Renaissance

RENEWABLE INTEGRATION & SUSTAINABILITY
IN ENERGY COMMUNITIES

D6.4 – FINAL ASSESSMENT REPORT: C2C MARKET ASSESSMENT, SECOND ASSESSMENT DEMONSTRATOR SITES, POLICY RECOMMENDATIONS LOCAL AUTHORITIES AND EC

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Executive summary

The objective of this report is to assess the potential of smart clusters of energy communities that can act as a virtual power plant and trade directly with the TSO-DSO market. The RENERGiSE tool developed in WP2 will be used to assess a virtual power plant consisting of the 4 demonstrator sites of the project and based on the collected data in WP5. Of course, since the sites are located at long distance from each other this can only be carried out virtually. Improvements with respect to the business-as-usual situations of each site will be assessed for various scenarios in which the communities are allowed to carry out peer-to-peer trading. Recommendations for smart clustering of communities will be set up, as well as the potential impact that C2C trading may have on the technical, and economic and environmental KPIs of the individual sites. Finally, policy recommendations towards local authorities and the EC that can foster the development of smart clusters will be developed.

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1. Introduction

As stated in the Grand Amendment of the RENAISSANCE project, Task 6.5 "Community to Community (C2C) Trading potential" has the objective to assess the potential of smart clusters of energy communities that can either carry out peer-to-peer trading or act as a single virtual power plant to trade directly with the energy market. In order to identify possible improvements with respect to various KPIs like levelized cost of energy, emissions reduction and grid independency, various scenarios are constructed to cover the different possible configurations that the four demonstration sites of the project can take. The RENERGiSE tool will be used to analyse the different scenarios and help us drafting possible recommendations for positive deployment of both C2C trading and virtual power plants composed by energy communities.

ACRONYM	
BAU	Business-As-Usual
BESS	Battery Energy Storage System
C2C	Community-to-community
GHG	Green House Gasses
KPI	Key Performance Indicator
LCOE	Levelized Costs of Energy
P2P	Peer-to-Peer
RES	Renewable Energy Sources
VPP	Virtual Power Plant

Table 1: List of acronyms

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2. Scenario construction

2.1. Description

Eight scenarios were designed to represent various situations. They are constituted by four different configurations with two sets of electricity prices: the ones of 2021 used for the calculation presented in a previous deliverable D2.5, and the increased ones of 2022 following the actual energy crisis that have caused prices to increase dramatically. The scenarios are described in Table 2.

Scenario name	Description
BAU low price	Business-as-usual situation for each pilot site with low electricity tariffs. Energy exchange and new assets are not allowed.
BAU high price	Business-as-usual situation for each pilot site with high electricity tariffs. Energy exchange and new assets are not allowed.
OPT low price	Optimized configuration of each pilot site individually with low electricity tariffs. Energy exchange not allowed.
OPT high price	Optimized configuration of each pilot site individually with high electricity tariffs. Energy exchange not allowed.
OPT P2P low price	Optimized configuration of each pilot site individually with low electricity tariffs. Energy exchange is allowed as a P2P mechanism.
OPT P2P high price	Optimized configuration of each pilot site individually with high electricity tariffs. Energy exchange is allowed as a P2P mechanism.
VPP low price	All the optimized configurations of pilot sites are aggregated in a single VPP to buy and sell energy directly at market prices. 2021 prices are used.
VPP high price	All the optimized configurations of pilot sites are aggregated in a single VPP to buy and sell energy directly at market prices. 2022 prices are used.

Table 2: Scenario descriptions.

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2.2. Electricity price assumptions

Since the RENERGiSE tool is a techno-economic optimization model, input prices play an important role on the results.

For all *low-price* scenarios, the same tariffs used and explained in detail in D2.5 are used. For the Kimmeria site a fixed tariff is considered and since injection is not allowed in the BAU case, no injection tariff is introduced. In the case of Eemnes a monthly fixed tariff is assumed, which is updated every month according to the Dutch average market price[1]. As until 2023 the net-metering system is in place, injection tariffs are equal to electricity prices. For Manzaneda the base tariff is composed by three different prices for six time-windows (P1 - P6) during weekdays, while for weekends and holidays the lowest price (P6) is used the whole day. The feed-in tariff for energy injected to the grid is fixed at 0.045 €/kWh. Finally, for the hospital site in Brussels a day and night tariff scheme is applied. With day prices of 0.11 €/kWh and night prices of 0.09 €/kWh. The relatively low prices can be explained by the fact that the hospital is a very large consumer (more than 24 GWh/year) and hence can sign long-term contracts with predefined prices. The injection tariff is fixed at 0.05 €/kWh.

P2P trading prices are constructed as hourly average of the average price between buying and selling electricity of each site. The P2P injection price is only 80 % of the final price as the last 20 % will cover distribution costs. This simple methodology was chosen to create attractive prices for both ends of the P2P exchange, as well as considering the grid operator rights.

In the **VPP scenario**, the pilot sites act together as a single one. For the resulting aggregated consumer, the 2021 Belgian electricity spot prices[2] are used. The final tariff is 30 % higher than the market price to take into consideration the various transmission and distribution costs, as well as

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1 https://opendata.cbs.nl/statline/?dl=5C019#/CBS/nl/dataset/84672NED/table

2 https://transparency.entsoe.eu/dashboard/show

taxes. Injection tariffs are 90 % of the market prices, again to reflect possible distribution and transmission costs. The choice of using Belgian prices was motivated by the fact that site in Brussels is by far the largest consumer of the VPP.

For the *high-price* scenarios, assumptions are required reflecting the actual volatility and uncertainty of electricity prices. To keep the tariff differences between sites, it has been decided to increase all individual electricity prices by a factor 3. P2P prices are again constructed as described for the *low-price* scenarios, but with the increased tariffs. For the VPP case, 2022 Belgian electricity spot prices were used to construct buying and selling tariffs. Injection tariffs stay the same for Kimmeria, Manzaneda and Brussels sites, while for Eemnes a fixed feed-in tariff of 0.075 €/kWh replaces the net-metering system, as explained in D2.5.

Scenario type	Buying from grid	Selling to grid	Buying P2P	Selling P2P
BAU	Each site has its own tariff*	Each site has its own tariff *	–	–
P2P	Each site has its own tariff *	Each site has its own tariff *	Hourly average of the average price between buying and selling electricity of each site	80 % of the value of "Buying P2P"
VPP	130 % (30 % for taxes and distribution costs) of 2021 Belgian electricity spot price	90 % of 2021 Belgian electricity spot price	–	–

Table 3: Summary of electricity tariffs assumptions for low price scenarios (* see details in D2.5).

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2.3. Pilot sites specifications

The details of all the pilots have been already mentioned in multiple deliverables, hence only the information required to properly follow this report and simplifications made to conduct this study will be reported here. In order to carry out the assessment of C2C trading and the VPP, each pilot site is considered as a single actor in the simulations. This highlights once again the versatility of the RENERGiSE tool: the same exact model can be used for single-site analysis, as done in previous work in D2.4 and D2.5, as well as for assessing C2C trading between multiple sites.

Data on carbon content of the grid for all sites are taken from the European Environment Agency[3], while CAPEX values are provided by the Flemish Energy and Climate Agency[4]. Additional PV capacity is restrained by assumptions on the available roof space left considering the existing installations. A rule of thumb of 1 kWh/1 kW BESS per potential new kWp of PV is used as upper bound for BESS size in the optimization model.

2.3.1. Brussels (hospital)

The Belgian pilot site is a quite complex energy system due to the need of redundancy of power supply for emergency situations. In this study the system is modelled from a high-level perspective: only what is consumed from the grid and what is injected back is needed. Hence, only its aggregated consumption and PV production are considered. The site has an annual consumption of 24.578 GWh/year and an installed 2576 kWp capacity of PV systems. For the optimized scenarios we consider the option to install a maximum of an additional 2500 kWp of PV and 2500 kWh/2500 kW of BESS for storing eventual surplus PV energy and increase self-

[3] https://www.eea.europa.eu/

[4] https://www.vlaanderen.be/veka

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consumption. PV CAPEX is set at 1100 €/kWp and BESS at 700 €/kWh. The public grid carbon content in Belgium is 161 gCO_2/kWh.

2.3.2. Eemnes (neighbourhood)

Consumption and production data of 50 households were aggregated for the simulations. There is currently a total of 86.2 kWp of solar PV installed on the roofs of 27 out of the 50 houses considered and their total electricity consumption amounts to 255 MWh/year. Based on roof space estimation, an additional maximum of 100 kWp will be allowed in the optimized case as well as 100 kWh/100 kW BESS. PV CAPEX is at 1100 €/kWp and BESS at 700 €/kWh. The public grid carbon content in the Netherlands is 328 gCO_2/kWh.

2.3.3. Kimmeria (university campus)

The system analysed is composed by the load of the buildings, 56.7 MWh/year, connected to the existing 51.7 kWp PV system and a 544 kWh/54 kW battery system. A maximum of additional 200 kWp of PV and 200 kWh/200 kW battery system are allowed. The public grid carbon content in Greece is 479 gCO_2/kWh.

2.3.4. Manzaneda (ski resort)

All the buildings of the ski resort in Manzaneda are aggregated into a single consumer with a total consumption of 1.5 GWh/year. In total there is 148 kWp PV installation and 37 kWh of batteries. A maximum of additional 1000 kWp of PV and 1000 kWh/1000 kW battery system are allowed. The public grid carbon content in Spain is 156 gCO_2/kWh.

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3. Results

To ease the comparison of the results between the scenarios, the KPIs are presented in an aggregated way in Table 4. The aggregated electricity consumption of the 4 sites is around 26.39 GWh/year, while the total 2862 kWp of installed PV (in the BAU cases) produce 2.97 GWh/year. A total initial 581 kWh of BESS is available. Regarding the optimized cases, a total additional 3800 kWp of PV can be installed, together with 3800 kWh of BESS.

Scenario	LCOE (€/kWh)	CO_2 emissions (t)	Self-consumption (%)	Self-sufficiency (%)	PV capacity (kWp)	BESS capacity (kWh)
BAU low price	0.09	3781	97.9	11.0	2862	581
BAU high price	0.27	3781	97.9	11.0	2862	581
OPT low price	0.08	3220	91.9	24.2	5715	581
OPT high price	0.23	3184	82.1	25.1	6498	581
P2P low price	0.08	3034	91.1	28.6	6662	781
P2P high price	0.22	3019	92.2	29.0	6662	919
VPP low price	0.11	3185	94.7	25.0	5715	581
VPP high price	0.28	3173	92.1	28.1	6498	581

Table 4: Results KPIs.

The KPIs “Self-consumption” and “Self-sufficiency” are defined as follows:

$$\textit{Self-consumption} = \frac{E_{PV,self}}{E_{PV,total}} \cdot 100\%$$

$$\textit{Self-sufficiency} = \frac{E_{PV,self}}{E_{demand}} \cdot 100\%$$

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where $E_{PV,self}$ is the total PV energy absorbed by local demand, $E_{PV,total}$ is the total PV energy generated and E_{demand} is the total aggregated demand.
The first important remark to make about the results is to highlight the high value of self-consumption for all the scenarios. This is due to the exceptionally large demand of the hospital in Brussels, which will absorb most of the PV production of all sites. This "dominance" of the Brussels' site is hiding the contribution of the other sites of the system, meaning that the final values of the various KPIs are strongly dependent on the assumptions and input used for the Brussels site. Nevertheless, differences between scenarios can help to identify different trends and open discussion points.
Firstly, we can notice that higher prices of electricity will lead to an increase in RES installation, as higher capacities become profitable with higher prices. More RES installed, also means higher independency from the main grid (higher self-sufficiency) and hence a reduction on GHG emissions.
The best scenarios in terms of costs and emissions are represented by the two P2P scenarios. In these two scenarios, PV installation is maximized for both electricity tariffs and they are the only scenarios where additional BESS are considered on top of the initial ones. Therefore, the lowest emissions are reached in the P2P scenarios thanks to the highest self-sufficiency reached. These results support the price mechanism chosen, as it will result in the best economic and environmental solutions.
Regarding the VPP scenarios, the assumptions made on the electricity prices results in a higher LCOE compared to all the other scenarios. This is once again explained by the fact that the Brussels site sets the rules for the whole system: its very low tariffs can't be compared with the more costly market prices used in VPP scenarios. Nevertheless, the increase in self-sufficiency due to the aggregation is a good signal: in the case of better balanced and complementary sites, the VPP could for sure be a good structure to encourage renewable energy investments.

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3.1. Extra analysis

To avoid the dominance of the Brussels site, we decided to create another fictive case where consumption and production of this pilot site are downscaled. As a result, this scenario represents the collaboration of sites of approximately the same order of magnitude, so that mutual sharing of surplus renewable generation becomes feasible, rather than all surplus absorbed by one large partner.

For doing this, the Brussels site electrical consumption is reduced to a twentieth of the original one, and its PV capacity is a tenth of the original one. Table 5 presents the results of this newly created study case, where all scenarios where considered, except the VPP where due to aggregation the size of each site is irrelevant.

Scenario	LCOE (€/kWh)	CO_2 emissions (t)	Self-consumption (%)	Self-sufficiency (%)	PV capacity (kWp)	BESS capacity (kWh)
BAU low price	0.09	397	91.0	18.8	543.5	581
BAU high price	0.27	397	91.0	18.8	543.5	581
OPT low price	0.08	319	79.0	35.1	1060.2	581
OPT high price	0.20	274	52.2	44.0	1925.0	586
P2P low price	0.07	305	84.6	37.9	1066.8	581
P2P high price	0.18	225	61.7	54.2	2005.7	1126

Table 5: KPIs of adapted case.

In this new case the trends identified in the normal case are highlighted even more. With a scaled consumption to match better the available PV

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production, higher levels of self-sufficiency can be achieved, which turns out to be favourable for both cost and emissions reduction. P2P scenarios once again result in the largest PV and BESS installations, which leads to the configuration with lowest LCOE and GHG emissions.

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4. Discussion and policy recommendations

As mentioned in the previous section, the main issue encountered in the assessment performed in this report was the unbalance in the size of the pilot sites considered, which made difficult to assess the contribution from each site. However, having a very large consumer is beneficial in the way that all available PV generation can be absorbed at any time, potentially leading to larger capacities of PV to be economically interesting. This shows that concepts of P2P and VPP can work in cases where sites are size-balanced, and in cases where they are not.

Regarding the C2C trading, clarity should be made on who takes over the responsibilities, and the risks, of trading energy as each community is constituted from different members. This could potentially be introduced into the “contract” for joining an energy community.

Finally, for VPPs the main difficulty encountered for this assessment was that the sites were located in different countries with different electricity prices. In this situation there is incertitude on which price applies. The same problem can be encountered even in the same country, as different regions can have different prices or even different types of consumers (normally categorized by yearly consumption and/or peak demand) in the same location have access to different tariffs. To counter these problems there could be a pre-condition when creating a VPP that all customers subscribe to a VPP similar to any retailer contract. Then, the VPP takes care of buying and selling energy at wholesale markets, in the same way as normal power plants do. Even cross-border operations can be considered for these transactions. End-user tariffs are not relevant here, but wholesale market prices. Inside the VPP, each player should be treated in a fair manner, paying, or being paid according to the overall benefits/costs of the VPP.

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Pricing should of course be good enough to attract actors but as mentioned before, the VPP should find its own tariffs or even employ smart contracts, which are not so much conditioned to what tariffs are in the market.

Of course, the VPP-retailer needs to be competitive with market tariffs, but it can freely define them inside the VPP (if it is assumed that all players subscribe to the VPP and do not buy/sell their energy elsewhere).

Apart from the issues encountered with different C2C trading scenarios, the RENAISSANCE project came across with another, much more fundamental problem: data needs to be shared, in order to make any advanced trading happen. Clear rules are needed on how data is shared and who can use it. Also, common data formats are needed to enable smooth sharing. Here, the concept of unified energy data spaces is a key enabler. Even though, cross-border VPP or even P2P trading was not a main objective of this project, a European energy data space with clear rules for data sharing and data security, would overcome manyfold obstacles regarding data sharing.

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