A multicriteria tool to support decision-making in the early stages of energy efficiency investments

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Abstract. The energy demand of modern communities contributes significantly to climate change, increasing the release of greenhouse gases into the atmosphere. Energy efficiency is recognised as the key pathway to reducing energy usage while sustaining an equivalent, contemporary economic activity. In other words, to avoid climate change, mainstreaming energy efficiency finance is considered a top priority. This study focuses on introducing a rating system based on a Multi-Criteria Decision Analysis method that aims to promote the implementation and financing of energy efficiency investments. To this end, a benchmarking Tool is being deployed in order to materialise the proposed methodology and introduce a standardised procedure for benchmarking energy efficiency potential projects during the preliminary stages of investment conceptualisation. The proposed Tool exploits the Multi-Criteria Decision Analysis method ELECTRE Tri, taking into account major key performance indicators that are broadly used by investors and financing institutions to identify bankable energy efficiency investments and promote green transition. The methodology has been applied to benchmark 114 energy efficiency investments from eight different European countries. It should be mentioned that for the successful and effective development of the proposed Tool, input and feedback has been received by a variety of stakeholders from the energy sector and financing community, who also tested the Tool and confirmed that the approach proved to be extremely helpful to those seeking for sustainable investments in energy efficiency. The analysis resulted in the conclusion that the Tool covers the necessity for a standardised benchmark, providing added value to the energy efficiency market.

Keywords: green transition, energy efficiency, sustainable investments, benchmarking, decision support

1 Introduction

Climate change and rising energy consumption are two interrelated phenomena. To a considerable extent, energy production and consumption are responsible for greenhouse gas (GHG) emissions and pollution in the environment. In order to minimise the growing energy demand in the European Union (EU), numerous targets and initiatives for Energy Efficiency (EE) have been set, while tentative national targets are to reduce energy consumption at a pan-European level [1]. When talking about EE investments, their needs have been quantified as around EUR 62.6bn, while the European Commission (EC) estimates that at least EUR 185bn per annum should be motivated, resulting in a much higher investment gap over the next decade [2].

Despite the fact that many worthwhile EE investments exist at the development stage, only a tiny percentage of them are ultimately funded. This issue has been named the "efficiency paradox," often known as the "EE gap" [3]. Hence, an effort is needed to stir investments in EE projects to reduce the EE gap as rapidly as possible. The lack of evidence on the performance of EE projects and the lack of available data on successfully implemented EE investments constitute a significant drawback to mainstreaming EE investments, making it difficult for project developers to benchmark their projects [4].

In this direction, the present manuscript introduces an applied methodology that aims to support the decision making of EE investments in order to facilitate investors to undertake such projects. The proposed methodology has been incarnated by an online tool, which takes into account principal Financial, Risk and Sustainable Development Goals (SDG) criteria. It uses the Multi-Criteria Decision Analysis (MCDA) method, ELECTRE Tri, to benchmark the project ideas in different classes according to their performance [5]. The ELECTRE-Tri was chosen to be used in the benchmarking procedure as it handles both qualitative and quantitative data, meaning that it can deal with the imperfect nature of knowledge [6].

The developed Tool has been applied to benchmark projects from different sectors of activities in eight European case study countries, namely: Bulgaria, the Czech Republic, Germany, Greece, Italy, Lithuania, Netherlands, and Spain, under the activities of the EU H2020 funded "Enhancing at an Early Stage the Investment Value Chain of Energy Efficiency Projects - Triple-A" project. The Triple-A scheme tries to identify which investments can be considered Triple-A investments, fostering sustainable growth while also having an extreme capacity to meet their commitments from the first stages of investments generation and pre-selection/ pre-evaluation [7]. The results reveal that the vast majority of the identified and benchmarked projects pertain to the Building Sector, while almost half of the submitted projects have a great capacity to meet their financial commitments.

Following the introductory Section, the 2nd Section of the manuscript presents the methodology that has been developed, Section 3 analyses the application of the proposed methodology through the selected MCDA method, while Section 4 presents and analyses the results of the application of the method through the online benchmarking Tool in the eight European case study countries. Finally, Section 5 summarises the main aspects of the paper.

2 Methodology

The proposed methodology aims to assess and benchmark EE projects based on their bankability, risk, and sustainability. The methodology is being applied to a web-based

Tool; the benchmarking is conducted by a Python 3.0 script running in the background.. The Tool's benchmarking of the project ideas is organised in four main steps, as depicted in **Fig. 1.**.

Fig. 1. Tool methodological steps

2.1 Project Data & User Preferences

The data collection is being performed by a user interface in which the Tool requires the user to provide the necessary data to calculate the Key Performance Indicators (KPIs) and perform the MCDA that follows. The user has to provide details on the project's basic information, such as name, country and region, sector of the project, and some contact details of the user to receive the results. In addition, the user should provide information related to the risks by answering 10 related questions. Facts and figures are also needed concerning the project's financial, energy, and CO2 data, the preferred KPIs for the evaluation and the weights these criteria should have. The order of the data input is summarised in **Fig. 2.**.

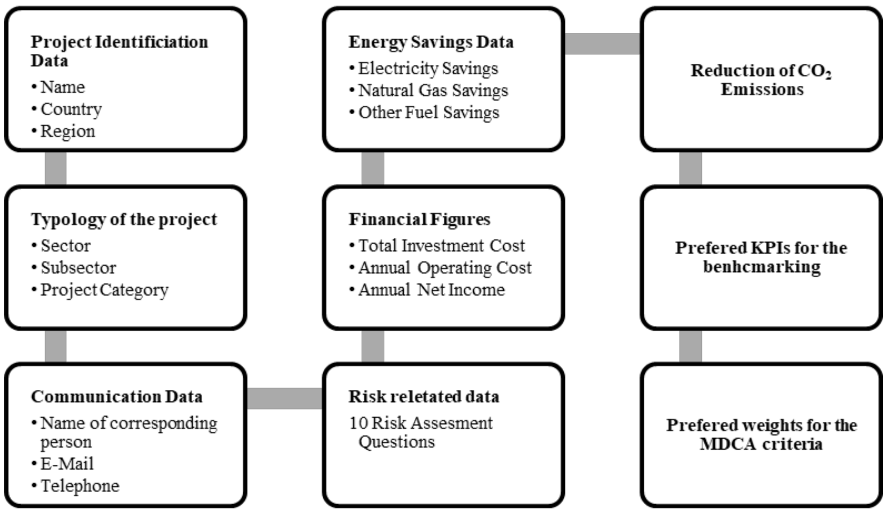

Fig. 2. Tool's input data

The typology of the sectors and project categories covered by the Tool is presented in **Table 1.** [8].

Table 1. Project Sectors and Categories

Sectors	Project categories
Buildings	Building envelope retrofits
	Heating, Ventilation, Air Conditioning (HVAC&R) retrofits
	Lighting appliances' retrofits
	Automatic control retrofits
	Renewable Energy Sources (RES) installations
	Construction of new buildings
Manufacturing	Manufacturing-specific retrofits
Transportation	Purchase of new vehicles
District Energy Networks	District Energy Networks retrofits/ expansion
Outdoor Lighting	Outdoor lighting retrofits

2.2 Calculation of Evaluation Criteria & KPIs

At this step, the KPIs used as benchmarking criteria are calculated based on the user's input and project data [9] (Table 2).

Table 2. Key Performance Indicators

Key Performance Indicators	
Financial Criteria	
Net Present Value (NPV)	NPV reflects the risk and cashflows discount by quantising it through the discount rate the profitability of the investment by involving the yearly income calculations
Discounted Payback Period	The discounted payback period is the number of years necessary to recover the project cost of an investment while accounting for the time value of money.
Internal Rate of Return (IRR)	IRR is a rate of return used in capital budgeting to measure and compare the profitability of investments.
Cost-Effectiveness	Cost-effectiveness measures whether an investment's benefits exceed its costs, calculated based on the project cost per kWh saved.
Risk Criteria	
Behavioural Risk	The criterion consists of the rebound effect, expressed as a ratio of the lost benefit compared to the expected environmental benefit when holding consumption constant.
Energy Market & Regulatory Risk	It reflects the uncertainty about energy prices and affects the decision to undertake an EE investment.

Economic Risk	The economic risk will be monitored by the interest rates volatility factor. Fluctuation in interest rates may lead to an unexpected cost of capital deriving from changes in the cost of debt for the borrower, preventing the accurate estimation of savings.
Technology, Planning & Operational Risk	It considers the maturity of the technology, the construction, operation and maintenance risk, and the capacity to predict the energy savings accurately.
SDG Criteria	
Arrears on utility bills	It reflects the share of (sub)population (%) having arrears on utility bills,
Total population living in a dwelling with a leaking roof, damp walls, floors or foundation, or rot in window frames or floor	It indicates the share (%) of the population experiencing at least one of the following basic deficits in their housing condition: a leaking roof, damp walls, floors or foundation, or rot in window, frames, floor.
Population unable to keep home adequately warm by poverty status	It indicates the share (%) of the population who cannot keep home adequately warm. Data for this indicator are being collected as part of the EU Statistics on Income and Living Conditions (EU-SILC)/.
Primary energy consumption	It quantifies the Gross Inland Consumption in tonnes of oil equivalent (toe), excluding all non-energy use of energy carriers.
Energy import dependency	The share (%) of total energy needs of a country met by imports from other countries.
Final energy consumption in the industry sector	It includes all the energy supplied to the industry sector in toe, excluding deliveries to the energy transformation sector.
Final energy consumption in the transportation sector	It measures the energy consumption of the transportation sector in toe, excluding deliveries to the energy transformation sector.
Final energy consumption in other sectors or commercial and public services	It indicates the energy supplied to non-categorised sectors, commercial and public services in toe.
Final energy consumption in households per capita	The indicator measures how much electricity and heat every citizen consumes at home in Kilogram of oil equivalent (kgoe/capita), excluding energy used for transportation.
GHG emissions from energy consumption	The data are based on the European Environmental Energy Agency measures and represent the GHG emissions in thousand tones of CO_2 equivalent.
GHG emissions from the industrial sector	This KPI reflects the GHG emissions (in thousand tones of CO_2 equivalent) caused by the industrial sector.

Sources: [10–12]

The financial criteria are based on scientific and economic equations corresponding to each indicator. In detail:

NPV is calculated based on the following equation:

$$\text{Net Present Value}=-C+\sum_{y=1}^{Y}\frac{CFy}{(1+i)^{n}} \quad (1)$$

Where:

C = Initial Investment Cost

CF = Cash Flow for the year y

The cash flow for each year is being calculated based on the energy savings of the candidate project:

$$\sum_{y=1}^{Y} CF_y(€) = \left(S_{el}\cdot p_{el}\right)_y + \left(S_{gas}\cdot p_{gas}\right)_y + \left(S_{oil}\cdot p_{oil}\right)_y + \Delta Cost_y \quad (2)$$

Where,

$S_{e\,l}$= energy savings: electricity (kWh)

S_{gas} = energy savings: gas (kWh)

S_{oil} = energy savings: other fuel (kWh)

p_{el},p_{gas},p_{other} = fuel prices,

and

$$\Delta Cost_y = \text{Annual Maintenance Cost before EE measures-} \\ \textbf{Annual Maintance Cost after EE measures} \quad (3)$$

The **Discounted Payback Period** is calculated as follows:

$$\textbf{Payback Period} = \mathbf{A} + \frac{\mathbf{B}}{\mathbf{C}} \quad (4)$$

Where,

A = the last period number with a negative cumulative discounted cash flow;

B = absolute value of cumulative discounted net cash flow at the end of period A;

C= the total discounted cash inflow during the period following period A;

The Discounted Cash Inflow of each period is being calculated according to:

$$\text{Discounted Cash Inflow} = \frac{\text{Actual Cash Inflow}}{(1+i)^{n}} \quad (5)$$

Where,

i is the discount rate, and

n is the period to which the cash inflow relates.

The **Internal Rate of Return** is calculated as follows:

$$\mathbf{0} = \mathbf{NPV} = \sum_{t=1}^{T}\frac{C_t}{(1+IRR)^{t}} - C_0 \quad (6)$$

Where:

C_t = Net cash inflow during period t

C_0 = Total initial investment costs

IRR = the Internal Rate of Return

t = number of time periods

Cost-Effectiveness is calculated based on the project cost per kWh saved, according to the following equation:

$$\textbf{Cost Effectiveness} = \frac{\textbf{Life Cycle Cost (€)}}{\textbf{Savings (kWh)}} \quad (7)$$

All the parameters needed to calculate the above financial indicators are based on the EU Directives and Regulations on Cost-Benefit Analysis of Investment, also reflected in EU official statistics by deploying a unique methodology for each case study country [13]. The risk criterion is calculated based on answers to 10 questions related to the project design, conceptualisation and legal requirements [14]. The questions require information regarding, among others, the calculations of the energy baseline, the energy savings assessment, the related project permits, the experience of the technical development team, the quality of the equipment, as well as the creditworthiness of the borrower.

The **Total Risk** is calculated as the aggregation of the risks identified in Table 2, in values that range from 0 to 1.

$$K_3 = \frac{B_1 + \ldots + B_n}{n} \quad (8)$$

Where:

$B_{i \ldots n}$ = The identified Risks

Finally, the **SDG** criterion is the average of the respective criteria, as presented in Table 2.

$$K_4 = \frac{C_1 + \ldots + C_n}{n} \quad (9)$$

Where:

C_i= each SDG criterion

n= the number of SDG criteria

The SDG criterion is a quantitative analysis that examines factors derived mainly from Eurostat indicators. These metrics indicate the current state of EE, energy poverty, and pollution of the country of the EE project idea. The methodology produces a parameterised SDG progress estimation (per project country and sector). The chosen indicators, primarily related to the energy industry and environmental protection, are linked to the United Nations Sustainable Development Goals Agenda [15].

3 MCDA Application

To run the MCDA, the user selects four criteria. The ELECTRE Tri algorithm is executed based on the user's input and settings. A set of two financial KPIs (one default and one selected by the user), the total risk and the SDG criterion are applied to the

ELECTRE Tri MCDA to build a consistent family of criteria [16]. The default financial KPI is cost-effectiveness, while the other can be chosen between the NPV, the Discounted Payback Period and the Internal Rate of Return.

ELECTRE Tri is an MCDA method proposed by Yu [17] and Mousseau et al. [18] and used for classification problems and, more specifically, in discrete classification problems, where the alternatives of the problem should be classified into predefined categories. The classification is made using pair-wise comparisons between the alternatives and the reference profiles based on concordance and discordance checks. The ELECTRE Tri was chosen to be used in the benchmarking procedure as it handles both qualitative and quantitative data, meaning that it can deal with the imperfect nature of knowledge [35]. In ELECTRE Tri, each outranking relation is constructed after comparing each alternative to a predefined category limit. As a result, if a new alternative should be later added to the classification process, the new alternative compares with the existing profile limits.

According to the nature of each KPI, the criteria values are directly input as determined in equivalent units, and the project is classified into one of three predefined categories. The first category is named "Triple-A", which contains projects that merit attention from the funding organisations. The Triple-A projects are extremely capable of meeting their energy-saving targets, already from their conceptual phase (where they are still considered project fiches).

The second category consists of "Reserved" projects. These projects have a good but not outstanding performance in the MCDA criteria. They are projects capable of repaying the initial capital invested and contributing significantly to the site's energy savings.

The last category contains projects marked as "Rejected". The rejected projects are the ones that have an unsatisfactory total performance in the examined criteria. They may have a risk higher than the maximum threshold, or they do not seem capable of recovering the total investment.

The classification thresholds have been defined using the input gathered through several stakeholder consultation activities (e.g., email exchanges, bilateral meetings, phone calls, questionnaires, structured interviews, webinars, workshops, etc.) within the framework of the Triple-A project. The Tool user is enabled to adjust the weights of the ELECTRE Tri criteria according to the importance of each factor based on the user's preferences. The importance of each factor is expressed through the linguistic variables "Very high", "High" ", Medium", "Low", and "Very Low". An arithmetic value is assigned to each linguistic variable, as depicted in Table 3:

Table 3 Assignment of Weights

Linguistic Values	Arithmetic Values
Very High	5
High	4
Medium	3
Low	2
Very Low	1

Based on the user selection of weights, the values are normalised to the total sum of the weights equal to one, as shown in the following equation:

$$\boldsymbol{W_{Sum}} = \sum_{1}^{4} \boldsymbol{W_i} \tag{10}$$

$$\boldsymbol{W'_i} = \frac{\boldsymbol{W_i}}{\boldsymbol{W_{Sum}}} \tag{11}$$

Where:

$W_i = the\ arithmetic\ weight\ selected\ by\ the\ user\ for\ each\ criterion$

$W'_i = the\ normalized\ weight$

Additionally, the weights are given some default values if the user does not wish to set some specific values. The default values are equal for all the criteria.

4 Result Analysis

The developed Tool has been used and tested by several EE professionals, investors, policymakers, and EE stakeholders. An extended stakeholder consultation approach has been realised, in which demonstrations and testing of the Tool have been conducted in bilateral meetings and training workshops to gather feedback in real-time when each step of the Tool was live presented. In these meetings and workshops, related key actors have participated, such as energy efficiency companies and project developers, financiers and investors interested in sustainable financing. As a matter of fact, 133 users have signed up and utilised the online Tool.

Though the stakeholder consultation, the Tool has received 114 EE investment ideas. The projects have been collected from the relevant stakeholders in the case study countries: (i) by directly using the Tool and inserting their projects and (ii) filling a predefined template. Thus, quality control of the input data provided by the users has been done and extensive debugging and optimisation of the Tool, using real projects data. The consultation followed a bottom-up procedure to build the respective Tools in a way that is practical to the energy efficiency business actors. The selection of the criteria and the deployment of the methodology have been realised in close cooperation with stakeholders. In this process, a real demonstration of the Tool has been performed to receive feedback and reinforce the methodology. In addition, hands-on webinars and bilateral meetings have been conducted, in which stakeholders provided real project ideas that have been entered into the Tool, and the stakeholders have commented on the benchmarking results. The comments, inputs and feedback received have been the major developing force for the Tools, while the potential issues and imprecisions have been rectified.

The chart in **Fig. 3.** reveals that most EU projects in need of private funding pertain to the building sector. These project ideas include, primarily, retrofits in the building envelope, HVAC&R and lighting upgrades. This result is reasonable, as the building sector is responsible for almost one-third of total global final energy consumption and nearly 15% of direct CO_2 emissions and efforts have been intensified towards decarbonising this sector [19]. On the other hand, the Manufacturing sector received just one (1) project into the Tool, demonstrating the urgent need to boost energy efficiency measures. The lack of projects in that sector can be explained by various reasons. First, the industry seems to prioritise other types of investments, such as expanding the production capacity rather than energy efficiency. Another reason is that the energy efficiency in industry is achieved along with other modifications of the production line, so energy efficiency measures are not treated as standalone investments. Finally, industries that do prioritise energy efficiency usually allocate equity for these measures, so there is no need to use such kind of Tool to seek financing.

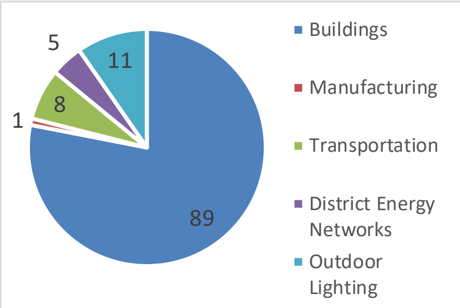

Fig. 3. Number of projects per sector

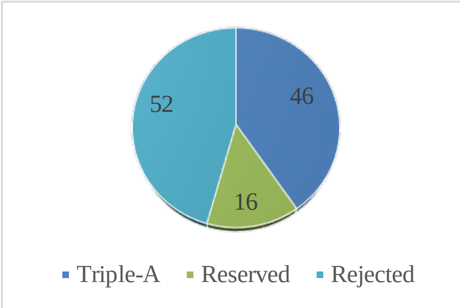

Fig. 4. Classification of projects by the developed Tool

In **Fig. 4.**, statistics of the classified projects by the Tool are presented. As it can be seen, more than half of the projects (64 out of 114) have been classified as either Triple-A or Reserved. This demonstrates that many project developers are taking the future financial performance of their EE projects seriously. In addition, this indicates that they are not seeking any public tender to finance their EE projects, but they are stirring towards private funding, which could be challenging for projects with abysmal financial indicators. Nevertheless, a significant number (53) of Rejected projects also appears, which means there is a huge potential for development and capacity building for stakeholders to design profitable and bankable EE project ideas [20].

As depicted in **Fig. 5.**, most projects entered into the Tools come from Lithuania, while most Triple-A projects are recorded in Bulgaria. Lithuania, even if it has a significant amount of EE project ideas, the majority of them have been classified as Rejected. Through the proposed Tools, these projects could identify their weaknesses and be redesigned to deliver a more attractive financial profile. As derived by the Tools' results, a significant role in the cashflows of EE projects play the estimated energy savings, along with the respective energy price. Suppose the impact of the Covid-19 pandemic on the energy sector [21] and the latest increase of 2022 in energy prices are considered, EE become even more crucial. Higher energy prices indicate that some Rejected projects could be easily redesigned to increase their overall rating and achieve a positive financial balance.

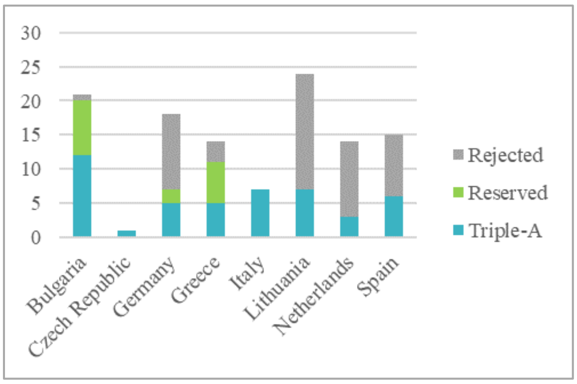

Fig. 5. Distribution of project benchmarking across the case study countries

5 Conclusions

The proposed methodology aims to promote decision-making in identifying sustainable energy efficiency investments. The benchmarking method considers a variety of financial, sustainability, and risk indicators. An MCDA namely ELECTRE Tri, is used to benchmark the project ideas, classifying them into one of the following categories: "Triple-A", "Reserved", or "Rejected". The methodology has been materialised through an online Tool that aims to support users in assessing and benchmarking their project ideas when they are in their early stages when seeking financing.

The Tool has been tested and validated by different stakeholders from the financing and energy sector, who gave feedback and input in all the implementation phases of the methodological steps. According to their feedback, the proposed Tool proves to be essential since it allows for quick identification of bankable project ideas through a user-friendly environment, establishes a common framework, and provides background material for project developers and investors to negotiate.

The benchmarking results reveal that almost half of the project ideas inserted and benchmarked in the Tool are classified as Triple-A, which means they are worth financing due to their outstanding performance in the KPIs. The results also indicate the Tool's potential to identify bankable EE investments, supporting investors in the EE investments decision making procedure. On the other hand, projects classified as "Rejected" would be able to identify their weaknesses in specific factors to try to improve their performance and then be more likely to find funding. In addition, project developers can easily benchmark their projects to get a preliminary insight on the estimated risk, profitability, and overall design of their EE project ideas. In conclusion, the proposed Tool proves to be able to address the challenges that emerge when seeking financing to implement an EE project, while it could assist the related key actors in identifying which investments can foster sustainable growth while also having a strong capacity to meet their commitments .

Further results could be extracted when more stakeholders use the Tools, and the project's database will be enriched with projects from various sectors, benchmarking and countries. By deploying further statistical data of the projects' benchmarking, more profound evidence and clues regarding the energy efficiency gap. Correlation between countries, sectors and poor project design could be achieved. In addition, the poor performance in certain financial indicators that cause the energy efficiency projects to fall short in private financing could be examined. In addition, further research with additional projects could be realised to perform a sensitivity analysis of the Tool and fine-tune the benchmarking results.

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