ANALYSING THE IMPACTS OF AN EXTERNAL POWER SUPPLIER IN A RENEWABLE ENERGY COMMUNITY

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Abstract: Renewable energy communities (REC) offer the possibility of joint production and supply of renewable energy sources. This article presents the framework conditions of REC in Austria and comprehensively analyses the financial and ecological effects of an REC using a newly developed analysis tool. The results show positive financial and ecological effects of the REC being investigated by introducing an external power supplier. A sensitivity analysis was applied to evaluate all parameters used in the simulation model and to identify the key influencing variables which are the grid electricity price, the inflation rate and the discount rate.

Keywords: Renewable energy community, external power supplier, net present value (NPV), financial feasibility.

1 Introduction

With the „Clean Energy for all Europeans Package“ (CEP), the European Commission adopted a comprehensive package of measures in 2019 to pursue the transformation of the European energy supply system considering both the Paris Agreement of 2015 as well as the decarbonization (or defossilization) of the European economic system by 2050. [1]

Based on that, the Austrian government adopted the Renewable Energy Expansion Act (REEA) in 2021 with the goal declared therein to convert Austria's electricity supply to 100% electricity (on balance) from renewable energy sources by 2030 [2]. The REEA significantly expanded the options of joint usage of power plants by several parties in the same building and made the model of establishing energy communities legally possible. This new model basically created the option for associations of people to produce, store, consume and sell energy across property boundaries. In this legal basis, the implementation of a spatially limited renewable energy community (REC) is made possible. [3]

In Austria, the operation of and participation in an REC are regulated in the Electricity Act 2010 (Section 16c) [4] on the one hand, and in the Electricity Act (Section 79) on the other. The basis for this can be found at European level in Article 22 of the Renewable Energy Directive (RED II) [5], which states: "Member States shall ensure that final customers and in particular households (...) may participate in a renewable energy community (...)". This regulation is at the heart of the CEP. According to EAG § 79 (1), a CEP may generate, consume, store or sell energy without restriction. The energy used for this purpose must come exclusively from renewable sources. In addition, an REC may also act as an aggregator in the form of a service provider for the provision of energy.

Members of an REC can be natural persons, small and medium-sized enterprises, municipalities, legal entities of public authorities in relation to local offices and other legal entities under public law. Energy supply companies and large companies are excluded from an REC. The REC must consist of at least two members, with no upper limit on the number of members. Possible legal forms of the REC include co-operatives, combines, partnerships or capital companies. The main purpose of the REC must not be to make a profit, but rather to provide economic and environmental benefits for the REC's territory and its members. [2,3]

The implementation of an REC is only permitted within the boundaries of a grid operator's concession area. A consumer installation in the concession area of grid operator A and a generation installation in the concession area of grid operator B cannot therefore be part of the same REC. The above-mentioned geographical restriction of an REC therefore requires that all members of an REC must have a "geographical proximity" and must therefore be located in the same concession area. This "geographical proximity" is divided into a "local area" (local REC) and a "regional area" (regional REC). In a "local REC", all members must be located in the same low-voltage area and therefore in grid levels (GL) 6 and 7. In a "regional REC", however, members of a supra-regional low- and medium-voltage area (GL 4 and 5) can also be included. The main difference between a local and a regional REC is the extent of economic efficiency incentives, with comparatively higher incentives being provided for local REC. The input of smart meters (intelligent measuring devices) is a prerequisite and, within the REC, the free choice of electricity supplier by consumers must not be restricted.

In addition to the usual investment support for renewable energy sources, for example for the installation/construction of a photovoltaic system (PV) or the commissioning of an associated storage system, further financial incentive mechanisms are provided by law for the operation of an REC. These include the cancellation of the renewable energy subsidy, an exemption from the electricity levy and a reduction in the grid usage fee depending on the type of REC and grid level. For local REC in the local grid (GL 6 and 7), the grid utilization fee is reduced by 57%, for regional REC in the local grid (GL 6 and 7) by 28% and for regional REC in the medium-voltage grid (GL 4 and 5) by 64% compared to the applicable grid tariff [3]. This incentive structure therefore results in a lower electricity price for members of an REC compared to the standard electricity prices (see Table 1).

Table 1: Comparison of the main elements of the electricity price (own calculations)

	Standard (grid)		**REC regional**[1]		**REC lokal**[1]	
	ct/kWh	**%**	**ct/kWh**	**%**	**ct/kWh**	**%**
Energy price[2]	*23,89*	*65,47%*	*22,80*[5]	*68,84%*	*22,80*[5]	*73,58%*
Grid charges	*6,52*	*17,86%*	*4,80*	*14,49%*	*3,02*	*9,76%*
.. Grid utilisation fee[3]	6,13	16,80%	4,41	13,33%	2,64	8,51%
Taxes[4]	*6,08*	*16,67%*	*5,52*	*16,67%*	*5,16*	*16,67%*
.. VAT	6,08	16,67%	5,52	16,67%	5,16	16,67%
Total	*36,49*	*100,00%*	*33,12*	*100,00%*	*30,99*	*100,00%*

[1] NE 7, [2] Tarif „SteirerStrom Fix“ of Energie Steiermark (Stand 08/2023),[3] Summer high tariff (SHT), [4] excl. Renewable energy subsidy (2023 in Austria not levied), [5] own assumption

This article analyses in detail the financial and ecological effects of taking an external power supplier in a spatially limited REC in Austria into account, in which only renewable electricity is exchanged. [4,5]

2 Methodological approach

The methodology used for this contribution to techno-economically analyze a local REC in Austria is explained in detail below.

2.1 Dynamic distribution model

A new techno-economic analysis tool that was being developed enables the simulation and analysis of different REC constellations and scenarios.

Inputs

Within that analytical tool, a basic distinction is made between "consumer", "prosumer" and "power supplier", each of which has different characteristics. Consumers are typical consumers such as private households. Prosumers can have their own power production system in the form of a PV system as well as a storage system. An external power supplier, on the other hand, only feeds renewable energy into the REC with its production systems, which could be a wind turbine or a small hydropower plant in addition to a PV system. The central technical input parameters include a consumption profile, a generation profile, the corresponding annual totals for consumption and generation, the capacity of the storage system and a factor to consider the degradation of PV and battery storage over their service life. The economic parameters include the electricity price (grid and REC) and its components, interest rates for financing and discounting, inflation, investment, operating and maintenance costs, insurance costs and financial subsidies in the form of grants, supplemented by a CO2 emission factor for electricity generation to estimate the ecological effects.

Standard load profiles

Specified standard load profiles illustrate a representative temporal course of electricity demand and electricity generation for various consumer and generator groups. The performance is given as a 15-minute average value for an entire year. These standardized profiles are either created using real measurements or are synthesized based on past consumption patterns. This allows forecasts for future electricity consumption to be made in simulations. In the analysis tool, the load profiles synthesized by E-Control for the year 2022 were used [6], whereby the difference in consumption between neighboring years only differs in the time of consumption.

Consumption and generation

The synthesized load profiles, which are standardized to a consumption (or generation) of 1.000 kWh per year, are scaled up using the annual consumption and annual generation in order to reflect the real consumption of all members. For a household with a consumption of 3.500 kWh, a factor of 3,5 is therefore taken into account in the calculation for the profile standardized to 1.000 kWh, whereby the quarter-hourly values are scaled accordingly. The procedure for generation profiles for PV is similar. If a prosumer also has a storage system, this is filled when there is momentary overproduction. The surplus energy is stored and continuously drained again when PV production is lower than the demand. This increases the degree of self-sufficiency of this member.

Dynamic allocation

At the end of this calculation, each member has a net demand or surplus at any given time, which is exchanged with the REC. The distribution of the surplus among the members at any given time is determined by the stored dynamic distribution model. This calculation thus provides four central parameters: (i) the amount of electricity fed into the REC, (ii) the amount of electricity fed into the grid, (iii) the amount of electricity accepted from the REC and (iv) the amount of electricity accepted from the grid. These electricity quantities are multiplied by the corresponding electricity prices for the purchase within the REC and for a purchase from the grid, resulting in a comparison of revenues and expenses.

2.2 Financial valuation approach

Based on this, a comprehensive economic efficiency analysis of the REC is carried out, taking into account various technical and economic input variables. For this purpose, key performance indicators such as investment costs, net present value (NPV), amortization period or profitability of a PV system and a storage system are determined using the NPV method considering a period of 25 years. The NPV_m of a member m in a REC is defined as follows

$$NPV_m = I + \sum_{i=1}^{n} \frac{(R_i - E_i)}{(1+d)^i}$$

with investments I, annual revenues R and expenses E, a discount rate d, a point in time i (in years) and the duration n (in years). The revenues for prosumers include all indirect revenues in the form of cost savings due to own consumption and the resulting lower electricity consumption from the grid. This generates a positive effect for prosumers compared to other members of the REC and is reflected in key performance indicators such as the amortization period or the absolute/relative savings. The revenues also take into account the distribution of the profit generated by the REC among the members of the REC. Furthermore, the effects of the technical wear and tear of the PV systems and the storage systems are integrated over the period under review. The economic efficiency of the REC as a whole is calculated by summarizing the net cash values of the individual REC members, which can vary accordingly due to their different characteristics. Table 2 shows an overview of all revenues and expenditure categories for each member group of the REC under consideration.

2.3 Ecological aspects

In addition to the profitability analysis, ecological factors such as the degree of self-sufficiency or savings in direct CO_2 emissions of individual member groups and the entire REC are determined. While the degree of autarky is derived directly from the energy balance, suitable CO_2 emission factors for the Austrian electricity mix and for the electricity production of PV systems are used to determine the direct CO_2 emissions and their savings.

Table 2: Classification of revenue and expenditure streams by group of members of the REC under consideration (own illustration)

		Consumer	Prosumer	Power supplier
Revenues	Revenue REC (consumer), partial	X	X	
	Revenue REC (producer), partial		X	X
	Feed-in REC		X	X
	Feed-in grid		X	X
	Cost savings REC	X	X	
	Cost savings auxiliary use		X	
Expenses	Membership REC	X	X	X
	Electricity consumption REC	X	X	
	Electricity consumption grid	X	X	
	Maintenance of production system		X	X
	Maintenance of storage		X	

3 Results

The key results and findings of a modelled reflection and analysis of a local REC in Austria are explained in detail below.

3.1 Scenario definition

The scenario analyzed in this contribution is based on the constellation of a local REC in Austria. This REC consists of a total of 30 members, which are divided into 22 ordinary households, six businesses (three general commerces, two shops/hairdressers and one bakery) and two prosumers (one general commerce and another bakery). The exact constellation and characteristics of the members are listed in Table 3. Of particular importance are the assigned load and generation profiles, the annual consumption, the annual generation (if applicable) and the capacity of an (energy) storage system (if available).

Table 3: Constellation and calibration of the REC under consideration (own assumptions)

Type	Count	Profile[1]	Consumption (kWh/a)	Production (kWh/a)	Storage (kWh)
Business	3	G1	18.000	-	-
Prosumer	1	G2 E1	72.000	60.000	60
Business	2	G4	30.000	-	-
Prosumer	1	G5 E1	50.000	40.000	40
Business	1	G5	50.000	-	-
Household	22	H0	3.200	-	-
Total	*30*	-	*223.200*	*100.000*	*100*

[1] G1: Commerce weekdays 8-18 o´clock; G2: Commerce with heavy to predominant consumption; G4: Shop/Hairdresser; G5: Bakery (once as Prosumer, once as Consumer); H0: Household; E1: Production profile for (Source. Energie-Control Austria).

All assumptions for the calculations are listed in Table 4. A uniform discount rate is assumed for all members of the REC. The period under review in the study covers 25 years. The profit generated by the REC is distributed proportionally one third to the consumers and two thirds to the producers. Consequently, a prosumer receives a share of the profit as a consumer and additionally as a producer, while consumers only receive a share of the profit as consumers.

Table 4: Economical, ecological and technical modelling assumptions (own calculations)

Factors	
Discount rate (p.a.)	3,0%
Inflation rate (p.a.)	3,0%
Wear and tear for PV and storage (p.a.)	0,5%
CAPEX	
PV (40 kWp), less subsidy	1.540 eur/kWp
PV (60 kWp), less subsidy	1.367 eur/kWp
Speicher, less subsidy	1.300 eur/kWp
OPEX	
O&M (REC)	350 eur/a
O&M (PV)	300 eur/a
Ecological	
CO_2 (grid)	202 g/kWh
CO_2 (PV)	14 g/kWh
Prices and renumerations	
Feed-in tariff (grid)	9,63 ct/kWh
Feed-in tariff (REC)	18,00 ct/kWh
Electricity price (grid)	36,49 ct/kWh
Electricity price (REC)	30,99 ct/kWh

3.2 Financial feasibility

As mentioned above, the members of the REC have different synthesized profiles for both demand and production assigned, the choice of which has a significant effect on the simulation results. This constellation of the REC under consideration has been expanded by including an external power supplier to be able to analyze its economic and ecological effects in detail. In general, the consideration of an external power supplier with an annual production of 30.000 kWh using a PV production system proves to be beneficial to the REC but also to the power supplier [7].

Figure 1 summarizes several effects that arise due to an external power supplier having a fluctuating production system (such as PV) with an annual production of 30.000 kWh. Such a constellation proves to be beneficial for the prosumers of the REC under consideration. Due to the renewable energy production by the external power supplier, CO_2 emissions are reduced for all members of the REC. Also, the level of autarky increases for all members.

In comparison, Figure 2 shows the effects of an external power supplier with a constant production profile keeping everything else unchanged (*ceteris paribus*). As illustrated, the financial benefit for both prosumers is significantly higher. Overall, the CO_2 emissions would decrease and the level of autarky within the REC would increase.

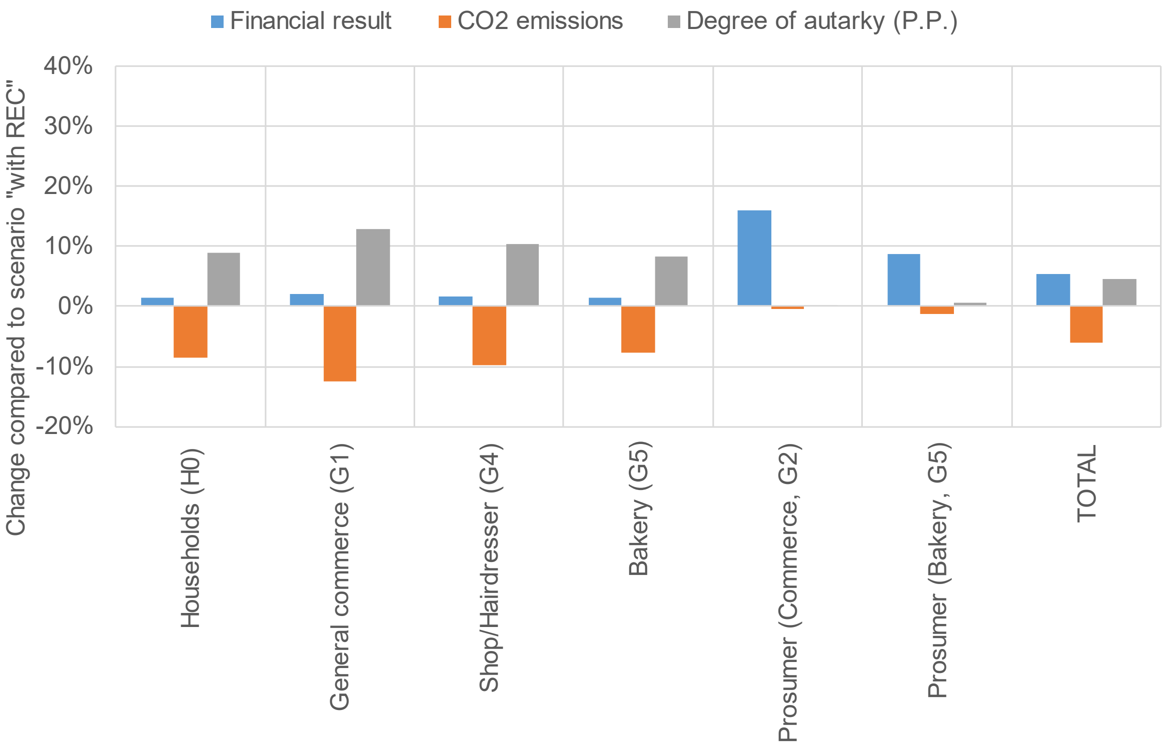

Figure 1: Effects with an external power supplier having a fluctuating production E1 (own calculations)

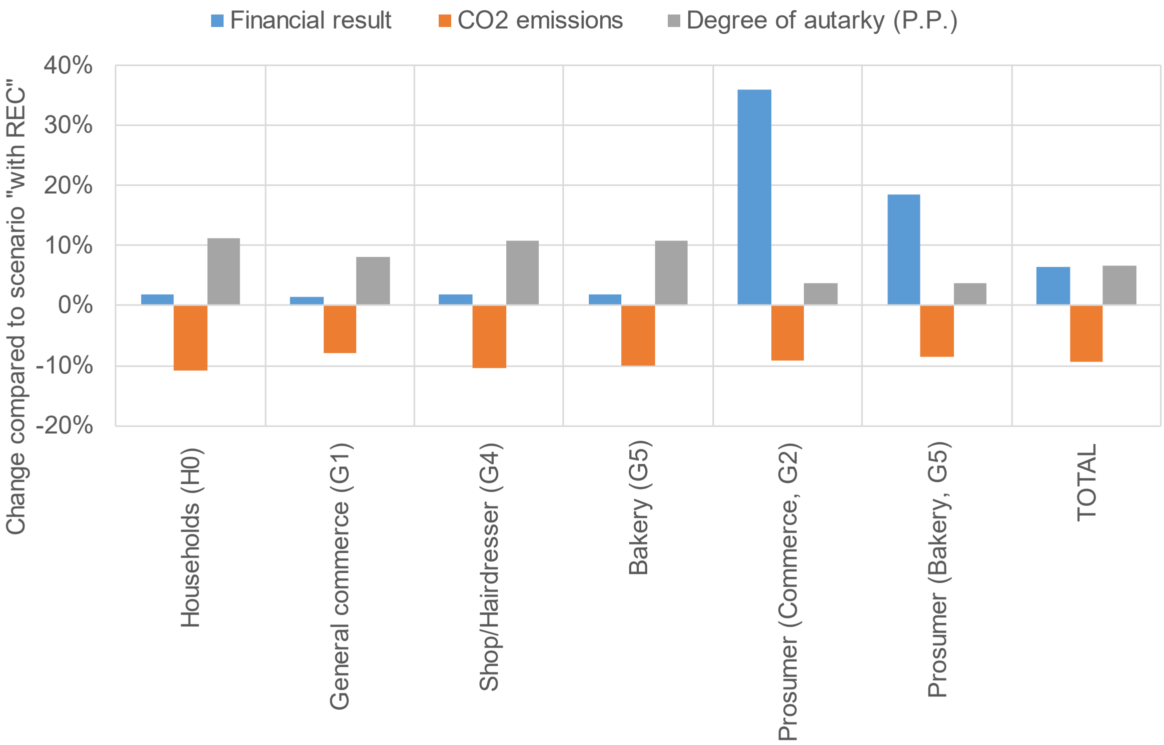

Figure 2: Effects with an external power supplier having a constant band production E0 (own calculations)

Figure 3 illustrates the effects with an external power supplier switching from fluctuating power production to constant band production for every single member of the REC. In this case, both prosumers would also be able to reduce their CO2 emissions due to the special constellation of load and production profiles within the REC.

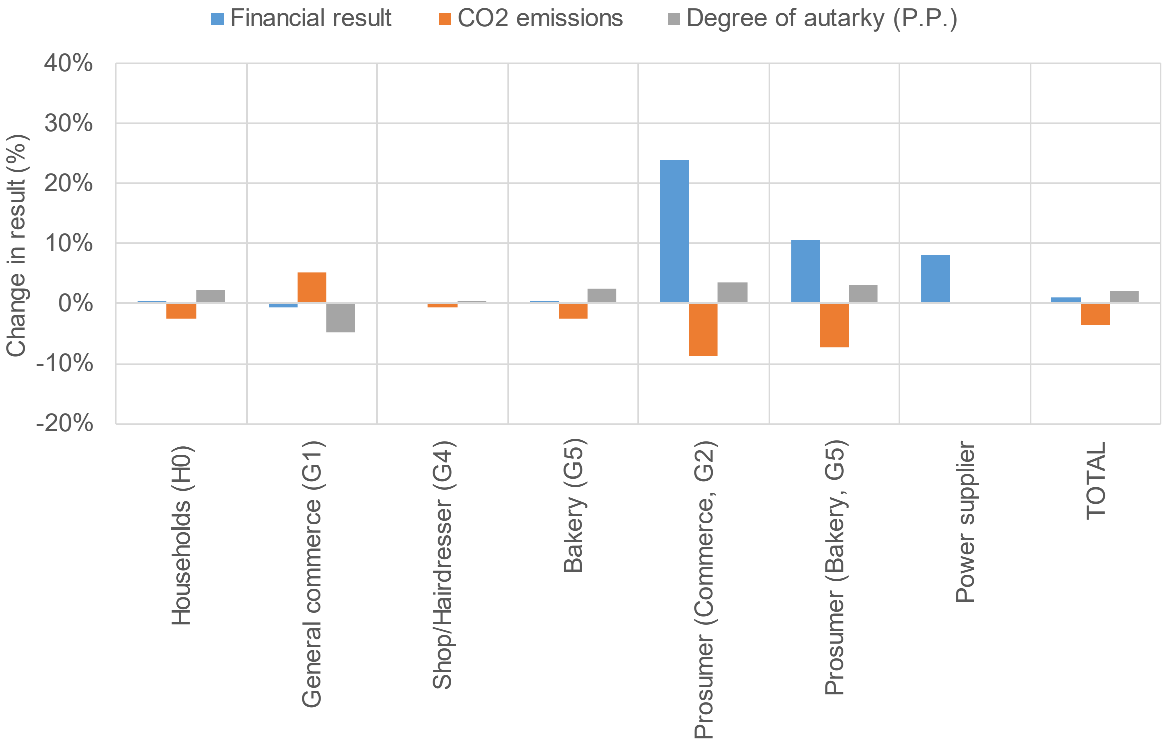

Figure 3: Effects with an external power supplier switching its load/generation profile from fluctuating production E1 to constant band production E0 (own calculations)

Finally, the external power supplier would also financially benefit in such a scenario. However, the amortization period for the external power supplier remains almost unchanged and would lie for both types of investment between 8 and 9 years assuming the same initial capital expenditure (CAPEX, or initial investment) and a uniform discount rate of 3%.

3.3 Sensitivity analysis

Sensitivity analyses are procedures to determine how sensitively a model calculation or an analysis reacts to changes in the parameters used in the methodology. For the NPV method described in this article, a sensitivity analysis is applied to analyze the extent to which the NPV is influenced by changes in the investment series such as changes in revenues and expenses. For this purpose, individual parameters are changed and the results of the investment appraisal are recalculated.

Figure 4 illustrates the results of a sensitivity analysis for the NPV of the overall REC using a sensitivity diagram considering an external power supplier having a constant-band production profile E0. All input parameters considered were changed by +/- 20% compared to the base calibration. A positive correlation (the more of these variables, the higher the NPV) is shown in particular by the discount rate, the production capacity of the external power supplier and the prosumer (P1) as well as the storage size of the prosumer (P1). The opposite, that is a negative correlation, is the case with the remaining input parameters such as the inflation rate, grid renumeration, electricity prices for REC and grid as well as the energy price for the REC. Interestingly, the remuneration within the REC proves to be a special case in that a change in this parameter only causes a redistribution effect within the REC. This means in this particular case that the overall effect for the REC is exactly zero.

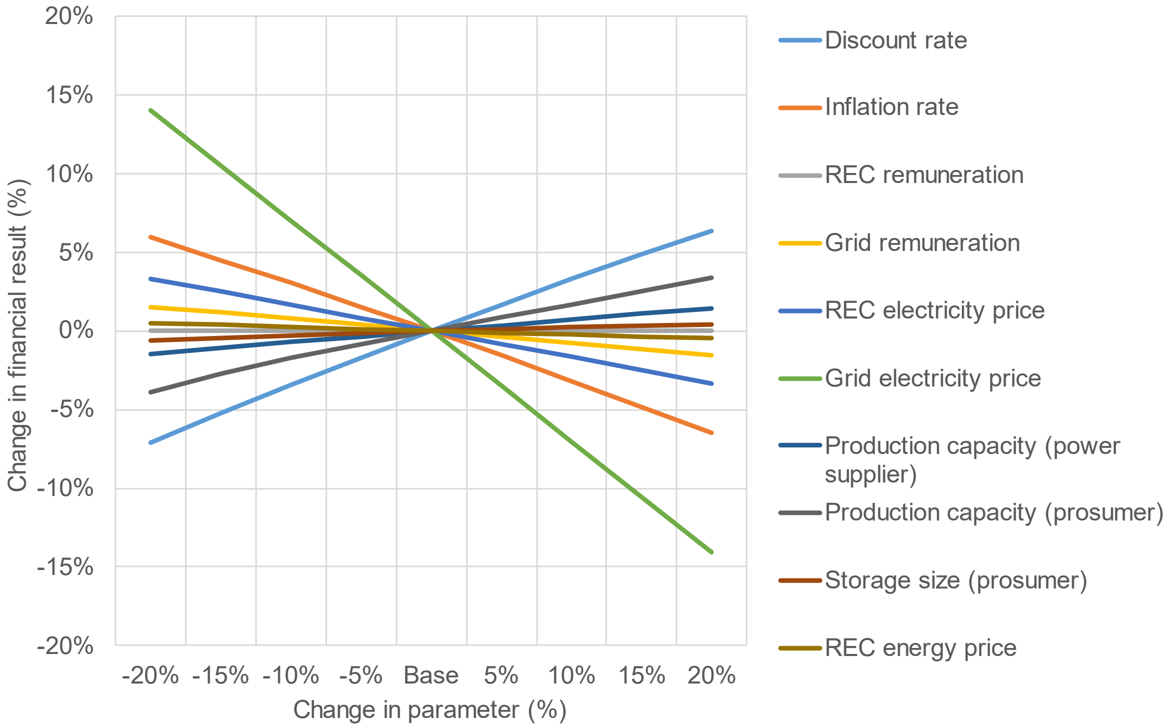

Figure 4: Sensitivity analysis for selected key parameters with respect to the financial result of the REC with an external power supplier having a constant load profile E0 (own calculations)

4 Discussion

Potential challenges and weaknesses of some of the assumptions made within this modelling approach are briefly discussed below.

A switch of the external provider's production capacities to a constant band production system is of course subject to a number of technical requirements as well as challenges. For the sake of simplicity, constant initial CAPEX were assumed, knowing that these initial CAPEX could possibly be higher for the external power supplier. This in turn would increase the amortization period accordingly keeping the production capacity constant.

The discount rate plays a special role, as it is the central factor in the overall NPV calculation. A lower discount rate increases the significance of future revenues and expenses and vice versa. For the sake of simplicity, a uniform discount rate is assumed for all members of the REC in this study. This uniform discount rate means that both revenues (for the prosumers and the external power supplier) and expenses (also for the consumers) are uniformly affected by a change in this variable. Interestingly, there is a positive correlation between the change in the uniform discount rate and the financial result of the REC. This is due to the fact that the discounting effects on expenses exceed those on revenues. However, it would be worth considering a variation in the discount rate according to the member groups of the REC.

Another parameter of particular importance in this modelling approach is the inflation rate. In economics, inflation (or price increase) refers to the increase in individual prices (or price level) in a country (or region) within a certain period. This modelling approach applies, for reasons of simplicity, a uniform inflation rate to all prices and remuneration over the entire period under review. This assumption has both advantages and disadvantages: a continuous inflation adjustment is not conclusive for all input variables such as the grid renumeration which is usually adjusted quarterly by the public sector using other factors. On the other hand, an annual inflation adjustment increases the price difference between (higher) electricity prices and (lower) feed-in tariffs (renumeration), from which only parts of the REC can regularly benefit. Prosumers in particular benefit from the latter through a continuous increase in the value of their own consumption which could theoretically create new incentives for the integration of new prosumers as well as a switch from existing consumers to new prosumers within the REC. In this case, a conservative scenario with an inflation rate of in average 3% per annum for the entire period under review was assumed, because from an economic point of view, a rather low inflation rate would be expedient in the long term.

A truly new finding is the impact of a change in the level of the REC renumeration. The REC renumeration describes the payment for every kWh of renewable electricity produced by REC members and consumed by other REC members. To incentivize producers, this renumeration must therefore be at least higher than the official feed-in tarif to the public grid, but also below the energy price of the REC to avoid a financial loss within the REC. The simulations show that a change in the REC renumeration leads to a redistribution within the REC: if the level of the renumeration falls, particularly consumers financially benefit while producers lose revenues, and vice versa.

For the technical wear and tear of electricity production capacities and battery storage a simplified approach was deliberately chosen. This approach could also be reconsidered in the future and replaced by a more precise approach. However, not taking it into account would have been wrong.

In this model-based analysis, (constant) synthesized load and production profiles were deliberately used, which are subject to certain assumptions and are adapted annually by the regulator. Due to these assumptions, certain variations in consumer behavior and also in electricity production cannot be partially reflected. In the future, the consideration of "real" load and production profiles could be considered in this modelling environment assuming that such profile will be available.

Another possible model extension would be the integration of an external power storage unit, for example in the form of a battery storage unit. This battery storage system could temporarily store a surplus in the production from members of the REC and feed out/distribute that temporarily stored energy at times of undersupply. Depending on the size of this external energy storage system, various scenarios such as outages could be simulated in a simple manner and its associated socio-economic effects analyzed.

5 Conclusion

The modelling approach shown in this article offers a simple way of analyzing different constellations of REC in Austria based on the NPV method using a large number of techno-economical parameters. Its potential effects are analyzed on three important levels: (i) the financial level, (ii) the ecological level, and (iii) a social level in a special form of self-sufficiency (the level of autarky). The model thus provides in advance helpful insights into the effects of various socio-economic parameters of REC. However, the model still offers options for future expansions to better reflect special features of the electricity economy.

In the analyses carried out in this article, the positive effects of integrating an external electricity producer into a local REC in Austria are underpinned. These effects are particularly evident in a positive financial effect, lower CO_2 emissions and a higher degree of autarky for the members of the REC analyzed.

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