RIGA TECHNICAL UNIVERSITY

Roberts Lazdiņš

DEVELOPMENT OF PROSUMER-CONSUMER ENERGY COMMUNITY PLANNING TOOL AND METHODOLOGY

Doctoral Thesis

RTU Press
Riga 2024

RIGA TECHNICAL UNIVERSITY
Faculty of Computer Science, Information Technology and Energy
Institute of Power Engineering

Roberts Lazdiņš
Doctoral Student of the Study Programme “Smart Power Systems”

DEVELOPMENT OF PROSUMER-CONSUMER ENERGY COMMUNITY PLANNING TOOL AND METHODOLOGY

Doctoral Thesis

Scientific supervisor
Professor Dr. sc. ing.
ANNA MUTULE

RTU Press
Riga 2024

Lazdiņš, R. Development of Prosumer-Consumer Energy Community Planning Tool and Methodology. Doctoral Thesis. Riga: RTU Press, 2024. 102 p.

Published in accordance with the decision of the Promotion Council "P-05" of 26 March 2024, No. 97/24.

Part of the research within the Doctoral Thesis was supported by the European Social Fund within Project No. 8.2.2.0/20/I/008, "Strengthening of PhD students and academic personnel of Riga Technical University and BA School of Business and Finance in the strategic fields of specialization" of the Specific Objective 8.2.2, "To Strengthen Academic Staff of Higher Education Institutions in Strategic Specialization Areas" of the Operational Programme "Growth and Employment".

Part of the research within the Doctoral Thesis was supported by Riga Technical University's Doctoral Grant programme.

ABSTRACT

Tackling the challenges of global warming and energy security requires substantial changes in energy systems. While large and centralised energy systems could transition towards renewables, thus creating the necessity for large amount of financial resources, non-governmental organisations and scholars have proposed a shift towards household-scale and more decentralised energy supply systems using electricity sharing and energy communities (EnCs). Although the concept of EnCs has gained wide popularity in several countries of the European Union, its implementation in Latvia is hindered with policy, economic, technical and social challenges and setbacks.

Doctoral Thesis is focussed on addressing aforementioned challenges by developing prosumer and consumer EnC planning tool and methodology under proposed peer-to-peer approach based business model. Its main objective is to effectively showcase the economic advantages of EnCs in Latvia, motivate interest in electricity sharing among the public and substantiate the effectiveness of external funding, thereby making it applicable and useful not only to electricity users, but also to legislators and policymakers in Latvia and other countries. With the help of various case studies and scenario modelling, the Doctoral Thesis provides recommendations and suggestions to improve economic viability and feasibility of prosumer and consumer EnCs in Latvia. Additionally, results evaluate various factor effect on the economic sustainability of EnCs.

ANOTĀCIJA

Globālās sasilšanas un energoapgādes drošuma problēmu risināšanai ir nepieciešamas būtiskas pārmaiņas energosistēmā. Kamēr lielās un centralizētās energosistēmas varētu pāriet uz atjaunīgajiem energoresursiem, tādējādi radot nepieciešamību pēc lielu finansiālo resursu apjoma, nevalstiskās organizācijas un pētniecības nozaru pārstāvji ierosina veikt energosistēmu pārveidi mājsaimniecību un decentralizēto energoapgādes sistēmu virzienā ar elektroenerģijas kopīgošanas un energokopienu (EnC) ieviešanas palīdzību. Lai gan EnC koncepts ir guvis plašu popularitāti vairākās Eiropas Savienības valstīs, tā ieviešanu Latvijā kavē politiski, ekonomiski, tehniski un sociāli izaicinājumi.

Promocijas darbs ir vērsts uz iepriekšminēto izaicinājumu risināšanu, izstrādājot aktīvā lietotāja un galalietotāja EnC plānošanas rīku un metodoloģiju saskaņā ar piedāvāto savstarpējās tirdzniecības pieejas balstītu biznesa modeli. Tā galvenais mērķis ir efektīvi demonstrēt EnC izveides ekonomiskās priekšrocības, rosināt sabiedrības interesi par elektroenerģijas kopīgošanu un pamatot ārējā finansējuma piešķiršanas efektivitāti, tādējādi padarot to izmantojamu ne tikai elektroenerģijas lietotājiem, bet arī likumdevējiem un politikas veidotājiem Latvijā un citās valstīs. Ar vairāku gadījumu izpētes un scenāriju modelēšanas palīdzību, promocijas darbā tiek sniegti ieteikumi, lai uzlabotu aktīvā lietotāja un galalietotāja EnC izveides ekonomisko pamatojumu un ilgtspēju.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

AF – Accumulated funds;

CAPEX – Capital expenditures;

CEB – Consumers’ economic benefits;

CEC – Citizen energy community;

CS – Case study;

EC – European Commission;

EnC – Energy community;

EU – European Union;

IEEE – Institute of Electrical and Electronics Engineers;

NECP – National Energy and Climate plan;

NPV – Net present value;

OPEX – Operational expenditures;

P2P – Peer-to-peer;

PEB – Prosumers’ economic benefits;

PV – Photovoltaics;

RE – Renewable energy;

REC – Renewable energy community;

RES – Renewable energy source;

SC – Scenario;

VAT – Value added tax.

INTRODUCTION

Background and relevance of the study

The European Union (EU) has taken a significant leap towards attaining climate neutrality through the implementation of a set of legislation acts: Clean Energy for All Europeans package [1] and Fit for 55 [2]. Their common goal is aimed to set balance between making decisions at EU and national level to promote energy efficiency and renewable energy (RE), along with a range of initiatives to safeguard vulnerable consumers, foster a more competitive energy market and mitigate the potential impact of global warming in the future. Nevertheless, the integration of RE into electricity consumption has long been a focal point in the EU's policy development.

In 2009, Renewable Energy Directive (2009/28/EC) [3] and Electricity Directive (2009/72/EC) [4] was the first EU documents which highlighted the advantages and potential for transitioning from the conventional energy system to locally established renewable energy sources (RES). Consequently, the directives mandated that EU Member States must simplify procedures and regulatory frameworks, granting households that generate electricity from RES and consume it (also known as "prosumers") simplified access to the electricity grid. In 2010, the Energy Performance of Buildings Directive (2010/31/EU) [5] further emphasised the use of RES by introducing the concept of "nearly energy-zero buildings" and efforts to increase households' self-consumption levels. To increase households' electricity self-consumption even further, in 2015 European Commission's communication on Delivering a New Deal for Energy Consumers [6] collective self-consumption idea was first mentioned thus laying the first foundation stone for facilitating electricity exchange and sharing among other households. By approving Clean Energy for All Europeans packages' revised Renewable Energy Directive (2018/2001/EU) [7] in 2018 and Electricity Directive (2019/944) [8] in 2019, EU has paved the way for expanded integration of RES at local and household level. Additionally, these directives have facilitated increased opportunities for easier and wider accessibility of RE by removing administrative and bureaucratic barriers for sharing locally produced electricity from renewables. Furthermore, aforementioned directives have officially recognised and defined a new concept known as energy communities (EnCs).

To determine different guidelines of operational tasks, expected goals, objectives and their adoption flexibility in EU Member States national legislation, Directive 2018/2001/EU and Directive 2019/944 have defined two types of EnCs:

- **renewable energy communities (RECs)**: a legal entity which primary purpose is to provide environmental, economic or social community benefits for its shareholders or members or for the local areas where it operates, rather than financial profits. Shareholders or members are natural persons, small and medium-sized enterprises or local authorities [7].
- **citizen energy communites (CECs)**: a legal entity which primary purpose to provide environmental, economic or social community benefits to its members or shareholders or to the local areas where it operates rather than to generate financial profits. It may engage

in generation, including from renewable sources, distribution, supply, consumption or provide other energy services to its members or shareholders. Shareholders or members are natural persons and local authorities [8].

Furthermore, aforementioned directives [7, 8] have determined additional emphasis for the effective and economically justified implementation of EnCs in the EU Member States:

- Member States shall provide an enabling **framework** to promote and facilitate the development of EnCs.
- **Distribution system operator must cooperate** with EnCs to facilitate energy transfers.
- Member States must develop **tools and mechanisms** to facilitate access to finance, technical and other community-related information.

It can be mentioned that EU Member States are obliged to implement directives issued by the EU institutions to achieve their stated goals not only in national legislation, but also in their developed strategies and plans with flexibility of the implementation and content of the articles stipulated in the directives [7-9].

Latvia, as a Member State of the EU, has identified the EnC concept and its implementation plan as a **one of the priorities** in the transformation of the energy system. Specifically, in Latvia's National energy climate plan (NECP) for 2021 – 2030 [10], as well as in legislation changes and amendments.

In order to successfully integrate EnCs into the existing electricity supply system, NECP has proposed the following action plan points:

- Renewable energy self-production, self-consumption and EnCs must be able to operate in an **economically justified environment without technical, financial or legislation barriers**.
- Development of EnC mutual electricity trading mechanism using **peer-to-peer** business model.
- Creating **legislation and environment** that supports and encourages the establishment of EnCs.

In order to take the first steps towards achieving NECP's determined EnC related goals, Latvia's legislation has adopted legislative changes in **Energy Law** [11] and **Electricity Market Law** [12], thus starting to resolve legislative related barriers. Due to the aforementioned changes, the national legal framework defined the concept of an EnC as a combination of renewable energy community and citizen energy community definitions mentioned in EU's Directive 2018/2001/EU and Directive 2019/944. Moreover, Energy Law makes a distinction between two definitions of EnCs: "Renewable energy community" and "Electricity energy community". In spite of these distinct definitions, the Energy Law specifies that EnC encompasses either the renewable energy community or the electricity energy community, or the conditions of both simultaneously. Instead of maintaining two separate definitions, the term "energy communities" is used to collectively refer to both of these EnC definitions. Thereby, Energy Law defines EnC as "a legal entity that deals with energy - mainly from renewables electricity and other types of renewable energy obtained from energy resources - production, selling, sharing, consumption and storage of electricity, provision of demand response service, electric provision of vehicle charging service, energy efficiency service or other energy services". Moreover, Electricity Market Law outlines specific operational guidelines that EnCs must follow to:

- Members or shareholders are **electricity consumers and prosumers** which are connected by a single system operator system.
- Electricity must be shared within one trading interval. Electricity not consumed **immediately** is not accumulated for sharing in another trading interval, but **must be sold to the electricity trader at the agreed price**.
- System objects which are participating in the electricity sharing activities **cannot participate in the net metering system, net settlement system or system of certificates of origin of electricity**.

In spite of the legislative support for the establishment of EnCs at both the European Union and national level, the broad and successful development and implementation of EnCs in Latvia encounters certain policy, economic, technical and social challenges.

First of all, Latvia's legislation has determined that the production and sharing of EnCs electricity is ensured with the help of prosumers [12]. Respectively, prosumers have the opportunity to share the electricity they produce with others, first covering their self-consumption. Due to historically implemented support measures for RE microgeneration: the net metering system [12] and state aid for the purchase of photovoltaic panels and wind generators [13]: in 2022, in Latvia there were more than **12 000 prosumers** [14] (and 904 717 household electricity users connected to the electricity distribution grids [15]), for which the maximum installed power of electricity generation source is below **11.1 kW** [14]. In addition, assessment study has determined that only 14% of total electricity users (including prosumers) in Latvia would be willing to participate in EnCs [16]. This suggests low willingness to participate in EnCs among prosumers and consumers. Moreover, prosumers are **geographically scattered** and **comparatively small in number** when compared to the overall number of electricity users.

Furthermore, the amendments of Electricity Market Law have determined that prosumers' self-consumption of generated electricity must be at least 80% of the annual amount produced from RES [17]. The same requirement applies for prosumers to qualify for state aid to partially cover the cost for the purchase of RES-based generation source [13]. Consequently, this reflects the relatively **limited amount of electricity** they could share within an EnC.

Bearing in mind all above, the limited number of prosumers and low amount of shareable electricity is insufficient for the formation of a large-scale, multi-prosumer and multi-consumer EnCs based on existing conditions. Thereby, there is a **considerable** and **high potential** for the formation of a prosumer and a conventional electricity consumer EnCs, thus fostering a **stronger sense of community** and **promoting RE accessibility** for those who cannot install their own RES.

Nevertheless, small-size EnCs, particulary those involving only prosumer and consumer, has considerable **advantages** over multi-prosumer and multi-consumer EnCs [18]:

- **Forecasting**: determination and planning of the economic benefits can be more accurate and easier to understand, as the impact of the flexibility of the predicted inputs of several participants (for example, electricity generation and consumption data) is significantly reduced.
- **Data exchange**: hourly electricity consumption and generation data, form of forecasted near-future data and additional payment-related information increases with the number of participants, thereby small-size EnCs can reduce the amount of information that have to be shared with distribution grid operator, electricity trader and members of EnC. Besides, prosumer and consumer EnC is the optimal solution for privacy preservation regarding electricity consumption data.
- **Management and cooperation**: A low number of participants in an EnC facilitates more coordinated decision-making concerning electricity cost payments and electricity sharing actions. This, in turn, makes it easier and clearer to predict the payback period and assess viability indicators.
- **Viability and efficiency**: Prosumer and consumer EnCs can attain a substantial portion of the economic and self-consumption advantages associated with multi-prosumer and multi-consumer communities at the same time maintaining aforementioned forecasting, data exchange, management and cooperation advantages and benefits.

It is important to highlight that the implementation of EU directives into national legislation and the existing variations in legislation among EU Member States contribute to differences in EnC regulations and legal frameworks across countries. Thereby, the legal **framework for EnCs is not standardised and unified among EU Member States**. [19-21] As a result, tools that have been developed for the planning and modelling of EnCs in specific countries **are difficult to apply or are not even compatible** to evaluate the efficiency and economic feasibility of EnCs in other countries [21], including Latvia.

Considering the aforementioned, Latvia's electricity consumers lack a framework to discern the potential advantages of electricity sharing activities and prerequisites for the creation and participation in prosumer-consumer EnCs. Moreover, lack of tailored **EnC planning tool** suitable for Latvia's specific conditions complicates the assessment of potential benefits. Both EU directives [7, 8] and Latvia's NECP [10] have indicated the importance and necessity of aforementioned tool that could be as a basis and an indicator for the determination of EnCs economic viability and justification. This proactive approch would be beneficial not only from the electricity consumer and prosumer point of view, but also for **policymakers**, thereby assessing the effectiveness of state aid and the effect of existing legislation on the economic indicators of EnCs.

Hypothesis, objective and tasks of the Thesis

Hypothesis

A comprehensive framework centred on the electricity users and outlining the economic benefits of energy sharing can facilitate EnC implementation in Latvia.

Objective and Tasks

The objective of the Doctoral Thesis is to develop a prosumer-consumer EnC planning tool tailored to Latvia's legislation and energy transition goals to demonstrably bridge knowledge gaps, clarify the economic viability and benefits of electricity-sharing for potential members of EnC, policymakers and other stakeholders.

To achieve the stated objective, the following tasks are determined:

1. Review legislation acts, scientific publications and media sources to determine EnC implementation requirements, guidelines, possible challenges and setbacks.
2. Develop a methodology and modelling tool for planning prosumer-consumer EnC initiatives under Latvia's legislation and energy transition goals.
3. Study the variable factor effect on the economic feasibility and sustainability of prosumer-consumer EnCs through case study and scenario modelling.

Research methods and tools

To enhance the research transparency, studies presented in the Doctoral Thesis were performed using widely available and user-friendly tools. Additionally, the author of the Thesis developed algorithms used in research studies at the Riga Technical University Institute of Power Engineering.

Chapter 1 involved empirical review and **PESTLE analysis** of diverse information sources: scientific publications (using **Scopus, Web of Science, IEEE Xplore and Science Direct databases**) and media sources to gather a **broad spectrum** of energy experts' and public viewpoints on EnC implementation progress, setbacks and challenges. Additionally, Microsoft Excel was used to collect and summarise key information from the publications and other information sources.

In **Chapter 2**, a prosumer-consumer **EnC planning tool** was developed based on a proposed peer-to-peer approach using accumulated funds and the acquisition of external funding. To promote its accessibility for potential EnC members, researchers, policymakers, and other stakeholders, the EnC planning tool is freely available on the **GitHub platform**. Furthermore, the Microsoft Excel environment was used to develop analysis graphs, figures, and illustrations.

In **Chapter 3**, the variable factor effect on economic feasibility and sustainability of prosumer-consumer EnCs are determined using **modelled case studies and scenarios**. Freely available Ninja_europe_pv_v1.1 and "Sadales Tīkls" **data repositories** were utilised for gathering input information on PV system electricity generation and household electricity consumption profiles. Furthermore, Microsoft Excel is used to collect input data, acquiring output data and detailed results of the study and developing analysis graphs, figures, and illustrations.

Scientific novelty

To facilitate and motivate the establishment of EnCs under Latvia's existing EnC and prosumer-related legislation and energy transition goals, a planning tool for prosumer-consumer EnCs was developed, thus **promoting open-access** electricity sharing and EnC modelling activities in Latvia. The tool incorporates a sophisticated and comprehensive algorithm that **determines power and cash flows** within the EnC and between the EnC and electricity trader using the electricity distribution grid. Additionally, the tool enables the calculation of prosumers' and consumers' **economic benefits** from participation in the EnC, along with an analysis of net present value related to the purchase of RES-based generation source. Thus, this developed **planning tool serves as an effective means** for demonstrating the economic viability of prosumer-consumer EnCs in Latvia. It also acts as a **catalyst** and provides rationale and openness for the proposed EnC to be implemented in other countries (if necessary, adapting and modifying it to the respective legislative guidelines).

Considering the operational approach of the tool, it **comprehensively models** prosumers' and consumers' **electricity tariff** plans (whether fixed or dynamic), **hourly electricity generation and consumption**, the amount of **external funding** received for the purchase and installation of electricity generation source and **financial indicators**, such as capital and operational expenditures, as well as determining how these expenditures can be repaid (whether from **initial investments** or through a **bank loan**). This flexibility allows the planning tool to simulate a **diverse range** of prosumer and consumer EnCs. Such adaptability enables the tool to **develop a broad spectrum of case studies and scenarios** involving EnC members' electricity consumption and electricity generation, as well as financial obligations among EnC members, the distribution grid operator, and the electricity trader.

Practical significance of the research

The work carried out during the development of this Thesis has contributed to the following research projects:

- "*Management and Operation of an Intelligent Power System (I-POWER)*", funded by the Latvian Council of Science (2018–2021).
- "*Supporting Energy Communities – Operational Research and Energy Analytics (SECOREA)*", funded by the ERA-NET Cofund grant under the CHIST-ERA IV Joint Call on Novel Computational Approaches for Environmental Sustainability (2019 – 2024).

Furthermore, research activities within the Thesis were carried out with financial support from the European Social Fund within Project No. 8.2.2.0/20/I/008, "Strengthening of PhD students and academic personnel of Riga Technical University and BA School of Business and Finance in the strategic fields of specialization" of the Specific Objective 8.2.2, "To Strengthen

Academic Staff of Higher Education Institutions in Strategic Specialization Areas" of the Operational Programme "Growth and Employment", as well as from Riga Technical University's Doctoral Grant programme.

The developed planning tool and methodology can serve not only as a determinant of the efficiency of potential prosumer-consumer EnCs and information dissemination means to inform the public about EnCs, but also as an **auxiliary tool for policymakers** to model the effectiveness of the amount and type of state aid, as well as the effect of existing legislation and potential legislation amendments on the viability and sustainability of the prosumer and consumer EnCs under the proposed business model. By being freely available on GitHub, the **planning tool can empower students, researchers, and energy enthusiasts** with valuable insights into the operation and development of EnCs, thus increasing their **knowledge and interest in RE and energy-sharing**-related activities.

Author's contribution

The literature review regarding EnC implementation guidelines, experiences, challenges and setbacks was carried out by the author of the Thesis in close collaboration with the Associate Professor D. Žalostība under the supervision of Professor A. Mutule. The author contributed to all stages of this work, particularly in the investigation, publication collection, review, analysis, publication writing, as well as the creation of visualisation materials.

The review of existing business models, development of the proposed EnC business model, prosumer-consumer EnC planning tool and modelling of case studies and scenarios was carried out by the author of the Thesis under the supervision of Professor A. Mutule. The author of the Thesis carried out publication collection, business model review and analysis, development of planning tool and its guidelines, collection of input data, case studies and scenario modelling, publication writing, as well as the creation of visualisation materials.

Approbation of the results

The research results included and related to this Thesis have been presented by the author at the following scientific conferences.

1. 2020 IEEE 61st International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON), 5–7 November, 2020, Riga, Latvia.
2. 2021 IEEE 62nd International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON), 15–17 November 2021, Riga, Latvia.
3. 2022 IEEE 63rd International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON), 10–12 October 2022, Riga, Latvia.
4. 2023 IEEE 64th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON), 9–11 October 2023, Riga, Latvia.

The results related to the Thesis have been presented by the author at the following international scientific workshops and events.

5. 1st follow-up meeting and workshop of the Latvia Country Desk, COME RES project, 6 October, 2022, Riga, Latvia.
6. World Congress of Latvian Scientists (Science Slam Competition), 27–29 June 2023, Riga, Latvia.
7. Workshop No. 4: Digital power system protection and control, Nordic–Baltic Co-Simulation Platform Towards Increasing the Stability of AC/DC Transmission Grids (COSPACT), 23–24 November, 2023, Trondheim, Norway.

The results included in the Thesis have been published in the following peer-reviewed scientific publications (indexed in Scopus/Web of Science).

1. **R. Lazdins** and A. Mutule, "Operational Algorithm for Natural Gas Boiler and Heat Pump System Optimization with PV Panel" in *2020 IEEE 61th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON)*, Riga, Latvia, 2020, pp. 1–4, doi: 10.1109/RTUCON51174.2020.9316571.
2. **R. Lazdins**, A. Mutule, and E. Kairisa, "Feasibilty Study in Energy Community Business Model Development for Latvia", in *2021 IEEE 62nd International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON)*, Riga, Latvia, 2021, pp. 1–5, doi: 10.1109/RTUCON53541.2021.9711730.
3. **R. Lazdins**, A. Mutule and D. Zalostiba, "PV Energy Communities—Challenges and Barriers from a Consumer Perspective: A Literature Review", *Energies*, vol. 14, art. no. 4873, 2021, doi: 10.3390/en14164873.
4. **R. Lazdins** and A. Mutule, "Scenario simulation of a small-scale energy community management", in *2022 IEEE 63th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON)*, 2022, pp. 1–5, doi: 10.1109/RTUCON56726.2022.9978828.
5. T. Korõtko, F. Plaum, T. Häring, A. Mutule, **R. Lazdins**, O. Borščevskis, A. Rosin, and P. Carroll, "Assessment of Power System Asset Dispatch under Different Local Energy Community Business Models", *Energies*, vol. 16, art. no. 3476, 2023, doi: 10.3390/en16083476.
6. **R. Lazdins** and A. Mutule, "Impact of Variable Factors on the Viability and Efficiency of Energy Communities: A Scenario Simulation Study in Latvia", in *2023 IEEE 64th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON)*, 2023, pp. 1–5, doi: 10.1109/RTUCON60080.2023.10413190.

The results included in the Thesis have been accepted for publication in the following peer-reviewed publications (indexed in Scopus/Web of Science).

7. **R. Lazdins** and A. Mutule, "Assessment of Various Factors Affecting Economic Indicators in Prosumer and Consumer Energy Communities: A Case Study in Latvia", *Latvian Journal of Physics and Technical Sciences*, 2024.

Other results obtained during the development of the Thesis have been published in peer-reviewed scientific publication (indexed in Scopus/Web of Science).

8. J. Stakens, A. Mutule, and **R. Lazdins**, “Agriculture Electrification, Emerging Technologies, Trends and Barriers: A Comprehensive Literature Review”, *Latvian Journal of Physics and Technical Sciences*, vol. 60, pp. 18–32, 2023, doi: 10.2478/lpts-2023-0015.

Structure of the Thesis

The Thesis is written in English. It comprises introduction, three main chapters, conclusions, bibliography with 95 references and three annexes. It contains 49 figures and 15 tables. The volume of the Thesis is 102 pages.

Chapter 1 is dedicated to identifying EnC implementation challenges in Latvia and in other countries that could emerge in Latvia after the post-establishment of EnCs. Within the framework of the chapter, recommendations are provided to help overcome challenges and setbacks by developing the prosumer-consumer EnC planning tool.

Within the framework of **Chapter 2**, a review of existing EnC business models is carried out. Within the framework of the chapter, the existing legislation related to Latvia’s EnCs is also considered. As a result of the review of business models and related legislation, a peer-to-peer approach-based business model with accumulated funds and external funding modification is proposed. In addition, the chapter presents the prosumer-consumer EnC planning tool, which is based on the proposed business model.

Chapter 3 presents models of three baseline EnCs, incorporating several case studies and scenarios to assess the effect of various factors on the economic feasibility and viability of the prosumer-consumer EnC under the proposed business model. Modelling results lead to recommendations for potential EnCs’ members, legislators, policymakers and other stakeholders. These recommendations focus on prerequisites that can enhance the economic viability and operational efficiency of the EnCs under the proposed business model.

1. IMPLEMENTATION OF ENERGY COMMUNITIES

1.1. The background to the implementation of the energy communities

Tackling the challenges of global warming and energy security requires substantial changes in energy systems. As of 2021, the energy supply sector stood as the leading emitter of carbon dioxide, contributing approximately 25% of total emissions (see Fig. 1.1) [22], thus creating discussions about the direction of energy transformation and a structure of a decarbonised energy system.

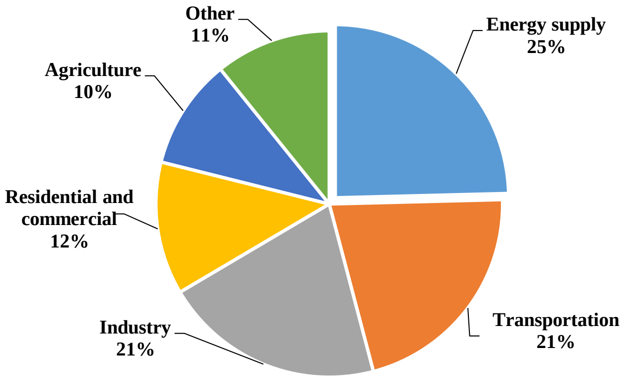

Fig. 1.1 Distribution of greenhouse gas emissions by the sector in the European Union [22]

While large energy systems could converse source of energy towards RE, thus creating the necessity for large amount of financial resources, non-governmental organisations and scholars have proposed a shift towards household-scale and more decentralised systems [23].

The first stage of the decentralisation of the electricity system was the transition of electricity users (consumers) to active users (also known as "prosumers") by installing RES based electricity generation sources, thus partially or even fully covering households' electricity consumption by self-consuming generated electricity. Furthermore, prosumers and RE self-consumption promotes environmental neutrality, increase households' autonomy, electricity supply security and reduce overall cost of consumed amount of electricity from the grid. [24, 25]

In order to accelerate the transition towards clean energy with help of local community engagement around renewable energy projects [26], as well as increase electricity consumers' participation in RE consumption and electricity efficiency measures [27], EU has defined a second stage of decentralisation of the electricity system and energy sharing concepts: "renewable energy communities" (RECs) [7] and "citizen energy communities" (CECs) [8].

Table 1.1 Difference between REC and CEC [7, 8]

	REC	**CEC**
Related EU legislation	EU Directive 2018/2001	EU Directive 2019/944
Energy technologies	RES-based	RES-based and fossils
Energy sector	Electricity, transport, cooling and heating	Electricity
Purpose	Environmental, economical and social benefits for the members of the EnC, shareholders or the local are in which EnC is operating	
Activities	Energy generation, consumption, sharing and trading activities, storage, aggregation and energy efficiency measures	Electricity generation, consumption, supply, sharing and trading activities, storage, aggregation, electric vehicles charging and energy efficiency measures

As mentioned in [7, 8], implementation of EnC concepts is associated with benefits not only for prosumers, but also for conventional electricity consumers. Primary benefits of engaging in EnCs include, but are not limited to following:

- Electricity sharing can fight energy poverty through reduced electricity consumption and lower supply tariffs provided by the EnC [28-30].
- EnC can provide RE to those electricity consumers who do not have the financial or technical opportunity to install their own the electricity generation source [31].
- Financial income from shared electricity can be used to promote energy efficiency measures, thereby improving both living standards and reducing electricity costs [32-34].

Nevertheless, participants in EnCs can experience other social, environmental and economic benefits, as highlighted in [35].

The total number of EnC implementations in the EU serves as an indicator of both their effectiveness and popularity. The overall count of EnCs throughout EU is not officially documented, but [36] has determined that there are more than 1900 renewable EnCs (as cooperatives) with approximately 1.25 million electricity consumers participating in them. However, [37] indicate that, as of 2022, over 9000 EnCs have been established across EU. Although EnCs are widely adopted, their acceptance rate is not consistent throughout the Member States. As indicated by [38-40], Latvia and five EU Member States (Cyprus, Hungary, Luxembourg, Malta, and Slovakia) do not have established fully operational EnCs. Considering the widespread adoption of EnCs and the benefits associated with their establishment, the absence of them is linked to existing challenges and setbacks for their formation and integration into the electricty supply system. Identifying and overcoming these challenges is essential for promoting the sharing of electricity and fostering the establishment of EnCs, as emphasised in the Latvia's NECP [10].

To identify them, the upcoming sections will focus on pinpointing and reviewing the challenges using on PESTLE analysis based approach [41], thus dividing review findings in four areas of interest: policy, economic, technical and social. Review will be conducted not only based in the context of Latvia but also by examining existing and overcomed EnC implementation challenges in other countries, that may arise post-establishment of EnCs. By delving into the experiences of surmounting these challenges, recommendations for overcoming them in Latvia can be provided.

1.2. Identified energy community implementation challenges in Latvia

Pinpointing identified challenges in scientific literature, project deliverables, reports for Latvia is one of key factors in assessing the national-level EnC implementation actions and progress in overcoming them from different perspectives. Moreover, by additionally collecting opinions of public and experts could develop a more comprehensive understanding of the challenges and opportunities associated with EnC development from the electricity users and non-governmental institutions point of view. In doing so, a focused compilation of challenges and setbacks identified from diverse information sources and perspectives facilitates a concise review and challenge interconnections, thus enabling the opportunity to provide recommendations and strategies for navigating through these challenges in Latvia more effectively.

A significant challenge for EnC development in Latvia is absence of relevant legislation. In spite of the amendments and legislative changes of Energy Law and Electricity Market Law, the establishment of EnCs in Latvia remains unattainable due to the lack of regulations from the Cabinet of Ministers outlining procedures for electricity sharing, responsibilities, oversight and EnC operating distance [12, 42]. This indicates an underdeveloped framework for EnCs, and as mentioned in [43], existing policies do not explicitly support community energy projects and initiatives. The deficiency in legislation has drawn criticism from the public and energy experts, who express frustration over the apparent delay in the development of related regulations. Additionally, the unavailability of drafts for the developed legal act to the public creates an impression of legislators being hesitant to introduce EnCs in Latvia [44]. This suggests a connection between the absence of legislation and challenges in not only policy aspect, but also in other dimensions: the adoption of supplementary regulations of Cabinet of Ministers is essential to efficiently develop the general EnC implementation framework [42].

Regarding economic EnC implementation challenges, [42] indicates that existing support instruments for RE are not sufficient to effectively facilitate the development of EnCs in Latvia, thereby suggesting diversification of support schemes to financially support not only the creation of EnC, but also developing economic incentives for planning and operational activities. In addition, [43] determines that net metering system used by electricity prosumers could not be compatible with the EnCs due to the fact that net metering system is not available for other organisational bodies, such as small and medium enterprises. Moreover, experts and the public sector highlight a deficiency in information and tools for assessing the viability and payback period of potential EnCs. This underscores the concern that, without a clear economic benefit forecast, the adoption of EnCs among electricity consumers might be limited and even non-motivating [44, 45].

Alongside the lack of legislation, economic support schemes and information availability, EnC implementation is also associated with other technical challenges. Electricity Market Law has defined that members of EnC must be under the same electricity trader and before the start of operations, as EnC must conclude an electricity sharing agreement with that electricity trader [12]. According to the Public Utilities Commission's Register of Merchants [46], in 2023 in Latvia there were 42 electricity traders. Since each of these electricity traders presents distinct tariff plans that are suitable and economically advantageous for different groups of electricity consumers, selecting a single electricity trader for all members of a community may lead to hesitancy in joining the EnC. This reluctance could result in the loss of existing electricity trader offers and discounts, creating the potential for increased electricity tariffs and overall costs for certain members of the EnC. By combining aforementioned with the low number of prosumers and their geographical distribution [14, 15], as well as low amount of electricity available for sharing after their self-consumption [13, 17], the establishment of a large-scale EnC in Latvia using existing prosumers and recently introduced amendments and legislative changes in the Electricity Market Law may be considered insufficient.

On top of that, aforementioned challenges also create several setbacks regarding the social aspect of EnC development in Latvia. The stakeholder survey conducted by [42] has clearly indicated that due to the absence of regulations and solutions to the aforementioned challenges, awareness of the EnC concept in the public and policy attention toward EnCs and their potential benefits is notably low. Consequently, the lack of information contributes to low civic engagement and acceptance rates concerning EnCs, as well as a lack of willingness to participate in energy sharing and cooperation activities [43].

Although the reviewed literature sources have identified policy as a main setback, it has an effect to economical, technical and social related challenges: lack of policy causes defficiency of vision towards the development of EnCs. In addition, lack of information sources and modelling tool availability do not allow to clearly determine the potential economic benefits for electricity consumers and prosumers from the creation and participation in EnCs. Nevertheless, Latvia's experience towards EnC implementation is too low for the the number of publications and their descriptive analysis of challenges to be able to comprehensively identify hurdles that may arise after the widespread development of EnCs. Thereby, the review of the experiences of other countries and their identified challenges would broaden the horizons in the direction of other difficulties, which for the time being are not possible to identify in the context of Latvia.

1.3. Identified energy community implementation challenges in other countries

To gain insights into potential challenges which might appear at the stage of widespread post-establishment of EnCs, the section explores implementation and acceptance challenges beyond the borders Latvia by reviewing a thematic set of scientific literature, thus offering an international perspective on difficulties faced in other countries and seeking to examine the broader global EnC landscape from policy, economic, technical and social perspectives [47]. This proactive approach can help to avoid the challenges encountered by other countries, thus facilitating a more rapid and seamless implementation and acceptance rate of EnCs.

Authors of [48] point out that government policies and support schemes in the Baltic States are key factors for the actions to increase the attractiveness and installed capacity of RES based electricty generation sources, thus motivating the creation of EnCs. Findings from the United States indicate that the electric utility companies' lobbying efforts, coupled with their limited attention to RES, can impede the progression of legislation acts [49]. The lack of EnC related legislation can be attributed not only to the lack of support from utilities, but also to insufficient involvement from other stakeholders: electricity consumers, policymakers, installers and electricity generation companies [50]. Overall, this indicates the weak dialogue between stakeholders, as well as availability of information about the benefits about transition towards RES and electricity sharing options. In addition, lack of policy and implementation non-acceptance can be caused by a non-existance of specific and different target group communication and information dissemination plans [51, 52]. Moreover, publication regarding Spain [53] indicate that not only government policies, but also policies within existing EnCs themselves could underscores the significance of their implementation and electricity users' willingness to participate. Specifically, the EnC policy related to electricity sharing have a greater economical effect than the policy concerning electricity pricing for the sale of excess energy outside the borders of EnC. Aforementioned study has determined neccessity for a structured approach, how these policies and their interactions can increase EnCs' overall efficiency. The publication concludes that, by fostering greater electricity sharing, there is no justification for the installation of electricity storage systems.

From the economic and technical point of view, scientific literature determines that type of remuneration and state aid [51], as well as increased level of self-consumption and determined electricity sharing and selling tariff system [54] are key factors that affect the payback period of EnCs. In order to determine the impact of these factors on the efficiency and viability of the EnC, modelling tools under various business models have been developed in numerous softwares, such as PVSYST [55], PV*SOL [56] and HOMER [57], as well as using artificial intelligence and neural network techniques [58]. While these software applications and modelling techniques enhance the design and planning, their use requires purchasing licenses, high programming skills and may pose user-friendliness and other challenges for their use by electricity users. The proposed and developed modelling tool blanks and scenarios are not universally applicable due to variations in EnC related legislations, business models and operational restrictions across different countries. Furthermore, [59] highlights that current business models are relatively complex and difficult-to-follow due inclusion of several industries stakeholders' interests and complicated technology and management systems. It indirectly slows down the development of new EnCs in England and creates a demand for greatly simplified business, financial payment and mutual settlement models.

Social studies have also focused on the analysis of electricity consumers', thereby determining which groups of society are most willing to purchase RES-based electricity generation source, as well as to participate in EnCs. The Swiss experience indicates that younger individuals with higher incomes and a less conservative attitude exhibit a greater willingness to participate in EnCs compared to those with lower incomes and conservative attitudes [60]. Similarly, a study conducted in Pakistan [61] identifies overall electricity costs, income levels, education and information accessibility about the advantages of EnCs as key factors affecting social acceptance and adoption rates. Another survey [62] concludes that the technological forms and equipment used in EnCs are not decisive factors for willingness to participate. The collective findings from these studies suggest that targeted information and educational campaigns focused on RES, climate neutrality and demonstrating the environmental and economic benefits of participating in EnC and energy sharing activities, can enhance adoption rates and willingness to participate among electricity users.

Taking all the aforementioned factors into consideration, EnC implementation challenges outside Latvia are not only linked to the lack of related legislation, but also the lack of communication, information and proposal exchange between to the parties involved, thus leading to conflicts of interest and non-support stance. The ineffective dissemination of information is further compounded by the insufficient knowledge among electricity users regarding the social, economic, and environmental benefits, resulting in fragmented support for the installation of RES-based electricity generation source and EnCs in general. Additionally, literature sources indicate the absence of easy-to-follow business models and the limited availability of user-friendly EnC modelling and planning tools, posing challenges to EnC planning activities. To offer strategies for overcoming both the identified challenges in Latvia and challenges that can be aligned with those identified in other countries, the following section will present recommendations and suggestions to help to overcome them.

1.4. Discussions and conclusions for overcoming the identified challenges

To expedite the implementation of EnCs in Latvia, it is crucial to formulate a strategy for overcoming the identified challenges and offer corresponding recommendations. This section consolidates the findings both within reviewed literature sources regarding Latvia and other countries, and present suggestions on how these challenges can be surmounted.

The main identified challenges from the previous sections can be summarised in following perpective groups:

1. Policy perspective: lack of Cabinet of Minister regulations, insufficient involvement from EnC-related stakeholders, information dissemination activities.
2. Economic perspective: lack of EnC oriented government support measures (state aid), lack of EnC economic benefit planning tools, complex business models.
3. Technical perspective: implementation of a single electricity trader for members of one EnC, low number of prosumers and their geographical distribution, small amount of electricity available for sharing after prosumers’ self-consumption.
4. Social perspective: low public and policy attention toward EnCs, low acceptance and willingness-to-participate rate, lack of targeted information campaigns.

Considering that amendments and legislative changes have been made to the Energy Law and Electricity Market Law, thus defining the concept of EnCs and introducing their operational guidelines, Regulation of Cabinet of Ministers can be considered as the key factor which hinders the creation of EnCs in Latvia from a legislative point of view. Respectively, with the development of related regulations the following electricity sharing arrangements would be defined: conditions and procedure for sharing electricity, the procedure for exchanging information between EnC participants and system operators, as well as EnC required information that has to be shared with an electricity trader [12]. To expedite this process and align it with the needs of all stakeholders, the responsible Ministries, including the Ministry of Climate and Energy, should conduct consultation activities. These consultations should extend beyond industry representatives, encompassing electricity consumers, prosumers, environmental non-governmental organisations and scientific institutions. Regarding the account for shared electricity, it could be recommended to assigning this responsibility to both the electricity trader and the system operator existing data processing activities, thus bypassing the need to establish dedicated platforms for tracking the quantity of shared electricity between the members of EnC and electricity trader. Such an approach aims to streamline the introduction of EnCs in Latvia and prevent unnecessary implementation delays.

In spite of the ongoing networking and information dissemination efforts related to EnCs, such as conferences [63, 64], discussions and seminars [65, 66], it is recommended to persist in information dissemination initiatives. This includes open-access discussions, sharing scientific findings and ideas, as well as disseminating informative content through various public media channels and the websites of government and non-governmental institutions. Enhanced information accessibility would not only foster awareness and education among electricity users, but also bring the topic of EnCs and their implementation benefits to the forefront for other stakeholders. This, in turn, would encourage cross-sectoral development and facilitate stakeholder discussions concerning RES and EnCs, including mouth-to-mouth information dissemination.

Although a single electricity trader may be used for the management of the shared, selled and imported amount of electricity, it is recommended to guarantee that, upon transitioning from their existing electricity trader to the one designated by EnC, the electricity tariff and price plans should align with the same rates as prior to their participation in EnC. Such an approach would overcome electricity consumers doubts about the potential increase in the electricity tariffs and prices after joining the EnC. The same effect can be created by including several electricity traders in the management of EnC - entrusting one with electricity sharing and monitoring services, while the others would provide consumer electricity supply activities (in case when EnC generation could not cover all electricity consumption), using the same tariff plans as before electricity users' participation in EnC. This, in turn, could create positive competition environment between electricty traders, preserving users' rights to independently choose the electricity trader.

In order to create a justification for the creation of multi-prosumer EnC, it is necessary to increase their total number in Latvia. This can be achieved by executing the aforementioned initiatives aimed at disseminating information, highlighting not only the implementation advantages of EnCs, but also emphasising the benefits of becoming a prosumer. Additionally, providing financial state aid to prosumers and EnC participants could serve as a catalyst for their engagement in electricity sharing activities for reasons extending beyond environmental considerations. Further recommendations for financial state aid may involve supporting the development of EnCs with financial resources from EU funds (such as the Cohesion Fund and European Regional Development Fund) and redistribution of financial resources from national and local government budgets, thereby directing financial support towards lowering the start-up and operational costs of the development of EnCs.

To validate the economic justification and efficiency of establishing EnCs in Latvia, it is crucial to concentrate on the planning and justification of their activities - from amount of electricity shared within the EnC and ending with financial benefit planning under individual approaches and restrictions. This process should be firmly grounded in existing legislation to encompass the interests not only of potential participants but also of other involved parties. Development of EnC planning tool specifically designed for the use in Latvia would address almost all aforementioned EnC implementation challenges. Respectively, tool would effectively showcase the economic advantages of EnCs under different electricity tariff and price plans, electricity generation capacities and individual constraints. Consequently, the use of planning tool would motivate interest in EnCs among the public and substantiate the effectiveness of external funding (such as state aid) and its effect on the EnC, thereby making it applicable and useful not only to electricity consumers and prosumers, but also to legislators and policymakers. Nevertheless, already different tools are used for EnC modelling and planning activities. Unfortunately, their utility is constrained not only in terms of application and accessibility, but also by the legislations of individual countries and used business models [67]. This limitation renders them to be less or even not usable under Latvia's legal and RES environment. Hence, with the motivation to address identified challenges and bearing in mind the limited number of prosumers and their relatively low amount of shareable electricity, there exists a substantial and well-founded demand for a planning model centered around prosumer and conventional consumer EnCs.

To encourage the establishment of EnCs in Latvia and assess the potential advantages to potential participants, the following chapter delves into the formulation of a planning tool specifically designed for prosumer and consumer EnCs, as well as detailed description of the associated modelling activities.

2. DEVELOPMENT OF PROSUMER-CONSUMER ENERGY COMMUNITY PLANNING TOOL

2.1. Determination of mutual interconnection between prosumer and consumer

As discussed in the previous chapter, lack of related legislation and electricity users' willingness to participate in energy sharing activities can be considered as one of the main setbacks and challenges for the EnC implementation in Latvia. In order to increase electricity users engagement in EnCs, it is crucial to offer them easy-to-understand and most appropriate mutual interconnection strategy (as business model) regarding cost allocations and electricity sharing activities, thus providing transparency regarding EnC operations. In addition, the choice of a business model for prosumer and consumer EnCs significantly affect the functionality of the proposed planning tool, given the diverse roles of EnC members in electricity sharing and cost distribution activities. Since EnC have already become widespread in the EU using different approaches, it is crucial to further study the experience of these countries regarding used business models. Therefore, this section conducts an analysis of different EnC business models, aiming to compare them and evaluate their potential applicability to EnCs in Latvia.

One of the first business models to be implemented in the EnCs in the United Kingdom was grant-based model. [59]

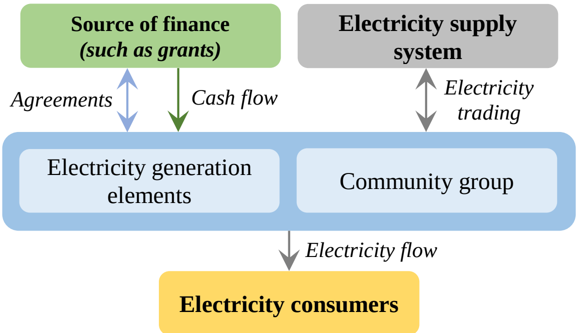

Fig. 2.1 Visualisation of grant-based business model [68]

Business model was based on external funding and cash flow from environmental organisations, societies or RES-motivated investors. Electricity generation source were provided and maintained free of charge by technological companies and other stakeholders which were included in the community group. Thereby, there was no need for the members of EnC to participate in electricity remuneration activities using sharing tariffs. In other words, electricity sharing between members of EnC was free of charge, as well as transfer the excess amount of electricity after self-consumption to the grid. Grid ensured the stability of the EnC by supplying electricity to users when electricity generation source would not cover their electricity demand. Nevertheless, such a business model was not considered self-sustaining and not viable due to the necessity for external funding to fully cover initial and operational costs of electricity generation source. After 2010, when United Kingdom introduced feed-in tariff system, grant-based business model was replaced by mutual electricity sharing and financial settlement business models. [59]

More advanced business model was created for experimental EnCs in the Netherlands based on multi-agent system approach. [69]

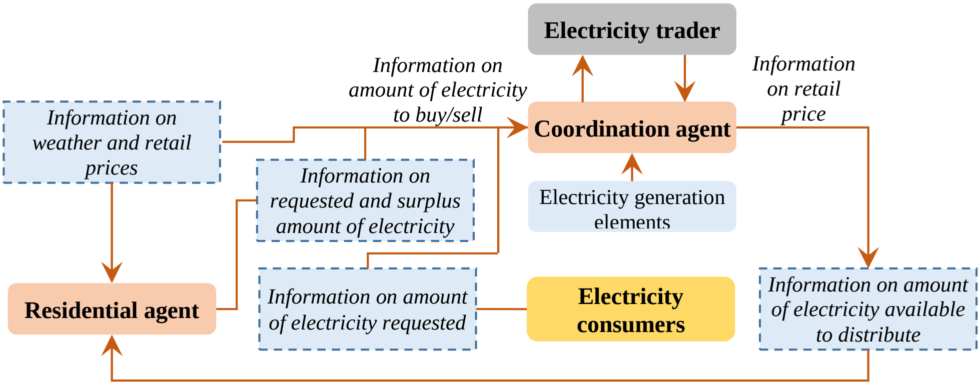

Fig. 2.2 Visualisation of information flow in multi-agent business model [68]

In multi-agent business model, community group was replaced by residential agent (electricity prosumers and consumers which would perform load management activities) and coordinator agent (one member of EnC which would decide amount of electricity shared between the members of EnC and the electricity trader). Although such a business model facilitated the coordinated operation of electricity sharing activities, it required a large amount of data related to electricity retail prices, weather prognosis and other data which made this business model particularly difficult-to-follow. Furthermore, communication and decision-making between residential and coordination agents could pose challenges for the EnC in executing the tasks of individual agents, potentially leading to a risk of conflict. [70]

To prevent potential risk of conflict and facilitate comprehensibility of business models, energy cooperative business model was introduced. [71]

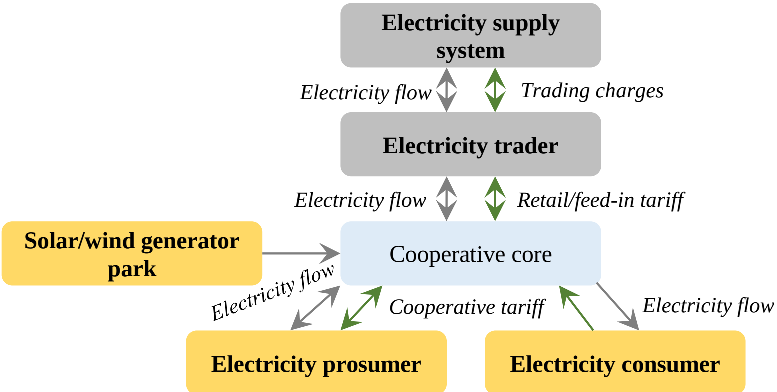

Fig. 2.3 Visualisation of energy cooperative business model [68]

In energy cooperative business model, residential and coordination agents were merged into one entity (cooperative core). In addition, business model included the opportunity to include autonomous electricity generation sources (solar and wind generator parks) and abilities for the prosumers to tranfer their excess amount of electricity after their self-consumption to other cooperative members using certain electricity sharing tariff. Due to the potentially stochastic manner of electricity generation from autonomous electricity generation sources and prosumers, cooperative electricity sharing tariff would fluctuate. In order to mitigate the effect of tariff fluctuations on overall electricity expenses, an adjustment has been made to an energy cooperative through the incorporation of an energy service company. [71]

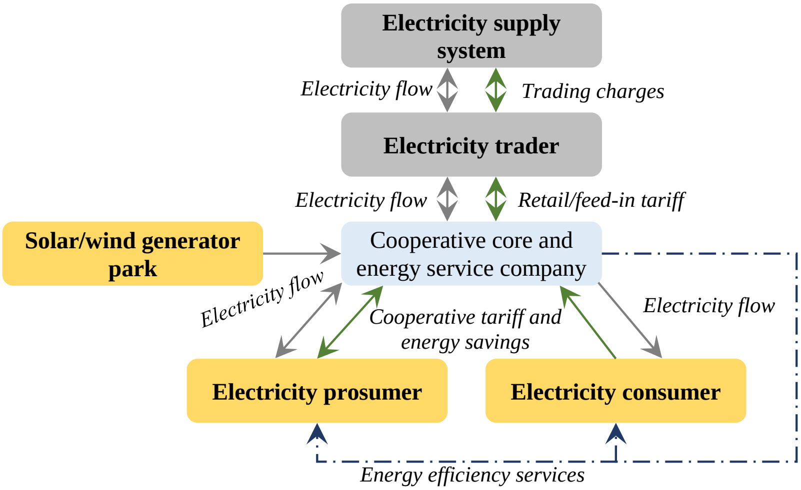

Fig. 2.4 Visualisation of energy cooperative business model with energy service company [72]

Its primary objective is to provide energy efficiency services, such as insulating households and installing energy efficient equipment. EnC members do not directly experience financial benefits, aside from increased comfort, as all cost savings from energy efficiency initiatives and EnC income are redirected to the energy cooperatives’ savings account. Additionally, a portion of this cash flow is allocated directly to the energy service company. [71]

It can be mentioned that energy cooperatives are one of the most used form on EnCs in Europe [72]: there are more than 1900 energy cooperatives with approximately 1.25 million electricity consumers participating in them [36], mainly in Denmark, Germany, France and Spain [73].

To extend the benefits of EnC implementation not only to its members but also to the electricity supply system by providing ancillary and flexibility services, virtual power plant business model has been developed. [74]

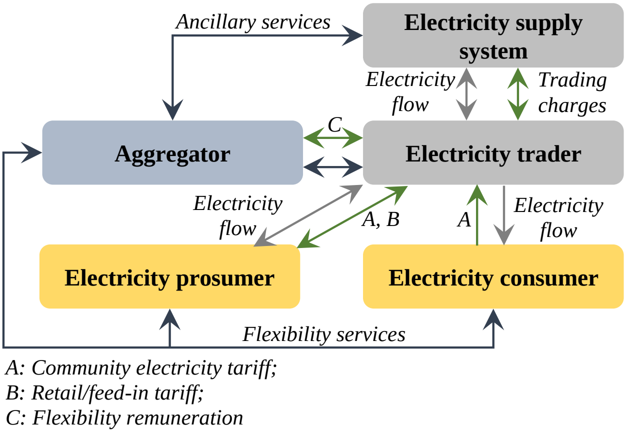

Fig. 2.5 Visualisation of virtual power plant business model [68]

Aforementioned business model heavily relies on direct load control, where aggregators adjust and control EnC member electricity demand or generation. In this setting, devices with on/off control owned by electricity users largely contribute to more efficient and cost-effective resource utilisation for self-consumption. Additionally, these devices offer ancillary services for the grid, enabling it to give or receive specific amount of electricity from or to the grid in exchange for financial compensation. [74]

Each of the previously discussed business models supplemented one another with innovative solutions concerning electricity and cash flow. However, these models lacked the capability for direct transfer of electricity between the members of EnC. To enable all members to engage independently and without discrimination in electricity sharing and trading activities, peer-to-peer (P2P) business model was suggested.

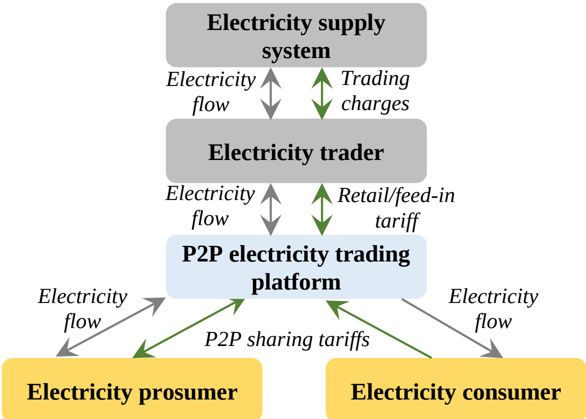

Fig. 2.6 Visualisation of P2P business model [68]

P2P electricity sharing is based on third-party developed platform, in which electricity prices are negotiated directly with all members of EnC, thus allowing prosumers to directly sell their excess amount of electricity after self-consumption to other members of EnC. Sharing process allows all participants to negotiate fairer prices for their generation rather than being forced to accept whatever price a supplier is prepared to offer. [74] By doing that, P2P business model has proven to be one of the most recognised business models in EnCs due to its ability to increase overall self-consumption level, reduce amount of electricity import from the grid and increase related electricity cost savings at higher level compared to other business models [36].

It is worth noting that Latvia's NECP identifies the development of a new market model based on a P2P approach as a key foundation for EnC implementation. [10] In spite of the potential use of this model to ensure the operation of EnCs, the aspects of other business models discussed above can serve as additional elements to enhance the efficiency of this model and benefits for prosumer and consumer EnCs. Considered business models and their adoption potential in Latvia can be summarised as follows:

- Grant-based business model: although such a business model is considered economically inefficient, it has indicated that there is a necessity for electricity sharing actions between prosumer and consumer using determined tariff, thus making the EnC financially independent and economically viable. Nevertheless, external funding as grants for installing electricity generation source or establishing the EnC could significantly impact the payback period and economic justification of the EnC. It is noteworthy that in Latvia, financial grant support is available for the purchase RES-based electricity generation sources. [13] However, a corresponding support mechanism for the establishment of EnCs is currently absent.
- Multi-agent business model: the implementation of such a model is related to its highly complex execution, as it requires accurate and large data weather and price modelling solutions which would make difficult to determine economic benefits for the creation of EnC. Nevertheless, multi-agent business model has proven that electricity sharing and payment activities must be managed by one and potentially independent member, thus facilitating electricity and cash flow monitoring and enforcement activities.
- Energy cooperative business models: they combine both the implementation of the autonomous electricity generation source described in the grant-based and multi-agent business models, as well as the opportunity for prosumers to participate in it with their excess amount of electricity after their self-consumption coverage. In spite of the widespread adoption of cooperative models across Europe, Latvia's Electricity Market Law [12] has determined, that only electricity prosumers and consumers can participate in EnCs, thus increasing the level of self-consumption with help of prosumers' locally generated amount of electricity. In other words, Latvia's existing legislation does not allow independent electricity producers, including solar or wind generator parks, to participate in EnCs, with the exception of the centralised electricity supply system. Nevertheless, energy efficiency measures to decrease electricity demand is highly encouraged: business model should include income diversion from electricity sharing and trading activities not

only for the repayment of electricity generation source, but also for energy efficiency measures in the future in the form of EnC accumulated funds. Furthermore, considering that the purpose of EnC is not to make a financial profit for individual members of EnC, redirection of EnC income to energy efficiency improvement or other welfare activities are indicated by the relevant EU directives [7, 8] and Latvia's Energy Law.

- Virtual power plant business model: while the flexibility of electricity demand could potentially balance the load in the electricity supply system, the registration of only one aggregator in Latvia offering its services [75], as per the Aggregator Regulations established in 2020, suggests a limited demand for load aggregation. Furthermore, Latvia's legislation has not established aggregation regulations and guidelines for EnCs. Nevertheless, one prosumer and one consumer EnC load aggregation might have a minimal effect on the electricity supply system, given the relatively low levels of electricity consumption, generation, and sharing within EnCs. To achieve a balance between electricity generation and consumption within the EnC, both prosumers and consumers can individually implement measures to enhance consumption flexibility without relying on an aggregator services.
- P2P business model: although the use of a P2P business model for prosumer and consumer EnC is determined to be suitable under Latvia's existing legislation and EnC development and implementation plans, it is recommended for independent P2P electricity platform to be replaced by assigning its tasks and duties to both the electricity trader and the system operator existing data processing and management systems, thus bypassing the necessity to establish dedicated platforms for tracking the quantity of shared electricity between the members of EnC and electricity trader. Such an approach aims to streamline the introduction of EnCs in Latvia and prevent unnecessary implementation delays.

By integrating elements from each examined business model and enhancing them with the P2P approach, a business model for EnC planning tool involving one prosumer and one consumer is proposed by the author of the Thesis.

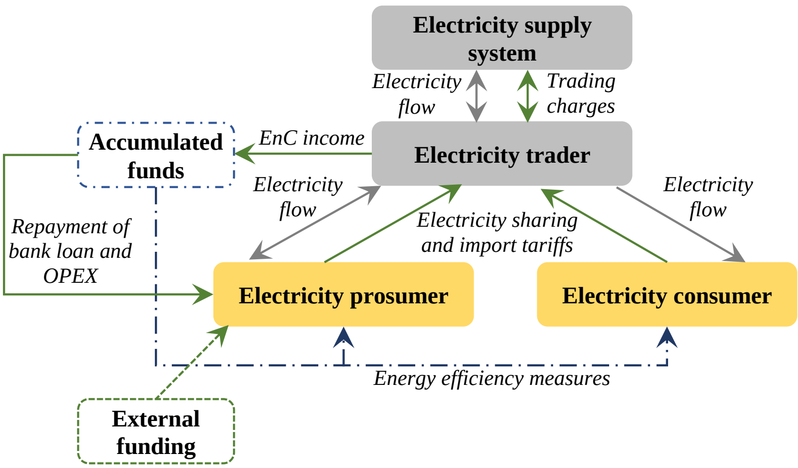

Fig. 2.7 Proposed EnC business model [76]

However, it is important to align it with the additional constraints and operational guidelines using comprehensive examination of legislative framework. The limitations included in the business model, as well as the operating principle of the model itself, are discussed in the next subsection.

2.2. Restrictions and guidelines

The primary objective of this subsection is to arrange the previously suggested business model with Latvia's existing legislation, thus incorporating specific operational guidelines and technological solutions for efficient electricity sharing within the EnC.

Electricity Market Law has defined that members of EnC must be connected to one system operator and and electricity sharing must be done independently through it. Furthermore, EnCs are not entitled to managing (owning, renting, buying etc.) distribution grids autonomously. Electricity sharing must be done with help of system operator infrastructure managed by electricity trader with which contract between EnC and electricity trader must be concluded. In spite of the study made which determined that theoretically net metering system could be efficiently used for sharing activities within the EnC [77], Electricity Market Law determines that amount of generated electricity not immidiately consumed by the members of EnC is not accumulated for sharing in another trading interval, but must be sold to the electricity trader at the agreed price. Furthermore, system objects (consumers and prosumers) participating in electricity sharing activities cannot participate in net metering system, net settlement system as well as the system of certificates of origin of electricity. Finally, members of EnC simultaneously cannot participate in other EnCs or electricity sharing activities to other individual electricity users. [12]

Energy Law has defined that primary purpose of the EnC is not to make a financial profit, but to provide economic, social and environmental quality improvements to the members or shareholders of EnC. The profit obtained by the EnC is not distributed or paid out as dividends, but is invested to achieve the goals set by the EnCs' articles of association. In addition, the Ministry of Economics must develop support programs for EnCs that use only renewable energy resources, including support for commercial activities. [11]

Due to existing constraints on state aid allocation [13], participation in the net metering system [12] and current microgeneration connection regulations [78], the majority of prosumers eligible to join EnCs must have installed RES-based electricity generation source with a capacity not exceeding 11.1 kW. The historical adoption of the net metering system, allowing prosumers to virtually store excess electricity in the distribution grid after self-consumption, has resulted in a lack of installed electricity storage (battery) systems. Furthermore, a well-cited study [79] highlights that their effectiveness is optimal when a prosumer self-consumption is up to 75% of the generated amount of electricity. Accordingly, if self-consumption level exceeds 75%, purchase of electricity storage system costs is not economically justified. In addition, batteries would require additional financial resources and the development of charging and discharging schedules and operations which could increase the complexity of EnCs operations and business model performance. Therefore, it is justified that, based on determined prosumers' self-consumption level of 80%, the inclusion of batteries in an EnCs involving one prosumer and one consumer is not economically viable.

Taking into account existing legislation regarding prosumer and EnC operational restrictions and guidelines, a visual representation of prosumer-consumer EnC (proposed by the author of the Thesis) is provided in Fig. 2.8.

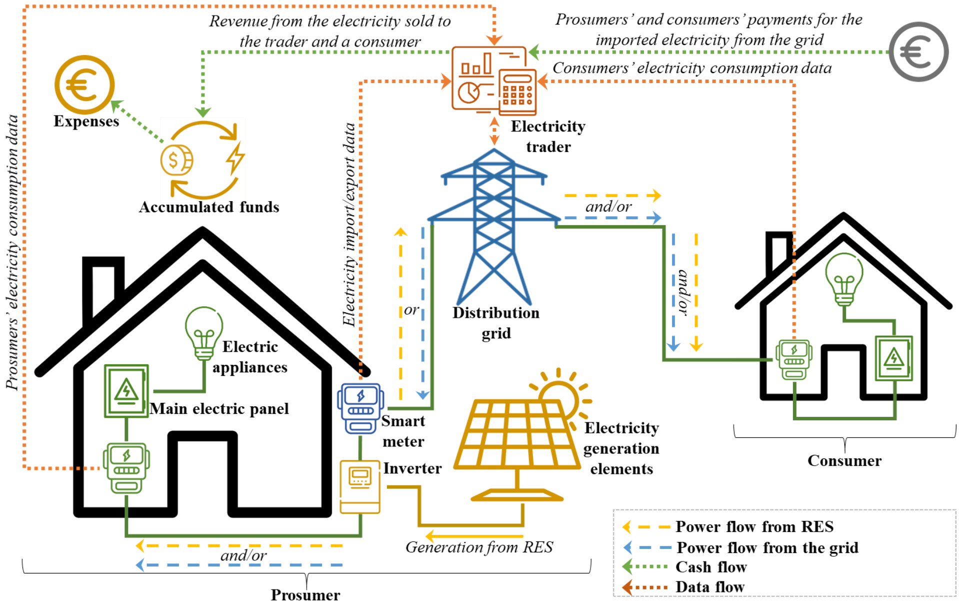

Fig. 2.8 Visualisation of proposed prosumer and consumer EnC [80]

The operation of the proposed EnCs business model is performed with the concept "prosumer→consumer→electricity trader". Respectively, amount of electricity generated from the prosumers' owned generation source is firstly self-consumed by the prosumer. If after its self-consumption there would be a surplus amount of electricity, it is shared with consumer through the distribution grid and electricity sharing tariff is used to remunerate consumers' received amount of electricity. In addition to that, the business model includes the possibility that the consumer can make a one-time initial investment payment for the purchase of the electricity generation source. If even after covering the consumers' electricity consumption there would be an excess amount of electricity, it is selled to an electricity trader using an electricity purchase price. In a case when an EnC member could not fully cover the electricity consumption by the electricity generation source, they still have the rights to purchase the remaining part from the electricity trader using the electricity import tariff. In this business model, it is assumed that electricity sharing activities are performed by the the electricity trader and not by any of EnC's members.

The widespread adoption of smart meters in Latvia has led to these devices being responsible for measuring the electricity transferred and received from various electricity sources. In this proposed EnC structure and according to relevant legislation [12], electricity trader is responsible for accounting shared and selled electricity. Furthermore, income obtained by EnC from sharing and selling activities can be credited to the specially accumulated fund, with the help of which prosumer could repay the bank loan and installed generation source operational expenses, as well as to allocate financial resources to ensure members' energy efficiency measures or other welfare increasing activities in the future. Moreover, accumulated fund can not be used to gain private financial profits or benefits by any members of the EnC.

To ascertain the economic feasibility of EnCs under proposed business model, it is necessary to develop a specifically designed tool to plan electricity sharing and selling activities according to each EnCs objectives and goals, as well as to determine the potential economic benefits for prosumer and consumer from the creation and participation in a such EnC. In addition, the tool should include not only the calculation of the financial mutual settlement mechanism, but also be able to assess the operation and economic validity of the installed generation source, thus justifying the efficiency of the implemented investments. Subsequently, the following section provides a comprehensive description and mathematical operations of the proposed EnCs planning tool.

2.3. Prosumer and consumer energy community planning tool

The primary objective of the proposed EnC planning tool is to effectively model the power flows between the members of EnC and electricity trader using electricity distribution grid, as well as to calculate payments for received or exported amount of electricity, thus making possible to calculate EnC economic indicators and economic benefits accruing to each member. In order to describe the activities included in the proposed planning tool, the following subsections will review the calculations included in this tool which are related to the determination of the participants' electricity consumption, generation, shared and selled amount of electricity, as well as the determination of specifically defined EnCs financial and economic indicators.

2.3.1. Prosumers' electricity generation

The RES-based generation source installed by a prosumer (typically in the form of photovoltaics) can be regarded as the backbone of the EnC. Its significance lies in its role as the primary source of electricity for a prosumer, as well as additional electricity source for the other member of the EnC. Electricity generation serves as the foundation for EnCs' income derived from the shared electricity between the prosumer and consumer, as well as electricity selling activities between the EnC and electricity trader.

To determine the EnC electricity production base, it is necessary to calculate the hourly amount of electricity which will partially or fully cover prosumers' self-consumption, as well as to potentially be shared with the consumer and sold to the electricity trader. By that means, the amount of electricity hourly generated from RES P_{RES}^{t} is expressed as:

$$P_{RES}^{t} = P_{RES\,cap.} \cdot \delta_{RES}^{t} \cdot \Delta_{\%}^{y}, \qquad (2.1)$$

where $P_{RES\ cap.}$ – the total capacity of the installed electricity source (kW).

δ_{RES}^{t} – hourly coefficients which determines amount of electricity hourly generated from 1 kW of installed capacity (kWh/kW).

$\Delta_{\%}^{y}$ – annual installed RES element degradation coefficient (%).

Equation (2.1) can be used to calculate hourly electricity generation calculation using multiple methods: when existing or historical electricity generation schedule would be used, then δ_{RES}^{t} value can be replaced by aforementioned generation datasets and $P_{RES\ cap.}$ and could be set as a value 1. Moreover, degradation coefficient $\Delta_{\%}^{y}$ can be ignored, if historical generation data is available. However, if electricity generation schedule is given from solar irradiation or wind speed data and then these data are transformed to coefficients which reflect a potential amount of electricity generated by element with a capacity of 1kW, then equation (2.1) can be used in the in the given form. Furthermore, in this case a degradation coefficient must be included due to the RES generation source efficiency reduction over the years.

2.3.2. Prosumers' electricity consumption and sharing activities

While bearing in mind that EnCs electricity generation is provided by prosumers' installed generation source, the produced electricity is first diverted to cover its self-consumption, thus reducing imported amount of electricity from the grid.

Prosumers' hourly consumed amount of electricity from its own electricity generation source $P_{RES\rightarrow Pros.}^{t}$ depends on amount of electricity generated, as well as prosumers' electricity consumption. Thereby, prosumers' consumed amount of electricity from the electricity generation source can be determined as:

$$P_{RES\rightarrow Pros.}^{t}=\begin{cases} P_{RES}^{t}, if\ P_{RES}^{t}<W_{Pros.}^{t} \\ W_{Pros.}^{t}, if\ P_{RES}^{t}\geq W_{Pros.}^{t}, \end{cases} \quad (2.2)$$

where $W_{Pros.}^{t}$ – prosumers' hourly electricity consumption (kWh).

Depending on level of electricity consumption and generation, prosumer may or may not cover its own electricity consumption. In the case, when electricity generation source would not cover electricity consumption, it can be covered by electricity import from the grid. To determine the amount of electricity imported ($P_{grid\rightarrow Pros.}^{t}$), following formula is used:

$$P_{grid\rightarrow Pros.}^{t}=\begin{cases} W_{Pros.}^{t}-P_{RES\rightarrow Pros.}^{t}, if\ P_{RES}^{t}<W_{Pros.}^{t} \\ 0, if\ P_{RES}^{t}\geq W_{Pros.}^{t}. \end{cases} \quad (2.3)$$

If produced amount of electricity is higher than prosumers' consumption, excess is shared with a consumer using the grid. Hourly amount of excess electricity available for sharing with the consumer $P_{RES,excess}^{t}$ can be determined as:

$$P^t_{RES,excess} = \begin{cases} 0, if\ P^t_{RES} < W^t_{Pros.} \\ P^t_{RES} - P^t_{RES \to Pros.}, if\ P^t_{RES} \geq W^t_{Pros.}. \end{cases} \quad (2.4)$$

With the help of formulas (2.2) and (2.3), the hourly power distribution can be determined so that the prosumer could fully cover its own electricity consumption either by using generation source, grid provided services or a combined elelctricity supply from aforementioned electricity sources (see Table 2.1).

Table 2.1 Prosumers' power flow distribution

Ratio between consumption and generation	**Distribution of power flows**
$P^t_{RES} \geq W^t_{Pros.}$	100% self-consumption and have excess amount of electricity for electricity sharing/selling
$P^t_{RES} = W^t_{Pros.}$	100% self-consumption
$0 < P^t_{RES} < W^t_{Pros.}$	Partial self-consumption and necessity to import electricity from the grid
$P^t_{RES} = 0$	Consumption is fully covered by imported electricity from the grid

The next objective is to ascertain the payment distribution. Considering the proposed EnCs planning tool ability to work with different payment methods, in the next steps tool can calculate both payments for the electricity received from the grid and in the case when the prosumer aims to contribute to the growth of the EnC income by paying for the electricity from its installed generation source.

In the instance when the prosumer decides to pay for the electricity generated by its own source, the tariff must encompass the value added tax (VAT). Accordingly, the prosumers' hourly electricity tariff for the amount of electricity received from the generation source with VAT $c^t_{Pros.\ EnC+VAT}$ could be determined as follows:

$$c^t_{Pros.\ EnC+VAT} = c^t_{Pros.\ EnC} \cdot (1 + VAT), \quad (2.5)$$

where $c^t_{Pros.\ EnC}$ – prosumers' determined electricity tariff for the received electricity from its own generation source without VAT (EUR/kWh).

In this case, prosumers' hourly payments for the amount of electricity received by its own generation source $C^t_{EnC \to Pros.}$ can be determined as:

$$C^t_{EnC \to Pros.} = P^t_{RES \to Pros.} \cdot c^t_{Pros.\ EnC+VAT}. \quad (2.6)$$

In the instance when the prosumer receives electricity from the grid, the tariff regarding only electricity cost component provided by electricity trader must include VAT. Accordingly, the prosumers' hourly electricity tariff for the amount of electricity received from grid with VAT $c^{t}_{Pros.\ grid+VAT}$ could be determined as:

$$c^{t}_{Pros.\ grid+VAT} = c^{t}_{Pros.\ grid} \cdot (1 + VAT), \quad (2.7)$$

where $c^{t}_{Pros.\ grid}$ – prosumers' electricity component tariff for the received electricity from the grid without VAT (EUR/kWh).

Prosumers' hourly payments for the received amount of electricity from the grid $C^{t}_{grid\to Pros.}$ (without other grid tariff components) can be determined as:

$$C^{t}_{grid\to Pros.} = P^{t}_{grid\to Pros.} \cdot c^{t}_{Pros.\ grid+VAT}. \quad (2.8)$$

In order to determine prosumers' annual payment for the electricity received from the grid, it must also include other cost components: the charge for the supply of electricity and charge for the connection maintenance (see Table 2.2).

Table 2.2 Grid cost components and other fees [81]

Electricity tariff components	**Affecting factors on overall electricity cost**
Electricity costs	Electricity traders' policy and the source of the electricity
Variable tariff: supply of electricity	Imported amount of electricity from the grid (kWh)
Fixed tariff: connection maintenance	Maximum rated current of connection (A) and number of phases

To allow the planning tool to compare each participants' economic benefits from participating in the EnC, these annual costs must be determined to both cases where the prosumer participates and does not participate in the EnC. The difference between these cases will be determined only by the inclusion or exclusion of $C^{t}_{EnC\to Pros.}$: the costs of received electricity from the grid does not depend on whether the prosumer shares the amount of electricity after self-consumption with the consumer or whether it acted as an individual prosumer without the possibility of sharing it with others.

Bearing in mind aforementioned, annual overall electricity costs (including other grid cost components) for the prosumer, when it participates in the EnC, $C^{y}_{Pros.with\ EnC+VAT}$ can be defined as:

$$C^{y}_{Pros.with\ EnC+VAT} = \Sigma C^{t}_{EnC\to Pros.} + \Sigma C^{t}_{grid\to Pros.} + (\Sigma P^{t}_{grid\to Pros.} \cdot c_{supply\ (grid).Pros.} + I_{conn.Pros.} \cdot c_{maintenance\ (grid).Pros.} \cdot 12) \cdot (1 + VAT), \quad (2.9)$$

where $c_{supply\ (grid).Pros.}$ – prosumers' tariff for the supply of electricity from the distribution grid without VAT (EUR/kWh).

$I_{conn.Pros.}$ – maxiumum rated current of prosumers' connection (A).
$c_{maintenance\ (grid).Pros.}$– prosumers' costs for connection maintenance without VAT (EUR/A/month).

Annual overall electricity costs for the prosumer, when it would not participate in the EnC, $C^{y}_{Pros.without\ EnC+VAT}$ can be expressed as:

$$C^{y}_{Pros.without\ EnC+VAT} = \Sigma C^{t}_{grid\rightarrow Pros.} + (\Sigma P^{t}_{grid\rightarrow Pros.} \cdot c_{supply\ (grid).Pros.} + I_{conn.Pros.} \cdot c_{maintenance\ (grid).Pros.} \cdot 12) \cdot (1 + VAT). \quad (2.10)$$

Considering that EnCs' hourly incoming cash flow is provided by the income from electricity sharing and selling activities, the following subsections determine how proposed plannng tool calculates the amount of electricity consumer receives from the prosumer and the grid, as well as equations regarding selling excess amount of electricity to the electricity trader.

2.3.3. Consumers' electricity consumption and selling activities

Consumer's participation in the EnC provides it with the opportunity to receive electricity both from the prosumer and the grid (if prosumers' provided amount of electricity would not fully cover consumers' electricity demand).

Consumers' hourly consumed amount of electricity from prosumers' owned electricity generation source depends on available amount of electricity after prosumers' self-consumption, as well as consumers' hourly electricity consumption. Thereby, consumers' hourly consumed amount of electricity from the prosumer $P^{t}_{RES,excess\rightarrow Cons.}$ can be calculated as follows:

$$P^{t}_{RES,excess\rightarrow Cons.} = \begin{cases} P^{t}_{RES,excess}, if\ P^{t}_{RES,excess} < W^{t}_{Cons.} \\ W^{t}_{Cons.}, if\ P^{t}_{RES,excess} \geq W^{t}_{Cons.}, \end{cases} \quad (2.11)$$

where $W^{t}_{Cons.}$ – consumers' hourly electricity consumption (kWh).

In the case, when prosumer could not fully cover consumers' electricity consumption, hourly amount of electricity imported from the grid ($P^{t}_{grid\rightarrow Cons.}$) can be calculated as follows:

$$P^{t}_{grid\rightarrow Cons.} = \begin{cases} W^{t}_{Cons.} - P^{t}_{RES,excess\rightarrow Cons.}, if\ P^{t}_{RES,excess} < W^{t}_{Cons.} \\ 0, if\ P^{t}_{RES,excess} \geq W^{t}_{Cons.}. \end{cases} \quad (2.12)$$

If there would be excess amount of electricity after covering the prosumers' and consumers' consumption, it must be sold to the electricity trader. To determine its hourly amount after covering the consumption of both EnC members ($P^{t}_{excess\rightarrow trader}$), the following calculation is used:

$$P^t_{excess\to trader} = \begin{cases} 0, if\ P^t_{RES,excess} < W^t_{Cons.} \\ P^t_{RES,excess} - P^t_{RES,excess\to Cons.}, if\ P^t_{RES,excess} \geq W^t_{Cons.}. \end{cases} \quad (2.13)$$

By using (2.11) and (2.12) formulas, four hourly electricity consumption scenarios for a consumer can be determined (see Table 2.3).

Table 2.3 Consumers' power flow distribution

Ratio between consumption and prosumer shareable amount of electricity	**Distribution of power flows**
$P^t_{RES,excess\to Cons.} \geq W^t_{Cons.}$	100% of consumption can be covered by prosumers' shared amount of electricity and excess is sold to the electricity trader
$P^t_{RES,excess\to Cons.} = W^t_{Cons.}$	100% of consumption can be covered by prosumers' shared amount of electricity
$0 < P^t_{RES,excess\to Cons.} < W^t_{Cons.}$	Consumption is partialy covered by prosumers' shared electricity and the rest of it must be covered by the imports from the grid
$P^t_{RES,excess\to Cons.} = 0$	Consumption is fully covered by the imported electricity from the grid

Proposed planning tool must be able to determine cash flow for the amount of electricity shared by the prosumer, consumers' expenses for this received electricity, as well as the EnCs' income for the electricity sold to the electricity trader. Thereby, it is necessary to calculate the distribution of the cash flow, which are based on both the calculation of the aforementioned power flows and the values of the related tariffs and prices.

In order for the amount of electricity shared with the consumer to bring income to the EnC, a sharing tariff without VAT $c^t_{Cons.\ EnC}$ is introduced. Electricity sharing with VAT can be determined using following formula:

$$c^t_{Cons.\ EnC+VAT} = c^t_{Cons.\ EnC} \cdot (1 + VAT), \quad (2.14)$$

where $c^t_{Cons.\ EnC+VAT}$ – electricity sharing tariff within EnC, including VAT (EUR/kWh).

With the help of formulas (2.11) and (2.14), it is possible to determine consumers' hourly expenses regarding consumption of prosumers' shared electricity (including VAT) $C^t_{EnC\to Cons.\ (with\,VAT)}$ by using following calculation:

$$C^t_{EnC\to Cons.\ (with\,VAT)} = P^t_{RES\to Cons.} \cdot c^t_{Cons.\ EnC+VAT}. \quad (2.15)$$

Analogous to the formula (2.15), these consumer expenses can be determined not only on an hourly basis, but also annually. Thereby, the consumers' annual cost of amount of electricity received from the prosumer (including VAT) can be determined as:

$$C^{y}_{EnC\to Cons.\ (with\,VAT)} = \Sigma C^{t}_{EnC\to Cons.\ (with\,VAT)}. \qquad (2.16)$$

The cash flow paid by the consumer for the shared electricity received does not mean that this cash flow goes directly to the EnCs' accumulated funds. This is explained by the fact that VAT is included in formulas (2.15) and (2.16), thus the EnCs' direct income for the amount of shared electricity from the amount of money paid by the consumer will decrease by the VAT portion.

To obtain this, analogously to the above-mentioned formulas, they can be calculated without including VAT. Respectively, consumers' hourly expenses regarding consumption of prosumers' shared electricity (excluding VAT) $C^{t}_{EnC\to Cons.\ (without\,VAT)}$ can be calculated as:

$$C^{t}_{EnC\to Cons.\ (without\,VAT)} = P^{t}_{RES\to Cons.} \cdot c^{t}_{Cons.\ EnC}. \qquad (2.17)$$

Thereby, annual cost of the consumer for the amount of electricity received from the prosumer (excluding VAT) $C^{y}_{EnC\to Cons.\ (without\,VAT)}$ can be determined using following formula:

$$C^{y}_{EnC\to Cons.\ (without\,VAT)} = \Sigma C^{t}_{EnC\to Cons.\ (without\,VAT)}. \qquad (2.18)$$

When the amount of shared electricity would not cover the consumers' hourly consumption, the remaining part must be imported from the grid. To calculate the consumers' electricity tariff for imported electricity from the grid (with VAT and without other grid cost components) $c^{t}_{Cons.\ grid+VAT}$, the following formula is used:

$$c^{t}_{Cons.\ grid+VAT} = c^{t}_{Cons.\ grid} \cdot (1 + VAT), \qquad (2.19)$$

where $c^{t}_{Cons.\ grid}$ – consumers' electricity component tariff for imported electricity from the grid, excluding VAT (EUR/kWh).

Thereby, consumers' hourly payments for the amount of imported electricity from the grid (including VAT and without distribution grid tariff components) $C^{t}_{grid\to Cons.}$ can be calculated with help of following formula:

$$C^{t}_{grid\to Cons.} = P^{t}_{grid\to Cons.} \cdot c^{t}_{Cons.\ grid+VAT}. \qquad (2.20)$$

In order to find out the annual total electricity costs of the consumer, both acting as an individual consumer and as an EnC member, it is necessary to introduce other grid cost components. Consumers' annual costs for the amount of received electricity by participating in the EnC (including VAT and other grid cost components) $C^{y}_{Cons.with\ EnC+VAT}$ can be calculated as:

$$C^{y}_{Cons.with\ EnC+VAT} = C^{y}_{EnC\rightarrow Cons.\ (with\ VAT)} + \Sigma C^{t}_{grid\rightarrow Cons.} + (W^{t}_{Cons.} \cdot c_{supply\ (grid).Cons.} + I_{conn.Cons.} \cdot c_{maintenance\ (grid).Cons.} \cdot 12) \cdot (1 + VAT), \quad (2.21)$$

where $c_{supply\ (grid).Cons.}$ – consumers' tariff for the supply of electricity from the grid without VAT (EUR/kWh).

$I_{conn.Cons.}$ – maximum rated current of consumers' connection (A).

$c_{maintenance\ (grid).Cons.}$– consumers' costs for connection maintenance without VAT (EUR/A/month).

In order to determine economic benefits for the consumer from participation in the EnC, it is necessary to calculate the annual electricity costs when it is not a member of EnC. Thereby, consumers' annual costs for the amount of received electricity by not participating in the EnC (including VAT and other grid cost components) $C^{y}_{Cons.without\ EnC+VAT}$ can be calculated as:

$$C^{y}_{Cons.without\ EnC+VAT} = \Sigma W^{t}_{Cons.} \cdot c^{t}_{Cons.\ grid+VAT} + (\Sigma W^{t}_{Cons.} \cdot c_{supply\ (grid).Cons.} + I_{conn.Cons.} \cdot c_{maintenance\ (grid).Cons.} \cdot 12) \cdot (1 + VAT). \quad (2.22)$$

The establishment of an EnC involves securing diverse financial resources, thus covering the purchase, installation and maintenance of electricity generating source. To explore how this breakdown of initial investment is incorporated into the planning tool, the next subsection will delve into the financial calculations, as well as the the determination and remuneration of necessary investments.

2.3.4. Investment calculations

Three distinct funding sources can be utilised in the proposed planning tool to secure the initial investments (also known as CAPEX – capital expenditures) required for the purchase and installation of RES-based electricity generation source in the EnC:

1. External funding (state aid, donations or grants from third-persons or organisations).
2. Voluntarily investment contributions by the members of EnC.
3. Bank loan.

It is noteworthy that, given the responsibility of prosumer for ensuring electricity sharing with help of the installed generation source, the planning model assumes that the prosumer is accountable for attracting these financial funds and repaying any essential bank loans. This approach aims to encourage the consumers' participation in the EnC without imposing financial risks and liabilities related to bank or other financial transactions.

Stade aid cannot be used to fully repay the costs of initial investments [13], but its acquisition can reduce the necessary amount funds from other sources to completely cover initial investment costs. Moreover, external funding and voluntarily investment contributions by the members of EnC are considered as sources of additional financing, which can accordingly reduce the required amount of bank loan.

Combined one-time investment contributions by the members of EnC I_0 can be defined as:

$$I_0 = I_{0,Pros.} + I_{0,Cons.}, \tag{2.23}$$

where $I_{0,Pros.}$ – prosumers' one-time payment for the coverage of initial investments (EUR).

$I_{0,Cons.}$ – consumers' one-time payment for the coverage of initial investments (EUR).

The value of total CAPEX depends on the installed capacity and price of the generation source, as well as amount of external funding. Consequently, its alternative value can be described as the investments needed to purchase and install generation source with a capacity of 1 kW (see Fig. 2.9). By receiving external funding, it can reduce amount of financial resources needed for the purchase and installation of generation source. In this regard, calculation the total CAPEX, including VAT related expenses, can be expressed as:

$$CAPEX = \left(C_{CAPEX\ per\ kW} \cdot P_{PV\ cap.}\right) \cdot (1 + VAT) - C_{grants}, \tag{2.24}$$

where $C_{CAPEX\ per\ kW}$ – value of CAPEX related to an installed generation source capacity of 1 kW without VAT (EUR).

C_{grants} – amount of received external funding (EUR).

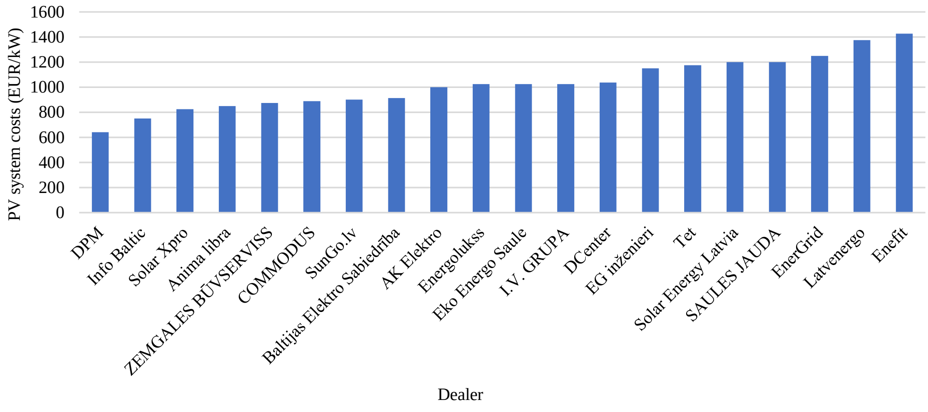

Fig. 2.9 Average photovoltaics (PV) system $C_{CAPEX\ per\ kW}$ offered by Latvia's dealers [82]

To assess the necessity for a bank loan to cover CAPEX and determine the required amount of the loan (if applicable), the ratio between CAPEX and combined one-time investment contributions by the members of EnC must be clarified. To do that, the following formula is used:

$$C_{bank \to EnC} = \begin{cases} 0, if\ I_0 \geq CAPEX \\ CAPEX - I_0, if\ I_0 < CAPEX, \end{cases} \tag{2.25}$$

where $C_{bank \to EnC}$ – amount of bank loan to fully cover the remaining part of CAPEX (EUR).

The amount of the bank loan received is less in its value than the amount of it that must be paid back to the bank during the specified years. This is explained by the fact that the repayment of the bank loan consists of two parts:

1. Interest rate for the base value of the loan.
2. Rate which is tied to the duration of the loan repayment period. In simpler terms, this bank loan repayment part is accountable for the increase of the repayable loan amount as the loan duration extends.

To calculate the annual bank loan payment amount $C^y_{EnC \to bank}$, the following formula can be used:

$$C^y_{EnC \to bank} = \begin{cases} C_{bank \to EnC} \cdot \left(1 + i_{\%,bank}\right) \cdot \\ \dfrac{i_{\%,bank} \cdot \left(1 + i_{\%,bank}\right)^{y_{loan}}}{((1 + i_{\%,bank})^{y_{loan}}) - 1}, when\ y \leq\ y_{loan} \\ 0, when\ y >\ y_{loan}\ , \end{cases} \tag{2.26}$$

where y_{loan} – loan duration (years).

$i_{\%,bank}$ – loan interest rate (%).

Apart from CAPEX, additional annual expenditures have to be assigned for electricity generation source to address operational costs (OPEX). These costs encompass expenses related to cleaning, rewiring connections, repairing damages or other maintenance activities. Similar to CAPEX, OPEX value can be applied to 1kW capacity and its total value depends on the overall capacity of the installed source.

In this regard, calculation the annual operational costs $OPEX^y$, including VAT related expenses, can be expressed as:

$$OPEX^y = \left(C^y_{OPEX\ per\ kW} \cdot P_{RES\ cap.}\right) \cdot (1 + VAT), \tag{2.27}$$

where $C^y_{OPEX\ per\ kW}$ – annual operational costs related to an installed generation source capacity of 1 kW without VAT (EUR).

The next subsection outlines the comprehensive structure of incoming and oucoming cash flows within the EnC. By doing that, it enables the planning tool to be able to determine not only the financial metrics of the EnC, but also the prosumer and consumer economic advantages from the electricity sharing activities.

2.3.5. Determination of cash flows, indicators and benefits

Economic sustainability and viability of EnC depends on ratio between income and expenses. To determine this ratio, it is neccesary to calculate the values of the incoming cash flow from the electricity sharing and selling activities and outcoming cash flows regarding initial investment repayments and operational investments.

To calculate EnCs' received hourly income from the amount of electricity sold to the electricity trader after covering prosumers' and consumers' electricity consumption $C^{t}_{excess\to trader}$, planning tool applies the following formula:

$$C^{t}_{excess\to trader} = P^{t}_{excess\to trader} \cdot c^{t}_{excess\to trader}\,, \tag{2.28}$$

where $c^{t}_{excess\to trader}$ – electricity traders' determined electricity purchase price without taxes (EUR).

In order to include the incoming cash flow from prosumer cost savings due to the self-consumption in net present value calculations, the annual payment that the prosumer would pay for the amount of electricity received from the grid if generation source were not installed is calculated as:

$$\begin{aligned} C^{y}_{el.Pros.\to trader.without\ RES} = \Sigma(W^{t}_{Pros.} \cdot c^{t}_{Pros.\ grid+VAT}) + \\ (\Sigma W^{t}_{Pros.} \cdot c_{supply\ (grid).Pros.} \\ + I_{conn.Pros.} \cdot\ c_{maintenance\ (grid).Pros.} \cdot 12) \cdot (1+VAT). \end{aligned} \tag{2.29}$$

By calculating (2.29), it is possible to determine prosumers' annual cost savings $\Delta C^{y}_{pros\to grid\ (with.without\ RES)}$ regarding reduction of amount of imported electricity due to the self-consumption of electricity:

$$\begin{aligned} \Delta C^{y}_{pros\to grid\ (with.without\ RES)} = \Sigma C^{t}_{grid\to Pros.} + (\Sigma P^{t}_{grid\to Pros.} \cdot c_{supply\ (grid).Pros.} \\ + I_{conn.Pros.} \cdot\ c_{maintenance\ (grid).Pros.} \cdot 12) \\ \cdot (1+VAT) - C^{y}_{el.Pros.\to trader.without\ RES}\,. \end{aligned} \tag{2.30}$$

The annual overall incoming cash flow of the EnC ($Income^{y}_{EnC,RES}$), which will also be used to calculate the net present value (NPV) of the installed generation sources, is affected by the incoming cash flow from the prosumers' payments for the received amount of electricity from its own generation sources, consumers' payments for the received amount of electricity from the prosumer, prosumers' annual savings from the reduction of the imported amount of electricity from the grid, as well as the income from excess electricity selling between the EnC and the electricity trader:

$$\begin{aligned} Income^{y}_{EnC,RES} = C^{y}_{EnC\to Cons.\ (without\ VAT)} + \Sigma(P^{t}_{RES\to Pros.} \cdot c^{t}_{Pros.\ EnC}) + \\ \Delta C^{y}_{pros\to grid\ (with.without\ RES)} + \Sigma C^{t}_{excess\to trader}\,. \end{aligned} \tag{2.31}$$

It must be specified, that consumers' annual savings from the reduction of electricity imports from the grid is not included in this calculation due to the fact that electricity generation sources are owned by the prosumer, thus taking financial responsibility for the repayment of these sources. Thereby, consumers' amount of cost savings from the reduction of amount of electricity imported from the grid does not affect the payback period of the generation sources which it does not own.

The annual expenses or outcoming cash flow $Expenses_{EnC,RES}^{y}$ consists of two components: the OPEX charges of the installed generation sources and annual repayment of the bank loan:

$$Expenses_{EnC,RES}^{y} = OPEX^{y} + C_{EnC \rightarrow bank}^{y} . \tag{2.32}$$

To ascertain whether installed electricity source generates higher income than expenses, it is essential to calculate the annual net cash flow $R_{EnC,RES}^{y}$. This can be derived by using following formula:

$$R_{EnC,RES}^{y} = Income_{EnC,RES}^{y} - Expenses_{EnC,RES}^{y} . \tag{2.33}$$

The planning tool uses NPV as a main economic indicator for the evaluation of installed electricity source. NPV describes the present value of an investment, evaluating the value of installed electricity generation sources over their 20-year lifespan after applying a discount rate and investment contributions by the prosumer. NPV calculation does not include investment contributions by the all members of EnC due to the fact that this indicator determines prosumers' owned generation sources, thus consumers' investment contribution is only taken into account to reduce overall CAPEX value which must be further repayed by the prosumers income flow from the shared and selled amount of electricity. For the purchased and installed electricity generation sources in the EnC to be considered financially viable, NPV must be equal to or greater than zero over a period of generation source lifespan. To calculate annual NPV (NPV^{y}), following formula can be used:

$$NPV^{y} = -I_{0,Pros.} + \sum_{i=1}^{y} \frac{R_{EnC,RES}^{y}}{\left(1 + i_{\%,d}\right)^{y}} , \tag{2.34}$$

where $i_{\%,d}$ – discount rate (%).

While NPV assesses the profitability and economic validity of generation source installed by the prosumer in the EnC, it should be noted that this metric alone cannot be used to determine the economic benefits for each participant involved in the EnC. This is due to the fact that the distribution of economic benefits and the source of these benefits are different for each participant.

To ascertain the economic benefits for a prosumer from the participation in the EnC, it is essential to initially determine the annual incoming cash flow from excess amount of electricity sold after meeting self-consumption needs when prosumer would not engage in the EnC, meaning the surplus electricity would be sold (or be transferred to a "virtual wallet" in the net settlement system) directly to an electricity trader instead of to a consumer. Thereby, prosumers' annual income from the electricity sold (or transferred under net settlement system) to the electricity trader without participating in the EnC $C^{y}_{Pros \to trader, without\ EnC}$ (excluding taxes) can be calculated as follows:

$$C^{y}_{Pros \to trader, without\ EnC} = \Sigma(P^{t}_{RES,excess} \cdot c^{t}_{excess \to trader}). \tag{2.35}$$

Following calculation of prosumers' annual economic benefits from the participation is affected by several factors:

1. Investment contribution: if the consumer makes a voluntarily investment payment, it decreases prosumers' financial payment burden for the purchase of electricity source.
2. Prosumers' voluntarily hourly payments for the amount of electricity received by its own RES-based generation source: if it did not operate in the EnC, then such payments would not be necessary, but by operating in it, payments could help to increase the accumulated funds, at the same time reducing the prosumer's own expenditure level.
3. Sharing/selling/transferring excess electricity with and without the participation in the EnC: economic benefits depend on whether sharing electricity first with the consumer and only then with the trader is more profitable than not participating in the EnC and selling or transferring all its excess amount of electricity only to the electricity trader.

While bearing in mind all above, prosumers' overall economic benefits from the participation in the EnC $EB^{y}_{Pros.}$ can be expressed as:

$$EB^{y}_{Pros.} = I_{0,Cons.} + \sum_{i=1}^{y} (-\Sigma C^{t}_{EnC \to Pros.} + C^{y}_{EnC \to Cons.\ (without\ VAT)} + \Sigma C^{t}_{excess \to trader} - C^{y}_{Pros \to trader, without\ EnC}). \tag{2.36}$$

The overall value of consumers' economic benefits depends on its investment contribution, as well as cost reduction by receiving prosumers' amount of electricity with different tariff than offered by the electricity trader. Thereby, consumers' overall economic benefits from the participation in the EnC $EB^{y}_{Cons.}$ can be calculated as follows:

$$EB^{y}_{Cons.} = -I_{0,Cons.} + \sum_{i=1}^{y} (C^{y}_{Cons. without\ EnC+VAT} - C^{y}_{Cons. with\ EnC+VAT}). \tag{2.37}$$

It can be mentioned, that income from the EnC operation must spent to increase overall energy efficiency to its members or other measures to increase their welfare (without making a direct profit), thus diverting the direct income into the accumulated funds (AF). If bank loan payments and OPEX exceeds direct income cash flow, then the prosumer balance it with his own funds. In that case, AF are restarted to zero. In order to planning tool be able to determine the amount of cash in this fund in each year AF^{y}_{EnC}, the following calculations (2.38 and 2.39) can be used. Annual amount of cash located in EnCs AF after coverage of annual bank loan payment and OPEX will be zero, if:

$$(\mathrm{C}^{\mathrm{y}}_{\mathrm{EnC\to bank}} + \mathrm{OPEX}^{\mathrm{y}}) \geq (\mathrm{C}^{\mathrm{y}}_{\mathrm{EnC\to Cons.\ (without\ VAT)}} + \Sigma(\mathrm{P}^{\mathrm{t}}_{\mathrm{RES\to Pros.}} \cdot \mathrm{c}^{\mathrm{t}}_{\mathrm{Pros.\ EnC}}) + \Sigma\mathrm{C}^{\mathrm{t}}_{\mathrm{excess\to trader}}). \tag{2.38}$$

Otherwise:

$$AF^{y}_{EnC} = C^{y}_{EnC\to Cons.\ (without\ VAT)} + \Sigma(P^{t}_{RES\to Pros.} \cdot c^{t}_{Pros.\ EnC}) + \Sigma C^{t}_{excess\to trader} - \left(C^{y}_{EnC\to bank} + OPEX^{y}\right). \tag{2.39}$$

Total amount of cash in EnCs accumulated funds in a specific year can be calculated as:

$$\Sigma AF^{y}_{EnC} = \sum_{i=1}^{y} AF^{y}_{EnC}. \tag{2.40}$$

In addition to the calculations made in the planning tool, prosumer have to be sure, that it meets with the definition of an active user, thereby getting the opportunity to create and participate in the EnC. As one of the main restrictions, which defines prosumer as an active-user and not as electricity producer, is self-consumption level: it must self-consume at least 80% of the electricity it produces annualy [17]. The following calculation is used to determine the prosumer's annual self-consumption level:

$$SC^{y}_{Pros.,\%} = \frac{\Sigma P^{t}_{RES\to Pros.}}{\Sigma P^{t}_{RES}} \cdot 100\%. \tag{2.41}$$

Prosumers' self-consumption level is affected not only by the electricity consumption and generation amounts, but also by interconnecting and adjusting these values to each other, thus overlap of consumption and generation schedule plays an important role to achieve the required self-consumption level.

To prioritise study transparency, as well as to seek open validation and user empowerment, the developed prosumer-consumer EnC planning tool is freely available and open-source on GitHub platform. [83]

2.4. Discussion and conclusions

To provide Latvia's electricity users with a tool which would be used determine prosumer and consumer EnCs economic viability, chapter reviewed existing business models, thereby analysing the potential of their implementation in Latvia. Considering that the Latvia's NECP has defined the use of the P2P approach to ensure the operation of EnCs, it was concluded that this approach can be served as a business model for EnC operations.

After reviewing the operation of grant-based, multi-agent, energy cooperatives and virtual power plant business models, the P2P model was supplemented with the possibility to receive external funding for the purchase of electricity generation source, as well as to use AF to cover the payment of the bank loan, operational expenditures and to implement energy efficiency measures for the members of the EnC in the future.

The proposed business model was adapted to the current guidelines and restrictions of the Latvia's legislation, as well as justification of the exclusion of battery systems was discussed.

Based on aforementioned, operation of the proposed EnC is performed with the concept "prosumer→consumer→electricity trader", thus increasing the consumption of produced electricity and ensuring mutual electricity sharing, as well as cost allocation and management activities with the help of electricity trader and distribution grid infrastructure.

A prosumer and consumer EnC planning tool was developed based on the proposed business model to evaluate the economic justification from its creation. Within the framework of the tool, its operation involves the following actions:

- Prosumers' electricity generation: determination of the amount of electricity produced by the prosumer depending on the capacity of the installed generation source, the generation schedule and the generation source annual degradation coefficient.
- Prosumer consumption and excess amount of electricity: a calculation that determines the amount of electricity received by the prosumer from generation source and the grid, as well as excess amount after prosumers' self-consumption which could be shared with the consumer with help of distribution grid infrastructure. In addition to that, planning tool determines prosumers' overall electricity costs when it would and would not be participating in the EnC.
- Consumers' electricity consumption and sales activities: determination the amount of electricity consumed by the prosumers' shared electricity from generation source and from the grid, as well as excess amount electricity which must be sold to the electricity trader. In addition to that, planning tool calculates consumers' overall electricity costs when it would and would not be participating in the EnC, amount of consumers' payments to the prosumer and electricity trader, as well as EnC incoming cash flow from the amount of electricity sold to the electricity trader.
- Investment calculations: determination of CAPEX and OPEX values. To cover the cost of purchasing and installation of electricity generation source, the planning tool uses three sources of finance: bank loan, voluntarily one-time investment payments from the members of EnC and external funding. By using possible variations of investment coverage by these sources, amount of annual bank repayment is calculated.
- Determination of cash flows, indicators and benefits: the main purpose of this section is to calculate incoming and outgoing cash flows, thus making it possible to obtain the specifically defined indicators included in the planning model: NPV, economic benefits for each member from the participation in the EnC, as well as accumulated funds. It can be mentioned, that NPV is used to describe the present value of an investment, evaluating the value of installed electricity generation source over its 20-year lifespan, however accumulated funds determines, if direct incoming cash flow from the electricity sharing and sales activities could cover bank loan repayments and OPEX, thus diverting excess funds to future energy efficiency improvement measures.

To prioritise study transparency, as well as to seek open validation and user empowerment, the developed prosumer-consumer EnC planning tool is freely downloadable and open-source on GitHub platform.

Tool serves the dual purpose of not only assessing the feasibility and economic justification for establishing potential prosumer and consumer EnCs, but also to be used by legislators and policymakers to evaluate the advantages and disadvantages of implementing such a business model. Moreover, planning tool can serve as a basis to assess the effect of future legislation changes on the operation and economic viability of EnC not only in the context of Latvia, but also in other countries (if necessary, adapting and modifying it to the respective legislative guidelines).

In spite of diverse and unique generation and consumption profiles among electricity users, the tool can be used to not only evaluate individual member contribution to the efficiency of the proposed EnC, but also be used to analyse the impact of various factors (such as generation, consumption, tariff structures and investment sources) on the viability of EnCs under proposed business model. This, in turn, allows to develop recommendations and prerequisites to potential stakeholders on factors and circumstances which would affect the effectiveness of proposed EnCs.

Bearing in mind aforementioned, the next chapter will examine various factor affect on the economic viability and justification of the proposed EnC through modelling of case studies and scenarios.

3. RECOMMENDATIONS TO IMPROVE ECONOMIC FEASIBILITY AND SUSTAINABILITY OF PROSUMER AND CONSUMER ENERGY COMMUNITY

Although the first steps have been taken for the introduction and development of EnC in Latvia, the prerequisites for their development and recommendations for their economically efficient development are not yet developed. To address this, Energy Law has determined that Ministry of Economics (in cooperation with the Ministry of Environmental Protection and Regional Development) must develop and publish guidelines for the formation of EnCs, including recommendations regarding support of EnCs and participation in them. [11]

To contribute to the development of aforementioned recommendations, planning tool can be used not only to assess economic advantages from electricity sharing and the potential benefits of creating EnC, but also offer insights into how the values of various EnC related factors and associated metrics may affect overall viability of the EnC. Such an approach allows not only to recommend and suggest prerequisites for ensuring effective operation of EnC, but also to allow policymakers and legislators to assess the effectiveness of related legislation and support measures under proposed business model.

Considering that EnC planning includes variables that can affect the viability of EnC, three baseline EnC cases are proposed using different generation source capacity, as well as prosumer and consumer electricity consumption. Moreover, case studies are supplemented with scenarios for each baseline EnC to assess the impact of both internal and external factors. Specifically, related electricity tariffs and prices (sharing, purchase of excess electricity from the EnC and electricity cost tariff component for the purchase of electricity from the grid), cost of prosumers' electricity generation source, loan duration, amount of external funding and scheme of initial investment allocation.

Although the developed planning tool can serve as a universal instrument to model proposed EnCs and obtain an evaluation of determined indicators using input data of various and wide amplitudes, assumptions are introduced in the development of recommendations to clarify and justify the results of modelled case studies and scenarios. Thereby, next section and following subsections describe the assumptions and limitations included in the modelled baseline EnCs.

3.1. Assumptions

3.1.1. Electricity consumption

The acquisition of electricity consumption data can present a challenge due to the protection of real-time information within the privacy policy, as governed by multiple regulations mentioned in [84]. In order to respect and comply with data protection regulations, freely available electricity consumption profiles are used for modelling the electricity consumption in determined case studies and scenarios.

Considering that EnC members may have different monthly electricity consumption and hourly consumption schedule, within case studies and scenario modelling the average monthly electricity consumption in an annual basis of both prosumer and consumer is determined from the proportion of typical Latvia's household electricity user consumption by month mentioned in [85].

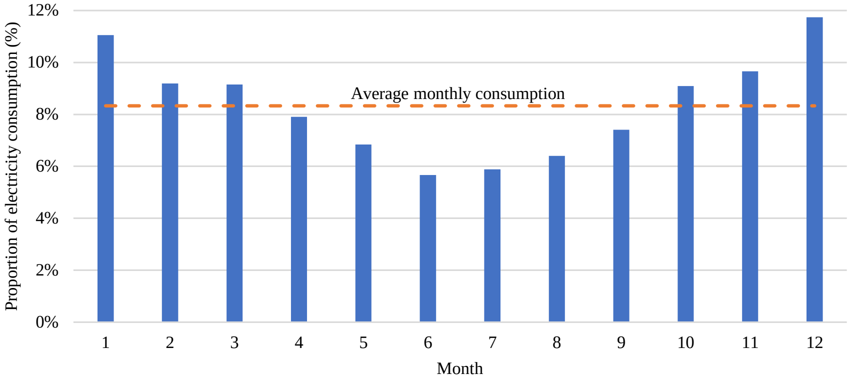

Fig. 3.1 Monthly percentage of electricity consumption by a typical household derived from the annual summary of electricity consumption [85]

Furthermore, hourly electricity consumption in each month can be determined using freely available daily electricity consumption profiles for hourly distribution of electricity consumption in Latvia for workdays (Fig. 3.2.) and weekends (Fig. 3.3.) [86].

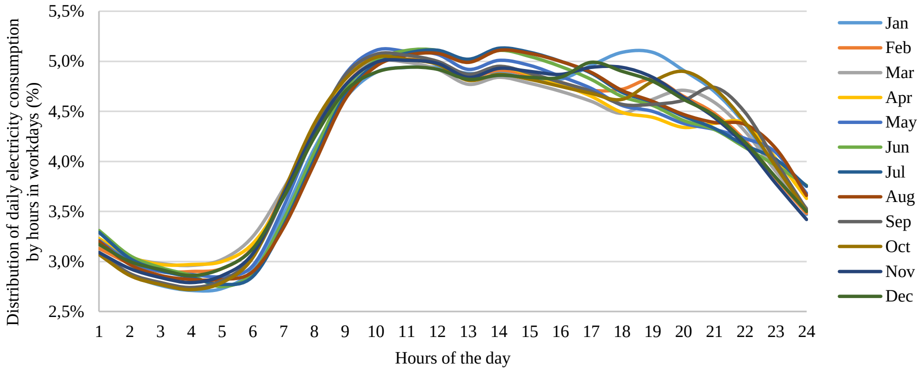

Fig. 3.2 Households' daily load distribution profile of electricity consumption in Latvia for workdays [86]

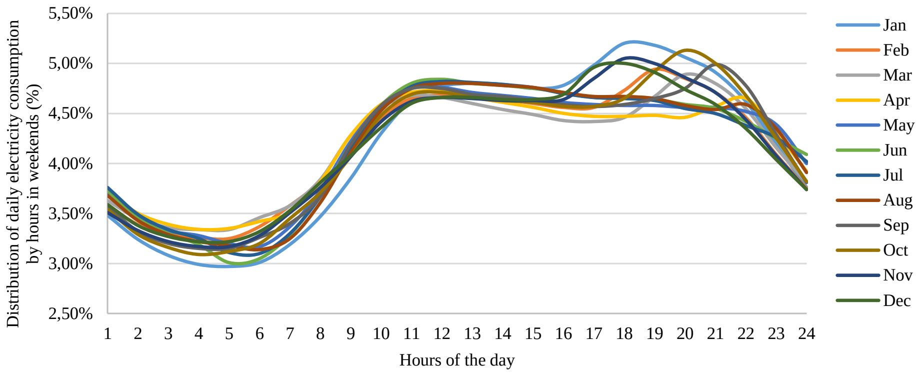

Fig. 3.3 Households' daily load distribution profile of electricity consumption in Latvia for weekends [86]

By using data mentioned in Fig. 3.1-3.3, as well as determining average monthly consumption for each of the EnC members, annual hourly electricity consumption data for household electricity users can be obtained. Moreover, with the help of such an approach, the hourly electricity consumption of each EnC member can be determined by using the average monthly electricity consumption on an annual basis. Complimentary example of annual hourly electricity consumption data for average monthly electricity consumption of 175 kWh in each month's 15th date is given in Fig. 3.4.

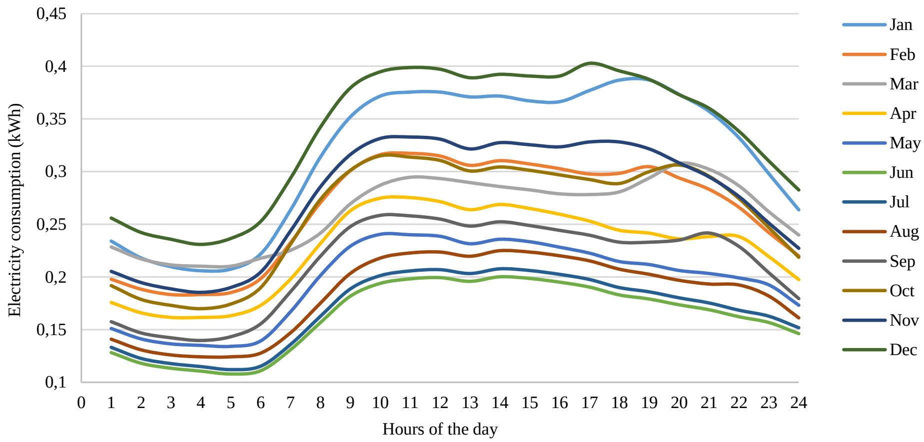

Fig. 3.4 Annual hourly electricity consumption data for average monthly electricity consumption of 175 kWh in each month's 15th date

To increase the accuracy of the output data issued by the EnC planning tool, prosumer and consumer can obtain historic hourly electricity consumption data by contacting either distribution grid operator or their electricity trader.

3.1.2. Electricity generation

Considering that photovoltaics (PV) panels have gained great popularity among Latvia's prosumers as their source of electricity generation [87], for case study and scenario modelling it is assumed that prosumer use PV panels as its electricity generation source.

Hourly coefficients which determines amount of electricity hourly generated from 1 kW of installed capacity under Latvia's climatic conditions are used from [88] database, with help of which hourly electricity generation from PV for the period of 20 years can be determined. Moreover, hourly coefficients take into account 10% of power losses from the amount of generated electricity which occurs in inverter, as well as in households' electricity wiring. [89]

By using data from [88], installed PV panel capacity and annual installed electricity source degradation coefficient, amount of hourly electricity in each of the 20 years can be determined. Furthermore, considering that these coefficients are obtained from satellite measurements and the accuracy of their values has been verified with data from installed PV panels, these coefficients take into account not only the angle of the sun to the earth's surface in each month in Latvia, but also the effect of cloudiness, precipitation and other weather conditions.

Example of hourly electricity generation from PV panels with capacity of 3 kW in the initial year on the 15th day of each month is given in Fig. 3.5.

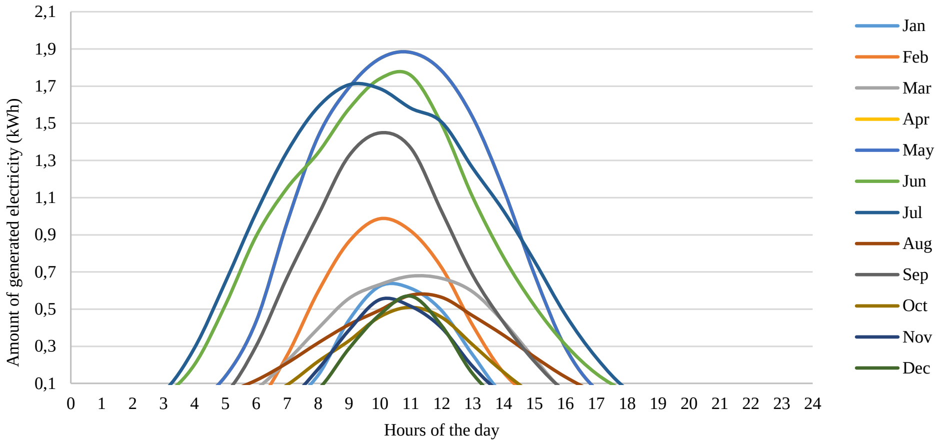

Fig. 3.5 Hourly electricity generation from PV panels with capacity of 3 kW in the initial year on the 15th day of each month

If EnC is developed using prosumers' already installed PV panels, electricity generation data can be obtained from smart inverters or smart meters.

3.1.3. External funding

Existing state aid programmes, such as [13], are intended to help prosumers to partialy cover the costs of purchasing RES-based electricity generation source under the capacity of 11.1 kW, however, the terms of their allocation do not correspond to the provision of the proposed EnC operation under the articles of the Latvia's Electricity Market Law and the Energy Law.

To address this, Energy Law has defined two objectives to supplement existing support and state aid mechanisms:

- The Ministry of Economics must develop support programs for EnCs that use only renewable energy resources, in compliance with the conditions of commercial activity support.
- The Ministry of Economics shall ensure the application and control of commercial activity support conditions within the framework of the support programs.

Respectively, Energy Law determines that state aid for the purchase of RES-based electricity generation source in the future EnCs must be overlap with existing support schemes including EnC related terms mentioned in Electricity Market Law and allowing commercial activity within the EnC, such as payments to the accumulated funds which are not used for profit purposes but to increase energy efficiency and other welfare activities for the members of EnC in the future.

Bearing in mind all above, the modelled baseline EnCs cases include following points from existing support scheme mentioned in [13]:

- The amount of external funding allocated for the purchase of PV panels and inverter is determined according to Table 3.1.
- The prosumer's self-consumption of electricity must be 80% of its produced amount on an annual basis (this is also indicated in the amendments to the Electricity Market Law [17] regarding the definition of active user).
- The amount of state aid does not exceed 70% of costs of purchasing RES-based electricity production equipment.

Table 3.1 Maximum state aid for the purchase of PV panels and inverter

Nominal capacity of the electricity generation equipment (kW)	**Amount of state aid (EUR)**
Up to 1 (not including)	700
From 1 to 2 (not including)	1 000
From 2 to 3 (not including)	1 400
From 3 to 4 (not including)	1 800
From 4 to 5 (not including)	2 200
From 5 to 6 (not including)	2 500
From 6 to 7 (not including)	2 800
From 7 to 8 (not including)	3 200
From 8 to 9 (not including)	3 500
From 9 to 10 (not including)	3 800
From 10 to 11.1 (not including)	4 000

Draft amendments for the determination of the amount of state aid for EnCs are not available, however, within the framework of the planning tool, it is possible to include the amounts of external funding in different values, thus adapting to both the increase and decrease of the amount of the existing support to the purchase of PV system. Moreover, EnC can also attract other external funding sources to cover the initial costs of PV equipment from third parties or institutions, as well as in the form of donations to financially support electricity sharing with low income household.

3.1.4. Electricity tariffs and prices

In the process of providing recommendations, it is necessary to include the electricity tariffs and prices in the planning tool which can affect not only the payback period of the PV panels, but also determine how the ratio between these tariffs and prices affects the viability of EnC.

It is assumed that both EnC members are connected to distribution grid under the maintenance of distribution grid operator “Sadales Tīkls”. In order to determine distribution system opertors’ variable and fixed electricity components, it is assumed that prosumer and consumer uses “Basic-1” pricing plan and are connected using 3-phase system with nominal current of the input protection apparatus of 20 A. Determination of connection parameters do not affect the values of EnC indicators used in the planning tool as these parameters are valid both with and without participation in the EnC, as well as under electricity generation activities. Fixed (connection maintenance) and variable (supply of electricity) grid service components under aforementioned pricing plan, as well as technical parameters of the connection are determined using data from Table 3.2.

Table 3.2 "Sadales tīkls" differentiated pricing tariffs for electricity distribution system services under “Basic-1” tariff plan and technical parameters of the connection [90]

Grid services	**Value**
Fixed: connection maintenance (EUR/kWh)	0,03985
Variable: supply of electricity (EUR/A/month)	0,92
Technical parameters of the connection	**Allowed power, kW**
3-phase, 20A	12,87

Considering that most Latvia’s households choose a constant electricity cost component tariff for the purchase of electricity from the grid (see Fig. 3.6), it suggests that electricity users are inclined towards effortlessly monitoring and anticipating the expenses associated with their electricity consumption without relying on the on the fluctuating Nord Pool market price. Thereby, it is assumed that tariffs and prices for the sharing, sales and import from the grid activities are fixed and with constant values.

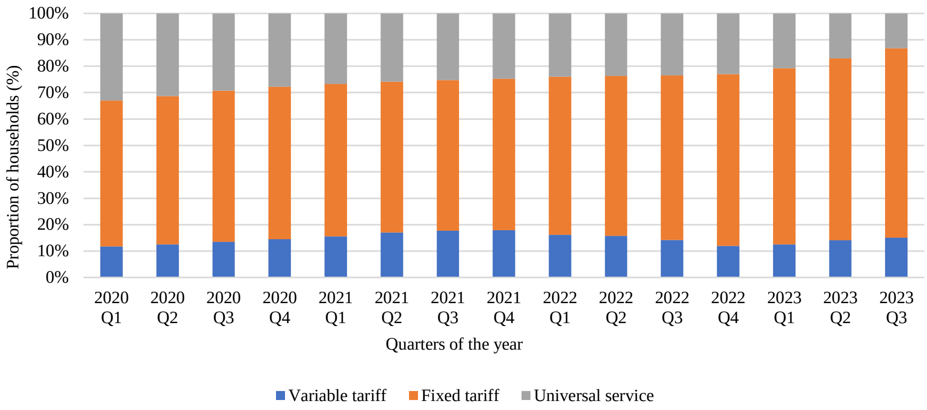

Fig. 3.6 Electricity cost component tariff contracts for Latvia's households [91]

The selection of the electricity cost tariff component for imported electricity from the grid are assumed to be flexible in the case study and scenario modelling, as electricity traders have the right to offer different values of this tariff (see Fig. 3.7) [92]. It means that EnC members should perform a thorough analysis to ascertain the aforementioned value, considering not only the current value of this tariff, but including the possibility that the value of tariff could potential change during the determined period of the EnC operation.

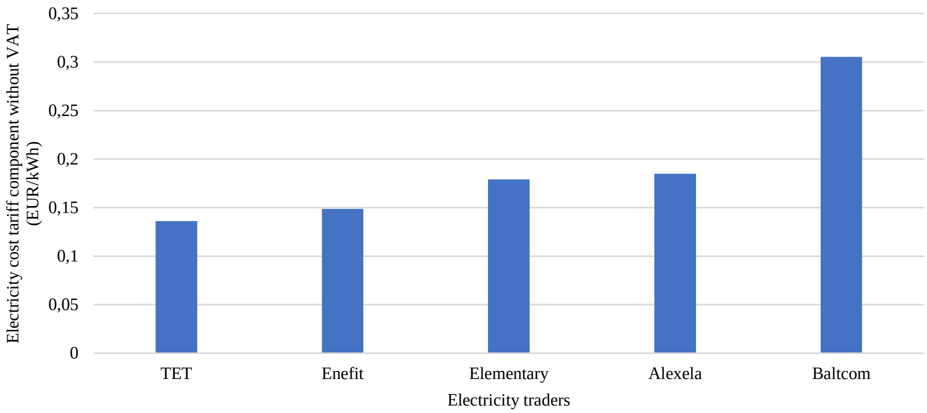

Fig. 3.7 Different electricity traders offered electricity cost tariff component for the imported electricity from the grid [92]

Similar to the above-mentioned tariff, the electricity traders' determined electricity purchase price for the excess amount of electricity from the EnC is also subject to free choice and their values are changed within developed scenarios (electricity trader has the right to offer tariffs' value individualy to each prosumer or EnC according to their agreement [12]). Moreover, it is assumed that aforementioned price is in force in cases when the prosumer both participates and does not participate in EnC because electricity trader has the right to set the same tariffs both for purchasing it from the prosumer and from the EnC [12]. If this price is different between the cases when the prosumer participates or does not participate in the EnC, prosumers' economic benefits from the participation in the EnC depends on the electricity generation, EnC members' electricity consumption level and profiles, which, in turn could make proposed recommendations debateable and questionable. If this price value is different between these cases, EnC participants are advised to use the developed planning tool to determine the effect of this difference on the economic feasibility of establishing an EnC.

The alterations in each tariff and price, along with the interplay of their respective ratios are considered during case studies and scenario modelling.

3.1.5. Other assumptions

To propose recommendations related to the affect of PV panel and inverter purchase costs on EnC economic indicators, in case study and scenario modelling it is assumed that value of CAPEX related to an installed generation source capacity of 1 kW without VAT is determined from the [82] by choosing PV system dealers with average, highest and lowest costs. Moreover, annual OPEX is linked and determined as a percentage of the cost of PV system.

As it is assumed that prosumer is the owner of electricity generation source, it is not assigned a tariff for the amount of electricity received from the PV panels. Additionally, electricity sharing, selling, and import services are facilitated through the collaboration of electricity trader and the distribution grid. It is important to note that the income from sharing and selling activities does not directly contribute to financial profits for either the prosumer or the consumer. Instead, this cash flow is directed, with the assistance and management of the electricity trader, to AF. This fund serves to cover bank loan payments, OPEX and future energy efficiency measures for the EnC. Consequently, none of the participants in the EnC have the right to use these funds for private needs, but aforementioned funds are used to repay bank loan and OPEX, as well as to improve energy welfare measures to all EnC members.

Furthermore, it is assumed that the EnC is formed using newly purchased PV system. If the planning model were centered on using already installed generation source, assessing the advantages of existing prosumers operating under net metering or net billing systems would prove challenging due to the activities related to determination of prosumers' economic savings from the installed PV system before its participation in the EnC. Moreover, the primary aim of the formulated case studies and scenarios is to provide insights for establishing economically efficient EnCs. Consequently, these recommendations remain applicable even when an already operational prosumer is integrated into the EnC.

The following subsections will delve into the introduction of the baseline EnC cases along with the variables used in the case studies and scenarios.

3.2. Baseline energy communities used in case study and scenario modelling

Baseline EnCs are considered prosumer and consumer EnCs which differ from each other in terms of both electricity consumption and electricity generation, thus forming a wider set of results of the developed case studies and scenarios.

The first EnC (abbreviated as EnC No.1) consists of PV system with a generation capacity of 3 kW. Using electricity generation profile and electricity consumption schedule mentioned in subsections 3.1.1. and 3.1.2., prosumers' consumed amount of electricity reaches 80% of its generated amount, thus allowing to share and sell the remaining amount of 20% annually. Consumers' average monthly electricity consumption is chosen freely, as its value increase is addressed in other baseline EnC. Baseline EnC No.1 PV capacity, monthly electricity consumption for prosumer and consumer, as well as amount of external funding of the respective capacity of PV system is given in Table 3.3.

Table 3.3 Data of EnC No.1

Data	**Value**
Installed capacity of PV system	3 kW
PV degradation coefficient, %/year	0,5 %/year [80]
Prosumers' average monthly electricity consumption	780 kWh
Consumers' average monthly electricity consumption	175 kWh
Amount of external funding	1800 EUR [13]

In the second EnC (abbreviated as EnC No.2) installed capacity of PV system, respective amount of external funding, as well as prosumers' average monthly electricity consumption remains unchanged, however, consumers' average monthly electricity consumption is twice as high as in EnC No.1. Thereby, these baseline EnCs would determine consumers' electricity consumption effect on EnC indicators. Data of baseline EnC No.2 is given in Table 3.4.

Table 3.4 Data of EnC No.2

Data	**Value**
Installed capacity of PV panels	3 kW
PV degradation coefficient, %/year	0,5 %/year [80]
Prosumers' average monthly electricity consumption	780 kWh
Consumers' average monthly electricity consumption	300 kWh
Amount of external funding	1800 EUR [13]

In the third EnC (abbreviated as EnC No.3) installed capacity of PV panels in increased from 3 kW to 4kW, as well as prosumers' average monthly electricity consumption is increased to maintain the self-consumption level of 80%. Consumers' average monthly electricity consumption is assumed to be the same as in baseline EnC No.1, however, amount of external funding is increased to be applied to the respective PV capacity. Therefore, EnC No.3 can be compared to EnC No.1 in order to determine the effect on increased amount electricity available to be shared to the consumer and selled to electricity trader, as well as effect on increased initial costs and external funding. Data of baseline EnC No.3 is given in Table 3.5.

Table 3.5 Data of EnC No.3

Data	**Value**
Installed capacity of PV panels	4 kW
PV degradation coefficient, %/year	0,5 %/year [80]
Prosumers’ average monthly electricity consumption	1050 kWh
Consumers’ average monthly electricity consumption	175 kWh
Amount of external funding	2200 EUR [13]

In addition to the included data, each baseline EnC includes the following unified data on the tariffs and prices (without taxes), CAPEX and OPEX (without VAT), bank loan data, discount rate, CAPEX payment scheme among EnC participants and the procentual value of the VAT:

- Consumers’ tariff for the received electricity from the prosumer: 0,16 EUR/kWh.
- Electricity traders’ price for the purchase of excess electricity from the EnC: 0,14 EUR/kWh.
- Electricity cost tariff component for the purchase of electricity from the grid: 0,18 EUR/kWh.
- Prosumers’ and consumers’ connection to the grid: 3 phases, 20 A. [90]
- Costs related for the supply of electricity from the grid: 0,03985 EUR/kWh. [90]
- Costs related or connection maintenance: 0,92 EUR/A/month. [90]
- PV system CAPEX of the capacity of 1 kW: 958 EUR/kW. [82]
- Annual OPEX: 1,2% of of the cost of PV system. [80]
- Loan duration: 5 years.
- Bank loan interest rate: 5,9%. [93]
- Discount rate: 9,96%. [94]
- Prosumers’ initial investments: 50% of total CAPEX.
- Consumers’ initial investments: 0% of total CAPEX.
- VAT: 21%. [95]

Before modelling case studies and their included scenarios, next section determines generation, consumption and external funding level effect on baseline EnCs defined indicators: NPV, AF, as well as prosumers’ and consumers’ economic benefits from the participation in the EnC (PEB and CEB, respectively).

3.3. Determination of NPV, AF, PEB, and CEB values in baseline energy communities

By utilising the planning tool under proposed business model and information from the baseline EnCs, NPV values are calculated and illustrated in Fig. 3.8.

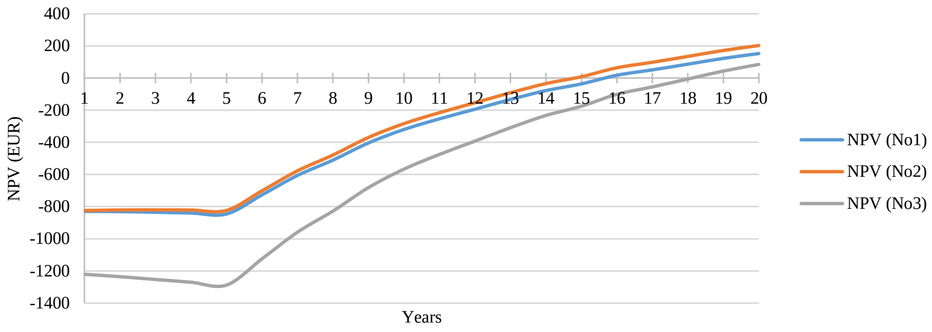

Fig. 3.8 NPV values under each baseline EnCs

As can seen from Fig. 3.8, the highest NPV has been achieved by EnC No.2, which requires relatively low investments, but the rise in consumer electricity demand from the prosumer has led to an increase in its value. Considering that in the included baseline EnCs electricity sharing tariff is higher that electricity traders' determined price for the purchase of excess amount of electricity from the EnC, higher consumers' electricity consumption leads to a higher income rate to the EnC. Furthermore, EnC No.3 experiences a relatively lower NPV than the other baseline EnCs. As the PV system capacity increases, the total CAPEX also increases (in spite of the larger amount of external funding), however, electricity sharing between prosumer and consumer bring too low income (due to low consumers' electricity consumption) to raise the NPV value. This, in turn, leads to higher amount of excess electricity which must be sold to the electricity trader at the lower price than determined sharing tariff under baseline EnCs.

In addition, Fig. 3.8 indicate that determined loan duration in baseline EnCs cases is too short and total CAPEX is too high to obtain positive NPV value in the loan duration. Thereby, bank may hesitate to approve a loan, if the payback period for the PV system exceeds the duration of the bank loan.

Visual representation of AF for each baseline EnC is illustrated in Fig. 3.9.

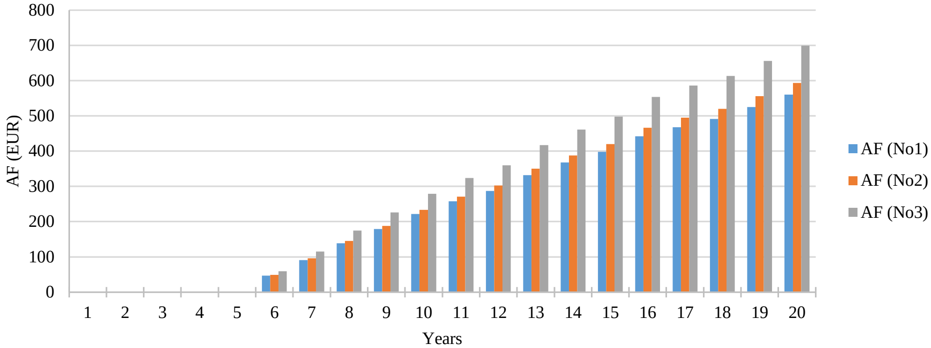

Fig. 3.9 AF values for each baseline EnC

In spite of relatively low NPV in EnC No.3, it has the highest AF among all baseline EnCs. This can be clarified by noting that the AF encompass the provision for bank payments (resulting in zero AF for the initial five years) and the annual OPEX. If EnC expenses exceed the EnC income from the electricity sharing and selling activities, the remaining portion is covered by the PV system owner (prosumer). Once the bank loan is fully repaid, the sole annual expenses are associated only with annual OPEX. Given that EnC No.3 has installed PV panels with a higher capacity, the amount of excess electricity after coverage prosumer self-consumption is greater compared to lower capacity PV systems. Consequently, the installation of higher capacity PV system has the potential to increase AF, but it may impose a higher financial burden on the prosumer. Moreover, increased consumers' electricity consumption can increase AF as seen from EnC No.1 and EnC No.2 AF values due to the fact that in baseline EnCs electricity sharing tariff is higher that electricity traders' determined price for the purchase of excess amount of electricity from the EnC.

Visual representation of PEB from its participation in each baseline EnCs is illustrated in Fig. 3.10.

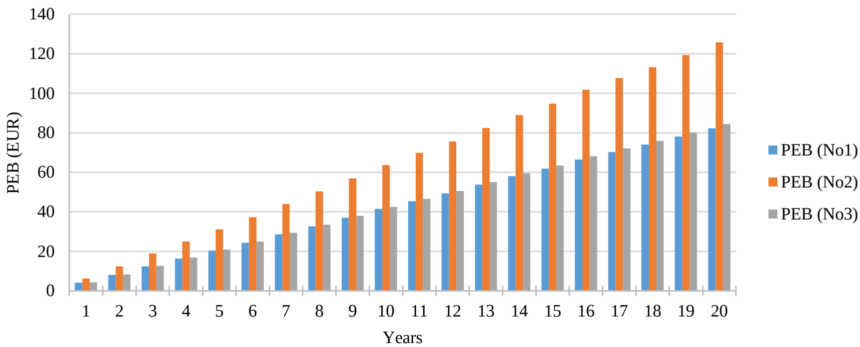

Fig. 3.10 PEB values for each baseline EnC

As can be seen from Fig. 3.10., increase of PV system capacity not always can increase PEB. It can be explained by the circumstance that consumers' electricity consumption of the respective hours in a day can be fully covered with the help of lower capacity PV systems. When consumers' electricity consumption is higher, its electricity demand and received amount of electricity from the prosumer increases. If electricity sharing tariff is higher that electricity traders' determined price for the purchase of excess amount of electricity from the EnC (as in all baseline cases), increased amount of consumers' electricity consumption means a higher PEB from the participation in the EnC.

Visual representation of CEB from its participation in each baseline EnC is illustrated in Fig. 3.11.

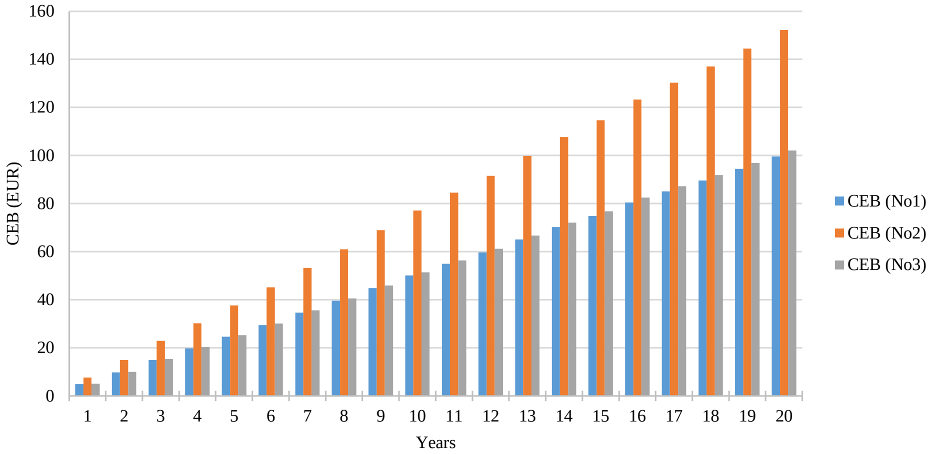

Fig. 3.11 CEB values for each baseline EnC

As can be seen from Fig. 3.11., increase of PV systems' capacity not always can increase CEB because consumers' electricity consumption in PV generation period can be covered by the lower capacity PV system. When consumers' electricity consumption is higher, received amount of electricity from the prosumer increases, thereby also increasing CEB (due to the ratio between sharing tariff and purchase price for the excess amount of electricity). Detailed information on the aforementioned EnC feasibility indicator values under every baseline EnC can be seen in Annexes 1-3.

In order to determine how these indicator values of the used baseline EnCs are affected by the diffrenent factors and their respective values, case studies and their related results are discussed in the next section and following subsections.

3.4. Case study and scenario modelling

3.4.1. Case Study I: sharing tariff and electricity traders' purchase price

Case Study I objective is to determine the effect of consumers' tariff for the received amount of electricity from the prosumer and electricity traders' tariff for the purchase of excess electricity from the EnC on the NPV, AF, PEB and CEB values. In order to analyse tariff increase or decrease against the values of these indicators determined under the baseline EnCs, five scenarios (SCs) are developed (see Table 3.6).

Table 3.6 Determined scenarios under Case Study I

Description	Base value	Values in each scenario (SC)				
		SC1	SC2	SC3	SC4	SC5
Consumers' tariff for the received electricity from the prosumer (EUR/kWh)	0,16	0,16	0,16	0,16	0,18	0,20
Electricity traders' tariff for the purchase of excess electricity from the EnC (EUR/kWh)	0,14	0,09	0,16	0,18	0,14	0,14

Under SC1, reduction of electricity traders' tariff for the purchase of excess electricity from the EnC results in a decline in NPV (see Fig. 3.12.). The aforementioned tariff reduction is most noticeable in EnC No.3, where the NPV in 20th year falls to negative value and payback period exceeds PV systems' lifespan period of 20 years. This can be attributed to the incapacity of electricity sharing income to offset the low purchase price of excess electricity. It can be concluded that low electricity traders' price can decrease overall income rate and feasibility of establishment of EnC. In addition, NPV value is still negative and payback period is longer than bank loan duration.

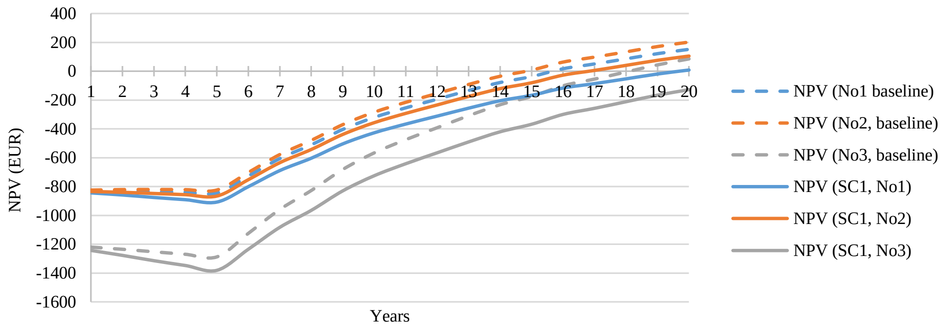

Fig. 3.12 NPV values under Case Study I: SC1

Similar to NPV values under SC1, AF is affected and decreases by the low electricity traders' price for the purchase of excess electricity from the EnC due to the reduction of EnC income (see Fig. 3.13).

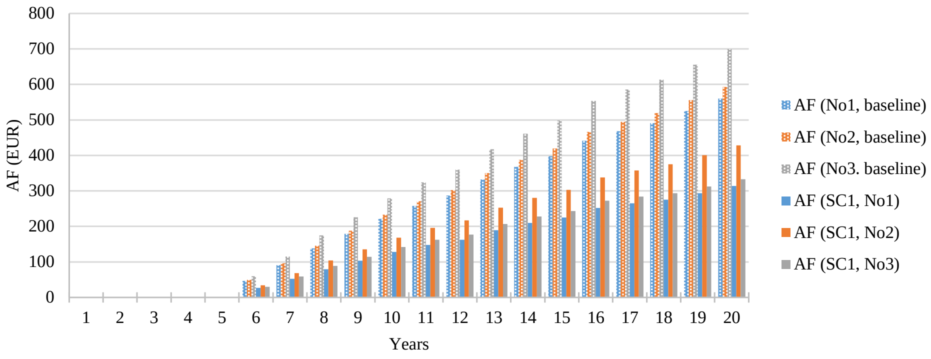

Fig. 3.13 AF under Case Study I: SC1

When considering PEB (Fig. 3.14.), it has a noticeable increase. For the prosumer, without participating in the EnC, the only option to transfer its excess electricity is to the electricity trader (whose purchase tariff is low in this scenario). If the prosumer participates in EnC, then it can share part of the excess amount of electricity to the consumer at a higher tariff, while the excess after the consumers' electricity consumption is selled to the electricity trader at a low price. Thus, the PEB in this scenario has an increased value than in the baseline cases. In addition to that, EnC No.2 obtains the greatest increase in PEB – higher consumers' electricity consumption ensures a lower amount of electricity sold to the electricity trader, thus effect of the considered electricity traders' tariff on PEB can be reduced. It can be mentioned that CEB is not affected by the increase or decrease of the reviewed electricity traders' price.

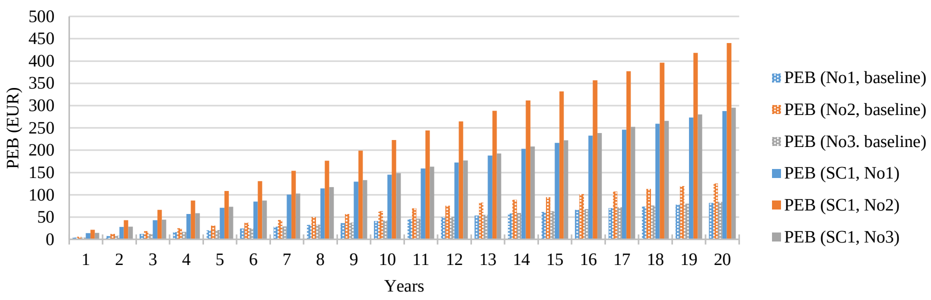

Fig. 3.14 PEB under Case Study I: SC1

If electricity traders' price for the purchase of excess electricity from the EnC and consumers' tariff for the received electricity from the prosumer increases (SC2 – SC5), it increases both NPV and AF because EnC income from the shared and selled electricity increases. Moreover, if consumers' tariff for the received electricity from the prosumer is higher than electricity traders' price for the purchase of excess electricity from the EnC (SC1, SC4 and SC5) then PEB value is positive. If electricity traders' price for the purchase of excess electricity is at the same value or higher, then electricity sharing activities do not bring (SC2) or lowers (SC3) additional economic benefits for the prosumer from the participation in the

EnC. Similar to SC1, changes in price for the purchase of excess electricity in SC2 and SC3 do not affect CEB. Complimentary example of PEB under EnC No.1 in SC2 and SC3 is given in Fig. 3.15.

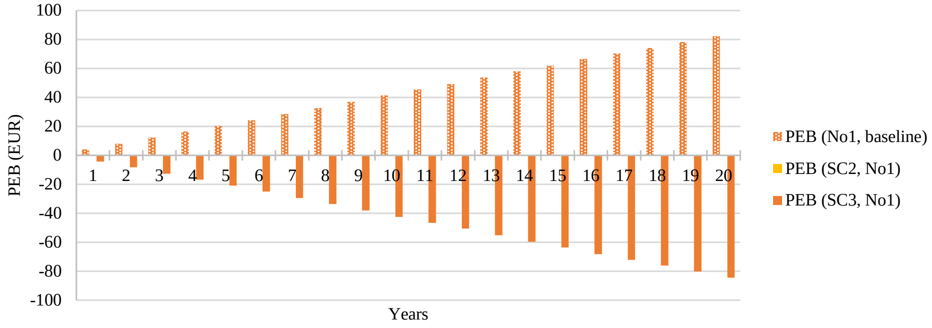

Fig. 3.15 PEB under EnC No.1 in SC2 and SC3

If SC4 and SC5 are considered from the CEB point of view, it can be concluded that there is no additional CEB in SC4 (CEB is equal to zero) and reaches negative value in SC5 in all three baseline EnC cases. This is due to the fact that the shared electricity tariff is equal to or higher than the tariff for which the consumer can cover his electricity consumption from imported electricity from the grid. Visualisation of CEB under EnC No.3 in SC4 and SC5 is given in Fig. 3.16.

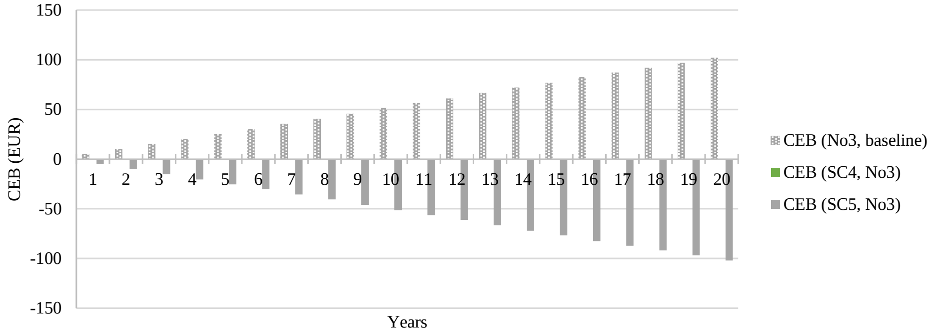

Fig. 3.16 CEB under EnC No.3 in SC4 and SC5

It can be concluded that an increase of sharing tariff and purchase price for the excess amount of electricity increase the NPV and AF values, thus motivating the creation of EnC from the economic viability point of view. PEB value is affected from the ratio between considered tariff and price: PEB value increases when electricity traders' price for the purchase of excess electricity from the EnC is lower than consumers' tariff for the received electricity from the prosumer (sharing tariff). Moreover, CEB increases when aforementioned sharing tariff is lower than electricity cost tariff component for the purchase of electricity from the grid.

Detailed information on the NPV, AF, PEB, and CEB values for each scenario presented in Case Study I under every baseline EnCs can be seen in Annexes 1-3.

3.4.2. Case Study II: electricity cost tariff component for the purchase of electricity from the grid

Given that the installation of PV system aims to decrease reliance on electricity supply from the grid and mitigate the effect of electricity market on the overall cost of imported electricity, Case Study II is designed to investigate the effect of the tariff for imported electricity from the grid on the determined EnC indicators. Two scenarios are included in this case study which consider a reduction and an increase in the fixed electricity tariff compared to the tariff included in the baseline cases (see Table 3.7.).

Table 3.7 Determined scenarios under Case Study II

Description	**Base value**	**Values in each scenario (SC)**	
		SC1	**SC2**
Electricity cost tariff component for the purchase of electricity from the grid (EUR/kWh)	0,18	0,16	0,20

When electricity cost tariff component is lower than in baseline cases, it leads to a corresponding decline in NPV and increase of PV systems' payback period (see Fig. 3.17). This is due to the inclusion of economic savings resulting from the prosumers' self-consumption of amount of electricity generated by the PV system. Consequently, as the electricity cost tariff component decreases, the economic savings from the installation of PV system lowers. Moreover, CEB value in SC1 reduces for the same reasons discussed in Case Study I under SC4 and SC5. Nevertheless, increase or decrease of electricity cost tariff component do not affect the values of AF and PEB: tariff applies to the cases when the prosumer both participates and does not participate in EnC.

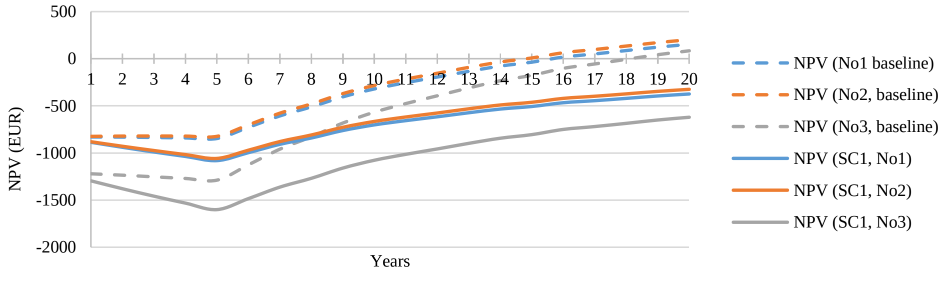

Fig. 3.17 NPV values under Case Study II: SC1

If electricity cost tariff component for the purchase of electricity from the grid is higher (SC2) than determined in the baseline EnC cases, NPV increase can be observed (see Fig.

3.18): as the tariff increases, so do the benefits cost savings of installing PV panels. Nevertheless, payback period under baseline data is still longer than bank loan duration.

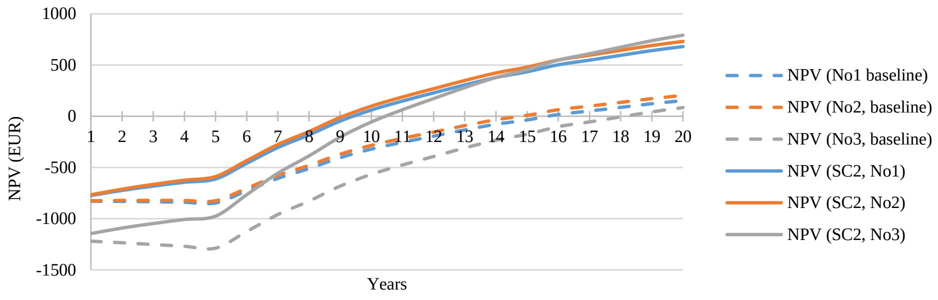

Fig. 3.18 NPV values under Case Study II: SC2

Moreover, higher electricity cost tariff component leads to the increase of the ratio between it and determined sharing tariff, causing an increase in CEB value and economic benefits from the received electricity from the prosumer (see Fig. 3.19).

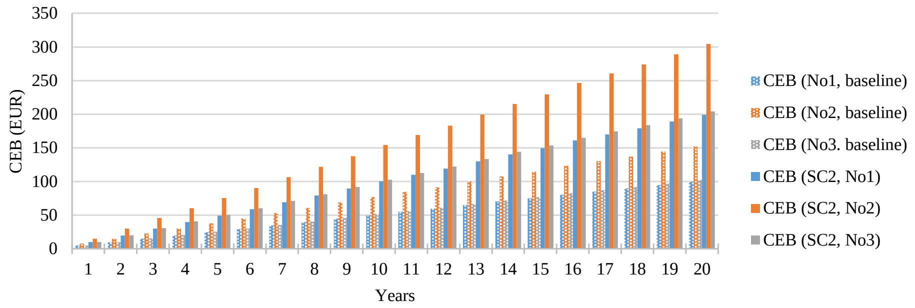

Fig. 3.19 CEB values under Case Study II: SC2

It can be concluded that external factor (in this case: electricity cost tariff component) affect not only the NPV, but also CEB values. If this tariff is relatively high, the installation of PV system and the development of EnC can reduce overall cost of electricity. When planning the establishment of EnC, potential participants should evaluate the situation and prognosis of electricity tariffs, thus avoiding the low economic efficiency of the installation of PV system, as well as the extension of the electricity generation source payback period.

Additional data on the NPV, AF, PEB, and CEB values under Case Study II scenarios is available in Annexes 1-3.

3.4.3. Case Study III: CAPEX related to installed generation source capacity of 1 kW

The initial costs of the established EnC are directly dependent on the costs associated with the purchase and installation of PV system. To see how the offer of different PV system dealers can affect the determined indicators of EnC, this subsection examine two scenarios (see Table

3.8) in which CAPEX related to installed generation source capacity of 1 kW is both higher and lower than in baseline cases.

Table 3.8 Determined scenarios under Case Study III

Description	Base value	Values in each scenario (SC)	
		SC1	SC2
CAPEX related to installed generation source capacity of 1 kW (EUR/kW)	958	641	1427

Selecting the PV system dealer with the most competitive offer (SC1) [82] for the purchase and installation of PV panels, it enhances the NPV value and significantly reduces payback period which in this scenario is shorter than determined bank loan duration (see Fig. 3.20). This is due to the reduction in both the initial investments from the prosumer and the amount of the bank loan necessary to cover the remaining part of total CAPEX. Moreover, as purchase and installation costs are reduced, the NPV of higher PV capacity (EnC No.3) can be observed to increase, as the financial burden of the prosumer is reduced, thus the ratio between EnC income and expenses increases.

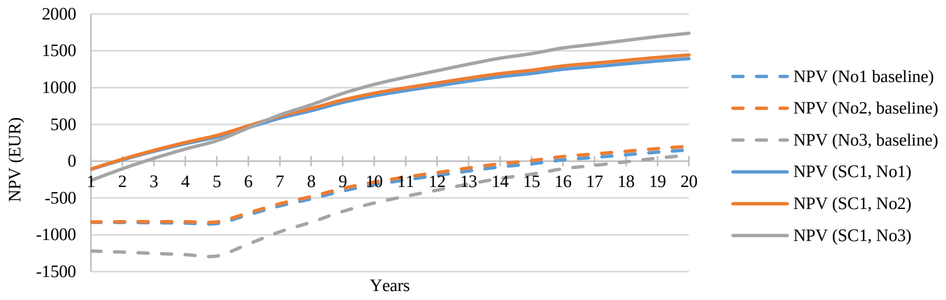

Fig. 3.20 NPV values under Case Study III: SC1

Along with the reduced cost of PV system, cheaper materials and units (such as wiring and control equipment) reduces the value of OPEX. If OPEX costs decrease, the annual cash outflow also decreases, thereby increasing the value of AF (see Fig. 3.21.).

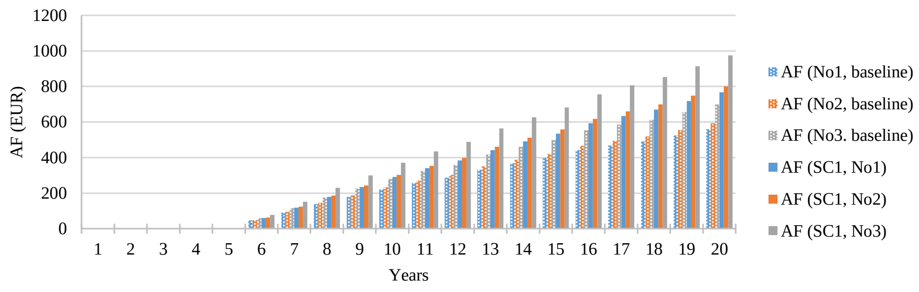

Fig. 3.21 AF values under Case Study III: SC1

Selecting the dealer with the least competitive offer (SC2) [82] for the purchase and installation of PV system, it significantly reduces the NPV and AF values (see Fig. 3.22. and Fig. 3.23.) for the same reasons discussed earlier. Moreover, payback period in this scenario is longer than bank loan duration and even lifespan of PV system itself.

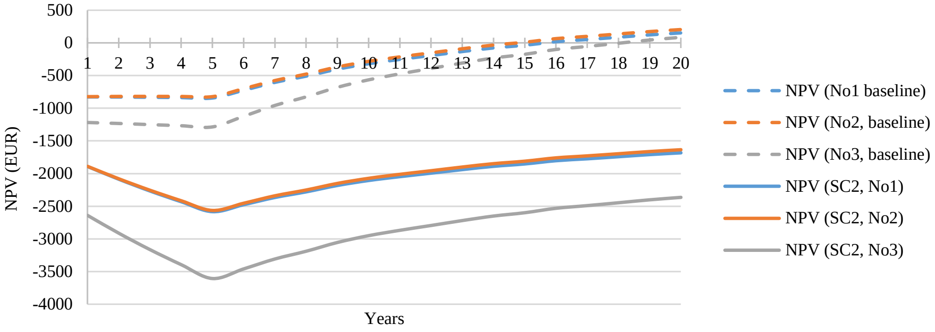

Fig. 3.22 NPV values under Case Study III: SC2

Respectively, higher PV system purchase and installation costs increase the neccesary amount of initial investments and bank loan to fully cover total CAPEX. As can be seen from Fig. 3.22, NPV values could reach negative value, thus concluding that the choice of a PV system dealer is one of the most important aspects that can affect the economic feasibility of creating an EnC. Furthermore, by using more expensive wiring and equipment, PV systems maintenance and replacement costs can rise, thereby increasing OPEX and reducing AF (Fig. 3.23).

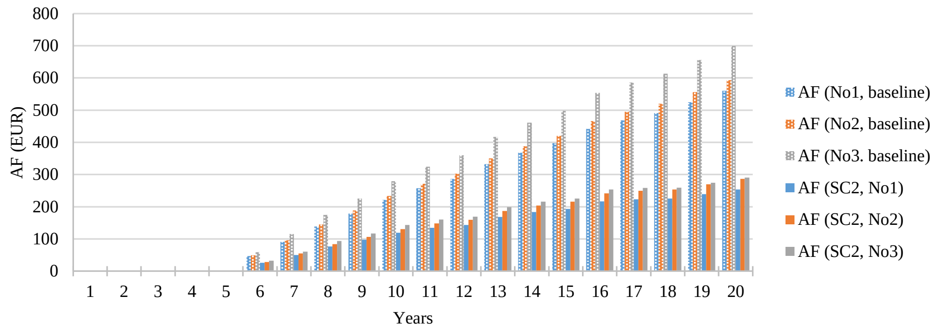

Fig. 3.23 AF values under Case Study III: SC2

Taking into account that the consumer does not make a one-time payment for the coverage of initial investments in baseline cases, CEB in discussed scenarios is not affected by the PV panel purchase and installation costs. Moreover, PEB is also not affected by the increase or decrease of aforementioned costs since such costs are included even if the prosumer does not participate in the EnC and operates as individual active user.

By analysing the results contained in Case Study III, it can be concluded that PV systems' purchase and installation costs significantly affect the viability and feasibility of EnC. High costs can increase the amount of initial investments required, as well as the amount of bank loan which, in turn, can have negative affect for the payback period of the PV system and reduced amount of AF. It would be strongly recommended for the potential EnC participants to evaluate the offer of each PV system dealer in order to avoid high initial costs and their effect on economic justification and viability of EnC.

Additional information on the NPV, AF, PEB, and CEB values under Case Study III is available in Annexes 1-3.

3.4.4. Case Study IV: bank loan duration

If the total CAPEX is not fully covered by initial payments from the members of the EnC and external funding, the remaining part can be covered by a bank loan, including both the bank interest rate and the duration of this loan. In order to determine whether a duration of bank loan affect the values of used EnC indicators, as well as to assess, if payback period of installed PV system can be increased by the aforementioned duration, Case Study IV consider two scenarios (see Table 3.9).

Table 3.9 Determined scenarios under Case Study IV

Description	Base value	Values in each scenario (SC)	
		SC1	SC2
Loan duration (years)	5	3	7

As can be seen in Fig. 3.24, a decrease in the loan duration does cause a slight decline in NPV and increase of payback period by one year (compared to baseline EnC cases). This can be explained by recognising that in baseline EnC cases, the discount rate is higher than the bank interest rate. In other words, devaluation of cash over time exceeds expenses related to bank loan total interest rate payments. Furthermore, shorter loan duration significantly reduces NPV over the duration of bank loan.

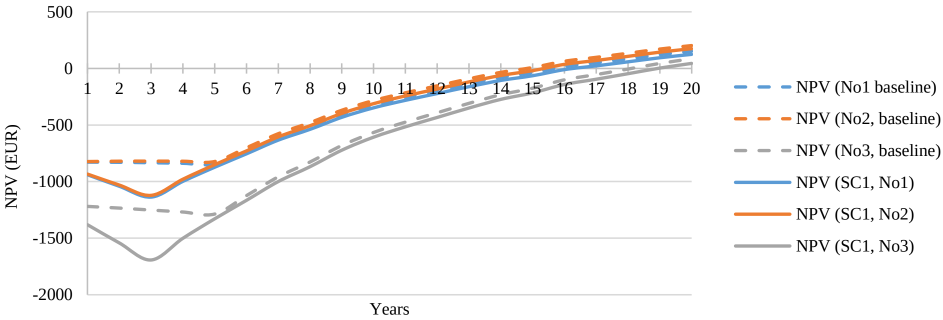

Fig. 3.24 NPV values under Case Study IV: SC1

Shorter loan duration shortens the period when EnC expenses exceeds direct income, thus increasing AF (see Fig. 3.25). As the duration of the bank loan is shortened, the prosumer must evaluate its financial capabilities to cover the increased amount of annual payments to the bank.

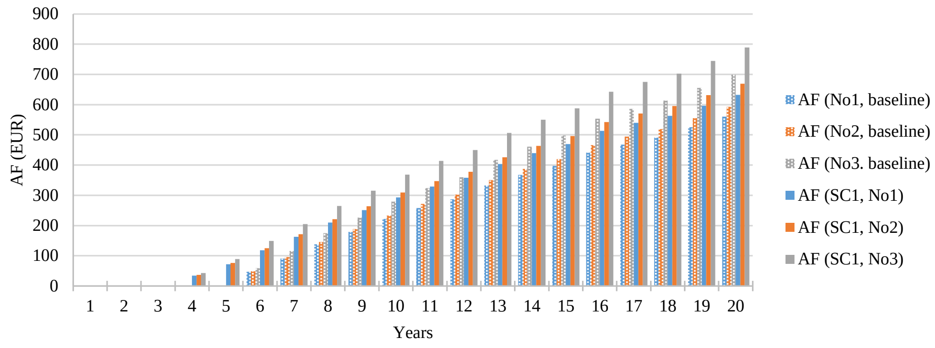

Fig. 3.25 AF values under Case Study IV: SC1

Opposite conclusions for both NPV and AF values can be observed in SC2 when the loan duration is longer than in baseline cases (Fig. 3.26 and Fig. 3.27). With an extension of the bank loan duration, there is an increase in the NPV value during the corresponding period. Nevertheless, due to the costs related to PV system purchase and installation, the NPV in this duration fails to attain a positive value.

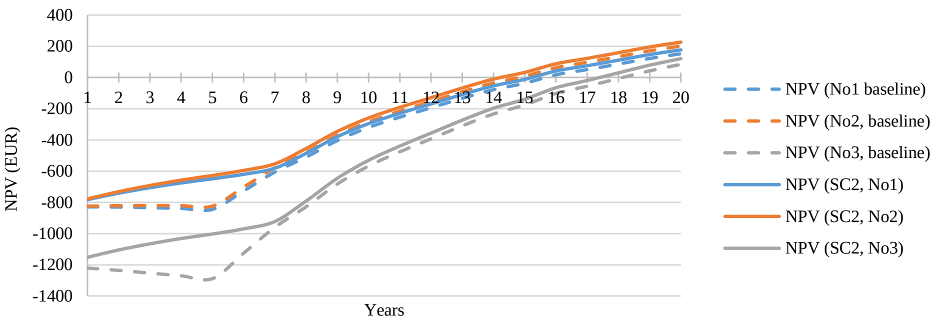

Fig. 3.26 NPV values under Case Study IV: SC2

Duration of bank loan do not affect CEB, as the prosumer bears the responsibility for the bank loan obligations and repayments. Additionally, PEB also remains unaffected, as reviewed loan durations remain valid when it would not be participating in the EnC.

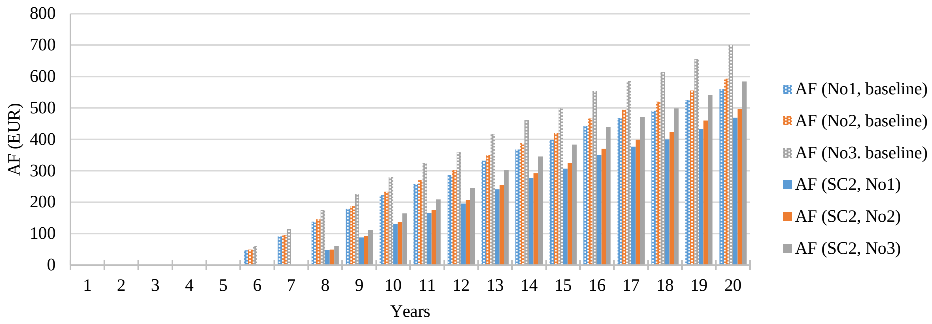

Fig. 3.27 AF values under Case Study IV: SC2

From the results of Case Study IV, it can be concluded that, if the discount rate is higher than the interest rate of the bank loan, a shorter duration of bank loan payments may marginally enhance the NPV value (and vice versa), but reduce AF value (in spite of the ratio between these rates). Moreover, longer bank loan duration can increase NPV value in the respective period, however, it could lead to reduced AF. Consequently, in the EnC planning process it is crucial to carefully consider the loan duration and aforementioned rates to align them with the economic objectives of the EnC.

Additional information on the NPV, AF, PEB, and CEB values under Case Study IV is available in Annexes 1-3.

3.4.5. Case Study V: external funding

Within the framework of the Energy Law, it is determined that Latvia's legislation must include not only state aid to partially cover expenses regarding the purchase of RES-based generation sources installed by individual prosumers, but also to adopt and adjust relevant legislation to financially support the creation of EnCs with the same amount of state aid as it is provided to individual prosumers. [11] Furthermore, external funding does not just depend on state aid, but also payments from third persons or institutions and donations. Thus, it is necessary to consider whether amount of external funding may affect not only the individual prosumers, but also the viability and justification of the establishment of EnC. The functions of proposed planning model and results of this case study can be used by not only potential EnC creators, but also policymakers and legislators to assess the importance and necessity of state aid and other external funding sources under the proposed business model. Thereby, the main objective of Case Study V is to determine effect of external funding on the economic feasibility of EnC using modelling three external funding acquisition scenarios (see Table 3.10).

Table 3.10 Determined scenarios under Case Study V

Description	Base value	Values in each scenario (SC)		
		SC1	SC2	SC3
Amount of external funding (EUR)	EnC No.1, No.2: 1800	1500	2100	0
	EnC No.3: 2200	1900	2500	

Bearing in mind that the main task of external funding is to reduce total CAPEX, its effect is related to value changes in the NPV, since it is assumed in determined baseline EnCs that the financial responsibility for the purchase and payment of the PV system is undertaken by the prosumer.

When evaluating SC1 (Fig. 3.28), in which the external funding is reduced by 300 EUR from the initial amount determined in baseline EnCs, significant reduction in NPV values can be observed. External funding reduction in SC1 can extend the baseline EnCs payback period by at least 5 years thus indicating its impact on the validity of EnC creation. Moreover, there is a noteworthy decrease in the NPV value during the bank loan duration.

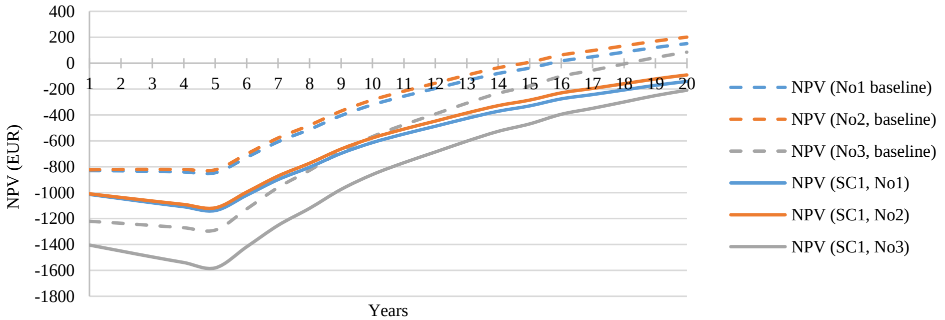

Fig. 3.28 NPV values under Case Study V: SC1

If SC2 is considered (Fig. 3.29), in which external funding is increased by 300 EUR compared to its value in baseline EnCs, NPV increases significantly and can reduce EnC payback period by at least 5 years (compared to baseline EnC cases). Furthermore, additional external funding increases the NPV value over the period of the bank loan.

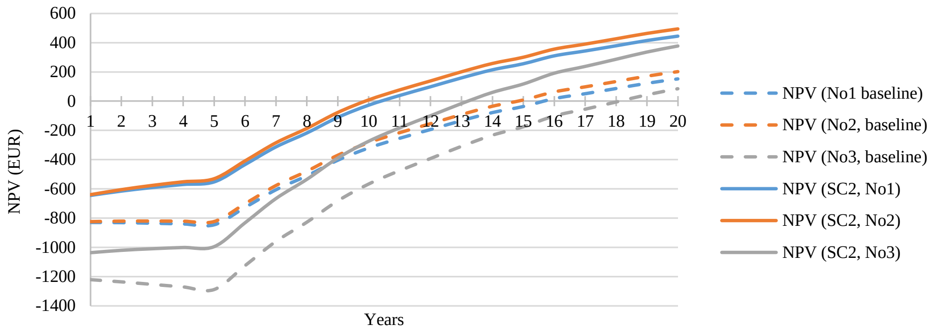

Fig. 3.29 NPV values under Case Study V: SC2

When assessing the economic feasibility of the proposed baseline EnCs without any external funding (SC3), it becomes apparent that the decline in NPV is substantial and payback period is longer than lifespan of PV system (Fig. 3.30). Enhancing NPV through adjustments in other factors, such as opting for a more affordable PV system or by concluding a higher purchase price contract with the electricity trader, may not be enough to achieve a positive NPV value for all three baseline EnCs without the help of state aid or other external funding options. Besides, no external funding leads to the reduction of NPV in the duration of bank loan, thus creating risks of not granting a bank loan to cover the total CAPEX of the PV system.

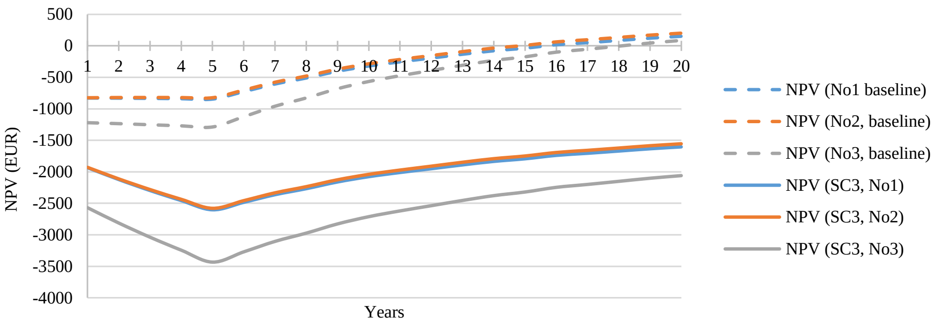

Fig. 3.30 NPV values under Case Study V: SC2

Within the scope of Case Study V, it was identified that even minor changes in external funding value have a noteworthy effect on the NPV value. Consequently, legislators and policymakers are advised to increase state aid or at least maintain the amount of state aid for the creation of EnC in the same amount as it is determined in the relevant legal acts. Nevertheless, it is recommended for potential EnC creators to aquire additional external funding to shorten the payback period. This, in turn, could serve as a basis for sharing tariff reduction or even its non-implementation in the structure of EnC payments, leading to additional increase of CEB from the participation in the EnC. If external funding is not aquired, the installation of a PV system may turn out to be economically unviable and unjustified, even if positive effect of other factors is introduced, such as installation of more affordable PV system.

Supplementary details regarding the NPV, AF, PEB, and CEB values in Case Study V can be found in Annexes 1-3.

3.4.6. Case Study VI: allocation of initial investments

Taking into account that the EnCs' objective is to function as a united mechanism for electricity generation and consumption, its establishment can yield advantages for all its members. Nonetheless, to purchase electricity generation source, it is crucial to determine how the allocation of initial investments and used repayment mechanisms may impact not just the payback period of the PV system, but also the financial benefits for each participant involved in the EnC. In order to analyse initial investment allocation and repayment mechanisms effect on determined EnC indicators, four scenarios are examined within Case Study VI (see Table 3.11).

Table 3.11 Determined scenarios under Case Study VI

Description	Base value	Values in each scenario (SC)			
		SC1	SC2	SC3	SC4
Prosumers' initial investments (% of total CAPEX)	50	100	0	50	50
Consumers' initial investments (% of total CAPEX)	0	0	0	5	50

If the prosumer covers 100% of the total CAPEX of PV system with its initial investments (SC1), it has a slight effect on the NPV and payback period compared to baseline cases (Fig. 3.31). Bearing in mind, that possibility to receive a bank loan is affected by the other factors mentioned in the above subsections, initial investment allocation to fully cover total CAPEX can be considered when granting a bank loan could prove challenging. However, prosumer has to make these savings to cover total CAPEX in advance in order to purchase and install PV system.

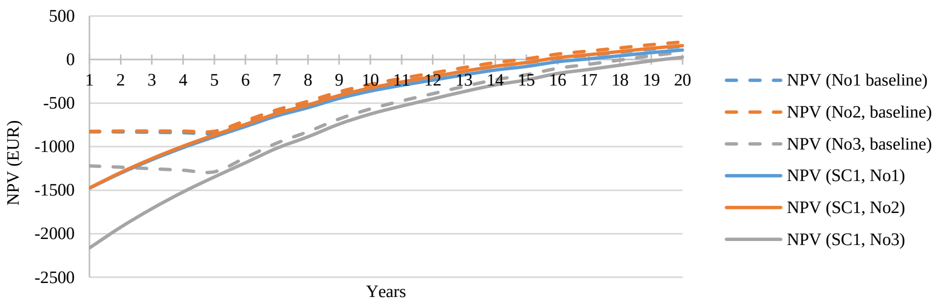

Fig. 3.31 NPV values under Case Study VI: SC1

If a bank loan is not taken (SC1 and SC4), AF can increase if EnC income from electricity is higher than annual OPEX related expenses (Fig. 3.32).

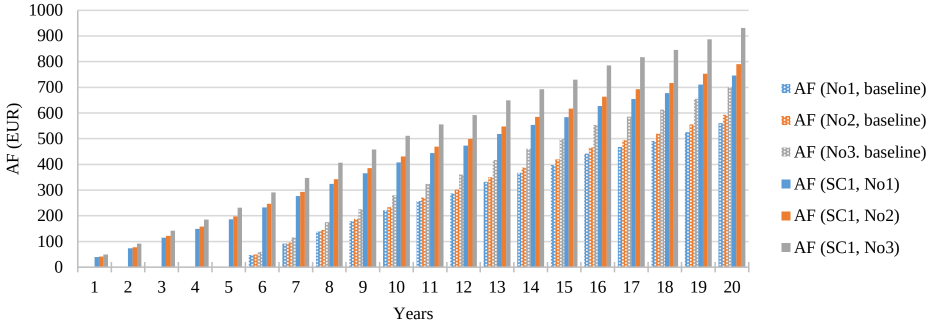

Fig. 3.32 AF values under Case Study VI: SC1, SC4

If SC2 is considered in which bank loan is used to fully cover total CAPEX, a similar observation can be made as in SC1: NPV slightly increases (Fig. 3.33) due to the ratio between the discount rate and the interest rate of the bank loan under the used data in baseline EnCs. NPV value significantly reduces in the duration of bank loan, thereby there is a risk that bank could not grant a loan under examined circumstances.

In order to achieve a positive NPV value during the loan period, it is necessary to evaluate the purchase of lower cost PV system, increasment the sharing tariff, attraction of additional external funding or initial investments from the consumer. Furthermore, it is necessary to evaluate whether the prosumers' financial burden is not too high to cover the annual repayments of the bank loan. It can be mentioned that PEB, CEB and AF values under SC2 remains at the baseline case level.

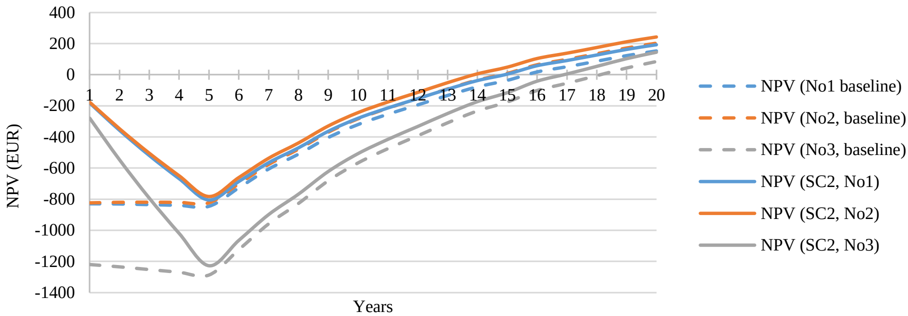

Fig. 3.33 NPV values under Case Study VI: SC2

In SC3, with the prosumer contributing 50% of the total CAPEX and the consumer making a modest initial investment payment of 5% of the total CAPEX, the amount for a bank loan to cover the remaining part of initial costs would be reduced, thereby reducing the prosumers' financial burden for purchasing a PV system. Morever, initial investment contribution from the consumer can increase NPV (see Fig. 3.34).

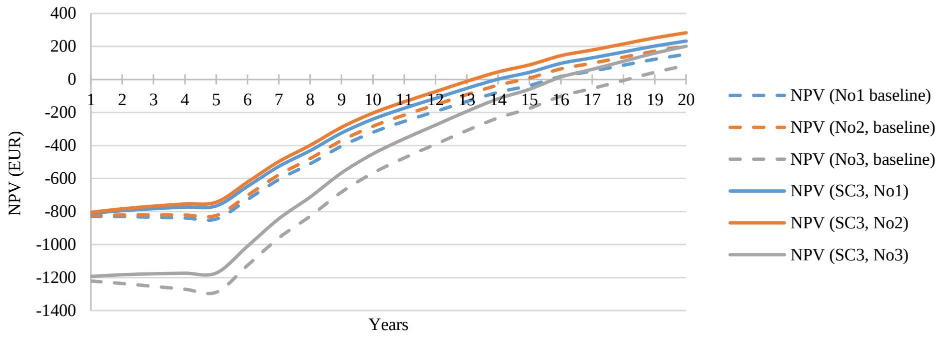

Fig. 3.34 NPV values under Case Study VI: SC3

In addition to that, initial investment payment from the consumer can increase PEB (Fig. 3.35), thereby increasing its economic interest regarding creation and participation in the EnC.

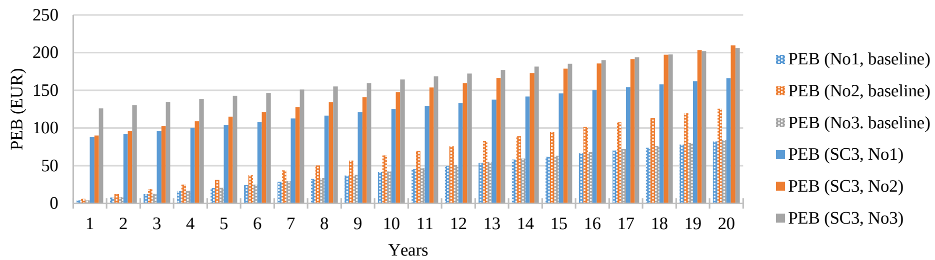

Fig. 3.35 PEB values under Case Study VI: SC3

5% initial investment payment of the total CAPEX can decrease CEB (see Fig. 3.36). This is attributed to circumstance, that consumers' electricity cost savings from the electricity sharing are insufficient to have a high enough economic benefits to additionally provide initial investment payments.

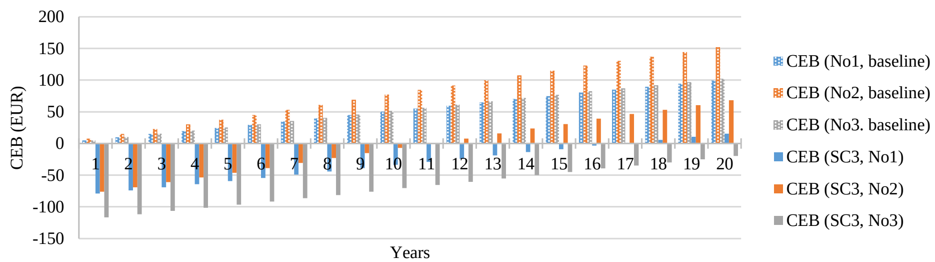

Fig. 3.36 CEB values under Case Study VI: SC3

If total CAPEX is covered in half by the prosumer and the consumer, NPV value is significantly higher than in baseline cases (Fig. 3.37). This is due to the fact that a acquirement of a bank loan is not necessary, thereby reducing both the value of the outgoing cash flow and also reducing the financial burden for the prosumer.

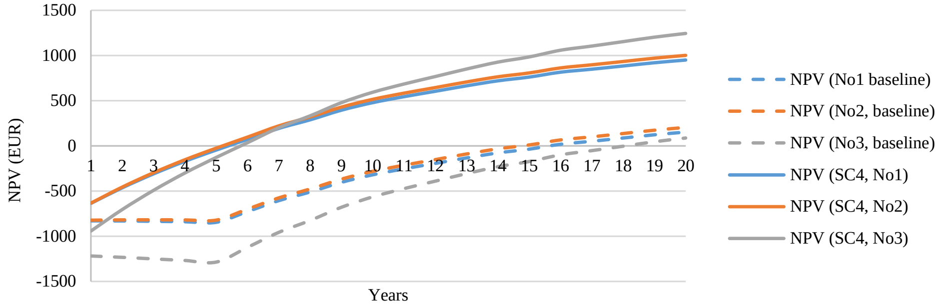

Fig. 3.37 NPV values under Case Study VI: SC4

If consumer contributes with high initial investment payment, PEB significantly increases (Fig. 3.38).

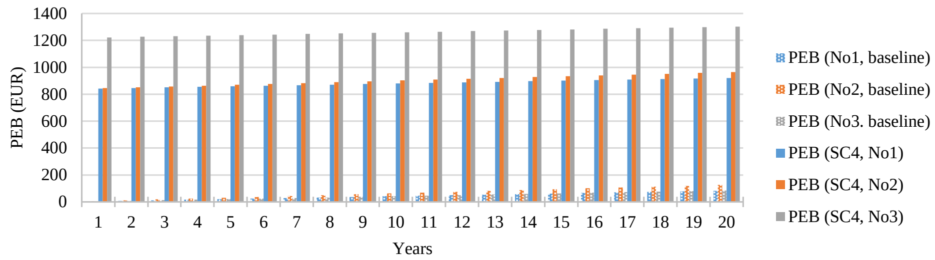

Fig. 3.38 PEB values under Case Study VI: SC4

Much like SC3, the CEB value significantly reduces under SC4 (Fig. 3.39). It can be explained by the fact, that consumers' electricity consumption and received amount of electricity from the prosumer is too low, as well as electricity sharing tariff is too high to offset the high initial investment payments.

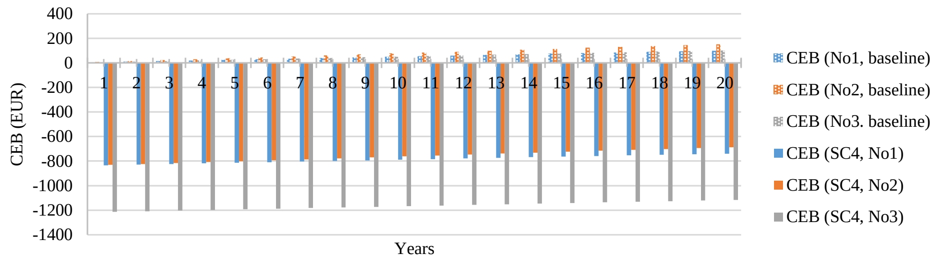

Fig. 3.39 CEB values under Case Study VI: SC4

It can be concluded that under baseline case data, the NPV value is not significantly affected, if either a bank loan or prosumer 100% initial investments are used for the purchase of PV system, but it significantly affects the AF value. If bank loan is taken then the AF is zero during the repayment period of the bank loan, thus reducing overall AF in the PV systems' lifespan. Moreover, to cover initial investments between 100% prosumers' initial investments and a bank loan, the prosumer's financial burden assessment must also be taken into account, thus determining which of these financing options is more beneficial.

If attention is being made at the scenario in which consumer funds also participate in covering the total CAPEX, it can be observed that even with 5% of total CAPEX coverage, its CEB value can decrease. It can be explained by the fact that the value of the initial investment exceeds the benefits it gets from consuming the prosumers' shared electricity at a lower tariff than, if it would not participate in EnC and cover all consumption with imported electricity from the grid. However, consumers' partial coverage of total CAPEX increase both NPV and PEB values, thus creating a positive effect both on the payback period and on prosumers' willingness to create and participate in EnC.

Moreover, if total CAPEX of the PV system is covered in half by the prosumer and the consumer, it significantly increases both NPV and PEB, thus reducing prosumers' financial burden for the purchase of PV system. Nevertheless, CEB value in this scenario decreases even more than in SC3. Thus, it can be concluded that, if the consumer makes initial investment payments, sharing tariff should be low enough (or even non-existent), consumers' electricity consumption and received amount of electricity from the prosumer should be high enough to make CEB a positive value. If the value of the sharing tariff is assumed to be zero, it is possible with the planning tool to determine what the value of these investments from the consumer side must be in order for the values of CEB and PEB to be positive. However, it depends on the level of electricity consumption of each individual EnC member, the prosumers' amount of generated electricity, electricity traders' purchase price as well as other variable factors, the mutual affect of which can have an impact on all the determined EnC indicators.

3.5. Discussion and conclusions

In order to contribute to the development of recommendations for the establishment of EnCs mentioned in the Energy Law, case study and scenario modelling were conducted with help of developed planning tool. The goal was to analyse how different factors and their potential values can affect the economic viability and efficiency of prosumer and consumer EnCs under proposed business model using four specifically defined indicators: NPV, AF, PEB and CEB. Repectively, case studies and scenarios included variable values of related electricity tariffs and prices (sharing, purchase of excess electricity from the EnC and electricity cost tariff component for the purchase of electricity from the grid), cost of RES-based electricity generation source, loan duration, amount of external funding and initial investment allocation.

To provide clarity on data and modelling conditions, assumptions were incorporated in case study and scenario modelling associated to the schedule of electricity consumption, the utilization of PV panels for electricity generation, associated electricity generation data, external funding, electricity tariffs and prices, as well as other relevant considerations.

Study proposed three baseline EnCs which differed from each other in terms of the average monthly electricity consumption of the EnC members and the capacity of the installed PV panels (thus also external funding in the form of state aid) to develop the relevant case studies and scenarios. Moreover, each baseline EnC included unified data on the tariffs and prices, CAPEX and OPEX, bank loan data, discount rate, CAPEX payment scheme among EnC participants and the procentual value of the VAT.

When looking at a side-by-side comparison between baseline cases, it can be concluded that used indicator values and payback period are highly affected by electricity consumption level, as well as installed PV systems' capacity. Considering that baseline cases included electricity sharing tariff which was higher than electricity traders' determined price for the purchase of excess amount of electricity from the EnC, NPV and AF increases and payback period shortens when consumers' electricity consumption is high, thus generating higher EnC income, which, in turn, can help to cover EnC expenses related to bank loan repayment and annual OPEX. Moreover, with increased consumers' electricity consumption and ratio between aforementioned tariff and price, CEB and PEB values increases. In spite of increased installed PV capacity, total CAPEX also increases which can lead to higher EnC expenses. Consequently, it lowers NPV and extends the payback period, as the determined sharing tariff and electricity traders' purchase price may compensate related expenses at a lower rate.

Case Study I analysed the effect on electricity sharing tariff and electricity traders' determined price for the purchase of excess amount of electricity from the EnC values on the defined EnC indicators by developing five scenarios. NPV and AF can be increased, if aforemenetioned tariff and price increases: the rise in their values contributes to an increase in EnC income, thus payback period of PV system can be reduced. However, value of PEB reduces when electricity sharing tariff is lower than electricity traders' determined price for the purchase of excess amount of electricity from the EnC, therefore, electricity sharing brings less income than selling all the excess amount of electricity after prosumers' self-consumption to an electricity trader. Moreover, if electricity sharing tariff is lower than electricity cost tariff component for the purchase of electricity from the grid, CEB increases due to the cost savings related to shared electricity consumption.

Within the Case Study II, the effect of the electricity cost tariff component for the purchase of electricity from the grid was examined, thus assessing whether situation in electricity market can affect the economic feasibility of EnCs. Considering that the NPV also depends on the reduction of prosumers' electricity costs which are related to self-consumption of the produced electricity, lower electricity cost tariff component reduces these benefits from installing PV system, thus extending payback period and reducing NPV value.

Results of Case Study III determined that cost of PV system is one of the most important factors that can affect EnC economic viability and sustainability. By selecting the dealer with lowest CAPEX related to PV system capacity of 1 kW, all baseline EnCs payback period was reduced to be under 3 years (shorter period than the duration of the bank loan), however, by choosing dealer with highest CAPEX related to PV system capacity of 1 kW, value of NPV reduced significantly, thus, its payback period in this scenario is longer than the lifetime of the PV system.

Within the Case Study IV, the effect of the duration of the bank loan on EnC determined indicators was studied. Considering the high discount rate and low bank interest rate, the results in this case indicate that a longer duration of the bank loan can slightly increase the NPV and reduce the payback period. Nevertheless, at the selected CAPEX related to PV system capacity of 1 kW in baseline EnCs cases, none of the baseline cases reached a positive value during the duration of the loan. In instances when the total CAPEX is high, the bank may hesitate to approve a loan, if the payback period for the PV system exceeds the duration of the bank loan. When looking at AF values at different loan durations, funds can be increased when duration is the shortest, however, shorter bank loan duration can lead to a greater financial burden on the prosumer, as the loan must be repaid in a shorter term. Thereby, it is necessary for potential EnC creators to assess whether the EnC income level, as well as the prosumers' own private funds are sufficient enough to repay the respective loan in a longer or shorter term.

By examining results of Case Study V, it can be concluded that external funding can considerably reduce total CAPEX, amount of bank loan, as well as payback period. Alterations in external funding value amounting to 300 EUR from the baseline value can result in changes of payback period for the PV system by 5 years. Moreover, if external funding is not aquired, NPV value significantly decreases and payback period for baseline EnCs in this scenario is longer than the lifetime of the PV system.

The results of Case Study VI indicate that, if prosumer fully cover total CAPEX, NPV value is not significantly affected when compared to baseline cases. Moreover, by fully covering initial costs of PV system, AF increases. If bank loan is not taken, expenses that have to be covered from the AF, decreases. If total CAPEX is fully covered by bank loan and without any initial investments by the members of EnC, NPV in bank loan period experiences a rapid decline, however, after bank loan duration increases and the PV systems' payback period shortens compared to baseline cases. Nevertheless, decline of NPV in bank loan duration can serve as a basis for the bank not to grant loan for the coverage of initial costs of PV system. Moreover, a bank loan can create a high financial burden for the prosumer for the loan repayment, thus it is necessary for potential EnC creators to evaluate whether the prosumer has the ability to cover the loan amount in the long term. If the consumer makes one-time payment for the coverage of initial investments, it can increase NPV and PEB, and decrease CEB. If consumer makes initial investment payments, sharing tariff should be low enough (or even non-existent), as well as consumers' electricity consumption and received amount of electricity from the prosumer should be high enough to make CEB a positive value.

Taking into account all the above and based on the modelling of baseline EnCs, case studies and scenarios, the following recommendations can be put forward to increase economic justification, feasibility and sustainability of prosumer and consumer EnCs under proposed business model:

- For the purchase and installation of PV system, EnC members must select the dealer with the most competitive offer (lowest CAPEX related to PV system capacity of 1 kW), thus reducing the payback period, increasing NPV and lowering the amount of necessary initial investments and bank loan (if applicable) to fully cover total CAPEX.

- EnC members should assess the market electricity price forecast to ascertain, if the savings generated through self-consumption and reduction of imported electricity from the grid are sufficient to offset the overall expenses associated with purchasing and maintaining a PV system. Cost savings related to self-consumption increases when electricity cost tariff component for the purchase of electricity from the grid is relatively high.
- Legislators and policymakers must acknowledge that providing state aid for the purchase of electricity generation source can notably enhance the economic sustainability of EnC. Consequently, it is advisable to introduce state aid for EnC to partially cover the initial costs at the same or higher level than what is set for individual prosumers. Moreover, potential EnC members should aquire additional external funding to lower payback period of installed PV system, thus lowering electricity sharing tariff within the EnC.
- If a bank loan is used to partially or fully cover total CAPEX, the prosumer must assess whether the ratio between discount rate and bank interest rate, as well as EnC income and the prosumers' private financial funds are sufficient enough to make the loan payment at the respective loan duration, as well as to assess the effect of bank loan to AF value over the determined period. Moreover, to receive a bank loan, prosumer must be sure that the payback period of installed PV system is shorter than or equal to the duration of the loan repayment. Results of the modelled scenarios showed that payback period can be significantly reduced by installing PV system with lowest CAPEX related to PV system capacity of 1 kW.
- If the consumer makes one-time initial investments for the purchase and installation of PV system, EnC participants must assess whether the amount of electricity to be shared and the consumers' electricity consumption are high enough to generate positive economic benefits for both the prosumer and the consumer. In addition, consumers' partial coverage of PV systems' initial costs opens the possibility to reduce or exclude the sharing tariff for the amount of electricity received from the prosumer, which in turn can reduce the neccesary amount of bank loan or even allow prosumer to cover total CAPEX only with initial investments.
- If sharing tariff is introduced to increase EnC income and cash flow in AF, then the PEB will increase, if sharing tariff is higher than electricity traders' price for the purchase of excess electricity, however, CEB can be increased when sharing tariff would be lower than electricity cost tariff component for the purchase of electricity from the grid. It can be mentioned that PEB and CEB are also affected by the amount of consumers' one-time initial investments mentioned in the paragraph above.

Among the above-mentioned recommendations, there is a mutual connection and the dependence of the respective values on each other. The effect of each included factor also depends on the individual level and profile of electricity consumption of each EnC member, capacity of the installed electricity generation sources, the amount of electricity produced, as well as the priorities of the EnC itself. These priorities can be related not only to the payback of the installed generation source, but also determining economic benefits of each participant and the objective and goals of the accumulation of funds.

CONCLUSIONS

- The development of a planning tool for prosumer-consumer EnCs, based on Latvia's legal framework and local RES availability, confirms the hypothesis of the Doctoral Thesis. This tool promotes the involvement of prosumers and consumers in EnCs, fostering electricity-sharing collaboration and advancing Latvia's energy transition goals. Through modelled case studies, scenarios, and analysis, the Thesis demonstrates recommendations to enhance the viability, justification, and feasibility of prosumer-consumer EnCs in Latvia, paving the way for more sustainable and engaged electricity-sharing actions.
- The tasks of the Thesis have been successfully carried out:
  - A review of legislation acts, scientific publications, and media sources was conducted to determine EnC implementation requirements, guidelines, and possible challenges and setbacks.
  - A methodology and a modelling tool were developed for planning prosumer-consumer EnC initiatives under Latvia's legislation and energy transition goals.
  - The variable factor effect on the economic feasibility and sustainability of prosumer-consumer EnCs was studied through case study and scenario modelling.
- The introduction of EnCs in Latvia faces challenges and setbacks related to a lack of regulations, information dissemination activities, support measures, planning tools, complex business models, low number of prosumers, a small amount of electricity available for sharing, low acceptance and willingness-to-participate rate.
- The developed EnC planning tool and methodology address almost all the aforementioned challenges: showcase the economic advantages of EnCs, motivate interest in EnCs among the public and substantiate the effectiveness of external funding, thereby making it applicable and useful not only to electricity users, but also to legislators and policymakers. A business model is proposed based on the P2P approach (as mentioned in Latvia's NECP) with AF, and external funding acquisition modification. The planning tool determines the consumption of produced electricity, evaluates mutual electricity sharing activities, determines cost allocation and proposes specifically defined EnC viability and feasibility characterising indicators: NPV, AF, PEB, and CEB. The planning tool can serve as a basis to assess the economic viability of EnC not only in the context of Latvia, but also in other countries (if necessary, adapting and modifying it to the respective legislative guidelines).
- To prioritise study transparency and user empowerment, the developed prosumer-consumer EnC planning tool is freely downloadable and open-source on GitHub platform.
- To contribute to the development of guidelines for the formation of EnCs (as mentioned in Energy Law), the modelled case studies and scenarios indicate that EnC viability can be increased by selecting a dealer with the lowest electricity generation system costs, acquiring external funding and when electricity cost tariff component for the purchase of electricity from the grid is relatively high. Moreover, the feasibility of the proposed EnC is affected by the amount of bank loan and its duration, the ratio between interest and discount rates, the sharing tariff and purchase price for the excess amount of electricity, and the used initial investment allocation mechanism.

REFERENCES

[1] European Commission, Directorate-General for Energy, *Clean energy for all Europeans*, Publications Office, 2019.

[2] G. Erbach and L. Jensen, *Fit for 55 package*, EPRS, 2022.

[3] EU, *Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC),* Official Journal of the European Union, 2009.

[4] EU, *Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/*EC, Official Journal of the European Union, 2009.

[5] EU, *Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast)*, Official Journal of the European Union, 2010.

[6] European Commission, *Delivering a New Deal for Energy Consumers*, EUR-LEX, 2015.

[7] EU, *Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast),* Official Journal of the European Union, 2018.

[8] EU, *Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast)*, Official Journal of the European Union, 2019.

[9] EU, *Consolidated version of the Treaty on the Functioning of the European Union*, EUR-LEX, 2007.

[10] Ministry of Economics of the Republic of Latvia, “National Energy and Climate Plan *(in Latvian)*”, 2020. [Online]. Available: https://www.em.gov.lv/lv/nacionalais-energetikas-un-klimata-plans [Accessed: 18-Dec-2023].

[11] Saeima of Latvia, “Energy Law *(in Latvian)*”, 2024. [Online]. Available: https://likumi.lv/ta/id/49833-energetikas-likums [Accessed: 02-Jan-2024].

[12] Saeima of Latvia, “Electricity Market Law *(in Latvian)*”, 2024. [Online]. Available: https://likumi.lv/ta/id/108834-elektroenergijas-tirgus-likums [Accessed: 02-Jan-2024].

[13] Cabinet of Ministers, “Regulations of the open competition "Reduction of greenhouse gas emissions in households - support for the use of renewable energy resources" of the project financed by the emission allowance auction instrument *(in Latvian)*”, 2022. [Online]. Available: https://likumi.lv/ta/id/330568-emisijas-kvotu-izsolisanas-instrumenta-finanseto-projektu-atklata-konkursa-siltumnicefekta-gazu-emisiju-samazinasana-majsaimniecibas [Accessed: 19-Dec-2023].

[14] Sadales Tīkls, *AS “Sadales Tīkls” Annual Report 2022 (in Latvian)*, Sadales Tīkls, 2023.

[15] Public Utilities Commission, “2022 Q4 Electricity Market *(in Latvian)*”, 2023. [Online]. Available: https://prezi.com/i/k5qayucvnqoo/sprk-elektroenergijas-tirgus-2022-gada-4-ceturksnis_nozares-raditaji/ [Accessed: 20-Dec-2023].

[16] COME RES, *Assessment report of potentials for RES community energy in the target regions*, COME RES, 2021.

[17] State Chancellery, “23-TA-1661: Amendments to the Electricity Market Law *(in Latvian)*”, 2023. [Online]. Available: https://tapportals.mk.gov.lv/structuralizer/data/nodes/63d59906-6b13-4a52-8457-6344e2cebd37/preview [Accessed: 22-Dec-2023].
[18] R. Duvignau, V. Heinisch, L. Göransson, V. Gulisano and M. Papatriantafilou, “Benefits of small-size communities for continuous cost-optimization in peer-to-peer energy sharing”, *Applied Energy*, vol. 301, art. no. 117402, 2021.
[19] M.H. Bashi *et al.*, “A review and mapping exercise of energy community regulatory challenges in European member states based on a survey of collective energy actors”, *Renewable and Sustainable Energy Reviews*, vol. 172, art. no. 113055, 2023.
[20] R. Leonhardt *et al.*, “Advancing local energy transitions: A global review of government instruments supporting community energy”, *Energy Research & Social Science,* vol. 83, art. no. 102350, 2022.
[21] E. Barabino *et al.*, “Energy Communities: A review on trends, energy system modelling, business models, and optimisation objectives”, *Sustainable Energy, Grids and Networks*, vol. 36, art. no. 101187, 2023.
[22] EEA, Statista, “Distribution of greenhouse gas emissions in the European Union (EU-27) in 2021, by sector”, 2021. [Online]. Available: https://www.statista.com/statistics/1325132/ghg-emissions-shares-sector-european-union-eu/ [Accessed: 19-Dec-2023].
[23] T. Bauwens *et al.*, “Conceptualizing community in energy systems: A systematic review of 183 definitions”, *Renewable and Sustainable Energy Reviews*, vol. 156, art. no. 111999, 2022.
[24] smartEn, *Smart Energy Prosumers – Eight ways in which people and companies are leading us to a smart and decarbonised energy system*, smartEn, 2020.
[25] R. Lazdins and A. Mutule, “Operational Algorithm for Natural Gas Boiler and Heat Pump System Optimization with PV Panel”, in *2020 IEEE 61th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON)*, 2020, pp. 1-4.
[26] G. Yiasoumas, K. Psara and G. E. Georghiou, "A review of Energy Communities: Definitions, Technologies, Data Management," in *2022 2nd International Conference on Energy Transition in the Mediterranean Area (SyNERGY MED)*, 2022, pp. 1-6.
[27] M.L. Lode *et al.*, “A transition perspective on Energy Communities: A systematic literature review and research agenda”, *Renewable and Sustainable Energy Reviews*, vol. 163, art. no. 112479, 2022.
[28] A. Parreño-Rodriguez *et al.*, “Community energy solutions for addressing energy poverty: A local case study in Spain”, *Energy and Buildings*, vol. 296, art. no. 113418, 2023.
[29] I.F.G. Reis *et al.*, *Fighting energy poverty through local energy communities: Insights from Portugal*, Routledge, 2023.
[30] L. Kiamba *et al.*, “Socio-Economic Benefits in Community Energy Structures”, *Sustainability*, vol. 14, art. no. 1890, 2022.

[31] W.V. Opstal and A. Smeets, “When do circular business models resolve barriers to residential solar PV adoption? Evidence from survey data in flanders”, *Energy Policy*, vol. 182, art.no. 113761, 2023.
[32] REScoop, *A supportive EU legal framework for energy communities in energy efficiency*, REScoop, 2021.
[33] G. Bohvalovs *et al.*, “Energy Community Measures Evaluation via Differential Evolution Optimization”, *Environmental and Climate Technologies*, vol. 26, pp. 606-615, 2022.
[34] REScoop, *Bringing the energy transition home: energy communities and the EPBD?*, REScoop, 2021.
[35] R. Roberto *et al.*, “Mapping of Energy Community Development in Europe: State of the Art and Research Directions”, *Energies*, vol. 16, art. no. 6554, 2023.
[36] T. Korõtko *et al.*, “Assessment of Power System Asset Dispatch under Different Local Energy Community Business Models”, *Energies*, vol. 16, art. no. 3476, 2023.
[37] European Commission, Directorate-General for Energy, “In focus: Energy communities to transform the EU’s energy system”, 2022. [Online]. Available: https://energy.ec.europa.eu/news/focus-energy-communities-transform-eus-energy-system-2022-12-13_en [Accessed: 18-Dec-2023].
[38] REScoop, “REScoop.eu network”, 2023. [Online]. Available: https://www.rescoop.eu/network/map/ [Accessed: 18-Dec-2023].
[39] European Commission, “Energy communities map”, 2023. [Online]. Available: https://energy-communities-repository.ec.europa.eu/energy-communities-repository-energy-communities/energy-communities-repository-map_en#discover-energy-communities-across-the-eu [Accessed: 18-Dec-2023].
[40] Energy Communities Hub, “Communities”, 2023. [Online]. Available: https://energycommunitieshub.com/communities/ [Accessed: 18-Dec-2023].
[41] LECo, *PESTLE Analysis of Barriers to Community Energy Development*, Agentur für Erneuerbare Energien, 2019.
[42] COME RES, *Final Policy Report and Recommendations*, COME RES, 2023.
[43] K. Pētersone, L. Vecvagare and R. Āboltiņš, *Recommendations for development of renewable energy communities in Latvia*, Green Liberty, 2020.
[44] E. Lesničenoka, “The development of energy communities in Latvia is hindered by incompletely developed regulatory acts *(in Latvian)*”, 2023. [Online]. Available: https://ir.lv/2023/06/28/energokopienu-attistibu-latvija-kave-nepilnigi-izstradatie-normativie-akti/ [Accessed: 20-Dec-2023].
[45] S. Diedziņa, “The creation of energy communities is stuck in disorganised regulations *(in Latvian)*”, 2023. Available: https://lasi.lv/par-svarigo/projekti/energokopienu-izveide-iestregusi-nesakartotos-normativos.4500 [Accessed: 20-Dec-2023].
[46] Public Utilities Commission, “Register of merchants *(in Latvian)*”, 2023. Available: https://app.powerbi.com/view?r=eyJrIjoiYmIyYjVmYjQtZGNhOS00YzgwLThiMmEtN2IwMWU2OTUwZGRkIiwidCI6ImU0MGNhOTA5LTg3YmEtNGQ2NS05MTllLTU1YjVlMGRlODUwNSIsImMiOjh9 [Accessed: 20-Dec-2023].

[47] R. Lazdins, A. Mutule and D. Zalostiba, “PV Energy Communities—Challenges and Barriers from a Consumer Perspective: A Literature Review”, *Energies*, vol. 14, art. no. 4873, 2021.
[48] L. Petrichenko *et al.*, “A Comparative Analysis of Supporting Policies for Solar PV systems in the Baltic Countries”, in *Proceedings of the 2019 IEEE International Conference on Environment and Electrical Engineering and 2019 IEEE Industrial and Commercial Power Systems Europe*, 2019, pp. 1-7.
[49] G. Michaud, “Perspectives on community solar policy adoption across the United States”, *Renewable Energy Focus*, vol. 33, pp. 1-15, 2020.
[50] A. Mittal *et al.*, “An agent-based approach to modeling zero energy communities”, *Solar Energy*, vol. 191, pp. 193-204, 2019.
[51] A. Stauch and K. Gamma, “Cash vs. solar power: An experimental investigation of the remuneration-related design of community solar offerings”, *Energy Policy*, vol. 138, art. no. 111216, 2020.
[52] D.N.-Y. Mah, “Community solar energy initiatives in urban energy transitions: A comparative study of Foshan, China and Seoul, South Korea”, *Energy Research & Social Science*, vol. 50, pp. 129-142, 2019.
[53] R. Alvaro-Hermana *et al.*, “Shared Self-Consumption Economic Analysis for a Residential Energy Community”, in *Proceedings of the 2nd International Conference on Smart Energy Systems and Technologies*, 2019, pp. 1-6.
[54] J. Radl *et al.*, “Comparison of Profitability of PV Electricity Sharing in Renewable Energy Communities in Selected European Countries”, *Energies*, vol. 13, art. no. 5007, 2020.
[55] C. Molotsi *et al.*, “Design of a solar photovoltaic system to power the community of Riverton in Droogfontein”, in *Proceedings of the 10th International Renewable Energy Congress*, Sousse, Tunisia, 2019, pp. 1-7.
[56] I. Ibrik, “Design and Verification the Results of Electrification Small Communities in Palestine by Using Decentralized Off-Grid PV Systems”, *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, vol. 8, pp. 983-987, 2019.
[57] R. K. Yadav, V. S. Bhadoria and P. N. Hrisheekesha, “Technical and Financial Assessment of a Grid Connected Solar PV Net Metering System for Residential Community”, in *2019 2nd International Conference on Power Energy, Environment and Intelligent Control (PEEIC)*, 2019, pp. 299-303.
[58] L. Wen *et al.*, “Optimal load dispatch of community microgrid with deep learning based solar power and load forecasting”, *Energy*, vol. 171, pp. 1053-1065, 2019.
[59] C. Nolden, J. Barnes and J. Nicholls, “Community energy business model evolution: A review of solar photovoltaic developments in England”, *Renewable and Sustainable Energy Reviews*, vol. 122, art. no. 109722, 2020.
[60] A. Stauch and P. Vuichard, “Community solar as an innovative business model for building-integrated photovoltaics: An experimental analysis with Swiss electricity consumers”, *Energy and Buildings*, vol. 204, art. no. 109526, 2019.

[61] I. Jan, W. Ullah and M. Ashfaq, “Social acceptability of solar photovoltaic system in Pakistan: Key determinants and policy implications”. *Journal of Cleaner Production*, vol. 274, art. no. 123140, 2020.
[62] T. Schunder *et al.*, “A spatial analysis of the development potential of rooftop and community solar energy”, *Remote Sensing Applications: Society and Environment*, vol. 19, art. no. 100355, 2020.
[63] Green Tech Cluster, “Energy communities *(in Latvian)*”, 2022. [Online]. Available: https://greentechlatvia.eu/lv/tresa-diena-energetikas-kopienas/ [Accessed: 20-Dec-2023].
[64] World Energy Council, “Energy Trilemma”, 2023. [Online]. Available: https://trilemmaconference.worldenergycouncil.lv/en [Accessed: 20-Dec-2023].
[65] Lampa, “Discussion “Energy communities in the Baltics: How to share renewable energy?” *(in Latvian)*”, 2022. [Online]. Available: https://festivalslampa.lv/lv/programma/pasakumi/1887 [Accessed: 20-Dec-2023].
[66] Latvian Rural Forum “Energy communities *(in Latvian)*”, 2023. Available: https://laukuforums.lv/lv/archives/tag/Energokopienas [Accessed: 21-Dec-2023].
[67] European Commission, *Digital Tools for Energy Communities*, Energy Communities Repository, 2023.
[68] R. Lazdins, A. Mutule and E. Kairisa, “Feasibilty Study in Energy Community Business Model Development for Latvia”, in *2021 IEEE 62nd International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON)*, 2021, pp. 1-5.
[69] R. Denysiuk *et al.*, “Multiagent System for Community Energy Management,” in *Proceedings of the 12th International Conference on Agents and Artificial Intelligence*, 2020, pp. 28-39.
[70] I.F.G Reis *et al.*, “A multi-agent system approach to exploit demand-side flexibility in an energy community”, *Utilities Policy*, vol. 67, art. no. 101114, 2020.
[71] I.F.G Reis *et al.*, “Business models for energy communities: A review of key issues and trends”, *Renewable and Sustainable Energy Reviews*, vol. 144, art. no. 111013, 2021.
[72] E. Caramizaru and A. Uihlein, *Energy Communities: An Overview of Energy and Social Innovation*, Publications Office of the European Union, 2020.
[73] REScoop, “REScoop.eu is the European federation of citizen energy cooperatives”, 2023. [Online]. Available: https://www.rescoop.eu/ [Accessed: 19-Dec-2023].
[74] D. Brown, S. Hall and M.E. Davis, “Prosumers in the post subsidy era: an exploration of new prosumer business models in the UK”, *Energy Policy*, vol. 135, art. no. 110984, 2019.
[75] Public Utilities Commission, *Annual Report 2022 (in Latvian)*, Public Utilities Commission, 2023.
[76] R. Lazdins and A. Mutule, “Assessment of Various Factors Affecting Economic Indicators in Prosumer and Consumer Energy Communities: A Case Study in Latvia”, *Latvian Journal of Physics and Technical Sciences*, 2024.
[77] R. Lazdins and A. Mutule, “Scenario simulation of a small-scale energy community management”, in *2022 IEEE 63th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON)*, 2022, pp. 1-5.

[78] Sadales Tīkls, “Connecting the microgenerator *(in Latvian)*”, 2023. [Online]. Available: https://sadalestikls.lv/lv/mikrogeneratora-pieslegsana [Accessed: 22-Dec-2023].
[79] E. Barbour and M.C. González, “Projecting battery adoption in the prosumer era”, *Applied Energy*, vol. 215, pp. 356-370, 2018.
[80] R. Lazdins and A. Mutule, “Impact of Variable Factors on the Viability and Efficiency of Energy Communities: A Scenario Simulation Study in Latvia”, in *2023 IEEE 64th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON)*, 2023, pp. 1-5.
[81] Sadales Tīkls, “Tariffs for distribution system services *(in Latvian)*”, 2023. [Online]. Available: https://sadalestikls.lv/en/tarifi [Accessed: 22-Dec-2023].
[82] EKII, “Support for households *(in Latvian)*”, 2023. [Online]. Available: https://ekii.lv/index.php?page=atbalsts-majsaimniecibam [Accessed: 22-Dec-2023].
[83] R. Lazdins, “GitHub: EnC planning tool”, 2024. [Online]. Available: https://github.com/RobertsLazdins/EnC-planning-tool [Accessed: 15-Feb-2024].
[84] EU, *Regulation (EU) 2018/1725 of the European Parliament and of the Council of 23 October 2018 on the protection of natural persons with regard to the processing of personal data by the Union institutions, bodies, offices and agencies and on the free movement of such data, and repealing Regulation (EC) No 45/2001 and Decision No 1247/2002/EC*, Official Journal of the European Union, 2018.
[85] Elektrum, “Elektroenerģijas tirgus atvēršana mājsaimniecībām *(in Latvian)*”, 2016. [Online]. Available: https://www.slideshare.net/Elektrumlv/elektroenerijas-tirgus-atvrana-mjsaimniecbm [Accessed: 26-Dec-2023].
[86] Sadales Tīkls, “Typical load distribution schedule *(in Latvian)*”, 2023. [Online]. Available: https://sadalestikls.lv/lv/tipveida-slodzu-sadalijuma-grafiks [Accessed: 26-Dec-2023].
[87] Sadales Tīkls, “The number of self-producing electricity households in Latvia reaches 10,000”, 2022. [Online]. Available: https://sadalestikls.lv/en/preses-relizes/number-self-producing-electricity-households-latvia-reaches-10000 [Accessed: 26-Dec-2023].
[88] Renewables.ninja, “Downloads”, 2016. [Online]. Available: https://www.renewables.ninja/ [Accessed: 26-Dec-2023].
[89] S. Pfenninger and I. Staffell, “Long-term patterns of European PV output using 30 years of validated hourly reanalysis and satellite data”, *Energy*, vol. 114, pp. 1251-1265, 2016.
[90] Sadales Tīkls, *AS "Sadales tīkls" differentiated tariffs for electricity distribution system services (in Latvian)*, Sadales Tīkls, 2023.
[91] Public Utilities Commission, “2023 Q3 Electricity market *(in Latvian)*”, 2023. [Online]. Available: https://infogram.com/sprk-elektroenergijas-tirgus-2023-gada-3-ceturksnis_nozares-raditaji-1hnq4107o8w1p23?live [Accessed: 27-Dec-2023].
[92] elektroenergija.lv, “Detailed 2024 Electricity tariff comparison for households in Latvia”, 2024. [Online]. Available: https://www.elektroenergija.lv/lv/detalizeti/?p=1f16&b=0&kwh=100 [Accessed: 02-Jan-2024].

[93] Swedbank, “Loan for solar panels”, 2024. [Online]. Available: https://www.swedbank.lv/private/credit/loans/solar [Accessed: 29-Dec-2023].
[94] State Treasury, “Discount rates *(in Latvian)*”, 2023. Available: https://www.kase.gov.lv/metodika/diskonta-likmes [Accessed: 29-Dec-2023].
[95] Saeima, “Value Added Tax Law”, 2023. Available: https://likumi.lv/ta/id/253451-pievienotas-vertibas-nodokla-likums [Accessed: 29-Dec-2023].

ANNEXES

Annex 1

Results of case study and scenario modelling under baseline EnC No.1

Table A1.1. Modelling results of baseline EnC No.1

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1	NPV	-829,3	-830,7	-834,6	-839,4	-845,3	-726,8	-605,9	-510,5	-403,9	-320,3	-254,1	-194,3	-133,6	-78,3	-36,8	17,2	50,5	86,0	122,0	152,0
	PEB	4,1	8,0	12,3	16,4	20,3	24,3	28,6	32,7	37,0	41,5	45,4	49,3	53,7	58,1	61,9	66,5	70,3	74,0	78,1	82,3
	CEB	5,0	9,7	14,9	19,8	24,6	29,4	34,7	39,6	44,8	50,2	55,0	59,7	65,0	70,3	74,9	80,5	85,0	89,6	94,5	99,6
	AF	0,0	0,0	0,0	0,0	0,0	46,9	91,2	138,3	179,0	221,6	257,5	286,7	332,1	367,5	397,6	441,7	468,1	491,1	525,0	560,3

Table A1.2. Modelling results of baseline EnC No.1 under Case Study I

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SC1	NPV	-844,91	-859,40	-876,55	-892,07	-908,47	-801,46	-689,95	-604,05	-504,71	-427,84	-367,39	-312,10	-256,86	-205,54	-167,64	-117,40	-86,77	-53,54	-20,12	7,59
	PEB	14,33	28,16	43,20	57,24	71,22	85,09	100,26	114,43	129,62	145,10	159,05	172,59	188,08	203,23	216,57	232,79	245,99	259,15	273,31	287,96
	CEB	4,95	9,74	14,94	19,79	24,62	29,42	34,66	39,56	44,81	50,16	54,99	59,67	65,02	70,26	74,87	80,48	85,04	89,59	94,49	99,55
	AF	0,00	0,00	0,00	0,00	0,00	26,53	52,52	79,47	103,13	128,26	147,84	162,72	189,66	209,89	225,19	251,87	264,72	275,38	293,82	313,55
SC2	NPV	-823,06	-819,16	-817,88	-818,33	-820,07	-696,97	-572,24	-473,13	-363,64	-277,29	-208,79	-147,12	-84,35	-27,40	15,47	71,04	105,45	141,82	178,81	209,77
	PEB	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	CEB	4,95	9,74	14,94	19,79	24,62	29,42	34,66	39,56	44,81	50,16	54,99	59,67	65,02	70,26	74,87	80,48	85,04	89,59	94,49	99,55
	AF	0,00	0,00	0,00	0,00	0,00	54,99	106,67	161,84	209,36	258,97	301,43	336,27	389,08	430,58	466,52	517,56	549,41	577,43	617,48	658,98
SC3	NPV	-816,82	-807,66	-801,11	-797,26	-794,81	-667,11	-538,61	-435,73	-323,33	-234,28	-163,48	-99,98	-35,06	23,49	67,78	124,88	160,37	197,64	235,64	267,54
	PEB	-4,09	-8,05	-12,34	-16,35	-20,35	-24,31	-28,65	-32,69	-37,03	-41,46	-45,44	-49,31	-53,74	-58,07	-61,88	-66,51	-70,28	-74,04	-78,09	-82,27
	CEB	4,95	9,74	14,94	19,79	24,62	29,42	34,66	39,56	44,81	50,16	54,99	59,67	65,02	70,26	74,87	80,48	85,04	89,59	94,49	99,55
	AF	0,00	0,00	0,00	0,00	0,00	63,11	122,13	185,38	239,71	296,32	345,31	385,85	446,05	493,63	535,47	593,48	630,75	663,72	709,95	757,68
SC4	NPV	-824,80	-822,19	-822,27	-823,71	-826,63	-705,41	-581,76	-484,14	-375,31	-289,60	-221,70	-160,35	-98,18	-41,45	1,10	56,38	90,62	126,92	163,69	194,48
	PEB	8,19	16,09	24,69	32,71	40,70	48,62	57,29	65,39	74,07	82,91	90,89	98,62	107,48	116,13	123,75	133,02	140,56	148,08	156,18	164,55
	CEB	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	AF	0,00	0,00	0,00	0,00	0,00	50,82	99,49	150,65	195,69	242,73	282,64	315,64	365,49	405,24	439,09	487,81	518,00	544,82	582,75	622,21
SC5	NPV	-820,30	-813,73	-809,90	-808,02	-807,93	-684,00	-557,66	-457,74	-346,67	-258,90	-189,30	-126,45	-62,72	-4,61	39,06	95,56	130,71	167,83	205,41	236,96
	PEB	12,28	24,14	37,03	49,06	61,05	72,93	85,94	98,08	111,10	124,37	136,33	147,94	161,21	174,20	185,63	199,53	210,84	222,13	234,27	246,82
	CEB	-4,95	-9,74	-14,94	-19,79	-24,62	-29,42	-34,66	-39,56	-44,81	-50,16	-54,99	-59,67	-65,02	-70,26	-74,87	-80,48	-85,04	-89,59	-94,49	-99,55
	AF	0,00	0,00	0,00	0,00	0,00	54,78	107,79	162,99	212,38	263,84	307,73	344,61	398,88	442,96	480,62	533,97	567,93	598,51	640,49	684,14

Table A1.3. Modelling results of baseline EnC No.1 under Case Study II

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SC1	NPV	-886,42	-939,08	-988,94	-1035,79	-1079,76	-995,75	-907,46	-840,39	-761,59	-701,91	-656,83	-616,36	-573,51	-534,56	-507,34	-467,42	-445,87	-421,60	-396,00	-375,13
	PEB	4,09	8,05	12,34	16,35	20,35	24,31	28,65	32,69	37,03	41,46	45,44	49,31	53,74	58,07	61,88	66,51	70,28	74,04	78,09	82,27
	CEB	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	AF	0,00	0,00	0,00	0,00	0,00	46,86	91,20	138,30	179,01	221,62	257,55	286,68	332,10	367,53	397,57	441,65	468,07	491,13	525,01	560,29
SC2	NPV	-772,18	-722,23	-680,35	-643,01	-610,89	-457,89	-304,29	-180,69	-46,29	61,30	148,62	227,85	306,23	377,96	433,64	501,82	546,93	593,62	639,95	679,14
	PEB	4,09	8,05	12,34	16,35	20,35	24,31	28,65	32,69	37,03	41,46	45,44	49,31	53,74	58,07	61,88	66,51	70,28	74,04	78,09	82,27
	CEB	9,90	19,47	29,87	39,58	49,25	58,83	69,33	79,12	89,62	100,32	109,97	119,33	130,05	140,52	149,74	160,96	170,08	179,18	188,98	199,10
	AF	0,00	0,00	0,00	0,00	0,00	46,86	91,20	138,30	179,01	221,62	257,55	286,68	332,10	367,53	397,57	441,65	468,07	491,13	525,01	560,29

Table A1.4. Modelling results of baseline EnC No.1 under Case Study III

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SC1	NPV	-110,20	19,17	134,06	237,42	329,82	456,13	584,19	685,98	798,45	887,43	958,49	1022,76	1087,40	1146,39	1191,16	1248,24	1284,32	1322,29	1360,53	1392,63
	PEB	4,09	8,05	12,34	16,35	20,35	24,31	28,65	32,69	37,03	41,46	45,44	49,31	53,74	58,07	61,88	66,51	70,28	74,04	78,09	82,27
	CEB	4,95	9,74	14,94	19,79	24,62	29,42	34,66	39,56	44,81	50,16	54,99	59,67	65,02	70,26	74,87	80,48	85,04	89,59	94,49	99,55
	AF	0,00	0,00	0,00	0,00	0,00	60,66	118,81	179,73	234,24	290,67	340,40	383,34	442,57	491,80	535,65	593,54	633,77	670,64	718,33	767,42
SC2	NPV	-1893,21	-2087,96	-2267,84	-2432,55	-2583,95	-2477,00	-2366,56	-2280,78	-2182,88	-2107,15	-2048,14	-1994,82	-1940,16	-1890,22	-1853,69	-1804,11	-1774,85	-1743,07	-1710,47	-1683,50
	PEB	4,09	8,05	12,34	16,35	20,35	24,31	28,65	32,69	37,03	41,46	45,44	49,31	53,74	58,07	61,88	66,51	70,28	74,04	78,09	82,27
	CEB	4,95	9,74	14,94	19,79	24,62	29,42	34,66	39,56	44,81	50,16	54,99	59,67	65,02	70,26	74,87	80,48	85,04	89,59	94,49	99,55
	AF	0,00	0,00	0,00	0,00	0,00	26,43	50,34	77,02	97,29	119,48	134,97	143,67	168,66	183,66	193,27	216,92	222,92	225,54	238,99	253,84

Table A1.5. Modelling results of baseline EnC No.1 under Case Study IV

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SC1	NPV	-939,70	-1041,45	-1136,75	-997,66	-872,77	-754,27	-633,32	-537,98	-431,39	-347,75	-281,55	-221,70	-161,09	-105,75	-64,30	-10,25	23,08	58,56	94,53	124,56
	PEB	4,09	8,05	12,34	16,35	20,35	24,31	28,65	32,69	37,03	41,46	45,44	49,31	53,74	58,07	61,88	66,51	70,28	74,04	78,09	82,27
	CEB	4,95	9,74	14,94	19,79	24,62	29,42	34,66	39,56	44,81	50,16	54,99	59,67	65,02	70,26	74,87	80,48	85,04	89,59	94,49	99,55
	AF	0,00	0,00	0,00	34,40	71,76	118,61	162,95	210,06	250,77	293,38	329,30	358,44	403,86	439,28	469,32	513,41	539,83	562,88	596,76	632,04
SC2	NPV	-782,25	-740,80	-705,87	-675,24	-648,98	-620,17	-580,79	-485,46	-378,86	-295,22	-229,02	-169,17	-108,56	-53,22	-11,77	42,28	75,61	111,09	147,05	177,09
	PEB	4,09	8,05	12,34	16,35	20,35	24,31	28,65	32,69	37,03	41,46	45,44	49,31	53,74	58,07	61,88	66,51	70,28	74,04	78,09	82,27
	CEB	4,95	9,74	14,94	19,79	24,62	29,42	34,66	39,56	44,81	50,16	54,99	59,67	65,02	70,26	74,87	80,48	85,04	89,59	94,49	99,55
	AF	0,00	0,00	0,00	0,00	0,00	0,00	0,00	47,11	87,81	130,43	166,35	195,48	240,90	276,33	306,37	350,45	376,87	399,93	433,81	469,09

Table A1.6. Modelling results of baseline EnC No.1 under Case Study V

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SC1	NPV	-1013,51	-1045,96	-1078,23	-1108,72	-1138,04	-1019,53	-898,58	-803,25	-696,65	-613,02	-546,81	-486,96	-426,35	-371,01	-329,56	-275,51	-242,18	-206,70	-170,74	-140,71
	PEB	4,09	8,05	12,34	16,35	20,35	24,31	28,65	32,69	37,03	41,46	45,44	49,31	53,74	58,07	61,88	66,51	70,28	74,04	78,09	82,27
	CEB	4,95	9,74	14,94	19,79	24,62	29,42	34,66	39,56	44,81	50,16	54,99	59,67	65,02	70,26	74,87	80,48	85,04	89,59	94,49	99,55
	AF	0,00	0,00	0,00	0,00	0,00	46,86	91,20	138,30	179,01	221,62	257,55	286,68	332,10	367,53	397,57	441,65	468,07	491,13	525,01	560,29
SC2	NPV	-645,10	-615,35	-591,05	-570,09	-552,62	-434,11	-313,16	-217,83	-111,23	-27,60	38,60	98,46	159,07	214,41	255,86	309,91	343,24	378,71	414,68	444,71
	PEB	4,09	8,05	12,34	16,35	20,35	24,31	28,65	32,69	37,03	41,46	45,44	49,31	53,74	58,07	61,88	66,51	70,28	74,04	78,09	82,27
	CEB	4,95	9,74	14,94	19,79	24,62	29,42	34,66	39,56	44,81	50,16	54,99	59,67	65,02	70,26	74,87	80,48	85,04	89,59	94,49	99,55
	AF	0,00	0,00	0,00	0,00	0,00	46,86	91,20	138,30	179,01	221,62	257,55	286,68	332,10	367,53	397,57	441,65	468,07	491,13	525,01	560,29
SC3	NPV	-1934,51	-2122,48	-2296,19	-2455,29	-2601,58	-2483,08	-2362,13	-2266,79	-2160,20	-2076,56	-2010,36	-1950,51	-1889,90	-1834,56	-1793,11	-1739,06	-1705,72	-1670,25	-1634,28	-1604,25
	PEB	4,09	8,05	12,34	16,35	20,35	24,31	28,65	32,69	37,03	41,46	45,44	49,31	53,74	58,07	61,88	66,51	70,28	74,04	78,09	82,27
	CEB	4,95	9,74	14,94	19,79	24,62	29,42	34,66	39,56	44,81	50,16	54,99	59,67	65,02	70,26	74,87	80,48	85,04	89,59	94,49	99,55
	AF	0,00	0,00	0,00	0,00	0,00	46,86	91,20	138,30	179,01	221,62	257,55	286,68	332,10	367,53	397,57	441,65	468,07	491,13	525,01	560,29

Table A1.7. Modelling results of baseline EnC No.1 under Case Study VI

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SC1	NPV	-1476,83	-1304,25	-1150,07	-1010,98	-886,09	-767,59	-646,64	-551,31	-444,71	-361,07	-294,87	-235,02	-174,41	-119,07	-77,62	-23,57	9,76	45,24	81,20	111,24
	PEB	4,09	8,05	12,34	16,35	20,35	24,31	28,65	32,69	37,03	41,46	45,44	49,31	53,74	58,07	61,88	66,51	70,28	74,04	78,09	82,27
	CEB	4,95	9,74	14,94	19,79	24,62	29,42	34,66	39,56	44,81	50,16	54,99	59,67	65,02	70,26	74,87	80,48	85,04	89,59	94,49	99,55
	AF	39,07	73,43	114,14	148,55	185,90	232,76	277,10	324,20	364,91	407,52	443,45	472,58	518,00	553,43	583,47	627,55	653,97	677,03	710,91	746,19
SC2	NPV	-181,78	-357,06	-519,22	-667,82	-804,56	-686,05	-565,11	-469,77	-363,17	-279,54	-213,34	-153,49	-92,87	-37,53	3,92	57,97	91,30	126,77	162,74	192,77
	PEB	4,09	8,05	12,34	16,35	20,35	24,31	28,65	32,69	37,03	41,46	45,44	49,31	53,74	58,07	61,88	66,51	70,28	74,04	78,09	82,27
	CEB	4,95	9,74	14,94	19,79	24,62	29,42	34,66	39,56	44,81	50,16	54,99	59,67	65,02	70,26	74,87	80,48	85,04	89,59	94,49	99,55
	AF	0,00	0,00	0,00	0,00	0,00	46,86	91,20	138,30	179,01	221,62	257,55	286,68	332,10	367,53	397,57	441,65	468,07	491,13	525,01	560,29
SC3	NPV	-810,18	-794,14	-782,31	-772,68	-765,53	-647,02	-526,07	-430,74	-324,14	-240,51	-174,31	-114,45	-53,84	1,50	42,95	97,00	130,33	165,81	201,77	231,80
	PEB	87,97	91,92	96,22	100,23	104,23	108,19	112,52	116,57	120,91	125,33	129,32	133,19	137,62	141,94	145,75	150,39	154,16	157,92	161,97	166,15
	CEB	-78,92	-74,14	-68,94	-64,09	-59,25	-54,46	-49,21	-44,32	-39,07	-33,71	-28,89	-24,21	-18,85	-13,62	-9,01	-3,40	1,16	5,71	10,61	15,67
	AF	0,00	0,00	0,00	0,00	0,00	46,86	91,20	138,30	179,01	221,62	257,55	286,68	332,10	367,53	397,57	441,65	468,07	491,13	525,01	560,29
SC4	NPV	-638,06	-465,48	-311,30	-172,21	-47,32	71,18	192,13	287,46	394,06	477,70	543,90	603,75	664,36	719,70	761,15	815,20	848,53	884,01	919,97	950,01
	PEB	842,86	846,82	851,11	855,12	859,12	863,08	867,42	871,46	875,80	880,23	884,21	888,08	892,51	896,84	900,65	905,28	909,05	912,81	916,86	921,04
	CEB	-833,82	-829,03	-823,83	-818,98	-814,15	-809,35	-804,11	-799,21	-793,96	-788,61	-783,78	-779,10	-773,75	-768,51	-763,90	-758,29	-753,73	-749,18	-744,28	-739,22
	AF	39,07	73,43	114,14	148,55	185,90	232,76	277,10	324,20	364,91	407,52	443,45	472,58	518,00	553,43	583,47	627,55	653,97	677,03	710,91	746,19

Results of case study and scenario modelling under baseline EnC No.2

Table A2.1. Modelling results of baseline EnC No.2

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Bāze	NPV	-823,99	-820,67	-820,05	-821,05	-823,43	-701,50	-577,34	-479,05	-369,92	-283,86	-215,65	-154,10	-91,64	-34,76	7,99	63,47	97,88	134,25	171,15	202,04
	PEB	6,27	12,33	18,92	24,98	31,10	37,32	43,99	50,39	56,95	63,72	69,83	75,67	82,47	88,97	94,80	101,86	107,66	113,26	119,43	125,76
	CEB	7,59	14,92	22,89	30,22	37,63	45,15	53,22	60,97	68,91	77,10	84,49	91,56	99,79	107,65	114,70	123,26	130,27	137,05	144,51	152,17
	AF	0,00	0,00	0,00	0,00	0,00	49,11	95,78	145,25	188,18	233,13	271,18	302,29	350,08	387,68	419,73	466,25	494,70	519,59	555,59	593,02

Table A2.2. Modelling results of baseline EnC No.2 under Case Study I

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SC1	NPV	-834,64	-840,10	-848,35	-856,61	-866,14	-752,53	-634,80	-543,19	-438,94	-357,38	-293,06	-234,50	-175,68	-121,39	-80,97	-27,97	4,75	39,70	74,94	104,30
	PEB	21,96	43,17	66,21	87,41	108,86	130,61	153,95	176,36	199,34	223,00	244,40	264,85	288,65	311,40	331,79	356,53	376,83	396,42	418,00	440,16
	CEB	7,59	14,92	22,89	30,22	37,63	45,15	53,22	60,97	68,91	77,10	84,49	91,56	99,79	107,65	114,70	123,26	130,27	137,05	144,51	152,17
	AF	0,00	0,00	0,00	0,00	0,00	34,42	68,58	103,77	135,22	168,53	195,56	217,35	252,60	280,43	302,78	337,97	357,93	375,02	400,88	428,12
SC2	NPV	-819,73	-812,90	-808,73	-806,83	-806,34	-681,10	-554,36	-453,39	-342,31	-254,44	-184,69	-121,95	-58,02	-0,11	43,58	100,04	135,13	172,06	209,63	241,14
	PEB	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	CEB	7,59	14,92	22,89	30,22	37,63	45,15	53,22	60,97	68,91	77,10	84,49	91,56	99,79	107,65	114,70	123,26	130,27	137,05	144,51	152,17
	AF	0,00	0,00	0,00	0,00	0,00	54,99	106,67	161,84	209,36	258,97	301,43	336,27	389,08	430,58	466,52	517,56	549,41	577,43	617,48	658,98
SC3	NPV	-815,47	-805,13	-797,41	-792,61	-789,26	-660,69	-531,37	-427,74	-314,70	-225,03	-153,72	-89,79	-24,41	34,54	79,16	136,62	172,39	209,88	248,12	280,23
	PEB	-6,27	-12,33	-18,92	-24,98	-31,10	-37,32	-43,99	-50,39	-56,95	-63,72	-69,83	-75,67	-82,47	-88,97	-94,80	-101,86	-107,66	-113,26	-119,43	-125,76
	CEB	7,59	14,92	22,89	30,22	37,63	45,15	53,22	60,97	68,91	77,10	84,49	91,56	99,79	107,65	114,70	123,26	130,27	137,05	144,51	152,17
	AF	0,00	0,00	0,00	0,00	0,00	60,86	117,55	178,43	230,55	284,81	331,68	370,24	428,07	473,48	513,30	568,88	604,12	635,26	679,37	724,94
SC4	NPV	-817,09	-807,70	-801,09	-797,08	-794,84	-668,67	-540,35	-438,44	-325,92	-236,69	-165,89	-102,08	-37,22	21,74	66,19	123,54	159,35	196,94	235,07	267,11
	PEB	12,55	24,67	37,83	49,95	62,20	74,63	87,97	100,78	113,91	127,43	139,66	151,35	164,94	177,94	189,59	203,73	215,33	226,52	238,86	251,52
	CEB	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	AF	0,00	0,00	0,00	0,00	0,00	55,33	108,67	164,54	214,03	265,74	309,91	346,86	401,45	445,55	483,43	537,01	571,26	601,75	643,92	687,68
SC5	NPV	-810,19	-794,73	-782,13	-773,11	-766,26	-635,83	-503,36	-397,82	-281,93	-189,53	-116,12	-50,05	17,20	78,25	124,39	183,61	220,82	259,64	299,00	332,18
	PEB	18,82	37,00	56,75	74,93	93,31	111,95	131,96	151,17	170,86	191,15	209,49	227,02	247,42	266,91	284,39	305,59	322,99	339,79	358,29	377,28
	CEB	-7,59	-14,92	-22,89	-30,22	-37,63	-45,15	-53,22	-60,97	-68,91	-77,10	-84,49	-91,56	-99,79	-107,65	-114,70	-123,26	-130,27	-137,05	-144,51	-152,17
	AF	0,00	0,00	0,00	0,00	0,00	61,54	121,55	183,82	239,88	298,36	348,63	391,43	452,82	503,42	547,12	607,78	647,83	683,91	732,25	782,34

Table A2.3. Modelling results of baseline EnC No.2 under Case Study II

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SC1	NPV	-881,11	-929,10	-974,35	-1017,44	-1057,87	-970,44	-878,93	-808,90	-727,57	-665,46	-618,37	-576,21	-531,51	-491,02	-462,50	-421,15	-398,52	-373,36	-346,83	-325,09
	PEB	6,27	12,33	18,92	24,98	31,10	37,32	43,99	50,39	56,95	63,72	69,83	75,67	82,47	88,97	94,80	101,86	107,66	113,26	119,43	125,76
	CEB	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	AF	0,00	0,00	0,00	0,00	0,00	49,11	95,78	145,25	188,18	233,13	271,18	302,29	350,08	387,68	419,73	466,25	494,70	519,59	555,59	593,02
SC2	NPV	-766,87	-712,24	-665,75	-624,66	-588,99	-432,57	-275,75	-149,20	-12,26	97,75	187,07	268,00	348,23	421,50	478,48	548,09	594,28	641,86	689,12	729,18
	PEB	6,27	12,33	18,92	24,98	31,10	37,32	43,99	50,39	56,95	63,72	69,83	75,67	82,47	88,97	94,80	101,86	107,66	113,26	119,43	125,76
	CEB	15,18	29,85	45,78	60,44	75,27	90,31	106,45	121,94	137,83	154,19	168,99	183,13	199,58	215,31	229,41	246,51	260,55	274,09	289,02	304,34
	AF	0,00	0,00	0,00	0,00	0,00	49,11	95,78	145,25	188,18	233,13	271,18	302,29	350,08	387,68	419,73	466,25	494,70	519,59	555,59	593,02

Table A2.4. Modelling results of baseline EnC No.2 under Case Study III

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SC1	NPV	-104,89	29,16	148,66	255,77	351,72	481,45	612,72	717,47	832,48	923,88	996,95	1062,91	1129,40	1189,93	1236,00	1294,50	1331,67	1370,53	1409,71	1442,67
	PEB	6,27	12,33	18,92	24,98	31,10	37,32	43,99	50,39	56,95	63,72	69,83	75,67	82,47	88,97	94,80	101,86	107,66	113,26	119,43	125,76
	CEB	7,59	14,92	22,89	30,22	37,63	45,15	53,22	60,97	68,91	77,10	84,49	91,56	99,79	107,65	114,70	123,26	130,27	137,05	144,51	152,17
	AF	0,00	0,00	0,00	0,00	0,00	62,92	123,40	186,67	243,41	302,17	354,03	398,95	460,55	511,96	557,82	618,15	660,40	699,11	748,91	800,15
SC2	NPV	-1887,89	-2077,98	-2253,25	-2414,21	-2562,05	-2451,68	-2338,03	-2249,30	-2148,86	-2070,70	-2009,68	-1954,67	-1898,16	-1846,68	-1808,85	-1757,85	-1727,50	-1694,83	-1661,29	-1633,46
	PEB	6,27	12,33	18,92	24,98	31,10	37,32	43,99	50,39	56,95	63,72	69,83	75,67	82,47	88,97	94,80	101,86	107,66	113,26	119,43	125,76
	CEB	7,59	14,92	22,89	30,22	37,63	45,15	53,22	60,97	68,91	77,10	84,49	91,56	99,79	107,65	114,70	123,26	130,27	137,05	144,51	152,17
	AF	0,00	0,00	0,00	0,00	0,00	28,68	54,92	83,96	106,46	130,98	148,60	159,28	186,65	203,81	215,44	241,53	249,55	254,01	269,58	286,58

Table A2.5. Modelling results of baseline EnC No.2 under Case Study IV

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SC1	NPV	-934,39	-1031,47	-1122,16	-979,31	-850,87	-728,95	-604,79	-506,50	-397,36	-311,30	-243,10	-181,55	-119,09	-62,21	-19,46	36,02	70,43	106,80	143,70	174,60
	PEB	6,27	12,33	18,92	24,98	31,10	37,32	43,99	50,39	56,95	63,72	69,83	75,67	82,47	88,97	94,80	101,86	107,66	113,26	119,43	125,76
	CEB	7,59	14,92	22,89	30,22	37,63	45,15	53,22	60,97	68,91	77,10	84,49	91,56	99,79	107,65	114,70	123,26	130,27	137,05	144,51	152,17
	AF	0,00	0,00	0,00	36,45	75,93	125,05	171,72	221,18	264,11	309,07	347,11	378,22	426,02	463,61	495,67	542,19	570,64	595,53	631,53	668,96
SC2	NPV	-776,93	-730,82	-691,28	-656,89	-627,08	-594,85	-552,26	-453,97	-344,84	-258,77	-190,57	-129,02	-66,56	-9,68	33,07	88,55	122,96	159,33	196,23	227,12
	PEB	6,27	12,33	18,92	24,98	31,10	37,32	43,99	50,39	56,95	63,72	69,83	75,67	82,47	88,97	94,80	101,86	107,66	113,26	119,43	125,76
	CEB	7,59	14,92	22,89	30,22	37,63	45,15	53,22	60,97	68,91	77,10	84,49	91,56	99,79	107,65	114,70	123,26	130,27	137,05	144,51	152,17
	AF	0,00	0,00	0,00	0,00	0,00	0,00	0,00	49,46	92,39	137,35	175,39	206,51	254,30	291,90	323,95	370,47	398,92	423,81	459,81	497,24

Table A2.6. Modelling results of baseline EnC No.2 under Case Study V

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SC1	NPV	-1008,19	-1035,97	-1063,64	-1090,37	-1116,14	-994,21	-870,05	-771,76	-662,63	-576,57	-508,36	-446,81	-384,35	-327,47	-284,72	-229,24	-194,83	-158,46	-121,56	-90,67
	PEB	6,27	12,33	18,92	24,98	31,10	37,32	43,99	50,39	56,95	63,72	69,83	75,67	82,47	88,97	94,80	101,86	107,66	113,26	119,43	125,76
	CEB	7,59	14,92	22,89	30,22	37,63	45,15	53,22	60,97	68,91	77,10	84,49	91,56	99,79	107,65	114,70	123,26	130,27	137,05	144,51	152,17
	AF	0,00	0,00	0,00	0,00	0,00	49,11	95,78	145,25	188,18	233,13	271,18	302,29	350,08	387,68	419,73	466,25	494,70	519,59	555,59	593,02
SC2	NPV	-639,79	-605,36	-576,46	-551,74	-530,72	-408,80	-284,63	-186,34	-77,21	8,85	77,06	138,60	201,07	257,95	300,70	356,18	390,59	426,96	463,86	494,75
	PEB	6,27	12,33	18,92	24,98	31,10	37,32	43,99	50,39	56,95	63,72	69,83	75,67	82,47	88,97	94,80	101,86	107,66	113,26	119,43	125,76
	CEB	7,59	14,92	22,89	30,22	37,63	45,15	53,22	60,97	68,91	77,10	84,49	91,56	99,79	107,65	114,70	123,26	130,27	137,05	144,51	152,17
	AF	0,00	0,00	0,00	0,00	0,00	49,11	95,78	145,25	188,18	233,13	271,18	302,29	350,08	387,68	419,73	466,25	494,70	519,59	555,59	593,02
SC3	NPV	-1929,20	-2112,50	-2281,60	-2436,94	-2579,68	-2457,76	-2333,60	-2235,31	-2126,17	-2040,11	-1971,91	-1910,36	-1847,90	-1791,02	-1748,27	-1692,79	-1658,37	-1622,01	-1585,11	-1554,21
	PEB	6,27	12,33	18,92	24,98	31,10	37,32	43,99	50,39	56,95	63,72	69,83	75,67	82,47	88,97	94,80	101,86	107,66	113,26	119,43	125,76
	CEB	7,59	14,92	22,89	30,22	37,63	45,15	53,22	60,97	68,91	77,10	84,49	91,56	99,79	107,65	114,70	123,26	130,27	137,05	144,51	152,17
	AF	0,00	0,00	0,00	0,00	0,00	49,11	95,78	145,25	188,18	233,13	271,18	302,29	350,08	387,68	419,73	466,25	494,70	519,59	555,59	593,02

Table A2.7. Modelling results of baseline EnC No.2 under Case Study VI

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SC1	NPV	-1471,51	-1294,27	-1135,48	-992,64	-864,20	-742,27	-618,11	-519,82	-410,69	-324,62	-256,42	-194,87	-132,41	-75,53	-32,78	22,70	57,11	93,48	130,38	161,27
	PEB	6,27	12,33	18,92	24,98	31,10	37,32	43,99	50,39	56,95	63,72	69,83	75,67	82,47	88,97	94,80	101,86	107,66	113,26	119,43	125,76
	CEB	7,59	14,92	22,89	30,22	37,63	45,15	53,22	60,97	68,91	77,10	84,49	91,56	99,79	107,65	114,70	123,26	130,27	137,05	144,51	152,17
	AF	41,25	77,72	121,46	157,91	197,39	246,50	293,18	342,64	385,57	430,52	468,57	499,68	547,47	585,07	617,13	663,64	692,09	716,99	752,99	790,41
SC2	NPV	-176,47	-347,07	-504,62	-649,47	-782,66	-660,74	-536,57	-438,28	-329,15	-243,09	-174,88	-113,34	-50,87	6,01	48,76	104,24	138,65	175,02	211,92	242,81
	PEB	6,27	12,33	18,92	24,98	31,10	37,32	43,99	50,39	56,95	63,72	69,83	75,67	82,47	88,97	94,80	101,86	107,66	113,26	119,43	125,76
	CEB	7,59	14,92	22,89	30,22	37,63	45,15	53,22	60,97	68,91	77,10	84,49	91,56	99,79	107,65	114,70	123,26	130,27	137,05	144,51	152,17
	AF	0,00	0,00	0,00	0,00	0,00	49,11	95,78	145,25	188,18	233,13	271,18	302,29	350,08	387,68	419,73	466,25	494,70	519,59	555,59	593,02
SC3	NPV	-804,87	-784,15	-767,72	-754,33	-743,63	-621,70	-497,54	-399,25	-290,12	-204,06	-135,85	-74,30	-11,84	45,04	87,79	143,27	177,68	214,05	250,95	281,84
	PEB	90,15	96,21	102,79	108,85	114,98	121,19	127,86	134,27	140,83	147,59	153,71	159,55	166,35	172,85	178,67	185,74	191,54	197,14	203,31	209,64
	CEB	-76,29	-68,95	-60,99	-53,66	-46,24	-38,72	-30,65	-22,91	-14,96	-6,78	0,62	7,69	15,91	23,78	30,83	39,38	46,40	53,17	60,63	68,29
	AF	0,00	0,00	0,00	0,00	0,00	49,11	95,78	145,25	188,18	233,13	271,18	302,29	350,08	387,68	419,73	466,25	494,70	519,59	555,59	593,02
SC4	NPV	-632,74	-455,50	-296,71	-153,87	-25,43	96,50	220,66	318,95	428,08	514,15	582,35	643,90	706,36	763,24	805,99	861,47	895,88	932,25	969,15	1000,04
	PEB	845,04	851,10	857,69	863,75	869,87	876,09	882,76	889,16	895,72	902,49	908,60	914,44	921,24	927,74	933,57	940,63	946,43	952,03	958,20	964,53
	CEB	-831,18	-823,85	-815,88	-808,55	-801,14	-793,62	-785,55	-777,80	-769,86	-761,67	-754,28	-747,21	-738,98	-731,12	-724,07	-715,51	-708,50	-701,72	-694,26	-686,60
	AF	41,25	77,72	121,46	157,91	197,39	246,50	293,18	342,64	385,57	430,52	468,57	499,68	547,47	585,07	617,13	663,64	692,09	716,99	752,99	790,41

Annex 3

Results of case study and scenario modelling under baseline EnC No.3

Table A3.1. Modelling results of baseline EnC No.3

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Bāze	NPV	-1220,29	-1235,26	-1252,69	-1269,93	-1287,79	-1124,67	-958,79	-827,51	-681,56	-566,61	-475,14	-392,39	-308,99	-232,81	-175,34	-101,34	-55,07	-6,08	43,36	84,76
	PEB	4,20	8,26	12,67	16,80	20,89	24,93	29,38	33,49	37,95	42,48	46,57	50,55	55,09	59,54	63,45	68,21	72,07	75,95	80,10	84,40
	CEB	5,09	10,00	15,33	20,33	25,27	30,16	35,55	40,53	45,92	51,40	56,35	61,16	66,65	72,05	76,77	82,53	87,20	91,90	96,92	102,12
	AF	0,00	0,00	0,00	0,00	0,00	59,43	115,22	174,93	225,83	279,27	324,10	359,92	417,12	460,99	498,11	553,34	585,65	613,46	655,49	699,31

Table A3.2. Modelling results of baseline EnC No.3 under Case Study I

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SC1	NPV	-1243,34	-1277,77	-1314,71	-1347,93	-1381,26	-1234,86	-1082,91	-965,40	-830,23	-725,33	-642,38	-566,45	-491,01	-420,86	-368,68	-300,37	-258,16	-212,56	-166,91	-128,99
	PEB	14,71	28,92	44,35	58,80	73,10	87,25	102,84	117,22	132,82	148,68	163,01	176,91	192,80	208,40	222,06	238,72	252,23	265,84	280,34	295,39
	CEB	5,09	10,00	15,33	20,33	25,27	30,16	35,55	40,53	45,92	51,40	56,35	61,16	66,65	72,05	76,77	82,53	87,20	91,90	96,92	102,12
	AF	0,00	0,00	0,00	0,00	0,00	29,88	58,60	88,86	114,44	141,87	162,51	177,02	206,88	227,95	243,09	272,33	284,26	293,37	312,35	332,94
SC2	NPV	-1211,08	-1218,26	-1227,88	-1238,73	-1250,40	-1080,60	-909,15	-772,35	-622,09	-503,11	-408,24	-322,76	-236,18	-157,59	-98,00	-21,72	26,16	76,51	127,47	170,26
	PEB	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	CEB	5,09	10,00	15,33	20,33	25,27	30,16	35,55	40,53	45,92	51,40	56,35	61,16	66,65	72,05	76,77	82,53	87,20	91,90	96,92	102,12
	AF	0,00	0,00	0,00	0,00	0,00	71,25	137,87	209,36	270,39	334,22	388,73	433,08	501,21	554,21	600,11	665,74	706,21	741,49	792,74	845,86
SC3	NPV	-1201,86	-1201,25	-1203,07	-1207,53	-1213,01	-1036,52	-859,50	-717,19	-562,63	-439,62	-341,34	-253,14	-163,38	-82,36	-20,66	57,89	107,40	159,10	211,58	255,76
	PEB	-4,20	-8,26	-12,67	-16,80	-20,89	-24,93	-29,38	-33,49	-37,95	-42,48	-46,57	-50,55	-55,09	-59,54	-63,45	-68,21	-72,07	-75,95	-80,10	-84,40
	CEB	5,09	10,00	15,33	20,33	25,27	30,16	35,55	40,53	45,92	51,40	56,35	61,16	66,65	72,05	76,77	82,53	87,20	91,90	96,92	102,12
	AF	0,00	0,00	0,00	0,00	0,00	83,07	160,52	243,79	314,95	389,18	453,37	506,24	585,31	647,43	702,12	778,14	826,77	869,53	930,00	992,41
SC4	NPV	-1215,67	-1226,57	-1239,99	-1253,81	-1268,59	-1102,71	-934,06	-800,45	-652,21	-535,13	-441,92	-357,63	-272,64	-195,03	-136,42	-61,16	-13,96	35,88	86,15	128,33
	PEB	8,41	16,53	25,34	33,60	41,77	49,86	58,76	66,98	75,90	84,96	93,15	101,09	110,17	119,08	126,89	136,41	144,13	151,91	160,19	168,79
	CEB	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	AF	0,00	0,00	0,00	0,00	0,00	63,48	123,72	187,54	242,89	300,86	349,78	389,58	451,32	499,65	540,66	600,66	636,83	668,52	714,70	762,82
SC5	NPV	-1211,04	-1217,88	-1227,29	-1237,69	-1249,40	-1080,75	-909,33	-773,39	-622,85	-503,65	-408,70	-322,87	-236,28	-157,24	-97,50	-20,98	27,15	77,84	128,94	171,89
	PEB	12,61	24,79	38,02	50,40	62,66	74,79	88,15	100,48	113,84	127,44	139,72	151,64	165,26	178,63	190,34	204,62	216,20	227,86	240,29	253,19
	CEB	-5,09	-10,00	-15,33	-20,33	-25,27	-30,16	-35,55	-40,53	-45,92	-51,40	-56,35	-61,16	-66,65	-72,05	-76,77	-82,53	-87,20	-91,90	-96,92	-102,12
	AF	0,00	0,00	0,00	0,00	0,00	67,52	132,21	200,14	259,95	322,46	375,47	419,24	485,52	538,30	583,22	647,98	688,01	723,59	773,91	826,33

Table A3.3. Modelling results of baseline EnC No.3 under Case Study II

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SC1	NPV	-1296,86	-1380,60	-1459,53	-1533,19	-1602,06	-1485,17	-1363,07	-1269,68	-1160,99	-1078,15	-1015,00	-958,22	-898,65	-844,45	-806,06	-751,00	-720,52	-686,56	-651,00	-621,89
	PEB	4,20	8,26	12,67	16,80	20,89	24,93	29,38	33,49	37,95	42,48	46,57	50,55	55,09	59,54	63,45	68,21	72,07	75,95	80,10	84,40
	CEB	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	AF	0,00	0,00	0,00	0,00	0,00	59,43	115,22	174,93	225,83	279,27	324,10	359,92	417,12	460,99	498,11	553,34	585,65	613,46	655,49	699,31
SC2	NPV	-1143,73	-1089,93	-1045,85	-1006,67	-973,52	-764,17	-554,52	-385,34	-202,13	-55,06	64,72	173,45	280,67	378,83	455,38	548,32	610,37	674,39	737,73	791,41
	PEB	4,20	8,26	12,67	16,80	20,89	24,93	29,38	33,49	37,95	42,48	46,57	50,55	55,09	59,54	63,45	68,21	72,07	75,95	80,10	84,40
	CEB	10,17	20,00	30,67	40,66	50,55	60,33	71,11	81,05	91,83	102,81	112,71	122,32	133,31	144,09	153,54	165,06	174,40	183,81	193,83	204,24
	AF	0,00	0,00	0,00	0,00	0,00	59,43	115,22	174,93	225,83	279,27	324,10	359,92	417,12	460,99	498,11	553,34	585,65	613,46	655,49	699,31

Table A3.4. Modelling results of baseline EnC No.3 under Case Study III

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SC1	NPV	-261,49	-102,16	38,92	165,83	279,07	452,60	627,95	767,85	921,63	1043,71	1141,66	1230,30	1319,06	1400,11	1462,01	1540,04	1589,97	1642,30	1694,77	1738,93
	PEB	4,20	8,26	12,67	16,80	20,89	24,93	29,38	33,49	37,95	42,48	46,57	50,55	55,09	59,54	63,45	68,21	72,07	75,95	80,10	84,40
	CEB	5,09	10,00	15,33	20,33	25,27	30,16	35,55	40,53	45,92	51,40	56,35	61,16	66,65	72,05	76,77	82,53	87,20	91,90	96,92	102,12
	AF	0,00	0,00	0,00	0,00	0,00	77,84	152,04	230,16	299,48	371,32	434,56	488,80	564,41	626,69	682,22	755,86	806,59	852,80	913,25	975,48
SC2	NPV	-2638,83	-2911,67	-3163,62	-3394,13	-3605,95	-3458,24	-3306,38	-3187,84	-3053,48	-2949,06	-2867,18	-2793,15	-2717,68	-2648,71	-2597,79	-2529,75	-2488,91	-2444,86	-2399,89	-2362,57
	PEB	4,20	8,26	12,67	16,80	20,89	24,93	29,38	33,49	37,95	42,48	46,57	50,55	55,09	59,54	63,45	68,21	72,07	75,95	80,10	84,40
	CEB	5,09	10,00	15,33	20,33	25,27	30,16	35,55	40,53	45,92	51,40	56,35	61,16	66,65	72,05	76,77	82,53	87,20	91,90	96,92	102,12
	AF	0,00	0,00	0,00	0,00	0,00	32,19	60,74	93,21	116,87	143,07	160,66	169,24	199,20	215,84	225,71	253,70	258,78	259,34	274,14	290,72

Table A3.5. Modelling results of baseline EnC No.3 under Case Study IV

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SC1	NPV	-1380,65	-1541,46	-1691,51	-1499,81	-1327,65	-1164,54	-998,66	-867,38	-721,43	-606,47	-515,00	-432,25	-348,86	-272,68	-215,21	-141,21	-94,94	-45,95	3,50	44,89
	PEB	4,20	8,26	12,67	16,80	20,89	24,93	29,38	33,49	37,95	42,48	46,57	50,55	55,09	59,54	63,45	68,21	72,07	75,95	80,10	84,40
	CEB	5,09	10,00	15,33	20,33	25,27	30,16	35,55	40,53	45,92	51,40	56,35	61,16	66,65	72,05	76,77	82,53	87,20	91,90	96,92	102,12
	AF	0,00	0,00	0,00	42,78	89,48	148,91	204,70	264,41	315,31	368,74	413,57	449,39	506,60	550,47	587,58	642,81	675,13	702,93	744,97	788,79
SC2	NPV	-1151,94	-1104,75	-1065,65	-1031,48	-1002,58	-969,75	-922,36	-791,08	-645,13	-530,17	-438,70	-355,95	-272,56	-196,37	-138,90	-64,90	-18,64	30,35	79,80	121,19
	PEB	4,20	8,26	12,67	16,80	20,89	24,93	29,38	33,49	37,95	42,48	46,57	50,55	55,09	59,54	63,45	68,21	72,07	75,95	80,10	84,40
	CEB	5,09	10,00	15,33	20,33	25,27	30,16	35,55	40,53	45,92	51,40	56,35	61,16	66,65	72,05	76,77	82,53	87,20	91,90	96,92	102,12
	AF	0,00	0,00	0,00	0,00	0,00	0,00	0,00	59,71	110,61	164,04	208,87	244,70	301,90	345,77	382,88	438,11	470,43	498,24	540,27	584,09

Table A3.6. Modelling results of baseline EnC No.3 under Case Study V

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SC1	NPV	-1404,49	-1450,57	-1496,28	-1539,24	-1580,50	-1417,38	-1251,50	-1120,22	-974,27	-859,31	-767,85	-685,10	-601,70	-525,52	-468,05	-394,05	-347,78	-298,79	-249,35	-207,95
	PEB	4,20	8,26	12,67	16,80	20,89	24,93	29,38	33,49	37,95	42,48	46,57	50,55	55,09	59,54	63,45	68,21	72,07	75,95	80,10	84,40
	CEB	5,09	10,00	15,33	20,33	25,27	30,16	35,55	40,53	45,92	51,40	56,35	61,16	66,65	72,05	76,77	82,53	87,20	91,90	96,92	102,12
	AF	0,00	0,00	0,00	0,00	0,00	59,43	115,22	174,93	225,83	279,27	324,10	359,92	417,12	460,99	498,11	553,34	585,65	613,46	655,49	699,31
SC2	NPV	-1036,09	-1019,96	-1009,10	-1000,61	-995,08	-831,96	-666,08	-534,80	-388,85	-273,90	-182,43	-99,68	-16,28	59,90	117,37	191,37	237,64	286,62	336,07	377,47
	PEB	4,20	8,26	12,67	16,80	20,89	24,93	29,38	33,49	37,95	42,48	46,57	50,55	55,09	59,54	63,45	68,21	72,07	75,95	80,10	84,40
	CEB	5,09	10,00	15,33	20,33	25,27	30,16	35,55	40,53	45,92	51,40	56,35	61,16	66,65	72,05	76,77	82,53	87,20	91,90	96,92	102,12
	AF	0,00	0,00	0,00	0,00	0,00	59,43	115,22	174,93	225,83	279,27	324,10	359,92	417,12	460,99	498,11	553,34	585,65	613,46	655,49	699,31
SC3	NPV	-2571,10	-2814,17	-3039,02	-3244,91	-3434,32	-3271,21	-3105,33	-2974,04	-2828,09	-2713,14	-2621,67	-2538,92	-2455,53	-2379,34	-2321,87	-2247,87	-2201,61	-2152,62	-2103,17	-2061,77
	PEB	4,20	8,26	12,67	16,80	20,89	24,93	29,38	33,49	37,95	42,48	46,57	50,55	55,09	59,54	63,45	68,21	72,07	75,95	80,10	84,40
	CEB	5,09	10,00	15,33	20,33	25,27	30,16	35,55	40,53	45,92	51,40	56,35	61,16	66,65	72,05	76,77	82,53	87,20	91,90	96,92	102,12
	AF	0,00	0,00	0,00	0,00	0,00	59,43	115,22	174,93	225,83	279,27	324,10	359,92	417,12	460,99	498,11	553,34	585,65	613,46	655,49	699,31

Table A3.7. Modelling results of baseline EnC No.3 under Case Study VI

		Year																			
Scenario	**Indicator**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SC1	NPV	-2160,85	-1923,19	-1710,86	-1519,16	-1347,01	-1183,89	-1018,01	-886,73	-740,78	-625,82	-534,35	-451,60	-368,21	-292,03	-234,56	-160,56	-114,29	-65,30	-15,86	25,54
	PEB	4,20	8,26	12,67	16,80	20,89	24,93	29,38	33,49	37,95	42,48	46,57	50,55	55,09	59,54	63,45	68,21	72,07	75,95	80,10	84,40
	CEB	5,09	10,00	15,33	20,33	25,27	30,16	35,55	40,53	45,92	51,40	56,35	61,16	66,65	72,05	76,77	82,53	87,20	91,90	96,92	102,12
	AF	48,94	91,69	142,26	185,04	231,74	291,17	346,96	406,67	457,57	511,00	555,83	591,66	648,86	692,73	729,84	785,08	817,39	845,20	887,23	931,05
SC2	NPV	-279,73	-547,34	-794,51	-1020,70	-1228,57	-1065,45	-899,58	-768,29	-622,34	-507,39	-415,92	-333,17	-249,77	-173,59	-116,12	-42,12	4,14	53,13	102,58	143,98
	PEB	4,20	8,26	12,67	16,80	20,89	24,93	29,38	33,49	37,95	42,48	46,57	50,55	55,09	59,54	63,45	68,21	72,07	75,95	80,10	84,40
	CEB	5,09	10,00	15,33	20,33	25,27	30,16	35,55	40,53	45,92	51,40	56,35	61,16	66,65	72,05	76,77	82,53	87,20	91,90	96,92	102,12
	AF	0,00	0,00	0,00	0,00	0,00	59,43	115,22	174,93	225,83	279,27	324,10	359,92	417,12	460,99	498,11	553,34	585,65	613,46	655,49	699,31
SC3	NPV	-1192,51	-1182,22	-1176,67	-1173,02	-1171,87	-1008,76	-842,88	-711,60	-565,64	-450,69	-359,22	-276,47	-193,08	-116,89	-59,42	14,58	60,84	109,83	159,28	200,67
	PEB	126,04	130,10	134,51	138,64	142,72	146,76	151,22	155,33	159,78	164,32	168,41	172,38	176,92	181,38	185,28	190,04	193,90	197,79	201,93	206,23
	CEB	-116,75	-111,84	-106,50	-101,51	-96,56	-91,67	-86,28	-81,31	-75,92	-70,43	-65,48	-60,68	-55,18	-49,79	-45,07	-39,31	-34,63	-29,93	-24,92	-19,72
	AF	0,00	0,00	0,00	0,00	0,00	59,43	115,22	174,93	225,83	279,27	324,10	359,92	417,12	460,99	498,11	553,34	585,65	613,46	655,49	699,31
SC4	NPV	-942,49	-704,83	-492,50	-300,80	-128,65	34,47	200,35	331,63	477,58	592,54	684,01	766,76	850,15	926,33	983,80	1057,80	1104,07	1153,06	1202,50	1243,90
	PEB	1222,56	1226,62	1231,03	1235,16	1239,25	1243,29	1247,74	1251,85	1256,31	1260,84	1264,93	1268,91	1273,45	1277,90	1281,81	1286,57	1290,43	1294,31	1298,46	1302,76
	CEB	-1213,27	-1208,36	-1203,03	-1198,03	-1193,09	-1188,20	-1182,81	-1177,83	-1172,44	-1166,96	-1162,01	-1157,20	-1151,71	-1146,31	-1141,59	-1135,83	-1131,16	-1126,46	-1121,44	-1116,24
	AF	48,94	91,69	142,26	185,04	231,74	291,17	346,96	406,67	457,57	511,00	555,83	591,66	648,86	692,73	729,84	785,08	817,39	845,20	887,23	931,05

Roberts Lazdiņš was born in 1996 in Gulbene. He received a Bachelor's Degree of Engineering Science in Electrical Engineering in 2018 and a Master's Degree in Power and Electrical Engineering in 2020 from Riga Technical University. He has worked at the Institute of Power Engineering of RTU since 2020. Currently, he is a researcher at this institute. His scientific interests are related to renewable energy resources, energy communities, and local energy systems.