norway enjoys significantly lower electricity prices than the other countries, while Spain benefits from optimal conditions for solar panels, characterized by low capital cost and high production capacities.

Table 11: Electricity bills of households that adopt shared investments in the four countries.

<table>
<thead>
<tr>
<th></th>
<th>Austria</th>
<th>Netherlands</th>
<th>Norway</th>
<th>Spain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shared investments</td>
<td>6164 (-10.3%)</td>
<td>6158 (-9.3%)</td>
<td>5301 (-3.1%)</td>
<td>5599 (-4.2%)</td>
</tr>
<tr>
<td>Individual investments</td>
<td>908</td>
<td>1034</td>
<td>125</td>
<td>1151</td>
</tr>
<tr>
<td>Shared investments</td>
<td>1220 (+34.4%)</td>
<td>1191 (+15.2%)</td>
<td>292 (+133.7%)</td>
<td>865 (-24.9%)</td>
</tr>
<tr>
<td>Installed PV (kW)</td>
<td>Individual investments</td>
<td>9.5</td>
<td>14</td>
<td>4.6</td>
</tr>
<tr>
<td>Shared investments</td>
<td>12.7</td>
<td>16.1</td>
<td>6.5</td>
<td>17.9</td>
</tr>
<tr>
<td></td>
<td>Average annual electricity bill (€)</td>
<td>Standard deviation (€)</td>
<td>Minimum bill (€)</td>
<td>Maximum bill (€)</td>
</tr>
<tr>
<td>------------------------------</td>
<td>-------------------------------------</td>
<td>------------------------</td>
<td>------------------</td>
<td>------------------</td>
</tr>
<tr>
<td></td>
<td>739</td>
<td>200</td>
<td>469</td>
<td>1016</td>
</tr>
<tr>
<td></td>
<td>735</td>
<td>195</td>
<td>466</td>
<td>999</td>
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<tr>
<td></td>
<td>559</td>
<td>157</td>
<td>350</td>
<td>804</td>
</tr>
<tr>
<td></td>
<td>646</td>
<td>159</td>
<td>420</td>
<td>848</td>
</tr>
</tbody>
</table>

As depicted in Figure 37, all households experience reduced electricity bills when they collaborate with other households compared to individual investments. This outcome confirms that adopting SPEN’s business model and employing Shapley values for cost allocation can provide economic advantages to all members. Fascinatingly, in the Norwegian context, the electricity bills remain consistent regardless of whether households invest individually or collectively. This leaves the choice of investment approach to the preferences of the community.

However, it is essential to consider that the optimization model does not consider economies of scale. Therefore, collective investment might yield economic benefits not visible in the figure. This potential for additional savings could be an incentive for households to adopt community-based investment strategies.

![Figure 37: Cost allocation when the residents individually invest and when they invest collectively.](image)

Observing the resulting electricity bills for each household it can be observed that household 10 has the maximum electricity bill in Austria, the Netherlands and Norway. The results are expected given that it is the dwelling with the largest electricity consumption 6686 kWh/year. Nevertheless, in the Spanish case we observe that this does not hold. Instead, houses 7 and 6 have larger electricity bills in spite of incurring in 5993 and 5807 kWh/year respectively.

Household 10 has a load profile that benefits from consuming excess power during hours when there is more solar generation than houses 6 and 7. This match with excess power implies that the operational cost incurred by the community due to household 10 (612€) is lower than the cost caused by house 6 (714€) and 7 (754€). This reduction of operational costs offsets the highest investment costs incurred in the community because of house 10 (172€).
Although the results might seem straightforward, still the computation of the Shapley values may not be easy to understand for people who are not familiarised with cooperative game theory. This supposes a barrier to adopting Shapley values: lack of trust in the method. Electricity bills calculated by Shapley values do not align with one of the main premises when designing electricity tariffs which are that they should be easy to understand and should be constant through time (Hennig 2022).

Additionally, calculating Shapley values imply a large computational expense that increases exponentially with the number of houses forming the coalition. In order to compute the Shapley values of the ten agents in this case, the number of model instances ran were 1024 instances for each of the countries considered. Hence, in SPENs with large number of agents, its computation might be intractable.

Results: Gneis Demo in Austria

The business model is now applied to the Gneis demo case in Austria. Given that the demo site is under construction, these numbers are based on simulations at the building level, thus, real-life implementation may not end up with the same numeric results. The demo case has 251 apartments. However, such a high number of agents leads to numerical issues for solving the Shapley Value. Therefore, in this case study, the buildings are treated as the agents who need to divide the cost between each other. The division of cost within each of them is out of the scope.

Table 12 presents the costs and investments in technologies obtained for the Gneis study. The cost reductions obtained by adopting the community-based shared asset business model are lower than those obtained in the comparative case of Austria. This is explained by the similar load profiles between buildings that do not allow for substantial improvements by combining their loads. Nevertheless, still, the effect of shared investments is the increase in PV capacity, although this does not apply to batteries, where the community decreases by more than 76% the need for batteries.

<table>
<thead>
<tr>
<th>Total annual cost* (thousand €)</th>
<th>Operational cost* (thousand €)</th>
<th>Investment cost* (thousand €)</th>
<th>Installed PV (kW)</th>
<th>Installed BESS (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gneis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>109.2</td>
<td>107.8 (-1.3%)</td>
<td>95.4</td>
<td>93.5</td>
<td>14.33 (+3.44%)</td>
</tr>
<tr>
<td>13.9</td>
<td>14.33 (+3.44%)</td>
<td>138</td>
<td>146 (5.77%)</td>
<td>7.02</td>
</tr>
</tbody>
</table>

The average electricity bill for a building in Gneis is about 9800 € per year (Table 13). However, we observe quite significant differences in savings between buildings, given that there is diversity in the size of the building groups. For instance, the group formed by buildings nine to twelve with the largest power consumption (103.3 MWh/y) has also the largest electricity bill. Meanwhile, building eight with 27.5 MWh/y incurs much lower costs.

<table>
<thead>
<tr>
<th>Average annual electricity bill (thousand €)</th>
<th>Standard deviation (thousand €)</th>
<th>Minimum bill (thousand €)</th>
<th>Maximum bill (thousand €)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gneis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.8</td>
<td>5.8</td>
<td>4.5</td>
<td>24</td>
</tr>
</tbody>
</table>

Zooming into the details on cost allocations, Figure 38 presents the annual electricity bills for the different groups of buildings with and without forming an energy community. Given that the decrease in total costs is
slightly above 1% when adopting shared assets, this is reflected as not so significant reductions in the total annual bills for each participant. However, there is an exception with buildings 2 and 3. This substantial decrease compared to the rest of groups. In this group of buildings, there is a kindergarten that induces a load profile in the group that matches more often with the local solar generation. Due to the adoption of more PV panels as well as this contribution to the cost reductions being captured by the Shapley value, this building group is the most benefited from all. The business model, therefore, benefits participants that have consumption patterns different from the average.

The business model based on Community-based shared assets can deliver significant benefits for households belonging to multi-dwelling buildings which need to use shared areas for installing energy resources. The cases presented in this study reflect the potential benefit for all the participants when allocating the costs using Shapley values. This indicates that for buildings installing solar panels, the proposed method guarantees a stable community where agreements between economic rational households can be reached.

Some differences between countries can be observed in the total social welfare achieved. While in Spain, the Netherlands and Austria, sharing the investments could yield more than 5% cost reductions, in Norway grouping resources does not induce cost benefits. In this country, the reduction of costs from higher resource efficiency when jointly investing are balanced out by the need for installing capacity. This reaches the same cost from just directly consuming from the grid. In this country, the decision to adopt or not this business idea will be more dependent on preferences of the community and risks assessment of future electricity prices.

The study explored here provides a comparative study between countries, where some potential constraints were relaxed. Real-life applications of the business model might require more detailed specifications on community’s composition and buildings’ architecture. The method provided is versatile enough to consider physical and economic parameters such as budget constraints of individual users or maximum rooftop areas of buildings if needed. Political incentives such as feed-in-tariffs or subsidies can be incorporated to capture the regulatory idiosyncrasy of each country and that might have a significant effect on the economic outcomes.
of communities. Also, it might be necessary to complement with feasibility studies looking into transactional costs or costs related to the physical implementation (e.g., energy management systems).

Finally, it is noteworthy mentioning also some possible limitations of this business idea. First, reaching agreements among community members can be a complicated task, especially if some participants are not interested in investing in solar panels. That is why it is relevant for communities to attract their members such that the economic and environmental benefits obtained are clear and transparent. Second, and as already mentioned, the formula of Shapley values might be complicated for households to understand and trust. Other tariff designs for cost allocation can be adopted or approximated methods are also available to compute Shapley values for larger coalitions. However, these must be carefully designed to guarantee fairness as much as possible. Finally, billing procedures considering single point smart meters are required. Behind-the-meter regulations might differ from country to country. If this is not allowed, community-based shared investments are not viable.

4.5 Business model 5 — Green Investor

4.5.1 Business model description

In most European Union member countries, carrying out investments in residential communities requires agreement among most residents. Thus, this includes the installation of solar panels. Lack of consensus can be attributed to various reasons, such as a lack of capital, as not all community owners may have the same purchasing power. Another reason may be the lack of incentives for tenants since they do not directly benefit from energy production or for landlords unwilling to invest in temporary housing.

The “Green Investor” BM focuses on using non-habitable roofs in SPENs formed by apartment buildings where no agreement can be reached to invest in renewable energy. The underlying idea is a third party covering all the cost assorted to the PV system and becoming a producer/retailer for the dwellings in the building. In exchange for utilizing the roof the green investor offers a compensation is based on market energy prices, providing discounts during solar production hours.

4.5.2 Background and methodology

Other business models, such as “roof renting”, already aimed to solve the issue of no agreement among residents. In this model, a third party provides the capital and management to install solar panels in exchange for a fixed rental payment. Then, the local electricity produced is sold in wholesale markets. This solves the problems of capital and incentives for rental properties. Other variation of this model commercial buildings reduced electricity costs through community programs or direct power purchase agreements (PPAs), thereby aiding in energy cost reduction.

The third-party pays the fixed monthly rent based on various factors such as the number of dwellings, geographic location, or energy price estimates during the installation’s lifespan. However, agreeing on a fixed rental payment for the dwellings can entail risks for the third party since market prices can vary considerably from year to year.

Contrarily, in the Green Investor business model, instead of offering fixed compensation, the third party provides variable payment based on the market price of energy at any given time. This compensation is translated into a previously agreed percentage discount of the energy. This way, the risk for the third party would be reduced if the future energy prices are below their estimates. Energy transactions would take place outside the domain of the DSO, so they may be exempt from paying grid tariffs depending on the regulatory
framework of each country. As the green investor would take this retailer role behind the DSO's domain, the DSO would need to install new smart meters to control the consumption of its customers/dwellings.

Furthermore, by assuming the role of energy producer, the third party maximise their revenue by selling any surplus energy generated by the solar panels to the daily market. It is important to highlight that in this model, selling energy to the dwellings would be prioritised before allocating any surplus to the market. This emphasis on selling energy primarily within the community would position this business model as internal.

In summary, by installing a wattmeter to measure energy consumption in each dwelling, the third party could act as a retailer and energy producer, providing discounts on electricity bills for the dwellings and generating additional income by selling surplus energy to the daily market.

The model has been implemented, and a sensitivity analysis has been conducted using the market prices of each country over the last 5 years, calculating their average. This action has been taken due to the notable variability of the European electricity market in recent years.

**Battery implementation**

Adding batteries to the system could lead to increased demand for housing, which in turn would diminish the benefits of the Green Investor. This happens because the energy sold within the community would likely be cheaper than the one sold to the energy market.

To handle this problem, we can consider three possible solutions:

- **Include Battery Rules in Contracts:** We could include specific rules about using batteries in the contracts between the Green Investor and the community. These rules could range from not allowing batteries at all to agreeing on a fee for installing them.

- **Green Investor Invests in Batteries:** Another option is for the Green Investor to invest in battery technology themselves. This could lead to a shift where the Green Investor mainly focuses on providing energy within the community, and the sale of excess energy to the wider market becomes even less important, and thus potentially transitioning to a purely internal model.

- **Transition to an External Business Model, similar a Power Purchase Agreement (PPA):** in this setup, the main goal would be to sell energy to the broader energy market, and households in the community would receive a set fee for their participation.

In summary, adding batteries to the system, while not explored in detail here, could have significant impact. To make it work, we can consider adjusting contracts, having the Green Investor invest in batteries, or shifting to a model where energy is primarily sold to the broader market, with households in the community receiving fixed payments. Each option has its own implications and should be further explored within the broader analysis.

### 4.5.3 Case Study and Results

This BM has been applied to all demos in syn.ikia. Figure 39 shows the gross benefits of the green investor from the demo in Spain. The X-axis represents the percentage of discount agreed upon by the third party with the dwellings. For example, a value of 90% would indicate that the third party would first sell the energy generated to the dwellings at a price equivalent to 90% of the market price, and any unconsumed surplus would be sold to the market. It is also possible to see how the variability of these profits would have been over the last 5 years. In addition, the following results will refer to the average of these results.
Figure 39: Gross benefits of the green investor from the demo in Spain

The following table presents the percentages of energy buying and selling among all participants, including the third party, the market, and the dwellings. These percentages are influenced by various factors, such as the relationship between energy consumption and production, as well as the temporal coincidence between generation and consumption. These indices reflect the relative monetary flows between producers and consumers.

Table 14: Energy valances of households/market

<table>
<thead>
<tr>
<th></th>
<th>Norway - Panorama</th>
<th>Netherland - Uden</th>
<th>Spain - Santa Coloma de Gramenet</th>
<th>Austria_ Wir inHAUSer</th>
<th>Austria_ GNICE</th>
<th>Austria_ Berchtesgadener Straße</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of energy purchased by households from the 3º party</td>
<td>40%</td>
<td>28%</td>
<td>30%</td>
<td>21%</td>
<td>35%</td>
<td>39%</td>
</tr>
<tr>
<td>% of energy purchased by households from the market</td>
<td>60%</td>
<td>72%</td>
<td>70%</td>
<td>79%</td>
<td>65%</td>
<td>61%</td>
</tr>
<tr>
<td>% of energy sell by 3ºparty to households</td>
<td>37%</td>
<td>59%</td>
<td>75%</td>
<td>25%</td>
<td>42%</td>
<td>31%</td>
</tr>
<tr>
<td>% of energy sell by 3ºparty the market</td>
<td>63%</td>
<td>41%</td>
<td>25%</td>
<td>75%</td>
<td>58%</td>
<td>69%</td>
</tr>
</tbody>
</table>

In the following table, you will find the average annual spot prices from 2018 to 2022. These will be some of the factors that will greatly affect the profitability of the business model, along with solar radiation or investment costs.
Table 15: Average annual spot prices

<table>
<thead>
<tr>
<th></th>
<th>Norway</th>
<th>Netherland</th>
<th>Spain</th>
<th>Austria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>72 €/MkW</td>
<td>78 €/MkW</td>
<td>99 €/MkW</td>
<td>102 €/MkW</td>
</tr>
</tbody>
</table>

In order to analyse the net benefits over the 30-year lifespan of the installations, all values have been presented in terms of present real value. To calculate the present real value, an annual inflation rate of 3% has been considered in all demonstrations. Additionally, to estimate the investment, it has been assumed to be subject to a financial burden with an interest rate of 5% over 30 years. For this purpose, the equivalent annual value (annuity) of each loan has been calculated.

Table 16: Revenue results of the Green Investor

<table>
<thead>
<tr>
<th>Norway - Panorama</th>
<th>Netherland - Uden</th>
<th>Spain - Santa Coloma de Gramenet</th>
<th>Austria_ Wir inHAUSer</th>
<th>Austria_ GNICE</th>
<th>Austria_ Berchtesgadner Straße</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue per year</td>
<td>€7,445</td>
<td>€4,383</td>
<td>€3,771</td>
<td>€11,419</td>
<td>€67,841</td>
</tr>
<tr>
<td>Total revenue</td>
<td>€223,358</td>
<td>€131,497</td>
<td>€113,126</td>
<td>€342,562</td>
<td>€2,035,222</td>
</tr>
<tr>
<td>Investment cost</td>
<td>-€164,012</td>
<td>-€71,088</td>
<td>-€30,000</td>
<td>-€93,500</td>
<td>-€555,500</td>
</tr>
<tr>
<td>Investment cost</td>
<td>-€219,790</td>
<td>-€95,264</td>
<td>-€40,203</td>
<td>-€125,298</td>
<td>-€744,419</td>
</tr>
<tr>
<td>with loan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annuity</td>
<td>-€10,669</td>
<td>-€4,624</td>
<td>-€1,952</td>
<td>-€6,082</td>
<td>-€36,136</td>
</tr>
</tbody>
</table>

The following graphs display the future net revenues in present real values:
The following table presents the return-on-investment rates corresponding to each region in the case of selling energy to the dwellings at 100% of the market price. These return-on-investment rates have been calculated by dividing the net balance data obtained from the previous graphs by the investment costs, considering a 30-year loan at 5% interest. It can be observed that the investment alternatives in Spain and Austria are much more profitable than investments in Norway and the Netherlands. This difference in profitability can be attributed to various factors, including high energy production per installed kilowatt in Spain and high electricity prices in Austria and Spain.
The presented results have considered a theoretical scenario in which the third party sells energy to the dwellings at 100% of the market price. However, this scenario could vary depending on the application of the grid tariff to the dwellings, which is a supplement paid along with taxes and the cost of energy. The calculation of the grid tariff can vary significantly from one country to another and even within the same country.

For example, the grid tariff can be a fixed type, which means it depends on the contracted maximum grid capacity, or it can depend on the peak demand of energy from the dwellings. It can also have a volumetric component, meaning it depends on the amount of energy consumed. In some cases, the grid tariff can be a combination of volumetric and fixed components.

In the case that the grid tariff is of a volumetric type, the dwellings would obtain an additional benefit. This is because when they purchase energy from the third party, they would be saving the grid tariff associated with that purchased energy. This is possible because the sale of energy from the third party to the dwellings is done behind the electricity service distributor’s meter (DSO).

This could allow the third party to negotiate a selling price of the energy to the dwellings above the market price. In the case of Norway, the grid tariff typically represents approximately 32% of the total cost, and in some regions, a significant portion of this tariff has a volumetric component. This would result in a theoretical maximum selling price of up to 191% above the market price, which would imply a theoretical increase in profitability of 18% in the case of the Panorama demonstration.

It is important to note that in reality, this theoretical maximum could never be achieved since the dwellings also have bargaining power, and the determination of selling prices is done in a negotiation context between both parties.

Figure 41: Return investment Green Investor over live span
5 SPEN stakeholder perspectives and adoption

5.1 Dialogues on consumer preferences and multi-actor decision perspectives

Consumer preferences play a pivotal role in shaping the effectiveness and adoption of business models for SPENs. Customer preferences, based on the syn.ikia demonstrations, can bring new understandings of how consumers value key objectives such as reducing CO2 emissions, achieving energy self-sufficiency, and adopting renewable energy sources. The project's approach to gather insights involved conducting digital presentations and questionnaires with syn.ikia partners and demo owners (e.g., building developers) to understand perceptions on BMs and their relevance to economic sustainability in SPENs. Also, a workshop was organized to gather multi-actor perspectives across other European projects and interested consumers. The summary of the main activities is summarized here.

Preferences based on syn.ikia demos

Throughout the development and brainstorming of the syn.ikia business models, there were various individual meetings organized with partners of each syn.ikia demo. Various initial ideas on business models were presented and discussed. The goal was to gather feedback on consumer or building-owner preferences in relation to the proposed business models and their suitability to the demo and the country context. These confirmed or ruled-out certain business models proposed (see chapter 2, section 2.4). There was more preference towards internal focused business models. That is, business models that focused on sustainability and community well-being by taking advantage of surplus energy within SPEN (see Table 1). For example, in Salzburg, the feedback was that some of these business models were highly relevant to similar commercialization activities in the region, e.g., the “Solar-top” for common pv systems, “EnoxShare” for energy communities, and “eFriends” for P2P local energy markets.

In the Norwegian case, Arca Nova (building developer / consumer perspective) highlighted positive experience on navigating local markets and facilitating energy sharing among buildings, so the preference was that his was compelling business model for further exploration. It was noted that the practical application of such shared energy systems is highly pertinent, as it leverages existing infrastructures and relationships, enhancing community resilience and sustainability. Also, Arca Nova preferences were in examining the retailer business model to assess its feasibility, understand its value proposition, and evaluate its potential to integrate it to the energy market. Battery storage in buildings was also the building developer/consumer. Arca Nova noted the need to understand the benefits and challenges of integrating storage solutions within SPENs.

In the demo in the Spain and Netherlands, the preference was mainly towards maximizing PV use. Focus on business models that aim to optimize RES local production, combine battery storage use with PPA, and interest on EV charging to maximize PV use. Both demos also emphasized to explore business models that exploit or are facilitated by the development of smart energy management systems and digital twins.

Open to the public workshop on Business models

The selected business models were then discussed in an open workshop, the idea was to further validate the idea and concept behind each designed business model. The workshop titled "Emerging Business models in +Energy Neighbourhoods and Smart Energy Communities" was held in Brussels (March 2023), bringing together experts to discuss and brainstorm the latest trends in SPENs. The event focused on the development of sustainable business cases for +energy neighbourhoods and energy communities, exploring their economic viability, the role of digital tools, and the potential benefits for consumers, stakeholders involved, including utilities, building owners, developers, and investors.
The workshop was divided into two parts. The first part emphasized business models related to value streams generated within and by various Smart Energy Neighbourhoods developed in different EU projects (syn.ikia, oPEN Lab, ARV, and BEYOND). The second part provided a platform for collective discussion on key questions and challenges within emerging business models. Key discussions in the workshop included: i) an overview of business models for SPENs, ii) business models considered in the syn.ikia project, and iii) short pitches on business model ideas in the oPEN Lab and ARV projects. The workshop also included breakout sessions that delved deeper into specific aspects of emerging business models. These sessions focused on the valorisation and quantification of value streams, Citizen Energy Communities (CEC), and challenges associated with predictive digital twins.

Overall, the workshop provided a valuable platform for experts and stakeholders to discuss, brainstorm, and share perspectives on the latest trends and challenges in developing sustainable business models for SPENs. The outcome of the workshop gave renewed feedback that the proposed business models developed and studied in this report were worth exploring and analysing.

5.2 Stakeholder’s perspectives in BMs

To gain an overview of stakeholders’ perspectives on adopting BMs in SPENs, we conducted meetings to understand their inputs on the central results and ideas of each BM. Then, an online presentation was conducted with syn.ikia partners to communicate the BM outcome and the results obtained for this deliverable. In these meetings, each partner was asked to fill out a questionnaire to understand her/his perception on BMs and the relevance of economic sustainability in SPENs. As such, the research question used as backbone for the design of the questionnaire is: What is the perceived relevance of BMs for syn.ikia partners in the development of SPENs? The entire questionnaire is attached in Appendix C.

The questionnaire aims to be as anonymous as possible. However, each respondent was linked to a particular stakeholder group. The groups considered were retrieved from Deliverable 2.7 of syn.ikia (see Table 17). The
goal of characterizing is to investigate possible differences in approaches towards BMs depending on the role of the partners within the development of SPENs.

Table 17. Stakeholder groups retrieved from Deliverable 2.7 of syn.ikia

<table>
<thead>
<tr>
<th>Stakeholder name</th>
<th>Target groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Public</td>
<td>Citizens, dwellers and tenants.</td>
</tr>
<tr>
<td>Urban Authorities</td>
<td>Local councils, regions and municipalities.</td>
</tr>
<tr>
<td>Housing Community</td>
<td>(Associations of) homeowners, tenants (representatives), landlords, portfolio managers, housing co-operatives, social/public housing companies, etc.</td>
</tr>
<tr>
<td>Non-residential Community</td>
<td>Retail, care &amp; health, education, hospitality, leisure, social services, and other commercial or public buildings.</td>
</tr>
<tr>
<td>Technology and Service Providers</td>
<td>RES provider, storage technology, SME energy management, ESCO, Architecture, Engineering and Construction (AEC) Industry, green technology companies, etc.</td>
</tr>
<tr>
<td>Regulatory Authorities</td>
<td>Distribution network operator, transmission network operator, distribution systems operator, transport authority, planning bodies, etc.</td>
</tr>
<tr>
<td>Developers and Investors</td>
<td>Private and public sector banks, investment funds, institutional investors, ESCOs, etc.</td>
</tr>
<tr>
<td>Sister Projects and related projects</td>
<td>Partners in relevant “Sister” projects under H2020 and other EU programmes.</td>
</tr>
<tr>
<td>Academia</td>
<td>Research institutes and universities.</td>
</tr>
</tbody>
</table>

Moreover, the questionnaire was intentionally designed to be anonymous to promote the freedom of respondents to answer without any compromise. The questionnaire was carried out online after the presentation of the BM ideas to each partner. The questionnaire was structured in 5 sections, each one with different aims:

General information

In the "General Information" section of the questionnaire, the aim is to understand the participant's background and familiarity with the subject matter. Participants are asked to categorize their organization and concrete their level of experience and knowledge in the field, serving as a basis for more specific inquiries in subsequent sections of the questionnaire.

The results indicate that the participating audience is diverse and provides representation for all types of stakeholders present in syn.ikia. Furthermore, these results reveal that they mostly have experience with the concept of SPENs, with a notable exception being the stakeholder group encompassing Policy Advisors/Consultants, who lack experience in this area. As for experience regarding the implementation of BMs in SPENs, there is a contrasting trend where a significant lack of knowledge and experience is evident among the participants.

Broad questions about SPENs and BMs

In the this section, the aim is to gather insights on the driving forces behind the adoption of BM and SPENs. Participants are asked about the motivating factors and about the involvement of residents and third parties on BMs.

The results indicate a consensus among participants that key drivers for the adoption of SPENs are governed by economic and political reasons. Furthermore, there is a strong consensus that the primary motivation from
residents is of an economic nature. Regarding who should benefit from SPENs in the context of social housing, all participants agree that residents should have the right of benefiting from it. Where there is a diversity of opinions is whether third-party entities can or should play a role in these matters, with a slight majority in favour of their participation.

Perceived benefits of BMs in SPENs

In the "Perceived Benefits of BMs in SPENs" section, the questionnaire seeks to understand participants' views on the advantages of BMs in SPENs. In these, questions aim to capture insights into the social, economic, and decision-making aspects of BM adoption in SPENs.

The results indicate that most respondents are uncertain about whether the adoption of BMs in SPENs leads to increased social cohesion among residents. Regarding the role that BMs are perceived to play in SPENs, respondents believe that they are primarily geared towards cost reduction, with a complementary focus on generating benefits. Notably, Policy Advisors and Urban Authorities think that the pursuit of profit should not be a primary objective.

As for when the adoption of BMs should be planned, participants agree that it should occur during the initial phases of strategic planning or design. Concerning who should decide which BMs are suitable, respondents believe it should be a collaborative decision involving all relevant stakeholders. It's worth noting that none of the respondents believe that residents should be the ones making these decisions.

Perceived barriers to BM implementation

In this section, the questionnaire aims to identify the main obstacles and policy-related factors in implementing Business Models BMs in SPENs. This seeks to uncover the challenges and policy-related considerations that may affect the successful implementation of BMs in SPENs, while also assessing the perceived role of existing policies and regulations in supporting innovative BMs.

The results indicate that there is consensus among respondents regarding the top three barriers to implementing BMs in SPENs, which are regulatory in nature, financial constraints, and resident resistance. When it comes to the perception of regulatory policies concerning SPENs and BMs, they are predominantly viewed unfavourably, particularly by the Policy Advisors.

Specific questions about the BM presented in syn.ikia

In this section, the questionnaire focuses on participants' preferences and intentions regarding BMs within the syn.ikia project. This seeks to understand participant preferences and how the syn.ikia project's BMs influence their future plans, while also assessing their views on the internal and external appeal of BMs for residential end users in SPENs.

The results reveal a clear preference for the internal model of Community-Based Shared Assets over other Business Models (BMs). Among the external BMs, the SPEN becoming a retailer/aggregator and Power Purchase Agreements (PPA) stand out. It is worth noting that none of the respondents expressed support for local communities despite their current popularity.

In terms of the preference between internal and external business models, there is a division of opinions, with a slight preference for internal models.
Finally, the respondents have positively assessed the work presented in this WP and believe that it has helped them gain a better understanding of the opportunities that BMs bring and how they can add value to their future work on SPENs.

More information about the questionnaire can be found in the Appendix C. In it can be found all the individual results of the surveyed stakeholders as well as all the questions and options.
6 Financing strategies and regulatory barriers

The economic returns and benefits discussed in previous Chapters focus on individual business models (BMs) and offer country-specific details to uncover potential revenue generation schemes based on the renewable potential of SPENs on both short-term (day-to-day operations) and long-term (yearly). However, an additional layer of benefit may come from government policies aimed at promoting the use of renewable energy. These policies, which vary considerably between countries like Austria, the Netherlands, Norway, and Spain, can include elements such as feed-in tariffs, tax incentives, grants, and subsidies (REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL, 2022). They are designed to make renewable energy projects more financially viable and could significantly alter the economics of various BMs discussed in previous Chapters. For instance, policies may lower the initial cost of renewable energy installations, provide tax exemptions, or even guarantee long-term income streams for energy producers. Therefore, integrating the impact of these policy initiatives into the BMs can offer a more holistic view of the economic returns and can potentially reveal improvements in revenue-generation methods that were not immediately apparent in the initial analysis.

6.1 Qualitative analysis of impact of policy measures on different BMs

Below we segregate policies, country-wise, to go deeper into how specific state interventions can influence the BMs outlined in previous Chapters. By disaggregating the policies of Austria, the Netherlands, Norway, and Spain, we aim to provide a better understanding of how regulatory landscapes can either improve or inhibit the economic benefits derived from SPEN-related activities.

6.1.1 Austria

Wohnbauförderung

The Wohnbauförderung program provides subsidies and loans to owner-occupiers, private sector landlords, and housing associations to promote the development of affordable housing through the support of energy efficiency measures. Examples include the thermal insulation of windows, outer walls, roofs, and ceilings, connection to district heating, and installation of central heating systems, solar thermal plants, heat pumps, and biomass heating systems.

As the scheme also provide support for PV installations (Walter, 2023), by subsidizing PV installations, it may indirectly facilitate the formation of PPAs and green investor by reducing the initial investment required for PV systems, making BMs more attractive or feasible for SPENs.

Energieförderung des Landes Salzburg

The Energieförderung des Landes Salzburg, or Salzburg State Energy Subsidy, offers a variety of benefits to individuals and businesses in Salzburg, Austria, who are investing in energy efficiency and renewable energy measures.

Table 18: photovoltaic systems subsidies.

| Photovoltaic systems for private households and farmers | Systems on or at private buildings - up to max. 10 kWp per kWp: (max. € 1,500, -) | 150 €/kWp |
| Systems on or at buildings of farmers-up to max. 20 kWp per kWp: (max. € 3,000, -) | |
| > 20 kWp - 100 kWp | 110 €/kWp |
Large-scale Photovoltaic Systems (max. fundable 200 kWp) | > 100 kWp - 200 kWp | 80 €/kWp  
---|---|---
**Plus a base amount of:**  
PV community systems | € 5,000  
PV systems guidelines with investment, operation, and maintenance by third parties | € 2,500  

The funding is limited to a maximum of 35% of the total gross investment costs. The policy’s subsidies can lower the initial investment costs in PV systems, making PPAs/Green investor more appealing. For example, a large-scale PV system of 100 kWp gets €11,000 (100 kWp * €110/kWp) in subsidies, reducing the capital needed upfront. This lower investment could lead to more favourable PPA terms, potentially resulting in lower electricity prices for the SPEN.

**Befreiungselektrizitätsabgabe**

The electricity tax (Elektrizitätsabgabe) is a tax on the consumption of electrical energy in Austria. It is levied by the federal government and currently amounts to 0.001 euros per kilowatt hour (kWh).

There are several exemptions from the electricity tax, where the exemption for electricity from PV generation is unlimited, while the exemption for electricity from other renewable energy sources is limited to 25,000 kWh per year. This means that the SPEN can generate and consume as much electricity from PVs as they want without paying the electricity tax. This exemption could make PV generation more cost-effective, potentially promoting solar PPAs as there would be no additional tax cost passed onto buyers, thus fostering a favourable environment for PPAs between PV generators and buyers. Moreover, by exempting photovoltaic electricity from the electricity tax, the cost of generating and sharing solar energy is reduced. This could encourage more P2P transactions of solar electricity, making P2P energy trading platforms more attractive and financially beneficial for participants.

Drawing upon the detailed examination of Austria’s energy policies, we can make some inferences about how these legislative measures influence various business models within SPENs:

*Table 19 Overview of policies in Austria and their applicability to BMs*

<table>
<thead>
<tr>
<th>Scheme Name</th>
<th>Source</th>
<th>Target Groups</th>
<th>Support Typology</th>
<th>Business Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wohnbauförderung</td>
<td>Federal States</td>
<td>Owner-occupiers, Landlords, Housing associations</td>
<td>Subsidies, Loans</td>
<td>PPA, Green investor</td>
</tr>
<tr>
<td>Energieförderung des Landes Salzburg</td>
<td>State of Salzburg</td>
<td>Owner-occupiers</td>
<td>Subsidies</td>
<td>PPA</td>
</tr>
<tr>
<td>Befreiung elektrizitätsabgabe</td>
<td>Federal Ministry of Finance</td>
<td>Energy communities</td>
<td>Tax reduction</td>
<td>P2P</td>
</tr>
</tbody>
</table>

- **PPA:** The policies Wohnbauförderung and Energieförderung des Landes Salzburg provide subsidies that can reduce the initial cost for PV installations and can make PPAs more financially attractive.
Green Investor: The policy Wohnbauförderung makes investments in PV installations more feasible due to lower initial costs.
P2P: As Befreiung elektrizitätsabgabe exempts renewable energy production from certain electricity taxes, it makes P2P cost-effective for both buyers and sellers.

6.1.2 Netherlands

ISDE

The ISDE policy in the Netherlands\(^5\) subsidizes solar installations at €125 per kW peak power, with a minimum peak power of 15 kW, thus providing a minimum subsidy of €1,875 per installation. This subsidy lowers the upfront cost in PPAs, potentially offering cheaper solar energy for buyers and making the project more attractive for green investors. The subsidy conditions—minimum net self-consumption of 50,000 kWh per year, eligibility for business entities, installation on or attached to a building. As SPENs in syn.ikia have a collective solar installation meeting the 15 kWp minimum requirement, this policy can benefit them for the specific business model P2P, green investor and PPA.

Subsidy Scheme for Cooperative Energy Generation (SCE)

SCE aids energy cooperatives and homeowners’ associations in generating renewable electricity from solar, wind, or hydropower. The SCE scheme supports renewable energy projects, making P2P, PPA, and community asset models more viable by lowering costs. Green investors might find such subsidized projects attractive due to lower risks and alignment with sustainability goals. While the exact financial benefits would depend on the subsidy amounts and project specifics, the policy provides a supportive framework for these business models, encouraging renewable energy generation and investment in the Netherlands.

DEI+

DEI+ policy in the Netherlands, focusing on pilot projects aimed at enhancing the flexibility of the energy system, storage, and conversion of renewable energy, alongside flexible demand. Projects improving the controllability of renewable energy generation can create a more predictable energy supply, for long-term agreements like PPAs. Encouraging storage, and flexible demand could benefit community-based energy initiatives, enabling communities to better manage and share their renewable energy resources. Therefore, DEI+ policy, by subsiding renewables can be helpful in promoting business models such as PPAs and green investor. Whereas, by promoting energy storage solutions can be helpful in promoting BMs such as aggregator/retailer.

Table 20 Overview of policies in Netherlands and their applicability to BMs

<table>
<thead>
<tr>
<th>Scheme Name</th>
<th>Source</th>
<th>Target Groups</th>
<th>Support Typology</th>
<th>Business Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISDE</td>
<td>Netherlands Enterprise Agency</td>
<td>Owner-occupiers Housing associations</td>
<td>Subsidies</td>
<td>PPA Green Investors</td>
</tr>
</tbody>
</table>

\(^5\) https://www.rvo.nl/subsidies-financiering/isde/zakelijke-gebruikers/zonnepanelen
• **PPA**: The SDE+ subsidy significantly offsets the initial installation costs, making PPAs more financially viable for producers and consumers alike.

• **Green Investor**: Both the ISDE and SCE schemes offer financial benefits that can make renewable energy projects more attractive for green investors. The ISDE lowers the initial costs of solar installations, whereas the SCE scheme provides ongoing support for energy cooperatives and homeowners’ associations, thus reducing investment risks and aligning with sustainability objectives.

• **P2P**: The SCE Scheme and the ISDE subsidy contribute to making P2P models more financially appealing by reducing the cost of renewable energy installations.

• **Retailer/Aggregator**: The flexibility of the energy system promoted in DEI policy can be seen as encouraging to aggregator business model.

### 6.1.3 Norway

**Enova grant**

The Enova grant in Norway reduces the initial cost of solar installations, potentially making PPAs more financially viable, attracting green investors, and enabling community-owned renewable energy assets. With subsidies of NOK 7,500 + NOK 1,250 per kW for PV, it lowers the financial barrier, promoting renewable energy projects and aligning with broader energy efficiency and carbon reduction goals.⁶

**Husbanken loans**

Loans for high-quality housing are available to individuals who are building or significantly upgrading their main home. Husbanken loans policy supports solar systems as part of its emphasis on low energy consumption and the use of renewable energy sources in housing projects.

<table>
<thead>
<tr>
<th>Scheme Name</th>
<th>Source</th>
<th>Target groups</th>
<th>Support Typology</th>
<th>Business Model</th>
</tr>
</thead>
</table>
| Enova grant | Enova SF | Private households | Subsidies | PPA 
Green Investors 
Fair Allocation |

---

- **PPA and Green Investor**: The Enova grant substantially reduces the initial costs of installing solar systems, thus making these BMs more financially viable.

- **P2P**: While the Enova grant does not directly target P2P energy trading, the subsidy’s effect on reducing installation costs for solar systems could indirectly make P2P models more financially viable.

- **Fair Allocation**: Enova support provides advice to homeowner associations and housing associations, possibly helping them make informed decisions about fair allocation of resources in community-based renewable energy projects.

### 6.1.4 Spain

**FOR RENEWABLE ENERGIES IN SELF-CONSUMPTION, STORAGE, AND THERMAL RESIDENTIAL SECTOR (RD 477/2021. PRTR)**

On June 29, 2021, Royal Decree 477/2021 was approved by the Council of Ministers, at the proposal of the Ministry for the Ecological Transition and the Demographic Challenge, which approves the direct concession to the autonomous communities and cities of Ceuta and Melilla of aid for the execution of various incentive programs linked to self-consumption and storage, with renewable energy sources.

<table>
<thead>
<tr>
<th>Program</th>
<th>Aid</th>
</tr>
</thead>
</table>
| Incentive program 4: Realization of self-consumption installations, with renewable energy sources, in the residential sector, public administrations and the third sector, with or without storage. | 1. Self-consumption Photovoltaic Installation: €300 - €600/kWp  
2. Self-consumption wind installation: €650 – €2,900/Kw  
3. Incorporation of self-consumption storage: €140 - €490/kWh |

This policy provides financial aid for installing energy storage solutions it can improve the viability of BMs which requires flexibility such as in retailer/aggregator model.

**DUS EELL**

The DUS EELL policy in Spain focuses on aiding public entities in municipalities facing demographic challenges. Two of its relevant measures for electricity systems are:

1. Reduction of energy demand and consumption in buildings and public infrastructures.
2. Renewable electricity generation facilities for self-consumption.

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The program considers as eligible investments all the expenses necessary for the execution of the projects (execution, assembly, equipment, materials, services, reports, project directions) including technical assistance to the municipalities for drafting them, processing the aid, adaptation of ordinances or regulations to implement them, as well as VAT (when it is not susceptible to recovery). The policy covers 85% of eligible project expenses, supporting sustainable local development.

Table 22 Overview of policies in Spain and their applicability to BMs

<table>
<thead>
<tr>
<th>Scheme Name</th>
<th>Source</th>
<th>Target Groups</th>
<th>Support Typology</th>
<th>Business Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>DUS EELL</td>
<td>Institute for Energy Diversification and Saving</td>
<td>Owner-occupiers Housing associations</td>
<td>Subsidies</td>
<td>Self-consumption</td>
</tr>
<tr>
<td>(RD 477/2021. PRTR)</td>
<td>Institute for Energy Diversification and Saving</td>
<td>Residential, public administrations</td>
<td>Subsidies</td>
<td>PPA Green investor Retailer/Aggregator</td>
</tr>
</tbody>
</table>

- **PPA and Green Investor**: The financial aid under Policy 1 FOR RENEWABLE ENERGIES IN SELF-CONSUMPTION, STORAGE, AND THERMAL RESIDENTIAL SECTOR (RD 477/2021. PRTR) can make investments in renewable energy installations more feasible due to reduced costs for energy storage systems.
- **P2P**: DUS EELL policy’s focus on self-consumption could indirectly boost the internal trading model by increasing the number of prosumers within the SPEN.
- **Retailer/Aggregator**: The financial aid for energy storage under RD 477/2021 can improve the viability of business models requiring flexibility, such as in the retailer/aggregator model. The subsidies potentially reduce the high costs associated with energy storage systems.
- **Fair Allocation**: The DUS EELL policy, covering large portion of the eligible project expenses, could support fair allocation models by providing financial support for renewable energy and energy efficiency projects. Its focus on public infrastructures and self-consumption facilities could also encourage community-owned projects.
7 Conclusions

7.1 Conclusions on BM

This section provides a detailed summary of the effectiveness, potential financial benefits, and implementability challenges associated with each BM. It aims to guide SPENs in selecting the most suitable strategies for flexible energy management, financial savings, and revenue generation opportunities aligning with current regulations and market conditions. The chapter concludes with a short discussion about the effect of the BMs on the market uptake of SPEN.

7.1.1 Collective self-consumption

Collective self-consumption is identified as a key BM for SPENs, aligning with the national regulations of several countries. This approach is strategically beneficial for optimizing energy consumption and gaining significant financial savings for residents within the same building. The report findings highlight the potential of utilizing electricity storage as a source of flexibility. Future analyses could expand to encompass other flexibility types, such as flexible loads and thermal assets. The financial benefit of collective self-consumption helps in two primary ways: a) by consuming electricity during less expensive hours, and b) through reductions in grid tariffs and taxes. By shifting energy usage to align with peak renewable (PV etc.) generation during the day, communities can reduce their dependence on external electricity sources and increase self-consumption.

By transferring a portion of their energy consumption to periods when market prices are lower (through BESS or other flexibility measures), SPENs in all countries can achieve substantial annual savings. However, it is important to note that these savings might be impacted by government subsidies designed to mitigate the effects of high market prices on end consumers. For instance, in Norway, government plans to subsidize a significant percentage of electricity bills when market prices exceed a certain threshold. In regions where taxes and grid tariffs are considerably high, implementing flexibility measures to enhance energy self-consumption can also lead to financial benefits. For example, in Norway, a SPEN could potentially save a considerable percentage annually in taxes and grid fees by strategically shifting a portion of its flexible energy loads from high demand periods at evening to daytime hours, coinciding with peak solar PV generation. However, the challenge in colder climates includes the seasonal imbalance between low electricity demand during summer and high PV generation, indicating a need for seasonal storage solutions. Such investments in seasonal storage systems could help SPENs not only in achieving energy independence but also in enhancing their financial outcomes.

Regulations allowing self-consumption within a property are present in countries like Norway (effective from October 2023), the Netherlands, Spain, and Austria, thereby rendering this business model applicable at all demo-sites of syn.ikia.

7.1.2 P2P Local Energy Markets

Self-consumption can be extended to account outside the limits of buildings. This is what we described in the BM of P2P Local Energy Markets. This BM promotes a better use of flexibility potential by aligning localized generation and consumption of residents from different buildings. This framework is usually promoted through subsidies that reward collective-self consumption. This is the case in Austria where the regulatory frameworks of Building-Based Generation Plant and REC would allow the adoption of this BM.

This would represent a suitable business model for both private and social housing, although it could also be adapted for connecting several localised social houses. This idea has been simulated for a hypothetical energy community form by all 3 demos in Austria. The results of the case study show that participation in a local
community provides about 11% higher profits compared to the collective self-consumption alternative (one single building). It also shows that the installation of small-size batteries is economically compelling.

7.1.3 Community-based shared assets

Self-consumption is based on collective financial goals of SPENs. However, a fair and stable economic value allocation method is needed to define the gains/costs of each member. The business model of Community-based share assets, based on Shapley values, provides a fair allocation method. It ensures that energy-related costs and/or revenues are distributed among residents, such that financial agreements promoting self-consumption are easily reached. By ensuring fairness we promote end users to come together in long-term contractual agreements within SPENs.

Case studies performed in all syn.ikia’s demos show that all residents can obtain the true value based on their contribution to the SPEN by adopting the proposed allocation method. For instance, members consuming from renewable production would be allocated lower costs than those whose consumption does not align with local production. Similarly, residents consuming at times with high prices would be allocated higher costs than those whose usage coincides with low prices.

Furthermore, the community-based share assets BM is suitable for either public or private projects that imply collective self-consumption and/or joint investments. In the case of public projects, investment costs may not be distributed among members, given that public entities may pay these. Instead, the focus would be on allocating common operational costs (i.e., grid tariffs, energy costs). Conversely, private projects involving joint investments in distributed energy assets would require allocating their investment costs. Note that despite this report being limited to renewable energy production and storage assets, this BM can be applied to include costs derived from other types of assets (e.g., heat pumps).

To implement this BM in SPENs, one must pay attention to the regulations on collective self-consumption and metering. Throughout the report, SPENs were assumed to share a common measuring point, such that residents must agree upon how the collective bill is distributed among them. Collective self-consumption is allowed in all countries covered by the syn.ikia project. Nonetheless, not all consider a common metering point of SPENs, which is necessary to adopt this BM. In Norway, for example, the new regulation from 2023 allows to have a common metering point in the same property. This means that behind-the-meter allocation methods can be implemented.

7.1.4 Green investor

In the previous BMs, it has not been looked at different financing alternatives. This proposes an alternative of financial scheme through an external private investor that has the potential to overcome several obstacles to the implementation of REC. This brings a low-risk option for households, eliminating the need for direct investments, as the financial burden is assumed by the third-party entity. This strategy is particularly advantageous for residential structures with limited financial means.

This BM is suitable for social housing where there might be stronger budget constraints. In this case, the capital cost of the SPEN project can be reduced by letting an external green investor to cover the capital costs. Moreover, it also benefits both public and private projects where landlords and tenants might be reluctant to pay for the capital cost of energy assets. This BM would not be attractive for homes with enough purchasing power, as it provides worse long-term returns than other business models.

This green investor would act as a retailer/producer. The involves the participation of an existing energy retailer that is engaged to make investments in solar rooftop installations. Empirical evidence suggests that, in the four countries hosting the syn.ikia demos, energy retailers are already offering services as installer companies. Iberdrola in Spain serves as a relevant case in point.
7.1.5 Power Purchase Agreements

PPAs offer a way to secure stable, long-term revenue by establishing contracts with predetermined prices. The report analysis suggests that in all countries, a PV system of a certain scale could generate annual revenue exceeding a significant percentage based on year 2022 average market prices. However, if the balancing responsibilities within the PPA contracts fall on the seller-SPENs, the inherent weather-dependent uncertainties of renewable energy systems, could lead to reduction in financial revenues.

Norway, until approximately 2019, had relatively low and stable market prices, potentially diminishing the necessity for PPAs in such a market environment. On the other hand, in countries like Spain, where market prices are more volatile and often higher, long-term PPAs present an important solution for securing stable revenue streams of selling surplus energy. Additionally, PPAs offer the flexibility of establishing contracts before the actual purchase of renewable resources (as in offsite renewable PPAs). This can allow new investments in renewables, like PV systems, by providing a secure long-term revenue framework through a contract between the SPEN and an external buyer.

However, the transaction costs involved in negotiating and implementing PPAs can be challenging for smaller SPENs. To mitigate this, standardised PPA templates could lower the entry barriers for smaller market participants such as energy communities. Moreover, aggregators can play a crucial role in assisting smaller SPENs in developing and managing PPAs. They can offer various services, including finding buyers for energy to be sold, negotiating PPA contracts, and overseeing the billing and payment processes.

7.1.6 Retailer/Aggregator

SPEN as retailer/aggregator demonstrates an ambitious approach in engaging with energy markets, integrating the complexities of renewable systems and market-based tariffs. It plans to incentivize SPENs to effectively manage generation for maintaining grid balance, profiting from the differences between day-ahead and real-time market prices. Particularly in the single price imbalance markets, this model encourages SPENs to explore energy arbitrage possibility to incur financial benefits. The model shows varied impacts across countries like Austria, Spain, Norway, and the Netherlands, with significant benefits observed in managing flexibility of BESS effectively, particularly in regions with volatile energy pricing.

While smaller SPENs may face challenges in participating in ancillary service markets due to their limited capacity, collaborating with an aggregator or combining several SPENs can effectively increase their capabilities and resource pool. A collective approach can enable smaller entities to engage in ancillary service markets, also leading to substantial improvement in balancing energy uncertainties of renewable generation.

7.2 Market Uptake: Opportunities and Challenges for SPEN

As we envision the future landscape of SPENs, the evolution of various BMs become crucial in shaping their trajectory. A key aspect of scaling up these BMs is the utilization of the economic value quantified per model to develop market uptake. This involves identifying additional revenue sources, other value capture opportunities, and financial strategies. So, the uptake of the BMs in the further development of SPEN will need to address the following research questions:

- In what ways can increased sophistication in managing electricity consumption impact the growth of future SPENs, especially during peak renewable generation periods?
- To what extent will P2P Local Energy Markets expand beyond individual buildings to foster interconnected SPENs, and what technologies will facilitate this expansion?
• How can community-based shared assets ensure the democratization of benefits within SPENs, and what allocation methods will incentivize long-term end-user commitments?
• What innovative financial schemes can green investors offer to diversify funding sources for SPEN projects, particularly for those involving social housing?
• How might the role of external investors evolve to incentivize renewable energy investments in SPENs, especially in contexts with budget constraints?
• How can collaboration between SPENs and retailers/aggregators enhance market participation, particularly in ancillary service markets, and what limitations might they overcome?
• What advancements in technology are necessary for SPENs to effectively engage in energy arbitrage, and how can this optimize generation in line with market price differentials?
• What strategies will ensure the successful growth of SPENs in relation to adaptability to changing market conditions, technological innovations, and regulatory landscapes?

In conclusion, the future of SPENs will be characterized by integration of technological advancements, evolving BMs, and a deepening understanding of consumer needs. The successful growth of SPENs will depend on the adaptability of these BMs to changing market conditions, technological innovations, and regulatory landscapes. As SPENs continue to evolve, these strategic approaches will collectively contribute to a sustainable, resilient, and widely adopted energy paradigm.
References


Ortega, L. (November 2021). Interviews within Metabuilding Labs project.


Walter, W. T. (2023). Wohnbauförderung – Kriterien, Berechnung, Rückzahlung. Von https://kreditvergleichsportal.at/wohnbaufoerderung/#:~:text=Wohnbauf%C3%B6rderung%20in%20Ober%C3%B6sterreich%0AL220%3A%20In,F%C3%B6rderung%20unterst%C3%BCtzt abgerufen

Wesley Cole and Akash Karmakar. (2023). Cost Projections for Utility-Scale Battery Storage: 2023 Update. NREL.
## Appendix A. Deliverable Dissemination and Exploitation activities

### A.1 Open access Publications

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Paper Title</th>
<th>Authors</th>
<th>Publication Outlet: Scientific Journal</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Economic Arbitrage Opportunities for LECs in Balancing Markets: A Bayesian Framework Leveraging Demand Flexibility</td>
<td>Bakul Kandpal, Stian Backe and Pedro Crespo del Granado</td>
<td>IEEE Transactions on Sustainable Energy (or Industrial Informatics)</td>
</tr>
<tr>
<td>4</td>
<td>Economic Incentives to Energy Communities for Grid Flexibility Services: The Role of Local Markets</td>
<td>Naser Hashemipour, Raquel Alonso Pedrero, Pedro Crespo del Granado and Jamshid Aghaei</td>
<td>Energy in Buildings</td>
</tr>
<tr>
<td>5</td>
<td>Fair Investment Strategies in Large Energy Communities: A Scalable Shapley Value Approach</td>
<td>Raquel Alonso Pedrero, Paolo Pisciella and Pedro Crespo del Granado</td>
<td>Energy (submitted, under review)</td>
</tr>
<tr>
<td>6</td>
<td>Investing in Bifacial Solar PV in Energy Communities: Role of P2P, batteries and small wind turbines</td>
<td>Joakim, Askild, Pedro Crespo del Granado</td>
<td>Smart Energy / Smart Cities</td>
</tr>
</tbody>
</table>
Appendix B. Data used

Business model 1 - Local Markets

Table 23. Table of variables and parameters for the optimisation model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Abbreviation</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery Discharge</td>
<td>D</td>
<td>W</td>
</tr>
<tr>
<td>Battery Charge</td>
<td>C</td>
<td>W</td>
</tr>
<tr>
<td>Battery State of Charge</td>
<td>SoC</td>
<td>Wh</td>
</tr>
<tr>
<td>Battery Max. (Dis-) Charge Rate</td>
<td>Cr</td>
<td>W</td>
</tr>
<tr>
<td>Upper Bound of Battery Capacity</td>
<td>Ub</td>
<td>Wh</td>
</tr>
<tr>
<td>Lower Bound of Battery Capacity</td>
<td>Lb</td>
<td>Wh</td>
</tr>
<tr>
<td>Battery (Dis-)Charge Efficiency</td>
<td>$\varepsilon_{\text{Bat}}$</td>
<td>%</td>
</tr>
<tr>
<td>PV Production</td>
<td>PV</td>
<td>W</td>
</tr>
<tr>
<td>Demand</td>
<td>Dem</td>
<td>W</td>
</tr>
<tr>
<td>Number of Trading Peers</td>
<td>Np</td>
<td>-</td>
</tr>
<tr>
<td>Energy Export to Grid</td>
<td>Ex</td>
<td>W</td>
</tr>
<tr>
<td>Energy Import from Grid</td>
<td>Im</td>
<td>W</td>
</tr>
<tr>
<td>Spot price</td>
<td>Sp</td>
<td>eur/W</td>
</tr>
<tr>
<td>Discount energy community</td>
<td>Dis</td>
<td>eur/W</td>
</tr>
<tr>
<td>Grid tariff</td>
<td>Gt</td>
<td>%</td>
</tr>
<tr>
<td>Grid tariff subsidy</td>
<td>Gts</td>
<td>%</td>
</tr>
<tr>
<td>Legislative authority Tax</td>
<td>Tx</td>
<td>%</td>
</tr>
<tr>
<td>Energy Export to P2P market</td>
<td>Exp</td>
<td>W</td>
</tr>
<tr>
<td>Power Import from P2P market</td>
<td>Imp</td>
<td>W</td>
</tr>
</tbody>
</table>
In Austria, three innovative energy sharing models have been employed across various demonstrations. These models vary in their management structures, geographical scope, and financial incentives, serving to facilitate energy distribution in multi-party buildings, communities, and even nationwide.

Table 24: Regulatory framework Austria

<table>
<thead>
<tr>
<th>Model Name</th>
<th>Scope</th>
<th>Management</th>
<th>Unique Feature</th>
<th>Case Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building-Based Generation Plant</td>
<td>Individual</td>
<td>Inhabitants or Third</td>
<td>Utilizes building's own electrical grid9.</td>
<td>N/A</td>
</tr>
<tr>
<td>Renewable Energy Communities</td>
<td>Local or Regional</td>
<td>Community Members</td>
<td>Offers tax and grid tariff exemptions10</td>
<td>Wir inHAUSer, Berchtesgadner Straße, GNICE11</td>
</tr>
<tr>
<td>Citizen Energy Communities</td>
<td>Nationwide</td>
<td>Community Members</td>
<td>No network-level restrictions12</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Key Financial and Regulatory Aspects:

- **Pricing**: Transactions often occur at the instantaneous spot price13
- **Taxation**: Constitutes 18.3% of the invoice14
- **Grid Tariff**: Forms 24.8% of the invoice, with energy procurement making up the remaining 56.9%

Table 25: Context used in the P2P model

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographic Scope</td>
<td>21 buildings across three demos in Austria</td>
</tr>
<tr>
<td>Battery Specs</td>
<td>30 kWh battery modules integrated per building</td>
</tr>
<tr>
<td>Per Apartment</td>
<td>Equivalent to 1.8 kWh battery per apartment</td>
</tr>
<tr>
<td>Community Storage</td>
<td>Total storage capacity references 21 x 30 kWh (for the entire energy community)</td>
</tr>
</tbody>
</table>

Table 26 Cumulative data for three demos in Austria

| Total PV size all 3 demos(kW) | 655 |

9 The Building-Based model doesn't utilize the DSO's grid, hence avoiding related costs.
10 Exemptions include 1.5 cents/kWh for electricity tax and 1.3 cents/kWh for Renewable Support Contribution
11 These case studies share common local or regional codes, affecting the grid tariff subsidies
12 These communities can span across multiple Distribution System Operators (DSOs).
13 Except for surplus energy, which is sold to the retailer at real-time spot prices.
14 Data derived from Salzburg AG, a leading energy and infrastructure service provider in Austria.
### Business model 4 – Community-based shared assets

**Data for the country-wise comparison**

Table 27. Parameters used in the investment model for the four countries.

<table>
<thead>
<tr>
<th></th>
<th>Austria</th>
<th>Netherlands</th>
<th>Norway</th>
<th>Spain</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capital costs PV panels (€/kW)</strong></td>
<td>1100</td>
<td>1175</td>
<td>1532</td>
<td>767</td>
</tr>
<tr>
<td><strong>Average electricity price from wholesale (€/MWh)</strong></td>
<td>40.4</td>
<td>41.2</td>
<td>39.3</td>
<td>47.7</td>
</tr>
<tr>
<td><strong>Grid tariff (€/kWh)</strong></td>
<td>0.072</td>
<td>0.026</td>
<td>0.04</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>Tax (€/kWh)</strong></td>
<td>0.0645</td>
<td>0.115</td>
<td>0.04</td>
<td>0.093</td>
</tr>
<tr>
<td><strong>Nominal interest rate (%)</strong></td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total electricity demand</strong></td>
<td></td>
<td></td>
<td>46 MWh</td>
<td></td>
</tr>
<tr>
<td><strong>Number of dwellings</strong></td>
<td></td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td><strong>Lifetime PV panel</strong></td>
<td></td>
<td></td>
<td>25 years</td>
<td></td>
</tr>
</tbody>
</table>

**Data for the Gneis demo case.**

The input data for this case is the same as the Austrian case, but some differences are applied to fit this case. Figure 43 shows the overview of all the buildings and groups of buildings considered.

---

15 The costs associated with the solar installation and battery are from an installer in Salzburg city.
16 The costs associated with the solar installation and battery are from an installer in Salzburg city.
Then, differently from the comparative case study, the total capacity of solar panels is restricted according to data for the rooftop areas. This capacity assumes that 1 kW of solar panels occupies 0.12 square meters. In total, the community of buildings has the potential to install 667 kW. This potential is calculated as the sum of the individual potential of each building. This case includes the option of investing in stationary batteries at the cost of 1000 €/kWh. Finally, simulated load profiles of each building were provided by the project developers based on specific building characteristics.

**Business model 5 - Green investor model**

For the implementation of this business model, the defined projections for each demonstration have been used. The following table presents the data used in this simulation of the business model.

<table>
<thead>
<tr>
<th>Norway - Panorama</th>
<th>Nederland - Uden</th>
<th>Spain - Santa Coloma de Gramenet</th>
<th>Austria_Wir inHAUSer</th>
<th>Austria_GNICE</th>
<th>Austria_Berchtesgadner Straße</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pv size (kW)</strong></td>
<td>107</td>
<td>60.5</td>
<td>39.1</td>
<td>85</td>
<td>505</td>
</tr>
<tr>
<td><strong>Pv production per year (kWh)</strong></td>
<td>107572</td>
<td>59994</td>
<td>39946</td>
<td>111672</td>
<td>663462</td>
</tr>
<tr>
<td><strong>Electric energy demand (kWh)</strong></td>
<td>98737</td>
<td>127840</td>
<td>99538</td>
<td>134231</td>
<td>790473</td>
</tr>
<tr>
<td><strong>Price per kW of PV (€/kW)</strong></td>
<td>2300</td>
<td>1630</td>
<td>767</td>
<td>1100</td>
<td>1100</td>
</tr>
<tr>
<td><strong>Investment total cost PV (€)</strong></td>
<td>-246100</td>
<td>-98615</td>
<td>-30000</td>
<td>-93500</td>
<td>-555500</td>
</tr>
<tr>
<td><strong>LCOE (€/kWh)</strong></td>
<td>0.0508</td>
<td>0.0395</td>
<td>0.0250</td>
<td>0.0279</td>
<td>0.0279</td>
</tr>
</tbody>
</table>

Information about the maximum generation capacity of the solar panels has been obtained from the preliminary startup report titled "2.7 Commissioning report draft_V3." Production data has been obtained from simulations performed with the PVGIS tool. On the other hand, demand data has been based on
simulations reflecting the electrical consumption of the dwellings in each demonstration. Price estimates per kilowatt of installation have been obtained from actual quotes provided by installation companies in each country.

The model has been implemented, and a sensitivity analysis has been conducted using the market prices of each country over the last 5 years, calculating their average. This action has been taken due to the notable variability of the European electricity market in recent years.
Appendix C. Stakeholder Questionnaire

1. Please select to which of the following stakeholders do you categorize your company/organization:
   - A. Technology and service providers
   - B. Academia
   - C. Policy Advisors/Consultancy
   - D. Housing Communities.
   - E. Urban Authorities
   - F. Developers and Investors
   - G. Sister Projects or Related Projects

2. Is syn.ikia your first project related to SPENs/Energy Communities/Sustainable Neighborhoods?
   - A. Yes
   - B. No

3. Are you familiar with the adoption of Business Models (BM) in SPENs?
   - A. Yes
   - B. No

Broad questions about SPENs and BMs

4. What do you believe is the most key factor driving the adoption of SPENs?
   - A. Company policy push
   - B. Government policy push
   - C. Economic attractiveness
   - D. Demand from customers/residents
   - E. Differentiation strategy from competitors

5. Please select on which consideration do you believe is the most relevant for SPEN’s residents.
   - A. Environmental benefits of the project
   - B. Social benefits for residents
   - C. Economic gains for residents
6. How do you believe residents and third parties (i.e., profit-oriented companies) should be involved in BMs of SPENs for social housing?

A. Residents should be allowed to actively participate in adopting BMs to increase their energy affordability.
B. Third parties should be allowed to actively participate in adopting BMs to improve residents' energy affordability.
C. The residents have already increased their affordability through social housing, so no additional BMs should be adopted.

Perceived benefits of BMs in SPENs

7. Do you believe the adoption of BMs in SPENs could lead to more social coherence among residents?

A. Yes
B. No
C. Unsure

8. When you visualise SPENs adopting BMs, do you perceive them as pursuing profit generation or achieving cost savings?

A. For generating positive profits
B. To reduce costs
C. Both, it only depends on the BM

9. In which phase of the SPENs’ development do you believe BMs should be considered and decided?

A. Strategic planning
B. Design planning
C. Construction phase
D. Once it is already in use
10. In your opinion, who should be primarily responsible for deciding which BM to apply in SPENs?

A. Property Developer/Company
B. External Consultants/Experts
C. Collaborative Decision Involving Multiple Stakeholders
D. Regulatory Authorities/Government Agencies
E. Resident communities

Perceived barriers to BM implementation

11. Please select the three biggest barriers you perceive when it comes to the implementation of BMs in SPENs.

A. Lack of financial resources
B. Limited technical expertise
C. Regulatory compliance challenges
D. Resistance to change within residents
E. Limited access to necessary technologies
F. Uncertainty about market demand
G. Lack of stakeholder buy-in
H. Lack of clear BM strategy
I. Difficulty in identifying required partners
J. Hiring/contacting experts on the domain of the BM

12. What is your perception about how well current policies and technical regulations support the success of innovative BMs in SPENs?

A. Extremely Supportive
B. Very Supportive
C. Moderately Supportive
D. Slightly Supportive
E. Not Supportive
F. Detrimental
G. Not sure

Specific questions about the BM presented in syn.ikia

13. Among the BMs models within syn.ikia, which one do you find most appealing or promising for your demo in syn.ikia?

A. Local Market
B. Community-Based Shared Assets
C. SPEN becoming a retailer/aggregator
D. Power Purchase Agreements (PPA)
E. Green Investor
F. Inter-SPEN concept
G. PEN Grid-flexibility services
14. Looking ahead, which of the mentioned BMs are you most interested in applying or exploring further? (Select all that apply)

A. Local Market
B. Community-Based Shared Assets
C. SPEN becoming a retailer/aggregator
D. Power Purchase Agreements (PPA)
E. Green Investor
F. Inter-SPEN concept
G. PEN Grid-flexibility services

15. Based on our distinction between internal (e.g., P2P or Community Based Shared Assets) and external (e.g., PPA, Green Investor) BMs, what do you believe is more appealing for residential end users in SPENs?

A. External BMs
B. Internal BMs

16. Has the work on BMs for syn.ikia influenced your plans to consider BMs in future SPEN projects?

A. Yes, it has helped me to understand more opportunities that can add value to my future work on SPENs.
B. Yes, it has helped me understand other economic alternatives, although it is beyond my scope as a partner in SPENs.
C. Not really. I do not consider it relevant to my job.
D. Not really. I was already aware of these possibilities.
Table 29: Individual results questionnaire.

<table>
<thead>
<tr>
<th></th>
<th>2. Is syn.ikia your first project related to...</th>
<th>3. Are you familiar with the adoption of Business...</th>
<th>4. What do you believe is the most key factor...</th>
<th>5. Please select on which consideration do you...</th>
<th>6. How do you believe residents and third...</th>
<th>7. Do you believe the adoption of BMs in SPENs...</th>
<th>8. When you visualize SPENs adopting BMs...</th>
<th>9. In which phase of the SPENs' development...</th>
<th>10. In your opinion, who should be primarily...</th>
<th>11. Please select the three biggest barriers you...</th>
<th>12. What is your perception about how well...</th>
<th>13. Among the BMs models within syn.ikia...</th>
<th>14. Looking ahead, which of the mentioned BMs are...</th>
<th>15. Based on our distinction between internal...</th>
<th>16. Has the work on BMs for syn.ikia...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academia</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>C</td>
<td>A</td>
<td>C</td>
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<td>D</td>
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<td>B</td>
<td>C</td>
<td>C</td>
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<td>C</td>
<td>C</td>
<td>B</td>
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<td>E</td>
<td>G</td>
<td>G</td>
<td>A</td>
<td>D</td>
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<td>Academia</td>
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<td>B</td>
<td>C</td>
<td>A</td>
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<td>C</td>
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<td>B, E</td>
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<td>B</td>
</tr>
<tr>
<td>Developers and Investors</td>
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<td>C</td>
<td>B</td>
<td>C</td>
<td>B</td>
<td>A</td>
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<td>D</td>
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<td>B, C, D</td>
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<td>Housing Communities.</td>
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<td>C</td>
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<td>C</td>
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<tr>
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</tr>
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<td>Technology and service providers</td>
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</tbody>
</table>
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FOR COMMUNICATION ACTIVITIES:

“This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 869918”.

[Logos of various institutions]