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Article

Achieving Net Zero Condominiums through Energy Community Sharing

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Abstract: The European energy transition process is geared toward improving the economic viability of the energy sector through its democratization, which includes enabling citizens to generate, share, and sell energy produced by renewable sources. The current directives have led to the creation of energy communities and collective self-consumption groups to engage and raise awareness among citizens, with the goal of achieving social, economic, and environmental benefits through shared renewable energy generation and consumption. In the near future, more and more of these initiatives are anticipated; therefore, innovative technological tools are necessary to assist their growth path. This research introduces a multi-criteria techno-economic simulation framework that enables the evaluation of several investment scenarios for various plant sizes and energy prices. The findings are useful during the investment planning phase as they help guide decision-making toward the objectives of economic, energy, and environmental sustainability. To evaluate the methodology, a case study of a collective self-consumption group located in a smart building in Italy is proposed. The results are discussed from statistical, technical, economic, and financial standpoints, demonstrating how the proposed approach can contribute to the development of collective self-consumption groups, risk hedging, and the goal of developing energy self-sufficiency based on the net-zero energy building concept.

Keywords: renewable energies; net zero condominiums; collective self-consumption; diffused self-consumption; energy transition; simulation framework; multi-criteria analysis; techno-economic evaluation

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1. Introduction

Energy communities (ECs), introduced by the RED II Directive [1], are emerging as a promising solution to combat climate change and expedite the transition to renewable energy sources. These communities comprise individuals, households, businesses, or public institutions that collectively generate, consume, share, and manage locally produced energy. (ECs) prioritize energy efficiency at the local level and aim to create a sustainable electricity system through the participation of local actors [2]. This active citizen participation fosters democracy and resilience at the local level [3]. The Integrated European Market Directive (IEM, 2019/944 [4]) envisions the participation of citizens, businesses, and public entities in electricity markets through aggregate forms. This necessitates investments in innovative technologies, such as internet and communication, energy management, blockchain, and more, to enable the end users' proactive involvement [5]. Energy communities come in various forms, ranging from small-scale local initiatives to large-scale urban developments, and are supported by diverse technologies, financing, and legal arrangements [6]. They emphasize energy justice, equity, fair transition, empowerment, and involvement, requiring the development of new consumption models and solutions using structured methodologies. By efficiently utilizing local energy resources, energy communities seek to generate inclusive benefits, pursuing environmental, social, and economic goals [7], as well as addressing issues related to energy security, greenhouse gas emissions, and energy efficiency. However, energy communities face challenges, such as regulatory barriers, technical limitations, and social acceptance. Another pivotal challenge is their optimal sizing in terms of consumption and production to locally balance the EC load and, at the same time, generate the best obtainable value for all stakeholders.

In Italy, two models have been defined to promote energy communities: renewable energy communities (RECs) and collective self-consumption groups (CSGs). While both aim to increase the share of renewable energy in the country's energy mix, there are significant differences between the two. RECs are typically implemented on a larger scale, involving multiple stakeholders collaborating to develop and manage large renewable energy projects. CSGs, on the other hand, focus on single buildings, such as condominiums. The incentive framework for both models encourages energy sharing among users, but the amount granted differs for CSGs and RECs. The management model also varies depending on the territorial extent and nature of participants in each form of aggregation. RECs require the establishment of a legal entity, while CSGs, associated with single buildings, are considered a "management entity" under Italian legislation.

From a local distribution network perspective, CSGs concentrate consumption points within a building or a block of adjacent buildings, while RECs have dispersed users throughout the territory. Consequently, the coordination and management of technologies and strategies differ due to the heterogeneous and widespread nature of users in RECs. Areas in which the low-voltage network is particularly weak, and there is a high density of PV production systems might require new investments for the secure and proper network operation [8]. ECs can be leveraged to defer non-programmed investments in the reinforcement of the network by providing demand-side flexibility.

In Figure 1, the virtual configuration model chosen by the Italian authorities is depicted for a CSG, where each user retains individual rights and obligations as an end customer.

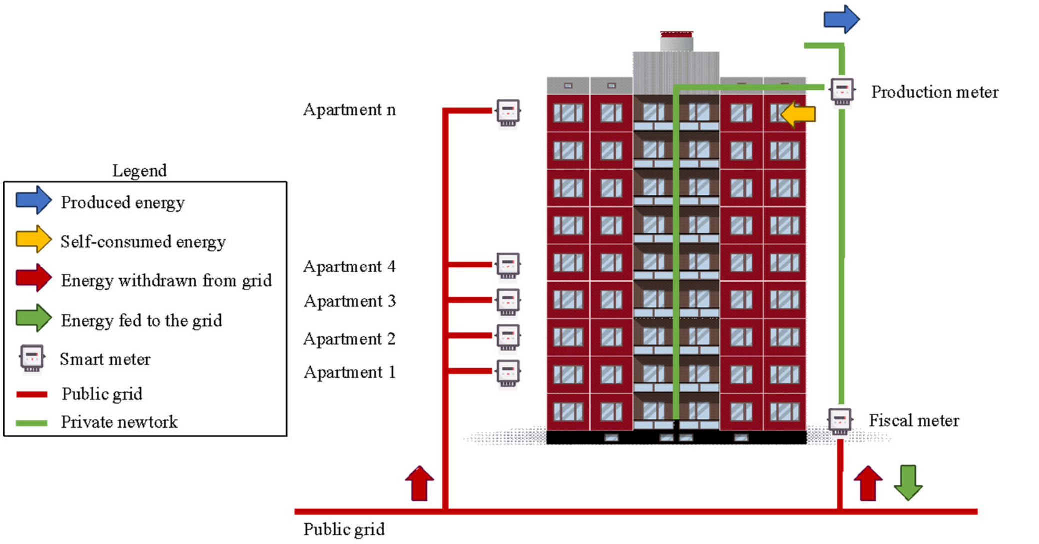

Figure 1. Virtual configuration model defined by the Italian authorities to enable diffused self-consumption.

This "virtual" model allows the connection of the condominium network to the public distribution network using multiple fiscal energy meters, enabling separate electricity supply contracts for general services and individual housing units [9].

This study contributes to the advancement of research on energy communities providing a useful tool for developing strategies for the optimal sizing and financial feasibility of collective self-consumption groups. It addresses the lack of practical tools in the literature that are purely dedicated to plant dimensioning. This research not only explores the potential social and economic benefits for members but also considers the effects of energy price variations and investment conditions. To this end, the authors developed, in Python (Version 3.12.1), a modeling and simulation tool that allows to assess different sizing alternatives in different scenario configurations. Details on the usage of the software are available at the dedicated GitHub repository [10]. Another novelty the tool introduces to the current state of the art is the possibility to easily simulate a significant amount of scenarios that differ in configuration parameters, such as the categories, number and localization of users, energy prices, techno-economic parameters (e.g., costs and investment parameters), etc., and the possibility to evaluate the generated scenarios under different perspectives, considering social, economic, and/or environmental factors. The developed tools enable the assessment of the viability of the CSG in different investment configurations, contemplating a possible external investor (e.g., an energy service company) and performing sustainability evaluations, varying the redistribution of revenues among the CSG and the investor. In the following sections, firstly, the state of the art and the drivers of this research are described, then the methodology employed will be described. Finally, a case study will be developed to assess the relevance of the produced results with the relative methodology.

The authors consider that the results generated by the developed tools can be helpful for a variety of expert and non-expert profiles, helping to evaluate possible solutions that best suit the needs of the CSG. This contribution is aimed at facilitating its successful realization and, ultimately, aligning with the decarbonization and sustainable goals of the UN agenda.

Literature Review

According to the Circularity Gap Report 2023 [11], the building sector is responsible for approximately 40% of the global greenhouse gas (GHG) emissions in the environment as a result of activities such as the production of building materials and building operations (which are responsible for approximately 55% of the global electricity consumption). Moreover, the construction industry is one of the most energy-intensive sectors: approximately 40% of total consumption is intended for energy services such as heating, lighting, and cooling of buildings.

GHG emissions from the building sector represented 35% of energy-related EU emissions in 2020 [12]. Similar percentages are recorded in Italy, where the high energy consumption is mainly due to the age of the buildings and their state of conservation [13]. According to the real estate market observatory (Osservatorio Mercato Immobiliare, OMI) [14], the Italian real estate stock registered consists of almost 78 million properties, of which 35.5 million are for residential use.

The majority of Italian buildings (85%) were built before 1991, before the introduction of the regulatory framework for building-energy performance introduced with Law 10 of 9 January 1991. With the aforementioned law, Italy regulated the design and management of the building/plant system, introducing the concept of energy efficiency certification [13]. Only 6.8% of buildings were built after 2005. More precisely, most of Italy's residential building stock was built after the Second World War, with a massive growth in the 60s and 70s, then slowing down in the following decades. The need for a fast reconstruction in the post-war period is often reflected in an often poor architectural quality and energy efficiency, particularly under current standards [15], causing high levels of energy consumption [16]. This important aspect, which also includes large-size building blocks, such as social housing districts [17], needs comprehensive improvement to foster deep energy renovations and reduce buildings' energy consumption [18] at different urban scales, within a broader regeneration strategy of the built environment, in line with the new circular economy model [19].

According to data published by Terna [20], the operator of the Italian electricity transmission grid, the annual electricity consumption in 2022 amounted to 295.8 TWh.

Between 2021 and 2022, there was a 1.7% (−5 TWh) decline in electricity consumption in Italy. In particular:

- The industry experienced a 4.2% fall, reaching 130.0 TWh. The most significant drops in absolute value were found in metallurgy (−2.3 TWh, equal to −9.4%), in the paper industry (−0.6 TWh, equal to −7.5%), and in the ceramics, glass, and cement sector (−0.6 TWh, equal to −6.4%).
- Services, on the other hand, increased by 3.6%, to 94.7 TWh. The greatest increase in absolute value affected tourism, i.e., hotels, restaurants, and bars (+0.9 TWh, equal to 8.2%), as well as the other scientific and technical professional activities class (+1.6 TWh, equal to 16.1%).
- Agriculture recorded a decline of 1.4%, with a consumption of 6.6 TWh.
- Household consumption decreased by 3.8% to 64.5 TWh.

Extending the analysis to the energy consumption from different sources [21], a constant growth in solar and wind energy consumption can be observed in the decades 1990, 2000, 2010 and 2020, up until 2022 (Figure 2). Hydroelectric energy consumption, however, recorded a decline in 2020 compared to 2010, a trend that also occurred in 2022.

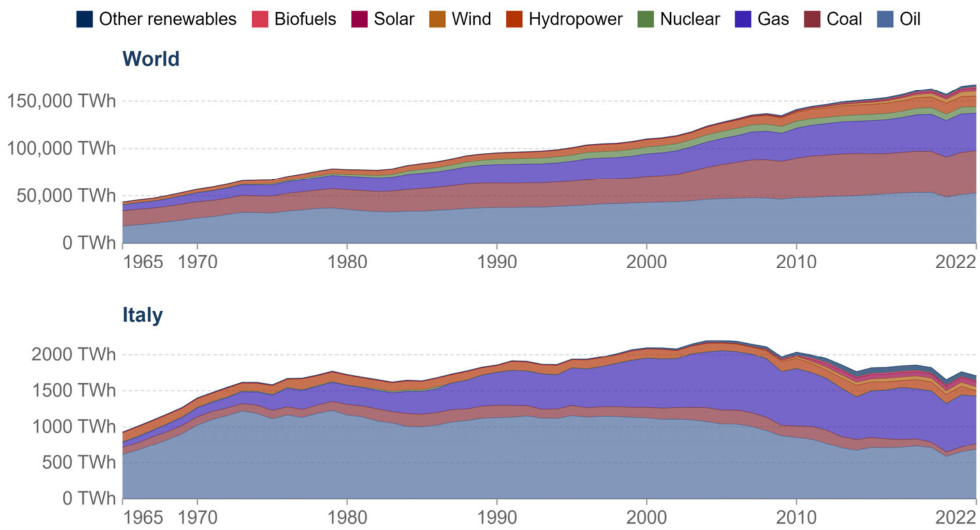

Figure 2. Energy consumption by source. Comparison between Italy and the rest of the world, related to the period between 1965 and 2022 [20].

In contrast to the energy consumption from renewable sources, consumption from fossil sources—gas, coal, and oil—decreased from 1990 to 2020, with the exception of 2010, which saw an increase in energy consumption from gas and coal. International geoeconomic and geopolitical events are among main causes of the increase in energy consumption from coal and oil in recent years.

In light of these figures of energy consumption, it should be specified that Article 7 of the Energy Efficiency Directive (2012/27/EU) promotes interventions for energy requalification and renovation of the building stock, which mainly involve the buildings' external surfaces, such as facades and roofs, and the energy plant components [22].

Incentive policies for improving the energy efficiency of the building stock have gradually created the preconditions for a scenario favorable for the widespread development of energy communities, a new dimension to support the transition towards clean, democratic and accessible energy. As a matter of fact, the scientific debate on the energy transition [23–25] may also be interpreted as the right to access electricity or the primary services that energy makes possible, such as heating, lighting, mobility, etc. [26,27]. Furthermore, another important distinction is that between the right to access and the right to use energy, with particular reference to the need to face and alleviate energy poverty through new energy policies and instruments, such as RECs and CSGs [28,29].

In particular, incentive policies, which mainly consist of tax deductions for energy efficiency interventions on existing building stock, were introduced by the Law no. 296 (27 December 2006) and still constitute the most used measures today to achieve energy efficiency in residential buildings, generating almost 1 Mtep/year of final energy savings in 2018, corresponding to over 2 million tons per year of CO2 not being emitted into the atmosphere [30].

Tax deductions constitute the main strategic government policy for achieving the energy transition objectives of the existing building stock, in line with the mid-century zero emissions strategy for the EU [31].

In Italy, the incentives between 2011 and 2021 activated investments of €310,789 million, and generated employment for approximately 3,093,000 people [32]. The energy savings resulting from tax deductions (i.e., Ecobonus, Bonus Casa, Superbonus, Bonus Facciate) amounted to 0.33 Mtep/year for 2021 and are expected to be 1.65 Mtep/year for 2025 [16]. In particular, the "Bonus Facciate" and the "Superbonus" had a strong impact in terms of private investments and public finance [33,34]. The "Superbonus", implemented from December 2020 to April 2023, involved over 400,000 buildings, corresponding to approximately 3.3% of existing buildings, allowing for an overall energy savings of 1.21 MTep [35].

Furthermore, the combined action of tax incentives and energy policies in Italy contributed to the 35% decrease in total GHG emissions from the EU buildings sector between 2005 and 2020 [12]. Within a significant framework of policies aimed at reducing GHG emissions and energy use from buildings, in line with the ambitious objectives and targets of the European Green Deal strategy [31], it is estimated that this positive trend will continue.

However, this is an ambitious objective that requires the increase in energy production from renewable sources, as well as through the establishment of renewable energy communities and collective self-consumption groups.

In Italy, thermoelectric energy still represents the pillar of the national electricity system [36]. In addition, hydroelectric generation, among the renewable resources, has seen a decrease in its share due to the impact of climate change, together with a reduction in the maintenance of the dedicated water basins. On the other hand, the improvements in technological performance and efficiency favor the production of wind and solar plants, with a significant increase compared to 2021 (+11% for photovoltaic; +5.1% for wind) [37]. Figure 3 shows the trend in renewable energy generation by source in Italy, between 1965 and 2022 [21], revealing the constant growth in energy production from solar and wind systems and the significant decline in hydroelectric energy production since 2020. The transition towards the implementation of renewable energy plants, the promotion of energy efficiency policies, especially in the construction sector, as well as the reduction of dependence on Russian natural gas imports, thanks to the acquisition of alternative suppliers (gas pipelines and LNG infrastructure), are in line with Italy's climate objectives.

According to the Legambiente Report [38], realized in 2022, in Italy, there are approximately 1.35 million renewable energy plants, with a total installed power of 60 GW, located in over 7000 municipalities. Although the outcomes are noteworthy, if the installation rate in the upcoming years mirrors the total power added over the past three years, it would still fall short of achieving the anticipated target of 85 GW by 2030 [39]. In fact, at the current pace, this goal would not be reached for another 40 years. A significant installation rate higher than that observed so far would therefore be needed to accomplish the 2030 target, together with the development of different policies.

Within this short overview, RECs, although historically widespread in the form of energy cooperatives in many EU countries, from Denmark (the wind cooperatives of the 70s) to Italy (the energy cooperatives of South Tyrol) [40], are now recognized as legal entities by the Renewable Energy Directive (RED II) in 2018 (revised in 2021) and the Clean Energy for all Europeans Package (2019). In Italy, renewable energy communities are regulated by Article 42-bis of the Milleproroghe Decree 162/2019 (enacted by Law n. 8/2020 of 28 February 2020) [41]. Preliminary studies show that RECs can be beneficial for the local territory [42]. The progressive growth of RECs and CSGs [43–45] may be associated with the triple model of economic, environmental, and social benefits between the global and local levels [46,47]. RECs and CSGs represent an opportunity to reduce GHG emissions and, therefore, to address problems related to climate change, but also to promote the use of local resources, democratic access to energy, and sustainable behavior within communities. In addition, they contribute to new economic investment and create local jobs.

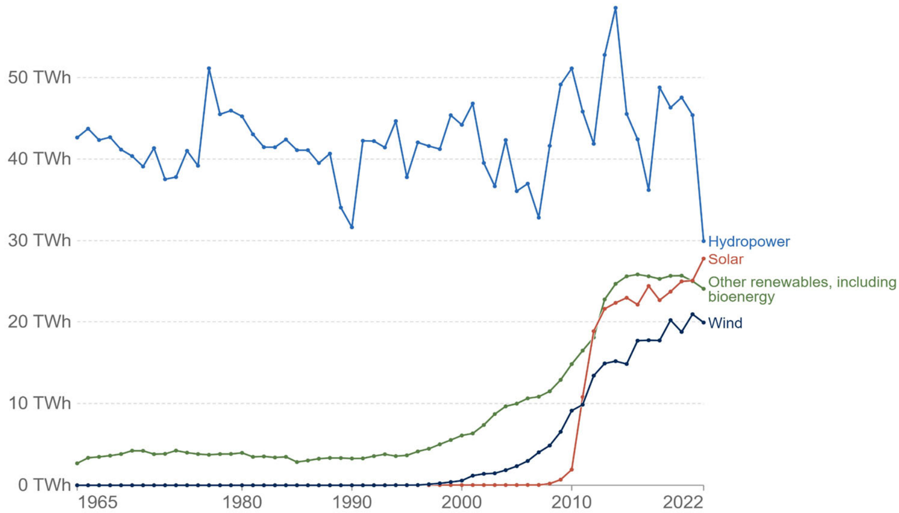

Figure 3. Modern renewable energy generation by source in Italy, between 1965 and 2022 [20].

The promotion of RECs and CSGs in Italy is supported by the combined action of direct economic contributions and tax incentives (tax deductions) [48] and digital monitoring tools (production and consumption). The map of primary cabins for renewable energy communities [49], introduced by the Energy Services Manager (GSE), represents another useful tool that allows stakeholders to programmatically promote RECs and CSGs. The map geolocalizes the areas served by the primary substations in Italy (2107), thus facilitating the localization of the service connection points for diffused self-consumption.

With the Integrated National Energy and Climate Plan (INECP) for the period 2021–2030 (2019) [50], the combined action of energy efficiency interventions of the building stock and self-consumption (single and/or collective) is confirmed to achieve the minimum quota of renewable sources in new buildings or renovations, in line with the objectives of nearly zero-emission buildings (NZEB).

Then, moving on to the neighborhood scale, within the concept of positive energy districts (PEDs) [51], highly energy-efficient buildings, smart grid technologies, and other sustainable practices are promoted to produce more renewable energy than they consume, resulting in zero net greenhouse gas emissions and a reduction in the carbon footprint [52]. Norway and Italy are among the European countries with the largest number of PED projects [53].

These interventions are fundamental to reaching the Italian target for the minimum cumulative final energy savings, to be achieved in the period 2021–2030, corresponding to approximately 51.4 Mtep (corresponding to over 9.35 Mtep of annual savings by 2030) [50].

In this sense, the harmonization of urban planning tools and financial incentives, in line with European policies, constitute a key factor in achieving full economic feasibility for RECs, CSGs, and other more ambitious policies. In particular, participatory urban planning actions contribute to progressive awareness for a just energy transition [48]. In the same COP 21 in Paris, the conference where global agreement for the reduction of emissions into the atmosphere was discussed, the central role of the Just Transition [54] was stressed, with explicit reference to a fair and balanced energy transition. More precisely, with an explicit reference to energy communities and their multiple organizational models, the aim is to deal with climate change, fight poverty, and promote the sustainable development of local communities [55].

2. Methodology

The approach adopted in this study is discussed in this section. The authors developed a simulation framework in the Python language, using Python version 3.12.1, which enables the techno-economic simulation of CSGs. Libraries such as Pandas and NumPy have been used for data handling. Scenarios are simulated with different input data, including electricity demand and wholesale market prices. The approach also allows the execution and analysis of a relevant number of tecno-economic scenarios for multiple solar power-generating and storage system-scale combinations. Simulation results are finally saved in Excel files for easier access to the outcomes.

In the Italian setting, CSGs can rely upon two sources of income: the first is a feed in tariff that remunerates the energy injected into the grid at the hourly zonal price (PZ), and the second one is generated by an incentive tariff defined by the Italian regulatory authorities and rewards the energy shared by members of the CSG. Both revenue items are computed in the software. The shared energy is calculated as follows:

$$\mathrm{SE_h} = \min(\Sigma \mathrm{w_{i,h}}, \Sigma \mathrm{i_{i,h}}) \tag{1}$$

where $\mathrm{w_{i,h}}$ represents the energy withdrawn from the distribution network by the i-th user, whilst $\mathrm{i_{i,h}}$ is the energy injected into the network. Both are referenced to as the h-th hour. When it comes to CSGs, the energy injected into the distribution network is the quantity released after the common loads' self-consumption. This is subjected to a reward tariff that amounts to 109 €/MWh.

The income generated by the selling of energy to the grid can be computed as follows:

$$\mathrm{RID_h} = \mathrm{PZ_h} \cdot \sum \mathrm{i_{i,h}} \tag{2}$$

where $\mathrm{PZ_h}$ is the zonal price during the h-th period.

2.1. Description of the Simulation Framework

The three primary stages of the methodology flowchart—initialization, simulation, and results saving—are depicted in Figure 4. Initialization involves setting up general parameters for defining the CSG and the scenarios that will be evaluated. This can be done in the "parametri.py" file. Each scenario differs in zonal pricing and sizing of the plants that the CSG is equipped with. The results associated with each scenario are then saved in an Excel file that located in a dedicated folder (Output). Finally, a summary of all simulated scenarios is prepared and stored in an Excel file as well. Further details regarding each stage hereafter are provided. Auxiliary functions are located in the "functions.py" file.

At the initialization stage, general information about the CSG geographical location is required. These will be used in the subsequent steps to estimate the photovoltaic (PV) electricity generation for which the PGGIS APIs have been used. During this first stage, it is mandatory to set either the average zonal price in the "parametri.py" file or an hourly custom price in the "PUN.xlsx" file, or both. These will be used during the simulation process. The next step requires the instantiation of the PV and the battery energy storage systems (BESS) capacities that will be evaluated. Finally, the cost and incentive structure that will be used while evaluating the economic feasibility of the scenarios need to be specified. Unitary costs for the PV system (€/kWp), the energy storage system (€/kWh), the required infrastructure (€/kW), and labor (€/kW) must be identified properly for a correct estimation of investment costs (CAPEX). Operating costs (OPEX) are then estimated by specifying management and insurance unitary costs.

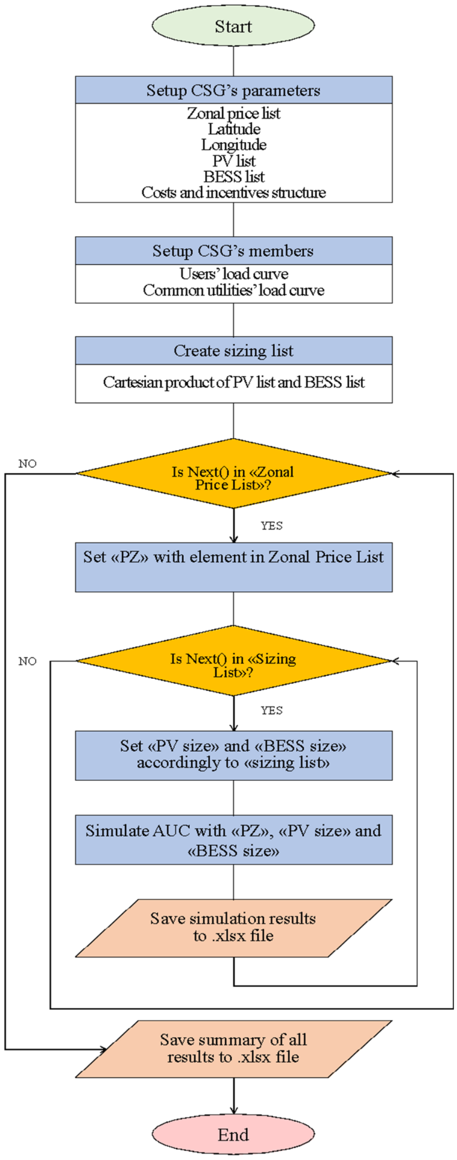

Figure 4. Collective consumption group simulation workflow.

The following stage is dedicated to the selection of the load curve of the relevant loads. Pre-defined load profiles are provided for selection in a dedicated Excel file called "Carichi_utenze_AUC.xlsx". Here, it is necessary to specify the load of the dwellers of the condominium and the load of the common utilities (e.g., elevator, lights, etc.). In a CSG configuration, the common load is solely responsible for instantaneous self-consumption: for a correct and precise simulation it must be modeled according to the specific case.

The third stage involves setting up the scenarios. This is achieved by performing the Cartesian product between the previously instantiated powers of the PVs, the storage system capacities and the list of PZs. Each alternative (i.e., combination of PZ, PV size, and BESS capacity) define a scenario that will be evaluated. For each scenario, a multitude of techno-economic information is provided in output.

Among the most relevant ones are the following:

- The hourly values of the energy injected into the distribution network.
- The hourly values of energy withdrawn from the distribution network.
- The hourly values of self-consumed energy.
- The hourly values of shared energy.
- The total energy bill for the CSG.

- The total revenues generated by the sharing and selling of energy.

In addition, for each scenario, it is possible to consider investing in tandem with a third-party actor (i.e., an energy service company (ESCo)) that provides its own capital to invest in the construction of the facilities intended for the CSG. The investor will be remunerated in time with a return derived from the revenues generated by the CSG itself. In the scenario in which such a third-party actor is envisioned, its revenues are composed of the sale of the electricity to the market and a portion of the revenues generated by the energy sharing. In this case, members are not required to make a direct investment in the realization of the facilities but can still benefit from the avoided expenditure through the self-consumption and receive a portion of the revenues generated by the incentivization of the energy shared. The identification of a scenario that is profitable both for the investor and for the members is a non-trivial problem and is influenced by many factors.

The apportionment of incentives [56,57] is determined by a private contract between the external investor and the CSG. In the literature, different approaches are proposed, based on game theory [58] or key performance indexes, for a proportional and meritocratic apportionment. Another important assumption is that the operational costs (OPEX) are always sustained by the CSG. For each simulated scenario, different financial parameters are computed for their single evaluation. For investment evaluation, the well-renowned and established methodology that involves discounting the cash flows generated during the investment period has been employed. Hence, the net present value (NPV), internal rate of return (IRR), profitability index (PI), and payback time of the investment (PBT) are calculated for each scenario. In Appendix A, the methodology for the calculation of the aforementioned metrics is illustrated. The analysis of the scenarios produced enables an investor to identify and tailor a scenario investment, thus providing a tool that is also useful for risk hedging.

Other parameters that have been computed to evaluate the investment are the total revenues generated during the first year of operation, the CSG expenditure variation (calculated comparing the case in which the CSG is not constituted), and the shared-to-produced energy ratio.

2.2. Selection of Best Cases

Each simulation generates a relevant amount of scenarios and data. Many scenarios are not worth analyzing for different reasons, such as their economic unfeasibility or inability to meet expectations, whether they be of a social or economic nature. For these reasons, it is necessary to filter and select results, and to this end, a selection procedure has been defined. The aforementioned selection is operated after having generated the results for all the scenarios in the file that contains the techno-economic outputs of each simulated scenario.

The authors developed an approach that is aimed at retaining economically profitable scenarios that, at the same time, are beneficial for members and characterized by virtuous energy performances in terms of sharing. To achieve these goals, scenarios that do not meet a certain constraint on the ratio between shared and produced energy are excluded from the final results. The authors identified such ratio as 65%. The results that are obtained are further filtered. In order to provide a minimum economic benefit to the members of the CSG, only the results that generate a cost reduction greater than 5 percent are kept. Finally, an additional filter is applied to eliminate all the simulations associated with a negative NPV. The dataset, containing the resulting scenarios is finally sorted by decreasing values of PI. This allows for an immediate skimming of profitable scenarios.

An analysis of the results obtained for the developed case study is performed in the following section.

3. Case Study

In the evolving landscape of energy production and consumption, the literature confirms the trend toward a distributed and decentralized system. Community-owned projects, such as RECs and CSGs, will play an important role in local energy management.

It is envisioned that they will be able to operate in an aggregate manner to provide services to the distribution network. As a result, it is critical to conduct a preliminary analysis of how they will perform over time from various perspectives. Adequate CSG sizing in terms of installed production power and energy demand is critical, as is meeting stakeholder expectations, based on funding availability. The goal of this analysis is to explore the landscape of generated scenarios and the different characteristics that distinguish them by investigating the interactions between variables and major system parameters such as PV, BESS, and PZ. By analyzing the obtained results, it is also possible to provide actionable insights for stakeholders in the energy sector. To demonstrate this, a CSG has been simulated with the methodology illustrated in the previous section. Seven different values of PV capacities and eight for the BESS have been considered, whereas three PZ values have been instantiated. Two conditions of investment realization have been assessed: the first foresees the direct investment of CSGs members without the support of an ESCo; the second case investigates the situation in which the investment is realized by an ESCo, and benefits are given to the dwellers. Overall, 336 scenarios have been generated, and the results-skimming methodology, which has been previously described, has been applied. After the filtering procedure, the number of remaining scenarios is 153.

In the following section, the simulation's setup is further discussed.

CSG Description: Simulation Parameters and Users Descriptions

As far as the production and storage plants are concerned, seven PV sizes have been assumed (5, 7.5, 10, 12.5, 15, 17.5, and 20 kWp) and eight BESS capacities have been instantiated (0, 5, 7.5, 10, 12.5, 15, 17.5, and 20 kWh). The cartesian product of the above capacities returns a grand total of 56 combinations. The impact of energy costs was assessed by taking into account three energy prices (50 €/MWh, 100 €/MWh, and 150 €/MWh) in the wholesale market. The CSG performance was thus evaluated for each combination of PV-BESS sizing under the different values of PZ, for a total of 168 scenarios which were further evaluated, considering two distinct investment frameworks. The first one posits that CSG members independently shoulder the financial responsibilities, without the involvement of an ESCo. Conversely, the second framework explores a model where the investment is primarily facilitated by an ESCo. It should be noted that operational expenses are consistently borne by the CSG in both frameworks. Revenue streams for the ESCo are derived from two sources: the sale of generated electricity to the distribution grid and a predetermined share of the incentives accrued from electricity sharing among CSG members. For the purposes of this study, this share has been fixed at 50%, although it is subject to modification based on mutual agreements between the involved parties.

In Table 1, the other major simulation parameters employed during the simulation of the CSG are reported.

Table 1. Parameters used in the simulation.

Parameter	Value
Latitude	39.205
Longitude	9.130
PV unitary cost (€/kWp)	1100
BESS unitary cost (€/kWh)	1000
Infrastructure unitary cost (€/kWx)	100
Labor unitary cost (€/kWx)	300
Management cost (€/kWx)	10
Insurance	0.5% of CAPEX
Discount rate	6%
Annual percentage rate	6%

After having defined the parameters regarding the scenarios and cost structures, the composition of the CSG must be defined. For the sake of this study, a CSG comprising twenty members was studied. Members have been designed considering persona profiles that suit typical dwellers. Three personas profiles have been identified: a working couple aged between 30 and 64 years old (WC 30–64), a retired couple (RC), and a working couple with two children, with one parent working from home (CWK). Their yearly consumption and the number of users instantiated in the configuration are reported in Table 2.

Table 2. Personas' (users') information.

Name	Yearly Consumption (kWh)	Number Instantiated
WC 30–64	3309	8
RC	2351	6
CWK	5841	6

Figure 5 depicts a line graph of the load profile for users on a typical day of the year. It is possible to see a variation in users' energy consumption attitudes during this typical day, which corresponds to the disparities in consumption attitudes of the selected profiles.

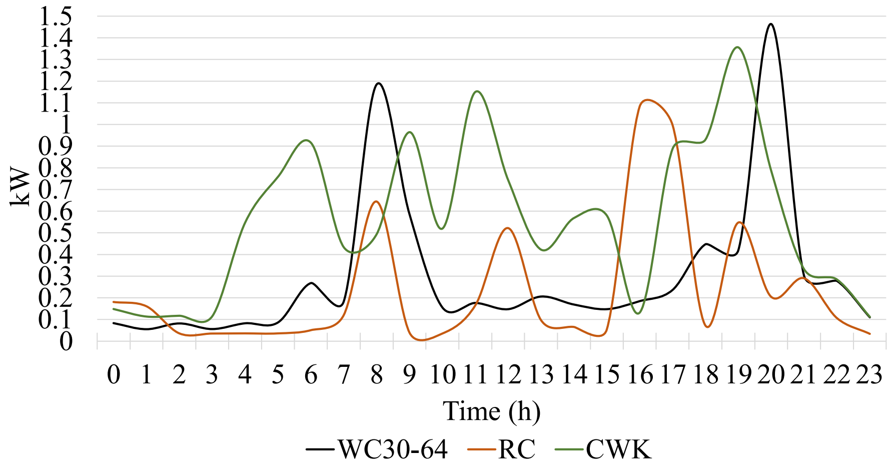

Figure 5. Load profiles for user categories on a typical day.

Figure 6 illustrates a line graph of the load of the common utilities for a typical day. It is interesting to notice that the common utilities (e.g., lighting, elevator, heating, etc.) are mainly used in the morning and during the evening throughout the year.

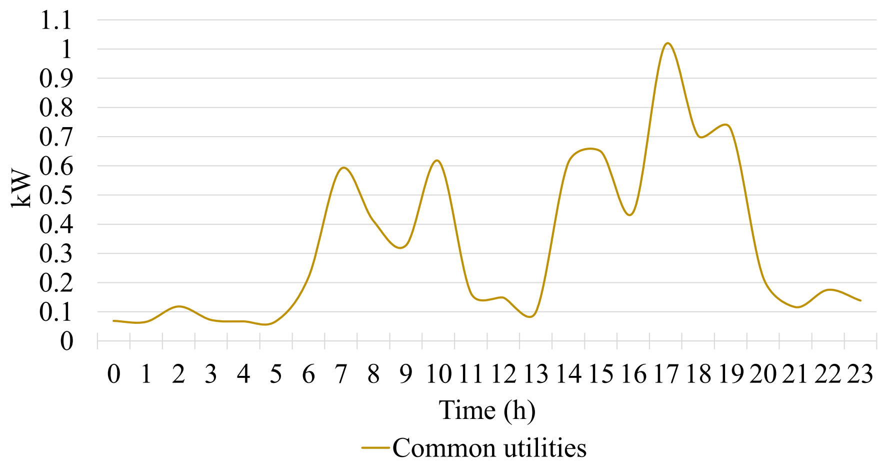

Figure 6. Load profile of the common utilities for a typical day.

After defining the parameters and members that will populate the scenarios, simulations are carried out. Then, results are filtered and sorted according to the methodology described in Section 2.2.

4. Discussion

In this section, a discussion of all the generated scenarios is provided without distinguishing the investment framework. In the following section, a detailed discussion of each investment approach, whether facilitated by an ESCo or independently managed by the CSG members, is provided as well.

In Table A1, the results of the first ten scenarios obtained after the filtering procedure are reported. Interestingly, all the listed scenarios do not include the presence of an ESCo investor. This is due to the sorting by ascending PI. It is equally interesting to note that there is only one scenario in which the CSG is equipped with a BESS. This can be attributed to the large cost involved in purchasing the storage system. Finally, it is noteworthy that all scenarios characterized by a high value of PI are associated with a high value of PZ: this is because it allows for higher revenues from the sale of energy to the grid. A statistical description of the results is provided in the following section to explain the characteristics of the obtained dataset, such as, for example, trends, data dispersion, and data distribution.

In Table 3, some general statistics (mean, minimum, maximum, standard deviation, and quantiles) of the main results for the full dataset are reported. Through the lens of descriptive statistics, it has been possible to investigate the subtle nuances and explicit trends that are otherwise not immediately obvious. Metrics such as NPV, IRR, and PI all indicate that these projects are generally profitable, suggesting that they are good candidates for investment. Both CAPEX and OPEX show a wide range, indicating that the projects vary significantly in terms of initial investment and operational costs. This can be tracked back to the various plant sizing that have been evaluated.

Table 3. Summary statistics for the entire dataset.

Statistic	CSG Expenditure Variation	NPV	IRR	PI	PBT	CAPEX	OPEX	Shared Produced Ratio
mean	−30%	10,965	11%	139%	11.96	30,833	381.29	90%
std	19%	8504	4%	32%	3.55	10,712	138.33	3%
min	−79%	12	6%	100%	5.40	7500	87.50	82%
25%	−44%	4127	8%	114%	9.33	23,250	291.25	88%
50%	−28%	9041	10%	132%	11.69	30,750	378.75	91%
75%	−12%	16,028	13%	154%	14.87	38,250	490.00	92%
max	−5%	38,702	21%	235%	18.97	52,000	660.0	93%

The intention is to focus on the value of PI and the factors that most influence it. To this goal, a feature analysis was performed to determine which aspects are most important in influencing PI. The results of this analysis are set forth in Figure 7. The interaction between the BESS capacity and the shared-to-produced ratio appears to be the most important factor. This evidence can be easily explained: the capital expenditure for the BESS is the most relevant, and the shared-to-produced ratio is directly linked to the revenues generated by the sharing incentive. But what is the relationship between BESS capacity, the shared to produced ratio and PI? Is it an inverse or a direct relationship? The answer is provided in Figure 8, which shows the partial dependance plot. It is interesting to note that for lower values of PI, the variation in BESS capacity is almost irrelevant, but for higher values of PI, the variation in the shared-to-produced ratio is of the utmost importance. It is also noticeable that BESS capacity is inversely proportional to PI, while the shared-to-produced ratio is directly proportional. Another interesting fact is that PUN alone is more relevant than BESS, but when jointly considered with the shared-to-produced ratio, it is less important than the combined term of BESS and the shared-to-produced ratio.

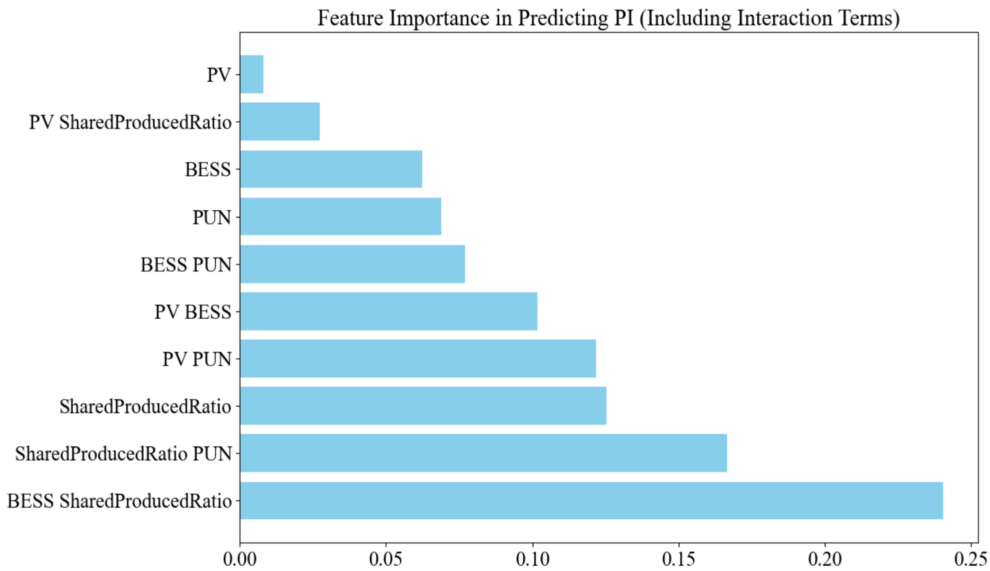

Figure 7. Feature importance.

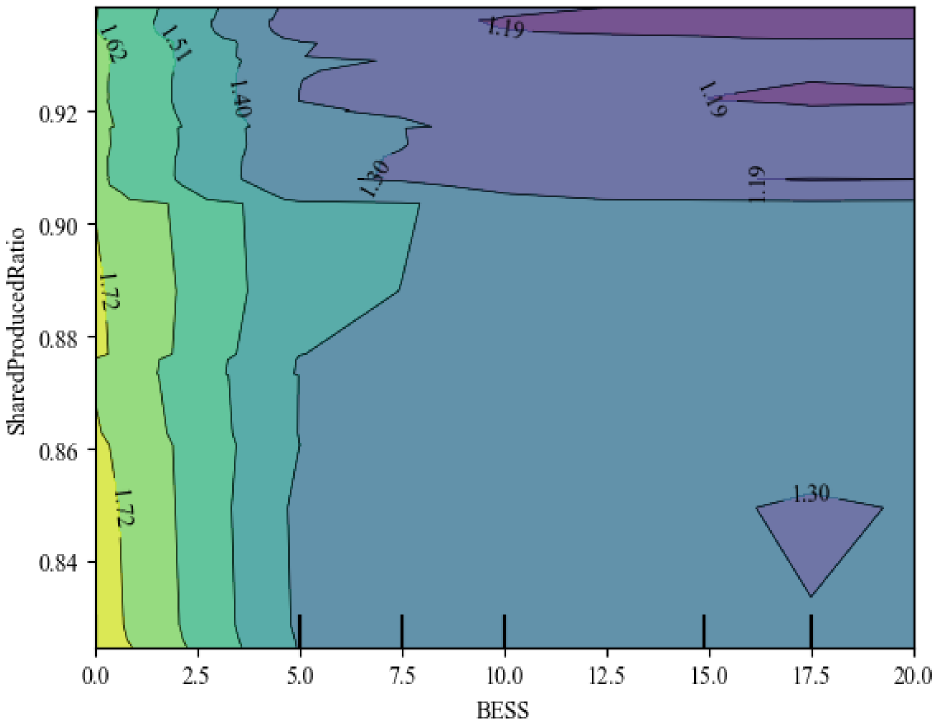

Figure 8. Relationship among BESS, shared-to-produced ratio, and PI value.

The figures reported in Appendix B are also provided for a better understanding of the relationship, in particular the distribution and dispersion of variables. Figure A1 shows an heatmap where the Spearman correlation index is plotted. Prominent positive correlations can be observed between FirstYearRevenue and PUN, CSGExpenditureVariation and %IncentiveToESCo, as well as between PV and CAPEX. The metrics "BESS" and "SharedProducedRatio" exhibit a moderate positive correlation. It is worth evidencing the high (positive) correlation between NPV, IRR, and PI, as well as the negative correlation with PBT. These findings should not go unnoticed, as they are all metrics to generate an estimation of the investment. The same holds true for the correlation between *CAPEX*, *OPEX*, and the values of *PV* and BESS. Overall, from the analysis of correlations between variables, it is possible to devise the correct behavior of the framework, as well as the mutual influence among the variables it is composed of.

Figure A2 illustrates a pairplot in which color codification is used to identify the points in the dataset pertaining to different values of PZ, thus offering a comprehensive visualization of the bivariate relationships between selected variables. The histograms along the diagonal show the distribution of individual variables, exposing any skewness or multimodality in the data. For example, the histogram for "CAPEX" shows a right-skewed distribution, whereas "SharedProducedRatio" appears more uniformly distributed. The scatterplots below the diagonal display the relationship between two distinct variables. The pairplot is a valuable diagnostic tool for detecting trends, patterns, and outliers, which may inform further statistical analysis or predictive modeling. The visualization of multiple bivariate relationships simultaneously allows for a more nuanced understanding of the complex interplay between variables in the dataset. It is interesting to notice a linear relationship between CAPEX and OPEX, and how the interdependence of some variables exposes their dependance on PZ: distinct colored patterns can be identified in the bivariate relationship between expenditure variation and PV power, as well as between OPEX and CAPEX. Finally, in Figure A3 a pairwise boxplot is presented. Each boxplot illustrates the distribution of one variable contingent on the range of another, with the primary variable divided into quartiles and represented by boxes. The boxplots comparing "SharedProducedRatio" against "PV", "BESS", and "PUN" offer a visual representation of how shared production ratios distribute across different levels of photovoltaic outputs, battery energy storage systems, and PUN. Outliers are present in several boxplots, such as SharedProducedRatio vs. PV and BESS vs. PV, suggesting exceptional cases that deviate from the general trend. This collection of boxplots serves as a valuable tool for summarizing the central tendencies and dispersions of variables and can help identify which pairs of metrics exhibit the greatest variability or the strongest signs of correlation.

In the subsequent portions of this section, two distinct investment frameworks are discussed: direct investment by the CSG and involvement of a third-party investor.

Overall, the results of this analysis are interesting, as they provide relevant insights on the behavior of data. However, they do not provide any usable information in a decision-making process, as decisions in investments are mainly made according to economic and financial results.

4.1. Direct Investment from CSG Members

A summary of the results of the simulation, filtered for the investment made only by the CSG members, is reported in Table 4.

Table 4. Summary statistics: CSG is investing.

Statistic	CSG Expenditure Variation	NPV	TIR	PI	PBT	CAPEX	OPEX	Shared Produced Ratio
mean	−39%	12,606	11%	145%	11.34	31,044	385	90%
std	16%	9025	4%	34%	3.49	10,886	140	3%
min	−79%	282	6%	101%	5.40	7500	87	82%
25%	−46%	5124	8%	117%	8.77	23,250	291	88%
50%	−38%	10,754	11%	138%	10.92	31,750	383	91%
75%	−27%	18,755	13%	161%	14.16	39,000	495	92%
max	−11%	38,702	21%	236%	18.77	52,000	660	94%

This sub-dataset of results consists of 107 observations and reveals several intriguing patterns. Most notably, the CSG expenditure variation has a mean of −39%, which is higher than the one reported in Table 3, Summary statistics for the entire dataset. However, high variability is present in the expenditure variation, as suggested by the standard deviation of 16%. In terms of financial viability, the NPV displays substantial variability, with a standard deviation of 9025 € around a mean of 12,606 €. This wide range could indicate differing levels of project profitability and/or risk. Interestingly, IRR exhibits less variability, with a relatively low standard deviation of 4% around an 11% mean. This could signify a more consistent rate of return across different projects or scenarios.

One of the most stable metrics appears to be the shared-to-produced ratio, with a high mean of 90% and a low standard deviation of 3%. This suggests that, irrespective of the financial and operational variability, the proportion of shared production remains consistently high across the observations. This might imply an effective collaborative strategies or resource sharing in the projects considered.

Table A2 provides detailed information on the first ten cases sorted in descending order based on the profitability index (PI), reflecting the efficacy of investments pertaining to CSG. FirstYearRevenue ranges from 1391 to 6615, capturing the initial annual revenue for the corresponding simulations. CSGExpenditureVariation showcases percentage deviations in expenditure, indicating a reduction across all scenarios, with values ranging from −12% to −45%. NPV exhibits values between 6946 and 38,702. The IRR ranges from 17% to 21%, signifying the efficiency of the investments. The PI values vary from 193% to 236%, indicating the relative profitability of the investments. CAPEX values are in monetary units, extending from 7500 € to 35,500 €, depicting the initial costs incurred for each project. OPEX spans from 87 € to 427 €. The PV column reveals values ranging from 5 to 20 kWp. BESS highlights no storage in most scenarios and, in a few cases, storage of up to 5 kWh, ranging from 82% to 89%.

Figure A4 shows the correlation heatmap for the subset of data associated with the investment realized entirely by the CSG. Despite slight differences in the correlation values of single variables, there are no substantial variations when compared to Figure A1. Figure A5 illustrates a pairwise boxplot associated with the 107 cases, offering a visual summary of the distributions and relationships between key financial metrics, in a CSG investment scenario devoid of ESCo. The boxplots convey the central tendency and dispersion of data points for metrics such as PI vs. PV, PI vs. BESS, and PI vs. PUN.

A discernible trend is observed in the CAPEX vs. PV and CAPEX vs. BESS boxplots, where higher values of CAPEX correspond to greater capacities of PV and BESS, indicating a direct relationship between these variables. The boxplots of OPEX vs. PV and OPEX vs. BESS similarly show a progression that reflects higher operational expenses, with increasing capacities of PV and BESS installations.

4.2. ESCo Investing

In Table 5, the summary results of the simulations with ESCo investment are reported.

Table 5. Summary statistics: ESCo is investing.

Statistic	CSG Expenditure Variation	NPV	TIR	PI	PBT	CAPEX	OPEX	Shared Produced Ratio
mean	−9%	7149	9%	126%	13.41	30,342	371	90%
std	2%	5577	3%	22%	3.28	10,395	134	3%
min	−15%	12	6%	100%	7.80	7500	87	82%
25%	−10%	2643	7%	110%	11.21	23,500	292	88%
50%	−9%	5910	9%	123%	13.13	30,375	376	91%
75%	−8%	10,780	10%	136%	15.73	38,000	465	92%
max	−5%	22,809	15%	176%	18.98	52,000	660	94%

This latest dataset comprises 46 observations and reveals several interesting phenomena. Particularly significant is the marked change in the CSG expenditure variation. The mean value has shifted significantly to −9%, contrasting with the higher negative values in previous datasets. This trend implies a considerable reduction in the cuts to CSG expenditure, potentially indicating a change in financial strategy. Moreover, NPV shows a mean value of 7149 €, which is lower than earlier datasets. This decline suggests a shift towards projects that are potentially less profitable or involve lower financial risks. Eventually, an ESCo that decides to invest in such projects should rely on a relevant number of condominiums.

Additionally, the dataset shows a mean IRR of 9%, a slight reduction compared to previous datasets, possibly pointing to more conservative financial expectations. On the other hand, metrics such as the PI and PBT have shown only minor variations in their means, although the minimum and maximum values show a shorter range of variation for these values, indicating less volatility. Furthermore, CAPEX and OPEX have displayed remarkable stability, both in terms of their mean values and standard deviations, indicating a consistent scale and complexity in the projects captured in this dataset.

In Table A3, the details of the first ten cases are reported, ordered by a descending PI. First year revenue ranges from 2377 to 6615, suggesting a diversity in the scale or success of the investments. Expenditure variations show a reduction across all scenarios, with a −5% to −12% change, pointing to potential cost reductions. The NPV figures vary widely, from 6287 to 22,809, highlighting differences in the long-term profitability of the investments. The IRR values are consistently in the double digits, between 11% and 15%. The PI values, used to rank the investments, range from 137% to 176%, with higher percentages representing more favorable returns on investment. PBT extends from 7.80 to 11.08 years, offering insights into the liquidity and risk profiles of the projects. CAPEX and OPEX also show significant variation, indicative of the differing initial and ongoing financial commitments required across the investment scenarios.

Figure A6 illustrates the correlation matrix for the sub-dataset under analysis. The comparison of Figures A1 and A6 reveal variations in the correlation coefficients across the full dataset. In Figure A1, certain metrics, such as FirstYearRevenue and CAPEX have a strong positive correlation, indicating that the initial revenues tend to increase with higher capital expenditures. Additionally, the negative correlations between PBT and IRR, PI, CAPEX, and OPEX in Figure A1 become less pronounced in Figure A6, implying different financial viability of the projects. Figure A7 shows a pairwise boxplot associated with the cases under analysis, which is quite helpful for visually comparing the variation of the parameters of the simulations.

When juxtaposing the results obtained with the two investment frameworks, several critical changes come to the fore. Notably, when the CSG is making the investment, the CSG expenditure variation's mean value is much more relevant. Simultaneously, there is a discernible reduction in the mean NPV, which is appreciable. This decline could indicate a movement towards less profitable or lower-risk projects in the latest dataset. Additionally, the mean IRR has experienced a slight reduction from 11% to 9%, which might be indicative of more conservative financial expectations in the case in which an ESCo is to pursue the investment. On top of that, CAPEX and OPEX have shown a high degree of stability, indicating that the scale and operational complexity of the projects have remained largely unchanged. The steadfastness of the shared produced ratio across both datasets is remarkable. With a mean value of 90%, this metric indicates a consistent approach to resource sharing and collaborative production, a feature that has been invariant across different datasets. Finally, it must be noted that the most profitable scenarios are achieved for a higher PZ. It goes without saying that these results should be further analyzed in consideration of the likeliest PZ.

5. Conclusions

This study is framed within the paradigm of energy communities developed according to EU directives, with a focus on collective self-consumption groups in Italy. The authors developed a multi-criteria technical-economic framework to evaluate different scenarios for the sizing of energy production and storage facilities, with the aim of supporting decisions in the planning phase of CSGs. Using a Python-based simulation tool, the authors evaluated the financial and social benefits of different configurations for a case study, considering different financial indicators. The results obtained from the simulation are discussed with a focus on different possible configurations of the condominium system. By comparing the CSG investment framework with a scenario in which an ESCo is responsible for the investment, a wide range of profitable scenarios that can meet different criteria in terms of CAPEX, avoided costs and return on investment are highlighted.

The simulation tool can help guide investment decisions towards the most viable energy solutions, highlighting their potential to deliver financial and social benefits under varying economic conditions.

Finally, the work provides insights for all stakeholders and parties involved in the development of energy communities, including politicians and investors, so that they can make informed decisions in the transition towards more sustainable and decentralized energy systems. In fact, Italy's policy and incentive framework must address both environmental sustainability goals and the social and economic needs of citizens.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A. Financial Metrics

This appendix provides some details on the financial metrics used in investment analysis and capital budgeting: net present value (NPV), internal rate of return (IRR), profitability index (PI), and payback time (PBT). Other indicators and parameters used in the paper are described as well.

Appendix A.1. Net Present Value

NPV is used to determine whether the investment is profitable. If the NPV is positive, the investment is considered worthwhile because the future cash flows generated by the project exceed the cost of capital invested. The NPV is the sum of the present values of all future cash flows. The formula is:

$$\mathrm{NPV} = \sum_{t=0}^{n} \frac{\mathrm{CF_t}}{(1+\mathrm{r})^{\mathrm{t}}} \quad \text{(A1)}$$

where:

- CF_t is the cash flow at time t.
- r is the discount rate.
- t is the index that indicates the period.
- n is the total number of periods.

To calculate the NPV first the cash inflows and outflows for each period must be identified. Then the appropriate discount rate must be figured out. Finally, the aforementioned formula must be applied.

Appendix A.2. Internal Rate of Return

Internal Rate of Return is the discount rate that makes the Net Present Value of a project equal to zero. In other words, IRR is the discount rate that balances the initial investment with the future cash flows generated by a project. In the model, it is calculated using the following formula:

$$\mathrm{NPV} = 0 = \sum_{t=0}^{n} \frac{\mathrm{CF_t}}{(1+\mathrm{r})^{\mathrm{t}}} \tag{A2}$$

The previous equation must be solved for r. The result is the IRR. Usually, it is solved using iterative methods like Newton-Raphson method.

Appendix A.3. Profitability Index

Profitability Index is a financial metric used in capital budgeting to evaluate the attractiveness of an investment or project. It is calculated as the ratio of the present value of future cash flows to the initial investment. A PI greater than 1 indicates that the investment is profitable, while a PI less than 1 suggests that the investment will likely result in a loss.

$$\mathrm{PI} = \frac{\text{Present Value of Cash Inflows}}{\text{Present Value of Cash Outflows}} = 1 + \frac{\mathrm{NPV}}{\text{Initial Investment}} \tag{A3}$$

The advantage to use PI to evaluate a project are that it takes time value of money into account, unlike some other metrics like the payback period. It also provides a relative measure of profitability, allowing for easy comparison between different projects.

Appendix A.4. Payback Time

The simple payback period indicates the period of time required to recover the initial investment through the cash flows generated by the project. The formula is as follows:

$$\mathrm{PBT} = \frac{\text{Investment}}{\text{Annual Cash Inflow}} \tag{A4}$$

Appendix A.5. Percentage Expenditure Variation

The parameter is computed to evaluate the benefits actually achieved by the members of the CSG. It is calculated as follows:

$$\mathrm{PEV} = \frac{\text{members}' \text{net costs with CSG} - \text{members}' \text{net costs without CSG}}{\text{members}' \text{net costs without CSG}} \tag{A5}$$

where

- *Members' net costs with CSG* are calculated as the instalment (if any) plus OPEX, plus energy expenditure, minus the total net income.
- *Members' net costs without CSG* are just the costs buried for the energy supply.

If PEV is advantageous for the members, it will be represented as a negative value. This negative figure indicates that the members are experiencing net benefits from the arrangement.

Appendix A.6. Shared-to-Produced Energy Ratio

The parameter is used to evaluate how the energy produced is actually being used locally, and whether it is generating revenues from the incentive mechanism. The parameter is calculated for a solar year as follows:

$$\mathrm{SPER} = \frac{\sum_{t=0}^{n} \mathrm{SE_t}}{\sum_{t=0}^{n} \mathrm{PE_t}} \tag{A6}$$

where

- $\mathrm{SE_t}$ is the shared energy at time t.
- $\mathrm{PE_t}$ is the produced energy at time t.

Appendix B. Tables and Figures

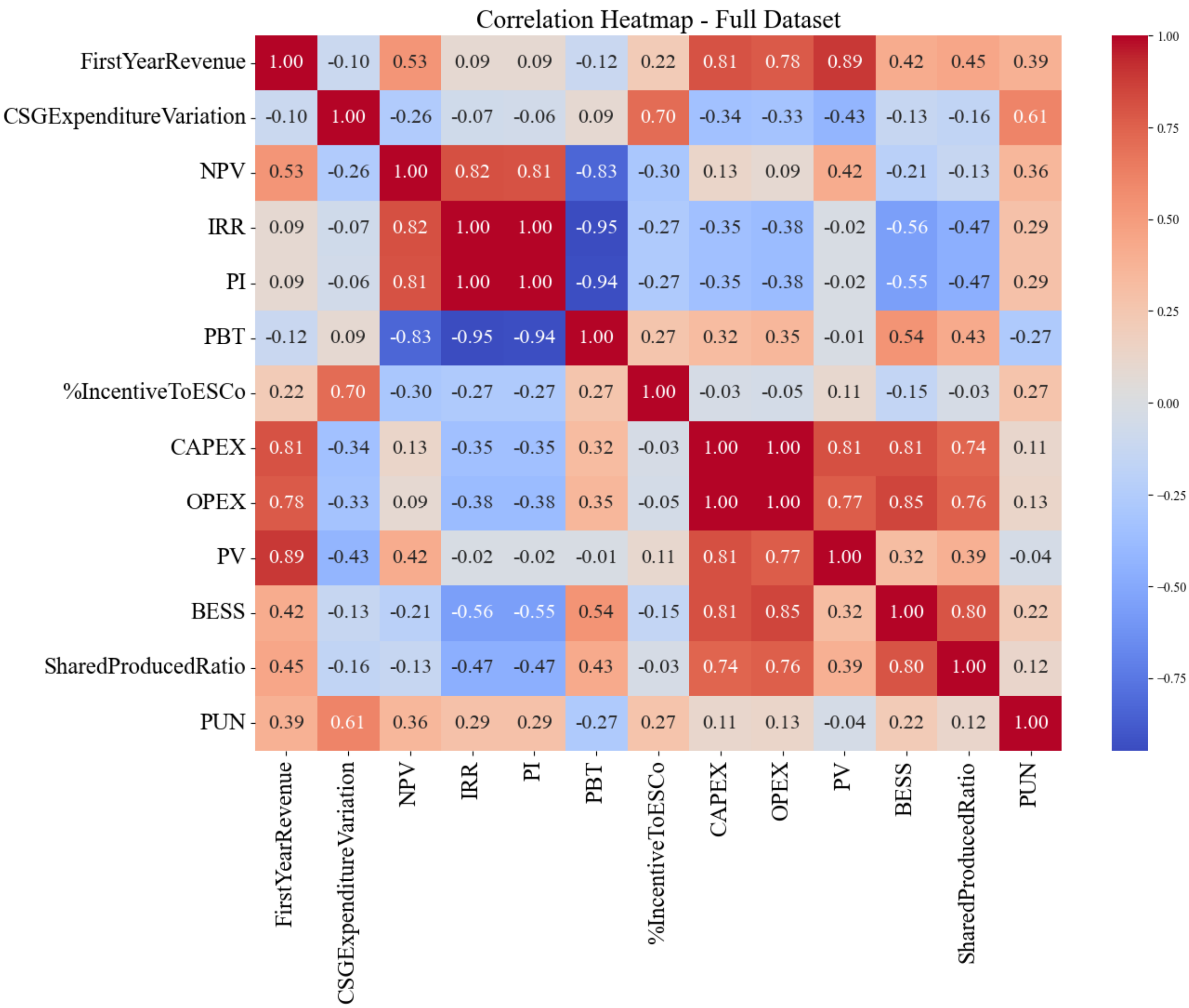

Figure A1. Correlation heatmap for the full dataset.

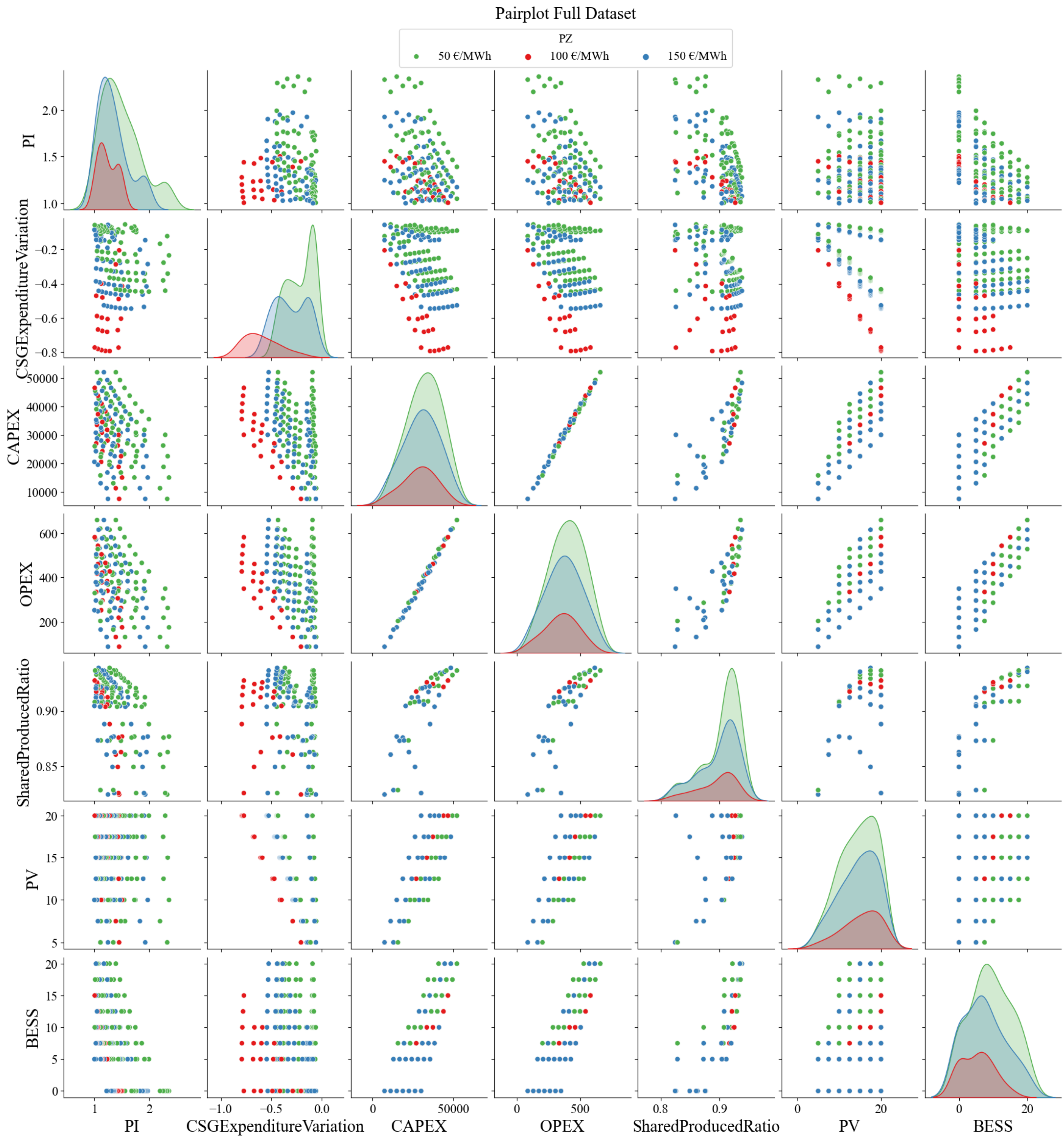

Figure A2. Pairplot for the full dataset.

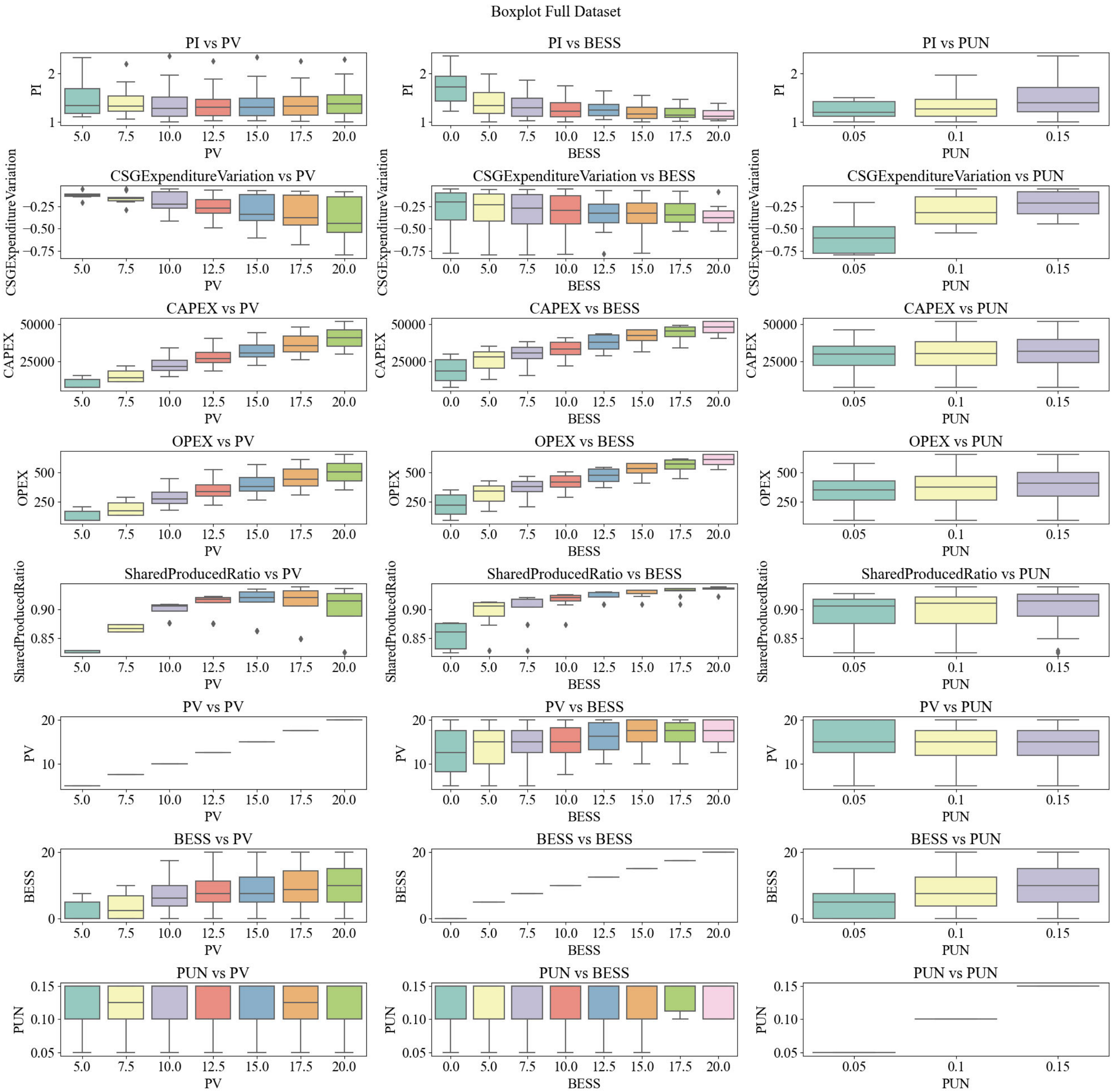

Figure A3. Pairwise boxplot for the full dataset.

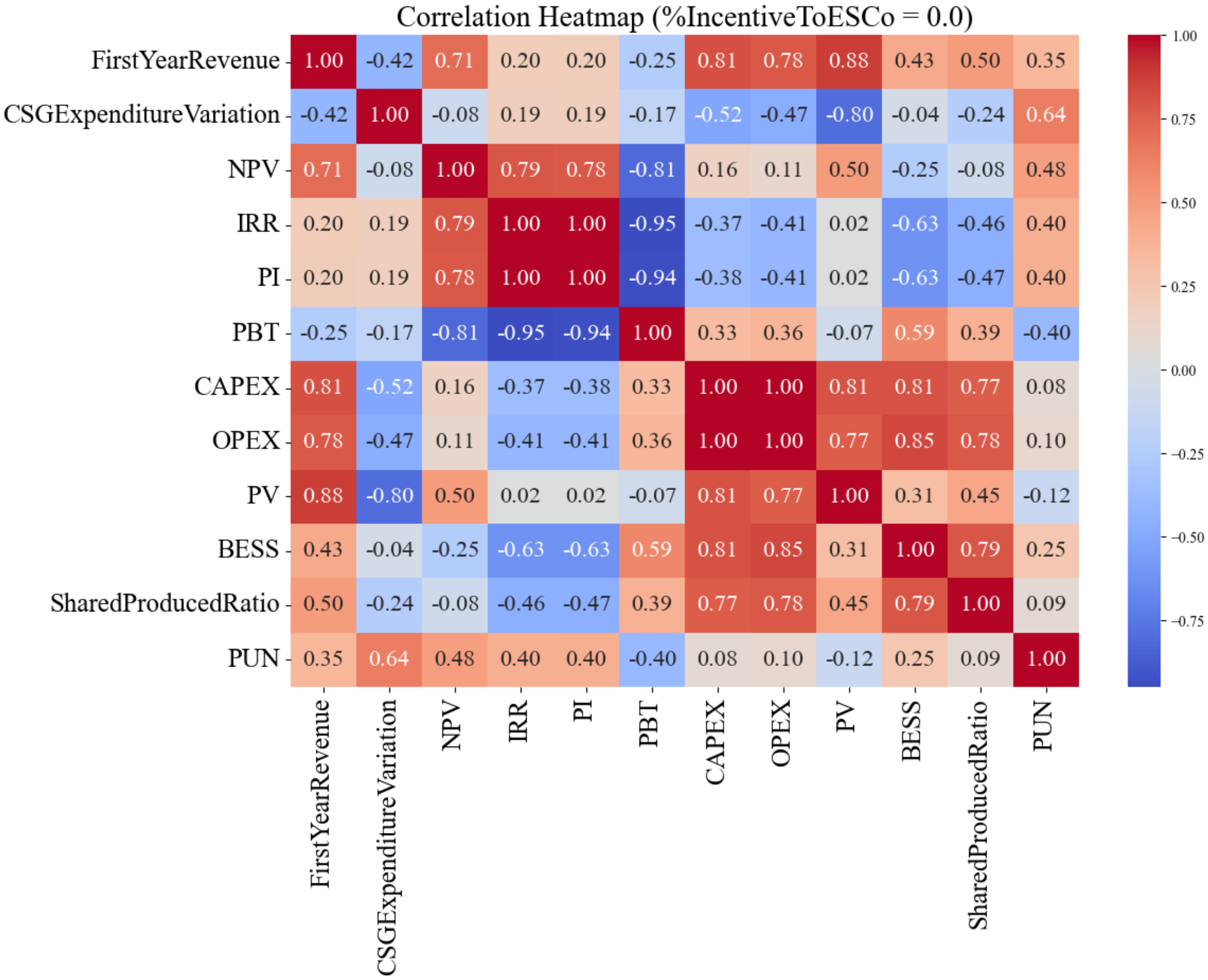

Figure A4. Correlation heatmap: investment made by the CSG.

Table A1. The first ten results of the simulation, ordered by descending PI, full dataset.

First Year Revenue	CSG Expenditure Variation	NPV	IRR	PI	PBT	CAPEX	OPEX	PV	BESS	SPER	PUN	% Incentive to ESCo
3406	−23%	20,380	21%	236%	5.40	15,000	175	10	0	88%	0.15	0
5058	−34%	30,031	21%	233%	5.47	22,500	262	15	0	86%	0.15	0
1679	−12%	9945	21%	233%	5.49	7500	87	5	0	82%	0.15	0
6615	−44%	38,702	21%	229%	5.60	30,000	350	20	0	83%	0.15	0
4079	−28%	23,610	20%	226%	5.69	18,750	218	12.5	0	88%	0.15	0
5692	−38%	32,862	20%	225%	5.71	26,250	306	17.5	0	85%	0.15	0
2377	−17%	13,443	20%	219%	5.89	11,250	131	7.5	0	86%	0.15	0
6811	−45%	35,234	17%	199%	6.65	35,500	427	20	5	89%	0.15	0
2847	−29%	14,574	17%	197%	6.74	15,000	175	10	0	88%	0.10	0
4223	−42%	21,358	17%	195%	6.84	22,500	262	15	0	86%	0.10	0
1391	−15%	6946	17%	193%	6.94	7500	87	5	0	82%	0.10	0

Table A2. The first ten results of the simulation, ordered by descending PI, CSG investing.

First Year Revenue	CSG Expenditure Variation	NPV	IRR	PI	PBT	CAPEX	OPEX	PV	BESS	SPER	PZ
3406	−23%	20,380	21%	236%	5.40	15,000	175	10	0	88%	0.15
5058	−34%	30,031	21%	233%	5.47	22,500	262	15	0	86%	0.15
1679	−12%	9945	21%	233%	5.49	7500	87	5	0	82%	0.15
6615	−44%	38,702	21%	229%	5.60	30,000	350	20	0	83%	0.15
4079	−28%	23,610	20%	226%	5.69	18,750	218	12.5	0	88%	0.15
5692	−38%	32,862	20%	225%	5.71	26,250	306	17.5	0	85%	0.15
2377	−17%	13,443	20%	219%	5.89	11,250	131	7.5	0	86%	0.15
6811	−45%	35,234	17%	199%	6.65	35,500	427	20	5	89%	0.15
2847	−29%	14,574	17%	197%	6.74	15,000	175	10	0	88%	0.10
4223	−42%	21,358	17%	195%	6.84	22,500	262	15	0	86%	0.10
1391	−15%	6946	17%	193%	6.94	7500	87	5	0	82%	0.10

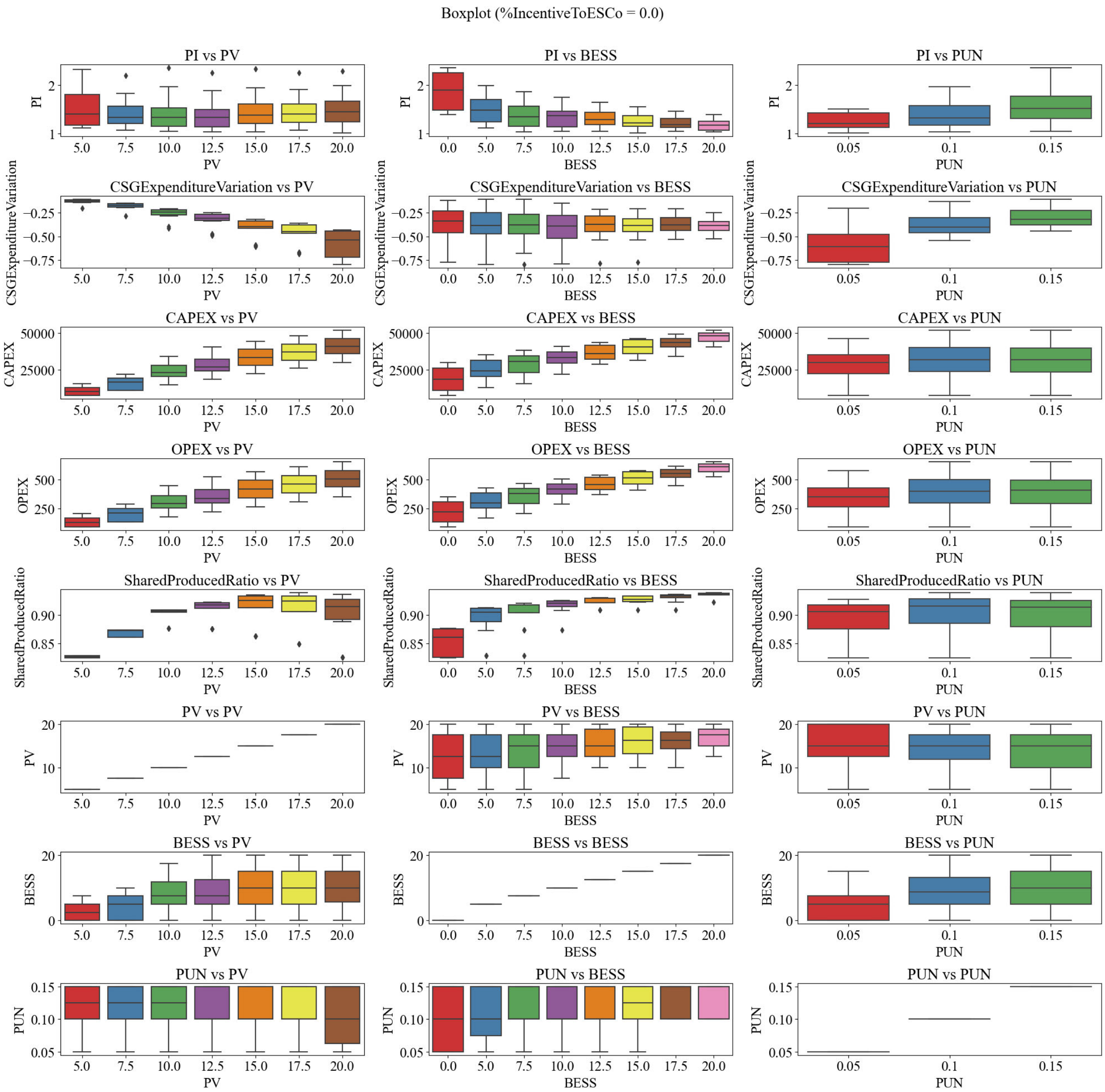

Figure A5. Pairwise boxplot: investment made by CSG.

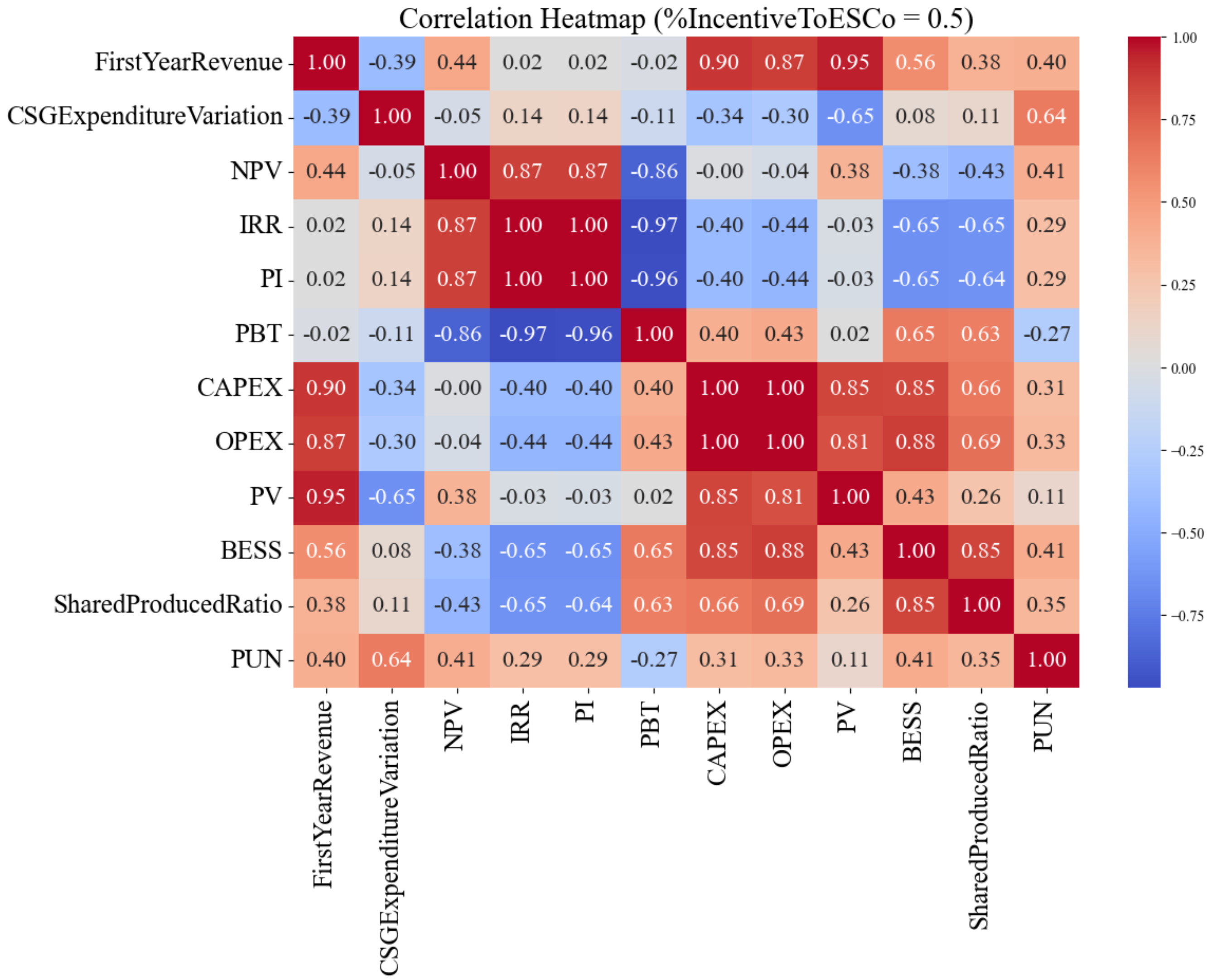

Figure A6. Correlation heatmap: investment made by ESCo.

Table A3. The first ten results of the simulation, ordered by descending PI, ESCo investing.

First Year Revenue	CSG Expenditure Variation	NPV	IRR	PI	PBT	CAPEX	OPEX	PV	BESS	SPER	PZ
6615	−10%	22,809	15%	176%	7.80	30,000	350	20	0	83%	0.15
5058	−8%	17,097	15%	176%	7.80	22,500	262	15	0	86%	0.15
3406	−7%	10,917	15%	173%	7.99	15,000	175	10	0	88%	0.15
5692	−9%	18,687	14%	171%	8.09	26,250	306	17.5	0	85%	0.15
4079	−7%	12,695	14%	168%	8.32	18,750	218	12.5	0	88%	0.15
2377	−5%	6287	13%	156%	9.20	11,250	131	7.5	0	86%	0.15
6811	−10%	18,310	12%	152%	9.57	35,500	427	20	5	89%	0.15
5842	−9%	13,957	11%	144%	10.30	31,750	383	17.5	5	91%	0.15
5175	−8%	12,194	11%	144%	10.34	28,000	340	15	5	91%	0.15
6860	−10%	15,804	11%	141%	10.58	38,250	466	20	7.5	90%	0.15
4223	−12%	8317	11%	137%	11.08	22,500	262	15	0	86%	0.10

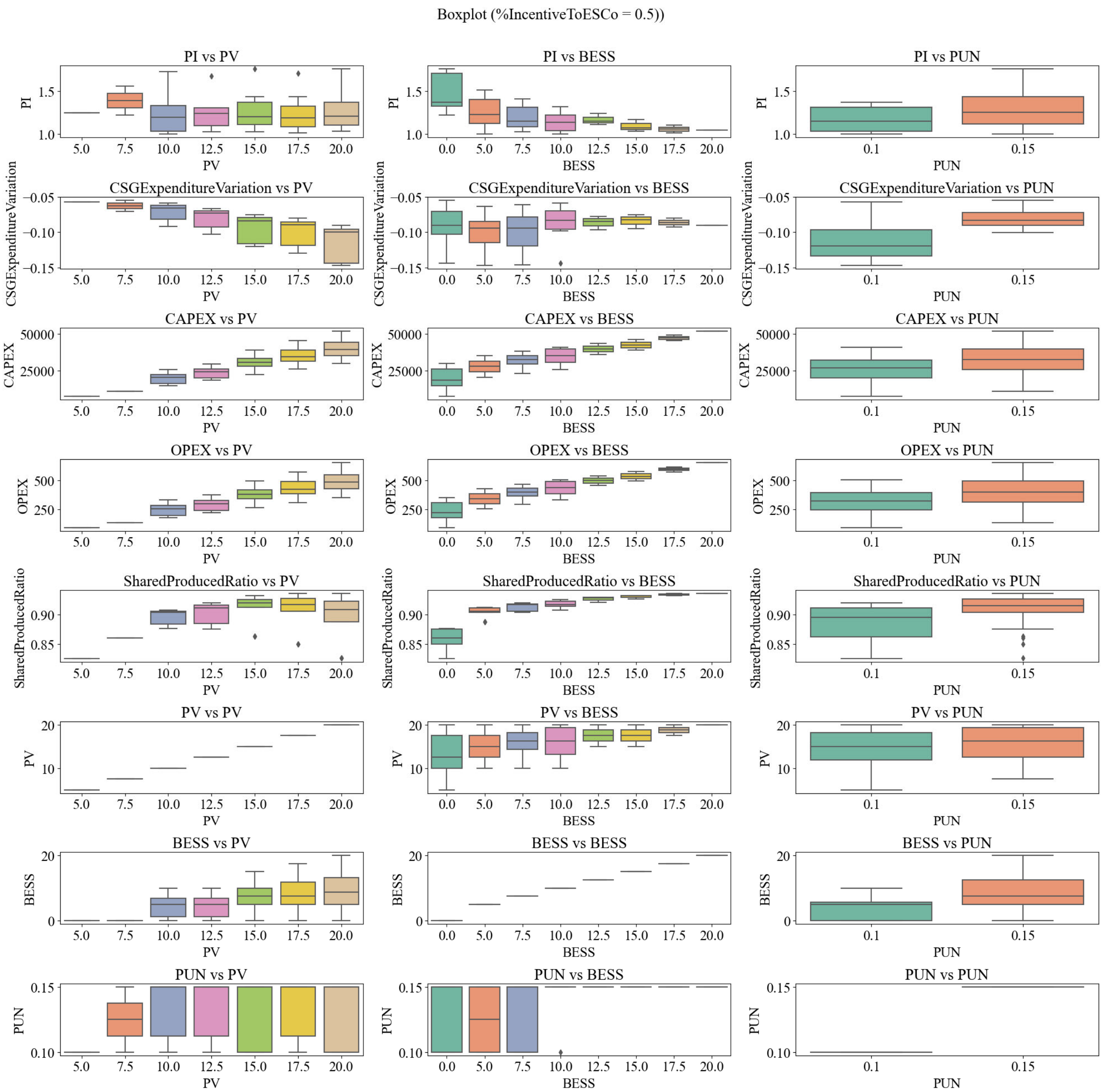

Figure A7. Pairwise boxplot: investment made by an ESCo.

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