Public-private partnerships for energy efficiency projects: A win-win model to choose the energy performance contracting structure

Public-Private Partnerships for Energy Efficiency Projects: A Win-Win Model to Choose the Energy Performance Contracting structure

1. Introduction

Nowadays the energy efficiency management represents a global issue that has gained considerable attention from national and local governments who are required to meet the needs of the population by addressing goals of energy costs saving, emissions' reduction, and, more broadly, sustainable development (European Commission, 2006; NDRC, 2004; 2008). In the European context, for example, the national governments are asked to match, within 2020, the targets fixed in the European Energy Policy Plan (20-20-20), consisting of: 1) CO2 emissions reduction by 20%; 2) improvement in energy processes by 20%; and 3) replacing primary energy with renewable energy by 20% (European Commission, 2007).
Effective energy-saving strategies that can be undertaken by local governments focus mainly on the energy consumption optimization in public utilities and buildings owned by municipalities (Fiaschi et al., 2012). The efficient management of energy consumption in such industry is strategic to improve the environment and the local public economy, and deliver beneficial effects to citizens, such as tax reduction and better quality in public services. All over the world several cities have already undertaken projects to improve energy efficiency in different areas, such as public street lighting, public buildings, public transport, educational buildings, distribution networks (Radulovic et al., 2011; Hannon et al., 2015; Yuan et al., 2016; Kamyab et al., 2016; Amini et al., 2015; Desideri et al., 2012; Amini et al. 2013). Although governments have launched several initiatives to promote the efficient management of energy consumption in response to these growing needs, the

implementation rate of energy efficiency actions as well as the adoption of energy-efficient technologies and best practices is still far from its vast potential (Painuly et al, 2003; Sarkar and Singh, 2010).

Among the various barriers that public sector faces in carrying out energy efficiency projects, the public budget constraints, in terms of both public spending cuts and contraction of the available public funds, and the lack of effective and efficient management and technical skills in the public administration, are the most important (Lee et al., 2003).

To overcome these barriers, alternative models of public procurement which increasingly exploit the private sector competencies in delivering energy efficiency projects, are required (Roshchanka and Evans, 2016).

Recently, several Governments have adopted Public Private Partnerships as a new method for developing energy efficiency projects. PPPs are contractual arrangements between the public and private sectors which work cooperatively to deliver public infrastructure or services to the community (Grimsey and Lewis, 2002; European Commission, 2003; Canadian Council for Public-Private Partnerships, 2004). Relying on the collaboration between two entities who jointly work to reach shared and/or compatible objectives, successful PPPs require that risks, responsibilities, resources investment are arranged to assure that the interests of the two parties are satisfied in a balanced way, namely a win-win condition. For energy efficiency projects delivered through PPP, the public sector uses private companies, the Energy Service Company (ESCO) to provide technical, commercial and financial services (Goldman and Dayton, 1996; Vine et al., 2003; Vine, 2005; Roshchanka and Evans, 2016; Pätäri and Sinkkonen, 2014). The contractual arrangements defining the contracting parties' obligations and rights are traditionally based on Energy Performance Contracting (EPC), which is a mechanism for procuring and implementing capital improvement interventions (i.e., the incremental investment of energy efficient systems) that are repaid through the potential saved energy consumption costs (Xu et al., 2011; Zhang et al., 2015). Under an energy performance contract, the ESCO is engaged in the design, installation, and finance of specific energy efficiency investment projects which allow the counterpart to have high-energy efficient facilities and obtain potential savings with little or even no direct investments (Taylor et al., 2007). The ESCO responsibilities include providing an energy saving plan, installing energy efficient facilities, offering maintenance in the contract period, and ensuring energy saving efficiency. The ESCO is responsible for all or most of the initial investment in energy efficient equipment (Zhang et al., 2015).

There are different ways to structure an EPC model, each characterized by a different risk allocation between the two parties, provision of finance, and repayment mechanisms of ESCOs.

The existing literature analyzed the advantages of EPC mechanism for delivering energy efficiency projects comparing with other traditional procurement systems (Zhao, 2007) and explored the critical success factors of EPC (Xu et al., 2011; Davies and Chan, 2001; Xu and Chan, 2013; Xu et al., 2013). However, it lacks of studies that benchmark among the different EPC structures in order to choose the most appropriate EPC schema to deliver an energy efficiency project through PPP, namely the energy performance contract which guarantee the achievement of a win-win condition, which is the essence of any PPP relationship.

To fill this gap, this paper proposes a model for assessing and benchmarking the net benefits of the different EPC structures, so as choosing the EPC schema that creates a ‘win–win’ solution for both the ESCO and the government, by balancing the private sector’s profitability needs and the public sector's economic interests. This will support the public authority in the decision-making process about the EPC structure to be adopted to develop an energy efficiency project together with the ESCO as a PPP.

To demonstrate the applicability of the proposed model, we apply it to an energy efficiency project launched by the Municipality of Noci (Southern Italy).

The paper is organized as follows. Next section reviews the state of art on the Energy Performance Contracting models, shedding light on the challenges of EPC for PPP energy projects. The research objectives of the paper are therefore discussed. Section 3 presents the the model developed for assessing and benchmarking EPC structures, which is then applied to a real case in the Section 4. Finally, the last section concludes the paper and discusses some policy implications of the research.

2. Energy Performance Contracting models review

The energy performance contracting (EPC) is a market-oriented mechanism for delivering energy efficiency projects. It is a contractual arrangement between an ESCO and its client, which involves an energy efficiency intervention on the client's facilities, whose performance is somehow guaranteed by the ESCO (Taylor et al., 2007). Under the EPC, the ESCO implements a project to deliver energy efficiency and repay the project's costs, including the investment costs, by using the stream of income from the cost savings.

According to the European Union (art. 2 of the Directive 2012/27/EU), EPC means a "contractual arrangement between the beneficiary and the provider of an energy efficiency improvement measure, verified and monitored during the whole term of the contract, where investments (work, supply or service) in that measure are paid for in relation to a contractually agreed level of energy efficiency improvement or other agreed energy performance criterion, such as financial savings". The approach relies on the transfer of technical risks from the client to the ESCO on the basis of performance guarantees provided by the ESCO. In EPC, the remuneration for the ESCO is generally based on demonstrated performance, namely the level of energy savings or energy service which is reached.

2.1 Classifying energy performance contracting models

Energy performance contracting is an umbrella term for different contractual relationships between energy-service providers and clients (Pätäri and Sinkkonen, 2014). Various possible contract schemes to structure an energy performance contracting arrangement have been devised over the years, such as Guaranteed Savings, Shared Savings, First Out, and variations of these main schemes (Han et al., 2006; Bertoldi and Rezessi, 2005; Hui, 2002; Hansen, 2003; Poole and Stoner, 2003; Kelly and Pollit, 2010; Costantino et al., 2012; Pätäri and Sinkkonen, 2014). Each of these different schemes includes variations in relation to risk allocation between the two parties, provision of finance, and repayment mechanisms of ESCOs.

In Guaranteed Savings contract, the ESCO is responsible of the design and implementation of the project, but not of its financing, although it may arrange for or facilitate financing. The client is required to take part of financing risk, whereas the ESCO guarantees minimum savings to customer, specifically those savings considered sufficient for the debt service payments (Bertoldi and Rezessi, 2005; Hui, 2002; Hansen 2003). If the savings are not enough for the debt service, then the ESCO has to cover the difference. If savings exceed the guaranteed level, then the client pays an agreed percentage of the savings to the ESCO. Therefore, in the Guaranteed Savings contract the ESCO takes over the entire performance and design risk, whereas the client assumes the investment repayment risk (Costantino et al., 2012).

Under a Shared Savings contract, the ESCO takes the responsibility for the project financing, designs, implements the project, verifies energy savings, and shares an agreed percentage of the actual energy savings over a fixed period with the customer. The cost savings are split between the two parties over a fixed period in accordance with a pre-arranged percentage of the actual energy savings. There is no ‘standard’ split as this depends on the project cost, the contract length and the risks borne by the ESCO and the consumer. The ESCO, therefore, assumes both performance and credit risk, whereas the client takes over some performance risk, but avoids assuming any credit risk. In this case, the customer accounts the financing off balance sheet (Sorrel, 2007; Sussex, 2001).

An important difference between guaranteed and shared savings models is that in the former the performance guarantee is the level of energy saved, while in the latter it is the cost of energy saved. Also, compared with Shared Savings contracts, Guaranteed Savings contracts specify a certain amount of energy savings guarantees in the contracts in order to meet the payback obligation (Hopper et al., 2005). According to Goldman et al. (2005), the ESCOs market shifted away from Shared Savings contract to Guaranteed Savings contract over the last decade, and 86% of EPCs currently use Guaranteed Savings contract. The main reasons for this shift are linked to the greater certainty of savings, the lower financing costs, and the lower transaction costs for Guaranteed Savings contracts from the owners’ perspective (Hopper et al., 2005).

In the ‘First Out’ contract, the ESCO finances the interventions and retains 100 percent of the energy savings until the project costs, including the ESCO profit, are fully paid or until the end of the contract, whichever occurs first (Taylor et al., 2007). The exact duration of such a contract actually depends on the level of savings which are achieved: the greater the savings, the shorter the contract (ECS, 2003). A variation of the First-Out contract is the 'Chauffage', that is an energy management contract where the ESCO provides the client with an agreed set of energy services (e.g., space heat, lighting, motive power, etc.). Differently form the other EPC contracts, the 'Chauffage' includes "performance" operations (i.e, operation of systems by ensuring a given level of comfort: temperature, humidity, etc.) without, however, explicitly committing to carry out energy efficiency investment (Hansen, et al., 2009).

Table 1 synthetizes the above discussed features of the main EPC arrangements, in terms of risk allocation, provision of finance, contract duration, and repayment mechanism.

Table 1. EPC models.

	Risk allocation		**Provision of finance**		**Contract duration**	**ESCO's remuneration**
	ESCO	**Customer**	**ESCO**	**Customer**		
Shared Savings	Performance risk Financial/credit risk	Part of performance risk	X		fixed period	Pre-arranged percentage of savings
Guaranteed Savings	Performance risk	Financial/credit risk		X	fixed period	Based on demonstrated performance; if the savings are less than expected the ESCO covers the shortfall
First Out	Performance risk Credit risk		X		variable period	ESCO receives 100 % of energy savings each year, until it has recovered its original capital and th rate of return

2.2 EPC for PPP energy projects

The characteristics of EPC schemes discussed in the previous section suggest that, under the right conditions, using EPCs to deliver energy efficiency projects in the public sector through PPP, rather than other traditional procurement systems, is beneficial to all parties, making them especially appealing (Roshchanka and Evans, 2016).

For public facility managers, energy performance contracting allows the public sector to minimize the cost of energy services through a single contract with an energy services provider, the ESCO. In fact, in traditional energy services public procurement models, the public authority contracts separately for each energy commodity and for different types of energy conversion equipment and efficiency interventions. Conversely, EPCs are comprehensive contracts, stipulated with the ESCO, that follow a one-stop-shop concept as they include installation, operation and maintenance of equipment, finance, energy audits, and even, in some cases, electricity purchasing. These contracts allow Governments, which usually suffer of limited resources, to avoid investment costs and keep off-balance sheet the energy investments, reduce energy costs. They can also have access to advanced technologies and exploit energy management expertise and skills of the ESCO. Moreover, the public body transfers part of investment, technical, market, and energy efficiency performance risks to a private engineering-savvy company (Sorrel, 2007; Roshchanka and Evans, 2016; Hannon et al., 2015; Hufen and de Bruijn, 2016; AlFaris et al., 2016).

For taxpayers, EPCs help effectively manage public finds, stretching tax dollars while also reducing emissions and improving energy security (Roshchanka and Evans, 2016).

On the other hand, for ESCOs, the public sector offers an exciting opportunity to conduct business with a public-sector leader (Roshchanka and Evans, 2016). ESCOs may, in fact, rely on contracting with a 'safer' client that does not normally go out of business, and that is increasingly experiencing the need for energy efficiency projects in their buildings and facilities (public administration buildings, public hospitals, public schools and colleges, etc.). The most common public projects in which ESCO are involved so far, in fact, include co-generation, public lighting, heating, ventilation, and air-conditioning (HVAC) of public buildings, and energy management systems (Bertoldi et al., 2006). Hence, entering into these types of partnership creates additional revenues through increased private economic activity, profits gained from the investment in the public good, new investment opportunities and new markets.

Although EPC is a valuable model for delivering mostly public energy efficiency projects by ESCOs, most middle-income countries have used this mechanism only in a limited way (Roshchanka and Evans, 2016). A broad roll-out of EPC in public sector is being prevented mainly because of two unresolved issues: the dilemma of equally sharing the benefits between the public and private parties, and the lack of adequate public procedures that, taking into account the specifics of energy service provisions, support the selection of the most appropriate EPC schema given certain circumstances and projects' characteristics (Bertoldi 2006, Xu et al. 2011; Marino et al., 2011; Painuly et al., 2003; Vine, 2005). The first issue refers to the need for assessing the benefits of EPC schema for contractual parties so as to ensure that the private sector's profitability needs and the public sector's economic interests are satisfied in a balanced way (win-win condition). The second issue refers to the need for having adequate procedures that allow the benchmark among the different EPC structures in order to choose the most appropriate EPC schema that guarantees the achievement of a win-win condition. Under certain circumstances and depending on projects' characteristics, not all the EPC structures regulating the public-private partnerships for delivering energy efficiency projects may ensure the win-win condition, where both parties are equally satisfied. A specific EPC may reveal inefficient for one party, while favoring only the other one. This raises the question about which EPC schema can guarantee such a win-win condition.

Considering the great generalization potential of EPC for PPP energy efficiency projects, a few academic studies have been carried out on this topic, although the number of works developed over the last two years leaves a great deal of development on the theme.

Hannon et al. (2015) explore how ‘demand pull’ national government policies could support Energy Service Company (ESCO) activity in the UK. Roshchanka and Evans (2016) report on the status of EPC development in Russia (to the time of the study) and provide recommendations aimed at increasing the success and expansion of the Russian model.

Yuan et al. (2016) investigate how to promote the development of EPC in China, which is experiencing a rapid development of EPCs due to the massive demand as well as the facilitation efforts from the governments.

Hufen and de Bruijn (2016) focus on the use of EPCs as a tool for property management by local government. They found that the incentives established between parties through EPCs triggered better performance and innovation, although balancing the responsibilities was crucial for their success. Energy performance contracts are a useful piece of the sustainability puzzle, but tailor-made refinements are necessary.

All these studies are driven by the common goal of exploring the ESCO business market and factors that can foster the use of EPCs. However, the existing literature lacks of studies that support making an appropriate choice among the different EPC structures (Hansen and Weisman, 1998; Bertoldi et al., 2003; Singer, 2002). Only Sorrell (2007) develops a theoretical framework to assess the feasibility of energy service contracting under different circumstances. In particular, the framework suggests that EPCs are appropriate for specific types of energy services within a subset of organizations, and they prove particularly unsuitable for final energy services at small sites and process-specific energy uses at large sites. The study however does not allow a benchmarking among the different EPC structures, based on the net economic benefits generated by an energy efficiency project, thus it does not support the decision makers in the choice of the most appropriate EPC structure.

Nevertheless, insights from studies on PPPs, which have already investigated issues related to the infrastructure PPP contracts that enable both parties being equally satisfied (Carbonara et al., 2014a; 2014b), have been rarely applied to the energy field, and specifically to relationship between ESCOs and public sector regulated by EPC schemes. As a result, models and methodologies developed for optimizing the PPP contracts are scarcely utilized for EPC schemes. To the best of authors' knowledge, only Deng et al. (2015), following the studies on contractual guarantee for PPP construction projects, develop a model to compute the energy cost savings under uncertainties. In particular, the authors develop a simulation-based study to assess the appropriate cost savings guarantee in EPC, adopting the ESCO's perspective. The method allows the ESCO to determine the amount of cost savings that should be guaranteed annually and the percentage of the excess profit that should be shared. The method could be considered as a standard procedure for energy cost savings guarantee design for the ESCO and a useful support to the public authority for bidding selection. However, the method does not design the contract in order to ensure that both parties are equally satisfied, or, in other words, it does not ensure the win-win condition that instead should underlie any form of public-private partnership.

Therefore, both the academic research and the industry practices do not provide any solution to address the discussed issues that hamper the adoption of EPCs in public sector, namely it does not provide methods to select the most appropriate EPC schema which is able to ensure the win-win condition between the public sector and the ESCO.

To fill this gap, this paper proposes a model for assessing the net benefits gained by the public sector and the ESCO through the different EPC structures and benchmarking them in order to select the one that better ensures the achievement of the win–win condition. With this aim, we focus on the EPC schemes discussed in Section 2.1, namely the Guaranteed Savings, Shared Savings, and the First Out.

3. The model for assessing and benchmarking EPC Contracts

We develop a model to assess and benchmark the different EPC schemas regulating public-private partnerships for delivering energy efficiency projects in order to select the one that better ensures the win-win condition achievement.

The assessment of the benefits of the EPC schema for contractual parties and the benchmark among the contracts are based on an economic approach. This means firstly quantifying the net benefit gained by each party through the three EPC contracts, expressed in monetary terms. Hence, the remuneration and the resulting profit of the ESCO and public body is calculated under each EPC schema (Section 3.1).

Secondly, in order to benchmark the three EPC schemas, we adopt the Net Present Value (NPV) method, which is the most common profitability index for investment projects (Braley and Mayers, 2000). NPV is the difference between the present value of cash inflows and the present value of cash outflows gained by the two parties by the EPC contract.

In order to comply with the win-win condition, our model selects the contract that minimizes the difference between the net profits (NPV) gained by the contractual parties. This will ensure that the interests of the ESCO and the government are simultaneously protected and satisfied in a balanced way.

Finally, the model takes into account the variability of factors affected by uncertainty due to the medium-long contracting period characterizing EPC arrangements by employing the Monte Carlo simulation. It is a powerful numerical method that can consider more uncertainty sources – as they are in the real world – into the evaluation and decision problem (Costantino and Pellegrino, 2010). Both historical data and experts' opinion are used to define the different probability distributions of each uncertain model input. Therefore, instead of a single "deterministic" value obtained with traditional techniques, the Monte Carlo simulation gives a "more realistic" probabilistic representation of the model outputs that can be used along with other (also qualitative) strategic considerations in order to estimate the fair value of these contracts in presence of uncertainty and, hence, support the decision-making process. Furthermore, this method can give a (probabilistic) result even when the system complexity does not have closed-form solutions.

3.1 ESCO's and public body's remuneration under EPC schemas

In the follow we calculate the remuneration of ESCO and public body which rely on the profit-sharing mechanism underlying the three EPC schemas (Figures 1, 2, 3).

Figure 1 illustrates the profit-sharing mechanism for the Guaranteed Savings Contract.

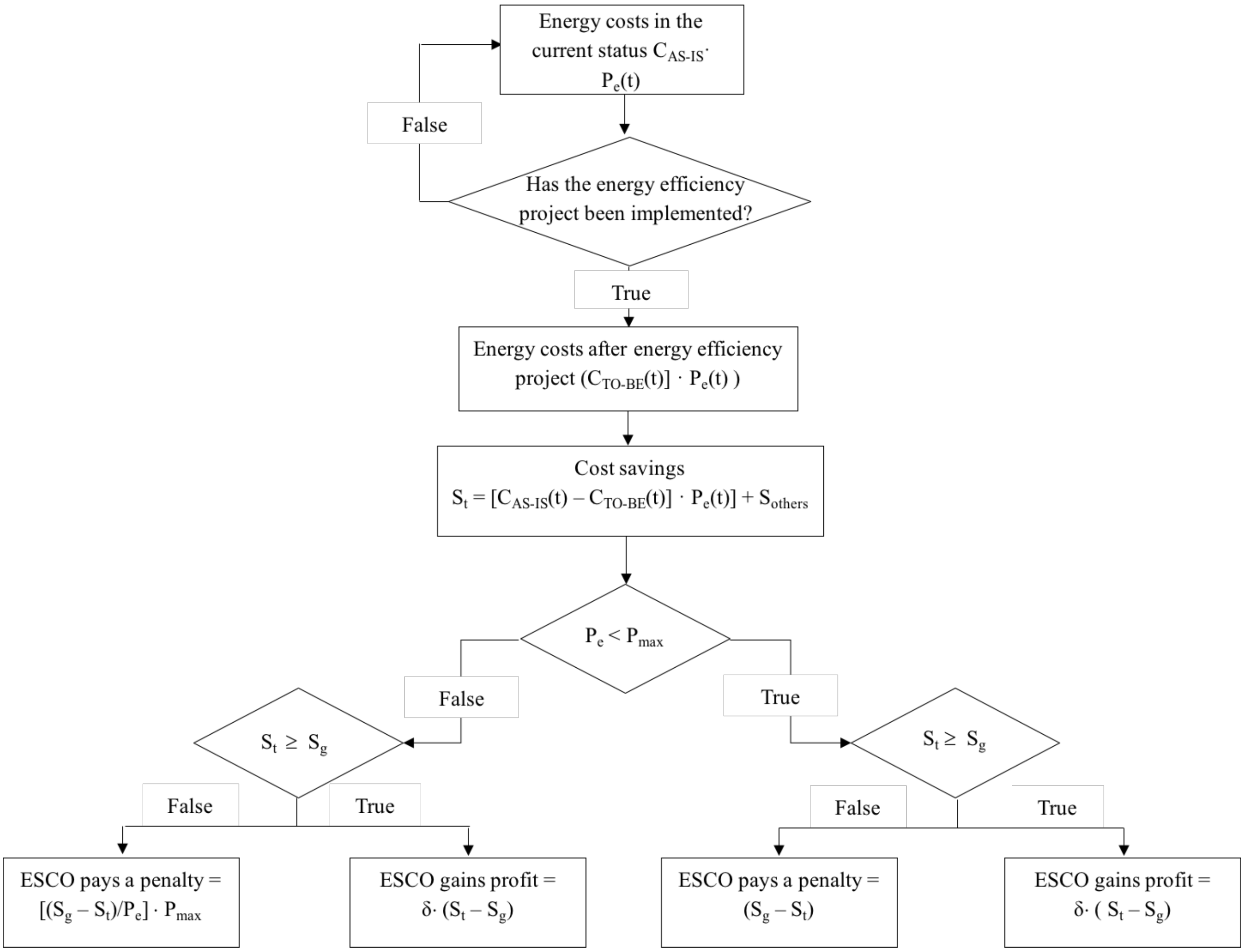

Figure 1. Profit-sharing mechanism in the Guaranteed Savings contract

Where:

C_{AS-IS} = Energy consumption in the current AS IS scenario, namely without the energy efficiency project

C_{TO-BE} = Energy consumption in the TO BE scenario, namely with the energy efficiency project

P_e = energy market price

P_{max} = maximum energy price, fixed by the contract

$S_t = S_e + S_{others}$, where:

S_e = energy cost savings at t due to the energy efficiency project calculated as follows:

$S_e = [C_{AS\text{-}IS}(t) – C_{TO\text{-}BE}(t)] \cdot P_e(t)$

S_{others} = other costs savings at t due to the energy efficiency project

S_g = minimum guaranteed cost savings

δ = ESCO's excess savings shared percentage

(1 – δ)= the public body's shared percentage

When the actual cost savings is above the guaranteed level, the ESCO's profit is:

(Actual cost savings - Guaranteed cost savings) · ESCO's excess savings shared percentage

Whereas the public body's profit is:

(Actual cost savings - Guaranteed cost savings) · public body's shared percentage

When the actual cost savings is below the guaranteed level, that is, the *(Actual cost savings < Guaranteed cost savings)*, then the ESCO reimburses the public body for the difference, that is:

Guaranteed cost savings - Actual cost savings

If this condition is due to an increase of the energy market price that goes up to the maximum fixed value, the ESCO reimburses the public body the following value:

$$\left[\frac{(S_g - S_t)}{P_e}\right] \cdot P_{max} \qquad (1)$$

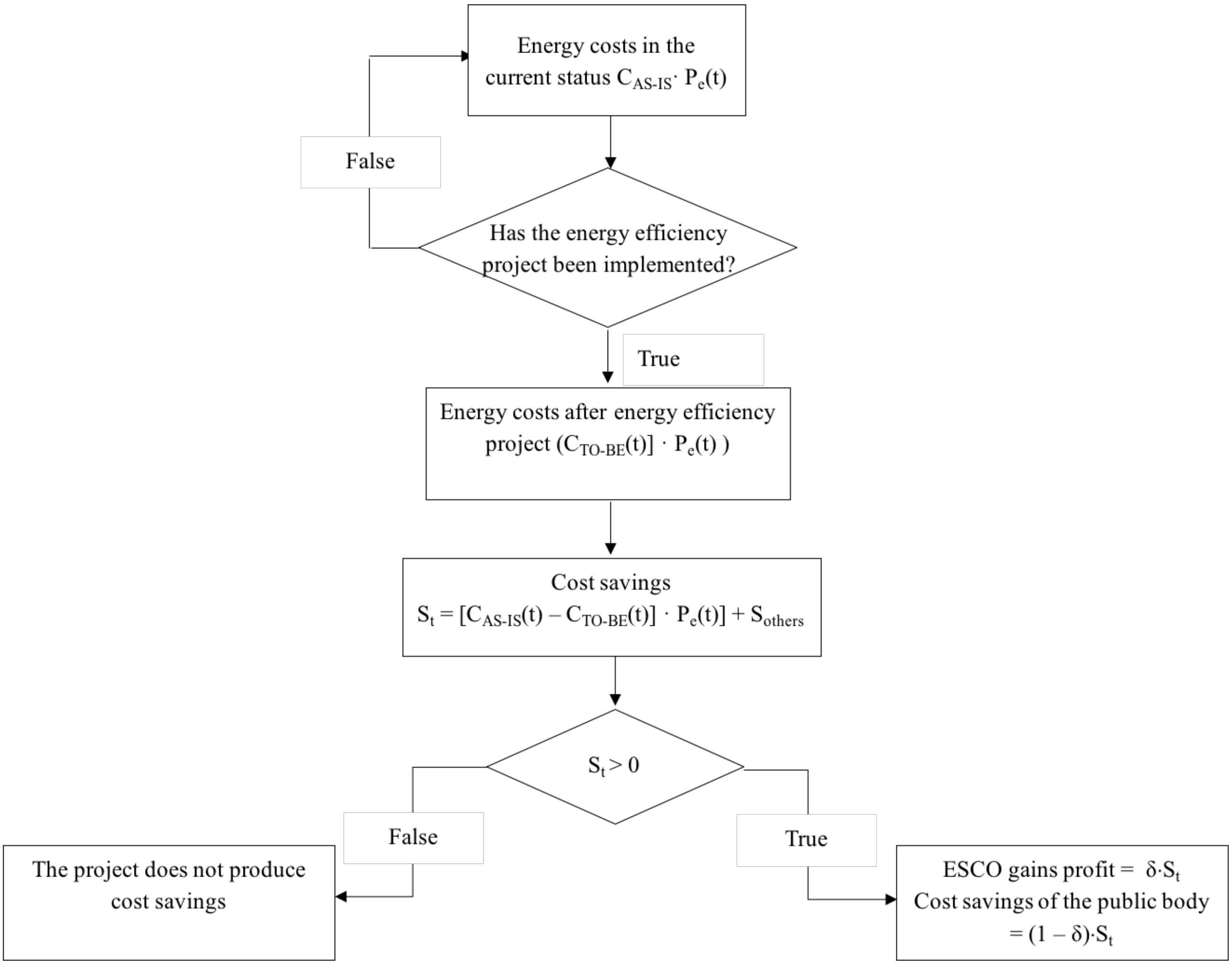

Figure 2. Profit-sharing mechanism in the Shared Savings contract

Figure 2 illustrates the profit-sharing mechanism for the Shared Savings Contract, where the actual cost savings are split in accordance with a pre-arranged percentage (δ). Thus, the ESCO's profit is:

Actual cost savings · ESCO's excess savings shared percentage

Whereas the public body's profit is:

Actual cost savings · public body's shared percentage

Differently, in a First-Out Contract (Figure 3) the entire amount of the realized cost savings (S_t) goes to the ESCO.

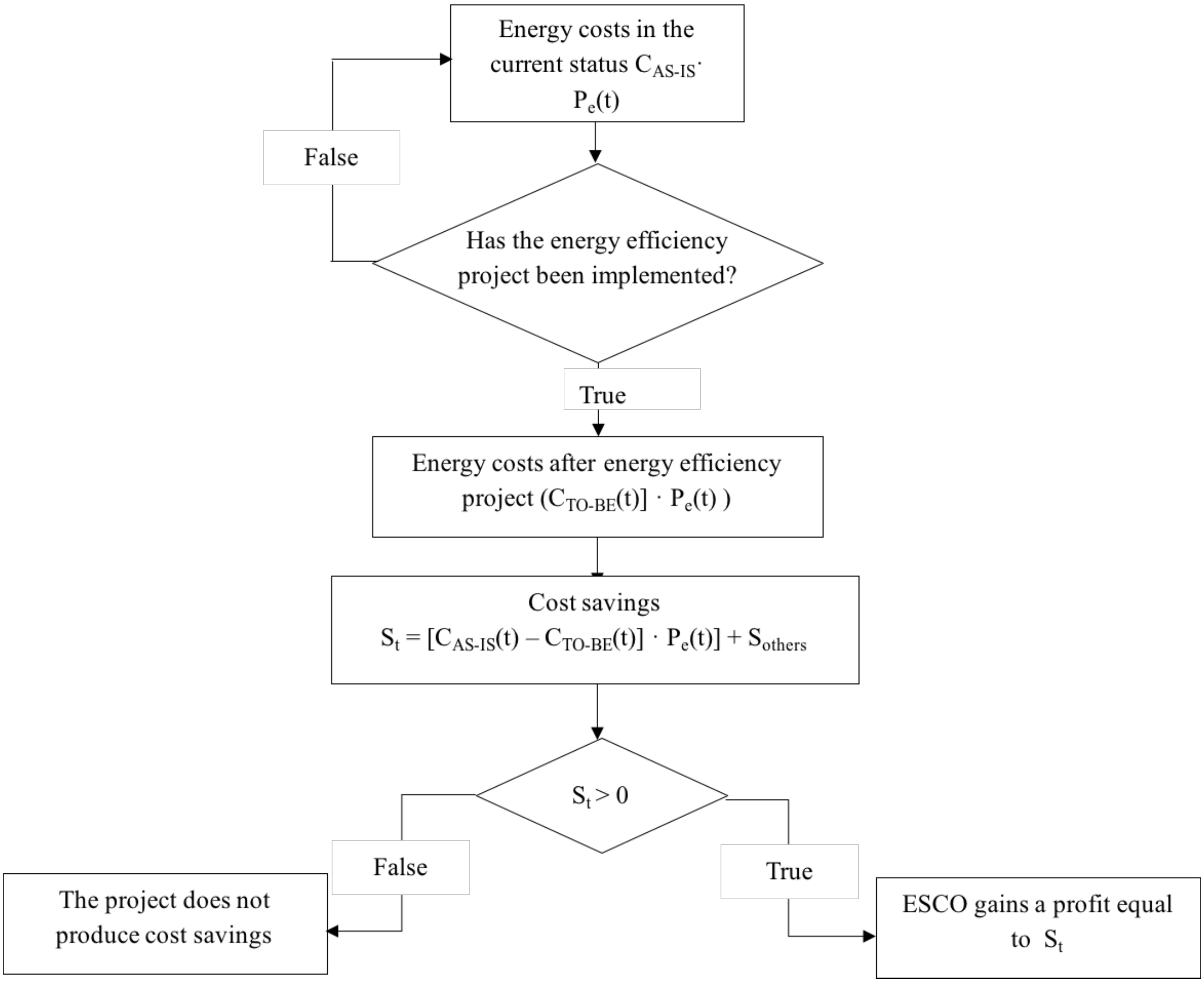

Figure 3. Profit-sharing mechanism in the First-Out contract

3.2 The computational model to select the EPC schema

This section presents the model to assess the benefits of each EPC schema for contractual parties (based on NPV) and benchmark the different contract structures based on their compliance with the win-win condition. Then, the contract that is better able to protect the interests of the ESCO and the government simultaneously and to assure that the interests of the two parties are satisfied in a balanced way is selected on the basis of the following equation:

$$Win - win\ EPC\ Schema = \ C_i \ni' \ min\big(NPV_{Esco}(i) - NPV_G(i)\big)\ with\ i = 1, 2, 3 \qquad (2)$$

Where: C_1, C_2, C_3 stand for Guaranteed Saving, Shared Savings, and First-Out contracts, respectively.

Equation 2 ensures the win-win condition by selecting the contract that minimizes the difference between the net profits (NPV) gained by the contractual parties.

The Net Present Value of the ESCO (NPV_{ESCO}) is obtained by the following equation:

$$NPV_{ESCO} = \ -I_0 + \sum_{t=1}^{T_c} \frac{CF_{ESCO}^t}{(1+r)^t} \qquad (3)$$

Where:

- I_0 is the total investment at year t_0
- T_C is the concession period
- r is discount rate
- CF_{ESCO}^t is the net cash flow at t, which varies depending on the specific EPC contract.

The Net present value of the government (NPV_G) is given by the sum of the net cash flows gained till the end of the contract (T_c), CF_G^{t1}, and the net cash flows gained from the end of the contract till the end of the life time of the project (F), CF_G^{t2}, as follows:

$$NPV_G = \sum_{t=1}^{T_C} \frac{CF_G^{t1}}{(1+r)^t} + \sum_{t=T_C+1}^{F} \frac{CF_G^{t2}}{(1+r)^t} \qquad (4)$$

Where CF_G^{t1} and CF_G^{t2} vary depending on the specific EPC contract.

For the Guaranteed Savings contract the net cash flow at t for the ESCO (CF_{ESCO}^{t}) is calculated according to Equations 5 and 6.

$$if\ S_t < S_g \Rightarrow CF_{ESCO}^{t} = \begin{cases} if\ P_e < P_{max} \Rightarrow -(S_g - S_t) + \alpha - \beta \\ if\ P_e > P_{max} \Rightarrow -\left(\frac{S_g - S_t}{P_e} \cdot P_{max}\right) + \alpha - \beta \end{cases} \quad (5)$$

$$if\ S_t \geq S_g \Rightarrow CF_{ESCO}^{t} = \delta \cdot (S_t - S_g) + \alpha - \beta \quad (6)$$

- Where: α are the additional revenues for the ESCO due to White Certificates/Energy Savings Certificates and other source of revenues;
- β are ESCO's costs due to maintenance and other operating costs.

The net cash flow at t for the Government (CF_G^{t1} and CF_G^{t2}) is calculated as follows:

$$if\ S_t < S_g \Rightarrow CF_G^{t1} = \begin{cases} if\ P_e < P_{max} \Rightarrow S_g \\ if\ P_e > P_{max} \Rightarrow \left(\frac{S_g - S_t}{P_e} \cdot P_{max}\right) \end{cases} \quad (7)$$

$$if\ S_t \geq S_g \Rightarrow CF_G^{t1} = S_g + (1 - \delta) \cdot (S_t - S_g) \quad (8)$$

$$CF_G^{t2} = S_t + \gamma - \varepsilon \quad (9)$$

Where:

- γ are additional revenues for the Government from the end of the contract (T_C) till the end of the life time of the project (F), due to White Certificates/Energy Savings Certificates and other source of revenues;
- ε are Government's costs charged from the end of the contract (T_C) till the end of the life time of the project (F), due to maintenance and other operating costs.

For the Shared Savings contract the net cash flow for the ESCO is calculated as follows:

$$if\ S_t \geq 0 \Rightarrow CF_{ESCO}^{t} = \delta \cdot S_t + \alpha - \beta \quad (10)$$

$$if\ S_t < 0 \Longrightarrow\ CF_{ESCO}^{t} = \alpha -\ \beta \tag{11}$$

The net cash flow for the Government is calculated with Equations 12, 13 and 14.

$$for\ S_t \geq 0 \Longrightarrow\ CF_G^{t1} = (1 -\ \delta) \cdot S_t \tag{12}$$

$$for\ S_t < 0 \Longrightarrow\ CF_G^{t1} = -\ S_t \tag{13}$$

$$CF_G^{t2} = S_t + \gamma - \varepsilon \tag{14}$$

For the First-Out contract the net cash flow of the ESCO is calculated with Equations 15 and 16.

$$for\ S_t \geq 0 \Longrightarrow\ CF_{ESCo}^{t} = S_t + \alpha -\ \beta \tag{15}$$

$$for\ S_t < 0 \Longrightarrow\ CF_{ESCo}^{t} = \alpha -\ \beta \tag{16}$$

The net cash flow of the Government is calculated as follows:

$$for\ S_t \geq 0 \Longrightarrow\ CF_G^{t1} = 0 \tag{17}$$

$$for\ S_t < 0 \Longrightarrow\ CF_G^{t1} = -\ S_t \tag{18}$$

$$CF_G^{t2} = S_t + \gamma - \varepsilon \tag{19}$$

Both NPV_{ESCO} and NPV_G are functions of a set of variables which are affected by uncertainty and which are modelled as random variables. A suitable theoretical distribution function for each variable is firstly selected and its parameters estimated. Then, we run the Monte Carlo simulation by using the Crystal Ball software. As simulation outputs, we obtain the statistical distribution of NPV_{ESCO} and NPV_G. Finally, applying Equation 2 we find the optimal EPC contract, namely that one that better ensures the win-win condition.

4. Case study

To illustrate the usefulness of the computational model developed in Section 3, we applied it to the case of the energy efficiency street lighting project in the Municipality of Noci (located in the province of Bari, Southern Italy). The project includes the renewal of the existing street public lighting system in order to comply with various technical norms and standards as well as generate financial savings based on the reduction of the energy used and of the maintenance and operation costs.

The local government entrusted to a selected ESCO the design, implementation, and maintenance of the energy efficiency street lighting project.

Table 2 reports the main project characteristics.

Table 2. Project characteristics.

Project scale	Replacement of 2050 street lights (of existing 3033) Installation of 80 new lighting points
Details	- Replacement program - Financing of installations - Operation and maintenance - Energy supply
Total investment cost (I_0)	2,788,308.47 €
Annual fee to the ESCO =Average annual historical costs	416,113 €
Savings	Energy savings of 52% Cost savings per street light of about EUR 51/year
Concession period (T_C)	20 years

The project consists in the replacement of 2050 bulbs (of the existing 3033) with energy efficient ones, and in the installation of 80 new lighting points. The city government estimated an Energy saving of about 52% and a cost saving per street light of about EUR 51/year.

The contract between the city government and the ESCO fixes the length of the concession to 20 years and establishes an annual fee of EUR 416,113 to be paid by the municipality of Noci to the ESCO. The amount is determined on the basis of the average annual historical costs sustained by the city, due to the energy cost and the maintenance cost. Hence, the contract allows the municipality of Noci to keep the same annual budget for the street lighting service, thus not burdening the public authority.

In order to assess and benchmark the Actual Contract with the three considered EPC contracts so as identifying the optimal one, that is, the contract that better ensures the achievement of the win-win condition, we have calculated the Net Present Value generated by the project to the ESCO and to the city government. Also, to take into account the effect of uncertainty, the input variables in the calculation of the cash flows are grouped into two categories: deterministic/certain and uncertain variables. The first category includes all the variables whose values are stable over time. The second, instead, groups those inputs subject to changes over time, and whose values are difficult to be predicted due to the high level of uncertainty.

The values for deterministic input variables are reported in Table 3.

Table 3. Deterministic variables.

Input deterministic data	**Symbol**	**Values**
REVENUE		
- White certificates/Energy savings certificates	a	19,912.84 €
- Revenues from MiniAeolian	b	21,690.00 €
- Others	c	17,700.00 €
COSTS		
- Maintenance cost in AS IS scenario	d	70,730 €
- Maintenance cost in TO BE scenario	e	12,000 €
- Operating costs	f	17,500.00 €
- Tele-management	g	26,980.00 €
Maximum energy price (P_{max})		300 €/MWh
Minimum guaranteed energy cost savings (S_g)		124,173.59 €
ESCO's excess savings shared percentage (δ)		80%

Investment cost (I_0)	2,788,108.47 €
Discount rate (*r)*	5%

The uncertain variables are:

- the energy price at year t (P_e);
- the energy consumption in the current AS IS scenario, namely without the energy efficiency project ($C_{AS\text{-}IS}$);
- the energy consumption in the TO BE scenario, namely with the energy efficiency project ($C_{TO\text{-}BE}$).

Table 4 summarizes the assumptions made for the statistical distributions modelling the uncertain variables. In particular, for each input random variable the corresponding probability distribution function and its defining parameters, defined on the basis of the historical empirical data, are reported.

Table 4. Statistical distribution of input random variables.

Input random variables	**Probability distribution function**	**Parameters**
Energy price at year t (P_e)	Mean Reverting stochastic process	s^*= 193.46 σ = 0.0246 μ = 0.0316 s_0= 166.73
Energy consumption in the current AS IS scenario ($C_{AS\text{-}IS}$)	Beta-PERT	Min = 2,347 MWh/year Max = 2,594 MWh/year Most Likely = 2,470 MWh/year
Energy consumption in the TO BE scenario ($C_{TO\text{-}BE}$)	Beta-PERT	Min = 1,125 MWh/year Max = 1,243 MWh/year Most Likely = 1,184 MWh/year

Given the stochastic nature of energy prices with the general trend and the temporal fluctuations, we assumed that the evolution process of the unit energy price (P_e) within the contracting period will vary stochastically in time following a Mean Reverting (MR) stochastic process, as widely accepted by the literature (Blanco and Soronow, 2001a; 2001b;

Blanco et al., 2001; Deng, 2000). This assumption reflects the real behavior of such prices that can vary, but gravitate towards a "normal" equilibrium level that is usually governed by the cost of production and the level of demand. Thus, if the price is above the mean, the price goes down, while if the price is below the mean, the price raises. Notice that the Mean reverting process overcomes the limitation of the Geometric Brownian motion (GBM) in modeling the stochastic price process as a "random walk" which assumes that price changes are independent of one another. In other words, the historical path the price followed to achieve its current price is irrelevant for predicting the future price path (prices follow a Markov process). Releasing such assumption, mean reversion modifies the random walk by assuming that price changes are not completely independent of one another, but rather they are related. Mathematically, the stochastic evolution of a variable that follows a mean reverting process can be modeled in each period *t* as a function of the value in previous period according to the following equation:

$$s_{t+1} - s_t = \mu \, (s^* - s_t) + \sigma \, \pi_t \qquad (20)$$

Where:

- s^* is the mean reversion level or long run equilibrium price
- s_t is the spot price
- μ is the mean reversion rate
- σ is the energy price volatility coefficient at year t;
- π is the random shock to price from t to t+1.

The long run mean (s^*) and volatility (σ) have been derived by using historical series of monthly data.

The energy consumption at year t_0, that is before the project starts, and energy consumption after the energy efficiency project, have been modeled with the Beta-PERT distribution (also called three-points estimation technique), which is a smooth version of the uniform distribution or triangular distribution. It is defined by:

- the minimum: the smallest value in a set;
- the maximum: the largest value in a set;
- the most likely (k): the most frequent number in a set; with min < k < max;

Like the triangular distribution, the PERT distribution emphasizes the "most likely" value over the minimum and maximum estimates. However, unlike the triangular distribution, the PERT distribution constructs a smooth curve which places progressively more emphasis on values around (near) the most likely value, in favor of values around the edges. In practice, this means that we "trust" the estimate for the most likely value, and we believe that even if it is not exactly accurate (as estimates seldom are), we have an expectation that the resulting value will be close to that estimate.

Table 5 shows the formulas for the computation of the model's parameters (α, β, γ, ε, S_{others} and S_e) on the basis of the deterministic and probabilistic input data reported in Tables 3 and 4.

Table 5. Formulas for the computation of the model's parameters.

FORMULAS
α = ESCO's additional revenues = a + b + c
β = ESCO's costs = d + f + g
γ = Government's additional revenues = b + c
ε = Government's costs = g
S_{others} = other costs savings at t due to the energy efficiency project = d – e
S_e = energy cost savings at t due to the energy efficiency project = $[C_{AS\text{-}IS} - C_{TO\text{-}BE}] \cdot P_e$

After establishing the input data modeling, the Monte Carlo simulation approach has been used to determine the NPV_{ESCO} and NPV_G. In particular, by running the model at the end of simulation consisting of 10,000 computer runs, we derive the statistical distributions of the NPV_{ESCO} and NPV_G for each type of contract. Table 6 shows the statistics of NPV_{ESCO} and

NPV_G distributions as well as of the distribution of the difference $|NPV_{ESCO} - NPV_G|$, namely, the mean value (Mean) and the standard deviation (St.dev.), for the Actual Contract and the three EPC contracts.

As a first result, we find that although the Actual Contract allows the municipality of Noci to keep the same annual budget for the street lighting service and the project to be economically feasible for the ESCO, it does not assure economic advantage for the public authority, generating an NPV_G well below zero. Furthermore, if we compare it with the NPV_{ESCO}, we find out that the actual contract generates a strong inequality with the exclusive advantage for the ESCO (Table 6). This means that alternative contracts should be considered to regulate the relationship between the two parties in order to balance the private sector's profitability needs and the public sector's economic interests.

Table 6. Simulation Results.

	Actual contract	**Guaranteed Savings**	**Shared Savings**	**First-Out**
NPV_{ESCO}				
Mean	612,507	1,776,328	339,192	889,343
St.dev	10,543	15,028	20,173	24,618
NPV_G				
Mean	-5,516,946	252,842	1,690,774	1,035,327
St.dev	10,314	13,091	10,687	8,755
$\lvert NPV_{ESCO} - NPV_G \rvert$				
Mean	6,129,454	1,523,485	1,351,582	**145,984**
St.dev	14,799	10,725	17,697	26,216

In order to support the decision maker in choosing the contract that distributes economic benefits between parties in a balanced way, we calculate the difference between NPV_{ESCO} and NPV_G. The contract that satisfies both the ESCO and Municipality by minimizing the difference between the NPV_{ESCO} and NPV_G values is the First-Out contract, whereas the

Guaranteed Savings and the Shared Savings are unbalanced, the former in favor of the private company, the latter in favor of the public authority.

To get a feel for the effect of the length of the concession period (T_C) on the choice of the appropriate contract, we perform a sensitivity analysis on T_C, by considering two further scenarios, one with a T_C = 25 years and the other with a T_C = 30 years.

Table 7 and Figure 4 report the results of the sensitivity analysis on the concession period T_C. Particularly, Table 7 reports the values of the mean and the standard deviation of the probability distributions of NPV_{ESCO}, NPV_G and the difference between the NPV_{ESCO} and NPV_G, for the two further scenarios considered, for all the EPC schema investigated. Figure 4 plots the variation of the mean value of the probability distribution of NPV_{ESCO} (a), NPV_G (b) and the difference between the NPV_{ESCO} and NPV_G (c), when the concession period increases, for the four EPC schemas.

As highlighted in Figure 4a, when T_C increases, the mean value of the probability distribution of NPV_{ESCO} increases for all the four EPC schemas: longer the concession period higher the economic benefits gained by the ESCO due to the operation of the energy efficiency project. As for NPV_G (Figure 4b), it decreases for the Actual contract and the First-Out. In the first contract, increasing the T_C means increase the period in which the public body pays the same fixed annual quantity as in the AS IS scenario, without any benefits. In the First-Out contract, where all the benefits come to the ESCO over the operating period of the energy efficiency project, increasing the T_C up to F - life time of the project - means reducing the residual benefits gained by the public body in the time window between the concession period and the end of the life time of the project. For the Shared Savings and Guaranteed Saving, increasing T_C seems to do not influence the NPV_G. Such a result may appear counterintuitive: one may expect that NPV_G increases when T_C decreases, since the period in which the public body operates exclusively the energy efficiency project (difference between F and T_C) increases. However, the additional benefits due to the operation of the project are eroded by the operating costs. Table 7 shows that when T_C increases the Actual Contract becomes more and more disadvantageous for the public authority (see also Figure 4b), the First-Out is no longer the best choice, while the Shared Savings contract results the most advantageous, in the sense that it allows an equal distribution of the project profits between the two parties, thus ensuring a win-win condition. When T_C is short, the First-Out better achieves the win-win condition since it enables to the higher exposed party, namely, the ESCO who made the capital investment, to recover its original capital, gain a profit without obtaining an excess of return that would create an imbalance for the public body. When T_C increases, being the investment equal, the win-win condition is achieved by ensuring that the excess profit, that the ESCO would gain once the investment is recovered, is shared between parties. This is ensured by the profit-sharing mechanism underlying the Shared Savings contract. On the other hand, the First Out contract ceases to produce any benefit to the public body: all the benefits come to the ESCO that manages the energy efficiency project till the end of the life time of the project (F). The Actual contract becomes even more imbalanced. It produces a very negative NPV_G, since the public body continues to pay the same annual (fixed) budget for the street lighting service as in the AS IS scenario, without gaining any benefits from the energy efficiency intervention (the standard deviation is zero).

Table 7. Sensitivity analysis results for T_c = 25 years and T_c = 30 years.

	Actual contract	**Guaranteed Savings**	**Shared Savings**	**First-Out**
T_c = 25 years				
NPV_{ESCO}				
Mean	1,284,426	2,051,214	780,139	1,404,533
St.dev	10,865	7,103	21,209	25,467
NPV_G				

Mean	-6,670,106	233,567	1,671,272	466,311
St.dev	2,247	5,923	10,876	5,440
$\vert NPV_{ESCO} - NPV_G \vert$				
Mean	7,954,539	1,817,647	**891,133**	938,223
St.dev	11,102	10,351	16,299	26,049
T_c = 30 years				
NPV_{ESCO}				
Mean	1,914,164	2,280,826	1,140,285	1,826,708
St.dev	14,068	15,815	21,981	25,942
NPV_G				
Mean	-7,824,690	218,489	1,656,235	-
St.dev	-	12,975	10,840	-
$\vert NPV_{ESCO} - NPV_G \vert$				
Mean	9,738,767	2,062,308	**514,951**	1,826,708
St.dev	14,068	7,667	15,491	25,942

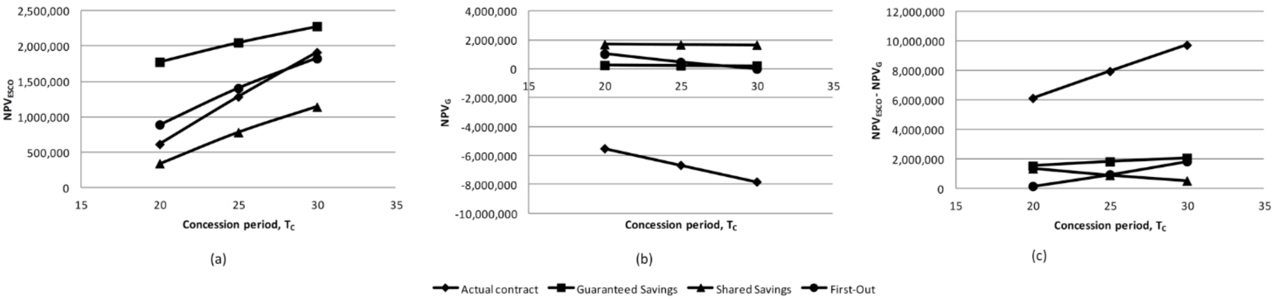

Figure 4. Sensitivity analysis results: mean values of the probability distributions of NPV_{ESCO} (a), NPV_G (b) and difference between NPV_{ESCO} and NPV_G (c) for different values of the concession period T_C

Finally, to get a feel for the effect of the discount rate (r) on the choice of the appropriate contract, we perform a sensitivity analysis on r, by considering two further scenarios (r = 2% and r = 8%). Table 8 and Figure 5 report the results of the sensitivity analysis on r. Particularly, Table 8 reports the values of the mean and the standard deviation of the probability distributions of NPV_{ESCO}, NPV_G and the difference between the NPV_{ESCO} and NPV_G, for the two further scenarios considered, for all the EPC schema investigated. Figure 5 plots the variation of the mean value of the probability distribution of NPV_{ESCO} (a), NPV_G

(b) and the difference between the NPV_{ESCO} and NPV_G (c), when the discount rate r increases, for the four EPC schemas. As highlighted in Figure 5a, when r increases, the mean value of the probability distribution of NPV_{ESCO} decreases for all the EPC schemas, in line with the meaning of r (i.e., time value of the money). As for NPV_G (Figure 5b), it decreases for all the EPC schemas except for the Actual contract, which, as discussed, means only costs (Government pays the same fixed annual quantity as in the AS IS scenario, without any savings): higher the discount rate r, lower the total discounted cost. Beyond the Actual contract, the difference between the NPV_{ESCO} and NPV_G does not significantly vary with r. Despite the impact that the discount rate r has on the net profits of both ESCO and public body, the interesting result from the sensitivity analysis on r is that the discount rate r seems to not strongly affect the choice of the appropriate contract, which, in all the considered cases, still remains the First out contract, as highlighted in Table 8.

Table 8. Sensitivity analysis results for r = 2% and r = 8%.

	Actual contract	**Guaranteed Savings**	**Shared Savings**	**First-Out**
r = 2%				
NPV_{ESCO}				
Mean	1,806,914	2,426,090	1,341,697	2,075,658
St.dev	13,644	19,953	26,597	33,032
NPV_G				
Mean	-7,346,107	1,990,019	3,071,745	2,155,293
St.dev	20,883	23,051	20,996	18,286
$\lvert NPV_{ESCO} - NPV_G \rvert$				
Mean	9,153,020	436,071	1,730,047	**78,683**
St.dev	25,401	20,134	28,280	38,496
r = 8%				
NPV_{ESCO}				
Mean	-142,991	1,346,730	-304,900	123,305
St.dev	8,423	11,862	15,614	19,212
NPV_G				
Mean	-4,238,377	-643,400	1,009,030	511,019
St.dev	4,791	8,909	5,859	4,387
$\lvert NPV_{ESCO} - NPV_G \rvert$				
Mean	4,095,460	1,990,130	1,313,930	**387,713**

St.dev	9,686	6,667	12,518	19,552

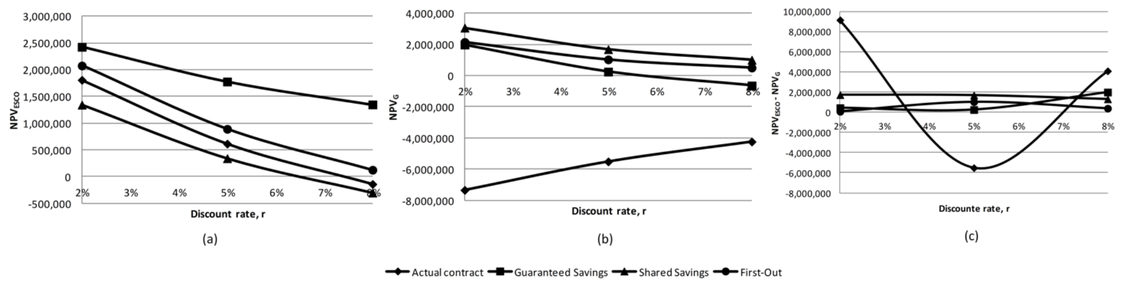

Figure 5. Sensitivity analysis results: mean values of the probability distributions of NPV_{ESCO} (a), NPV_G (b) and difference between NPV_{ESCO} and NPV_G (c) for different values of the discount rate r

5. Conclusion and Policy Implications

The paper provides a computational model for assessing and benchmarking different EPC structures on the basis of the net economic benefits generated by an energy efficiency project. The novelty of our study lies in developing a model to benchmark different EPC structures and to choose the EPC structure which ensures that interests of the two parties, namely the private sector's profitability needs and the public sector's economic interests, are satisfied in a balanced way, according to a win-win approach that should underlie any form of public-private partnership.

Beyond the specific numerical results obtained through the case study, the overall finding shows the merits of the study. First, the assessment of net benefits gained by each party through EPC contracts, expressed in monetary terms, makes the contract efficiency evaluation encompass both technical and economic aspects. Second, the outcome confirms the importance of benchmarking the EPC schemes since they can reveal not beneficial to all parties, generating, under different conditions, unequal net economic benefits for the two parties. So far, such an imbalance makes the EPCs not enough appealing, limiting their use. Furthermore, the results of the sensitivity analysis show the importance of taking into account the uncertainty in the contracts' benchmark and selection.

The increase of uncertainty due to the contract period extension affects the contract selection in compliance with the win-win condition. In particular, we found that, when T_C increases, the Shared Savings contract results the most advantageous, in the sense that it allows an equal distribution of the project profits between the two parties, thus ensuring a win-win condition. Whereas, the First Out contract ceases to produce any benefit to the public body: all the benefits come to the ESCO that manages the energy efficiency project till the end of the life time of the project. Thus, when T_C increases, the profit-sharing mechanism underlying the Shared Savings contract reveals more efficient in resolving the potential unbalances, i.e. unequal gain, that might be generated by the uncertainty.

Contrarily, we found that the discount rate r, which impact the profits of both the ESCO and public body, does not seem to have a strong impact on the choice of the EPC schema able to ensure the win-win condition achievement.

The paper offers three main contributions to the literature on EPC and PPPs. First, we fill the gap of the literature that, focusing on single EPC, lacks of tools that allow the benchmark among the different EPC structures, so as supporting the decision-making in the choice of the most appropriate EPC structure. Second, we enrich the existing studies on PPP that, focusing on the infrastructure PPP, have been rarely applied to the energy field, and specifically to relationship between ESCOs and public sector regulated by EPC schemes. Third, we enhance the literature on EPC by fully capturing the essence of a PPP arrangement, namely creating a ‘win–win’ solution for both the ESCO and the government, to assess and benchmark the different EPC structures.

Our research has also two main contributions for the practitioners. Firstly, the developed model represents a useful tool for supporting the public authority in the decision-making process about the structure of the energy service contract. At present, governments generally structure the energy service contract guided almost solely by the need to reduce the energy costs or at least to keep fixed their budget gaining advantage only in terms of carbon emissions’ reduction and higher energy performance. Narrowing their focus merely on the environmental and energy performance, the public body may lose additional economic benefits generated by an energy efficiency project. This is ensured by adopting the proposed tool to choose the most appropriate EPC schema, which encompasses both technical and economic aspects.

Second, the low computational burden of the model, which allows its implementation on a Microsoft Excel spreadsheet, enables both ESCO and public authority, interested in assessing and benchmarking EPC structures, to perform the analysis simply by entering the information related to the context and clicking a button.

Future work can still be done to improve the proposed methods. In the current model, for the sake of simplicity we do not consider the price elasticity effect on the amount of energy savings. We could expect that if the energy price rises, measures to control the amount of energy usage might be adopted. Thus, the energy cost savings might be less than the current estimation. Besides, though we conduct our study on the three main EPC contracts, variations of these schemes could still to be considered for completion. Finally, further research could be devoted to better evaluate the risk borne by the two parties in the different

EPC structures so as making decision on the basis of a fairly allocation of rewards as well as risks.

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