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# ASSESSMENT OF VARIOUS FACTORS AFFECTING ECONOMIC INDICATORS IN PROSUMER AND CONSUMER ENERGY COMMUNITIES: A CASE STUDY OF LATVIA

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This study explores the recent legislative changes allowing prosumers and consumers in Latvia to form energy communities (EnCs). In spite of legal advancements, the absence of supporting regulations and potential barriers, such as the lack of tailored support schemes and forecasting tools, pose challenges. International experiences highlight additional hurdles, including weak stakeholder dialogue and limited EnC modelling tools. To address these issues, the study proposes a prosumer and consumer EnC business model aligned with Latvia's legislation, emphasising a peer-to-peer (P2P) trading approach. The model incorporates state aid, electricity trader responsibilities, and reinvestment of EnC profits, eliminating the need for a dedicated trading platform. The study introduces a user-friendly planning tool in MS Excel, evaluating economic viability through case studies and scenarios. Findings emphasise the optimisation of EnC effectiveness by adjusting tariffs, minimising initial investment costs, securing external funding, and managing loan durations. The planning tool serves as a universal instrument, offering insights into individual EnC economic indicators based on their unique characteristics. The research provides valuable guidance to stakeholders and policymakers in Latvia's evolving energy landscape.

***Keywords:*** *Energy community, peer-to-peer, case study, modelling.*

## 1. INTRODUCTION

Due to the legislative change made to the Latvia's Electricity Market Law [1] and the Energy Law [2], electricity active consumers, also known as prosumers, and consumers are one step closer to soon being allowed to create the first EnCs in Latvia. In spite of the legal changes made, it is necessary to develop Cabinet of Ministers Regulations related to the conditions and procedures for sharing electricity, the process for information exchange between market participants and system operators, criteria for the EnC territorial borders and other relevant factors [1], [2].

In spite of the lack of legislation, the EnC implementation and acceptance may also face other implementation barriers, which are already identified in Latvia: lack of support schemes designed specifically for EnCs [3], lack of tools which would forecast economic benefits from the creation of EnCs [4], [5], concerns about the economic impact of the introduction of a single electricity trader for all members of one EnC [1], a small number of existing prosumers [6], [7] and limited amount of shareable electricity [8], [9], as well as EnC-related information and awareness [3], [10].

Other countries have revealed additional barriers that may emerge in Latvia, which based on their experiences can slow down the implementation of EnCs. A comprehensive review [11] identified that a weak dialogue between stakeholders and information dissemination activities does not actualise the benefits of creating EnC, thus creating insufficient interest in participating in them. Moreover, lack of user-friendly and open-access EnC modelling and planning tools makes it difficult for prosumers and consumers to identify economic benefits from the participation in the EnCs, and high complexity of existing business models creates non-transparency of EnC operations, which in turn discourages participation in energy sharing activities [11].

Given the diverse renewable energy and EnC related legislations [12], electricity tariff structures and settlement schemes [13] across the European Union countries, it is not feasible to establish a uniform structure and operational mechanism for EnCs that can be universally applied across countries.

In order for Latvia's electricity consumers to provide an opportunity to overcome the above-mentioned barriers and challenges, which are based on concerns about the economic efficiency of EnC and the availability of related information to a wider part of society, it is necessary to inform the public about the advantages of EnC implementation and the potential structure of it. Moreover, a relatively small number of prosumers in Latvia and the limitation that a prosumer must self-consume at least 80 % of the electricity generated [9] indicate the high potential of prosumer and consumer EnC implementation in Latvia [14], [15].

The choice of the EnC operating scheme is important, thus ensuring the sustainability and viability of the EnC. Studies conducted in [16], [17] determined that it would be advisable to use a P2P energy trading approach, which is also recommended by Latvia's Energy and Climate Plan (NECP) [18]. In addition, this approach can be supplemented with the provisions of the Latvia's Electricity Market Law [1] and Energy Law [2]:

- Members of the EnC can apply for the state aid to partially cover the purchase costs of the system;
- Electricity trader is responsible for accounting of both shared and sold electricity, as well as management of payment mechanisms;

- The profit obtained by the EnC is not distributed or paid out in dividends, but it is invested to achieve the goals set in the EnC statutes (such as for the implementation of measures to increase energy efficiency).

This suggests that the P2P approach can be strengthened by obtaining external funding, such as state aid, and by dispensing with the necessity for a dedicated P2P electricity trading platform, which would be utilised by the existing electricity trader services. Moreover, the primary purpose of the accumulated funds would extend beyond covering EnC costs, including operational expenditures (OPEX) or loan repayments. Instead, the intention is to leverage these saved funds to enhance energy efficiency or implement other welfare measures for the EnC members.

Considering all the above, the following prosumer and consumer EnC business model, compatible with Latvia's existing legislation, can be proposed (see Fig. 1).

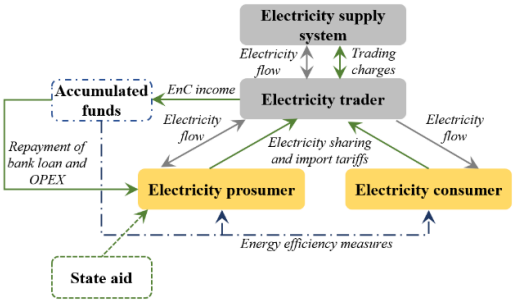



*Fig. 1*. The proposed business model for prosumer and consumer EnC.

To use the proposed business model, as well as to evaluate the potential and efficiency of its implementation, it is necessary to develop a specifically designed tool to plan sharing-related activities according to each participant's electricity consumption. Moreover, determination of initial investment distributions, as well as the value of the electricity sharing tariff would allow planning EnC in such a way that electricity sharing would not only remunerate cost of the installed electricity generation source, but also generate economic benefits for each EnC member.

Referring to [14], [15], the development of the aforementioned planning tool could effectively tackle the previously mentioned barriers and challenges related to information availability. The necessity and application of the planning tool can be related not only to the modelling of electricity sharing and payment mechanisms, but also to provide recommendations to potential members and other stakeholders about the effects of various factors (generation and consumption level, electricity sharing, import and purchase tariffs, cost allocations and other) on the specifically defined EnC indicators. In addition, ensuring the open-access and user-friendly environment of this planning tool plays an equally important role, thus allowing it to be used with basic programming skills and without the use of specific coding languages, platforms and applications.

While bearing in mind all above, the study aims to present in detail the prosumer and consumer EnC planning tool designed in a freely accessible and user-friendly environment (MS Excel) under Latvia's existing EnC-related legislation, EnC operational guidelines and restrictions. With the help of the developed case studies and scenarios, the study aims to offer recommendations to potential EnC creators, participants and other stakeholders. Moreover, the task is to assess the effect of various factors on the proposed EnC economic viability, as well as economic benefits of the participation in the proposed electricity sharing activities.

The study is structured as follows: Section 2 presents EnC-related legislation guidelines and restrictions, as well as

operation and calculations within EnC planning tool. Assumptions of the used data are determined, and case study and scenario modelling is performed in Section 3. Section 4 provides an analysis of the modelled scenarios and draws conclusions about the effect of the considered factors on the defined indicators and viability of the EnC.

## 2. AN OVERVIEW OF THE PROSUMER AND CONSUMER ENC PLANNING TOOL

### 2.1. Legislation Guidelines

Taking into account that the main task of the proposed planning tool is to evaluate the operation of the EnCs in Latvia, it must comply with the assumptions and restrictions set by Latvia's legislation.

The Electricity Market Law has determined the following guidelines:

- EnC members are prosumers and consumers;
- Electricity sharing and sales activities must be done using one distribution system operator. Furthermore, EnC cannot manage distribution grid autonomously;
- Electricity trader is responsible for accounting of both shared and sold electricity, as well as management of payment mechanisms;
- Members of EnCs conclude a sharing agreement with each other and also conclude an agreement with the electricity trader on sharing-related obligations;
- Prosumers' generated electricity must be shared with other members of EnC and the excess amount must be sold to the electricity trader at the agreed price;
- Parties involved in electricity sharing cannot participate in net metering system, net settlement system and system of certificates of origin of electricity;
- EnC members cannot participate in several EnC at the same time.

In addition to the aforementioned, amendments to the Electricity Market Law have introduced a new definition of an active user (prosumer): active user – an end-user who produces electricity for his/her own or his/her EnCs needs and can transfer the surplus of electricity produced, which is no more than 20 % of the electricity produced by the user in a 12-month period, to an electricity trader within the net settlement system, sell it, engage in flexibility services or energy efficiency schemes [9].

State aid cannot be applied for without achieving 80 % self-consumption by prosumers, leading to a reduction in costs associated with the purchase of RES-based electricity generation source. Moreover, state aid does not include the purchase of battery energy storage systems [8]. However, a thoroughly cited study [19] has established that when prosumers' self-consumption level surpasses 75 %, there is no economic justification for the acquisition and utilisation of batteries. Based on the decelerated limitations of the EnC operation, the next subsection will be devoted to a detailed review of the steps included in the proposed planning tool with the help of mathematical formulations.

### 2.2. An Overview of Planning Tool Mathematical Formulations

To determine the EnC electricity production, it is, first, necessary to calculate the hourly amount of electricity produced by the prosumer:

$$P_{RES}^{t} = P_{RES\,cap.} * \delta_{RES}^{t} * \Delta_{\%}^{y}, \quad (1)$$

where $P_{RES\,cap.}$ – the total capacity of the installed RES-based electricity source (kW), $\delta_{RES}^{t}$ – hourly coefficients, which determine the amount of electricity hourly generated from 1 kW of installed capacity (kWh/kW), $\Delta_{\%}^{y}$ – annual installed RES-based electricity source degradation coefficient (%).

Prosumers' hourly consumed amount of electricity from their own electricity generation source can be determined as follows:

$$P_{RES\to Pros.}^{t} = \begin{cases} P_{RES}^{t}, \text{if } P_{RES}^{t} < W_{Pros.}^{t} \\ W_{Pros.}^{t}, \text{if } P_{RES}^{t} \geq W_{Pros.}^{t} \end{cases}, \quad (2)$$

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

To determine prosumers' amount of electricity consumed from the grid, the following calculations can be made:

$$P_{grid\to Pros.}^{t} = \begin{cases} W_{Pros.}^{t} - P_{RES\to Pros.}^{t}, \text{if } \mathrm{P_{RES}^{t}} < \mathrm{W_{Pros.}^{t}} \\ 0, \text{if } \mathrm{P_{RES}^{t}} \geq \mathrm{W_{Pros.}^{t}} \end{cases} \quad (3)$$

Hourly amount of surplus electricity after prosumers' self-consumption, which would be available for sharing with the consumer, can be defined as follows:

$$P_{RES,excess}^{t} = \begin{cases} 0, \text{if } \mathrm{P_{RES}^{t}} < \mathrm{W_{Pros.}^{t}} \\ P_{RES}^{t} - P_{RES\to Pros.}^{t}, \text{if } \mathrm{P_{RES}^{t}} \geq \mathrm{W_{Pros.}^{t}} \end{cases} \quad (4)$$

In the instance when the prosumer would like to pay for the received electricity from their own electricity source, the tariff must encompass the value added tax (VAT):

$$c_{Pros.\ EnC+VAT}^{t} = c_{Pros.\ EnC}^{t} * (1 + VAT), \quad (5)$$

where $c_{Pros.\ EnC}^{t}$ – prosumer's tariff for the received electricity from their own generation source without VAT (EUR/kWh).

Prosumer's hourly payments for the amount of electricity received by its own electricity source can be calculated as follows:

$$C_{EnC\to Pros.}^{t} = P_{RES\to Pros.}^{t} * c_{Pros.\ EnC+VAT}^{t}. \quad (6)$$

Prosumer's hourly electricity tariff component for the amount of electricity received from grid with VAT can be determined as follows:

$$c_{Pros.\ grid+VAT}^{t} = c_{Pros.\ grid}^{t} * (1 + VAT), \quad (7)$$

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

Thereby, prosumer's hourly payments for the amount of electricity received from the grid (without other distribution grid components) is calculated as follows:

$$C_{grid\to Pros.}^{t} = P_{grid\to Pros.}^{t} * c_{Pros.\ grid+VAT}^{t}. \quad (8)$$

Annual overall electricity costs (including other grid cost components) for the prosumer, when they participate in the EnC, can be written as follows:

$$C^{y}_{Pros.with\ EnC+VAT} = \Sigma C^{t}_{EnC\rightarrow Pros.} + \Sigma C^{t}_{grid\rightarrow Pros.} + (\Sigma P^{t}_{grid\rightarrow Pros.} * c_{supply\ (grid).Pros.} + I_{conn.Pros.} * c_{maintenance\ (grid).Pros.} * 12) * (1 + VAT), \quad (9)$$

where $c_{supply\ (grid).Pros.}$ – prosumer's tariff for the supply of electricity from the grid without VAT (EUR/kWh), $I_{conn.Pros.}$ – maximum rated current of prosumer's connection (A), $c_{maintenance\ (grid).Pros.}$ – prosumer's costs for connection maintenance without VAT (EUR/A/month).

Prosumer's total electricity costs without participating in the EnC can be calculated as follows:

$$C^{y}_{Pros.without\ EnC+VAT} = \Sigma C^{t}_{grid\rightarrow Pros.} + (\Sigma P^{t}_{grid\rightarrow Pros.} * c_{supply\ (grid).Pros.} + I_{conn.Pros.} * c_{maintenance\ (grid).Pros.} * 12) * (1 + VAT). \quad (10)$$

Consumer's hourly consumed amount of electricity from prosumer's electricity source can be defined as follows:

$$P^{t}_{RES,excess\rightarrow Cons.} = \begin{cases} P^{t}_{RES,excess}, \text{if } \mathrm{P^{t}_{RES,excess}} < \mathrm{W^{t}_{Cons.}} \\ W^{t}_{Cons.}, \text{if } \mathrm{P^{t}_{RES,excess}} \geq \mathrm{W^{t}_{Cons.}} \end{cases}, \quad (11)$$

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

Consumer's hourly amount of electricity imported from the grid can written as follows:

$$P^{t}_{grid\rightarrow Cons.} = \begin{cases} W^{t}_{Cons.} - P^{t}_{RES,excess\rightarrow Cons.}, \text{if } \mathrm{P^{t}_{RES,excess}} < \mathrm{W^{t}_{Cons.}} \\ 0, \text{if } \mathrm{P^{t}_{RES,excess}} \geq \mathrm{W^{t}_{Cons.}} \end{cases} \quad (12)$$

To determine hourly amount of electricity sold to the electricity trader, the following calculation is used:

$$P^{t}_{excess\rightarrow trader} = \begin{cases} 0, \text{if } \mathrm{P^{t}_{RES,excess}} < \mathrm{W^{t}_{Cons.}} \\ P^{t}_{RES,excess} - P^{t}_{RES,excess\rightarrow Cons.}, \text{if } \mathrm{P^{t}_{RES,excess}} \geq \mathrm{W^{t}_{Cons.}} \end{cases} \quad (13)$$

Electricity tariff for received electricity from the prosumer should include VAT:

$$c^{t}_{Cons.\ EnC+VAT} = c^{t}_{Cons.\ EnC} * (1 + VAT), \quad (14)$$

where $c^{t}_{Cons.\ EnC}$ – electricity tariff for received electricity from the prosumer without VAT (EUR/kWh).

The hourly costs for consumer for receiving electricity from the prosumer (including VAT) are calculated as follows:

$$C^{t}_{EnC\rightarrow Cons.\ (with\ VAT)} = P^{t}_{RES\rightarrow Cons.} * c^{t}_{Cons.\ EnC+VAT}. \quad (15)$$

Thereby, annual costs for consumer for receiving electricity from the prosumer (including VAT) are determined as follows:

$$C^{y}_{EnC\rightarrow Cons.\ (with\ VAT)} = \Sigma C^{t}_{EnC\rightarrow Cons.\ (with\ VAT)}. \quad (16)$$

Consumer's hourly costs for the received amount of electricity from the prosumer (excluding VAT) can be written as follows:

$$C^{t}_{EnC\rightarrow Cons.\ (without\ VAT)} = P^{t}_{RES\rightarrow Cons.} * c^{t}_{Cons.\ EnC}. \quad (17)$$

Consumer's annual costs for the received amount of electricity from the prosumer (excluding VAT) can be expressed as follows:

$$C^{y}_{EnC\rightarrow Cons.\ (without\ VAT)} = \Sigma C^{t}_{EnC\rightarrow Cons.\ (without\ VAT)}. \quad (18)$$

Consumer's electricity component tariff for imported electricity from the grid with VAT can be determined as follows:

$$c^{t}_{Cons.\ grid+VAT} = c^{t}_{Cons.\ grid} * (1 + VAT), \quad (19)$$

where $c^{t}_{Cons.\ grid}$ – consumer's electricity component tariff for imported electricity from the grid without VAT (EUR/kWh);

Consumer's hourly payments for the imported electricity from the grid with VAT (excluding other distribution grid tariff components) can be calculated as follows:

$$C^{t}_{grid\rightarrow Cons.} = P^{t}_{grid\rightarrow Cons.} * c^{t}_{Cons.\ grid+VAT}. \quad (20)$$

Consumer's annual costs (with VAT) for the amount of consumed electricity by participating in the EnC including other grid costs components can be determined as follows:

$$C^{y}_{Cons.with\ EnC+VAT} = C^{y}_{EnC\rightarrow Cons.\ (with\ VAT)} + \Sigma C^{t}_{grid\rightarrow Cons.} + (W^{t}_{Cons.} * c_{supply\ (grid).Cons.} + I_{conn.Cons.} * c_{maintenance\ (grid).Cons.} * 12) * (1 + VAT), \quad (21)$$

where $c_{supply\ (grid).Cons.}$ – consumer's tariff for the supply of electricity from the grid without VAT (EUR/kWh), $I_{conn.Cons.}$ – maximum rated current of consumer's connection (A), $c_{maintenance\ (grid).Cons.}$ – consumer's costs for connection maintenance without VAT (EUR/A/month).

Similar to the aforementioned formula, consumer's annual electricity costs without participating in the EnC can be expressed as follows:

$$C^{y}_{Cons.without\ EnC+VAT} = \Sigma W^{t}_{Cons.} * c^{t}_{Cons.\ grid+VAT} + (\Sigma W^{t}_{Cons.} * c_{supply\ (grid).Cons.} + I_{conn.Cons.} * c_{maintenance\ (grid).Cons.} * 12) * (1 + VAT). \quad (22)$$

Capital expenditure (CAPEX) for the purchase of electricity generation source can be covered by three funding sources: external funding (such as state aid), investment contributions by the prosumer and/or consumer, as well as bank loan. In order to calculate one-time investment contributions by the prosumer and consumer, the following formula can be used:

$$I_0 = I_{0,Pros.} + I_{0,Cons.}, \quad (23)$$

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

Total CAPEX (including VAT) can be determined as follows:

$$CAPEX = \left(C_{CAPEX\ per\ kW} * P_{PV\ cap.}\right) * (1 + VAT) - C_{grants}, \quad (24)$$

where $C_{CAPEX\ per\ kW}$ – CAPEX related to an installed generation source capacity of 1 kW without VAT (EUR), $C_{grants}$ – the amount of external funding (state aid) (EUR).

Required amount of bank loan to fully cover CAPEX can be calculated as follows:

$$C_{bank\rightarrow EnC} = \begin{cases} 0, \text{if } I_0 \geq \text{CAPEX} \\ CAPEX - I_0, \text{if } I_0 < \text{CAPEX} \end{cases}. \quad (25)$$

To calculate the amount of annual bank loan repayment, the following formula is used:

$$C_{EnC\to bank}^{y} = \begin{cases} C_{bank\to EnC} * \left(1 + i_{\%,bank}\right) * \\ \dfrac{i_{\%,bank} * \left(1 + i_{\%,bank}\right)^{y_{loan}}}{((1 + i_{\%,bank})^{y_{loan}}) - 1}, \text{when y} \leq \text{ y}_{\text{loan}}, \\ 0, \text{when y} > \text{ y}_{\text{loan}} \end{cases} \quad (26)$$

where $y_{loan}$ – loan duration (years); $i_{\%,bank}$ – loan interest rate (%).

Annual operational costs (including VAT) for electricity generation source can be written as follows:

$$OPEX^{y} = (C_{OPEX\ per\ kW}^{y} * P_{RES\ cap.}) * (1 + VAT), \quad (27)$$

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

To calculate EnC received hourly income from the electricity sold to the electricity trader, the following formula is used:

$$C_{excess\to trader}^{t} = P_{excess\to trader}^{t} * c_{excess\to trader}^{t}, \quad (28)$$

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

Prosumer's annual overall electricity costs if they do not own the electricity generation source can be determined using the following formula:

$$C_{el.Pros.\to trader.without\ RES}^{y} = \Sigma(W_{Pros.}^{t} * c_{Pros.\ grid+VAT}^{t}) + (\Sigma W_{Pros.}^{t} * c_{supply\ (grid).Pros.} + I_{conn.Pros.} * c_{maintenance\ (grid).Pros.} * 12) * (1 + VAT) \quad (29)$$

Prosumer's annual cost savings regarding reduction of amount of imported electricity from the grid due to the self-consumption of power generated by the installed generation source can be calculated as follows:

$$\Delta C_{pros\to grid\ (with.without\ RES)}^{y} = \Sigma C_{grid\to Pros.}^{t} + (\Sigma P_{grid\to Pros.}^{t} * c_{supply\ (grid).Pros.} + I_{conn.Pros.} * c_{maintenance\ (grid).Pros.} * 12) * (1 + VAT) - C_{el.Pros.\to trader.without\ RES}^{y} \quad (30)$$

The annual overall incoming cash flow of the EnC can be determined as follows:

$$Income^{y}_{EnC,RES} = C^{y}_{EnC\rightarrow Cons.\ (without\ VAT)} + \Sigma(P^{t}_{RES\rightarrow Pros.} * c^{t}_{Pros.\ EnC}) + \Delta C^{y}_{pros\rightarrow grid\ (with.without\ RES)} + \Sigma C^{t}_{excess\rightarrow trader} \quad (31)$$

The annual expenses or outcoming cash flow of the EnC is calculated as follows:

$$Expenses^{y}_{EnC,RES} = OPEX^{y} + C^{y}_{EnC\rightarrow bank}. \quad (32)$$

Thereby, annual net cash flow is determined:

$$R^{y}_{EnC,RES} = Income^{y}_{EnC,RES} - Expenses^{y}_{EnC,RES}. \quad (33)$$

Annual net present value for the electricity generation source is calculated as follows:

$$NPV^{y} = -I_{0,Pros.} + \sum_{i=1}^{y} \frac{R^{y}_{EnC,RES}}{\left(1 + i_{\%,d}\right)^{y}}, \quad (34)$$

where $i_{\%,d}$ – discount rate (%).

The annual income for prosumer from the sale of electricity to the electricity trader, assuming non-participation in the EnC (excluding taxes), can be expressed as follows:

$$C^{y}_{Pros\rightarrow trader,without\ EnC} = \Sigma(P^{t}_{RES,excess} * c^{t}_{excess\rightarrow trader}). \quad (35)$$

Prosumer's annual economic benefits from the participation in the EnC is calculated as follows:

$$EB^{y}_{Pros.} = I_{0,Cons.} + \sum_{i=1}^{y}(-\Sigma C^{t}_{EnC\rightarrow Pros.} + C^{y}_{EnC\rightarrow Cons.\ (without\ VAT)} + \Sigma C^{t}_{excess\rightarrow trader} - C^{y}_{Pros\rightarrow trader,without\ EnC}) \quad (36)$$

Similar to the aforementioned formula, consumer's economic benefits from the participation in the EnC are calculated as follows:

$$EB^{y}_{Cons.} = -I_{0,Cons.} + \sum_{i=1}^{y}(C^{y}_{Cons.without\ EnC+VAT} - C^{y}_{Cons.with\ EnC+VAT}) \quad (37)$$

EnC direct incoming cash flow is credited into accumulated funds, which can help cover the annual costs associated with bank loan repayments and OPEX, as well as making savings for future energy efficiency measures for EnC members. Thereby, annual amount of cash located in EnCs accumulated funds after coverage of annual bank loan payment and OPEX will be zero, if:

$$AF_{EnC}^{y} = \begin{array}{l}(C_{\mathrm{EnC}\rightarrow\mathrm{bank}}^{y} + \mathrm{OPEX}^{y}) \geq (C_{\mathrm{EnC}\rightarrow\mathrm{Cons.\ (without\ VAT)}}^{y} + \\ \Sigma(P_{\mathrm{RES}\rightarrow\mathrm{Pros.}}^{t} * c_{\mathrm{Pros.\ EnC}}^{t}) + \Sigma C_{\mathrm{excess}\rightarrow\mathrm{trader}}^{t})\end{array} \quad (38)$$

If the previous formula does not hold, then:

$$AF_{EnC}^{y} = \begin{array}{l}C_{EnC\rightarrow Cons.\ (without\ VAT)}^{y} + \Sigma(P_{RES\rightarrow Pros.}^{t} * c_{Pros.\ EnC}^{t}) + \\ \Sigma C_{excess\rightarrow trader}^{t} - (C_{EnC\rightarrow bank}^{y} + OPEX^{y}))\end{array} \quad (39)$$

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

$$\Sigma AF_{EnC}^{y} = \sum_{i=1}^{y} AF_{EnC}^{y}. \quad (40)$$

Finally, to make sure that prosumer's self-consumption level is within the allowed limits, the aforementioned level is calculated as:

$$SC_{Pros.,\%}^{y} = \frac{\Sigma P_{RES\rightarrow Pros.}^{t}}{\Sigma P_{RES}^{t}} * 100\%. \quad (41)$$

In order to demonstrate the developed planning tool in action and determine inclusive tariffs, CAPEX, loan duration, state aid and initial investment coverage scheme effect on indicators characterising the economic efficiency of the EnC, the upcoming paragraph delves into modelling selected EnCs, starting with assumptions included in the modelling process.

## 3. CASE STUDIES AND SCENARIO MODELLING

### 3.1. Assumptions

The subsequent case studies and scenarios incorporate the following assumptions:

- To determine prosumers' and consumers' electricity consumption schedule, the 2023 load profile for households [20] was used and it was equated to the monthly average electricity consumption for the year [21];
- Photovoltaics (PV) are used as the prosumer electricity generation source. Hourly coefficients which determine the amount of electricity hourly generated from 1 kW of installed capacity are determined using [22];
- For the creation of the proposed EnC and ensuring its operation, the amount of state aid is allocated, which corresponds to the amount mentioned in [8];
- When modelling electricity tariffs, fixed tariffs are used, as only 15 % of Latvia's electricity consumers in 2023 settle with Nord pool market price [23];
- To calculate the CAPEX associated with an installed generation source capacity of 1 kW (excluding VAT), reference [23] is utilised. This involves selecting PV panel suppliers with the lowest, highest, and average prices on the market.

- Electricity traders' price for the purchase of excess amount of electricity from the EnC is chosen freely due to the fact that electricity traders have the right to offer an individually concluded contract to the prosumer and EnC [1]. In addition, the greatest importance of this price may lie not in its value, but in the value of the relationship between it and the tariff for which the prosumer will share the generated electricity to the consumer.
- As it is assumed that a prosumer is the owner of electricity generation source, it does not make payments for the amount of electricity received from the PV panels.

Taking into account the used modelling assumptions, the following chapter provides the basic data of the three EnCs used, as well as a detailed description of the modelled case studies and scenarios.

## 3.2. EnCs, Case Studies and Scenarios

The primary objective of modelling is to assess the impact of various selected factors on the NPV, economic benefits for prosumer and consumer participating in the EnC, as well as the accumulation of funds. In order to expand the application of the modelled scenario data to different prosumer and consumer generation and consumption values, three EnCs will be used for modelling (see Table 1).

**Table 1.** Basic Data of the Modelled EnCs

| Data | EnC No1 | EnC No2 | EnC No3 |
|---|---|---|---|
| Installed capacity of PV panels | 3 kW | 3 kW | 4 kW |
| PV degradation coefficient [15] | 0,5%/year | | |
| Prosumers' average monthly electricity consumption | 780 kWh | 780 kWh | 1050 kWh |
| Consumers' average monthly electricity consumption | 175 kWh | 300 kWh | 175 kWh |
| Amount of external funding (state aid) [8] | 1800 EUR | 1800 EUR | 2200 EUR |
| **Data applicable to all modelled EnCs (without taxes):**<br>Prosumers' annual self-consumption level (80 %) [8], [9];<br>Consumers' tariff for received electricity from the prosumer: 0.16 EUR/kWh;<br>Electricity traders' price for the purchase of electricity from the EnC: 0.14 EUR/kWh;<br>Electricity tariff component for the purchase of electricity from the grid: 0.18 EUR/kWh;<br>CAPEX related to installed generation source capacity of 1 kW: 958 EUR/kW [24];<br>Prosumers' and consumers' connection to the grid: 3-phases, 20A [25];<br>Distribution grid tariff for the supply of electricity: 0.03985 EUR/kWh [25];<br>Distribution grid tariff for connection maintenance: 0.92 EUR/A/month [25];<br>Annual OPEX: 1.2 % of PV system costs [15];<br>Loan duration: 5 years;<br>Interest rate: 5.9 % [26];<br>Discount rate: 9.96 % [27];<br>Prosumers' initial investments: 50 % of total CAPEX;<br>Consumers' initial investments: 0 % of total CAPEX;<br>VAT: 21 % [28]. | | | |

In order to analyse an inclusive factor effect on NPV, economic benefits from the participation in the EnC and accumulated funds after 20 years of EnC operation, Table 2 displays the formulated case studies along with scenarios illustrating the increase and decrease in the different variables.

**Table 2.** Modelled Case Studies (CS) and Scenarios (SC)

| CS | Description | Base | SC 1 | SC 2 | SC 3 | SC 4 | SC 5 |
|---|---|---|---|---|---|---|---|
| 1 | Consumers' tariff for received electricity from the prosumer (EUR/kWh) | 0.16 | 0.16 | 0.16 | 0.16 | 0.18 | 0.20 |
| | Electricity traders' price for the purchase of electricity from the EnC (EUR/kWh) | 0.14 | 0.09 | 0.16 | 0.18 | 0.14 | 0.14 |
| 2 | Electricity tariff component for the purchase of electricity from the grid (EUR/kWh) | 0.18 | 0.16 | 0.20 | | | |
| 3 | CAPEX related to installed generation source capacity of 1 kW (EUR/kW) | 958 | 641 | 1427 | | | |
| 4 | Loan duration (years) | 5 | 3 | 7 | | | |
| 5 | Amount of external funding (such as state aid) (EUR) | 1800<br>2200 | 1500<br>1900 | 2100<br>2500 | | | |
| 6 | Prosumers' initial investments (% of CAPEX) | 50 | 100 | 0 | 50 | 50 | |
| | Consumers' initial investments (% of CAPEX) | 0 | 0 | 0 | 5 | 50 | |

Subsequent subsection provides the results of modelling the studied EnC base data and related case studies and scenarios to determine NPV, accumulated funds, prosumers' and consumers' economic benefits from the participation in the EnC.

## 3.3. Results

Given that the aim of the conducted case studies and scenarios is to determine the effect of the specified factor value on predefined indicators, the next subsections will delve into the values of each indicator corresponding to each Case Study (1–6) and related scenarios. Moreover, values of EnC indicators are reflected at the end of 20-year period, thus reflecting their value at the end of the lifetime of the PV panels.

### 3.3.1. Net Present Value

The graphic representation of the NPV (the data are reflected for the 20th year) obtained by the planning tool is given in Fig. 2.

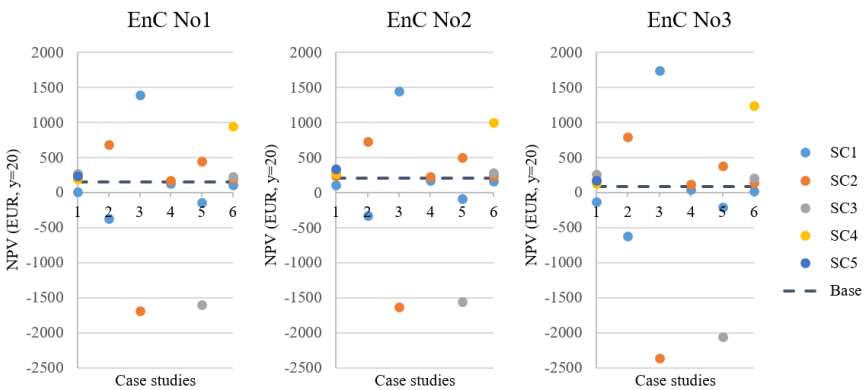



*Fig. 2.* NPV values under used EnCs, case studies and scenarios (SCs).

The acquired data reveal that among the used baseline EnCs, EnC No 2 yields the highest NPV. Comparing NPV data between EnC No 2 and No 1, it is evident that under baseline conditions, when the electricity traders' purchase price for the excess electricity is lower than the tariff at which the prosumer shares produced electricity with the consumer, an uptick in the consumer's electricity consumption results in a greater amount of electricity available for sharing between the prosumer and consumer, thereby increasing the EnC income. In contrast, comparing NPV data between EnC No 2 and No 3 indicates a decrease in the shared amount of electricity between the prosumer and consumer, leading to a reduction in the EnC income. In spite of the increase of external funding (state aid), the installation of higher-capacity PV panels not only raises the costs associated with covering the prosumer's initial investment but also amplifies the bank loan amount necessary to fully cover CAPEX. Furthermore, the PV panel capacity contributes to a rise in annual OPEX, leading to an increase in an outgoing cash flow and a subsequent reduction in NPV value. Considering the aforementioned factors, prosumer must ensure that, with an increased PV panel installed capacity, consumers' electricity consumption (and, consequently, the shared amount of electricity with the consumer) is sufficiently high to offset the overall expense increment.

By modelling the scenarios included in Case Study 1, it can be observed that as the considered tariff and price increase, the corresponding increase of income from both the prosumer's shared electricity to the consumer and from the sold electricity to the electricity trader can be observed, leading to an overall rise in NPV in all baseline EnCs. If after covering the prosumer's self-consumption most of the electricity is transferred to the consumer, the value of the sharing tariff is more important for the provision of income (as well as NPV) than the traders' electricity purchase price. Thus, it can be concluded that consumers' electricity consumption level can be decisive in determining the impact on NPV with the ratio between sharing tariff and the electricity trader price for purchase of surplus electricity.

Considering that the prosumer's savings from the reduced amount of electricity imports due to the self-consumption of electricity produced by PV panels are also taken into account for determining the NPV, findings from Case Study 2 suggest that the level of savings can decline when the tariff for imported electricity is lower, and, conversely, it can increase when the tariff for imported electricity is higher. Therefore, the NPV of PV panels in the EnC is not only affected by factors within the EnC itself, but it is also significantly impacted by the prevailing conditions in the electricity market.

One of the main factors affecting NPV is initial cost of PV panels. The results of Case Study 3 clearly indicate that the cost of PV panels per installed kW can result in both strongly positive and negative NPV values, thus indicating that its value has a greater effect on NPV than sharing, selling and import tariffs and prices. Thereby, it is highly recommended to choose the most economically advantageous PV panel dealer and installer in order to achieve both the planned payback period and to avoid the forced increase in the sharing tariff, which could partially compensate for the negative NPV, at the same time also causing doubts for the consumer about its potential economic benefits from the participation in the EnC.

Scenario simulation results in Case Study 4 indicate that the duration of the bank loan has a minimal effect on the NPV value,

but a slight increase in its value is observed in SC2 when the repayment period of the bank loan is longer. In spite of the additional interest rate-related costs each year, the value of money decreases faster than the interest rate payment increases over the considered period.

Taking into account that external funding (state aid) partially covers the related purchase costs of PV panels, the results in Case Study 5 underscore its significance in achieving a positive NPV. Case study results have shown that a potential decrease in the external funding or no funding at all in the future may not only jeopardise the economic viability of the creation of EnCs but also could heighten prosumer apprehensions regarding the economic efficiency of installing PV panels. Therefore, policymakers and legislators should contemplate either increasing or, at the very least, maintaining the current level of state aid for the development of EnC, as indicated in [8]. This approach not only incentivizes the installation of PV panels at the microgeneration level but also substantiates the economic viability of EnCs.

Results from Case Study 6 have indicated that NPV can be increased if prosumers' initial investment coverage do not exceed 50 %. Respectively, NPV is higher when total CAPEX is fully covered from the bank loan (this is justified in the description of Case Study 4) or by receiving additional one-time payments from the consumer (thus indirectly reducing total CAPEX which have to be covered by the prosumer). Although these two scenarios can increase NPV, their implementation could lead to a decrease in both consumers' economic benefits and accumulated funds (it is discussed in the following subsection).

### 3.3.2. Accumulated Funds

The graphic representation of the accumulated funds (the data are reflected for the 20th year) obtained by the planning tool is given in Fig. 3.

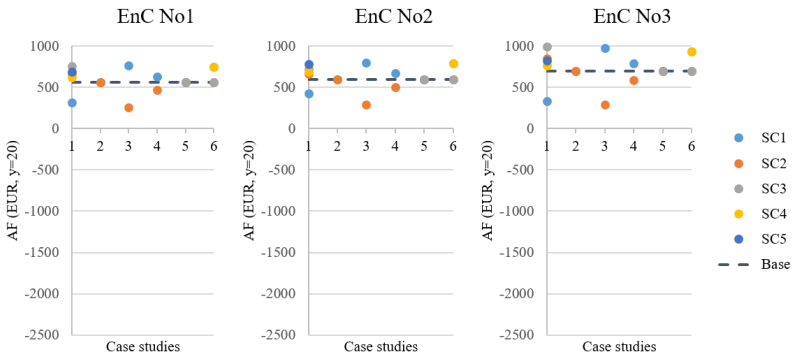



*Fig. 3.* Accumulated funds (AF) under used EnCs, case studies and scenarios (SCs).

EnC No3 has the highest AF among used baseline EnCs due to the increased amount of electricity generation, which leads to a higher incoming cash flow. Similar to NPV related recommendations, during the planning of the EnC, its potential members must make sure that by installing higher capacity PV panels, consumers' electricity consumption is high enough to generate more income into accumulated funds.

Results of Case Study 1 indicate that an increase in EnC sharing tariff and electricity traders' price for the purchase of excess electricity can increase the value of AF.

However, if electricity traders' offered price is significantly low, EnC income reduces considerably.

As can be seen from Fig. 3, an increase or a decrease of imported electricity tariff in Case Study 2 does not affect AF due to the fact that this indicator includes only direct cash flows and not savings in electricity costs.

The results of Case Study 3 indicate that the increased cost of PV panels per installed kW could increase OPEX, thus significantly reducing the value of AF.

Extending the duration of a bank loan leads to increased additional interest payments, CAPEX and OPEX values and in Case Study 4, the AF indicator shows a slight rise when the repayment period is shorter.

Case Study 5 indicates that external funding could reduce total CAPEX, thereby reducing the amount of bank loan. Given that the prosumer is responsible for the coverage of total CAPEX, changes in subsidies value do not affect the value of AF.

Results of Case Study 6 show that one-time payments for the full coverage of initial investments can significantly increase AF due to the fact that there is no need for bank loan, thereby also reducing annual outgoing cash flow.

### 3.3.3. Prosumers' Economic Benefits

The values of overall prosumers' economic benefits in the modelled case studies and scenarios are shown in Fig. 4.

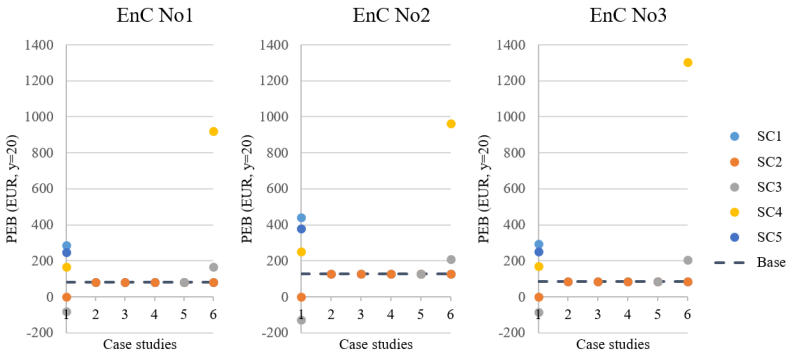



*Fig. 4.* Prosumers' economic benefits (PEB) under used EnCs, case studies and scenarios (SCs).

Similar to the analysis of NPV, EnC No 2 indicates the highest PEB value of all included baseline EnCs. Considering that in all reviewed EnCs, the prosumers' sharing tariff was higher than the electricity traders' price for the purchase of surplus electricity. An increase in consumers' electricity consumption means a higher income from the shared electricity, thus increasing PEB from the participation in the EnC.

As a result of Case Study 1, it can be concluded that PEB increases when electricity sharing tariff is higher than electricity traders' determined price for the purchase of excess electricity. Respectively, activities of electricity sharing and electricity selling to the electricity trader generate more income than selling all prosumers' excess amount of electricity only to the electricity trader. It is also indicated in SC2: when electricity sharing tariff and traders' purchase price are the same, PEB is equal to zero because participation in the EnC would generate the same revenue as when prosumer would

not participate in the EnC and would sell its excess amount of electricity only to the electricity trader. Thereby, to increase PEB value, electricity sharing tariff should be higher than electricity traders' price for the purchase of surplus electricity.

Case Studies 2–5 indicate that an increase or a decrease in electricity import tariff, cost of PV panels per installed kW, loan duration and state aid will not affect PEB due to the fact that these changes are also applicable when the prosumer does not participate in the EnC.

The same can be stated about Case Study 6 SC1 and SC2. Nevertheless, if consumer makes one-time payments to partially cover the total CAPEX, it will be advantageous for the prosumer. Consequently, PEB increases when consumers make one-time payments, helping alleviate the financial burden of prosumer in covering PV initial costs.

### 3.3.4. Consumers' Economic Benefits

The values of overall consumers' economic benefits in the case studies and scenarios are shown in Fig. 5.

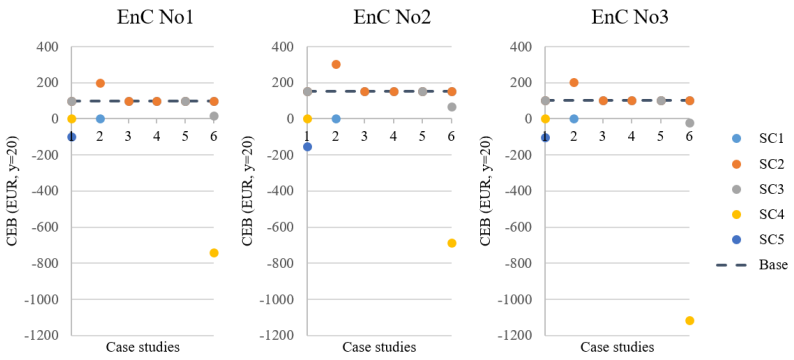



*Fig. 5.* Consumers' economic benefits (CEB) under used EnCs, case studies and scenarios (SCs).

Similar to the results of NPV and PEB, EnC No 2 indicates the highest CEB value of all included baseline EnCs. CEB increases when consumers' electricity production is higher, thus covering a greater proportion of its total electricity consumption with prosumer shared electricity which tariff is lower than electricity import tariff from the grid.

Case Studies 1 and 2 indicate that CEB increases when sharing tariff is lower than electricity import tariff. In addition, CEB is not affected by electricity traders' purchase price. If electricity import tariff is lower than prosumers' sharing tariff, consumer financial motivation to participate in the EnC would decrease because it would be more beneficiary to fully cover its electricity consumption with cheaper electricity from the grid than by receiving it with a higher tariff from the prosumer.

Similar to PEB values, changes to the contained data in Case Studies 3–5 do not affect CEB due to the fact that the costs associated with PV panels and the payment mechanism are the responsibility of the prosumer.

Results in Case Study 6 show that consumers' one-time payments to partially cover the total CAPEX reduce CEB. Nevertheless, depending on the amount of payment, CEB may still have a positive value.

## 4. DISCUSSION AND CONCLUSION

To motivate overcoming the identified barriers, the planning tool was developed based on the proposed business model using a P2P approach with accumulated funds and state aid implementation option. Moreover, the operations and mathematical calculations included in the developed planning tool were presented, thus allowing the stakeholders of the EnCs to determine NPV, AF, PEB and CEB.

To provide recommendations on measures to increase the efficiency and sustainability of the proposed EnC, planning tool modelled 3 EnCs (using different electricity consumption levels and installed PV panel capacities), 6 case studies and a total of 17 scenarios, thus allowing to analyse the impact of the following values on the specified indicators of EnC:

- consumers' tariff for received electricity from the prosumer,
- electricity traders' price for the purchase of electricity from the EnC,
- electricity tariff component for the purchase of electricity from the grid,
- CAPEX related to installed generation source capacity of 1 kW,
- loan duration,
- amount of external funding (such as state aid),
- prosumers' and consumers' one-time payment for the coverage of initial investments.

The findings from case studies and scenario modelling suggest that the effectiveness and sustainability of the creation of the proposed prosumer and consumer EnC can be enhanced through the implementation of the following recommendations:

- If electricity sharing tariff is higher than electricity traders' price for the purchase of excess electricity but lower than electricity tariff component for the purchase of electricity from the grid, members of EnC would receive positive economic benefits from the participation in the EnC;
- CAPEX related to installed generation source capacity of 1 kW must be as low as possible, thus reducing the amount of necessary one-time payment for the coverage of initial investments and amount of bank loan;
- Receiving external funding can significantly increase the NPV. It is strongly reccomended that Latvia's legislators and policymakers develop a support mechanism that would be applicable to the procedure for receiving financial support not only for prosumers, but also for the creation of EnC;
- Loan duration affects NPV and AF values and does not affect PEB and CEB. Nevertheless, to increase AF for the energy efficiency or other welfare activities in the future, it is recommended to reduce the aforementioned duration as short as possible;
- Coverage of total CAPEX must be done either from combination of prosumers' initial one-time payment and a bank loan or fully covering total CAPEX by prosumers' investments, thus raising not only the value of AF but also CEB.

Before the creation of EnC, prosumer have to be sure than consumers' electricity consumption level is high enough to increase the overall income from the shared electricity relative to the cost of PV panels.

Furthermore, the primary goal of modelled EnCs, case studies, and scenarios is to assess the impact of the specified factors on

the NPV, AF, CEB and PEB generated by the planning tool. It is essential to note that the levels of consumption, generation, tariffs, costs and other factors within potential EnCs in Latvia may vary, potentially affecting the values of the aforementioned indicators – while preserving the nature of their positive or negative effects mentioned in the reccomendations. As a result, the developed planning tool can be employed as an universal instrument to analyse each prosumer and consumer EnC in Latvia individually. Furthermore, the offered business model has the potential to be used and applied in other countries. The developed planning tool and its mathematical formulations can serve as a foundation, open to further modifications for alignment with the legislative guidelines of other countries.

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