POTENTIAL OF RENEWABLE ENERGY COMMUNITIES IN LATVIA'S ENERGY SECTOR TRANSFORMATION

Ivars Kudrenickis, Gaidis Klavs, Janis Rekis
Institute of Physical Energetics, Latvia
ivars.kudrenickis@lu.lv, energy@edi.lv, janis.rekis@gmail.com

Abstract. Renewable energy communities (REC) are one of the instruments to increase uptake of renewable energy (RE) sources. The EU policy underlines the necessity of citizen wide involvement in the energy system transformation processes to meet the renewable energy (RE) targets. In the article, the energy community is understood as mostly locally-rooted form of co-operation in order to jointly use RE sources with the aim of producing RE dominantly for collective self-consumption and providing socio economic benefits for REC participants and particular local areas. The article estimates the potential of the households regarding rooftop solar photovoltaic (PV) uptake in Latvia. Evaluation is based on the cascade approach: starting with the technical solar PV potential, housing type analysis, then estimating the financial capacity of households and household investments statistics, finally the household willingness to invest in joint energy production is considered. As a result, REC potential to attract additional household investments to increase solar PV electricity production is calculated in the range from 43.69 MEUR to 87.42 MEUR. The REC potential to scale up RE in power generation is calculated for 76.6 GWh electricity in 2030, or 11.6% of the additional electricity from solar PV installations planned in the national energy-climate plan scenario. REC facilitating is understood as one of the policy wheels of municipal sustainable energy and climate action plans. By applying the regional model for climate change mitigation measure impact evaluation, the potential contribution of REC in greenhouse gas emission reduction and providing socio economic benefits for both REC participants and municipality are evaluated at the city level.

Keywords: energy communities, modelling, private investments, solar photovoltaic.

Introduction

The European Union (EU) climate-energy policy sets the aim ensuring challenging renewable energy (RE) share in EU gross final energy consumption in 2030 – at least 42.5% endeavouring to increase it up to 45%. Participating in the collective efforts of the EU member states, Latvia will also have to significantly increase the share of RE in final energy consumption - up to 60%. The envisaged Latvia's RE share in the electricity consumption is around 70% (several alternative scenarios had been modelled resulting in the RE share varying 67-70% [1]).

The EU energy policy requires the citizen involvement by transforming them from passive energy users to active energy self-producers (prosumers) as a highly important instrument for uptake of RE sources. Based on the successful experience of energy co-operatives in "old" EU states, particularly, Germany, the Netherlands, and others, the concept of renewable energy community (REC) has been included in the re-casted Renewable Energy Directive [RED II, 2] in 2018, while the Internal Energy Market Directive [3] includes the concept of citizens energy community. REC is understood as a provider of environmental, economic or social community benefits for its participants or for the local areas where it operates. Re-casted Energy Performance of Buildings Directive [EPBD, 4] provides that one of options to cover any very low residual amount of energy still to be required for the zero-emission building is the supply of energy from REC. Re-casted EPBD provides for solar energy uptake in buildings, and at the same time the EU Solar Energy Strategy [5] concludes that rooftops have been the place for most of the solar energy deployment so far, but huge untapped potential remains and envisages as the indicative target setting up at least one REC in every municipality with population more than 10000 by 2025. Currently more than 9000 energy communities already operate in EU acting for smart, decentralised, flexible generation and consumption [6], during the last five years the number of energy communities has tripled, in 2019 the Horizon 2020 project RESCOOP MECISE accounted for around 3500 renewable energy co-operatives [7].

In Latvia, in 2022 and 2023 the installed solar photovoltaic (PV) capacity in single-family buildings considerably increased, to a great extent due to availability of state support programmes, net metering system, as well as the rise in the electricity price. In 2021, only 7 MW solar PV (total commerce sector and households) operated. In its turn, the total number of household microgenerators (capacity up to 11.1 kW) connected to the power distribution system at the end of 2023 was around 19 000, with the total production capacity close to 160 MW [8].

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Meanwhile the collective forms of solar PV ownership in Latvia are not yet in operation, though the REC legal status and principal operational procedures are stated by the Energy Law [9] and the Electricity Market Law [10], a full national legislative framework, including the relevant governmental regulations, is not yet finished. The completeness of implementing key provisions stated by RED II that apply to REC are analysed in [11].

Why is it important to develop also collective prosumerism, not only the individual one? In case of REC the power generation is optimized for its participant aggregated consumption. Besides the economic, social and/or environmental benefits REC, particularly if consisting of diverse participants, may provide a smooth load profile within the area, without overloading the power distribution grid and decreasing the necessary investments for the grid development. Impact on the distribution grid relates to the three following key parameters characterising the grid operation: annual losses in the grid, loading of each branch (the maximum loading registered on the network and the number of overloaded elements) and the voltage profile. REC is seen as one of the instruments to provide the flexibility services for the grid [12-15]. Last, but not the least, REC is considered as the attractor of additional private investments.

The motivation and willingness of households to engage in collective energy production is investigated in a range of studies. For instance, [16] provides "a comprehensive review of the scientific literature and a survey of 1000 German households indicating that an economically driven majority of potential participants of energy communities can be attracted by cost-oriented arguments. On the other hand, a substantial number of interested individuals can be attracted by social value propositions". In its turn, as a result of the on-line survey [17], three different reasons have been identified: (1) preferring and following an environmental and sustainable lifestyle, (2) getting together and carrying out RE projects that would not come true without collective efforts, and (3) REC offers some type of income for initial investments together with providing renewable electricity; next, the research concludes "consequently, being a green investment is an important motivating factor for becoming a REC member". The recent study [18] shows "that when purchasing rooftop PV, households incorporate both private financial benefits and other non-financial and societal impacts in their decision-making. The operational costs (immediate financial savings and hedging against future energy prices) were the most important variable to the respondents. The results suggest that homeowners regard PV as part of the solution to their complete energy system. Environmental considerations play a moderately important role".

Some insight into the motivation of Latvian residents can be given by the representative surveys by SKDS [19], the latest conducted at the end of 2023. The majority of respondents (78%) support the transition to wider use of RE in Latvia, important, in the age groups up to 24 and up to 34 years the idea is supported respectively by 91% and 84% of respondents. In its turn, 73% of the respondents agree that the decentralization of electricity generation is essential in order to reduce risks of a complete blackout in case of critical situations. Under equal price, 71% of respondents would prefer renewable electricity. Regarding electricity generation, the most important factor is the final price of electricity noted by almost 60% of respondents.

The rooftop solar PV potential (all buildings) for EU-28 countries is evaluated in [20], for Latvia the technical annual potential is evaluated as 1.43 TWh, corresponding to 22% of the annual average (2018-2022) final electricity consumption. In its turn, we have calculated 0.59 TWh total annual rooftop solar PV potential of multi-apartment buildings (calculation based on total floor area, applying the roof/floor area ratio factor 0.23 and the roof suitability factor to install solar PV technologies 0.4). The technical operation aspects of rooftop solar PV installation in a five-storey (60 apartments) multi-apartment building [21] prove economic viability of grid-connected rooftop PV systems within Latvia urban setting.

Materials and methods

To evaluate the potential of household-participated REC, the cascade approach based methodology has been used, developed by the Technical University Eindhoven [22]. Based on the average size of households [23], annual gross disposable income of households per capita, household investment rate [24] and the share of investment in RE production technologies, the theoretical upper limit of household investments was determined, on assumption that every household will actually invest. Regarding the investments in RE production technologies, we use the share of 4% of the total household investments. Such cautious assumption is based on the fact that among the overall energy related investment, energy efficiency investment dominates and investment in RE technologies is still lagging behind [25].

In this article we consider only households in multi-apartment buildings to be interested in collective energy production investments, as the single-family buildings most probably will invest in individual prosumerism. Latvia's multi-apartment buildings contribute to around 71% of total dwellings.

Continuing, the socio-economic investment potential based on the percentage of households that would like potentially to invest in collective RE projects is estimated. It should be noted that the willingness to invest in collective production will be lower than the overall recognition of green electricity.

Regarding the maximum (latent) potential to invest in collective energy production we have used the results of several studies [26, 27] which evaluate the share of "rather yes/likely" participation in energy communities by up to 40% of respondents. Interest to invest in prosumerism also correlates with the electricity consumption of the particular household. For more than 30% of Latvian households the annual electricity consumption [28] exceeds 2000 kWh. Thereby, we assume 30% of households in multi-apartment buildings as the cautious latent potential.

For the minimum potential to invest in collective energy production we use the Latvia's results (600 respondents) of the experiment conducted in all EU-28 countries [29] regarding the willingness to invest in community-administrated wind farms (20-years holding period, market-based profit rate, visible), the willingness to invest is evaluated at 14.7% (no particular survey regarding solar PV technologies available). The non-representative survey (129 respondents, [30]), indicating 15.5% respondents would participate in community wind farms, matches well the above-noted choice experiment. Thereby, we assume 15% of households as the minimum potential.

Based on the specific investment rate (EUR/kW) and the annual full load hours, the calculated total investment is transferred to the installed capacity and annually produced electricity. The calculated electricity production, potentially to be provided by RECs, is compared with the national political commitments for 2030 regarding renewable electricity production. Understanding REC as the instrument to attract additional private investments, we estimate also the potential share of RECs in total investments required for new RE production capacity.

Although traditionally RECs are mostly involved in the electricity production from RE sources, they can also engage in a range of other activities, including energy efficiency improvement in buildings. In order to assess the contribution of RECs, to be established in the territory of a particular municipality, in reducing greenhouse gas (GHG) emissions and thus providing input for local political commitments (e.g. set by the municipality sustainable energy and climate plan), the scenarios of RECs activities in solar PV installation and renovation of apartment buildings are evaluated. A city with about 80 thousand inhabitants has been chosen for this assessment. A regional model created by the Institute of Physical Energetics, which calculates GHG emissions for the municipal/city level and evaluates the impacts of different GHG emissions reduction measures, has been used for the evaluation. In turn, extensions of the model allow to calculate socio economic impacts like economical savings for REC participants, new workplaces and additional tax income.

Results and discussion

Using the Eurostat data regarding 2022, adjusted gross disposable income of households per capita (18 018 EUR) and household investment rate (4.4%), considering 4% share for investment in RE 497.3 EUR investment per household in RE production technologies per 2024-2030 period is calculated. The calculated different investment potentials are presented in Table 1.

Contribution to national renewable electricity target

NECP2030 [1] envisages to produce 6.47 TWh renewable electricity in 2030. Taking into account the currently installed renewable electricity production capacities and their potential to generate power, it can be concluded that about 2.5 TWh is missing to meet the 2030 target.

Filling the gap to a great extent depends on the expected large scale wind park development in Latvia, moderate (600 MW new capacity with 1.38 TWh annual production) and active (800 MW new capacity with 1.84 TWh annual production) wind energy scenarios are projected. One can see, in both scenarios the gap in renewable electricity production will still exist in 2030.

Table 1

Step-by-step investment in renewable energy production technology calculation layout for 2024-2030 period

Parameter	Unit	Value
Total investment per household	EUR	12 432
Investment in RE production technologies per household	EUR	497.3
Number of dwellings in multi-apartment buildings	thousand	586
Theoretical investment potential in RE production (all households invest)	thousand EUR	291 398
Maximum (latent) socio economic investment potential in RE production (30% households invest)	thousand EUR	87 420
Minimum socio-economic investment potential in RE production (15% households invest)	thousand EUR	43 686

The "active wind energy" scenario is used in the further analysis to evaluate the REC contribution. We assume the necessary additional renewable electricity of 0.66 TWh in 2030 will be provided by solar PV, both small microgenerators preferably in households, and medium and large scale capacity installations in the commerce sector, see Table 2.

Table 2

Specific parameters of solar PV technologies used in calculation

Parameter	Microgenerators	Medium and large installations
Relative contribution in production of additional renewable electricity	45%	55%
Annual full load hours	1000	1050
Specific investment, EUR per kW_{peak}	1000	870

To evaluate the potential contribution of RECs in meeting the national renewable electricity target, four scenarios (2x2 matrix) are used, presented in Table 3. The scenarios consider the financing rates without (100% financing rate by citizens) and with the state support programme for RECs investments.

Table 3

Socio economic and financial scenarios for RECs contribution evaluation

Scenario	Socio-economic investment potential	Financing rate by citizens
Scenario 1	Minimum	100%
Scenario 2	Maximum	100%
Scenario 3	Minimum	43%
Scenario 4	Maximum	43%

The total necessary investment for solar PV installation in the active wind energy development scenario is around 600 MEUR. If compared with the potential investment by RECs, presented in Table 1, one can see that RECs may provide 7.3% and 14.6% of the required financial volume up to 2030, respectively, cases of minimum and maximum (latent) socio economic investment potential.

The calculated amount of electricity to be produced by RECs is compared with the required additional solar PV electricity in 2030. As shown in Figure 1, the contribution of RECs ranges from 6.6% to 23.2%. As most likely in the initial stage of RECs development in Latvia, the scenario of minimum socio economic investment potential and appropriate state support programme can be adopted, this scenario may contribute 76.6 GWh RECs produced electricity, or 11.6% contribution in covering the additionally required renewable electricity in 2030.

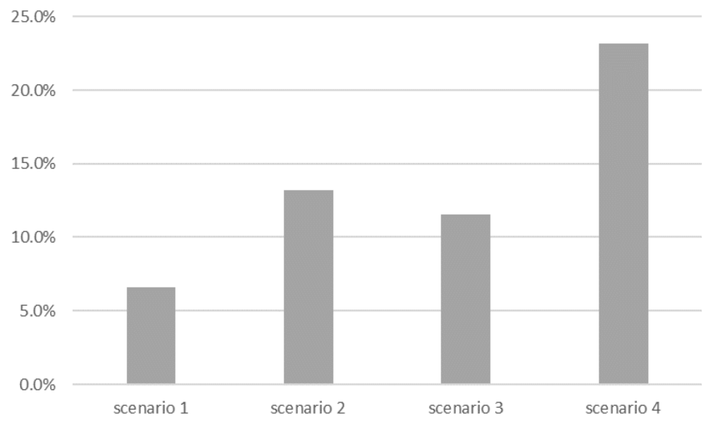

Fig. 1. **Calculated potential contribution of RECs to the required additional electricity production from solar PV for 2030**

Local environmental and socio-economic benefits

In the case of a city with the population of 80 000, the total financing, to be attracted by the apartment buildings residents established RECs, is calculated assuming that REC can qualify for state support programmes for both the renovation of apartment building and the installation of solar PV. Two scenarios are compared. In the first scenario REC performs both renewable power generation and energy efficiency improvement activities, while in the second one – only the energy efficiency improvement activities. The total investment in both scenarios is the same and amounts to 8.65 MEUR, total for the 7-year period of 2024-2030. The results show that in the first scenario REC attracted financing provides the opportunity to renovate around 2.6% of the total floor area of apartment buildings within the city, while in the second – around 3.5%. It should be noted that the potential contribution of RECs in the renovation of multi-apartment buildings is even slightly higher than the average annual rate of building renovation implemented until now within the state support programmes.

As shown in Figure 2, RECs greater contribution in reducing GHG emissions might be achieved in the scenario with both activities, assigning 75% of the total investments to building renovation and 25% to solar PV installations. In the first scenario, the solar PV installed by REC provides about 15% of the electricity consumption of the potential REC participants.

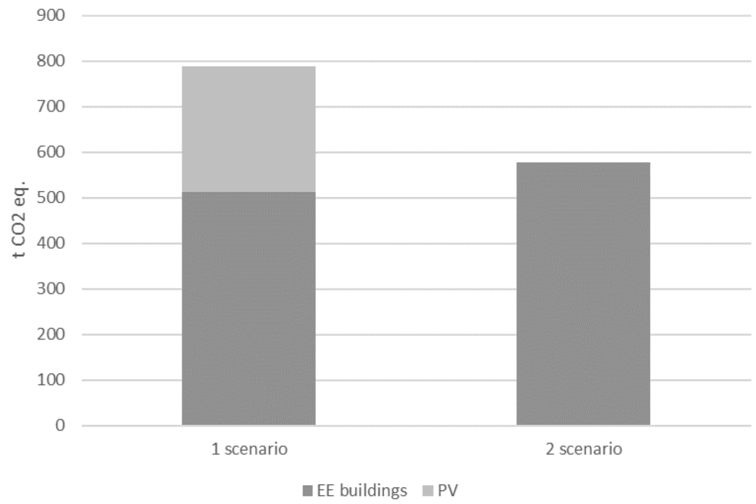

Fig. 2. **Estimated contribution of activities, implemented by REC for reduction of GHG emissions at the city level**

Changes in GHG emissions at the municipal level are also affected by the fact that heat energy is supplied to multi-apartment buildings dominantly by district heating systems, in which heat energy is produced by boiler houses and combined heat-power plants. By increasing the energy efficiency in buildings, the demand for heat energy is reduced and the amount of electricity produced in the combined heat-power mode is also affected.

In addition to GHG emission reduction, other socio economic benefits at the city level due to implementation of RECs activities have been calculated as well. The total annual economic benefit to RECs participants is about 303 000 EUR, consisting of benefits from saved heat energy and self-produced electricity. RECs activities create about 33 full time equivalent jobs and about 279 000 EUR tax payments.

Conclusions

1. Using the data of gross disposable income of households and household investment rate, by applying the cascade evaluation approach the multi-apartment building residents' potential for attracting private funds in the period 2024-2030 by establishing RECs has been estimated. The estimated investment ranges from 43.69 MEUR to 87.42 MEUR.
2. RECs established by residents of multi-apartment buildings can provide significant contribution to the increase of RE in power generation. REC, by investing both private financing of participants and attracted funding from state support programmes, can produce about 76.6 GWh electricity, or 11.6% of the additional electricity from solar PV installations planned in the national energy-climate plan scenario for 2030.
3. In the above REC development scenario around 13% of the total rooftop solar PV potential of multi-apartment buildings is utilised in 2030.
4. By applying the regional model for climate change mitigation measure impact evaluation, the contribution of RECs, established by residents of multi-apartment buildings, to the reduction of GHG emissions of the particular city with population of 80 000 is calculated. In case RECs perform both energy efficiency improvement in buildings and rooftop solar PV installation activities, GHG emission reduction goal of up to 800 tons of CO_2 equivalent might be reached. In addition, RECs' socio-economic benefits provided to their participants and the municipality have also been evaluated.

Author contributions:

Conceptualization, I.K. and G.K.; methodology, I.K. and G.K.; regional model, G.K. and J.R.; formal analysis and investigation, I.K., G.K., and J.R.; writing-original draft preparation, I.K. and G.K.; writing-review and editing, I.K., G.K., and J.R.; visualization, G.K and J.R. All authors have read and agreed to the published version of the manuscript.

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