Multi-Objective Financial Optimization of Shared-Savings ESCOs for Renewable Energy Self-Consumption

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***Abstract*—This paper presents a multi-objective optimization model for structuring financially viable contracts in self-supply energy projects based on Energy Service Companies (ESCOs). The proposed methodology employs Pareto frontier analysis to evaluate the trade-off between user benefits, represented by savings allocation (β), and ESCO revenues, defined by the cost-sharing factor (α), while incorporating a levelized cost approach to ensure financial balance under a project finance framework. Key decision variables, including the optimal ESCO contract duration and the sensitivity to electricity tariffs, discount rates, and system capacity factor, are analyzed using Pareto frontiers and contour maps to identify regions of optimal financial performance. The methodology is validated through a case study, demonstrating its applicability for structuring optimal Energy Savings Performance Contracts (ESPCs). Furthermore, debt coverage indicators, including DSCR, LLCR, and PLCR, are integrated to assess project bankability and financial feasibility from a lender's perspective. The proposed approach provides a robust decision-support tool for users, investors, and regulators seeking sustainable distributed generation business models supported by project financing structures.**

Link to graphical and video abstracts, and to code:
https://latamt.ieeer9.org/index.php/transactions/article/view/10470

***Index Terms*—ESCO, ESPC, Multi-objective Optimization, Pareto Front, Renewable Energy Financing, Levelized Cost, Self-Consumption, Distributed Energy Resources, Project Financing.**

I. INTRODUCTION

IN recent years, distributed generation (DG) has experienced significant global growth, driven by renewable technologies, system decentralization, and the need for enhanced energy resilience. This growth is particularly relevant in the context of self-consumption, where users aim to reduce grid dependence and optimize energy costs [1], [2]. However, the high initial investment required for DG implementation remains a significant barrier for many potential self-consumers. In this context, the Energy Service Company (ESCO) business model emerges as a viable solution, facilitating the financing and implementation of DG projects without requiring users to assume the initial capital costs. This model allows clients to benefit from long-term energy savings and sustainability through a contractual agreement known as an Energy Services Performance Contract (ESPC) [3]–[6].

In the literature, financial risk analysis is a primary concern due to the inherent revenue uncertainty of shared-savings agreements within Energy Service Company (ESCO) business models. For instance, [7] proposed a risk-adjusted financial viability model and a "Pay-for-Savings" (PFS) approach. Their analysis of optimal shared-savings rates for energy efficiency projects suggests a scheme where the client receives 0% of the savings. However, there remains a need to evaluate sensitivity across the full range of shared-savings percentages.

The economic viability of various ESCO financing modalities was compared in [8]. Their simulations indicate that, in specific case studies, a 15-year Shared-Savings Contract allows both the client and the ESCO to achieve a high and balanced Net Present Value (NPV), while the client assumes no financial or energy-related risks. Similarly, [9] introduced a multi-objective optimization process using genetic algorithms to design photovoltaic (PV) capacity. Their model identifies the optimal tradeoff between economic competitiveness and environmental performance, focusing on the Levelized Cost of Electricity (LCOE) and Cumulative Environmental Benefit.

The complexities of the ESCO model and the lack of market knowledge often deter investors [10], [11]. Research in [10] provides policy recommendations for governments to stimulate the market, while [11] implemented the *FinSESCo* platform to democratize and diversify investments in building energy efficiency. To mitigate risk, [12] established early-warning signals for ESCO models in existing buildings to enhance viability and efficiency. Furthermore, [13] characterized financial resources for self-consumption in Spain, emphasizing that alternative financing and banking intermediation are crucial for the transition to a low-carbon economy.

Despite these contributions, the literature review reveals a scarcity of studies that integrate financial optimization to determine parameters that minimize risk in the ESCO business model. There is a clear need for analytical models to establish critical parameters, such as the optimal shared-

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savings allocation between the user and the ESCO, the optimal financing period, and the model's sensitivity to variables like electricity tariffs, discount rates, and the capacity factor of the self-consumption system. Motivated by this gap, this paper proposes a methodology that provides an optimal solution for the ESCO business model coupled with a comprehensive sensitivity analysis.

The remainder of this paper is organized as follows: Section II describes the principles and operation of ESCOs. Section III presents the financing formulation, while Section IV details the simulation methodology. Section V formulates the multi-objective problem for the optimal financial design of the ESCO. Section VI discusses the simulation cases and results, highlighting the performance of the multi-objective optimization. Finally, Section VII concludes the paper.

II. ENERGY SERVICE COMPANIES (ESCO)

A. *ESCO Operation*

ESCOs are private entities that design, implement, and finance energy efficiency projects, offering a scheme where the savings obtained cover the investment made. Their operation is based on three fundamental pillars [14]:

1) **Comprehensive Services**: Identification of opportunities, implementation of efficiency measures, and verification of savings.
2) **Risk Sharing**: Through ESPC contracts, the ESCO assumes part of the technical risk.
3) **Financial Support**: Collaboration with banks and investors for project execution [3].

An Energy Service Company (ESCO) is defined as a business that develops, installs, and finances comprehensive performance-based projects, typically spanning 5 to 10 years, aimed at improving energy efficiency or reducing energy consumption in client facilities [2]. While ESCOs primarily focus on selling equipment and services for efficiency implementation, they are generally not financial entities [3]. Consequently, many ESCOs facilitate financing through third-party institutions (banks) under *Energy Services Performance Contract* (ESPC), rather than financing projects directly.

B. *ESCO Operating Modalities*

ESCOs operate under various contractual models, adapted to client needs [14], [8]:

- **Shared-Savings Contracts** (Fig. 1a): The *ESCO* fully finances the project and recovers its investment through a percentage of the realized energy savings. The user makes no initial investment, and the financial risk is primarily borne by the *ESCO*.
- **Guaranteed-Savings Contracts** (Fig. 1b): The client finances the project, but the *ESCO* contractually guarantees a minimum level of savings, compensating the client if the guarantee is not met. The financial risk is primarily retained by the client.
- **Chauffage-Type Discount Model** (Fig. 1c): The *ESCO* owns and operates the energy infrastructure, selling the useful energy service (e.g., heating, steam) to the client at an agreed tariff. The contract is based on service provision rather than explicit savings reporting.
- **Leasing (Energy Performance Lease - EPL)** (Fig. 1d): The *ESCO* provides equipment under an operational lease. The client pays fixed periodic fees, and the link to energy savings is often implicit or secondary.

Fig. 1 schematically illustrates the main operating modalities of *ESCOs* [3], [8]. While other models exist (e.g., Energy Outsourcing or Power Purchase Agreements), they generally fall outside the scope of traditional energy efficiency financing models. Table I further complements the discussion by presenting a summary comparison of the main types of business models, including the ESCO model.

C. *The Energy Services Performance Contract (ESPC)*

The ESPC contract is the foundation of the ESCO model and follows a structured process involving several stages:

1) **Walk-Through Audit (WTA)**: Preliminary assessment of the savings potential without high costs.
2) **Investment Grade Audit (IGA)**: Detailed analysis of the investment and expected savings.
3) **Negotiation and contract signing**: Definition of financial and technical terms.
4) **Implementation and monitoring**: The ESCO measures and verifies the savings achieved [3].

D. *ESCO Viability Assessment*

To evaluate the viability of an ESCO in energy self-consumption projects, the following key factors must be considered:

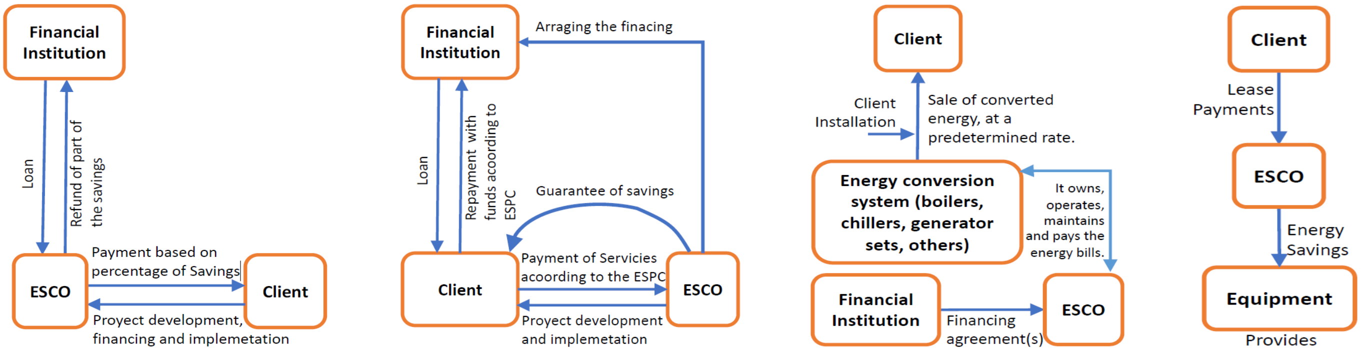
1) **Target Market:** ESCOs typically focus on large energy consumers, such as industry, the commercial sector, and government.
2) **Financing:** Access to loans and tax incentive schemes is essential to ensure the project's financial viability.
3) **Regulation and Public Policies:** The existence of favorable regulatory frameworks can boost the development of ESCO projects.
4) **Measurement and Verification (M&V):** The implementation of standardized methodologies, such as the *International Performance Measurement and Verification Protocol* (IPMVP), ensures accuracy in estimating savings [3].

III. FORMULATION OF THE MATHEMATICAL MODEL AT ESCO

This section presents the mathematical formulation of the shared-savings ESCO model (see Fig. 1a), where the savings are allocated between the user (β) and the ESCO (α). The annual self-consumed energy $E_{self,t}$ is defined as a fraction λ of the user's average consumption E_u, as expressed in

$$E_{self,t} = E_u \cdot \lambda, \tag{1}$$

where λ represents the self-consumption ratio (up to 100%).



(a) Shared Savings (b) Guaranteed Savings (c) Savings (Chauffage) (d) ESCO Leasing

Fig. 1. Overview of ESCO Business and Financial Modalities [3], [8].

TABLE I
COMPARATIVE SUMMARY OF MAIN ESCO CONTRACT TYPES

Contract Type	Financing	Risk	ESCO Compensation	Typical Application
Shared Savings	ESCO	ESCO	Share of generated energy savings	Users without investment capacity
Guaranteed Savings	Client / third party	Client	Savings guarantee with penalty if unmet	Public sector or creditworthy entities
Chauffage Model	ESCO	ESCO	Tariff for delivered energy service (heat/steam)	District heating or HVAC systems
Leasing	ESCO	Shared	Fixed periodic equipment leasing fees	Regulated customers with individual metering

The cost savings due to self-consumption, referred to as the avoided energy cost (AEC), are given by

$$AEC_t = E_{self,t} \cdot T_e \cdot (1+g)^t, \tag{2}$$

where T_e is the electricity tariff and g is the annual growth rate.

The annual savings AEC_t are divided into two components for ESCO financing, as defined by

$$AEC_t = SACU_t + PAY_t^{ESCO}, \quad \forall t, \tag{3}$$

where $SACU_t$ is the user's savings and PAY_t^{ESCO} represents the ESCO revenues.

These components are determined by the allocation factors α and $\beta = 1-\alpha$, respectively. The distribution of these savings throughout the contract stages is illustrated in Fig. 2.

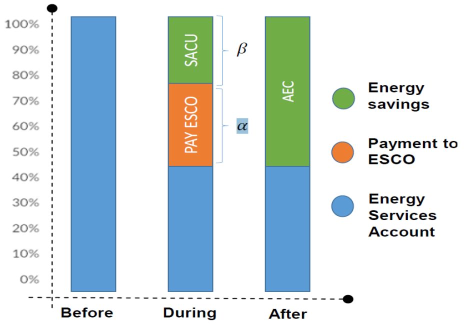


Fig. 2. Savings distribution in the ESCO model.

The allocation of AEC_t to $SACU_t$ during and after the contract period t_E is defined as

$$SACU_t = \begin{cases} \beta \cdot AEC_t, & t \leq t_E \\ AEC_t, & t > t_E \end{cases}, \tag{4}$$

while the ESCO revenues are given by

$$PAY_t^{ESCO} = \begin{cases} \alpha \cdot AEC_t, & t \leq t_E \\ 0, & t > t_E \end{cases}. \tag{5}$$

The discounted net cash flows of the ESCO, $DNCF_t^{ESCO}$, are calculated as

$$DNCF_t^{ESCO} = \begin{cases} PAY_t^{ESCO} - OpEx_t, & t \leq t_E \\ 0, & t > t_E \end{cases}, \tag{6}$$

where $OpEx_t$ represents the operational costs at time t.

The discounted cumulative cash flows $DCCF_t^{ESCO}$ are defined as

$$DCCF_t^{ESCO} = \begin{cases} -CapEx, & t = 0 \\ DCCF_{t-1} + DNCF_t^{ESCO}, & t < t_E \end{cases}, \tag{7}$$

where $CapEx$ is the initial investment cost.

Based on the LCOE principle [15], [16], where $NPV = 0$, $r = IRR$, $BCR = 1$, and $PBP = UL$ define the profitability threshold, the ESCO model is structured under the same levelized cost framework. Under these conditions, the equality between costs and benefits is expressed as

$$\sum_{t=1}^{N} \frac{PAY_t^{ESCO}}{(1+r)^t} = CapEx + \sum_{t=1}^{N} \frac{OpEx_t}{(1+r)^t}. \tag{8}$$

Substituting PAY_t^{ESCO} into the previous expression yields

$$\sum_{t=1}^{N} \frac{\alpha \cdot AEC_t}{(1+r)^t} = CapEx + \sum_{t=1}^{N} \frac{OpEx_t}{(1+r)^t}. \tag{9}$$

IV. METHODOLOGY AND MULTI-OBJECTIVE OPTIMIZATION FRAMEWORK

This section presents the methodology and the multi-objective optimization framework proposed for the ESCO business model.

Algorithm 1 Algorithm for Computing the Pareto Front of the ESCO Model Using MOGA

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Require: Annual energy use $E_u$, self-supply ratio $\lambda$, self-generated energy $E_{self,t}$, growth rate $g$, discount rate $T_d$, system parameters $(CF, OpEx, CapEx)$, tariff $T_e$
Ensure: Pareto front $(\alpha, t_E)$
Decision variables: $\alpha \in [0,1]$, $\beta \in [0,1]$, $t_E \in [1,25]$
Set fixed parameters $E_{self,t}$, $CF$, $CapEx$, $OpEx$, $g$, $T_d$
Compute installed capacity as $kWp \leftarrow \frac{\lambda E_{self,t}}{CF \cdot 8760}$
Annual self-generation as $E_{self,t} \leftarrow kWp \cdot CF \cdot 8760$
Evaluate objective functions: $\min T_e$ and $\min \alpha$
Define nonlinear operational and financial constraints
Configure MOGA parameters (population, generations, crossover)
Solve using gamultiobj
Retrieve and plot Pareto-optimal set $(\alpha, T_e)$
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A. Workflow of the Proposed Algorithm

This section describes the methodology used to evaluate the sensitivity of the proposed ESCO model. The analysis is conducted using a multi-objective optimization framework in which the Pareto frontier is obtained through a Multi-Objective Genetic Algorithm (MOGA). The overall simulation procedure adopted to analyze the ESCO model and identify Pareto-optimal solutions is summarized in Algorithm 1.

Algorithm 1 describes the procedure used to compute the Pareto frontier of the ESCO contract design problem. First, the input parameters of the model are defined, including the annual energy demand, the self-supply ratio, the economic parameters of the photovoltaic system, and the electricity tariff. The decision variables correspond to the ESCO participation factor α, the user share β, and the contract duration t_E.

Based on these parameters, the installed photovoltaic capacity is estimated according to the desired self-supply level and the system capacity factor. The annual energy generation is then calculated and used to evaluate the objective functions while satisfying the operational and financial constraints of the project.

The optimization is implemented using the *gamultiobj* solver available in MATLAB, which is based on an elitist evolutionary approach derived from the Non-dominated Sorting Genetic Algorithm II (NSGA-II) [17], [18]. The algorithm evolves a population of candidate solutions through selection, crossover, and mutation operators. At each generation, solutions are ranked according to Pareto dominance, and the best non-dominated individuals are preserved, progressively approximating the Pareto frontier.

In the different case studies analyzed in this work, the objective functions are modified to evaluate several sensitivities of the ESCO model. However, the computational procedure and optimization methodology described in Algorithm 1 remain unchanged. The resulting Pareto frontier identifies feasible combinations of ESCO participation and contract duration that balance the economic viability of the ESCO with the benefits obtained by the energy user.

B. Multi-objective Optimization for the ESCO Business Model

The multi-objective optimization problem is formulated by combining the objective functions defined in (10) and (11). The first objective minimizes the regulated tariff T_e, while the second minimizes the ESCO participation factor α, which represents the fraction of AEC_t allocated to the ESCO.

Objective functions are defined as

$$\min T_e, \tag{10}$$

$$\min \alpha, \tag{11}$$

subject to the following constraints:

$$\sum_{t=1}^{N} \frac{\alpha E_{\text{self},t} T_e (1+g)^t}{(1+r)^t} = CapEx + \sum_{t=1}^{N} \frac{OpEx_t}{(1+r)^t} \tag{12}$$

$$\alpha + \beta = 1, \tag{13}$$

$$0.1 < T_e < 0.15, \tag{14}$$

$$0 < \alpha < 1, \tag{15}$$

$$0 < \beta < 1. \tag{16}$$

Equation (12) ensures the economic balance of the ESCO model, while (13) enforces the complementary relationship between α and β. Constraints (14)–(16) define the feasible ranges of the decision variables.

V. APPLICATION OF THE PROPOSED MODEL

A. Case Study

To evaluate the proposed methodology, the case study shown in Table II is established.

TABLE II
DATA CONSIDERED IN THE CASE STUDY

ELECTRICITY SERVICE USER DATA		
Parameter	**Unit**	**Value**
Annual energy consumption	[MWh]	12
Regulated Tariff (T_e)	[USD/kWh]	0.10
Rate growth rate (g)	[%]	2
Share of the energy self-supplied (λ)	[%]	100
DISTRIBUTED GENERATOR DATA FOR SELF-CONSUMPTION		
Rated capacity of DG	[kW]	8
$CapEx_u$	[USD/kW]	550
Useful life (UL)	[years]	25
$OpEx_u$	[USD/kW/year]	20
Capacity factor (CF)	[%]	17
ECONOMIC AND FINANCIAL PARAMETERS OF THE ESCO		
Discount rate	[%]	10
ESCO Contract Duration t_E	[years]	10

The case study implements a *shared-savings* scheme (see Fig. 1a) where the ESCO provides project financing. During the 10-year ESPC, savings are distributed with an allocation of $\alpha = 66.86\%$ for the ESCO and $\beta = 33.14\%$ for the user. Once the contract concludes at year t_E, the user perceives the entirety of the generated savings for the remainder of the project's useful life.

Furthermore, sensitivity analyses are conducted to determine the optimal allocation factor α. These simulations evaluate the ESCO model's robustness by varying objective functions and constraints according to key financial and technical

TABLE III

OBJECTIVE FUNCTIONS, CONSTRAINTS, AND PARAMETERS USED IN EACH SIMULATION

Sim	Obj. Func.	Constr.	Parameters
1	T_e, α	$0.10 \leq T_e \leq 0.15$	$CF = 17\%$, $r = 10\%$, $t_E = 10$y
2	CF, α	$0.15 \leq CF \leq 0.25$	$T_e = 0.10$, $r = 10\%$, $t_E = 10$y
3	t_E, α	$5 \leq t_E \leq 25$	$CF = 17\%$, $r = 10\%$, $T_e = 0.10$
4	r, α	$0.08 \leq r \leq 0.15$ $0.03 \leq i \leq 0.17$	$CF = 17\%$, $T_e = 0.10$, $t_E = 10$y
5	i, $LLCR$, $PLCR$	$0 \leq LLCR \leq 5$ $0 \leq PLCR \leq 5$	$CF = 17\%$, $T_e = 0.10$, $t_E = 10$y, $r = 10\%$

parameters. To clarify the role of each variable in the optimization framework, Table III summarizes the objective functions, constraints, and fixed parameters considered in each simulation scenario, in addition to the data considered in Table II and Table V.

B. Sensitivity of α vs. Regulated Tariff T_e and Capacity Factor CF

There is a direct relationship between the economic model's input variables and the percentage of savings allocated to the *ESCO*. Fig. 3a presents the sensitivity analysis of the payment allocated to the *ESCO* (PAY_t^{ESCO}) as a function of the initial regulated tariff (T_e) considered during the contractual period t_E. The Pareto front shows that the higher the regulated tariff, the lower the percentage of savings the *ESCO* requires to recover its investment. This is because a higher T_e value increases the annual avoided cost (AEC), thus improving the profitability and economic viability of the *ESCO* model.

The sensitivity of the savings percentage α allocated to the *ESCO* as a function of the self-consumption generation system's Capacity Factor (CF) is presented in Fig. 3b. It is observed that the higher the capacity factor, the lower the percentage required by the *ESCO* to recover its investment. This is due to the fact that, keeping investment and operational costs constant, a higher CF implies greater annual energy generation, which increases the annual savings and improves the economic viability conditions of the *ESCO* model.

C. Sensitivity of α vs. ESCO Contract Duration t_E and Discount Rate r

The sensitivity of the annual payment percentage allocated to the *ESCO* (α) as a function of the contractual time of the ESPC model (t_E) is presented in Fig. 4a. It is observed that, as the contract duration t_E increases, the percentage α required by the *ESCO* to recover its investment decreases. This is because, with investment and operational costs remaining constant, a longer time t_E allows the investment recovery to be distributed over a wider horizon, thus reducing the necessary annual revenues and improving the economic viability of the *ESCO* business model.

Fig. 4b shows the Pareto front of the percentage α and the discount rate r, which allows for reviewing the sensitivity between both variables. As the discount rate rises, the ESCO Payment percentage rises because the discount rate has a direct implication on the costs of the *ESCO* business model.

D. Sensitivity Analysis with Contour Map

The contour map technique is used as a visualization tool to represent the complete solution space of the financial model. The color bar indicates the range of the parameter α within $0 < \alpha < 1$, highlighting regions of higher sensitivity.

In Fig. 5a, the horizontal axis represents the regulated tariff T_e [USD/kWh], and the vertical axis represents the capacity factor (CF). This visualization allows the identification of regions where the ESCO model is most favorable from the user's perspective. Higher capacity factors and tariffs lead to lower values of α, meaning that a larger share of the savings is retained by the end user, thereby improving project profitability.

From a regulatory perspective, for a given tariff (e.g., $T_e = 0.10$), the map enables the identification of technical conditions (such as CF) under which the shared-savings model remains economically viable.

To validate consistency with the Pareto fronts in Fig. 3, two points are analyzed: ($T_e = 0.10$, $CF = 0.17$) and ($T_e = 0.14$, $CF = 0.17$). The contour map yields $\alpha_1 = 0.67$ and $\alpha_2 = 0.479$, respectively, which correspond to solutions on the Pareto front, confirming the consistency of the multi-objective analysis.

Fig. 5b shows the sensitivity of α as a function of the contract duration (t_E) and the discount rate (r). The required ESCO share decreases as the contract period increases or the discount rate decreases, improving the economic attractiveness for the user.

Consistency with the Pareto fronts (Fig. 4a) is verified using two points: ($t_E = 10$ years, $r = 0.10$) and ($t_E = 20$ years, $r = 0.10$), which yield $\alpha_1 = 0.667$ and $\alpha_2 = 0.485$. These values match the Pareto-optimal solutions, confirming the coherence of the multi-objective sensitivity analysis.

E. Financial Analysis of the ESCO Model

To evaluate the financial viability of the project from the lender's perspective, key debt coverage indicators are considered: the debt service coverage ratio (DSCR), the loan life coverage ratio (LLCR), and the project life coverage ratio (PLCR). The DSCR measures the ability of the project to meet its debt obligations from operating cash flows, while the LLCR and PLCR evaluate the capacity of the ESCO to cover debt service over the loan term and the project lifetime, respectively. Table IV summarizes the minimum threshold values adopted for these indicators.

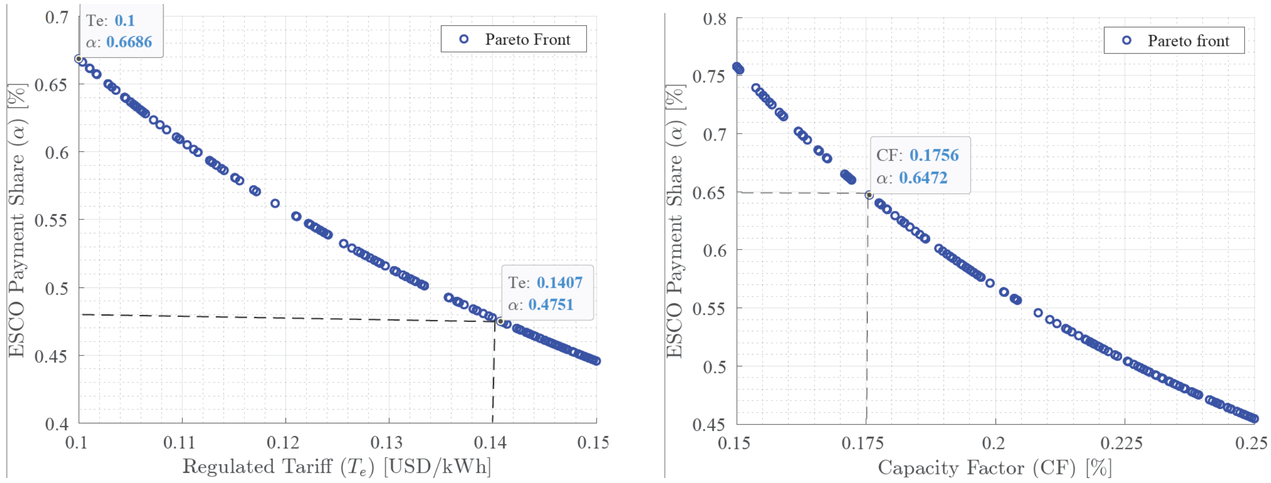
TABLE IV

MINIMUM THRESHOLDS OF DEBT COVERAGE INDICATORS

Indicator	Definition	Min.
$\mathbf{DSCR_t}$	Debt service coverage ratio. See (17).	> 1.2
LLCR	Loan life coverage ratio. See (18).	> 1.2
PLCR	Project life coverage ratio. See (19).	> 1.5

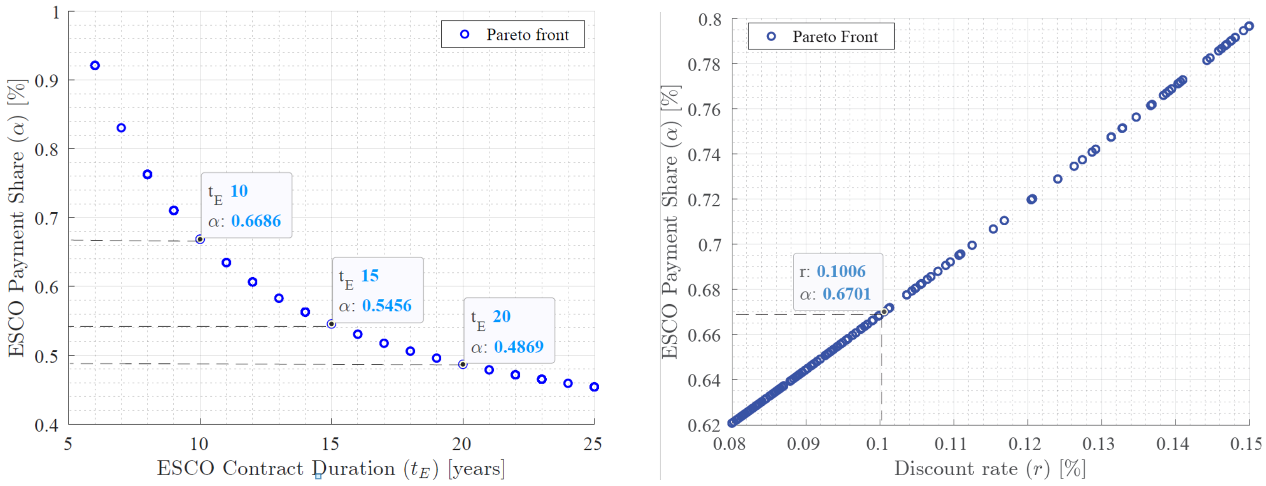
The DSCR at time t is defined as

$$DSCR_t = \frac{Revenue_t - OpEx_t}{DebtService_t}, \tag{17}$$



(a) Sensitivity of α vs. T_e (b) Sensitivity of α vs. CF

Fig. 3. Sensitivity of α vs. Regulated Tariff T_e and Capacity Factor CF



(a) ESCO Payment % (α) vs. Contract Time t_E (b) ESCO Payment % (α) vs. Discount Rate r

Fig. 4. Sensitivity of α to contract duration and discount rate.

where $Revenue_t$ represents the project revenues, $OpEx_t$ the operational costs, and $DebtService_t$ the debt service at time t.

The LLCR is expressed as

$$LLCR = \frac{\sum_{t=1}^{t_{de}} \frac{Revenue_t - OpEx_t}{(1+i)^t}}{D_{out}}, \tag{18}$$

while the PLCR is given by

$$PLCR = \frac{\sum_{t=1}^{t_E} \frac{Revenue_t - OpEx_t}{(1+i)^t}}{D_{out}}, \tag{19}$$

where D_{out} denotes the outstanding debt, i is the interest rate and t_{de} is the debt term.

The multi-objective problem used to determine the debt coverage indicators is formulated by considering the objective functions defined in (20)–(22). These functions are combined with the constraints defined in (23) and (24), which are incorporated into the general multi-objective framework described in Section IV-B.

The objective functions are defined as

$$\min i, \tag{20}$$

$$\min LLCR, \tag{21}$$

$$\min PLCR, \tag{22}$$

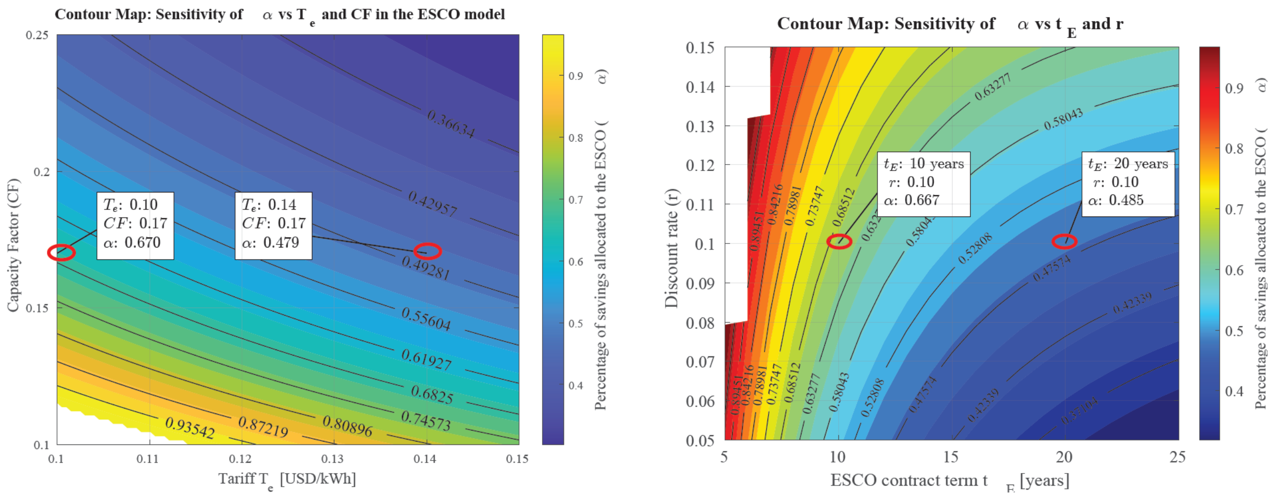
subject to

$$LLCR \cdot D_{out} = \sum_{t=1}^{t_{de}} \frac{\alpha \cdot AEC_t - OpEx_t}{(1+i)^t}, \tag{23}$$

$$PLCR \cdot D_{out} = \sum_{t=1}^{t_E} \frac{\alpha \cdot AEC_t - OpEx_t}{(1+i)^t}. \tag{24}$$

The data used to determine the debt coverage ratios are summarized in Table V.

Fig. 6a shows the Pareto frontiers of the $LLCR$ and $PLCR$ as a function of the interest rate (i). For the project to be bankable, both indicators must exceed their respective threshold values. As observed, the $PLCR$ indicates that a



(a) Contour map of Payment % (α) vs. Regulated Tariff T_e and Capacity Factor CF

(b) Contour map of Payment % (α) vs. contract time t_E and discount rate r

Fig. 5. Sensitivity analysis of ESCO payment fraction α under variations of contract time and discount rate.

TABLE V
ADDITIONAL DATA FOR DETERMINING DEBT COVERAGE RATIOS

Parameter	**Unit**	**Value**
Equity financing percentage (EFP)	[%]	0.30
Debt financing percentage (DFP)	[%]	0.70
Debt term (t_{de})	[years]	8
ESCO Payment Share (α)	[%]	66.862
Outstanding debt (D_{out})	[USD]	$CapEx \cdot DFP$
Financing type	[−]	French amortization

minimum interest rate of 8.7% is required, while the $LLCR$ requires a minimum rate of approximately 10% to ensure sufficient coverage over the project lifetime and the loan term, thereby guaranteeing the financial viability of the project.

For the evaluation of the $DSCR$, an interest rate of $i = 8.4\%$ is considered. The resulting $DSCR$ values, shown in Fig. 6b, remain above the minimum threshold of 1.2 for all 8 years, confirming the financial viability of the ESCO-based financing scheme.

VI. CONCLUSIONS

This work presents a multi-objective financial optimization methodology for distributed generation (DG) projects under the Energy Service Company (ESCO) model. The main contribution is a rigorous framework that establishes an optimal economic balance between the ESCO and the regulated user through the levelized allocation of the avoided energy cost, aligned with project finance principles.

The model ensures that the ESCO recovers its investment (via an optimal α allocation) without compromising user sustainability. The proposed methodology incorporates a multi-objective analysis that includes debt coverage indicators (DSCR, LLCR, and PLCR), enabling the identification of critical parameters (such as the interest rate) required to ensure the project's bankability.

Sensitivity analyses demonstrate the applicability and versatility of the approach for evaluating different contractual configurations. In addition, contour maps provide a valuable visual tool for regulators and policymakers to define technical and tariff conditions that support the large-scale deployment of DG under financially robust schemes.

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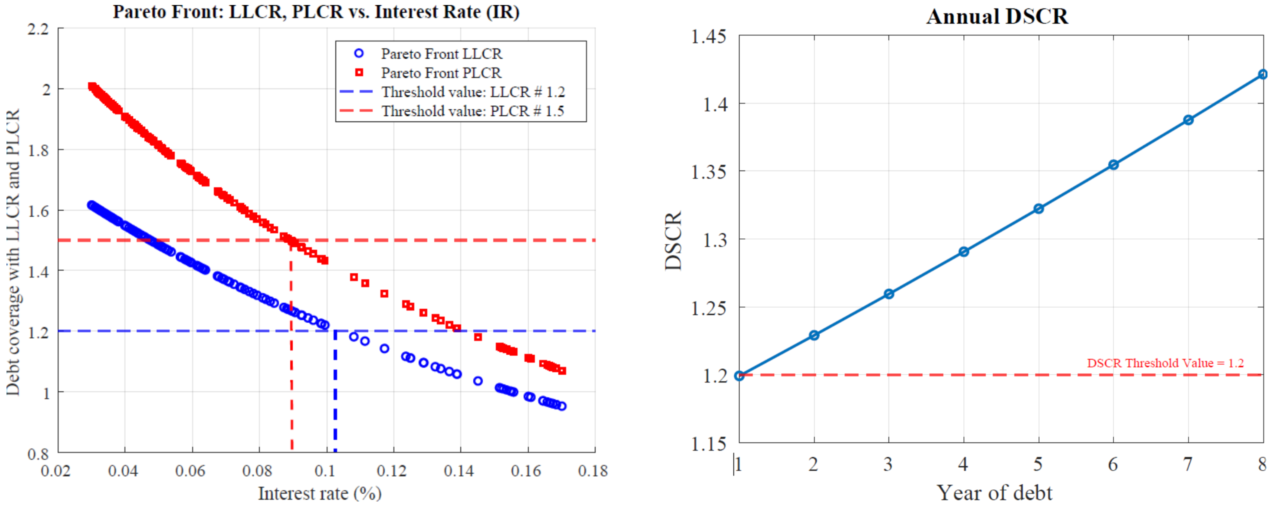

(a) Sensitivity of LLCR and PLCR vs. interest rate (i)

(b) DSCR for each year during the project's debt period

Fig. 6. Financial ratios for debt coverage.

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