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Project Portfolio Selection of Solar Energy by Photovoltaic Generation Using Gini-CAPM Multi-Criteria and Considering ROI Covariations

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Citation: Isaias, J.C.; Balestrassi, P.P.; Marcondes, G.A.B.; Silva, W.V.d.; Pereira Mello, C.H.; Veiga, C.P.d. Project Portfolio Selection of Solar Energy by Photovoltaic Generation Using Gini-CAPM Multi-Criteria and Considering ROI Covariations. *Energies* **2021**, *14*, 8374. https://doi.org/10.3390/en14248374

Academic Editor: Pedro Faria

Received: 3 November 2021
Accepted: 7 December 2021
Published: 12 December 2021

Abstract: For some time, renewable solar energy generations using cellular photovoltaic panels have stood out among the options, especially in the segment of micro and small companies, where the return on investment is usually higher. In this context, when micro and small companies do not have the capital for the enterprises, several others, mainly small ones, have emerged to finance. However, significant difficulties occur for financiers in selecting investment portfolios, especially when considering the trade-off between return and risk and the covariations of return on investment, which are very common. In this type of selection, the Capital Asset Pricing Model criteria using the Gini risk can help significantly because this one is a more robust risk coefficient for assessments of non-normal probability distributions. However, searches for methods that meet the selection needs using the adjacent criteria are unsuccessful. Thus, this work seeks to help minimize the gap by presenting a new method for selection using the criteria. Historical and simulations data stochastic evaluations indicate that the portfolios selected by the method are attractive options for implementations. These portfolios have reasonable probabilistic expectations and satisfactory protection to avoid mistakes caused for not considering covariations in return on investment, which indicates a significant advance on the current knowledge frontier and will likely allow the increased use of the concept. The method also presents theoretical contributions in adaptations of the benchmark models, which help to minimize the adjacent literary gap of similar methods.

Keywords: project portfolios selection; trade-off between Gini risk and return considering covariations; renewable energy sources; photovoltaic solar energy microgeneration; financial feasibility; social welfare

1. Introduction

The world is being held hostage to non-renewable energy sources, which is a significant problem. As the resource is limited, it has become the center of conflicts in several segments: economic, market, ideological, and military, among others [1]. Moreover, with the advance of demanding technologies and the population in general, energy consumption is significantly increasing, which will cause the reserves of non-renewable sources to end quickly [1,2].

The growing energy demand is undoubtedly one of the significant challenges today. Its segmental conflicts generate dire consequences for society, such as political barriers, underdevelopment, hunger, and wars [3]. Therefore, the constant change in the world energy matrix towards more excellent renewable sources is desirable, especially if the fossil and nuclear options have significant reductions [4,5].

An excellent and desired feature of renewable energy sources is reducing CO_2, which significantly degrades the ozone layer and intensifies the greenhouse effect. The undesirable gas comes from fossil fuel consumption representing approximately more than 80% of the world matrix [6,7]. In addition, RES offers several other benefits. With technological advances, their use for the business sector becomes increasingly robust, mainly due to reductions in investment costs, a fundamental characteristic, as the business segment has excellent power to leverage RES [8].

Among renewable energy sources, solar photovoltaic stands out for its great potential due to the increasingly affordable cost of implementation. It is clean, sustainable, and has a significant margin for generation and growth. With the emergence of smart grids, the photovoltaic solar system has become increasingly interesting to complement traditional distribution networks, micro-networks, and smart homes, among others [9,10].

In renewable sources, solar energy by photovoltaic cells (SEPC) has been the first option of the current society to correct the energy matrix. The choice is mainly due to the significant benefits of the technology. Also, it is essential to note that they are among the most sustainable, do not emit pollutants or use scarce raw materials, and reduce noise pollution. They also do not require exhaustive maintenance, can last up to 2.5 decades at least, and have a considerably reduced payback [11–13].

As solar energy by photovoltaic cells (SEPC) is a relatively new technology, there is no well-defined policy for its implementation in general. Some countries offer significant incentives, while others impose substantial taxes. Generally, developed countries are encouraging, and developing countries charge large taxers [14–16]. Small and micro companies typically receive significant incentives for the implementation of SEPC. However, in developing countries, the sector is in constant economic and financial recession, often caused by inappropriate policies and legislation for the medium-term and long-term [17–19].

Due to the justifications, the models, methods, procedures, and programming, among others, emerge from developing the SEPC technology [20–23]. However, the SEPC project portfolio analysis and selection (PPAS) is still deficient. In other words, we found some models to perform the selection, but they are few, do not consider the risk and return trade-off, and do not consider the covariations (nor the most important, of the risk of return on investment—ROI), among others [24–27]. The covariations (also called interdependence) between projects can occur in any input or output parameters in the adjacent portfolio. It is simply the formation of portfolios with two or more components. Among the options, the covariations of ROI risk parameters are the most significant [28,29].

The Gini Capital Asset Pricing Model (Gini-CAPM) is an appropriate methodology to contribute to the presented questions' solutions. The model has several benefits when used for asset portfolio management. Because it derives from the Modern Portfolio Theory (MPT), the methodology fully considers the interactions between portfolio assets. These interactions, in turn, can strongly influence the results [30,31].

The Gini-CAPM mainly arose because we shouldn't apply the traditional CAPM risk measure (the variance) in in non-normal variables. Still, its conceptual basis in the mean-variance (MV) model is an obstacle to developing methodologies for applications in PPAS. The reason is why, in PPAS, the assets have non-normal random variables and parameters [31–33].

Among several options tested as alternatives to variance, the so-called Gini risk coefficient stands out. Its concept is as intuitive as that of standard deviation. Moreover, it is mathematically a more robust metric to applications in non-normal distributions. And this is due to the structure of its probability density function [34–36]. The Gini coefficient can replace the standard deviation to minimize the main obstacle for applying CAPM in non-normal distributions. This development is the so-called Gini-CAPM [31,32].

However, photovoltaic cells work in volatile environments concerning climatic and environmental conditions, which generally significantly influences the actual power generation capacity, as it alters the adjacent parameters themselves. Furthermore, the most comprehensive analytical methods would be needed to consider the various assumptions and operating conditions for using cellular photovoltaic generation systems [37]. On the other hand, the stability of photovoltaic cells in the environments where they work is essential, mainly when the environment in question differs considerably from the ideal. Among the various factors that can interfere in the level and quality of generation, temperature and humidity are among the most critical that affect photovoltaic stability. Nevertheless, these same two factors are significant causes of accelerated degradation of optoelectric and material properties [38].

Thus, with this study, we can contribute scientifically and significantly according to the justifications presented, seeking to solve identified problems and minimizing the literary gaps found. In summary, the proposal is a method for appreciation, evaluation, and publication in the renowned Energies Journal. We structured the method for applications in PPAS SEPC, using multi-criteria similar to the Gini-CAPM, considering the possible Gini-covariations of ROI, and in an innovative way. We organized the study to present as follows: Section 2 shows the essential concepts used for the design of the method; Section 3 presents the materials and methods used in conducting the study; Section 4 presents the method application and results discussions; and finally, Section 5 presents the major research conclusions.

2. Literature Review

In this section, we presented the fundamental theoretical concepts to the research. These concepts refer to the Gini correlation coefficient and the Gini variations/covariations of return on investment. The other essential concepts for the new method are in Section 3.2 with adaptations, or theoretical contributions, for applications in PPAS. In fact, in this section, we present the fundamental theoretical concepts, but the theoretical contributions of the research are in Section 3.2. Thus, the search for advancement in the frontier of knowledge is in Section 3.2, where existing methods and models are modified and adapted to the needs of this research in an innovative way. Therefore, in Section 3.2 are the contributions to help minimize the identified literary gap.

2.1. Gini Correlation Coefficient

It is vital to consider the iterations or interferences that the composition of the portfolios may cause. These interferences represent a great source of risk [27,39]. To consider interactions between assets is a level of precaution that presupposes financial management, and in this sense, CAPM is the most used methodology for asset management throughout history [40,41]. The Gini-CAPM is a more appropriate methodology for project portfolio management [32,42].

As in the method media-Gini (MG), in Gini-CAPM, we can derive the efficient portfolios similar to MV way analytically. For this, if we imposed the same restrictions as the MV model, these MG portfolios can also be obtained using optimization techniques for restricted minimization problems [31]. However, there is an essential difference between the derivations of MG concerning those of MV, where MG has two correlation coefficients between each pair of assets. At the same time, those from MV are associated with only the well-known Pearson correlation coefficient [32].

We can describe the values of the random return variables of the distributions of assets i and j as r_i and a r_j; its two possible correlation coefficients of Gini between the assets Γ_{ij} and Γ_{ji}; and, finally, $F(r_i)$ and $F(r_j)$ as the values of the cumulative probability density distribution for r_i and r_j. Thus, we can describe the Gini correlations in Equation (1) [31,32].

$$\Gamma_{ij} = \frac{cov\left[r_i, F\left(r_j\right)\right]}{cov\left[r_i, F\left(r_i\right)\right]} \qquad \Gamma_{ji} = \frac{cov\left[r_j, F\left(r_i\right)\right]}{cov\left[r_j, F\left(r_j\right)\right]} \tag{1}$$

2.2. Projects ROI Variations and Covariation

The covariations between projects can occur in any input or output parameters in the adjacent portfolio simply by the composition of at least two assets. A classical and more significant covariation between project portfolios is the ROI risk [43,44]. In the sets with two projects $j \leq 2$, both Gini correlation coefficients described in Equation (1) are necessary to break down individual ROI risk contributions by combinations of assets in pairs [28,29]. The two Gini correlation coefficients are not necessarily equal, and they will be identical only if the distributions of i and j are interchangeable in a linear transformation [45–47].

In measuring the Gini variation (or individual Gini risk) together with the covariation of a portfolio Δ_p^2 between two assets i and a j according to Equation (2), it is necessary to consider that: α_i and α_j are the proportions of assets i and j in the portfolio, and Δ_i and Δ_j are the Gini risks referring to the same assets [31,32]. Both Gini correlation coefficients described in Equation (1) are necessary to break down individual risk contributions into combinations of assets [32].

$$\Delta_p^2 = \alpha_i^2\Delta_i^2 + \alpha_j^2\Delta_j^2 + 2\alpha_i\Delta_i\alpha_j\Delta_j\left[\left(\Gamma_{ij} + \Gamma_{ji}\right) / \ 2\right] \quad (2)$$

However, researchers in the scientific community generally assume that the correlation coefficients of Gini Γ_{ij} and Γ_{ji} are equal [31,32]. By the structure of the Gini covariation mapping in Equation (2), the components or terms of the same are for $i = 1\ldots\ (n-1)$ and for $j = 2\ldots\ n$, and on the main diagonal is the individual Gini variation conform Equation (3) [28,29].

Analyzing Equation (3), it is possible to state in this case, the mapping of the Gini variation added to the Gini covariation is identical to that of the variance and covariance [48].

$$\Delta_p^2 = \alpha_i^2\Delta_i^2 + \alpha_j^2\Delta_j^2 + 2\alpha_i\Delta_i\alpha_j\Delta_j\left(\Gamma_{ij}\right) \quad (3)$$

3. Materials and Methods

This section presents the method development to seek the objectives and detailed guidelines for reproducing the application. The research proposes a method to PPAS, using multi-criteria similar to Gini-CAPM, considering ROI covariations, and for SEPC application, and for use by small businesses in selecting microgeneration. Figure 1 shows the synthesized method sequence.

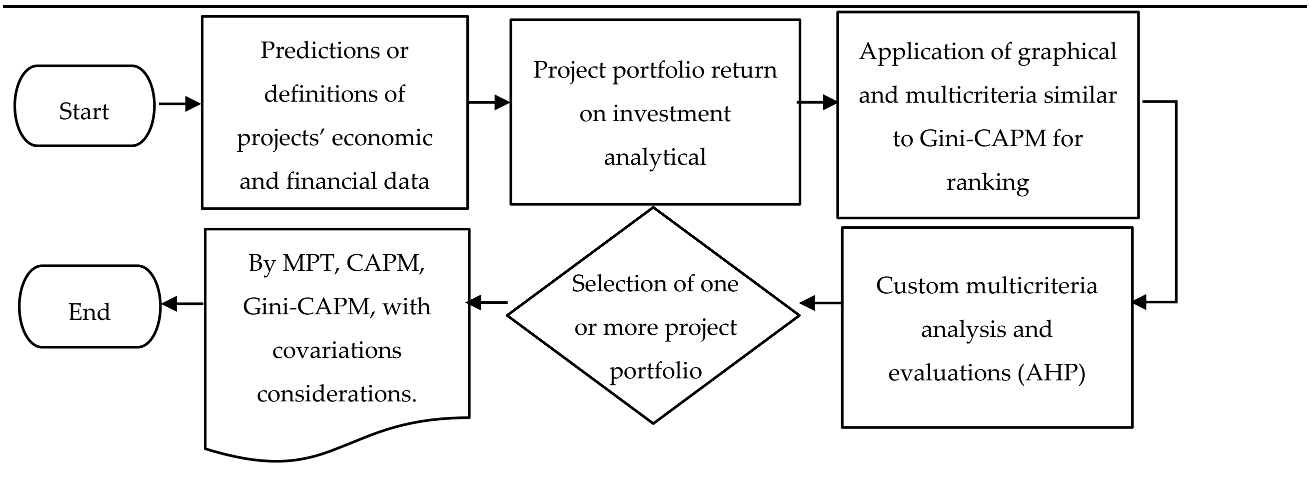

Figure 1. Synthesized method sequence.

3.1. Method Assumptions

This section presents only the most relevant assumptions that differ between the original CAPM and the "Gini-CAPM for projects" introduced in this work. The identical premises for both we have not discussed here, and we consider them to be valid. The first assumption derived from the CAPM states that "data on returns from the assets under study have normal probabilities distributions" [49,50]. This conceptual foundation (derived from the MV model) is the main barrier to developing a methodology similar to Gini-CAPM but specific for PPAS. Therefore, the first assumption is not acceptable for this research's method. The reason is that method uses a risk measure, the Gini coefficient, that is less restrictive.

Another essential Gini-CAPM assumption states that "the assets are divisible, that is, it is possible to obtain and retain assets fractions following the investment strategies adopted" [51,52]. However, this assumption is not valid for the method because this is not a reality observed in selecting project portfolios.

Among the implications of not validating the last premise, it highlights the possibility of non-compliance with optimality conditions according to the method reference models (developed for continuous assets). Therefore, negative consequences arise, and among them is that which prevents the use of base algorithms towards the gradient for the solutions of the new method. It is a pity because these algorithms are very efficient in solving adjacent mathematical models.

In projects, the most critical input data, the returns mean, are estimated in probability distributions, commonly binomials, triangular, or beta types [50,53,54]. Among the distribution types, those recommended are the triangular or betas. The reason is that both have the three-point technical calls to define their parameters, and therefore, the estimation occurs in a more efficient form [33]. Based on the references cited, the mean return distribution adopted for the method is triangular. Therefore, it stands out concerning the second possibility because its parameters are more intuitive and allow for less intense calculations required.

CAPM is a methodology that can indicate an optimal portfolio in excess returns per unit of deviation risk, which is the one with the highest Sharpe ratio. This portfolio is supposed to the more representative in the financial securities scenario, and it is the best estimate of the market [55,56]. Therefore, this research has this portfolio as the market index, as detailed in Section 4.

The last assumption implies another of great importance for the method. Its applications discarded all the composition strategies with a portfolio similar to that of the market. This applies to all possible operations: short, long, leveraged, hybrid, and others. The premise assumes that the portfolio similar to the market is optimal but not differentiable. The last assumptions certainly increase the method acceptability by the scientific community imposing a more realistic structure. However, it is essential to infantize that the composition with the risk-free rate for capital available and uninvested is possible.

3.2. Problem Variables and Mathematical Modelling and Development

Despite having a new proposal, the method which our research presents is simple. The study proposes a project portfolio select method of SEPC using multi-criteria similar to the Gini-CAPM. The aim is to propose a structured way for small and micro investors to choose SEPC project portfolios. Also, due to the legislation's incentives, the scope of dimension limits is small and micro companies. The reason is that national legislation allows more advantageous uses of photovoltaic energy in this companies' dimension.

However, changes in solar cell parameters in the application environment are significant, mainly due to heat and humidity. Therefore, it would be necessary several tests to verify the absolute reliability and durability of the equipment according to their respective installation locations. A significant factor that must be considered is the temperature, which usually varies a lot between periods of day and night. Thus, comparative studies are essential to determine the actual efficiency, as well as the useful life of photovoltaic cell systems. The ageing of photovoltaic modules due to high levels of heat and humidity is also very strategic in considering the life and efficiency of the modules [57,58].

However, another initial definition of data to the method application is the risk-free rate R_f. This rate represents a scalar value, and generally, its adopted value corresponds to the national treasury bills. In practice, it means the minimum level of profitability without risk to a country. However, also it is possible to follow organizational particularities such as minimum rates of attractiveness.

Another critical input parameter is the ROI that each project will offer. For this, we need dates to calculate the cash flows of all projects accordingly and then generate a matrix R_{ij}, where $i = 1 \ldots\ m$ represents the distribution parameters of each project from $j = 1 \ldots\ n$.

In the matrix R_{ij}, each term T in dimension i represents, respectively, the minimum, the most probable, and the maximum value of the triangular probability distributions for each project j. The values must be estimated according to organizational convenience, for example, using the Program Evaluation and Review Technique (PERT). The PERT t also receives the name of "Three-Point Estimation" and is more recommended by the ©PMBOK bestseller [33].

$$R_{ij} = \begin{bmatrix} T_{11} & \ldots & T_{1n} \\ \ldots & \ldots & \ldots \\ T_{31} & \ldots & T_{3n} \end{bmatrix} \tag{4}$$

At this moment in the method the Gini correlation matrix $\Gamma_{jj\prime}$ should be established. The matrix is necessary to calculate the Gini's covariations between projects, the Beta-Gini, and the Gini price. "There are other established project estimation methodologies, according to PMI (2017) [33], such as the parametric, or any other, as appropriate (analogues, by the experts, bottom-up, PERT, among others".

We can describe the values of the random return variables of the distributions of assets j and $j\prime$ as r_j and a $r_{j\prime}$; its two possible Gini correlation coefficients between the assets as $\Gamma_{jj\prime}$ and $\Gamma_{j\prime j}$ and, finally, $F(r_j)$ and $F(r_{j\prime})$ as the values of the cumulative probabilities densities distributions for r_i and a r_j, are strictly according to Equation (1).

In addition, with the information available, it is possible to calculate the individual Gini risk Δ_j of each asset, and the contributions of that risk by forming portfolios mapped in pairs Δ_{jj} concerning ROI. We can describe the ROI variations and covariation by $\sqrt{\Delta_s^2}$. Still, Equation (3) presents the formulation for Gini risk calculating intuitively. Also intuitive is the formulation for the individual calculation of the Gini risk in Equation (5) [32].

$$\Delta_j = 2Covar\left(x_j, F\left(x_j\right)\right) \tag{5}$$

It is important to emphasize that, from this point on in this section, the models presented receive adaptations for application in the scenario (PPAS). According to research in the Web of Science and the Scopus database, the transformations represent theoretical contributions.

The next step is to calculate the optimal market portfolio GS_s^* similar to that of Sharpe from Gini-CAPM. This portfolio is not differentiable as its calculation does not have the constraint of $x_j \in [0,1]$ for all $j = 1 \ldots\ n$. The set of equations from Equation (6) to Equation (10) are necessary and sufficient to determine the optimal portfolio GS_s^*. In Equation (6) to Equation (10), we have not yet described L, which represents the desired lower ROI limit, $P_{ij}x_j$, which is the investment cost value of each project segmented by period i; B represents the upper limit of total spending on investments, and z_j is the respective vector of maximum investment values.

$$\text{Max } GS_s^* = \left[\left(\sum_{i=1}^{m}\sum_{j=1}^{n} r_{ij}x_jz_j\right) - r_f\right].\left\{2\ Covar\ \left[r_{ij}x_jz_j,\ F\ \left(r_{ij}x_jz_j\right)\right]\right\}^{-1} \tag{6}$$

$$\text{s.t.} \sum_{i=1}^{m} \sum_{j=1}^{n} r_{ij} x_j z_j \geq L \tag{7}$$

$$\sum_{i=1}^{m} \sum_{j=1}^{n} P_{ij} x_j z_j \leq B \tag{8}$$

$$\sum_{j=1}^{n} x_j z_j \leq 1 \tag{9}$$

$$GP_s = R_f + (R_m - R_f)\{2\, Covar\, \{\, r_{ij} x_j z_j,\ [F(R_m)]\}/\Delta_m\} \tag{10}$$

The optimal portfolio with x_j^* according to model Equation (6) to Equation (10) is necessary to calculate the non-diversifiable Gini risk and Gini price. Also, according to CAPM and Gini-CAPM, x_j^* presents the maximum excess of return per unit of risk, the maximum deviation from the mean in units of risk to R_f, and the minimum probability of returns less than R_f, among others.

In the method, now we can elaborate on the boundaries of risk and return. These boundaries are similar to Sharpe from Gini-CAPM and could make the application more intuitive. We used these boundaries in the application of Section 4. The boundaries are the continuous and similar optimal market portfolios to CAPM, the discrete and real or feasible, and similar to the market line, the discrete and real or feasible, and similar to the market line by R_f compositions.

At this point in the method, we arrive at the first selection criterion. For this, we must apply Equation (11) under the restrictions of the expression Equations (12) and (13), where the model does not assume optimized solutions but all possibilities. The value resulting from Equation (11) is the index GS_s, derived from the Sharpe index, and uses the Gini coefficient as a risk metric. The portfolio $x_j^* \in [0,1]$ in this case is differentiable. Then, it is really the best option in excess of return per unit of risk, in deviation from the average in units of risk, with the minimum probability of undesirable returns, among others.

$$GS_S = \left[\left(\sum_{i=1}^{m} \sum_{j=1}^{n} r_{ij} x_j z_j \right) - R_f \right] . \left\{ 2\, Covar \left[r_{ij} x_j z_j\ ,\ F\left(r_{ij} x_{j z_j} \right) \right] \right\}^{-1} \tag{11}$$

$$x_j \in [0,1] \quad \text{for all } j = 1 \ldots\ n \tag{12}$$

$$0 \leq z_j \leq 1 \quad \text{for all } s = 1 \ldots\ n \tag{13}$$

Following the method, we have the necessary information to calculate the non-diversifiable risk values of the portfolios to use as a second selection criterion. We can use the non-diversifiable Gini-risk to make accurate decision-making. A classic definition of non-diversifiable risk Beta is the expected relationship between excess returns for a given portfolio and excess returns for the market portfolio.

Equation (14) presents the Beta-Gini non-diversifiable risk. As the name implies, this index is where it is not possible to eliminate it through diversification. However, on the other hand, knowing values and learning how to manipulate them is strategic. Equation (14) must be applied considering $j = 1 \ldots n$ and $x_j \in [0,1]$, for all $C_{sj} \in s = 1 \ldots p$, and $p = 2^n - 1$, and under the restrictions of the expression Equations (12) and (13).

$$BG_S = 2\, Covar\, [\, r_{ij} x_j z_j,\ (FC(R_m)]/\Delta_m \tag{14}$$

Aiming to make the method more intuitive and understandable, the similar graphical representation of the market line is strategic at this moment. We used this graph in the application seen in Section 4. Thus, we can represent the variation of ROI by non-diversifiable risk for all the differentiable portfolio options. Over time we hope to identify that assets to move in the same direction in the capital markets, albeit in different proportions. For example, assets try to go up when the market goes up, but according to their Beta risk. Therefore, the non-diversifiable risk is essential and strategic information.

Now we calculate Gini's pricing values. These are the third selection criterion. According to Gini-CAPM, this pricing can indicate the return rate according to the non-diversifiable risk of an asset. Moreover, the rate, compared to what the asset can offer, can indicate opportunities. Equation (15) presents the formula for Gini-CAPM pricing, and again we must apply the equation under the restrictions of Equations (12) and (13).

$$GP_s = R_f + (R_m - R_f)\{2\,Covar\,\{\,r_{ij}x_j z_j,\ [F(R_m)]\}/\Delta_m\} \tag{15}$$

And finally, it is now necessary to use a tool to weigh the criteria, classify the investment options, and highlight the best opportunities. For this purpose, we use Analytic Hierarchy Process (AHP), which is a multi-criteria decision method based on hierarchical structuring. With the AHP, we can structure the problem using criteria to evaluate, and for this, we must use hierarchical diagrams structured to compare. The choice of the AHP model is because the model is the most applied in decisions based on multiple criteria that involve complexity. The pseudocode in Appendix A summarizes the steps of the method that we detailed in that section.

4. Method Application

This section evaluates the specific scenario where the method is applied, executes the application in a real case, and uses the application for results discussions. The scenario assessment is necessary to identify the project's characteristics to adjustments in the method, according to the dimensions, inputs features, country legislation, strategies adopted, etc. The results and discussions present inferential graphs and tables, always accompanied by interpretations to support selection.

4.1. Scenario Specificities

According to the scope of the research, to apply the method, we chose project options for small and micro companies, where a monthly consumption level is approximately 3500 kWh. This level of consumption is strategic to comply with the range that receives the most significant incentives from the country's legislation. The enterprise that accepted participating in the study is a small electrical installations company located in Machado city, Minas Gerais, Brazil. It saw the opportunity to offer finance to small and micro businesses in the region in installations of SEPC, which has provided some service in recent years. The financing proposals offer legal procedures for authorization, equipment, installations, and maintenance during the amortization period.

The repaying period for financing is 144 months, with payments at the end of all of them and in amounts proportional to only 85% of the price charged by the energy concessionaire. Therefore, at the financing end to micro and small companies, the installation will be fully amortized and still have a useful life of at least 13 years (according to guarantees from the equipment suppliers). Furthermore, the micro and small businesses will have the opportunity to use the equipment and still depreciation and the reduction in interest on the financing can be used to leverage their real profits.

However, the benefits are not only concentrated for the environment and for the micro and small companies that will be able to install the SEPC, but also for the small electrical installation company that is offering the financing. It will also significantly benefit from returns on investment with a high degree of attractiveness and low-risk activity. The ROI values calculated by the small enterprise and by the method are in Section 4.2.

In the method we did not discard the form of the small financing company's ROI predictions. However we considered that form has excellence, and its values are compared with method pricing to identify opportunities. Also, we used both ROI values to compose a first cut-off line for the study, but in conjunction with high levels of Gini risk, very unfavourable Gini correction, necessary initial investments far above average, and production capacity. In this case, among the 19 initial project options, only 11 remained eligible.

We used the Maximin strategy to project a less unfavourable result among the options in the worst scenario projection of cash flows. Thus, if the worst possibilities for the investment materialize, the results will still be satisfactory in the investment. Or the other way around, the tendency for the results to be better than projected has a significant probability. Within this strategy, we projected that the price of kWh will not undergo readjustment, that the growth trend will be minimum, and that the increase in initial investment will occur in line with the dollar's rise.

Other relevant pieces of information for the projection of cash flows to calculate the ROI amounts is the deduction of all IRPJ, ICMS, CSLL, COFINS, and PIS (Corporate Income Tax, Tax on Circulation of property and Provision of Services, Social Contribution on Net Income, Contribution to Social Security Financing, and Social Integration Program), and a monthly maintenance fee of 0.5%. We defined the lower limit of the adjacent triangular distribution to calculate the ROI values when the worst possibilities were all gathered. However, when only the most probable possibilities (among them some pessimists) remained, the result was assumed as the most possible value for the distribution. Finally, when we eliminated all pessimistic predictions, the adjacent result was considered the upper limit.

For projections, we used the ARIMA method (Autoregressive Integrated Moving Averages). The setting configuration of non-seasonality was of p = 0, d = 0, and q = 1, and regarding the seasonality, P = 0, D = 1, and Q = 1. The setting (0 1 1) (0 1 1) would have a superior fit but would not minimize the trend of consumption growth in our Maxmin strategy. However, other simpler prediction models are perfectly acceptable (for example, the Classic Decomposition Additive or Multiplicative). The reason is that unlike observed for the equity markets, the forecast consumption of energy is relatively trivial. Also, simpler models will be more intuitive and do not require specialist software.

4.2. Results and Discussions

A significant contribution of the Gini-CAPM is to minimize the possibility of prediction mistakes based on history. For example, when you choose a historical number of periods that do not reflect reality well, the regressive pricing of the methodology adjusts the error. Mainly based on the tangent, or the first-order derivative, the risk was called Beta-Gini. Likewise, if we used methods in theoretical evaluations, the results will be identical between distributions and pricing parameters.

Unlike most situations in project evaluations, in the applications of the new method, there is data history of its main input, which is the energy consumption of each of the micro and small companies studied. Table 1 presents the business sectors of micro and small companies and determines an alphanumeric encoding to each. The table also shows the results of average ROI predictions according to the know-how of the small company offering the financing. It is possible to observe that, given the scope of specifications for potential project searches, the funder ended up selecting more than one option within specific sectors. This strategy can be harmful because it is a potential obstacle to diversification.

Table 1. Identifications and annual ROI estimated.

Identification	Microenterprise Sector of Activity	ROI Annual Mean Predicted by Financier
A	Construction company	17.14%
B	Coffee production farm	23.09%
C	Coffee production farm	27.31%
D	Food industry for export	27.92%
E	Food industry for domestic market	22.79%
F	Retail supermarket	21.02%
G	Retail supermarket	23.55%
H	Wholesale and retail supermarket	19.52%
I	Mall of medium-sized	18.49%
J	Metal mechanic industry	22.20%
K	Beef slaughter industry	28.13%

Table 2 presents the main inputs for the method. It contains the results of ROI projected by method, the parameters of the obtained triangular distributions, the necessary initial investments, and the vector z_j of maximum possible participations. It is also necessary to add that the risk-free rate $-R_f$ adopted for the study is an approximate average value of the SELIC (Special Settlement and Custody System) for the last 30 months and annualized (3.00% per year). SELIC is used as the main parameter to define returns on government bonds in Brazil.

Table 2. Main inputs for the method.

Projects	ROI	Parameters of Triangular Distributions			Investments	Participation
		Pessimistic	Likely	Optimistic		
A	20.39%	8.73%	19.84%	32.61%	129,470	8.69%
B	21.32%	9.49%	21.69%	32.77%	133,983	9.00%
C	24.41%	16.01%	24.41%	32.81%	149,475	10.04%
D	25.00%	16.77%	25.10%	33.13%	137,558	9.24%
E	20.46%	9.72%	20.79%	30.87%	123,472	8.29%
F	23.06%	14.07%	23.02%	32.09%	133,397	8.96%
G	25.35%	13.78%	25.55%	36.72%	143,165	9.61%
H	21.95%	9.59%	22.02%	34.24%	131,635	8.84%
I	21.29%	8.61%	20.49%	34.77%	132,802	8.92%
J	20.08%	9.14%	20.20%	30.91%	131,144	8.81%
K	25.54%	17.01%	26.13%	33.49%	143,091	9.61%

Other important information related to R_f is that it is a source of investment, both to the investment capital slack (when at least one of the projects is not in the selected portfolio) and for applications of the cash flows of the projects themselves. The last condition mentioned does not change the selection results, as it raises all the ROI values precisely in the dimension R_f, and was implemented to simulate a situation closer to reality in professional financial management. The suppositions also imply that the investor has initial capital available to implement all the projects. It is worth noting that a minor total capital will mean more significant risks.

With the definitions, predictions, and calculations so far, we carried out the first three steps according to the pseudocode of Appendix A. The next step is to calculate the Gini correlations between the energy consumption values of the micro or small companies studied. Table 3 shows these values, where it is possible to observe that, unlike the Pearson correlation, the Gini between $jj\prime$ and $j\prime j$ can be different.

Table 3. Gini correlation between projects.

	A	B	C	D	E	F	G	H	I	J	K
A	1.00	−0.09	−0.11	−0.17	0.16	0.09	0.09	0.09	0.07	0.44	−0.22
B	−0.09	1.00	0.44	−0.06	−0.24	−0.35	−0.33	−0.33	−0.11	−0.28	−0.05
C	−0.10	0.43	1.00	−0.07	−0.22	−0.30	−0.34	−0.32	-0.09	−0.25	−0.07
D	−0.17	−0.05	−0.08	1.00	−0.36	−0.13	−0.15	−0.08	−0.22	−0.38	0.43
E	0.15	−0.24	−0.22	−0.35	1.00	0.17	0.17	0.08	0.21	0.35	−0.35
F	0.09	−0.36	−0.31	−0.15	0.17	1.00	0.44	0.42	0.34	0.17	−0.16
G	0.10	−0.32	−0.33	−0.15	0.17	0.44	1.00	0.45	0.35	0.18	−0.12
H	0.09	−0.33	−0.32	−0.08	0.08	0.43	0.44	1.00	0.37	0.18	−0.08
I	0.07	−0.10	−0.08	−0.21	0.22	0.34	0.36	0.38	1.00	0.14	−0.25
J	0.43	−0.28	−0.26	−0.38	0.36	0.18	0.18	0.17	0.13	1.00	−0.33
K	−0.22	−0.06	−0.08	0.44	−0.35	−0.16	−0.13	−0.07	−0.24	−0.34	1.00

Table 3 also allows abstracting essential information concerning observed levels of correlation. As expected, projects related to micro-enterprises in the same sector have high positive and undesirable values, making diversification difficult (example: between F, G, and H). On the other hand, the first signal that selection may offer significant benefits is that some negative correlations were found (example: between D and J), which may help to minimize total risks and obtain good diversification among other reasons.

Now, in method application, it is possible to design a dynamic matrix (similar to the variance and covariance), in which the matrix name "Gini-variation and Gini-covariation $\Delta_{jj\prime}$" can be given. Thus, we completed the first 11 steps of the Appendix A pseudocode of the new method. Subsequently, it is possible to calculate various strategic parameters. Initially, we must obtain the optimal global portfolios similar to the Sharpe-Gini-CAPM, to continuous $\left(\text{to } 0 \leq x_j \leq 1 \text{ and } 0 \leq x_j z_j \leq z_j\right)$, and to discrete $\left(\text{to } x_j \in [0,1] \text{ and } 0 \leq x_j z_j \leq z_j\right)$.

Table 4 shows these results, where the second column presents the upper limits investment z_j. In the third and fourth are, respectively, the continuous and discrete optimal. Table 4 shows the variable participations corresponding to the global and discrete optimal portfolio in the fifth and sixth columns. These values are calculated simply by multiplying the decision variables with the upper bound vector z_j. Finally, in the last three lines, the table presents the main information related to the two optimal portfolios: the ROI, the Gini risk, and the Sharpe-Gini CAPM.

Table 4. Optimal global participation.

Projects	Upper Limit z_j	Optimal Global Participation x_j^*	Optimal Discreet Participation $x_j \in [0, 1]$	Real Global Optimal $x_j^* z_j$	Real Discreet Optimal $x_j z_j$
A	8.69%	11.75%	0.00%	1.02%	0.00%
B	9.00%	53.06%	100.00%	4.77%	9.00%
C	10.04%	84.81%	100.00%	8.51%	10.04%
D	9.24%	88.09%	100.00%	8.14%	9.24%
E	8.29%	64.67%	100.00%	5.36%	8.29%
F	8.96%	51.12%	100.00%	4.58%	8.96%
G	9.61%	29.43%	0.00%	2.83%	0.00%
H	8.84%	17.93%	0.00%	1.59%	0.00%
I	8.92%	3.25%	0.00%	0.29%	0.00%
J	8.81%	57.62%	100.00%	5.07%	8.81%
K	9.61%	80.22%	100.00%	7.71%	9.61%
		ROI		13.11%	15.74%
		Gini Risk		0.25%	0.35%
		Sharpe-Gini CAPM		41.078	36.637

It is noteworthy that, if numerically the results of the three variables do not seem very distant (ROI, Gini risk, and Sharpe-Gini between Global Optimal and Discreet Optimal), for returns and financial risks of high investments they are significantly high. It is also important to remember that the portfolios must receive complementation by the product of the risk-free rate R_f by investments slack to obtain Table 4 values. At that moment, in the new method pseudocode, we performed the first 17 steps in the application.

A satisfactory understanding of the method can occur using graphic resources. Figure 2 presents some of the main results obtained so far between the Gini risk x ROI dimensions. It is possible to observe in Figure 2 the continuous efficient frontier of the system, where the optimal global portfolio is x_j^*.

According to the assumption that the investment slack between the maximum necessary and the effective capital will be applied in R_f, then a typical deleveraging behavior can be observed in the continuous efficient frontier, similar to compositions with the global optimum x_j^*. In this case, the continuous frontier starts at R_f, runs linearly up to x_j^*, and from there, it begins to configure itself with a typical concavity (since there is no leverage assumption at R_f), until it touches the discrete differentiable region. The continuous frontier of the system is, in fact, utopian and presented because it contains the optimal market portfolio x_j^*, which helps didactically understand the new method.

The differentiable and discrete region to $x_j \in [0,1]$ and $0 \leq x_j z_j \leq z_j$, composed of 2047 options, is significantly essential and presented in Figure 2. This is because, although the continuous boundary dominates the differentiable region completely (as it should be), it fulfils the factual assumption of actual possibilities in the scenario. Therefore, it is here that the analyses in the method and the selection itself are concentrated. Furthermore, the optimal portfolio chosen in applying the method (BCDEFJK) is also in the differentiable region.

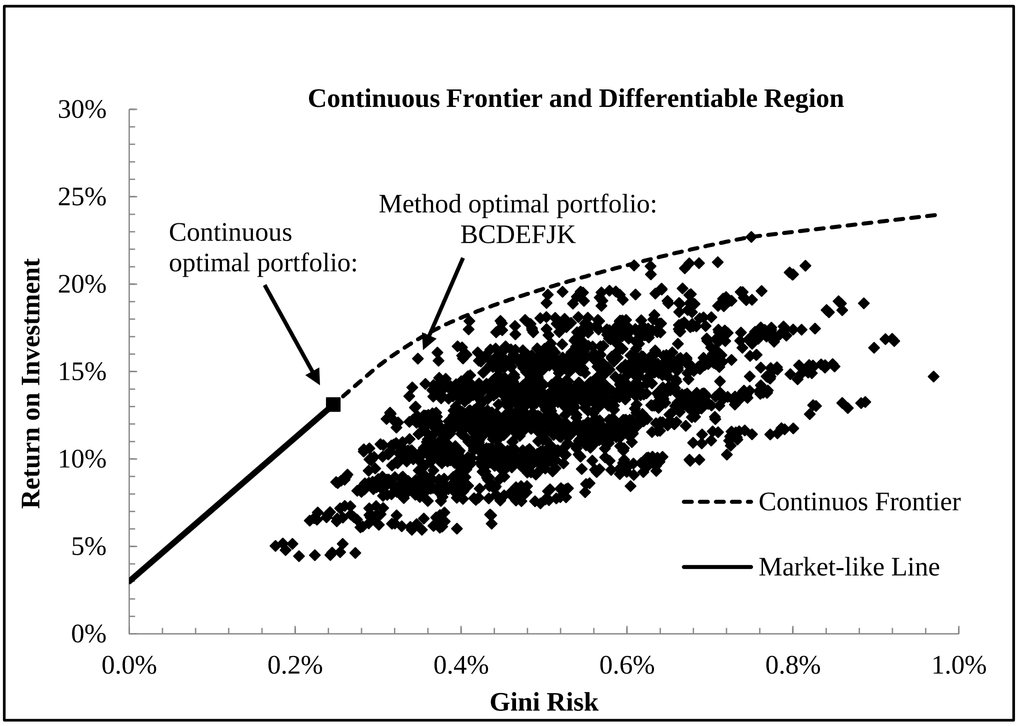

Figure 2. Continuous frontier and differentiable region.

With the parameters and variables defined, esteemed, and calculated in the method executions so far, it is possible to calculate the values of the selection criteria. The first is GS_s and must be obtained for all differentiable portfolios of $s = 1{:}p$. With the index, according to the CAPM and Gini-CAPM theories, we can select portfolios with the best probabilities of excess of satisfactory returns per risk unit, lower probabilities of losses, among others. In Section 3.2, the set with Equations (11)–(13) presents the formulations for the calculation of GS_s. In the pseudocode of Appendix A, the calculation corresponds to steps 16, 17, and 18.

After GS_s calculations, we must calculate the non-diversifiable Beta-Gini risk values GB_s. The strategic use of this variable has three basic possibilities: avoiding losses when the recession is inevitable, taking advantage of the trend when growth is evident, or just being in tune with the market when the future is uncertain (we assumed the latter for the application). The formulation of variable GB_s is given by set Equations (12)–(14).

The third among the main variables of the method is GP_s. In the CAPM and Gini-CAPM theories, its result is used to define values adjusted to the assets under study according to historical data and, in this way, highlight opportunities. The formulations for calculating GP_s are the set Equations (12), (13), and (15). In the pseudocode, the calculation corresponds to steps 22, 23, and 24.

Table 5 presents the results for GS_s, GB_s, and GP_s. In the first table column are the descriptions of the best-ranked portfolios according to the new method. The following three columns present the values found, respectively, for the variables Sharpe-Gini GS_s, Beta-Gini GB_s, and Price-Gini GP_s. The fifth column, which determines the descending order of presentation, shows the results of the AHP multi-criteria tool. To obtain the AHP results, the small company that participated in the study determined that GS_s should have five times more importance than GB_s and seven times more importance than GP_s. GB_s should have three times more importance than GP_s.

Table 5. Final results for selection.

Best Portfolios	Sharpe-Gini	Beta-Gini	Price-Gini	AHP Results
BCDEFJK	36.637	1.261	15.744%	0.000803
BCDEFGJK	36.317	1.473	17.893%	0.000786
BCDEGJK	35.261	1.295	16.096%	0.000776
BCDEFHJK	35.254	1.426	17.419%	0.000769
BCDEHJK	33.853	1.248	15.622%	0.000753
BCDFGJK	33.973	1.330	16.445%	0.000751
BCDEFGK	33.374	1.324	16.388%	0.000740
CDEFJK	32.518	1.098	14.096%	0.000736
ABCDEFGK	33.304	1.474	17.901%	0.000731
BCDEGHJK	32.885	1.461	17.771%	0.000724
BCDEFHK	32.199	1.277	15.915%	0.000721
BCDFJK	31.653	1.117	14.297%	0.000719
BDEFJK	31.397	1.048	13.595%	0.000718
BCDFHJK	31.901	1.283	15.972%	0.000715
ABCDEFHK	32.311	1.427	17.427%	0.000715
ABCDEFJK	32.238	1.410	17.256%	0.000715
ABCDEFK	31.693	1.261	15.752%	0.000712
BCDEFIJK	31.975	1.422	17.375%	0.000709
BCDGJK	31.186	1.152	14.648%	0.000709
ABCDEFGJK	32.514	1.623	19.405%	0.000709
CDFJK	30.697	0.954	12.649%	0.000705
ABCDEGK	31.192	1.296	16.104%	0.000701
BCDEFK	30.649	1.112	14.240%	0.000701
CDEFK	30.437	0.949	12.592%	0.000700
ABCDEGJK	31.421	1.445	17.608%	0.000698
CDEGJK	30.425	1.132	14.448%	0.000696
ABCDEFHJK	31.677	1.576	18.931%	0.000696
ABCDFGJK	31.348	1.479	17.957%	0.000695
BCDEGK	30.393	1.147	14.592%	0.000695
BCDEFGHJK	31.728	1.639	19.568%	0.000693
CDEJK	29.986	0.920	12.299%	0.000691
BCDEJK	29.971	1.083	13.947%	0.000690
ACDEFK	29.959	1.098	14.104%	0.000689
BCDEGHK	30.486	1.312	16.267%	0.000688
ABCDEGHK	30.716	1.462	17.779%	0.000684
BCDFIJK	30.096	1.279	15.928%	0.000682
BCDGHJK	30.171	1.318	16.323%	0.000682
ABCDEHK	29.968	1.249	15.630%	0.000681
ABCDEHJK	30.380	1.398	17.135%	0.000681
BCDEGIJK	30.448	1.457	17.727%	0.000679

When processing the data before applying the AHP, the values of GB_s were replaced by the modulus of their distances to the constant 1.00, which represents a minimum non-diversifiable risk. The values were still inverted (multiplied to -1) to reverse the logic that the smaller, the better these values would be, and these two manipulations was added to move away from zero. In GP_s, we subtracted its values from the values of the small company under the assumption that it has relevant information in such pricing to identify opportunities.

In this case, we also added the two manipulations to move away from zero, and the smaller the difference result, the more deprecated the portfolio should be. The variable GS_s did not receive any treatment. It is important to emphasize that Table 5 shows only 2% of the portfolios ranked according to the method. As per scope, all of these best portfolios are eligible, and we must choose the best in the rank. However, the small company decided to implement a more conservative investment, where we should apply a maximum of R$ 1,000,000.00 in projects, with the remainder applied in R_f. Thus, we cannot choose the first in the classification (BCDEFGJK), as it would require an investment above the limit. Therefore, the best two options are BCDEFJK and BCDEGJK.

4.3. Preliminary Results Validations

Preliminary validation of the new method only at an initial level is possible by evaluating the selected portfolio (BCDEFJK) in Figure 2, which we drew from historical data. First, it is possible to note that BCDEFJK stands out in the discrete, efficient frontier. Furthermore, by the position of BCDEFJK, we can affirm that it exerts stochastic dominance over most options due to its position in the risk and return dimensions. In portfolio selection by the trade-off between return and risk, we desired stochastic dominance.

The graph in Figure 3 also evidences the excellence expectations of the selected portfolio. The chart shows that, unlike the other two portfolios presented (BEJ and ACDFGHIK), it is close to the line that demarcates the minimum non-diversifiable risk. In the analysis, it is also possible to state that the pricing performed by the small company for BCDEFJK has elements that lead to believe that it has a trend of ROI among the best options. This is similar to BEJ, which has optimistic pricing performed by the small business, unlike the option ACDFGHIK.

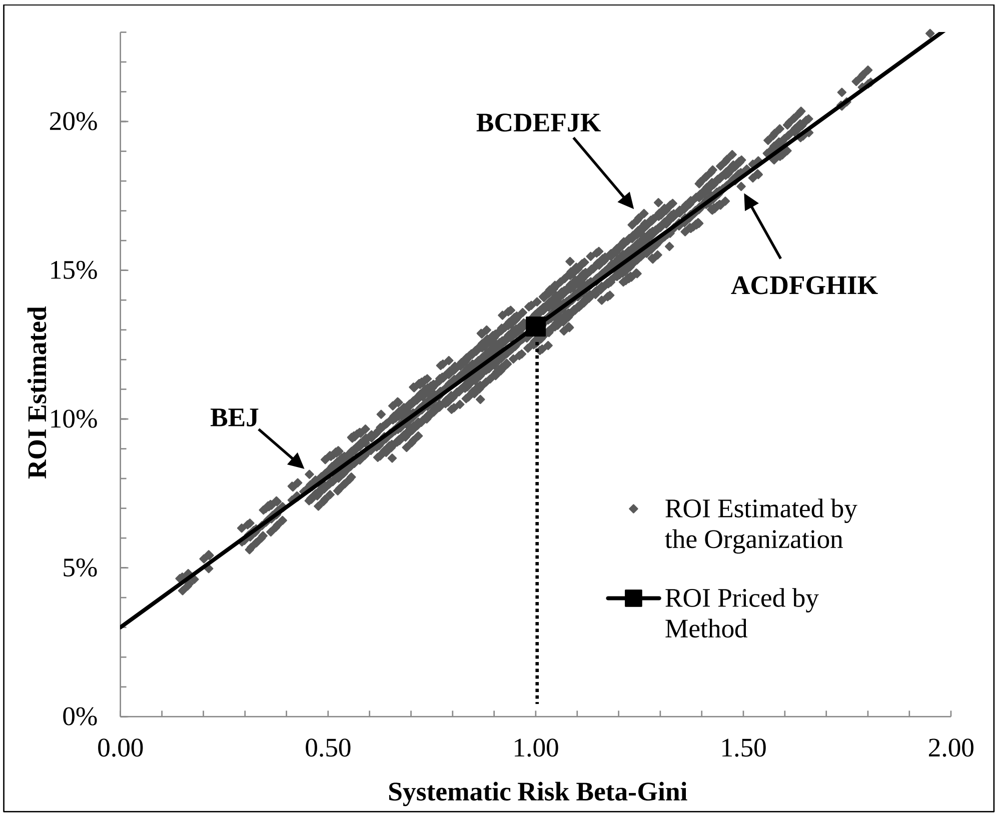

Figure 3. Similar security market line and return predicted by the small enterprise.

Both portfolios used as an example for comparison are not in the research scope strategy of seeking accordance with the portfolio similar to the market. BEJ is used in times of evident recession, and ACDFGHIK for when the economy is growing. However, according to the research scope, by determination of the small company applying the method, the preference should be to seek to have more correlation with the market due to the moment of future uncertainty.

It is essential to emphasize that "a complete validation of a mathematical and statistical method only happens in the long term by confirming results close to those expected and with vast replications to prove efficiency and effectiveness. Statistically, a number between 30 and 60 periods would be reasonable for evaluating a method's results. For example, submitting these results to hypothesis tests to compare them with classical, more user options, between others. However, in the absence of application results, a widely accepted theory for initial validations in portfolio selection is the Monte Carlo Simulation, where it is a possible project the probabilities of interest in stochastics ways" [59,60].

At this time, there are not enough data to prove or refute the efficiency of the new method vehemently, at least not in period extensions for statistically valid studies. Nevertheless, if there were minimum periods, the last 20 months would have significant distortions due to the current economic crisis caused by the COVID-19 pandemic. On the other hand, portfolio implementations are unnecessary for these assessments, as the main input for the analysis, adjacent energy consumption, does not depend on implementations.

Therefore, the solution to reinforce the new method's preliminary validations (based on historical data so far) is to use the Monte Carlo Simulation Theory, which is significantly accepted and applied. Thus, we generated 10^6 data for each project in the simulations according to their triangular probability distributions. Then, in sequence, we compared portfolios selected by the new method with those selected by Net Present Value (NPV), Internal Rate of Return (IRR), and Pay-Back (PB). The reason is that these models are the most used contemporaneously for the selection of discrete asset portfolios, including for investment projects, which is the case observed in this research.

Respectively and in that order, we selected 15 portfolios using the NVP method, 15 portfolios using the IRR, and 14 portfolios using the PB. Also, we used an exclusive selection not to generate portfolio redundancies, and the order was according to the highest level of use of each of the three options. For the new method, we included only the two best-classified portfolios (BCDEFJK and BCDEGJK). And as established, we applied an initial investment limit both for the new method and for its competitors of R$ 1,000,000.00.

The restriction of the initial investment imposed was that the portfolios had a maximum of seven components. However, we observed that the maximum number of elements did not limit the benefit of portfolio diversification, according to the results shown in Table 6. The reason is that the portfolios have results of probabilities less than $2R_f$ and less than $3R_f$, which are significantly low. The levels of $2R_f$ and $3R_f$ refer to the Minimum Attractiveness Rate (MAR) possibilities stipulated by the small financing company. For values smaller than $2R_f$, the percentages were very close to 0.00%, and for values smaller than $3R_f$, they were between 0.00% and 0.50%.

Table 6 also presents in its first column the portfolio compositions in ascending alphabetical order. Its second column presents the method identification that selected the portfolio, where MT is the method proposed by this research. The third and fourth columns show fundamental criteria according to the Utility Theory: at high levels of investments, the most significant concerns are related to possible losses. The reason is that in the two columns, there are, respectively, the classification of each of the portfolios analyzed according to excellence in minimum ROI probabilities for levels lower than $2R_f$ and $3R_f$. In these two criteria, the portfolios selected by the new method occupy the first and second place rankings (BCDEFJK and BCDEGJK).

The fifth column of Table 6 presents rankings according to probabilities of significantly satisfactory ROI levels. The company that is applying the method defined the criteria, where the analyzed ROI probabilities were higher than $4R_f$. (the values for all 46 portfolios were greater than 98%). In this case, the portfolios selected by the method do not have ratings as good as those observed for previous criteria, but they were still reasonable. In the criterion, the classification of BCDEFJK got fourth place, and the classification of BCDEGJK got second place.

The sixth Table 6 column presents the rankings of the portfolios according to the highest levels of Gini correlation that they have with the market optimum x_j^*; the values for all 46 portfolios were between 0.44 and 0.90. We analyzed this characteristic in the simulation to determine the ability of the portfolios to behave similarly to the market. In fact, according to the CAPM and Gini-CAPM theories, portfolios with higher correlations with the market can be expected to protect investors more in uncertain scenarios or without clear prospects for both growth and recession. In this criterion, the portfolios selected by the new method again occupy first and second place (respectively, BCDEFJK and BCDEGJK).

Table 6. Results of Monte Carlo simulations.

Portfolio	Select. Criteria	Rank $\leq 2R_f$	Rank for $3R_f$	Rank for $4R_f$	Rank for Correl.	General Rank	Without Covar.
ABCDEGK	PB	5	5	8	5	5	22
ABCDFGK	NVP	8	8	5	8	8	8
ABCDGHK	NVP	14	15	15	14	15	21
ABCDGIK	MAR	19	19	18	19	19	33
ABCDGJK	MAR	10	10	11	10	10	23
ABCFGHK	PB	31	32	35	30	32	39
ABCFGIK	PB	37	37	38	37	37	44
ACDEFGK	MAR	12	12	12	12	12	7
ACDEGHK	MAR	21	21	22	22	21	23
ACDEGIK	PB	23	23	27	23	24	34
ACDFGHK	NVP	36	36	30	36	36	9
ACDFGIK	NVP	33	30	29	34	31	15
ACDFGJK	MAR	16	16	17	16	16	10
ACDGHIK	MAR	40	40	40	40	40	35
ACDGHJK	MAR	34	34	34	33	34	27
ACDGIJK	MAR	30	31	32	29	30	37
ACFGHIK	PB	45	45	45	45	45	45
BCDEFGK	NVP	4	4	3	4	4	1
BCDEFJK	MT	1	1	4	1	1	20
BCDEGHK	MAR	6	6	6	6	6	16
BCDEGIK	MAR	13	13	14	13	13	25
BCDEGJK	MT	2	2	2	2	2	17
BCDFGHI	PB	43	43	43	42	43	43
BCDFGHK	NVP	15	14	13	15	14	5
BCDFGIK	NVP	18	17	16	20	17	11
BCDFGJK	NVP	3	3	1	3	3	4
BCDFHIK	PB	28	29	33	28	29	31
BCDGHIK	NVP	35	35	31	35	35	26
BCDGHJK	NVP	7	7	7	7	7	18
BCDGIJK	MAR	11	11	10	11	11	28
BCEFGHK	PB	22	22	26	21	22	36
BCFGHIK	MAR	41	42	42	41	41	40
BCFGHJK	PB	24	24	28	24	26	38
BCFGIJK	PB	32	33	36	32	33	41
BDFGHIK	PB	44	44	44	44	44	42
CDEFGHK	NVP	26	26	21	26	25	2
CDEFGIK	NVP	27	27	25	27	27	11
CDEFGJK	MAR	9	9	9	9	9	3
CDEGHIK	MAR	38	39	39	38	39	28
CDEGHJK	PB	17	18	19	17	17	19
CDEGIJK	PB	20	20	23	18	20	30
CDFGHIK	NVP	42	41	41	43	42	13
CDFGHJK	NVP	29	28	24	31	28	6
CDFGIJK	NVP	25	25	20	25	23	14
CDGHIJK	MAR	39	38	37	39	38	31
CFGHIJK	PB	46	46	46	46	46	46

The seventh column of Table 6 presents a final rank for each portfolio according to the average rating to all criteria analyzed. Therefore, this column shows a final result synthesized. The BCDEFJK and BCDEGJK portfolios occupied first and second place in the study, which corroborates statements about the excellence of portfolio selection by the new year method. The eighth column represents another crucial result for each portfolio: Values were found using a calculation identical to the previous column but not considering the Gini covariation. When comparing this column's results with the one in the seventh, it is possible to observe significant differences in classification amongst most portfolios. These differences can lead to substantial selection errors.

Therefore, according to analyses based on those historically presented and mainly on the numerical results of the simulations, it is possible to predict that the new method will select significantly excellent portfolios. Its selections are compared with selections by traditional and more often used methods (NPV, IRR, and PB) contemporarily. Among the beneficial characteristics to be expected for portfolios selected by the method, the following stood out: The lowest ROI probabilities below the risk-free rate or minimum attractiveness rates, the highest probabilities of ROI attractive to investors, and greater protections against market uncertainties, among other reasons.

The method also contributes to deciding on selection portfolios with more precision, accuracy, and clarity. The reason is that, again, based on historical and numerical simulations data, using the method in the adjacent selection helps avoid mistakes caused by not considering Gini-covariations in the ROI. These covariations are significantly common, and the traditional methods do not take them into account.

5. Conclusions

This research presented a new method for selecting photovoltaic solar energy generation portfolios projects for installations in small and micro companies. In addition, we structured the method for utilization for other small businesses that want to invest in the finance of the projects. In fact, we looked for a method to try to benefit the various parties involved: small and micro companies that will install systems for their energy generation and that will amortize the investments in the short and medium-term; small companies that will use the method to select the possible financing investments in a professional way; and society in general with the technological development that supports and encourages the generation of clean, sustainable, and environmentally friendly energy. The main research conclusions are as follows:

- We developed the method structure for selections using multi-criteria similar to the main ones of the Gini-CAPM and in an innovative way, where the criteria derived from the Modern Theory of Portfolios. Their central premise considers the trade-off between risk and return and the covariations between projects' investment returns. Among the main innovations of the model are contributions with theoretical developments that adapted the original models to the research needs, the use of an alternative risk coefficient (the Gini) that is more robust against the non-normal distributions observed in projects evaluations, a structure customized for applications by small businesses to finance generations of clean and sustainable energy, and the installation of microgenerators in small and micro-enterprises.
- According to the evaluations based on historical data and, mainly, on data obtained by Monte Carlo simulation, it is possible to hope that the new method would select significantly satisfactory portfolios compared with others selected by traditional and more often used models. Historical and simulations data in the stochastic evaluations project that the portfolios selected by the method are attractive options for implementation. The evaluations show that the portfolios have reasonable probabilistic expectations and satisfactory protection to avoid mistakes for not considering covariations in return on investment. The method also presents theoretical contributions in adaptations of the benchmark models.
- It is possible to affirm that we achieved the main objective of developing and proposing a method that minimizes literary gaps; helps small and micro-enterprises grow; and supports and encourages clean, sustainable, and responsible energy generation projects. However, the excellence of the method will only be statistically proven after evaluations of post-selection data, using an expressive periods number, based

on replications in significant numbers, and when the economic recession due to the COVID-19 pandemic is not influencing the results.

- We must also emphasize that the proposed method represents the first contribution to Brazil's photovoltaic solar energy generation projects. This considers the adjacent project's dimensions, the theory from which we abstracted the criteria used, the theoretical adaptations for the used criteria, the steps of sequential structuring, and the relevance attributed to the trade-off between risk and returns in account of the covariation in return on investments.
- Finally, we must emphasize that future work is needed to continue this research. These works will be of great value in the development of other methods, improving the method proposed by this research, and mainly for proving or refuting the expectations of the performance of this method.

Author Contributions: J.C.I. designed the study; P.P.B., G.A.B.M. and W.V.d.S., analyzed and interpreted the data; J.C.I., P.P.B. and C.H.P.M., wrote the manuscripts with the support of C.P.d.V. and W.V.d.S. All the authors provided critical feedback and approved the final version of the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by Pro-Rectory of Research and Graduate Studies of Federal University of Itajubá by funder process number 23088.036884/2021-56.

Data Availability Statement: The data presented in this study are available on request from José Claudio Isaias (joseclaudio.isaias@unifei.edu.br).

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

Nomenclature

α_j	Project *j* participation in the portfolio
B	The upper limit of initials investment
C_{sj}	Matrix with all binary combinations of portfolios *s* and projects *j*
$F\left(r_j\right)$	The cumulative distribution function of project or portfolio *j* return
GB_s	Vector of non-diversifiable Gini risk of all portfolios *s*
GP_s	Vector of estimated Gini-price of all portfolios *s*
GS_s	Vector of maximum excess return per Gini-risk unit of all portfolios *s*
ij	Projects or portfolio *j* in period *i*
P_{ij}	Matrix of investment required for each project *j* in the period *i*
L	The lower limit of acceptable returns
p	The portfolio total number
s	Identification vector of all portfolios
r_{ij}	Matrix of return of the project or portfolio *j* in the period *i*
R_e	Return or price of the project or portfolio *e*
R_f	Risk-free rate
R_m	Return of the market portfolio
$\Gamma_{jj\prime}$	Matrix of Gini correlation between projects *j* and *j′*
x_j	Decision variables vector to each project *j*
z_j	Vector of maximum relative participation of each project *j*
Δ_j	Gini risk of project or portfolio *j*

Abbreviations

AHP	Analytic Hierarchy Process
CAPM	Gini Capital Asset Pricing Model
ISI	Institute Scientific Information
MG	Mean-Gini
MPT	Modern Portfolio Theory
MRA	Minimum rates of attractiveness
MV	Mean-variance

PERT	Program Evaluation and Review Technique
PPAS	Project portfolio analysis and selection
ROI	Return on investment-
SELIC	Special Settlement and Custody System
SEPC	Solar energy by photovoltaic cells

Appendix A

Proposed method pseudocode.

BEGIN
  R_f ← load the risk − free rate scalar
  R_{3j} ← load the ROI matrix of all projects
  FOR $j = 1{:}n,\ j' = 1{:}m$
    $\Gamma_{jj'}$ ← calculate the Gini correlation matrix
  END FOR
  IF $j = j'$
    $\Delta_{jj'} = [\Delta_j]^2$ ← calculate all the projects Gini risk individual
  ELSE $j \neq j'$
    $\Delta_{jj'} = [\Delta_{jj'}]^2$ ← calculate the Gini − covariations to all projects pairs
  END IF
  FOR $j = 1{:}n$
    GS_s^* ← calculate the optimal portfolio similar to of Sharpe
  END FOR
  GP_1 ← generates the boundaries graph of returns per risk Gini
  FOR $s = 1{:}p$
    GS_s ← calculate all discret portfolios excess ROI per Gini risk unit
  END FOR
  FOR $s = 1{:}p$
    GB_s ← calculate all the portfolios the beta Gini − CAPM
  END FOR
  FOR $s = 1{:}p$
    GP_s ← calculate all the portfolios princing Gini − CAPM
  END FOR
  Rank ← apply the AHP model on the GB_s, GB_s and GR_s
  Selection ← select the best portfolios
  GP_2 ← generates the graph similar to securities market line
END

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