Economic Assessment of Self-Consumption Rate in the Context of Energy Communities: A Latvian case study

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***Abstract*—In Latvia, achieving an 80% self-consumption rate is a key requirement for electricity prosumers to access renewable energy support schemes. However, individual photovoltaic systems often fail to meet this threshold due to a mismatch between electricity generation and consumption patterns. This paper examines how self-consumption rates influence the economic justification for establishing energy communities. Results show that mixed-source setups, such as integrating diverse consumer types (e.g., residential, educational and commercial), and, by combining electricity prosumers and consumers, it significantly enhances energy communities self-consumption rate. The paper explores their economic feasibility under Latvia's net billing system, assessing key financial indicators like net present value, payback period and internal rate of return. The findings provide recommendations for Latvia's energy transition, emphasising the integration of renewable energy sources and supportive regulatory frameworks to increase self-consumption rate and promote sustainable energy communities.**

***Index Terms*- energy communities, consumption profiles, electricity prosumers, renewables, economic assessment, electricity consumer, electricity sharing.**

I. INTRODUCTION

In 10th of December 2024, Latvia's Cabinet of Ministers' Regulations for registration and operation of energy communities (EComs) [1] entered into force, thereby concluding the development of final legislation on EComs and allowing their creation in Latvia. These regulations, supplemented by Latvia's Energy Law [2] and Electricity Market Law [3] (which provide definitions of EComs and their objectives), determine comprehensive guidelines for registration and operation, covering both technical aspects and electricity sharing. Moreover, they establish limitations on maximum installed generation capacity and, more importantly, govern the use of either net billing system (NBS) or electricity trading mechanism, based on the communities' annual and immediate self-consumption rates (SCR).

Although the creation of EComs creates a wide range of social benefits, regardless of the legal and climatic conditions of different countries [4, 5], economic benefits for communities' participants is heavily affected by aforementioned conditions, as well as electricity pricing mechanisms and the foremost: used remuneration scheme from the excess electricity fed into the grid (in Latvia's case: NBS or electricity trading). [6, 7]

While numerous studies have explored various configurations of EComs, research on the impact of country-specific regulatory frameworks, particularly taxation and tariff policies, on their economic viability and efficiency remains limited. In the context of Latvia, the implementation of the NBS and taxation policies create distinct challenges and opportunities for EComs. However, these factors have not been thoroughly examined in the existing literature.

Previous study [7] has demonstrated that the participation of electricity prosumers in EComs significantly increases the SCR of renewable energy sources. Additionally, findings suggest that engagement in the NBS can be more economically beneficial than traditional electricity trading mechanisms. Despite these insights, a gap remains in understanding the economic justification for ECom development under different configurations of prosumers and consumers, as well as the role of SCR in influencing key financial indicators.

To address this gap, this study evaluates the economic feasibility of Latvia's EComs under the NBS, with a particular emphasis on the impact of taxation and tariff policies on SCR. The key objective of this paper is to analyse how Latvia's NBS framework affect the financial viability and operational structure of EComs.

The feasibility analysis quantifies key financial indicators, including net present value (NPV), payback period and internal rate of return (IRR). The findings provide a basis for the strategic development of electricity sharing and ECom configurations in Latvia, aiming to enhance their economic viability within the national legal framework and climatic conditions. Additionally, this study seeks to contribute to the broader discourse on ECom models by offering insights applicable to other countries with similar regulatory structures, fostering further exploration of innovative electricity-sharing mechanisms.

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II. METHODOLOGY OVERVIEW

A. PV potential and generation

To evaluate PV potential and electricity generation, this paper follows an approach based on real PV system data and energy modeling techniques. The assessment incorporates historical consumption data, solar irradiation levels and system efficiency parameters. The PV generation is estimated using the specific generation value per installed kW, derived from empirical observations and validated through the SolarEdge Monitoring Platform [8]. The installed PV capacity for each prosumer is determined based on their annual energy consumption patterns and legislative constraints.

B. Self-consumption rate

The SCR model assesses the proportion of generated electricity that is consumed on-site. This model integrates multiple consumer profiles and PV, considering both individual and ECom configurations. The calculations are based on monthly consumption and generation values, aligning with Latvia's net billing system regulations.

C. Net Billing system

The recently introduced NBS in Latvia marks a significant change in the remuneration of electricity fed into the grid by the electricity prosumer by replacing net metering system. As of March 1, 2024, the billing period aligns with the calendar year, running from March 1 to February 28/29, to better reflect electricity consumption and production cycles. Under this system, electricity fed into the grid is monetised based on NordPool market prices [3]. Households and businesses must consume at least 80% of their generated electricity annually to participate in the NBS. If annual SCR falls below this threshold, electricity prosumers are required to register as electricity traders and adhere to the associated regulations without the possibility to participate in the NBS.

D. Total electricity costs and economic assessment

Billing regulations vary across countries, allowing electricity prosumers to select the most suitable option from the available frameworks. In many cases, electricity costs depend on fixed charges, consumption patterns, market electricity prices and additional tariffs like distribution and transmission services. In the case of Latvia, the total electricity cost consists of several components: the electricity price, which depends on the selected tariff plan (economic, dynamic, stable, etc) [9] and consumption; the transmission and distribution service tariffs, covering the cost of delivering electricity to the consumer's connection point, including a fixed part for maintaining connection capacity (based on technical parameters like the number of phases and nominal current of the input circuit braker) and a variable part based on actual consumption (€/kWh); and the VAT. Most connections have two available distribution tariff plans: "Basic" and "Special," which differ in the proportion of fixed and variable costs. The most suitable tariff plan depends on the monthly electricity consumption. [10]

For the EComs' SCR analysis and scenario evaluation, a feasibility study is conducted, where key economic criteria include NPV, payback period and IRR. Detailed calculation equation of these parameters can be found in [11]. However, it is important to note that calculating NPV requires determining avoided costs (hereafter referred to as profit) for different cases, comparing an individual electricity prosumer and an ECom. For the base scenarios, profit is defined as the difference between electricity costs in the absence of renewable energy technologies and electricity costs when renewable energy technologies (in our case, PV) are installed. In the case of ECom scenarios, profit is determined by the difference between the total electricity costs of individual electricity prosumers and the electricity costs of the entire ECom. Additionally, the accumulation of cash remaining at the end of the NBS period is also considered as part of the profit and is included in the NPV calculations.

While the detailed equations and methodology have been extensively described in prior work [7], this study provides a structured application of these principles, enabling an accurate assessment of renewable energy self-consumption potential.

III. CASE STUDY

Through a detailed analysis of various load consumption profiles and different ECom scenarios from [7], the findings of the previous publication demonstrated that combinations of residential and educational electricity consumption profiles, as well as residential and commercial profiles, offer better SCR improvements. These configurations form the foundation for the economic assessment of SCR presented in this paper.

In the case studies, small wind turbines were not considered due to regulatory and environmental constraints. The installation of wind turbines requires obtaining permits from local municipalities, ensuring compliance with building and zoning regulations [12]. Additionally, noise and vibration standards must be met to prevent disturbances in urban areas. Environmental concerns, particularly the impact on bird populations, are also under review, with new guidelines being developed [13]. These factors make small wind installations less practical for widespread adoption in Latvia.

A. Objects under review

For this study, we randomly selected in the database [14] three types of load profiles from commercial (*C*), residential (*R*) and educational (*E*) sectors. The residential profile is always considered as an electricity prosumer (R_{act}), while the commercial and educational can act either as electricity prosumers or consumer. We analysed eight scenarios of ECom configurations, along with three baseline scenarios where each category operates individually as an electricity prosumer.

The analysed scenarios and their combinations are as follows:

- Scenario 1: $R_{act}+C_{act}$,
- Scenario 2: $R_{act}+E_{act}$,
- Scenario 3: $R_{act}+C_{act}+E_{act}$,
- Scenario 4: $R_{act}+C$,
- Scenario 5: $R_{act}+E$,
- Scenario 6: $R_{act}+C+E$,
- Scenario 7: $R_{act}+C_{act}+E$,
- Scenario 8: $R_{act}+E_{act}+C$.

The base scenarios are as follows: R_{act} (base scenario *R or* 9th scenario), C_{act} (base scenario *C or* 10th scenario) and E_{act}

(base scenario *E or* 11th scenario). R_{act}, C_{act} and E_{act} refer to electricity prosumers of residential, commercial and educational load profiles, respectively, while *C* and *E* represent customers with commercial and educational load profiles.

B. Assumptions

The following limiting conditions and assumptions were considered:

- The billing period of the NBS is retained in compliance with the existing legislation [3], i.e., from 1 March till the last day of February.
- The dynamic electricity price plan tariff is chosen.
- The Basic-1 distribution tariff is applied.
- Photovoltaics (PV) efficiency decreases by 0.80% annually. [15]
- The assumed planning period of the PV equipment is 20 years.
- Nord Pool market electricity prices are used. [16]
- NPV is calculated for two alternatives: in Alternative 1, it is assumed that a loan is taken for the purchase of PV equipment, whereas Alternative 2 with no loan.
- Operation and maintenance costs for PV system are assumed 1.2 % annually from the initial costs. [17]
- The loan interest rate is assumed in accordance with the interest rates laid down by the Swedbank of Latvia, i.e., 5.9% per annum. [18] Loan period is 5 years.
- The discount rate is assumed to be 10.8%. [19]
- Microgenerator owners (electricity prosumers) can sell surplus electricity to traders without adding value-added (VAT) registration, as long as their sales stay within the legal limits [20]. However, when electricity prosumers or consumers buy electricity, they pay the standard VAT (21%) included in the price, as set by the supplier.
- A flat 25.5% [21] personal income tax on most income types, including wages, business profits and capital gains is applied.

The methodologies for calculating PV potential and electricity generation, along with the description of the SCR model, are thoroughly detailed in our previous publication and are not reiterated here. The total capital investment is estimated using a unit cost of 641 €/kWh of installed PV capacity (minimum value applied from [22]). The required PV system capacities and corresponding capital expenditure (CAPEX) values are summarised in Table I.

TABLE I. DATA ON PV INSTALLED CAPACITY AND CAPEX

Objects	**Private house (*R*)**	**Office (*C*)**	**Kindergarten (*E*)**
Installed capacity of PV, kW	6.3	39	37
CAPEX*, €	3786.3	23439	22237

*The support system is available for electricity prosumers with a SCR of at least 80%. In this case study, due to national regulations only the residential qualifies for this support (2,800 €) [23] in Scenario 4-8.

Table II presents the differentiated tariffs for electricity distribution system services applicable to selected load profile categories.

TABLE II. DIFFERENTIATED TARIFFS FOR ELECTRICITY DISTRIBUTION SYSTEM SERVICES

Category of load profile	**Nominal current of the input circuit braker, A**	**Distribution tariff (consumption-based tariff), €/kWh [24]**	**Distribution tariff (fixed capacity tariff), €/annually**
Private house (R)	25	0.0479	24.75
Office (C)	63	0.0479	62.37
Kindergarten (E)	63	0.0479	62.37

*Each object is connected to a 0.4 kV three-phase line under the Basic-1 tariff. The tariff values already include VAT.

C. Results

The Fig.1 presents the SCR results of all calculated scenarios. The calculations show that individual electricity prosumer R_{act} with installed PV system achieve an SCR of 77%, while C_{act} and E_{act} customers reach 60%, and 61% accordingly. These individual rates are all below the required 80% threshold. In scenarios where all participants are electricity prosumers (scenarios 1-3), the SCR drops to 62-63%, showing that combining multiple electricity prosumers does not effectively increase SCRs. However, scenarios that involve combining different customers (scenarios 4-5), such as electricity prosumer R_{act} with *C* or *E* electricity consumers, achieve a 100% SCR. The electricity prosumer fulfils the necessary requirements of the NBS, while the consumers receives surplus electricity (at the moment, when the internal sale of electricity in the ECom in Latvia is prohibited, this can be, e.g., the second real estate of the electricity prosumer [3]). Mixed scenarios with two electricity prosumers and one electricity consumer (scenarios 6-7) also show improvement, with SCR levels rising to 82-83%, which is above the required threshold.

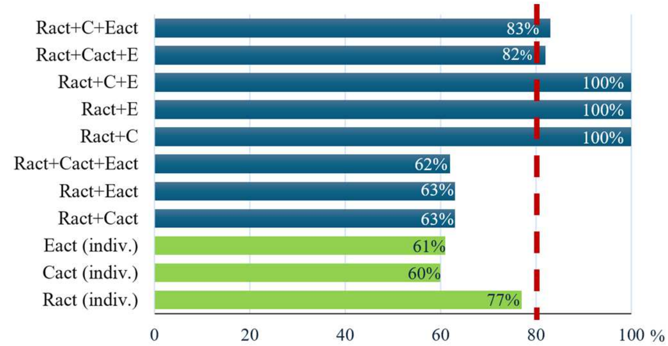

Figure 1. SCR: individually and within ECom configurations

Table III provides the overview of the results of electricity consumption, generation and profitability, highlighting the impact of different ECom configurations on self-consumption, profits, the exchange of electricity between ECom and the power grid. In scenarios 1 to 3, where all participants are electricity prosumers, total electricity consumption ranges from 62,170 kWh to 118,022 kWh, with significant reliance on grid electricity, accounting for 73% to 75% of total consumption. The excess electricity fed into the grid varies between 38% and 45% of total generation, resulting in final profits ranging from 1,103 € to 2,104 €, mainly driven by high electricity generation. In contrast, in scenarios 4 and 5, grid dependency remains high at around 91% to 95% of total consumption, and excess electricity export is minimal (0.4%–0.6%), leading to lower profits between 333 € and 338 €. In scenarios 6 and 7, which integrate one consumer and two prosumers, the grid reliance is reduced to approximately 79%–80% of total consumption. The surplus electricity exported to the grid is around 38%–39% of total generation, obtaining final profits between 1,646 € and 1,784 €.

The results indicate that as SCR increases, the amount of surplus electricity fed into the grid decreases, leading to lower profits. However, this does not necessarily imply a financial disadvantage. In scenarios where the SCR exceeds 80%, a larger share of the generated electricity is directly consumed, reducing reliance on grid electricity purchases. Consequently, while direct profit from surplus electricity sales is lower, overall electricity costs are also minimised. This is because, in high-SCR scenarios, customers only need to pay the distribution of fixed capacity tariff, rather than distribution consumption-based tariff. Furthermore, the following NPV graphs (Fig. 2-3) and IRR graph (Fig. 4) clearly illustrate the scenario payback period and the financial viability.

TABLE III. RESULTS OF THE CASE STUDY*

Scenario No.	ECom configuration	Electricity consumption, kWh	Electricity generation, kWh	SC, kWh	Amount of imported electricity from the grid, kWh	Amount of electricity fed into the grid, kWh	Profit**, €
1	*Ract+Cact*	64909.77	41067.77	17784.52	47125.25	23283.25	1103.00
2	*Ract+Eact*	62169.81	39334.22	16112.87	46056.94	23221.35	1133.30
3	*Ract+Cact+Eact*	118022.05	74671.38	32107.01	85915.04	42564.30	2104.09
4	*Ract+C*	64909.77	5730.61	5478.41	59431.36	252.20	333.50
5	*Ract+E*	62169.81	5730.61	5359.10	56810.70	371.51	335.46
6	*Ract+C+E*	118022.05	5730.61	5721.14	112300.92	9.47	338.00
7	*Ract+Cact+E*	118022.05	41067.77	24480.95	93541.10	16586.82	1645.78
8	*Ract+Eact+C*	118022.05	39334.22	23952.96	94069.09	15381.26	1783.68
9	*Ract*	9057.53	5730.61	2305.84	6751.70	3424.77	279.75
10	*Cact*	55852.24	35337.16	14881.39	40970.85	20455.77	1326.82
11	*Eact*	53112.28	33603.61	13309.45	39802.83	20294.16	1036.51

* All data presented in the table correspond to the first calculation year. **The profit values have been calculated after deducting personal income tax.

The payback period for the CAPEX of PV equipment for each scenario vary significantly: from 4 to over 20 years. The highest NPV is reached in Scenario 6 (R_{act}+C+E, no loan is taken), namely, 1659.70 €. The payback period is four years. NPV curves for Scenarios 4, 5 and 6 are difficult to distinguish, as they exhibit very similar values (NPV values around 1615-1659 € (without a loan) and 743-787 € (taking a loan)) and overlap on the graphs. The lowest NPV is reached in Scenario 3 (R_{act}+C_{act}+E_{act}, a loan is taken), namely, -80969.60 €.

The IRR analysis shows that only Scenarios 4, 5, and 6 are financially viable, with IRRs of 32.0%, 32.7%, and 33.1% (without loan) and 18.0%, 18.1%, and 18.4% (with loan), all exceeding the 10.8% discount rate. The results highlight that EComs with mixed consumer types provide the highest financial returns.

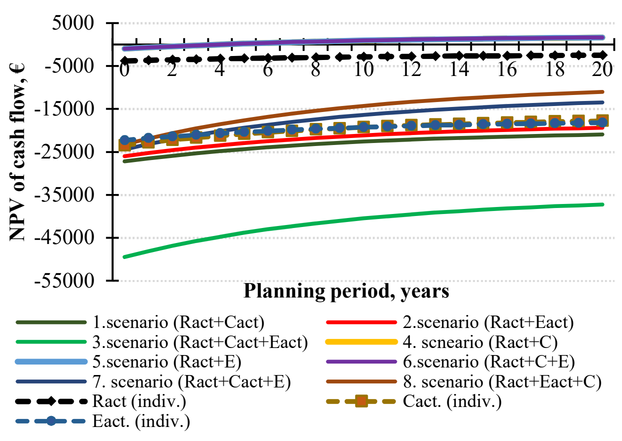

Figure 2. NPV cash flow (without a bank loan)

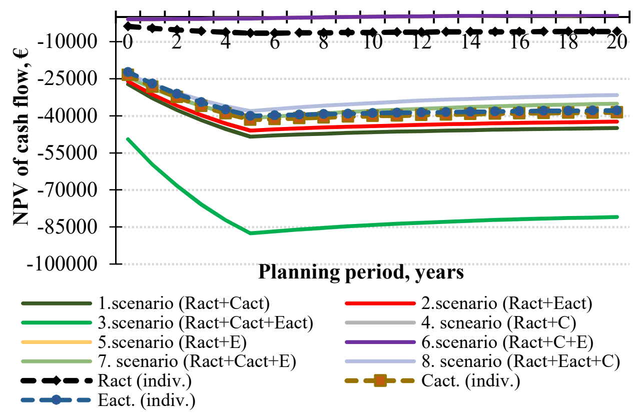

Figure 3. NPV cash flow (bank loan is taken)

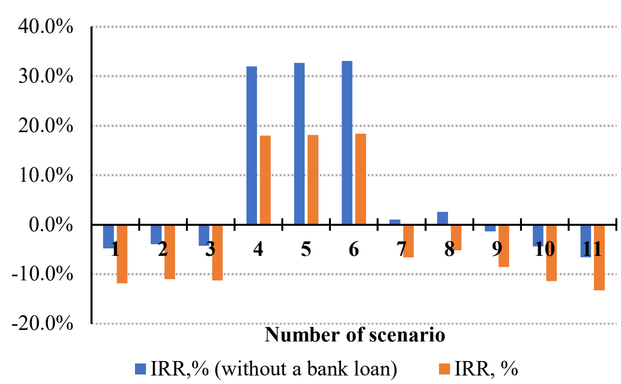

Figure 4. IRR results

CONCLUSIONS

The findings indicate that EComs with a combination of electricity prosumers and consumers, as well as diverse energy profiles, offer an effective approach to maximising SCR and ensuring compliance with NBS requirements.

The economic performance of different ECom configurations was primarily affected by the alignment between electricity generation and consumption, grid dependency and surplus electricity export. Scenarios 4, 5 and 6 with a mix of electricity prosumer and consumers demonstrated the best SCR (100%) and economic parameters (e.g., Scenario 6 with an NPV of 1,659.7 € without a loan and payback period of 4 years). Mentioned scenarios benefit from a well-balanced energy flow, where electricity consumers, representing commercial and educational load profiles, efficiently utilise excess PV generation from residential prosumer, reducing surplus exports and increasing SCR. In contrast, fully prosumer scenarios (Scenarios 1-3) lead to high surplus electricity exports (up to 45%) and low profitability, as seen in Scenario 3, which had the worst financial outcome (-80,969.6 € NPV with a loan and payback period over 20 years) due to excessive surplus generation and low SCR. Scenarios 7 and 8, which included two electricity prosumers and one electricity consumer, improved SCR (~82-83%), but still faced financial challenges from surplus electricity exports. These findings confirm that economic success depends on minimising surplus electricity fed into the grid.

However, the practical implementation of EComs in Latvia faces several challenges. The economic assessment also shows that under a high discount rate—reflecting both national policy and investment risk—the majority of ECom configurations result in marginal or negative NPVs, especially in fully prosumer cases. Moreover, high investment costs, along with technical constraints, can hinder project development. Additionally, distribution tariffs, especially the fixed capacity fee, remain payable even with high SCR, limiting cost savings. Only when SCR exceeds 80% can participants avoid the more expensive consumption-based tariff, slightly improving profitability.

Regulatory adjustments, such as allowing internal electricity trading and simplifying administrative barriers, would enhance ECom feasibility, while financial support mechanisms like preferential loans, grants and tax incentives could help overcome high upfront costs. Implementing demand flexibility mechanisms, such as adjusting electricity usage to align with peak PV generation hours, can further improve SCR of EComs.

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